Grand River Watershed

Water Management Plan

floodcontrol

water**quality**

watersupplies

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Steering Committee:

- County of Brant
- City of Brantford
- City of Guelph
- Haldimand County
- Region of Waterloo
- Six Nations of the Grand River
- Ministry of the Environment and Climate Change
- Ministry of Natural Resources and Forestry
- Ministry of Agriculture, Food and Rural Affairs
- Agriculture and Agri-Food Canada
- Environment Canada
- Department of Fisheries and Oceans

Project Team:

- County of Brant
- City of Brantford
- City of Guelph
- City of Waterloo
- City of Kitchener
- City of Cambridge
- Township of Centre Wellington
- Haldimand County
- Region of Waterloo
- Six Nations of the Grand River
- Ministry of the Environment and Climate Change
- Ministry of Natural Resources and Forestry
- Ministry of Agriculture, Food and Rural Affairs
- Environment Canada

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Partner Endorsement

The Plan is the product of a voluntary partnership of municipalities, provincial and federal agencies, First Nations and the Grand River Conservation Authority. Representatives sat on a Steering Committee, a Project Team, and participated in working groups to develop the Plan. There are no legal or financial obligations for any partner to the plan. The following agencies have endorsed the Plan and agree to continue to collaborate to voluntarily implement best value solutions to water management issues in the Grand River watershed.

Municipality	Endorsed on:
Municipality of North Perth	April 28, 2014
Region of Waterloo*	April 29, 2014
Township of Southgate	May 7, 2014
Wellington County	May 8, 2014
City of Kitchener *	May 12, 2014
Haldimand County *	May 13, 2014
Oxford County	May 14, 2014
Township of Melancthon	May 15, 2014
Township of North Dumfries	May 20, 2014
Township of Wellesley	May 20, 2014
Town of Erin	May 20, 2014
City of Brantford *	May 20, 2014
City of Cambridge *	May 20, 2014
Township of Centre Wellington *	May 20, 2014
Township of Blandford Blenheim	May 21, 2014
Township of Wellington North	May 26, 2014
City of Waterloo *	May 26, 2014
Town of Grand Valley	May 27, 2014
County of Brant *	May 27, 2014
Township East Zorra - Tavistock	May 28, 2014
Township of Puslinch	June 4, 2014
Mapleton Township	June 10, 2014
Township of Perth East	June 17, 2014
The Region of Halton	June 18, 2014
City of Guelph*	June 23, 2014
Township of Woolwich	June 24, 2014
City of Hamilton	July 7, 2014
Conservation Authority	
Grand River Conservation Authority	June 27, 2014
First Nations	
Six Nations of Grand River	August 12, 2014
Province of Ontario	
Ministry of Environment and Climate Change	September 18, 2014
Ministry of Agriculture, Food and Rural Affairs	September 18, 2014
Ministry of Natural Resources and Forestry	July 31, 2014
Government of Canada	
Environment Canada	September 18, 2014

* Plan Partner

A Message from Paul General, Six Nations of the Grand River

To many First Nations communities water is infused into their culture.

For example, water is mentioned several times in the Haudenosaunee thanksgiving: first, when we give thanks for the waters themselves; second, when we give thanks for the fisheries; and third, when we give thanks for the thunders announcing the coming of the rains that cleanse the earth and nourish all living things.

Water is also at the core of our Creation Story:

During the Before Times, the earth was covered entirely with water. Humans lived in a place above the Earth called the Sky World. One day a tree became uprooted, leaving a hole down through Sky World to the Earth. One of the inhabitants of Sky World, a woman, looked down through the hole. She noticed the Earth was covered with water. As she crept closer for a better look, she fell through the hole. She fell and fell until she landed on the back of a great turtle, who had seen her falling and quickly swam to provide her with a way to climb out of the water. She was alone, only having creatures of the water as companions.

The story continues to describe how we, the Haudenosaunee, came to be living on Turtle Island.

The Grand River watershed, as part of Turtle Island, has been home to the Haudenosaunee for centuries. The Grand River is central to Haudenosaunee cultural and spiritual beliefs. Not so long ago the watershed and the river provided almost everything we needed to exist: drinking water, transportation, irrigation, habitat for fish and other aquatic creatures, and refuge for terrestrial creatures we used, such as deer.

The people were also taught that we have the responsibility to protect the creatures we have given thanks for. So when we see negative impacts on the river, it not only affects the creatures but the people as well

As the Water Management Plan has developed, I have been reminded of the many things I have been taught over the years. There are far too many to list but some stand out.

- Patience: Changes are slow to happen so patience is more than a virtue – it's a necessity.
- Persistence: It is extremely easy to become discouraged when change does not happen when or how we would like. So persistence must be a part of one's personal arsenal: the ability to keep at it, to stay the course.
- Pragmatism: An understanding of what is pragmatic -- what is realistic and achievable -- is important. Even though we may demand the world, the government may not be able to deliver, even if the government wanted to.
- Flexibility: We must realize that all things may not be achievable and that an ability to adapt is required. Such is the case with environmental issues and concerns, especially water governance.

This is not to say we should not set our targets high. We should always strive for improvement and not just status quo.

I see the need for more meaningful collaborative initiatives, focusing on an equitable and fair use and governance of not only water but all resources.

And I see the need for an entirely new system of sharing, whereby First Nations concerns are not only put on the table, but acted upon equally.

An Oneida elder once told me he could not understand why we had to meet to discuss the importance of water. He was truly puzzled as to why governments and academics needed to be reminded of something so intuitive to us: Do not use the river as a sewer or a convenient place to dispose of contaminants.

Grand River Watershed
Water Management Plan (2014)

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1 Introduction

Water management in Ontario is shared among many agencies. Federal departments, provincial ministries, municipalities and conservation authorities all play a role in managing water. Water Management in the Grand River watershed has a long history of being collaborative; water has been managed under a water management plan for over 80 years.

The first water management plan was conceived in the 1930's in response to significant water quality and flooding issues facing many of the communities along the Grand River. Governments of the day recognized that their communities could not individually deal with these issues alone and needed to work together to solve them. Since then, the water management plan for the watershed has been updated in 1954, 1971 and most recently in 1982. The 1982 Grand River Basin Water Management Study produced a number of recommendations along with a preferred plan to tackle water quality, water supply and flooding issues. Most of those recommendations were carried out.

Recognizing the need to ensure a healthy river system and linkage to Lake Erie, secure water supplies, manage flood risks and deal with climate change, the Grand River Conservation Authority (GRCA), watershed municipalities, provincial governments, federal departments, and First Nations came together in 2009 to review and update the Grand River Water Management Plan (the '*Plan*'). This update reflects the considerable knowledge, tools and networks that have been developed since 1982.

The *Plan* is a key component of a broader integrated watershed plan. The watershed plan pulls together plans such as forestry, fisheries, natural heritage, drinking water source protection, recreation and other planning processes so that linkages can be made for larger scale watershed planning.

The update to the Water Management Plan addresses the management of surface and ground water resources in the Grand River watershed to 2031. The *Plan* is based on currently available data and information and the assembly of knowledge of plan partners.

1.1 The Collaborative Process

In 2008, the GRCA initiated dialogue with potential partners to discuss the need for a concerted and collective effort to deal with water problems in the Grand River watershed. Since water management activities are undertaken by several agencies at different government levels, a business case was developed, emphasizing that the resolution of water issues in the watershed requires a collaborative approach which recognizes the complexity and inter-relatedness of hydrological and ecological processes and acknowledges that solutions to address the impacts of multiple inputs throughout the river system must be watershed based.

In 2009, a voluntary, multi-stakeholder, collaborative initiative to update the Grand River Watershed Water Management Plan (WMP) was launched. Plan partners signed a Project Charter which outlined the purpose and goals, benefits, scope and deliverables, and timelines for the project and described the governance structure and roles of the partners. Four goals were identified for the Water Management Plan.

The Project Charter also stressed that the updated WMP would represent a 'Joint Call to Action' by aligning the efforts of all partners and galvanizing them to achieve mutually-supported targets for water management. Underlying success factors were identified in the Project Charter and included:

- The plan development process stays collaborative;

- There are 'Early Wins' to celebrate;
- The project is scoped appropriately for the available time, funding, resources, data and science;
- Funding is available to get answers to some fundamental questions;
- There is a rollout strategy to launch implementation;
- For any action item coming out of the plan, the partner organization responsible for implementation endorses the action and agrees in principle to undertake it;
- Targets and measures are practical and achievable;
- Monitoring and performance measures recognize time lapse to see results;
- Processes are put in place to ensure continuous improvement, adaptive management continuity.

The *Plan* was a collaborative process that brought the following agencies together as partners:

Plan Partners

Municipalities represented by:

- Township of Centre Wellington
- City of Guelph
- Regional Municipality of Waterloo
- City of Waterloo
- City of Kitchener
- City of Cambridge
- County of Brant
- City of Branford
- Haldimand County

Six Nations of the Grand River
Grand River Conservation Authority
Ontario Ministry of the Environment and Climate Change
Ontario Ministry of Natural Resources and Forestry
Ontario Ministry of Agriculture, Food and Rural Affairs
Environment Canada

The compilation of the *Plan* was a ***voluntary partnership***. By working together, these agencies set out an integrated action plan, based on agreed-upon local objectives and targets, to meet the needs of the ecosystem and watershed communities. The integrated action plan will also assist each partner to fulfill their role and to support each other throughout the process.

The process for updating the *Plan* was governed by a Steering Committee and supported by a Project Team and technical working groups.

The Steering Committee provided overall direction and guidance, oversaw project accountability, made decisions concerning the *Plan*, and reported on progress to their respective partner organizations.

The Project Team was responsible for the overall coordination of the *Plan* and integration of decisions. The Project Team led the development and management of each project and acted in an advisory capacity to the Steering Committee.

Working groups carried out specific tasks aligned on a topical basis and hosted technical forums with experts to explore the state of the science and practice around topics such as science-based targets, wastewater assimilative capacity, water demand management, groundwater and surface water interactions, wastewater treatment plant optimization and urban stormwater management approaches. These working groups reported directly to the Project Team.

An arms-length Science Advisory Committee (Appendix C) provided the Steering Committee, Project Team and GRCA staff with scientific and technical advice.

1.2 Guiding Principles for the Plan

The following are the guiding principles that underpin the overall process of updating the *Plan* and the compilation and identification of the broad water objectives for the watershed.

Healthy communities and a healthy ecosystem

- A healthy river system is crucial for sustaining prosperity, growth and well-being in the Grand River watershed.
- The *Plan* is guided by an ecosystem approach. We will strive to maintain and restore critical natural system interactions, functions and resiliency.
- Ecosystem services – those services provided by natural processes such as waste assimilation or water retention are acknowledged, maintained and enhanced.

Managing water resources is a shared responsibility

- Managing water requires common goals, collaborative decision making and co-operation.
- Implementation is shared by all levels of government, landowners, businesses and residents.
- Implementers are committed to joint action and own their piece of the *Plan*.
- Stakeholder participation is essential.

Water is best managed on a watershed basis

- The watershed is the most appropriate unit for managing water and the linkages between water and other natural resources.
- The Water Management Plan is a critical component of a broader watershed management plan.

Decision making must be transparent and responsive

- Water management decisions are integrated and transparent, taking into consideration the broad range of uses, needs and values for water and the needs of a healthy ecosystem.
- Water management strategies are designed to be responsive to changing conditions, priorities, vulnerabilities and pressures; adaptation is supported by monitoring and progress reporting.

Management of water resources must be effective and efficient

- The concepts of sustainability, adaptive management and continuous improvement guide decision making and implementation.
- Best value solutions are sought.
- Best available science, expert advice and local knowledge are inherent to the *Plan*.

1.3 Communications and Engagement

The Steering Committee acknowledged that the assembly of the Water Management Plan required strong partner and stakeholder participation to ensure its success. Early in the process of assembling the Water Management Plan, the Steering Committee developed a Project Charter and Communications and Engagement Strategy to guide the work.

The Communications and Engagement Strategy focuses on engaging the following stakeholder groups

- Interested public,
- Agricultural community,

- Environmental non-government groups,
- Broader watershed community (including multi-stakeholder groups that undertake collaborative projects and programs such as the Grand River Fisheries Management Plan Implementation Committee), and
- Municipal councils.

Key stakeholder groups were invited to provide input on the aspects of the *Plan* that interested them, using a variety of communication and engagement techniques. A dedicated website was designed to provide open access to background information, technical reports, newsletters, meeting minutes, workshop notes, surveys, and other materials pertinent to the *Plan*. Presentations at conferences such as the A.D. Latornell Conservation Symposium and the Grand River Watershed Water Forum and exhibits at the 2012 International Ploughing Match and the University of Waterloo Water Institute's Water Week event provided additional opportunities to increase general awareness about the initiative.

Public input was obtained through an online survey completed by 600 people and targeted meetings with specific groups. For example, representatives of the County Federation of Agriculture and the Grand River Fisheries Management Plan Implementation Committee met directly with GRCA staff to discuss aspects of the *Plan*. In addition, the GRCA received valuable input from a Non-government Organization Roundtable attended by 33 people.

Invitations to a series of "roadmap" workshops held in the spring of 2013 were extended to a wide range of stakeholders. These workshops were held to discuss the specific goals of the *Plan*, share key findings and discuss actions which could be part of the *Plan*.

In January and August 2013, GRCA staff and partners met with representatives from watershed municipalities to provide an overview of the *Plan* process, discuss management priorities, actions, barriers and opportunities, and obtain advice about how best to gather support for the *Plan*.

The reports from these various workshops are available online at www.grandriver.ca.

1.4 Goals of the Water Management Plan

The *Plan* is a ***Joint Action Plan*** that aligns water management efforts over the next 30 years in support of a shared vision for the watershed. Four specific *Plan* goals were identified by the Steering Committee and have guided the Project Team in creating the *Integrated Action Plan* (IAP):

- Ensure sustainable water supplies for communities, economies and ecosystems;
- Improve water quality to improve river health and reduce the river's impact on Lake Erie;
- Reduce flood damage potential; and
- Increase resiliency[1] to deal with climate change.

Each partner signed a Project Charter and agreed to identify and undertake complementary actions to address watershed water management challenges.

The development of the Water Management Plan has leveraged much of the work that has gone into the characterization and assessment of municipal drinking water supplies, both groundwater wells and surface water intakes, as part of the provincial source protection program under the Clean Water Act, 2006. The scope of the Water Management Plan goes beyond municipal drinking water uses and includes considerations for aquatic ecosystems and flood risk reduction. The *Plan* complements the Source Protection Plan for the watershed as well as other plans including the Fisheries Management Plan, Watershed Forest Plan among others. The Water Management Plan also acknowledges the influence the Grand River has on the eastern basin of Lake Erie and recognizes the Lake Erie Lake-wide Action Plan (LaMP).

This first half of this document provides a brief description of the natural and physical features of the watershed that influence water; profiles the key hydrologic processes and key hydrologic functions provided by important watershed features; and also highlights the critical water management issues facing the watershed into the future.

The process through which the *Plan* was developed is outlined in the section: *A Foundation for Integrated, Adaptive Water Management.* This chapter acknowledges that the management of water is shared across many agencies in Ontario and highlights the importance of providing a forum for and fostering collaborative working relationships among partners.

The means with which to integrate water management in the watershed is discussed in the chapters on *Ensuring Sustainable Water Supplies* (quantity), *Improving Water Quality*, and *Reducing the Risk of Flood Damage*. Considerations are made for both surface water and groundwater; the river; and the river's influence on Lake Erie.

The *Integrated Action Plan* is the chapter that lists the many actions that *Plan* partners have agreed to implement over the life of the *Plan* (to 2031). These actions are written by Plan partners and it is the result of four years of collaborative work planning and the sharing of information on issues that transcend municipal boundaries.

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[1] Resiliency is the long-term capacity of a natural system, or watershed, to deal with change – either gradual or sudden, such as a large storm event, and continue to function as expected. Increasing the resiliency of the watershed is to implement practices or (green) infrastructure, to maintain its ability to function as expected.

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2 The Grand River Watershed

The Grand River watershed is located in southwestern Ontario, west of the Greater Toronto Area, and drains an area of 6800 square kilometres from Dundalk in the Dufferin Highlands and flowing over 300 kilometres to Lake Erie, at Port Maitland. Along the way, it picks up its major tributaries, the Conestogo, Nith, Speed, Eramosa, Whitemans and Fairchild (Figure 2-1).

There are 39 upper, lower and single tier municipalities wholly or partly in the Grand River watershed as well as two First Nations reserves, Six Nations of the Grand River and Mississaugas of the New Credit.

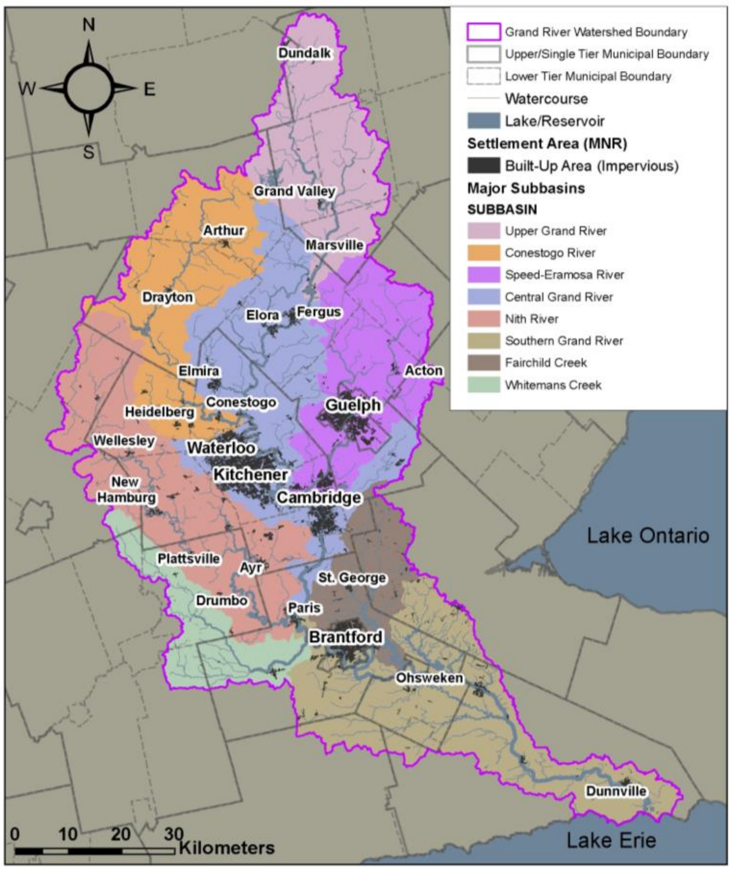

Figure 2-1. The Grand River watershed showing areas of settlement and the major subbasins

2.1 The Landscape

The physiography of the Grand River watershed can be viewed as three distinct areas - dominated in the north and west by the Dundalk and Stratford Till Plains (green), in the centre and east by the Horseshoe Moraines (orange and yellow), and in the south by the Haldimand Clay Plain (blue) as illustrated in Figure 2-2.

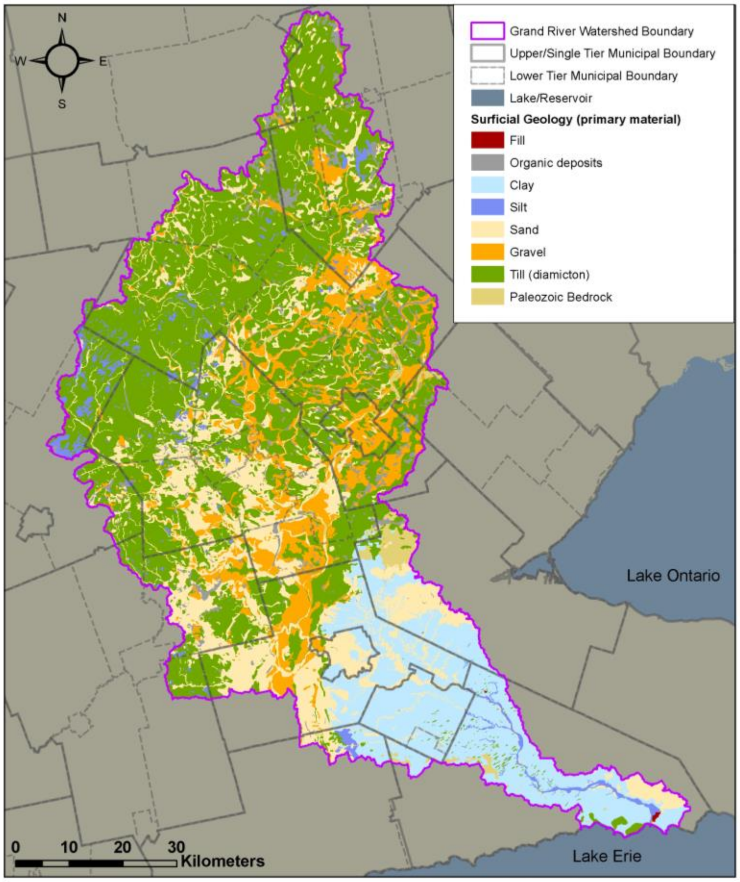

Figure 2-2. Physiography of the Grand River watershed

The Stratford Till Plain, located in the northwest, is characterized by silty, clay-rich soils which are generally level and often poorly drained. Artificial drainage has made this a rich and productive agricultural region and, as a consequence, only a small portion of the land remains in woodlot, wetland or rough pasture.

The Horseshoe Moraine region consists of a series of moraines and gravel outwash plains within much of southwestern Ontario. Some of this region is very hilly, often with steep irregular slopes and small enclosed basins. This region has large sand and gravel deposits with many aggregate extraction operations in southern Wellington County, southern Waterloo Region, and the northern portion of the County of Brant. Approximately 30% of the moraine region is forested, and fencerow vegetation is often well developed. The region hosts a number of cold-water streams that receive groundwater discharge including the Eramosa River and Mill Creek. Groundwater discharge also feeds the Grand River itself, particularly between Cambridge and Brantford, providing a significant portion of the river's flow during summer months. The Waterloo Hills region, located in the centre of the watershed, is characterized by sand hills, gravel terraces and many swampy valleys. The soils of the hilly areas are rich and well drained. The Norfolk Sand Plain, in the southwestern part of the central zone, is also rich in water and is intensively used for both mixed farming and cash crops.

The Haldimand Clay Plain southeast of the City of Brantford is characterized by heavy clay soils; much of the land is poorly drained and is used predominantly as livestock pasture and for soybean, corn and hay production. Groundwater in this area is often poor in quality as a result of naturally elevated concentrations of sulphur, salts and minerals in the water. For this reason, municipal and

First Nations drinking water supplies have tended to be sourced from the Grand River, Lake Erie or Lake Ontario.

Underlying the surficial material, several bedrock units have the ability to transmit significant quantities of groundwater making them potentially important for municipal or private use. These units, which are shown in Figure 2-3, include the Gasport, Guelph and Salina Formations.

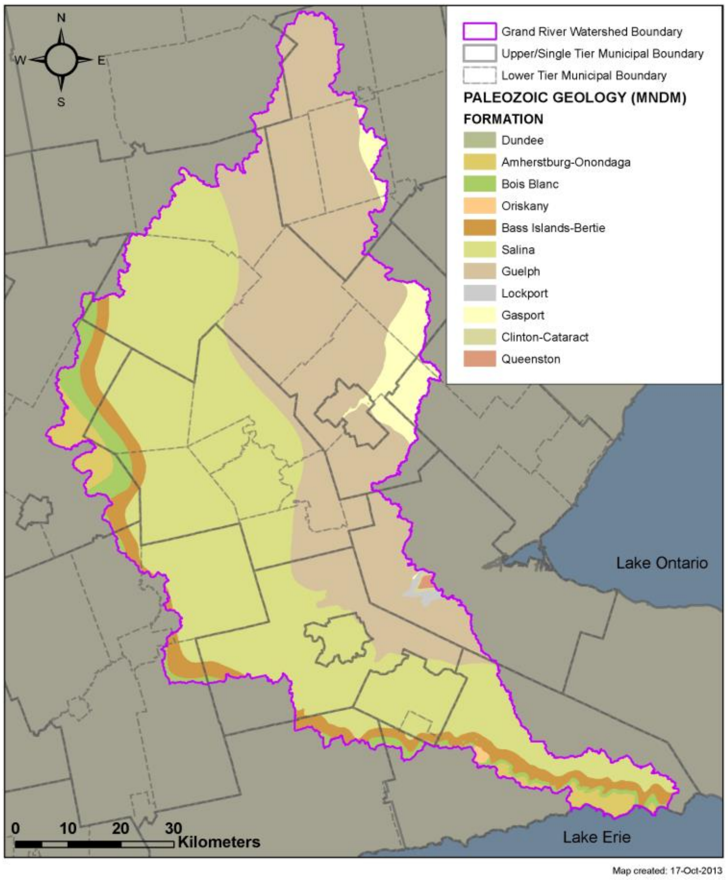

Figure 2-3. Bedrock geology of the Grand River watershed

The Guelph and Gasport Formations are highly productive aquifers and provide groundwater of excellent natural quality. The Salina Formation is a moderately productive aquifer; however, the natural groundwater quality is often poor. As a result, municipal water supplies in the western half of the watershed tend to be sourced in deep overburden aquifers while in the eastern half of the watershed, supplies tend to be sourced in the bedrock aquifers.

Within the watershed, bedrock formations generally outcrop (bedrock exposed at surface) or subcrop (bedrock directly overlain by unconsolidated sediment) in long parallel bands of varying width and are aligned in a north-west to south-east direction. Bedrock outcrops are most commonly found in the central-eastern and southern areas of the watershed. Within the central-eastern area, outcrops, which are commonly found along river valleys, generally consist of the Guelph and Gasport Formations. In the southern part of the watershed, outcrops are generally associated with the Onondaga Escarpment and consist of the Bass Island, Bertie and Bois Blanc Formations[1].

In total, there are 11 different bedrock formations outcropping or subcropping within the Grand River watershed, all of which were initially deposited horizontally. Regionally, they now dip approximately 2 degrees to the west as a result of subsequent structural deformation. Figure 2-4 is a cross-section which illustrates the stratification of the bedrock complexes across the watershed from east to west.

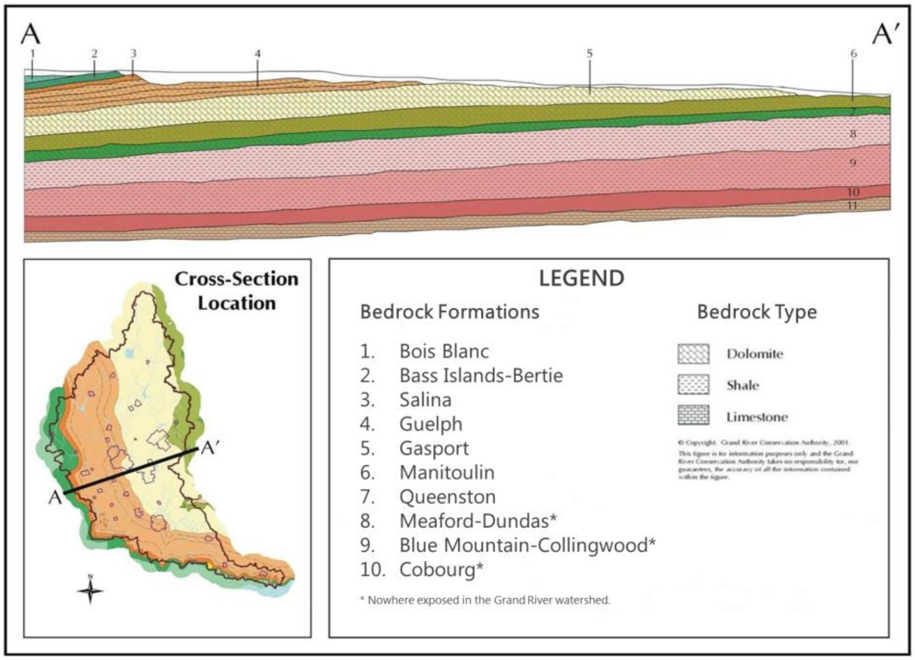

Figure 2-4. Cross-section of bedrock geology within the watershed

The Gasport Formation is generally comprised of limestone and dolostone. This formation surfaces in the watershed at three points along the eastern boundary of the Grand River Watershed: i) in Amaranth Township near Laurel; ii) in a relatively large area surrounding the town of Rockwood; and iii) in a band surrounding the Dundas Valley. The formation is subject to karstification due to its surface or near-surface exposure. Karst features tend to develop over time by the dissolution of limestone (and to a lesser extent dolostone) bedrock which enhances the porosity of the bedrock, making it easier for groundwater to move though the rock.

Overlying the Gasport Formation, the Guelph Formation is one of the most important bedrock formations in terms of groundwater supply in the watershed. It forms the uppermost bedrock layer over a large portion of the watershed, stretching in a 30 km wide swath from Dundalk to Carluke (east of Brantford). It is middle Silurian in age, and is generally composed of brown or tan dolostone.

The Salina Formation overlays the Guelph Formation and, similar to the Guelph Formation, it also underlies a large portion of the Grand River watershed, stretching from Drayton to Dunnville. The formation is comprised of evaporites (salts, gypsum, anhydrite), shales, and interbeds of carbonate rock. The gypsum mines present in the Caledonia area are set within the Salina Formation.

2.2 Surface Water System

The Grand River is a managed river system where reservoir operations, water supply, and wastewater management were designed as an integrated system on a watershed basis. The upper till plains generate high surface runoff that result in high flood flows, but little to no flow in watercourses during sustained dry periods. Figure 2-5 illustrates the areas with the greatest runoff potential. Multi-purpose reservoirs were built on the fringe of these till plains to manage surface runoff following significant floods and droughts in the 1930's. The reservoirs capture runoff from spring snow melt and heavy rains, and release stored water during the summer and fall to maintain flow in the river system.

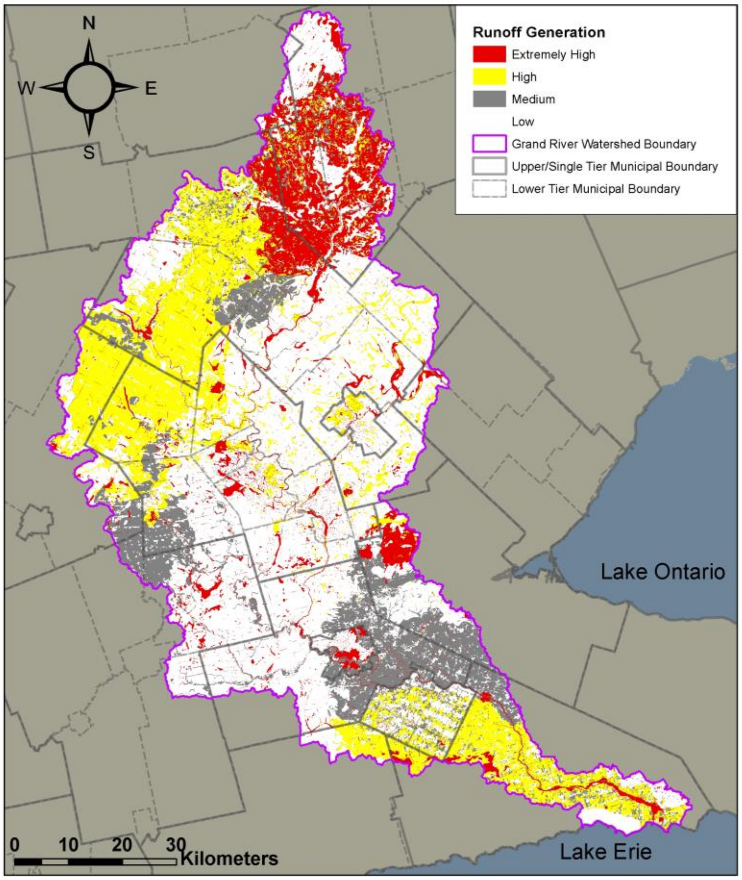

Figure 2-5. Areas with the greatest runoff potential.

The central portion of the watershed contains most of the watershed's moraines and sand/gravel deposits left by glaciation. The drainage network is not well defined and stream flows are maintained by groundwater discharge and flow augmentation from upstream reservoirs. Urbanization in this part of the watershed has led to an increase in surface runoff from impervious areas and localized flooding issues.

The southern portion of the watershed is dominated by the Haldimand Clay Plain. The landscape produces extremely high surface runoff and has a dense drainage network. Grand River flows are sustained by upstream flow augmentation and groundwater discharge while smaller watercourses have very little flow during dry periods.

2.2.1 Multi-Purpose Reservoirs

The Grand River Conservation Authority (GRCA) operates seven dams and reservoirs that are vital to protecting the health and safety of watershed communities, their locations are shown in (Figure 2-6). The dams were built between 1942 and 1976. Today, it would cost over one billion dollars to build them.

The major dams, Shand, Luther, Conestogo and Guelph, are operated as a system to provide flow augmentation and flood control for the main Grand River. The others, Woolwich, Laurel Creek and Shade's Mills, influence the local tributary on which they are situated.

The reservoirs are managed to provide maximum flood storage when it is needed most - in the spring to handle the spring snow melt and in the fall to deal with remnants of tropical hurricanes. Water levels in the reservoirs are at their highest around June 1 and their lowest over the winter.

Figure 2-6. The location of large multipurpose reservoirs/dams in the watershed and the locations for the low flow operation targets

During high flow periods, water is held in the reservoirs, reducing the amount that flows downstream, lowering flood peaks. The reservoirs can reduce peaks significantly. For example, during a major flood in December 2008, peaks were reduced between 35-75%. Without the reservoirs, flood levels would have matched or exceeded the levels seen in May 1974 (one of the largest floods on record).

The water stored during the spring is released during the summer and fall to maintain minimum flows in the river system. Low flow augmentation is critical to the operation of municipal wastewater treatment plants to assist with assimilating wastewater effluent and to provide sufficient supplies for municipal drinking water systems that serve 500,000 residents in Waterloo Region, Brantford and Ohsweken.

The current river low flow targets guide the operation of the multi-purpose reservoirs and were established as part of the Grand River Basin Water Management Study in 1982. The river low flow targets were based on the volume of water that the reservoirs could reliably supply throughout the year.

2.3 Groundwater Systems

2.3.1 Overburden Aquifers

Major moraine systems, including the Orangeville and Waterloo interlobate moraines, and the Paris and Galt recessional moraines, are found in the Grand River watershed. The moraines are comprised of extensive sand and gravel units and provide significant amounts of groundwater for municipal and private use across the watershed. Figure 2-7 shows the location of moraines in the watershed. Additional significant groundwater resources are found within the Norfolk Sand Plain, which is located to the southwest of the City of Brantford.

The Orangeville Moraine, located in the northern portion of the Grand River watershed, is situated on the east side of Belwood Reservoir, and extends up to the west side of Orangeville. A high water table elevation is associated with this feature. A portion of the groundwater within the moraine tends to flow to the northwest towards the Grand River, while the remainder flows to the southwest towards the Credit River watershed[2]. Although not used for municipal supplies, the Orangeville Moraine is a highly permeable feature and has been identified as an area of significant recharge[3].

Located to the south of the Orangeville Moraine, the Waterloo Moraine is one of the largest moraines within the Grand River watershed. A number of aquifers situated within the moraine are used by the Region of Waterloo for municipal drinking water supply. Groundwater from the large aquifers within the moraine discharges to and maintains baseflow in many small coldwater tributaries and provincially significant wetlands (Figure 2-8).

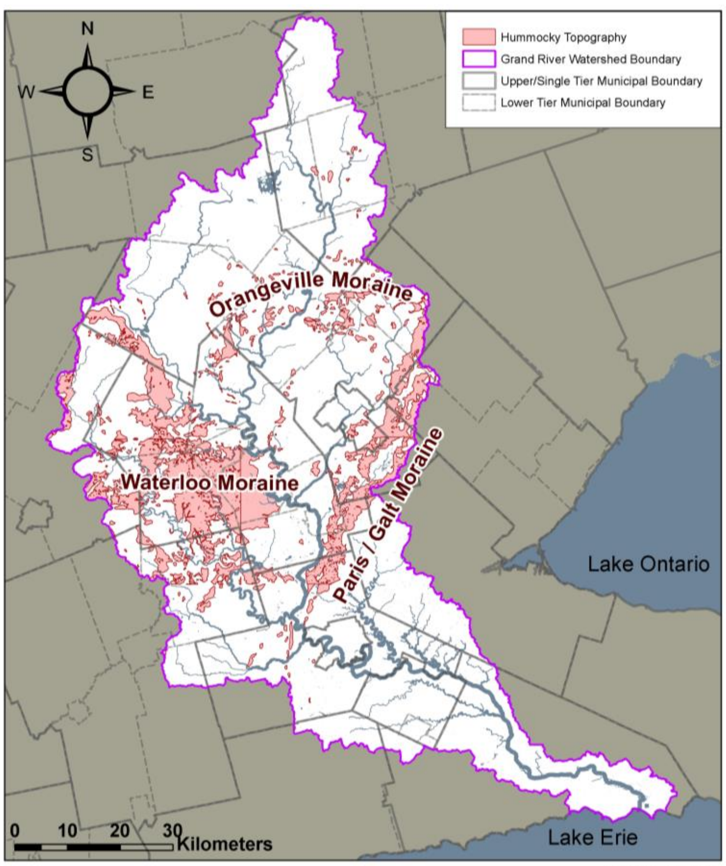

Figure 2-7. Moraine systems within the Grand River watershed.

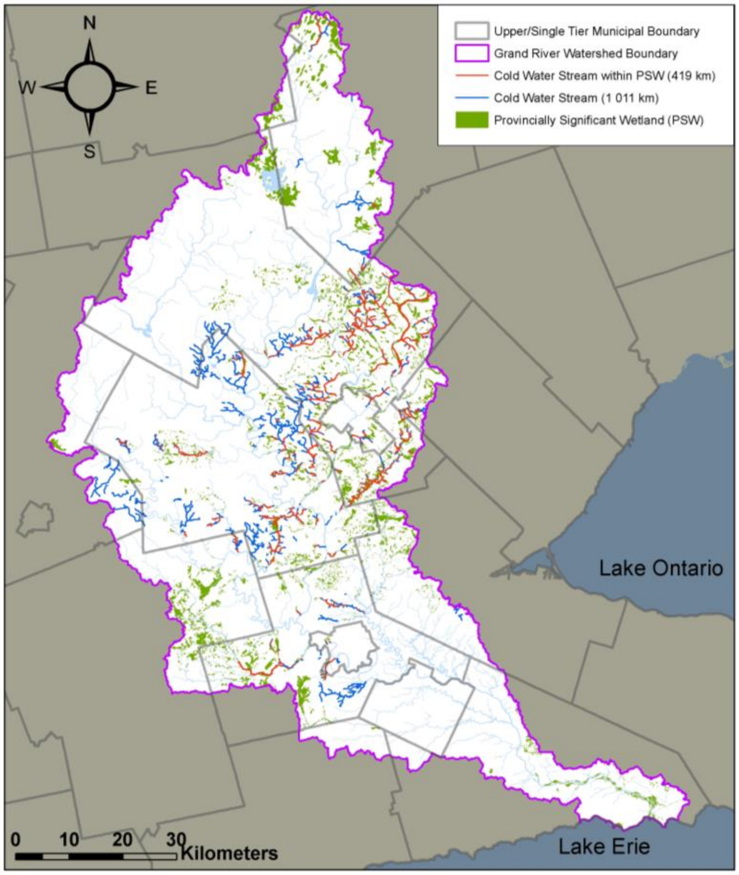

Figure 2-8. Location of cold water streams and provincially significant wetlands

Three major overburden aquifers, Mannheim, Greenbrook, and Parkway, are found within the Waterloo Moraine and supply 50% of the municipal groundwater supplies for the Region of Waterloo[3]. The Mannheim aquifer, composed of extensive thick sand and gravel layers is the primary aquifer within the moraine. Most of the Mannheim aquifer is unconfined and recharged by surface waters. The Greenbrook aquifer is located beneath the Lower Maryhill Till, an ice-deposited clay till which acts as a major aquitards, and generally within or above the Catfish Creek Till. The Greenbrook aquifer consists of layered gravels, sands and silts and is found on the flanks of the moraine. The Parkway aquifer, which is comprised of layered sands and gravel, generally overlays the Catfish Creek Till. It is found on the eastern flank of the moraine but is discontinuous and not laterally extensive.

In the St. George area, just north of Brantford, the Galt Moraine yields two local aquifers; a deeper aquifer which consists of 3 to 5 m of gravel deposits and a shallow sand and gravel aquifer [3].

Another significant groundwater system is within the Norfolk Sand Plain, located in the southwest portion of the Grand River watershed. The sand plain is composed of coarsely textured glaciolacustrine sand and silt deposits up to 25 m thick. The permeable sand and gravel deposits associated with the Norfolk Sand Plain yield good water supplies; however, they are particularly vulnerable to impacts from land use activities.

2.3.2 Bedrock Aquifers

Within the Grand River watershed, several bedrock units have the ability to transmit significant quantities of groundwater making them important for municipal and private use. These units include the Gasport Formation, the Guelph Formation and the Salina Formation.

The Gasport Formation underlies the Guelph Formation throughout the Grand River watershed with the exception of where it subcrops in the far eastern extents of the watershed. The formation, which is predominantly comprised of limestone and dolostone, ranges in thickness from 10 to 45 metres. Portions of the Gasport Formation have been subjected to varying degrees of solution enhancement (karstification), resulting in areas of higher porosity, which have enhanced the ability of the rock to transmit groundwater. A key example has been documented through recent work in the City of Guelph[4]. Here, the Gasport Formation is a highly productive aquifer where significant groundwater yields are derived from the middle section of the Formation, which is often termed the 'Production Zone'. The Production Zone exhibits a higher secondary porosity relative to the less fractured upper and lower zones. To date, the exact lateral extents of the production zone are unknown.

In the vicinity of the Production Zone and near the community of Rockwood, the Gasport Formation is overlain by the Eramosa Formation, which can be up to 20 m thick. This member, characterized by its black, shale-rich nature, behaves as an aquitard. Where the Eramosa Formation is present, the underlying Gasport Formation is not highly influenced by shallow groundwater recharge and discharge.

Overlying the Gasport Formation, the Guelph Formation forms a moderately productive aquifer. The largest groundwater yields from this formation are from the upper portion of the bedrock which exhibits a higher secondary porosity (typically more weathered and fractured) than lower sections of the Formation.

The Salina Formation overlies the Guelph Formation in the western and southern portion of the watershed. This formation is considered a moderately productive regional aquifer, supplying groundwater for both municipal and private use. Higher transmissivity values are a result of mineral dissolution and fractures which have developed in the upper bedrock. As a groundwater resource however, many wells are not drilled into this aquifer because of water quality concerns, as the natural water quality is often poor.

2.3.3 Aquifer Vulnerability

As a part of the Source Water Protection Program for the Grand River watershed, an aquifer vulnerability assessment was completed. Aquifer vulnerability is the analysis of an aquifer's susceptibility to contaminants introduced at the ground surface. The assessment is a physically-based evaluation of the geologic and hydrogeological character of the overlying sediments. The resulting calculations provide a rating of the intrinsic vulnerability of the aquifer of interest. The calculated vulnerability is highly dependent upon a number of factors which include the geologic structure, the hydraulic character of the sediments, the vertical hydraulic gradient and the hydraulic connection between the surficial recharge water and the aquifer of interest.

Figure 2-9 is a map of the aquifer vulnerability across the Grand River watershed. Details regarding the mapping are provided in the Source Water Protection Assessment report[5] for the Grand River watershed. For areas mapped as having highly vulnerable aquifers, it is estimated that the time of travel from the ground surface to the aquifer of interest is less than 5 years. For medium vulnerability, the travel time is from 5 to 25 years, and for low vulnerability, travel time is greater than 25 years.

Aquifers mapped as having high and medium vulnerability are generally shallow aquifers and although not used for municipal water supply, may be used for private, domestic use. These aquifers are most sensitive to impacts from land uses such as road salt, manure, and fertilizer applications.

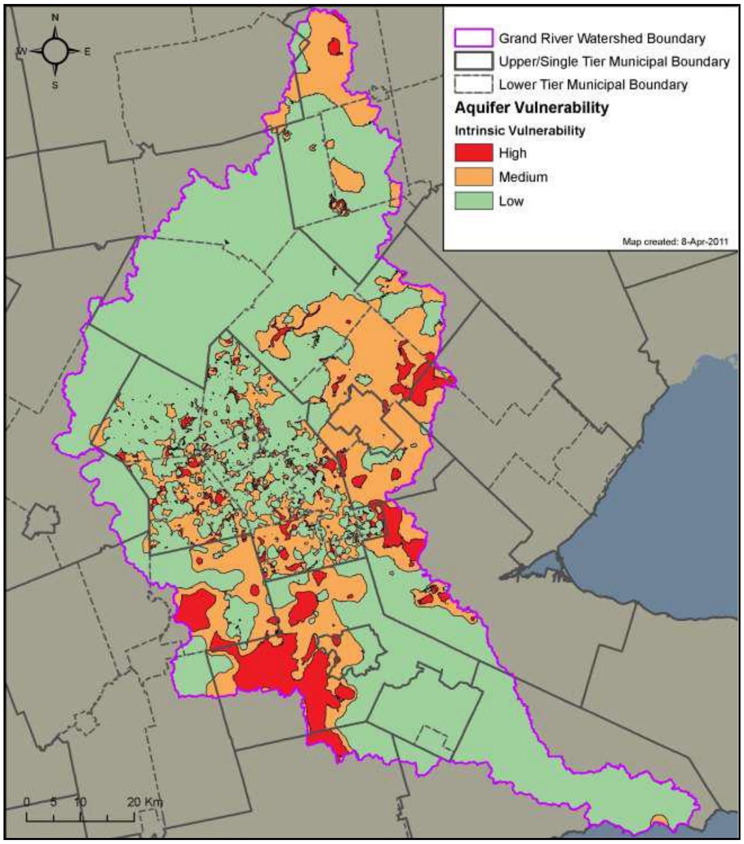

Figure 2-9. Aquifer vulnerability across the Grand River watershed

2.4 Key Hydrologic Processes

The movement of water above, on and below the surface of the earth is called the hydrologic cycle. Key processes within the hydrologic cycle include evaporation, transpiration, precipitation, infiltration, and runoff. The movement of water over the land surface (runoff) and movement of water down to the groundwater system (groundwater recharge) and back into surface water (groundwater discharge) are very important processes in the Grand River watershed and are described in more detail below.

2.4.1 Surface Runoff

Surface runoff, including snowmelt and urban runoff, is a key hydrologic process and contributes a large portion of the annual stream flow in watercourses throughout the watershed. Surface runoff will vary seasonally and is very weather dependent with much of the river flow produced from snow melt and after heavy rainfall. Areas that contribute the greatest runoff are illustrated in Figure 2-5.

Changes to the landscape of the watershed, including deforestation and urbanization, has greatly increased surface runoff resulting in higher flood flows and erosion. The multi-purpose reservoir system was built to manage high surface runoff from the upper till plains. The reservoirs capture the high flows from surface runoff and release the water slowly over a longer period to augment flows in the lower river system, thereby changing surface runoff from flood flow to base flow.

Surface runoff is highest in areas of tight soils with little vegetation cover and impervious areas. The upper till plains, especially in the upper Conestogo and Nith River watersheds, is an area of high surface runoff. Watercourses respond quickly to rain events and can carry high amounts of nutrients and sediment off the agricultural or rural landscapes. The Haldimand Clay Plain in the southern part of the watershed is another area of high runoff. This area is characterised by a tight drainage network and very high sediment loads.

Runoff is also generated from impervious surfaces in urban areas and tends to generate extreme amounts of streamflow over very short periods of time (i.e., streams are very flashy). Urban runoff is concentrated in the central portion of the watershed and either enters watercourses directly through storm sewers or through stormwater retention ponds. Urban runoff can contribute to localized flooding issues which may be further enhanced with an increase in intense storm events expected with climate change.

2.4.2 Groundwater Recharge and Discharge

Within the Grand River watershed, municipal and private well supplies and the baseflows in many cold water creeks and wetlands are reliant upon the processes of groundwater recharge and groundwater discharge.

Streams, creeks and wetlands depend on groundwater baseflows to sustain aquatic plant and animal communities (see Figure 2-8). Land uses such as urban development, and management practices such as the application of road salt, manure or fertilizer within groundwater recharge areas can directly impact the quality and quantity of groundwater discharge to these surface waters.

Glacial features within the watershed, such as moraines, hummocky topography, sand plains, gravel terraces, and exposed fractured or karstified bedrock function to encourage significant recharge to the groundwater system.

Areas that support high groundwater recharge, as shown in Figure 2-10, are primarily associated with the Orangeville, Waterloo and Paris/Galt moraines through the central portion of the watershed and the Norfolk Sand Plain in the southwest. Where recharge within the Paris/Galt and Waterloo moraines contributes to the groundwater within the overburden, the Orangeville moraine is a major recharge area that contributes to the bedrock aquifers in the region. In addition to the moraines, areas within the upper Grand watershed contain isolated, interspersed pockets of coarse-grained glaciofluvial outwash deposits which allow for high recharge rates. Areas with thin overburden cover, or exposed fractured or karstic bedrock also facilitate recharge to the groundwater system.

Substantial amounts of sand and gravel are associated with the moraines as outwash plains and spillways. Groundwater supported coldwater streams are quite common in these areas given the high permeability of the outwash deposits (see Figure 2-8). These features are often found adjacent to the flanks of the moraines, such as southeast of Cambridge, or in between the moraines, such as the Paris/Galt moraines in the Puslinch area.

The ice contact nature of the moraines also provides opportunity for kettles and kettle lakes, such as Puslinch Lake to form. Kettle features, along with the general hummocky topography of the moraines, give rise to many local wetland features. Wetland features are quite common adjacent to moraines where runoff from the slopes may collect.

Of the numerous moraines within the watershed, the centrally-located Waterloo Moraine is the largest, occupying approximately 9% of the total land area of the watershed.

Groundwater recharge within the Waterloo Moraine discharges to local surface water features in addition to critical down gradient reaches of the Grand River. Local tributaries which originate within the Waterloo Moraine include Laurel, Schneider and Strasburg Creeks. Much of the central core of the moraine is drained by Alder Creek, southward to the Nith River, and the western portion of the moraine is drained by several tributaries of the Nith River, including Bamberg, Baden, and Hunsburger Creeks.

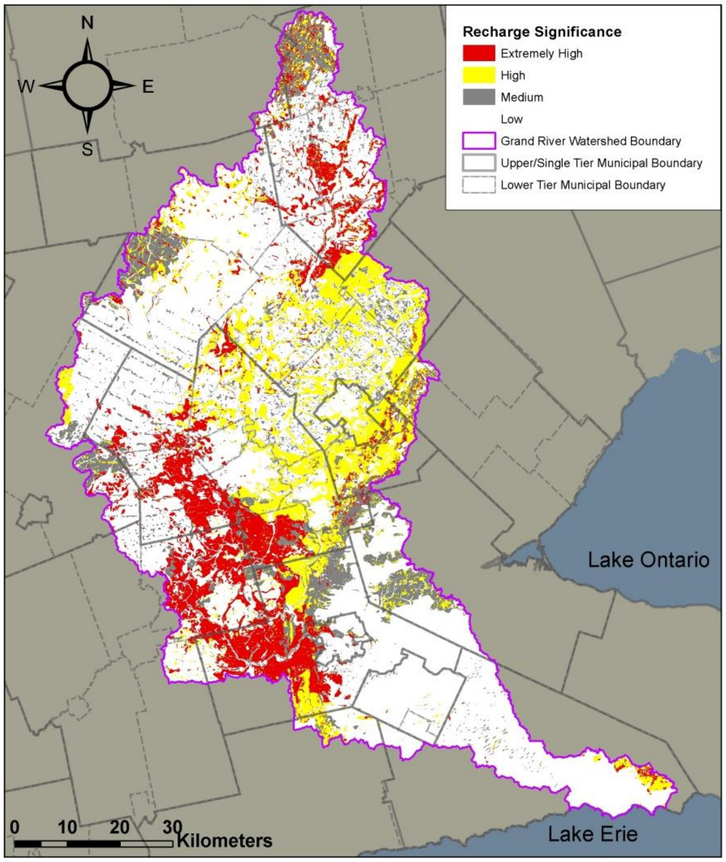

Figure 2-10. Areas that support significant groundwater recharge.

Groundwater discharge from the Waterloo Moraine to the Grand River provides substantial water quality benefits, as it helps to dilute pollutants from upstream wastewater treatment plants and runoff from urban and rural areas. In the reach between Cambridge and Paris, groundwater discharge, in combination with the river's steep gradient and limited direct drainage, contributes to water quality improvements downstream, including moderating temperatures and increasing dissolved oxygen levels[6].

The reaches of highest estimated groundwater discharge in the watershed are shown in Figure 11.. Other major areas of potential discharge to the Grand River include the reach between Legatt and Shand Dam, the reach below Elora through Kitchener, and the reach from Cambridge to Brantford[7].

The lower Nith River and some of its tributaries including Cedar Creek receive large quantities of groundwater discharge from moraines and other coarse-grained deposits. This area of the Nith River watershed is characterized by thick deposits of coarse-grained sand and gravel which support extensive overburden aquifers. Both local and regional groundwater flow systems may contribute to groundwater discharges through this subwatershed.

The lower Eramosa River including Blue Springs Creek and the Speed River below Guelph pass though areas receiving groundwater discharge. The lower Eramosa River receives discharge from both bedrock aquifers and overburden sediments[8]. Unconfined aquifers are located along much of the river's length in this area. Groundwater discharge contributes to healthy coldwater aquatic ecosystems in this subwatershed.

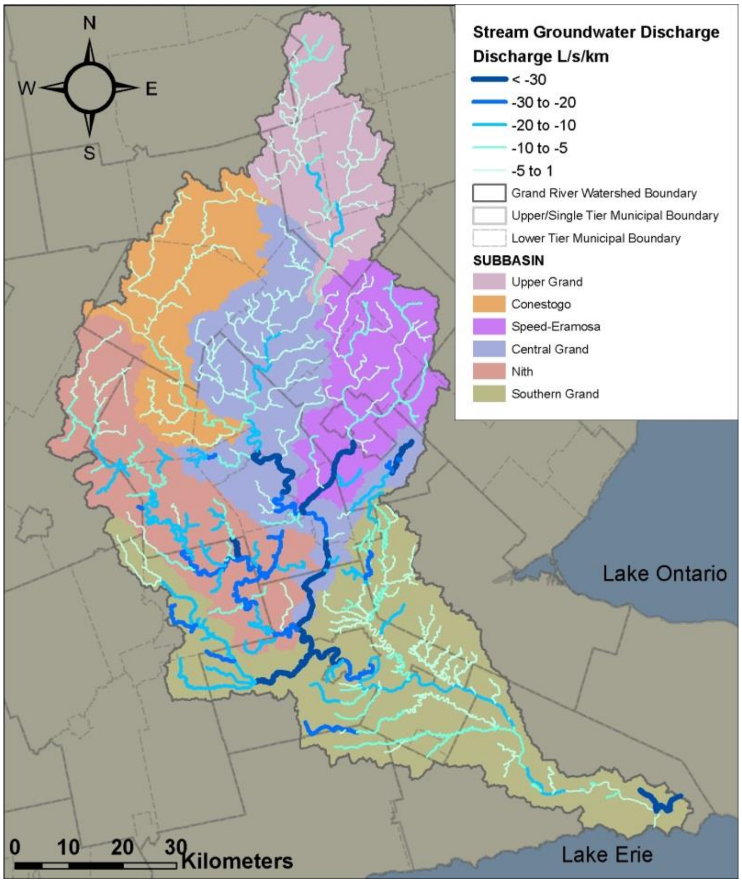

Figure 2-11. Potentially important groundwater discharge reaches in the Grand River watershed.

