GRAND RIVER WATERSHED
Water Management Plan

Grand River Watershed Water Management Plan

Drought Contingency Plan: Local Actions in the Grand River Watershed

Version 1.0

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Definitions and Abbreviations

Ontario Low Water Response Program (OLWR)* – provincial program to respond to low water conditions in the Province of Ontario. The program is intended to ensure provincial preparedness, to assist in coordination and to support local response in the event of a drought.

* the OLWR program is under review as of 2014. The updated program is expected to be launched late in 2014 or early in 2015.

Ontario Water Directors Committee (OWDC) – provincial committee made up of water policy directors from five provincial ministries with leadership roles in water management: Ministry of Municipal Affairs and Housing, Ministry of Economic Development and Trade, Ministry of Agriculture, Food and Rural Affairs, Ministry of the Environment and Climate Change and the Ministry of Natural Resources and Forestry.

Water Managers Working Group (Water Managers) – a watershed based group of municipal, provincial and federal water managers who represent partners to the water management plan in the Grand River watershed and have direct water management responsibilities in the watershed.

Low Water Response Team (Response Team) – a watershed based group of local water users, who coordinate local activities under the OLWR program to help to mitigate low water conditions at Levels 1 and 2, and prepares recommendations for actions to the Province when conditions in the watershed reach Level 3. Representation in the group includes representatives from municipalities, provincial agencies, local water use sectors, First Nations and special interest groups.

Senior Operator – a GRCA engineer who is responsible for reservoir operations. Usually 4 to 5 active senior operators rotate the responsibilities of reservoir operations on a weekly basis.

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Preface

Drought contingency planning is a very complex undertaking in a watershed such as the Grand River where there is a variety of water users and overlapping jurisdictions regarding water management. A comprehensive plan for drought needs to be integrated into all water management planning decisions and requires integration of multiple planning levels. This report is one part of the drought planning process and focusses on local actions during a drought and recommendations for future water management planning in terms of drought readiness. Proactive and integrated water management will ultimately be needed to find long term solutions for drought in the Grand River watershed.

The Drought Contingency Plan described in this document is not a static plan, but will evolve overtime. It is expected that the document will likewise undergo multiple revisions with time. A version number and date will be given to each version and included in the foot note to each page, with older versions archived at the Grand River Conservation Authority.

Summary

The plan begins by stating the objectives of the drought plan and giving a description of the limitations of this type of document. The next section describes the watershed including current water use, areas of water use conflict, types of water sources and their potential vulnerability, as well as drought monitoring. The drought plan section begins with general actions and priorities of water use and then provides separate plans for each type of water use for the largest water users in the watershed including reservoir operations. The main document finishes up with a section on drought recovery.

Two appendices accompany the document. The first details different indicators of drought including: Ontario Low Water Response indicators, reservoir indicators, environmental flows and groundwater levels. The second appendix provides an outline for conducting a reservoir operation's review during a drought event and details past actions taken when deviating from normal reservoir operations. These two appendices may be updated more or less frequently than the main plan and support the information in the drought plan. A third appendix is provided as a link to the report on the Whiteman's Creek Drought Pilot Project in 2013, which is the main source of information for agricultural irrigation section presented in the plan. This project continued into 2014 and additional reports may be added in the future.

The plan and appendices will be updated as needed with changes discussed with the Low Water Response Team at their annual start up meeting each spring.

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1. Introduction

The drought contingency plan for the Grand River watershed details procedures to be carried out in times of extreme low water conditions to ensure water is available for essential use and all users in the watershed share the burden of low water conditions. The objections of this plan (see Box: Objectives) were formed as part of previous drought planning in the Grand River watershed.

This plan is meant to work in tandem with the Ontario Low Water Response Program (OLWR), which is administered by the Ministry of Natural Resources and Forestry and coordinated within the Grand River watershed by the Grand River Conservation Authority (GRCA). The OLWR program defines thresholds for three increasing levels of severity for low water conditions and outlines increasing levels of action for each level. The first two levels include voluntary water use reductions to mitigate low water conditions. The third level is the point of extreme low water (or drought) and is the point when regulations may be enacted to mitigate drought conditions. Decisions to enact regulations are in the hands of provincial ministries through the Ontario Water Directors Group (OWDG). This plan is focused on local actions during more severe drought conditions (e.g. Levels 2 and 3).

Objectives

- maintain municipal, domestic and livestock water supplies
- minimize economic loss
- avoid long term loss of fish and wildlife populations and habitats
- avoid actions that risk the security of future supplies
- share the impact of water shortage among the users, in accordance with the priorities for water allocation during a drought:
    - **essential** – required for health
    - **important** – social and economic importance
    - **non-essential** – aesthetic uses

(adapted from Grand River Response Team Terms of Reference)

For this plan there will not be a direct definition of drought or a specific threshold as to when drought starts, instead a set of watershed conditions will be used to determine when alternative action needs to be taken to lessen the impact of drought conditions and continue to provide water for essential use. Different indicators of drought for the watershed are included in Appendix A. Each drought situation is unique and will require different responses based on conditions. In some cases additional work is recommended to determine actions available to lessen the impact of drought.

Drought is a complex phenomenon with no standard definition (Environment Canada 2012). There are varying definitions available based on: area affected, duration, intensity, antecedent conditions, and the watershed's ability to adapt to water shortages (Environment Canada 2012). In the Grand River watershed, recent drought conditions were the result of extended periods of low precipitation that resulted in low stream flows and a drop in groundwater levels. Low groundwater levels result in low groundwater discharge to streams and wetlands, and can lead to a reduction in water available for domestic and municipal supply. Increased water use during dry conditions can worsen drought conditions. In addition, for parts of the river system where flows are augmented by reservoirs, unplanned emptying of a reservoir (e.g. for safety or maintenance reasons) can have similar effects as meteorological drought and will be included in this plan.

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2. Grand River Watershed

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. Multi-purpose reservoirs capture runoff from snow melt and heavy rains and release stored water to maintain flow in the central and lower river system to support water supply, wastewater assimilation and aquatic ecosystems (GRWMP 2013). Groundwater discharges further augment surface flow and support cold water streams in the central part of the watershed. The lower watershed is influenced by activities upstream with the ultimate outlet of the river to Lake Erie at Port Maitland.

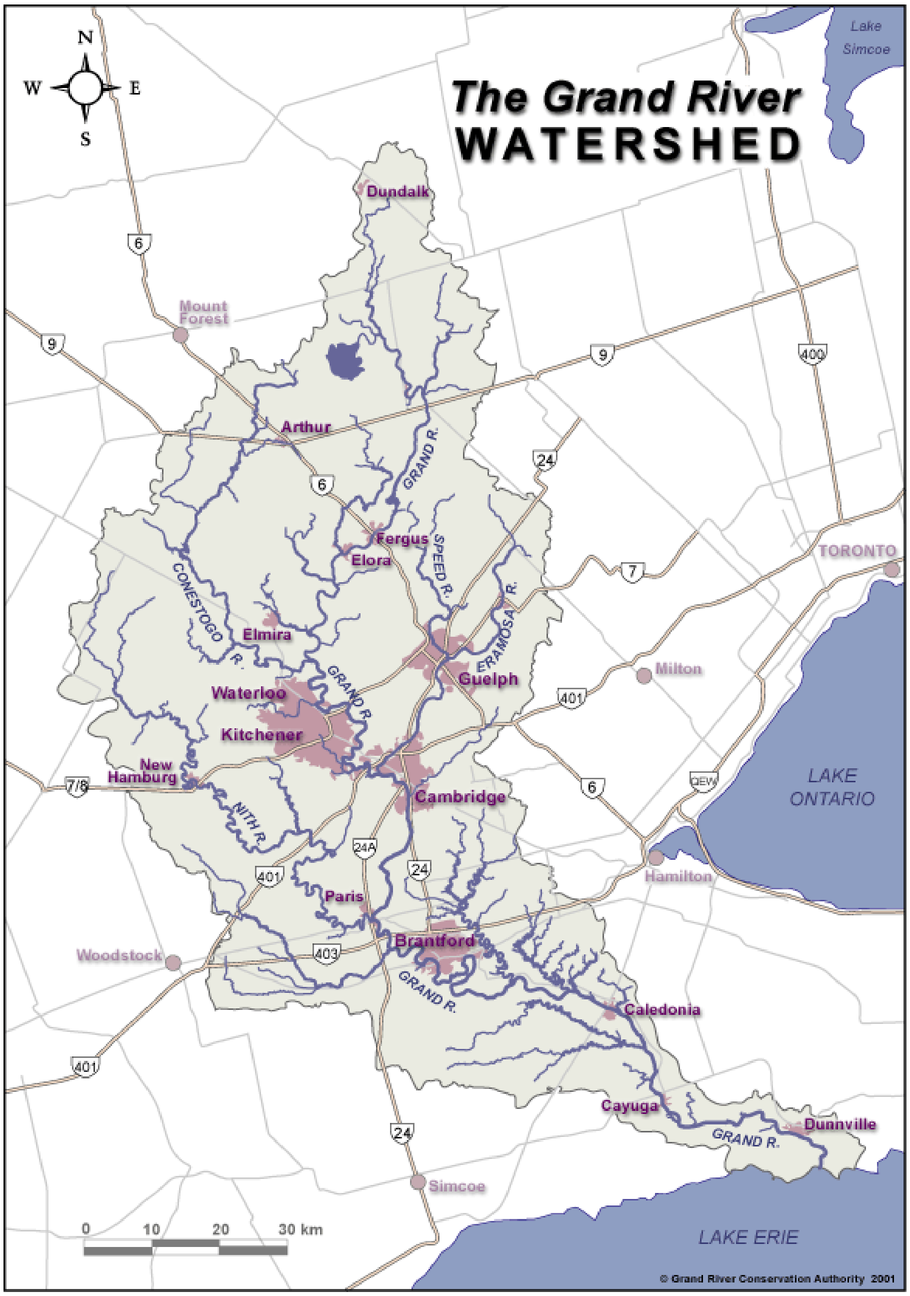

Figure 1. Map of the Grand River Watershed

Although the predominant land use across the watershed is agriculture, most of the population of the watershed lives in urban areas in the central part of the watershed. Municipal supply is the largest water use (Wong 2011). Urban areas in the central part of the watershed rely mostly on groundwater resources, both overburden and bedrock, while the City of Brantford gets all of its water from the Grand River. Other large water users include agricultural irrigation, livestock watering, rural domestic supply and aggregate washing (Wong 2011). There are many sources of water including watercourses, groundwater and the Great Lakes.

The Grand River watershed has experienced droughts and low water conditions in the past. One long term data set that shows drought periods over the last century is the average annual water level in Lake Erie (Figure 2). Droughts of the 1930's and the 1960's are clearly visible as periods of low water levels. These decades were especially dry periods with reports of wells and streams going dry and high crop losses (Klaassen 2000). The late 1990's and early 2000's appear on Figure 2 as a short and less intense dry period, but the Grand River watershed had some of the lowest stream flows on record, low groundwater levels, low reservoir levels and agriculture stresses (ECO 2008). Conditions experienced during 1998/1999 in part, prompted action from the provincial and municipal governments resulting in: development of the OLWR program, re-establishment of a provincial groundwater monitoring program and development of water use limits such as outdoor water use bylaws by municipalities. More recently, the watershed experienced short but significant low water conditions in 2007 and 2012. These droughts were too short and localized to be seen in the level of Lake Erie.

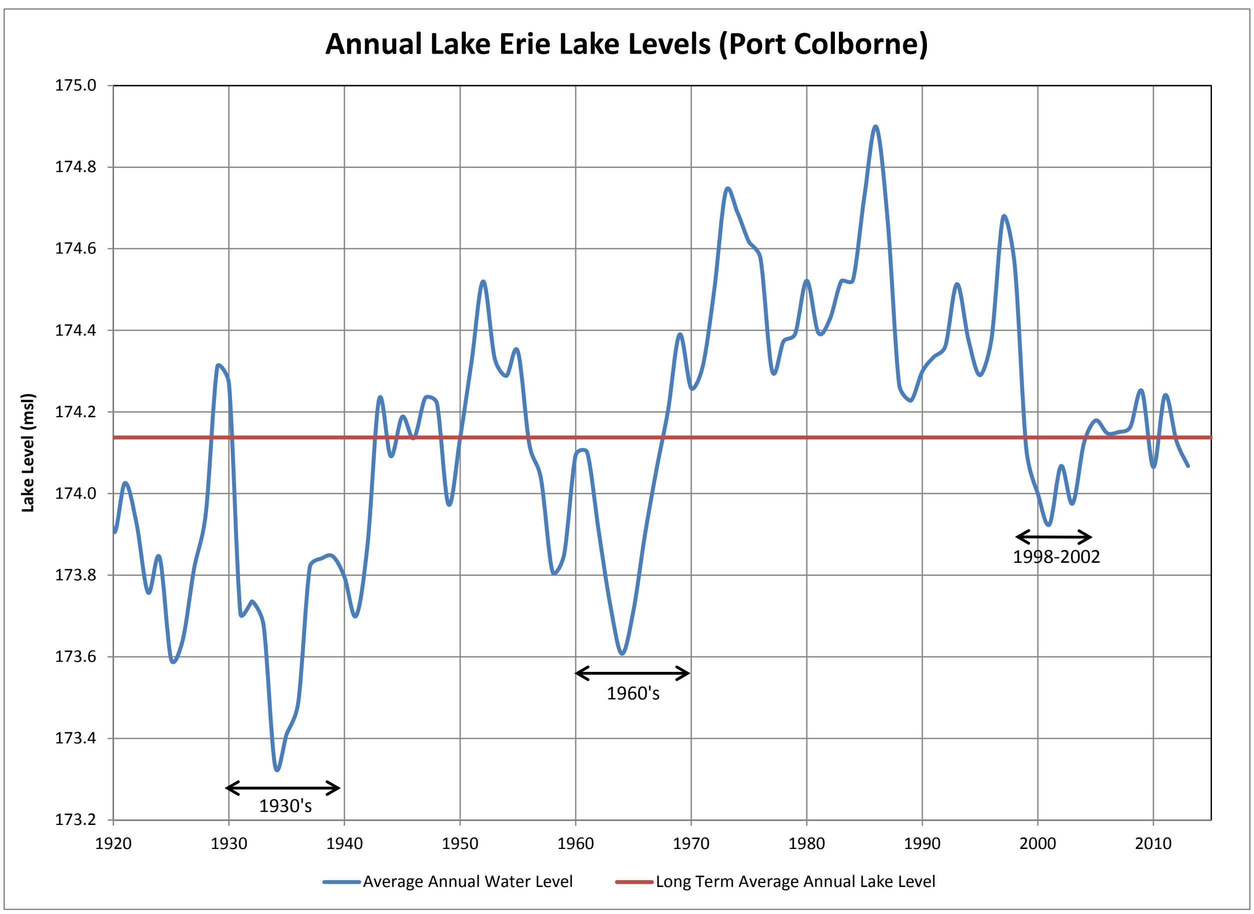

Figure 2. Annual lake levels for Lake Erie at Port Colborne (Source: Canadian Hydrographic Service)

2.1. Water Sources

Water sources fall under two categories: surface water and groundwater. Surface water sources include watercourses, reservoirs, ponds and the Great Lakes. Surface water originates from direct precipitation, runoff from rainfall and snow melt, reservoir discharges, groundwater discharges and anthropogenic discharges such as treated wastewater effluent or dewatering operations. Groundwater sources include shallow and deep overburden aquifers, and bedrock aquifers. Groundwater is accessed through sand points, dugouts, dug wells, bored wells and drilled wells. Recharge for the groundwater system can originate within the local area for shallow systems, while for the deeper bedrock system recharge can extend outside the watershed boundaries.

Drought will affect each water source differently. Decisions on use of one source versus another should be based on the vulnerability of the source to drought and the effects of the taking to other water users including ecological requirements. During a drought all water takings should be reduced as much as possible.

