Assessing the Resilience of Ontario's Low Water Response Plan under a Changed Climate Scenario: An Ontario Case Study

by

Jenna Disch

A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Environmental Studies
in
Environment and Resource Studies

Waterloo, Ontario, Canada, 2010

Author Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Jenna Disch

Abstract

Water is essential to sustaining aquatic environments and is also a resource upon which many human-sectors depend. During times of reduced supply, competition or conflict may arise regarding its distribution due to its importance to local economies and its life giving benefits. The Ontario Low Water Response (OLWR) Plan is designed to deal with how water might be allocated under situations of reduced supply. When forced with data from the Coupled Global Climate Model 1 (CGCM1), the Guelph All Weather Storm Event Runoff (GAWSER) hydrologic model projects scenarios of reduced flows for the Grand River watershed, an area within the Province of Ontario. A level III declaration, which marks the highest stage of water emergency has never before been declared in the Province of Ontario, meaning there is uncertainty regarding how OLWR might operate. Using one scenario of climate change, this study explores the resiliency of the OLWR mechanism to operate under the demands of a changing climate and a growing population through interviews. Results show that the mechanism is not resilient enough to operate under conditions of reduced flow due to ambiguity in the mechanism and the tendency for humans to trump environmental uses of water, leading to detrimental effects on the fishery. Recommendations from this study suggest that ambiguities in the mechanism be revisited and clarified with a shift towards a proactive approach in order for environmental integrity to be upheld under scenarios of reduced flow.

Acknowledgements

First and foremost, thank-you to my supervisors, Paul Kay and Linda Mortsch. Your insight, commitment, and continuous feedback have been an integral component in developing this thesis. I am appreciative of your guidance over my academic development during the last two years and would be hard pressed to find a team of more supportive and understanding advisors.

I would also like to note my appreciation to the participants in this study who were willing to donate their time and contribute to this research. Thank-you for sharing your thoughts and opinions. This research could not have been completed without your input.

To James Etienne, thank-you for your ideas and guidance during the initial stages of the interview process and for the thoughtful comments you provided on my questions.

To the vanLenthe's, the staff at Horseback Adventures, and the wonderful horses themselves, thank-you for keeping me happy and for keeping me young at heart.

And most importantly, a very special thank-you to my family, whose unconditional love, support, and encouragement enabled the completion of this thesis.

Table of Contents

Author Declaration……………………………..……………………………………ii

Abstract…………….…………………………………..…………………………iii

Acknowledgements………………………………………………………………….iv

Table of Contents…………………..……………………………….………………...v

List of Tables………..…………………………………………………………….x

List of Figures……………………………………………………………………….xi

List of Abbreviations……………………………………………………………….xii

Chapter 1 – Background and Purpose

1.0 Study Background…..……………………………………………………...………1

1.1 Problem Statement……..…………………………………………….……….…3

1.2 Study Significance……...……………………………………………..……4

1.3 Study Purpose and Objectives…………...………………………….....……….……5

1.4 Thesis Overview……………………………………………………………………6

Chapter 2 – Literature Review

2.0 Environmental Flows…………………………...……………………….…..……7

2.1 Low Water Flows and the Fishery……………………..………………….....……….7

2.1.1 Wetlands………………………………………….……..…………..……8

2.1.2 Algal Blooms……………………………………........................……8

2.1.3 Sediment Transport……………………………………..….………......9

2.1.4 Water Quality and River Connectivity……………….……….……………9

2.2 Water Management in Ontario…………………………………………..……..…...9

2.2.1Permit to Take Water……………………………………..…………..10

2.2.2 Ontario Low Water Response…………………………………...……11

2.2.3 The Definition of Drought in OLWR……………………………...…15

2.3 Climate Change Impacts…………………………………….………………15

2.3.1 Climate Change Scenarios…………………………………………………15

2.3.2 Climate Change Hydrologic Impact Assessment…………………………16

2.4 Chapter Summary…………………………….……..…….…………………18

Chapter 3 – The Grand River Watershed

3.0 An Overview of the Grand River Watershed……………………………….….….20

3.1 Water Use in the Watershed…………………………………………………....22

3.2 The North, South and Central Regions of the Watershed ……………………...……22

3.3 A Brief History of Water Resources Management…………………….……………….23

3.4 The Grand River and its Tributaries…………………………………………………25

3.5 Drought…………………………………………………………………………28

3.6 A History of Drought in the Grand River Watershed……………………………….…29

3.7 The Grand River Watershed Low Water Response Team…..…………………….……32

3.8 Whitemans Creek: An Area of Particular Concern……………………..…………33

3.9 The Grand River Watershed as Case Study……………………………………….36

3.10 Chapter Summary………………………………………………………………..37

Chapter 4 – Research Design and Methods

4.0 Case Study Methodology……..………………………………………………38

4.1 The Interview as Method……………………………………………………….39

4.2 Ethical Considerations……………………………………………………………44

4.3 Selection of Participants…………………..……………………………………44

4.4 Interview Design and Methods…………………………………………………45

4.4.1 Interview Etiquette………………………………………………….…...46

4.4.2 Interview Agenda………………………………………..…………………47

4.5 Data Analysis…………………………………………………………………...49

4.6 Chapter Summary…………………………………………………………………50

Chapter 5 - Results

5.0 Introduction…………………………………..……………………………………51

5.1 Profile of the OLWR Team Profile……………………………..…………………52

5.1.1 Awareness of the Issues Associated with Drought……………………..…..53

5.1.1.1 Competition and Areas of Vulnerability…………...……………53

5.1.1.2 Lessons learned from Previous Droughts……………………….53

5.2 OLWR Shortcomings……………………………………………………...…….54

5.2.1 The Challenge of Allocation Prioritization……………………………...54

5.2.2 Distinguishing Essential, Important, and Non-essential
Water Uses ……………………………………..…………………....55

5.2.3. A Step Towards Prioritizing the Essential Uses…………………….…….57

5.3 The Ecosystem-based Approach……………..……………………………………58

5.3.1 The Critical Fisheries and Threshold Values…………………….……...61

5.4 Allocation during Reduced Supply……………………………………………..63

5.4.1 Dealing with Reduced Flows under Climate Change……………….……..63

5.5 Strengthening the OLWR Mechanism …………………………….……………...65

5.5.1 Preparing for the Future...……………………………………………….65
5.5.2 Incorporating Policies and Management Actions into OLWR for Resilience…………………………………………………………68

5.6 Evaluating OLWR…………………………………………………………...71

5.7 Chapter Summary……………………………………………………………71

Chapter 6 – Discussion

6.0 Uncertainty Surrounding Categories of Prioritization………………….…………72

6.1 Understanding shortcomings of the OLWR mechanism using the Hydro-illogical Cycle…..…………………...…………………………….……...79

6.2 The Ecosystem-based Approach……………………………………….…………81

6.3 The Problem with OLWR Thresholds………………………………………………82

6.4 Integrating Environmental Flows into OLWR and PTTW…………………….…….85

6.5 Incorporating a Proactive Approach into OLWR……………………………………86

6.6 Further directions to incorporate resilience into OLWR…………………...……..89

6.6.1 Better Partnership……………………………………………………..89

6.6.2 Infrastructure Upgrades…..………………………………………….……90

6.6.3 Social Change………………………………………………….………..90

6.6.4 Continued Research and Monitoring………….…………….…………91

6.7 Evaluating OLWR…………………………………………………….………..92

6.8 Conclusions…………………………………………………………….……….93

6.9 Study Limitations…………………………………………………….…..…..97

6.10 Future Research Directions……………………………………….…......…98

Permissions…………………………………………………………….………..99

References…………………………………………………………………………...102

Appendices

Appendix A: Recruitment Document………………………..………………………111

Appendix B: Consent of Participant…………………………………………………113

Appendix C: Thank-you letter…………………………………….…………………114

Appendix D: Letter for Review of Transcript…………….…………….……………115

Appendix E: Interview Questions……………………………………………………116

List of Tables

Table 1. OLWR streamflow levels and thresholds……………………………...……12

Table 2. OLWR goals and targets……………………………………………………..13

Table 3. Canadian Global Climate Model 1 Projections………………………………...18

Table 4. Water-dependent environments……………………….………..………27

Table 5. Fish species in the Grand River Watershed…………………………………….27

Table 6. OLWR team profile…………………………………………………………….33

Table 7a. Level III social impacts in Whitemans Creek…………………………………34

Table 7b. Level III economic impacts in Whitemans Creek…………….………………35

Table 7c. Level III environmental impacts in Whitemans Creek…………………..……35

Table 8. Interview framework……………………………………………………………43

Table 9. OLWR participants……………………………………………………………..45

Table 10. Hierarchy of essential water uses…………………………………..……….58

Table 11. Coding of ecosystem-based approach to mean………………………….……….60

Table 12. The critical fisheries…………………………………………………………...63

Table 13. Preparing for future water shortages………………………………………..67

Table 14. Directives toward a proactive management approach…………………….69, 70

Table 15. Instream Flow Indices for Whitemans Creek………………………………....84

List of Figures

Figure 1. The Grand River Watershed…………………………………………………......21

Figure 2. The hydro-illogical cycle……………………………………………………81

List of Abbreviations

CA: Conservation Authority

CGCM1: Canadian Global Climate Model 1

ECO: Environmental Commissioner of Ontario

GAWSER: Guelph All Weather Storm Event Runoff

GCM: Global Climate Model

GRW: Grand River Watershed

IPCC: Intergovernmental Panel on Climate Change

LWRT: Low Water Response Team

MEDT: Ministry of Economic Development and Trade

MMAH: Ministry of Municipal Affairs and Housing

MOE: Ministry of Environment

MNR: Ministry of Natural Resources

OLWR: Ontario Low Water Response

OMAFRA: Ontario Ministry of Agriculture, Food and Rural Affairs

OWRA: Ontario's Water Resources Act

PTTW: Permit to Take Water

WRT: Water Response Team

Chapter 1

Background and Purpose

"Water, like religion and ideology, has the power to move millions of people. Since the very birth of human civilization, people have moved to settle close to it. People move when there is too little of it. People move when there is too much of it. People journey down it. People write, sing and dance about it. People fight over it. And all people, everywhere and every day, need it."

-Mikhail Gorbachev, President of Green Cross International quoted in Peter Swanson's Water: The Drop of Life, 2001

1.0 Study Background

Freshwater is a natural resource crucial to the economic and environmental well-being of Ontario. Necessary for sustaining aquatic ecosystems and all other forms of life, water also supports almost all aspects of human activity including health, industrial development and recreation. The demands of multiple users, rapidly increasing urbanization and increasing economic development, combined with Provincial dedication to maintaining sufficient environmental flow to sustain the aquatic environment, results in a complex and challenging water resource management regime in Ontario. Because many sectors rely on water as a resource, competition or conflict may arise regarding its distribution during times of reduced supply.

Ontario's current population is approximately 13 million. By the year 2031 it is expected to rise to 16 million (Ontario Ministry of Finance 2009), during which time 80% of this growth will be concentrated in the Greater Golden Horseshoe area. The anticipated growth in the Greater Golden Horseshoe region will be the largest in all of Ontario and distribution of water will become increasingly challenging in view of competing and growing sectoral demands. If efficiency and conservation efforts are not improved to meet this change, this translates to increased demand for water in the region (Chiotti & Lavender 2008).

Compounding the challenge of water allocation amongst a growing population is the issue of climate change. Scientists have projected that Ontario is likely to warm over the next 75 to 100 years by an annual average of 2-5°C (NRC 2007). Associated with warming are a number of other climate changes such as the amount, intensity and distribution of precipitation, changes in the amount and distribution of snowcover, and more evaporation and evapotranspiration. High intensity rainfall events will be interspersed with more severe and frequent periods of drought (IPCC 1996; Whetton *et al.*, 1993). Although estimates of climatic conditions are subject to uncertainty, increases in air temperature and evapotranspiration and changes in the amount and distribution of precipitation are likely (Lavender *et al.*, 1998). These conditions could result in an increase in the frequency and duration of low water conditions in southern Ontario. Under some scenarios of climate change, the frequency and intensity of droughts are expected to increase (Gabriel & Kreutzwiser, 1993; CCIAD 2002).

One result of increasing temperatures due to climate change is that average winter flows are anticipated to increase and summer flows are expected to decrease due to shifts in timing and amount of precipitation, and earlier onset and reduced spring freshet and reductions in groundwater reharge (Mortsch & Quinn 1996; Lavender *et al.*, 1998; Mortsch *et al.,* 2000). Higher evaporation rates caused by higher average air temperatures, particularly in the summer, will likely counteract any potential increases in precipitation, resulting in low streamflows and groundwater levels (Frederick & Major, 1997; Mortsch *et al.,* 2000). During prolonged periods of drought characterized by little rainfall and increased temperatures, less water will be available to recharge aquifers, resulting in lower base flows in watercourses, with serious implications for ecosystems (Sousounis & Glick 2000). Higher sectoral demand for water throughout the Province during summer months will further stress water supplies and contribute to low summer flows.

Regions of Ontario within the Great Lakes basin have already been affected by low-water flows and drought-like conditions in the past. Water conservation practices are starting to emerge in response. In Essex County, one of the most drought-prone areas of

Ontario, excavation of small storage reservoirs has taken place. In the Haldimand-Norfolk Region, more efficient irrigation systems are being developed and utilized (ECO 2008). Although drought management plans have been developed and implemented in some US states (e.g. TDEC 2010), they are only starting to be developed and implemented in the Canadian provinces (e.g. Saskatchewan Watershed Authority, 2008). A national drought management plan is starting to be assembled in Canada, but this plan is still in its infancy. In Ontario, the provincial government created the Ontario Low Water Response Program in 2001. Its purpose is to assist in water allocation during times of shortage. Its intention is to ensure provincial preparedness in the case of low water conditions.

1.1 Problem Statement

Within Ontario there are 2,000 lakes that contain trout, more than 3,500 lakes with walleye, and 400 lakes and rivers that are home to muskellunge. Freshwater fisheries are among Ontario's most valued natural resources and anglers spend more than $2.3 billion annually on fishery related expenditures (MNR 2009). Fish are an important part of Ontario's economy via the tourist and commercial fishing industries and it has been estimated that 1.4 million anglers fish for warm-water, cool-water, and cold-water fish species in Ontario's 250,000 lakes, and thousands of miles of rivers and streams (MNR 2009). A changing climate and anticipated stresses on water supply in Ontario point to future water supply problems and although the Province of Ontario has a long-standing commitment to the protection of its natural resources and ecological health, whether this commitment will hold against growing sectoral demands for water under a changed climate remains unclear.

Current water management practices may not be adequate to cope with future climatic change because they rely on past hydrological data to predict future conditions and these may no longer be reliable (Bates *et al.,* 2008). Failure to incorporate future climate conditions therefore affects the resiliency of current water management practices. To avoid vulnerability, it is necessary in the planning process to consider future projections of climate change and the impacts on hydrological conditions. The incorporation of climatic change information increases the capability to assess and thereby limit future drought impacts by enhancing drought management approaches and allowing for better adaptive management. Many existing municipal drought plans however, do not factor climate change into planning and management strategies (Jacobs *et al*., 2005).

To date, numerous studies have been conducted on low water conditions in Southern Ontario (e.g. Koshida *et al*., 1999; Southam *et al*., 1999; Klaassen 2000; GRCA 2007; GRCA 2008). Koshida *et al*., (1999) assessed the lessons learned from previous drought years in Southern Ontario, Southam *et al*., (1999) observed the hydrologic impacts of climate change on supply and demand issues in the Grand River Basin, and Klaassen (2000) conducted a climatologic assessment of drought years in Ontario. Both studies conducted by the GRCA (2007, 2008) examined the effects of declaring a Level III condition in the Whitemans Creek subwatershed in the Grand River Basin. None of these studies, however, have assessed whether Ontario's low water response mechanism will be resilient enough to operate under climate change-induced low-flow conditions coupled with the demands of a larger population. Compounding this problem is that there has not yet been an extreme, long duration low-water event that could test the low water response mechanism, meaning there is uncertainty surrounding its current ability to operate effectively.

1.2 Study Significance

Resilience refers to the capacity of a system to absorb disturbance without crossing a threshold into a different system regime (Walker & Salt 2006). Resilient social-ecological systems are a fundamental criterion for sustainability as they are suited to resist surprises in the face of disturbance and can thus provide humans with goods and services that support a quality of life so desired. In social-ecological systems with little resilience, a sudden shock such as drought may result in changes that can cause societal problems through disruption of previous ways of life (Folke *et al.,* 2002).

A key component to the creation of resilient social-ecologic systems is resilient planning and management policies that help to define and govern the system. This study will explore whether the mechanism of Ontario's Low Water Response (OLWR) plan is resilient enough to cope with the future challenges of climate change, thus contributing to the sustainability of Ontario's freshwater resources and thus its social-ecological systems.

One way in which to develop better, more resilient, water management approaches is to assess future threats to the resource. Using climate change as a possible threat to water resource availability and fishery integrity, this study will assess the resilience of current low-flow planning and response in relation to ecological flow management. It will identify how communities and local water managers within a watershed might develop future management strategies so that a balance between ecological and societal needs can be found and recommendations on adaptation and better future preparedness can be made within the realm of anticipatory resource management.

1.3 Study Purpose and Objectives

This study will explore whether Ontario's Low Water Response mechanism will be able to withstand the demands of climate change and a growing population whilst simultaneously upholding provincial dedication to environmental integrity. It focuses strictly on hydrologic drought-related changes to surface and ground water resources as a result of climate change and uses the Grand River watershed as a case study to answer the research question: "Is the Ontario Low Water Response mechanism resilient enough to operate under a changed climate scenario and will it uphold the Province's dedication to environmental integrity in its water allocations amongst various stakeholders and the aquatic environment during times of water scarcity under a climate change scenario?" The objectives of this research are as follows:

- Objective one**:** To develop an evaluative framework for the assessment of Ontario's Low Water Response mechanism under current climate and population conditions using the interview technique;

- Objective two: To apply the evaluative framework in an assessment of Ontario's Low Water Response mechanism and its ability to allocate water to the natural environment under future reduced flow conditions; and,

- Objective three: To propose recommendations for improving the resilience of Ontario's Low Water Response mechanism for climate change adaptation and the demands of a growing population while upholding environmental integrity.

1.4 Thesis Overview

Chapter One provides the purpose and rationale for this thesis and outlines the research objectives. Chapter Two provides a literature review that is pertinent to: the importance of establishing environmental flows; the consequences of reduced water flows on the aquatic environment; the selection of a climate change and hydrologic model for this research; and the overview of water management in Ontario. Chapter Three provides an explanation of why the Grand River watershed was chosen for a case study and Chapter Four describes the methods used for this research. Chapter Five describes the results of this study including: the background of the OLWR team, the weaknesses of the OLWR mechanism and the ecosystem-based approach, and how OLWR team members believe the mechanism might operate under changed climate scenarios. Finally, Chapter Six provides descriptions and evaluations of the resilience of the OLWR mechanism under a changed climate scenario and offers recommendations to incorporate future resilience into the plan to aid in the protection of Ontario's fisheries.

Chapter 2
Literature Review

Chapter Two of this thesis is a literature review which aims to address the critical points of low-water flows and the fishery, water management in the Province of Ontario, and the hypothetical climate change scenario under which this research will be carried out. This chapter places specific emphasis on the Ontario Low Water Response document, which will be the focus of the study.

2.0 Environmental Flow

An environmental flow is the amount of water provided within a flow-regulated river to maintain ecosystems and their benefits where competing water uses exist. In regulated rivers, maintaining sufficient environmental flow is important because water-flow provides critical contributions to river health, economic development and societal well-being. Deciding the environmental flow for a particular river will depend on the values for which the river is to be managed. The best flow program balances the needs of water allocations to satisfy the ecological water requirement as well as societal water needs. One main goal of defining environmental flow is to provide a flow regime that will be adequate to support the quantity, quality, and timing of water flows necessary for sustaining the health of a river and other aquatic ecosystems (Dyson *et al*., 2008). If environmental flows are not regulated in rivers where extensive water taking occurs, a decline in riverine biodiversity and ecosystem health could result.

2.1 Low Water Flows and the Fishery

Increasing sectoral demands due to a growing population coupled with reduced water supply as a result of a changing climate are likely to lead to increased stress on natural aquatic environments. Studies factoring these two stressors (i.e. growing population, reduced water supply) have not yet been conducted on aquatic systems in Ontario, but previous studies of decreased flows on natural aquatic systems can be used as a parallel to infer the possible effects that these stressors might cause. They are discussed below.

2.1.1 Wetlands

Wetlands are essential ecosystems for the provision of fish stocks, providing important nursery and spawning habitat for young fish. Wetland vegetative cover is particularly important to fish species as it provides protection from both predators and weather conditions, and may act as a substrate for both feeding and reproduction. Lower water levels in wetlands during the spring, summer, and fall months have the potential to prevent fish from reaching critical spawning areas, with the reduction and possible permanent loss of nursery grounds (Manny 1984; Mingelbier *et al,.* 2008). If water levels decrease between the spawning and hatching of eggs, then eggs could be exposed to air, resulting in decreased in number of offspring (Hanna & Michalski 1982). Wetlands also enhance the quality of water by filtering and trapping sediments and removing pollutants such as heavy metals, nutrients, and pesticides (Sather & Smith 1984; Rubec *et al.,* 1988). Low water flows could therefore result in greater volumetric loads and concentrations of pollutants. This could stress sensitive aquatic vegetation downstream with cascading effects for the entire food web.

2.1.2 Algal Blooms

Increased temperatures and higher concentrations of nutrients due to decreased volumetric flows can result in algal blooms of larger biomass within aquatic systems (Ochumba *et al.,* 1989; Ojala *et al.,* 2002). This change occurs in response to increased temperatures, higher nutrient concentrations, and reduced current velocities, all characteristic of low flows (McIntire 1966; Poff *et al.,* 1990). Algal blooms could alter natural system regimes, oxygen availability, and food web processes characteristic of aquatic ecosystems with serious implications to predatory fish situated at the top of the aquatic food chain.

2.1.3 Sediment Transport

An increased amount of sedimentation occurs as the flow of lotic systems decreases due to decreased kinetic energy of the water (Bickerton *et al.,* 1993; Castella *et al.,* 1995; Wood & Petts 1999; Wood & Armitage 1999). High concentrations of fine sediments deposited as a result of reduced flow regimes can result in the degradation of spawning habitats. The infiltration of fine sediments into spawning gravels and the reduction of oxygen flow to developing ova during the period in which they incubate within the redd is associated with poor egg survival.

2.1.4 Water Quality and River Connectivity

As previously discussed, changes in streamflow and water quality are inextricably linked, with lower flows tending to lead to higher pollutant concentrations. Higher concentrations of pollutants could adversely affect fish species, as well as the entire aquatic food web. Decreased flows could also have serious implications to annual upstream fish migrations (Jonsson 1991) or result in the loss of usable habitat for fish (Glova 1985; Harvey 1991). Loss of usable habitat implies increased competition with potential declines in fish populations. At its extreme, decreased flows could affect overall river connectivity, leaving fish stranded in pools.