Whitemans Creek flows through a large groundwater discharge zone. Springs and seeps can be found along parts of the creek, which also supports a coldwater fishery. Whitemans Creek flows through the upper part of the Norfolk Sand Plain, an area characterized by thick deposits of coarse-grained and highly permeable sand. High recharge in this subwatershed supports an unconfined overburden aquifer, which in turn discharges to the creek.

Beneath the overburden cover, the Gasport, Guelph and Salina bedrock aquifers extend from the Bruce Peninsula in the north towards Burlington in the south. Regional recharge to these formations can occur where the aquifer is unconfined or exposed, as in the eastern portion of the watershed. Other areas that allow for recharge waters to enter the aquifer, such as the Dundalk Dome located to the north, or along the Niagara Escarpment to the east, are located outside the Grand River watershed. Groundwater recharge to these systems does not exclusively enter and discharge within the watershed. These formations are a regional aquifer system, and therefore do not have flow boundaries that coincide with the watershed. Therefore land use activities outside the boundaries of the watershed may impact the quality and quantity of the groundwater within these aquifers within the Grand River watershed.

Numerous reaches of the Grand River and its tributaries, notably the Grand River through Fergus-Elora, the lower Eramosa River and Blue Springs Creek are supported, in part, by baseflows originating from bedrock.

2.5 Key Hydrologic Functions of Watershed Features

In addition to the key hydrologic functions provided by the large dams and reservoirs (e.g., maintaining water on the land, flood reduction and low flow augmentation), water management in the Grand River watershed is highly dependent on the key hydrologic functions provided by many of the natural physical features of the watershed. These features allow for critical hydrologic processes, such as infiltration and groundwater recharge, groundwater storage and discharge, depression storage and overland runoff, to occur. Natural watershed features include the general physiography and topographic relief, the permeability of the soils and geologic materials and the stream and river system itself. While not a comprehensive list, the following natural hydrologic functions of key watershed features were noted during the development of the *Plan* to be particularly important:

- Moraines (e.g., Waterloo, Paris Galt, Orangeville), closed drainage features (e.g., hummocky topography), gravel terraces, sand plains and exposed bedrock provide key hydrologic functions for precipitation to recharge and replenish the groundwater system;
- Forests, wetlands and closed drainage features/depressions (e.g., hummocky topography) provide a key function by holding water and soil on the land to reduce flood flows, recharge the groundwater system, and reduce erosion and sediment delivery to surface waters;
- Streams and rivers and their associated floodplains and riparian areas provide for key hydrologic functions by conveying water, transport sediment and assimilating nutrients from both natural sources and human and animal wastes;
- Aquitards (e.g., overlying clay-rich till units, Eramosa bedrock formation) provide natural protection for groundwater resources to prevent aquifer contamination and direct groundwater flow;
- Aquifers within the watershed provide for groundwater storage which then sustains groundwater discharge that maintains baseflows in streams and rivers as well as maintain wetlands; and
- Healthy soils, with high organic content, provide an important hydrologic function by keeping moisture and water on the landscape.

In general, these key hydrologic functions are provided by the soils, geology, topography and vegetative cover within the watershed and are part of the watershed's natural heritage system. Important linkages between the Water Management Plan, Forest Plan and Natural Heritage Strategy are through the natural watershed features that provide these key hydrologic functions. Therefore, it is important to consider both the local and watershed scale effects that these important watershed features provide within municipal and watershed planning processes.

2.6 Critical Watershed Issues

2.6.1 Land Use and Population Growth Trends

The Grand River watershed is one of the richest agricultural regions in Canada. About 70 % of the land is actively farmed. Agricultural production in the watershed is evenly split between cash crops (e.g., corn, soya bean, grains, hay) and livestock (e.g., cattle, hog, chickens) production.

Specialty crops such as vegetables and root crops make up a small portion of the total watershed area but are concentrated mostly in the Norfolk Sand Plain. These crops rely heavily on irrigation, sourced from both surface and groundwater sources. During periods of drought, conflicts among water users have occurred in the lower Whitemans, Mount Pleasant and McKenzie Creek subwatersheds.

Given the importance and extent of agricultural production in the watershed, fertilizers, farm chemicals and animal waste must be properly stored, handled and used to minimize impact on rivers, streams and groundwater.

Although rural land use is not expected to alter dramatically in the future, trends in agriculture are difficult to predict and hard to quantify. What happens in the future will depend on several factors including costs of production, market opportunities, commodity prices, and the value of the Canadian dollar. Some recent trends noted by the Ontario Ministry of Agriculture and Food and Rural Affairs (OMAFRA) are decreasing numbers of farms and fewer farmers, increasing farm sizes, more retirement and lifestyle farms, and increased mechanization[9]. The most recent data shows that the trend in the number of small farms may be reversing because of the growing popularity of local food markets. All of these factors can influence agricultural production and its impact on the water resources in the watershed into the future.

The large urban areas are concentrated in the central region of the watershed and represent about 7% of the total area. However, much of the urban settlement in the watershed is on the moraine features within the central region. Urban land use covers as much as 30% of the Waterloo Moraine[6]. With the Province's growth strategy focusing on urban intensification, the extent of the urban land area is not expected to increase substantially over time yet protecting the key hydrologic functions of the moraine features in the watershed becomes increasingly important given the intensification of land use.

Forests and wetlands combined cover about 20% of the total watershed area however; forest and wetland cover ranges from a low of 13% in the Conestogo River basin to a high of 34 % in the Eramosa River basin. Significantly increasing forest cover watershed-wide is a slow process but must be continued to protect vulnerable/highly erodible areas, keep water and nutrients on the landscape, and protect stream channels. Active tree planting programs are making gains in riparian buffer establishment and in retiring or sheltering erodible soils throughout the watershed.

The Grand River watershed is located directly west of the Provincial Greenbelt, and much of the watershed falls within the Greater Golden Horseshoe. Significant population growth is estimated to occur in the watershed over the next 25 years, specifically in the downtown core areas of the cities of Kitchener, Waterloo, Cambridge, Guelph and Brantford which have been identified as urban growth centres.[10] About 80% of the watershed's 970,000 residents live in these five cities.

A 2010 analysis of municipal growth projections for the Grand River watershed estimated that by 2051, the watershed population will reach 1.53 million people.[11] Figure 2-12 shows the 2010 population projections for the Grand River watershed, compared to the population forecasts used in the 1982 Basin Study. The population growth projections in the 1982 study closely approximate the current "medium" growth forecast for the watershed to 2031.

The policies of the provincial growth strategy – The Growth Plan for the Greater Golden Horseshoe[12], direct development to uptown or downtown cores of the currently designated urban areas and serviced settlement areas. In June 2013, these growth projections were extended to 2041. The projections suggest that the growth rates between 2031 and 2041 in watershed municipalities will slightly exceed those identified in the 2010 population projections for the Grand River watershed.

Since the ground and surface water systems in the watershed provide for municipal drinking water supplies and waste assimilation, the projected population growth in the watershed will require careful and ongoing water supply, wastewater and stormwater planning to ensure safe and secure water supplies and to improve ground and surface water quality.

Generally, the municipal representatives on the Project Team believe that the population increase can be accommodated within the currently designated urban areas. For this reason, the additional land area (if any) required to accommodate the projected population growth and the impacts of an expanding urban footprint beyond the currently designated urban areas and serviced settlement areas have not been factored into this *Plan* (IAP A.3).

Without careful planning, population growth, combined with the effects of urban and agricultural land use, can lead to reduced availability of water supply, acceleration in water demand and increased contaminant loads to surface and ground water, directly affecting the hydrology and ecology at the watershed scale beyond municipal boundaries.

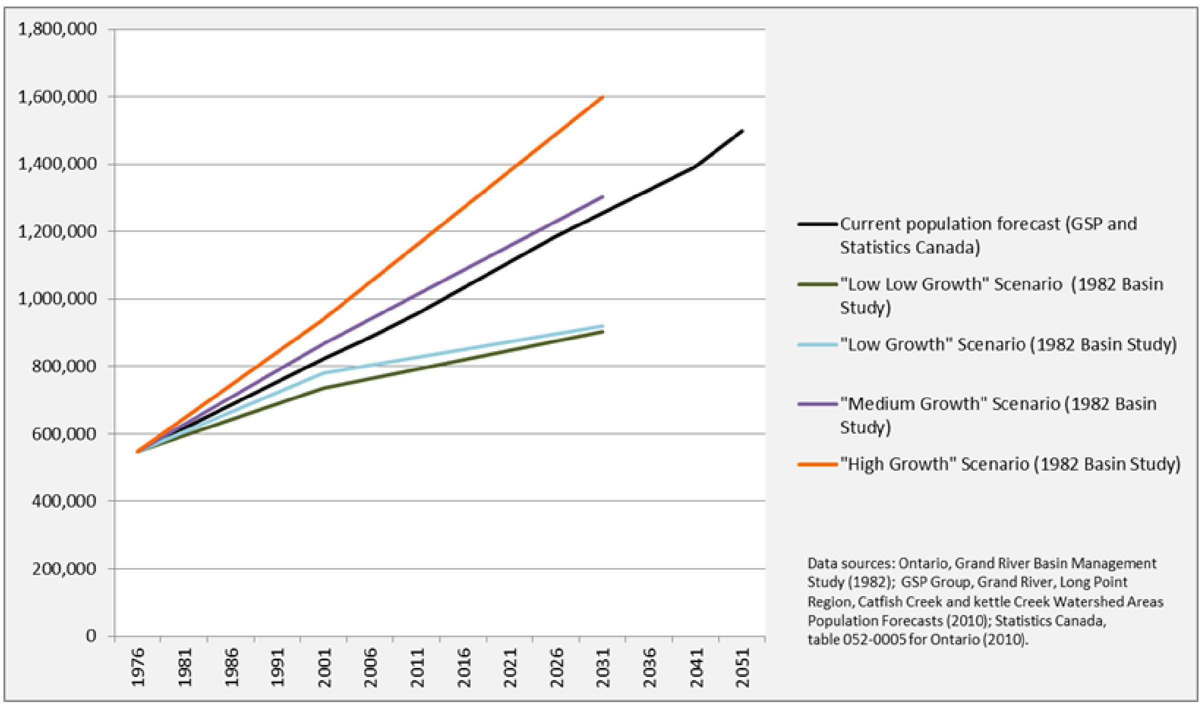

Figure 2-12. Population growth projections for the Grand River watershed.

2.6.2 Climate Change

A changing climate will undoubtedly affect the key hydrologic processes in the watershed. Possible effects, as predicted by global climate models, may include changes to temperature and precipitation on both an average annual and average seasonal basis.

Most climate change models predict that the winter season will be warmer and receive a greater amount of precipitation. Warmer temperatures will likely cause more mid-winter melt events with more precipitation falling as rain rather than snow. This will result in higher winter stream flows, a smaller snow pack, less ice cover and more winter runoff and groundwater recharge. Consequently, there may be a shift in the timing and magnitude of runoff events which will have implications to the management of the large water management reservoirs to mitigate floods or augment flows during the summer. Further, increased runoff during the winter and spring has the potential to move more nutrients off the land and into watercourses affecting water quality while changes to ice cover and fluctuating winter temperatures may increase ice jams and associated flooding.

Climate models also predict that the variability in weather patterns will increase with more year to year variability as well as an increase in both intense storms and prolonged droughts. Current global climate models show strong trends towards shifts in seasonal and average annual conditions. Although intense weather events will likely increase in the future, there is less certainty in the frequency and magnitude of these events. Nonetheless, intense rainfall events can produce high runoff that can overload storm sewer systems resulting in localized urban flooding and increased rural erosion and soil loss.

Climate modeling also shows a trend toward a shift in the seasons with spring and summer conditions occurring earlier and fall conditions starting later. This can result in a prolonged low flow period. There is also a weak trend to a drier, warmer summer period. Warmer air temperatures will likely warm water temperatures and affect the water's ability to hold oxygen. Warmer water may impact aquatic life such as cool or coldwater fish species. Longer periods of dry conditions will put more pressure on the water management reservoirs to continue to augment flows to assist with wastewater assimilation as well as ensure adequate supply for municipal water supply takings. Longer dry periods will increase water use conflict and put stress on the aquatic ecosystems.

It is unknown how the seasonal shift in precipitation will impact critical groundwater recharge processes in the watershed. Groundwater recharge and discharge helps to sustain baseflows in many local creeks and helps to moderate water temperatures.

Although many of the climate change models are at a global scale, attempts have been made to scale down to account for local or regional weather patterns such as convective storms and lake-effect snow from the influence of the Great Lakes. Climate change modelling in the Grand River watershed was completed using the change field method to adjust future climate data sets and input into a hydrologic model of the Grand River watershed and reservoir yield model to evaluate changes in watershed scale hydrologic processes and stream flow[13]. Results of this study suggest:

- Air temperature is likely to increase; increases ranging from 1.8 to 4.0 C;
- Greater precipitation in the winter; less precipitation in the summer and high variability precipitation through the spring and fall;
- More frequent winter melts with less frozen ground conditions; earlier spring; more runoff and infiltration in the winter and reduced infiltration in the summer;
- Annual changes in infiltration ranging from -10% to +14% across the watershed; and
- Longer low flow season now extending from April/May through October. The May-September period saw lower flows for all but one future climate data set.

Overall, the range of variability in future climates will be similar to that experienced in the past. Large changes outside the range previously observed are not expected; however, it is likely that the frequency of extreme events, both floods and droughts, will increase.

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3 A Foundation for Integrated, Adaptive Water Management

To build a strong foundation for an integrated, adaptive water management plan for the watershed, it must align with the watershed *Vision*. It must also have specific goals (see Introduction).

The management of water is shared across many agencies in Ontario. Therefore, the foundation for integrated, adaptive water management is having a process through which all watershed stakeholders, including the '*implementers'*, provide input and guide the development of a Plan. *Implementers* are key decision makers who can take ownership of and complete specific actions.

Part of the foundation includes the identification of the human uses, ecological needs and the social and cultural values of water in the watershed. These 'uses, needs, and values' underpin the broad water objectives for the watershed.

To measure progress towards achieving the broad water objectives, indicators were identified. The list of indicators for the Water Management Plan is not comprehensive but provides a start with which to monitor and report on progress. Further, a broad range of information was reviewed to identify quantitative targets or thresholds with which progress towards achieving the broad water objectives could be measured. Indicators were identified for aquatic ecosystems, water supply, public health and safety and recreational, cultural and tourism uses. Indicators were identified for both surface water and ground water as well as both water quality and quantity.

3.1 A Vision for the Watershed

The process for updating the *Plan* is based on the shared *Vision* for the watershed by all of the watershed stakeholders and key implementers. The watershed *Vision* was derived from The Grand Strategy[14] which was developed as part of the designation of the Grand River as a Canadian Heritage River in 1999 and updated in 2004. The *Vision* for the Grand River watershed includes the following elements:

- Ecological integrity;
- Clean, sufficient water;
- Minimal flooding and erosion;
- Economic prosperity and growth;
- World class outdoor recreation;
- Heritage appreciation and diversity; and
- A superior quality of life.

3.2 Broad Water Objectives

Support for the *Vision* of a healthy watershed and the goals for the Water Management Plan is developed through the process of compiling implicitly and explicitly stated ***Broad Water Objectives*** in the Grand River watershed. *Broad water objectives are qualitative descriptions of a desired state or system condition in the Grand River watershed that meets the current uses, needs and values of ecosystems, communities and economies*.

The process of compiling these broad water objectives was fundamental to the Water Management Plan because it gathered the collective viewpoints of the *Plan* partners and other stakeholders to build a common understanding and collective approach to water management in the Grand River watershed.

The *Broad Water Objectives* are based on the human uses, ecological needs and social and cultural values (i.e., uses, needs, and values) for water in the watershed and are listed in Table 3-1. The objectives, listed in Table 3-2, build on and reaffirm existing community values and aspirations expressed in plans that have been developed in the Grand River watershed through public input. Both the uses, needs and values and broad water objectives are fully documented in a report[15].

3.3 Indicators and Targets

To assess the status of current conditions relative to desired conditions as expressed by the *Broad Water Objectives*, sets of resource condition *indicators* and *targets* were established for the *Broad Water Objectives*.

An ***Indicator*** is a variable that is typically measurable and reflects a quantitative or qualitative characteristic of a water resource. Further, a ***Target*** is a science-based, quantitative description of a resource condition that will cause the objectives to be met. *Targets* can be a minimum, maximum, range, single value or regime, general to the Grand River watershed or specific to a selected area.

To provide science-based measures of desired conditions, targets were derived through consultation with technical experts and a review of the most current information available. This process resulted in the identification of resource condition indicators and targets for the Water Management Plan that focuses on:

- Healthy aquatic ecosystems;
- Water supply;
- Public health and safety; and
- Culture, recreation and tourism uses.

The list of indicators and targets in the *Plan* is not comprehensive, but the data and information gaps highlighted by this process have led to a number of recommendations and actions that will enable the creation of additional indicators and targets in the future.

Table 3-1. Uses, needs and values for water in the watershed.

Theme	Use/Need/Value
Healthy, resilient natural system	Aquatic, riparian, wetland and associated Lake Erie habitat is dependent on the quantity, quality and flow of surface and ground water.
	Aquatic species in the river system and portions of Lake Erie are dependent on the quantity, quality and flow of water.
	Wildlife use surface water for foraging and drinking.
Community services	Surface and ground water provide a source of water for municipal supplies that support people and industry.
	Groundwater is a source for private domestic drinking water supplies.
	Surface waters receive treated wastewater and storm water.
A strong economy	Surface and ground water provide a source of water for municipal supplies that support business and industry.
	Surface and ground water are a private source of water for commercial/industrial activities that are not on municipal water services, including: • food and beverage production, • aquaculture, and • aggregate washing.
	Surface and ground water are a source of water for crop irrigation and livestock watering.
	Agricultural lands are dependent on adequate drainage and optimal soil moisture to support productivity.
	Grand River – Lake Erie commercial fisheries are supported by water quality and quantity.
	The flow of water supports hydroelectric power generation.
Culture, recreation and tourism	Rivers, streams, lakes and reservoirs are used for recreation: • swimming at public beaches, water skiing, • paddling, sailing, • motorized boating, • angling, and • passive enjoyment of trails and natural areas.
	Surface and ground water are used to irrigate the landscape in public and private recreational areas.
	Aquatic and riparian systems, wetlands and associated Lake Erie near shore have cultural importance: • as a community amenity and focal point, • for cultural heritage, and • traditional and spiritual values.

Table 3-2. Broad water objectives.

Theme	Broad Water Objective
Aquatic ecosystem health	Water quality supports the health, resiliency and biodiversity of aquatic, riparian and wetland communities.
	The flow regime supports the lifecycle requirements of aquatic and riparian species.
	Water quality does not promote excessive growth of aquatic vegetation or harmful algal blooms in rivers, reservoirs and lakes.
	Interactions between the Grand River and Lake Erie support the chemical, biological and physical integrity of both systems.
	The flow regime supports healthy river processes.
	Groundwater recharge and discharge function is maintained, such that water quality, water availability and habitat are supported.
Water supply	Quantity of water for municipal supplies is reliable and able to meet current and future needs.
	Quantity of water for agricultural and commercial/industrial users is reliable and able to meet their current and future needs.
Public health & safety	Surface and ground water used by municipalities is of suitable quality to produce safe drinking water using economically feasible treatment processes.
	Surface and ground water used by the agricultural industry for crop irrigation or livestock watering is suitable to produce safe, quality food.
	Groundwater supplies used for private drinking water supplies meet or are better than the drinking water quality standards, with the exception of natural conditions related to geology.
	The risk to life and property from flooding and erosion is managed.
	Water quality does not restrict human consumption of fish.
	Restrictions on swimming at public beach areas are minimized.
Culture, recreation & tourism	The rivers are an amenity in the communities through which they pass.
	The rivers are aesthetically pleasing to support recreational, cultural and destination tourism uses.
	River flow is sufficient to reasonably support paddling where river flow is regulated.
	Water quality and quantity needs of sport fish populations are met, such that angling opportunities and community benefits are realized.
River services	The provision for wastewater assimilation is optimized without adverse impacts on the ecosystem or human uses.
	The provision for urban drainage is optimized without adverse impacts on the ecosystem or human uses.
	The provision for drainage of productive agricultural land is optimized without adverse impacts on the ecosystem or human uses.
	Hydroelectric power production is a secondary benefit of river flow when it is cost effective.
	Water quantity and quality are sufficient for optimal production of Grand River-specific stocks for commercial fisheries.

3.3.1 Healthy Aquatic Ecosystems

The *Broad Water Objectives* stated for the Water Management Plan describe many aspects of healthy aquatic ecosystems such as:

- Healthy, resilient and diverse aquatic, riparian and wetland communities;
- Striving for a moderate amount of aquatic vegetation and algae growth that is beneficial for aquatic food webs, but not excessive growth that can be harmful to aquatic organisms;
- Ensuring the chemical, physical and biological integrity of the river and lake ecosystems; and
- Meeting the water quality and quantity requirements of aquatic species including those targeted by sport and commercial fisheries.

The desired conditions described by the *Broad Water Objectives* require the maintenance, enhancement or restoration of critical watershed functions which in turn, help to sustain healthy aquatic communities. Targets were identified that are supportive of healthy aquatic ecosystems; these provide quantitative measures of indicators that characterize the resource conditions required by aquatic communities. Technical experts were consulted through a series of working group meetings and workshops to derive indicators and targets for the environmental flow regimes and water quality requirements that meet the broad water objectives for healthy aquatic ecosystems. Details of the rationale and development of the indicators and targets are documented in a number of technical reports which can be found at www.grandriver.ca/wmp:

- "*A Framework for Identifying Indicators of Water Resource Conditions*"[16],
- "*Water Quality Targets to Support Healthy and Resilient Aquatic Ecosystems in the Grand River Watershed*"[17] ; and
- "*Environmental Flow Requirements in the Grand River Watershed*"[18].

3.3.1.1 Water Quality

To identify indicators for water quality supporting ecosystem health, an approach was piloted for the Lake Effect Zone – the interface between the Grand River and Lake Erie. This process considered the needs of Lake Erie and the Grand River system, and highlighted conditions which would be of mutual benefit to both systems. A framework was developed to identify potential indicators, which built on recent directives that were derived using a science-based approach and developed with public input. Because the framework for indicator identification builds on these existing directives, it describes a process that is grounded in science and supports the values of local communities and other stakeholders.

The approach for identifying resource condition indicators for water quality was based on the most current collective knowledge and understanding of critical ecosystem functions. Detailed information about a small subset of aquatic species was synthesized to identify some of the critical water quality needs that are not currently met in the area of focus. This synthesis of information worked towards an ecosystem approach using a subset of the broader community. It is expected that actions that are beneficial to the selected species will have broader benefits for the entire aquatic community.

A high level assessment of information on other key areas of the watershed, such as the central Grand River region and the headwater regions, indicates that some of the basic resource condition requirements for a broad range of ecosystems are covered by the initial list of indicators. However, toxic forms of nitrogen (ammonia and nitrate) and chloride were also identified as important indicators.

Partners participating in the water quality working group will continue to develop a more complete set of indicators, using a process similar to the framework applied in the Lake Effect Zone, in other areas of the Grand River watershed with unique ecological characteristics, natural resources, and driving pressures (e.g., Exceptional Waters, Tailwater reaches, central Grand River) (IAP B.2). Work will also continue, in partnership with academia, to develop appropriate biological indicators that best represent the health of the river system which will assist with evaluating the goal to improve river health (IAP D15).

To develop targets for each of the resource condition indicators, information was sought on the desired ecological endpoints and potential natural sources of variability (e.g., seasonality, flow regime). Existing guidance and supporting scientific information were reviewed from various jurisdictions (e.g., Canadian, provincial and United States) and evaluated in the context of the Grand River watershed.

Water Management Plan water quality targets for the indicators of resource conditions required for ecosystem health are listed in Table 3-3, along with the specific ecosystem requirements the target supports.

Work will continue to develop targets for total suspended sediments/solids, turbidity and nutrients (IAP B.2).

3.3.1.2 Flow Regime

Environmental flows (e-flows) describe "*the quantity, quality and timing of water flows required to sustain freshwater ecosystems and the human livelihoods and well-being that depend on these ecosystems:* (Brisbane Declaration, 2007)".

The E-flows Working Group recommended a critical suite of flow processes or functions necessary to support the broad water objective of "*a flow regime that supports healthy river processes*", and is described in Table 3-4 along with the required frequency and duration needed for these processes and functions to occur.

Flows that support ecological health and healthy river processes for specific river reaches are listed in Table 3-5.

The choice of indicators and the identification of flow regime targets for aquatic ecosystem health are documented in *Environmental Flow Requirements in the Grand River Watershed* [18].

Since many of the flow thresholds are deterministic (i.e., have been determined from physical channel and substrate measurements), it is recommended that the flow thresholds be verified during the next several years to determine whether the flows are meeting their intended purpose. This will require spot verifying in the field as these events occur (IAP C.9).

Table 3-3. Recommended water quality targets for aquatic ecosystem health in the Grand River watershed

Indicator	Frame of reference for target	Target
Dissolved oxygen (daily fluctuation)	Sufficient to support **physiological requirements** of aquatic organisms (Low risk of hypoxia or lethal effects in sensitive species)	*Daily minimum above a threshold of:* 4 mg/L; or 5 mg/L where a coldwater fish community is expected to be present; or 6 mg/L where sensitive species or early life stages are expected to be present
Dissolved oxygen (chronic conditions)	Sufficient to support **physiological requirements** of aquatic organisms (Low risk of sub-lethal effects from long term exposure, e.g., reduced growth or reproduction)	*Average of daily minima over 30 days above a threshold of:* 5.5 mg/L; or 6.5 mg/L where a coldwater fish community is expected to be present
Suspended sediment (event-driven peaks)	**Low risk of harmful effects** of suspended sediment (e.g., harm to fish and invertebrates from smothering, gill clogging)	Tiered framework, based on background* and dose-response for the most sensitive type of organism expected to be present Further work needed to develop site-specific numeric targets
Turbidity (chronic conditions)	**Water clarity** that supports processes leading to healthy plant and animal communities (e.g., visual cues to behaviour, underwater plant growth)	Background *below* a threshold of 20 NTU during the growing season
Nitrate (toxicity)	**Low risk of toxicity causing harmful effects** including sub-lethal effects from long term exposure	Concentrations of nitrate *below* a threshold of 3.0 mg/L as N (as representing chronic conditions)
Ammonia (toxicity)	**Low risk of toxicity causing harmful effects** including sub-lethal effects from long term exposure	Concentrations of unionized ammonia *below* a threshold of 20 µg/L (or expressed as total ammonia concentrations, varying with temperature and pH)
Water temperature (shift in thermal regime)	**Thermal regime** consistent with physiological requirements of natural communities (range of preferred or tolerable temperatures)	Tiered framework, based on the most sensitive members of the aquatic community expected to be present
Phosphorus and nitrogen (nutrient enrichment)	**Productivity regime** supporting mesotrophy in rivers and streams (as defined by desired ecosystem features and functions)	Further work needed to develop numeric targets for all types of rivers and streams in the watershed

**Background does not include high flow events; and should be assessed on the basis of hydrologic state (e.g., clear flow or turbid flow)*

Table 3-4. Key thresholds for healthy flow regime functions and processes

Category	Threshold	Description	Frequency	Duration
Channel Maintenance	**Bed Mobilizing ($>D_{50}$)**	A maintenance flow to resort or loosen the top 5-10 cm of the river bed, mobilize finer sediments	Every year or two	A flow event that reaches the flow threshold for a day
	Scour / Deposition (D_{50})	A maintenance flow to suspend and move superficial fines and organic material, prevent homogeneity in the channel	Twice annually	A flow event that reaches the flow threshold for a day
Nutrient Management and Biological Function	**Floodplain Inundation for Spawning** (>bankful+30cm)	A flow depth of 30 cm over low-lying spawning areas in the lower order streams suitable for spring spawning	Once every two to five years in the spring spawning season	For two consecutive weeks with slow recession
	Floodplain Nutrient Cycling (>bankful)	Inundation of floodplain areas allowing settling of fine sediments and nutrients to the floodplain	Annually	For a few hours to days
	Macrophyte Flushing	To remove excess and nuisance aquatic vegetation	Twice annually, summer and fall	Daily average flow
Low Flows	**Littoral Zone Maintenance**	Flow that maintains a littoral zone of 10 cm depth	May to Nov; Dec to March	Minimum 7-day average flow
	Longitudinal Connectivity	A water depth that allows fish movement between pools	Year-round	Minimum daily flow

Table 3-5. Flow needs for aquatic ecosystem health and healthy river processes

Flow Thresholds (m^3/s)	Grand River near Doon	Grand River above Brantford	Speed River below Guelph	Speed River at Hespeler	Eramosa River above Guelph	Whitemans Creek near Mt Vernon
	(m^3/s)					
Bed Mobilizing (D50)	187	161	25.6	47	n/a	n/a
Scour / Deposition	85	78.5	7.9	36.6	n/a	n/a
Floodplain Inundation for Spawning	100-150	300-350	24	50	n/a	n/a
Floodplain Nutrient Cycling	400	>405	>37.6	>31.7	n/a	n/a
Macrophyte Flushing*	297	102	56.7	30.8	n/a	n/a
Littoral Zone Maintenance	8.5	19	1.1	1.5	n/a	n/a
Longitudinal Connectivity	6.8	8.8	0.52	1.1	0.5	1.0

*could use bed mobilizing flows as a surrogate

3.3.1.3 Groundwater Recharge and Discharge

Maintenance of the groundwater recharge and discharge processes and functions, such that water quality, water availability and habitat are supported, is a *Broad Water Objective*.

Groundwater recharge can be monitored through programs such as the Provincial Groundwater Monitoring Network (PGMN). Within the Grand River watershed, there are 28 PGMN wells at 21 locations. The Grand River Conservation Authority (GRCA) also maintains a number of other monitoring wells associated with various studies, such as the Dundas Valley investigative study[19].

The groundwater recharge function can also be monitored through sensitive wetlands such as fens. These systems are supported largely by groundwater discharge; therefore, changes to sensitive wetlands can be indicative of changes to the local groundwater regime.

Groundwater discharge to the river and its tributaries is of key importance because it sustains baseflow for streams and wetlands and moderates water temperatures year round.

Streamflow, and more specifically baseflow, in groundwater-fed streams is another indicator of groundwater recharge and discharge. Maintenance of recharge and discharge can be monitored through the analysis of long-term trends at stream gauge locations.

Although monitoring for long term trends in baseflows is advised for important groundwater discharge areas such as the Grand River between Cambridge and Brantford, the lower Speed River and the lower Nith River (IAP C.10), baseflow separation is complicated by the effects of reservoir and wastewater treatment plant discharge. Analysis on smaller, unregulated streams (e.g., Blue Springs Creek, Mill Creek, Hunsberger Creek) can provide an alternative, particularly where there is a long enough streamflow record to establish a baseline (IAP C.11).

3.3.2 Water Supply

A goal of the Water Management Plan is to ensure sustainable water supplies for communities, economies and ecosystems.

One of the *Broad Water Objectives* is to ensure that surface and groundwater quality is of suitable quality to produce safe drinking water using economically feasible treatment processes. The municipal supply, in turn, supports communities and industries, and is fundamental to the continued prosperity of the communities in the watershed.

A multi-barrier approach to managing drinking water safeguards public health. The first barrier in a multi-barrier approach is watershed management to maintain or improve source water quality. Improving source water quality may reduce the required amount of water treatment which can reduce the production of treatment by-products and minimizes operational costs.

3.3.2.1 Groundwater Supplies as Drinking Water Sources

Approximately 82% of the population of the Grand River watershed relies on groundwater as a clean, safe, domestic water supply. Groundwater resources are found within both bedrock and overburden aquifers. In addition to providing the population with a source of water, groundwater is used in agriculture, industrial, and commercial operations. Municipal groundwater systems are described in more detail in the Grand River Source Protection Area Approved Assessment Report[5].

There are 42 municipal supply systems within the Grand River watershed that rely on groundwater as a drinking water source. The systems are found in the following counties and cities: County of Grey (1 system), County of Dufferin (3 systems), County of Wellington (7 systems), County of Perth (1 system), City of Guelph (1 system), Regional Municipality of Waterloo (21 systems), County of Oxford (3 systems), County of Brant (4 systems) and City of Hamilton (1 system).

Outside of municipal use, approximately 23,000 non-municipal domestic wells exist in the Grand River watershed. Of these wells, approximately 60% are bedrock wells and 40% are overburden wells. Bedrock wells for domestic use are located across the watershed; however domestic overburden wells, which are also located throughout the watershed, are found in clusters that correspond to the moraine features[20].

Treatment of municipal groundwater supplies varies for each municipality, and is dependent on the source and any issues related to the groundwater. All groundwater used as a municipal drinking water supply must meet the Ontario Drinking Water Quality Standards (ODWQS) albeit groundwater does not have to meet the ODWQS for parameters which can be treated[21].

For private well owners, the Ontario Ministry of Environment and Climate Change (OMOECC) recommends that the water supply be tested a minimum of three times per year to ensure potability.

3.3.2.2 Water Quality of Surface Water Supplies

The Grand and Eramosa Rivers are valued as a municipal drinking water supply. Five communities rely on the river system as a source of drinking water: the Regional Municipality of Waterloo, City of Brantford, County of Brant (connected to the City of Brantford supply), Six Nations of the Grand River and City of Guelph.

Each municipality monitors water quality to inform their operational water treatment requirements. Table 3-6 outlines the water quality parameters and their operational targets for each municipality.

Given the uniqueness of the City of Guelph's Artificial Recharge System, and that the surface water is infiltrated into the ground, the standard water quality indicators for surface water intakes, as listed in Table 3-6, do not necessarily apply to this intake. The City routinely monitors for bacteriological indicators (e.g., *E. coli*) and turbidity, but does not have specific targets or thresholds for operational purposes.

Table 3-6. Resource condition indicators and targets for municipal surface water sources.

Indicator	Description	Targets		
		Regional Municipality of Waterloo	City of Brantford	Six Nations of the Grand River
Turbidity	High turbidity levels can interfere with the efficiency of the treatment process, filtration and disinfection stages	< 50 NTU	< 20 NTU	< 20 NTU
Organic Nitrogen	Organic compounds can compromise the chlorine disinfection capacity; cause disinfection by-products and cause taste and odour problems.	-	< 0.15 mg/L	< 0.15 mg/L
Ammonia	High ammonia levels can interfere with treatment processes; and cause disinfection by-products	-	< 1.0 mg/L	< 1.0 mg/L
Nitrate	Nitrate is a conservative parameter, very difficult to treat; can cause infant methemoglobinemia (blue baby syndrome)	< 10 mg/L	< 10 mg/L	< 10 mg/L
Sodium	Sodium is a conservative indicator that cannot be removed through treatment; sodium is a concern to patients with hypertension	< 20 mg/L	< 20 mg/L	-
Chloride	Chloride is a conservative indicator that cannot be removed through treatment; chloride is an aesthetic concern	< 250 mg/L	< 250 mg/L	-
Organic Carbon	Organic carbon can compromise the chlorine disinfection capacity; cause disinfection by-products and cause taste and odour problems.	-	< 5 mg/L	-
Colour/TOC	Indicator of high organic materials, also an aesthetic concern	-	< 20 TCU	High levels*

* Operator judgement

3.3.2.3 Flows Required to Support Drinking Water Supplies

There must be sufficient depth of water at the location of the surface water supply intake to physically allow the intake to function. The Waterloo Region Grand River intake at Hidden Valley, the Brantford Grand River intake, the Six Nations intake at Chiefswood and the Guelph Eramosa

River intake near Arkell are supported by run-of-the-river weir dams that provide sufficient depth of flow in the river. For this reason, the flows required to provide sufficient depth are quite low in comparison to the flows required to meet other needs.

Table 3-7. Flow targets required for drinking water supply withdrawals

Municipality	Source	Weir	Flow (m^3/s)
City of Guelph	Eramosa River	Arkell Weir	To be determined
Region of Waterloo	Grand River near	Hidden Valley Weir	>2.9
City of Brantford	Grand River	Wilkes Weir	>6.5
Six Nations	Grand River	Caledonia Weir	To be determined

3.3.3 Public Health & Safety

3.3.3.1 Human Consumption of Fish

The *Broad Water Objective*: "*Water quality does not restrict human consumption of fish*" strives for high water quality, such that fish consumption is not impeded by aquatic sources of toxins in the watershed.

The current status of the objective was assessed using the current Guide to Eating Ontario Sport Fish by the Ministry of the Environment (OMOECC)[22] for the consumption of sport fish for locations in the watershed, as described in *Current Status of the Broad Water Objective for Human Consumption of Fish*[23].

In the OMOECC guidelines, consumption advice is provided for each size and species of sport fish from a specific location in order to limit human intake of contaminants below levels which may pose a health risk. The guidelines recommend some level of restriction on sport fish consumption at all locations in Ontario since contaminants such as mercury and PCBs are subject to long-range transport and can accumulate in fish, even in remote areas.

Increased levels of restriction in localized areas have been used here as an indicator of contaminant "hotspots" or source areas for contaminants, although some of the variations in the restrictions are also influenced by the longevity or feeding habit of the fish species.

A summary of the data from the ministry's guide indicate that many locations in the watershed have sport fish with low levels of contaminants that compare favorably with relatively undisturbed areas[23]. Just over half of the locations in the watershed sampled by the OMOECC (14 out of 27) do not have restrictions above the lowest level.

Many of the restrictions at the remaining locations are for sizes or species of fish which have a high potential to accumulate contaminants, even if they are present at low concentrations in the water (e.g., large carp, catfish or pike). However, there are a few locations where higher levels of restriction may be due to local sources of contaminants. For instance, high concentrations of dioxins/furans restrict consumption of fish in Canagagigue Creek and portions of the central Grand River, where riverbed sediments carry the legacy of past contamination by a local source. There are also moderate to high restrictions on fish that live at least part of their life in the Great Lakes (e.g., rainbow trout) or the river mouth where it connects to Lake Erie (e.g., channel catfish). This is consistent with information about the distribution of contaminants in the Great Lakes that indicates legacy sources continue to cause restrictions on the consumption of some fish.

3.3.4 Recreational, Cultural and Tourism Uses

Three *Broad Water Objectives* specifically relate to recreational, cultural and tourism uses of the river. These three *Broad Water Objectives* are:

- The rivers are an amenity in the communities through which they pass;
- The rivers are aesthetically pleasing to support recreational, cultural, and destination tourism; and
- River flow is sufficient to reasonably support paddling where river flow is regulated.

These broad water quality objectives support the designation of the Grand River and its major tributaries, the Conestogo, Nith, Speed, and Eramosa Rivers, as Canadian Heritage Rivers. The heritage river designation for the rivers of the Grand River watershed was based on the outstanding human heritage features and recreational values associated with the rivers.

3.3.4.1 Water Quality Indicators and Targets for Secondary Contact Recreation

Guidelines for recreational water quality across Canada are provided in a Health Canada report entitled *Guidelines for Canadian Recreational Water Quality, Third Edition*[24]. These guidelines apply to both primary and secondary contact recreation. However, except for public beaches in the Grand River watershed, primary contact recreation (i.e., any recreational river use where the body is frequently immersed and where it is likely that some water will be swallowed) is not encouraged. Most recreational use of the river is secondary contact recreation and includes activities such as rowing, sailing, canoeing, kayaking, and fishing.

Table 3-8 has been derived from the Health Canada guidelines and refers specifically to indicators and targets for secondary contact recreation.

Table 3-8. Water quality indicators and targets for secondary contact recreation

Guidelines		
Parameter	**Considerations**	**Guideline**
Escherichia coli	Geometric mean concentration (minimum 5 samples)	≤ 1,000 *E. coli*/100 mL
Enterococci	Geometric mean concentration (minimum 5 samples)	≤ 175 Enterococci/100 mL
Pathogenic Microorganisms (bacteria, viruses, protozoa)	Testing only needed when there is epidemiological or other evidence to suggest that this is necessary	No numerical guideline value
Cyanobacteria	Total Cyanobacteria	≤ 100,000 cells/mL
Cyanobacterial toxins	Total Microcystins	≤ 20 µg/L
Other Biological Hazards (e.g., schistosomes causing swimmer's itch; aquatic vascular plants and algae)	Recreational activities should not be pursued in waters where the responsible authority deems the presence of these organisms poses a risk to the health and safety of users	No numerical guideline value.
pH	For waters used for primary contact recreation	5.0 to 9.0
Temperature	Should not cause an appreciable increase or decrease in the deep body temperature of swimmers	No numerical guideline value
Chemical Hazards	Risks associated with specific chemical hazards will be dependent on the particular circumstances of the area and should be assessed on a case-by-case basis	No numerical guideline value
Aesthetic Objectives		
Parameter	**Considerations**	**Aesthetic Objective**
Turbidity	To satisfy most recreational uses	50 NTU
Clarity	Clarity should be sufficient for users to estimate depth and to see subsurface hazards	Secchi Disc visible at a depth of 1.2 m
Colour	Colour should not be so intense as to impede visibility in areas used for swimming	No numerical value
Oil and Grease	Should not be present in concentrations that can be detected as a visible film, sheen, discolouration or odours or that can form deposits on shorelines or bottom sediments that are detectable by sight or odour.	No numerical value
Litter	Areas should be free from floating debris as well as materials that will settle to form objectionable deposits	No numerical value

The Grand River Conservation Authority (GRCA) monitors for pH, temperature and turbidity in selected river reaches. Monitoring of the other parameters listed in Table 3-8 is not carried out.

3.3.4.2 River Flows for Recreational Paddling

The Ancient Mariners Canoe Club has suggested flow thresholds that, based on their observations, are adequate to support river paddling. These flows are shown in Table 3-9, along with the proportion of days between May 1 and Sep 30 when these flows have been available. The percentages also factor in the number of days when flows are too high.

Other paddling clubs and outfitters may recommend different thresholds. Note that these flows are related to the availability of water depth to pass a canoe and do not imply a safe experience since safety depends on many other factors.

Table 3-9. Range of flows that support recreational paddling

Location		Reference Flow Gauge Station	Adequate Flow (m^3/s)	% Time Flow Supports Recreational Paddling (May-Sep)
Grand River	Fergus to Wilson Flats	West Montrose	5 - 8	72%
	Wilson Flats to Freeport	Galt	14 - 21	82%
	Freeport to Galt			
	Galt to Paris			
	Paris to Cainsville	Brantford	18 - 26	91%
	Cainsville to Caledonia			
	Caledonia to Cayuga	York	28 - 41	34%
	Cayuga to Dunnville			
Speed River	Guelph to Preston	Beaverdale	6 - 9	31%
Conestogo River	Glen Allan to St. Jacobs	St. Jacobs	6 - 9	12%
	St. Jacobs to Conestogo			
Nith River	New Hamburg to Ayr	Ayr	4 - 5	31%
	Ayr to Canning			

Indicators and targets for describing when the “amenity” objectives are fully met are difficult to quantify. The appeal of a river, which makes it a focal point for a community, encompasses more than the physical condition of the river. It includes the water-land interface (i.e., the cultural and natural features which abut the river) and the associated recreational activities, both in and beside the river. Additional work to identify and describe appropriate indicators and targets that measure the full suite of cultural, recreational and tourism aspects associated with the two broad water objectives is required and has been initiated by the Grand Strategy’s Heritage Working Group. However, this additional work is beyond the scope of the Water Management Plan.

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4 Ensuring Sustainable Water Supplies

Grand River watershed residents rely heavily on groundwater sources for municipal drinking water supplies. Over 70% of the volume of water used is from groundwater. The total (actual) water taking (both surface and ground water) in the watershed is estimated to be about 152 million cubic metres per year; however, the total permitted taking is about 626 million cubic metres per year[25]. Although the actual water taking is about 24% of the total permitted, careful water supply planning and permitting is needed into the future to ensure sustainable water supplies.

The largest water taking is for municipal supply (61%), which includes most industry in the watershed. The next largest takings are for dewatering (6%), agricultural irrigation (6%), aggregate washing (4.5%) and agricultural livestock watering/farm operations (4.4%). Rural domestic (4.25%)[25].

Future water supply needs are assessed for three water taking sectors: municipal; agriculture; and aggregate operations as these sectors have the highest demand for water supply and account for over 80% of the water use in the watershed. The other 20% of water taking is distributed among a number of other sectors.

The assessment of the sustainability of future water supplies includes a number of component pieces described in the following sections and is aimed at answering a series of questions set out in the Steering Committee's Project Charter:

- Are future municipal water supply needs identified, sourced and secured?
- Are other large water supply needs (i.e., agriculture, aggregate washing) identified, sourced and secured?
- What river flows support healthy river processes and aquatic ecosystems? Are these flows being met? What flows can reliably be met by the reservoirs? Can the reservoirs do more?
- What areas have potential for water conflict or constraint, now, in the future, with climate change?

The following sections step through each of these questions, followed by a discussion on the need to protect key hydrologic functions of watershed features to ensure key hydrologic processes (groundwater recharge/discharge) can continue to occur into the future.

4.1 Municipal Water Supply

Residents in the Grand River watershed receive drinking water from both private and municipal supplies. There are 41 municipal drinking water systems and two First Nation drinking water systems in the watershed (Table 4-1), servicing a total of over 800,000 people[26]. Municipal water systems range in size from one well servicing under 100 residential customers to complex systems servicing a population of close to 500,000 including industry, commercial and institutional customers. Water sources include groundwater wells, artificial recharge systems, river intakes, Great Lakes intakes and combinations of these sources**.**

The policies of the provincial growth strategy, Places to Grow, and the Growth Strategy for the Greater Golden Horseshoe[27], direct development up to 2031 to the currently designated urban areas and serviced settlement areas. Servicing needs of currently unserviced communities have not yet been factored into this *Plan*.

Approximately 82% of the population of the Grand River watershed relies on groundwater for drinking water. The Region of Waterloo, the City of Brantford and the Village of Ohsweken on the Six Nations Reserve, use the Grand River as a source of drinking water supply.

All municipal water supplies in the watershed are sustainable, that is, they take much less water annually than is recharged to the source[28].

Table 4-1. Municipally serviced communities and sources of supply

Municipality	Community	Source of Supply
Grey County (Southgate)	Dundalk	Groundwater
Dufferin County (Grand Valley, Amaranth, E. Garafraxa)	Grand Valley, Waldemar and Marsville	Groundwater
Wellington County(Wellington North, Mapleton, Centre Wellington, Guelph-Eramosa)	Arthur, Moorefield, Drayton, Fergus, Elora, Hamilton Drive, Rockwood	Groundwater
City of Guelph	Guelph	Groundwater and Eramosa River
Perth County (Perth East)	Milverton	Groundwater
Region of Waterloo	Integrated Urban System (serving Waterloo, Kitchener, Cambridge, Elmira, St. Jacobs, Hidden Valley, Wilmot Centre)	Groundwater and Grand River
	Ayr, Branchton Meadows, Roseville, Linwood, St. Clements, Wellesley, Foxboro Green, New Dundee, Baden, New Hamburg, Conestogo, Heidelberg, Maryhill, West Montrose.	Groundwater
Oxford County	Bright, Drumbo, Plattsville	Groundwater
County of Brant	Paris, Airport, St. George and Mount Pleasant	Groundwater
City of Hamilton	Lynden	Groundwater
City of Brantford	Brantford (including Cainsville)	Grand River
Haldimand County	Dunnville	Lake Erie
	Caledonia and Cayuga	City of Hamilton, Lake Ontario
	Hagersville	Nanticoke, Lake Erie
Six Nations of the Grand River	Ohsweken and parts of the Reserve	Grand River
Mississaugas of the New Credit	Parts of the Reserve	Nanticoke, Lake Erie

4.1.1 Future Water Supply Needs

Municipal systems in most communities in Grey, Dufferin, Wellington, Perth, Oxford, Brant and Haldimand Counties as well as the Cities of Hamilton and Brantford and small rural centres in the Region of Waterloo have sufficient supplies to meet long term needs[29]. In particular, the following systems have sufficient supplies to meet long term needs beyond 2041:

Dundalk	Branchton Meadows	Heidelberg	Lynden
Waldemar	Roseville	Maryhill	Brantford
Marsville	Linwood	Maryhill Heights	Dunnville
Arthur	St. Clements	West Montrose	Caledonia
Moorefield	Wellesly	Bright	Cayuga
Drayton	Foxbro Green	Drumbo	Hagersville
Hamilton Drive	New Dundee	Plattsville	Ohsweken
Milverton	Conestogo Plains	Mount Pleasant	
Ayr	Conestogo Golf	Airport (County of Brant)	

Most municipalities expecting significant growth have completed a Water Supply Master Plan that sets out where they intend to source their long term water supply needs. These long term plans may be documented in Water Supply Master Plans, Servicing Master Plans or Class Environmental Assessment Reports.

For the purposes of this Water Management Plan, future demand and capacity calculations were completed for each of the municipal water systems identified as growth areas. These calculations were based on 20- and 40-year population growth projections[30]. Information in municipal long-term water supply plans was used when available.

The projected water system capacities were based on future water supply plans. If no future plans were found, the current capacity was assumed. System resiliency and storage for short term peaks was not taken into account, nor have changes in water use trends and changes in industry or commercial establishments. Although this approach is simplistic, it does highlight some municipal systems that may need to undertake a more detailed study to ensure they have sufficient water available over the next 20 to 40 years (IAP C.1).

Water use, both industrial and residential, has been steadily dropping over the last several years for a combination of reasons including water efficiency and conservation programs, more aggressive seasonal water use by-laws and changes in industrial and commercial establishments. The Region of Waterloo and the City of Guelph expect to complete their Water Supply Master Plan updates in 2014. Centre Wellington is in the process of developing a Water Supply Master Plan and the County of Brant is planning to complete a Master Servicing Plan for Paris in 2015. These updated plans will take into consideration the changing trends in water use (IAP C.1).

4.1.2 Municipal Water Demand Management

As part of the process to update the Water Management Plan, a Municipal Water Demand Working Group was formed to provide input into a review of best practices that are currently used by municipalities or proposed for proactive municipal water demand management (WDM).

Municipal water managers identified the following key points for consideration when evaluating municipal WDM programs:

- There is a trend towards declining water use by municipal customers due to the success of existing municipal water conservation and efficiency programs, a downturn in the economy, uptake in the manufacture and installation of water efficient fixtures and appliances in new home construction and higher water costs associated with implementing the Clean Water Act, 2006;
- Declining water demand and aggressive water conservation programs are affecting sustainable revenues for water utilities;
- Retrofitting customers with water meters is difficult to justify without large subsidies to cover the one-time cost of new meters;
- Most municipal water supply providers are delivering Low Water Response programs to address acute water supply shortages; and
- The provision of WDM best practice assumes that water supply operations are optimized to address water leakage and loss situations and water managers acknowledge that reduction of unnecessary water pumping can reduce variable costs for electricity and water treatment consumables.

A toolkit of best practices was developed to assist water managers with developing water demand management objectives for their municipality that could be consolidated in the *Plan* as an approach to meet the goal: '*sustainable water supplies for communities, economies and ecosystems'* in the watershed. The Municipal Water Demand Management Primers[31] are a series of fact sheets describing best management practices to manage and reduce municipal water demand. The Primers include the following best practices:

1. Securing your municipal supply for the long-term
2. Easing the flow: getting past water demand management barriers
3. Community outreach
4. Water metering
5. Outdoor water use bylaw
6. Rebates and capacity buy-backs
7. Water loss control
8. Conservation pricing
9. New technologies and next generation water demand management strategies

In addition, a *Municipal Water Demand Management Matrix* was developed as a tool to assist with evaluating the merits of each of the tools described in the primer series. This information will assist Water Mangers with incorporating proactive water demand management into water supply master plans (IAP C2).

The information from the draft report: '*Status Report on Municipal Long Term Water Supply Strategies'*[29] was updated to confirm the total annual use to December 31, 2011 and peak day for 2012. It was important to update peak day use for 2012 as this year was an extremely dry year. This information was applied to 2011 population and projected growth forecasts to assess the potential for each municipal water supply system to satisfy long term needs to 2041 using existing and proposed WDM objectives. Table 4-2 lists the long term municipal water demand management objectives for watershed municipalities. The projected long term municipal water use will be compared to non-municipal water use by subwatershed to identify potential water use conflicts as part of the Tier 3 Water Quantity Risk Assessment work being completed in 2014 for source protection planning.

Most of the municipal water supply constraints by the year 2041 are driven by potential peak day water demand. Municipal water managers are encouraged to employ the water conservation strategies identified in the *WDM Primer Series* to control the increase in baseline average day demand. Water conservation experts have identified that the “low hanging fruit” of conservation savings can be achieved through water metering and the installation of water efficient fixtures and appliances which are now considered standard practice. These standards are applied to all new homes and are helping to reduce the per capita demand of every new housing unit which in turn is lowering average municipal per capita demand. In addition, control of water losses from the water distribution network can help reduce average day demand without creating a loss in utility revenue (IAP C.2).

Managing peak day water demand requires a combination of physical and behavioural best practices to help control occasional spikes that govern the total water supply capacity needs of the municipal water supply. Taking a “Water Soft Path” approach to assessing future water supply needs can help offset the need for costly supply expansions in several communities if well designed municipal outside water use programs are used to reduce the ratio of peak day to average day pumping (IAP C.2).

The “***water soft path***” is a planning approach for water that differs fundamentally from conventional, supply-focussed water planning.

Instead of viewing water as an end product, the soft path views water as the means to accomplish certain tasks. The role of water management changes from building and maintaining water supply infrastructure to managing demand and making current practices more efficient.

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Table 4-2. Summary of long term municipal water demand management (WDM) objectives

Municipality	Water System	Long Term Water Supply Needs			Notes (Sufficient Supply assumes OLWR participation and industry accepted efforts to reduce water loss)
		Avg. Day	Peak Day	WDM Objective	
Southgate	Dundalk	OK	OK	Status Quo	Sufficient Supply
Amaranth	Waldemar	OK	OK	Status Quo	Sufficient Supply
East Garafraxa	Marsville	OK	OK	Status Quo	Sufficient Supply
Grand Valley	Grand Valley	OK	OK	Status Quo	Sufficient Supply
Centre Wellington	Fergus-Elora	OK	X	Reduce 14% by 2028, 38% by 2040	Water Supply Master Plan in progress. Soft Path Report identified staged water demand management objectives.
Mapleton	Drayton	OK	OK	Status Quo	Sufficient Supply
	Moorefield	OK	OK	Status Quo	Sufficient Supply
North Wellington	Arthur	OK	OK	Status Quo	Sufficient Supply (no expansion needed)
Guelph-Eramosa	Rockwood	OK	X	Strengthen WDM program	Expansion required by 2031 to satisfy peak day needs could be deferred with WDM.
	Hamilton Dr.	OK	OK	Status Quo	Sufficient Supply
Perth East	Milverton	OK	OK	Status Quo	Sufficient Supply
Region of Waterloo	Integrated Urban System	X	X	Will review a reduction in residential demand	The Region will be commencing a Water Conservation and Efficiency Study Update in late 2013 to review the long term residential use target. An aggressive target could help defer the long term need for significant water supply expansion projects and help satisfy peak day needs.
	Baden/ New Hamburg	X	X		
	Ayr	OK	OK		
	Wellesley	OK	OK		
	St. Clements	OK	OK		
	Non-Growth Rural Systems	OK	OK	Status Quo	Sufficient Supply
Guelph	Guelph	X	X	Reduce 20% by 2025	Expansion and demand management required to satisfy long term needs.
Hamilton	Lynden	OK	OK	Status Quo	Sufficient Supply
County of Oxford	Bright	OK	OK	Status Quo	Sufficient Supply
	Plattsville	OK	OK	Status Quo	Sufficient Supply
	Drumbo	OK	OK	Status Quo	Sufficient Supply
County of Brant	Paris	OK	X	Status Quo	Sufficient Supply
	St. George	OK	OK	Status Quo	Sufficient Supply
	Mt. Pleasant	OK	OK	Status Quo	Sufficient Supply (with treatment system)
	Airport	OK	OK	Status Quo	Sufficient Supply
Brantford	Brantford	OK	OK	Status Quo	Sufficient Supply
Haldimand County	Caledonia/ Cayuga	OK	OK	Status Quo	Sufficient Supply (currently connected by pipeline to Hamilton)
	Dunnville	OK	OK	Status Quo	Sufficient Supply (no expansion needed)

Note: OK implies water system can meet demand beyond 2041, X implies water system may not be able to meet average and/or peak day demand.