Surface Water

Drought conditions often appear first in the surface water system when low precipitation results in reduced surface runoff. Watercourses with low baseflow will be affected by relatively short dry periods, and these watercourses routinely run dry. Watercourses with high baseflow, from either groundwater discharge or augmentation from reservoirs, will become affected as the drought progresses. Loss of groundwater discharge during a drought, as a result of a low water table, can affect watercourses following the perceived end of the drought as it can take years for the groundwater system to recover to pre-drought levels.

The reservoir system and regulated river are a special case in the Grand River watershed. Operation of the reservoirs was designed to reduce flooding and provide water for municipal supply and wastewater assimilation during periods of low flow (GRWMP 2013c). The system was designed to meet or exceed low flow targets 95% of the time. Small short-term dry periods typically do not affect reservoir operations and flows remain stable in the lower river. A prolonged dry period or dry conditions during the normal reservoir filling period can affect reservoir water levels and result in reduced river flows. These effects may last longer than the perceived end of the drought, often until the next filling cycle of the reservoirs. The sustained flows in the regulated river system are highly managed for wastewater assimilation, municipal water supply and minimum environmental flows, with little capacity for additional water taking.

Maintaining flow in watercourses is essential to avoid long-term damage to the aquatic ecosystem and to support municipal water takings and wastewater assimilation. To maintain flow during dry periods the rate of water takings is more important than the total amount of water taken from the watercourse. As well the cumulative taking of water from a watercourse needs to be considered and plans should take into account both upstream and downstream conditions when evaluating the amount of water available for taking.

Groundwater

Groundwater resources in the Grand River watershed are robust and are essential for human and ecosystem health. The groundwater system is slower to react to drought conditions because of the inherent storage within the subsurface and the delay between the surface and subsurface systems. A reduction in recharge because of a lack of rain may not be seen in groundwater levels for months.

Groundwater systems also takes longer to recover following drought, as infiltrated water may take weeks, months or years to reach and replenish affected aquifers. The effects of a drought may not appear in the groundwater system until years later, in some instances after the meteorological drought has passed.

Groundwater is very important in the Grand River watershed. Not only do most of the people depend on groundwater for drinking water, but it is also a key source of water for industrial and commercial needs. Groundwater discharges also maintain many ecological features including: wetlands, cool and cold water ecosystems, and sustains flow for many water courses. A drop in groundwater levels will not only result in a decrease in discharge to surface water features, but may result in surface water features losing water to the groundwater system.

Droughts will first affect the shallow groundwater system, especially unconfined aquifers, while deeper groundwater systems will be affected by longer droughts. The timing of the drought will also affect the groundwater system differently, drought during a key recharge period (i.e. spring) has a much greater effect than drought during a low recharge period (i.e. summer). The longer the drought, the more depleted the groundwater system and the longer it will take to recover.

Drought Vulnerability of Sources

Vulnerable water sources are sources that are at risk of being unavailable during a drought. Reasons that sources are unavailable include low water levels, restrictions on the source, and interference with other water users. Vulnerable sources include most surface water sources, with small order streams and unregulated rivers especially vulnerable to drought. Shallow groundwater sources are also vulnerable, especially close to streams and wetlands where groundwater discharges support ecosystem health. Deep overburden and bedrock takings are usually the least vulnerable, unless there is interference with local domestic or municipal wells. If the drought is for a prolonged period even the deep groundwater sources will be affected and it generally takes longer to recover following the drought, so the impact to the deeper groundwater system may last for years. Another source of vulnerability is excess takings of a single source, for example a high concentration of shallow groundwater takers in the Norfolk Sand Plain region (See Section 2.2).

2.2. Water Use Conflicts

Water conflicts are related to the regional availability of water, population and various water user groups. The major water users in the watershed are municipal supply, dewatering activities, agricultural use and aggregate operations (Wong 2011); ecosystems are also a major water user. Conflicts originate when multiple users require the same water source. Conflicts can originate between water user groups or within groups in the same geographic region. Key geographic regions with reoccurring or projected future water conflicts are: Central Grand River, Norfolk Sand Plain Region, the Lower Nith River and the Eramosa River (Figure 3).

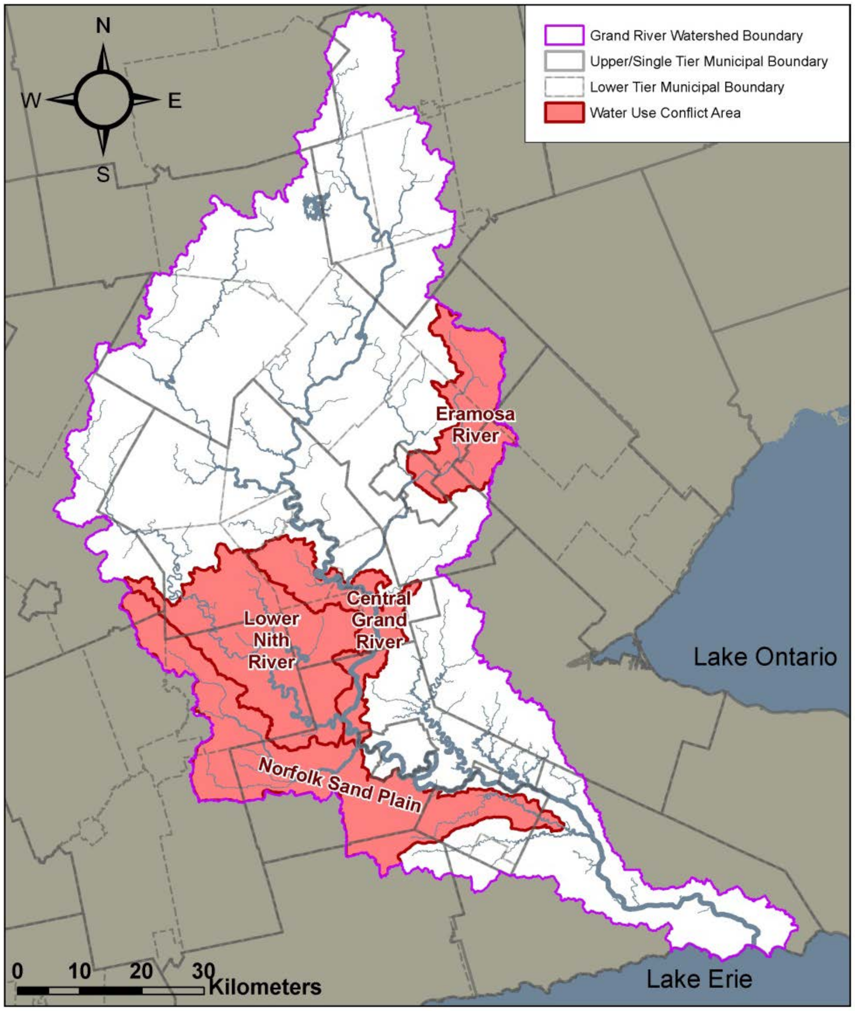

Figure 3. Water Use Conflict Areas

Central Grand River

The central Grand River, from the Conestogo River to Brantford, has a diverse collection of water takers. Much of this area is urbanized, including the Cities of Waterloo, Kitchener, Cambridge and Brantford. Municipal water use is by far the largest water user for both groundwater and surface water, with many of the other water takings in close proximity but outside municipally serviced areas. At peak demand during dry spells, there could be as much as 20 percent of the water removed from the Grand River for a variety of uses (GRWMP 2011). High groundwater takings in the Region of Waterloo have resulted in a Water Quantity Risk Assessment for the groundwater portion of the Integrated Urban System as part of the Source Water Protection program. The Water Quantity Risk Assessment is expected to be completed in 2014.

The potential for water user conflict is high in this area. There are a high number of water users, high economic dependence on water and a potential for interference with municipal water sources. On the other hand, municipal use is the dominant user and municipalities in this area have highly developed water conservation strategies and water use bylaws. In the case of a severe drought, these bylaws will help municipalities reduce overall water use and lessen the overall impact of the drought.

Norfolk Sand Plain (Whitemans Creek, Mt. Pleasant Creek and McKenzie Creek)

The Norfolk Sand Plain is located in the Southwestern corner of the watershed. The area is characterized by well-drained soils, high water table, low runoff and good connection between the groundwater and surface water systems leading to high groundwater discharge to watercourses. Groundwater discharge supports healthy aquatic ecosystems including a Brown Trout fishery in the Lower part of Whitemans Creek (GRFMPIC 2005). The Norfolk Sand Plain has some of the largest specialty crop operations in Southern Ontario, particularly tobacco and vegetables. Specialty crops and well drained soils create a heavy demand for irrigation, especially in July and August (Wong 2011). This heavy demand places the aquatic ecosystem under stress as irrigators take water from both the creeks and the shallow groundwater system thereby reducing discharge to the watercourses.

Current water use in the Norfolk Sand Plain is almost exclusively for agricultural irrigation (Wong 2011). Water user conflicts are between separate irrigators or between agriculture and aquatic ecosystem needs. Rich deposits of granular material in the area are expected to result in more aggregate operations moving into the region in the future. There may also be pressure from expanded urban development for the City of Brantford and nearby smaller communities. Additional water users for aggregate washing or municipal needs will increase water conflicts in this already stressed region. As well, changes to precipitation and the timing of recharge, expected with climate change, can result in alterations to the groundwater system and discharge to watercourses (Shifflett 2013). This region is a high priority for future studies and water management programs.

Nith River

The Nith River is a major tributary of the Grand River, located in the western part of the watershed. The upper part of the river drains an area of till plains where runoff is high, resulting in flashy responses to rainfall. Natural stream flow is minimal during dry periods. Downstream from New Hamburg, the lower Nith passes by the western and then southern flank of the Waterloo Moraine. In this area the river picks up substantial groundwater discharge resulting in less flashy runoff and more stable flows during dry seasons. Groundwater modelling results suggest a very significant net outflow of groundwater from the Lower Nith River watershed (AquaResource 2009). This water likely flows to the east and may discharge to the Grand River in the Cambridge to Paris reach.

The lower part of the Nith River watershed has fairly high water use. The largest use of water is for municipal water supply, followed by agricultural and golf course irrigation (Wong 2011). Parts of this watershed have similar soil conditions as the Norfolk Sand Plain region and as such there is potential for an increase in agricultural irrigation in the future for specialty crops. The area also has rich aggregate resources, although there are already many aggregate operations in the area, there is potential for increased production and expansion of aggregate operations.

Eramosa River

The Eramosa River produces a steady flow of high quality water, but has been affected by recent droughts in 1998/99 and 2012. The river is considered a mixed water fishery with sections of suitable habitat for cold water fish species and other sections more suitable for warm water fish species (GRFMPIC 2005). To maintain these habitats it is critical that the water table level is maintained to support groundwater discharge into the river and tributaries (GRWRT 2012). The watershed is also home to provincially significant wetlands (PSW), areas of natural and scientific interest (ANSI) and environmental sensitive areas (ESA).

Water takings are not numerous in the Eramosa River, but there is pressure for growth and development of the subwatershed. Surface and groundwater taken from the Eramosa River watershed is used for agriculture, aquaculture, golf course irrigation, municipal water supply and recreation (Wong 2011). Development of municipal water takings in the lower part of the watershed for the City of Guelph has caused concerns and an extensive monitoring program has been developed to study the effects of the water takings. The extensive monitoring program is part of a larger adaptive management plan for the area. The City of Guelph also has a surface water intake on the Eramosa River, but it is not used during drought periods. Discharge from the Eramosa River aids in effluent assimilation for the City of Guelph wastewater treatment plant on the Speed River.

2.3. Monitoring for Drought

Drought can manifest itself in different ways depending on the timing, length, extent and severity of the dry period. Monitoring for drought includes review of precipitation, stream flow, reservoir levels and groundwater levels. Different triggers or indicators are available to predict and determine the occurrence of drought conditions. These indicators can be set based on difference from normal conditions or as a point when adverse effects are expected. Which indicator to use will be dependent on individual water courses and conditions of the drought period. Specific flows, water levels and conditions that indicate drought are included in Appendix A.

An example of an indicator that is set based on differences from normal conditions is the OLWR triggers. In the OLWR program the stream flow triggers are based on reduction from normal summer low flow and are given as: Level 1 <70%, Level 2 <50% and Level 3 <30% (MNR 2010). An example of indicators set based on adverse effects are environmental flows, such as flows needed for fish migration between pools. One way of estimating flow needed for fish migration is to analyze the stream bed to determine the minimum flows required to maintain 20cm water depth over riffles (GRWMP 2013). Figure 2 shows low water flows for Whitemans Creek near Mount Vernon over the period of record. The colour of the dots represents when flows were below the OLWR program triggers and the labeled lines represent the environmental flows required for fish migration (GRCA 2005). Although these flows may be similar in some cases they represent different considerations when managing for drought conditions.

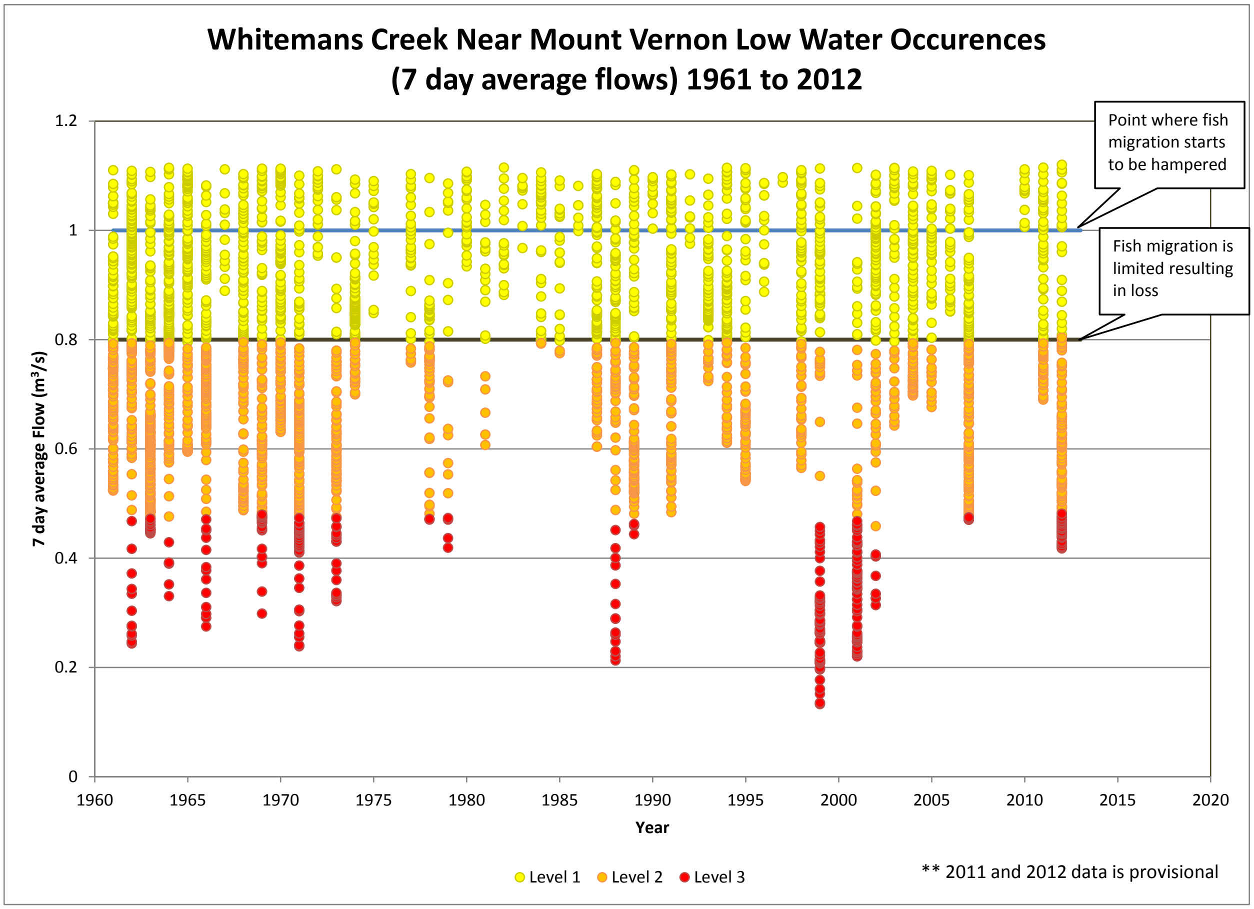

Figure 4. OLWR stream flow triggers for Whitemans Creek at Mount Vernon

To plan affectively for pending droughts, GRCA staff monitors conditions on a daily, weekly and monthly basis. The senior operator reviews reservoir levels, flow targets and weather forecasts each day as part of the daily planning cycle. There is a senior operator meeting once a week where conditions over the past week are discussed along with the outlook for the upcoming week. During the summer or a dry period OLWR triggers are reviewed at least weekly, but often daily. Each month, monitoring data is reviewed and presented to the GRCA board as a Watershed Conditions Report. The report includes analysis of precipitation, temperature, reservoir conditions, water quality, stream flow, augmentation levels, groundwater levels and the level of Lake Erie, along with updates on activities related to flood preparedness and low water response. Potential low water or drought conditions are caught early allowing for early action and mitigation.