2.2 Water Management in Ontario

The sustainability of water resources lies within the provincial mandates of the Ontario Ministry of Natural Resources (MNR) and the Ontario Ministry of Environment (MOE), although Conservation Authorities (CAs) also play a critical role in implementation at the local level. Under the *Lakes and Rivers Improvement Act*, MNR is responsible for the management, protection, and preservation of Ontario's lakes and rivers, including the management, perpetuation, and use of their fish. For this to be done, MNR monitors flow in rivers and streams, as well as water levels in lakes and reservoirs in order to predict and minimize the potential impacts of flood and drought on aquatic ecosystems. MNR also plays an integral role in the delivery of *Safeguarding and Sustaining Ontario's Water Act*, *Federal Fisheries Act*[1], and the *Ontario Water Resources Act (OWRA),* the latter of which is directed towards the protection of the quality and quantity of Ontario's surface and groundwater resources. MOE plays a significant role in protecting drinking water and freshwater resources from pollution and also monitors instream flows. Additionally, MOE plays an integral role in the Permit to Take Water (PTTW) as governed by the *Ontario Water Resources Act* and *Water Taking and Transfer Regulation.* Under OWRA, numerous powers are afforded to the Director of MOE to restrict water use and to ensure that the water quantities being allocated and withdrawn by users promote ecosystem protection and sustainability. During low water conditions MOE will delegate responsibility for determining the relative importance of various water uses and hence water allocation to the Low Water Response Team (LWRT).

2.2.1 Permit to Take Water (PTTW)

There are two major provincial institutional agreements for managing water quantity: the Permit to Take Water (PTTW) Program, which is the primary water allocation mechanism under *Ontario's Water Resources Act (OWRA)* and Ontario Low Water Response (OLWR), which is a framework designed for the purpose of drought management, as will be discussed in the next section. All water takings from a surface source or well in excess of 50,000 litres per day require a PTTW, but exceptions are made for water used for domestic purposes, livestock watering, and firefighting. The issuing and revising of PTTW by MOE under Section 34 of OWRA are the principle mechanisms available to provincial regulators to control takings of ground and surface water. In the event of interference with other users or the natural environment, the PTTW program relies on permit holders to reduce water use. In the case of a severe drought, MOE has the power to control new water takings and limit water takings by existing permit holders.

---

[1] Conservation Authorities also have the authority to administer some sections of the federal Fisheries Act to maintain base flows to protect aquatic life.

Under the PTTW, MOE has stated that it will use an ecosystem-based approach to water allocations. This approach will consider both "reasonable needs" for water takers and the "natural function" of the ecosystem, where the highest priority will be placed on preventing significant environmental harm to aquatic environments as well as all other natural environments (MOE 2005). Water takings are managed by MOE to ensure sustainability of the water resource and the aquatic environment.

2.2.2 Ontario Low Water Response (OLWR)

The OLWR framework was created in 2001 by the Ontario Ministry of Natural Resources in collaboration with several other ministries and organizations responsible for the management of water in Ontario. Under OLWR, three levels of low-water conditions were designated based on average historical precipitation and streamflow (Table 1). Each low water condition results in a water management response from a regional Water Response Team aimed towards reducing the amount of water used (Table 2). The Level I condition is the first indication that a water supply problem exists and signals voluntary water conservation to the public. Precipitation and flow indicators are used to declare the Level I (warning, voluntary conservation) condition and the condition is confirmed by observations from the CA or MNR staff. Once the Level I condition has been established, WRTs are brought together to lead the local community on voluntary water reduction strategies (ECO 2008). Level II (conservation) indicates a potentially serious problem requiring water conservation and restrictions on water for non-essential uses. A Level III (conservation, restriction, regulation) condition indicates failure of the water supply to meet local demands and often results in serious adverse socioeconomic effects. Before declaration of a Level III condition, the provincial Low Water Committee requires the local WRT to have: a) clearly implemented and documented the conservation and reduction efforts taken through Level I and Level II strategies and demonstrated that the majority of the water users have participated in these efforts; b) documented and adequately described significant social, environmental, and economic impacts arising from current low water conditions; and c) provided recommendations on priorities for water use restrictions and other reduction activities within the watershed (ECO 2008).

For a Level III condition to be reached, precipitation must be less than 40% of the historical average for a specified period of time and monthly stream flow must be less than 50% (spring) or 30% (summer, fall, and winter) of the lowest average summer monthly flow. There have been periods in Ontario's past which have met the physical criteria for declaration of a Level III condition (e.g. GRCA 2008), however a Level III condition has never been declared by local LWRTs or the Province. Political reluctance to declare a Level III condition could signify that there is vulnerability in the way the plan operates and lack of effectiveness in its mechanism. If a Level III drought is declared for a watershed, the MOE enforces water taking restrictions through the PTTW program, displacing the decision-making power of the LWRT (OLWR 2001). Penalties for non-compliance with the act and its regulations can range from cancellation of a permit, to a $305 provincial offence ticket and ultimately, court appointments with additional fines of $20,000 (MOE 2000).

Table 1. Summary of streamflow and precipitation thresholds that aid in the declaration of Level I, II, and III conditions in Ontario (OLWR 2003).

Condition	Indicator	
	Precipitation	Streamflows
Level I	<80% of average	**Spring:** monthly flow <100% lowest average summer monthly flow. **Other times:** monthly flow <70% of lowest average summer montly flow
Level II	<60% of average weeks with <7.6mm	**Spring:** monthly flow <70% of lowest summer month flow. **Other times:** monthly flow <50% of lowest average summer month flow
Level III	<40% of average	**Spring:** monthly flow <50% of lowest average summer month flow. **Other times:** monthly flow <30% of lowest average summer month flow

Table 2. Levels of low water conditions and associated response actions (MOE 2005).

Description of level	Level I - Warning; Voluntary Conservation	Level II - Conservation and Restrictions on non-Essential Use	Level III - Conservation, Restriction, Regulation
Goal	Promote voluntary water conservation and management among all users to reduce further water shortages.	Target further water conservation and management messages more directly. Publicize water use restrictions. Consider priorities for water restrictions and other water use reductions at Level III.	Develop and implement priorities on water management strategies and water use restrictions.
Target	10% voluntary reduction in water use among all sectors	Further 10% water use reduction (20% total).	Reduce and manage water use demands to the maximum extent. Response designed to mitigate impending impacts of an escalated drought condition.

The composition of Low Water Response Teams varies across the province with respect to sectoral representatives. Membership is representative of water use sectors to reflect the different water takers in that watershed. Although the Province provides overall direction to the LWRT, a partnership is often formed between provincial and local authorities in order to best respond to drought events at the local level. Typically, a local LWRT is headed by CAs, but where no CA exists, the District Office of the Ministry of Natural Resources assumes the role. The LWRT establishes priority for water allocation and sets up mitigation strategies in response to serious low flows.

There are five provincial agencies with an interest in water management in Ontario—MOE, MNR, the Ministry of Municipal Affairs and Housing (MMAH), the Ministry of Economic Development and Trade (MEDT), and the Ministry of Agriculture, Food and Rural Affairs (OMAFRA) (OLWR 2003). During periods of reduced flow such as those in Level I and Level II conditions, the mechanism under which OLWR allocates water maintains the needs of all five of these provincial agencies, calling for water conservation and restrictions on non-essential uses. During Level III conditions when water must be allocated during times of serious water shortage, water uses identified as essential and important are given priority over non-essential uses. During extreme scenarios of reduced flows, essential uses take priority over all other uses. These uses are described below:

Essential

Essential uses of water are those pertaining to human life and health. These include maintaining a reasonable supply of water for drinking and sanitation, water for health care, water for public institutions, and water for public protection including wastewater treatment and fire protection. Also included within essential uses of water are basic ecological functions (OLWR 2003).

Important

Important uses of water include those for the social and economic well being of a particular area. This category includes activities critical to industrial processes, commercial facilities such as hotels and restaurants, and key agricultural crops. During times of water scarcity this category poses the greatest challenges for determining water allocation, as it may be necessary to establish priorities and rank activities (e.g., between farm irrigation and a local car manufacturing plant, or between food or non-food agriculture irrigation). Such rankings can cause tension amongst water users. Rankings of these priorities vary between watersheds depending on the local context and conditions (OLWR 2003). There are no ecological uses/categories within this group.

Non-Essential

Non-essential uses of water are those that can be interrupted for a short term without significant impact (definitions of “short term” and “significant impact” are not provided within the document). Non-essential uses include filling private swimming pools, lawn watering, filling public and private fountains, and vehicle washing. Many Ontario jurisdictions have bylaws restricting water usage to deal with this category during periods of low water (OLWR 2003).

2.2.3 The Definition of Drought in OLWR

Drought is a complex term that may have various definitions depending on individual perspectives. The Ontario Low Water Response document defines drought as weather and low water conditions characterized by one or more of the following:

a) below normal precipitation for an extended period of time (3 months or more), potentially combined with high rates of evaporation that lower lake levels, streamflows and/or baseflows, and reduced soil moisture and/or groundwater storage;

b) streamflows at the minimum required to sustain aquatic life while meeting only high priority demands for water; water wells becoming dry; surface water in storage allocated to maintain minimum streamflows; and

c) socio-economic effects occurring on individual properties and extending to larger areas of a watershed or beyond (OLWR 2003).

2.3 Climate Change Impacts

2.3.1 Climate Change Scenarios

The Intergovernmental Panel on Climate Change (IPCC) has defined climate change scenarios as coherent, plausible descriptions of a possible future state of the world, representing a future climate that has been constructed for explicit use in investigations of the potential consequences of anthropogenic climate change (IPCC, 2001). Climate change scenarios are derived from global climate model runs projecting 50 to 100 years into the future. Their usefulness lies in their ability to provide data for vulnerability, impact, and adaptation assessment studies. They may also be used as awareness-raising devices that aid in strategic planning, or encourage proactive policy formation by scoping a wide range of plausible futures (IPCC 2010). Although 'scenario' is a formulation of how the future *might* unfold, multiple future scenarios are possible.

Different methods have been used to develop climate change scenarios for use in climate change impact and adaptation assessments (IPCC 2001). The most commonly used climate change scenario-generating technique is based on the global climate model (GCM). To explore responses to low water conditions as part of a plausible future scenario in the Grand River watershed, a run based on the Canadian Centre for Climate Modelling and Analysis (CCCma) Coupled Global Climate Model 1 (CGCM1), was used as the basis for developing the climate change scenario to assess hydrologic impacts on the Grand River watershed. CGCM1 is made up of four key components: an atmospheric general circulation model, an ocean general circulation model, a thermodynamic sea ice model, and a simple land surface model (Hengeveld 2000). The model is forced with a series of greenhouse gas (GHG) and sulfate emission scenarios based on the IS92 GHG emission scenarios which provide six alternative emission trajectories (IS92a-f) spanning the years 1990 through 2100 for greenhouse-related gases including carbon dioxide, carbon monoxide, methane, nitrous oxide, and sulfur dioxide (Tegart *et al.,* 1992). The CGCM1 run incorporated in this research was forced with the IS92a scenario. This scenario has an effective CO_2[2] concentration increasing at 1% per year after 1990. Often referred to as the "business-as-usual" scenario, it represents how future greenhouse gas emissions might evolve in the absence of climate policies beyond those already adopted.

2.3.2 Climate Change Hydrologic Impact Assessment

Application of hydrological models provides quantitative estimates of the impacts of climate change on the hydrologic cycle. To date, numerous climate change hydrologic impact assessments have been conducted in the Great Lakes Basin and many of these assessments project lower net basin supplies and water levels for the Great Lakes-St. Lawrence Basin (Mortsch et al., 2000; Quinn & Lofgren, 2000; Lofgren *et al.,* 2002)

[2] Represents the climate forcing due to CO_2 and also the forcing associated with all other greenhouse gases.

Higher temperatures as a result of climate change in the Great Lakes area will likely cause increased evaporation and evapotranspiration, lower runoff into rivers and lakes, higher lake temperatures, and reduced ice formation with shorter periods of ice cover. Additionally, rainstorms may be more intense and more precipitation may fall as rain rather than snow as a result of higher temperatures[3]. Overland evapotranspiration will increase and total runoff to the lakes will be lower due to the higher temperatures. This will result in reduced channel flows and water levels on all of the Great Lakes (Lofgren *et al.,* 2002).

The hydrologic impact of climate change at the scale of a single hydrological basin has been the focus of several studies in Ontario. In Southam *et al*. (1999) several scenarios of future climate change were input into a water use model for Ontario's Grand River Basin. The results suggest that wastewater assimilation and water supply functions of the Grand River will decline during the summer and fall. A second study of climate change scenario and hydrology was completed by the Grand River CA in the Grand River basin (Bellamy *et al.,* 2002). This study used output from two GCMs (CGCM1 and HadCM2) and a hydrological model (GAWSER) that had been calibrated to the Grand River basin so that future changes in runoff and groundwater recharge in the basin could be identified. Results from this study showed that yearly average precipitation increased in both climate scenarios, although net streamflow over the basin was shown to either increase (HadCM2) or decrease (CGCM1) depending on the GCM scenario used.

This study has adapted the assessment conducted by Bellamy *et al.* (2002), which projects low flows using CGCM1 to assess the resilience of Ontario's low water response mechanism. The assessment by Bellamy *et al.* (2002) of the hydrologic impacts of climate change scenarios is the most recent assessment in the Grand River watershed, although there are more recent climate change scenarios available. For the purpose of this research, climate data developed from the output of CGCM1 from the Canadian Centre for Climate Modelling and Analysis was input into the hydrologic model, Guelph All

[3] Increases in precipitation may not be sufficient to counter the projected increase in evaporation and evapotranspiration (Mortsch and Quinn 1996).

Weather Storm Event Runoff Model (GAWSER) to assess the effect of climate change on the water resources of the Grand River watershed (Bellamy *et al*., 2002).

GAWSER is a deterministic storm-event hydrologic model used to simulate major hydrologic processes or stream-flow hydrographs resulting from precipitation inputs for the purposes of planning, design, or evaluating effects of physical changes in the drainage basin. When output from the CGCM1 is input into GAWSER, the model projects approximately a 20% decrease in summer flows within the Grand River watershed, with a reduction in groundwater recharge and baseflow (Table 3). This sets the hydrologic drought scenario upon which this research will be based.

Table 3. Percent difference of summer and annual streamflow as projected by the Canadian Global Climate Model 1 in the Grand River watershed (Bellamy *et al*., 2002).

	CGCM1 2090	
	Summer	Annual
	Percent Difference From Existing Flows	
Nith at Canning	-19.0	12.8
Eramosa Above Guelph	-18.0	19.1
Conestogo Above Drayton	-13.8	44.5
Whitemans Creek	-23.5	-2.6

2.4 Chapter Summary

This chapter has outlined the management of water resources within Ontario and the various Ministries, authorities, and sector representatives composing the low water response team under OLWR. It has discussed one future scenario of low summer flows for the Grand River watershed as projected by CGCM1 coupled with GAWSER.

Questions for this research will be based on this hypothetical scenario in order to examine how water might be allocated in this watershed using an ecosystem-based approach during times of scarcity. Specifics of the Grand River watershed, including its history, are discussed in the next chapter.

Chapter 3
The Grand River Watershed

Chapter 3 provides background information on the watershed and explains why the Grand River watershed was chosen as a case study. It commences with an outline of various water and land uses and a brief history of drought in the watershed. This is followed by discussion of the Whitemans Creek watershed, an area that has previously been subject to low water conditions.

3.0 An Overview of the Grand River Watershed

The Grand River watershed (GRW) is southern Ontario's largest watershed and is located west of the Greater Toronto Area, between Lake Huron, Georgian Bay, and Lake Erie. It covers an approximate area of 7,000 km^2 and is composed of all the land that drains into the Grand River through tributary creeks and rivers including the Conestogo, Speed, Eramosa and Nith (Nelson *et al.*, 2003). The total drainage area of the watershed contributes about 10% of the direct drainage to Lake Erie (GRCA 2005). There are several large cities, including Guelph, Waterloo, Kitchener, Cambridge, and Brantford within the watershed. Smaller towns and villages include Fergus, Elora, St. Jacob's, Paris, Caledonia, Cayuga, and Dunnville (Figure 1). Currently, 925,000 people live within the watershed's borders (City of Brantford, 2010).

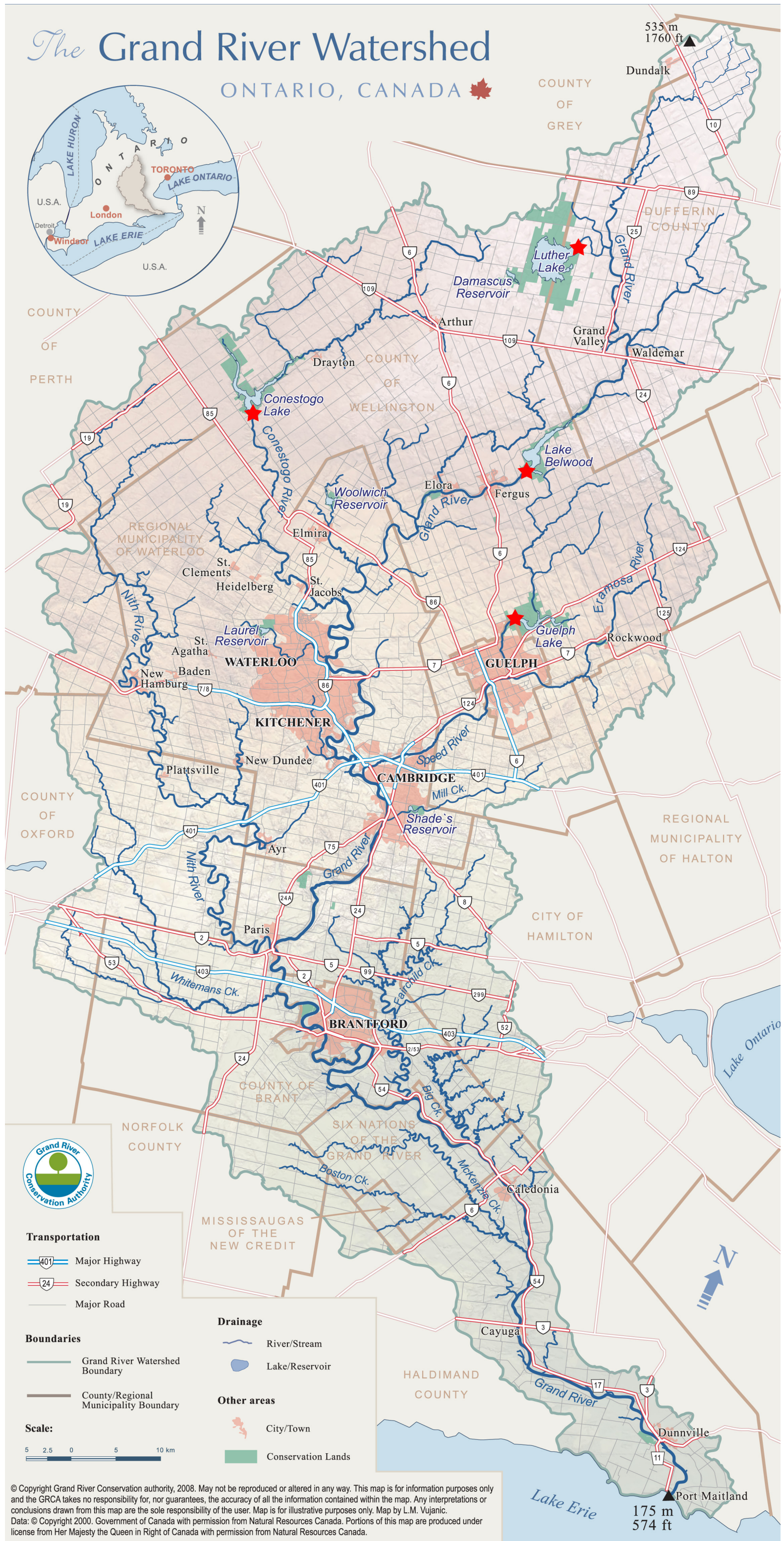

Figure 1. The Grand River watershed and its location within Southern Ontario (inset) (GRCA 2010). Red stars show the location of major dams used to regulate flows.

3.1 Water Use in the Watershed

Fifty-four local area municipalities (cities, towns, townships), eleven regional or county municipalities, two First Nations communities, and several provincial and federal government departments are involved in managing or using the water resources of the Grand River Basin (Francis 1996). Various sectors including agricultural, industrial, municipal, and recreational are major users of water in the watershed. Groundwater serves as the primary source of water for 80% of the residents of the watershed. Numerous industrial and agricultural users also depend on groundwater for their operations. The City of Brantford however, remains entirely dependent on surface water supplies (City of Brantford 2010). Increased growth projected for urban communities in the Grand River watershed will put pressure on water resources, potentially resulting in serious consequences for the aquatic biota of the region.

Water in the Grand River watershed is apportioned amongst the following sectors:

- municipal water use (comprising 60-70% of the total water use in the basin),
- agricultural water use (including water for livestock and crops),
- aggregate water use,
- industrial water use (including water for manufacturing and cooling),
- water use for business (e.g. supermarkets, coffee shops and offices),
- private water use,
- water-bottling use,
- recreational water use,
- water used for golf courses and sod farms, and
- water needed for the fishery and the natural environment (Etienne, October 29, 2009, *pers. comm*).

3.2 The North, South, and Central Regions of the Watershed

In the Grand River watershed the majority of urban land use is concentrated in the central region. Urban land use accounts for approximately 5% of the total land use in the watershed. Because of the growing population in the central region, rapid urban growth and sprawl are a major challenge. The majority of agricultural land use is in the northern and southern parts of the Grand River watershed. These areas are heavily farmed, favoured by temperate climate and good soils (City of Brantford 2010). Within the entire watershed, agricultural activity predominates, accounting for 80% of the total land use. Commonly grown and raised are corn, grain, and soybean, as well as cattle, pigs, and poultry. The northern and southern regions of the watershed are less prone to urban sprawl than the central region, but their natural landscapes and biodiversity remain threatened by construction, gravel mining, and other development actions. Economic and social challenges are linked to increasingly intensive agricultural practices.

3.3 A Brief History of Water Resource Management

The Grand River watershed was rapidly industrialized by Europeans settlers in the late nineteenth century due to technological advances. These advances encouraged more productive agricultural practices throughout many parts of the watershed. By the 1890s significant portions of the watershed's forest had been cleared resulting in major floods and increasingly rapid runoff, causing significant damage into the early twentieth century.

By the mid 1930s, problems associated with flooding, low summer flows, and more discharge of waste into the Grand River resulted in extremely poor water quality. The Grand River Commission, precursor to the current day Grand River CA, was formed to address these issues. In the 30 year time period between 1940 and 1970, dams were built throughout the watershed in response to previous floods. These dams included the Shand Dam built in 1942 forming Lake Belwood, the Luther River Reservoir Dam built in 1952 forming Luther Lake, the Conestogo Dam built in 1958 forming Conestogo Lake, and the Guelph Lake Dam built in 1974 forming Guelph Lake (Figure 1). The dams continue to be used for flood control during wet years and the yearly spring snowmelt and are also used to augment low flow conditions during dry years (Nelson *et al*., 2003), although the GRCA also monitors an additional 3 reservoirs in the watershed. The reservoirs store water during times of surplus and release it during times of drought. This provides downstream communities along the Grand River adequate summer flows to maintain water quality. Low flow augmentation also ensures that there is enough water in the river to assimilate the effluent from sewage treatment plants. Maintaining minimum flows is also important for aquatic life. It ensures that there is enough space and food for fish and other aquatic creatures. Additionally, the water coming out of the reservoirs is usually cool, so that makes the river a better habitat for cold water fish such as trout. During the driest periods in the summer, water from the reservoirs can represent more than 80% of the flow in the Grand River (Watershed Report, 2004).