4.1.3 Future Sources

Most of the municipal water supply systems in the Grand River watershed will be able to meet future growth with current water sources over a 30 to 40 year planning horizon based on population projections and current peak water use alone. A number of the larger water systems that are projecting that average day demand will exceed supply by 2051 have plans in place which identify additional sources that are readily available. A number of smaller water systems are also predicted to be at or near peak day capacity by 2041. The systems where future plans may meet barriers are discussed below.

4.1.3.1 Grand Valley

The Grand Valley system was designed in 1991 with a 20 year design period. Although this plan has come to the end of its life, the current capacity of the system should be sufficient to support the average day growth requirements of the community to 2041. However, due to higher than average outside water use, peak day demand may exceed supply by 2031. Since the current plan has come to an end, the municipality is encouraged to update its water supply master plan. Incorporating demand management strategies that target outside water use and water loss control could allow the municipality to serve growth in the community over the next 30 years without the need to increase the capacity of this system. It is anticipated that this community should be able to meet future needs with groundwater sources.

4.1.3.2 Fergus-Elora

With high growth pressures on the Township of Centre Wellington (Fergus-Elora), the current water system will not be able to handle future population growth. The municipality has identified this issue and has initiated a Water Supply Master Plan (WSMP). Centre Wellington has initiated a Water Supply Master Plan (WSMP) including groundwater resource investigations. The WSMP is expected to be complete by 2015 (IAP C.1). Solutions for meeting future water supply needs have not been established; however, the Township participated in a "*Water Soft Path*" Pilot Project in 2010-11 which identified aggressive Water Demand Management objectives to achieve per capita reductions by 2041. The Township has agreed to present the *Water Soft Path* Pilot as an alternative solution for consideration when the WSMP is brought forward for public consideration.

4.1.3.3 Rockwood

Rockwood, in Guelph-Eramosa Township, is expected to see high population growth that would double the size of the community over the next 40 years. Based on current per capita trends water demand and wastewater treatment could exceed capacity by 2041. Rockwood has relied on groundwater for its water supply and may continue to do so, but future planning will need to be coordinated with the City of Guelph and the Town of Halton Hills as there may be competing interests for groundwater supplies in this area. Rockwood is also considering options to address peak sewage flow capacity for wastewater that is pumped to and treated in Guelph. On the basis of these limitations, the Township could consider maintaining existing outside water use, toilet rebate, water loss control and inflow/infiltration programs to maximize their existing water and wastewater capacity.

4.1.3.4 Guelph

The City of Guelph has a long term water supply plan with plans to 2054. Plans include expansion to the groundwater system including sources outside of the city limits and local surface water sources with aquifer storage/recovery (ASR). The City has chosen not to pursue a pipeline option and instead has been focusing on alternative water sources including a '*Water Soft Path'* approach to maximize the use of existing water supply resources in their 2009 Water Conservation and

Efficiency Strategy. There are increasing conflicts for groundwater resources in and around Guelph and this could create limitations to securing additional supplies outside of the city. In 2013, the City of Guelph is updating its Water Supply Master Plan (WSMP) to define how they will continue to access a sustainable supply of water for residential and industrial use over the next 25 years (IAP C1; C.2).

4.1.3.5 Region of Waterloo Integrated Urban System (IUS)

The Region of Waterloo is responsible for water supply to the Integrated Urban System servicing the majority of the areas within Cambridge, Kitchener, Waterloo, and Woolwich. The Region's current Water Supply Master Plan, completed in 2007, provides direction on water supply to these areas and broadly consists of 1) development of additional groundwater sources, 2) aquifer storage and recovery to augment water supply until 2035 and 3) a Great Lakes based water supply after 2035 (IAP A.3).

The Region of Waterloo has initiated a Water Supply Master Plan Update that will account for recent trends in water demand and water supply (IAP C.1). The result of this study, expected in 2014, will be an updated, comprehensive master plan to identify preferred strategies for both the short term (10 to 20 years) and long term (30 to 40 years). The study will also identify the individual projects required to implement these strategies, and prioritize these projects based on need.

4.1.3.6 New Hamburg/Baden

The population is projected to increase by more than double in the area serviced by the New Hamburg/Baden water supply system, causing the water system to be near capacity by 2041. The Region of Waterloo completed a WSMP in 2011 for the Baden-New Hamburg water and wastewater systems which identified sufficient water sources to the 2041 planning horizon.

4.1.3.7 Paris

The County of Brant has recognized that the high development pressures in Paris may put stress on the water supply system. A new groundwater source in south Paris was developed and commissioned in mid-2014. Even with the addition of the new source, the Paris water system is projected to be near peak day capacity by 2051.

The County of Brant has recently initiated a Master Servicing Plan for the urban settlement area of Paris and is expected to be completed by 2015 (IAP C.1). The County will need to investigate additional sources of water to ensure demand can be met in the future.

4.1.4 Security of Supply

The question set out in the Steering Committee's Project Charter is, "Are future municipal water supply needs identified, sourced and secured?"

For the purposes of this Water Management Plan, "secured" means reasonable certainty (reduced uncertainty) that the current and future sources of municipal water supplies will be available when they are needed[32]. "Available" refers to both physical and regulatory availability. "Secured" from a physical perspective means that the source will still be viable (available, sustainable, feasible, of suitable quality) at the time it is needed. "Secured" from a regulatory perspective means that the municipality will be able to obtain and keep provincial approval to use the water.

Water sources are secured from a water quality perspective by the implementation of policies in the Grand River Source Protection Plan[26] to reduce the risk of contamination from activities, existing or future, that are deemed to be significant drinking water threats. The policies direct municipal land use planning and prescribed provincial instruments, as well as establish a formal process to provide for risk management plans. The proposed Grand River Source Protection Plan[20] is under review by the Ontario Ministry of the Environment (OMOECC) and is expected to come into effect in 2015.

Since the Source Protection Program is a new program, it is recommended that the Water Managers' Working Group observe for ten years to gauge whether Source Protection Plan implementation improves security of water sources from a water quality perspective.

Water sources are secured from a water quantity perspective by the implementation of policies in the Grand River Source Protection Plan where a Tier 3 Water Quantity Risk Assessment has been completed or by the Permit to Take Water (PTTW) program.

Uncertainty about the availability of water to meet long term needs can be reduced by maintaining a long-term water supply master plan. OMOECC recommends that municipalities use the regular Official Plan Reviews to trigger updates to Water Supply or Servicing Master Plans or addenda to approved Environmental Assessments to meet those needs and incorporate considerations for demand management (IAP C.1).

Water in Ontario is a common resource and permits are required on a "first come-first served" basis to take water for most uses. Although permit renewals are required under the Ontario Water Resources Act PTTW program, existing approvals are considered, for the purposes of this Water Management Plan, to be secure from a regulatory perspective.

Uncertainty about the ability to obtain approvals for new or expanded supply takings can be reduced by completing municipal Environmental Assessments (EAs) and PTTW as early as practical.

PTTW applications are (with a few exceptions) circulated to the municipality and the conservation authority for comment. This provides the municipalities with an opportunity to bring their interests related to existing and planned water supplies to the OMOECC's attention and to request that proponents be required to undertake appropriate studies (i.e., impact on planned municipal takings, sustainability of taking). Municipalities also have the ability to make Official Plan policies restricting new water taking in designated areas as required to secure planned sources of water supply needed to meet their projected future needs.

The established Water Managers' Working Group provides a forum for municipal staff to keep provincial staff informed about municipalities' long term water supply plans (IAP C.3).

4.2 Water Supply for Agriculture

The Dundalk and Stratford till plains in the north-west third of the watershed in Dufferin, Wellington, Waterloo and Perth Counties are areas of highly productive livestock and mixed farming. Water supply is sourced from groundwater. Overall water use in these areas is low.

The Norfolk Sand Plain on the south-west side of the watershed in Oxford and Brant Counties is an area of fairly-intensive crop irrigation. Water supply is sourced from groundwater-fed creeks as well as groundwater wells. Overall water use in these areas is moderate to high. There is currently potential for water conflicts and constraints.

Agricultural water use includes crop irrigation, livestock watering and general farm operations.

4.2.1 Future Water Needs for Livestock and Farm Operations

Livestock watering is estimated to be approximately 7,500,000 m^3/year and accounts for approximately 4.4% of water consumption in the Grand River watershed, the fifth highest user of water[25]. As shown in Figure 4-1 most of the livestock production is in Wellesley, Wilmot and

Mapleton Townships in the west-central portions of the Grand River watershed in the Conestogo and Nith River basins.

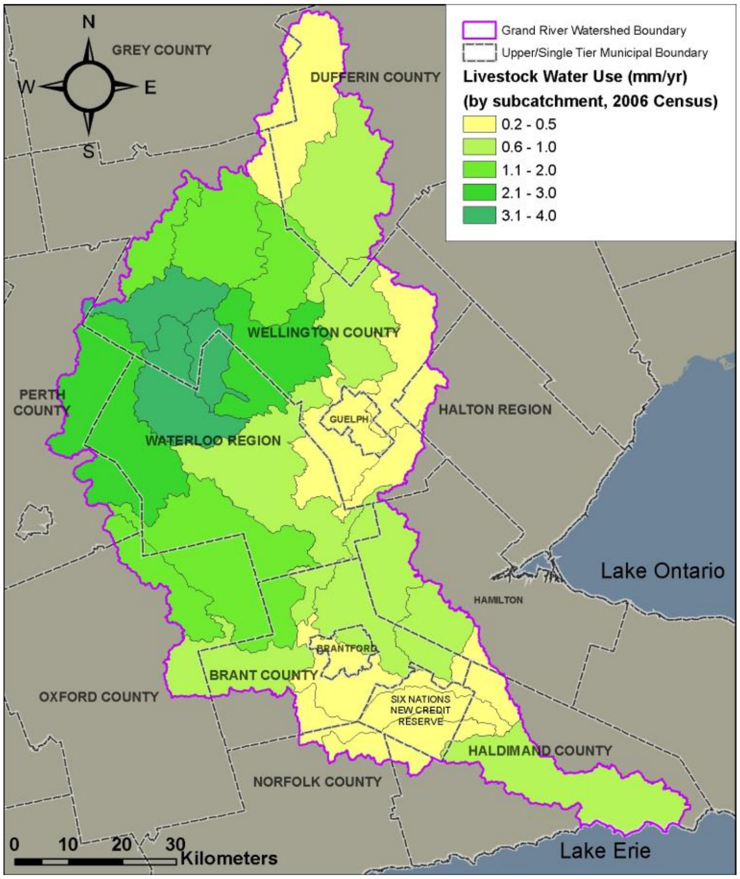


Figure 4-1. Livestock water use across the watershed

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) specialists project that populations of livestock in the watershed are likely to increase in response to human population increases in the coming decades[33]. The trends show increasing populations of chickens, a decrease in cattle and a cyclical pattern for hogs, signalling an increase in consumption from livestock. However, in terms of washing, new technologies in water efficiency may offset an increase in consumption. Under the warmer conditions of climate change, more water may be needed for livestock watering and evaporative cooling.

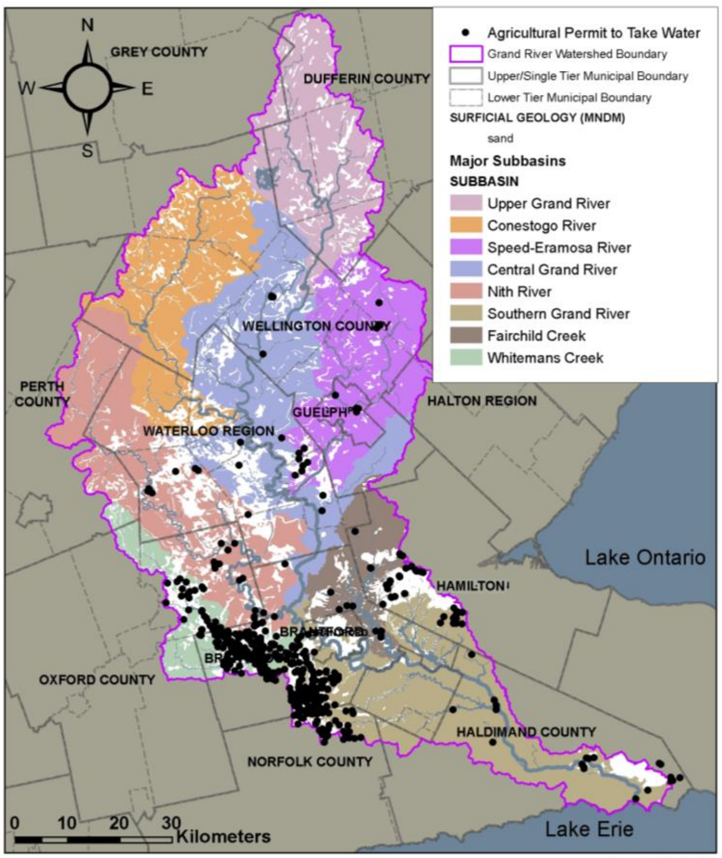
Population growth estimates for several livestock commodities are based on Agriculture and Agri-food Canada's medium term outlook which accounts for factors such as international demand for the products, national per capita consumption of the products and also the size of breeding herds[34]. Projections, in the range of 0.2-2% per year, have been extrapolated to 2031 and 2051 for the purpose of projecting long-term agricultural water needs.

To account for climate change, the increased water intakes for drinking and additional water for evaporative cooling have been added to the daily water needs. The increased water needs are based on increased monthly temperatures between April and September with the number of days with maximum daily temperature over 25˚C increasing from 59 to 97 days. The details of the methodology and projected agricultural water needs for livestock operations are documented in the report, *Livestock Water Use and Future Water Needs*[35].

Livestock population growth increases the water use by one third by 2031 and half by 2051. Climate change results show an increase in water use by half by 2031 and doubling by 2051 under the most severe climate change scenarios. However, the largest increases in livestock populations and demand are in subwatersheds where total water use is low.

4.2.2 Future Water Needs for Crop Irrigation

Crop irrigation is the third highest annual water use in the watershed, after municipal water taking and dewatering. Crop irrigation is also the highest seasonal water use in the watershed, peaking in the summer months of July through September, coinciding with the low flow season. There are currently about 340 Permits to Take Water (PTTW) for agricultural irrigation purposes, with approximately 205 or 60% of them being located in the Whitemans and McKenzie Creek subwatersheds (Figure 4-2).



Map created: 18-Oct-2013

Figure 4-2. Permits to take water for crop irrigation

Five potential scenarios for future crop irrigation were investigated (Table 4-3), one low, two moderate and two high water use scenarios[36].

Current: The low agricultural water use scenario assumes that irrigated acreage remains roughly the same as it is now, fluctuating somewhat with market trends. This is the most likely scenario.

Scenario 2: The two moderate agricultural water use scenarios assume that irrigated acreage increases 10% and 25% respectively, reflective of an increase in market and specialty crop production in specialty crop areas. The moderate scenarios increase irrigation in the sand plains in the southern half of the watershed but do not materially affect the remainder of the watershed.

Scenario 3: The two high water use scenarios reflect an expansion of irrigation to crops not traditionally irrigated (e.g., corn, soybeans) and assume that a) there is a significant increase in irrigation where 10% of cropland on sandy soils is irrigated (the soil type most needing irrigation in dry years), and b) an extreme increase in irrigation where 5% of cropland across the watershed is irrigated. The two high agricultural water use scenarios are very unlikely and can be seen as representing an upper limit on the extent of irrigation that is physically possible in the watershed.

New water for crop irrigation is assumed to be sourced from groundwater or storage and not directly from the creeks (IAP C.4).

Table 4-3. Average annual irrigation demand

Scenario		Average annual irrigation demand (L/sec)	
		4 events per year	10 events per year
Current	**Current**	250	626
2a	10% increase	275	688
2b	25% increase	313	783
3a	10% of sandy cropland	577	1443
3b	5% of cropland	728	1820

To interpret the significance of crop irrigation relative to water availability and total water use, percent water demand (total consumptive water use as a percentage of available water) and percent irrigation (irrigation as a percentage of total water use) were estimated for each scenario in each subwatershed. The methodology is based on the water quantity stress assessment completed under the Source Protection Program.[37]

Under historical climate conditions (4 irrigation events per year on average), total water demand in most subwatersheds remains low (less than 10% of available water) in all scenarios. In the moderate and high water use subwatersheds in the central portion of the watershed, crop irrigation is a very small percentage (less than 3%) of total water use. The Irvine Creek subwatershed shows moderate water use with a moderate percentage as crop irrigation in the more extreme scenarios 3a and 3b.

Under scenarios of climate change (10 irrigation events per year on average), several more subwatersheds demonstrate conditions of moderate total water use with a moderate proportion being crop irrigation.

All crop irrigation scenarios are sustainable on a subwatershed scale (i.e., total water use is much less than renewable water) if sourced from groundwater and storage and not taken directly from surface water streams.

However; as the total percent water demand increases, resiliency to deal with change is reduced and there is more risk of local impacts and water conflicts among users.

To minimize the potential for local effects and build resiliency for climate change, efficiency in irrigation water use is strongly encouraged (IAP C.4).

It is recommended that water use information be kept current to observe trends in total water use, including crop irrigation, across the watershed (IAP C.4).

Regional water management strategies are needed in the Whitemans, Mount Pleasant and McKenzie Creek sand plain areas to deal with current and potential future agricultural water challenges (IAP C.4).

4.3 Water Supply for Aggregate Production

The central region of the watershed is rich in aggregate resources that support local needs and are exported out of the watershed to the Greater Toronto Area and Niagara Region.

While aggregate production varies each year, it is expected that aggregate production will increase in response to local population growth and growth in export demand[38.]

Aggregate production is also expected to shift over the next 10, 20 and 30 years from Puslinch Township to North Dumfries Township, and then to the County of Brant as accessible resources in each are depleted.

For the purposes of water use projections in this Water Management Plan, it is assumed that there will not be new pit dewatering operations in the planning horizon of this Plan. The most significant water need for aggregate production considered in this Plan is for aggregate washing.

Water needs for aggregate washing have also been declining as operations have moved from open loop water cycling to closed loop water cycling. New water is required only to top up the wash ponds to account for evaporation and infiltration from the wash pond and water trucked out on the aggregate.

GRCA's investigation of long term water supply needs and their significance in the overall water budget is in preparation. However, a future shift in aggregate production to west County of Brant in combination with agricultural crop irrigation in this area will need to be factored into discussions about solutions to current water use conflicts and constraints (IAP C.12).

4.4 Environmental Flow Needs

Environmental flows describe the quantity, quality and timing of flows required to sustain healthy river ecosystems, as well as the human livelihoods that rely on these ecosystems [39]

The E-Flows Working Group established a suite of flow-related natural river processes which, in their expert opinion, are critical for maintaining healthy aquatic ecosystems in the Grand River watershed. The environmental flow regimes include eight environmental flow thresholds in three categories: channel maintenance and formation; nutrient management or biological functions; and low flow considerations[40]. The flow thresholds are included as flow targets in Table 4-4 for four regulated reaches of the Grand and Speed Rivers. Low flow thresholds for two natural flow reaches of the Eramosa River and Whitemans Creek are also included.

In general, the environmental low flow needs are less than the reservoir operational flow targets, as shown in Table 4-4, and are only a challenge in the driest years.

These environmental low flows should inform future drought contingency planning discussions (IAP C.9/C.13).

Further work is recommended to field verify the thresholds, particularly for the Brantford littoral zone maintenance threshold where the threshold is currently estimated to be higher than the operational flow target (IAP C.9).

The higher environmental maintenance flow needs (e.g., flushing flows) are poorly to moderately met for the regulated reaches of the Grand and Speed Rivers. The GRCA plans, as a next step, to field verify the flow thresholds and investigate the feasibility of operating the reservoirs to meet these flows more reliably without sacrificing the reliability of meeting the low flow requirements or causing flooding (IAP C.9).

Table 4-4. Environmental low flows for selected river reaches

Flow Thresholds	Grand R. near Doon	Grand R. above Brantford	Speed R. below Guelph	Speed R. at Hespeler	Eramosa R. above Guelph	Whitemans Creek near Mt Vernon
	(m^3/s)					
Littoral Zone Maintenance	8.5	19	1.1	1.5		
Longitudinal Connectivity	6.8	8.8	0.52	1.1	0.5	1.0
For comparison						
Operational low flow target	9.9*	17	1.7		0.42	
Historical frequency met	>95% May-Oct	Met most years May-Oct	>95% May-Oct	Continuously met	Met > 3 of 4 years May-Oct	Met 2 of 3 years May-Oct
90th percentile flow – lowest month	9.8	18	2.4		0.43	0.70

*summer flows

4.5 Reservoir Reliability

The primary operating objectives of the Shand, Conestogo, Luther and Guelph Dams are flood damage reduction (i.e., reduction of flows during floods) and low flow augmentation (i.e., addition of flows during low flow periods). The reservoirs are filled in the spring with the runoff from the melting snow pack and spring rains. Water is released over the summer and fall period, to supply sufficient flow to the rivers to dilute treated wastewater effluent, provide water for municipal water supplies and maintain the river's ecological functions.

Figure 4-3 illustrates the regulated reaches in the Grand River watershed and the operational low flow target locations.

The two objectives of the reservoirs (flood control and water supply) are conflicting. For instance, to provide flood control, as much available storage as possible is desired. To provide flow augmentation, as much water as can safely be stored in the reservoir is desired. The approved reservoir operating policy[41] resolves these conflicting objectives.

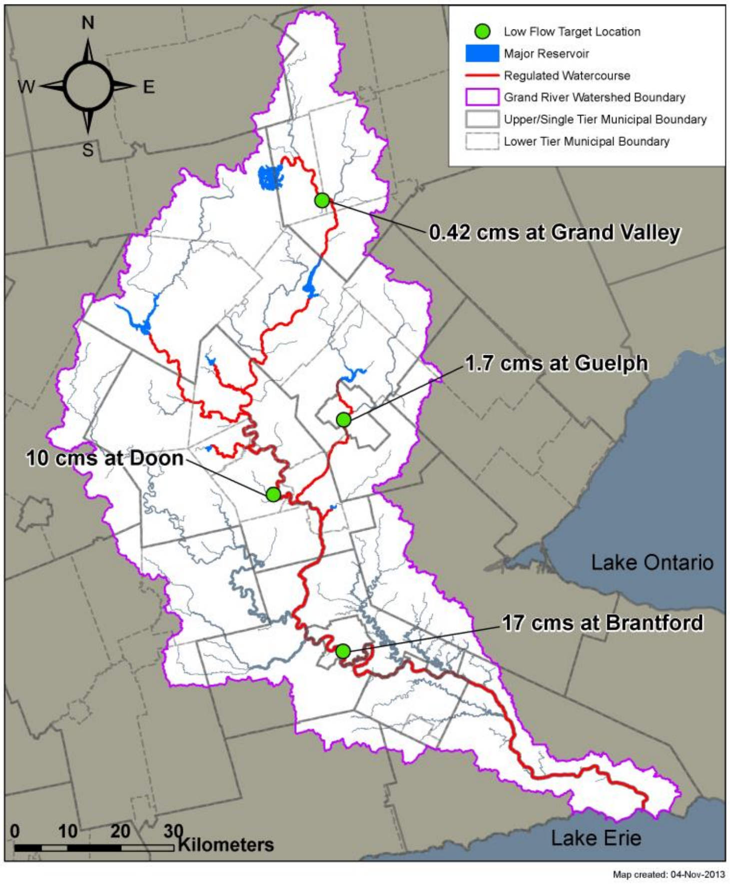


Figure 4-3. Major multipurpose reservoirs and locations for the low flow operating targets

4.5.1 Reservoir Operating Policy

The existing reservoir operating ‘rule curves’ and policies for GRCA reservoirs date back to early 1978 and incorporate the recommendations of the 1974 Flood Inquiry[42]. The reservoir operating rule curves are intended to balance flood control and low flow augmentation objectives. In 1982, the reservoir operating policy that dealt with low flow targets was changed to implement the recommendations of the 1982 Grand River Basin Water Management Study[43]. These changes were adopted and continue to this day with a few minor revisions in 1988 and 2004.

The existing operating procedures and guidelines specify:

1. Target reservoir levels for February 15th, April 1st, May 1st, June 1st and October 15th to balance flood control and low flow augmentation needs;
2. Minimum discharges from the Shand, Conestogo and Guelph Dams; and
3. Minimum low flow targets at Guelph (Edinburgh Road), Kitchener (Doon) and Brantford, for water quality and water supply.

Existing low flow targets are summarized in Table 4-5, along with the reference that was used to establish these targets.

Average augmentation since 1984 during the July to September period is approximately 50% at Doon, 30% at Brantford and 30% below Guelph. During dry periods, augmentation has reached persistent levels of 80% of the flow at Doon, 50% of the flow at Brantford and 70% of the flow below Guelph. For short periods, augmentation levels have approached 90% of the flow at Doon on the Grand River and below Guelph on the Speed River.

Table 4-5. Low flow operation targets for operating the large multipurpose water management reservoirs

Location	Operational Low Flow Target			Reference	Last Confirmed/ Revised
	Jan-Apr (m^3/s)	May-Sept (m^3/s)	Oct-Dec (m^3/s)		
Grand Valley	0.42	0.42	0.42	1986 Reservoir Yield Study	2004
Below Shand Dam[1]	2.8	2.8	2.8	1982 Basin Study	2013
Doon[2]	2.8[4]	9.9	7.1	1982 Basin Study	2013
Brantford		17		1982 Basin Study	2013
Below Conestogo Dam[1]	2.1	2.1	2.1	1982 Basin Study	2013
Below Guelph Dam[1]	0.57	0.57	0.57	1982 Basin Study	2013
Edinburg Road City of Guelph[3]	1.1	1.7	1.1	1982 Basin Study	2004/2013
Elmira	0.3	0.3	0.3	Operations Manual Woolwich Dam	1980

[1] Lessor of flow target or inflow to the dam
[2] Flow before the Mannheim surface water taking of 0.9 m3/s, Doon gauge is located downstream of taking
[3] Summer operating season for the Speed River is June 1 to Sept 30, fall/winter season is Oct 1 to May 31
[4] Winter low flow target estimated based on available winter augmentation storage below gate sill at Shand Dam

4.5.2 Reliability of the Existing Operational Low Flow Targets

The reliability of meeting the existing operational low flow targets was reviewed with both observed flow data and modeled results from the Reservoir Yield Model[44]. The reliabilities were then compared against those developed for the 1982 Basin Plan. Downstream flow targets were set in the 1982 Basin Plan based on a reliability of meeting them at least 95% of the time.

The 1984 to 2010 period is used for comparison with observed values since it coincides with the same time period as the current operating procedure of the reservoir system, established after the completion of the 1982 Basin Plan.

4.5.3 Grand River Flow Reliability

The reliability of meeting the Grand River flow targets downstream of the major reservoirs is presented in Table 4-6, along with the number of years that the target was not met.

Table 4-6. Reliability in meeting existing flow targets at Doon and Brantford

	Doon			Brantford		
	Jan-Apr	**May-Sep**	**Oct-Dec**	**Jan-Apr**	**May-Sep**	**Oct-Dec**
	Percent Reliability					
1982 Basin Plan	100	98.9	94.5	NA	99.6	NA
Reservoir Yield (1950-2010)	99.8	99.5	95.2	97.7	99.9	94.3
Reservoir Yield (1984-2010)	99.6	99.6	96.6	99.1	99.9	97.0
Observed (1984-2010)	**100**	**98.7**	**98.9**	**99.2**	**99.7**	**98.9**
	Number of Years with Target Violations					
Reservoir Yield (1950-2010)	2/60	5/60	8/60	8/60	3/60	11/60
Reservoir Yield (1984-2010)	1/27	2/27	2/27	2/27	1/27	2/27
Observed (1984-2010)	**0/27**	**2/27**	**4/27**	**2/27**	**2/27**	**2/27**

The reliability in meeting the Doon target for each of the seasonal periods is at or above 95% and the observed record had greater than 98% reliability.

The Brantford flow target was originally intended to be used for the summer period only as part of the 1982 Basin Plan, but in practice, it has become the year round operational flow target. This target has been met with a high reliability of 99%.

While the statistics indicate the winter period has the highest reliability, this is the season that has the highest risk of failure; the reservoir storage could be depleted and flow augmentation would no longer be possible. Changes to winter operations in the mid-1990s, and formal adoptions of modified rule curves in 2004 to store more water over the winter, has helped to reduce this risk; however, long periods of drought still present risk.

4.5.4 Speed River Flow Reliability

The reliability of meeting the Speed River operational low flow target at the Below Guelph gauge (Edinburgh Road) is given in Table 4-7. The 1982 Basin Plan presented a 93% reliability of meeting the summer target. Based on the observed record, the target has had a 94% reliability since 1984, but results of the Reservoir Yield Model show that a higher than 95% reliability by time is achievable.

There have been a number of dry years since the summer flow target was increased to 1.7 m^3/s in 1984. This has resulted in some changes to the rule curve to allow for more early spring storage. Modifications were implemented in 1989 and slot gates installed in the early 1990s to allow retention of spring storage in the reservoir into the early summer. These operational changes since 1984 may be the reason the Reservoir Yield Model shows a higher reliability and may be more indicative of future reliability.

Table 4-7. Reliability in meeting existing operational flow targets - Speed River

	Jan-May	June-Sep	Oct-Dec	Jan-Apr	May-Sep	Oct-Dec
	Percent (%) Reliability			Years with Violations/ Total Years of record		
1982 Basin Plan	100	93.0	95.5	--	--	--
Reservoir Yield (1950-2010)	100	96.8	99.3	0/60	11/60	3/60
Reservoir Yield (1984-2010)	100	96.7	99.2	0/27	5/27	2/27
Observed (1984-2010)	**100**	**93.9**	**100**	**0/27**	**7/27**	**0/27**

4.5.5 Considerations for Changes to Operations

Scenarios to investigate reduced spring filling levels (for enhanced flood control), increased downstream flow targets and a longer summer operating season show that the current operating strategy provides the best reliability of meeting downstream flow targets [44] (IAP C.5).

4.5.6 Reduction in Spring Water Levels

Shand and Conestogo reservoirs have spring filling targets on April 1st, May 1st, and June 1st. In the scenario where the April 1st filling target is achieved on May 1st and any additional water after May 1st is taken into storage according to the regular rule curves, the results indicate that there is some robustness to the filling cycle. However, it is important to reach the May 1st filling targets in order to maintain downstream flow reliabilities at or above 95%. Taking in more water after May 1st increases the reliability of meeting downstream flow targets.

4.5.7 Changes to Downstream Flow Targets

Under existing conditions, the Reservoir Yield Model uses a summer target of 9.9 m^3/s at Doon but, if there is water available, it increases the flow rate at Doon to 11 m^3/s. Increasing or extending the summer flow targets will lower the reliability in meeting the fall flow targets outside of acceptable levels; therefore, no change in flow targets is recommended. Although no change is recommended, it is standard practice to operate above the minimum target flow if water is available, and this is often the case in the fall season.

4.5.8 Consideration for Climate Change

A separate study was conducted that ran 10 different climate change scenarios through the continuous stream flow model of the Grand River watershed to investigate changes to stream flow, runoff, recharge and evapotranspiration[44]. The results of these climate change runs suggested that there would be more mid-winter melts, more winter precipitation and a longer, hotter and drier low flow season. These conditions result in a greater demand on the reservoirs for augmentation and affect the filling cycle.

Output from the surface water model was then incorporated into different scenario runs for the Reservoir Yield Model to investigate potential challenges to reservoir operations under a changing climate.

Flow reliability in a regulated system is described as a percentage of time meeting or exceeding low flow operation targets. Reliabilities are calculated using the 7-day running average and are reported over the given multi-year period. Table 4-8 lists the reliabilities of meeting river low flow operation targets for the historic climate run and ten climate change scenarios assuming the May

1st storage target was met each year. Climate change scenarios are described in more detail in the report "Climate Change Scenario Modelling" (Shifflet, 2014).

There was no significant change to the reliabilities of meeting winter flow targets. For the Grand River, most of the scenarios suggested that meeting the summer targets would have similar reliabilities to the historic climate data set, but there would be challenges to meeting the low flow targets through the fall period. Two scenarios, with extremely dry summer periods, resulted in some very low reliability values for meeting the summer and fall low flow targets. For the Speed River, there may be challenges to meeting the summer low flow operational target, but little change in the reliability in meeting the fall flow target.

Table 4-8. Reservoir reliabilities for meeting or exceeding low flow operation targets for ten climate change scenarios and the historic climate record

	Doon			Brantford			Below Guelph		
	Jan-Apr	May-Sep	Oct-Dec	Jan-Apr	May-Sep	Oct-Dec	Jan-Apr	May-Sep	Oct-Dec
	Percent (%) of Time Meeting Low Flow Operation Targets (Reliability)								
*Historic Climate	100	99	96	99	100	96	100	98	99
Scenario 30	100	100	99	98	100	98	100	99	100
Scenario 31	100	100	99	100	100	97	100	96	99
Scenario 34	100	98	**90**	100	97	**86**	100	**93**	98
Scenario 52	100	100	99	100	100	97	100	97	99
Scenario 53	100	99	96	99	99	**93**	100	96	98
Scenario 58	100	100	**90**	99	98	**82**	100	**90**	98
Scenario 65	100	**93**	**89**	100	**90**	**79**	100	**88**	98
Scenario 66	100	**94**	**90**	100	**90**	**84**	100	**88**	98
Scenario 71	100	99	95	100	99	**93**	100	96	99
Scenario 72	100	100	98	100	100	**95**	100	**93**	99

* modeled output based on observed climate data
**model output shows that operational flow is consistently maintained assuming May 1st fill level is achieved by May 1

The results from the reservoir yield climate change scenarios runs assumed the May 1st filling level in each reservoir was achieved; however, there are expected to be large differences in winter precipitation and snowpack in a changed climate that could affect the normal filling cycle of the reservoirs. The current winter operating procedures may not be robust enough to ensure the reservoirs are filled on a regular basis. Winter precipitation is stored on the landscape in the snowpack and then becomes runoff during spring melts, which helps to fill the reservoirs. If winter precipitation is not stored in the snowpack, or is released throughout the winter with mid-winter melts, it will not be available in the spring to fill the reservoirs. Flexibility in winter operations should be incorporated into the reservoir operating procedures to capture mid-winter melt water while continuing to manage flood risk.

4.5.9 Summary

The existing reservoir operating procedures and flow targets gave the highest reliabilities in meeting the low flow operation targets based on historical climate data. Increases in flow targets, or decreases in spring filling levels, will decrease the reliability of meeting flow targets. Decreased reliabilities may still be above 95% under historic climate conditions, but there will be little capacity to adapt to a changing climate. The climate change scenarios suggested that meeting low flow targets, as well as filling the reservoirs in the spring, may be more challenging in the future.

Flexibility in the spring filling cycle may be needed to ensure adequate storage to meet fall flow targets. Operating reservoirs in a changing climate will require more adaptive management. A review of Flood Risk Management during the filling cycle will be conducted as part of the Strategic Flood Review (IAP C.6).

4.5.10 Surface Water Taking Affecting River Flow Reliability

In addition to the Region of Waterloo and City of Brantford municipal water supply withdrawals, for which the water control system is designed, there are many other water takings from the regulated reaches of the Grand, Conestogo and Speed Rivers and the tributaries that contribute flow to these regulated reaches. Most of these takings are for crop irrigation, golf course irrigation and aggregate washing. All but one taking are seasonal.

The total permitted non-municipal water taking from the central Grand and tributaries below the reservoirs, as shown in Table 4-9 is 4.2 m^3/s. This potential withdrawal is significant compared with the summer operational flow target for the Grand River at Brantford at 17.0 m^3/s. However, the reported actual water taking in 2011 was much less at 1.5 m^3/s.

Table 4-9. Maximum seasonal water takings relative to operational flow targets

Watershed	Total Permitted Taking (m^3/s)	Total Actual Taking (reported, estimated) (m^3/s)	Operational Flow Target (m^3/s)	% of Target Potentially Removed
Speed / Eramosa above Guelph	0.68	0.34	1.7	40
Grand above Doon	0.57	0.03	9.9	6
Grand above Galt	1.3	0.37	12	11
Grand above Brantford	4.4	1.5	17	25

Given that the reliability of reservoir low flow augmentation is sensitive to target changes in the order of 1 m^3/s on the Grand River, care must be taken that the accumulation of new surface water takings from the river system upstream of Brantford does not undermine the reliability of river flows.

All new surface water permits should include conditions that require the water supply system to be designed such that the rate of withdrawal can be drastically reduced (e.g., 60%) for a period of time when river flows drop below the operational flow target, for example, by incorporating storage and/or variable rate pumps (IAP C.8). Almost all of the current users incorporate storage into their water supply systems (e.g., irrigation pond, wash pond) and can reduce water withdrawal rates by up to two thirds by pumping at a lower rate over a longer period of the day.

4.6 Areas with Potential for Water Use Conflict or Constraint

The continued refinement of information supporting Water Use and Water Budget studies in the Grand River watershed has helped to identify areas with potential for water use conflict or constraint. The areas requiring further refinement continue to be the municipal groundwater takings in the central moraines in the watershed and the agricultural surface water takings in the Norfolk Sand Plain (Figure 4-4).

Most municipalities have water supply master plans for their growth centres and have investigated the long term sustainability of their supply sources. Trends towards reduced per capita water use due to aggressive municipal water conservation programs, combined with technological water efficiency improvements that are making their way into all water use sectors, are helping to control the growth of new water needs for municipal purposes. Tier 3 Water Budget studies to be completed in 2014 are also confirming the sustainability of water supplies to satisfy long term human and ecological needs as well as giving consideration to the potential for climate change to influence existing water sources (IAP C.12).

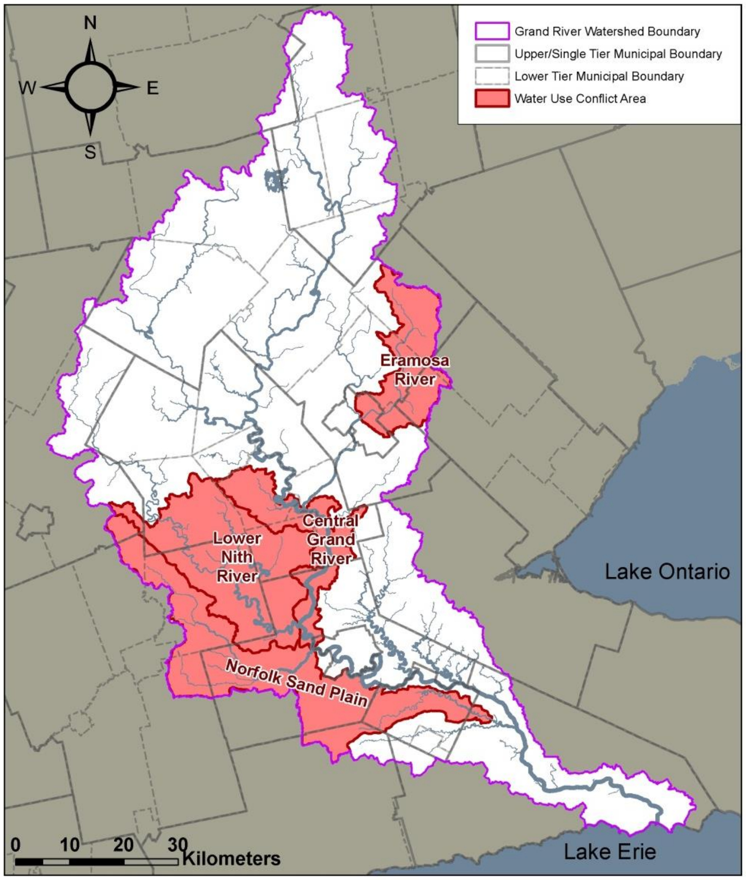


Figure 4-4. Areas of conflict or constraint.

Livestock water needs, while expected to increase over the duration of this plan are focussed in the northwest portions of the watershed, in areas of low water use that are not expecting significant urban growth. Water needs for crop irrigation may increase, particularly in areas with coarse textured soils; however, the projected water use is expected to be sustainable provided that water is sourced from groundwater and/or storage and not taken directly from the creeks and rivers (IAP C.4).

Aggregate production is expected to increase in step with population growth, with the largest production shifting from Puslinch Township to North Dumfries Township to the County of Brant over the next twenty years as reserves are depleted. While water taking for aggregate production (wash operations) is not expected to increase significantly, a shift in aggregate production to west County of Brant in combination with agricultural crop irrigation in this area will need to be factored into discussions about solutions to current water supply challenges there (IAP C.12).

The regions where there are potential water use conflicts or constraints include the Eramosa River subwatershed and the lower Nith, Whitemans, Mount Pleasant Creek and McKenzie Creek subwatersheds. Further information on constraints and/or conflicts in these regions is documented in the Drought Contingency Plan report[45]. Further detail on the Whitemans, Mount Pleasant and McKenzie Creek region is below.

4.6.1 Whitemans, Mount Pleasant, McKenzie Creeks

Whitemans Creek is located in west County of Brant and north-east Oxford County and enters the Grand River just upstream of Brantford. The flows in Whitemans Creek are largely dependent on groundwater from the high water table. The shallow sand aquifer that feeds Whitemans Creek provides sustained coldwater baseflows and supports a good coldwater fishery.

The portion of the Whitemans Creek watershed in the Norfolk Sand Plain has some of the largest cash crop operations in Southern Ontario, with a heavy demand for water for irrigation, particularly in July and August. There are 130 permits to take water in the Whitemans Creek watershed, 124 of which are for agricultural irrigation, two for golf course irrigation, one other commercial use and three municipal wells. Of the crop irrigation permits, 91 are from groundwater and 33 are from surface water. The maximum permitted water taking represents 57% of the average summer low flow of 1.6 m^3/s (1600 l/s).

Field studies in Whitemans Creek show that a flow of 0.8 m^3/s (800 l/s) is required in the creek at Cleaver Road to maintain connection between the riffles to sustain the fish population. Flows in Whitemans Creek drop below 0.5 m^3/s one year out of three on average. The neighbouring McKenzie and Mount Pleasant Creeks have similar conditions.

While there are currently water management challenges in dry years, a preliminary look at the water budget using the Tier 2 Water Quantity Stress Assessment methodology developed under the Source Protection Program shows that overall water use is relatively low in comparison to water availability in this area[37]. The water management challenges seem to be related to the reliance on direct withdrawals from the creeks during low flow periods, rather than an overuse of water in general.

The Grand River Low Water Response Team has recommended the following pro-active measures: less reliance on the creek for water needs, more efficient irrigation systems and practices, and an irrigation scheduling program among neighbours (IAP C.4).

In 2013, Federal and Provincial funding administered by Farm and Food Care Ontario helped establish a pilot project to develop pro-active drought contingency strategies for irrigators who draw directly from Whitemans Creek. The study has looked at ways to better inform irrigators of soil moisture conditions as it applies to watering requirements, identify potential alternative surface water sources and enable the community to share alternate resources in a drought condition (IAP C.4).

The Ministry of Natural Resources and Forestry and GRCA are discussing the development of an integrated water budget model to look in more detail at the carrying capacity of the area for agricultural, municipal and other takings, and the measures most likely to ensure sustainable water supplies. (IAP C.12).

4.7 Protection of Key Hydrologic Functions

Ensuring water supplies for communities, ecosystems and economies requires the balancing of key hydrologic processes and protecting the key hydrologic functions of critical landscape features. Key landscape features include the large multipurpose reservoirs, provincially significant wetlands and moraine complexes within the watershed.

Maintaining water storage on the landscape through the continued upkeep and operation of the seven multipurpose reservoirs is required to ensure water supplies for communities, ecosystems and economies (IAP C5; E1). The seven multipurpose reservoirs retain water within the watershed and thereby reduces the risk of flooding further downstream. The water stored in the reservoirs also helps to augment river flows during periods of low flow. Base flow augmentation effectively ensures that downstream water supplies are maintained and helps to improve water quality by diluting wastewater effluents and stormwater runoff from point and non-point sources.

Wetlands are considered fundamentally important for flood control and help regulate water quantity and improve water quality. Prominent wetland areas that currently provide a water storage function on the landscape include the Luther Marsh Provincially Significant Wetland (PSW) Complex, which is managed as a reservoir in part, and the Puslinch Lake - Irish Creek PSW Complex, a naturally occurring and unmanaged wetland (see Figure 2-8). Coastal wetlands in the Dunnville area also help mitigate flooding during high water events on Lake Erie.

In addition to flood control, many other provincially and locally significant wetlands provide important hydrologic processes such as groundwater recharge and discharge. Wetlands that help to recharge local and regional aquifers include the Spongy Lake PSW Complex – a rare bog community that typically occurs in more northern climates. Other wetlands that provide critical recharge and discharge functions, which in turn support extensive coldwater creek systems in the watershed, include the Speed-Lutteral-Swan Creek PSW, Eramosa River - Blue Springs Creek PSW, Roseville Swamp – Cedar Creek PSW, Mill Creek Puslinch PSW, Whitemans Creek - Kenny Creek PSW, Fairchild Creek Headwater PSW, Oakland Swamp PSW, and Brantford Northwest PSW. Brantford Northwest PSW supports a rare perched fen community. Protection of these and other provincially significant wetlands in the watershed, as well as the smaller and more isolated locally significant wetlands, should continue through diligent land use and subwatershed planning (IAP D6; E3), stewardship, and education (IAP D7). Further, there is a need to update regional groundwater-surface water models and mapping to better reflect the key hydrologic processes such as groundwater recharge and discharge that supports significant wetland features in the watershed (IAP C11).

In addition to retaining water on the landscape in reservoirs and wetlands, there are numerous watershed features that facilitate the movement of surface water into the groundwater system. These features include:

- The permeable deposits and hummocky topography associated with the moraines;
- Glacial outwash sands and gravels;
- Gravel terraces;
- Sand plains; and
- Exposed fractured and/or karstified bedrock

The quality and quantity of surface water entering these significant recharge features impacts the groundwater aquifers that support drinking water supplies, wetlands, and river baseflows. Further, these closed drainage areas also help to reduce downstream flooding.

Approximately 40% of the land area that covers the watershed is considered to have a high recharge potential (see Figure 2-10). The largest areas for potential recharge are located throughout the central portion of the watershed, within the moraine systems and the Norfolk Sand Plain. Although recharge within the Paris/Galt and Waterloo moraines contributes to the groundwater within the overburden aquifers, the Orangeville moraine is a major recharge area that contributes to the bedrock aquifers. Areas with thin overburden cover, or exposed fractured or karstified bedrock also facilitate recharge to the groundwater system. These areas have yet to be reflected on the groundwater recharge map; however, work will continue to best describe this key hydrologic process associated with karst topography (IAP C.10).

A significant portion (about 60%) of the moraine systems in the watershed is urbanized. Groundwater recharge is most affected by activities, such as drainage and paving that intercept precipitation and facilitate the movement of water off the land in surface runoff.

Land use within these significant recharge areas can have a major influence on both groundwater quality and quantity. Intensive cropping practices with repeated manure and fertilizer applications have the potential to impact groundwater quality while paving, drainage and intensive activity associated with urban development can interrupt groundwater recharge and impact both groundwater quantity and quality. Since these areas have ecological, sociological, and economical significance within the watershed, they are important features on which the sustainability of both groundwater and surface water supplies depends. Strategic planning is needed to protect these recharge areas that support critical groundwater recharge processes in the watershed (IAP C.10).

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[43] Grand River Implementation Committee. 1982. *Grand River Basin Water Management Study.* Available online at: http://www.grandriver.ca/WaterPlan/1982_BasinStudy.pdf

[44] *Flow Reliability in Regulated Reaches of the Grand River Watershed*. D. Boyd and S.Shifflett, Grand River Conservation Authority, (in preparation) August 2012.

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5 Improving Water Quality

A goal of the *Plan* is to improve water quality to improve river health and reduce its impact on Lake Erie. There are many uses, needs and values for surface and ground water in the watershed that desire high quality water including the health of the river and the aquatic ecosystem; aesthetics, recreation, municipal and private drinking water supplies; commercial fisheries; and agricultural production. Although the background or natural water quality across the watershed varies considerably due to geology, land use and land management practices such as runoff from urban and rural areas, and waste assimilation from 30 wastewater treatment plants heavily influence the water quality issues seen in both surface and ground water. Further, a changing climate will undoubtedly influence water quality into the future. Consequently, the need for long term datasets becomes critical to evaluate trends over time and evaluate progress toward achieving the goals of the *Plan*.

5.1 Ground Water

The Province of Ontario initiated source protection planning for municipal drinking water sources in 2005. An extensive description of the groundwater systems and quality issues is described in the Grand River Characterization report[46] and the Grand River Assessment Report[47]. The following briefly describes the general groundwater quality across the watershed as well as highlights some of the key water quality issues.

5.1.1 Natural Groundwater Quality

The geochemical composition of groundwater is a result of many processes, including interaction with atmospheric gases, reaction with minerals, bacteriological processes, and anthropogenic effects among others. Although there is a public perception that all instances of undesired compounds in groundwater are a result of anthropogenic contamination, groundwater may be rendered unusable due entirely to natural geochemical processes. For instance, some groundwater is very hard and therefore not usable for some industrial processes. Groundwater may naturally have high concentrations of arsenic or total dissolved solids which makes it a poor or unsuitable source of potable water. Consequently, it is important to understand the natural or ambient quality of groundwater and the processes controlling it. This in turn allows for a stronger understanding of the impacts other contaminants may have on groundwater and provides insight into pollution trends and their effects on the aquifer system.

Ambient groundwater geochemistry generally evolves as it moves along its flow path. Typically, groundwater originates as precipitation and is generally low in total dissolved solids, is slightly acidic, and somewhat oxidizing[48]. As the groundwater moves along its flow path, it can collect different anions. This results in a change in the quality of the groundwater spatially as well as over time.

Although there have been no regional, long-term groundwater quality monitoring programs within the Grand River watershed, some inferences can be made with observations collected at the time of drilling or through the results of sampling of ambient groundwater conducted through the Provincial Groundwater Monitoring Network (PGMN).

Some basic observations of groundwater type are made by drillers at the time of drilling and submitted to the Ministry of the Environment (OMOECC) water well information system. Groundwater type is classified through odour and taste as fresh, salty, sulphur or mineral. This method of classification provides a crude indication of groundwater quality at the time the well is drilled and, when mapped, can provide insight into the general geochemical conditions in a particular location and within a particular hydrogeologic unit. Figure 5-1 and Figure 5-2 show the spatial distribution of these observations in the overburden and bedrock, respectively.

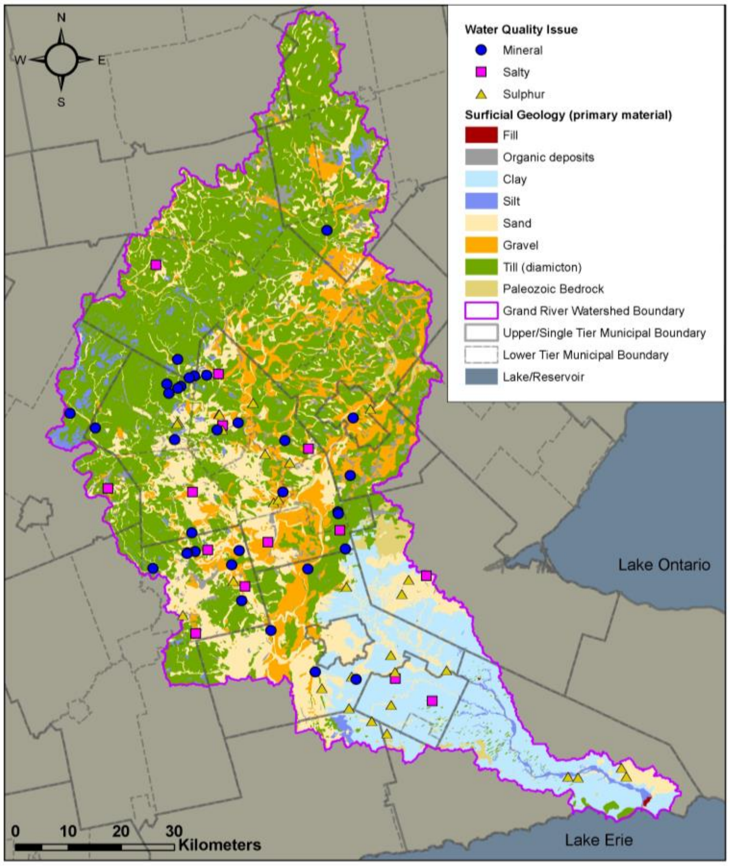

Figure 5-1. Natural water quality issues in overburden wells

Examination of the distribution of the water types reported indicates that there is a general bias towards the sulphur classification in bedrock wells, likely because the sulphur odour is such a strong distinguishing feature.

A regional groundwater study illustrated that ambient water quality ranges from good to poor across the watershed[49]. High sulphur content was the most common water quality problem and was associated with bedrock throughout the watershed. The Guelph, the Salina, and the Onondaga–Amherstburg Formations are the bedrock formations with most of the wells with high sulphur. Within these formations, the wells classified as having high sulphur content were clustered, indicating that there might be some other control on the water quality in addition to the bedrock geology. These clusters did not correspond to any known sub-members, however the elevated sulphur content may be related to the presence of common sulphur bearing minerals such as gypsum or pyrite.

Several bedrock wells were also reported as having a high salt content. Of these, almost half were located in the Guelph Formation. High salt content is also reported in wells drilled in the Salina Formation. Wells with high concentrations of salt could be indicative of groundwater discharge from deeper, more regional groundwater flow systems. Generally, the longer groundwater remains in the subsurface the greater the concentration of dissolved ions.

Water quality problems associated with overburden aquifers can be found throughout the watershed. However, no obvious geographic patterns could be deciphered. One exception to this is a small cluster of wells with a mineral water quality problem found to the west of Elmira in Waterloo Region. Little explanation for this grouping is obvious as some wells have been drilled into tills while others have been drilled into sands and gravels.