3. Drought Plans

There are limits to drought contingency planning at the watershed scale because of the complexities in jurisdictions regarding water in Ontario. This plan is focused on past work the GRCA and watershed partners have completed for actions during and prior to drought and gives recommendations for future long term planning. In many cases actions to mitigate drought are limited and losses can be expected. The focus of this plan is to identify ways to minimize economic and ecological losses, while maintaining human health. Drought should be included in all aspects of water management planning.

The OLWR program focuses on all water users voluntarily reducing water use by equal amounts. Although the equal sharing of water restrictions may seem fair, it discourages development of less vulnerable sources or more efficient water use and restricts options for water users during a drought. This plan recognizes that not all water sources are the same and conservation efforts should be taken into account. During a drought reducing use of some water sources will have a larger impact than other water sources. By focusing on alternatives to drought vulnerable sources, the entire watershed can be in a better position to reduce the negative ecological and economic effects of drought. That being said, during severe drought there may be few actions available and long term ecological damage or high economic losses may be unavoidable.

3.1. Priority of Water Use

During a drought water will be limited. As the drought escalates and conditions worsen, the effects of continued water takings will further deplete supplies and priority must be put on some water uses over others. The OLWR program divides water uses into three classes: essential, important and non-essential (MNR 2010). These water use categories have been adopted for use in the Grand River watershed.

Essential water uses deal with human and animal life and health. These include: domestic water for drinking, cooking and washing; water for livestock needs; water for public institutions such as hospitals and schools; and water needed to retain basic ecological functions. Generally, there are no arguments with these needs being essential, although conflicts have arisen in the past about the needs for ecological functions versus needs for agricultural food production.

Important water uses are those that are important for the social and economic well being of a particular area. Uses include: commercial, industrial, agricultural irrigation and some recreational uses. This class covers a wide variety of water uses and there often needs to be priorities within this class. Decisions on priorities within this class will result in economic hardship to certain businesses. In the past, water use reductions in this class have focused on equal sharing of the burden of low water for all users, but if future droughts are extensive or over the long term, there may be the need to prioritize one use over another.

Non-Essential water uses are uses for aesthetic purposes and uses where there are no long term damages if the use is stopped for a short period. These include: lawn watering, fountains, swimming pools and vehicle washing. Bylaws in most municipalities limit these uses during dry conditions for users on the municipal system, but there are limitations to controlling these uses for users on private systems.

During a drought essential water uses have the highest priority and will be maintained throughout the drought whenever possible. Important water uses have the second highest priority and will be maintained as long as there are no short or long term impacts to essential water uses. Non-essential water use should be stopped at the first signs of a drought or low water situation.

3.2. Roles

Action during drought periods involves multiple agencies and programs within the Grand River watershed. The two main local groups that will direct actions during drought conditions are the Grand River Water Response Team (Response Team) who are the local group which deliver the OLWR program in the Grand River watershed, and the Water Managers Working Group (Water Managers) who coordinate the implementation of the Grand River Watershed Water Management Plan and other water management programs within the Grand River watershed. Both groups have many of the same agencies represented, including municipalities who are the largest water user group.

The Response Team will take a lead role in coordinating drought messaging to the media. Any of the agencies and water user groups represented by the Response Team and the Water Managers Group, can use their own messaging and media contacts, but should ensure messaging is consistent across the watershed by relying on the Response Team media releases as a starting point. Media messaging by all agencies should be shared with the Response Team in order to complete documentation for Level 3 requests under the OLWR program.

The GRCA has both a direct and an indirect role during drought conditions. Indirectly, the GRCA is the facilitator of both the Water Managers Group and the Response Team and as such will coordinate response from these two groups. Directly, the GRCA is responsible for reservoir operations and maintains an extensive monitoring network in the watershed. Discharges from the reservoirs mitigates dry conditions in the lower Grand and Speed Rivers, and supports municipal surface water takings at Kitchener, Brantford and Oshweken. The GRCA monitoring network includes stream flow, reservoir level, precipitation, temperature, and groundwater level monitoring equipment. The GRCA uses the data from this network to monitor for drought on a routine basis.

However, it is the water users in the watershed who have one of the greatest roles during a drought. Water use is one of the few parts of a drought that humans have some control over. Reducing water use and moving to less vulnerable water sources is dependent on the individual water users for both permitted and unpermitted use.

3.3. General Actions

There are a number of actions during and prior to a drought that are applicable to all water users. These actions are listed in Table 1, along with some examples of each action. The list in Table 1 is not exhaustive. Some of the actions are repeated again in the following sections when a particular action is especially tied to the type of water use.

Generally, these actions can be undertaken by all water users both prior to and during drought. These are individual actions that require little coordination between water user groups, but may require prior planning. During a drought it is important to minimize water use and impacts to other water users whenever possible.

Table 1. Actions for all water users

Timing	Action	Examples
Prior to Drought	increase water storage	- build onsite ponds to store water during high flow periods - build cisterns, reservoirs or install storage tanks
	develop less drought vulnerable water sources	- develop alternatives to surface water from small order streams - use deeper groundwater systems instead of shallow systems - develop sources disconnected from sensitive ecological features
	develop redundant water sources	- backup wells to use when surface water source is unavailable - wells in different aquifers
	develop water conservation strategies	- review water use to look for changes to processes - develop a leak detection program - install drip irrigation
	include drought contingency in business plans	- build reserve funds to cover production losses - make a plan to shift production to other facilities or time of year during a drought
During a Drought	reduce water taking	- use water from storage - increase conservation efforts - stop unnecessary water use - reduce or shift production
	lessen impact of water takings	- reduce pumping rate for surface water sources - reduce total taking from groundwater sources - switch to less vulnerable water sources - spread takings amongst multiple sources - stop taking from sources connected to ecological features or interfering with other users
	stop water use	- stop production - do not plant crops - stop all water use, unless essential - coordinate sharing of water with essential uses

3.4. Reservoir Operations

There are five large multi-purpose reservoirs (Shand, Conestogo, Guelph, Luther and Woolwich) owned and operated by the GRCA in the Grand River watershed. Flow in reaches downstream of the reservoirs is regulated by the operation of the dams, resulting in flow that is more consistent. This consistent flow supports municipal water supplies, wastewater assimilation and ecological function (GRWMP 2013). There are additional medium and small reservoirs that can be used for flow augmentation during periods of low flows, but these smaller reservoirs are not primary flow augmentation reservoirs. The reservoir operating policy and procedures date back to the early 1980’s with the most recent update in 2004 (Boyd 2004).

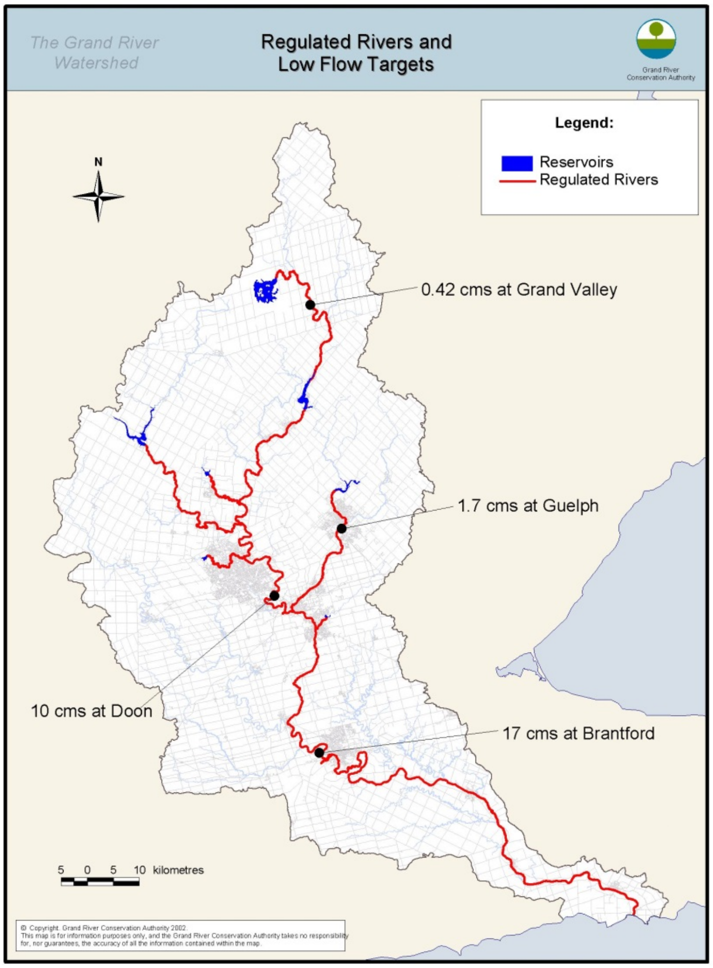

Figure 5. Major reservoirs and flow target locations

A set of low flow targets for different locations in the river system, have been established based on being met with 95% reliability. The targets were set based on the assumption that 5% of the time the targets may not be met. Drought conditions, along with emergencies and required maintenance, are captured within this 5%. Table 2 gives the low flow targets within the watershed. For more information on the reservoir system, flow reliability and minimum river flows see the document *Flow Reliability: Regulated Reaches of the Grand River Watershed* (GRWMP 2013c).

Table 2. Normal low flow targets within the Grand River watershed.

Location	Watercourse	Jan-Apr (m^3/s)	Mary-Sep (m^3/s)	Oct-Dec (m^3/s)
Grand Valley	Grand	0.42	0.42	0.42
Below Shand Dam[3]	Grand	2.8	2.8	2.8
Doon	Grand	2.8[1]	9.9	7.1
Brantford	Grand	17[2]	17	17[2]
Below Conestogo Dam[3]	Conestogo	2.1	2.1	2.1
Below Guelph Dam[3]	Speed	0.57	0.57	0.57
Below Guelph Gauge	Speed	1.1	1.7	1.1
Elmira	Canagagigue	0.3	0.3	0.3

1. Winter target at Doon under review
2. Brantford target is officially during the summer only, but has been used as a year round target
3. Targets are the lesser of the flow target or inflow to the Dam

The drought plan for the reservoirs comes into effect when there is a potential to deviate from the normal operating strategy because of a water shortage or an anticipated water shortage to meet flow targets. When there is concern regarding a water shortage (see Box: Reservoir Review Triggers) a Senior Operator will initiate a detailed review of reservoir conditions. Instructions for conducting a reservoir conditions review are provided in Appendix B. If the reservoir review results in a recommendation to alter the operating strategy or if it is anticipated that there will need to be a change to operating strategies in the near future the Senior Operator will contact the Chair of the Water Managers group to call a meeting to discuss the situation. A decision to drop below the flow target for a short period (i.e. less than 7 days) or during an emergency is at the desecration of a Senior Operator and does not require consultation with the Water Managers Group.

Reservoir Review Triggers

- major reservoir near lower rule curve (May – September)
- major reservoir below the lower rule curve for an extended period (year round)
- major reservoir does not reach or is expected to reach May 1st levels
- low reservoir levels for winter augmentation
- augmentation season starts before May 1st or augmentation demand of greater than 70%
- very dry conditions (e.g. 10th percentile for cumulative precipitation, Level 2 or 3 precipitation trigger, no winter snowpack, etc.)
- major reservoir offline for an extended period (e.g. repairs)

*(Major reservoirs are Shand, Conestogo, Guelph, Woolwich and Luther)

GRCA staff will provide the Water Managers Group with a report, based on the reservoir review, outlining the situation including a recommendation for reservoir operations. This report will include a description of the current situation and forecast conditions for the normal operating strategy, the recommended operating strategy and other alternative strategies as required. Examples of past reports and a template for reports are given in Appendix B.

The Water Managers will discuss the situation and will, by consensus:

(a) agree with the GRCA's recommended operating strategy, or

(b) agree with an alternative operating strategy provided by the GRCA, or

(c) give direction to the GRCA for additional scenarios to be considered.

In the case of (c), GRCA staff will bring additional information back to the Water Mangers Group for further discussion. Throughout the drought, GRCA staff will continue to provide updates on the situation and will consult with the Water Managers Group regarding additional changes to reservoir operations following the above procedure.

GRCA staff will inform the GRCA board when deviating from the normal reservoir operating policy. Alternative operating policies will be included in the monthly watershed conditions report along with an update on conditions. A separate report will be prepared for the board detailing operations when it is anticipated that lower flow targets are needed for an extended period or when a report is requested by the board or recommended by the Water Managers Group.

A return to normal reservoir operations is at the discretion of GRCA staff through discussion amongst the Senior Operators. The Senior Operators will take into consideration precipitation, snowpack, reservoir levels, weather forecast and groundwater levels. The Water Managers may be consulted regarding a return to normal reservoir operations and will be notified by GRCA staff when the decision is made to return to normal operations.

Drought Actions – Reservoirs

GRCA Staff will:

- review water levels daily
- present and recommend alternative flow targets to Water Managers
- operate reservoirs to meet agreed on flow targets
- report to Water Managers, Response Team and GRCA Board on a regular basis regarding watershed and reservoir conditions
- determine when to return to normal operations

Water Managers will:

- review report provided by GRCA regarding reservoir operations
    - agree with the recommended operating policy;
    - agree with an alternative operating policy that was provided; or
    - give direction to an alternative scenario
- coordinate response within own organizations

Response Team will:

- declare a watershed wide Level 2 Low water condition upon adoption of alternative flow targets
- liaison with water user groups regarding actions at Level 2
- prepare documentation and recommendations for the Province to move to Level 3 as needed

Recommendations for future action:

- GRCA will evaluate reservoir yield and augmentation capabilities on a regular basis as part of the Grand River Water Management Plan

3.5. Municipal Water Supply

The predominant water taking in the Grand River watershed is for municipal supply. Municipal water supply systems provide drinking water to approximately 770,000 people and service the majority of industry in the watershed. Approximately 80% of municipal supply is from groundwater sources, 17% from surface water and the remainder from the Great Lakes (Wong 2011). There are a total of 48 municipal drinking water systems and one First Nation drinking water system within the watershed.

Most of the municipalities who own and operate water systems have a water conservation bylaw in place that restricts outdoor water use and allows for escalating levels of restrictions during times of water shortage. Some of the bylaws are tied to the OLWR program, while others are at the desecration of the system operator or municipal council. Given the potential delay in the province declaring a Level 3 under the OLWR, it is recommended that these bylaws are reviewed to ensure they can be enacted prior to a Level 3 declaration, if needed. It is also recommended that all municipalities should have a water use bylaw.