Since the 1930s about three quarters of the original marshes and wetlands of the watershed have been drained due to development. Development (more impervious surfaces) has led to decreased water storage capacity resulting in more rapid runoff and changes in streamflow and the loss of plant and animal habitat contributing to the decline in the number and abundance of species. Fish populations in particular have suffered because of the number of dams and weirs built, water pollution, destruction of riparian vegetation, and changes in stream temperature and flow. These changes have been exacerbated by the introduction of numerous exotic species, including species of trout. Lake salmon have all but become extinct (Nelson *et al*., 2003).

To protect and restore the watershed's natural environment, while providing the watershed's growing population with recreational opportunities, the Grand River Conservation Authority (GRCA) was formed in 1966. Since then it has protected many aquifers, wetlands, old growth and significant secondary forests, as well as biodiversity and other natural values of the watershed. The GRCA manages the release of water from the reservoirs during dry periods and operates a network of automatic gauges throughout the watershed to monitor river and streamflows, weather conditions and water quality. These stations provide GRCA staff with up-to-the minute information to guide decisions about reservoir operations to help reduce the impact of floods or to maintain minimum flows during dry weather (GRCA 2010a). In 2000 the GRCA received the Thiess Award for excellence in river management in recognition of its efforts in the improvement of the environmental conditions of the Grand since the 1930s. To this day, the GRCA manages water and other natural resources on behalf of 925,000 residents scattered throughout 38 municipalities within the watershed (GRCA 2010a).

3.4 The Grand River and its Tributaries

The Grand River is one of the few rivers in Canada designated as a Canadian Heritage River, meaning that it receives national and international recognition. Due to its status as a heritage river, the Province encourages the public to enjoy and appreciate it because it reflects the diversity of Canada's river environments and commemorates the role of rivers in Canada's history and society. It is the ultimate vision of both the Province and the GRCA to ensure that the heritage features of the Grand River are protected for generations to come (NRC 2009).

It has been estimated that the Grand River and all of its tributaries form an intricate stream network totaling 11,329 km of stream habitat (Sawyer 2005), although a number of other water dependent environments are also found throughout the watershed. (Table 4). While the MNR has documented and classified approximately 22% of the streams and rivers in the Grand River watershed based on habitat type, many streams and rivers remain unclassified. About 19% of these classified streams are cold-water habitats, indicating that they are heavily dependent on groundwater discharge. Of the classified streams 16% are considered *potential* cold-water habitat and the remaining 65% of the classified streams have been identified as warm-water habitat (Sawyer 2005). Cold-water fish are common in the central parts of this watershed due to ground water base-flows created by the ideal geology of this region. The Grand River watershed is home to a world-class brown trout fishery and other fish species (Koshida 1992) (Table 5). The quotation below from *Grand Actions* captures the importance of the Grand River as aquatic habitat:

> Amazingly, there are 83 species of fish found in the Grand River watershed, representing 62% of all fish species found in Canada. These include six species that are considered vulnerable, threatened, or endangered in Canada. Species like the Sand Darter, Redside Dace, and Black Redhorse sucker are not only uncommon but most

> fishermen would find them impossible to identify and inconsequential in size. Nevertheless the habitat supporting these unique species continues to be provided in certain sections of the river and its tributaries. This is a testament to good quality water and habitat conditions.
>
> Even non-anglers know that trout are a very sensitive species. In the water world, they can be considered the canary in the coal-mine. Citizens in Fergus and Elora can stroll beside the river and watch brown trout rising to a mayfly hatch. Those same residents recognize that those fish in essence are an expression of the habitat, water quality, and supporting ecosystem of the river. Those people have the security of knowing that the water in their community is clean enough to support the finned canary (Grand Actions 2000).

One consequence of human development in the Grand River watershed is the release of pollution into its waters and onto its land. In the 1930s drought, deforestation, and human use of water resources resulted in uneven seasonal flows in the Grand River as well as high levels of sewage and other waste along its course. The GRCA, along with municipal and provincial agencies, have since been able to restore the river to a healthier state using water treatment plants and other measures (Nelson *et al*., 2003).

Table 4. Percentage of water dependent environments in Southern Ontario's Grand River watershed (GRCA 2005).

Aquatic-related Environment	Area (ha)	% of Total Watershed Area
Water - Deep	4,212	0.6
Water - Shallow or sediment	2,523	0.4
Deep/shallow water marsh	7,92	0.1
Meadow marsh	85	0
Hardwood thicket swamp	7,571	1.1
Conifer swamp	2,659	0.4

Table 5. Various species of fish found in the Grand River watershed. Species that are threatened (*) or of special concern (**) are identified (Nelson *et al*., 2003).

Common Name		**Scientific Name**
Bass	rock bass	*Ambloplites rupestris*
	white bass	*Roccus chrysops*
	striped bass	*Roccus saxatilis*
	largemouth bass	*Micropterus salmoides*
	smallmouth bass	*Micropterus dolomieui*
Black Redhorse*		*Moxostoma duquesnei*
Bluegill		*Lepomis macrochirus*
Brown Trout		*Salmo truta truta*
Carp		*Cyprinus carpio*
Channel Catfish		*Ictalurus punctatus*
Eastern Sand Darter*		*Ammocrypta pellucida*
Mooneye		*Hiodon tergisus*
Perch	white perch	*Roccus americanus*
	yellow perch	*Perca flavescens*
Pike		*Esox lucius*
Rainbow Trout		*Salmo gairdneri*
Redhorse Sucker		*Moxostoma duquesnei*
Redside Dace**		*Clinostomus elongatus*
Salmon		*Oncorhynchus kisutch*
Silver Chub**		*Macrhybopsis storeriana*
Silver Shiner**		*Notropis photogenis*
Sturgeon		*Acipenser transmontanus*
Red-breast Sunfish		*Lepomis auritus*
Walleye		*Stizostedion vitreum*

3.5 Drought

Drought occurs when there is a deficiency of precipitation from expected over an extended period of time, usually for a season or more. This deficiency results in water shortage for some activity, group, economic sector, and the environment, and may cause significant damage to local economies, environments, and social systems (Koshida 1992). High temperatures, high winds, and low relative humidity are often associated with drought and can intensify its severity. Three types of drought will be discussed below: meteorological, agricultural and hydrological. This research however, specifically focuses on hydrologic drought.

Meteorological drought is defined both on the degree of dryness in comparison to some 'normal' or average amount, as well as the duration of the dry period. Definitions of meteorological drought are region specific since atmospheric conditions resulting in precipitation deficiencies are highly variable from region to region. Some definitions of meteorological drought identify periods of drought on the basis of the number of days with precipitation less than some specified threshold (NDMC 2009).

Defining characteristics of hydrological drought include prolonged period of below-normal precipitation causing deficiencies in water supply, as measured by below-normal streamflow, lake and reservoir levels, groundwater levels, and depleted soil moisture content. Hydrological drought usually lags the occurrence of meteorological and agricultural drought. This is because a precipitation deficiency resulting in rapid depletion of soil moisture is almost immediately discernible to agriculturalists, but may not be immediately apparent on reservoir levels (NDMC 2009). Climate is a primary contributor to hydrologic drought (Koshida 1992).

Agricultural drought links the characteristics of meteorological drought (or hydrological drought) to impacts on livestock and crop growth. It focuses on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and reduced ground water or reservoir levels (NDMC 2009).

3.6 History of Drought in Southern Ontario and Grand River Watershed

The Province of Ontario has not been immune to drought-like conditions in the past. The 1930s, 1940s, and 1960s have all had notable periods of hydrologic drought, with the most recent occurrence around the turn of the twenty-first century (Klaassen 2000). During the 1930s, large areas of the United States and Canada experienced widespread drought conditions and Southern Ontario was significantly impacted. Although the majority of the 1930s decade was subject to dry conditions, the years of 1933, 1934, and 1936 were considered to be the most severe for agricultural losses. In 1936 the deadliest heat wave in southern Ontario's history was recorded, exacerbating the impacts of agricultural drought in the region. Temperatures in mid-July reached 40^{o}C in several locations, setting daily maximum temperature records that remained unsurpassed until 2001. More than 550 deaths were directly attributed to the heat in 1936 and agricultural production was reduced by 25% as crops wilted and fruit literally baked on the trees in the Niagara Peninsula (Klaassen, 2000). During this exceptionally dry period people could walk across the Grand River at Cambridge in the summer (Nelson *et al*., 2003).

In the 1960s, southern Ontario experienced hydrologic and agricultural drought. In 1963 and 1964, wells in farming communities dried up and tank trucks were used to supplement dwindling water supplies for human and livestock use. In the spring and autumn of 1964, water levels on some of the Great Lakes fell to record lows. The economic impact was estimated to exceed $100 million, with the majority of the losses sustained by the shipping industry (Klaassen 2000). During this time, dust storms in the London-Kitchener area were reminiscent of the American Midwest in the 1930's (Bruce 1963). Drought affects agriculture by drying out soils, making them more susceptible to wind erosion (Gabriel & Kreutzwiser, 1994). Erosion of topsoil can reduce agricultural productivity by 30 to 40%, depending on the soil properties and crop adaptability (GLC 1990). Consequently, during the 1963 agricultural drought, crops suffered and the production of soybean and corn was drastically cut.

In 1998 and 1999, above-normal temperatures again made weather headlines over southern Ontario. Along with above-normal temperatures, precipitation over southern Ontario was well below normal in 1998 and 1999. The high temperatures and low precipitation caused a hydrologic drought with significant impact on water resources in southern Ontario. Low water levels in reservoirs, streams, and rivers occurred in Grey, Bruce, Waterloo, and Wellington counties of southwestern Ontario (*Toronto Star*, October 12 1998). As a result, wildlife populations dependent on these water sources such as waterfowl, beavers, and fish declined or were placed under stress (Koshida *et al.,* 1999). Due to drought conditions and resulting low streamflows, the first ever voluntary fishing ban on brown trout was issued for the upper Grand River's Fergus and Elora areas. Immediate economic losses were estimated at $300,000, but the ban left a lingering negative impression among fisherman about the recreational fishery in the region (*Kitchener-Waterloo Record*, September 12, 1998).

By the end of 1999, water levels in all of the Great Lakes had fallen below the 80-year average and by the summer of 1999, groundwater levels in the Grand River Basin had dropped to their lowest values since the 1930s (Klaassen 2000). During this time, the lowest flows since the 1960s were recorded in the Grand River, and the Grand River's four main reservoirs were reported to have record low water levels due to significant water draw downs and low amounts of precipitation. At Galt, a record low 120-day flow was observed, an event that might be expected approximately once every 60-100 years (Koshida *et al.,* 1999).

In 1998, both the length of the flow augmentation period and the amount of water released from the Conestogo, Guelph, Belwood, and Luther River reservoirs were unprecedented since 1983. In order to maintain a minimum river flow and ensure river quality at Kitchener, Brantford and Guelph, discharge from the reservoirs was increased during the summer months by the GRCA. The reservoirs provided between 30-60% of the flow at Kitchener-Waterloo for an extended period, and on one occasion in May, the reservoirs accounted for virtually all of the streamflow. It is estimated that the Belwood reservoir levels dropped 30 cm every week during the summer. For every 30 cm drop, the water edge receded by six meters (*Kitchener-Waterloo Record*, September 12, 1998). At one point, cottages at Belwood Lake were about 450m from the water as compared to the usual 90m (*Kitchener-Waterloo Record*, September 12, 1998). Conditions during 1998 were so dry that the GRCA predicted that if the reservoirs received no additional precipitation after November 1998, Belwood Lake, the largest reservoir on the Grand created by the Shand Dam, could be depleted as early as the end of March 1999. Fortunately this scenario never unfolded, because in December 1998 the watershed received a significant amount of precipitation (Koshida *et al.,* 1999).

In September of 2002 the Waterloo Record reported that only trace amounts of rain had fallen over the past few weeks, contributing little water to local reservoirs. Cambridge and Guelph were reported to have had only 20mm of rain in the last month, and streamflow in the Grand River was one-third less than the historical average for September. Grand River water levels were augmented through the addition of water from the watershed's reservoir network, and reservoir water levels were drawn down to the bottom of the normal range. Users of water along the upper Speed and Eramosa Rivers, Guelph, Mill Creek, McKenzie, Whitemans and Mount Pleasant Creeks were all urged to cut consumption by 20% (*Kitchener-Waterloo Record*, September 12, 2002).

For the period 2002 to 2010 the weather in southern Ontario has been highly variable with warm periods, cool periods, wet periods, and dry periods. On average, the watershed has received approximately 900 millimeters of precipitation per year, but precipitation data from the Shand Dam climate station in the Grand River watershed shows a ten-year deficit of approximately 350 millimeters in the region. Deficits of precipitation, if cumulative and over a long period of time, could lead to the development of drought conditions in the future. Additionally, the summer of 2007 had very dry periods during which the low storage in the reservoirs challenged the ability to provide sufficient flows to maintain ecological health in the Grand and water temperatures in rivers and streams peaked, resulting in low dissolved oxygen levels that placed stress on the aquatic communities within the watershed (Farwell *et al.*, 2008).

3.7 The Grand River Watershed's Low Water Response Team

In the Grand River watershed, the LWRT is activated when a Level I low water condition is reached. The team is comprised of 16 voting members and 8 non-voting members with the GRCA acting as the chair and secretary. Members represent major water taking sectors. For example, the GRCA has identified the golf industry to be a major water taker within the basin. Consequently, the golf courses in the area are represented by one of their number on the Team. When additional advice is needed in the decision-making process, the GRCA will often draw upon federal and provincial ministry and agency representatives for technical advice so that the many diverse water-taking needs including municipalities, First Nations communities, agricultural, recreational, and industrial water-use sectors can be met. Federal and provincial ministry and agency representatives are considered non-voting members. Their input helps to guide decisions made on the OLWR team, but these members are not given a vote in the consensus making process. A profile of the Grand River Water Response team is given below with number of representatives given in parentheses (Table 6).

Table 6. OLWR team profile in the Grand River watershed. The team consists of 16 voting members and 8 non-voting members (Etienne, October 29, 2009, *pers. comm*).

Voting Members	Non-voting Members
Municipal	**Federal**
Centre Wellington, Southgate (1)	Environment Canada (1)
Regional Municipality of Waterloo (1)	Fisheries and Oceans Canada (1)
City of Guelph (1)	
County of Brant (1)	**Provincial**
City of Brantford (1)	MOE (1)
Guelph Eramosa Township (1)	MNR (1)
	OMAFRA (1)
First Nations	MMAH (1)
Six Nations (1)	
	Technical Advisors
Sectors	Trout Unlimited (1)
Agriculture (4)	GRCA (1)
Brant Federation of Agriculture	
tobacco/ginseng grower	
vegetable grower	
ginseng	
Golf Course Superintendent (1)	
Aggregate Producer (1)	
Commercial Bottler (1)	
Anglers and Hunters (1)	
GRCA (1)	

3.8 The Whitemans Creek Subwatershed: An Area of Particular Concern

One particular area that has received special attention in the Grand River Basin with respect to low water conditions is the Whitemans Creek subwatershed, an area that is heavily used for agricultural purposes. This subwatershed regularly experiences low water periods during the summer months and on a number of occasions has had no flow. An historical assessment of the previous 40 years of data available in the Whitemans Creek watershed was conducted on precipitation and streamflow to determine the relative severity of droughts in this subwatershed (GRCA 2008). In the approximately 40-year period between 1961-2007, Whitemans Creek has had 19 annual occurrences of daily streamflow values reaching Level III OLWR levels of low flow with multiple annual occurrences of these low flows (GRCA 2008). This prompted a closer examination of water resources management within the subwatershed by the MNR and GRCA. Two pilot studies explored the impacts of low flows and how water management and allocation decisions might be made during a Level III condition (GRCA 2007; GRCA 2008). Although a Level III condition has not been declared in the Grand River watershed or elsewhere in Ontario, these pilot studies document how reduced water supplies could affect the social, economic and environmental fabric of Whitemans Creek as well as provide insight on responses to minimize economic impacts and to mitigate social and environmental impacts due to water scarcity. The social, economic, and environmental impacts of Level III low water conditions are summarized in Tables 7a, 7b, and 7c.

Table 7a. Predicted social impacts of a Level III condition in the Whitemans Creek subwatershed (GRCA 2007).

Social Impacts
- tension between water uses creating hostility due to differences in perceived water allocation needs (e.g. residential lawn irrigation versus agricultural irrigation)
- stress on the cold-water fishery resulting in requests to stop fishing the Creek thus impacting local recreation
- fishing restrictions impacting local outdoor recreation membership numbers
- health impacts from self-supply sources being depleted (e.g., residential wells going dry) as most residents in the watershed are on private wells
- family stress associated with the need for agricultural producers to pick up additional work in order to provide for their families

Table 7b. Predicted economic impacts of a Level III condition in the Whitemans Creek subwatershed (GRCA 2007).

Economic Impacts
- less profit or total loss of profit from lowered crop yield or total loss of crop
- food suppliers looking to alternate producers to replace lost crops making it more difficult for producers to recover losses
- food suppliers looking to alternate producers to replace lost crops may drive up food prices for the average consumer or increase the food quality and safety concerns on imports
- lower profits for golf courses that must close due to poor course conditions
- increased water use by-law enforcement increasing costs for municipalities

Table 7c. Predicted environmental impacts of a Level III condition in the Whitemans Creek subwatershed (GRCA 2007).

Environmental Impacts
- significant loss of fish habitat due to the lack of hydraulic connectivity at flows between Level II and Level III (meaning that fish are isolated and cannot migrate between pools)
- fish kills occur if fish are unable to get to a deep pool for refuge or if water temperatures and dissolved oxygen concentrations are outside the optimal range for the fish species

The Whitemans Creek subwatershed case study highlights the social, economic, and environmental sensitivity associated with low water conditions. It is evident from these impacts that in order to encourage sustainability of a region, ecology, economy, and society must be treated as interdependent, and ways to serve all three in a manner that is mutually reinforcing is paramount. Finding this inclusive balance continues to be a challenging prospect.

3.9 The Grand River Watershed as a Case Study

A combination of factors enhance the challenge of water management within the Grand River watershed in light of climate change: a growing urban population; dependency on the Grand River for wastewater assimilation and a portion of municipal drinking water supplies; high reliance on groundwater by some municipalities; a history of significant droughts in the past century; and, location well inland from alternate sources of water. Changes in temperature and precipitation as a result of climate change are also likely to have significant impacts on the hydrologic cycle—especially at the basin scale which is the most pertinent for water managers (Frederick & Major, 1997; Mortsch *et al.,* 2000). For these reasons the Grand River watershed was chosen as a case study to explore the implications of climate change on the resilience of Ontario's Low Water Response mechanism.

The Grand River watershed is anticipated to be sensitive to warmer and drier conditions resulting from anthropogenic climate change and drought-like conditions have been a serious cause for concern in the past. The Grand River watershed's vulnerability to drought conditions in the past gives an indication of future issues due to climate change. This sensitivity is demonstrated below by an excerpt from *Grand Actions, the Grand Strategy Newsletter* describing the conditions in the watershed in 2001, a drought year:

> With record heat and low rainfall this summer, people experienced the effects of drought conditions. Restrictions and even bans on lawn watering were put in place by municipalities throughout southern Ontario. Many farmers watched their crops wither in the heat and dry weather. Golf course operators were asked to voluntarily reduce their water use for irrigation. Water quantity and allocation issues rose dramatically over the summer months (Grand Actions 2001).

The Grand River watershed serves as an interesting test case in Ontario because it has an active Low Water Response Team due to occurrences of low flows since OLWR was implemented. The GRCA is also actively committed to sustaining the natural resources of the region. Furthermore, the Region of Waterloo's Long Term Water

Strategy is seriously pursuing the idea of building a pipeline from Lake Erie due to increasing water needs of the future, proposing that construction could start in 2029 and be completed by 2034. The City of Guelph has also put a pipeline on its list of alternatives for its own long-term water needs (GRCA 2005a). Although a pipeline pushes beyond the natural limits of living sustainably within the watershed, it is viewed as a solution to anticipation of societal demands outstripping water supply. In itself, the need to construct a pipeline exemplifies the anticipated severity of future water shortages for this watershed. Institutional arrangements and low-water management tools of Ontario will consequently be explored in this watershed to assess whether they are resilient enough to projected decreases in water.

3.10 Chapter Summary

This chapter has provided an overview of the GRW. It has detailed the occurrence and subsequent impacts of drought, and the various water use sectors in the region. Due to its history of drought, the GRW has an active, well-established OLWR team. Members on this team will be interviewed in order to explore the resiliency of the OLWR mechanism under conditions of severe water scarcity. The next chapter will discuss the methodology and design of this study.

Chapter 4
Research Design and Methods

This chapter presents the methodology used in this thesis. Before data collection commenced, a literature review of the Low Water Response process was conducted and a review of climate change scenarios coupled with hydrologic models specific to the Grand River watershed was carried out in order to set the hypothetical scenario upon which the research would be based. Next, members of the Low Water Response team in the Grand River watershed were selected, contacted, and interviewed. First, they were asked about the current and past decision-making process under OLWR. They were then asked to provide their thoughts on allocation decisions in response to the climate-change scenario projecting decreased flows for the watershed. A variety of methods were used to obtain and analyze the data during the research phase of this project. They are described in the following sections.

4.0 Case Study Methodology

A case study is a research methodology common in social science. It is based on in-depth investigations of a single individual, group, or event. Researcher Robert K. Yin defines the case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context. The research design used in this study follows a case study research strategy, described by Yin (2003) as being useful in understanding complex social phenomena. Case study research may be used to conduct in-depth investigation of a specific issue and may help to uncover attitudes, perception, beliefs, and interactions of groups the researcher is examining. Although representing depth of information rather than breadth of information, case studies are useful as an indication to the general situation (Yin 2003). Case studies concerning areas of resource management are an effective way for managers to explain social trends related to a particular area or issue and allow informed decisions to be made.

4.1 The Interview as Method

The interview can be used to fill a gap in knowledge which other methods, such as observations or use of census data are unable to bridge efficaciously (Dunn 2000). Since the interview can be used to investigate complex behaviours and motivations, it allows the researcher to collect a diversity of opinions and experiences (Dunn 2000). For these reasons, the interview is an effective method to use when investigating complex, complicated issues. The interview is relevant to this research because in order to assess the resilience of the OLWR mechanism, opinions and experienced of OLWR team members will need to be gathered so the mechanism can be assessed (Babbie 2007).

The interview as means to collect data for this research is supported for three key reasons. First, interviews allow for question and data acquisition to be specifically targeted to the case study topic (Yin 2003). Second, interviews provide the opportunity to clarify or restate questions that a participant may not understand. The researcher may also clarify the answers of participants through the use of non-biased probes. Answer clarification is an advantage of interviews over questionnaires, as not much interaction between the researcher and the respondent exists in the latter (Singleton & Straits 2005). Finally, the interview method is also superior if the researcher is interested in hearing respondents' opinions in their own words, particularly in exploratory research, where the researcher is not entirely clear about what range of responses might be anticipated (Palys & Atchison 2008). Open-ended questions characteristic of interviews encourage the participant to answer in the way he or she chooses, providing a feeling of control and encouraging broader, in-depth answers from the study participant.[4]

While there are advantages to using the interview as means of data collection, there are also methodological challenges that must be addressed related to: question bias, poor recall, and reflexivity (Babbie 2007). There are similar challenges in alternative methods of data collection (i.e. questionnaires and research groups), so these alone do not

[4] Due to the relatively small sample size of this research, responses to open-ended questions were presumed to be manageable.

undermine the interview as a choice of research method. Several strategies can be used to reduce the import of these challenges.