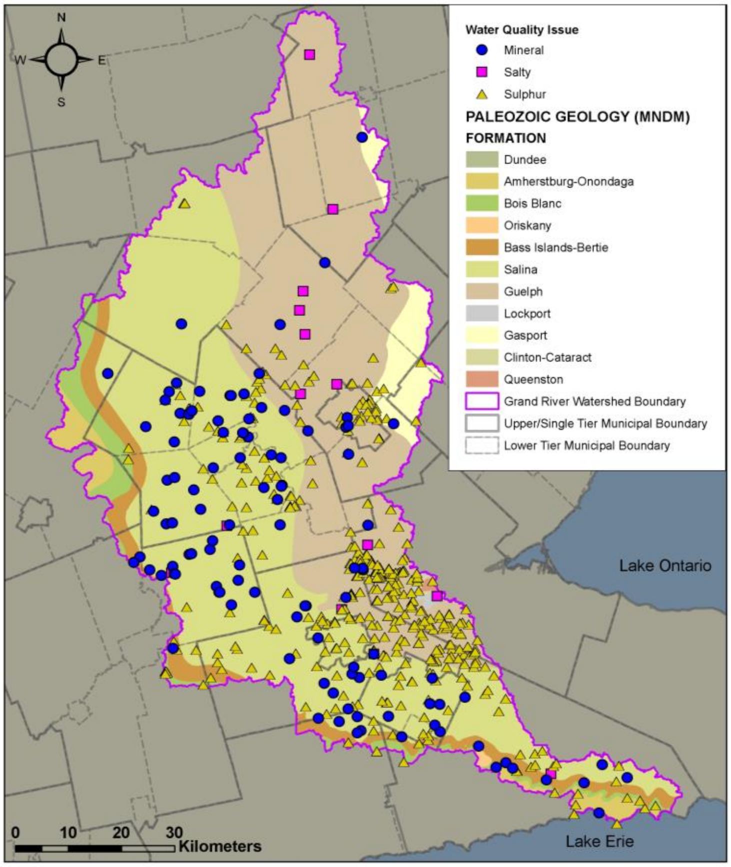

Figure 5-2. Natural groundwater quality issues in bedrock wells

5.1.2 Groundwater Quality Issues

Groundwater, because it is generally a non-visible resource is often 'out of sight, out of mind', and not as well understood as many surface water resources.

Although some groundwater quality issues can be from natural conditions, many ground water quality issues are the result of historic land use and management activities. Groundwater quality issues in municipal drinking water supplies are described extensively in the Grand River Characterization report [46] and the Grand River Assessment Report [47]. The following highlights some of the water quality issues found in municipal drinking water supplies:

- Presence of pesticides;
- High nitrates;
- Elevated levels if chlorides, sodium, and sulphates; and
- Presence of industrial contaminants (e.g. chlorinated organics, VOCs, TCE, and Benzene).

Groundwater quality concerns can also be related to naturally occurring chemicals such as fluoride, hardness, iron and manganese, which are often derived from geologic sources.

Groundwater contamination can fall into two categories: contamination originating from point sources, such as chemical spills and leaking storage tanks and non-point sources where contaminants enter the groundwater system over a broad area. An example of non-point sources are when agricultural fertilizers and pesticides are applied to fields and migrate into the local groundwater system.

The movement of groundwater is often much slower than that of surface water, and it generally takes considerably more time for groundwater to respond to environmental changes. As a consequence, the residence time of persistent contaminants tends to be much longer in groundwater when compared to surface waters. Additionally, many groundwater contamination issues are recognized for decades, and contaminants can be detected in groundwater at significant distances from their sources.

Historic land use practices from both point and non-point sources such as the use of road de-icers, fertilizer and pesticide use, and leaking storage tanks containing petroleum products, for example, and have a slow but progressive impact on regional groundwater quality. This can lead to both degraded drinking water supplies and ecological health.

Once groundwater becomes contaminated, it can be difficult and costly to remediate. Best practices to promote the reduction or prevention of contaminants into groundwater should be encouraged (IAP D7).

Recent river surveys are showing very high nitrate levels in the Grand River during the winter. The nitrate is thought to be from shallow groundwater. Research is required to confirm the source and pathways of the nitrate in the central Grand River region however; it is recommended that nutrient management practices be implemented in areas of high groundwater recharge to help facilitate the reduction of nitrate in shallow groundwater (IAP D7 & D8).

In addition to the above ‘legacy’ contaminants, there are also ‘contaminants of emerging concern’ such as pharmaceutical residues, personal care products, and perchlorate, among others. Less is known about the occurrence and effects of these emerging contaminants in the ecosystem, and research is currently underway to determine the prevalence and fate of such compounds in the environment.

5.1.3 Protection of Key Hydrologic Functions

Many aquifers used for groundwater supply, including municipal supply, are afforded a certain degree of protection by the overlying geologic units. Aquitards, which have a much lower permeability than aquifers, control groundwater recharge and contaminant transport to adjacent aquifers, and are of sufficiently low hydraulic conductivity, areal extent, thickness and geometry to impede groundwater flow between aquifers[50]. Aquifers that are not overlain by aquitards (unconfined aquifers) are substantially more prone to contamination.

Important aquitards within the Grand River watershed include the Eramosa bedrock formation and clay-rich overburden till units.

The Eramosa Formation, which averages about 15m in thickness, is a particularly important bedrock aquitard in protecting the City of Guelph’s groundwater supplies. The City draws most of its water from the Gasport Formation, which in this area is heavily karsted and often referred to as the ‘production zone’. The Eramosa Formation, which directly overlies the Gasport Formation, forms an important barrier to protect the City’s water supply from surface contamination. Aquitards protecting important groundwater sources can be breached by quarry operations, unsealed abandoned wells and wells that are constructed with screens through the aquitard. All efforts should be made to protect this important aquitard from being breached to ensure the safety and cleanliness of the City’s water supply.

The numerous till units present across the watershed are often high in silt and clay content, allowing for them to behave as aquitards, thus impeding groundwater flow from the surface to deeper, confined aquifers. Of particular note are the Tavistock and Mornington tills on the northwest side of the watershed and the Mary Hill, Tavistock and Port Stanley tills within the Waterloo Moraine. As aquitards, till units can protect both underlying overburden and bedrock aquifers from contamination from surficial sources. The protection that till units provide to water supply aquifers can be improved by sealing old and abandoned wells that create conduits for surface water to access the underlying aquifers. The Ontario Drinking Water Stewardship program offered funding support to rural properties in high vulnerable areas however funding for this program has concluded. The rural water quality program continues to provide funding to rural landowners, mostly farmers, for the proper decommissioning of wells. It is recommended that funding for well decommissioning be offered watershed wide (IAP D.7).

In addition to the protection of aquitards and active well abandonment programs, municipalities across the watershed have created Wellhead Protection Areas (WHPAs) for all municipal wells through the Source Water Protection program. WHPAs are extensively documented in the Grand River Assessment Report. The purpose of WHPAs is to characterize time-related groundwater capture zones for each municipal well, such that within the Source Protection Act, land uses can be regulated within these areas to limit negative impacts to municipal groundwater quality.

5.2 Surface Water

Surface water quality in the Grand River and its tributaries is heavily influenced by land use however, geology does play a role. The northern till plains, drained by the Nith, upper Conestogo and upper Grand Rivers, support livestock operations and general cash crop production. The lack of permanent vegetative cover results in higher water temperatures and higher nutrient concentrations from runoff in this area.

The central portion of the Grand River, including the Canagagigue Creek, Conestogo River and lower Speed River, tends to be the area within the watershed where water quality is most impaired. A high concentration of phosphorus and nitrogen contributes to prolific aquatic plant growth which can lead to low dissolved oxygen. The impact stormwater and wastewater discharges from the urban areas is reflected by the significant increase in the concentration of phosphorus, total ammonia and chloride as the river flows through the Region of Waterloo from Bridgeport to Blair.

Similar impacts are also found within the Speed River below Guelph; however, the effects of high phosphorus concentrations are not as pronounced in the Speed River as they are in the Grand River. In addition, nitrate and chloride concentration tend to be higher in the Speed River, especially downstream of the Guelph wastewater treatment plant.

A steeper longitudinal gradient in the Grand River between Cambridge and Brantford and the significant groundwater discharge in this area contribute to the partial ‘recovery’ or improvement in river water quality above Brantford.

Water quality in the lower reaches of the Grand River reflects the cumulative impact of the upstream watershed, the lake-like conditions due to a very slow flowing river that is constrained by multiple on-line dams and the underlying local geology – the Haldimand Clay plain. This is reflected in the very high phosphorus concentrations seen in the Grand River throughout the lower reach from Brantford to Dunnville. The influence of the Haldimand Clay Plain is readily apparent as the river becomes more turbid, carrying a lot of suspended sediments and clay particles but the turbidity may also be influenced by higher concentrations of phytoplankton due to the nutrient-rich lake-like conditions.

Overall, high total phosphorus and suspended sediment concentrations in the Grand River in Dunnville are the major water quality concerns as the river discharges to Lake Erie. The high phosphorus concentrations have been hypothesized to be one of the many causative factors in the observed increased *Cladophora* (algae) growth and distribution that fouls large portions of the north shore on the eastern basin of Lake Erie.

The nutrient index shown in Figure 5-3 provides an illustration of the relative water quality at different locations in the watershed, as affected by enrichment of phosphorus and different forms of nitrogen. Degraded water quality resulting from consistently high concentrations of nutrients is a concern, particularly in the central reaches of the Grand River, Canagagigue Creek and in the southern Grand River near the Dunnville Dam.

The following sections highlight some of the key water quality issues currently experienced in the watershed, the most important sources of the problem and some solutions.

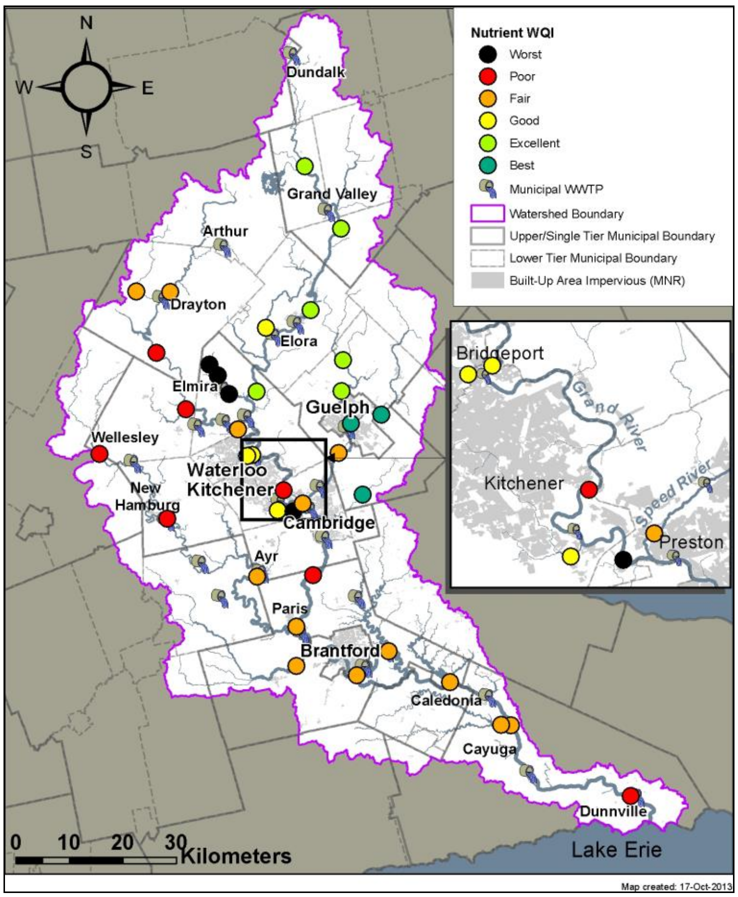

Figure 5-3. Water quality index for nutrient concentrations (2008-2012).

5.2.1 Surface Water Quality Issues

5.2.1.1 River Eutrophication (Nutrient Enrichment)

A high concentration of phosphorus in most rivers and streams in the Grand River watershed has long been recognized as an issue as it is the primary nutrient that promotes nuisance growth of aquatic plants and algae in the rivers. Dissolved oxygen concentration fluctuates from oxygen super-saturation resulting from daytime photosynthesis to oxygen depletion due to overnight plant respiration. The overnight decrease in dissolved oxygen can result in conditions that are harmful or even lethal to sensitive aquatic organisms, such as fish.

Recent assessments of the ambient conditions in the Grand River watershed have illustrated high phosphorus concentrations in many of the larger reaches of the Grand River and its tributaries, but concentrations are particularly high in central reaches of the Grand River, Canagagigue Creek and in the southern Grand River near the Dunnville dam (Figure 5-4).

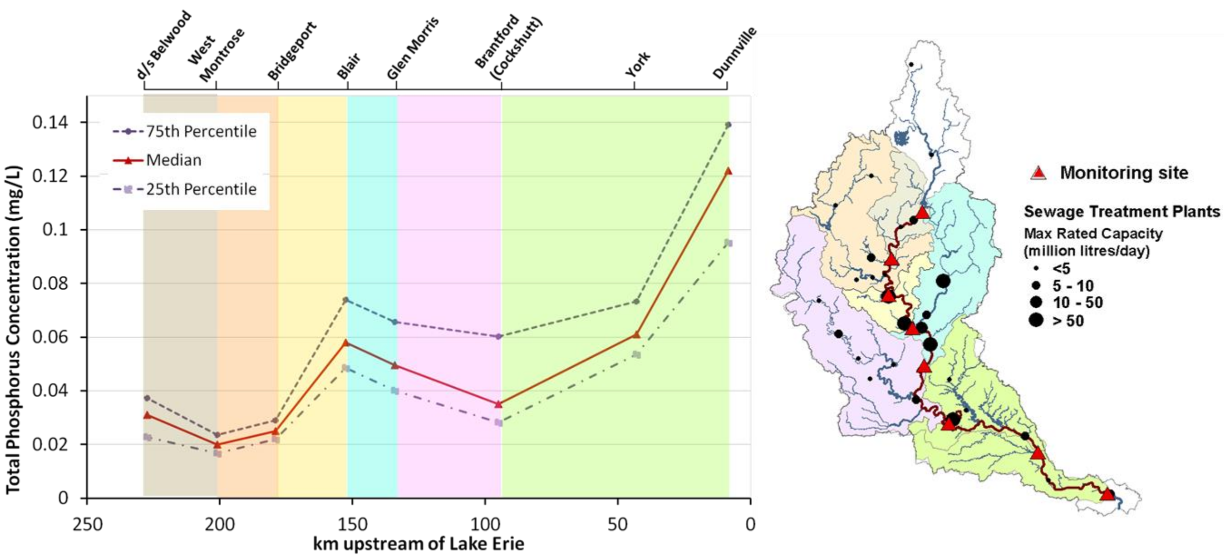

Figure 5-4. Summer phosphorus concentrations along the Grand River from the Shand dam to Dunnville

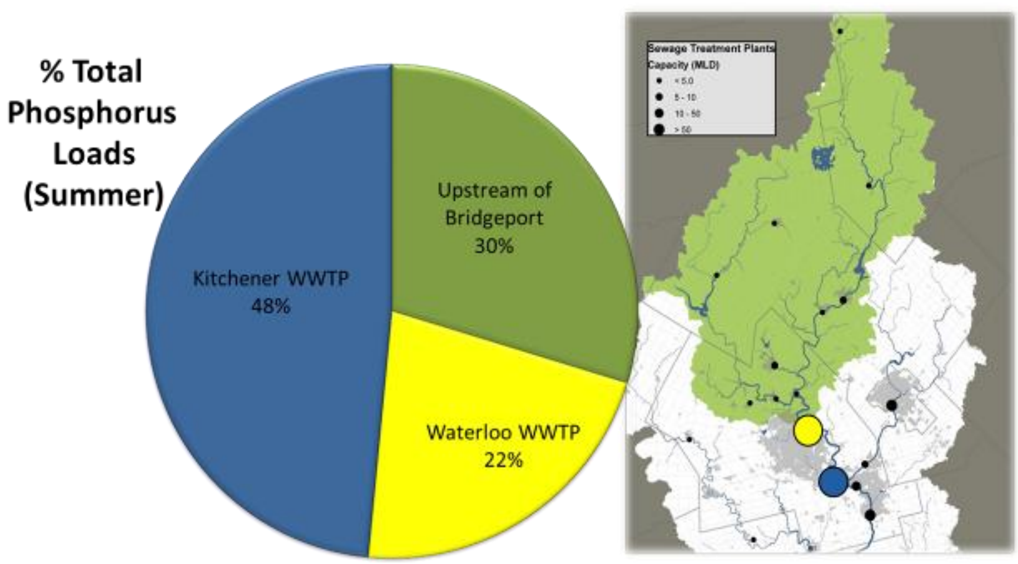

Figure 5-5. Sources of phosphorus in the central Grand River region in the summer

The central portion of the Grand River from Bridgeport to Glen Morris and the Speed River downstream of Guelph receive phosphorus loading from many large wastewater treatment plants. The wastewater treatment plants have been shown to be a major source of total phosphorus in the central Grand River under summer conditions and triple the concentration of total phosphorus in the river[51] (Figure 5-5). These sources have a profound effect on the river. The high phosphorus levels result in substantive aquatic vegetation growth, which can impact dissolved oxygen levels in the river. Low dissolved oxygen concentrations are particularly apparent in the central Grand River region during the summer; the daily minimum dissolved oxygen in the river falls well below the threshold for target concentrations (>4.0 mg/L for warm water communities) frequently and for long periods of time.

Wastewater discharges of dissolved phosphorus, the form of phosphorus that is readily available to aquatic plants, directly contribute to the eutrophication of the rivers in the central region of the watershed during the summer. Although phosphorus concentrations in the rivers below wastewater treatment plants have decreased substantially since the 1970's, they remain high enough to support prolific aquatic plant growth that subsequently influence the dissolved oxygen regimes.

Planned wastewater treatment plant upgrades, as set out in municipal Wastewater Treatment Master Plans, are underway and will improve surface water quality into the future (2031) (IAP D.1). A study of future water quality conditions in the Grand and Speed rivers, using the Grand River Simulation Model,ests that summer phosphorus concentrations can be reduced by as much as 25% by implementing planned wastewater treatment plant upgrades[52]. The study also suggests that an additional 19% reduction in summer river phosphorus concentrations can be realized with the adoption of enhanced process control through the Composite Correction Program (CCP) to achieve effluent quality performace targets (IAP D.2). The CCP has also demonstrated the ability to reduce the frequency and severity of spills and bypasses from WWTPs. Through Source Protection Planning, spills have been identified as a concern by watershed municipalities who own and operate drinking water intakes[47]. Watershed municipalities using the CCP include Guelph, Haldimand, and Brantford and they have successfully demonstrated appreciable improvements in effluent quality as a result.

> ***Wastewater Treatment Plant Optimization*** is a continuous improvement process that invests in people – operators, managers and administrators, to make effective use of existing resources and infrastructure to manage wastewater treatment processes more effectively. Optimization is considered a best practice in the Grand River watershed.

Wastewater treatment plant upgrades and optimzation will go a long way toward achieving a reduction of in-river phosphorus concentrations that contribut to the eutrophication of the rivers. Milestones have been developed for total phosphorus, ammonia and dissolved oxygen at specific monitoring sites in the central Grand River and lower Speed River that focus on summer conditions.

A data collection plan will have to be developed over the near-term to determine if the milestones for total phosphorus and ammonia concentrations are being met in the future (IAP D.15). The data collection plan will need to consider the variability of total phosphorus and ammonia concentrations under low flow summer conditions; this will impact the timing and frequency of sampling.

Water quality surveys in the southern Grand River above the Dunnville Dam have documented high concentrations of phosphorus and suspended sediment and periodic anoxic (low-oxygen) conditions in the lake-like, slow moving reaches of the Grand River near Cayuga[53]. In this region, the river flows over the Haldimand Clay Plain which makes the water naturally turbid. The high nutrient concentrations and the slow flowing, warm waters in this region also lead to hyper-eutrophic conditions.

Investigations continue by Plan partners to further understand the interconnections between the lake-like conditions and static water level regime caused by the Dunnville Dam, as well as the high phosphorus and sediment concentrations that contribute to the current hyper-eutrophic state of the southern Grand River and the poor health of the Dunnville Marsh and other coastal marsh complexes (IAP D.13).

5.2.1.2 Algal Blooms in Reservoirs and Along the Nearshore of Lake Erie

Springtime is generally characterized by high runoff events due to snow melt and heavy rainfall which mobilize nutrients and sediment from the land and transport them downstream. Significant rainfall during the summer can also mobilize nutrients and sediments. It is during these times that the highest concentrations of total phosphorus and sediment are typically seen in the Grand River system and the greatest loads (e.g., kilograms) are delivered to reservoirs and Lake Erie. The loads from nonpoint sources are significant and act as a reservoir of ‘food’ for aquatic plants and algae to grow once water temperatures and light availability increase [51]. These loads contribute to the annual blooms of algae in the reservoirs; likely contribute to the in-river reserve of nutrients; and also likely contribute to the growth of *Cladophora* (algae) that fouls the nearshore in the eastern basin of Lake Erie.

Nonpoint sources have a substantive effect on downstream water bodies such as reservoirs or Lake Erie. Agricultural areas that have a surplus of nutrients from manure or inorganic fertilizers, and are well drained or hydrologically connected to streams and rivers, contribute to the high levels of phosphorus and sediment in the river observed in the springtime. During the high flows in the springtime (.e.g., March – April), the largest portion of the total phosphorus load (approximately 94%) is estimated to come from rural, agricultural and urban nonpoint sources in the upper middle region of the watershed. Conversely, it is estimated that point sources only account for 3% of the phosphorus load (Figure 5-6).

Undertaking subwatershed plans for priority areas of the watershed, including the upper Conestogo, upper Grand and upper Nith River will assist with understanding the relative contributions of point and nonpoint sources in order for improved water management planning and to identify best value solutions for the smaller, rural municipalities (IAP D.6).

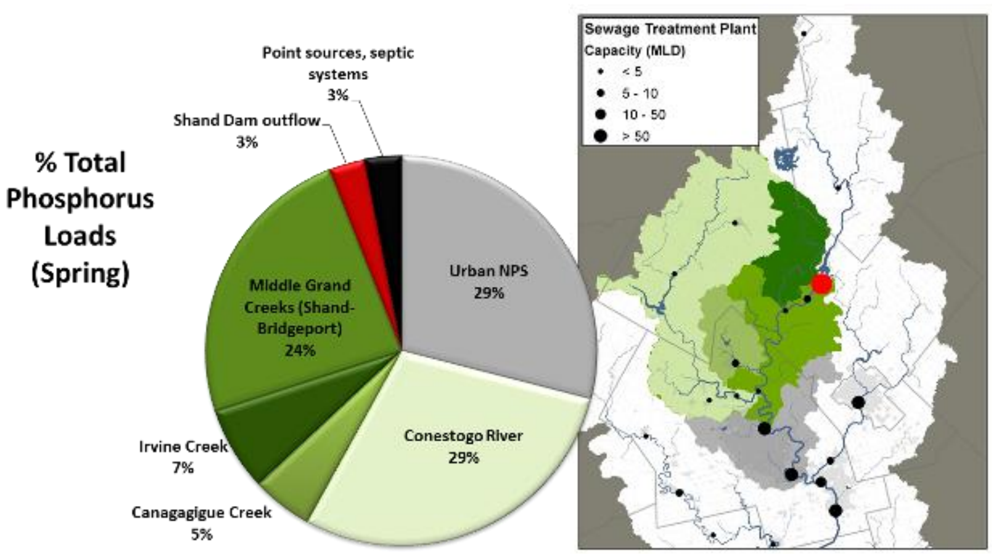

Figure 5-6. Phosphorus loads in the upper-middle Grand River region, above Blair during spring high flows

A full range of rural best management practices (BMPs), including both structural solutions and conservation practices, as promoted through the Rural Water Quality Program, will continue to address rural nonpoint sources in the Grand River watershed. Enhanced assistance of BMPs in priority subwatersheds for nonpoint source management of phosphorus and sediment include the upper Grand River, Conestogo River, Nith River, Canagagigue Creek, and Fairchild Creek (IAP D.7).

5.2.1.3 Erosion and Sedimentation

Sediment delivery is a natural river process. However, high concentrations of suspended sediments can impact aquatic life and their habitat and disrupt drinking water treatment processes if it they persist or elevate above critical thresholds. Although periodically high suspended sediment levels are natural due to seasonal variations in hydrology, extreme, prolonged events are a concern. Improved data collection is required to characterize extreme events and better understand their effects on the aquatic organisms (IAP D.15).

Suspended sediment concentrations tend to correlate well with total phosphorus concentrations as much of the total phosphorus tends to be in the particulate form. A regional assessment of total phosphorus loads suggest that almost one-third of the total spring loading to the upper-middle Grand River region was delivered from urban areas while the remaining load was delivered from rural areas[51]. Only a small portion (3%) of the total load was contributed by point sources. Historic studies in the Grand River watershed have documented the significance of urban and rural nonpoint sources of sediment; however, suspended sediments sourced from in-stream erosion remains unknown yet studies elsewhere suggest this source to be significant.

5.2.1.3.1 Rural Stormwater

Preliminary estimates of Grand River tributary sediment loads suggest that some tributaries deliver greater sediment loads than others. Greater sediment loads are exported from Fairchild, Nith and McKenzie Creek subwatersheds. Phosphorus and sediment management strategies should be focussed for greater uptake in the Conestogo and upper Nith Rivers and Canagagigue, Irvine, Fairchild and McKenzie subwatersheds. (IAP D8)

The Grand River watershed has a well-established agricultural nonpoint source management program (Rural Water Quality Program) in the Region of Waterloo and the counties of Wellington, Oxford, Brant, and Haldimand. The municipalities provide financial assistance to farmers to promote the adoption of best management practices to improve and protect water quality. The Grand River Conservation Authority provides technical assistance and delivers the program.

Through the RWQP, farmers and rural landowners have completed about 4000 projects to address sources of agricultural pollution in the Grand River watershed. The capital costs of these projects exceed $34 million. RWQP funding programs have provided over $13.5 million dollars in grant, while in-kind contributions to these projects from the farming community are valued at about $3.5 million.

As a result of RWQP projects completed as of August 2013 that address phosphorus, it is estimated that 94,000 kg of phosphorus annually are being kept on the land[54]. Work will continue to continually improve a phosphorus accounting methodology to track the progress of BMP implementation (IAP D.7).

While best practices will benefit landowners and communities everywhere, the program could provide enhanced incentives in priority subwatersheds to reduce phosphorus, nitrate and sediment movement from hydrologically connected source areas. Work is underway to illustrate the hydrologically connected areas in smaller subwatersheds of the upper Nith River to assist extension staff in focusing phosphorus and sediment management strategies (IAP D.7).

5.2.1.3.2 Urban Stormwater

Urban stormwater is considered an important source of sediment and total phosphorus in the central Grand River region in the springtime and after significant rainfall events.

In Ontario, stormwater management emerged in the 1970s and was focused on flood control. Requirements to address the quality of stormwater discharged into the receiving rivers were not in place until the early 1990s. Most urban areas built prior to the 1980's within the watershed predate this requirement and have no stormwater management controls.

Currently, the Ontario Ministry of the Environment provides guidance on stormwater facility design and performance criteria (water balance, water quality, erosion and water quantity) through its *Stormwater Management Planning and Design Manual*[55]. Additional requirements are defined in municipal stormwater management master plans, drainage policies and through the development of master drainage and subwatershed plans.

Through the Stormwater Managers Working Group, Grand River Conservation Authority (GRCA) and urban watershed municipalities (County of Brant, Brantford, Cambridge, Centre Wellington, Guelph, Kitchener and Waterloo) are collaborating to compose a list of best practices for stormwater control for both new and existing developments that they all agree their municipality should pursue to reduce sediment and nutrient loads to the receiving rivers (IAP D.10).

Further monitoring and evaluation is required to characterize the impact that urban stormwater may have regionally and at the watershed scale (IAP D.10).

5.2.1.3.3 In-river Sources

Turbidity, a surogate measure of particulate matter which includes suspended sediment among other materials, measures the penetration of light through the water column. High turbidity causes shading of benthos and a reduction in light available for growth of submergent macrophytes. The southern Grand River is highly turbid, in part due to the local geology as the river flows over the Haldimand Clay Plain, but also from impaired sediment delivery processes resulting from a modified water level regime due to the Dunnville Dam. These conditions likely contribute to the highly eutrophic state of the southern river. Although a significant amount of research and monitoring has already been done on the Dunnville Dam, work is required to evaluate the interrelationships between water levels, turbidity, sediment delivery and phosphorus levels. Partners will continue to work to confirm the role of in-river sediment and water levels in the overall state of the southern Grand River (IAP D.13).

There are over 150 run-of-the-river dams or weirs on streams or rivers in the Grand River watershed. These structures have been constructed over the last 175 years for a variety of purposes, mainly to power mills and for crop irrigation. Ownership of dams in the Grand River watershed is listed in Table 5-1.

Table 5-1. Ownership of dams and in-river weirs in the Grand River watershed (numbers based on GRCA database (2013))

Ownership	Number of Dams/In-river weirs*
Grand River Conservation Authority	29
Municipal	9
Private	65
Unconfirmed	50

The dams/weirs in the Grand River watershed have a variety of water management functions. Seven dams (Luther, Shand, Conestogo, Woolwich, Guelph, Laurel Creek, and Shade's Mill) are multi-purpose water control structures operated by GRCA for flood control and/or low river flow augmentation. Four in-river weirs (e.g. Hidden Valley, Arkell, Wilkes, and Caledonia) support municipal/Six Nations water supply by ensuring sufficient in-river levels for the intakes to operate properly. Several in-river weirs (e.g. Caledonia, Paris, and Parkhill) provide desired barriers to invasive/non-native species (e.g. rainbow trout, sea lamprey) and for fisheries management objectives[56]. Several dams/in-river weirs (e.g. Shand, Bissell, Drimmie, Conestogo, Guelph, Parkhill, Paris, and Caledonia) support or have potential to support water power generation as a secondary benefit of river flow. Most dams/in-river weirs have heritage value and are considered community amenities. GRCA continues to update the inventory of dams in the watershed (IAP D.14).

All dams or weirs affect the physical and geomorphic condition of the river and alter the hydrologic regime in both upstream and downstream reaches. However, the extent to which any one impoundment contributes to water quality and ecosystem health issues is variable. A number of factors can influence the effects of a dam or weir, including natural channel structure (e.g., gradient, depth), water retention time, sediment accumulation and composition, exchange between the water column and accumulated sediments, and the aquatic and riparian plant/algal community.

Run-of-the-river dams or weirs can affect sediment transport, nutrient cycling, and thermal regimes and block fish passage[40]. The Grand River Fisheries Management Plan[56] provides guidance regarding existing run-of-the-river dams from a fishery management perspective. Some existing run-of-the-river dams are a benefit for fisheries management by limiting the movement of introduced species that may be detrimental to native species. Other run-of-the-river dams are a barrier to sediment movement and impede the river's ability to process nutrients. An inventory of run-of-the-river in the Grand River watershed is needed to: 1) summarize the functions of existing dams, along with a qualitative assessment of their impacts from a sediment transport, nutrient processing and fisheries perspective, and 2) provide context and identify opportunities to improve or enhance the resiliency of the river to pass sediment, process nutrients and allow fish migration in the Grand River watershed. Studies of these factors at each of the dams or in-river weirs would support and help scope further discussions about in-river improvements as an option for improving water quality (IAP D.14). These studies would complement those which investigate other aspects of run-of-the-river dams/weirs (e.g., reductions in connectivity or barriers to movement of fish and other aquatic organisms) and further, prioritize removal/modification as recommended by the *Grand River Fisheries Management Plan*[56]. Specific attention should be paid to those structures on coldwater streams or streams/rivers with coldwater potential.

5.2.1.4 Nitrogen Toxicity

Nitrate and ammonia are forms of nitrogen that are important for aquatic plant growth however, they also can have direct toxic effects on aquatic organisms at high concentrations.

5.2.1.4.1 Ammonia Toxicity

High levels of un-ionized ammonia occur in the Grand River watershed in reaches downstream of wastewater treatment plants. In addition to the potential effects from toxicity, high levels of ammonia can cause conditions that are harmful to aquatic organisms as it acts as an oxygen scavenger and reduces in-river dissolved oxygen levels. The effects of ammonia tend to be located relatively close to the source of input, since it is rapidly converted to nitrate in the presence of oxygen. Ammonia can persist in the river where there is ice cover that limits oxygenation of the water. High ammonia levels can interfere with drinking water treatment processes.

The assessment of future water quality conditions suggests that un-inonized ammonia levels can be reduced by as much as 97% by implementing planned wastewater treatment plant upgrades, thereby achieving the target for un-ionized ammonia through the middle Grand River[57] (IAP D.1).

5.2.1.4.2 Elevated Nitrate Levels in Surface and Ground Water

Nitrate is a required nutrient for growth of plants and algae but, at elevated concentrations, it can have harmful effects on sensitive aquatic life. Very high nitrate concentrations can also cause human health concerns if present in sources of drinking water. The increasing trend over time in nitrate concentrations in both surface water[58] and groundwater[59] at some sampling sites in the watershed is a cause for concern. Some river sites already exceed the Canadian guideline[60] to protect aquatic life (3.0 mg/L as N) during some times of the year.

Although nitrate levels in the the central Grand River do not usually exceed the Ontario Drinking Water Quality Standard (< 10 mg/L as N), periodic sampling for nitrate during the winter months in the central Grand River above Bridgeport has shown levels approaching this guideline. Surface water nitrate levels are particuarly high during the winter months in some of the streams and rivers that drain coarse textured sediments like the Waterloo Moraine (e.g., Alder Creek), the gravel terraces in the central Grand River (e.g., Cox and Carroll Creeks) and the Norfolk Sand Plain (e.g., Whitemans Creek). In this season, biological uptake of nitrate is low and groundwater accounts for a relatively large proportion of river flow. The nitrate concentration in the groundwater of unconfined overburden aquifers in these watershed areas also tends to be high, such that it poses a risk to private and municipal drinking water supplies.

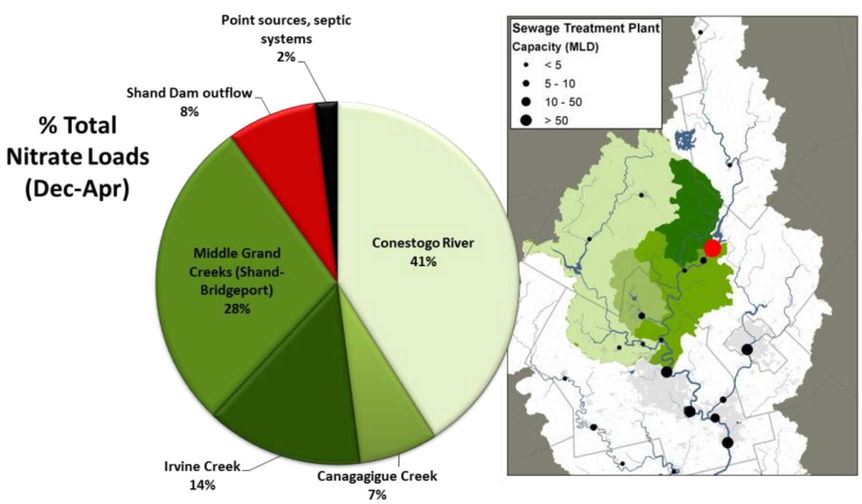

Figure 5-7. Sources of nitrate in the Grand River above Bridgeport during the winter (Dec-April)

Regional assessment of winter nitrate loading to the Grand River above Bridgeport illustrates that most (98%) of the loads to surface water along this reach in the winter come from nonpoint sources [51] (Figure 5-7). Investigation is underway to identify the landscape activities that are contributing to elevated nitrate concentrations, the pathways by which nitrate enters the river, and the management approaches that can be applied to address the issue. Some recent studies in the watershed have documented elevated nitrate levels in shallow groundwater that resulted from the leaching of nitrate from commercial fertilizer and manure applied in areas of coarse textured sediments[59]. Where this nitrate-rich shallow groundwater discharges to surface water, it can elevate nitrate levels in rivers and streams (e.g., Alder Creek, Whitemans Creek). The role of tile drains in moving nitrogen from the land to surface water streams may also be a factor. Nutrient management plans will be an important activity in these high priority subwatersheds (IAP D8). Additional monitoring of winter nitrate levels will help to determine the pathway by which nitrate is transported from sources to these reaches (IAP D.15).

In contrast to the seasonal trend in the Grand River, nitrate concentrations remain elevated in the Speed River below Guelph throughout most seasons. Treated effluent from the Guelph wastewater treatment plant (WWTP) is high in nitrate since the plant nitrifies. Inputs from the Guelph WWTP can account for a large proportion of the river flow, particularly during low fllows, so the plant has a large effect on nitrate concentrations in the river. To address this issue, efforts are underway to implement new technologies at the Guelph WWTP that may help to reduce nitrate levels in the final effluent and subsequently, in the Speed River (IAP D.1).

It is important to note that upgrades to wastewater treatment plants that reduce nitrate concentrations in effluent (i.e., denitrification) are not an effective means to reduce nitrate concentrations in the Grand River. The dominant source of nitrate in the Grand River during the winter will continue to be nonpoint sources into the future, even as future upgrades to wastewater treatment plants in the watershed are implemented. To improve nitrate conditions in the Grand River, emphasis should be placed on understanding the nonpoint sources of nitrate in the central Grand River region, and rural BMPs like nutrient management planning should be promoted in areas of coarse textured soils (e.g., Waterloo Moraine, Norfolk Sand Plain and central gravel terraces) (IAP D.8/D.15).

5.2.1.5 Chloride Toxicity

Chloride is the ionic form of the element chlorine and in sufficient quantities, can pose a risk to plants, animals and the aquatic environment. According to Canadian guidelines[61], very high concentrations (> 640 mg/L) can be acutely toxic to aquatic life while moderately high levels (> 120 mg/L) can cause harm over longer periods of exposure. High concentrations of chloride can also impair the use of the water for raw drinking water supplies and for irrigation. Sources include salt used for de-icing of roads and pavements and water softener salt as it appears in wastewater effluents.

There is an increasing trend in chloride concentrations in rivers and streams in the Grand River watershed, particularly downstream from urban areas where levels are approaching the guideline for chronic, long term exposure. This is of particular concern as these levels may affect the endangered and '*of special concern'* freshwater mussels indigenous to the watershed as they are particularly sensitive to high chloride concentrations. Chloride concentrations exceeding the guideline for short term exposure have also been documented in urban or urbanizing streams in the watershed, particularly during snow melt events. It is important that these trends continue to be monitored and new tools be developed to better characterize transient conditions such as melt events (IAP D.15)

Since chloride is readily dissolved in water, it can migrate to groundwater relatively easily. Many studies in the central region of the watershed have documented chloride contamination of municipal drinking water wells due to the infiltration of chloride from salt applied on roadways and other paved surfaces. Where chloride-contamined groundwater discharges, it may also contribute to elevated chloride levels in the river system.

In areas where chloride is a significant threat to sources of municipal drinking water, policies in the Grand River Source Protection Plan direct actions to limit risk of contamination[20]. Effective strategies to reduce sources of chloride associated with de-icing activities are also outlined in Environment Canada's *Code of Practice*[62] and Transportation Association of Canada's *Synthesis of Best Practices*[63]. Adoption and education about such practices for de-icing activities (e.g., the *Smart About Salt* Program) as well as similar efforts to reduce salt use associated with water softeners are important to try to mitigate the increasing trend seen in urban streams and rivers (IAP D.11).

5.2.1.6 Pathogens

Waterborne pathogens are a public health concern. They are also a concern to municipalities who use the Grand River as a supply of drinking water. Sources of pathogens include improperly treated sewage or sewage spills, fecal matter from pets, livestock and wildlife. Other than at drinking water intakes and at public beaches, bacteria such as *E. coli*, or other pathogens are not routinely monitored in the Grand River watershed and therefore people who swim or recreate in the river do so at their own risk.

To reduce the threat of pathogens in drinking water, municipal water treatment plants have highly sophisticated water treatment including disinfection, shut down of the intakes during high flows when turbidity and pathogen loads are high, and maintain a robust warning system for upstream spills and by-passes.

Studies have shown that concentrations of various pathogens are highly variable and causal relationships to identify sources or transport mechanisms are difficult to determine. The causes of spikes in pathogen loads (beyond high flow periods and upstream bypasses noted above) remain a concern for municipal water treatment plant operators.

Given that municipalities monitor for pathogens, a study to associate pathogen spike events with watershed events (e.g., local storms) may shed some light (IAP D.12). Source tracking research may also be able to identify whether sources for certain types of pathogen spike events are predominantly wildlife, livestock (rural), pets (urban) or human (IAP D.12).

To reduce the frequency and severity of spills and bypasses in the Grand River watershed on downstream drinking water intakes, watershed municipalities who own and operate wastewater treatment plants will continue to implement best practices as outlined in the report "*Best Practices: Municipal Wastewater Treatment Plant Bypass And Spill Prevention And Reporting In The Grand River Watershed*"[64] (IAP D.4).

5.2.1.7 Trace Contaminants and Chemicals of Emerging Concern

A number of trace contaminants have been detected in surface and ground water in the Grand River watershed. Many of these contaminants that occur at very low concentrations and the risks to aquatic organisms or people are not fully known.

Trace contaminants can include pharmaceuticals and personal care products, pesticides and industrial chemicals. Personal care products and pharmaceuticals refer to substances used by individuals for personal health or cosmetic reasons or used in agriculture to enhance growth or health of livestock.

Recent research has suggested that the combination of many trace contaminants in the central region of the watershed contribute to the feminization of fish. Research is ongoing in the river system to determine the scope and magnitude of the issue in the river. Other research is aimed at understanding how water and wastewater treatment processes can remove these trace contaminants.

Historic contamination by trace contaminants from industrial manufacturing continues to contribute to localized groundwater contamination. Some industrial trace contaminants include PCBs, TCE, dioxin, and 1,4-dioxane. Other trace contaminants of household or commercial origins may enter the waste stream and be directed to wastewater treatment systems, where they may be treatable or only partly treatable. Source control, accomplished through municipal sewer use bylaws can be an effective means of preventing or limiting introduction of these substances into the environment that occurs via the waste stream (IAP D. 3).

5.2.2 Protection of Key Hydrologic Functions

Water quality is intrinsically linked to flows in river systems. Streams and rivers and their associated floodplains and riparian areas provide for key hydrologic functions by conveying water, transporting sediments and assimilating nutrients. In the Grand River watershed, the flow and sediment regimes were historically altered when much of the forestland was converted to agricultural production and much of the wetland areas were drained. Large reservoirs were built in the watershed to put water storage back on the landscape – an important hydrologic function, and shifted the altered flow regime back to a more natural state. This allows for improved sediment delivery and nutrient processing in downstream river reaches.

Improving river flows and water quality can also be attained through the protection/stabilization of stream banks and ensuring the connection of the river with its floodplain. Stable streambanks erode less while floodplains can help to trap sediment and sediment-bound nutrients. The Rural Water Quality program continues to work with landowners to naturalize streams and rivers through fencing and planting riparian buffers to reduce erosion, minimize soil and nutrient loss. These activities assist with reducing phosphorus and sediment loads and it is recommended that these activities continue watershed-wide (IAP D.7).

Run-of-the-river dams or weirs alter the natural hydrologic regime which fundamentally changes sediment delivery and impedes the river's ability to process nutrients often resulting in impaired water quality. To improve water quality into the future, it is recommended that further studies be undertaken to prioritize and evaluate opportunities for water quality improvement at priority run-of-the-river dams/weirs (IAP D14).

Maintaining water storage on the landscape through the continued maintenance and operation of the seven multipurpose reservoirs is required to ensure water supplies for communities, ecosystems and economies (IAP C5; E1) as well as improve water quality. The water stored in the reservoirs helps to augment river flows during periods of low flow. Base flow augmentation helps to improve water quality by diluting wastewater effluents and rural and urban stormwater runoff.

All wetlands are considered fundamentally important for flood control but also help regulate water quantity and improve water quality. Provincially and locally significant wetlands, especially in the central region of the watershed provide important hydrologic processes such as groundwater recharge and subsequent groundwater discharge that supports the extensive coldwater creek systems in the watershed (see Figure 2-8) and helps to maintain water quality. Some complexes include the Speed-Lutteral-Swan Creek PSW, Eramosa River - Blue Springs Creek PSW, Roseville Swamp – Cedar Creek PSW, Mill Creek Puslinch PSW, Whitemans Creek - Kenny Creek PSW, Fairchild Creek Headwater PSW, Oakland Swamp PSW, and Brantford Northwest PSW. Brantford Northwest PSW supports a rare perched fen type community. The Spongy Lake PSW complex is unique and helps to recharge local and regional aquifers.

Protection of these and other provincially significant wetlands in the watershed, as well as the smaller and more isolated locally significant wetlands, should continue through diligent land use and subwatershed planning (IAP D6; E3), stewardship and education (IAP D7). Further, there is a need to update regional groundwater-surface water models and mapping to better reflect the key hydrologic processes such as groundwater recharge and discharge that supports significant wetland features and important coldwater creeks in the watershed (IAP C11).

5.3 Consideration for Climate Change

Climate change is expected to result in warmer air temperatures and reduced flows during the summer growing season[65]. Such changes suggest shifts in a variety of factors affecting water quality. Reduced flows can increase water temperatures and the light available for the growth of nuisance algae increases the risk of water quality problems associated with low dissolved oxygen.

It can also be expected that water levels in aquifers will be affected by climate change. Timing however, is an important aspect with the groundwater system; while surface waters typically see a rapid response to climate variability, the response of groundwater systems is often difficult to detect because of the magnitude of the response is lower and delayed[66]. As an integral part of the hydrologic cycle, it is predicted that changes in climate will affect groundwater resources by altering the recharge to aquifers, the nature of interactions between groundwater and surface water systems, and changes in water use (i.e. increased demand on groundwater resources).

The effect of warmer air temperatures and changes in precipitation patterns can be reduced by actions to maintain the groundwater discharge that moderates surface water temperatures by protecting the important recharge areas in the watershed (IAP C.11).

Decreases in dissolved oxygen are currently an issue in the central Grand River and may worsen with climate change. Future scenarios during low flow summer conditions were modelled to assess the sensitivity of the Grand River Simulation Model (GRSM) to predict changes in dissolved oxygen resulting from reductions in flow or increases in water temperature[67]. Further work is required to refine the algorithms in the model to adequately reflect the relationships between aquatic plants, water temperature and flow (IAP D.5).

Other anticipated changes to climate, such as increased frequency of extreme events and less frozen ground, could increase water quality issues caused by the erosion of sediments, nutrients and other pollutants from the landscape into the river system. Actions to keep soil on the land and reduce sediment and erosion will reduce the effects of an increased frequency of storms (IAP D.8/D.9).

If management actions to improve water quality are to consider the expected effects of climate change, it is important that they are guided by information about long-term trends and supplemented with ongoing data collection (IAP D15).

5.4 Future Considerations

The continuing advances in wastewater treatment technology and in operational control of treatment processes present a continuing challenge to municipalities. The decision of the Province of Ontario to foster the growth of water/wastewater treatment technologies as a special strength of the provincial industrial economy offers good prospects for provincial assistance in the adoption of new and improved technologies by municipalities in their wastewater treatment plants.

To inform future wastewater master planning in the watershed, considerations must be made to evaluate both point and nonpoint sources of pollution to identify the best value solutions to reduce nutrients in the Grand River and its tributaries. However, there is a lack of decision support tools and data to assist with evaluating nonpoint sources. Therefore, a predictive landscape/nonpoint source model, coupled with the existing in-river model (GRSM), is needed to evaluate the effectiveness of both point and nonpoint source management strategies (IAP D.16).

However, the current watershed monitoring program is not sufficient to quantify loads or characterize trends in phosphorus, sediment or nitrate levels, particularly in response to implementing nonpoint source best management practices. Currently, there is no monitoring of dissolved phosphorus, which is an important form of phosphorus being identified for specific management strategies in other jurisdictions (e.g., Ohio). Investigations are also needed on the key processes (e.g., flow regimes) responsible for in-stream release of phosphorus from sediment behind on-line dams and weirs, as this may be an important source contributing to in-river levels of phosphorus (IAP D.14).

Further, to identify "best value" solutions, it will be necessary to evaluate the economics of implementing expensive wastewater treatment plant upgrades versus nonpoint source management strategies. The data to carry out such an analysis is not available or included in the current data collection programs (IAP D.16).

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6 Reducing Flood Damage Potential

The flood risk reduction program is relatively mature and includes structural and non- structural methods of reducing flood damages. Structural methods include dams, dykes, flood proofing and channelization. Non-structural methods include flood forecasting, flood warning, emergency preparedness and regulation of development in floodplains.

It is estimated that the works to date have reduced average annual damages by 80%. In addition, municipal zoning and Grand River Conservation Authority (GRCA) floodplain regulations have controlled new development in floodplain areas since the mid-1970s.

While efforts have been made to reduce the flood risk, several communities still remain vulnerable. In addition, it is speculated that flood damage potential has been increasing over the last 30 years because of increased use of basements and more recognition of the health impacts of mold.

The 1982 Basin Study recommended dykes and/or channelization in Kitchener (Bridgeport), Cambridge (Galt), Brantford, Paris, Caledonia, Dunnville and New Hamburg. Of these, works have been completed in Kitchener (Bridgeport), Cambridge (Galt), Brantford, and Caledonia.

Since the dyke construction projects were completed or locally resolved and provincial cost-share funding for these types of mitigation measures ceased in the mid-1990s, GRCA has shifted focus to dam safety studies and implementation. Among the major works recommended by the dam safety studies, dam stilling basins have been extended at Shand Dam and Conestogo Dam. Several other dam safety recommendations have been implemented including gate refurbishments and embankment works at Conestogo Dam and gate control system upgrades at Shand Dam, to name a few. GRCA is currently evaluating the need for an emergency spillway at Conestogo Dam.

The current flood management system follows recommendations from the Provincial Inquiry into the 1974 Flood[68]. The 21 recommendations from the 1974 flood inquiry are discussed in detail in the support technical document, *Flood Management in the Grand River Watershed*[69].

An overview of the flood management system in the Grand River watershed is followed by an update on those communities that are still vulnerable to flooding.

6.1 Events that Cause Flooding

The factors that result in flooding vary among flood damage centres throughout the Grand River watershed. The common factors that result in flooding include:

- high river flows due to rapid snowmelt, snowmelt combined with rainfall, wide spread heavy rainfall and localized intense rainfall (urban and rural flash flooding);
- surge flooding from Lake Erie (Lake Erie shoreline and Grand River downstream of the Dunnville Dam); and
- ice jam floods.

6.1.1 Snowmelt Floods

Most maximum annual flood peaks have historically occurred in the March to April period of the year when the combination of snowmelt and rainfall on frozen ground often generates the highest river flows of the year. In recent years, floods due to snowmelt have been observed during the December through to February months. Figure 6-1 illustrates the annual maximum flood by day of the year. Since the early 1990's, there appears to be a trend towards more variability in the time of year that the annual flood occurs. A flood in December 2008 resulted in high flows throughout the watershed and the second highest flow on the Nith River through New Hamburg for the period of

1951 to 2008. The December 2008 flood would have resulted in flows similar to May 1974 along the Grand River if not for the flood reduction provided by the major reservoirs. The December 2008 flood was followed by another large flood in February of 2009.

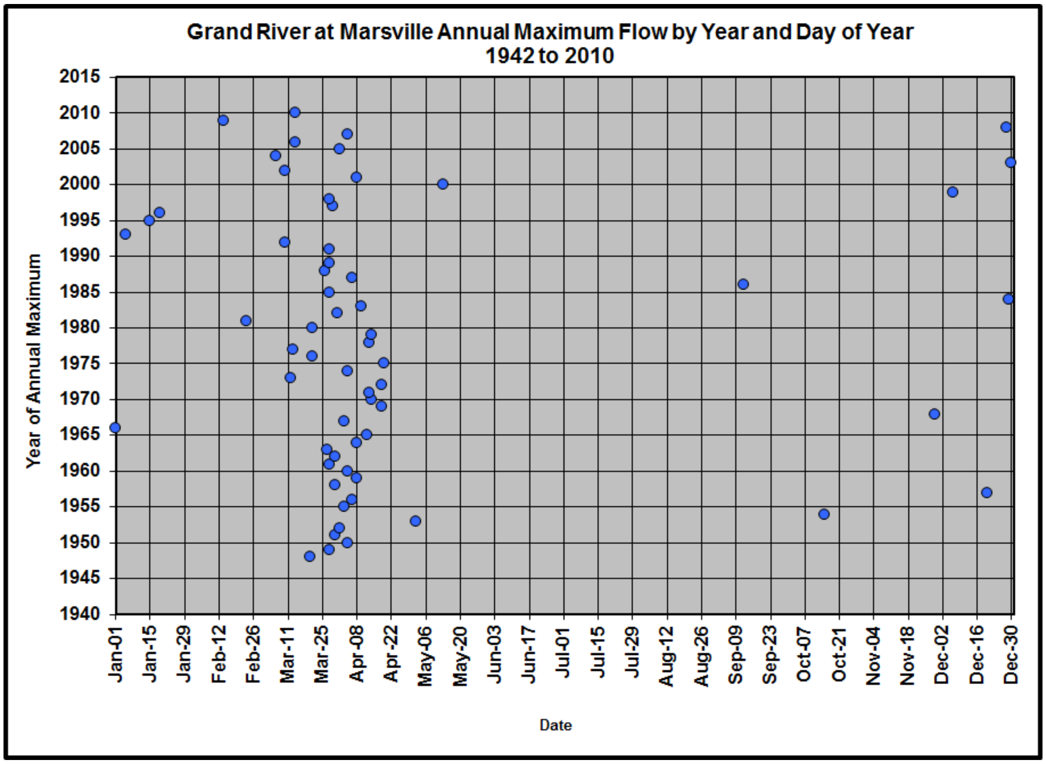


Figure 6-1. Annual maximum floods by month of the year. Grand River at Marsville flow gauge.

6.1.2 Rainfall Based Floods

Widespread rainfall on wet or saturated ground can also produce large floods. The highest risk for floods resulting from wide spread rainfall exists during the late spring and early summer and during the fall hurricane season. Floods in May 1974, June 1976, May 2000 and June 2000 are examples of late spring floods. Potential for runoff from the land is higher during this time of year since crops have not fully established. Also there is limited flood control storage in the large water management reservoirs to manage floods during this time of year.

Wide spread flooding can also occur during the late summer and fall as a result of wide spread weather systems fueled by tropical moisture. Runoff potential from the landscape increases as crops mature and are harvested and as air temperatures drop, reducing evaporation causing soils to stay wet or saturated.

The hurricane season runs from July 1st through the end of October. The highest frequency of hurricanes crossing through southern Ontario occurs from late August through to October. The most notable hurricane to affect southern Ontario was Hurricane Hazel in 1954. While totals in the Snells Grove area reached 212 mm over a 12 hour period, wide spread accumulations of 100 mm occurred over the Grand River watershed.

Localized heavy rainfall has a higher potential to occur during the summer months when large temperature differentials between weather systems spawn convective events along the interface of the two weather systems.

Another factor influencing significant weather and rainfall events in the western region of Grand River watershed is a phenomenon known as the '*Lake Breeze Front Effect*' (Figure 6-2). This phenomenon occurs when lake breezes from Lake Erie and Lake Huron that are high in moisture converge along the London-Kitchener corridor in southern Ontario. These breezes combine with warm air over the landscape and develop severe weather events and thunderstorms[70].

