Strengthening Rural Community Capacity for Adaptation to Low Water Levels

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Preface

In the water sector, the persistence of human impacts and associated costs of climate events point clearly to the need to identify strategies for coping with climate variability and change, and to develop an enhanced capacity to respond effectively (Hofmann *et al*., 1998). Rural communities – especially those in the rural-urban fringe – are challenged by the need to balance human uses (e.g., rural industry, recreation, municipal water supply) and ecosystem protection (e.g., maintenance of base flow to support fisheries, protection of wetlands that depend on shallow groundwater aquifers). Key stakeholders comprising rural communities in the rural-urban fringe include municipal water managers, rural residents and industries, farmers, golf course operators, anglers, and conservation groups. Not only are these people and groups experiencing increasing conflict and competition over water, particularly groundwater (Kreutzwiser and de Loë, 1998), but also they must cope with capacity-related challenges. Two issues are particularly important:

- First, not much is known about the impacts of climate-induced water shortages on rural communities in Canada and the ecosystems upon which they depend (Climate Change Action Fund, 1998; Hofmann *et al*., 1998).
- Second, in Ontario, recent reductions in provincial support for water management and land use planning (Kreutzwiser, 1998) have had serious implications for rural communities. For many rural communities, the capacity to mount effective climate change adaptation strategies is in question.

Our *Climate Change Action Fund* research project # A258 assessed the capacity of rural communities in the upper Credit River watershed in southern Ontario to adapt to climate-induced water shortages. The research effort was organized around three objectives:

1. Identify the actual and potential impacts of climate-induced variability on hydrologic systems in the upper Credit River watershed.
2. Identify adaptation responses and determine and assess factors that facilitate and constrain the ability of rural communities to balance human uses of water and ecosystem protection under increasing climate variability.
3. Recommend strategies to enhance the capacity of rural communities to adapt to climate-induced variability in hydrologic systems.

Four documents were created to summarize the findings of the research:

- *Potential Effects of Climate Change-Induced Low Water Levels on Rural Communities in the Upper Credit River Watershed* addresses Objective 1,
- *Climate Change, Water Resources, and Rural Community Capacity to Adapt: Workshop Session on Adapting to Low Water Levels in the Upper Credit River Watershed* is a reference document prepared as background information for participants of a workshop held in Orangeville in April 2001 to address objectives 2 and 3,
- *Adapting to Low Water Levels in the Upper Credit River Watershed – Workshop Summary* summarizes the findings of the workshop, and

- This document, *Strengthening Rural Community Capacity for Adaptation to Low Water Levels* summarizes the findings of objectives 2 and 3, including a case study on subwatersheds 16/18 and 19 of the Credit River watershed.

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1.0 Introduction

A key challenge facing rural communities, especially those in rural-urban fringe areas, is balancing utilization of water for human purposes against protection of water for natural systems. This challenge may be magnified in the future due to development pressures and the possibility of a climate change-induced increase in hydrologic variability. The purposes of this report are to identify measures taken by upper Credit River communities to balance human and environmental water needs, and to assess factors that affect the ability of rural communities to respond to climate change-induced water shortages.

2.0 Adapting to low water conditions

For the purpose of this report, *droughts* are "periods of time when natural or managed water systems do not provide enough water to meet established human and environmental uses because of natural shortfalls in precipitation or streamflow" (Werick and Whipple 1994, iii). *Low water levels* occur when drought conditions are approached.

To adapt to low water conditions is to make changes that will maintain or improve the ability of a system (e.g., municipal water supply, agriculture) to continue to serve its functions (e.g., domestic water supply, production of food) during low water periods (Smithers and Smit, 1997). Historically, water users have always had to adapt to climate. The tools of adaptation, presented in Box 1, are by-and-large conventional practices already in use in water management. However, despite having adapted somewhat to existing climatic variability, droughts still cause damage and costs are incurred among virtually every sector that uses water. For instance, the 1988 drought in Ontario resulted in crop insurance payouts of $55.7 million, $12 million in relief for cattle farmers, municipal water use restrictions on nonessential uses (e.g., lawn watering), the second worst forest fire season since 1917, an increase in dredging, and reduced hydroelectricity generation (Great Lakes Commission, 1990; Gabriel and Kreutzwiser, 1993). By becoming better adapted to current climatic variability, communities can reduce their vulnerability to climate change-induced drought, and to water shortages brought on by development and population growth. Adaptation may also lessen the potential for water-related conflict.

There are a number of different tools available for adapting water management to more frequent or severe dry periods (Box 1). Review of the literature suggests a wide variety of measures that reside generally within five areas: planning, demand management, supply management, data management, and public involvement. Adaptation measures can be institutional (e.g., bylaws), technological, structural (e.g., reservoirs), or behavioral in nature; they can be adopted by private or public agencies, at local, regional, provincial, national, or international levels (de Loë *et al*., In Press).

Planning activities, both for water and land management in general, and for drought contingency in particular, should explicitly incorporate the possibility of increasing climatic variability. Both activities designed to reduce demand for water (e.g., water conservation bylaws), and those designed to increase available water supplies (e.g., leak detection and repair), can help a community to adapt to more frequent or severe

Box 1: Selected activities for adapting to climate change-induced water shortages

Planning

- Long term planning (e.g., for land use, water supply, infrastructure) incorporating the possibility of climate change
- Watershed planning and management
- Management of growth and development
- Drought contingency planning, disaster relief
- Assess vulnerability to climate change
- Inventory adaptation options

Demand management

- Voluntary/mandatory water conservation
- Water use metering
- Pricing structures
- Water conservation standards (e.g., for appliances)
- Conflict resolution

Supply management

- Changing operations protocols to increase efficiency (e.g., reservoir releases)
- Interbasin transfers
- Managing water allocation
- Development of new or modification of existing infrastructure and water sources
- Artificial recharge of groundwater
- Conjunctive groundwater-surface water use
- Leak detection/repair
- Pollution control programs

Data management

- Existing and new data collection (e.g., water levels, supplies, use)
- Research

Public involvement

- Development of literature and training/education initiatives for the general public and other water users (e.g., industry, agriculture, etc.)
- Public involvement in decision-making

Sources: Nuttle, 1993; Smith and Lenhart, 1996; Strzepek *et al*., 1998; de Loë and Kreutzwiser, 2000; de Loë *et al*., In Press.

droughts. Collection and analysis of existing available data, as well as new data, is essential to provide background information for decision-making. Finally, public information and involvement in decision-making and implementation of adaptation responses will help to ensure success. In order to adapt to increasing hydrologic variability, it is likely that more than one type of tool will have to be used. For instance, monitoring water quality and quantity, and water and land resource planning, will provide the information and direction for selection of demand or supply management activities. The appropriateness of a given tool varies with the specific situation and locality. Nevertheless, successful adaptation activities have some common characteristics (Table 1).