Bias is often associated with the poor wording and construction of questions that may inadvertently lead a respondent to answer in a certain way (Yin 2003). To address this challenge, all questions for this research were pre-tested in two mock interviews prior to the actual interviews (Babbie 2007), allowing for discovery of any biases that were not considered when the questions were developed. Proactive refinement of the questions was also undertaken during the course of the interviews to reduce bias in participant responses. Since few refinements to the questions were made throughout the interview process, pre-testing proved to be sufficient. Additionally, all questions were designed in a neutral[5] manner to further reduce biasing respondents' answers (Palys & Atchison 2008).

Another challenge of the interview process is inaccuracy due to poor recall on the part of the participant (Yin 2003). Interview surveys rely almost exclusively on self-reported behaviour rather than observations of behaviour. Consequently, measurement error may occur due to the inability of the participant to recall past events accurately and by the instability of his or her opinions and attitudes (Singleton & Straits 2005). Since recall inaccuracy is affected by the inability to recall information, or memory distortion, it is more likely that a participant will accurately recall an experience when there is a short duration between the event being studied (Singleton & Straits 2005). This research was conducted within approximately two years after the Ontario Low Water Response team met in the summer of 2007 to discuss low water issues pertaining to Whitemans Creek. To adjust for inaccuracies due to memory distortion, participants were contacted by email prior to the interview. They were provided with a preliminary list of questions as well as some context on previous low water conditions in the GRW and the hypothetical climate change scenario of reduced flows in the Grand River. This allowed participants to prepare prior to the meeting with the researcher. Other techniques utilized to minimize recall inaccuracy included: allowing extra time for the participants to formulate a response; allowing participants to check their personal records prior to

[5] unleading

holding the interview; and, using of close-ended questions as probes (Singleton & Straits 2005). Finally, reflexivity may arise, wherein participants produce socially desirable answers to sensitive questions (Singleton & Straits 2005). Strategies used to address these challenges included the use of indirect questions[6], careful wording of sensitive questions, assurances of anonymity and scientific importance, and the building of rapport between researcher and participants (Singleton & Straits 2005).

The interviews conducted in this study were a hybrid of a structured and semi-structured interview methodology. Each interview followed a structured process, and utilized the same open-ended questions. This ensured that each participant was presented with the same questions in the same order so that answers could be reliably aggregated and comparisons could be made with confidence. Benefits of the structured interview approach include: its legitimacy and reliability; its ability to control the flow of the interview while directly addressing the research questions at hand; its ability to standardize the interview for every participant; its ability to reduce nervousness of the researcher because questions are pre-written; and its ability to maximize the use of the researcher's time. Since a structured interview standardizes the order in which questions are asked, questions are always answered within the same context. Such a structure minimizes the impact of context effects, where the answers to a given question may depend on the nature of preceding questions. Although context effects can never be avoided, it is desirable to hold them constant across all respondents. Where answers were not clear in the participant responses, probes were used to acquire the information desired and to elicit more thoughtful, thorough responses.

The semi-structured nature of the interview process used in this research is reflected in the fact that the interviews themselves were flexible, with new questions being brought up by the researcher during the interview as a result of what the participant said. The researcher also encouraged the participant to freely express ideas and provide

[6] Indirect questions do not close with a question mark but with a period. Like direct questions they demand a response, but they are expressed as declarations without the formal characteristics of a question. That is, they have no inversion, no interrogative words, and no special intonation. (ex. Can you tell me, could you tell me…)

information that the interviewer thought was important. Due to the novel and exploratory nature of this research this interview style was used so that any unexpected information would be obtained.

The framework below was used for designing and organizing the results from the interview questions in relation to the study purpose (Table 8). It provides a conceptualization of how the data will be analyzed, synthesized, and organized in the Results Section (Chapter 5).

Table 8. Framework used to design and categorize anticipated responses for assessing the resilience of the OLWR mechanism in the Grand River watershed.

Characteristics of the Group	Question
Concept Synthesis: Team profile	
Education	1, 1a, 1b
Current employment	as above
Employment history	as above
Sector represented	as above
Decision making process	3
Concept Synthesis: Awareness of issue	
Competition over water	2
History of drought in watershed	2, 2a, 2b, 2c
Lessons from previous droughts	2d
Components of Outcomes	**Question**
Theme: OLWR shortcomings	
Allocation	
Categorization of uses	5
Prioritizing the essential uses	6
Ecosystem-based approach	
Definition	13
Incorporation in decisions	13a
The critical fisheries	
Defining thresholds	7
Consideration of biologically critical sites	8
Minimum flows	9, 9a, 9b
Identification of	10
Theme: Allocation during reduced supply	
Allocation	
Sector priority	15, 15a
Maintaining equity	16, 17, 17a
3 low flow scenarios	18, 18a, 18b, 18c
Theme: Areas for improvement	
Strengthening the OLWR mechanism	
Policies and management actions	11, 16
Direction towards resilience	19

4.2 Ethical Considerations

The University of Waterloo Office of Research Ethics (ORE) granted full ethics clearance for this research in mid-October 2009. The approval process involved a review of recruitment materials, sample questions, potential risks posed to study participants, and the informed consent process for use with participants.

During the interviews, some participants wished to remain completely anonymous, while others allowed attribution of their comments. With permission of all participants, interviews were audio recorded. Additionally, extensive notes were taken by the researcher during all interviews. Upon completion of the research all interview transcripts and notes were confidentially shredded and electronic records were deleted.

4.3 Selection of Participants

The contact information for the 23 decision making and non-decision making members of the Grand River Low Water Response team was obtained through the Chair, James Etienne, of the Grand River Conservation Authority. These were members serving on the committee during 2007, after which time the team has not had any formal meetings[7]. Twenty-one members were contacted with a participation email as there was no current contact information for two members. Thirteen members agreed to be interviewed and they represented each major water use sector on the Low Water Response Team (Table 9). Because there was representation from each major area of importance on the team, this selection was deemed to be an adequate representation of the Grand River Low Water Response Team. Of the 13 OLWR participants interviewed, one was not available during the arranged interview time due to unexpected professional commitments. A fellow colleague, knowledgeable on OLWR and affiliated with water conservation issues answered the interview questions in place of this participant.

---

[7] Both decision making members and non-decision making members were contacted for this research for comprehensive coverage of how OLWR operates in the GRW.

Table 9. Eleven decision-making members and two non-decision members on the Grand River's OLWR team were interviewed.

Decision Making Members	Non-Decision Making Members
<u>Municipal and First Nations - 5 interviewed</u>	**<u>Federal</u>**
Centre Wellington, Southgate	Environment Canada
Regional Municipality of Waterloo	Fisheries and Oceans Canada
City of Guelph	
County of Brant	**<u>Provincial - 1 interviewed</u>**
City of Brantford	MOE
Guelph Eramosa Township	MNR
Six Nations	OMAFRA
	MMAH
<u>Sectors - 6 interviewed</u>	
Agriculture	**<u>Technical Advisors – 1 interviewed</u>**
Brant Federation of Agriculture	Trout Unlimited
tobacco/ginseng grower	GRCA
vegetable grower	
ginseng	
Golf Course Superintendent	
Aggregate Producer	
Commercial Bottler	
Anglers and Hunters	
GRCA	

4.4 Interview Design and Methods

The interview strategy utilized by the researcher incorporated the technique known as funneling (Palys & Atchison 2008). First broad open-ended questions were asked, followed with successively narrower and more specific questions. For example, the very first question of the interview asked about the history and background of the participant, so that the researcher could gain some knowledge on the participant, and set the pace and question-response cycle for the remainder of the interview. The participants were then asked about their previous contributions to the Low Water Response Team, its historical context and the current process of decision-making. Next, they were asked to explore the Low Water Response mechanism under a climate change scenario. One benefit of presenting the questions in this logical order was that it decreased the likeliness of data distortion.

All interviews were audio recorded for the purpose of data collection. Audio recording the interview allowed the interviewer to pay careful attention and to concentrate on what the participant was saying, so as to have time to plan follow-up questions. It has been noted that some participants may become shy or hesitant if they are being electronically recorded and that electronic recordings might influence what people say (Rubin & Rubin 2005). The use of the laptop as the audio recording device seemed to minimize any hesitancy, as it could be completely closed while recording and blended into personal office settings. Its presence seemed to be forgotten by the participant shortly after the start of the interview. Moreover, it is unlikely that the audio recording influenced participant responses, as in all cases, participants were informed that no one but the researcher would be listening to it. Thus it can be presumed that the participants spoke honestly and openly.

Additionally, notes were taken throughout the duration of all interviews. Note-taking forces the researcher to listen carefully enough to jot down main points, and also provides a back-up in case the audio recorder fails. It also allows the researcher to write down potential questions for later use in the interview, while allowing the participant to keep track of what is being said. Since the participant is likely to slow down until the researcher is finished writing, note-taking also encourages the participant to keep a reasonable pace (Rubin & Rubin 2005).

4.4.1 Interview Etiquette

During all interviews, the researcher remained as tolerant, friendly, interested, detached, and professional as possible. An attempt was made to keep the demeanor of the researcher neutral during the data collection so that her presence would not have any effect on the responses given (Babbie 2007). It has been suggested that this type of demeanor generates a general feeling of understanding between researcher and participant in a way that imposes minimally on the participants' views, thus minimizing bias (Palys & Atchison 2008).

To further minimize the effects of bias during the interview, both the words and tone of the researcher were kept as neutral as possible. The words "I understand" or "ok" were used to relate to the participant that he or she was being listened to and understood, but a positive or negative tone during enunciation was avoided. To keep the participants at ease that the quality of their answers was not being judged, they were reminded that there was no right or wrong answer, but that the researcher was interested in collecting their experiences, including what they did and what they thought.

To demonstrate that the researcher was interested in detailed, in-depth responses, eye contact was made, although not to the extent to make the participant nervous. Upon rendition of events, the researcher listened intently and without interruption. Where further explanation was required, a probe[8] was used by the researcher. The probe was kept neutral so as not to affect the nature of the subsequent response. All responses were recorded manually on a clipboard placed on the office desk. Lying the clipboard on the desk assured the participant that their responses were not being hidden. Furthermore, because the participant could see the notes, he or she could make suggestions to what was being written if that was the desire.

4.4.2 Interview Agenda

As previously discussed, data collection for this research was in the form of 13 in-person interviews, with initial contact with the participant being made through a participation email. Interviews took place between October and December 2009, and lasted between 50 and 90 minutes. The steps below were followed during all interviews:

1. A setting with few distractions was chosen. For the majority of the interviews, this was in the interviewees' office. Here an electrical outlet for the audio recording

[8] Non-directive question (i.e. "anything else?")

device was available and responses could be kept confidential.

2. The researcher introduced herself and the purpose of the study was explained. The participant was given a brief summary on the background pertaining to the research and of the study's significance. The participant was told that a brief summary of the results would be sent to them following completion of the study.
3. Terms of confidentiality were addressed. The participant was asked to sign the consent form. The form had a checkbox if the participant agreed to have the interview audio recorded.
4. The interview format was explained. The participant was told that the first part of the interview would explore the historical context of Low Water Response and the latter part of the interview would explore the Low Water Response mechanism under a climate change scenario.
5. The participant was told how long the interview would last.
6. The interview was carried out.
7. Immediately following the interview, the participant was allowed to clarify any doubts they might have had about the interview.
8. The participant was given the researcher's contact information and told that the final transcripts would be forwarded to the participant for review.

Upon completion of an interview, notes were reviewed before the next interview took place. This allowed the researcher to clarify any unclear points while the interview was still fresh in mind, and follow-up information was obtained from the participant when deemed necessary. Transcription was carried out as soon as possible after the interview to ensure that minimal information would be lost if the recording was in parts unclear, as it would still be fresh in mind. Transcripts were then sent back to the participants to confirm the accuracy of the conversation and to add or clarify any points. Transcripts returned from the participants were those used for data analysis.

4.5 Data Analysis

Coding of interview results is an interpretive technique that organizes social science data in an attempt to discover patterns which ultimately lead to theoretical understanding. In general, coding first requires the researcher to read the data and demarcate segments within it. The segments are labeled with a code, which can be a word or short phrase suggesting how the associated data segments lead to better understanding of the research objectives. Upon completion of coding, the researcher is able to shed light on the research topic by either summarizing the prevalence of codes, discussing the similarities and differences in related codes across distinct sources, comparing the relationship between one or more codes, or a combination of all three. This section describes the coding method used to produce the results presented in the next Chapter.

Following review of Rubin and Rubin's (2005) chapter entitled "Analyzing coded data," the coding took place in the following fashion. First, participant responses were taken from the transcribed interview documents and listed with respect to each question in the interview, which involved some cutting, pasting and rearranging of the original transcripts. Next, the questions, along with all of the participant responses, were read a minimum of two times each so the researcher would have a clear understanding of the scope and detail of what each participant was trying to convey in their response. Coding categories were then formed by grouping together reasons deemed similar from the research perspective to form a theory surrounding the research questions. When presented in the results, the column entitled "Participant Responses" represents views and opinions that were mentioned by three or more participants. The second column "Grouping of Responses," organizes the responses in the first column into more encompassing themes to narrow the direction of analysis. The third column "Emergent Themes", lists themes that overarch columns one and two. Finally, the far right column represents overarching themes that encompass all stages of analysis.

As the data were grouped into categories representing themes, concepts, and ideas, sometimes important information did not fit into any of these categories or that one category blurred two or more separate concepts. When this was the case, new categories were made to fit the data and material previously examined was recoded. Final data analysis involved grouping into one category all of the materials consistent with one theme or concept. The ultimate goal was to integrate these themes and concepts into a theory. Data analysis was considered complete once all individual concepts and themes were found and a theory offering an accurate and detailed interpretation of the resiliency of the OLWR mechanism had been developed.

It should be noted that for questions where coding was not deemed appropriate by the researcher, such as where background information on the OLWR team was obtained and their awareness of the issue to provide context to the research at hand, a conceptual synthesis of responses was used to present the data. For the question that was assigned a numerical score, the overall ranking was determined in the following fashion. In the interviews, participants were asked to list the essential uses of water from the most to least essential. Upon analysis, these lists were numbered for each participant, with a score of one being assigned to the first essential use mentioned, and successive numbers being assigned to the other uses. An inclusive list of all the mentioned essential uses was made, and the assigned number from every mentioned use was transferred to this list. Once all uses were entered onto the list, the numbers were summed for each essential use. The total number for each use was then divided by the number of times it had been mentioned, with a lower score indicating a higher level of essentiality.

4.6 Chapter Summary

This chapter discussed the research design and methodologies used, detailing how Low Water Response team members in the Grand River watershed were chosen, contacted, and interviewed. It has subsequently examined how data from these interviews were coded and analyzed. Presentation of results follows in the next chapter.

Chapter 5
Results

5.0 Introduction

In this chapter, data collected during the 13 interviews are summarized. The first two sections of the results section (*Profile of the OLWR Team* and *Awareness of the Issue*) are presented as a synthesis of salient topics and responses from participants. This is because they were intended to provide context and scope regarding the issue at hand and were not suited for theme coding. The third section of this chapter (*Allocation*) is also presented as a synthesis of responses, as participants were asked to identify the categorizations of water uses in the watershed. Data gathered for this section was in list format and was also not suitable for coding.

When it is first presented in the results, the ecosystem-based approach is described as a synthesis of opinions. However, salient topics from this approach were then coded into one general theme to express an overview of what team members believed the ecosystem approach to mean. A synthesis of the shortcomings of the ecosystem-based approach are next presented. To identify the most critical fishery in the watershed and the ways in which OLWR could be improved to better meet the demands of reduced flows under a climate change scenario, coding was used.

Presentation of the results in this chapter is not in order of importance and the results are not presented proceeding question by question with a mere 'reporting' of responses. Rather, results are presented by synthesis of major topics that have emerged about OLWR and its operation using the framework introduced in the previous chapter. Because the research was exploratory and qualitative in nature, all salient themes derived from the data set were considered to hold equal importance.

5.1 Profile of the OLWR Team

The 13 members of the OLWR team interviewed had a solid background related to water management, ranging from 4 to 33 years of experience, with half of the team members having spent more than 12 years working in their field, or a closely related field to water management (e.g., aquatic environmental consulting, private consulting for water contamination, water infrastructure and demand management, sewer engineering). Four members had worked in a water management field for over 30 years. Many had post graduate education (Masters and PhD degrees) in areas including hydrogeology, geotechniques, and water engineering. Some team members had biological and ecological backgrounds, while others had practical experience in demand management and water conservation strategies. Team members possessed a strong working knowledge of the sectors, industries, and corporations they represented, with the majority expressing genuine interest in the interrelationship between water resource management and the natural environment.

Decision-making on the OLWR team is consensus-based. All team members have a voice and contribute opinions until general agreement is reached. The final decision on water management issues and allocations are made with guidance from technical reports and recommendations from the CA, and Federal and Provincial Ministries. Representation on the team is broad enough to encompass all sectors with an interest in water taking with most members believing that they have "advisory power to [the] decision being made by the Conservation Authority" (respondent F). One team member believed that the team did not have the right representation proportion. Respondent H states that "close to half the people on [the team] should be agriculture [representatives]… because it is the biggest business in the area."

5.1.1 Awareness of the Issues Associated with Drought

5.1.1.1. Competition and Areas of Vulnerability

Competition for water in the watershed, although termed "friendly" by respondent E, is most evident in specific reaches along the river where extensive water taking occurs, but competition becomes more intense during periods of low flow conditions. Competition between municipal and agricultural water taking, as well as "between the human users of water and the needs of the river [ecosystem]" is evident (respondent I). "One of the reasons [why] the low water response team was put together for the Grand River watershed was to try to address some of [these] issues about allocations and who [would] get priority [during] different levels of concern," states respondent G. "There always has been [competition]. It doesn't matter where in the world you go, there [always has been] competition for the water. There's nothing unique here," states respondent H.

OLWR team members identified vulnerable areas including Whitemans Creek, the Cambridge, Kitchener, and Waterloo urban areas (due to development), the region around Guelph and Wellington, and parts of the river along the Eramosa, the Nith, and the upper Speed. In the past, the section of the Grand River between Cambridge and Brantford has also been a vulnerable area from a nutrient assimilative capacity standpoint.

5.1.1.2 Lessons Learned from Previous Droughts

Team members were well-informed about previous drought occurrences in the region, as responses generated were consistent with the literature surveyed for the period 1960-2010 (Klaassen 2000; Koshida *et al.*, 1999). The agricultural industry was perceived to be the most vulnerable water use sector during periods of reduced water supply. "Tobacco farms … and … other cash crops that required [heavy] irrigation were starting to suffer," respondent G comments.

During periods of reduced flows in the past, it was evident within municipal sectors that water use restrictions were not completely effective unless residents were well-informed about current water situations and restrictions on water use were clearly communicated to the public. "You can put … restrictions in [place], but if people don't know why they are being put in there, then they're not as prone to follow them," states respondent G. Team members also felt that implementing the OLWR program was easiest in the municipal setting:

> because [municipalities have] more control from one source serving thousands of people [to track] what the [quantity of water uses] are. [Municipalities] can track if they are reducing consumption very quickly because it is all metered on a daily basis, and there [are] lots of mandated records that go back, so you can see results. In retrospect, it is very difficult to track water consumption in individual wells and rural settings because permits may not even be required for individual rural households, for livestock watering, or for other uses under 50 cubic meters a day (respondent M).

Due to the difficulties associated with monitoring water use in rural areas and from private well takings, progress in terms of water reductions is difficult to observe. This suggests that water monitoring within the basin should be improved.

5.2 OLWR Shortcomings

5.2.1 The Challenge of Allocation Prioritization

OLWR has attempted to prioritize water use by assigning them to essential, important and non-essential categories. Within these categories, however, there has been "nothing formally set up" in terms of determining priority of allocation (respondent E). "There's never been a hierarchy of who would get water," confirms Respondent D. "We hate to go down that road, because… we are impacting the livelihood of somebody" states respondent C.

OLWR team members stated that it would be the Province's responsibility to make priority-based decisions, but "no one [in higher levels of government] is going to put their head out initially to start that because it's just too difficult to work with… we want to have working relationships with our local peers in the different [sectors]" (respondent F). Although a formal method of prioritizing water allocation has yet to be determined, team members have stated that the highest use priority "should always be human consumption" (respondent C) alongside "sustaining [the] health and safety of the population" (respondent K). There was agreement that the first areas to undergo cutbacks would be "geared towards … aesthetic[9] use first," suggesting that these uses are of lowest priority (respondent M). The economy of the Province would also take "very high priority" (respondent K).

5.2.2 Distinguishing Essential, Important, and Non-essential Water Uses

Team members had different perspectives of essential, important, and non-essential uses of water. Overlap existed amongst these three categories, with agricultural and livestock water use, water for business and industry, and even water for car washing spanning different categories depending on the water use the member represented. From the water uses listed by the participants, it is apparent that some uses are much more salient. These uses include water for human drinking and agriculture (specification was not made for irrigation purposes or livestock watering). Uses such as effluent dilution and water for fire protection, on the other hand, were not as frequently thought of and mentioned. Water needed for the natural environment was only mentioned by a total of 6 of the 13 participants.

When asked to list the essential uses of water in the Grand River watershed, potable water for human consumption and drinking was listed by all 13 participants as

[9] e.g. lawn watering, water in fountains, and personal car washing

essential. Agricultural water use was the next most commonly mentioned essential use and was listed by 7.5[10] respondents as essential. Five participants felt that water for livestock was essential and 6 respondents listed water for the natural environment as essential. Water for fire systems was listed by three participants, and diluting effluent was listed by two participants as essential. One participant listed water for business as an essential use. Placement of agricultural water use and water for livestock within the three categories varied. Three respondents placed water for agriculture as important and one respondent listed water for livestock as important.

When asked to list the important uses of water in the Grand River watershed, 7 participants listed water for business and/or industry as an important use.[11] Two participants considered water for business to be essential and one participant considered water for industrial use as non-essential. One participant specifically listed water for food manufacturing as important. Aggregate washing, water for public parks, and water for car washing were considered by one participant each as important. Respondent G stated that amongst the three categories of water use, "nothing fits in the middle," which suggests that this respondent feels that only two categories of water use (essential and non-essential uses) are critical within this context. There was great variance amongst participants whether car-washing businesses, sod production, nurseries and garden centers, and golf course operations should be considered under this category.

When asked to list the non-essential uses of water in the watershed, 4 participants stated that water for golf courses would be a non-essential use. Six-and-a-half[12] participants listed water for lawn watering as non-essential, 3 listed personal car-washing and 3 listed water for aesthetic purposes. Three participants reported sod production to be a non-essential water use, while water for swimming pools, manufacturing of non-food

---

[10] Where it was hard to interpret the meaning of a respondents answer, a half mark was assigned to the category. For example, one respondent listed "core services" under the essential uses of water. Core services might include agriculture, as people need to eat, so a half mark was assigned.

[11] Little distinction was made between water for business and water for industry by respondents and so these uses were considered together upon analysis.