Groundwater Sources

Groundwater sources for municipal supply are fairly robust in the Grand River watershed. There have been no reports of impacted municipal wells during past drought conditions, but instances of prolonged drought do not occur often and many of the municipal sources in the watershed have not been tested during a prolonged drought. As part of the Water Quantity Stress Assessment (AquaResource 2010b) under the Source Water Protection program, modeling was conducted to assess municipal wells under drought conditions. Only a handful of wells were flagged as having large drawdowns during drought periods and further study was recommended for only one municipal system.

Most municipal wells are either bedrock or deep overburden, which are not highly impacted by short droughts. Vulnerable groundwater sources include shallow wells, wells in unconfined aquifers and municipal systems that rely on one well or one aquifer. Municipalities, through planning processes, review water needs and supply on a regular basis. It is recommended that drought assessment of municipal groundwater sources is included during the review process and a municipal water use bylaw is in place to reduce non-essential water use during times of drought.

Surface Water Sources

The municipal surface water intakes on the Grand River are affected by reservoir operations and are considered when recommending alternative operating strategies for the reservoirs. The intakes at Brantford and Ohsweken are the only source of water for these communities and as such are an essential use of flow augmentation water. The intake for the Regional Municipality of Waterloo represents 20% of their required water supply. All three intakes on the Grand River are within backwaters created by in-river dams. As long as water flows over the dams there is enough depth to take water, although some of the water taking permits for the intakes include additional criteria to maintain ecological function and not impact water quality. Table 2 shows estimates of minimum flows to maintain municipal in river takings based on quantity only.

Flow in the Grand River has not dropped below these levels since the current operating strategy for the reservoirs was adopted in 1984. The late fall and winter season have the highest probabilities of extreme low flows because of the reservoir operating policy. A dry year with high augmentation demands will result in low reservoir levels coming into the winter season. Then if the winter is dry or very cold there is little river flow and little water left in the reservoirs for augmentation, similar conditions occurred in January 2003. A review of reservoir operations using the reservoir yield model with flow data back to 1950 and current operation policies flagged 1961 and 1999 as other possible years where these conditions could have occurred. In 1999 reservoir operations were modified early and flows remained above those listed in Table 3 (See Appendix B for more information on 1999).

Table 3. Estimated minimum river flow for municipal water supply intakes on the Grand River

Location	Est. Min Flow	Explanation
Region of Waterloo	3	1 m^3/s through each fish ladder and taking of 0.9 m^3/s, more flow is needed to maintain ecological function and water quality as per PTTW
Brantford	6 - 8	8 m^3/s in 2003 did not create issue for the intake, estimate 6 m^3/s to keep water across the 200m crest of the dam
Oshweken	6 – 8*	Information on the new intake structure was not available, but requirements are most likely similar to Brantford

The City of Guelph has a surface water intake on the Eramosa River. This intake is not affected by reservoir operations and represents a small portion of Guelph's total water needs. The permit for this taking has restrictions during drought conditions, as such this intake does not function during a drought and the City of Guelph cannot rely on this source during drought conditions.

Drought Actions – Municipal Supply

GRCA Staff will:

- manage reservoir discharges to support municipal water takings from the Grand River

Response Team will:

- coordinate with the province to protect municipal drinking water as an essential use as part of Level 3 recommendations

Municipalities will:

- enact water use bylaws to minimize the wasting of water
- bring online back-up supply sources as needed
- ensure wastewater treatment plants are producing high quality effluent to maintain river water quality

Recommendations for future:

- municipalities review water use bylaws to ensure water use restrictions can be enacted without the province declaring a Level 3
- municipalities identify drought vulnerable sources and ensure alternative sources are available and are permitted if need be
- the MOE develop procedures to fast track permitting of emergency backup sources during drought for municipal drinking water

3.6. Agriculture

Agricultural water use falls into two categories: irrigation and livestock watering. Agricultural irrigation is considered an important use of water from an economic perspective, while livestock watering is an essential use of water for humane reasons.

Livestock Watering

Livestock watering is estimated to be the 5th largest water user in the watershed with an estimated 4 to 6% of total water used (GRWMP 2013b, Wong 2011). Livestock watering estimates include: the amount of water directly consumed by livestock, cooling water, animal washing and some equipment washing, but does not include barn clean out. Water consumption by livestock is estimated to increase in the future (up to 8% of total water use) because of an increase in animals and greater demand for cooling water with hotter summers (GRWMP 2013b). Areas with high livestock watering demands coincide with areas not prone to water use conflict. Livestock watering is considered an essential use of water in the watershed.

Livestock watering does not require a water taking permit as such it is difficult to determine where water is taken from. Traditionally, it has been assumed that 50% of water was from surface water and 50% from groundwater. Observations from those working with the agriculture community, estimate that most livestock operations now use wells for the main source of water and only a small number of pastured animals use surface water during the summer period. Since livestock require a consistent water supply and herds are increasing in size most farms have replaced older dug wells with drilled wells to ensure a stable water supply. The switch to drilled wells is also in response to recent droughts when some dug wells could not keep up with demand.

With much of the livestock water sourced from deep drilled groundwater wells, livestock water is not vulnerable to short term drought. Longer droughts, which affect the deeper groundwater system, and cases where livestock are using surface water or in groundwater poor areas do require contingency planning. For the limited number of livestock operations using vulnerable sources it is recommended that alternative sources are found or water storage facilities are built for bulk water deliveries.

Drought Actions – Agriculture Livestock Watering

<u>Response Team will:</u>

- coordinate with the province to protect livestock watering as an essential use as part of Level 3 recommendations

<u>Livestock Operations should:</u>

- inspect watering and cooling equipment for leaks and inefficiencies
- ensure wells are maintained
- reduce the use of surface water and switch to other sources when possible

<u>Recommendations:</u>

- farms in groundwater poor areas install onsite storage for bulk water deliveries
- older dug wells are replaced with deep drilled wells in areas with good groundwater resources
- plan alternatives for any livestock depending on surface water sources

Irrigation

The drought contingency plan for irrigation presented in this document is based on a project completed in 2013 in the Whitemans Creek watershed. The full project report 'The Whitemans Creek Subwatershed Drought Contingency Project' prepared by Hajnal Kovacs is provided in Appendix C. The project was a collaboration by a multi-agency team in partnership with the Brant Federation of Agriculture and received funded through the Water Resources Adaptation and Management Initiative. The project focused on a collaborative approach to water management in the Whitemans Creek watershed by giving irrigators the tools they needed to manage their water use and plan for drought conditions. A drought contingency specialist worked with individual irrigators with a focus on improved irrigation efficiency and establishment of alternative water sources to taking irrigation water directly from the creek.

Agricultural irrigation is estimated to be the third largest water user in the watershed (Wong 2011). Although irrigation occurs throughout the watershed, it is concentrated in the Norfolk Sand Plain region with some pockets of high use in other areas where sandy soils are prevalent. Specific watersheds with high agricultural irrigation include: Whitemans Creek, McKenzie Creek, Mt. Pleasant Creek and the lower Nith River. There is the potential for high water use conflict in these areas between irrigators, with other water users and with ecosystem needs. Water sources for irrigation include watercourses, dugouts, sand points and wells.

Although not unique to irrigation, the conflict between water needed for human livelihood and water for ecosystems is especially heated in the Norfolk Sand Plain region where a healthy cold water fishery exists in an area with heavy demand for irrigation water. With the high potential for economic hardship with a loss of irrigation water, the agricultural community is under a lot of stress resulting in the potential for negative social and economic consequences during a drought. Long term water management planning is needed in this region to alleviate this issue. One goal to date has been to move irrigation to water sources that are less likely to interfere with ecosystem water needs, such as dugout ponds instead of watercourses. Additional work on drought and water management planning for this region is ongoing.

Agricultural irrigators in the Grand River watershed are generally very responsible with their water use not just because it is costly to irrigate, but because they understand the value of water to their farm operation. In order to maximize revenue, farmers need to produce high quality and high yielding crops with the least amount of inputs. During drought, decision making becomes more serious as the fate of the crop is often at stake. Many farms in the watershed are independent operations and the loss of crops result in severe economic hardship.

Drought contingency planning for irrigation, as stated in the Whitemans Creek project, consists of four steps: 1) ensure irrigation systems are appropriate for their crops and are working accurately, 2) use Best Management Practices year round, 3) secure a permitted and reliable water source before a drought, and 4) plan options if the regular water source is vulnerable to drought or may create interference with an essential water use during a drought (Kovacs 2014). Table 4 lists recommended actions for irrigators prior to a drought, while Table 5 gives recommended actions during a drought. It is important to recognize that solutions to drought for heavily irrigated areas will most likely come from long term watershed planning at the community level, rather than individual contingency plans.

Table 4. Recommendations for actions prior to a drought for agricultural irrigation

Suggested Actions	Examples/Explanation
- choose irrigation system based on crop type - switch to highest efficiency irrigation system for crop type	examples: - plastic mulch and drip for produce - overhead for larger crops - drop nozzle pivots for potatoes
- routinely have irrigation systems assessed to improve efficiency	- assessments can highlight the ways irrigations systems need to be adjusted to maximize efficiency
- use a moisture meter - use evapotranspiration values	- used to determine the right time to irrigate to ensure healthy crops - can prevent over and under irrigating
- increase organic content in soil - match crops to soil types	- increases soil water holding capabilities - reduce amount of irrigation needed
- assess vulnerability of water sources	- Is there sufficient stream flow to maintain flow during taking? - How often does the source fail? - How close is a groundwater source to a stream or wetland? - How close is a groundwater source to a domestic or livestock well? - How much of the total stream flow is being taken for irrigation?
- develop less vulnerable water sources	examples: - dugouts away from streams and wetlands - deep or drilled wells
- plan alternatives if using vulnerable water sources	examples: - assess neighbouring dugouts and wells - ensure permission and permits for alternative sources are obtained - assess equipment needs to access alternative sources - build storage for bulk water deliveries

* adapted from The Whitemans Creek Subwatershed Drought Contingency Project. For more information refer to Appendix C.

Table 5. Recommendations for actions during a drought for agricultural irrigation

Suggested Actions	Examples
- prevent wastage of water	- refrain from over irrigating - prevent irrigation of non-crop areas - inspect pipes for leakage - shift irrigation to the cooler part of the day - refrain from irrigating when its windy
- maximize efficiency of irrigation system	- have an irrigation system assessment done - use moisture meter and/or evapotranspiration values to calculate amount of water needed - tune up system
- lessen impact of water takings	- switch to less vulnerable water sources - reduce pumping rate from all surface water sources - stop taking from smaller watercourses
- focus irrigation on highest return crops (prolonged or severe drought)	- review crops and conditions - consider stopping irrigation on crops with expected low rate of return - consider not investing in extra plantings - consider switching irrigation to multi-season crops when water is limited

* adapted from The Whitemans Creek Subwatershed Drought Contingency Project. For more information refer to Appendix C.

Drought Actions – Agricultural Irrigation

Response Team will:

- coordinate response within and between water use sectors
- provide direction to the province on water use restrictions based on source of water and impact to other water users within the essential and important water use categories

Agricultural Irrigators should:

- prevent wastage of water
- switch to less vulnerable water sources or contingency sources
- stop the use of water from small watercourses
- slow the pumping rate of all watercourse based takings
- evaluate the feasibility of continued irrigation

Recommendations:

- continue water management programs in areas with high agricultural irrigation
- continue support to programs to get surface water takers on small watercourses onto groundwater sources
- continue to development alternative water sources at the subwatershed or community level where required

3.7. Industry and Commercial (IC)

Most of the IC sector within the watershed is supplied by municipal water systems, but there are a few categories of large water users that are predominantly self-supplied. Aggregate washing is estimated to be the fourth largest water user in the watershed, accounting for approximately 5% of total water use in the watershed. Golf course irrigation is estimated to be the 11^{th} largest water user and accounts for less than 2% of water use. Both of these industries are dependent on water and are active during the summer low flow season. Other IC water users outside of municipal supplies and with more than 0.5% of the total estimated water use in the watershed include: miscellaneous industrial (1.4%), cooling water (0.9%), food processing (0.7%) and bottled water (0.6%) (Wong 2011).

Drought planning for self-supplied industries is the responsibility of the permit holder. These industries are part of the local economy and represent an important economic water use, therefore a drought plan is needed to maintain operations when practical during drought conditions in order to minimize economic loss.

Water dependent industries are vulnerable to drought. For IC operations in the watershed there are some actions that can be taken to prepare for drought. Water sources can be evaluated for susceptibility to drought or to restrictions that may be enacted during a drought situation. Equipment and processes can be reviewed for water efficiencies and reuse. Additional options may include connecting to a municipal supply if available, building onsite storage or finding new sources that are less susceptible to drought. It is recommended that self-supplied IC operations undertake drought contingency planning that includes economic implications of reduced operations during a significant drought. More details for the largest two IC water users are given below.

Aggregate Washing

There are a number of small and large aggregate washing operations in the Grand River watershed. Aggregate washing facilities use a recirculating system where used wash water is discharged to a settling pond where fines settle out and then recirculated back into a wash pond for reuse. Consumptive water use is minimized with some water lost to the final product and water lost through evaporation and infiltration from the ponds. The source of the wash pond water is from groundwater seeping into the pond if below the water table, as well as outside sources such as wells and rivers from which water is pumped into the pond. The water demand thus primarily comes from the need to fill the washing ponds and also to top it up when the ponds get too low (GRWMP 2012).

Most aggregate sites in the watershed have not had any issues with water availability in the past, especially for sites with below water table extraction. More vulnerable sites are ones with mostly above water table extraction, sites with perched aquifers and sites that rely on river intakes to top up wash ponds. These sites run the risk of water sources being unavailable or restrictions on takings in times of drought.

With water readily available in the past, there have been little contingency built into older aggregate operations. New sites are planning some additional water storage on the site or lining above water table ponds to reduce losses to infiltration. In water limited sites additional deep wells are often sited and permitted to provide extra water when needed.

A number of recommendations for the aggregate industry are given in Table 6. All aggregate sites need to develop their own plans for operations during droughts and should include some contingency within operating and business plans. Companies with multiple sites may also investigate shifting operations to different sites based on water availability. This will require prior planning to ensure aggregate is sourced correctly.

Table 6. Recommendations for drought contingency for the aggregate industry

Timing	Suggested Actions
Prior to Drought	build additional onsite storage
	line above water table ponds
	maintain maximum water levels when water is available
	divert site drainage to settling ponds
	develop alternative sources on water limited sites
	stockpile product when practical
	include drought contingency in business and site plans
During a Drought	use water from storage
	limit topping up of ponds
	schedule operations to allow pond levels to recover
	inspect equipment for leaks and wastage
	stop other consumptive uses
	refrain from filling new ponds
	use stockpiled product
	enact drought contingency plan

Golf Courses

Water use at golf courses varies throughout the watershed depending on course conditions and irrigation management. Changing trends in turf health, pest control, irrigation technology and public perception on course conditions has helped to lower water use on golf courses in recent years. Water sources include groundwater wells, groundwater fed ponds, direct surface water takings and ponds filled by surface runoff. Many of the courses have onsite storage reservoirs that are filled when water is plentiful and then used for irrigation during dry periods. Development of onsite storage and secondary sources increased following dry conditions in 1998/99.

During a drought, golf courses may face restrictions on water use and/or some water sources may be unavailable for use. Dugout ponds may be low because of low groundwater levels and high evaporation. Surface water sources usually have restrictions built into the PTTW to limit takings during dry conditions, especially for smaller streams. Onsite storage ponds may also be low with high evaporation and water use.

Drought and a reduction in watering can lead to poor turf that is more susceptible to pest infestation and can lead to high damage rates and the need for turf replacement. There is also conflicting public perception on brown courses with some players expecting it during dry periods and some expecting lush green turf regardless of a lack of precipitation. This can lead to economic losses with fewer players using the course and higher competition between courses with different irrigation practices.