Table 1: Characteristics of successful adaptation responses

Adaptation characteristic	Characteristic description
Anticipatory	The adaptation response should be undertaken in anticipation of future droughts, not in reaction to existing low water conditions.
Flexible	The adaptation response should maintain or improve the functioning of the target system under many different water level conditions.
"No regrets"	Undertaking the adaptation response should be justified under existing hydrological conditions, as well as anticipated future conditions.
Implementable	The legal, institutional, technical, human, financial, social, and political resources and support should exist to implement the action.
Responsive	The adaptation response should be consistent with many of a community's social, economic, and environmental goals and objectives.

Sources: Burton, 1996; Smith, 1996; Smith and Lenhart, 1996; Toman and Bierbaum, 1996; Wheaton and MacIver, 1999.

3.0 Adaptive capacity

Once a community has decided upon appropriate measures to use to adapt to low water conditions, the measures must be implemented. There are many factors affecting the ability of a community to carry out adaptation activities (Box 2). Some factors pertain to the ability of specific organizations within the community to develop and deliver programs and services, and to make effective use of their resources (in general, and with respect to water and disaster management). Other factors relate to the activities and perceptions of a variety of community stakeholders, including public interest groups and private industry. Whereas some confidence may be warranted in the case of large urban communities' ability to implement measures, the ability of small rural communities in Ontario to manage their water resources effectively is not certain.

In the institutional environment, the public policies, rules, regulations, and power relationships that influence the management of water quantity, and the activities of all related organizations, affect the capacity of a community adapt to low water conditions. Key issues include the necessity for clear and comprehensive definition of the roles and responsibilities of all agencies involved in water quantity management, the availability to implementing agencies of appropriate adaptation tools, and the need for financial, political, and technical support from senior government agencies. At this level, communication and coordination among local agencies (e.g., conservation authorities and municipalities) and senior government agencies (e.g., Ontario Ministry of the Environment, Fisheries and Oceans Canada) is critical.

Box 2: Factors affecting the capacity of communities to adapt to climate change-induced low water levels

How do institutional arrangements affect capacity?

- The roles and responsibilities of federal, provincial, and local agencies (i.e., municipalities, conservation authorities, non-governmental organizations) must be clear, consistent, and comprehensive
- Appropriate adaptation activities (see Box 1) must be available to decision-making and implementing agencies according to their roles and responsibilities
- Rural communities need commitment and support (e.g., financial, political, technical) from federal and provincial agencies to implement adaptation activities

How does the nature of the watershed community affect capacity?

- Stakeholder perceptions and awareness regarding climate change, impacts on human and ecological systems, and the legitimacy of institutions, all affect a community's capacity to adapt
- Communication and coordination (e.g., sharing information, coordinating activities, providing leadership) among all economic sectors and agencies is necessary
- Public involvement in water management decision making and implementation of activities will help to ensure compliance with adaptation activities

How do a community's resources affect capacity?

- Sufficient and secure financial resources are needed to decide upon and implement adaptation activities
- Communities need enough staff with the appropriate training and technical expertise to implement activities
- Selection and implementation of adaptation tools requires information (e.g., about water resources and impacts) and technical resources that are accessible and of appropriate quality

Sources: Lauermann, 1985; Reibsame, 1988; Hoban, 1990; Wolensky and Wolensky, 1990; Burton, 1996; Toman and Bierbaum, 1996; Hobbs *et al*., 1997; Burton *et al*., 1998; Basher, 1999; de Loë *et al*., 1999; O'Connor *et al*., 1999; Wheaton and MacIver, 1999; Bryant *et al*., 2000; de Loë and Kreutzwiser, 2000; Reilly and Schimmelpfennig, 2000.

For the purpose of this research, a community is defined as "a specific locality, including its inhabitants" (Allen 1990, 230). Within a particular community, a number of factors can affect the ability of the community to adapt to water shortages. The literature focuses on the importance of public information and involvement, stakeholder perceptions, local commitment and leadership, and communication and coordination among key players. Additionally, the resources available to a community, in particular its financial, human and information resources for decision-making, affect its capacity to adapt to low water conditions.

4.0 Case study: Credit River subwatersheds 16/18, 19

The purpose of this case study is to describe examples of rural community adaptation to low water conditions, and to identify factors that facilitate and constrain the ability of rural communities to balance human uses of water with ecosystem protection. The following capacity evaluation is structured around the factors identified in Box 2. Data sources included municipal and conservation authority documents, key informant interviews, and workshop breakout group discussions. A preliminary list of potential interview subjects was identified by Credit Valley Conservation. Additional interview subjects were identified during key informant interviews, and from agency web sites. In total, 15 people were interviewed, and 19 people attended the workshop (Table 2). Interviews were semi-structured, and based on the list of interview questions in Appendix A.