[12] Half marks were assigned to the lawn-watering category when a participant listed "water for golf course irrigation" and not specifically "lawn watering", as these two uses of water are very similar.

related products, boating, fishing, and recreational water uses were all listed as non-essential by one participant each. Water used for cosmetic purposes made up the majority of the non-essential water use category.

5.2.3 A Step Towards Prioritizing the Essential Uses

Ontario Low Water Response Team members reported that potable water for human use, water to maintain ecosystem integrity, water for agricultural uses, water for diluting effluent, water for business and industry, and water for fire protection were considered to be essential uses in the Grand River watershed (Table 10). Amongst these uses, potable water for human consumption was the most frequent use discussed, being mentioned by all 13 team members interviewed. This suggests it is also the most salient amongst the essential uses. Following potable water for human consumption was ecosystem health[13], and agricultural uses. Effluent dilution, water for business and industry, and water for fire protection were mentioned by less than one third of the team, suggesting that these uses are not as prominent within their realm of thinking.

Amongst the water uses considered essential, water for human consumption was considered most important, receiving a ranking score of 1.1, as calculated using the methods stated on page 62 of Chapter 4[14]. Ecosystem protection was ranked second with an overall importance of 1.6, followed by business, fire protection and agricultural uses.[15] Effluent dilution had the lowest level of importance amongst the essential uses of water and was only mentioned by one of the Low Water Response Team members as an

[13] In this stage of data analysis, participants were told by the researcher to include water for natural ecosystems under the essential category, as stated in OLWR. One member, however, failed to mention this use, meaning that it was mentioned 12 times, as opposed to 13.

[14] To reiterate the methodology used in this analysis, participants were asked to list the essential uses of water from the most to least essential. These lists were then numbered for each participant by the researcher, with a score of one being assigned to the first essential use mentioned, and successive numbers being assigned to the other uses. An inclusive list of all the mentioned essential uses was made. The assigned number from every use mentioned was then transferred to this list. Once all uses were entered onto the list, the numbers were summed for each essential use. The total number for each use was divided by the number of times it had been mentioned, with a lower score indicating a higher level of essentiality.

[15] Some respondents made no distinction between water for crops and water for livestock. Where there was no specification amongst these uses, responses were classified simply as "agricultural uses."

essential use, even though this use is very important and is mandated by provincial legislation.

Table 10. The essential uses of water and their hierarchy of importance.

Water Use	Times mentioned	Overall importance
Human - potable	13.0	1.1
Ecosystem	12.0	1.6
Business	3.0	1.8
Fire Protection	3.0	1.8
Agricultural	6.0	2.0
Agriculture (livestock)	6.0	2.0
Industry	2.0	2.5
Agriculture (crop)	1.0	3.0
Diluting Effluent	1.0	4.0

5.3 The Ecosystem-based Approach

The Permit to Take Water mechanism outlines how water will be allocated amongst water users and the natural environment.

> The Province of Ontario's Ministry of Environment has claimed that it will use an ecosystem-based approach to water allocations. This approach will consider both the reasonable needs for water takers and the natural function of the ecosystem, whereupon the highest priority will be placed on preventing significant environmental harm to aquatic environments as well as all other natural environments (MOE 2005).

As is evident, the PTTW was designed to limit how much water can be withdrawn by water users without harming the environment and is one framework under which the environment can be protected. When asked about the Ministry of the Environment's ecosystem-based approach to water allocation, the majority of the respondents replied that they believed this to mean that water should not be taken if detrimental effects to the environment would occur. This can be seen in Table 11, where participant responses concerning the meaning of the ecosystem-based approach were coded (Appendix E; Question 13, 13a). Coding was used to group participant responses into one general theme summarizing what OLWR members believed the ecosystem approach to mean. The final theme encompassing the meaning of this approach is presented in the column on the far right. In order to maintain environmental integrity, respondents felt that various types of environmental monitoring should be used, including comparisons to historical flows, the regulation of water taking, and measuring and maintaining flows to ensure the best management decisions are made (Table 11, Participant Responses).

Table 11. Interpretation of the ecosystem-based approach by the Grand River watershed's OLWR team members.

Participant Responses	**Grouping of Responses**	**Emergent Themes**	**Overarching Themes**
Knowledge Stay informed Common sense Scientifically based Historical usage Communication	Knowledge and awareness	Informed approach	Informed approach with the underlying principle of environmental stewardship
Water taking Regulate pumping Adjust withdrawal amounts Stop extracting Limit where close linkage to surface water	Management	Management	
Sharing through prioritization of needs	Partnership		
Commitment to protect ecology	Commitment		
Flows Measure Maintain Monitor	Environmental flow	Environmental Practices	
Practices Conservation Restriction Regulation	Environmental practices		

During times of severe water shortage team members were skeptical whether the ecosystem-based approach could be maintained. Regardless of the intent of the MOE concerning the ecosystem approach and the protection of aquatic resources, respondent K stated that during times of shortage, "there is no question that survival of the human race will be the number one priority - without question." Other members also acknowledged that during times of scarcity humans would take top priority. Respondent L reported that although the Province is dedicated to protect and preserve the environment "the thing they will protect first is human health and employment." This was reiterated by respondent G who offered similar evidence: "when the rubber hits the road … and we have to make a choice between the ecology and giving people fresh drinking water…. people with fresh drinking water are going to win regardless of what the policy says."

A few members even stated that the MOE was not capable of implementing the ecosystem approach, because for this type of approach to be successful it needed to be "spearheaded on a watershed basis, more so than on a provincial basis" (respondent A). Furthermore, it was clear across some responses that some team members believed this statement by the MOE to be ambiguous and for this reason that it was also deficient. The statement by respondent K illustrates the thinking, "they want their policy statement to reflect a high interest in the natural environment… But when they say an ecological approach, that's like a holistic approach where all of the different stakeholders will be addressed. So in kind of a backwards way, they are saying [aquatic environments] are [the] most important thing, unless people need water. And that's why I find that that's a bit of a foggy statement, because by saying they are doing it on a ecological basis, humans are part of that ecological network…. and what they are basically saying in kind of a shrouded way [is that the aquatic environment] will be our most important thing, unless something else is more important… and people are more important" (respondent K).

Many of the respondents think that the ecosystem approach is a broad brush concept with good intentions, but due to its component of inclusively spanning all levels of the ecosystem, humans included, environmental protection of fisheries and other aquatic life may not in fact be guaranteed under time of water stress and shortage due to the "shrouded concept" of this integrated approach. The human component of an integrated ecosystem based approach could thus potentially trump environmental needs.

5.3.1 The Critical Fisheries and Threshold Values

It was evident from participant responses that cold water fish communities are probably the most sensitive in the Watershed, because "they require both a combination of colder temperatures than the warm water animals, and much higher dissolved oxygen levels… [thus making them] most sensitive to change" (Respondent I). This trend was evident amongst most of the participants interviewed, as when responses were coded, the identification of cold-water habitats being the most vulnerable was an emergent theme (Table 12).

There is inconsistent data amongst participants in regards to whether biologically critical sites are given consideration in the water allocation process during times of drought or water scarcity. About one-third of the team members stated that they were not considered in the allocation process under OLWR, but that biologically critical sites were considered under the PTTW. Another third of the team members stated that biologically critical sites were given attention under OLWR by joint efforts of the GRCA, MNR and MOE. The remaining team members were unable to answer this question due to lack of knowledge on this topic. Regardless, if the ecosystem approach encompasses all components of the ecosystem, humans included, the critical fisheries of the watershed could be negatively impacted, as they are most sensitive to change.

When asked how OLWR thresholds between Levels I, II, and III were determined, the majority of respondents stated that they were defined consistently as a percentage of historical low flow base values and that these base values would vary geographically. Movement from one level to the next is triggered when these thresholds are crossed, as indicated in OLWR. Biologically critical sites, such as the cold-water fisheries, are not subject to more stringent threshold values.

Table 12. The critical fisheries as identified by respondents.

Participant Responses	Emergent Themes	Overarching Theme
Brook trout, brown trout	Cold water fishery	Cold water fishery
Whitemans Creek		
Areas of cold water, high oxygen and low temperature		
Groundwater fed areas High water quality		
Limited conditions for survival	Areas with limited survival conditions	

5.4 Allocation during Reduced Supply

5.4.1 Dealing with Reduced Flows under Climate Change

When asked how water might be apportioned when river flow is 25, 50, and 75% below average summer low flow, it was agreed by all team members that human consumption would take precedence and few or no new permits to take water would be issued. Under the three scenarios, all respondents were in agreement that aesthetic uses of water would be the first water use to be eliminated, implemented by mandatory restrictions on personal lawn watering, personal car washing, and water used to fill private swimming pools (although some respondents believed that municipal swimming pools would be treated differently as they serve a collective purpose for the residents of a given region). In order to enforce these water restrictions, there was agreement that more aggressive enforcement and use of fines should be put in place, especially within the municipal and residential sectors. After recreational water uses, golf courses and water-bottlers were two water use sectors suggested by team members as having to be eliminated.

Three team members could not imagine a scenario with 50% reduced flows, and two additional respondents could not imagine a scenario at 75% below average summer low flow. Two more members suggested that the only way to deal with 75% below average summer low flow would be for people to move out of the watershed. It was suggested by many team members that one option for dealing with water shortages under the 50 and 75% scenarios would be to consider exploring new sources of potable water, notably, building a pipeline and importing water from Lake Erie.

There was no agreement across participants on which water use sector would be the first to be eliminated during periods of extreme water shortage. Some members suggested that when average stream flows were 50% below average historical flows, industrial use would be shut down selectively on a priority basis. This priority basis remains yet to be determined and the industries have yet to be identified. Other members suggested that instead of eliminating water use sectors completely during times of shortage, "some relative percentage" of water reduction proportional to the priority ranking of each sector would need to be determined in order to maintain fairness (respondent F). A few team members suggested that during water shortages around 50% below average summer low flow only irrigation for non-water intensive crops would be tolerated. Regardless of the range of opinions generated concerning how society would deal with these three scenarios of reduced flows, one trend was evident: that priority rank would be assigned following OLWR guidelines and that water to sustain human life would take highest priority. Although such an approach seems intuitive in making the best out of water short periods, due to the ambiguity of essential and non-essential uses as outlined in OLWR, basing decisions on the current OLWR document would be challenging. "Not until the Province provides us with some *better* [emphasis mine] direction on how to do the allocation under [these] kind of emergency scenarios will we know for sure how water will be allocated amongst the various sectors," states Respondent F. It is evident that the OLWR document, as it stands, needs some revision and more specific category clarification for it to be of use in future water short periods.

5.5 Strengthening the OLWR Mechanism

5.5.1 Preparing for the Future

"The least effective way of managing water during low flows is when [there is a] low flow, because at that point [there is] no other option… than to make somebody suffer," stated respondent I. Respondent A stated that the "issue with [the OLWR process] is that it has to build on a longer term, more systemic analysis of water management and water use on a watershed basis, with programs in place to start to manage water better on the landscape *before* [there is a] a crisis … to deal with." To encourage aquatic ecosystem protection and equitable water allocations in the future under conditions of water shortage, a proactive approach to water management is necessary. This pattern emerged from the data after it was analyzed and grouped into larger, more summative themes (Table 13). The first column in Table 13 (Participant Responses) groups all responses that were listed by three or more participants in the interviews. The second column in Table 13 (Grouping of Responses) expands on the responses and groups them into more encompassing themes in an attempt to narrow the direction of analysis. The third column in Table 13 (Emergent Themes), lists themes that overarch columns one and two. The far right column in Table 13 represents overarching themes that encompass all stages of analysis. As can be seen in Table 13, the proactive approach to water management would include water managers and planners raising public awareness on water issues, and incorporating conservation and efficiency strategies to address potential future shortages (Participant Responses, Table 13).

"If we truly want to be proactive, [we] need to figure out how to better use water on and in [our] landscape over the long term, so when [we] have times of plenty, [we] store it better in aquifers, wetlands, and in reservoirs so during periods of extreme drought [we] have more flexibility in how [it is managed]," noted respondent I. Respondent L suggested that, "we can prescribe on a local level what building standards may be knowing that in turn we [will] have limited resources available." And finally, as is evident throughout much of the data, it was mentioned by respondent K that "a little

[more] guidance … [in determining] what [is] essential, what [is] of mid importance, and what [is] of low importance" should be given to various uses of water in the Watershed. In order to effectively cope with water shortages in the future, "it's better to do that [now] than … under a time of panic or stress" (respondent K).

Table 13. Using the proactive approach to prepare for future water shortages.

Participant Responses	Grouping of Responses	Emergent Themes	Overarching themes
Educate industry and golf courses Better education Inform public of what is being done Awareness of issues Understand water-taking system Educate farmers	Awareness	Engage	Proactive water- management approach
Communicate with general public to understand their needs Better communication Communicate issues	Communication		
Understand when/where demand is Develop better management plans with the industrial sector better water management Manage water correctly demand management	Management	Proactive management approach	
Conserve Reduce direct on-line takings Reduce water use Scaling back use	Conservation		
Financial incentives	Incentives		
Set up redundancies	Redundancy		
Provincial direction	Provincial direction and guidance		
Research Next step study template Research which wells could be closed down	Research		
Proactive approach Planning in advance	Proactive planning and management		
Equitable reduction among all water users	Equity		
Upgrade irrigation systems to be more efficient	Efficiency-upgrades	Upgrade	
Outline of essential / non-essential and mid-range uses			
Housing standards Building standards	Refinement of Ontario Building Code		

5.5.2 Incorporating Policies and Management Actions into OLWR for Resilience

As part of the proactive management approach, five directions emerged from the interview process that could move OLWR in the direction of promoting greater resilience for water allocation and ecosystem protection during times of scarcity (Table 14, Overarching Themes). These included: better partnership and involvement between water use sectors at the local scale and the Province at the regional scale; implementation of infrastructure upgrades; a solid water management framework stressing a proactive approach incorporating conservation practices and efficiency strategies; the encouragement of social change towards public water use attitudes in an attempt to loosen the firmly entrenched "myth of water abundance"; and finally, continued research and monitoring of aquatic habitat under changing climate conditions to optimize preservation strategies and techniques. Team member responses, as listed in Participant Responses of Table 14, are all components of the six different directives which have emerged.

Table 14. Directives toward a proactive management approach.

Participant Responses	**Grouping of Responses**	**Overarching themes**
Public OLWR program awareness to public OLWR program understanding to public Stronger focus on public education	Public education about OLWR program	Partnership, involvement and awareness System upgrades and implementation Water management framework stressing proactive approach Encouragement of social change towards water use attitude Continued research and monitoring
Better internal communication with involved organizations	Partnership	
Improve relationships between Provincial governing authorities and watershed Conservation Authority regulates		
Conservation Water conservation programs Decrease water use Recycle water Grey water	Water conservation practices	
Implement more efficient ways of using water across sectors Drip irrigation		
More incentives Rebate programs		
Research Better understanding of the watershed More technical studies to understand how the system works Greater understanding of how climate change may affect conditions in the watershed Better understanding of climate change and water supplies Pilot studies	Research	
Apply GRCA environmental flow methodologies		
Demand management programs	Water taking/use	
Water taking/use Minimize water taking Reuse water Grey-water systems		
Storage Create more storage space on site Create more reservoir space Systems in place to hold water Build river pools Encourage off-line ponds	Proactive approach Precautionary approach	
Efficiency More efficient ways of getting rid of waste Grey-water systems		

Enforce Implement and enforce Administrative ability to enforce Enforcement of OLWR restrictions		
Building code changes New subdivision and commercial industrial park standards		
Education Education all around (sectorial)		
Awareness Awareness of the issues		
Better water management Develop list of priorities and best management practices		
Policy change – collect roof water, add water meters on every house		
Knowledge of the water resources		
More monitoring	Monitor	
Improve quality of water from wastewater plants by building new features (add segments and modules) now	Treatment plant changes	
Plan Build and plan for what is expected to occur in the future		
Change/modification Social change Change building code standards PTTW changes Proactive approach React now, not when there is problem Proactive approach, not reactive Initiate programs to help make the situation better beforehand Project forward and plan in advance Precautionary approach	Social change Water taking changes	
Ensure all agency involvement	Involvement	
Provincial Provincial orders and regulations on water use Provincial regulation Additional Provincial guidance and direction	Provincial guidance, direction, and regulation	
Evaluate water footprints	Footprint consideration	

5.6 Evaluating OLWR

When OLWR team members from the Grand River watershed were asked about the ability of the OLWR mechanism to allocate water equitably between human users and the natural aquatic environment during times of water scarcity, respondents expressed being "not very confident" to "confident." Hope remains for the future of water resources and aquatic ecosystems in Ontario, as the response median was 3 ("neutral")[16] with the distribution of responses being unimodally centered around the median. This suggests that there is impetus for more research on this subject.

5.7 Chapter Summary

This chapter has presented the results of the study, with emphasis placed on the challenges of OLWR's water use classification system. The results from this study have shown that there is ambiguity with respect to the meaning of the ecosystem approach and that during times of serious water scarcity respondents thought that priority would be given to human uses (e.g., drinking, sanitation and health care) over environmental needs for water. Although the OWWR was designed to be a proactive mechanism, many members of the Grand River OLWR team thought that it was still used in reactive mode. Due to the issues identified in this section, effective and efficient decision-making under times of serious water scarcity using the current OLWR mechanism may not be promising. Likely, it will be to the detriment of the environment. Hope remains, however, for change.

[16] "Neutral" means uncertain in this context.

Chapter 6
Discussion

This study used interviews of OLWR Team members from the Grand River watershed to explore whether the Ontario Low Water Response mechanism would be resilient enough to operate under a climate change scenario of longer, more intense periods of low flow and whether it could be used to ensure environmental integrity in water allocation amongst stakeholders and the aquatic environment during conditions of reduced flow. Chapter 6 discusses the results presented in Chapter 5 and emphasis is placed on answering the research question identified in Chapter 1.

The first part of the discussion is focused around the weaknesses surrounding OLWR's water use prioritization and why these weaknesses might cause uncertainty in decision-making under a climate change scenario. The hydro-illogical cycle developed by Whilite (1993) is introduced as a conceptualization of why these weaknesses remain in the mechanism. The discussion then moves on to talk about the importance of integrating environmental flows into the OLWR mechanism and concludes with emphasis on how resilience might be incorporated into the mechanism using a proactive approach and other directive measures that have emerged from the results.

6.0 Uncertainty in OLWRs Water Use Classification System

OLWR team members identified cold-water fisheries as sensitive aquatic habitat due to the oxygen and temperature requirements needed to sustain life. Previous literature has reported that water temperature tends to increase as streamflow decreases (Cowx *et al.,* 1984; Meier *et al.,* 2003; Rader & Belish 1999). This ultimately affects dissolved oxygen levels as water temperature and oxygen levels are intricately linked. When conditions of low flow are encountered, such as those projected by GAWSER under one climate change scenario, decisions made by OLWR team members are essential to protect these sensitive areas. Lack of clarity and agreement amongst OLWR team members in water use prioritization or ambiguity within the OLWR mechanism could waste valuable time and cause detrimental environmental effects if streamflows decrease drastically, or cease completely. A number of shortcomings in OLWRs mechanism, however are revealed in the results of this study. These shortcomings could jeopardize aquatic biota when challenging decisions on water allocation are needed during periods of reduced flow.

First and foremost, results reveal a lack of agreement on priority of water use allocation between team members and the OLWR mechanism concerning placement of water uses within essential, important, and non-essential water use categories. Within the essential category, OLWR lists uses of water dealing with human life and health, water for drinking, water for sanitation and health care, water for public institutions and public protection[17], and water necessary for basic ecological functions (OLWR 2003). Although OLWR team members agreed that water for drinking, fire protection, sanitation (effluent dilution), and the natural environment should be considered essential uses, many team members believed that water for agriculture and livestock should also be included in this category. In total, agricultural water use was listed by 7.5[18] respondents as essential and 5 participants felt that water for livestock was essential. Both agriculture respondents reported agriculture as an essential use, but other sector representatives also believed that these uses should be included within the essential category. Respondent C, an agriculture representative, specified that only food crops would be considered essential, and would not include crops such as tobacco.

Within the important category, OLWR lists uses of water for the social and economic well being of an area, including activities critical to industrial processes, commercial facilities (hotels and restaurants), and key agricultural crops. When team members were asked to list the important uses of water in the Grand River watershed, there was again a lack of agreement between the OLWR document and what team members reported. Two participants considered water for businesses to be essential uses, one participant

[17] wastewater treatment, some fire protection, schools

[18] Where it was hard to interpret the meaning of a respondents answer, a half mark was assigned to the category. For example, one respondent listed "core services" under the essential uses of water. Core services might include agriculture, as people need to eat, so a half mark was assigned.

considered water for industrial use as non-essential, and some members considered water for public parks and water for car washing important uses. There was further disagreement amongst participants whether car-washing businesses, sod production businesses, nurseries and garden center businesses, and golf course operations should be considered under this category, as these uses of water are ‘business-oriented’ aesthetic purposes. Without some agreement on water use prioritization, it will be very challenging to manage water allocation.

There was general agreement amongst team members on non-essential uses for the Grand River watershed and what is listed in OLWR as non-essential. However, although OLWR lists water for private swimming pools, lawn watering, and vehicle washing as non-essential uses, there was hesitancy amongst respondents whether water for public swimming pools, water for golf turf watering, and water for car washing businesses should also be considered non-essential uses. The current OLWR mechanism does not address these grey areas.

The failure of OLWR to address under which category water dependent businesses (i.e. car-washing businesses, golf courses, or garden centers and nurseries) and water for public swimming pools would fit suggests weakness in the operation of the mechanism. Furthermore, there is lack of agreement amongst team members concerning what the essential uses of water in the Grand River watershed should be. Some OLWR team member believe that essential uses of water should include water for agriculture and livestock, whereas other team members believe that these should not be considered essential. Lack of clarity and agreement exists amongst team members concerning these areas of categorization. If OLWR team members must discuss categorization for apportionment of water uses during a Level III declaration, response efforts could be hindered and valuable time could be wasted during which time the cold water fishery and other sensitive aquatic habitats could suffer. If the Province of Ontario wishes to uphold environmental integrity under times of stress, there needs to be agreement concerning water use categorization within the OLWR mechanism. To increase the resilience of the

OLWR mechanism, areas of water-use categorization need to be re-discussed, clarified and negotiated before there is a crisis.

Another inherent weakness in the OLWR mechanism is that there is no statement within OLWR concerning when non-essential water use restrictions should come into effect. In 2008, a pilot study for the Whitemans Creek watershed was conducted by the GRCA addressing how water might be apportioned amongst water use sectors. Recommendations from the study were to completely ban (in both rural and urban areas) in a Level III situation: all residential, commercial and industrial uses of water for watering lawns and gardens; washing of cars (including commercial car washes), driveways, sidewalks and store fronts; filling of swimming pools, both private or public; and any other use of water for aesthetic reasons including decorative water fountains. A complete ban on water use for any recreational facilities including golf courses, public parks, splash pads, and pools would follow with enforcement of all the above by municipal bylaw officers and the Ministry of the Environment. But should water used for golf courses, lawn watering, personal car washing, and decorative fountains only be exempted at the Level III conditions, the most severe stage of emergency? Golf courses in the Whitemans Creek subwatershed had adapted to historical water supply variability by investing in extra storage reservoirs and lined ponds and were not drawing water directly from the creek during low water conditions, but this was not the case for all users. If the OLWR mechanism is to be effective in protecting the aquatic environment under low-flow climate change scenarios, more specification needs to be directed towards when restrictions on non-essential uses should come into effect and perhaps they should be exempted in a Level II condition in order to protect the fishery. Because monitoring is difficult and often by-laws poorly enforced when restrictions have been placed on water uses, OLWR would also need to consider addressing this issue as well if the mechanism is to be resilient.