Many golf courses have some contingency built into their overall irrigation system. As mentioned before, onsite storage reservoirs are present at many courses; these can be topped up during wet periods and then used during dry conditions. They can also be used to hold water from other sources that may have pumping restrictions such as surface water takings that should be pumped at a slower rate during dry conditions and deep groundwater wells. Golf courses also can use deeper groundwater where available. Healthy turf prior to a dry spell can go a long way to ensuring it can come back after drought conditions. Selective irrigation, greens and tees more often than fairways, is a common practice that goes a long way to minimizing water use. Courses can also step up public education about course conditions during dry periods and ways that players can help keep the turf healthy and conditions good during a drought.

Table 7. Recommendations for drought contingency for the golf course industry

Timing	Action
Prior to Drought	build onsite storage into course design
	line above water table ponds
	maintain max water levels when water is available
	divert site drainage to storage ponds
	develop alternative water sources
	invest in irrigation systems including moisture meters
	maintain healthy turf
	include drought contingency in business and site plans
During a Drought	use water from storage
	reduce irrigation to key features (e.g. greens and tees)
	use deeper groundwater sources
	reduce pumping rate for surface water sources
	inspect equipment for leaks and wastage
	time irrigation to reduce loss to evaporation or wind
	step up public education about golf courses and drought

Drought Actions – Industrial and Commercial (IC)

<u>IC PTTW holders:</u>

- include drought contingency planning in site design (e.g. increase onsite water storage)
- move to less vulnerable sources and utilise water in storage during a drought
- include drought contingency in business plans
- adopt water conservation practices

<u>Water Response Team:</u>

- coordinate response within and between water use sectors
- provide direction to the province on water use restrictions based on source of water and impact to other water users within the essential and important water use categories

3.8. Rural Domestic and Communal

Rural domestic water use is estimated to be the 6th largest water use in the Grand River watershed with approximately 4.25% of the total water use, while communal water systems are the 9th largest water user with 1.7% (Wong 2011). Water supply is almost entirely from groundwater (private and communal wells) and is considered an essential use of water to support human health. Availability of water will be dependent on the nature of the drought and the condition of each individual well. Shallow or dug wells are often more susceptible to drought conditions than deep, drilled wells. Unconfined aquifers are more susceptible than confined overburden or bedrock aquifers. Many older wells are susceptible to drought and have been replaced recently because of insufficient water.

It is up to the private well owner to plan for drought contingency. In many cases, a reduction in non-essential water use can help if water levels are low during a drought. Problem wells can be replaced, but this can be quit costly. Maintenance of private wells and pumping systems can help to keep the supply running. Another option for home owners in areas with limited groundwater resources is to install a cistern to be used during droughts. These units are supplied with bulk licensed water haulers usually from municipal systems. Proper maintenance of cisterns is important if the water is to be used for drinking water.

In cases where a private domestic well owner believes there is interference from other nearby wells they can contact the Ministry of the Environment and Climate Change.

Drought Actions – Rural Domestic/Communal

Private/Communal Well Owners:
- maintain well and ensure water use is minimised during drought
- replace dug or shallow wells with deeper wells, if available
- investigate alternative water sources (e.g. cistern or municipal)
- report to the Ministry of the Environment and Climate Change suspected well inference

Response Team:
- coordinate with the province to protect rural domestic and communal water wells as an essential use as part of Level 3 recommendations

Recommendations for future:
- programs to replace rural dug wells
- temporary cistern systems or supplies during a drought

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4. Drought Recovery

Drought conditions build overtime and recovery of a watershed from drought also takes time. A study conducted by the US Geological Survey on the North Carolina Drought of 1998-2002 showed there was a lag time of 2 to 7 months for the surface water system to respond to a return of normal rainfall, but the groundwater system did not respond for 3 to 10 months (Weaver 2005). Full recovery of the system took much longer, but in this case was quicker than previous droughts because of greater than normal precipitation in 2003.

The Grand River watershed also experienced a drought during this same period. Both 1998 and 1999 were dry years and resulted in some of the lowest stream flows recorded on tributaries of the Grand River during the summer period (Klaassen 2000). The summer of 2000 was very wet and flows were high in the surface water system, but a return to below normal precipitation in 2001 showed that groundwater levels had not recovered during the wet conditions in 2000 and groundwater fed stream flow returned to near record lows. Data from the PGMN well in Burford showed that groundwater levels in the Whitemans Creek area did not recover until 2004, almost 2 years after the return of normal precipitation.

To aid in drought recovery, contingency measures should remain in place until both the surface water and the groundwater systems have recovered to pre-drought levels or there is a risk of prolonging the effects of drought. In particular, during drought recovery groundwater takings should be reduced as much as possible and in some cases it may aid recovery to switch to surface water sources rather than groundwater. For the reservoir system a return to normal operating levels is one measure, but analysis should also look at baseflows both at the low flow target locations and for reservoir inflows to ensure reservoirs can handle a return to normal augmentation levels.

Determining when the watershed has recovered from drought is not straight forward. Below is a list of measures that can be used to determine if the watershed is back to pre-drought conditions.

Measures of Drought Recovery

- flow in watercourses are at or above the normal seasonal low flow for a period of at least one month
- during short periods with little runoff from rainfall stream flow does not dip below OLWR Level 1 stream flow indicator
- reservoir levels are back within normal operating levels or there is more than enough water in the snowpack to fill the reservoirs
- Brantford flow target is automatically met when Doon target is met
- groundwater levels in PGMN wells are near seasonal averages
- precipitation during key recharge times of the year (fall and spring) is near normal
- levels in dugouts and ponds are near seasonal levels and recover quickly following water taking
- OLWR precipitation indicator for 18 month cumulative precipitation is above Level 1

Actions – Drought Recovery

Water Use:

- continue to reduce use as much as possible from all sources
- for watercourse takings:
    - continue to use lower pumping rates
    - monitor stream and river levels
- for groundwater takings
    - reduce total pumping
    - switch takings to aquifers with highest levels if possible
    - switch to surface water sources if runoff is high

Reservoir Operations:

- baseflow analysis should be completed to determine if augmentation and reservoir levels can be maintained before returning to normal reservoir operations
- reservoir conditions should be monitored carefully during drought recovery

Response Team:

- keep the watershed in a Level 1 or 2 until both the groundwater and surface water systems recover from the drought

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GRAND RIVER WATERSHED
Water Management Plan

Drought Contingency Plan

Appendix A: Indicators of Drought

Version 1.0

Prepared by: Stephanie Shifflett

2014

Summary

Appendix A contains a list of indicators of drought for the Grand River watershed. This list is not exhaustive; there are some indicators of drought that may not be included. This appendix is meant to be updated on a regular basis as more indictors are developed or changes are made to different indicators.

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5. Introduction

Drought indicators in the Grand River watershed include precipitation, stream flow, reservoir levels and, in the near future, groundwater levels. Drought indicators change as more information becomes available and with changing climate conditions. This Appendix will be updated on a regular basis to ensure the most up to date indictors are listed.

6. Ontario Low Water Response

Low water indicators for the Ontario Low Water Response (OLWR) program were developed as a consistent way of determining low water conditions with data that was readily available (MNR 2010). Present indicators are based on stream flow and precipitation, but indicators based on groundwater levels are being developed.

Local water response teams are encouraged to use local knowledge to confirm conditions once an indicator has been met. The Grand River Response Team has modified some of the indicators based on local knowledge. Indicators are calculated on a frequent basis by Grand River Conservation Authority (GRCA) staff.

6.1. Stream Flow

Stream flow indicators are based on a percent reduction from the normal summer low flow. The normal summer low flow is defined as the lowest average monthly flow for July, August or September; with Level 1 70% of normal summer low flow, Level 2 50% of normal summer low flow and Level 3 30% of normal summer low flow (MNR 2010). Within the OLWR program stream flow indicators are different for the spring period, but the alternate spring indicators are not typically used in the Grand River watershed.

In order to catch dry conditions early in the Grand River watershed, indicators are calculated using a 7 day running average instead of monthly flows. Conditions are reviewed by GRCA staff on a weekly basis during an average summer and on a daily basis during dry periods. Reports of conditions are provided to the Response Team weekly during dry conditions and as conditions change during a normal summer season.

The Response Team uses modified normal summer low flow definitions for a number of locations in the watershed, since the lowest average flow does not represent conditions at these sites. For locations on water courses regulated by dams and with a low flow target, the normal summer low flow was set based on the low flow target resulting in Level 1 or Level 2 conditions. For watercourses with flashy response to rain events and low summer baseflow, the median was used to replace the mean in calculating the normal summer low flow.

Stream flow indicators used by the Response Team in the Grand River watershed are given in Table 1 along with notes on how they differ from indicators as defined in the OLWR guidance documents. Stream flow indicators are reviewed regularly and updated as needed.

Table 8. OLWR stream flow indicators within the Grand River watershed.

Gauge	Normal Summer Low Flow (m^3/s)	Level 1 (m^3/s)	Level 2 (m^3/s)	Level 3 (m^3/s)	Notes
Leggatt	0.6	0.42	0.30	0.18	Flow target is Level 1
Marsville	0.9	0.63	0.45	0.27	Median
Below Shand	4.5	3.15	2.25	1.35	Reservoir operations
West Montrose	7.3	5.1	3.7	2.2	Mean
Doon	16	11.2	8.0	4.8	Flow target is Level 2
Cambridge	20	14.0	10.0	6.0	Flow target based
Brantford	25	17.5	12.5	7.5	Flow target is Level 1
Above Drayton*	0.12	0.08	0.06	0.04	Median
Glen Allen	4.2	2.94	2.10	1.26	Mean
St. Jacobs	5.1	3.57	2.55	1.53	Mean
Armstrong Mills	0.3	0.21	0.15	0.09	Median
Eramosa	1.05	0.74	0.53	0.32	Mean
Blue Springs	0.3	0.21	0.15	0.09	Mean
Hanlon	2.2	1.5	1.1	0.7	Flow target based
New Hamburg	0.6	0.42	0.30	0.18	Median
Hunsburger	0.1	0.07	0.05	0.03	Mean
Alder*	0.07	0.05	0.04	0.02	Median
Canning	4.7	3.29	2.35	1.41	Mean
Aberfoyle	0.2	0.14	0.10	0.06	Mean
Mill Creek	0.5	0.35	0.25	0.15	Mean
Horner	0.5	0.35	0.25	0.15	Mean
Mt. Vernon	1.6	1.12	0.80	0.48	Mean
Fairchild*	0.9	0.63	0.45	0.27	Mean
McKenzie	0.4	0.28	0.20	0.12	Mean

* these sites are reviewed for information only

6.2. Precipitation

There are two different precipitation indicators in the OLWR program: percentage below normal and number of days without rain. The number of days with no measurable rainfall is only used to move from Level 1 to Level 2 and is defined as 2 or more consecutive weeks with less than 7.6mm of rain or 1 or more weeks for areas with a high demand for water (MNR 2010). This indicator is not used often in the Grand River watershed.

The main precipitation OLWR indicator that is used in the Grand River watershed is percentage below normal. This indicator is based on 1, 3 and 18 months of cumulative precipitation. The trigger changes throughout the year and for different climate stations within the watershed. Table 2 gives typical average values for these indicators based on a 'normal' month of precipitation. The Level 1 indicator only applies to 3 month and 18 month cumulative precipitation and is 80% of the normal precipitation for those periods. Level 2 and Level 3 apply to all three cumulative time periods and is defined as 60% of normal for Level 2 and 40% of normal for Level 3 (MNR 2010).

Table 9. Average OLWR precipitation indicators within the Grand River watershed.

Time Period	Climate Station	Average monthly (mm)	Level 1 (mm)	Level 2 (mm)	Level 3 (mm)
Average 1 month	Shand	76	--	46	30
	Conestogo	81	--	49	32
	Guelph	71	--	43	28
	Luther	80	--	48	32
	Woolwich	69	--	41	28
	Laurel	77	--	46	31
	Shades	75	--	45	30
	Brant/Burford	65	--	39	26
	New Hamburg	72	--	43	29
Average 3 months	Shand	229	183	137	92
	Conestogo	243	194	146	97
	Guelph	213	170	128	85
	Luther	239	191	143	96
	Woolwich	208	166	125	83
	Laurel	232	186	139	93
	Shades	224	179	134	90
	Brant/Burford	195	156	117	78
	New Hamburg	216	173	130	86
Average 18 month	Shand	1372	1098	823	549
	Conestogo	1456	1165	874	582
	Guelph	1280	1024	768	512
	Luther	1433	1146	860	573
	Woolwich	1249	999	749	500
	Laurel	1395	1116	837	558
	Shades	1345	1076	807	538
	Brant/Burford	1170	936	702	468
	New Hamburg	1297	1038	778	519

7. Reservoirs

Triggers for a review of reservoir operations are given in Section 3.4 of the Drought Contingency Plan. The triggers are not set based on specific values; rather they are descriptions of conditions that would warrant a further review of conditions. Further information on reservoir reviews is given in Appendix B.

Reservoir Review Triggers

- major reservoir near lower rule curve (May – September)
- major reservoir below the lower rule curve for an extended period (year round)
- major reservoir does not reach or is expected to reach May 1st levels
- low reservoir levels for winter augmentation
- augmentation season starts before May 1st or augmentation demand of greater than 70%
- very dry conditions (e.g. 10th percentile for cumulative precipitation, Level 2 or 3 precipitation indicator, no winter snowpack, etc.)
- major reservoir offline for an extended period (e.g. repairs)

A secondary set of indicators are based on if reservoir discharges cannot be maintained to support wastewater assimilation in rivers downstream of reservoirs. Table 3 lists the $7Q_{20}$ values for different discharge points along the river (GRWMP 2013). Flows at or below these values would indicate drought.

Table 10. $7Q_{20}$ values set for wastewater treatment plants discharging downstream of reservoirs.

WWTP	Winter/Spring	Summer	Fall	Gauge
Grand Valley	0.4	0.4	0.4	Leggatt
Fergus	1.4	2.7	1.5	Below Shand
Elora	1.7	2.8	1.6	Below Shand plus Salam
Waterloo	3.2	8.4	4.9	Doon
Kitchener	3.2	8.4	4.9	Doon
Preston	6.7	10.5	8.6	Galt
Galt	6.7	10.5	8.6	Galt
Paris	12.4	14.9	12.4	Brantford minus Mt Vernon
Brantford	13.8	15.4	13.2	Brantford
Caledonia	13.8	15.4	13.2	York
Cayuga	14.3	15.5	13.4	York plus McKenzie Creek
Dunnville	14.3	15.5	13.4	York plus McKenzie Creek
Guelph	1	1.3	1	Below Guelph
Hespeler	1.7	2.5	1.9	Speed at Cambridge
St. Jacobs	2	2.7	1.3	St. Jacobs
Elmira	0.2	0.3	0.3	Near Elmira

8. Environmental Flows

Environmental flows or 'e-flows', has developed into a field of research to 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).

E-flows have been calculated for various locations in the watershed. Typically e-flows cover the whole range of flow conditions from extreme high flows, such as valley forming flows, to extreme low flows, such as longitudinal connectivity. As an indicator of drought only low e-flows are included in this section. This is an evolving area of study and it is expected that using e-flow for drought management will change over time. Eventually it is hoped that e-flows can replace the stream flow indicators in the OLWR program.

E-flow values provided in Table 4 are consolidated from two reports: *Environmental Flow Requirements in the Grand River Watershed* (GRWMP 2014) and *Evaluation of Ecological Flow Assessment Techniques for Selected Streams in the Grand River Watershed* (GRCA 2005). Different reports give different types of e-flows for different watercourses. In Table 4, e-flows have been grouped under flows needed for habitat maintenance and flows needed for connectivity. Notes beside each value give explanations of the specific type of e-flow calculation. Work is ongoing throughout the watershed to have e-flows calculated for additional watercourses in the Grand River watershed.