Table 2: Stakeholder groups involved in data collection

Interview subjects	Workshop participants
3 Credit Valley Conservation staff 2 municipal staff 1 OMOE staff 1 OMNR staff 5 agricultural community representatives 3 recreational anglers' representatives	1 Credit Valley Conservation staff 6 municipal staff 1 OMOE staff 1 OMNR staff 2 OMAFRA staff 4 recreational anglers' representatives 2 aggregate industry representatives 2 public interest group representatives

4.1 The Upper Credit River watershed

The Credit River watershed covers an area of approximately 1,000 km^2, draining the Credit River and its tributaries from its headwaters near the Town of Orangeville south to Lake Ontario, west of the City of Toronto (Figure 1). The northern portion of the watershed is predominantly rural, while the southern portion encompasses the largely urban areas of the cities of Brampton and Mississauga. The upper portion of the watershed (subwatersheds 15 to 19) runs from the headwaters down to the Village of Belfountain (Figure 2).

Subwatersheds 16 and 18 are located in the Town of Caledon, in the Region of Peel. The area is predominantly rural, with the main areas of settlement being the villages of Alton and Caledon, and the hamlets of Melville and Belfountain. Subwatershed 19 covers the Town of Orangeville, as well as parts of the towns of Caledon and Mono, and the townships of Amaranth and East Garafraxa. Land use in these areas is dominated by agriculture and human modified natural areas. Aggregate mines are prominent features in subwatersheds 16 and 18, while the urban development of the Town of Orangeville dominates subwatershed 19.

In subwatershed 19, Monora Creek and two unnamed tributaries flow into Island Lake (the Orangeville Reservoir); outflow from Island Lake, Mill Creek, and the Caledon tributaries forms the main branch of the Credit River as it flows south to the dam at Melville (Aquafor Beech Ltd. *et al*., 1997). Groundwater discharges contribute significantly to the baseflow of Monora Creek, Mill Creek, and the Caledon tributaries, while outflow from the Orangeville Sewage Treatment Plant contributes to the flow of the Credit River (Aquafor Beech Ltd. *et al*., 1997). Some sections of the Credit's tributaries support relatively healthy cold-water fish communities, while Island Lake supports a warm-water aquatic community. Environmentally significant wetlands in the subwatershed include Rosehill Swamp, areas around Island Lake, and the Melville Marshes (Aquafor Beech Ltd. *et al*., 1997).

Caledon Creek and part of the Credit River run through subwatersheds 16 and 18. While much of Caledon Creek supports warm-water aquatic communities, groundwater upwellings occur in the lower portions of Caledon Creek and the Credit River supporting cold-water communities of brown and brook trout (Credit Valley Conservation *et al*., 1997). The Rosehill and Caledon Creek swamps are provincially designated Environmentally Significant Areas, serving as headwaters for Caledon Creek and supporting rare and uncommon plant and animal species (Credit Valley Conservation *et al*., 1997). For more information regarding ecological and human systems, and water use in the upper Credit River watershed, consult *Potential Effects of Climate Change-Induced Low Water Levels on Rural Communities in the Upper Credit River Watershed*.

Local concerns about water quantity management in the watershed at large were solicited in 1999 by Credit Valley Conservation, which hosted a meeting, in partnership with Peel and Halton regions, to which all known Permit to Take Water holders in the watershed were invited (Barron, ND). Thirty water users from all economic sectors, except water bottling, attended the workshop. Discussion at the workshop revealed a number of concerns about the present condition of the Credit River watershed, and possible future conditions. Water quantity concerns outlined by permit holders included recent low water conditions, increased consumption of water, the lack of a water budget and groundwater data, and concerns about priorities for water use, and means for ensuring future water supply (Credit Valley Conservation, 1999a). Concerns regarding the implications of increased incidence of drought and global climate change on water resources in the watershed were also expressed (Credit Valley Conservation, 1999a). Issues relating to balancing human and ecological management goals, in particular as they pertained to development, gravel extraction, and water management, were highlighted (Credit Valley Conservation, 1999a).