The definition of a “reasonable supply of water” listed under OLWRs essential water uses is poorly defined and this suggests another weakness in the operation of the mechanism. OLWR defines essential uses as those that “deal with human life and health:

a reasonable supply of water for drinking and sanitation, water for health care, water for public institutions and public protection (e.g. wastewater treatment, some fire protection, schools)" (OLWR 2003). The term "reasonable supply" of water is ambiguous with differing perspectives on what is considered a "reasonable supply" of water. The ambiguity of this wording in the OLWR mechanism could result in apportionment of too much water to human consumptive uses by OLWR team members and this could be detrimental to the fishery or instream ecological needs. Due to lack of specificity in OLWR, the mechanism could fall short in protecting the aquatic environment due to its lack of specificity. This in itself could be a topic for future research. Moreover, although the OLWR framework of water use categorization is a starting point on how water might be allocated amongst various water use sectors during times of water shortage, another shortcoming of the mechanism is that there are no specifications concerning how much water each water user or water use sector is entitled to. Some respondents suggested that during times of shortage, "some relative percentage" of water reduction proportional to the priority ranking of each sector would need to be determined in order to maintain fairness, but these proportions are currently left unaddressed by the mechanism (respondent F). The OLWR mechanism further fails to address at what level (I, II, or III) important uses of water should be eliminated. Some members suggested that at 50% reduced streamflows, some important uses (i.e. industry) would be shut down selectively on a priority basis, but this priority basis remains yet to be determined and when this might happen remains unclear. Team members stated that it would be the Province's responsibility to make priority based decisions, but "no one [in higher levels of government] is going to put their head out initially to start that because it's just too difficult to work with….. we want to have working relationships with our local peers in the different [sectors]" (respondent F). This is perhaps why these difficult decisions remain unaddressed. Team members reported that under a climate change scenario, priority rank would be assigned following OLWR guidelines and that water to sustain human life would take highest priority. Due to the problems with categorizing essential and non-essential uses and ambiguity in the mechanism, allocation using the current OLWR mechanism would be challenging under such situations. Time wasted coming to agreement on water use prioritization means that sensitive areas and cold water fisheries might suffer detrimental effects.

Water use data collected by the GRCA suggests that municipalities are one of the most significant water use sectors in terms of consumptive use (GRCA 2009). Consumptive use refers to water that is not returned directly to the source from which it was pumped. The GRCA water demand assessment estimated the breakdown of consumptive water demand by sector in the Grand River watershed as follows:

Water Use	Consumptive Use (%)
Municipal Water Supply	53
Industrial Purposes	8
Dewatering	9
Commercial Purposes	9
Agricultural Irrigation	7
Private Water Supplies	4
Livestock & Unserviced Domestic	5
Groundwater Remediation	3
Miscellaneous	2

Municipalities require the largest volumes of water to deal with human life and health due to their population densities. Ironically, however, because consumptive water is not returned to the system from which it came, added stress could be placed on the withdrawal region. In the Grand River watershed, many municipalities draw from groundwater sources, but this water is not returned to the aquifer from which it was taken, meaning that it is a consumptive water use (GRCA 2009). If at some point this groundwater discharges into surface water bodies such as rivers or streams, aquatic biota in the region could be adversely affected. Stream biologists have observed a strong positive relationship between the discharge of groundwater to streams and stream fish (GRCA 2005) and streamflow is a combination of overland flow, flow below the ground surface but above the water table, and groundwater discharge. The constant discharge of groundwater maintains baseflow in streams during periods of little precipitation. To date, several important relationships between fish and groundwater have been demonstrated, including:

1) Groundwater discharges create and maintain baseflow regimes in streams,

2) Groundwater discharge patterns provide opportunities for reproduction and thermal refugia during temperature extremes.

3) Groundwater moderates stream temperatures during critical times of year (midsummer and midwinter) and maintains suitable temperatures for thermally sensitive fish species (GRCA 2005).

As human uses of water for life and health trump aquatic ecosystem needs (as will be discussed later), ecosystems in areas from which municipalities draw water could be seriously compromised. It seems that OLWR could unintentionally be overlooking environmental protection in areas where patterns of groundwater flow remain unknown and municipal water conservation efforts and efficiency strategies are not implemented beforehand, despite the fact that the OLWR program is more easily performed in the municipal setting "because [municipalities have] more control from one source serving thousands of people [to track] what the [quantity of water uses] are" (respondent M).

Upon review of other water management strategies in Canada, OLWR is not out of line in placing human uses first. The Manitoba Water Rights Act (2000), for example, orders priority of water uses or diversion as follows:

1. domestic purposes,
2. municipal purposes,
3. agricultural purposes,
4. industrial purposes,
5. irrigation purposes,
6. other purposes.

Newfoundland & Labrador's Policy for Allocation of Water Use (2001), which applies to the use or diversion of all surface, ground and shore waters for any beneficial purpose, places precedence on applications for water rights in the following order:

1. domestic, municipal,
2. commercial and industrial,
3. water power,
4. recreation,
5. other purposes.

Furthermore, in the state of Minnesota, when water supplies are not sufficient to assure water to six water use priorities, domestic water supply has the highest priority (Pirie *et al.*, 2004). In order of decreasing importance, these priorities are: domestic water supply; water uses consuming less than $37.85m^3$ per day; agricultural irrigation and processing of agricultural products involving consumption in excess of $37.85m^3$ per day; power production in excess of the use provided in the Minnesota contingency plan; uses other than agricultural irrigation; processing of agricultural products and power production involving consumption in excess of $37.85m^3$ per day; and lastly, non-essential uses (i.e. lawn sprinkling, vehicle washing, golf course and park irrigation, and other non-essential uses). Both the Provinces of Manitoba and Newfoundland and Labrador, and the state of Minnesota have listed water for humans (domestic and municipal purposes) as a number one priority. OLWRs important and non-essential uses parallel these examples of prioritization. This suggests that there is strength in OLWRs ordering, despite what shortcomings may exist in the mechanism.

6.1 Understanding Shortcomings in the OLWR Mechanism Using the Hydro-illogical cycle

The hydro-illogical cycle proposed by Whilhite (1993) is one possible explanation why there remains so much ambiguity in the OLWR response mechanism (Figure 2). This cycle could be applied to the Grand River watershed as follows. Following a period of precipitation, the realities of a reduced water supply are made evident to water mangers and planners. They may realize that they are not immune to water shortages and that they might be faced with them again in the future. This can lead to state of concern, where speculations are made surrounding their capacity to deal with drought. Granted they are not, a state of panic is reached when managers and planners realize shortcomings in their management plans. Should a water shortage occur, they will be unable to cope. When it rains again, however, the panic generated from the previous stage dissipates and realizations brought to the table in the state of panic are forgotten. A stage of apathy, or uncaring, sets in. The cycle is repeated again when drought sets in, but solutions to the drought problem continue to remain unaddressed due to the fact that the period of water shortage is never prolonged enough to necessitate difficult management decisions. Because droughts occur infrequently in watersheds within Ontario (every 5-7 years), there has never been need for the OLWR mechanism to be firmly established, as the hydro-illogical cycle demonstrates. This has consequently led to weaknesses in the mechanism. To truly be effective under changed climate scenarios, water managers within Ontario need to address how the mechanism might deal with water short scenarios during conditions of hydrologic drought by testing the mechanism through "gaming" or "mock" scenarios. "We need the Province to take the information that we gave them from [the] Whiteman's Creek [study] and say if this was the scenario under these assumptions, this is what we would have done. And take it that next step. Then we could work with that because it would at least be a template for how they might decide to make [future] decisions," states respondent F. This respondent goes on to say that "it's a Provincial responsibility to determine what the rules and the procedures are for water taking, and so we're waiting for some Provincial direction, and no one is going to put their head out initially to start that because it's just too [challenging] to work with." Hesitancy surrounding water prioritization may in part be due to political aspects of distribution, including job creation and tax base, which are necessary for the survival of the economy. Determining water allocations under scenarios of future water shortages is likely to cause heated political debate, and is perhaps one reason why the final step has not been taken. No one wants this responsibility within the watershed, as no one wants to spoil working relationships. Even at the Provincial level this sensitive topic remains unaddressed, as never before has there been a situation which required such management decisions. Hence, the hydro-illogical cycle continues.

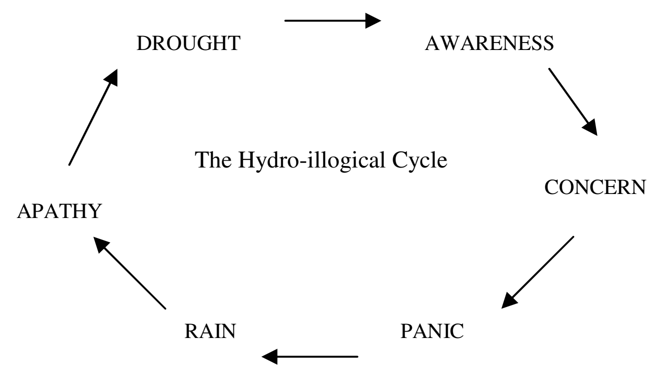

Figure 2. The hydro-illogical cycle (Whilhite 1993).

6.2 The Ecosystem-based Approach

The Canadian Federal Fisheries Act (1985) was developed to govern and protect fisheries and fish habitat in Canada and international waters. In Section 35.(1) it is stated that: “No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat” unless authorized by the Minister of Fisheries and Oceans Canada. The Act further states that the federal government has the power to order dam operators to ensure that there is sufficient water downstream to protect fish. Violations to the *Fisheries Act* can result in substantial fines and the risk of imprisonment.

From the results of this study, should there be a period of severe water scarcity in the Province of Ontario, legislation such as the Canadian Fisheries Act may not be sufficient to protect aquatic habitat. There was agreement amongst many OLWR members that people are ultimately more important than fish. If a time should come when reduced flows are prevalent and not enough water is available for apportionment amongst humans, in-stream aquatic organisms and habitat could be the first to suffer.

The current ecosystem based approach to water allocation may not be able to uphold environmental integrity because its scope is too broad in nature and the ecosystem based approach is inclusive of humans. When asked to list the essential uses of water in the Grand River watershed, only 6 out of 13 participants listed water for the natural environment as an essential use (Chapter 5), suggesting that environmental protection is given a lower priority and not at the forefront of OLWR thinking. Instead, water for human uses trumped water required by aquatic ecosystems, with potable water for human consumption listed by all 13 participants as essential. This suggests that under conditions of low flow, the PTTW could allocate water to people over fish. Throughout history and for his own profit, humans have exploited and conquered nature due to inherent greed, creating a schism between the two. The result is deepening inequity between the division of resources amongst humans and nature. The only hope for sustainability is seeing ecology, economy and society as interdependent and finding ways to serve all three at once in ways that are mutually reinforcing (Gibson, 2009). This is no doubt easier said than done and perhaps the attempt has not yet been made in Ontario due to the fact that drought is infrequent and management actions are on par with the hydro-illogical cycle. One idea to encourage more ecosystem protection under the OLWR mechanism would be to raise awareness of ecosystem needs to the OLWR team members so that there is less likelihood of the environment being overlooked when challenging decisions need to be made.

6.3 The Problem with OLWR Thresholds

OLWR defines degrees of water shortage by assigning three levels of impact. Level I indicates that streamflow is less than 70% of the lowest average summer monthly flow and level III indicates that streamflow is less than 30% of the lowest average summer monthly flow (Table 1). As confirmed by both the OLWR document and OLWR team members, OLWR triggers and thresholds are defined consistently as a percentage of historical base-value average summer low flow, and thus vary geographically throughout the watershed and province. Historical streamflow data are used for both the implementation and subsequent lifting of bans or restrictions. Although the announcement of these levels is paramount in raising awareness amongst the community of a potential water shortage, it is oftentimes overlooked that fish habitat may already have been compromised in some areas prior to declaration of these levels.

In 2005, the Grand River watershed was selected for a pilot study on calculating and assessing environmental flows (GRCA 2005). The GRCA selected 8 pilot reaches to test, compare, and attempt to validate a number of different methods and approaches (e.g. Tenant Method, Tessmann Method, Physical Habitat Simulation System (PHABSIM) model, Instream Flow Incremental Methodology (IFIM), Aquatic Base Flow Method, Indicators of Hydrologic Alteration (IHA Method), and Range of Variability Approach (RVA) for setting in-stream flow quantities in a variety of reaches and streams. It also investigated options for transferring the requirements established for these pilot reaches to other areas in the watershed to provide a process for estimating in-streamflow requirements in southern Ontario. In the Whitemans Creek subwatershed, low flows for a Level II had already impacted ecological functions and the connectivity that fish require for migration (GRCA 2005). Minimum flows of approximately 1.0 m^3/sec were required in the Whitemans Creek at Mount Vernon stream gauge to allow movement of fish from one pool to the next through riffles, thus allowing fish to find refuge, food, cooler temperatures, and avoid predators (GRCA 2005). When pools are isolated, fish biomass decreases and the quality and availability of fish habitat are diminished. The flow rate of 1.0 m^3/sec occurred between OLWR Levels I and II. Furthermore, the threshold in Whitemans Creek for hydraulic connectivity[19] was determined to be 0.80 m^3/s, which coincides with the Level II OLWR threshold (Table 15) (GRCA, 2008). The Level II flow also coincides with another hydraulic low flow indicator called the Tessman Method, deeming the river habitat to be at 'fair to poor' status. At Level III conditions,

[19] The hydraulic connectivity is the flow below which pools become isolated and fish migration between pools is not possible.

water levels are already detrimentally low, approaching the Tessman level for poor habitat and environmental quality (GRCA 2008).

Table 15. Calculated Instream Flow Indices for Whitemans Creek (GRCA 2005).

Thresholds and Hydraulic Inflections	Flow (m^3/sec)
Tessman Summer Flow (Poor)	0.44
Ontario Low Water Level III	0.48
Hydraulic connectivity for fish migration Significant Loss	0.80
Ontario Low Water Level II	0.80
Tessman Summer Flow (Fair to Poor)	0.87
Hydraulic connectivity for fish migration	1.00
Ontario Low Water Level I	1.12
Tessman Summer Flow (Fair)	1.31
Ontario Low Water Normal	1.60
Tessman Summer Flow (Good)	1.75
Tessman Summer Flow (Excellent)	2.19
Tessman Summer Flow Outstanding	2.62
Mean Annual flow	4.37

An apparent weakness of the OLWR mechanism is that threshold levels have not been determined for specific reaches using detailed assessment. Therefore, they may not necessarily provide for adequate environmental flows in some waterways. In fact, in some regions, OLWR already fails to maintain environmental flows (GRCA 2008). Especially in areas where there are sensitive species or cold water habitats, OLWR should incorporate more stringent threshold values based on environmental flows so that these sensitive habitats can be protected and preserved, rather than basing threshold levels on percentages of the average summer low flows, under which aquatic life could already have been compromised. Due to the uncertainties in both future water demands and environmental flow requirements, however, it remains highly inadvisable to make any water allocation formula immutable (Richter et al., 2003). For this reason, should OLWR incorporate methods for calculating environmental flows, it would be essential that they be adaptive in approach.

The incorporation of environmental flows into drought management plans is not a new concept. Melbourne Water's "Drought Response Plan for Licensed Water Users," which aims "to protect the environment and consider the needs of water users," has been developed to "work in conjunction" with a number of different mechanisms including Streamflow Management Plans and Local Management Rules (Melbourne Water, 2007). In Australia, Streamflow Management Plans have been developed to ensure the sharing of available water sustainably between all users, allowing licensed diverters and the environment to receive the water they need. The Drought Response Plan and Local Management Rules aim to maintain *minimum* flows to protect the environment, thus minimizing risks to instream integrity. For this to be done, protection of remnant pool habitat in rivers and streams when instream biota are under stress is ensured by limits placed on water extractions.

6.4 Integrating Environmental Flows into OLWR and PTTW

Results show that there is confusion amongst OLWR team members concerning whether biologically critical sites are given consideration in the water allocation process. About one-third of the team members stated that they were not considered in the allocation process under OLWR, but that they were considered under the PTTW. Another third of the team members stated that they were given attention under OLWR by joint efforts of the GRCA, MNR and MOE. The remaining team members were unable to answer this question. This research has shown that there is uncertainty surrounding the OLWR mechanism to protect the aquatic environment during times of reduced flow due to inherent weaknesses in the mechanism and the tendency of humans to trump environmental needs. It has already been established that MOE may limit water withdrawals through the PTTW, but due to the unclear nature of the term "ecosystem-based approach" given in the PTTW, there is also uncertainty surrounding the PTTWs ability to protect the aquatic environment.

Using Melbourne Water's "Drought Response Plan for Licensed Water Users" as an example, there should be more integration of environmental flows into both OLWR and PTTW so that aquatic environments are not trumped by human needs (Melbourne Water, 2007). Once they have been more thoroughly researched and defined, environmental flows should be a major component of these documents and utmost importance should be placed on maintaining them so that the aquatic environment can be sustained to the best of our ability under current climate variability and future climate change. Because various stakeholder groups exhibit a strong tendency to set established environmental flows aside due to the "drought emergency" resulting in serious threats to the environment, it is essential that sound, robust, and proper allocation mechanisms are established before drought conditions to ensure aquatic resource integrity. This highlights the importance of re-examining the shortcomings of the OLWR mechanism and places impetus on its movement towards a proactive approach, discussed next.

6.5 Incorporating a Proactive Approach into OLWR

Although the intention of OLWR is to proactively deal with future drought situations, for the most part, it is still implemented in reactive mode. This could, in part, be due to the hydro-illogical cycle resulting in robust drought management practices never being implemented because of infrequent drought occurrences in the Province. Regardless, OLWR's current mechanism for dealing with low water situations, through restricting water use, is reactive in approach, and only a short-term solution to water scarcity. Having in place a solid low water response plan is an essential step toward the reduction of societal and environmental vulnerability and to be effective, it must not treat drought-like conditions in an emergency response mode, but rather pursue a proactive approach emphasizing the principles of anticipatory risk management and sustainable development. This is emphasized by the following quote by James R. Lyons, Assistant Secretary of Agriculture for Natural Resources and the Environment, speaking at Drought Management in a Changing West (Lyons 1994):

> Unfortunately, we tend to focus on drought when it is upon us. We're then forced to react—to respond to immediate needs, to provide what are often more costly remedies, and to attempt to balance competing

> interests in a charged atmosphere. That's not good policy. It's not good resource management. And it certainly adds to the public's perception that government is not doing its job when it simply reacts when crises strike. To the contrary, we must take a proactive approach to dealing with drought. We must anticipate the inevitable—that drought will come and go and take an approach that seeks to minimize the effects of drought when it inevitably occurs.

If under the ecosystem-based approach, water will be allocated to human uses first and foremost during periods of reduced supply, there will be less water left instream to support the fisheries and the aquatic environment. Because results of this study have shown that the OLWR mechanism is not likely to uphold environmental integrity during times of reduced supply, it is imperative that a more proactive approach is adopted by OLWR to minimize the impacts on the aquatic environment during such a situation.

Respondents had numerous suggestions for how the OLWR could become more proactive in nature (Table 13). The approaches included: better education and awareness programs for water users; better communication amongst the watershed in regards to water management; water conservation tactics; improved housing and building standards; and system upgrades of sewage treatment infrastructure and water appliances encouraged by incentives through the Province. Since the Grand River watershed had a high proportion of land use for agriculture, members also had specific proactive approach recommendations to agriculture including: incorporating drip irrigation systems; changing to more drought tolerant crops; watering at night when the wind effect is less; and being more conscious of how to keep the land more suited to using less water.

Some sectors within the Grand River watershed are already taking proactive measures in response to reduced water supply. Respondent I noted that golf courses were utilizing lined ponds to store water in an effort to maintain business during water scarce situations. Incorporating redundancy into the watershed's water supply would be another way to add resilience, and yet even this approach is hardly stressed through OLWR. This could be accomplished through the creation of more reservoirs, dug off line ponds, and storage facilities which would be used in addition to water takings from rivers, streams, and groundwater sources. In areas where the weather is dry and hot, such as in the southwest regions of the United States, this technique is being used in many urban areas. This "redundancy of supply has gotten the major urban areas through a string of really dry years," says Gregg Garfin of the University of Arizona and co-chair of Arizona's Drought Monitoring Technical Committee (Thompson 2007). The Province of Ontario should look at adaptation measures that other more drought-prone areas use for ideas on management techniques for further incorporation into OLWR.

The GRCA also currently carries out watershed restoration programs through the Rural Water Quality Program (RWQP). Some of the effective land management practices are:

- implementing riparian buffers
- planting trees
- enhancing and restoring wetlands
- restricting livestock access to watercourses

These are proactive measures which maximize ecological and social resilience to cope drought by building resilience, a key component in ensuring the watershed is best prepared respond to the coming pressures of climate change. So why then, if suggestions towards proactive management are so numerous and proactive measures have already started to emerge in related areas, does OLWR still operate in reactive mode? The answer could again lie in the hydro-illogical cycle—there is not enough impetus to shift OLWR to this type of approach because droughts occur infrequently in Ontario. The importance for establishing robust drought response plans is therefore overlooked.

6.6 Further Directions to Incorporate Resilience into OLWR

A proactive approach incorporating conservation practices and efficiency strategies is just one direction that OLWR could take to incorporate resilience into its mechanism. Additionally, four other directive themes have emerged promoting sustainable water management in order to add resilience to the mechanism: better partnership and involvement between water use sectors at the local scale and the Province at the regional scale; infrastructure upgrades; the encouragement of social change towards public water use attitudes in an attempt to dislodge the entrenched "myth of water abundance"; and finally, continued research and monitoring of aquatic habitat under changing climate conditions to optimize aquatic preservation strategies and techniques (Table 14).

6.6.1 Better Partnership

Results of this study have shown that the OLWR mechanism is not resilient enough to uphold environmental integrity during reduced water supply due to inherent weaknesses in the mechanism such as fundamental flaws in deciding levels of priority, the mechanisms tendency to respond in reactive mode, and the ambiguity surrounding the ecosystem based approach. It has been suggested that for the mechanism to be more robust towards ecosystem protection, incorporation of environmental flows and coupling of the OLWR and PTTW should occur. But if humans will trump environmental needs for water due to the ambiguity of the ecosystem-based approach and if it is established that various stakeholder groups become agitated, exhibiting a strong tendency to set established environmental flows aside due to the "drought emergency," how might this be accomplished? First of all, sound and proper allocation mechanisms developed before water short periods are essential in order to ensure aquatic resource integrity. This means that the OLWR mechanism and the PTTW need to be re-examined and fundamental flaws in the OLWR mechanism need to be addressed. Secondly, for allocation mechanisms to be upheld, mutually enforcing partnerships between various levels of local, Provincial, and Federal of government are essential and coordination of efforts and dedication of various government agencies to uphold environmental integrity through enforcement of environmental flows is paramount. Policy directed towards sustaining environmental flows could be used to strengthen and enforce this strict governing partnership and could be incorporated into existing legislation such as the *Federal Fisheries Act* for better environmental stewardship.

Strict legislation and other mechanisms enforcing environmental flow policy amongst various levels of government should not be the only change to better protect aquatic ecosystems. There should also be communication amongst MNR, MOE and Environment Canada to encourage infrastructure upgrades (discussed next) and social changes.