Table 11. Low flow environmental flow requirements in the Grand River watershed.

Gauge	Habitat Maintenance		Connectivity	
Doon	8.5	littoral zone	6.8	longitudinal
Brantford	19	littoral zone	8.8	longitudinal
Below Guelph	1.1	littoral zone	0.52	longitudinal
Speed at Cambridge	1.5	littoral zone	1.1	longitudinal
Canning	2.5	wetted perimeter	2.25	fish migration
Eramosa	0.5	wetted perimeter	0.5	fish migration
Blair	0.15	residual pool	0.13	fish migration
Mill Side Rd 10	0.2	wetted perimeter	0.05	fish migration
Mt. Vernon	1.0	fish migration good	0.8	fish migration loss
Grand at Blair	4.5	wetted perimeter	3.0	fish migration

Littoral Zone – maintenance of littoral zone for habitat
Wetted Perimeter –changes in the wetted areas of the stream indicate changes in available habitat
Residual Pool – flow required to maintain residual pools in the streambed
Fish Migration (good/loss) – flows where fish migration start to be hampered or there is significant loss
Longitudinal – to maintain connection between riffles and pools with 0.2m of flow depth over riffles

9. Groundwater Levels

Groundwater monitoring varies throughout the watershed. There has not been a formal drought indicator developed for groundwater levels in the Grand River watershed, although the Ministry of Natural Resources and Forestry (MNRF) and the Ministry of the Environment and Climate Change (MOECC) are working on one for the OLWR program. The GRCA monitors water levels at PGMN (Provincial Groundwater Monitoring Network) wells throughout the watershed. Some of these wells have been used in the past to review conditions during a drought, but in the future it is hoped that groundwater levels can be used as a formal indicator of drought.

In addition to the PGMN wells, water levels in kettle lakes, dugouts, and groundwater fed wetlands are used as a relative indicator of the shallow groundwater levels. Again there is no formal indicator level developed, but local knowledge of typical water levels in these groundwater dependant systems are good indicators of drought. Another indicator of the severity of the drought is a review of baseflow in groundwater fed watercourses. Low baseflow is often an indicator of a prolonged drought and a return of normal baseflow an indicator of the end of the drought. Baseflow will be further characterized as part of the Water Management Plan and low water indicators developed.

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GRAND RIVER WATERSHED
Water Management Plan

Drought Contingency Plan

Appendix B: Reservoir Conditions Review and Alternative Operating Strategies

Version 1.0

Prepared by: Stephanie Shifflett

February 2014

Summary

Appendix B gives detailed instructions and examples for conducting a review of reservoir operations including evaluation of alternative operating strategies. Considerations for recommending different low flow targets are given along with examples of strategies used and reports provided to the water managers group.

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10. Introduction

Early drought contingency planning in the Grand River watershed included building reservoirs in the mid-20th century. The large reservoirs are dual purpose reservoirs designed to both mitigate flood flows and provide flow augmentation during periods of low flow. Flow augmentation during the summer months has reduced the number of reoccurring low water issues. The reservoir operating policy was designed such that low flow targets can be met 95% of the time (GRWMP 2013). Flows below targets are possibile within the other 5% of the time. This Appendix gives guidance on reservoir operations when flow augmentation is outside of normal operations, in order to mitigate impacts to downstream users and prolong partial flow augmentation.

The large reservoirs in the Grand River watershed are operated based on a policy that balances flow augmentation and flood control. The policy has developed over time with the current policy formed in the late 1970's and early 1980's with some minor revisions in 2004. Information on flow reliability and reservoir operations can be found in "Flow Reliability: Regulated Reaches of the Grand River Watershed" (GRWMP 2013) and "Grand River Conservation Authority – Reservoir Operating Policy" (Boyd 2004).

Operation of the reservoir system is very active with daily, weekly and monthly review of reservoir conditions. The reservoir operations planning cycle is designed to identify potential issues early, giving plenty of time to warn in the case of floods and plan alternatives in the case of droughts. Reservoir operations are reviewed on a daily basis by a Grand River Conservation Authority (GRCA) engineer through the role of the Senior Operator. The Senior Operator reviews reservoir levels and ensures flow targets are met on a daily basis. On a weekly basis senior operators meet to discuss reservoir operations, weather conditions and the future outlook for both flood and drought conditions. Each month watershed conditions are reviewed by GRCA staff and presented to the GRCA board.

The daily and weekly review of reservoir operations are part of routine operations and are the mechanism to identify potential issues early. The Comprehensive Reservoir Conditions Review takes place only when there is concern of not being able to meet low flow targets. A number of reservoir conditions triggers are given in Section 3.4 of the Drought Contingency Plan. A Comprehensive Reservoir Conditions Review is different than routine daily, weekly and monthly reviews in that it involves forecasting reservoir conditions into the future including alternative reservoir operating policies.

11. Comprehensive Reservoir Conditions Review

From Section 3.4 of Drought Contingency Plan:

> "The drought plan for the reservoirs comes into effect when there is a potential to deviate from the normal operating strategy because of a water shortage or an anticipated water shortage to meet flow targets. When there is concern regarding a water shortage (see Box: Reservoir Review Triggers) a Senior Operator will initiate a detailed review of reservoir conditions. … GRCA staff will provide the Water Managers Group with a report, based on the reservoir review, outlining the situation including a recommendation for reservoir operations. This report will include a description of the current situation and forecast conditions for the normal operating strategy, the recommended operating strategy and other alternative strategies as required. "

11.1. What to include in a reservoir review

The reservoir review should be set up as a technical memo using the current GRCA memo template and be addressed to the Water Managers Group. The basic outline for the memo is included below.

Recommendation: summarize the recommended operating strategy

Report:

Current conditions: precipitation, conditions at the reservoirs of concern, groundwater levels or discharge, other watershed conditions of interest e.g. wetland levels (see section 2.2)

Forecast Conditions: short and long range weather forecasts, reservoirs under normal or the current operating strategies (see Section 2.3)

Operating strategies: optional depending on number of strategies investigated, provide a description of each strategy, the resulting river flows and any concerns or implications of each strategy (see Section 2.4)

Recommended Operating Strategy: discuss the reasons for the recommended strategy, flow targets and reservoir conditions

Subsequent memos to the Water Managers Group should follow the same template with slight changes to the content covered based on agreed upon changes to reservoir operations.

11.2. Current Conditions

The main body of the report starts with a section detailing current conditions and describes the conditions that have led to concern regarding reservoir levels and river flow targets. Most of the information for this part of the report is summarized monthly in the Watershed Conditions Report to the GRCA board and the associated spread sheets. There should be sections on precipitation, stream flow, water quality, reservoir conditions and groundwater levels. Additional topics that may be included are: wetland conditions, aquatic ecosystem observations and water use activities.

Further updates to the water managers group should include an update to conditions including the resulting changes to reservoir conditions based on previous changes to reservoir operations and how changes to the flow targets are affecting water quality and aquatic health.

11.3. Forecast Conditions

The next section deals with forecast conditions, starting with a discussion of short and long term weather forecasts. Short-term weather forecasts are available from Environment Canada, the Weather Network, NOAA and the MNR extranet site. Long term weather forecasts, or seasonal forecasts, are available from Environment Canada and NOAA websites. During a drought there is a focus on precipitation, but temperature is also an important factor. In the summer temperature can affect river water quality and will affect evaporation from the reservoirs. In the winter, temperature is important to determine whether precipitation falls as rain or snow and how the snowpack will melt. Forecasts of snow and the condition of the snowpack are also key pieces of information for drought planning.

The other main component of the forecast conditions is the forecast of reservoir conditions. All memos to the Water Managers Group should include a forecast of reservoir conditions under the current operating strategy. This may be the normal operating strategy or an alternative strategy that has been previously approved.

There are two main ways of forecasting reservoir conditions: doing a storage balance using a spread sheet or using a reservoir yield model. The main difference between the two methods is the complexity of the scenarios. In a short term drought or when a single reservoir is involved then the storage balance method is sufficient to make decisions. During a multi-year drought or when multiple reservoirs need to be optimized a more complex approach such as the reservoir yield model can be used. An example of the storage balance method is given at the end of this section.

Similar assumptions are needed for both methods including assumptions of reservoir inflows, evaporation from the reservoir and local inflows to the targets. It is easiest to assume that these values will remain static during the course of the forecast, but in reality they will very, especially during short rainfall events. Assuming these values are static or only change seasonally is a conservative approach. Tables 1 and 2 give suggested assumptions for estimating reservoir inflow and local flows. Each drought is different and alternative assumptions may be more appropriate. All assumptions need to be stated and included in the discussion of alternatives.

Table 12. Assumptions of inflows to reservoirs.

Reservoir	Inflow Assumptions during a drought
Luther	No inflow
Shand Dam[1]	Estimate baseflow at Marsville[2] and add in any discharge changes at Luther
Conestogo	Upper Conestogo has very little flow during drought. Can assume no inflow or very little inflow based on Drayton and Moorefield
Guelph	Estimate baseflow at Armstrong Mills…during drought Armstrong Mills can be <0.1m^3/s
Woolwich	Estimate baseflow at Floradale…during drought Floradale can be <0.1m^3/s

1. Inflow to Shand Dam is the most complex and needs to include operations at Luther Dam
2. During low flows Marsville sometimes under estimates flows, review flow record carefully

Table 13. Assumptions of local flows to downstream flow targets.

Target Location	Local Flow Assumptions during a drought
Grand Valley	Estimate: Leggatt minus Luther discharge or assume no local inflow
Doon	Estimate: Doon minus West Montrose and St. Jacobs
Brantford	Estimate: Brantford minus Galt
Hanlon	Estimate: Eramosa gauge or use past low flow for Eramosa ($0.3m^3/s$ 2007, $0.2m^3/s$ 2001, $0.1m^3/s$ 1999)
Elmira	Assume no local inflow

1. Inflow to Shand Dam is the highest and the most complex based on operations at Luther Dam

<u>Storage Balance</u>

Example: Guelph Dam

Work in 1 day time steps.

1. Assume an inflow series (Armstrong Mills) and convert to m^3/day.
2. Assume a local flow series for the Hanlon Target (Eramosa) in m^3/s
3. Subtract the local flow series from the flow target (or modified flow target) to get the needed discharge from the dam in m^3/s. Convert the value to m^3/day
4. Use most recent storage value for Guelph Lake as a starting point. Add inflow to reservoir (1) and subtract discharge from dam (3) to calculate new reservoir storage value. Ensure all values are in similar units (dams/day or m^3/day).
5. Proceed to the next day

Notes: these procedures can be used for the Grand River Flow targets, but the storages, inflows and discharges from Conestogo and Shand Reservoirs need to be combined as through it is one reservoir. With the Grand River flow targets the inflow and local series should be fairly constant to not introduce too much error in the calculations because of delays in reaching downstream targets.

<u>Reservoir Yield Modeling</u>

There are currently three reservoir yield models. Luther Dam and Guelph Dam have separate "stand-alone" models that are in spread sheets. There is also the larger reservoir yield model which includes Shand, Conestogo and Guelph reservoirs. This model operates in DOS, with text input and output files. Reservoir yield modeling uses more complex decision algorithms than the storage balance method, but there are many assumptions in the models which need to be understood before using the model.

More information on reservoir yield modeling is available in: Flow Reliability: Regulated Reaches of the Grand River Watershed 2013, Technical Memos for the City of Guelph Long Term Supply Project 2005, and Luther March Reservoir Yield Analysis 2004.

11.4. Operating Strategies

The alternative operating strategies given in this section focus on changes to the low flow targets to extend augmentation, additional strategies that deal with filling the reservoirs or using additional water in storage are given in Section 3 of this Appendix.

Although alternative operating strategies are given separately below, in practice a combination of strategies over time or for each reservoir is often the most appropriate and examples are given at the end of this section. Reservoir operations during drought conditions must balance the needs for current water usage, while not jeopardizing the ability for the reservoirs to provide water into the future.

Specified Lower Flow Targets

The flow target is dropped to a specified flow rate (e.g. target at Brantford is lowered from 17 to 15 m^3/s). This alternative operating strategy can occur as a one-time decrease or in steps. It can be timed to coincide with a change in river processes, such as a drop in water temperature, or based on calendar date (e.g. fall target starts on Sept 1st instead of Oct 1st). A one-time decrease can also occur early in the season in anticipation of prolonged drought conditions or during subsequent years of a multi-year drought. When the flow target is decreased early it is usually by a smaller amount and can be very effective at conserving water in storage to prolong augmentation. Often targets are lowed in steps with small changes to the flow target on a periodic basis (e.g. target dropped from 17 to 16 m^3/s on Sept 1st then target dropped to 15 m^3/s on Oct 1st).

Advantages:

- Easy to follow and straight forward.
- Water managers know what flows to expect in the river.
- Good preservation of water in storage.
- Timing and amounts of each decrease can be tied to river processes.

Disadvantages:

- Can result in sudden decreases in flow.
- Tying changes to river processes or seasons can be problematic resulting in waiting too long with higher discharge rates.
- Early flow decreases can result in flows that are low for a prolonged period

Examples:

Early Decreased flow target (1999)

1999 was the second year of a multi-year drought. Dry conditions in 1998 resulted in very low reservoir levels at the end of 1998. The winter months did not result in a large snowpack and by the spring of 1999 it was evident that Conestogo and Luther reservoirs would not be filled to their normal spring filling levels. In March of 1999 an alternative operating strategy was proposed with the flow target at Doon decreased to 8m^3/s from 10m^3/s for the summer period. By mid-July sufficient precipitation had fallen to increase the target up to 9m^3/s.

The early reduction in the flow target in this case allowed for more flexibility in terms of reservoir operations in 1999 and resulted in a higher flow being maintained for a longer period. With a multi-year drought groundwater discharge is lower resulting in low baseflow. Even with higher precipitation for a period, flows can drop quickly in between precipitation events. A return of normal precipitation helped to alleviate low water conditions in 1999.

Stepped Decrease (2007)

In 2007, dry conditions occurred in the latter half of the summer. By mid-September alternative flow targets were adopted. The alternative operating strategy resulted in a monthly decrease in flow targets through the fall (Table 3). An effort was made to decrease flows gradually at each step to minimize sudden changes to flows and prevent the stranding of fish.

Table 14. Low flow targets in 2007 within the Grand River watershed.

Location	Normal Targets			2007 Targets		
	Sept (m^3/s)	Oct (m^3/s)	Nov-Dec (m^3/s)	Sept (m^3/s)	Oct (m^3/s)	Nov-Dec (m^3/s)
Doon	*9.9*	*7.1*	*7.1*	8.0	5.9	5.0
Brantford	*17*	*17*	*17*	14	14	12
Below Guelph Gauge	*1.7*	*1.1*	*1.1*	1.1	1.1	1.1

The reduction of flow targets preserved storage in the Shand and Conestogo Reservoirs, shown in Figure 1. Flow dropped below the normal flow target for periods, but was not stable Figure 2. Flows increased as the result of rainfall events throughout the period.