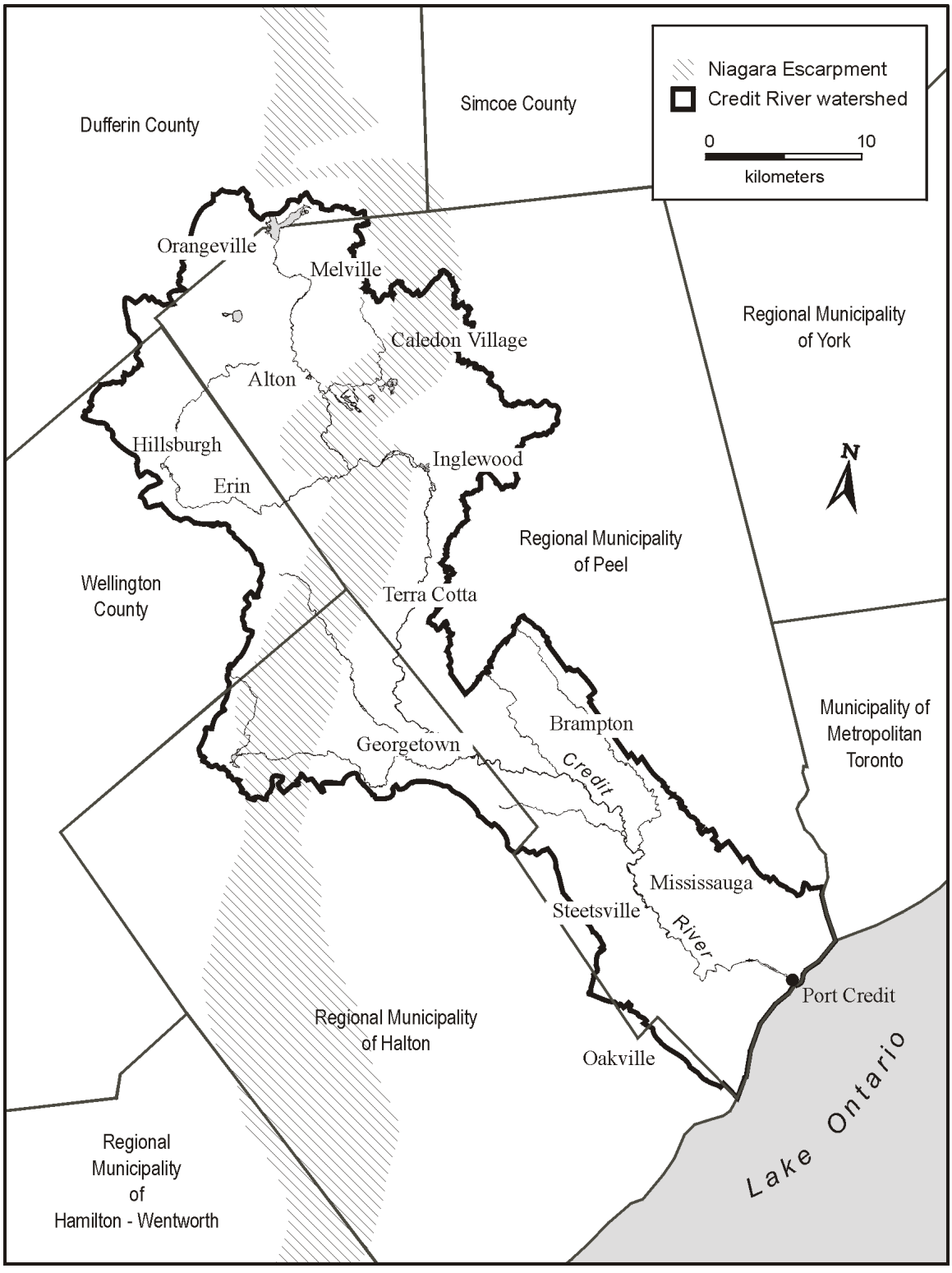

Figure 1: The Credit River watershed

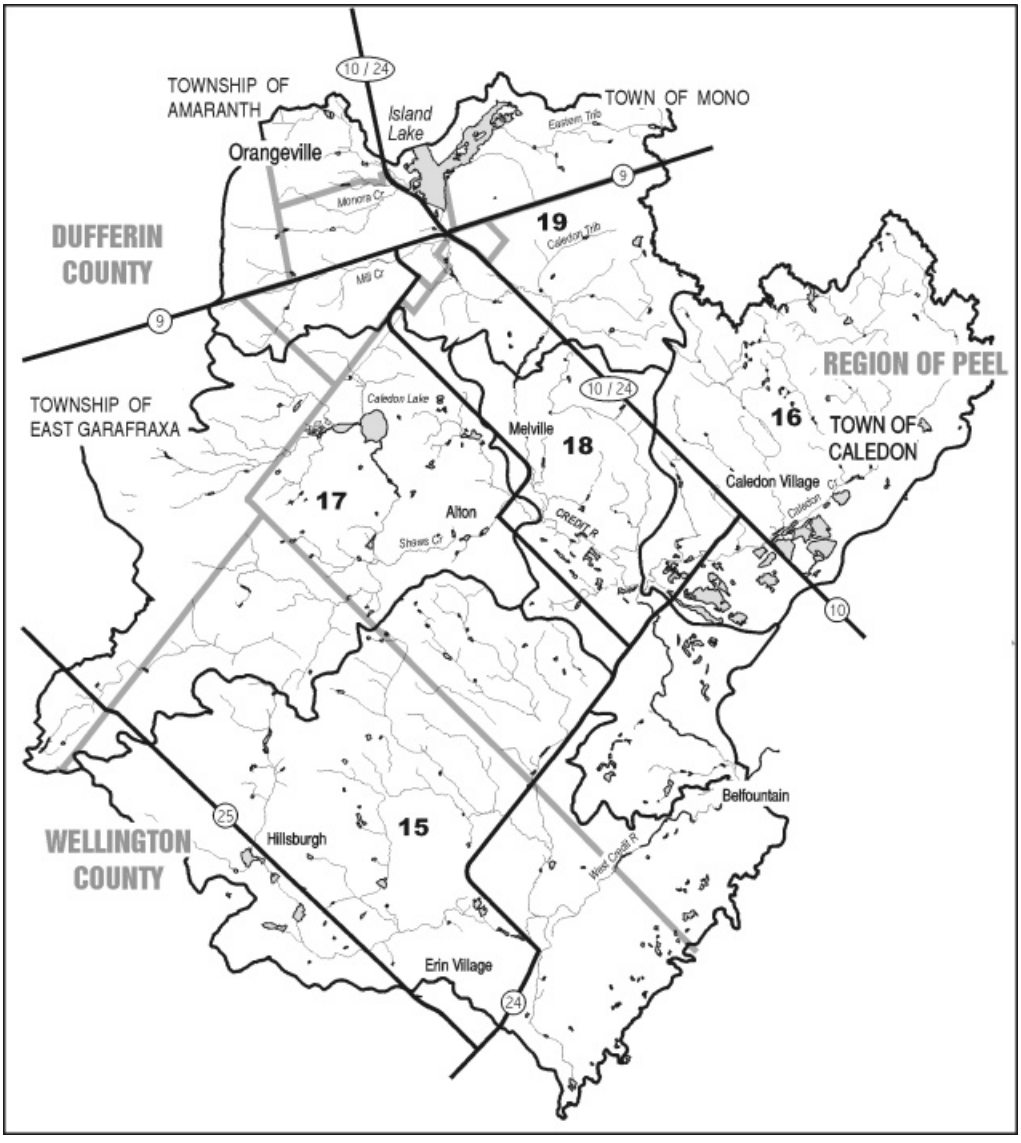

Figure 2: The upper Credit River watershed

Concerns specific to subwatersheds 16, 18, and 19 relate to interactions between groundwater and surface water systems. Excessive groundwater withdrawals can impact stream baseflow, fish habitat, and wetlands. In the past, Town of Orangeville water takings have impacted the flow of Mill Creek (Aquafor Beech Ltd. *et al*., 1997; Gartner Lee Ltd., 1998). Other areas in subwatershed 19 sensitive to groundwater withdrawals include Monora Creek, the Caledon tributaries, and part of the Credit River (Aquafor Beech Ltd. *et al*., 1997). Fish communities within and south of the Town of Orangeville, and those near intensive agricultural operations, are already under stress (Aquafor Beech Ltd. *et al*., 1997). Concerns relating to the protection of recharge areas, drinking water sources, wildlife and wetlands, and balancing environmental needs with development, were expressed at an open house for the subwatershed 19 study (Aquafor Beech Ltd. *et al*., 1997). In subwatersheds 16 and 18, concerns exist regarding the impacts of large water users, especially aggregate extraction and municipal pumping, on water quality and quantity, and aquatic ecosystems (Beak Consultants Limited *et al*., 1992; Credit Valley Conservation *et al*., 1998; Morris, 2001, Pers. Comm.).