Several Lake Breeze Front flood events have occurred in the Grand River watershed, the most notable occurring in August 1975, June 1976, July 1997, and June 2004. These events generate high volumes of rain over a short period of time and cause flash flooding. The June 2004 event resulted in 160 mm of rainfall in a 4-hour period; 200 mm was recorded over a 24-hour period. The July 1997 event was centred over the hamlet of Punkeydoodles Corners, located to the west of New Hamburg. Rainfall totals of 120 mm over a 6-hour period were recorded by the GRCA rain gauge located in New Hamburg and rainfall totals of 200 mm were estimated to have occurred over a 5-hour period over the hamlet itself. Runoff from this event resulted in washouts of Highway 7/8 between New Hamburg and Stratford.

Figure 6-2. Lake breeze frontal zones

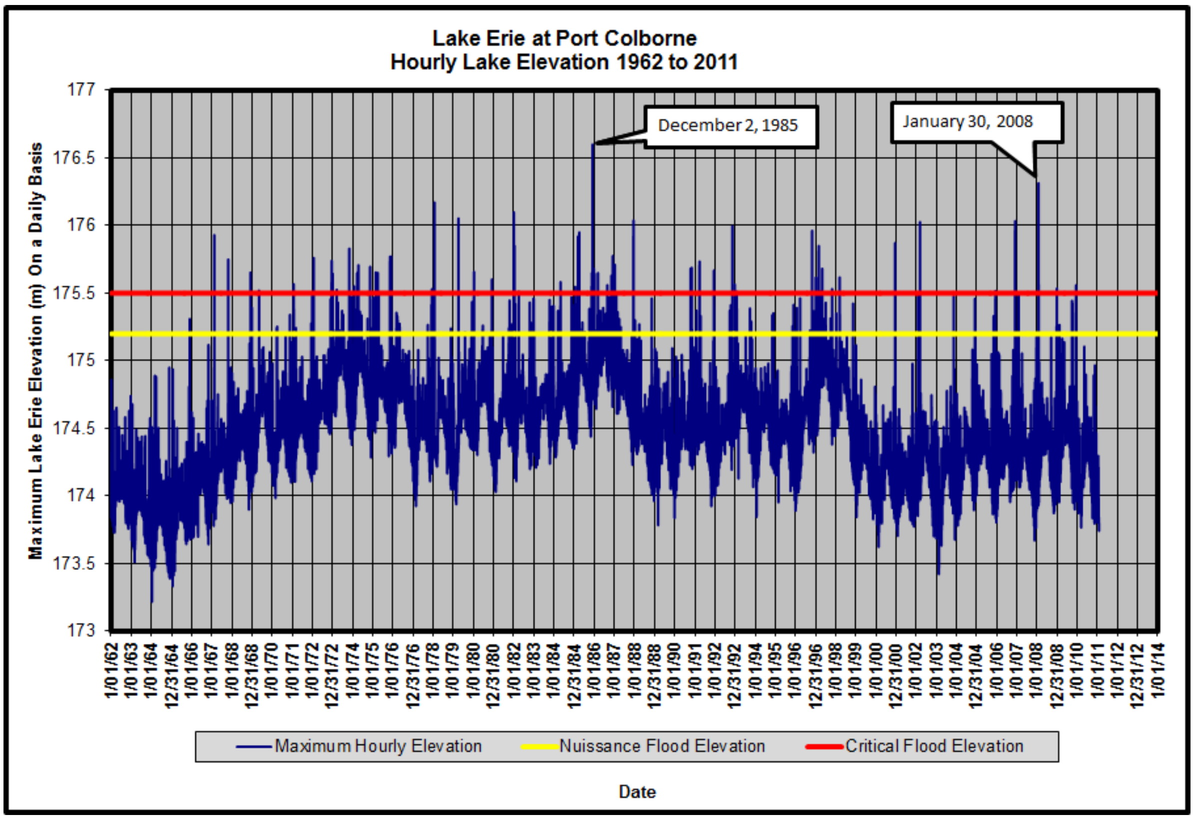
(Source: http://www.islandnet.com/~see/weather/elements/lakebreezewx.htm)

The Lake Breeze Effect raises a serious concern for both rural and urban flash flooding. If a lake breeze event were to occur over an urban area such as Kitchener or Waterloo, serious flooding would result, potentially exceeding the limits of the regulatory floodplain. The potential for urban flash flooding highlights the need to design urban drainage systems to function in a passive manner with no manual interventions being required to pass flood flows. Municipalities are encouraged to complete comprehensive assessments of municipal urban drainage systems to identify and reduce vulnerability to sever weather events (IAP E.2).

6.1.3 Lake Erie Flooding

The Grand River downstream of Cayuga to Port Maitland and the Lake Erie shoreline are subject to flooding from Lake Erie. Strong winds from the southwest can affect lake elevations in the eastern end of Lake Erie, causing them to rise by several metres and flood riverine and lake shorelines. Wind direction, speed and duration influence the magnitude of the event. The risk of flooding is affected by the static level (non-wind affected elevation) of Lake Erie – the higher the static level, the more chance that lake setup will cause flooding.

One of the highest lake setups occurred on December 2, 1985. The Port Colborne elevation reached 176.6 metres and resulted in flooding of lakeshore cottages and residences along the Grand River downstream of the Dunnville dam. Beyond the flooding associated with this event, the spray from the waves caused ice accumulation on many structures and ice damage compounded the flooding and erosion damage. The second highest event since 1961 occurred on January 30, 2008. This event reached an elevation of 176.3 metres. Both of these events resulted in water elevations that exceeded the crest of the main weir at Dunnville dam, backing water upstream of the dam. Figure 6-3 illustrates the cyclic nature of Lake Erie levels, highs occurred in the 1970's, 1980's and early 1990's. Lows occurred in the 1930's and 1960's.



Source of Data: Canadian Hydro Graphic Service

Figure 6-3. Daily maximum Lake Erie elevation at Port Colborne.

6.1.4 Ice Jams

Ice jams are another potential source of flooding at several flood damage centres and along some rural reaches of river. Ice jams can form during freeze-up or break-up.

Freeze-up ice jams result from the formation of frazil ice during or after initial freeze up. Flooding caused by freeze-up ice jams is common in the Grand River at West Montrose and through the Kitchener-Waterloo and Paris-Brantford reaches. Frazil ice jams can also follow mid-winter melts if cold temperatures follow the melt and river flows are high. Large frazil ice jams in Paris occurred in 1979 and 2004. During 2004, frazil ice filled the river channel from upstream of the Paris dam to downstream of Brantford. Frazil ice has the potential to compromise the capacity of the dyke through Brantford. This situation will be assessed as part of future dyke safety studies for the Brantford dykes (IAP E.1). The backwater areas upstream of low head weirs or run-of-the-river dams throughout the watershed reduce the potential for frazil ice generation and act as storage areas for ice.

Break-up ice jams occur when flows increase during spring or mid-winter melts. Increased flow raises and breaks ice sheets that have been formed in the river over the winter. The dislodged ice flows downstream until it encounters a restriction (e.g., intact ice sheet, break in slope). Common locations for break-up ice jams are in the Grand River above the river oxbow in Brantford and through Cayuga above the leading edge of the ice sheet upstream of the Dunnville Dam.

Other communities with a history of ice jam flooding include Grand Valley, Bridgeport, Doon, Blair, Caledonia, Eden Mills, New Hamburg, Haysville and Plattsville. A full description of ice jams flooding is provided an unpublished GRCA report, *Ice Jams in the Grand River Basin*[71].

6.2 Areas of the Watershed that Contribute to Flooding

Hydrologic studies show that the majority of the runoff contributing to the flood peaks in the flood damage centres along the major rivers (Grand, Conestogo, Speed, Nith) originates from the till plains in the northern region of the watershed[72]. Shand and Conestogo dams have been located in or on the fringe of the till plain area to help regulate flood flows from these areas. Figure 6-4 highlight the areas of the watershed that are controlled by the large dams and reservoirs.

The runoff potential across the watershed is illustrated in Figure 2-5 with the red areas representing the areas with highest runoff potential. The runoff potential is influenced primarily by the underlying geology and the land use.

The red areas in the northern region of the watershed are associated with the till plains where the fine-textured, tight soils promote rapid storm runoff. The northern till plains are also an area of the watershed with extensive agricultural activity. Percent forest and wetland cover is low and drainage has generally been improved under the municipal drainage program to increase agricultural productivity. Evolving best practice in municipal drain design and maintenance may provide new solutions for reducing or slowing storm runoff from these areas while maintaining agricultural productivity (IAP D.9).

Wetlands and forests help retain water on the landscape which can aid in reducing the magnitude or frequency of flooding. Increasing the area of wetland and forest cover is one of the available options to increase the resiliency of the landscape to reduce floods. Subwatershed studies are recommended in the headwater areas (upper Grand, Conestogo, and Nith) to assess the relative role of wetland, forest and riparian zone restoration, along with alternative municipal drainage designs, for reducing flood frequency as well as sediment and erosion control (IAP D.6).

The central region of the watershed has less runoff potential due to the granular outwash soils and the closed drainage systems associated with the Waterloo, Paris and Orangeville moraines. The characteristics of the closed drainage systems and more pervious soils in the central portion of the watershed provide natural flood reduction and groundwater recharge functions. Further work is needed to fully understand the groundwater recharge, discharge and flood mitigation functions provided by the central moraines in the watershed (IAP C.10).

The high runoff areas in the southern region of the watershed do not generally contribute to the flood peaks on the large rivers (Grand, Nith and Speed) as the runoff from these areas reaches the Grand River well before the accumulated runoff from the northern till plain reaches the river.

There is potential for flooding along the urban water courses from local urban drainage. Subwatershed plans and urban drainage master plans focus on management options to reduce flooding along urban water courses. The integrity of the urban major drainage system (the planned course for water that exceeds storm sewer capacity) is also important in reducing flood damage particularly for the high intensity local storms that we expect to see more frequently in the future (IAP E.2).

6.3 Current Flood Damage Reduction Program

6.3.1 Flood Control Reservoirs

Reservoirs are used to collect runoff and store water to regulate flood flows that will help to reduce the risk of flooding in downstream areas.

The locations of major flood control reservoirs are illustrated in Figure 6-4. These major reservoirs are dual-purpose reservoirs serving both a **(1) flood control** and **(2) flow augmentation** function. This dual function results in fluctuating amounts of flood control storage throughout the year. The three largest reservoirs, Shand, Conestogo and Guelph, are filled with runoff from spring snowmelt and rainfall. This stored water is released during summer low flow periods to assist with downstream wastewater assimilation. During dry years, there is just enough water to fill these reservoirs. During wet years there is excess water.

The characteristics of the major dams are presented in Table 6-1. In total, the drainage area upstream of reservoirs accounts for 27% of the total watershed area (Figure 6-4).

Table 6-1. Major flood control dams/reservoirs

Reservoir Name	Primary Reservoir Function	Year Built	Dam Height (m)	Upstream Drainage Area (km^2)	Storage Capacity (m^3)
Shand Dam	Flood Control, Flow Augmentation	1942	22.5	802	63,874,000
Conestogo Dam	Flood Control, Flow Augmentation,	1958	23.1	563	59,457,000
Guelph Dam	Flood Control, Flow Augmentation, Recreation	1976	14.3	242	22,387,000
Luther Dam	Flood Control, Flow Augmentation, Wildlife Management	1952	5.0	51.6	28,075,000
Woolwich Dam	Flood Control, Flow Augmentation	1974	11.7	62.43	5,491,000
Shade’s Mill	Flood Control, Induced Infiltration, Recreation	1973	9.8	97.7	3,240,000
Laurel Creek	Flood Control, Recreation	1968	5.6	31.3	2,450,000
Damascus Dam	Flood Control, Flow Augmentation	1978	6.8	4.3	1,540,000

The level of flood reduction that can be provided by the reservoirs varies depending on the available storage in the reservoir and the magnitude of the flood. The reservoirs have limited storage capacity available in May, June and July to regulate floods. The 1974 flood of the Grand River occurred in May.

An analysis of the regulated versus natural annual instantaneous flows at Cambridge and Brantford on the Grand River was completed to estimate the average flood reduction provided by the large dams. The results suggest that, over the long term, the 2-year flood is reduced on average by 41% and 33%, respectively. A 100-year flood would be reduced by 30% and 18%, respectively. However, for any given event, the flow reduction may be much less or more depending on the available reservoir storage and the magnitude of the event. For instance, in December 2008, flood flows were reduced by 57% and 37% at Cambridge and Brantford respectively due to the large amount of flood control storage available at that time of year.

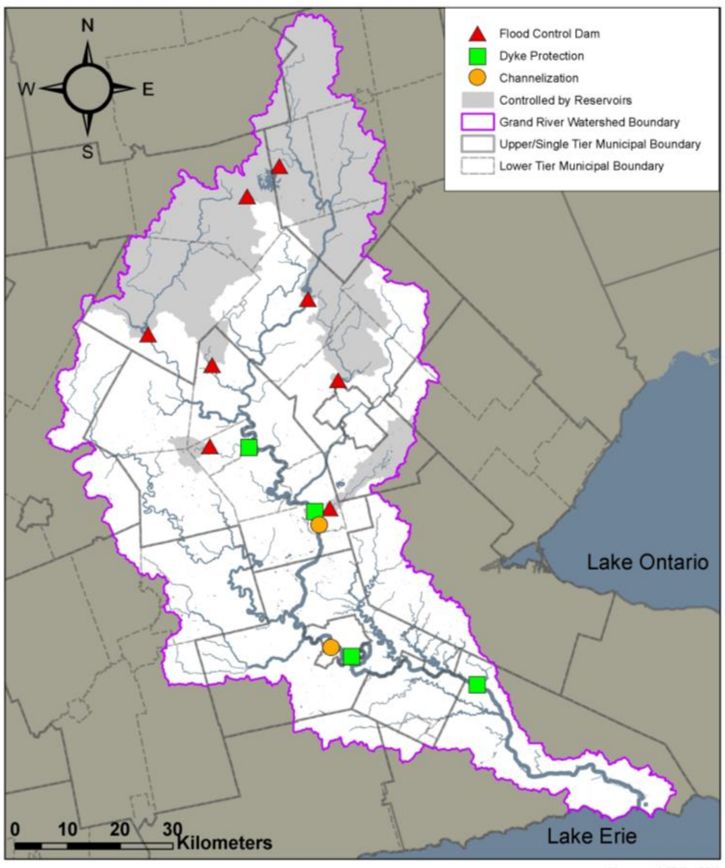


Figure 6-4. Location of flood management structures in the Grand River watershed.

6.3.2 Dykes and Channelization Works

Dykes reduce the risk of flooding for specific flood damage areas. Channelization works increase the rivers' capacity to pass flood flows and may include increasing bridge capacities, deepening or widening the river or implementing by-pass structures. By-pass structures have not been used to date in the Grand River watershed. A bypass channel was investigated in the early 1970's for the Village of Grand Valley[73] however, it was found to be not financially feasible at the time. A new by-pass proposal has been suggested recently and the feasibility of a by-pass channel is being evaluated.

While dykes reduce the risk of flooding, they do not eliminate the possibility of flooding. Every dyke has a design capacity and an associated risk of the design capacity being exceeded. A false sense of security can affect floodplain management behind dykes and is to be avoided.

Communities in the Grand River watershed with major dykes and the characteristics of these dykes are summarized in Table 6-2.

Dykes can be a very effective means of reducing flood damages. Cost benefit analyses are used to assess the practicality of implementing structural measures. Often there are several different alternatives and conflicting demands to consider when defining a program of structural measures.

The assessment of structural measures to reduce flood damages in the Grand River watershed was a component of the 1982 Grand River Basin Water Management Study[74]. A thorough economic analysis was completed at that time. Table 6-3 describes the reduction in average annual flood damage at key flood damage centres in the watershed.

Table 6-2. Grand River dykes – locations and design standards.

Community	Dyke Protection	Design Standard For Dyke	Average Height of Dyke (m)
Bridgeport	Full	Regional Flood[1]	3 to 4
Cambridge(Galt)	Full	Regional Flood plus 0.3 m	2 to 3
Paris	Partial	100-year Flood	2 to 3
Brantford	Full	Regional Flood plus 1 m[2]	4 to 5
Caledonia	Partial	Regulatory	2 to 2.5
Dunnville	Partial	Regulatory	1 to 2
Drayton	Full	100-year Flood	0.5 to 1.5
New Hamburg	Partial	100-year Flood	1.0 to 1.4
Guelph	Partial	100-year Flood	0 to 1
Hespeler	Partial	100-year Flood	3 to 4

[1]The Regional Flood in the Grand River watershed is based on the 1954 Hurricane Hazel storm, the largest storm that has occurred in the geographical area. The Regional Flood is the regulatory flood in the Grand River watershed. It has an estimated recurrence interval of once in 500 to once in 1000 years.

[2]The Brantford dykes are designed for the Regional Flood without the Regulatory effect of the upstream flood control reservoirs.

Where community support was sufficient, the most cost beneficial dykes and channel works were completed. These works reduced most of the potential average annual flood damages. Major dykes were completed in Kitchener (Bridgeport), Cambridge (Galt) and Brantford. Table 6-3 also shows the reduction in average annual flood damage accomplished with the completion of dyke systems in 1996 (the current situation). Note that the average annual damage amounts are reported in 1979 dollars.

Dyke works remain partially completed or not started in other areas of the watershed.

The GRCA has commenced dyke safety studies for the Bridgeport and Brantford dykes, a dyke safety study is being initiated for the Cambridge dykes in 2013. The dyke safety studies generally have four components which include hydrotechnical, geotechnical, vegetation and general assessments. The general assessment summarizes the dyke safety assessment and recommends necessary works. A capital forecast is created to forecast capital works.

The Bridgeport dyke safety study has confirmed the capacity of the Bridgeport dyke to be 1500 m^3/s. The geotechnical analysis is ongoing. From a geotechnical perspective, the Bridgeport dyke is stable. The Bridgeport dyke is founded pervious material. A seepage analysis is being refined to determine the period of time flood waters can be active against the dyke before seepage under the dyke becomes a concern. The seepage analysis will identify what, if any, remedial measures are required. Vegetation management plans have been developed and will be implemented over the five year time frame (IAP E.1).

Vegetation and general assessments of the Brantford dykes have been completed. Geotechnical and structural assessments are being planned for the two year time frame. The hydrotechnical assessment of the Brantford dykes will focus on the potential risk posed by ice jams. It is important to better understand the risk posed by ice jams in the vicinity of the dyke reach. The existing hydraulics model was updated in the mid -1990's and does not require additional refinement. The dyke capacity of the Brantford dyke has been confirmed to be 3400 m^3/s and corresponds to the unregulated Regulatory Flood flow.

Table 6-3. Reduction in flood damages as a result of flood control / protection works

Location	Natural Condition No Dykes No Reservoirs	With Reservoirs No Dykes No Channelization (1979 Condition)	With Reservoirs With Dykes With Channelization (1996 Condition)
Grand Valley	$28,000	$28,000	$28,000
Cambridge	$1,500,000	$505,000	$36,900
Paris	$200,000	$64,000	$64,000
New Hamburg	$25,000	$25,000	$25,000
Plattsville	$2,202	$2,202	$2,202
Ayr	$8,972	$8,972	$8,972
Brantford	$625,000	$360,000	$10,500
Caledonia	$10,000	$8,000	$8,000
Dunnville	$35,000	$20,000	$20,000
TOTAL	**$2,406,174**	**$993,174**	**$175,574**
% Reduction over Natural		**59%**	**93%**
% Reduction over 1979 Condition			**82%**
Note: Damages expressed in 1979 Dollars			

Assessment of the Cambridge dykes is starting in 2013. The Cambridge dyke safety assessment will focus on confirming the capacity of the dykes and three bridges, Parkhill Road, Main Street and Concession Street (IAP E.1). It will also address the structural stability of the flood walls; a section of floodwall is schedule for replacement in 2014, and a second section of floodwall that may need replacement will be assessed in 2013. Vegetation assessments will be completed to guide vegetation management.

Dyke assessments will be planned for the Drayton and New Hamburg dykes in the five year time frame (IAP E.1).

6.3.3 Floodplain Regulation

Regulating floodplains is the most effective means of avoiding new flood damages or putting people at risk and, over time, reducing the risk and damages associated with existing development located in floodplains.

The GRCA, through the implementation of the Fill, Construction and Alteration to Waterways Regulation (until May 4, 2006) and the Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation (Ontario Regulation 150/06), regulates development in floodplains. The GRCA updated and consolidated its policies for implementing Ontario Regulation 150/06 in 2007, amended to January 2013. These policies complement the Ontario Provincial Policy Statement.

In 1995, the Ministry of Natural Resources and Forestry (OMNRF) delegated responsibility for municipal plan input and review for natural hazards to the GRCA. Currently, GRCA staff review and comment on municipal policy documents and development proposals to ensure they are consistent with the Ontario Provincial Policy Statement.

New development is generally directed to areas outside of the floodplain, unless the area is designated as a two-zone or special policy area.

Two-zone policy areas have been identified through agreement with the GRCA and the municipality where the application of a one-zone policy area would affect community viability. Development and redevelopment is allowed in the flood fringe provided that flood-proofing to the elevation of the Regulatory Flood is undertaken, safe access and egress is available, and no basement is proposed. There are two-zone policy areas in most urban communities throughout the Grand River watershed.

In urban areas that have historically existed within the floodplain and where the application of a two-zone policy area is too restrictive to allow for the continued viability of existing uses, a special policy area may be designated, provided that it is approved jointly by the municipality, the GRCA, the Ministries of Natural Resources and Forestry and Municipal Affairs and Housing. Policies within a special policy area accept a higher risk and are less restrictive, although structural flood-proofing and safe access and egress are still required.

Special policy areas have been approved for Brantford, Cambridge (Galt), Drayton, Dunnville, Guelph, New Hamburg, Paris and Waterloo (Laurel Creek). The constraints to development are outlined in each special policy area agreement.

Most floodplain mapping in the watershed was completed between 1975 and 1985. The availability of continuous, engineered digital floodplain mapping along the large rivers (Grand, Nith, Conestogo, Speed and Eramosa) is a gap that would facilitate improved floodplain management, flood risk assessment, emergency preparedness and maintenance. Costs to develop engineered digital floodplain mapping have significantly declined due to advancements in mapping technology. It is recommended that digital floodplain mapping be pursued along the large rivers focussing on areas at risk including flood damage centres, trailer parks and rural properties in the floodplain (IAP E.3).

A digital elevation model is being developed for the overall watershed based on the 2010 OMNRF SWOOP aerial photography. Areas of the watershed currently completed included the upper Nith subwatershed and Dufferin County. It is recommended that a digital elevation model be completed for the entire watershed based on the OMNRF 2010 SWOOP aerial photography (IAP E.3). The watershed wide digital elevation model would act as a base for engineered floodlines where they exist, facilitate the creation of engineered floodplain mapping in areas where estimated floodlines exist and provide a base for refinement of hydrology and nonpoint source pollution models.

In urban areas, two dimensional hydraulic modelling should be considered where complex hydraulics exist and several structures are located in the floodplain. Two dimensional models provide a better technical representation and understanding of the hydraulics of flood flows that can be used to improve flood warning accuracy and identify means and opportunities to reduce flood risk (IAP E.3).

As better technical and digital floodplain mapping becomes available, floodplain policies should be updated in Special Policy and Two Zone areas (IAP E.3).

6.3.4 Flood Forecasting and Warning

The GRCA operates a flood forecasting and warning system to support effective operation of reservoirs to reduce downstream flood damages and timely flood warning to municipal officials throughout the watershed. The GRCA's role is to forecast floods, operate reservoirs to reduce flood damages and issue flood warnings to municipal flood co-ordinators.

Based on the above purposes, a system has evolved based on experience and contributions from several individuals who have played a role in this system over several years. The main components of the system can be summarized into the following categories;

- Weather Forecasts;
- Real-time Hydrologic Monitoring Network and Data Collection System;
- Forecasting and Decision Support Models and Techniques; and
- Flood Warning Dissemination System.

6.3.4.1 Weather Forecasts

Weather forecasts are the first alert to a potential flooding situation. Weather information and weather warnings are obtained from Environment Canada, the OMNRF, private vendors and online American and Canadian sources. Typically these forecasts provide a synopsis of the 24 hour and daily outlooks up to five days into the future.

6.3.4.2 Hydrologic Monitoring Network and Data Collection System

The Grand River Conservation Authority operates a hydrologic monitoring network to collect the information needed to provide flood forecasts. The network operated by the GRCA monitors air temperature, precipitation, reservoir information, stream level, stream flow, wind speed and wind direction. In addition to the real-time monitoring network, daily climate observations are collected at seven major dams.

Information from individual stream gauge or rain gauge sites is telemetered to the closest reservoir or the flood control centre using phone lines or wireless technology. Monitoring information is organized in a database that is used to supply information to decision support tools and models.

Monitoring data is posted to the GRCA website on an hourly basis to communicate watershed conditions to municipal officials and the general public in near real-time.

The current monitoring network is mature and provides a good level of redundancy such that if information from a few gauges is unavailable, sufficient information would still be available to make operational decisions and prepare flood forecasts.

The largest uncertainty is in the spatial extent of precipitation, both rainfall and snowfall. Given that climate experts suggest there will be more frequent extreme rainfall events and more frequent winter snow melts, better spatial estimates to quantify precipitation are needed to improve flood forecasts and to adapt to climate change.

GRCA collects and organizes weather radar data and modelled snow pack information available from the US National Oceanographic and Atmospheric Administration (NOAA). While this information provides qualitative estimates of spatial rainfall and snow pack information, additional refinement is needed to improve the accuracy of this information in Canada.

Environment Canada is developing a new precipitation analysis production system (CaPA) with the goal to provide the best possible estimates of precipitation accumulation on a spatial grid of 10 km currently and 2.5 km by 2016. The CaPA product uses a range of weather models, radar and satellite sources along with ground based precipitation gauges. A barrier to the success of CaPA is real-time sharing of automated precipitation and manual observed precipitation information. GRCA is working with Environment Canada and the OMNRF to facilitate real-time sharing of automated precipitation information and to expand the network of manual climate observers in the Grand River watershed. It is recommended that the GRCA continue to work with Environment Canada and other partner agencies to facilitate the real-time sharing of precipitation information to enhance the CaPA product in the Grand River watershed. The CaPA product will help improve near real-time flood forecasts and improve documentation of precipitation events (IAP E.6).

6.3.4.3 Streamflow and Runoff Forecasting Techniques

GRCA maintains the Grand River Integrated Flood Forecast Model (GRIFFS), a sophisticated deterministic model, to forecast flood flow to support reservoir operations and flood warning. In addition, GRCA maintains an auxiliary suite of simple (manual, empirical) forecasting tools for early assessment, back-up and training.

6.3.4.4 Flood Warning

Dissemination of the flood-warning message is a vital component of any flood warning system. In the Grand River watershed, a combination of police, media, internet and social media is used to get the message out to the general public, residents and business located in the floodplain.

The current system follows recommendations from the Provincial Inquiry into the 1974 Flood[75] and the Ministry of Natural Resources and Forestry Provincial Flood Forecasting and Warning Guidelines[76].

Standard provincial flood message terminology has been established to provide consistency in message terminology across the Province. Flood messages include Watershed Conditions Statements, Flood Watches and Flood Warnings. The flood warning messages are designed to alert municipal officials to expected flooding in a municipality in support of the municipal response to a flood emergency.

With the exception of urban Waterloo and Kitchener, which are subject to flash flooding, sufficient warning times (4-12 hours) are available to flood damage centres along the larger rivers and watercourses to warn affected residents and businesses and take action.

Each municipality has a flood co-ordinator responsible for co-ordinating the municipal response to a flood. An annual meeting is held with municipal flood co-ordinators and Police Services to review the role of each agency during a flood emergency. Hosting an annual meeting is a recommendation from the 1974 Flood Inquiry and will continue to be held annually (IAP E.7).

The GRCA has established 12 river watch areas, with specific field staff assignments, across the watershed. The river watch are the eyes in the field to monitor vulnerable reaches of river, provide manual confirmation of monitoring station information liaison with Municipal Flood Co-ordinators during flood emergencies to enhance two-way communications.

Flood inundation mapping helps to support municipal response to flood emergencies. The flood inundation mapping products identify, in zones, the extent of areas that flood during specific flood flows as well as the properties and infrastructure that would be flooded. Flood messages refer to zones of expected flooding (e.g., warn residents to the level 1 zone in New Hamburg). Warning lists (addresses) help organize the municipal response to a flood, improve business continuity, expedite recovery after the emergency and support succession planning (IAP E.4).

Both data and voice communications are used during a flood. Lessons learned from many previous disasters show that normal channels of communications often fail during a disaster; cellular and phone line networks can become overwhelmed. As a back-up, the GRCA operates a watershed wide low band radio system. This radio system is currently being replaced and the GRCA is investigating public safety radio grade solutions (IAP E.5).

Cost effective satellite data communication is now available on an hourly basis through the GOES satellite system. Given the increasing vulnerability of wireless and landline connectivity during emergency events, it is recommended that the GRCA implement GOES satellite communications as a secondary means of transmitting data collected at monitoring stations (IAP E.6).

6.4 Existing Flood Damage Centre Vulnerabilities

A flood damage centres are communities that have several structures located within the floodplain (see Figure 6-5). The following flood damage centres (communities) have an annual probability of flooding homes and businesses greater than 1:25 or a risk of urban flash flooding:

- New Hamburg
- Ayr
- Plattsville
- Wolverton
- Peacehaven
- Paris
- Caledonia
- Cayuga
- Dunnville
- Grand Valley
- Waldemar
- Elora
- West Montrose
- Waterloo (Laurel Creek)
- Kitchener (Schneider Creek)
- Cambridge (Preston)
- Drayton

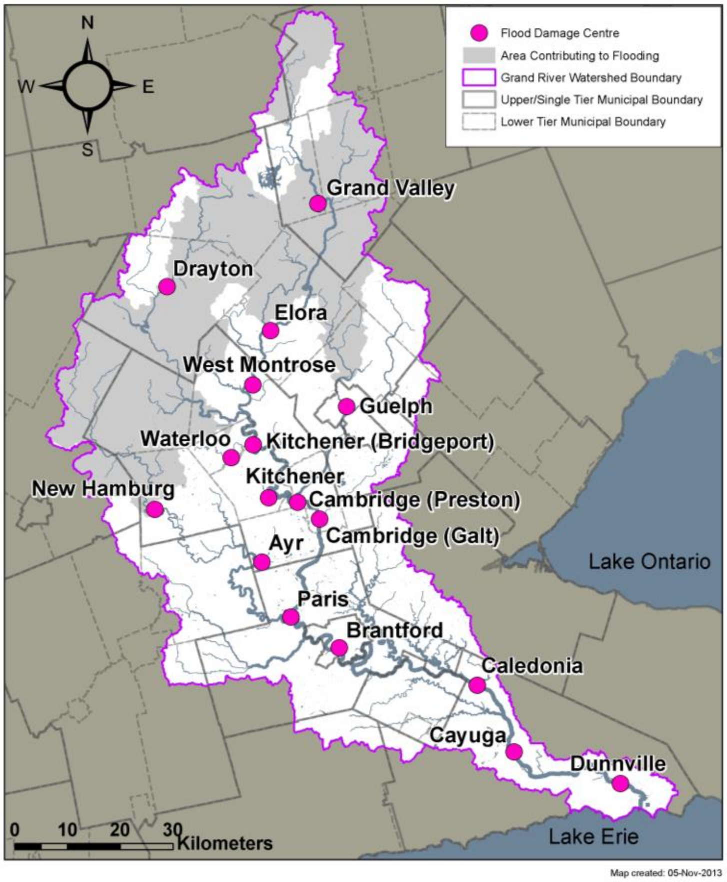


Figure 6-5. Location of flood damage centres in the Grand River watershed.

The relative risk of flooding at flood damage centres in the Grand River watershed is summarized in Table 6-4. This table qualitatively ranks the risk of floods, taking into account how frequently structures are flooded and whether or not mitigation works are in place to help reduce the risk of flood damage. Mechanisms that can result in flooding at a particular damage centre are identified. The estimated frequency of flooding is provided to indicate, on average, how often flood damage centres experience flooding. Frequency of flooding is based on flow events; flood damage centres that experience ice jam events have a higher frequency of flooding. This is reflected in the qualitative ranking. Also included in the ranking is consideration of whether the risk of flooding is reduced by upstream reservoirs or mitigation works such as dykes.

Estimates of flood damages available from previous studies are listed. While this information is dated, it does provide a means of estimating differences in potential flood damages from one damage centre to another.

Information in Table 6-4 differentiates between nuisance flooding and flooding of structures. Some damage centres, including New Hamburg and Ayr, experience frequent nuisance flooding. While flood protection may not be feasible, mitigation works to reduce the frequency of very frequent nuisance flooding may be worth investigating.

Table 6-4 also summarizes whether flood inundation mapping is available for the flood damage centre to support effective municipal flood preparedness and emergency response. Efforts to develop digital floodplain information have been on-going, particularly in high-risk flood damage centres that frequently flood.

The flood risk to trailer parks is significant and is summarized in Table 6-5. Trailer parks are mostly seasonal and trailers can be moved either outside the floodplain or to higher, less frequently flooded portions of the floodplain during the non-active trailer season from October 30th to May 1st. Trailer parks experience the most frequent risk of flooding since some sites are located immediately adjacent to the banks of the river. Also, some trailer parks have more permanent sites. Occupancy of trailer sites in the floodplain needs to be confirmed; currently, it is understand or assumed that trailer parks are seasonally occupied.

6.5 Next Steps to Reducing Flood Damage

The information in Table 6-4 helps identify vulnerabilities and next steps that could be taken to further reduce flood risk in the Grand River watershed. The following general steps apply to all flood damage centres:

- Continue to implement dam and dyke safety assessments to ensure their ability to safely manage floods and comply with dam safety and dyke safety guidelines;
- Continue to restrict floodplain development through municipal policies/zoning and GRCA regulations;
- Prepare and maintain emergency preparedness plans for dams and dyke structures where they do not exist;
- Update and maintain dyke maintenance agreements with municipal partners;
- Prepare and implement flood inundation mapping where it does not yet exist, first at a flood damage centre scale, then by municipality along the large rivers.
- Investigate options to retain more water on the landscape to increase resiliency for a more variable climate and the increasing frequency of severe storms.

The following outlines next steps for some of the communities in the Grand River Watershed

6.5.1 Town of New Hamburg

An initial review of flooding in New Hamburg suggests that, due to physical constraints, it is not practical to provide Regulatory Flood protection through New Hamburg. Next steps would be to investigate with the municipality the feasibility to increase the protection provided by the existing partial dyke. Options should also be investigated to reduce flood damage potential for the most frequently flooded properties and roads in the Level 1 flood zone (IAP E.8).

6.5.2 Village of Ayr

An initial review of flooding in Ayr suggests that there are few practical options to reduce flooding to the most frequently flooded properties along Tanner Street. Next steps will focus on flood preparedness, implementing flood inundation mapping and increasing awareness of those residents located in the floodplain (IAP E.4).

6.5.3 Town of Cayuga

Portions of the Town of Cayuga have flooded several times in recent years as a result of high river flows and ice jam flooding. Currently there are no proposed plans to implement flood mitigation works. The next steps for this flood damage centre would include:

- Completion of a technical investigation into the cause of ice jam flooding and what, if any, remedial options might be available to reduce the potential for ice jam flooding (IAP E.9).
- Installation of a monitoring gauge to detect ice jams (IAP E.9).

6.5.4 Village of Drayton

Partial dyking and channel works exist in the Village of Drayton and provide a level of flood protection. The completed dyke provides protection to the 100 year flood; however, flooding of the village occurs about once every 15 to 20 years. Additional channelization would not reduce the frequency of large flooding events since the capacity of the bridge governs flood elevations for larger floods. Next steps in the Village of Drayton would include:

- Working with the municipality to clear accumulated sediment in the channel from just downstream of the Main Street bridge to just upstream of the Wellington Street bridge. This work is intended to restore lost channel capacity to reduce nuisance flooding from frequent flow events (IAP E.8).
- At the request of the municipality, investigate alternatives to enhance the level of protection provided by existing dykes, building on work from previous studies (IAP E.8).

6.5.5 Villages of Grand Valley and Waldemar

Currently, there are no flood mitigation measures proposed for the villages of Grand Valley or Waldemar. The focus in the short term is to develop and implement flood inundation mapping to improve flood preparedness. This is important given the limited lead time for flood warnings to Grand Valley and Waldemar.

The next steps with respect to reducing the potential for flooding in Grand Valley include:

- Assess the technical and financial feasibility of a flood by-pass option currently proposed as part of a gravel pit rehabilitation proposal (IAP E.8).
- Complete a detailed baseline survey of the sediment delta at the outlet of Boyne Creek. Monitor the development of the delta and establish a dredging plan to reduce the potential for ice jams. This delta was last dredged in the mid 1980's. That action proved to be effective in reducing the frequency of ice jam floods through Grand Valley (IAP E.9).

6.5.6 Town of Paris

Flood inundation mapping has been completed for the Town of Paris. The focus in the short term will be to work with municipal staff to implement the flood inundation mapping information into emergency response plans.

Next steps to reduce the potential for flooding in the Town of Paris would be to:

- Revisit previous flood mitigation options with new flood inundation information (IAP E.4).
- Investigate the need for 2-D hydraulic analysis to improve confidence in flood elevation estimates for large flood events (IAP E.4).
- Encourage the municipality to complete a dyke safety study.
- Investigate the mechanism for ice jam flooding and what, if any, options exist to better anticipate or reduce the potential for ice jam floods through this reach of river.

6.5.7 City of Brantford

The dykes and channel works implemented through the City of Brantford provide a high level of protection. The dykes are designed to convey the unregulated regulatory flow of 3400 m^3/s. Additional freeboard was included in the design of the Brantford dykes to account for ice jams. A major ice jam flood occurred in 1996 that came within 0.3 metres of overtopping the dykes. An investigation was completed after the 1996 ice jam and remedial works were completed to remove a remnant dyke.

The next steps in the City of Brantford reach will be to complete a dyke safety study. A component of this study will investigate the mechanisms of ice jam flooding through this reach. A better understanding of the risk of ice jam floods is needed to assess the capacity of the dykes to manage ice jam floods (IAP E.1).

6.5.8 Urban Waterloo and Kitchener

Flooding from urban runoff is a potentially increasing risk associated with climate change. As the climate warms, there is potential for more frequent and more intense localized rainfall events. This potential is compounded by the area of Lake Breeze effect west of Kitchener and Waterloo.

The next steps with respect to urban flash flooding are:

- Investigate the effect that the July 1997 and June 2004 Lake Breeze storms that occurred west of Kitchener and Waterloo would have had if they were transposed over the Laurel Creek and Schneider Creek watersheds; suggest remedial actions.
- Work with Environment Canada to implement the CaPA product to provide better documentation of storm extent and volume in an effort to better document storms and assess risk (IAP E.2).
- Work with Environment Canada to provide updated Intensity Duration Frequency design information (IAP E.2).
- Encourage municipalities to use the July 1997 and June 2004 events as part of their assessment of major overland flow system capacities (IAP E.2).
- Encourage the province to review the urban drainage guidelines major overland flow system drainage design standards (IAP E.2).

6.6 Protection of Key Hydrologic Functions

Reducing flood damage potential in the Grand River Watershed requires managing surface runoff and protecting the key hydrologic functions of important landscape features (IAP E3). Consequently, the large multipurpose reservoirs are vital watershed infrastructure assets however, other green infrastructure such as provincially significant wetlands and moraine complexes are just as important.

Maintaining water storage on the landscape through the continued maintenance and operation of the seven multipurpose reservoirs is required to reduce flood damage potential (IAP E1). The seven multipurpose reservoirs hold onto runoff in the upper portions of the watershed which then reduces the risk of flooding further downstream. The water stored in the reservoirs also helps to augment river flows during periods of low flow. Base flow augmentation effectively ensures that downstream water supplies are maintained and helps to improve water quality by diluting wastewater effluents and stormwater runoff from point and non-point sources.

Wetlands are considered fundamentally important for flood control and help regulate water quantity and quality throughout the watershed. Prominent wetland areas that currently provide a water storage function on the landscape include the Luther Marsh Provincially Significant Wetland (PSW) Complex, which is managed as a reservoir in part, and the Puslinch Lake - Irish Creek PSW Complex, a naturally occurring and unmanaged wetland. In addition, the coastal wetlands in the Dunnville area also help mitigate flooding during high water events on Lake Erie. Protection of these and other provincially significant wetlands in the watershed, as well as the smaller and more isolated locally significant wetlands, should continue through diligent land use planning, stewardship, and education.

In addition to retaining water on the landscape in reservoirs and wetlands, there are numerous watershed features that facilitate the movement of surface water into the groundwater system. These features include:

- the permeable deposits and hummocky topography associated with the moraines;
- glacial outwash sands and gravels;
- gravel terraces;
- sand plains; and
- exposed fractured and/or karstified bedrock

The quality and quantity of surface water entering these significant recharge features impacts the groundwater aquifers that support drinking water supplies, wetlands, and river baseflows. Further, these closed drainage areas also help to reduce downstream flooding.

Approximately 40% of the watershed area is considered to have a high recharge potential (see Figure 2-10). The largest areas for potential recharge are located throughout the central portion of the watershed within the moraine systems and the Norfolk Sand Plain. Although recharge within the Paris/Galt and Waterloo moraines contributes to the groundwater within the overburden aquifers, the Orangeville moraine is a major recharge area that contributes to the bedrock aquifers. Areas with thin overburden cover, or exposed fractured or karstified bedrock also facilitate recharge to the groundwater system. These areas have yet to be reflected on the groundwater recharge map; however, the GRCA will continue to work with others to best describe this key hydrologic process associated with karst topography (IAP C.10).

About 60% of the moraine systems in the watershed are urbanized. Groundwater recharge is most affected by activities that intercept precipitation such as drainage and paving, and facilitate the movement of water off the land in surface runoff. The shift in the dominant hydrologic process from recharge to runoff can result in local flooding. Furthermore, the increase in the frequency and magnitude of severe events from a changing climate may contribute to the increased frequency of localized flooding. Consequently, it is recommended that municipalities' undertake stormwater major system assessments to identify and reduce the vulnerability to severe storm events (IAP E2). Alternatively, actively managing urban development in sensitive recharge areas to ensure that these important hydrologic processes are protected may also assist with reducing localized flooding (IAP C11). Subwatershed planning (IAP D6) provides for a broad approach to managing key hydrologic processes of important watershed features so that land use planning can be implemented to assist with flood reduction among other objectives (i.e. improve/maintain water quality).

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Table 6-4. Flood damage centres - flood risk vulnerability.

Damage Centre	Flood Risk	Mechanism of Flooding	Associated Gauge Station	Flow Threshold Nuisance Flooding (m^3/s)	Estimated Return Period of Nuisance Flooding Threshold (years)	Flow Threshold Structures Flood (m^3/s)	Estimated Return Period of Structure Flooding Threshold (years)	Estimated Capacity of Mitigation Works (m^3/s)	Estimated Return Period of Flood Mitigation Works Capacity (years)	Estimated Number of Structures at Risk in the Regulatory Floodplain	Average Annual Damages (1979$)	Flood Risk Reduced by Upstream Reservoirs	Flood Protection Works	Flood Protection Works Previously Proposed	Digital Elevation Model Available to Support Flood Inundation Mapping	Flood Inundation Mapping Available
New Hamburg	High	High Flows and Ice Jams	New Hamburg	142	2	250	4			120	25,000			Yes	Yes	Yes
Ayr	High	High Flows	Canning	142	1	240	3			21	10,000				Yes	Yes
Cayuga	High	High Flows and Ice Jams	York	300	< 1	600	2			116		Yes			No	
Drayton	High	High Flows and Ice Jams	Above Drayton	200	5	290	17		17	74			Partial	Yes	Yes	Yes
Grand Valley	High	High Flows and Ice Jams	Leggatt	135	4	200	20			155	44,000[1]			Yes	Yes (old Map Base)	In Progress
Plattsville	High	High Flows and Ice Jams	New Hamburg	250	2 - 5	350	10			90	2,000				No	
Wolverton	High	High Flows	Canning	200	2	350	10 -20			25					Yes	Yes
Waldemar	High	High Flows	Marsville	186	2	290	8			27					No	In Progress
West Montrose	High	High Flows and Ice Jams	West Montrose	108	1	283	4		4	17		Yes			Yes	
Paris	High	High Flows and Ice Jams	Galt/Brantford	850/500	14	1000	25 (Grand)		25 (Nith) 100 (Grand)	217	65,000	Yes	Partial	Yes	Yes	In Progress
Paris-Nith River	High	High Flows and Ice Jams	Canning	350	10	400	100 (Nith) 25 (Grand)		>100	0				Yes	Yes	In Progress
Schneider Cr. Kitchener	High	Urban Flash Flooding	Ottawa St.	30	3	60	10		Partial 100	Hundreds			Partial		Partial	
Laurel Cr. Waterloo Uptown	High	Urban Flash Flooding	Weber St.	50	45	55	73	55	Partial 73	63 uptown	221,000[2]	Yes	Partial	Yes	No	
Dunnville	High	High Flows and Ice Jams	York/Dunnville	900	5	1250	16		16	700	92,000[3]	Yes	Partial	Yes	Yes	
Elora	High	High Flows	Below Shand	108	2	600	>100			15		Yes			Yes	
Peace Haven Scout Camp	High	High Flows	Canning	140	1	300	10-20			5					No	
Caledonia	Medium	High Flows	Brantford/York	585	2	1141	11		11	120	8000	Yes	Partial	Yes	No	
Elmira	Medium	High Flows	Below Elmira	>60	50 -100	75	50-100			15		Yes			Yes	In Progress
Fergus	Medium	High Flows	Below Shand	>300	10	590	100			37		Yes			Yes	
St. Jacobs	Medium	High Flows	St. Jacobs	35	1	566	26			3		Yes			Yes	In Progress
Lake Erie Port Maitland	Medium	High Lake Erie Levels	Port Colborne	n/a	n/a	n/a	n/a			36					Yes	
Cambridge (Preston)	Medium	High Flows and Ice Jams	Beaverdale	50	2	153	>100			103	15,000	Yes		Yes	No	
City of Guelph	Medium	High Flows	Edinburgh Road	80/127	20/>100	200	>500		>500	600	30,000	Yes	Partial		Yes	
Lake Erie Lake Shore	Medium	High Lake Erie Levels	Port Colborne	n/a	n/a	n/a	n/a								Yes	
Haysville	Medium	High Flows	New Hamburg	400	24	550	>100			3					No	
Cambridge (Galt)	Low	High Flows	Galt	573	4	1100	42	2300	1000	503	<1000	Yes	Complete	Complete	No	
Kitchener (Bridgeport)	Low	High Flows	Bridgeport	1250	100	1250	100	1500	100	95	<1000	Yes	Complete	Complete	Yes	
Brantford	Low	High Flows and Ice Jams	Brantford	300/600	1	608	2	3400	1000	2700	<1000	Yes	Complete	Complete	Yes	
Cambridge (Hespeler)	Low	High Flows	Beaverdale	50	2	255	>500	255	>500			Yes	Partial		No	
Rockwood	Low	High Flows	n/a	40	100	40	100			22					No	
Eden Mills	Low	High Flows and Ice Jams	n/a							41					No	
Village of Conestogo	Low	High Flows and Ice Jams	Bridgeport	1500	>100	1500	>100			11		Yes			Partial	
Glen Allan	Low	High Flows	Glen Allan	175	10	800	100-500					Yes			Yes	In Progress

1:1976 Dollars, 2: 1989 Dollars, 3: 1985 Dollars

Note: Frequency of Flood Based on Flow Events Exclusive of Ice Jams

Table 6-5. Trailer parks - flood risk vulnerabilities

Damage Centre	Flood Risk	Mechanism of Flooding	Associated Gauge Station	Flow Threshold Trailer Park Flooding (m^3/s)	Estimated Return Period of Trailer Park Flooding Threshold (years)	Flow Threshold Structures Flood (m^3/s)	Estimated Return Period of Structure Flooding Threshold (years)	Flood Risk Reduced by Upstream Reservoirs	Digital Elevation Model to Support Flood Inundation Mapping
Conway Park	High	High flows and ice jams	York	300	<1			Yes	No
Grand River RV Resort	High	High flows and ice jams	York	300	<1			Yes	No
West Montrose Campground	High	High flows, ice jams and flash flooding	West Montrose	125	<1			Yes	No
Camp Real Grande	High	High flows and ice jams	Brantford	200	<1			Yes	No
Lafortune Park	High	High flows and ice jams	Brantford	200	<1			Yes	No
Brown's Campground	High	High flows and ice jams	Brantford	250	<1			Yes	No
Bruce's Landing	High	High flows and ice jams	York	280	<1			Yes	No
Byng Island Park	High	High flows and ice jams	Dunnville	300	<1			Yes	Yes
Grand Oaks Trailer Park	High	High flows and ice jams	York	300	<1			Yes	No
Grove's Campground	High	High flows and ice jams	Brantford	425	<1			Yes	No
Brant Park	High	High flows and ice jams	Brantford	550	2			Yes	No
Bingeman's Park	High	High flows	Bridgeport	400	3	1400	>100	Yes	No
Everglades Trailer Park	High	High flows	Galt	565	4			Yes	No
Pioneer Sportsmen's Club	High	High flows	Doon	710	11			Yes	No
Riverbend Trailer Park	High	High flows and ice jams	Edinburg Rd	60	2			Yes	No
Sunny Bank Trailer Park	High	High flows and ice jams	York	350	<1			Yes	No
Willoway Park	High	High flows and ice jams	York	400	<1			Yes	No
Grand Valley Trailer Park	Medium	High flows	Leggatt	270	100			Yes	No
Summer Place Trailer Park	Medium	High flows	Leggatt	280	100			Yes	No

Note: Frequency of flood based on flow events exclusive of ice jams

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7 Integrated Action Plan

The Grand River Conservation Authority (GRCA) is working with municipalities, the federal and provincial governments, First Nations and others to update the Grand River Water Management Plan. Based on the assembly of existing data and knowledge, this update reflects the considerable knowledge, tools and networks that have been developed since 1982 when the Water Management Plan was last revisited.

The *Plan* is looking ahead 20-30 years to ensure that the Grand River watershed can be healthy and sustainable as the population grows. It is **a joint plan** by the municipalities, First Nations, conservation authority, provincial ministries and federal departments to align our efforts and identify those practical actions that will make the biggest difference. It is **a voluntary plan**, not a legal requirement, so a spirit of cooperation and shared responsibility is critical to its success.

The *Plan* is **an integrated water management plan** with goals to:

1. Ensure sustainable water supplies for communities, economies and ecosystems;
2. Improve water quality to improve river health and reduce the river's impact on Lake Erie;
3. Reduce flood damage potential; and
4. Increase resiliency to deal with climate change.

The integration of the Plan is achieved by building strong working partnerships of the many agencies whose mandate include water management; aligning partner workplans, sharing approaches and lessons learned; and identifying actions that, when implemented, will achieve more than one goal. For example, maintaining flows in the river through the operation of the large water management reservoirs will not only support downstream municipal water supplies but also assist with assimilating wastewater effluent.

The Grand River Water Management Plan is **a collaborative process** that brings water management agencies together as partners. Regular meetings of Project Team members facilitated the sharing of information and aligning of workplans. By working together, Plan partners have set out a strategy, based on agreed-upon local objectives and targets, to meet the needs of the ecosystem and watershed communities. The strategy will assist each partner to fulfill their role and to support each other throughout the process.

Throughout the process, municipal councils, the agricultural community, aggregate producers, urban development organizations, environmental non-government organizations, groups that undertake collaborative projects under the broader Grand Strategy umbrella and the interested public, have participated and provided input to the *Plan* using a variety of communication and engagement techniques of their choosing.

The following outlines the key aspects for an integrated action plan for water management in the Grand River watershed.

A. Maintain a Process for Reporting, Updating and Continuous Improvement

The success of the water management plan will depend on maintaining a mechanism for regular communication to update the partners as to the progress in implementing actions; share information on the evaluations of the effectiveness of the actions (i.e. are we achieving our goals?); identification of information/data gaps or barriers to implementing actions; developing plans and actions to address the information/data gaps; working together to remove barriers; and reporting on and celebrating the collective successes of our actions to achieve the goals of the plan.

A1. The implementation structure of the Water Management Plan is recommended to be as follows:

<u>Leadership</u>

a) An Implementation Committee, comprised of Director/Commissioner/General Manager level staff from the partner organizations, be established to champion the *Plan*, remove barriers to implementation and advocate for continuous improvement.

b) The Implementation Committee will hold an annual meeting/forum to review progress in *Plan* implementation.

<u>Project Management</u>

c) The Water Managers' Working Group, with representatives from the partner organizations, will assume the role of the Project Team. Water Managers' Working Group meetings provide an important venue for enhanced communication that builds strong working relationships among partners to develop best value solutions to water management issues. Reporting to the Implementation Committee, the Water Managers' Working Group integrates workplans; oversees and implements actions; reports on implementation; and evaluates the effectiveness of the actions for the watershed.

Action:

- ✓ The Water Management Plan partners (the Counties of Brant and Haldimand, Township of Centre Wellington, Regional Municipality of Waterloo, the Cities of Brantford, Cambridge, Guelph, Kitchener and Waterloo, Six Nations of the Grand River, Grand River Conservation Authority (GRCA), Ontario Ministry of Environment and Climate Change (OMOECC), Ministry of Natural Resources and Forestry (OMNRF), Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), and Environment Canada (EC) will name senior representatives to an Implementation Committee. The Implementation Committee will prepare a terms of reference and 5-year project charter to be signed by participating agencies.
- ✓ The Water Managers' Working Group will include representatives from the *Plan* partners and will update its terms of reference to reflect its responsibility to the Implementation Committee for project management related to the joint implementation and continuous improvement of the Water Management Plan.
- ✓ The GRCA will provide administrative support to the Implementation Committee and the Water Managers' Working Group and will assign a staff role responsible for taking the lead in keeping the Water Management Plan implementation, reporting and review moving forward.

A2. Regular communication and reporting mechanisms are important for accountability; communicating progress and celebrating success or set-backs, toward achieving the vision and goals for the watershed. It is a key aspect of the *Plan's* guiding principle of continuous improvement. Communication and reporting mechanisms include annual progress reports on plan implementation and 5-year technical monitoring reports.

Action:

- ✓ The GRCA will call an annual meeting of the Implementation Committee. Additional meetings of the Implementation Committee can be called at the request of any partner organizations to deal with watershed issues: changes to the assumptions made in the

Watershed Management Plan; gaps in information or knowledge; or barriers to implementing actions.

- ✓ The GRCA will host quarterly Water Managers Meetings to facilitate regular updates and to share information on the progress toward implementing the *Plan,* and discuss watershed management issues. Additional meetings may be called at the request of any partner organization.
- ✓ The GRCA will assist the Water Managers' Working Group in assembling annual progress reports on the implementation of actions, starting in 2015 (see the chapter: *Reporting on the Integrated Action Plan*).
- ✓ The GRCA will assist the Water Managers' Working Group in assembling a technical watershed report on the progress toward achieving the resource condition milestones (interim targets (see the chapter: *Reporting on the Integrated Action Plan*)) every five years beginning in 2019.

A3. As part of the principle of continuous improvement, the Water Management Plan should be reviewed and updated regularly. If there are major changes to the three underlying assumptions in the Water Management Plan, the Project Team recommends that the Plan be reviewed and updated. The major assumptions include:

I. that future population growth to 2041 will be accommodated within the currently designated urban areas. The watershed scale impacts of significant area expansions of the urban footprint in the watershed have not been considered in developing this *Plan*.