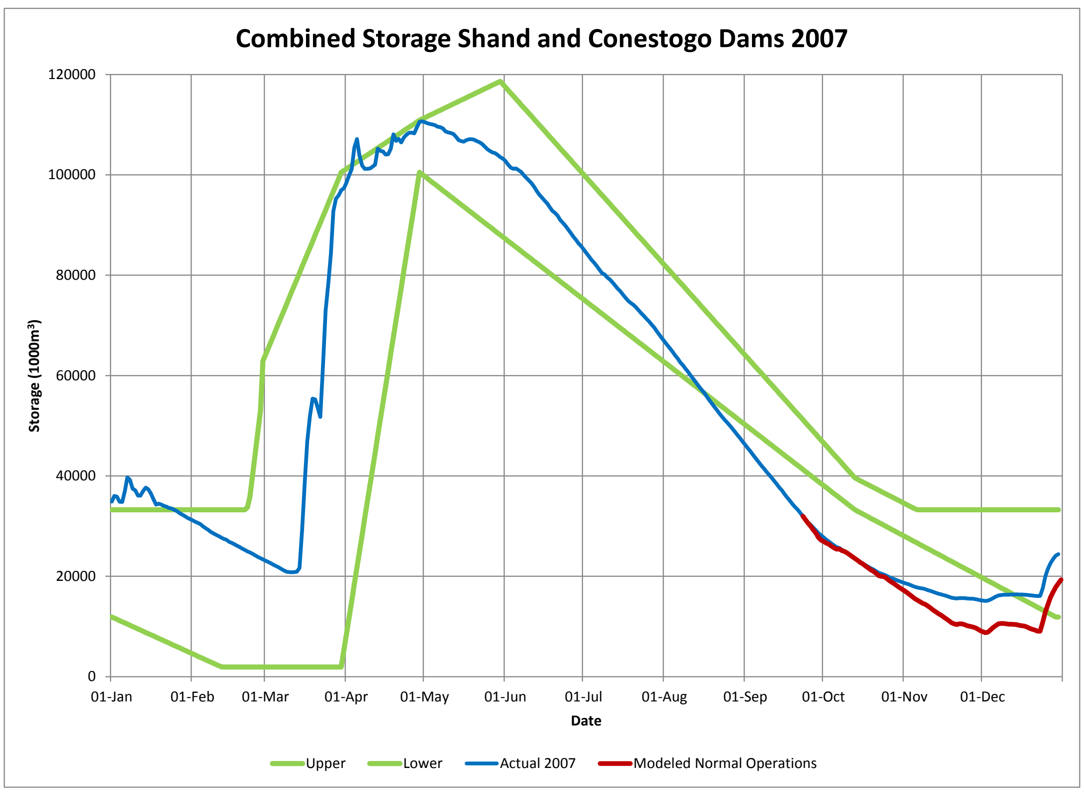

Figure 6. Storage chart for Shand and Consestogo Dams in 2007

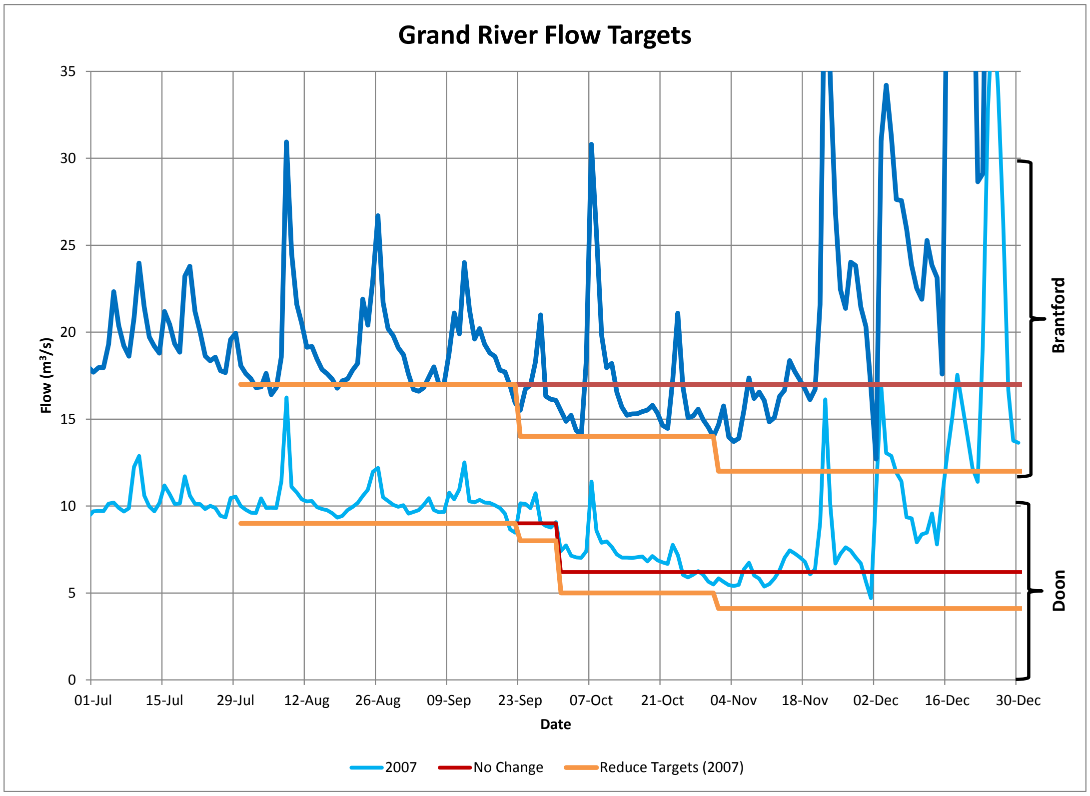

Figure 7. Flow rates at Brantford and Doon in late summer and fall of 2007

<u>**Percentage Decrease by Shortage**</u>

The flow target is decreased by a percentage to match the storage deficit (e.g. if there is a storage deficit of 5% below the lower rule curve then the flow target is reduced by 5%). This alternative strategy is very similar to the one provided in the Reservoir Yield model. Each flow target is looked at differently based on the upstream reservoirs to that target.

Advantages:

- Result in a gradual decrease in flow in the river.
- Return to normal operations is also gradual.
- Good for short term shortages.

Disadvantages:

- Constantly changing flow targets.
- Requires more reservoir operations.
- No consideration of river processes.
- Not effective at preserving storage beyond the short term.

Examples:

Speed River August 2012

Dry conditions in 2012 resulted in the Guelph Reservoir dropping below the lower rule curve by mid-July. By the start of August an alternative operating strategy was adopted in which the low flow target at Hanlon was decreased by the same percentage that the storage in the Guelph Reservoir was below the lower rule curve.

Figure 3 shows the water in storage in 2012 at the Guelph reservoir and the estimated storage if normal operating procedures were followed. The alternative operating policy did preserve some water in storage throughout the month of August, but not a lot. In early September the flow target was dropped to the fall flow target. The decrease in the flow target in September preserved more water in storage than the percent decrease by shortage method used in August.

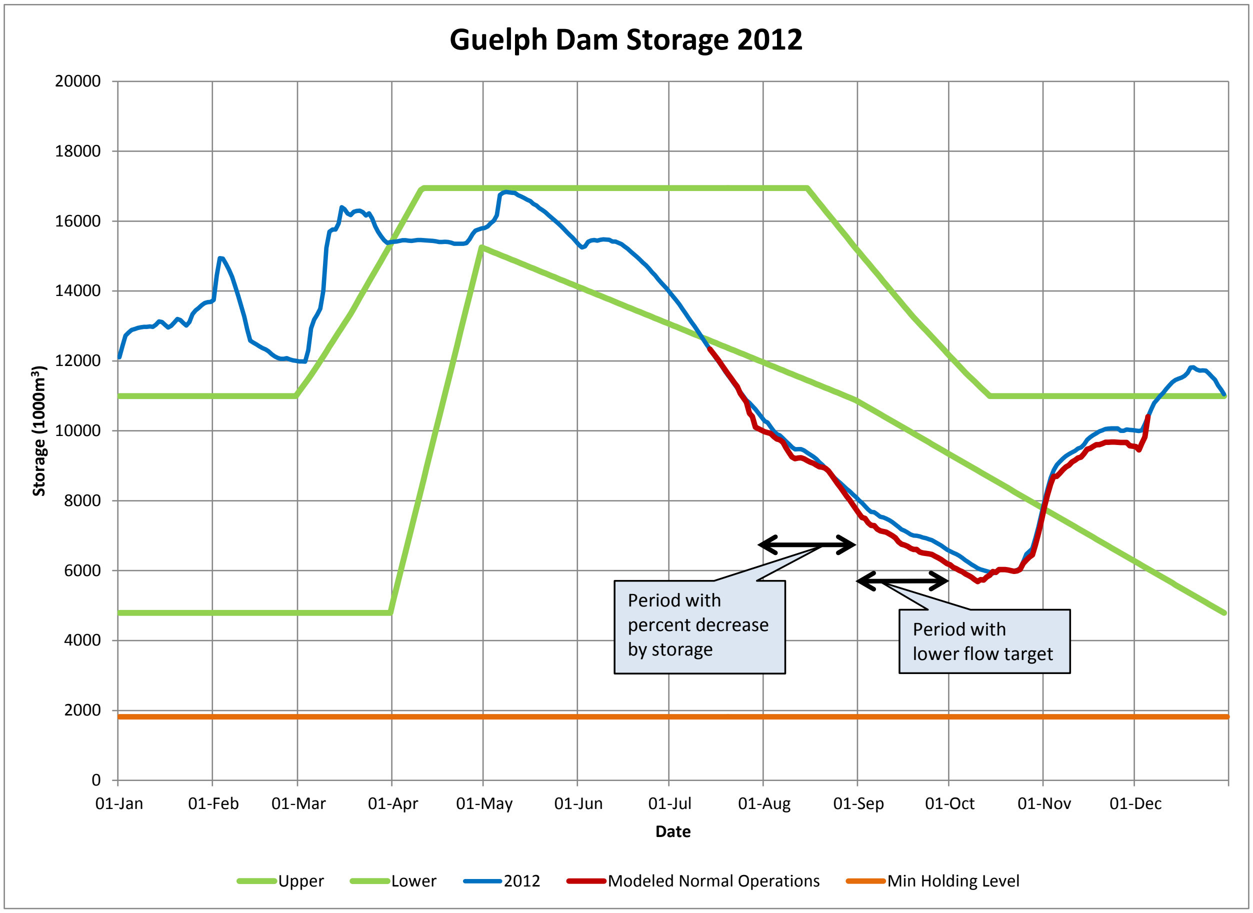

Figure 8. Storage chart for Guelph Dam in 2012, including modeled storage under the normal operating policy

A further example of the combination of strategies that was used in 2012 is given in the final example in this section.

Hold Reservoirs above a specified level

Instead of focusing on downstream flow targets, a minimum reservoir level is set and if levels reach it the dam will pass inflows only. This strategy is not used on its own, but with other strategies to provide a minimum level of flow augmentation and avoid running the reservoirs dry or damage the in reservoir fishery. Discharges are not static and will change with changes to inflows. The specified level may be based on operational constraints, but can also be above reservoir minimums in order to protect the in reservoir aquatic ecosystem or to maintain minimum storage from one season to the next during a multi-year drought. During normal operations many of the smaller reservoirs use this strategy during the winter (i.e. winter holding level).

Advantages:

- Avoid running reservoirs dry.
- Can be used to hold water from one season to the next.
- Often based on operational constraints of the reservoirs.

Disadvantages:

- Can result in very low discharge.
- Not practicable as the only strategy during a drought and should be paired with other strategies.

Example:

Table 4 gives the minimum operating levels for the three largest dams from 2012 and the reasons each level was chosen. These levels were not reached in 2012 because of a return to normal reservoir operating levels in early November as a result of higher precipitation in October.

Table 15. Minimum operation level for three largest reservoirs.

Reservoir	Level	Explanation
Shand Dam	410.7 m	Avoid freezing of the 48” valve and hydro intake. Provide a conservation pool for the in reservoir fishery.
Conestogo Dam	381 m	Avoid freezing of the gates. Provide a conservation pool for the in reservoir fishery.
Guelph Dam	340 m	Maintain water above the top of the gates. Provide a conservation pool for the in reservoir fishery.

<u>**Combination of strategies**</u>

Most drought situations will require a combination of the above strategies, along with some of the additional reservoir operating considerations given in Section 3 below. A typical response to drought will progress through stages with very minor changes to operations in the beginning, larger reductions in flow targets during the middle part and ultimately a minimum reservoir level.

Example:

Summer and Fall 2012

Dry conditions in 2012 affected the entire watershed. By August an alternative operating strategy was adopted in which the low flow targets were decreased by the same percentage that the storage in the upstream reservoirs were below the lower rule curve. This strategy affected the Speed River target more so than the targets on the Grand River and is described in an earlier example.

By September there was no recovery in reservoir levels and additional decreases to the targets was needed. The low flow targets were decreased to specified lower levels in September with a second stepped decrease planned for the start of October. Planning for the event of a dry fall and winter began and minimum reservoir levels were reviewed and stated in correspondence to the Water Managers Group. Precipitation increased in the latter half of October and reservoir levels recovered by November ending the need for the alternative operating strategy. The minimum holding levels for the reservoirs were not reached in this instance.

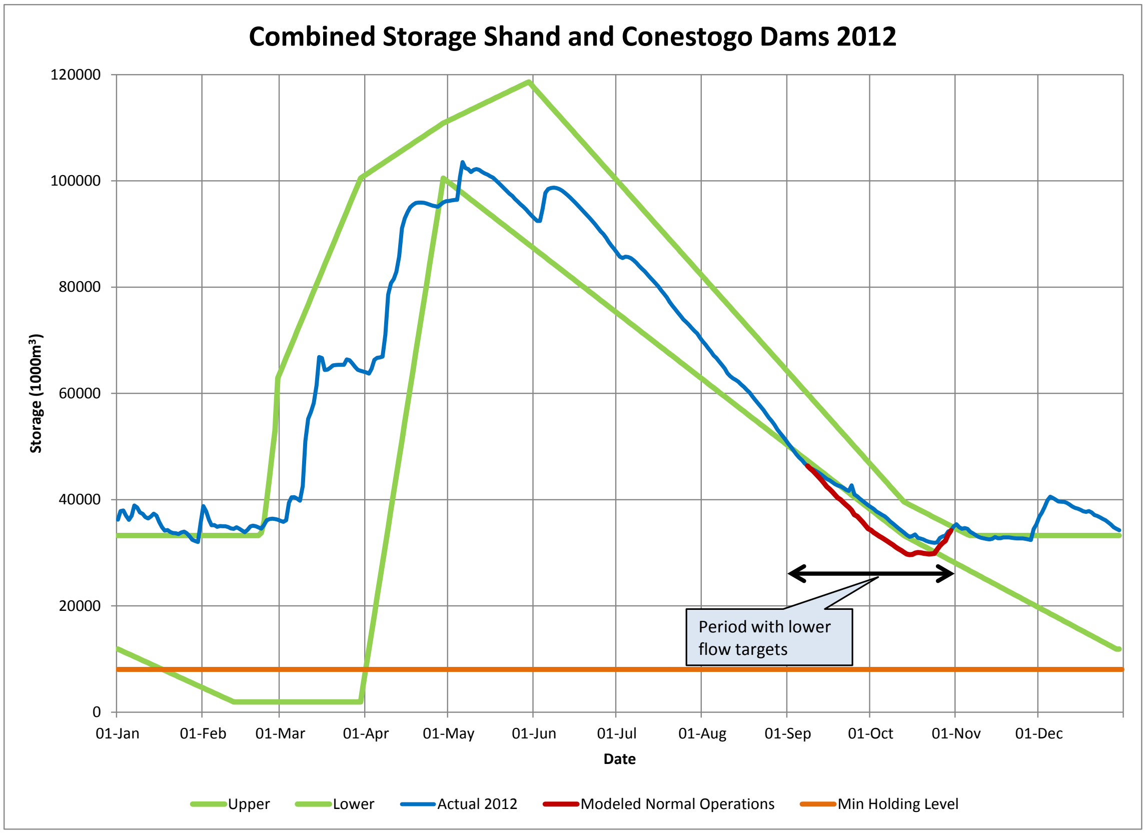

Figure 9. Combined storage chart for Shand and Conestogo Dams in 2012, including modeled storage under the normal operating policy