Development pressures in the towns of Orangeville and Caledon, existing hydrologic variability, and possible future increases in the incidence and duration of droughts will make balancing human and ecological water needs increasingly difficult. At present, a number of agencies in the upper Credit River community have taken steps to address water supply concerns. The following sections outline the steps the community has taken to balance human and environmental water needs, and identify factors that facilitate and constrain the ability to adapt to existing and future climatic variability.

4.2 Institutional arrangements

Roles and responsibilities

Ontario's rural communities manage water within a complex set of institutional arrangements. The *British North America Act* and its replacement the *Constitution Act* grant the provinces primary jurisdiction over the management of water resources in Canada. In Ontario, the management of water quality and quantity is affected by numerous pieces of legislation under the authority of a variety of provincial and federal agencies (Box 3). The Ontario ministries of the Environment (OMOE), Natural Resources (OMNR), and Agriculture, Food and Rural Affairs (OMAFRA) play key roles in water quantity management in the province.

The OMOE is responsible for administering the Permit to Take Water Program (PTTWP) under the *Ontario Water Resources Act*, which supplements riparian rights. Under the PTTWP, permits are required for all water withdrawals in excess of 50,000 L/day, except those for the purposes of private domestic water supply, livestock watering (when water is not taken into storage), and fire fighting (Kreutzwiser *et al*., 1999). In some cases, permit applications are circulated to local agencies (e.g., CAs and municipalities) for comment (Schiller, 2001, Pers. Comm.; Worte, 2001, Pers. Comm.). Also under the *Ontario Water Resources Act*, the OMOE has the authority to resolve disputes regarding water quality and quantity interference (Estrin and Swaigen, 1993).

Box 3: Senior government agencies' roles in water quantity management

Ontario Ministry of the Environment (OMOE)

- *Ontario Water Resources Act*: legislative authority for the Permit to Take Water Program (PTTW program) (permits for withdrawals > 50,000 L/day), well construction permits, water conflict resolution
- Water monitoring and mapping: past mapping and monitoring activities, new Provincial Groundwater Monitoring Program in partnership with conservation authorities
- Provincial Water Protection Fund (1998-2001): provides funding for municipal water and sewage infrastructure, and environmental studies (e.g., groundwater management plans)

Ontario Ministry of Natural Resources (OMNR)

- *Lakes and Rivers Improvement Act*: legislative authority to grant approvals for, and regulate construction and operation, of water works
- *Public Lands Act*: authorizes construction and operation of dams, power generation projects
- Management of fish populations (*Strategic Plan for Ontario Fisheries*)
- Land Information Ontario: initiative to integrate land information in Ontario (including data on soils, municipal drains, tile drains, water well records, groundwater monitoring, climate) spearheaded by OMNR
- Ontario Water Response 2000: draft provincial drought response plan

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)

- Ontario Whole Farm Relief Program: provides financial assistance for farmers who have suffered financial losses due to declining prices, yield losses (e.g., from drought), or increased expenses
- Healthy Futures for Ontario Agriculture: pilot project in Norfolk County to encourage pond creation for water storage

Department of Fisheries and Oceans Canada

- *Fisheries Act*: provides for the protection of fish habitat, implementation agreements with conservation authorities
- Great Lakes Water-Level Emergency Response Program: provides financial assistance to Great Lakes marinas for dredging activities

Department of Transportation

- *Navigable Water Protection Act*: prohibits construction and dumping of wastes interfering with navigation

Environment Canada

- *Canada Water Act*: authorizes agreements with provinces for flood and erosion control
- *International Rivers Improvement Act*: protects flows of rivers that cross international boundaries

The OMOE is funding groundwater studies through the Provincial Water Protection Fund, and is in the process of reestablishing a groundwater monitoring network with the assistance of conservation authorities. The OMNR spearheaded the development of the *Ontario Water Response 2000*, a provincial drought response plan, in partnership with other Ontario ministries, Conservation Ontario, and the Association of Municipalities of Ontario (Ontario Ministry of Natural Resources *et al*., 2000). OMAFRA's Healthy Futures for Ontario Agriculture initiative has a pilot project underway in Norfolk County to promote pond creation for water storage (Warbick, 2001, Pers. Comm.). The federal department with the most impact on local water quantity management is Fisheries and Oceans Canada, which administers the *Fisheries Act*, in partnership with conservation authorities, to protect fish habitat.

Local agencies involved in water quantity management include conservation authorities (CAs) and municipalities (Box 4). Many conservation authorities have been historically concerned with both flood control and low flow management (Shrubsole, 1996). CAs have experience monitoring surface water flows, and are forming partnerships with OMOE to engage in groundwater monitoring. CAs affect water quantity management by managing reservoir releases, reviewing municipal plans, and by protecting fish habitat on behalf of Fisheries and Oceans Canada. Municipalities play a key role in water quantity management through their responsibilities for public water supply and land use planning. For instance, municipal stormwater management plans and groundwater protection areas may enhance aquifer recharge. As providers of public water supply, municipalities can influence water use behavior through pricing structures, and promotion of water conservation.