II. that the need for a Great Lakes pipeline to meet municipal water supply needs is beyond the planning horizon for this *Plan*. Consequently, the consideration of watershed-scale implications of a Great Lakes water supply pipeline has been deferred.

III. that there will be no new municipal wastewater treatment plants discharging to the regulated reaches of the Grand, Conestogo or Speed Rivers. The possibility of a new wastewater treatment plant has not been considered in projecting future water quality conditions.

Action:

- ✓ Beginning in 2019, the GRCA will assist the Implementation Committee in completing a review and update, if necessary, of the Water Management Plan.

B. Maintaining a Framework for Integrated Water Management

Integrated water management requires the coordinated management of water, land and related natural resources. Because of the linkages between land and water, the watershed is the most appropriate geographical unit for managing water.

B1. To ensure sustainable water supplies, improve water quality and reduce flood damages, key hydrologic processes such as groundwater recharge, groundwater discharge, and surface runoff must continue to be maintained or managed in the watershed. It is critical to identify and protect important watershed features that provide these hydrologic functions so that they can be considered in subwatershed plans and regional-scale municipal planning documents.

Cross-referencing important watershed features and their hydrologic functions they provide in other watershed management plans will underscore their importance and help to ensure they continue to function in the future. Therefore, the Project Team recommends that key hydrologic processes of watershed features as outlined in the water management plan be cross-referenced and integrated with other watershed or regional resource plans or strategies. Such plans include the Fisheries Management Plan; Source Protection Plan; GRCA Land Acquisition Policy (2003); Luther and Dunnville Marsh Management Plans; Natural Heritage Strategy; and other local watershed restoration strategies. Further, the Water Management Plan should be an integral part of the Watershed Plan.

Action:

- ✓ GRCA will update its Land Acquisition Policy and Natural Heritage Strategy by 2016 to identify priority lands that include watershed features providing important hydrologic processes like significant recharge areas and significant wetlands that help store water on the landscape.
- ✓ GRCA will work with partners to update the Luther Marsh Management Plan by 2020.
- ✓ GRCA will continue to protect existing lands and acquire new lands, where appropriate, for future water management options near West Montrose and Everton.

Managing water resources is a shared responsibility of many agencies whose mandate includes water management. Consequently, all decision-making by Plan partners for the management of water in the watershed should consider the wide-ranging uses, needs and values for water in the watershed as expressed in the *Broad Water Objectives*. The preliminary list of indicators and targets identified in the *Plan* should be used to evaluate the water resource conditions required to meet the *Broad Water Objectives*.

B2. The identification of Indicators and targets that are quantifiable and measurable enable the monitoring and reporting of water resource conditions. It is this information that allows water resource managers to learn, evaluate and adapt in a continuous improvement process and evaluate whether the goals of the water management plan are met. Therefore, the Project Team recommends that work continue to complete the suite of resource condition indicators and targets for the watershed so that progress toward achieving the *Broad Water Objectives* and the Water Management Plan goals can be measured.

Action:

- ✓ GRCA, OMOECC, OMNRF, EC, OMAFRA and Region of Waterloo staff will continue to work together as the Water Quality Working Group and task teams;
- ✓ Water Quality Working Group will adapt the ecosystem assessment framework developed by the Grand River – Lake Erie Working Group to identify resource condition indicators and targets for other ecologically significant areas;
- ✓ Water Quality Working Group will work on developing quantifiable targets for suspended sediments, turbidity and nutrients; and
- ✓ Environment Canada (EC), under the Great Lakes Nutrient Initiative (2013-2016), will undertake the development of science-based nutrient loading targets for the Grand River that are supportive of the Great Lakes Water Quality Agreement.

C. Ensuring Water Supply

Future water supply needs of communities, economies and ecosystems can be sustainably met. However, as water use increases, the resiliency of the watershed to deal with increasing population growth, shifts in agricultural production, climate variability (i.e., floods and droughts) and climate change is reduced. Efficiency in water use is strongly encouraged across all sectors including municipal supply, crop irrigation and other commercial, industrial and domestic uses. The following recommendations and actions are intended to ensure sustainable water supplies by improving security, reliability and resiliency to deal with variability and change.

C1. Water Supply/Servicing Master Plans assist with identifying future water supply needs and sources to meet those needs. Therefore, to reduce uncertainty around the availability of water supplies to meet long term needs, the Project Team recommends that municipalities, especially those with growth centres, maintain long term Water Supply Master Plans. Municipal Official Plan reviews should trigger updates to Water Supply or Servicing Master Plans or addenda to approved Environmental Assessments for meeting identified future water supply needs.

Action:

- ✓ Centre Wellington has initiated a Water Supply Master Plan with groundwater resource investigations underway and completion expected in 2015.
- ✓ The Region of Waterloo has initiated a Water Supply Master Plan Update for the Integrated Urban System that is expected to be completed in 2014.
- ✓ The City of Guelph has initiated a Water Supply Master Plan Update that is expected to be completed in 2014.
- ✓ The County of Brant has initiated a Master Servicing Plan for the urban settlement area of Paris that is expected to be completed in 2015.
- ✓ Six Nations of the Grand River plans to improve the capacity and reliability of their Ohsweken water supply system by completing construction of the new water treatment plant by 2015.

C2. Proactive water demand management is an approach that Municipalities can take to find additional supply. Therefore, the Project Team recommends that municipalities, particularly those in growth centres, incorporate considerations for demand management into water supply master plans; establish proactive demand management objectives; and continue to promote water conservation best practices that help to control average- and peak-day water demand as well as reduce the ratio of peak-day to average-day demand.

Action:

- ✓ Centre Wellington will incorporate a “soft path” approach as one of the options to be evaluated in their public consultation for their Water Supply Master Plan, expected to be completed in early 2015.
- ✓ The Region of Waterloo plans to develop proactive water demand management objectives as part of its Water Supply Master Plan update in 2014 and then update its Water Efficiency Master Plan in 2015 to set out its plan for meeting the WDM objectives.
- ✓ The City of Guelph plans to update its water demand management objectives as part of its 2013-14 Water Supply Master Plan update.
- ✓ The City of Brantford will discuss water demand management as part of the Master Servicing Plan that is currently in development (2013-2014).

C3. Municipalities require water supplies to be both secure and available, with reasonable certainty, from both a regulatory and physical perspective for long term municipal water supply planning. Therefore, to reduce regulatory uncertainty, the Project Team recommends that the Water Managers' Working Group continue to provide a forum for sharing information and building strong working relationships among municipal, provincial and conservation authority staff. To ensure the security of water sources from a water quantity perspective, the

Project Team recommends that the Grand River Water Budget be maintained as a valuable tool to inform decision making around Permits to take water applications and amendments.

Action:

- ✓ GRCA will continue to host and facilitate the Water Managers' Working Group to share information on long term water supply planning
- ✓ GRCA will continue to use the OMOECC PTTW database to maintain a current understanding of subwatershed stress as a result of cumulative water takings
- ✓ GRCA will continue to review large PTTW applications (>1M L/day) throughout the Grand River watershed that could potentially affect the stress assessments of subwatersheds and the sustainability of all water takings especially municipal PTTWs
- ✓ GRCA will work with watershed municipalities to develop a process for coordinating a review of large PTTW using more advanced tools developed for the Tier Three Risk Assessments.

C4. Agricultural water use is important in the Whitemans, Mount Pleasant and McKenzie creek areas of the watershed. With considerations for a changing climate, permitted water users are encouraged to continue water conservation best practices to reduce water demand. Therefore, to maintain the sustainability of these water supplies, the Project Team recommends that:

a) irrigation water be sourced from off-line storage ponds and/or groundwater to avoid direct withdrawal from surface water streams during low flow periods;

b) water use efficiency advice be available to irrigators to ensure that gun irrigation is timed to minimize evaporation and overspray, piping systems are maintained to minimize losses; soil moisture is assessed prior to irrigation events; and ponds are maintained and sized to satisfy the needs of summer irrigation; and

c) water use information be kept current for all sectors to observe trends in total water use across the watershed.

Action:

- ✓ OMAFRA will make sure that irrigators and livestock farmers have access to good information and advice on agricultural water use efficiency.
- ✓ OMOECC will maintain an inventory of water taking permits and actual water use across the watershed.
- ✓ GRCA will report on trends in water use (permitted and reported actual) as part of the Implementation Committee's five-year watershed report.
- ✓ GRCA will continue to facilitate the Low Water Response Team and recommend that member organizations promote industry water efficiency standards and best practices within their sectors.

C5. The seven major reservoirs were built to facilitate the augmentation of river flows to meet downstream flow requirements of waste assimilation and water supply. Therefore, the Project Team recommends that the operational river low flow targets (see Table A) set out in the current operating policy be maintained.

Action:

- ✓ GRCA will review their Reservoir Operating Policy (2004) every five years, starting in 2019, and update the policy if warranted.
- ✓ GRCA will review winter reservoir operational constraints to determine feasibility of increasing the winter flow target at Doon.

Table A. Low flow operation targets for the water management reservoirs.

Location	Operational Low Flow Target			Basis	Last Confirmed/ Revised
	Jan-Apr (m^3/s)	May-Sept (m^3/s)	Oct-Dec (m^3/s)		
Grand Valley	0.42	0.42	0.42	1986 Reservoir Yield Study	2004
Below Shand Dam[1]	2.8	2.8	2.8	1982 Basin Study	2013
Doon[2]	2.8[4]	9.9	7.1	1982 Basin Study	2013
Brantford		17		1982 Basin Study	2013
Below Conestogo Dam[1]	2.1	2.1	2.1	1982 Basin Study	2013
Below Guelph Dam[1]	0.57	0.57	0.57	1982 Basin Study	2013
Edinburg Road City of Guelph[3]	1.1	1.7	1.1	1982 Basin Study	2004/2013
Elmira	0.3	0.3	0.3	Operations Manual Woolwich Dam	1980

[1] Lessor of flow target or inflow to the dam

[2] Flow before the Mannheim surface water taking of 0.9 m3/s, Doon gauge is located downstream of taking

[3] Summer operating season for the Speed River is June 1 to Sept 30, fall/winter season is Oct 1 to May 31

[4] Winter low flow target estimated based on available winter augmentation storage below gate sill at Shand Dam

C6. Climate change studies indicate that there will be a shift in the timing and type of precipitation the watershed receives as there is a higher likelihood of warmer winters in the future. Therefore, the Project Team recommends that GRCA investigate a means to incorporate more flexibility into the reservoir operating policy for the spring filling cycle.

Action:

- ✓ GRCA will review their Reservoir Operating Policy (2004) for the spring filling period.

C7. In addition to flood control, another primary function of the water management reservoirs is to augment river flows during low-flow periods to assist with the assimilation of wastewater effluent in the regulated reaches. The following river flows termed '$7Q_{20}$ equivalent flows' (Table B) are for the design of wastewater treatment plant upgrades or expansions in the regulated reaches of the Grand, Conestogo and Speed Rivers.

Action:

- ✓ GRCA and OMOECC will review the $7Q_{20}$ equivalent flows every five years starting in 2019.
- ✓ When planning assimilative capacity studies, watershed municipalities (Region of Waterloo; City of Guelph, Haldimand County, County of Brant, City of Brantford, Centre Wellington, Grand Valley) will consult with the OMOECC and GRCA to

determine whether the 7Q20 equivalents for the regulated reaches have changed significantly from those presented in the Water Management Plan.

Table B. Design $7Q_{20}$ equivalent flows for wastewater treatment plants (WWTP) discharging to the regulated river system. Note that seasons coincide with reservoir operations.

WWTP	Winter/ Spring (Jan-May)	Summer (June-Sept)	Fall (Oct-Dec)	Appropriate Stream Flow Gauge
	m^3/sec			
Grand River				
Grand Valley	0.4	0.4	0.4	Leggatt gauge
Fergus	1.4	2.7	1.5	Below Shand gauge
Elora	1.7	2.8	1.6	Below Shand plus $7Q_{20}$ from Irvine River
Waterloo	3.2	8.4	4.9	Doon after the Region of Waterloo Municipal taking
Kitchener	3.2	8.4	4.9	Doon after the Region of Waterloo Municipal taking
Preston	6.7	10.5	8.6	Galt gauge
Galt	6.7	10.5	8.6	Galt gauge
Paris	12.4	14.9	12.4	Brantford gauge minus $7Q_{20}$ from Whitemans Creek
Brantford	13.8	15.4	13.2	After City of Brantford municipal taking
Caledonia	13.8	15.4	13.2	Brantford gauge $7Q_{20}$ for York
Cayuga	14.3	15.5	13.4	Same as Caledonia plus $7Q_{20}$ from McKenzie Creek
Dunnville	14.3	15.5	13.4	Same as Caledonia plus $7Q_{20}$ from McKenzie Creek
Speed River				
Guelph	1.0	1.3	1.0	Below Guelph gauge
Hespeler	1.7	2.5	1.9	Speed at Cambridge gauge
Conestogo River				
St. Jacobs	2.0	2.7	1.3	St. Jacobs gauge
Canagagigue Creek				
Elmira	0.2	0.3	0.3	Near Elmira gauge

C8. In the future, Permits to Take Water on regulated river reaches may have a direct influence on the reliability of the major water management reservoirs to meet downstream flow requirements. Therefore, the Project Team recommends that Permits to Take Water for new water takings from the regulated reaches of the Grand, Conestogo and Speed rivers have requirements to reduce the rate of taking when river flows drop below the operational low flow targets. Off-line storage or variable rate pumps could be considered.

Action:

- ✓ The GRCA will continue to review and provide input to the OMOECC for new Permits to Take Water, amendments or renewals with a direct influence on a regulated river reaches of the Grand, Conestogo and Speed rivers, and Permits to Take Water for large (>1M L/day) groundwater users within high water use areas.
- ✓ OMOECC will consider including conditions on Surface Water Permits to Take Water to manage consumptive water takings during low flow conditions in the regulated reaches of the Grand, Conestogo and Speed Rivers based on input from GRCA for applications for new Permits to Take Water or amendments or renewal of existing Permits to Take Water.

C9. Aquatic communities require certain river flows and river flow processes to remain healthy. Therefore, the Project Team recommends that the environmental low flow thresholds identified in the Plan be field verified and used to inform reservoir operations and drought management planning.

Action:

- ✓ GRCA plans to field verify the flow thresholds, particularly the flows required to maintain the littoral zone at Brantford, which is currently estimated to be higher than the operational flow target.
- ✓ GRCA plans to investigate the feasibility of meeting higher environmental flow thresholds more reliably without sacrificing low flow reliability or cause flooding.

C10. Groundwater in the central Grand River region is valued as a municipal supply, for sustaining baseflows in small streams and larger rivers and for maintaining important coldwater aquatic habitat. To protect the sustainability of, and cumulative impacts on, these regionally important groundwater resources, the Project Team recommends that a better (shared) understanding about the linkages between the significant regional recharge areas, water supply sources and important groundwater discharge areas is needed by Water Managers.

Action:

- ✓ GRCA will facilitate the Hydrology – Groundwater Working Group and engage key partners including the Ontario Geologic Survey, Environment Canada (EC), City of Guelph, Region of Waterloo, County of Brant, researchers and others provide a forum to discuss and share technical information on regional groundwater-surface water issues, research and projects.
- ✓ GRCA will work researchers and the Hydrology - Groundwater Working Group to undertake technical studies to better understand the regional recharge areas that are supporting important groundwater discharge areas such as the middle Grand River, the lower Nith River, the lower Speed River, and the Eramosa River.
- ✓ GRCA will continue chair the joint committee on cumulative effects assessment on below-water aggregate operations and encourage the use of the best practices paper “Cumulative effects assessment (water quality and quantity) Best Practices Paper for Below-Water Sand and Gravel Extraction Operations in Priority Subwatersheds in the Grand River Watershed” by aggregate operators within high priority subwatersheds.

C11. The maintenance of critical groundwater recharge processes is important to the sustainability of municipal groundwater supplies but also to the groundwater discharges that help maintain water quality and support valued aquatic habitat. Therefore, the Project Team recommends that municipalities with urban areas consider important groundwater recharge areas in developing their growth strategies.

Action:

- ✓ Region of Waterloo intends to manage the western ‘countryside line’ set out in the Regional Official Plan to protect the groundwater recharge areas of the Waterloo Moraine.
- ✓ GRCA will update groundwater recharge mapping to add consideration of exposed, fractured or karsted bedrock as areas allowing for significant recharge, and make this information available to municipalities.
- ✓ GRCA will update models and mapping to reflect key hydrologic processes (e.g. groundwater recharge and discharge) that support significant wetland features in the watershed.
- ✓ GRCA will analyze and report on trends in baseflows in selected unregulated, groundwater-fed streams
- ✓ GRCA and watershed municipalities with Tier Three Risk Assessments will collaborate to refine recharge areas and hydrologic processes identified through these projects

C12. Local water management plans can help facilitate discussions and resolve potential conflict among users. Therefore, local water management plans for are recommended for water users in the Whitemans, Mount Pleasant, and McKenzie creek subwatersheds (Norfolk Sand Plan area of Brant and Oxford counties) to reduce the potential for water use conflicts and constraints.

Action:

- ✓ GRCA, OMNRF and OMAFRA will work together on a water budget study for Whitemans, Mount Pleasant and McKenzie Creeks.
- ✓ OMAFRA, with assistance from OMOECC, OMNRF and GRCA will continue to work with farmers and farm organizations to find permanent, pro-active water quantity solutions to the water management challenges in the Whitemans, Mt Pleasant, and McKenzie Creek areas in Brant and Oxford Counties.

C13. Current climate models are predicting a greater variability in weather patterns which can result in an increase in both intense storms and prolonged droughts. Therefore, the Project Team recommends that a proactive drought contingency plan be developed among water users to deal with low water conditions.

Action:

- ✓ GRCA will work with municipalities and water use sectors in 2014-15 to facilitate the development of a joint, proactive watershed-wide drought contingency plan to deal with extreme low water events.
- ✓ GRCA will continue to facilitate the Low Water Response Team.

D. Improving Water Quality

Water quality issues in surface and ground water vary across the watershed and are influenced by geology, land cover, and land management practices. Water quality issues include nutrients, sediment, chloride, and pathogens among others. Surface water quality issues tend to be season-specific and driven by large hydrologic events such as spring runoff or conditions such as summer low water flows. The various geologic settings in the watershed influence groundwater quality; however, land management practices (e.g., fertilizer use) and historic land use (e.g., industry) play an important role in local groundwater quality issues.

The water quality of the surface and ground water resources in the Grand River watershed will continue to be a concern for water managers as population continues to increase; agricultural production intensifies and climate becomes more variable. Consequently, to achieve the goal of improving water quality to improve river health and reduce the Grand River's impact on Lake Erie, the Project Team recommends that the focus now and into the future be on both point and non-point source management strategies to ensure that the best value solutions are in place to achieve the goal. The following recommendations and actions will improve water quality.

Point Source Pollution Strategy

Most of the point source discharges in the watershed are wastewater treatment plants although there are a few direct discharges from industry. Point sources tend to significantly influence water quality in the river during summer low flows and therefore minimum flows are required in the regulated river reaches to assist with wastewater assimilation (see IAP C7.).

D1. River water quality conditions will improve considerably in the future with planned upgrades to wastewater treatment plants in the watershed. The following plants are planned to be upgraded over the next 10 years:

Action:

- ✓ Centre Wellington will upgrade the Elora WWTP to include nitrification and tertiary filtration by mid-2014.
- ✓ Region of Waterloo plans to continue to upgrade to the Kitchener WWTP to include nitrification and tertiary filtration by 2018.
- ✓ Region of Waterloo plans to continue to upgrade the Waterloo WWTP to include nitrification by 2014 and plans to expand the Waterloo WWTP and include tertiary filtration by 2030.
- ✓ Region of Waterloo plans to upgrade the Hespeler WWTP to include nitrification in a future expansion.
- ✓ Region of Waterloo plans to initiate a Wastewater Master Plan in 2015 to revise population growth estimates and WWTP requirements for their 13 wastewater treatment plants.
- ✓ The City of Guelph plans to implement the Anammox® process for sidestream treatment of high strength dewatered filtrate, with anticipated completion in 2015. It is anticipated that nitrate loading from the Guelph WWTP to the Speed River may be reduced following the implementation of this process.
- ✓ The County of Brant intends to carry out studies with plans to upgrade the Paris and St. George WWTP by 2021.
- ✓ Oxford County is currently pursuing upgrades and improvements to the Drumbo WWTP to increase capacity while maintaining effluent mass loadings

D2. The Composite Correction Program (CCP) helps wastewater treatment plant operators and managers identify performance limitations which may impact final effluent quality. A study modelling future river water quality conditions suggest that water quality will incrementally improve with the adoption of effluent quality performance targets achieved through enhanced process control techniques as set out in the CCP. These performance targets are not to be confused or interpreted as being in any way related to Environmental Compliance Approval (ECA) limits or performance objectives.

To achieve the goal of improved water quality in the watershed, the Project Team recommends that watershed municipalities who own WWTPs adopt voluntary effluent quality performance targets that go beyond the compliance objectives as stated in ECAs. Although performance targets should be established for each plant based on its own capability, the following are proposed as general performance targets:

Voluntary Proposed effluent quality performance targets for phosphorus:

a) Secondary WWTPs (e.g., Waterloo, Hespeler, Preston, Paris and Brantford) could aim for a monthly average total phosphorus concentration of 0.4 mg/L until tertiary filtration is implemented.

b) WWTPs equipped with tertiary filtration (e.g., Guelph, Galt and Fergus. Elora is expected to commission tertiary filtration in 2014) could aim for a monthly average total phosphorus concentration of 0.2 mg/L.

c) As the implementation of CCP matures, secondary WWTPs could aim to meet a monthly average performance target of 0.3 mg/L and WWTPs equipped with tertiary filtration should establish an optimized treatment target of 0.15 mg/l total phosphorus.

Voluntary Proposed effluent quality performance targets for ammonia:

a) Plants that are currently nitrifying could aim for an interim performance target of 2 mg-N/L total ammonia-nitrogen in the summer and 4 mg-N/L in the winter.

b) As the implementation of CCP matures, plants could aim to achieve performance targets of 1 mg-N/L in summer and 2 mg-N/L in winter.

c) Plants that are currently not nitrifying could investigate the capability of the plant to achieve stable nitrifying conditions.

Action:

✓ The City of Guelph will continue to apply the CCP and maintain their focus on WWTP performance to meet the voluntary performance targets for total phosphorus of 0.15 mg/L and total ammonia of 1 mg/L.

✓ The City of Brantford will continue its optimization efforts by applying the CCP to establish stable nitrifying conditions and reduce total phosphorus concentrations in the final effluent. Once these conditions have been achieved, the City will adopt voluntary performance targets for total phosphorus of 0.4 mg/L and total ammonia of 2.0 mg-N/L (May – Nov) and 4.0 mg-N/L (Dec – April).

✓ Haldimand County will continue its optimization efforts by applying the CCP to the following plants:

- Caledonia voluntary targets (tertiary treatment): total phosphorus target of 0.15 mg/L and total ammonia target of 0.75 mg/L (May – Nov) and 1.5 mg/L (Dec – Apr);

- Cayuga voluntary targets (secondary treatment): total phosphorus target of 0.5 mg/L and total ammonia target of 3.0 mg/L (May – Nov) and 5.0 mg/L (Dec – Apr); and
- Dunnville voluntary targets (secondary treatment): total phosphorus target of 0.5 mg/L and total ammonia target of 3.0 mg/L (May – Nov) and 5.0 mg/L (Dec – Apr).

✓ Although the County of Brant already achieves a significant reduction in phosphorus, the County intends to continue to optimize treatment processes at the Paris WWTP to reduce effluent phosphorus concentrations and intends to incorporate the goal of reducing final effluent total phosphorus concentrations as part of a future Class Environmental Assessment for plant expansion. The plant expansion is currently scheduled for approximately 2021.

✓ Centre Wellington will consider adopting the CCP approach to optimizing the operation of WWTPs discharging into the Grand River with the goal of meeting the recommended voluntary performance targets described above.

✓ The Region of Waterloo will consider adopting the CPP approach to optimizing the operation of WWTP's discharging into the central Grand and lower Speed Rivers with the goal of meeting the recommended voluntary performance targets described above.

✓ Municipalities implementing CPP will share their successes and benefits with the Water Managers' Working Group.

✓ GRCA will assemble information on optimization successes and effluent performance to update water quality projections for the Grand River Implementation Committee's 5-year review of the Plan.

✓ Grand River Conservation Authority and the OMOECC will continue to facilitate a watershed community of practice for wastewater optimization to share lessons learned.

✓ The OMOECC will, where appropriate, use the wastewater treatment plant composite correction program as a viable approach for capacity re-ratings and effluent quality improvement

D3. An important aspect of achieving effective wastewater treatment is having a good understanding of the waste stream being collected by the sewer system. Therefore, the Project Team recommends that all municipalities who own wastewater treatment plants have and enforce an effective sewer use bylaw.

Action:

✓ Municipal members of the Water Managers' Working Group will share information on sewer use bylaws for proactive maintenance and enforcement to ensure effective wastewater treatment.

D4. To reduce the frequency and severity of sewage spills and bypasses from municipal wastewater treatment plants in the Grand River watershed, the Project Team recommends that the watershed municipalities, GRCA and the OMOECC continue to implement the actions identified in the report "*Best Practices: Municipal Wastewater treatment plant Bypass and Spill Prevention & Reporting in the Grand River Watershed*".

Action:

- ✓ Watershed municipalities who own wastewater treatment plants and sewage collection systems, GRCA and the OMOECC will provide an annual update at a Water Managers' Working Group meeting on the implementation of the actions to reduce the frequency and severity of sewage spills and bypasses including:
  - spills reporting procedures and information management;
  - infiltration and inflow reduction programs;
  - implementation of backup power at pumping stations and wastewater treatment plants;
  - wastewater master planning;
  - continuous improvements in the time of travel model for spill notification; and
  - wastewater treatment plant performance and the watershed community of practice for wastewater optimization (as recommended in IAP D.2).

D5. A regional approach is needed to evaluate the cumulative effects of the ten wastewater treatment plants discharging to the central portion of the Grand River and the lower Speed River. Consequently, the Project Team recommends that the Grand River Simulation Model (GRSM) – an effective assimilative capacity planning tool – be maintained which includes on-going data collection for calibration and validation and to continually improve the model to reflect the current science of in-river nutrient, sediment and dissolved oxygen processes.

Action:

- ✓ GRCA will remain the custodian for the Grand River Simulation Model (GRSM) for watershed wastewater planning.
- ✓ GRCA will continue to work with watershed municipalities (Region of Waterloo, City of Guelph, City of Brantford, Centre Wellington, and County of Brant) to continually improve the Grand River Simulation Model through ongoing data collection for model calibration/validation for effective long-term watershed wastewater planning.
- ✓ OMOECC will provide advice on the Grand River Simulation Model (GRSM) to GRCA and watershed municipalities for assessing assimilative capacity
- ✓ GRCA will work with EC, and OMNRF to evaluate approaches for extending the Grand River Simulation Model (GRSM) or coupling the GRSM with a fluvial lake model in the southern Grand River.
- ✓ GRCA will maintain the network of nine continuous monitoring stations for dissolved oxygen, temperature, pH, conductivity and turbidity to validate and calibrate the Grand River Simulation Model for municipal wastewater management planning processes.

D6. A broader approach is needed to evaluate the effects of small municipal wastewater treatment plants in those areas where the Grand River Simulation Model does not apply. A broader subwatershed study may help to identify additional opportunities for addressing water quality and quantity issues. Consequently, the Project Team recommends that subwatershed studies be updated or completed for the upper Grand, upper Conestogo and upper Nith rivers and Fairchild and Canagagigue creeks to evaluate the best value solutions for broad scale water quality, quantity and flood reduction measures. A broader approach may provide additional options for future wastewater treatment plant upgrades/expansions.

Action:

- ✓ GRCA will work with watershed municipalities (Dundalk, Grand Valley, Mapleton, Arthur, Region of Waterloo, Oxford County, and County of Brant) to undertake subwatershed studies to evaluate the best value solutions for managing water quantity and water quality.

Nonpoint Source Pollution Strategies

Nonpoint sources of pollution are generated from the landscape and facilitated by key hydrologic processes such as overland runoff and groundwater recharge. Nonpoint sources are influenced by the type of land use and land management practices.

Rural Nonpoint Source Pollution Strategy

The rural nonpoint source pollution strategy is aimed at rural/agricultural and non-municipal lands.

D7. Nonpoint sources of nutrients and sediment are significant, especially during the spring. To reduce nutrients and sediments in surface waters and protect the integrity of groundwater aquifers, is recommended that the Rural Water Quality Program be continued and be enhanced to:

a) expand the range of best management practices (BMPs) eligible for grants in some areas of the watershed to provide a well-rounded program watershed wide;

b) promote the adoption of conservation practices in addition to the current grants for capital projects;

c) enhance assistance in priority areas or subwatersheds;

d) extend the program to rural non-farm properties;

e) include funding for well decommissioning across the watershed to protect groundwater aquifers; and

f) Include a monitoring program to measure the effectiveness of BMP implementation at the subwatershed scale.

Action:

- ✓ Wellington County, City of Guelph, Region of Waterloo, County of Brant, City of Brantford and Haldimand County intend to continue supporting the Rural Water Quality Program.
- ✓ Oxford County intends to continue to support the Clean Water Program, administered by the Upper Thames River Conservation Authority and delivered by the GRCA, to implement best management practices in the Grand River watershed.
- ✓ GRCA will continue to deliver the Rural Water Quality Program watershed-wide on behalf of the municipalities.
- ✓ The Grand River Implementation Committee will seek to identify funding and funding opportunities to match municipal contributions to the Rural Water Quality Program.
- ✓ GRCA, on behalf of watershed municipalities, will maintain a phosphorus accounting methodology and estimate the amount of phosphorus kept on the land with the implementation of BMPs.
- ✓ GRCA, on behalf of watershed municipalities, will report on the kilograms of phosphorus kept on the land as a result of BMP implementation as part of the five year reporting cycle of the Water Management Plan, starting in 2015.

- ✓ GRCA will work with OMAFRA, watershed municipalities and researchers to develop a monitoring, modeling and research project for priority subwatersheds including the upper Nith River subwatershed to evaluate the effectiveness of BMP's over time.

D8. River nitrate levels tend to be high during the winter months. A modelling study of future water quality conditions suggests that river nitrate levels will continue to increase. The study demonstrated that most of the nitrate in the river will be from nonpoint sources rather than from wastewater treatment plant upgrades. It is thought that the nitrate may be coming from shallow groundwater; however, research is required to confirm this. To reduce nitrate concentrations in the river in the future, the Project Team recommends that nitrogen application to the land in areas of high groundwater recharge be optimized to maintain productivity while minimizing environmental losses in priority subwatersheds including the central Grand River, lower Nith River, and Whitemans Creek.

Action:

- ✓ GRCA, on behalf of watershed municipalities, will continue to promote nutrient management strategies and plans in priority subwatersheds through the Rural Water Quality Program.
- ✓ Water Managers' Working Group will work together to synthesize recent and upcoming studies to support continued discussion on further action to reduce nitrate levels from nonpoint sources.

D9. Municipal drains are designed to remove excess water from the land. For effective management of sediment loads, soil erosion and flooding downstream, the Project Team recommends that municipalities pursue best practices for municipal drain design and maintenance.

Action:

- ✓ OMAFRA will continue to support the municipal use of the Drainage Act in an environmentally sustainable manner. This includes:
  - ▪ On-going training for Drainage Superintendents
  - Revision of Drainage Engineers' "Design and Construction Guidelines, Second Edition" by 2016
- ✓ Headwater municipalities (the townships of Southgate, Melancthon, Grand Valley, Amaranth, East Garafraxa, Wellington North, Mapleton, Wellesley, North Perth and Perth East) will continue to work with their drainage superintendents and drainage engineers to pursue best practices for drain design and maintenance.

Urban Nonpoint Source Pollution Strategy

D10. Urban stormwater contributes significantly to the phosphorus and sediment levels in the central Grand River. To reduce sediment and phosphorus loads and associated pathogens from urban stormwater in the middle Grand River, the Project Team recommends that the central Grand River watershed municipalities implement best practices as listed in the '*Best Practice Guide for Reducing Urban Non-point Source Pollution of the Grand and Speed Rivers'*. Best practices focus on:

- Sustainable funding to support an appropriate stormwater management program;
- Development and implementation of stormwater management master plans ;
- Improvements to sediment and erosion control implementation and enforcement for developing sites;

- Enhanced communication and education programs;
- Opportunities to retrofit existing uncontrolled areas; and
- Maintenance and operations of facilities.

Action:

- ✓ GRCA will continue to facilitate a watershed Stormwater Management Working Group (Cities of Waterloo, Kitchener, Cambridge, Guelph, Brantford, Centre Wellington and County of Brant) and host biannual meetings to share information and identify roles and responsibilities among watershed urban municipalities.
- ✓ The Cities of Waterloo, Kitchener, Cambridge, Guelph, Brantford, Centre Wellington (Fergus, Elora) and County of Brant (Paris) plan to pursue stormwater management best practices as listed in the '*Best Practice Guide for Reducing Urban Non-point Source Pollution of the Grand and Speed Rivers*'.
- ✓ GRCA, municipalities (Cities of Waterloo, Kitchener, Cambridge, Guelph, Region of Waterloo, Central Wellington, County of Brant, and Brantford) will work together to optimize current stormwater monitoring programs to characterize the effects of stormwater on the central Grand River.

D11. Chloride levels are increasing in both ground and surface water across the watershed but are of particular concern in the central urban areas of the watershed and in areas of high groundwater recharge. Further, source protection planning has identified chloride as an issue in many municipal groundwater wells. Sources of salt in the watershed include the use of salt for de-icing and for softening water.

Although municipalities are required to develop risk management plans for chloride in identified vulnerable areas for Source Protection Planning, the Project Team recommends that municipalities continue to proactively manage the use of chloride in the watershed by following Environment Canada's Code of Practice for the Environmental Management of Road Salt, participating in programs like "Smart about Salt' and promoting salt and water efficient water softeners.

Action:

- ✓ The Region of Waterloo, City of Waterloo and City of Guelph plan to continue activities and programs to promote reduced salt use for de-icing, both public and private.
- ✓ The Region of Waterloo and City of Guelph plan to continue activities and awareness regarding the use of water and salt efficient water softeners.

D12. Pathogens (e.g., *E. coli*, Cryptosporidium and Giardia) are a concern to surface water treatment plants in the Grand River watershed. Consequently, the Project Team recommends that studies be carried out to characterize conditions when pathogens are a concern so that appropriate actions can be identified to mitigate these conditions.

Action:

- ✓ The City of Brantford will continue to monitor pathogens in their raw water and document pathogen spike events.
- ✓ The City of Brantford and GRCA will continue to work together to look for opportunities to engage the research community to undertake research on identifying the sources of pathogens in the watershed.

<u>In-river Improvement Strategy</u>

D13. Water quality in the southern Grand River is poor, in part due to the cumulative inputs from the upstream watershed but also due to the lake-like conditions created by the Dunnville Dam. The river is highly turbid, experiences periods of low dissolved oxygen, and has very high phosphorus levels that impact the health of the river; the Dunnville Marshes; river/coastal wetlands; the Lake Erie nearshore; and impacts the operation of the river intake for emergency water supplies for the town of Dunnville. The Project Team recommends that the effects of the Dunnville dam be mitigated to improve the conditions of the southern Grand River and improve the health of the Dunnville Marshes and other river/coastal wetlands.

Action:

- ✓ The Southern Grand River Ecosystem Rehabilitation Working Group, including Environment Canada (EC), OMNRF, Six Nations, GRCA, Haldimand County and others (e.g. Department of Fisheries and Oceans) will continue to oversee and support studies to investigate the role of altered hydrology on water quality and sediment delivery.
- ✓ OMNRF and EC will co-lead facilitated workshops and consultations with multiple stakeholders to consider water quality collectively with hydrology, fisheries and connectivity issues. A Strategic Decision Making (SDM) approach is being used to determine comprehensive remediation solutions for the southern Grand River.
- ✓ Once the investigations are complete, the GRCA, with support from the Southern Grand River Ecosystem Rehabilitation Working Group, will plan to undertake a feasibility study for modifying the Dunnville Dam.
- ✓ GRCA will review and update the Dunnville Marsh Management Plan starting in 2017.
- ✓ OMOECC will establish and maintain a long term monitoring site below the Dunnville Dam (proposed as part of the Great Lakes Index Station monitoring) to support continued assessment of the conditions of the southern Grand River.

D14. Weirs and in-river structures alter the hydrology and sediment delivery of a river system causing sediment to accumulate behind them. In-river sediment is closely associated with phosphorus so in-river sediment is likely a source of phosphorus to the river. To account for and determine the relative role of in-river sediment-bound phosphorus on in-river summer phosphorus levels, the Project Team recommends that studies be carried out on priority run-of-the-river dams to assess the relative likelihood that modifications or removal of these weirs will improve water quality and important natural river flows/processes needed by river ecosystems.

The Grand River Fisheries Management Plan identified small dam removal as a way to improve water quality, water temperatures and improve connectivity for fish. Consequently, the Project Team recommends that Water Managers work with the Fisheries Management Implementation Committee to prioritize in-river structures for study and/or removal to improve water quality. In addition to studies related to the Dunnville Dam (IAP D.13), priority for studies should be given to the dams on the Speed River in Guelph and Cambridge, the lower Conestogo River, the lower Nith River and the coldwater streams throughout the watershed.

Action:

- ✓ GRCA will work with the OMNRF and the Grand River Fisheries Management Plan Implementation Committee to evaluate and prioritize in-river weirs and investigate the effect that dam modifications or removal will have on water quality and in-river processes.
- ✓ Water Managers' Working Group and the Grand River Fisheries Management Plan Implementation Committee will work together to identify priority river reaches and facilitate studies on the benefits of structural channel modifications to improve natural river processes and nutrient assimilation.
- ✓ GRCA will continue to update the dam inventory of the watershed.

<u>Data Collection and Monitoring</u>

D15. Additional data/information is needed to make more informed water management decisions in the future. Many of the current monitoring programs are insufficient to characterize seasonal and hydrologic conditions adequately to have a high degree of confidence with which to make decisions. Addressing these gaps through a coordinated approach will ensure that information is generated in a strategic manner and is useful for addressing water issues now and into the future.

<u>Coordination and Optimization of Monitoring and Data Management</u>

To evaluate further options, measure the effectiveness of actions and answer outstanding questions, the Project Team recommends that water quality data collection and management be coordinated and optimized as follows:

Action:

- ✓ Members of the Water Quality Working Group (e.g. GRCA, Region of Waterloo, OMOECC and others) who collect water quality information as part of ongoing programs or research projects plan to continue to collaborate to review and optimize monitoring efforts to ensure there is sufficient water quality data (e.g., nutrient, oxygen, temperature, chloride and sediment data) to provide the necessary information with which to measure current conditions, monitor trends and report on progress toward achieving the milestones and targets.
- ✓ Beginning in 2015, the Water Quality Working Group will work with researchers and other partners to identify appropriate biological indicators and to design a biomonitoring program that will detect change in management actions (e.g., wastewater treatment plant upgrades) and assess the health of the aquatic ecosystem. The design of the program will incorporate the outcomes and recommendations of the Canadian Water Network's Aquatic Cumulative Effects Assessment project in the Grand River. Environmental flow needs will also be considered. Plan partners will collaborate to implement the biomonitoring program starting in 2016.
- ✓ GRCA will implement a data management framework for hydrometric data, including flow, quality, precipitation, groundwater wells etc., (e.g., WISKI) using open data standards (e.g., WaterML2.0) that will support Web-based tools for sharing data.

Existing Programs

To evaluate the effectiveness of rural and urban nonpoint source controls for future watershed wastewater treatment planning and Great Lakes Water Quality Agreement objectives it is essential that sufficient long term data be available. Evaluation of improvements in response to management actions will require adequate data to detect trends in water quality conditions. The Project Team recommends that existing programs address this need as follows:

Action:

- ✓ The Region of Waterloo will continue their long-term river monitoring program to measure resource condition trends above and below their wastewater treatment plants on the Grand, Nith and Speed Rivers as a result of planned WWTP upgrades. River water quality data will be shared with Plan partners.
- ✓ GRCA will maintain the network of nine continuous monitoring stations for dissolved oxygen, temperature, pH, conductivity and turbidity to validate and calibrate the Grand River Simulation Model for watershed municipality's wastewater management planning processes (IAP D.5). Through regular strategic reviews, GRCA will update the water quality monitoring instrumentation (e.g., data sondes) and SCADA systems using updated technologies and will consider including additional parameters (e.g., phosphorus) once the technologies become more accurate and reliable.

Monitoring ambient groundwater conditions in the watershed through the Provincial Groundwater Monitoring Network (PGMN) provides regionally significant data to support such issues as drought response, trends in climate change, and provides a basis of support for informed resource management decisions.

Action:

- ✓ GRCA to maintain a monitoring network of 27 PGMN wells within the watershed. These wells are equipped to measure water levels hourly, and are sampled yearly for a suite of inorganic water quality parameters.
- ✓ GRCA to complete a review of the monitoring network to ensure its effectiveness in monitoring regionally significant ambient groundwater levels and quality.
- ✓ GRCA will facilitate discussion among partners to explore developing a tiered approach to groundwater condition monitoring including important areas of groundwater and surface water interaction

Data Collection and Focused Studies

Additional data are needed to evaluate the effectiveness of rural and urban nonpoint source controls to support future watershed wastewater treatment planning and Great Lakes Water Quality Agreement objectives.

a) Additional phosphorus and sediment data are required from rural and urban priority subwatersheds during high flows to estimate loads. Priority areas for nonpoint source controls include the upper Nith, upper Conestogo, Canagagigue and Fairchild subwatersheds.
b) Additional turbidity and sediment data are required from high priority urban subwatersheds to determine aquatic health thresholds/targets and loads.
c) Although limited, preliminary survey data indicate that nitrate levels are an issue in some parts of the watershed. To increase confidence in the characterization of nitrate concentrations; determine long term trends; and determine the relative importance of nitrate sources, data are required during the winter above drinking water intakes.
d) Temperature and flow data are required on sentinel coldwater streams to characterize conditions and monitor trends given a changing climate.

The Project Team recommends that these and other data and information needs are addressed as follows:

Action:

- ✓ GRCA will install continuous nitrate monitor in the Grand River at Bridgeport and partner with the City of Brantford to install a monitor at the Brantford station.
- ✓ GRCA will instrument the Phillipsburg water level station with automatic sampling equipment for characterizing phosphorus and sediment loads and concentrations from the upper Nith subwatershed, a priority subwatershed for nonpoint source pollution.
- ✓ GRCA will develop relationships with continuous monitors (e.g. turbidity, conductivity) and standard laboratory parameters (e.g. total phosphorus, total suspended solids, chloride) to better quantitatively describe loads and trends over time. Further, ISCO automatic samplers will be employed at existing stations to build relationships between phosphorus, suspended sediments and other parameters during event flows.
- ✓ GRCA and the OMNRF will work together to identify and fill information gaps concerning the characterization of priority cool and coldwater creeks in the watershed recognizing a changing climate and the importance of groundwater recharge and discharge functions to sustain coldwater creeks that help to moderate in-river temperatures, (see also IAP C.10).
- ✓ OMOECC will undertake studies to determine the importance of dissolved phosphorus in Ontario agricultural streams.
- ✓ OMOECC will collaborate with Plan partners to undertake studies on small, agricultural watersheds to assess the role of land use and land management on stream nutrient and sediment loading.

Geospatial Data

Data needs also extend to land cover, land use, terrain and soils data. Landscape data are fundamentally important to explore relationships between water quality and management actions. This information serves as the foundation for developing models for identifying priority nutrient/sediment source areas for rural best management practices. Consequently, routinely updated land cover, land use, soils and terrain data are required for building approaches to inform future watershed water management decisions.

Action:

- ✓ OMNRF will continue to update land cover data for the province, including the Grand River watershed, as appropriate.
- ✓ OMAFRA will work toward updating soils data and collecting agricultural land use information for the Grand River watershed as resources would allow.
- ✓ GRCA, with support from OMAFRA and other Plan partners, will continue to update the stream hydrology network using 3D Softcopy and GIS technology to produce high resolution digital elevation models.

E. Reducing Flood Damage

The flood risk reduction program is relatively mature and the combination of structural and non-structural methods is effective. It is estimated that structural measures implemented to this date have reduced average annual flood damages by 80%. Floodplain regulation has avoided the creation of any new flood damage potential and is critical to reduce future flood damage potential. However, the potential for large floods still exist. Climate change may increase the frequency and time of year that floods occur. The following recommendations are intended to enhance flood preparedness, adapt to a changing climate and continue to reduce the flood damage potential over time.

E1. The seven multipurpose dams/reservoirs and extensive dyke system are significant watershed infrastructure assets that require ongoing investment, maintenance and operation. Therefore, the Project Team recommends that GRCA continue to complete or update dam and dyke safety studies for major reservoirs and dykes to maintain flood control infrastructure that is safe and ready to respond to floods.

Action:

- ✓ GRCA will inventory the status of dam and dyke safety studies and budget in the capital forecast the necessary funds to complete safety studies and implement recommendations from these studies.
- ✓ GRCA will encourage OMNRF to continue providing matching funds for capital maintenance and studies through the Water Erosion Control Infrastructure program.
- ✓ GRCA will work with the local municipalities to update dyke maintenance agreements to confirm the responsibilities of each agency.
- ✓ Municipalities with large dykes (City of Kitchener, City of Cambridge and City of Brantford) or small Dams (e.g. City of Waterloo, Columbia Lake) will maintain operational plans and train municipal staff to carry out operational actions (e.g., installing stop logs at bridges) and surveillance of dykes during a flood.

E2. An increase in the frequency and magnitude of severe storms will put stress on urban stormwater systems. Therefore, the Project Team recommends that municipalities undertake a stormwater major system assessment to identify and reduce vulnerability to severe storm events. Considerations should be made for climate change.

Action:

- ✓ The cities of Cambridge, Kitchener and Waterloo have completed stormwater major system assessments or master plans and plan to take action to reduce vulnerability to severe storm events.
- ✓ City of Guelph completed a stormwater management master plan in 2012. Major system assessments were undertaken and plans to take action to reduce the vulnerability to severe storm events were part of the Master Plan work. A stormwater Funding Study commenced in 2013 to review the funding requirements of the Stormwater Management Master plan and to sustainably fund City stormwater assets.
- ✓ The City of Brantford plans to include stormwater major system assessment in the Servicing Master Plan studies currently underway. Completion is expected by 2014.
- ✓ Township of Centre Wellington and the County of Brant (Paris) intends to undertake stormwater major system assessments in the future to identify potential impacts from and reduce vulnerability of severe wet weather events.
- ✓ GRCA will work with Environment Canada Meteorological Services Branch to incorporate evolving technology such as the Canadian Precipitation Analysis (CaPA) spatial precipitation information into processes and methods used to develop the intensity duration frequency statistics that are used for design purposes across the Grand River watershed.

- ✓ GRCA will encourage the Province of Ontario to review the urban drainage standards with respect to major overland flow systems to reduce the potential for flooding of new urban development given the implications of climate change.

E3. Floodplain mapping is the foundation for floodplain management, emergency preparedness planning and flood damage assessment. Therefore, the Project Team recommends that GRCA complete digital floodplain mapping in flood damage centres, along the large rivers, and urban water courses throughout the watershed.

Action:

- ✓ GRCA will prepare an inventory of digital floodplain mapping focusing on areas at risk including flood damage centres, trailer parks and rural properties in the floodplain along large river systems.
- ✓ GRCA will continue to work with partners to complete the watershed-wide digital elevation model that would act as a base for engineered floodline determination as well as assist to refine hydrology and nonpoint source pollution models.
- ✓ GRCA will undertake two dimensional hydraulic modelling in complex urban areas to improve flood warning and accuracy and identify means and opportunities to reduce flood risk.
- ✓ GRCA will incorporate the cost to update or create digital floodplain mapping in their capital forecast. The time frame for implementation will be based on availability of funding.
- ✓ GRCA will work with Conservation Ontario to encourage the Federal and Provincial governments to restore funding to the Floodplain Damage Reduction Program as a means to finance the development or updating of digital floodplain mapping.
- ✓ GRCA will update the mapping for Special Policy and Two Zone areas as better technical and digital floodplain mapping becomes available and work with municipalities and the province to update the policies.
- ✓ GRCA will continue to work with municipal partners to incorporate floodplain information, updated mapping, and policies into municipal planning
- ✓ GRCA will continue to implement floodplain regulations to reduce flood damage potential.

E4. Emergency preparedness provides a mechanism with which to respond to floods in a timely and effective manner. Therefore, the Project Team recommends that flood inundation mapping and a flood vulnerable structures databases be developed to improve preparedness and support municipal emergency response plans.

Action:

- ✓ GRCA plans to complete flood inundation mapping in flood damage centres, as digital floodplain mapping becomes available.
- ✓ As inundation mapping becomes available, GRCA will assist municipalities to develop flood vulnerable structures databases and flood warning lists (addresses) that correspond to flood warning zones.

E5. Reliable communication is essential to effectively respond to flood emergencies and severe weather events. Therefore, the Project Team recommends that GRCA maintain a watershed wide voice radio system for operational purposes so that voice communications can be maintained during severe weather events.

Action:

- ✓ GRCA will maintain and test a watershed wide means of voice communications separate from landline and cellular based phone communication systems.
- ✓ As technology evolves, GRCA plans to explore implementing a voice radio system with public safety communications capabilities to allow seamless communications with fire, police and other emergency services staff.

E6. Flood forecasting using up-to-date monitoring information on precipitation, streamflow and streamflow routing models such as the GAWSER model are essential for enabling timely and effective response to flood events. Therefore, the Project Team recommends that GRCA continue to improve forecasting and decision support tools as new data and technologies become available.

Action:

- ✓ GRCA will continue to integrate improved weather forecast information into operational decisions, decision support tools and forecast models as improved information becomes available.
- ✓ GRCA will continue to collaborate with EC, OMNRF and other Conservation Authorities to enable EC's implementation of the new precipitation analysis production system (CaPA) to provide better spatial estimates of observed and forecasted precipitation.
- ✓ GRCA will continue to maintain and adapt the local monitoring system to provide reliable, timely delivery of information to forecast floods and support reservoir operations decisions.
- ✓ To improve the reliability of data communications, GRCA will implement GOES satellite communications capabilities for monitoring data collected at monitoring stations and dams as existing monitoring equipment is upgraded.

E7. Regular communication with emergency response agencies, municipalities and government agencies is crucial for effective response to flood events. Therefore, the Project Team recommends that GRCA continue to refine the delivery of flood warning messages and annually confirm the role of various agencies to continually improve flood warning.

Action:

- ✓ GRCA will continue to hold annual flood co-ordinators meetings to confirm expectations of different agencies and to receive input of how to further improve the flood warning system.
- ✓ GRCA will continue to refine and improve the delivery of flood messages as technology and media evolve.

E8. Damages to property and a risk to life can occur during significant flood events. Therefore, the Project Team recommends that additional ways to reduce the flood damage potential in the communities of Drayton, Grand Valley, Paris, New Hamburg, Ayr, Caledonia, Cayuga and Dunnville be investigated.

Action:

- ✓ GRCA will work with municipalities to investigate means to reduce the flood damage potential at their request.

E9. Ice jams in the river have the potential to cause significant flooding. Some areas are more prone to ice jams including the communities of Grand Valley, West Montrose, Paris, Brantford, Cayuga and Dunnville. Therefore, the Project Team recommends that the technical report titled "Ice Jams in the Grand River Basin"[71] be updated and that site specific ice jam investigations be carried out for these communities.

Action:

- ✓ GRCA will plan to update the technical report titled "*Ice Jams in the Grand River Basin"* [71] describing the ice jam flooding vulnerabilities in the Grand River watershed.
- ✓ GRCA will work with the municipality to investigate means to reduce the risk of ice jam flooding, at the request of the municipality.
- ✓ GRCA will consider implementing a water level gauge in the Town of Cayuga to better detect and document ice jam flooding.
- ✓ GRCA plans to monitor the delta at the confluence of Boyne Creek and the Grand River downstream of Grand Valley and establish thresholds to trigger dredging of the delta to reduce the potential for ice jam flooding through Grand Valley.

F. Next Steps

For innovative, best value solutions to manage water beyond 2030, Water Managers must keep local, regional and watershed-scale water planning a priority in their workplans. Population growth, agricultural production and a changing climate will continue to challenge water managers into the future. Persistence by all water managers is needed to achieve a resilient watershed that can deal with these challenges.

Steps need to be taken now to update, improve and evolve our decision support tools. For instance, improved information and tools are needed to evaluate the costs, benefits and predicted outcomes of options for future wastewater management planning for overall water quality improvement. Most of the physical upgrades to the wastewater treatment plants will be implemented by approximately 2022. Improving the performance of these plants to achieve higher quality effluent is ongoing. However, there is a need to look broader and incorporate strategies to manage both point and nonpoint sources together and allow water managers to identify the combination of options that provides the best value solutions. To accomplish this, long-term data collection and tool development is needed now to inform decision making in the future.

In addition to maintaining a commitment to evaluating all options to improve water quality, Water Managers must be innovative to ensure future water supplies for communities, economies and ecosystems. Global trends include the integration of municipal water and wastewater management systems. Wiser use through conservation and demand management should continue to be encouraged; however, municipal funding models for water infrastructure will likely require updating. Further, reuse of water/wastewater within municipalities and industries must be investigated and uses that could be satisfied by water reuse identified. Policies and best practices need to be developed to support a wider adoption of reuse approaches.

Given the importance of groundwater within the watershed, water managers must also move toward managing surface and ground water as a single, integrated resource. Consequently, our knowledge of groundwater - surface water interactions must continue to improve with local (e.g. municipal), regional and watershed scale studies.

With a goal to achieving a healthy river system that is resilient, the Project Team recommends that the Water Managers Working Group maintain the following elements as part of an ongoing workplan.

Action:

- ✓ Water Managers Working group members will continue to share updates on recent water management activities which can assist with aligning workplans and priorities
- ✓ Water Managers Working Group will reinforce the urgency of implementing actions in D.13, D.14, and D.15 as the foundation for making future best value solution decisions
- ✓ Water Managers' Working Group will continue to promote the integration of data/information through web-based tools, and common data management protocols to maximize benefits across programs, studies and projects.
- ✓ Water Managers Working Group will encourage studies to evaluate the effectiveness of best management practices in priority nonpoint source subwatersheds
- ✓ Water Managers' Working Group will sponsor a study to evaluate the economics of implementing wastewater treatment plant upgrades versus additional rural nonpoint source management strategies to identify best value solutions
- ✓ Water Managers' Working Group will investigate the feasibility of nutrient recovery technologies for watershed wastewater treatment plants.
- ✓ Water Managers Working Group will investigate the feasibility for producer-municipal partnerships for jointly run manure/municipal organic waste (source separated organics, septage) biogas technology for nutrient management and energy production.
- ✓ Water Managers Working Group will continue to discuss climate change and support watershed scale studies to inform future reservoir and river management.
- ✓ Water Managers Working Group will continue to discuss tile drainage to determine best management practices to reduce their influence on water quantity and quality
- ✓ Water Mangers Working Group will explore the feasibility for integrating water and wastewater systems to encourage reuse or repurposing wastewater.