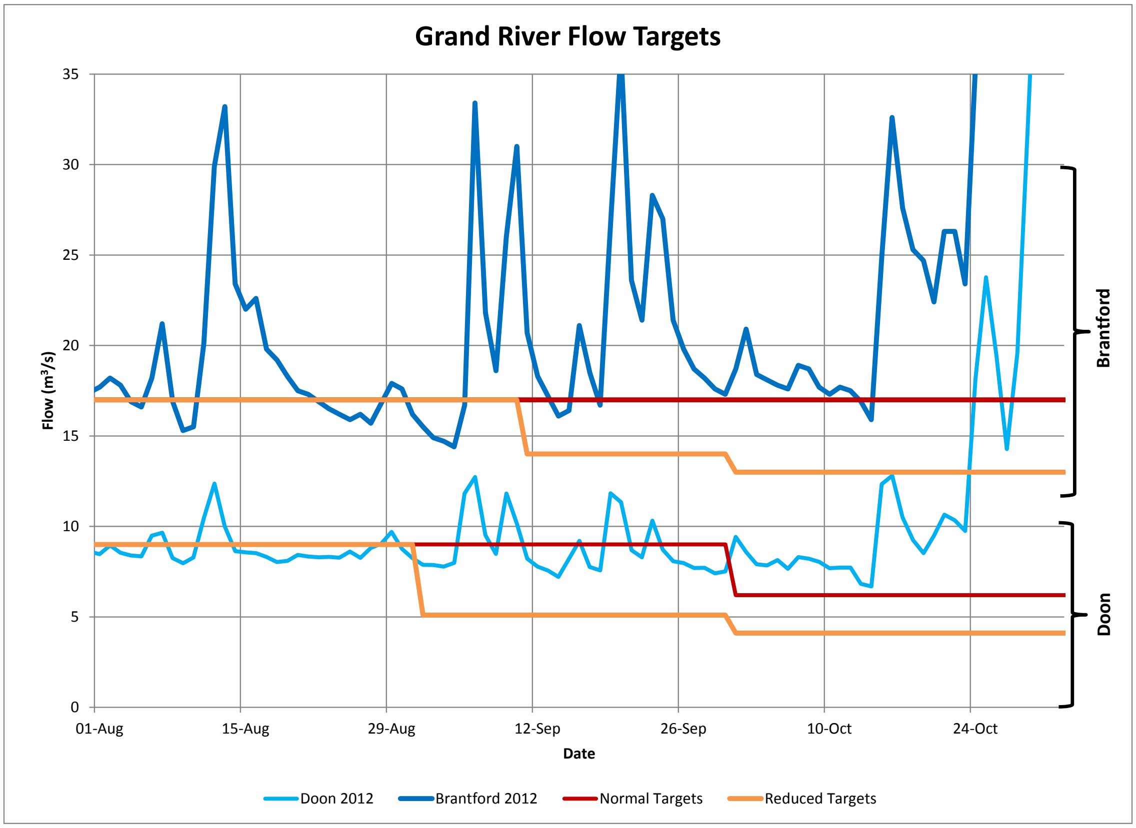

Figure 10. Grand River flows and targets in late summer and fall 2012

12. Additional Strategies for Reservoir Operations during a Drought

Changes to the low flow targets are not the only changes to reservoir operations during a drought. There can also be changes to the reservoir filling cycle and there is additional water in storage in other reservoir or below regular operating levels that can be used to help to alleviate low flow conditions.

12.1. Filling Cycle/Winter Holding Levels

Changes to augmentation and low flow targets are just part of the reservoir cycle that needs to be considered during drought conditions. The filling cycle is a key period to ensure reservoirs are replenished each year and continue to provide water for augmentation. The worst situation is a dry summer and fall resulting in low reservoir levels followed by a winter with a limited snow pack and resulting small spring freshet.

Traditionally reservoirs are filled to April 1st levels with snowmelt during March and then filled to May 1st levels with spring rains. Augmentation reliability calculations are based on reservoirs reaching the May 1st level. In low snowfall years or when a warm winter results in multiple melt events, this traditional way of filling the reservoirs may need to be modified to ensure the reservoirs reach May 1st targets. Two strategies have been used in the past to ensure reservoirs reach spring filling targets: higher winter holding level and capturing mid-winter melts. Both of these methods result in low winter augmentation levels and can result in reservoir levels above the upper rule curve for an extended period.

Example:

Guelph Dam Winter (2012)

The winter of 2012 had low precipitation and fairly warm temperatures. The snowpack was light with many small mid-winter melts. A decision was made early in the winter to hold the reservoir level slightly above the upper rule curve unless a snowpack started to form. Melt water from an early March melt was captured and the level remained above the upper rule curve until the start of April. Reservoir levels at Guelph Dam in 2012 are given in Figure 6.

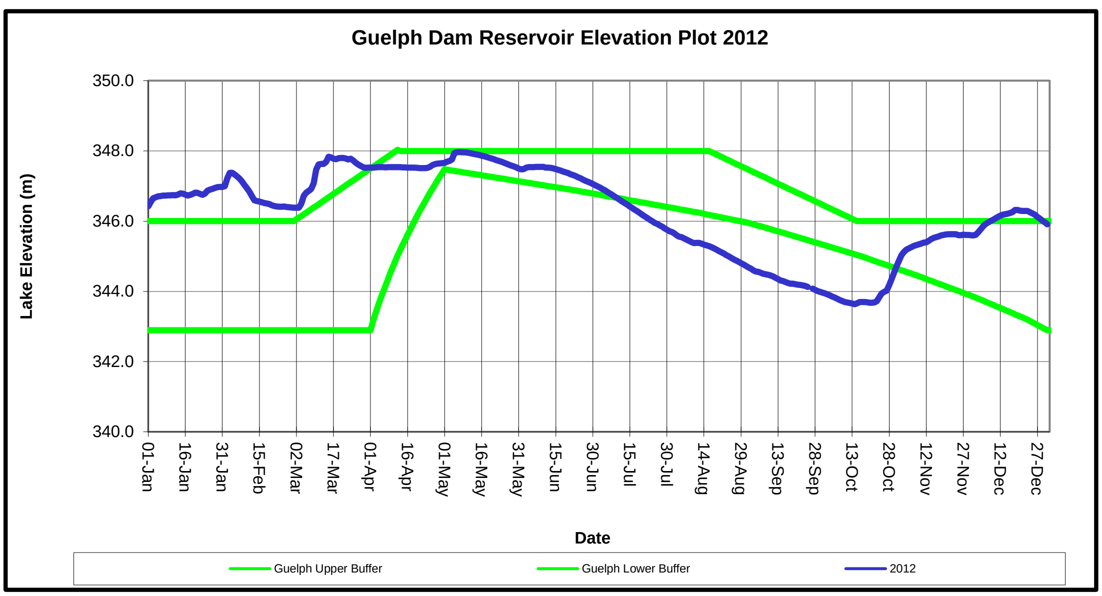

Figure 11. Lake level chart for Guelph Dam in 2012.

2012 was a dry year and even with capturing water early, the Guelph reservoir dipped below the lower rule curve in July and alternative flow targets were needed. Conditions would have been worst without the extra water captured early in the filling season and the water held over from the fall of 2011.

12.2. Additional Capacity/Alternative Reservoirs

There is additional augmentation capacity in GRCA reservoirs that is not used on a regular basis. Some of the additional capacity is in the large reservoirs, but below the normal low operating level. There are other reservoirs in the watershed that are predominantly used to reduce flood flows and for recreation, but can be used for some limited augmentation. Caution should be exercised when using water in storage below the lower rule curve as these curves have been set such that sufficient water is available for future augmentation and reservoir level can recover during the spring filling cycle. If levels are dropped too low there is a greater chance of not filling these reservoirs in the next season. This is especially true for reservoirs with little catchment area such as Luther Dam.

There are some additional issues with operating below certain levels. During the winter certain levels are needed in the reservoirs to prevent freezing of gates and valves. If levels are lowered too much there is also a potential of damaging the in reservoir fishery. A large fish kill can create added expense for cleanup of the biomass and the potential for poor water quality with biomass decay. Refer to Table 4 for minimum operating levels proposed in 2012 to prevent freezing of equipment and to protect the in reservoir fishery.

Table 5, gives the additional augmentation calculated for each reservoir, where the additional water is from and specific notes on using this water. Also included in Table 5, is the part of the river system or low flow target location that is affected. Some target locations have no back up. Grand Valley, Hanlon and Elmira totally rely on single reservoirs. Conestogo has limited upstream augmentation, while Shand has Luther upstream.

Table 16. Additional augmentation capacity within Grand River watershed reservoirs.

Reservoir	Augment to	Additional Capacity	Additional Capacity From	Notes
Luther	Upper Grand and Shand Dam	$90m^3/s$/day 214 days at $0.42m^3/s$	Below the winter lower rule curve	May take a few years of normal precipitation to achieve normal operating levels again
Damascus	Upper Conestogo and Conestogo Dam	204,800 m^3 5 days at $0.5m^3/s$	Below the winter lower rule curve to bottom of logs	Limited capacity to augment Conestogo Dam. Can provide some flow to upper Conestogo
Shand	Grand River, Doon and Brantford	9,950,000 m^3 60 days at 2 m^3/s	Storage available below the winter lower rule curve and the invert of the 48" valve	
Conestogo	Doon and Brantford	3,780,000 m^3 22 days at 2 m^3/s	Between the top of gates (normal winter minimum) and the bottom of the reservoir	Dropping storage below the top of gates may result in freezing of the gates. Winter lower rule curve is at the bottom of the reservoir.
Guelph	Speed River and Brantford	2,971,000 m^3 69 days at $0.5m^3/s$	Between the lower rule curve and the gate sill	Could result in fish kill and difficulty in filling the reservoir in future years
Woolwich	Canagig, Grand Doon and Brantford	< 80,000 m^3	Based on current operating and storage curves.	Most likely closer to zero due to silting of the reservoir.
Laurel	Grand River Doon and Brantford	945,000 m^3 summer 22 days at $0.5m^3/s$	Between summer and winter lower rule curves	Only available during the summer and fall period. Very limited water available at winter levels.
Shades	Grand River Brantford	800,000 m^3 18 days at $0.5m^3/s$	400,000 m^3 between summer and winter lower rule curves and another 400,000 m^3 below winter lower rule curve	

Notes: storage below the lower rule curve is for the lowest level of the lower rule curve, often during the mid-winter period

13. Considerations for Alternative Strategies

The reservoir system in the Grand River watershed is operated for a number of objectives including flood damage reduction and low flow augmentation. Water management during the low flow season has evolved around minimum flow rates at key locations in the watershed that have been in place since 1984, when the current reservoir operating policies were first adopted. Municipal supply, wastewater assimilation and aquatic ecosystems all rely on a certain amount of water in the river system downstream of the large reservoirs. Planning for short term changes to flow augmentation amounts requires consideration of flow requirement needs for these various essential uses.

This section gives a number of minimum flow requirements for different aspects of water management that should be considered when deciding on alternative operating strategies. Table 6 gives the normal low flow targets on the regulated parts of the river system.

Table 17. Normal low flow targets within the Grand River watershed.

Location	Jan-Apr (m^3/s)	Mary-Sep (m^3/s)	Oct-Dec (m^3/s)
Grand Valley	0.42	0.42	0.42
Below Shand Dam[3]	2.8	2.8	2.8
Doon	2.8[1]	9.9	7.1
Brantford	17[2]	17	17[2]
Below Conestogo Dam[3]	2.1	2.1	2.1
Below Guelph Dam[3]	0.57	0.57	0.57
Below Guelph Gauge	1.1	1.7	1.1
Elmira	0.3	0.3	0.3

1. Winter target at Doon under review
2. Brantford target is officially during the summer only, but has been used as a year round target
3. Targets are the lesser of the flow target or inflow to the Dam

Municipal takings

Table 7 gives estimated minimum flow requirements for each of the three active municipal intakes on regulated parts of the river system from a water quantity perspective only. Additional flow may be required to maintain water quality or aquatic habitat as per PTTW. Municipal use is considered an essential use of water, as it provides drinking and sanitation water to the majority of the watershed residents. Municipal takings at Brantford and Oshweken represent the only source of water for those communities.

Table 18. Estimated minimum river flow for municipal water supply intakes on the Grand River

Municipal Taking	Gauge	Est. Min Flow	Explanation
Region of Waterloo	Doon	3	1 m^3/s through each fish latter and taking of 0.9 m^3/s, more flow is needed to maintain ecological function and water quality as per PTTW
Brantford	Brantford	6 - 8	8 m^3/s in 2003 did not create issue for the intake, estimate 6 m^3/s to keep water across the 200m crest of the dam
Oshweken	Brantford	6 – 8*	Information on the new intake structure was not available, but requirements are most likely similar to Brantford

Municipal WWTP assimilation

Table 8 gives the 7Q20 equivalent flows used for wastewater treatment plant assimilation studies. These values are the lowest 7 day average values for flow that have a 20 year return period. Flow rates should be kept above these values whenever possible to ensure wastewater effluent can be assimilated into the river system with minimal disruption to water quality and aquatic ecosystems. Wastewater assimilation flows can be considered essential use of in river water since they support human and aquatic ecosystem health.

Table 19. 7Q20 values set for wastewater treatment plants discharging downstream of reservoirs.

WWTP	Winter/Spring	Summer	Fall	Gauge
Grand Valley	0.4	0.4	0.4	Leggatt
Fergus	1.4	2.7	1.5	Below Shand
Elora	1.7	2.8	1.6	Below Shand plus Salam
Waterloo	3.2	8.4	4.9	Doon
Kitchener	3.2	8.4	4.9	Doon
Preston	6.7	10.5	8.6	Galt
Galt	6.7	10.5	8.6	Galt
Paris	12.4	14.9	12.4	Brantford minus Mt Vernon
Brantford	13.8	15.4	13.2	Brantford
Caledonia	13.8	15.4	13.2	York
Cayuga	14.3	15.5	13.4	York plus McKenzie Creek
Dunnville	14.3	15.5	13.4	York plus McKenzie Creek
Guelph	1	1.3	1	Below Guelph
Hespeler	1.7	2.5	1.9	Speed at Cambridge
St. Jacobs	2	2.7	1.3	St. Jacobs
Elmira	0.2	0.3	0.3	Near Elmira

Ecosystems

Aquatic ecosystems need a sufficient quantity and quality of water to avoid catastrophic damage during a drought. Water quality is often poor during a drought because of low dilution ratios for waste assimilation and high temperatures from high solar radiation and low groundwater discharges. The surrogate water quality monitor in the watershed is dissolved oxygen. The target is to keep dissolved oxygen above 4 mg/l. Dissolved oxygen is affected by temperature and by in river nutrient cycling processes. Specific flow targets to maintain dissolved oxygen above the target of 4 mg/l do not exist, but careful review of the real-time water quality network should be included when making decisions to alter reservoir operations.

In addition to water quality consideration, there are also flow considerations to maintain habitat and provide connectivity between refuge areas. Locations on regulated reaches of the river system with low flows values calculated for habitat maintenance or connectivity are given in Table 9. These values have yet to be field verified and additional sites with these values calculated are expected in the future.

Table 20. Low flow environmental flow requirements in the regulated rivers of the Grand River watershed.

Gauge/location	Habitat Maintenance		Connectivity	
Doon	8.5	littoral zone	6.8	longitudinal
Brantford	19	littoral zone	8.8	longitudinal
Below Guelph	1.1	littoral zone	0.52	longitudinal
Speed at Cambridge	1.5	littoral zone	1.1	longitudinal
Grand at Blair	4.5	wetted perimeter	3.0	fish migration

Littoral Zone – maintenance of littoral zone for habitat
Wetted Perimeter –changes in the wetted areas of the stream indicate changes in available habitat
Residual Pool – flow required to maintain residual pools in the streambed
Fish Migration– flows where fish migration start to be hampered or there is significant loss
Longitudinal – to maintain connection between riffles and pools with 0.2m of flow depth over riffles

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