Box 4: Local agencies' roles in water quantity management

Conservation Authorities

- *Conservation Authorities Act*: outlines CA responsibilities for construction and operation of flood control structures (e.g., dams), regulation of flood plain development
- Provincial groundwater monitoring network (begins 2001), surface water monitoring
- Fisheries management agreements with DFO to implement the *Fisheries Act*
- Municipal plan review

Municipalities

- *Municipal Act*: outlines municipalities' authorities for the construction and operation of drains, dams, and flood control works
- *Public Utilities Act*: outlines municipalities' authorities for operation of water supply works
- *Planning Act*: guides municipal planning activities
- *Drainage Act*: guides municipal construction, operation, and maintenance of drainage systems
- *Emergency Plans Act*: requires municipalities to develop an emergency plan for providing basic services during an emergency caused by the forces of nature, an accident, or an intentional act

Both public interest groups and individual members of a community's general public can affect the way water quantity is managed (Box 5). Public interest groups may monitor the characteristics of water bodies (e.g., angling and environmental groups), and act as watchdogs by notifying CAs or municipalities when concerns develop. Private individuals and businesses have the ability to impact water management through their own water use habits, and their influence over local decision-making. For instance, some industrial users reuse and recycle water supplies, while local residents may take steps to reduce domestic and lawn and garden water use.

Box 5: The role of the public in water quantity management

Interest groups

- A variety of public interest groups, including industry and commodity groups, and environmental and social groups, play a role in water quantity management. For instance, angling organizations may monitor water temperatures and fish populations, while environmental groups may inform the public about water conservation. Interest groups also have the ability to influence decisions made by their members, by other groups, and by government agencies.

General public

- Individual members of the public affect water quantity management through their own water use habits, their perspectives on water management, and their involvement in local decision-making.

Adaptation activities

Box 1 identified a number of possible activities for adapting to climate change-induced water shortages, while Boxes 3-5 outlined the roles and responsibilities of federal, provincial, and local agencies with respect to water quantity management. Tables 5-9, in Appendix B, summarize the activities of three organizations involved in low water management in the upper Credit River watershed: Credit Valley Conservation, the Town of Orangeville, and the Region of Peel. The tables are organized to capture the full range of activities listed in Box 1. Empty cells in a table indicate that the activities in question are not being pursued. The following subsections provide a summary and overview of adaptation activities.

Credit Valley Conservation

Credit Valley Conservation has played strong roles in water quantity-related data management, planning, and public information in the upper Credit River watershed. Key activities have included watershed and subwatershed planning, managing Orangeville Reservoir levels, surface water monitoring, publicizing local water allocation concerns, and soliciting water users' input (Worte, 2001, Pers. Comm.). Future endeavors include the development of a formal water budget for the watershed, a water quality strategy, and

groundwater monitoring (Worte, 2001, Pers. Comm.). CVC hopes that the water budget will provide "An understanding [of] the relationship or balance between recharge and discharge within the watershed and how alteration of this balance in the future, through a change of land use or *climatic changes*, would affect the water budget" (Credit Valley Conservation NDb, 1; emphasis added).

Town of Orangeville

The Town of Orangeville has undertaken a number of activities to respond to low water conditions, and to balance ecosystem water needs against human water uses. For instance, in order to prevent development from outpacing water supply, the Town employs a Holding Bylaw to delay development until additional water supplies are secured. The Town also participates in, and provides financial support for, CVC's watershed and subwatershed planning efforts.

Despite never having been severely affected by low water conditions, the Town issued voluntary water restrictions to its residents, and reduced water pressure to part of the Town, in order to ensure adequate water supplies during the dry summer of 1999 (*Orangeville Citizen*, 1999a). Additional demand management measures include a lawn and garden watering bylaw, official plan policies supporting the principle of water conservation, and metering of non-residential water users and new residential users.

In order to manage water supplies, the Town has put a freeze on approvals for new residential developments until additional water supplies are developed. A Class Environmental Assessment is underway to locate new water sources for the Town of Orangeville. In order to minimize the impact of municipal water takings on surface water systems, the Town has modified seasonal well pumping rates and supplements water flows into Monk Pond (on Mill Creek) to offset reduced groundwater upwellings (Tupling, 2001, Pers. Comm.). The quality of Orangeville's water supply is protected through a Wellhead Protection Program.

As conditions on its PTTWs, the Town monitors surface flows and groundwater levels, and modifies well pumping rates seasonally in order to minimize the impact of municipal water takings on surface water systems and fish habitat. The Town of Orangeville promotes public awareness of water conservation through distributing literature and water saving kits to the general public, and by soliciting public involvement during a water efficiency study.

Town of Caledon, Region of Peel

Official plan policies are used by the Town of Caledon and the Region of Peel to ensure adequate water supplies and to protect ecological water needs. For instance, the Town of Caledon contributes to the protection of surface water systems and fish habitat through official plan policies outlining Core Fishery Resource Areas, where new development is prohibited. Additionally, the Town requires applicants to prove access to adequate private water supplies prior to approving permits for construction in agricultural and rural areas. The Region of Peel has official plan and strategic plan policies in support of watershed management, and provides financial support for CVC's studies.

The Region of Peel owns and operates public water supplies for the villages of Alton and Caledon in the Town of Caledon. During the drought of the late 1980s, the Region issued a call for voluntary water use restrictions for the Town of Caledon

(Schiller, 2001, Pers. Comm.). More recently, the Region issued voluntary water use restrictions for the City of Bolton (in the Humber River watershed, east of the study area) in 1999 (Schiller, 2001, Pers. Comm.). Other demand management measures include a lawn and garden watering bylaw, official plan policies to promote water conservation and develop a water efficiency strategy, and volumetric water pricing for all metered water users. The Region has engaged a variety of supply management tools in order to ensure adequate water supplies for rural communities on public water supply, and for rural residents with private wells. For instance, Peel has connected the water supply systems for the villages of Caledon and Mono Mills, and is pursuing the development of another well to supply the combined system (Schiller, 2001, Pers. Comm.). The Region banned water haulers from filling from the City of Bolton's groundwater supplies in 1999, and constructed a water filling station at Snelgrove to provide better access to water for the agricultural community in southwest Town of Caledon which has experienced water shortages (Schiller, 2001, Pers. Comm.). Water supply quality is protected under a Wellhead Protection Area Program.