6.6.2 Infrastructure Upgrades

It has been established that the vulnerability of water resources to climate change impacts is highly dependent on the adaptation of water management systems to changing hydro-climatic conditions. Despite this fact, OLWR, while operating in reactive mode, does nothing to encourage the upgrade to more efficient water appliances or infrastructure, such as waterless sanitation methods and grey-water systems. To incorporate more resilience into the mechanism, incentives and rebates for upgrading water appliances could be incorporated into the low water management plan, as they may be useful for adaptation to changing hydro-climatic conditions. Policy incorporating efficient water measures through partnership of various levels of government could strengthen such transitions and should be moved to center stage.

6.6.3 Social Change

Most Canadians, Ontario residents included, assume that water is plentiful and accessible, despite the fact that there have been well-documented cases of water shortage and scarcity in the past (Sprague, 2007). The reason for this view is partially due to the fact that Canada has considerable water resources in its rivers, lakes and aquifers relative to many other countries. This perceived wealth of water has rooted deep within Canadian minds and attitudes the "myth of abundance," which has contributed to the neglect and misuse of Canadian water resources with detrimental effects to aquatic ecosystems as a result. Further hindering the sustainability of aquatic ecosystems is the fact that there are significant institutional barriers for ecosystem protection. Existing, long-term water allocations to human uses, for example, can create a sense of entitlement that is difficult to challenge, especially when these allocations are established through mechanisms that are considered inalienable. To shift this type of thinking so firmly entrenched, public education concerning the importance of protecting aquatic resources for generations to come is essential and should be stressed through policies in all levels of government.

6.6.4 Continued Research and Monitoring

The GRCA currently has in place regulated flow targets for some stretches of river in the Grand River watershed. In the Grand Valley for example, there is a low flow target of 0.42 m^3/sec. At Guelph, there is a flow target of 1.7 m^3/sec, and at Brantford and Doon these target flows are 17 and 10 m^3/sec respectively (GRCA 2005). The GRCA has also established an extensive stream gauge monitoring network, allowing for flow measurement at certain locations within the watershed. Establishment of these monitoring networks demonstrates movement towards better protection of aquatic ecosystems, but continued, more extensive research still needs to be conducted on the ecological flow requirements of different species in order to understand their needs so that they can be protected. Having established these requirements, they should next be incorporated into the OLWR mechanism and there should be movement away from basing threshold and trigger targets on percentages of historical flow as there is uncertainty surrounding the OLWR mechanism to protect the aquatic environment this way. Rivers and streams that currently have no gauges established need more monitoring because if the system is not regulated, then there is little "control" other than restricting water takings. More research in these reaches needs to be conducted so that aquatic life can be protected. Although the GRCA has stated that it plans to implement some of the findings from its study on ecological flows into the daily operations of the regulated reaches, more research is required towards finding a method of developing sufficient environmental flows for other regions throughout the watershed.

Further research should also be focused on how various sectors might fare under conditions of reduced supply, and on what the minimum amounts of water required for sustaining human health and businesses might be. This could aid in development of water allocation formulas to which water use-sectors would need to abide under scenarios of reduced flow. Additionally, further research might focus on how stakeholders can negotiate amongst themselves when challenging decisions need to be made, rather than using the top-down approach characteristic of the current mechanism. Attention should also be paid to more monitoring of water uses outside of municipalities, such as in rural areas, or where private water takings occur. Additionally, water use restrictions should also be more firmly enforced.

6.7 Evaluating OLWR

When asked about the ability of OLWR to allocate water equitably between human uses and the natural aquatic environment during times of water scarcity, the median response was "neutral," suggesting that there is uncertainty in whether the mechanism will be able to uphold environmental integrity amongst water allocations to various sectors. This uncertainty could in part be due to some of the weaknesses of the mechanism revealed by this study and could also be attributed to the fact that difficult management decisions on water allocations have not yet been addressed by higher levels of government, thereby leaving OLWR team members hesitant to comment on the mechanisms ability to equitably allocate the resource. This response also suggests that team members are evaluating their own past decisions using the OLWR mechanism in the Grand River watershed. Based on the median response, it would seem that team members believe that room for improvement exists in the way the mechanism operates within the watershed. In itself, this result suggests that more research in the area of water allocations under changed climate scenarios is necessary so that the mechanism can further be strengthened in order to adapt to future projections of climate change and the demands of a growing population.

Despite the focus on its shortcomings, there are positive aspects of the OLWR mechanism. The intention of OLWR is to be proactive in managing drought situations and credit must be given to the Province for actively thinking about how challenging decisions on a resource entitled to all might be undertaken. “We’re continuing to take more water, the ecosystem is continuing to be stressed, if we now add on top of that the factor of reduced precipitation events and changed frequency of which those events come, and /or warmer or dryer winters … and a growing population, we’re moving towards a path which says eventually we’re going to get a point where some of these decisions are going to have to be made – and they’re not going to be easy ones.” stated respondent F. Development of OLWR at the Provincial level and implementation of OLWR at the local level has helped to raise awareness amongst the public, and has challenged GRW LWR team members to make the initial effort and explore how difficult decisions might be made. This is a step in the right direction in preparing for a future of reduced flows.

6.8 Conclusions

This research has been focused on the following question: Is the Ontario Low Water Response mechanism resilient enough to operate under a climate change scenario and will it be able to uphold the Province’s dedication to environmental integrity in its allocations amongst stakeholders and the aquatic environment during conditions of reduced flow projected by the climate model?

Results from this research suggest that although the OLWR mechanism has *intentions* of being proactive to alleviate the impacts associated with drought, there remain shortcomings in the way it operates. Due to lack of clarity surrounding the categorization and prioritization of uses, ambiguity in its wording, and timing on when restrictions should come into effect, there remains uncertainty surrounding the mechanism's ability to operate efficiently under reduced flow scenarios. The broad nature of the ecosystem-based approach, coupled with the tendency of humans to trump environmental uses of water, and lack of environmental flow information integration into the mechanism suggests that under climate change scenarios the OLWR mechanism will not be resilient enough to operate and this could result in detrimental effects to the ecosystem.

To add resilience to OLWRs ability to function under changed climate scenarios, this research has suggested revisiting and re-discussing specific areas of the low water response mechanism and recommends it shift towards a proactive approach to reduce negative consequences and promote the efficient use of water resources. Additionally, ways in which to change social attitudes towards water, infrastructure re-design, and better partnership between different levels of government should also be integrated into the mechanism. For the mechanism to be successful at upholding environmental integrity during times of reduced water supply, continued research, monitoring, and incorporation of environmental flow requirements is paramount. In conclusion, data gathered from this research provides insight into the resiliency of the OLWR mechanism in the Grand River watershed. This in turn could direct future research efforts for the remainder of the Province and inspire creation of a more robust drought management response plan.

Residents of the Grand River watershed take pride in their water resources and the habitats they create, as well as their ability to live within the bounds of their watershed:

> We are lucky to have a management system of reservoirs and innovative people and technologies that allows us to be productive and economically competitive with cities located on large bodies of water like Lake Ontario. Lake-dependent cities can be prone to international influences and whims, while in the Grand River watershed we have a certain control of our own destiny, to live within the needs and bounds of our communities (Grand Actions 2000).

Results of this study have shown that if no effort is devoted to strengthening the weaknesses of the OLWR mechanism it will not be resilient enough to operate under changed climate scenarios. This could be devastating to the diversity of fish and other aquatic species in the Grand River watershed. If aquatic ecosystems are to be sustained in this case, there may be no other option than to consider exploring other sources of potable water under changed climate scenarios projecting decreased flows. A few team members suggested that one option in dealing with water shortages under the 50 and 75% scenarios would be to consider exploring new sources of potable water, notably, building a pipeline from Lake Erie. This could alleviate the stress of reduced water supply and ensure that water is available to the natural environment after it has been diverted to human uses. Although this is one possible solution to dealing with future water shortages in the watershed, it introduces another area of uncertainty and is a controversial topic in itself. If OLWR fails to incorporate greater resilience into its mechanism Grand River watershed residents will no longer be able to pride themselves for living sustainably within the bounds of their watershed.

Although this study has identified a number of areas where the strength of the OLWR mechanism could be improved, the Grand River LWRT should not be responsible for action on all of these recommendations. In being proactive, the Grand River LWRT could now actively start to move water conservation into center stage by promoting the importance of water. This could be accomplished through employing water specialists who could offer water-saving tips to the community along with advise on how one might go about saving water. The Grand River LWRT could also sit down together and start to negotiate which uses of water in the watershed might be most important to maintain during reduced flow scenarios and come to agreement on water use prioritization before there is a crisis. The team could also go about being proactive by coming to agreement concerning when restrictions on non-essential uses should come into effect. Additionally, the team could sponsor public announcements through the news (television, radio, and newspaper) and hold public clinics concerning what a potential scenario of future water shortage in the region might entail for aquatic ecosystems. This would enable residents to picture what might happen if conservation efforts are not taken in the present and provide impetus for them to change their water-use habits. Incorporating awareness about the importance of water and aquatic ecosystems through school education programs targeting young students is another way in which the Grand River LWRT might be proactive. Furthermore, the Grand River LWRT could also educate the public about the needs and requirements of aquatic species, as residents may not be aware of the importance of sufficient environmental flows for their integrity and therefore may not be as inclined to change their current water-use habits. Finally, the Grand River watershed LWRT could also conduct residential water audits on a regular basis to help people find leaking pipes and other sources of water waste in an attempt to be proactive.

In addition to the above recommendations, the Grand River LWRT could also examine annual water taking volumes through the PTTW Water Taking Regulation mechanism. The Water Taking Regulation took effect on January 1, 2005 and introduced improvements to the Permit to Take Water Program by introducing mandatory monitoring and reporting of water takings by all permit holders (MOE 2010). Section 9 of the Water Taking Regulation requires all permit holders to collect, record, and report data on the volume of water taken daily from January 1 to December 31 by March 31 of the following year to the MOE (MOE 2010). Using this information, the LWRT in the Grand River watershed could identify areas currently experiencing the highest rates of water withdrawals. In turn, the team could devote extra attention to these areas, as they are likely to be the regions most sensitive to reduced water supply in the future. Special attention could be focused on these areas by the LWRT, with emphasis placed on the importance of conservation and efficiency strategies to alleviate the impacts of reduced flows on the aquatic environment.

Although a number of options exist concerning the ways in which the LWRT could be more proactive, the GRCA should not be entirely responsible for the more challenging decisions, such as which water use sectors would have priority and which would be eliminated completely during periods of water shortages. This would be better left to higher forms of government to decide as these are politically sensitive topics and for these decisions to be made, the OLWR mechanism would need to be tried and tested.

In order to guide decisions made in higher levels of government, however, the GRCA could do more research on what the general public perceives to be the most essential uses of water in the watershed. Meanwhile, higher levels of government could stress the importance of water conservation measures and turn their attention to how better legislation could be enforced to ensure that aquatic ecosystems are protected even under climate change scenarios and to how penalties might be enforced when legislation is broken. Of course, the GRCA should continue in its efforts in establishing environmental flow requirements for aquatic species, as this would be a major component of sustaining aquatic ecosystems.

6.9 Study Limitations

One noteworthy limitation to this study exists. The findings of the research cannot be generalized to the entire Province of Ontario and its management of low water flows as a whole. A sample of 13 members from the Low Water Response team in the Grand River watershed is insufficient to determine the resilience of the low water response mechanism under changed climate scenarios for the entire Province of Ontario due to singularity of the study at hand. Low Water Response Teams in other areas of the province may be influenced by many other factors determining how water is managed and allocated (community composition, water source and availability, and Provincially protected areas). The sectors represented on the Grand River LWRT, are however more or less representative other parts of the province and therefore this single case study holds utility. The study further holds utility due to the fact that the GRCA is actively involved in the low water response program due to periods of low water in the past and is therefore a good choice to assess the resilience of the OLWR mechanism as team members are aware and have dealt with these issues in the past. Conducting a study such as this in a watershed that has very little history with low water response meetings would not produce as accurate results. As mentioned in Chapter 4, case study research is useful as it helps to uncover attitudes, perception, beliefs, and interactions of groups the researcher is examining and are useful as an indication to the general situation (Yin 2003). For this reason case studies concerning areas of resource management are an effective way for managers to explain social trends related to a particular area and allow informed decisions to be made.

6.10 Future Research Directions

This research has revealed potential shortcomings of the OLWR mechanism and has explored areas where OLWR could be strengthened and refined in order to make the mechanism more resilient for the protection of Ontario's natural aquatic resources. One area left unexplored by this research, however, is minimum amounts of water required to sustain normal daily uses at optimal levels of functioning. For example, how much water is a "reasonable supply" for human health and sanitation purposes? Environment Canada has stated that 335 liters is the amount of water used daily in the average Canadian home (2007), but how much can this figure be reduced to uphold current standards of living while still providing a "reasonable supply"? Other countries use considerably less water than Canadians and to use such an excessive amount might not even be necessary on a daily basis. Alleviating such ambiguity in the OLWR document through research could prove useful during periods of hydrologic drought when water must be carefully allocated or rationed amongst various sectors.

Another area that this research has failed to address is the term "basic ecological functions" which is listed under essential uses in OLWR (OLWR 2003). If this study were to be conducted again, there would be greater attention paid to what OLWR team members perceive this term to mean. It is unclear in context whether this refers to natural ecosystems or, as it is listed at the end of a string of human related needs, whether these "basic ecological functions" pertain only to humans. If the first is the true, then OLWR does give consideration to environmental needs, albeit in a shrouded form that could likewise be trumped by human needs. If the latter is true, then OLWR has failed to consider the needs of the aquatic environment in its categorization of water uses, pointing to a serious shortcoming of the mechanism.

In order to ensure resilience of the OLWR mechanism after action on the recommendations from this study, one final step needs to be taken: it needs to be tested in a hydrologic drought scenario. Despite the sensitive nature of this topic and the heated political debate this might generate, taking this "last step" is the only true way to find out whether the mechanism holds enough resilience to operate. This could be accomplished if the OLWR team comes together and works through a number of reduced flow scenarios to develop potential responses through mock trials or gaming scenarios.

Permissions

-----Original Message-----
From: Jenna Disch [mailto:jdisch@uwaterloo.ca]
Sent: Friday, September 03, 2010 1:55 PM
To: James Etienne
Subject: copyright information

Hi James,

I am wondering whether it would be okay to use a map that has a copyright to the Grand River Conservation Authority in my thesis at the University of Waterloo. Do you have any idea how I would go about doing this? If I need to get permission from someone at the GRCA, would you know whom to contact? I am hoping to use the Grand River Waterhshed map (attached), and also one other image that has a copyright from your CA.

Any ideas?
Jenna

-----Original Message-----
From: James Etienne
Sent: September-03-10 2:03 PM
To: Lara Vujanic
Subject: FW: copyright information

Hi Lara:

What is the formal process for using a copyrighted GRCA map product in a thesis?

Jbe

-----Original Message-----
From: Lara Vujanic
Sent: Friday, September 03, 2010 2:05 PM
To: Graham Smith
Subject: FW: copyright information

Can you answer this?

Not sure that we have a formal process?

Hi Jenna,

As long as your cite the GRCA as the source, and show the copyright and disclaimer, it will be fine.

Let me know if you have any more questions with regard to this.

Graham Smith
Geomatics Coordinator
Grand River Conservation Authority
400 Clyde Road, Cambridge Ontario. N1R 5W6
(519) 621-2763 x2282
gsmith@grandriver.ca www.grandriver.ca

References

Babbie, E. 2007. *The Practice of Social Research*. (11th ed.) Belmont: Thomson Wadsworth.

Bellamy, S., D. Boyd, & L. Minshall. 1992. Determining the effect of climate change on the hydrology of the Grand River Watershed. Feb. 8., GRCA. Project report prepared for the Climate Change Action Fund.

Bickerton, M., G.E. Petts, P.D. Armitage, & E. Castella. 1993. Assessing the ecological effects of groundwater abstraction on chalk streams: three examples from eastern England. *Regulated Rivers: Research and Management.* 8:121-134.

Bruce, H. 1963. Ontario's first real drought: the long, hot summer that dried up several million dollars. *Macleans*, 76(23): 1.

Castella, E., M. Bickerton, P.D. Armitage, & G.E. Petts. 1995. The effects of water abstractions on invertebrate communities in UK streams. *Hydrobiologia.* 308:167-182.

[CCIAD] Climate Change Impacts and Adaptation Directorate. 2002. *Climate Change Impacts and Adaptation: A Canadian Perspective. Water Resources*. Ottawa: Government of Canada.

Chiotti, Q., & B. Lavender. 2008. Ontario. *In* From Impacts to Adaptation: Canada in a Changing Climate 2007. Eds. D.S. Lemmen, F.J. Warren, J. Lacroix, and E. Bush. Ottawa: Government of Canada. pp. 227-274.

City of Brantford 2010. *Watershed facts.* Retrieved March 21, 2010, from: http://www.brantford.ca/govt/projects/waterfrontmasterplan/Pages/WatershedFacts.aspx

Cowx, I.G., W.O. Young, and J.M. Hellawell. 1984. The influence of drought on the fish and invertebrate populations of an upland stream in Wales. *Freshwater Biology.* 14:165-177.

de Loë, R.C. and A. Berg. 2006. *Mainstreaming Climate Change in Drinking Water Source Protection in Ontario.* Prepared for Pollution Probe and the Canadian Water Resources Association (Ontario Branch). Ottawa, ON: Pollution Probe.

Dunn, K. 2000. Interviewing. In I. Hay (Ed.), *Qualitative Research Methods in Human Geography.* Oxford University Press: Melbourne. pp. 50-82.

Dyson, M., G. Bergkamp, & J. Scanlon (eds). 2008. *Flow – The Essentials of Environmental Flows (*2nd ed). Gland, Switzerland: IUCN. Gland, Switzerland:

IUCN.

[ECO] Environmental Commissioner of Ontario. 2008. Drought in Ontario? Groundwater and surface water impacts and response. *Getting to Know, ECO Annual Report, 2007-08.* Toronto: The Queen's Printer for Ontario. pp. 49-56.

Environment Canada. *2007. Municipal Water Use Report: Municipal Water Use, 2004 Statistics*. Ottawa, Environment Canada, 2007.

Etienne, J., October 29, 2009. Personal Communication. Grand River Conservation Authority Senior Water Resources Engineer.

Falkenmark, M., & J. Rockstrom. 2004. *Balancing Water for Humans and Nature: The New Approach in Ecohydrology.* Earthscan, London.

Farwell, J., D. Boyd, & T. Ryan. 2008. Making Watersheds More Resilient to Climate Change A Response in the Grand River Watershed, Ontario Canada. Available at: http://www.grandriver.ca/AboutGrand/ClimateChange08.pdf

Folke, C., S. Carpenter, T. Elmqvist, L. Gunderson, C. S. Holling, & B. Walker. 2002. Resilience and sustainable development: Building adaptive capacity in a world of transformations. *Ambio* 31(5): 437-40.

Francis, G. 1996. “Governance: how might we Approach it?” *Grand Actions, The Grand Strategy Newsletter*. 4:7-8.

Frederick, K.D., & D.C. Major. (1997). Climate change and water resources. *Climate Change*. 37:7-23.

Gabriel, A. O. & R.D. Kreutzwiser. 1993. Drought impacts in Ontario: a review of impacts, 1960–1989 and management implications. *Canadian Water Resources Journal*. 18:117–132.

Gibson, R. 2009. “Balance.” *Alternatives. Canadian Environmental Ideas and Action: New Energy*. December 36(1): 40.

Gibson, R. B., S. Hassan, S. Holtz, J. Tansey, & G. Whitelaw. 2005. *Sustainability Assessment: Criteria and Processes*. London: Earthscan Publications Ltd.

Giorgi, F., & L. O. Mearns. 1991: Approaches to regional climate change simulation: A review. *Reviews of Geophysics.* 29:191–216.

Gleick, P.H. (Ed.). 1993. *Water in Crisis. A Guide to the World’s Fresh Water Resources.* Oxford University Press: New York.

Glova, G. J., & M.J. Duncan. 1985. Potential effects of reduced flows on fish habitats in a large braided river, New Zealand. *Transactions of the American Fisheries Society.* 114(2):165-181.

Grand Actions. The Grand Strategy Newsletter. April 2000. "Wetting Your Boots in the Grand." Volume 5, Number 4. Retrieved April 6, 2010, from: http://www.grandriver.ca/GrandStrategy/pdf/ga_apr00.pdf>

Grand Actions. The Grand Strategy Newsletter. October 2001. "Focus on Water." Volume 6, Number 7. Retrieved April 6, 2010, from: http://www.grandriver.ca/GrandStrategy/pdf/ga_oct01.pdf

GRCA 2005. Establishing Environmental Flow Requirements for Selected Streams in the Grand River Watershed: Pilot Project Enhancing Water storage and water quality within a watershed through Wetland Restoration. Synthesis available at: http://www.conservation-ontario.on.ca/projects/pdf/Synthesis.pdf

GRCA 2005a. Watershed Report 2005. Pipeline Possibility. Retrieved March 18, 2010, from: http://www.grandriver.ca/WatershedReportCard/2005_Fall_Grand_Pg5.pdf

GRCA 2007. Pilot Study: Recommending a Low Water Level III Condition for the Whitemans Creek Watershed. Prepared by: Grand River Conservation Authority. Prepared for: Ministry of Natural Resources. Revised December 10, 2007.

GRCA 2008. Requirements for Recommending Level III in Whitemans Creek Phase II. Prepared by: Grand River Conservation Authority. Prepared for: Ministry of Natural Resources. August 16, 2008.

GRCA 2009. Integrated Water Budget Report: Grand River Watershed. Prepared by: Grand River Conservation Authority. Retrieved August 4, 2010, from: http://www.sourcewater.ca/swp_watersheds_grand/Grand_2009WaterBudget_final.pdf

GRCA 2010. Where is the Grand? Watershed Map. Retrieved July 6, 2010 from: http://www.grandriver.ca/index/document.cfm?Sec=12&Sub1=55&Sub2=24

GRCA 2010a. River flow, water quality and weather data. Retrieved July 14, 2010 from: http://www.grandriver.ca/index/document.cfm?Sec=2&Sub1=0&sub2=0

Great Lakes Commission. 1990. *A Guide-book to Drought Planning, Management and Water Level Changes in the Great Lakes*. *Commission Publications*. Ann Arbor, MI.

Hanna, J.E. & M.F.P. Michalski. 1982. Fisheries productivity and water level fluctuations in Lac Seul, Northwestern Ontario. *Canadian Water Resources Journal.* 7:365-388.

Hari, R.E., D.M. Livingston, R. Siber, P. Burkhardt-Holm & H. Guttinger. 2006. Consequences of climatic change for water temperature and brown trout populations in Alpine rivers and streams. *Global Change Biology*. 12:10-26.

Harvey, B.C. & A.J. Stewart. 1991. Fish size and habitat depth relationships in headwater streams. *Oecologia*. 87(3):1432-1939.

Hengeveld, H.G. 2000. *Projections for Canada's Climate Future*. Science Assessment and Integration Branch Report. Minister of Public Works and Government Services, Canada. pp. 26.

[IPCC]. Intergovernmental Panel On Climate Change. 1994. *Climate Change 1994*. J.T. Houghton, L. G. M. Filho, J. Bruce, H. Lee, B.A. Callander, E. Haites, N. Harris, & K. Maskell. Radiative forcing of climate change. Cambridge University Press, Cambridge, 1995. pp. 231.