The Water Managers Working Group is a community of practice for managing water in the Grand River watershed. The success of the Water Management Plan will be in maintaining the process of sharing information and experiences among members which helps to elicit action toward achieving the goals of the Plan. It also fosters continuous improvement.

8 Reporting on the Integrated Action Plan

Reporting on both the implementation of actions (output) and resource conditions (outcomes) are required to track the success of the Integrated Action Plan. The following outlines the monitoring and reporting components for the Plan over the next 10 years.

8.1 Implementation – Reporting on Actions

Reporting on the actions that the Plan partners have taken to ensure water supplies, improve water quality, reduce flood damages and build resiliency to deal with climate change is a fundamental mechanism to monitor the success of the plan. The actions included in the plan are not recommendations but are activities that are in progress, planned or committed to by Plan partners. In order to report on progress the progress of the Plan and evaluate the success of implementation, data and information should be gathered on a regular basis, compiled and reported on in annual implementation reports.

Each Plan partner will provide regular updates to the Water Managers Working Group on the progress of their actions and any additional activities that have since been started (IAP A2). Actions can include the progress of projects underway to upgrade wastewater treatment plants; the status of water supply master plans and conservation efforts; and the number of rural water quality program projects completed in priority subwatersheds. GRCA will assist the Water Managers Working Group to compile and assemble an annual progress report on the implementation of actions by all Partners, starting in 2015.

8.2 Resource Condition – Reporting on Milestones (Interim Targets)

Although a target is a quantitative measure of a resource condition that will cause the broad water objectives to be met (i.e. healthy aquatic ecosystem), a ***milestone***, or interim target, refers to a quantitative description of the expected or anticipated water quality conditions that will be observed in the future as a result of the implementation of management actions within a given timeframe. Reporting on the *resource condition milestones* is a mechanism to gauge the progress of the integrated action plan to achieve the stated goals of the plan – to ensure water supplies, improve water quality, reduce flood damages and build resiliency to deal with climate change. A review and rationalization of the collective monitoring undertaken by Plan partners is required to determine whether there is sufficient data and information to report on the stated milestones (IAP D15). The GRCA will assist the Water Managers Working Group to assemble a technical watershed report on the progress toward achieving the resource condition milestones and targets every five years (IAP A2).

Water quality milestones are considered to be the water quality that is reasonably achievable, balancing the needs of the aquatic ecosystem and local communities taking into consideration sustainable economic development, population growth, efficient use of public resources, etc. They have been considered for indicators that are expected to change in response to management actions in the *Plan*. Milestones include dissolved oxygen, un-ionized ammonia, nitrate, phosphorus and flow.

The approach to identify milestones for issue-specific indicators related to river eutrophication, nitrogen toxicity and algal blooms in reservoirs and along the nearshore of Lake Erie is described in the technical memorandum, *Development of Water Quality Milestones for the Water Management Plan*[77]. The milestones are based largely on water quality modeling[78] that describes how water quality is expected to improve as a result of point source management actions. Further work is needed to develop approaches to evaluate nonpoint source management actions and develop associated milestones to measure the effectiveness of these actions (IAP D7; D15).

Table 8-1 summarizes the water quality milestones that have been developed for specific reaches of the river and it is expected that these milestones will be reached within the timeframe associated with management actions in the Plan such as wastewater treatment plant upgrades. A summary of the operational targets for river flows is in Table 8-2.

Milestones could not be identified for winter nitrate and springtime phosphorus loads at this time. Most of the nitrate and phosphorus loads appear to be coming from nonpoint sources in subwatersheds that are dominated by agricultural activity. An approach needs to be developed to evaluate the effectiveness of nonpoint source management actions that will support future decision making for best value solutions for managing nutrients from both point and nonpoint sources (IAP D6; D7; D15).

References:

[77] Development of Water Quality Milestones for the Water Management Plan, M. Anderson, July 2013.

[78] Assessment of Future Water Quality Conditions in the Grand and Speed Rivers, Report from the Assimilative Capacity Working Group, January 2012.

Table 8-1. Summary of milestones for water quality.

Sampling site	Acute effects of low dissolved oxygen	Chronic effects of low dissolved oxygen	Un-ionized Ammonia	Summer Total Phosphorus	Proposed Management Actions and Implementation Schedule
Grand River at Bridgeport	Daily minimum DO > 4 mg/L, 95% of time Jun 1-Sep 30	30 day average minimum DO > 4.5 mg/L, 95% of time Jun 1-Sep 30	Un-ionized ammonia concentrations < 0.016 mg-N/L	Median TP less than 0.027 mg/L and 75th percentile < 0.029 mg/L	Upgrade Elora WWTP, optimize Fergus WWTP; expect to maintain existing conditions
Grand River at Victoria Road	Daily minimum DO > 4 mg/L, 95% of time Jun 1-Sep 30	30 day average minimum DO > 4.5 mg/L, 95% of time Jun 1-Sep 30	*n/a*	*n/a*	Upgrade Elora & Waterloo WWTPs, optimize Fergus WWTP; expect to achieve milestones after 2015
Grand River at Blair	Daily minimum DO > 4 mg/L, 95% of time Jun 1-Sep 30	30 day average minimum DO > 4.5 mg/L, 95% of time Jun 1-Sep 30	Un-ionized ammonia concentrations < 0.016 mg-N/L	Median TP less than 0.035 mg/L and 75th percentile < 0.049 mg/L	Upgrade & optimize Elora, Waterloo & Kitchener WWTPs, optimize Fergus WWTP; expect to achieve milestones after 2018
Grand River at Glen Morris	Daily minimum DO > 4 mg/L, 95% of time Jun 1-Sep 30	30 day average minimum DO > 4.5 mg/L, 95% of time Jun 1-Sep 30	Un-ionized ammonia concentrations < 0.016 mg-N/L	Median TP less than 0.029 mg/L and 75th percentile < 0.046 mg/L	Upgrade & optimize Elora, Waterloo, Kitchener & Hespeler WWTPs, optimize Fergus, Preston & Galt WWTP, maintain optimized performance of Guelph WWTP; expect to achieve milestone after 2018
Brantford	Daily minimum DO > 4 mg/L, 95% of time Jun 1-Sep 30	30 day average minimum DO > 4.5 mg/L, 95% of time Jun 1-Sep 30	*n/a*	*n/a*	Upgrade & optimize Elora, Waterloo, Kitchener, Hespeler & Paris WWTPs, optimize Fergus, Preston & Galt WWTP, maintain optimized performance of Guelph WWTP; expect to achieve milestone after 2021
Speed River at Wellington Road 32	Daily minimum DO > 4 mg/L, 95% of time Jun 1-Sep 30	30 day average minimum DO > 4.5 mg/L, 95% of time Jun 1-Sep 30	Un-ionized ammonia concentrations < 0.016 mg-N/L	Median TP less than 0.036 mg/L and 75th percentile < 0.039 mg/L	Maintain optimized performance of Guelph WTP to maintain existing conditions

Table 8-2. Summary of operational targets for river flows.

Location	Operational Targets: Average daily flow exceeds threshold >95% of the time (m^3/sec)			Wastewater Assimilation: Design $7Q_{20}$ equivalent flows for wastewater treatment plants discharging to the regulated river system (m^3/sec)			Environmental Low Flow Needs: Littoral Zone Maintenance (m^3/sec)	Environmental Low Flow Needs: Longitudinal Connectivity (m^3/sec)	Notes
	Jan-Apr	May-Sep	Oct-Dec	Jan-Apr	May-Sep	Oct-Dec	May-Sep	Jan-Dec	
Grand River, Grand Valley	0.42	0.42	0.42	0.40	0.4	0.4			Leggatt gauge
Grand River Shand Dam/ Fergus	2.8	2.8	2.8	1.4	2.7	1.5			Below Shand gauge
Grand River, Elora				1.7	2.8	1.6			Below Shand plus $7Q_{20}$ from Irvine River
Grand River, Waterloo				3.2	8.4	4.9			Doon after the Region of Waterloo Municipal taking
Grand River, Doon / Kitchener	2.8	9.9	7.1	3.2	8.4	4.9	8.5	6.8	Doon after the Region of Waterloo Municipal taking
Grand River, Preston/ Galt				6.7	10.5	8.6			Galt gauge
Grand River, Paris				12.4	14.9	12.4			Brantford gauge minus the $7Q_{20}$ from Whitemans Creek
Grand River, Brantford		17		13.8	15.4	13.2	19	8.8	After City of Brantford municipal taking
Grand River, Caledonia				13.8	15.4	13.2			Brantford gauge $7Q_{20}$ for York
Grand River, Cayuga/ Dunnville				14.3	15.5	13.4			Same as Caledonia plus $7Q_{20}$ from McKenzie Creek
Speed River, Below Guelph Dam	0.57	0.57	0.57						
Speed River, Edinburgh Rd, Guelph	1.1	1.7	1.1	1.0	1.3	1.0	1.1	0.52	Below Guelph gauge (Edinburgh Rd)
Speed River, Hespeler				1.7	2.5	1.9	1.5	1.1	Speed at Cambridge gauge
Conestogo River, below Dam	2.1	2.1	2.1						
Conestogo River, St. Jacobs				2.0	2.7	1.3			St. Jacobs gauge
Canagagigue Creek, Elmira	0.3	0.3	0.3	0.2	0.3	0.3			Near Elmira gauge

9 Appendix A: Acknowledgments

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Many people have contributed their time and knowledge in the process of updating the Grand River Watershed Water Management Plan. The following is a list of contributors.

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10 Appendix B: Glossary and Acronyms

BMP – Best Management Practice

Best Solutions or Best Value Solutions – a suite of structural and non-structural management options that address driving issues in the watershed, make effective and efficient use of existing water infrastructure, incorporate cutting-edge technologies and staff training to optimize efficiencies, and consider 'soft' approaches like water demand management to reduce water use and consumption and avoid unnecessary capital expenses.

Broad Water Objective: *a qualitative description of a desired state or system condition in the Grand River watershed that meets the current uses, needs and values of ecosystems, communities, and economies.*

Comprehensive Technical Assistance (CTA) – means a component of the Composite Correction Program that involved an independent, external facilitator working with the wastewater operators and management to identify and address performance limiting factors that prevent the WWTP from achieving the optimized effluent quality target without substantial capital investment.

Composite Correction Program (CPP) – means a systematic approach to identifying and eliminating the factors that limit waste water treatment plant performance. Its major benefit is that it optimizes the capability of existing facilities to perform better and or treat more wastewater

DEM – Digital Elevation Model

DSS – Decision Support System

EC – Environment Canada

Eutrophic: Is a term used to describe a high level of biological productivity in a water body, usually as a result of high levels of nutrients such as nitrogen and phosphorus that promote the excessive growth of aquatic plants and algae.

GRCA – Grand River Conservation Authority

GRSM – **Grand River Simulation Model -** a dynamic, one-dimensional water quality simulation model that enables users to study the impacts of alternative water management strategies on nutrients and dissolved oxygen concentrations in a river.

Implementers – Key decision makers working for watershed agencies responsible for managing water. E.g. senior municipal water services staff, senior government agency staff,

Indicator: is a variable, typically measurable, that reflects a quantitative or qualitative characteristic; that is important for making judgments about resource conditions; and relates back to the Broad Water Objectives.

Mesotrophic Is a term used to describe a moderate level of biological productivity in a water body, usually as a result of the presence of a moderate amount of nutrients such as nitrogen and phosphorus that enable the growth of aquatic plants, usually not at levels considered 'nuisance'.

Milestone (Interim Target): a quantitative description of a system condition that is expected to be achieved as a result of implementing the specific actions set out in the Water Management Plan. A milestone has a specific timeline, against which achievement is measured and represents a step toward achieving the ***Target***.

OMAFRA – Ontario Ministry of Agriculture, Food and Rural Affairs

OMNRF – Ontario Ministry of Natural Resources and Forestry

OMOECC – Ontario Ministry of Environment and Climate Change

Resiliency is the long-term capacity of a natural system, or watershed, to deal with change **–** either gradual or sudden, such as a large storm event, and continue to function as expected. Increasing the resiliency of the watershed is to implement practices or (green) infrastructure, to maintain its ability to function as expected.

Target: a quantitative description of a system condition that will cause the Broad Water Objectives to be met. They are science-based and reference the ecological requirements of aquatic species.

SWM – Stormwater Management

SWOOP – South-western Ontario Ortho-imagery Project

Threshold: a level beyond which a system undergoes significant change.

WMP – Water Management Plan

WWTP – Wastewater Treatment Plant

11 Appendix C: Working Groups

The following lists a number of working groups either formed for specific tasks identified by the Water Management Plan or engaged to provide specific input.

Objectives Working Group

Group members were tasked with the development of a set of broad water objectives that express the aspirations for resource conditions meeting the range of uses, needs and values of water in the watershed. The group considered how water supports biodiversity, ecosystem integrity, and hydrologic function of the watershed, as well as the role of the river system in supporting water supply, river services, culture, recreation and tourism.

Organizations Represented: Grand River Conservation Authority, Ontario Ministry of Environment and Climate Change, Ontario Ministry of Natural Resources and Forestry, Ontario Ministry of Agriculture, Food and Rural Affairs, Environment Canada, Six Nations of the Grand River.

Lake Erie-Grand River Working Group

With a focus on the Lake Effect Zone that connects the Grand River and Lake Erie, the group developed a framework to identify indicators for the water quality conditions that will support healthy aquatic ecosystems.

Organizations Represented: Grand River Conservation Authority, Ontario Ministry of Natural Resources, Ontario Ministry of Environment and Climate Change, Ontario Ministry of Agriculture, Food and Rural Affairs, Environment Canada.

Water Quality Working Group

The Water Quality Working Group included members with a broad range of expertise and perspective, including wastewater and agricultural nutrient management and fisheries ecology and management. Reflecting on existing management directives, current science and knowledge of conditions in the Grand River system, the group produced a set of recommended targets for water quality conditions that meet the broad water objectives for healthy aquatic ecosystems. In addition, the group provided a synthesis of current state of science and knowledge about the relative importance of nutrient and sediment sources in the Grand River watershed.

Organizations Represented: Grand River Conservation Authority, Region of Waterloo, Ontario Ministry of Natural Resources, Ontario Ministry of Environment and Climate Change, Ontario Ministry of Agriculture, Food and Rural Affairs, Environment Canada, Agriculture and Agri-food Canada and City of Brantford.

Water Supply and Demand Management Working Group

The majority of the group's efforts centered on discussions with municipal water supply managers from across the watershed with water resources staff from the Grand River Conservation Authority (GRCA) and the Ministry of Environment and Climate Change. These discussions established the Terms of Reference for the development of a demand management framework within which to identify best management practices in the creation of individual municipal demand management strategies to be assembled in the Water Management Plan. Input on the status of municipal water demand and the identification of best practices that could be shared across the watershed was solicited at two workshops facilitated by LURA Consulting.

With respect to non-municipal water demand management, the GRCA consulted with the Grand River Low Water Response Team to solicit input on non-municipal water use. The Low Water Response Team, which also included municipal and provincial representatives, consult regularly during periods of summer low flow to identify the water conservation activities in their sector that can help reduce water use conflicts.

Organizations Represented: Grand River Conservation Authority, Region of Waterloo, City of Brantford, City of Guelph, County of Brant, Guelph/Eramosa Township, Bridgewater Research

Low Water Response Team

The Grand River Water Response Team (WRT) is established to coordinate local short-term activities in response to low water conditions, to balance efficient use, protection of the resource and equity among users. The Grand River WRT is responsible for (1) active promotion of voluntary local response under Level I and II low water conditions, and (2) making recommendation for water restrictions and water allocation to the Ontario Resource Directors Committee under Level II and III low water conditions.

The WRT membership consists of local water users and local and provincial water managers. The standing Water Managers Working Group will form the WRT base membership, and members representing major user sectors will be added. Membership will ideally reflect a balance among the sectors within the watershed. The WRT Chair and Secretary will be elected from and by the membership.

E-flows Working Group

Comprised of local experts in the fields of hydrology/hydraulics, water resources engineering, biology/ecology of freshwater systems, geomorphology and water quality the E-flows Working Group established e-flows for the Grand River watershed that support healthy natural aquatic ecosystems.

Organizations Represented: Grand River Conservation Authority, University of Guelph – School of Engineering, Trout Unlimited Canada, Parish Geomorphic Ltd.

Hydrology-Groundwater Working Group

The ad-hoc working group brought together key local experts in geology, hydrogeology and hydrology to discuss specific topics, including groundwater-surface water interactions at the broader scale. A specific meeting was held to discuss the groundwater-surface water interactions in the reach of the Grand River between Cambridge and Paris. Future meetings will be held to discuss components of the Water Management Plan such as the protection of aquitards and the link between local groundwater recharge and discharge.

Organizations Represented: Ontario Geological Survey, Universities of Waterloo and Guelph, Trout Unlimited, Region of Waterloo, City of Guelph, County of Brant, Ministry of the Environment, Matrix Solutions, Waterloo Numerical Modelling Corp., Blackport Hydrogeology, Ontario Ministry of Agriculture, Food and Rural Affairs, Toronto Region Conservation Authority, Oak Ridges Moraine Coalition, and Grand River Conservation Authority.

Stormwater Managers' Working Group

The Stormwater Management Working Group developed a set of best practices to reduce loading from urban non-point sources of pollution to the Grand River. The group also assisted with the development and peer review of protocols for stormwater facility and river system monitoring to support further characterization and quantification of loadings from urban nonpoint sources of pollution to the Grand River.

Organizations Represented: Grand River Conservation Authority, City of Waterloo, City of Kitchener, County of Brant, City of Cambridge, City of Brantford, Township of Centre Wellington, RAIN Program, Reep Green Solutions

Assimilative Capacity Working Group

The purpose of the Assimilative Capacity Working Group is to provide input into the development of future scenarios to be run through the Grand River Simulation Model to evaluate sensitivity of the model to changes in flow and temperature and assess potential impact of population growth, planned upgrades, optimization, and NPS reduction.

Organizations Represented: Grand River Conservation Authority, Region of Waterloo, City of Guelph, County of Brant, City of Brantford, Township of Centre Wellington, Ontario Ministry of Environment and Climate Change.

Grand River Fisheries Management Plan Implementation Committee

The Grand River Fisheries Management Plan Implementation Committee formed in 1998 and has since worked to prioritize and complete high priority fisheries management projects including large cover placement for fish habitat, improvements to the Dunnville fishway and the creation of the Grand River Tailwater Fishery.

The implementation committee was engaged through the development of indicators and targets for the Water Management Plan. They provided a key role in identifying valued aquatic species in the watershed.

Heritage Working Group

The Heritage Working Group was formed in 1995 to help increase community involvement and commitment to the celebration and management of human heritage resources in the Grand River watershed which was declared a Canadian Heritage River in 1994. Membership of the Heritage Working Group is drawn from all areas of the Grand River watershed and includes representation from government agencies, universities, heritage groups, national historic sites, museums, the Grand River Conservation Authority and interested individuals.

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12 Appendix D: Science Advisory Committee

Dr. Isobel Heathcote is a retired professor of Environmental Engineering and Environmental Sciences at the University of Guelph, where she was also Dean of Graduate Studies from 1999 to 2008.

Relocated now to Muskoka, she is currently President of Wyndham Research Inc., a consulting company specializing in water resources policy, environmental management, and watershed restoration.

Isobel has served on the boards of directors for a number of non-profit organizations, including the Canadian Environmental Law Association, the Canadian Institute for Environmental Law and Policy, and the Canadian Centre for Pollution Prevention. She has also served on many science advisory committees, including the (Canada-US) International Joint Commission's Science Advisory Board (which she chaired from 2001 to 2006). Her volunteer experience includes work with the Girl Guides of Canada; Action Read, Guelph (adult literacy tutoring); and the Muskoka Watershed Council. She holds a B.Sc. from the University of Toronto and an M.S. and Ph.D. from Yale University.

Dr. Rob de Loë holds the University Research Chair in Water Policy and Governance at the University of Waterloo, and is Director of the multi-university Water Policy and Group (www.wpgg.ca). Previously, he held the Canada Research Chair in Water Management at the University of Guelph.

During the past two decades, Rob has written extensively about water security and related concerns such as source water protection, water allocation and climate change adaptation. His advice on water policy and governance concerns is widely sought by government and non-government organizations. He is a frequent speaker about water to audiences that include school children, the general public, and leaders in business and government.

In 2008, Rob was named Chair of the Advisory Panel for the Royal Bank of Canada's Blue Water project, a $50 million, 10-year charitable grant program to support fresh water conservation, protection and accessibility. In 2010, in recognition of his contributions to graduate education, he was awarded the Award of Excellence in Graduate Supervision at the University of Waterloo.

Dr. David Rudolph is a Professor in the Department of Earth and Environmental Sciences at the University of Waterloo specializing in physical hydrogeology and groundwater protection and management. He has over 25 years of experience as a practitioner and academic in the field of physical hydrogeology. His specific areas of research activity include field investigation and numerical modeling related to regional groundwater flow, groundwater-surface water interaction and contaminant transport with a special interest in fractured sediment and unsaturated porous media.

David has worked extensively in the development and application of field data collection techniques for application to groundwater resource management problems and unsaturated zone flow and transport investigations. He has been involved in the investigation of groundwater seepage and subsurface contaminant mobility from oil sands tailings facilities over the last eight years. He also participates with municipal authorities both nationally and internationally in the development of groundwater protection and management strategies. David is currently a member of the Peer Review Committee for the Grand River water budget studies under the Source Protection Program.

Dr. Mark Servos is a Professor of Biology at the University of Waterloo and holds a Canada Research Chair in Water Quality Protection. Mark specializes in the broad areas of ecotoxicology and integrated water resources management. Current research activities are evaluating the environmental exposure and effects of emerging contaminants such as pharmaceuticals and personal care products in the environment. The development and application of new approaches for risk assessment and risk management of priority substances and effluents, including municipal and industrial contributions, are an area of ongoing interest.

In addition to evaluating urban-based impacts on water quality, Dr. Servos is interested in the evaluation and development of best management practices for controlling pollution from intensive agricultural practices. From 2003-2011, Mark was Scientific Director of the Canadian Water Network (CWN), a national Network of Centres of Excellence. In this role, he led the development of an innovation network focused on providing clean, safe water across Canada and internationally. Mark is the lead Principle Investigator for the Grand River Watershed Consortium research project sponsored by the Canadian Water Network.

Dr. Hugh Whiteley is an adjunct Professor of Water Resources Engineering at the University of Guelph. His areas of expertise include investigation and modeling of the hydrological processes that determine watershed water balance, govern generation of streamflow, and control the transport of pollutants. These processes include evapotranspiration, snowmelt, infiltration, groundwater recharge and discharge, and streamflow routing. In addition he has expert knowledge and experience in issues of watershed governance and development of water management protocols for stormwater in both rural and urban settings. Hugh is currently a member of the Peer Review Committee for the Grand River water budget studies under the Source Protection Program.

13 Appendix E: Technical Reports

Broad Water Objectives for the Grand River Watershed, Report from the Objectives Working Group, April 2012.

This report describes the process through which Water Management Plan partners compiled the implicitly and explicitly stated ***broad water objectives*** for the Grand River watershed. *Broad water objectives are qualitative descriptions of a desired state or system condition in the Grand River watershed that meets the current uses, needs and values of ecosystems, communities and economies.* In developing the *broad water objectives*, key water *uses*, ecological *needs* and social and cultural *values* of water across the watershed were identified and compiled from various participatory planning processes including municipal Official Plans, The Grand Strategy for the Grand River as a Canadian heritage River, Grand River Watershed Fisheries Management Plan, Lake Erie Lake-wide Management Plan and Species at Risk Recovery Strategies. Water Management Plan partners and Grand River Conservation Authority staff also provided direct input. Twenty-three draft *broad water objectives* were developed and grouped under five themes: a healthy, resilient natural system; community services; a strong economy; culture, recreation and tourism; and river services. This report also outlines the approach through which various watershed stakeholders were consulted to ensure that the *broad water objectives* were complete and reflective of the goals of the Water Management Plan. The development of the *broad water objectives* was a fundamental process with which to build a common understanding and collective approach to water management in the Grand River watershed.

Available online at http://www.grandriver.ca/waterplan/Report_WaterObjectives_2012_V2.pdf

Water Quality in the Grand River Watershed: Current Conditions & Trends (2003-2008). H.A. Loomer and S.E. Cooke, Grand River Conservation Authority, October 2011.

This report summarizes the general chemical and physical characteristics of water quality in the six major subbasins of the Grand River watershed. Data are from the 37 long-term water quality monitoring sites that are sampled in partnership with the Ministry of the Environment, from 2003 to 2008, and the Grand River Conservation Authority's continuous water quality stations. Highlighted watershed water quality issues include nutrients (phosphorus and nitrogen), chloride, suspended sediments, temperature, and dissolved oxygen levels. In addition, spatial longitudinal trends, for example evaluating how water quality changes from the head waters to the river mouth where it discharges to Lake Erie are summarized. Conditions in the river are compared to existing guidelines and thresholds such as the Provincial Water Quality Objectives, the federal environmental quality guidelines or established basin-specific benchmarks. Investigation into the relationship between variables (e.g., total suspended sediment and total phosphorus; total phosphorus and flow) is also described. A number of recommendations were made with respect to evaluating the state of water quality in the watershed including, among others, the need for biological monitoring that best integrates with the chemical and physical monitoring programs that best describes the health of the Grand River system; a more detailed analysis of the relationships between watershed stressors (land use/cover) and water quality; and the need for increased sampling frequency to characterize the inherent variability of chemical and physical parameters across seasons.

Available online at http://www.grandriver.ca/water/2011_WaterQualityReport.pdf

A Framework for Identifying Indicators of Water Resource Conditions: Support of Ecological Health by Water Resources in the Grand River-Lake Erie Interface, Report from the Grand River-Lake Erie Working Group, July 2012.

Water resource conditions are evaluated quantitatively using indicators while desired resource conditions are quantified by targets. This report describes a framework that was developed by the Grand River-Lake Erie working group to identify water resource condition indicators that can be used to describe conditions supportive of healthy aquatic ecosystems. Initial focus was on the Grand River – Lake Erie interface, or Lake Effect Zone and the framework reflected on the water resource conditions needed by aquatic species which were ecologically important; underperforming and had the potential for rehabilitation or reintroduction; or were highlighted as important by the scientific literature or recent agency initiatives. The aquatic species identified in this framework were used as a tool to help identify some of the critical water quality needs of the aquatic community and not to function as indicators themselves. Parameters that convey information specific to the processes by which water quality directly or indirectly affects the health of aquatic communities were chosen as indicators and include phosphorus; turbidity (or total suspended sediments/solids); temperature; dissolved oxygen; flow regime; and macrophyte community. These indicators quantify some of the most critical resource conditions required by the aquatic communities in the Lake Effect Zone. Information compiled as part of the development of the framework for indicator identification points to the coastal wetlands of the Grand River as a sensitive and ecologically important area.

Available online at

http://www.grandriver.ca/waterplan/WaterResourceIndicatorFramework_V2.pdf

Water Quality Targets to Support Healthy and Resilient Aquatic Ecosystems in the Grand River Watershed, Report from the Water Quality Working Group, February 2013

This report details the targets for the water resource condition indicators identified in a companion report "*A Framework for Identifying Indicators of Water Resource Conditions: Support of Ecological Health by Water Resources in the Grand River-Lake Erie Interface"*. A target was defined as a quantitative description of a water resource or system condition that will cause the broad water objectives to be met. Existing guidance and supporting scientific information from other jurisdictions (e.g., other provinces, Canadian or United States, etc.) was synthesized and evaluated to identify a quantitative measure, or target appropriate for the Grand River watershed for the following indicators: dissolved oxygen, suspended particulate matter (turbidity, suspended solids), toxic forms of nitrogen (nitrate and ammonia), temperature, and nutrients (i.e., biological productivity). Some of the targets take the form of a single threshold value separating a desired range of conditions from an undesirable range while other targets include multiple criteria, to account for a broader range of conditions. Where it was not feasible or information was lacking to specify numeric criteria, a narrative description of indicator conditions was given. The targets recommended in this report complement the existing set of water management tools in Ontario; they are not intended to replace existing objectives (e.g., Provincial Water Quality Objectives) or policies, etc. Work will continue into the future to identify targets for other resource condition indicators (e.g., macrophyte community, flow, chloride). Targets will be used to gauge whether water resource conditions are able to support the desired features of healthy and resilient aquatic ecosystems as stated in the broad water objectives now and into the future.

Available online at http://www.grandriver.ca/waterplan/waterQualityTargetsFeb192013.pdf

Environmental Flow Requirements in the Grand River Watershed, Report from the E-Flows Working Group, Grand River Conservation Authority, August 2013.

Environmental flows (e-flows) describe the quantity, quality and timing of flows required to sustain healthy river ecosystems, as well as the human livelihoods that rely on these ecosystems. This report summarizes the findings of past work to identify environmental flow requirements in the Grand River watershed and was prepared by the E-Flows Working Group. The report establishes high and low flow thresholds for maintaining healthy aquatic ecosystems in the Grand and Speed Rivers. The e-flows regime includes eight e-flows thresholds in three categories: channel maintenance and formation; nutrient management or biological functions; and low flow considerations. Flow values were established for each threshold in four reaches in the Grand and Speed Rivers. This report examines their historic occurrences and whether these occurrences have been sufficient to perform environmental flow functions. In addition, low flow thresholds on Whitemans Creek and the Eramosa River, both unregulated watercourses, were determined for the protection of longitudinal connectivity flows for coldwater fisheries. Findings show that, in general, the environmental low flow needs are less than the flow targets established for reservoir operations, but there is a challenge to meet e-flow requirements during extremely dry periods. In Whitemans Creek, findings suggest that water taking in the summer months is not sustainable from an ecological perspective and a potential for conflict and constraint exists. The higher environmental maintenance flow needs (e.g., flushing flows) are poorly to moderately met. Further investigation and field verification of the e-flows thresholds are recommended. In addition, the feasibility of operating the reservoirs to satisfy e-flow needs more consistently without sacrificing their reliability to meet low flow requirements or endangering recreational users should be explored.

Available online at www.grandriver.ca/wmp

Grand River, Long Point Region, Catfish Creek and Kettle Creek Watershed Areas Population Forecasts. GSP Group Inc., January 2010.

This report provides an updated consolidation of existing population and employment forecasts for the municipalities in the jurisdictions of the Lake Erie Source Protection Region (i.e., the Grand River Conservation Authority, the Long Point Region Conservation Authority, the Catfish Creek Conservation Authority and the Kettle Creek Conservation Authority). The forecasts represent the available information as of August 2009, and the methodologies for calculating population forecasts are described in the report. In addition to consolidating the available forecasts, updated population and employment growth trends have been extrapolated to provide estimates of population at 5-year intervals to 2056. This report identifies on-going growth management strategies, population and employment forecast exercises, Official Plan reviews and similar studies that should be monitored by the Conservation Authorities as these studies may update the information consolidated by this project. It is anticipated that the work consolidated through this exercise will be continually up-dated as new population forecasts are developed through planning studies undertaken by the various levels of government. Information gaps are also identified in the report.

Available online at http://www.sourcewater.ca/swp_watersheds_Grand/PopReport_Jan2010.pdf

Climate Change Scenario Modeling in the Grand River Watershed. S. Shifflett, Grand River Conservation Authority, August 2014.

The Climate Change Modeling Project was initiated in 2011 under both the Water Budget Program and as part of the Water Management Plan Update. The study used existing watershed models, including hydrologic, groundwater and reservoir models, and future climate data sets to study possible effects of climate change on water availability and movement in the Grand River watershed. Most of the scenarios investigated were provided by the Ministry of Natural Resources and Forestry and were produced by applying a change factor to past observed climate data. Change factors were based on monthly average change of the parameter from Global Circulation Models running emission scenarios from the Intergovernmental Panel on Climate Change Fourth Assessment Report. Using this method limits analysis to average monthly changes in parameters and results cannot be used to describe changes to intensity or frequency of storm events. Analysis in this study includes: annual and seasonal changes to temperature, precipitation, runoff, recharge, evapotranspiration, stream flow and key watershed processes; annual changes to groundwater discharge; and effects to reservoir operations. Additional work is planned on transient groundwater modeling to look at seasonal changes in groundwater discharge.

Available online at **www.grandriver.ca/wmp**

Water Use Inventory Report for the Grand River Watershed. Amanda Wong, Grand River Conservation Authority, February 2011.

This report is a summary of the water demand in the Grand River watershed, and describes the methodology used for conducting a comprehensive assessment of water takings. Water use is categorized into subgroups of: municipal water supply systems, rural domestic water demand, agricultural water uses and permitted water takings. Water demand estimates for this report have vastly improved since the previous report published in 2005. The inclusion of actual water taking records from over half of the almost 1200 sources of water (80% are sourced in groundwater), were submitted by permitted water takers. The remaining uses were estimated using the best available information. The total assessment of all water takings for the Grand River watershed amounts to 152 million m^3/year. The municipal demand, comprised entirely from actual reports, accounts for approximately 60% of the total water use and is ten times greater than the next highest water using sector. Finally, this report addresses the concept of consumptive use ratios. The relative influence of each type of water taking as well as the source of supply, factors into the consumptive nature of the taking. An assessment of the consumptive nature of each use is provided in brief.

Available online at http://www.grandriver.ca/Water/2011_GRCA_WaterUse.pdf

Tier 2 Water Quantity Stress Assessment Report: Grand River Watershed, AquaResources Inc., December 2009.

In addition to the development of a subwatershed-based water budget, the *Clean Water Act, 2006* requires the completion of a Water Quantity Stress Assessment to estimate potential subwatershed stress. This assessment estimates a Percent Water Demand for each subwatershed in the Grand River watershed by calculating the ratio of estimated water demands to available surface and groundwater supply and then assigns a level of stress to the watershed based on the Percent Water Demand. The Stress Assessment is a two-tiered process whereby subwatershed areas identified to have higher water demands are studied in greater detail than those subwatersheds that have lower water demand. The assessment areas classified by this Subwatershed Stress Assessment may be under a Moderate or a Significant potential for stress. This classification is important for municipalities having water supplies located in those areas, because those municipalities may be required to complete a Tier 3 Water Quantity Risk Assessment. The methodology followed in this report is consistent with the Technical Rules prepared by the Ministry of Environment and Climate Change for the preparation of Assessment Reports under the *Clean Water Act, 2006.*

Available online at http://www.sourcewater.ca

Integrated Water Budget Report – Grand River Watershed, AquaResource Inc., June 2009.

The population in the Grand River watershed is expected to grow by 300,000 people in the next 20 years, and with this growth, there will be increased demands on the water resources of the watershed. Recognizing the hydrologic stresses that current and future water demands place on the watershed, the Grand River Conservation Authority (GRCA) initiated the Water Budget Project in the mid 90's to quantify the significant components of the hydrologic cycle, including anthropogenic water takings. This document summarizes the current status and application of a water budget framework for the Grand River watershed. This framework is based on the integration of a continuous streamflow-generation model (GAWSER) and a three-dimensional steady-state groundwater-flow model (FEFLOW) to represent the conceptual hydrology and hydrogeology conditions at a scale appropriate for subwatershed assessment. With these models in place, the GRCA is able to better characterize hydrological processes throughout the watershed and quantify key water budget parameters. Historically, hydrologic investigations focused on either the surface water or the groundwater perspective, with limited recognition of the inter-connectedness of the systems. In this report, modelling tools that represent both the surface water system and the groundwater system were coupled to help visualize the complete hydrologic system. Groundwater recharge values predicted by the regional continuous streamflow-generation model were used as input for the three-dimensional groundwater flow model. The groundwater flow model was then calibrated to ensure results of both models were consistent with observed conditions and consistent with one another. This resulted in a streamflow-generation model and groundwater flow model that are consistent with one another; the coupling also allowed a regional understanding of the complete hydrologic cycle to be developed.

Available online at http://www.sourcewater.ca

Status of Future Municipal Water Supplies. DRAFT. S. Shifflet, J. Etienne, Grand River Conservation Authority, July 2013.

One of the goals of the integrated Grand River Water Management Plan is to ensure sustainable water supplies for communities and ecosystems. This report outlines the status of future municipal water supplies, and exists as a technical brief to support the recommendations/actions of the Water Management Plan. There are forty municipal and one First Nations drinking water systems in the Grand River watershed servicing a total of approximately 800,000 people. Water sources include groundwater wells, artificial recharge systems, river intakes, Great Lakes intakes and combinations of these sources. There is high population growth projected for the Grand River watershed, which will put strain on some of the current water sources over the next 20 to 40 years. This report provides an update to the 2011 summary of various municipal water systems and an analysis of whether future water supply needs are identified, sourced and secured. Projected population growth rates and current water usage rates were used to determine future water use unless additional municipal information was available. Plans for Municipal Water Systems with future water supplies not sourced and secured, or where additional information is needed, are discussed.

Considerations for "Securing" current and planned sources of municipal water supply, Discussion Paper from Water Managers Working Group, June 2013.

This Discussion Paper was compiled as one of the fundamental deliverables of Goal # 3 of the WMP Project Charter, which is to "secure water supplies". This paper provides an assessment of the extent to which future municipal water supply needs are identified, sourced and secured, and defines the term "secured" from both a physical and regulatory perspective. Linkages between municipal water supply planning cycles and provincial policies/approvals influencing water supply planning are discussed. Also considered are characteristics of a regulatory environment that supports security of municipal water supplies, and the challenges and opportunities for achieving that security. Through this paper, the Water Manager's Working Group provide several recommendations for ultimately increasing the security of existing and planned municipal water supplies, including: enhanced working relationships between municipalities and the Ministry of the Environment, improved approval processes for Permits To Take Water, and the implementation of the Grand River Source Protection Plan.

Available online at:

http://www.grandriver.ca/waterplan/June2013_Securing_Municipal_Water_Supplies.pdf

Assessment of Future Water Quality Conditions in the Grand and Speed Rivers, Report from the Assimilative Capacity Working Group, January 2012.

This report details the analysis of future river water quality conditions using a 20 year planning horizon (2031). The Grand River Simulation Model, a dynamic nutrient and dissolved oxygen river water quality model, was used to evaluate four scenarios that included wastewater treatment plant upgrades in current municipal wastewater master plans, wastewater treatment plant optimized performance targets and rural / agricultural and urban nonpoint source load reductions. The model study area includes the Grand River from the Shand Dam to Ohsweken and the Speed River from the Guelph Dam to the confluence with the Grand River. The model includes discharges from 10 of the 30 wastewater treatment plants in the watershed which service approximately 92% of the watershed's population. Within the 2031 planning horizon, planned wastewater treatment plant upgrades will significantly improve river water quality especially during the summer period during low river flows. Phosphorus levels are predicted to improve by as much as 25% in some reaches while there will be a significant reduction in the severity and frequency of low dissolved oxygen levels in the central Grand River. The optimization of wastewater treatment plants to achieve lower total phosphorus operating targets is predicted to achieve additional significant improvements in total phosphorus levels in the Grand River of up to 19%. A reduction in the rural nonpoint sources of phosphorus also show a benefit to river water quality however, work remains to identify which land management practices will best improve water quality. In contrast, nitrate levels in the Grand River will increase into the future. The magnitude of increase resulting from wastewater treatment plant upgrades is small relative to background levels from cumulative upstream sources. Urban nonpoint source impacts on the Grand and Speed Rivers are not well quantified or characterized and their influence on the physiochemical/biological processes in the large rivers is poorly understood. Further work is needed to characterize urban nonpoint sources and to understand its relationship with in-river dissolved oxygen levels. A number of recommendations were made to continually improve the in-river model and to link the in-river model to a landscape model(s) for more effective evaluation of rural/urban nonpoint sources.

Addendum to Assimilative Capacity Technical Report, M. Anderson, Grand River Conservation Authority. January 2012.

An addendum to the technical report entitled "Assessment of Future Water Quality Conditions in the Grand and Speed Rivers" includes additional scenarios to assess the sensitivity of the Grant River Simulation Model to reduced boundary flows (i.e., tributaries and reservoir discharges) and increased temperatures. Scenario 5 was based on Scenario 2 (future growth and anticipated upgrades to 2031) using low flow summer conditions and consisted of the following:

- Scenario 5a: Reduce boundary flows by 10%
- Scenario 5b: Reduce boundary flows by 25%
- Scenario 5c: Increase water temperatures by 0.5°C
- Scenario 5d: Increase water temperatures by 1.0°C

The reductions in boundary flows and increases in temperatures listed above were selected arbitrarily for the purposes assessing model sensitivity but it is important to note that additional work is being carried out to determine how climate change may impact water quality.

Reducing the boundary flow results in shallower water depths and lower channel velocity in each reach. In turn, this influences the reaeration rate of dissolved oxygen causing model predicted daily minimum dissolved oxygen concentrations to be somewhat lower and the daily maximum concentrations to be higher. A 10% reduction in boundary flow has little impact on the daily minimum dissolved oxygen levels but a 25% reduction can result in minimum dissolved oxygen levels that are up to 0.5 mg/L lower than Scenario 2.

Increasing the temperature has a number of effects on water quality as all of the kinetic processes included in GRSM are temperature sensitive and kinetic rates increase with temperature. The temperature also affects the growth rate of aquatic plants, however this relationship is not linear and increasing temperature may result in either more or less aquatic plant growth depending on the optimum temperature range for each plant species. In general, GRSM predicts that aquatic plant biomass will decrease in most reaches as water temperature increases. This behaviour is related to the fact that the respiration rate of aquatic biomass is predicted to increase more than the production rate and the net effect is that there is less biomass produced at higher water temperatures. Model results for Scenarios 5c and 5d showed that the daily minimum value is not sensitive to an increase in water temperature of 0.5 or 1.0°C. The daily maximum dissolved oxygen concentration, on the other hand, is quite sensitive and decreases in response to lower biomass densities at higher water temperatures. The lack of sensitivity of the daily minimum dissolved oxygen and aquatic plant biomass to changes in temperature should be further explored. In addition, the temperature-plant growth response algorithm currently included in GRSM should be reviewed to ensure that the model reflects the current state of the science.

Available online at http://www.grandriver.ca/waterplan/TechBrief_AssimilativeCapacity_2012.pdf

Sources of Nutrients and Sediments in the Grand River Watershed, Report from the Water Quality Working Group, December 2013.

This report details a synthesis of information in an effort to characterize nutrient and sediment sources and their relative importance in the Grand River watershed. It is focused on nutrient and sediment inputs from broadly characterized sources – point and nonpoint. Limited availability of data and information specific to the watershed prevented a full ‘accounting’ or ‘budgeting’ of nutrients and sediment from various areas and during specific times of the year; however, the weight of evidence from the collective approaches synthesized in this report provides insight into the relative importance of the sources of nutrients and sediment in the watershed. The relative importance of a source was assessed relative to its contribution to key water quality issues: the eutrophication of the river system; sedimentation and turbidity in river reaches; phosphorus loading of the reservoirs and Lake Erie; and the impairment of water uses by high nitrate concentrations. There is no single source of nutrients or sediment that prevails as being the most important in a large complex watershed. Whereas point sources of phosphorus and nitrogen such as municipal wastewater treatment plants that directly discharge nutrients to the central Grand River region are very important during summer low flows, nonpoint sources dominate annual loads to reservoirs and Lake Erie due to high contributions during high flows (e.g., spring). Important nonpoint source areas for phosphorus include the Canagagigue, Conestogo, Nith and Fairchild’s subwatersheds whereas Fairchild, McKenzie and Nith subwatersheds dominate sediment export. Nitrate source areas include the tributaries in the middle Grand (e.g., Irvine, Canagagigue) and Whitemans. A number of recommendations were made to improve the information upon which this assessment was made, including improved monitoring of nutrient and sediment from key source areas to reduce the uncertainty in load estimates and predictions in the in-river dissolved oxygen model that evaluates point and nonpoint source management scenarios. A point/nonpoint source decision support system that links landscape and in-river management scenarios would enable more strategic investments in stewardship practices as well as enable a more holistic approach to nutrient management in the watershed.

Available online at http://www.grandriver.ca/waterplan/Nutrientsources_Dec2013.pdf

An Assessment of Aquatic Habitat in the Southern Grand River, Ontario: Water Quality, Lower Trophic Levels, and Fish Communities. T. MacDougall and P. Ryan, Ministry of Natural Resources, 2012.

The lower reach of the Grand River, particularly the dynamic interface between river and lake, constitutes a unique environment which many lake and river species utilize and to which they are adapted. Major alterations to the watershed since European settlement have resulted in an ecosystem no longer able to support the full historical compliment of biota. To inform future rehabilitation work, a detailed assessment of the aquatic ecosystem downstream of the City of Brantford was conducted between 2003 and 2005. Subsequent findings, as outlined in this report, provide a comprehensive picture of the state of the southern Grand River, depicting a nutrient rich environment where a high biomass of planktonic algae occurs and benthic invertebrate and fish communities are dominated by species tolerant of organic pollution and low oxygen conditions. The purpose of the report is to assess aquatic habitat (based on water quality, lower trophic levels, and fish community), infer ecological connections where possible, help to inform rehabilitation targets, and guide future monitoring to detect change.

Available online at http://www.grandriver.ca/waterplan/MNR_SouthernGrandHabitat.pdf

Water Quality in the Lower Grand River in 2001: Data Summary prepared for the Water Quality Working Group. T. Howell, K. Chomicki, and S. Carpenter, draft June 2012.

This data report provides information collected in the lower Grand River as part of the 2001 study in support of the efforts of the Grand River Conservation Authority's Nutrient Working Group to develop water quality objectives and indicators for the lower Grand River as part of the broader update of the Grand River Water Management Plan. The 2001 study, conducted by the Great Lakes unit of the Environmental Monitoring and Reporting Branch (EMRB) involved a series of surveys of nearshore water quality in the eastern basin of Lake Erie as part of a recently initiated program of spatially detailed surveys of coastal water quality in the Great Lakes. A design feature of the study was to include data collection in the downstream reaches of tributaries discharging to study areas concurrent with nearshore surveys. The 2001 study areas included the nearshore adjacent to the mouth of the Grand River and the segment of the Grand River extending from below the Dunnville Bridge to the mouth of the river at Port Maitland).

Grand River Source Protection Area Assessment Report, Report prepared by the Lake Erie Region Source Protection Committee, August 2012.

This Assessment Report summarizes the technical studies undertaken in the Grand River Source Protection Area (watershed) to delineate areas around municipal drinking water sources that are most vulnerable to contamination and overuse. Within these vulnerable areas, historical, existing and possible future land use activities were identified that could pose a threat to municipal water sources. Technical studies include a characterization of the human and physical geography of the watershed, a water budget and water quantity stress assessment, an assessment of groundwater and surface water vulnerability, a land use activity inventory, and an evaluation of existing water quality contamination threats and issues. The results of these technical studies were used to develop policies to protect sources of municipal drinking water contained in the Grand River Source Protection Plan.

Available online at http://www.sourcewater.ca/index/document.cfm?Sec=7&Sub1=8&Sub2

Flow Reliability in Regulated Reaches of the Grand River Watershed. D. Boyd and S. Shifflett, Grand River Conservation Authority, (DRAFT) August 2012.

Knowledge of flow reliability is required along reaches of the Grand River and its tributaries to support design and management decisions. This report provides a seasonal analysis of flow reliabilities for the regulated reaches of the Grand River watershed, to support a range of disciplines that use flow reliability information to make informed decisions, carry out analysis and complete assessments. The primary operating objectives of several of the large dams in the Grand River watershed are flood damage reduction (reduction of flows during floods) and low flow augmentation (addition of flows during low flow periods); two functions with conflicting objectives and various challenges throughout fluctuating seasonal conditions. The approved reservoir operating policy resolves these conflicting objectives. The operating policy is expressed on the rule curves for each of the seven multi-purpose reservoirs and by the downstream low flow operating targets and flooding constraints, as outlined in this report. These operational low flow targets are used to guide operational decisions regarding the required discharge from the large dams to meet the established low flow targets.

Agricultural Irrigation: Forecasts for Future Water Needs. Stephanie Shifflett, Hajnal Kovacs and Amanda Wong, Grand River Conservation Authority, 2014

Agricultural water use is the highest seasonal water use in the Grand River watershed, peaking in the summer months of July through September. Annually, irrigation is estimated to be the third (3^{rd}) highest water use in the Grand River watershed, following municipal and dewatering (Wong, 2011). The current and future water needs for agricultural irrigation are being investigated as part of the Water Management Plan update to ensure that the future water needs can be sustainably met and to highlight, for future action, any areas that, from a regional perspective, have potential for conflict or water use constraint, now or in the future, as a result of the combined water demands by municipalities, the agricultural sector, the aggregate sector and other water users in the watershed. The peak use months coincide with low flow season and the potential for water use conflicts amongst agricultural irrigators or other water using sectors including the environment could be a concern. With the uncertainty of climate change affecting both the availability of water and the demand by agricultural irrigation in the watershed, a better understanding is needed to determine how much water is required. The purpose of this report is to refine water use information available about water needs for agricultural irrigation.

Livestock Water Use and Future Water Needs. DRAFT. Amanda Wong, Grand River Conservation Authority, July 2013.

Agricultural water use is the highest seasonal water use in the Grand River watershed, peaking in the summer months of July through September. These months also coincide with low flow season and the potential for water use conflicts amongst water-using sectors, including the environment, could be a concern. With the uncertainty of climate change affecting both the availability of water and the demand by agricultural irrigation in the watershed, a better understanding is needed to determine how much water is removed – or consumed – from the environment to get a more complete assessment of whether the future water needs of the agricultural sector can be sustainably met. The purpose of this report is to refine water use information available about water needs for livestock watering and general farm operations. With consultation with specialists and the forecasting group at the Ontario Ministry of Agriculture and Food and Rural Affairs (OMAFRA), and the information gathered from Statistics Canada, a more detailed estimate of livestock water needs can be completed.

Available online at http://www.grandriver.ca/waterplan/LivestockWaterNeeds.pdf

Water Quality in the Grand River: A Summary of Current Conditions (2000-2004) and Long Term Trends. S.Cooke, Grand River Conservation Authority. March 2006.

Water quality conditions for the period 2000-2004 and long term trends are summarized for the six major subbasins in the Grand River watershed: the upper, middle and lower Grand River; and the Conestogo, Speed and Nith River subbasins. Data are from long-term water quality monitoring sites that are sampled in partnership with the Ministry of the Environment, and the Grand River Conservation Authority's continuous water quality stations. The evaluation also included a limited amount of data on pesticides and trace organics; metals; bacteria and pathogens. An assessment of conditions by comparison of data to provincial objectives, federal guidelines or basin targets indicated that conditions reflect the inherent influence of the underlying geology combined with the effect of current landuse practices. There is a progressive deterioration in water quality towards the southern reaches of the watershed, due to the cumulative impact of the upstream areas. Water quality is most impaired in the central portion of the Grand River, including the major tributaries draining into this reach such as the Canagagigue Creek, Conestogo River and lower Speed River. Key issues include widespread eutrophication due to elevated phosphorus concentrations and more regional or local elevation of ammonium, nitrate, suspended sediments, and chloride; likely sources of each are identified. Spills and bypasses were highlighted as a significant source of water quality impairments, and the development of an effective response protocol was recommended. Specific recommendations were also made on how to improve sampling, monitoring and reporting to better identify issues and long term trends in water quality.

Available online at http://www.grandriver.ca/Water/2006_WaterQuality_complete.pdf

Grand River Fisheries Management Plan, Report prepared by the Grand River Fisheries Management Plan Implementation Committee, August 2005.

This document reviews the status of the fish resource within the Grand River watershed and provides direction on how this resource and the land base which affects it can be managed. The fish resource potential and limitations of the Grand River watershed can be attributed, in part, to physiographic and geomorphological features of the region. Limitations imposed by these features are that many watercourses originating in the upper and lower sections of the watershed can be characterized as having low base flow, flashy runoff, turbid water as well as warm water temperatures during the summer. Moraines found throughout the central portion of the watershed provide an excellent source of water throughout the year, and as a result base flows are maintained year round. Good water quality also exists, providing a suitable environment for coldwater species such as trout. The Fisheries Management Plan examines seven sub-basins within the Grand River watershed and categorizes the types of water (cold, mixed or warm) which are found there. The Fisheries Management Plan also summarizes the fish community objectives, issues affecting the fish resource of the watershed, management strategies and management tactics for each sub-basin.

Available online at http://www.grandriver.ca/fisheriesmanagement/fishplan_cd.pdf

***Current Status of the Broad Water Objective for Human Consumption of Fish,* Nigel Ward and Claire Holeton, Grand River Conservation Authority, May 2013.**

This report summarizes the current watershed status of toxic compounds in fish as it relates to human consumption of sport fish. Ontario Ministry of Environment and Climate Change guidelines for the consumption of sport fish have been used to assess the status of the broad water objective that strives for high water quality, such that fish consumption is not impeded by aquatic sources of contaminants in the watershed. Advisories based on elevated levels of bioaccumulative toxins are predominantly due to contamination by mercury or PCBs. Since the distribution of these contaminants is widespread and they are known to travel large distances through the atmosphere, it is unlikely they represent localized sources within the watershed. Where relatively high levels of these toxins cause more stringent restrictions, they can be linked, at least in part, to accumulation of toxins in fish through bioaccumulation due to a piscivorous diet or greater longevity. A small number of restrictions are based on high dioxin/furan concentrations. These restrictions have a localized distribution area, which includes Canagagigue Creek and the adjacent reaches of the Grand River, and are likely the result of legacy contamination at a single source. Data also suggests that additional sources of contaminants outside the watershed (e.g., in Lake Erie) may be transported into the watershed with fish that travel large distances, such as rainbow trout.

Available online at http://www.grandriver.ca/waterplan/TechBrief_FishConsumption_2013.pdf

Flood Management in the Grand River Watershed. Dwight Boyd. **Grand River Conservation Authority, draft 2014.**

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14 Appendix F: Recommendations from the 1982 Grand River Basin Study

The main investigative period of the Basin Study extended from 1977 to 1981. Its purpose was to define the water management problems confronting the Grand River basin and to develop a viable set of alternative water management plans. These plans were designed to meet the following water management objectives:

- Reduce flood damages;
- Provide adequate water supply;
- Maintain adequate water quality.

This study provided a comprehensive framework to help elected representatives, officials, and citizens resolve water management problems. The framework was flexible to accommodate changing water management priorities and needs and provided a means to evaluate new projects and other plans.

Large-scale water management problems were largely confined to the urban and industrial middle portion of the basin. Over 85% of the $980,000 average annual flood damages in the basin were experienced in Cambridge and Brantford. Water supply was a key issue in the Kitchener-Waterloo-Cambridge area. The addition of more surface and ground water to supplement existing industrial and domestic water supplies was considered imperative within the next five years. Water quality in the central portion of the Grand River between Kitchener and Glen Morris and in the Speed River downstream from Guelph was a concern where consistently low oxygen levels during the critical summer period were experienced. This condition was caused by organic waste discharges and nutrient inputs from six municipal sewage treatment plants and by upstream rural non-point sources.

While water management problems were often the most apparent in the middle portion of the basin, flooding, water shortages and water quality impairment were encountered throughout the basin in rural as well as urban areas. However, it was also recognized that pollution control measures implemented to maintain or improve the water quality within the river basin, particularly measures to reduce nutrient input, would also benefit Lake Erie.

Twenty-six different water management plans, incorporating a different mix of implementation measures were assessed. An evaluation process narrowed the alternatives down to five main plans.