In addition to groundwater quality and quantity monitoring, Peel has conducted a number of studies to gather information to aid in water quantity management, such as a water efficiency study, a groundwater quantification study and flow model, and a water supply interconnection study. In order to inform the public about water conservation, the Region distributes literature and water conservation kits, and hosts an annual Children's Groundwater Festival (Schiller, 2001, Pers. Comm.). Public input regarding water management was solicited at a workshop for PTTW holders organized in partnership with the Region of Halton and CVC in 1999. Also, the Region has received input regarding water and environmental issues from the Caledon Environmental Advisory Committee, and an advisory group associated with the Caledon Community Resources Study, a study devoted to managing aggregate resources in the Town of Caledon.

Interest groups

In addition to its agreement with the federal Department of Fisheries and Oceans to protect fish habitat, CVC works with local non-governmental organizations to protect and rehabilitate fish habitat. For example, CVC has joined together with the Greg Clark Chapter of Trout Unlimited Canada in a 3-year project to rehabilitate streams in the Upper Credit (Ewaschuk *et al*., 2000; Warrian, 2001, Pers. Comm.). The focus of the first field season of the project (2000) was the Sauriol property in the upper watershed (North of highway 24). Activities intended to create brook trout habitat and lower water temperatures include tree transplantation, channel clearing, and creation of sediment traps, springs and riffle structures (Ewaschuk *et al*., 2000). Other local interest groups, such as the Izaak Walton Fly Fishers' Club, the Coalition of Concerned Citizens of Caledon, and agricultural and other industry groups, have expressed concerns regarding the quality and quantity of water in the Credit River watershed (Kuehnbaum, 2001, Pers. Comm.; Thompson, 2001, Pers. Comm.).

Individual members of the public also take action in order to adapt to low water levels and to balance human and ecological water needs. For instance, local agricultural and nursery producers may install cisterns, haul in water, drill new wells, switch to conservation tillage practices, use more efficient irrigation technologies, complete Environmental Farm Plans, plant riparian vegetation, create wetlands, or pasture cattle in

areas where water is more plentiful (Dickison, 2001, Pers. Comm.; Lyons, 2001, Pers. Comm.; Thompson, 2001, Pers. Comm.). Anglers fish less during low water periods, and when air temperatures are high, in order to minimize the stress on fish (Kuehnbaum, 2001, Pers. Comm.; Warrian, 2001, Pers. Comm.; Whiting, 2001, Pers. Comm.).

Commitment and support

The provincial government has shown support for local water quantity management in the upper Credit River watershed primarily through three programs: the Provincial Water Protection Fund, the provincial groundwater monitoring network, and *Ontario Water Response 2000*. The Fund provides financial assistance to municipalities for water and sewage infrastructure, and for studies aimed at protecting and conserving groundwater resources (Ontario Ministry of the Environment, 1998). The objectives of the funding for groundwater-related projects are to:

- promote innovative groundwater management strategies and action to protect groundwater resources
- encourage municipalities to undertake an assessment of water resources and to develop protection measures to manage municipal groundwater supplies for drinking water and other water uses
- assist the municipality in analysing the cost effectiveness of implementing groundwater management measures which protect the resources and reduce or defer municipal capital water and sewage infrastructure costs (Ontario Ministry of the Environment 1998, 3).

The Provincial Water Protection Fund, administered by the OMOE, has allocated over $3.5 million in funding to 34 municipal groundwater management studies in Ontario (Ontario Ministry of the Environment, 2000). Municipalities, public utilities commissions, and local service boards were eligible to apply for funding under the program (Ontario Ministry of the Environment, 1998). In the upper Credit River watershed, studies are being funded in the towns of Mono, Erin, and Orangeville, and the townships of East Garafraxa and Amaranth. The total amount of the grants allocated to upper Credit River municipalities is $382,763 (Ontario Ministry of the Environment, 2000). Funding for eligible projects is allocated using a “sliding scale” based on the population of the municipality (Ontario Ministry of the Environment, 1998). “Where the municipal population is 1,000 or less, 90 per cent of the study cost will be funded. Assistance declines to 10 per cent of study costs for municipalities with populations of 100,000 or more” (Ontario Ministry of the Environment 1998, 2). For example, the Town of Erin, with a population of about 10,700, received funding amounting to 74% of its project’s cost, while the Town of Orangeville, population 22,629, received only 26% (Ontario Ministry of the Environment, 2000). This sliding scale may favour rural communities over urban communities.

The provincial groundwater monitoring network was announced on May 8, 2000, at a joint meeting of the Ontario Water Works Association and the Ontario Municipal Water Association. At the meeting, the Minister of the Environment announced that MOE will be devoting $6 million dollars over three years to the establishment of a groundwater monitoring network (Ontario Ministry of the Environment, 2000). The Minister stated that the network will be a partnership between the OMOE and

conservation authorities, and between the OMOE and municipalities where CAs are not established (Ontario Ministry of the Environment, 2000). CVC will be involved in a pilot groundwater monitoring program during the summer of 2001 (Worte, 2001, Pers. Comm.).

Ontario Water Response 2000 is a drought response plan developed by OMNR, in partnership with OMOE, OMAFRA, the Ontario Ministry of Municipal Affairs and Housing, the Ontario Ministry of Economic Development and Trade, the Association of Municipalities of Ontario, and conservation authorities (Ontario Ministry of Natural Resources *et al*., 2000). The plan relies heavily on the establishment of local water response teams, composed of representatives from conservation authorities, watershed municipalities, agriculture, rural private industry and business, recreation, public interest groups, First Nations, and provincial ministries (Ontario Ministry of Natural Resources *et al*., 2000). The tasks of the water response teams are to

- Identify local water supply needs and concerns
- Identify severity of low water crisis
- Implement water conservation, preservation and allocation strategies
- Evaluate effectiveness of local actions
- Provide advice to local and provincial decision-makers (Ontario Ministry of Natural Resources *et al*., 2000).