[IPCC] Intergovernmental Panel On Climate Change. 1996. *Climate change 1995: The Science of Climate Change.* Cambridge University Press, Cambridge, UK.

[IPCC] Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: The Scientific Basis*, eds. Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K., and Johnson, C.A., Cambridge University Press, Cambridge, U.K.

[IPCC] Intergovernmental Panel On Climate Change. 2008. *Climate Change and Water*. Eds. B.C. Bates, Z.W. Kundzewicz, S. Wu and J.P. Palutikof. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, pp. 210.

[IPCC] Intergovernmental Panel On Climate Change. 2010. *Climate Model Output: Period-Averages.* Retrieved May 2, 2010, from: http://www.ipcc-data.org/ddc_climscen.html

Jacobs, K. L., G. M. Garfin, & B. J. Morehouse. 2005. Climate science and drought planning: The Arizona experience. *Journal of the American Water Resources Association*. (4):427-445.

Jonsson, N. 1991. Influence of water flow, water temperature and light on fish migration in rivers. *Nordic Journal of Freshwater Research*. 66:20-35.

Kitchener-Waterloo Record. September 12, 1998. Page C1.

Kitchener-Waterloo Record. September 6, 2002. Page C3.

Klaassen, J., 2000. A Climatological Assessment of Major 20th Century Drought Years in the Grand River Basin. Contracted Report for the Grand River Conservation Authority, Meteorological Service of Canada-Ontario-Region, Environment Canada, Downsview, Ontario. (Published as an Internal MSC- Ontario Region report, ASD-01-1, 2001.)

Koshida, G., 1992. *About Drought in Canada*. CLI-01-92. Downsview: Environment Canada. pp. 41.

Koshida, G., B. Mills & M. Sanderson. 1999. Adaptation lessons learned (and forgotten) from the 1988 and 1998 southern Ontario droughts, in I. Burton, M. Kerry, S. Kalhok & M. Vandierendonck (eds.), *Report from the Adaptation Learning Experiment*. Environment Canada, Environmental Adaptation Research Group, Downsview, Ontario, pp. 23-35.

Kreutzwiser, R.D., R.C. de Lo ë, J. Durley, & C. Priddle. 2004. Water allocation and the Permit to Take Water Program in Ontario: challenges and opportunities. *Canadian Water Resources Journal* 29(2):135-146.

Lavender, B., J.V. Smith, G. Koshida and L.D. Mortsch. 1998. *Binational Great Lakes-St. Lawrence Basin Climate Change and Hydrologic Scenarios Report*. Downsview, Ontario: Environment Canada, Environmental Adaptation Research Group.

Lofgren, B. M., F. H. Quinn, A. H. Clites, R. A. Assel, A. J. Eberhardt, and C. L. Luukkonen. 2002. Evaluation of potential impacts on Great Lakes water resources based on climate scenarios of two GCMs. *Journal of Great Lakes Research*.

Lyons, J. R. 1994. Assistant Secretary of Agriculture for Natural Resources and the Environment, speaking at Drought Management in a Changing West: New Directions for Water Policy, a conference in Portland, Oregon, in May 1994. Retrieved May 6, 2010, from: http://www.drought.unl.edu/plan/handbook/risk.pdf

Manitoba Water Rights Act. Manitoba Laws. June 13, 2006. Retrieved August 1, 2010: http://web2.gov.mb.ca/laws/statutes/ccsm/w080e.php

Manny, B.A., 1984. Potential impacts of water diversions on fishery resources in the Great Lakes. *Fisheries*. 9:19-23.

McIntire, C.D. 1966. Some effects of current velocity on periphyton communities in laboratory streams. *Hydrobiologia.* 27:559-570.

Meier, W., C. Bonjour, A. Wuest, & P. Reichert. 2003. Modeling the effect of water diversion on the temperature of mountain streams. *Journal of Environmental Engineering.* 129:755-764.

Melbourne Water. 2007. *Drought Response Plan: Licensed Water Users*. Melbourne Water Corporation. Diversion Management Team. Retrieved August 1, 2010, from: http://www.melbournewater.com.au/content/library/rivers_and_creeks/waterway_diverters/drought_response_plan_-_licensed_water_users.pdf

Mingelbier, M., P. Brodeur, & J. Morin. 2008. Spatially explicit model predicting the spawning habitat and early life stage mortality of Northern pike (*Esox lucius*) in a large system: the St. Lawrence River between 1960 and 2000. *Hydrobiologia.* 601:55-69.

[MNR] Ontario Ministry of Natural Resources. 2009. *Ontario's Fish*. Retrieved June 3, 2010, from: http://www.mnr.gov.on.ca/en/Business/LetsFish/index.html

[MOE] Ontario Ministry of the Environment Brief. 2000. Review Process for Permits To Take Water. Queen's Printer for Ontario, Ontario. pp. 2.

[MOE] Ministry of the Environment. 2005. *Permit to Take Water (PTTW) Manual*. Retrieved April 6, 2009, from: http://www.ene.gov.on.ca/envision/gp/4932e.pdf

[MOE]. Ministry of the Environment. 2010. *Technical Bulletin. Permit to Take Water Program. Monitoring and Reporting of Water Takings*. August. Retrieved September 24, 2010 from: http://www.ene.gov.on.ca/publications/6003e.pdf

Mortsch, L.D. & F.H. Quinn. 1996. Climate change scenarios for Great Lakes Basin ecosystem studies. *Limnology and Oceanography*. 41(5):903-911.

Mortsch, L., H. Hengeveld, M. Lister, B. Lofgren, F. Quinn, M. Slivitzky, & L. Wenger. 2000. Climate change impacts on the hydrology of the Great Lakes-St. Lawrence system. *Canadian Water Resources Journal*. 25(2):153-179.

Mortsch, L. D., M. Alden, & J. Klassen. 2005. *Development of Climate Change Scenarios for Impact and Adaption Studies in the Great lakes - St. Lawrence Basin.* A report prepared for the International Joint Commission. Environment Canada, Adaptation and Impacts Research Group. Research Report 05-01. Downsview, Ontario: Environment Canada.

[NDMC] National Drought Mitigation Center. 2009. "What is drought?" University of Nebraska-Lincoln. Retrieved on August 3, 2010, from: http://www.drought.unl.edu/index.htm

Nelson, J.G., J. Porter, C. Farassoglou, S. Gardiner, C. Guthrie, C. Beck & C. Lemieux. 2003. *The Grand River Watershed: A Heritage Landscape Guide*. Heritage Landscape Guide Series #2. Heritage Resources Center, University of Waterloo, Waterloo, Ontario.

Newfoundland and Labrador Department of Environment and Conservation. 2001. Policy for Allocation of Water Use. Retrieved July 13, 2010, from http://www.env.gov.nl.ca/env/waterres/regulations/policies/water_use.html

[NRC] Natural Resources Canada. 2007. Weathering the Changes: Climate Change in Ontario. Retrieved July 16, 2010, from: http://www.adaptation.nrcan.gc.ca/posters/on/on_02_e.php

[NRC] Natural Resources Canada. 2009. The Atlas of Canada: Canadian Heritage Rivers. Retrieved March 10, 2009, from: http://atlas.nrcan.gc.ca/site/english/maps/peopleandsociety/tourismattractions/ecotourism/heritage_rivers/1

Ochumba, P.B. & D.I. Kibaara. 1989. Observations on blue green algae blooms in the open waters of Lake Victoria, Kenya. *African Journal of Ecology*. 27(1):23-34.

Ojala, A., P. Kankaala, & T. Tulonen. 2002. Growth response of *Equisetum fluviatile* to elevated CO_2 and temperature. *Environmental and Experimental Biology*. 47(2):157-171.

Ontario Ministry of Finance. 2009. Ontario Population Projections Update. Accessed June 6, 2010. Retrieved March 2010, from: http://www.fin.gov.on.ca/en/economy/demographics/projections/#s3a

[OLWR] Ontario Low Water Response. 2003. Ontario Ministry of Natural Resources, Ontario Ministry of the Environment, Ontario Ministry of Agriculture, Food and Rural Affairs, Ontario Ministry of Municipal Affairs and Housing, Ontario Ministry of Economic Development and Trade, Association of Municipalities of Ontario, Conservation Ontario 2001. Queen's Printer for Ontario, Ontario.

Palys, T. & C. Atchison. 2008. *Research Decisions: Quantitative and Qualitative Perspectives.* (4th ed.) Toronto: Thomson Nelson.

Pirie, R.L., R. C. de Loë, & R. Kreutzwiser. 2004. Drought planning and water allocation: an assessment of local capacity in Minnesota. *Journal of Environmental Management.* 73:25-38.

Poff, N.L., N.L. Voelz, J.V. Ward, & R.E. Lee. 1990. Algal colonization under four experimentally-controlled current regimes in a high mountain stream. *Journal of the North American Benthological Society.* 9:303-318.

Quinn, F. H., and B. M. Lofgren. 2000. The influence of potential greenhouse warming on Great Lakes hydrology, water levels, and water management. Proceedings, 15th Conference on Hydrology, American Meteorological Society Annual Meeting. Long Beach, CA. 9-14 January, 2000. pp. 271-274.

Radar, R.B. & T.A. Belish. 1999. Influence of mild to severe flow alterations on invertebrates in three mountain streams. *Regulated Rivers: Research & Management* 15: 353-363.

Richter, B.D., R. Mathews, D.L Harrison, & R. Wigington. 2003. Ecologically sustainable water management: managing river flows for ecological integrity. *Ecological Applications*. 13:206–224.

Rubec, C.D.A., P. Lynch-Stewart, G. Wickware, & I. Kessel-Taylor. 1988. 'Wetland Utilization in Canada,' in National Wetlands Working Group, *Wetlands of Canada*, Ecological Land Classification Series, No. 24, Sustainable Development Branch, Environment Canada, Ottawa, Ontario and Polyscience Publications Inc., Montreal, Quebec. 379-412.

Rubin, H. J., & I. Rubin. 2005. *Qualitative interviewing: The Art of Hearing Data*. 2nd ed. Thousand Oaks: Sage Publications.

Saskatchewan Watershed Authority. 2008. North Saskatchewan River Watershed Source Water Protection Plan. Retrieved August 20, 2010 from: http://www.swa.ca/Publications/Documents/NorthSaskatchewanRiverWatershedSourceWaterProtectionPlan.pdf

Sawyer, A., C. Cooke, J. Pitcher, & P. Lapcevic. *State of the Great Lakes 2005. Groundwater Dependant Plant and Animal Communities*. Grand River Conservation Authority, Cambridge, Ontario.

Sather, J.H., & R.D. Smith. 1984. *An Overview of Major Wetland Functions*, Report-FWS/OBS-84, U.S. Fish and Wildlife Service. pp. 67.

Singleton, R. A. & Straits, B. C. 2005. Approaches to Social Research. (4th ed.) New York: Oxford University Press.

Sousounis, P., & P. Glick. 2000. Great Lakes: The potential impacts of global warming on the Great Lakes Region. Retrieved March 23, 2010, from: http://www.climatehotmap.org/impacts/greatlakes.html

Southam, C.F., B.N. Mills, R.J. Moulton, & D.W. Brown. 1999. The potential impact of climate change in Ontario's Grand River Basin: water supply and demand issues. *Canadian Water Resources Journal*. 24:307-330.

Sprague, J. 2007. Great Wet North? Canada's Myth of Water Abundance. In Bakker, K. ed. *Eau Canada: the Future of Canada's Water*. UBCPress. Vancouver, Canada.

Tegart, W.J., G.W. Sheldon, & J.H. Hellyer. 1992. *Climate change: The Supplementary Report to the IPCC Impacts Assessment*. Intergovernmental Panel on Climate Change. Australian Government Publishing Service, Canberra.

[TDEC] Tennessee Department of Environment and Conservation. 2010. Drought Management Plan. Retrieved on August 21, 2010 from: http://www.tennessee.gov/environment/dws/pdf/droughtmgtplan.pdf

Thompson, A. 2007. Man vs. Nature and the New Meaning of Drought. Environment Live Science. April 20. Retrieved on August 23, 2010 from: http://www.livescience.com/environment/070420_drought_defn.html

Toronto Star, October 12, 1998 pg A4.

Walker, B., & D. Salt. 2006. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World.* Washington: Island Press.

Watershed Report. 2004. Water Quantity Issues. Reservoirs play a critical role in water supply, flood control. GRCA. Retrieved on August 30, 2010 from: http://www.grandriver.ca/WatershedReportCard/2004_Fall_Grand_Pg8.pdf

Whetton, P.H., A.M. Fowler, M.R. Haylock, & A.B. Pittock. 1993. Implications of climate change due to the enhanced greenhouse effect on floods and droughts in Australia. *Climatic Change* 25:289-317.

Wilhite, D.A. 1993. Planning for drought: A methodology. In *Drought Assessment, Management, and Planning: Theory and Case Studies* (ed. D.A. Wilhite). Kluwer Academic Publishers: Boston. pp. 87-108.

Wood, P.J., & P.D. Armitage 1999. Sediment deposition in a small lowland stream – management implications. *Regulated Rivers: Research and Management.* 15:199-210.

Wood, P. J., & G.E. Petts. 1999. The influence of drought on chalk stream macroinvertebrates. *Hydrological Processes.* 13:387-399.

Yin, R. 2003. *Case Study Research: Design and Methods.* (3rd ed.) Thousand Oaks: Sage Publications, Inc.

Appendices

Appendix A: Recruitment Document

October 2009

Dear (Insert Participant's Name)

This letter is an invitation to participate in a study I am conducting for a Master's thesis at the University of Waterloo. My faculty supervisor is Dr. Paul Kay (Department of Environment and Resource Studies). I would like to provide you with more information about this project and what your involvement would entail if you decide to take part.

The broad question that this research addresses is how water will be equitably allocated amongst stake-holders and the natural aquatic environment using an ecosystem based approach during times of serious water scarcity as projected by climate change scenarios. I have chosen to contact you because I feel that you possess valuable knowledge that is relevant to my study based on your involvement in water management issues in the Grand River region.

Please note that participation in this study is voluntary. If you choose to participate, it will involve an interview lasting no more than one hour, at a mutually convenient location and time. I will provide you with a copy of the interview questions prior to the interview. You may decide to withdraw from this study at any time simply by letting me know, and you can decline to answer any of the interview questions. With your permission, I would like to audio record the interview. Shortly after the interview has been completed, I will send you a copy of the transcript to give you an opportunity to confirm the accuracy of our conversation and to add or clarify any points that you wish. Quotations, names and affiliations will only be used with permission; if you indicate that you would like to remain anonymous, then all information you provide will be treated with anonymity. All data – including audio recordings – will be securely stored on a password-protected computer, and upon completion of the study (in approximately two years) all data will be erased or destroyed. There are no known or anticipated risks to you as a participant in this study. After I've completed my thesis, I will send you an executive summary of the research results. If you wish, I can also send you a copy of the final thesis itself.

If you would like to participate in this study, have any questions regarding this study, or would like additional information to assist you in reaching a decision about participation, please contact me by email at jdisch@uwaterloo.ca. If I do not hear a response from you, I will be contacting you by phone within the next few days to further discuss the project. You can also contact Dr. Paul Kay at 519-888-4567, ext. 35796 or by email (pkay@uwaterloo.ca).

I would like to assure you that this study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. If you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes, Director, Office of Research Ethics at 519-888-4567 ext. 36005 or by email at ssykes@uwaterloo.ca.

I look forward to speaking with you and thank-you in advance for your assistance in this project.

Yours Sincerely,
Jenna Disch
Student Investigator

Appendix B: Consent of Participant

I have read the information presented in the information letter about a study being conducted by Jenna Disch of the Department of Environment and Resource Studies at the University of Waterloo. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

I am aware that I have the option of allowing my interview to be audio recorded to ensure an accurate recording of my responses. I am aware that I will have the opportunity to review and approve the quotations as they are written in the paper prior to finalizing the paper.

Below I have indicated my preference regarding attribution. If I indicate that I can be quoted, I understand that excerpts from the interview may be included in the thesis and/or publications to come from this research.

This project has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact Dr. Susan Sykes, Director, Office of Research Ethics at 519-888-4567 ext. 36005 or by email at ssykes@uwaterloo.ca.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

___ YES ___ NO

I agree to have my interview audio recorded.

___ YES ___ NO

Regarding quotation and attribution of things that I say during the interview in the thesis and or publications to come from this research, the following is my position:

___ My comments can be quoted with attribution (including the name of the organization I represent)
___ My comments can be quoted anonymously
___ I do not wish to be quoted or attributed

____________________________	____________________________
Participant Name (Please Print)	**Witness Name (Please Print)**
____________________________	____________________________
Signature of Participant	**Witness Signature**
____________________________	
Date	

Appendix C: Thank-you Letter

University of Waterloo

(Date)

Dear (Insert Participant's Name):

I would like to thank-you for your participation in this study. As a reminder, the purpose of this study is to uncover how water might be equitably allocated amongst stakeholders and the natural aquatic environment during times of serious water scarcity.

The data collected during interviews will contribute to a better understanding of how water is currently allocated using the 'ecosystem-based' approach, and how Ontario's Low Water Response mechanism might be strengthened in the future in order to sustain aquatic resources. This is meant to aid in the development of more effective water management strategies in Ontario.

As has already been mentioned, any data you have provided will be kept confidential and you will not be identified in the thesis or any publications unless you gave permission for attribution. You will again be contacted to review the transcripts from your interview which will give you the opportunity to confirm the accuracy of our conversation and to add or clarify any points that you wish. Once all the data have been collected and analyzed for this project, I plan on sharing this information with the research community through conferences, presentations, and journal articles. If you have any questions or concerns, feel free to contact me at the email address listed at the bottom of the page. Alternately, you can contact Dr. Paul Kay at 519-888-4567, ext. 35796 or by email (pkay@uwaterloo.ca). If you would like a summary of the results, please let me know. Otherwise, I will send you a copy of the study when it is completed by August 2010.

As with all University of Waterloo projects involving human participants, this project was reviewed by, and received ethics clearance through the Office of Research Ethics at the University of Waterloo. Should you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes, Director, Office of Research Ethics at 519-888-4567 ext. 36005 or by email at ssykes@uwaterloo.ca.

Jenna Disch

University of Waterloo
Department of Environment and Resource Studies

jdisch@uwaterloo.ca

Appendix D: Letter for Review of Transcript

Hi (Insert Participant's Name),

Thank you once again for your participation in my study: Assessing the Resilience of Ontario's Low Water Response Mechanism under a Changed Climate Scenario. Your transcript from our audio recorded interview has been competed. I am attaching it in this email for your review.

If you have time and would like to read over your transcript for clarity and consistency, please feel free to do so, making changes as necessary. To remind you, everything typed on your transcript was taken directly from the audio recording.

If I do not hear back from you within one week, I am assuming that you have no changes to submit and your transcript will be used for data analysis as it stands.

Sincerely,

Jenna Disch
Master's Candidate
Department of Environment and Resource Studies
University of Waterloo
jdisch@uwaterloo.ca

Appendix E – Interview Questions

1. What is your personal involvement with water management and how long have you held this position with your current organization?

    a. How did you come to this position and why?

    b. What is your particular expertise as a member of the Water Response team?

2. What are the uses of water in the Grand River Watershed and is there currently competition for water amongst various sectors and/or economic activities within the watershed or sub-watersheds?

    a. Are there particular areas within the watershed that you can identify as vulnerable? (map).

2. Has this water basin ever experienced drought [conditions of low flows] in the past? If so, when?

    a. How was allocation priority rank determined amongst water use sectors, and what were the actual water allocations (in proportions) during this time?

    b. What were some of the impacts of this shortage on various sectors (i.e. aquatic environmental impacts, impacts on agriculture, impacts on urban economies)?

    c. If any types of water restrictions were used during this time, were they successful? Was anything of importance learned?

    d. What other lessons were learned from that experience about allocations during low-flow conditions?

3. How are recommendations or decisions concerning low water flows reached amongst members of the Water Response Team? Does each representative on team have equal decision-making power?

5. During times of drought (or low flow), the uses of water are classified in OLWR into three different categories: essential, important, and non-essential. OLWR states that ecological health is considered essential and is covered under basic ecological functions. Which uses of water are considered essential, important, and non-essential in this watershed?

6. Please list the essential uses of water in this watershed. In what priority are the "essential" uses of water determined in OLWR and which user has top priority?

Where does ecological health rank amongst the other essential uses of water? Why?

7. How are the OLWR thresholds defined and are they different in this watershed?

8. Are biologically critical sites (key spawning, rearing and staging areas, important migration corridors and areas of thermal refugia) given special attention in the water allocation process during times of drought or water scarcity?

9. Are minimum flows determined for the fishery? How?

   a. Are minimum low flows for the benefit of fisheries factored into water allocation procedures?

   b. Is there a monitoring program in place to assess their effectiveness?

10. What are the most critical fisheries in this watershed and why are they considered critical?

11. What types of policies and management actions could be incorporated into OLWR in order to make the fisheries in the Grand River Watershed more resilient?

The Province of Ontario's Ministry of Environment has claimed that it will use an ecosystem-based approach to water allocations. This approach will consider both the *reasonable needs for water takers and the natural function of the ecosystem, whereupon the highest priority will be placed on preventing significant environmental harm to aquatic environments as well as all other natural environments (PTTW, 2005).*

13. The Ministry of the Environment has stated that it will use an ecosystem-based approach to water allocation. What do you understand this approach to mean?

    a. How do you apply the ecosystem-based approach to water management in your personal low water decisions and recommendations to the Team?

Here I have for you a map of the Grand River Watershed. A climate change scenario was input into a hydrologic model (GAWSER) for specific regions in the watershed and has projected that in certain regions, reductions in average summer flow will occur in the future. This map summarizes the results and depicts the regions where there will be reductions in average summer flow. I would like you to answer the following questions within the context of this future scenario. In other words, you will now be asked questions on how the Ontario Low Water Response might function during times of serious water scarcity under changed climate conditions.

14. How confident are you in OLWR's ability to allocate water equitably during times of water scarcity? (Please rank on a scale of 1-5) 1: very not confident; 2: not confident; 3: neutral; 4: confident; 5: very confident; 6: do not know

15. In a changed climate scenario where there is a shortage of water, which sectors do you believe will be given priority for water? Why?

    a. Which sectors, in your opinion will be first to undergo water cutbacks? Why?

16.What might water managers and planners do to make water allocation more equitable under stressed conditions?

17. Future climate change scenarios suggest that this water basin will reach a level three shortage. If this basin has never before reached a level three shortage, how will water allocation decisions be made under OLWR?

How will allocation priority be determined?

a. What types of measures will be taken to protect the fisheries during this time?

18. How might water be allocated under OLWR in this watershed when river flow is 25% below the lowest average summer monthly flow in July or August 2090 with a recurrence interval of one year?

a. 50% below the lowest average summer monthly flow in July or August 2090 with a recurrence interval of one year?

b. 75% below the lowest average summer monthly flow in July or August 2090 with a recurrence interval of one year?

c. Will priority rank of various water use sectors stay the same, or will it change under these various flow regimes?

19. In your opinion, does OLWR move in a direction that promotes greater resilience and flexibility over water allocation decisions during times of scarcity? Is there anything else that can be done to OLWR to encourage greater resilience? (Resilience means able to withstand stress and shocks.)