1. Plan A1 proposed dyking and channelization to minimize flood damages, advanced sewage treatment to improve water quality, and induced infiltration wells and artificial recharge of aquifers using river water to augment ground water supplies.

2. Plan A4 was the same as plan A1, but, in addition, this plan preserved the option of using the Montrose reservoir site for possible future water management purposes.

3. Plan B2 included the immediate construction of the Montrose multi-purpose dam and reservoir. Also proposed were dyking and channelization to reduce flood damage, advanced sewage treatment and low flow augmentation from the reservoir for improving water quality, and infiltration wells and artificial recharge to supplement ground water

supplies. Requirements for advanced sewage treatment, when compared to plan A, were reduced or delayed.

4. Plan C1 was the same as plan A1 with respect to the water quality and water supply measures proposed. In addition, flood protection was provided through the construction of a single-purpose or dry reservoir on the Conestogo River at St. Jacobs.

5. Plan D incorporated the same flood protection and water quality measures as plan A1, but proposed that water supply be augmented by the construction of a Lake Erie pipeline.

During the initial review of these plans, lower rankings were assigned to plans C1 and D because plan C1, the St. Jacobs single-purpose reservoir option, did not give provide flood protection and plan D, the Lake Erie pipeline option, was deemed to be too expensive.

A detailed evaluation of plans A1, A4 and B2 was then carried out. Three of the four public consultation working groups, made up of citizens from different geographical areas of the basin, preferred plan A1 with minimal environmental and social impacts; the fourth group, representing the southern basin, preferred plan B2. The water managers who were charged with the day-to-day responsibility of operating major flood control, water supply and sewage treatment services preferred plan B2 because, in their view, it offered a more reliable and secure water management system.

The overall results of the evaluation incorporating the preferences of all those who participated showed that plans A1, A4 and B2 were ranked very closely.

After a detailed review of the various inputs, the Grand River Implementation Committee, the basin study's coordinating committee, identified plan A4 as the preferred plan to meet the water management needs of the basin. The recommendations and the status of their implementation are outlined in the following section.

Recommendations

A. The Recommended Plan

1. It is recommended that plan A4 and the measures described in the following recommendations be implemented.

The basin study concluded that plan A4 was cost-effective in meeting the water management objectives. It was preferred over plan B2 (the Montrose dam option) for the following reasons:

a) plan A4 was $25 million cheaper than plan B2
b) the environmental and social impacts of implementing plan A4 were deemed to be moderate and public input suggested that there would be opposition to the selection of plan B2
c) flexibility was maintained in plan A4 by preserving the option of constructing the Montrose dam should future water quality or water supply problems be experienced
d) a high degree of flood protection for urban areas was provided
e) anticipated population growth was accommodated by fully meeting projected municipal water demands and improving water quality in the central Grand River
f) implementation would result in improved water quality in the central Grand River, although it was acknowledged that the dissolved oxygen levels in this reach would not fully meet the provincial water quality objectives. While plan A4 did not provide as high a

level of water quality as plan B2, it provided a reasonable level of protection for most water uses at a substantially lower cost.

Plan A4 was the same as plan A1 with the exception of the construction of a water supply dam and reservoir at West Montrose. Preserving the West Montrose site increased the total plan costs by $4 million. The additional cost was for land acquisition and increased social impacts. However, plan A4 was preferred over plan A1, primarily because it maintained future flexibility by preserving the Montrose reservoir lands.

In the opinion of the Grand River Implementation Committee, plan A4 represented the best overall solution to basin water management problems. However, the recommendation of plan A4 did not necessarily preclude selection of all or part of another plan.

Plan A4, 'The Recommended Plan', was represented by the sum of all the implementation recommendations. The current implementation status of each recommendation contained in plan A4 is provided in the next section.

B. Recommendation for Reduction of Flood Damages

The basin study investigated both structural and non-structural methods of reducing flood damages. Structural methods include dyking, channelization, reservoirs and flood proofing. Non-structural methods include regulations, zoning and land use practices.

1. It is recommended that channelization and dyking be constructed to reduce flood damages at the major flood damage centres.

The basin study stated that channelization and dyking could reduce the average annual flood damages in New Hamburg, Cambridge, Brantford, Paris, Caledonia, and Dunnville by 91 percent compared to a 54-56 percent reduction by a reservoir at West Montose, the most efficient of the eight reservoirs investigated. Channelization and dyking was considered to be the most cost-effective structural method for reducing flood damages and it was recommended that each project be completed as soon as possible.

Implementation Status = Partially Implemented. Dyking and channelization were completed in Cambridge (Galt) and Brantford in 1995, partially completed in Caledonia (Haldimand County) in 1987-1988 and in Paris during the mid-80s. A dyke demonstration project was completed in Dunnville in the early 1990s, but the dyking system recommended in the Basin Study was not completed. The dyking and channelization projects recommended for Cambridge (Preston) and New Hamburg have not been completed.

Table 1 summarizes the recommended flood mitigation works. The average annual flood damages are a measure of the flood damage potential that existed in 1982. The implementation of mitigation works was focused on communities with the largest flood damage potential (**Table 2**). While flood damage estimates have not been updated, it is expected that revised estimates would improve the cost-benefit ratio associated with flood mitigation works in the communities where channelization and dyking have not been completed. However, this work is required in order to analyse the benefits and costs of new mitigation works as funding opportunities arise.

Between 1982 and 1995, a cost-sharing formula was used to fund mitigation works; 50 per cent provincial, 40 per cent municipal, and 10 per cent conservation authority general levy. Provincial funding ceased in 1995.

Table 1: Summary of Flood Mitigation Recommended in the Basin Study

(Present Value of Flood Damages and Construction Costs in 1979 Dollars at 6% Discount)

Community at Risk	Average Annual Flood Damages	Recommended Mitigation Works	Status	Estimated Cost 1979$
Cambridge-Galt	$7,720,000	Dykes and Channelization	Complete	$8,500,000
Cambridge-Preston	$240,000	Dykes	Not started	$900,000
Paris	$1,020,000	Dykes and Channelization	Partially Complete	$5,300,000
Brantford	$5,680,000	Dykes	Complete	$6,400,000
Caledonia	$60,000	Dykes	Partially Complete	$850,000
Dunnville	$320,000	Dykes	Started	$1,200,000
New Hamburg	$390,000	Dykes	Not started	$900,000
TOTAL in 1979$:	**15,430,000**		**TOTAL in 1979$:**	**23,950,000**

Source: GRIC (1982) Grand River Basin Management Study. Tables 9.1 and 10.2

Table 2: Reduction in Flood Damages As a Result of Flood Control and Protection Works

(Damages Expressed in 1979 Dollars)

Location	**Natural Condition No Dykes No Reservoirs**	**With Reservoirs No Dykes No Channelization (1979 Condition)**	**With Reservoirs With Dykes With Channelization (1996 Condition)**
Grand Valley	$28,000	$28,000	$28,000
Cambridge	$1,500,000	$505,000	$36,900
Paris	$200,000	$64,000	$64,000
New Hamburg	$25,000	$25,000	$25,000
Plattsville	$2,202	$2,202	$2,202
Ayr	$8,972	$8,972	$8,972
Brantford	$625,000	$360,000	$10,500
Caledonia	$10,000	$8,000	$8,000
Dunnville	$35,000	$20,000	$20,000
TOTAL	**$2,406,174**	**$993,174**	**$175,574**
% Reduction over Natural		**59%**	**93%**
% Reduction over 1979 Condition			**82%**

2. ***It is recommended that Grand River Conservation Authority policies for regulating floodplain development be continued in accordance with provincial policies and guidelines and that basin municipalities incorporate floodplain restrictions in their official plans and zoning by-laws.***

The Grand River Implementation Committee (GRIC) felt that regulating floodplain development was the best means of reducing or eliminating future flood damages because, while structural projects are useful in reducing flood damages, they do not guarantee immunity from floods at all places and at all times.

Implementation Status = Implemented. The Province of Ontario released its first provincial policy on flood plain planning under the Planning Act in 1988 (Provincial Flood Plain Planning Policy Statement, 1988). This statement was consolidated into the Provincial Policy Statement issued May 22, 1996. On March 1, 2005, the Provincial Policy Statement was updated. These provincial statements require municipalities to initiate appropriate policies to protect residents from the flooding hazard. Guidelines were developed in 1988 to assist in this regard.

Several floodplain mapping studies were completed between 1978 and 1998. Some of these were funded through the Federal-Provincial Floodplain Damage Reduction Program (FDRP). The FDRP studies and other selected studies are identified in **Table 3**. Some of these studies included an analysis of flood mitigation works.

Table 3: Floodplain Mapping in the Grand River Watershed

Floodplain Mapping Studies	Year	Flood Mitigation Options Assessed	Floodway/Flood Fringe Modelled
FDRP-Funded Studies			
Irish Creek	1984		
Mill Creek (Galt Creek)	1984		
Hanlon Creek Floodplain Mapping Study	1985		
Conestogo River Floodplain Mapping Study	1985	Yes	
Nith River Floodplain Mapping Study	1985		
Laurel Creek Floodplain Mapping Study	1985		
Speed and Eramosa River Hydrology Study	1987		
Baden Floodplain Mapping Study	1987		
Speed and Eramosa River Floodplain Mapping Study	1988		City of Guelph, City of Cambridge
Grand River Hydrology Study	1988		
Non-FDRP Funded Studies			
Belwood to Black Creek Floodplain Mapping	1975	Yes	
Laurel Creek	1985	Yes	Yes
Colonial Creek	1990		

Table 3: Floodplain Mapping in the Grand River Watershed			
Floodplain Mapping Studies	**Year**	**Flood Mitigation Options Assessed**	**Floodway/Flood Fringe Modelled**
Forwell Creek	1985/1991		
Upper Laurel Creek	1991		
Schneider Creek Floodplain Mapping Study	1992	Yes	Yes
Dunnville Floodplain Mapping Study	1994		
Blair Bechtel Creek Floodplain Mapping Studies	1995		
Grand River Brantford Floodplain Mapping Study	1995		
Grand River Cayuga	1995		

The Belwood to Black Creek floodplain mapping report undertaken in 1975 for the upper Grand River investigated the creation of a flood bypass channel to reduce flooding in Grand Valley, but this option was deemed to be too expensive. A modified proposal for a flood bypass is currently being considered as part of a development proposal and gravel pit restoration plan.

In 1985, flood mitigation options for Laurel Creek in Waterloo between University Avenue and Regina Street were also considered to facilitate the passage of the 100-year flood. Channel works were completed between Erb and Regina Streets to contain the 100-year flood. A culvert under University Avenue was twinned by the Region of Waterloo to convey the 100-year flood. Other proposed works were not completed. The City of Waterloo modified the outlet from Silver Lake to the culvert beneath uptown Waterloo to pass the 100-year flood in 1997. The original outlet structure was a stop log structure that required manual intervention during floods. The new design incorporates a passive weir, requiring no manual intervention.

The Schneider Creek floodplain mapping study recommended flood mitigation works to reduce flooding along Schneider Creek upstream of the spur line servicing the Kitchener business park. An Environmental Assessment (EA) was completed by the City of Kitchener to assess options in this reach. The recommended alternative is being implemented.

The Grand River Conservation Authority has worked closely with watershed municipalities to ensure that floodplain mapping is incorporated into official plans, accompanied by appropriate flood plain land use designations and policies in keeping with the provincial policies.

The province enacted a provincial floodplain policy in 1988 which was accompanied by Floodplain Technical Guidelines (OMNRF 1988a) and Floodplain Policy Implementation Guidelines (OMNRF 1988b) which were updated in 2002 as the Natural Hazard Guidelines (OMNRF 2002). These guidelines lay out the protocol for how provincial policies are to be applied and how exceptions are to be dealt with. Three floodplain policy areas have been defined: one-zone policy area, two-zone policy area, and special policy area.

One-zone policy areas apply to the entire floodplain of the Grand River and its tributaries, except where designated otherwise. New development is generally directed to areas outside of the one-zone policy area. In urban areas, a two-zone policy area may be defined where development within the flood fringe can be allowed subject to appropriate floodproofing to the elevation of the Regulatory Flood. In urban areas that have historically existed within the floodplain and where the application of a two-zone policy area is too restrictive to allow for the continued viability of existing uses, a special policy area may be applied, provided that is approved by the Ministers of Natural Resources and Municipal Affairs and Housing. Policies within a special policy area accept a higher risk and are less restrictive, although structural flood proofing and safe access and egress are still required. Special policy areas have been approved for Brantford, Cambridge(Galt), Drayton, Dunnville, Guelph, New Hamburg, Paris, and Waterloo (Laurel Creek).

In 1995, the Ministry of Natural Resources and Forestry delegated responsibility for municipal plan input and review for natural hazards to the GRCA. Currently, GRCA staff review and comment on municipal policy documents and development proposals to ensure they are consistent with the Ontario Provincial Policy Statement, 2005 – Section 3.0, Protecting Public Health and Safety.

In addition, the GRCA, through the implementation of the Fill, Construction and Alteration to Waterways Regulation (until May 4, 2006) and the Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation (Ontario Regulation 150/06), regulates development in flood hazard areas. The GRCA updated and consolidated its policies for implementing Ontario Regulation 150/06 in 2007, amended to January 2013. These policies complement the 2005 Provincial Policy Statement.

3. ***While existing Grand River Conservation Authority policies control the placing and dumping of fill in defined areas, it is recommended that these policies be strengthened by the inclusion of a registered fill line along the river valleys.***

GRIC noted that Section 28 (f) of the Conservation Authorities Act enabled conservation authorities to prohibit or control the placing or dumping of fill in defined areas. In order to enforce this section of the Act, it was recommended that the GRCA define fill lines along watercourses so that these areas could be protected from dumping in addition to those sources areas that had already been delineated and protected.

Implementation Status = Implemented. At the time that the Basin Study was completed, the GRCA administered the Fill, Construction and Alteration to Waterways Regulation 356/74. This regulation applied to construction in or on a pond or swamp or in any areas susceptible to flooding during a regional storm, or the placing or dumping of fill in any area defined by schedules (this area could contain wetlands and adjacent features, steep slopes, springs, poorly drained soils and floodplains), or changing or interfering with a watercourse. In 1974, there were 10 schedules appended to the regulation. By 2003, twenty-three schedules delineated fill lines on maps, but with the exception of the stretch of the Grand River through Kitchener, most of the schedules pertained to small creek systems and source areas.

The current regulation approved in 2006 (Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation, Ontario Regulation 150/06), was broadened to permit the GRCA to prohibit development (including the placing or dumping of fill) within any river valley within the Grand River watershed, regardless of whether or not the area has been delineated by mapping. The GRCA has mapped most river valleys within the watershed. This information is available to the public through the GRCA's website and Geographic Information Systems (GIS) mapping tool.

4. ***It is recommended that the Eramosa valley wetlands be preserved and protected from development by planning controls and by acquisition.***

Wetlands adjacent to the river reduce flows by retarding runoff and reducing peak flows. They also maintain high water quality by acting as buffer strips between the adjoining agricultural lands and the river. GRIC felt that high water quality in the Speed River would ensure a low cost supplementary water supply for Guelph and a suitable habitat for a cold-water fishery in the Eramosa River.

Implementation Status = Partially Implemented. In 1969, the GRCA began acquiring valleylands near Everton for a potential reservoir site. By 1980, 1,376 acres (556 ha) had been purchased. Although considered in the Basin Study, this site was not identified for a future reservoir site in the recommended plan. However, it was acknowledged that the lands already acquired were valuable wetlands and an integral part of the water management plan. The need to protect wetlands and sensitive, ecologically fragile areas in the Eramosa watershed was reinforced in the Eramosa River–Blue Springs Creek Linear Corridor Initiative (1995) and the Eramosa-Blue Springs Watershed Study (1999).

Between 1984 and 1987, the GRCA acquired an additional 212.3 acres (82.92 ha) at the Everton site, bringing the total acreage to 1,588 acres (642 ha). In addition, the Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation, (Ontario Regulation 150/06) gave the GRCA the ability to regulate interference with wetlands and development in wetlands and adjacent areas (120 metres from the boundary of a Provincially Significant Wetland and other wetlands greater than or equal to 5 acres (2 ha) and 30 metres (100 feet) from smaller non-provincially significant wetlands).

Municipal policies have also been put into place to protect wetlands. Most wetlands in the Eramosa watershed are located within the County of Wellington. A small portion of Blue Springs Creek, a cold-water tributary, is located within the Region of Halton. The County of Wellington Official Plan (dated May 6, 1999 and revised May 15, 2013) states that all wetlands in the County of Wellington are included in the Core Greenlands designation. The policies state that "development and site alteration will not be permitted in wetlands which are considered in provincially significant…all other wetlands will be protected in large measure and development that would seriously impair their future ecological functions will not be permitted". The Region of Halton's Official Plan, 2006 also includes policies to protect the area and functions of Provincially Significant Wetlands (Greenlands A) and to recognize the ecological importance other wetlands (Greenlands B).

While planning controls and land acquisition are underway, acquisition of lands is not complete. The GRCA recognized the Eramosa valley wetlands as a priority acquisition area in its 2003 Board-approved Land Acquisition Policy.

5. ***It is recommended that a study be carried out to determine what land use practices are causing an increase in flood flows and flood volumes on the Grand River and what the effects of future land use practices upon flood flows might be.***

In 1982, it was observed that at Cambridge (Galt), flood volumes had increased 18 percent and the frequency of flood occurrences had more than doubled in the last forty years, but the study was unable to come to a firm conclusion as to the causes.

Implementation Status = Not Implemented. A specific study has not been carried out to determine what upstream land use practices aggravate flooding in Cambridge. The concerns at the time of the study were based on an increasing trend towards larger floods. During the mid-1970s and early 1980s, several large floods occurred in a cluster. There were several moderate floods of a lower order of magnitude after this time period. Larger floods were not experienced again until a series of floods in 2008 and 2009. Floods appear to occur in cycles, depending on the period analysed. Land use conversion and drainage can have the largest influence on the frequency of flooding and on the flood hydrograph volume. A study was completed in 1998 to determine the areas of the watershed that contribute to the peak flood flows in each of the major damage centres.

C. Recommendations for Providing Adequate Water Supply

The basin study determined that the future water needs of the major urban areas can be obtained by:

- Developing new ground water sources for Cambridge and Guelph;
- Developing a new surface water source from the Grand River for Waterloo and Kitchener;
- Continuing withdrawal from the Grand River for Brantford.

All other basin communities except Elora and Fergus could meet future demands from existing supplies. In order to meet future demands, Elora and Fergus would have to develop new ground water sources.

1. It is recommended that the municipal ground water supplies from Kitchener-Waterloo be supplemented by further water withdrawals from the Grand River.

GRIC felt that withdrawals from the Grand River could be accomplished by induced infiltration wells near the river and by pumping from the river to recharge ground water at the Mannheim well field. At the time, testing of this approach was being carried out by the Regional Municipality of Waterloo to determine the feasibility of this scheme.

Implementation Status = Implemented. In 1989, the Region of Waterloo constructed the Hidden Valley weir, surface water intake and low-lift pumping station in Kitchener. In 1992, the Mannheim Water Treatment plant was commissioned.

The Mannheim Water Treatment Plant receives raw water from the Hidden Valley pumping station. After the water is treated, it is pumped to the Mannheim Pumping Station Reservoir. There, the treated water mixes with groundwater from seven other wells. The combined reservoir capacity at Mannheim is 15.28 million litres. From the reservoir, the water is then distributed through the Integrated Urban System that serves the residents of Kitchener, Waterloo, Cambridge and other select communities in the Region.

The induced infiltration wells (3 production wells) near the Grand River at Woolner's Flats in Kitchener are in place. The water from these wells is treated and passed through an Ultraviolet (UV) system, which provides primary disinfection. The Woolner's Well Supply is part of the Region's Urban Integrated Water System.

2. ***It is recommended that prior to the final development of the above water supply system:***
   a) ***industrial organics presently seeping from abandoned industrial waste disposal sites at Breslube Enterprises, near Kitchener, be eliminated or prevented from reaching the adjacent Grand River.***
   b) ***a water quality surveillance program be established to evaluate risks from possible contamination of the water supply from any sources of synthetic organic compounds*****.**

   GRIC concluded that the most notable potential sources of organic chemicals were the Uniroyal Ltd. plant at Elmira on Canagagigue Creek and the Waterloo sewage treatment plant on the Grand River. The surveillance program was recommended to protect existing and future surface water supplies, particularly for the Cities of Kitchener, Waterloo and Brantford.

   Implementation Status = Partially Implemented. The issue of contamination, either existing or potential, is dealt with by the Ministry of the Environment. Breslube, now Safety-Kleen, is one of the largest used oil re-refiners in North America. A remediation action plan for contamination on-site was approved by the Ministry in 2002 and efforts to clean up the site are ongoing.

   In 2002, the Province of Ontario passed the Safe Drinking Water Act to protect human health through the control and regulation of drinking-water systems and drinking-water testing. The act requires that all municipal drinking water systems be approved by the Ministry of the Environment and provides legally binding standards for testing of drinking water and requires that testing be done in licensed and accredited laboratories.

   The Region of Waterloo and Brantford routinely monitor raw and treated surface water as required under the act. Monitoring of Canagagigue Creek is conducted by Chemtura (previously Crompton and Uniroyal). Remediation efforts have been effective in preventing the migration of contaminants off the plant site and into surface water and are ongoing.

3. ***It is recommended that:***
   a) ***new ground water supplies be developed for Cambridge to meet future demands***
   b) ***the City of Guelph investigate the feasibility of developing new ground water supplies, directing its attention toward the southeast of Guelph in order to meet future demands past the year 2001***
   c) ***Elora and Fergus carry out test drilling in a nearby buried bedrock valley to assess its potential for future municipal supplies.***

   Studies undertaken by the Regional Municipality of Waterloo in the late 1970's indicated that there were additional ground water supplies located in the areas east and south of Cambridge. For Elora, Fergus and Guelph, it was estimated that existing supplies could meet average daily demands for a 2001 medium population projection. The Grand River basin study identified favourable locations for test drilling in these areas.

   Implementation Status = Implemented. In 1995, the Cambridge East Water Supply Project commenced with the building of three water treatment plants, a well pumping station, two replacement wells, two new wells and two transmission mains. In 2005, the Region of Waterloo initiated an Urban System Groundwater Optimization and Expansion Project, for the purpose of identifying new wells across the integrated Urban System supplying Cambridge, Kitchener and Waterloo. This project included a Class Environmental

Assessment to assess the overall aquifer capacity, restore the capacity of existing well fields and optimize groundwater extraction in the Cambridge East area. A number of test wells were drilled in the area and long term pumping tests conducted on four potential supply wells in 2007 and 2008. Evaluation of the impact of these test wells is ongoing concurrent with a review of water demand as part of an update to the Master Water Supply Plan being undertaken through a Class Environmental Assessment. Completion of the Cambridge East EA is anticipated in 2014.

In 1990, the City of Guelph began a multi-phase study of its water system. Through this project, it was recognized that the use, conservation and protection of existing groundwater resources through the implementation of multiple initiatives was needed. Investigating expansion of the existing water system to meet growth requirements was one aspect of the study. In 1999, the City initiated a Class Environmental Assessment to evaluate the groundwater potential for the Arkell Spring Grounds. Guelph has developed additional water in the southeast quadrant of the City through the Arkell Spring Grounds Class EA which was completed in 2006 following a protracted Class EA review process from the OMOECC. Pumping in the Arkell Springs bedrock well field was increased by about 7,000 m^3/day in 2011. Full development of the system, adding another 1,800 m^3/day will be brought on line in 2013/2014 subject to the outcome of monitoring programs.

Through Guelph's Water Supply Master Plan (WSMP), completed in 2007 and slated for update in 2013/2014, additional areas of potential new water supplies have been identified in: 1) the southwest quadrant of the city as part of the Southwest Quadrant Class EA, 2) the south end of Guelph from the South Guelph Groundwater Supply Investigation project, 3) the northwest quadrant through the Smallfield/Sacco Wells Return to Service project and, 4) the northeast quadrant from the Clythe Creek Well Class EA. While the WSMP update will confirm the estimates, these projects are expected, if fully realized, to satisfy the short-term needs of the City (i.e., next 5 to 10+ years).

Current water supply capacity is estimated at about 78,000 m^3/day (subject to confirmation from the WSMP Update) while average day demands are currently in the range of 46,000 m^3/day with max day demand in the range of 58,000 m^3/day over the last five years.

In 2012, an aquifer capacity study was initiated by the Township of Centre Wellington (including Elora and Fergus). Following the completion of this investigation, a long-term water supply strategy will be developed.

4. It is recommended that a ground water quality network be established to monitor the major water supply aquifers within the basin.

GRIC advised that a ground water surveillance network, in conjunction with the recommended surface water surveillance program, be established as soon as possible to deal with existing site-specific problems of contamination or possible contamination of usable ground water supplies. It was felt that the focus of such a network should be on heavy metals, pesticides and other inorganic and organic compounds.

Implementation Status = Partially Implemented. In 2000, the Ministry of the Environment revitalized the Provincial Groundwater Monitoring Network (PGMN) in partnership with the conservation authorities. The purpose of the program is to monitor ambient groundwater levels and quality over the long term; wells are sited away from areas where water levels are potentially influenced by pumping or groundwater contamination. All the wells are equipped with data loggers which measure water levels and temperature on an hourly basis.

New wells are sampled for a full suite of organics, pesticides, metals, and general chemistry. Each subsequent year the wells are sampled for inorganics only. The monitoring infrastructure is owned by the OMOECC. There are currently 28 PGMN wells at 21 locations in the Grand River watershed. In general, the OMOECC is responsible for establishing the monitoring network and the associated information system (PGMIS), program coordination, data analysis and reporting, maintaining the information system and technology transfer and training. The GRCA is responsible for the field operations including maintaining field equipment, collecting water level data and water samples, the chemical analyses of samples, and data analysis and reporting on a local level.

In addition to the PGMN, individual several municipalities have their own groundwater monitoring programs (e.g., Region of Waterloo, City of Guelph).

Monitoring of heavy metals and organics is not done on a routine basis.

5. It is recommended that the water conservation program be continued in the Regional Municipality of Waterloo, particularly in Waterloo, Kitchener and Cambridge, in order to reduce municipal water demands. For other municipalities, the pursuit of water conservation programs should be evaluated in relation to future needs and supply capabilities.

GRIC noted that water conservation programs embrace a range of actions that aim at reducing average and maximum day municipal water demands. At the time, it was believed that a moderate conservation program could be expected to reduce average day demand in Kitchener-Waterloo by 10 percent, and in Cambridge by 15 percent. GRIC supported and encouraged the conservation practices adopted by Guelph in light of the potential water supply problem that were predicted after the year 2001.

GRIC also recommended that revisions to the existing water rate structure be considered as a part of any conservation program and noted that where appropriate, municipalities should consider moving from a decreasing rate structure to a rate structure that encourages water conservation.

System losses or unbilled consumption were estimated to be approximately 9 percent higher than the provincial average for Guelph and Brantford. GRIC advised that existing programs to trace and reduce these losses should be continued.

Implementation Status = Implemented. In 1974, the Region of Waterloo began water conservation initiatives and created a water efficiency program, with an emphasis on reducing residential water use. Pilot projects promoting the installation water-efficient plumbing devices such as water-efficient showerheads and toilets and lawn watering restrictions were established. A long-term water strategy was developed in 1991 and has since been revised and updated. The current program actively promotes water efficiency across residential, commercial, industrial and institutional sectors. The goal of the program is to reduce local water consumption by 1.8 million imperial gallons per day (MIGD) by 2015. Over 70,000 toilets have been replaced and 50,000 rain barrels have been distributed. Conservation education is an important component to the program. Between 1999 and 2011, water conservation efforts achieved a 9 percent decrease in water consumption, even though the population increased 26 percent during this time.

In 1990, the City of Guelph initiated a multi-phase Water Supply Study that identified water conservation as a key strategy. In 1998, a comprehensive Water Conservation and Efficiency Plan, although not approved as the catalyst for a ban on outside water use during peak summer months (2001) and a toilet rebate program (2003). In 2006, a Water Supply Master Plan was developed to establish a sustainable water supply that would continue to serve the city's growing needs. The overall goal is to reduce total water usage of 20 percent before 2023. Strategies include public education and awareness, water audit programs, rebate programs to encourage water conservation and water use bylaws. These programs have achieved measurable success resulting in an 11% reduction of overall water-use between 2006 and 2011.

Other municipalities in the Grand River watershed have initiated water conservation programs, including the City of Brantford and the County of Oxford.

As a result of the Walkerton tainted water tragedy, where an unfortunate *E. coli* outbreak associated with contaminated drinking water claimed the lives of 7 people in 2000, the province passed the Sustainable Water and Sewage Systems Act to ensure full cost recovery of operating water and waste water systems. Regulation 453/07 under the Safe Water Drinking Act was approved in 2007, requiring all municipalities to develop a Financial Plan for drinking water systems. As a result, municipal water rates have increased and contributed to a general trend towards declining water demand. Some municipalities have introduced conservation pricing. For example, the County of Oxford has introduced a new water rate structure to encourage conservation, while also promoting commercial and industrial development. It consists of a fixed base rate/service charge, plus a volumetric charge.

Detection programs for determining water losses from leaks at distribution lines, service connections and storage tanks and unauthorized uses (unaccounted for water) are now a common practice for urban municipalities. Leak detection programs continue to be active in the Cities of Guelph and Brantford.

D. Recommendations to Maintain Adequate Water Quality

The basin study concluded that water quality in the central Grand River could be improved by increased levels of sewage treatment at Kitchener and Waterloo sewage treatment plants. Some improvements in water quality could also be obtained by reducing upstream rural non-point sources, particularly through the use of erosion control measures.

Water quality in the Speed River could be improved by the recently completed advanced sewage treatment facilities at Guelph. If required, further improvement could be attained by the installation of additional phosphorus removal facilities.

1. In order to increase the dissolved oxygen levels and eliminate ammonia toxicity in the central portion of the Grand River, it is recommended that advanced sewage treatment facilities be installed at the Kitchener sewage treatment plant as soon as possible, and at the Waterloo sewage treatment plan at a later date depending on population growth (advanced treatment at the Waterloo plant would be needed by the year 2001 for a medium population projection).

Technical studies carried out for the basin study predicted that an increased level of sewage treatment at Kitchener and Waterloo would improve the water quality to a reasonable level in the central Grand River. However, it was acknowledged that the provincial water quality objective for dissolved oxygen of 4 mg/L would not always be met in certain sections. Plan B2, through the use of flow augmentation from the Montrose reservoir, would come closest to achieving the objective.

Converting ammonia nitrogen to the nitrate form using rotating biological contactors (RBCs) and accompanying dual-media filters at Kitchener and Waterloo was accepted as one method of improving the quality of sewage effluent, thus increasing dissolved oxygen levels and reducing ammonia toxicity in the rivers. The cost of this treatment was included in all plan cost estimates.

Achieving the dissolved oxygen objective continuously in all sections of the central Grand River was viewed as exceedingly expensive since drastic reductions of oxygen-demanding wastes and phosphorus from all point and upstream rural non-point sources would be required. Large reductions from non-point sources were thought to be difficult to achieve, requiring long-term, continuing improvements in technology and land use practices.

Implementation Status = Partially Implemented. This recommendation was made when the Ministry of the Environment owned and operated the Waterloo and Kitchener wastewater treatment plants. In 1994, the ownership of and responsibility for operating and maintaining these wastewater treatment plants was transferred to the Region of Waterloo. Also in 1994, the Ontario Clean Water Agency was initially formed to assume the Ministry of the Environment's facility operation responsibilities. In 1995, the Region negotiated a three-year agreement with OCWA to provide operations and maintenance services. OWCA has been operating and maintaining all of the Region's wastewater treatment plants since that time.

Master Plans for wastewater treatment within the entire Region of Waterloo were completed in 1997 and 2007. Upgrades to both the Kitchener and the Waterloo Wastewater Treatment Plant (WWTP) were recommended.

The Kitchener Wastewater Treatment Plant (WWTP) is a conventional activated sludge process with chemical phosphorus removal, anaerobic sludge digestion and sodium hypochlorite disinfection. The treated effluent is discharged to the Grand River. The plant was constructed in two major phases (Plants 1 and 2): Plant 1 was constructed in the 1960s and Plant 2 was constructed in the late 1970s.

Since 2008, the Waterloo and the Kitchener WWTP upgrades are high-priority projects for the Region to improve water quality in the Grand River. A phased approach to implement upgrades began in 2012. These upgrades are expected to be completed by 2020. Included in the upgrades are a standby disinfection facility, UV disinfection and effluent pumping facilities, nitrification, decommissioning of the existing biosolids storage lagoons and construction of a dewatering facility, and tertiary treatment for enhance phosphorus removal. The upgrades will increase plant reliability and energy efficiency, improve effluent quality, reduce the volume of biosolids, and lessen odours. Upgrades to the Kitchener WWTP are expected to be completed by 2020.

The Waterloo WWTP was originally constructed in 1962. Extensive additions and renovations were done with last major upgrade in 1987. Another upgrade was initiated in 2010 to improve effluent quality for the Grand River and maintain reliability and energy efficiency by replacing aging equipment. Upgrades to include nitrification are expected to be complete in 2014.

2. ***It is recommended that the impact of the Guelph advanced sewage treatment facilities on the water quality of the lower Speed River be evaluated throughout the next few years to determine if additional treatment is required.***

The total effluent characteristics of the sewage treatment addition (rotating biological contactors and dual-media filtration) that had been completed just prior to the basin study were not known. Assumed effluent characteristics were used for analyzing the basin study water management alternatives. If, after a 2-3 year evaluation period, the Speed River between Guelph and Cambridge (Hespeler) was experiencing very low oxygen levels, GRIC advised that consideration be given to further reducing the levels of phosphorus in the sewage effluent. One method of reducing phosphorus considered by the basin study was the addition of chemical treatment and multi-media filtration at the Guelph sewage treatment plant. The cost of this treatment was included in all the plan cost estimates.

Implementation Status = Implemented. The Guelph waste water treatment plant discharges into the Speed River. Guelph's original facility was constructed over 100 years ago but components have been upgraded, expanded or replaced over time to meet effluent quality requirements. Several of these expansions and upgrades occurred after the release of the Basin Study recommendations, based on assessments of the water quality and assimilative capacity in the Speed River. Beyond the conventional secondary biological treatment (activated sludge), the plant now employs tertiary treatment, including nitrifying biological contactors and sand filtration to reduce ammonia loads, suspended solids, phosphorus and particulate organic matter loads in the final effluent.

In 2008, rather than committing to an expansion, the City decided to undertake an optimization program. The program examined each treatment process looking for bottlenecks and assessing cause-and-effect relationships to identify opportunities to improve the performance of the facility and increase its capacity. The program focused heavily on developing the facility's "human infrastructure" by investing in staff training and skills development to enable the staff to improve the facility's process control.

As a result, the facility reduced the concentration of ammonia in its treated effluent and now consistently meets stricter effluent limits. Lower chlorine limits were achieved by improving the process control of the existing chlorine removal system. Latent processing capacity has been identified and the expenditure of an estimated $20 million to expand the facility was avoided.

3. ***In order to evaluate the effects of existing and proposed water quality improvements, it is recommended that the Ministry of the Environment and the Grand River Conservation Authority jointly maintain the existing six continuous water quality monitoring stations in the central Grand River and the lower Speed River.***

GRIC noted that with the addition of remote sensing, the existing gauges would also aid in the real-time operation of existing reservoirs and sewage treatment plants.

Implementation Status = Implemented. In 1979, there were 7 continuous water quality monitoring stations in the Grand River system – six within the central Grand River and lower Speed River (Table 4)

Table 4: Continuous Water Quality Monitoring Stations				
Location	**Station No.**	**Instrument System**	**Distance above mouth of Grand River (km)**	**Remarks**
Grand River at Bridgeport	E2	EIL	176.8	Installed in May 1975 on east bank about 0.5 km upstream of bridge; relocated in April 1977 on west bank about 1km upstream of the bridge
Grand River at Woolner Flats	E6	EIL	166.4	Installed in July 1975
Grand River at Blair	N134	NERA	150.0	Installed in September 1975
Speed River at Canadian Gypsum Plant	E3	EIL	166	Installed in June 1975 with housing on the Canadian Gypsum property; housing relocated on the Guelph WPCP property during Nov 1978
Speed River at Glen Christie	N135	NERA	163.5	Installed in Sept 1975
Speed River at Preston	E5	EIL	149.5	Installed in May 1975
Grand River at Glen Morris	E4	EIL	132.8	Installed in June 1975
Grand River upstream of Wilkes Dam	E8	EIL	108.8	Installed in May 1979
Grand River at Newport Bridge	E7	EIL	78.4	Installed in July 1978

EIL: records dissolved oxygen (DO) and temperature

NERA: records DO, temperature, pH, conductivity, and oxidation–reduction potential

When the Basin Study was completed in 1984, GRCA in partnership with the OMOECC, took over the operation of three stations at Bridgeport and Blair on the Grand River and Road 32 on the Speed River. The continuous water quality monitoring network has been reviewed, modified and expanded several times since then. The GRCA now operates nine stations at Shand Dam, Bridgeport, Blair, Glen Morris, Brantford and York on the Grand River, and Edinburgh Road and Road 32 on the Speed River.

4. ***It is recommended that the Ministry of Agriculture and Food, as the lead agency, carry out studies to determine the effectiveness, type and site-specific locations of rural non-point source controls. Initially, efforts should be concentrated in the Canagagigue Creek, middle Grand River, Irvine Creek, Cox Creek, Conestogo and Nith River sub-basins.***
   Studies should be carried out to determine:

   a) ***those critical areas contributing the greatest loading of sediments and nutrients to streams. Improved management practices should be concentrated in these areas***
   b) ***the applicability and effectiveness of various rural non-point source management practices***
   c) ***the relation between the costs of these measures and the agricultural and water quality benefits obtained***
   d) ***priority of the areas to be treated.***

Implementation Status = Not Implemented. In 1985, the Ontario Ministry of Agriculture and Food (OMAF) and the GRCA formed the Joint Agricultural Soil and Water Conservation Program. The main thrust of this program was to aid farmers in reducing soil erosion from agricultural lands through the joint implementation of several programs. Tillage 2000 was a four-year project initiated in 1985 to undertake field-sized research and on-farm demonstrations. The Ontario Soil Conservation and Environmental Protection Assistance Program (OSCEPAP II) provided capital grants for structural erosion control projects such as grassed waterways and water and sediment control basins, manure storage, milkhouse and parlor washwater disposal and pesticide handling facilities between 1986 and 2000. The Soil and Water Environmental Enhancement Program, or SWEEP, was a five-year joint federal-provincial agreement to improve soil and water quality in southwestern Ontario and reduce phosphorus loading into the Lake Erie basin from cropland runoff. A three-year Land Stewardship Program was initiated in 1987 to provide grants to farmers for the adoption of new conservation practices to reduce soil erosion and compaction and restore soil organic matter and structure. The Rural Beaches Program, funded by the Ministry of the Environment (OMOECC) and delivered by the GRCA promoted good livestock and waste management practices in rural areas to improve recreational water quality was active from 1986-1991. The successor to this program, the Clean Up Rural Beaches (CURB), was started in 1991. Under the CURB program, provincial funds were made available for projects such as improving manure storage, milkhouse washwater disposal systems, fencing and crossings to restrict livestock access, and private sewage systems. The GRCA delivered the CURB program until 1996 and focused on the Nith, Conestogo and Canagagigue watersheds.

The Rural Water Quality Program, funded by Waterloo Region, Wellington County, Guelph, Oxford County, Brant County and Brantford, and delivered by the GRCA, was initiated in 1998. Haldimand County and Dufferin County have recently undertaken to fund the RWQP. This program promotes best management practices and provides financial assistance to farmers implementing projects to improve water quality. Famers wishing to participate must complete an Environmental Farm Plan administered by the Ontario Soil and Crop Improvement Association and the proposed project must exhibit a potential to protect and improve water quality prior to being accepted. Improvement projects eligible for funding include livestock waste management, retirement of fragile agricultural land, erosion control projects, conservation cropping practices, and well water protection.

Watershed Municipalities have provided more than $9 million to fund this program. Other agencies and levels of government have contributed an additional $3 million to the program. Over 4,000 best management practices have been implemented in the watershed. Seventy percent of the projects and funding have been targeted to the Canagagigue Creek, middle Grand River, Irvine Creek, Cox Creek, Conestogo and Nith River sub-basins.

Although on-the-ground programs continue to be implemented to reduce soil erosion and improve rural water quality, the studies recommended in the Basin Study have not been carried out and are still outstanding today.

5. ***It is recommended that urban areas adopt storm water management practices to reduce local flooding and improve stream water quality.***

The technical studies undertaken as part of the basin study indicated that existing urban runoff did not affect the flood peak flows of the major rivers nor did it materially affect the dissolved oxygen regime in the Grand or Speed Rivers. However, studies did show that urban runoff increases bacteria levels immediately downstream of the major urban centres on these rivers. It was acknowledged that increased levels of bacteria pose potential health hazards for incidental contact such as children playing at the river’s edge. While studies concluded that major rivers were not significantly impacted by urban runoff, it was noted that urban runoff causes more serious flooding and water quality problems in small tributaries by raising stream levels rapidly and increasing concentrations of metals, bacteria and nutrients.

Implementation Status = Implemented. The City of Kitchener incorporated storm water management (SWM) into its Urban Drainage Policy in 1979 and others followed in 1979-1984. The GRCA issued SWM guidelines in 1982. The Province, with input from the Ministries of Natural Resources, Environment, Municipal Affairs, and Transportation and Communication, the Municipal Engineers Association, Association of Conservation Authorities of Ontario and the Urban Development Institute, issued Urban Drainage Design Guidelines in 1987, followed by OMOECC Stormwater Quality Best Practices in 1991. Following release of the guidelines and policies, all new urban developments were required to implement storm water management measures. Early SWM implementation focused on flood control whereas water quality management measures for storm water discharging directly to the Grand River and the major tributary rivers and creeks began in the late 1980’s.

Master Drainage plans typically began as components of Floodline mapping studies in the late 1970’s. The first watershed-based subwatershed plan was initiated by the City of Kitchener in 1987. Subwatershed plans are typically required ahead of official plan amendments for urban development within the Grand River watershed. Several municipalities have conducted stormwater master plans or master drainage studies to identify existing SWM practices and opportunities to improve stormwater quality by retrofitting SWM facilities in existing urban areas.

6. ***In order to achieve the flow requirement of plan A4 for both water supply and water quality, it is recommended that the Grand River Conservation Authority operating policy for the existing reservoirs be modified to achieve the following target flows (Table 5).***

Table 5: Flow Requirements for Basin Study Plan A4					
Location	**Period**	**Minimum Flow Targets**		**Operating Range***	
		Present (1982)	**Recommended**	**Present**	**Recommended**
Grand R. at Shand Dam	Jun–Sept	2.8 m^3/s	2.8 m^3/s	N/A	N/A
	May-Oct	2.8 m^3/s	2.8 m^3/s	N/A	N/A
	Nov-Apr	None	2.8 m^3/s	N/A	N/A
Grand R. at Doon	May-Oct	11.3 m^3/s	9.9 m^3/s	11.3– 12.7 m^3/s	9.1-10.8 m^3/s
	Nov-Dec	No Target	7.1 m^3/s	N/A	6.2-7.9 m^3/s
	Jan-Apr	Ice Conditions**			
Grand R. at Brantford	May-Oct	17.0 m^3/s	17.0 m^3/s	17.0-18.4 m^3/s	15.6-18.4 m^3/s
	Nov-Dec	No Target	No Target	N/A	N/A
	Jan-Apr	Ice Conditions**			
Conestogo R. at Conestogo Dam	May-Oct	2.1 m^3/s	2.1 m^3/s	N/A	N/A
	Jan-Apr	No Target	No Target	N/A	N/A
Speed R. at Guelph Dam	May-Oct	0.6 m^3/s	0.6 m^3/s	N/A	N/A
	Jan-Apr	No Target	No Target	N/A	N/A
Speed R. at City of Guelph (Hanlon Expy)	Jun-Sept	1.1 m^3/s	1.7 m^3/s	N/A	N/A
	May-Oct	1.1 m^3/s	1.1 m^3/s	N/A	N/A
	Jan-Apr	Ice Conditions**			

* *Because of the travel time from the reservoirs to the point of interest, the daily flows can vary from the target flow. The travel time from the reservoirs to Doon and Brantford are 30 and 48 hours respectively.*

** *When the river is ice covered, flows cannot be continuously measured.*

N/A Not Applicable

Implementation Status = Implemented. The GRCA's reservoir operating procedures were amended to incorporate the recommended flow targets in 1984. In 2004, a new reservoir operating policy was approved, but the targets derived in 1982 remain, with minor modifications, part of today's approved operating procedures.

E. Recommendation to Protect the Montrose Reservoir Site

1. It is recommended that the Montrose reservoir site be protected for possible future water management purposes.

GRIC concluded that protection of the Montrose reservoir site could be achieved through land acquisition (by purchasing available land at the prevailing market price over time) and planning controls such as land use regulations and zoning. In the future, the land could be sold, used for the construction of a dam and reservoir, or preserved for other uses. In the interim, the existing agricultural land use could be maintained to protect the site from development.

Implementation Status = Implemented. Prior to 1982, the GRCA acquired about 1,293 acres (523 ha) at the Montrose reservoir site. Between 1982 and 1997, the GRCA acquired an additional 373 acres (150 ha), bringing the current land holding to 1,666 acres (675 ha).

The County of Wellington and the Region of Waterloo have both recognized the Montrose Reservoir site in their Official Plans. The Official Plan for the Region of Waterloo, 2006 (policy 4.5.15) states that "The Region will, in co-operation with Area Municipalities and the Grand River Conservation Authority, not support settlement designations on lands identified for future dykes, reservoirs or similar major water management projects until such projects are formally abandoned or receive approval pursuant to the Environmental Assessment Act. Area Municipalities will be requested to protect such sites through land use planning controls." The County of Wellington Official Plan (dated May 6, 1999 and revised May 15, 2013) identifies the Montrose Water Management Protection Area in the official plan and indicates that this area is recognized "to ensure that present and future landowners are aware of the proposal and that development activities will not impair the use of the potential site for reservoir purposes. All planning authorities shall consult with the Grand River Conservation Authority prior to approving any development application within these protection areas. Chief Building Officials are encouraged to consult with the Grand River Conservation Authority prior to issuing building permits within these protection areas."

F. Recommendation to Implement the Plan and Coordinate Government Activities

1. ***It is recommended that the water management plan be implemented by existing government agencies.***

Traditionally, the components of plan A4 have been implemented by the following agencies:

Plan Component	Agency
Flood control, flood warning, dyking and channelization	• Grand River Conservation Authority • Municipalities • Ministry of Natural Resources
Flood proofing	• Individual landowners
Water supply projects and sewage treatment plants	• Municipalities • Ministry of the Environment
Acquisition of Montrose reservoir land	• Grand River Conservation Authority
Non-point source pollution control	• Individual landowners • Municipalities • Grand River Conservation Authority • Ontario Ministry of Agriculture and Food

	• Ministry of the Environment • Ministry of Natural Resources
Planning controls	• Municipalities • Grand River Conservation Authority • Ministry of Municipal Affairs and Housing • Ministry of Natural Resources

Implementation Status = Partially Implemented. Since the Basin Study was undertaken, existing government agencies and institutions have continued to carry out water management activities in support of the recommendations, many of which have been fully implemented. The success of the plan was attributed to the fact that the plan was developed by the people in provincial ministries and senior staff from municipalities charged with the day-to-day responsibility for addressing water issues. Most of the recommendations were completed by the government agencies and institutions as listed.

2. ***It is recommended that a committee be established to coordinate the activities of the existing agencies in implementing the water management plan preferred by governments.***
GRIC envisaged a committee consisting of members from implementing ministries agencies and basin municipalities. The committee would deal with the scheduling and implementation of measures selected to meet the water management needs of the basin.

Implementation Status = Not Implemented. After the Basin Study was completed, it did not receive provincial status through the Cabinet Committee on Resources. A coordinating committee was not established. However, the determined efforts of local agencies (including local provincial offices, municipalities and the GRCA) enabled most of the recommendations to be implemented.

3. ***It is recommended that such a coordinating committee play a lead role in carrying out a periodic re-evaluation of the plan, coordinating investigations and recommending new or modified alternatives to achieve the water management objectives of the Grand River basin.***
GRIC advised that the recommendations should be reviewed on an on-going basis and re-evaluated every five years to ensure that the latest developments in water resources management are considered and that the assumptions made in deriving the original plan are still valid.

Implementation Status = Not Implemented. Since a coordinating committee was not established to periodically review the status of the plan, many of co-ordinating functions for water management were assumed by the GRCA. For example, a Water Managers Working Group was facilitated by the GRCA to discuss watershed-wide issues and solutions, carry out technical studies, and advance modeling for water quality (e.g., Grand River Water Quality Simulation Model).

4. ***It is recommended that the coordinating committee be assisted in its ongoing review by a small technical staff responsible to the coordinating committee.***
GRIC felt that technical staff should aid the coordinating committee in reviewing the management plan and undertaking specific water management studies. It was noted that capability of staff could be expanded, as the need required, by drawing upon the expertise of basin universities and other agencies.

Implementation Status = Not Implemented. The recommendations for establishing a coordinating committee supported by a small technical staff were not implemented.

Implementation of the Basin Study Recommendations Summary

A total of 22 recommendations were included in the Basin Study. **Table 6** summarizes the status of these recommendations. While no official approval of the Basin Study was given through the Cabinet Committee on Resources, the majority of recommendations have been either fully or partially completed.

Table 6: Implementation of the Basin Study Recommendations

1982 Recommendation	2013 Status of Implementation
Recommendations for Reduction of Flood Damage	
Undertake channelization and dyking to reduce flood damages at Cambridge, Brantford, Paris, Caledonia, Dunnville and New Hamburg	Completed in 1995 – Cambridge (Galt)
	Not implemented - Cambridge (Preston)
	Completed in 1995 - Brantford
	Completed in mid-1980s - Paris
	Partially implemented in 1988 - Caledonia
	Demonstration project completed in early 1990s - Dunnville
	Not implemented - New Hamburg
Continue GRCA policies for regulating floodplain development in accordance with provincial policies and guidelines.	Implemented.
Incorporate floodplain restrictions in municipal official plans and zoning by-laws.	Implemented. After the 1988 Provincial Planning Policy Statement, all municipalities incorporated floodplain restrictions into their planning documents.
Strengthen GRCA policies controlling the placing and dumping of fill in defined areas by including a registered fill line along the river valleys.	Implemented. Some river valley fill lines were registered after 1985 but changes to the Section 28 regulation under the Conservation Authorities Act in 2006 enabled the GRCA to regulate development (including the placing and dumping of fill) in all valleylands within the Grand River watershed.
Preserve and protect the Eramosa valley lands from development by planning controls and by acquisition.	Partially implemented. GRCA has acquired 1,588 acres.
	Implemented. Municipal planning controls are included in the County of Wellington Official Plan and Region of Halton Official Plan.
Undertake a study to determine what land use practices are causing an increase in flood flows and flood volumes on the Grand River and the effects of future land use practices upon flood flows might be.	Not implemented.

Table 6: Implementation of the Basin Study Recommendations	
1982 Recommendation	**2013 Status of Implementation**
Recommendations for Providing Adequate Water Supply	
Supplement municipal groundwater supplies for Kitchener-Waterloo from the Grand River using induced infiltration wells near the river and pumping from the river to recharge groundwater at the Mannheim well field.	Implemented. Induced infiltration wells were put near the Grand River at Woolner's Flats. Implemented. The Hidden Valley Intake and Mannheim Aquifer Storage and Retrieval system were constructed and are in operation.
Eliminate or prevent industrial organics presently seeping from abandoned industrial waste disposal sites at Breslube Enterprises near Kitchener from reaching the adjacent Grand River.	Partially implemented. Remediation at both the Uniroyal and Breslube sites is ongoing
Initiate a water quality surveillance program to evaluate risks from possible contamination of the water supply from any sources of synthetic organic compounds (most notable sources – Uniroyal Ltd plant at Elmira, Waterloo sewage treatment plant).	Implemented. Monitoring is undertaken along Canagagigue Creek by Chemtura (formerly Uniroyal) and the Region of Waterloo monitoring raw water and treated water according to the Safe Drinking Water Act.
Develop new groundwater supplies for Cambridge to meet future demands	Implemented. Investigations are ongoing.
City of Guelph - investigate the feasibility of developing new groundwater supplies for the City of Guelph (southeast of Guelph) to meet future demands past 2001	Implemented. In 1990, the City of Guelph began a multi-phase study of its water system. Investigating expansion of the existing water system to meet growth requirements was part of the study.
Elora and Fergus - carry out test drilling near Elora and Fergus at a nearby buried bedrock valley to assess its potential for future municipal supplies.	Implemented. A study to investigate aquifer capacity was started in 2012.
Establish a groundwater surveillance network to monitor contamination of usable groundwater supplies.	Partially implemented. The Provincial Groundwater Monitoring Program in the Grand River watershed consist of 28 wells, however, monitoring of heavy metals and organics is not done on a routine basis.
Continue water conservation programs in the Regional Municipality of Waterloo, particularly in Waterloo, Kitchener and Cambridge, and in Guelph.	Implemented. Water conservation programs are active in all noted municipalities.
Municipalities - consider moving away from a decreasing rate structure to a rate structure that encourages water conservation.	Implemented. All municipalities are now required to have full cost recovery for water services.
Guelph and Brantford – trace water system losses and find ways to reduce these losses.	Implemented. Guelph and Brantford are actively investigating water system losses.
Recommendations to Maintain Adequate Water Quality	
Install advanced sewage treatment facilities at the Kitchener sewage treatment plant as soon as possible.	Partially implemented. Completion of upgrades planned for 2020.
Install advanced sewage treatment facilities at the Waterloo sewage treatment plant by 2001.	Partially implemented. Completion of upgrades planned for 2014.
Evaluate the impact of the Guelph advanced	Implemented. Additional upgrades have been

Table 6: Implementation of the Basin Study Recommendations	
1982 Recommendation	**2013 Status of Implementation**
sewage treatment facilities on the water quality of the lower Speed River	made and an optimization program initiated.
OMOECC and GRCA - jointly maintain six continuous water quality monitoring stations.	Implemented.
OMAF - study effectiveness, type and site-specific locations for rural non-point source controls, with focus on Canagagigue Creek, middle Grand River, Irvine Creek, Cox Creek, Conestogo and Nith River sub-basins.	Not implemented. Several rural programs to assist landowners to improve management of soil and water resources have been implemented.
Urban areas - adopt storm water management practices to reduce local flooding and improve stream water quality.	Implemented.
GRCA - modify reservoir operating policies.	Implemented in 1984. Generally, these targets are still in effect.
Recommendation to Protect the Montrose Reservoir Site	
Protect the Montrose reservoir site for possible future water management purposes by land acquisition and planning controls.	Partially implemented. The GRCA has acquired 1,666 acres - about 30% of the required land.
	Implemented. Municipal planning controls are included in the Region of Waterloo Official Plan and County of Wellington Official Plan.
Recommendation to Implement the Plan and Coordinate Government Activities	
Establish a committee to coordinate the activities of the existing agencies in implementing the water management plan.	Not implemented.
Establish a coordinating committee to lead periodic re-evaluation of the plan and recommend new or modified alternatives.	Not implemented.
Establish a small technical staff responsible to the coordinating committee to assist in an on-going review.	Not implemented.