While the plan's emphasis on local decision-making is appropriate, it presumes that all watershed communities, including rural communities, have the capability to undertake the above-mentioned tasks, and that representatives from all sectors are able to communicate about, select, and implement water conservation tools and approaches. This may or may not be an appropriate assumption, depending on circumstances in the watershed.

The development of the response plan indicates that provincial ministries acknowledge the challenges faced by local communities during periods of water shortages. While the involvement of representatives from conservation authorities and municipalities in the development of the document, and the plan's reliance on watershed-based local water response teams, indicates that senior government is aware that local level agencies will bear the brunt of low water level management, concerns exist regarding the ability of local agencies to carry out the assigned tasks of the water response teams. In its official review of the *Ontario Water Response*, CVC addressed concerns that the plan is reactive, focusing on the formation of local response teams only after low water levels became problematic, and isolates drought response from the larger picture of water management (Worte, 2000, Pers. Comm.). During key informant interviews, CVC staff also expressed concerns that the only response tool local agencies have the authority to implement is a call for voluntary water use restrictions. Despite the plan's focus on local response, the OMOE remains the only agency with the authority to regulate actual water withdrawals (Worte, 2001, Pers. Comm.).

Provincial ministry representatives have often served on the steering committees of CVC watershed and subwatershed studies (e.g., Credit Valley Conservation, 1997). However, an OMNR staff member stated that provincial representatives are often not

available to be involved in local planning as they have been in the past, due to budget cuts in the mid-1990s (Imhof, 2001, Pers. Comm.).

4.3 Nature of the watershed community

Perceptions and awareness

Stakeholder perceptions and awareness regarding climate change, impacts on human and ecological systems, and local drought management, all affect a community's capacity to adapt to climate change-induced hydrologic variability. In an effort to raise public awareness regarding low water level concerns in the watershed, CVC launched a media blitz in the summer of 1999. CVC's *Water Report*, detailing water supply and demand issues in the watershed, received press coverage from local and provincial media (Barron, ND; *Orangeville Citizen*, 1999b; Calleja, 1999; Stewart, 1999; Tallyn, 1999). The CA produced press releases calling for a review of the Permit to Take Water Program, and a moratorium on the issuance of permits in the Credit River watershed (Credit Valley Conservation, 1999b; Credit Valley Conservation, 1999c).

In order to solicit feedback from local water users, CVC, in partnership with the regions of Peel and Halton, held a workshop for PTTW holders in the Credit River watershed in October of 1999. Of the 14 PTTW holders that completed a survey, 3 indicated that they had experienced water quantity problems (Credit Valley Conservation *et al*., 1999). As part of the closing discussion at the workshop, the issue of unknown future conditions due to climate change was brought up (Credit Valley Conservation, 1999a). Water quantity concerns outlined by permit holders included recent low water conditions, increased consumption of water, the lack of a water budget and groundwater data, and concerns about priorities for water use and means for ensuring future water supply (Credit Valley Conservation, 1999a). Issues relating to balancing human and ecological management goals, in particular as they pertain to development, gravel extraction, and water management, were highlighted (Credit Valley Conservation, 1999a). When asked about the OMOE's PTTW program, 4 of 14 permit holders thought that there was a problem with the program (e.g., no metering, no enforcement, slow administration), and all thought that there should be a monitoring and enforcement component to the program (Credit Valley Conservation, 1999a). The workshop revealed concern and some awareness on the part of local stakeholders of conflict between human and ecological water use, and the possibility of climate change affecting local hydrological conditions.

When asked "who should be responsible for ensuring that water taking does not deplete the available water in the watershed", respondents mentioned a variety of scenarios, but CVC and OMOE were mentioned most often, 4 and 3 times, respectively (Credit Valley Conservation, 1999a). These results indicate strong preference for both local involvement and senior government involvement in water allocation.

Nineteen local water managers and users participated in a workshop, held in April 2001, by the Rural Water Management Group, as part of this research project. From a list of local drought management activities similar to Tables 5-9, in Appendix B, watershed participants identified planning activities as being the most effective at reducing human vs. human, and human vs. environment water-related conflict. Particularly popular were

watershed and subwatershed planning, municipal official plans and policies, and natural resource stewardship planning. Habitat restoration, monitoring, and enhanced public involvement in studies and decision making, also received strong support.

Workshop participants were asked to assign a number of generic water management activities among local stakeholder groups, to build a scenario for local drought response. Two strong themes that emerged from the groups' discussions were that contributions to each function should be made by many stakeholder groups, and that the appropriate roles for a given stakeholder group (e.g., conservation authority) should vary according to local conditions and resources. For instance, all stakeholder groups could be involved in monitoring, with each group responsible for collecting data at a different scale. Local agencies, CAs and municipalities in particular, were assigned a broad range of tasks, from monitoring, to regulation and public information.

Participants identified a number of capacity-related needs for three water quantity-related management activities: watershed planning, development controls, and water use metering/pricing by volume. Capacity-related needs that were common to each activity were the need to clarify the roles and responsibilities of all key players in water management, to raise public awareness regarding water supply issues, to have public input in decision-making, and to have adequate human, financial, and information resources to support implementation. For a more complete summary of the workshop findings, consult *Adapting to Low Water Levels in the Upper Credit River Watershed – Workshop Summary*.

Communication and coordination

Sharing of information and coordination of activities among all local stakeholders and water managers in the upper Credit will improve the community's capacity to adapt to climate change-induced low water levels. Both municipalities and CVC have made efforts to share data and coordinate water management activities. For instance, local municipalities contributed to the development of CVC's subwatershed studies for subwatersheds 15, 16/18, and 19 (Aquafor Beech Limited *et al*., 1997; Credit Valley Conservation, 1997; Credit Valley Conservation *et al*., 1997). CVC also communicates with municipalities through plan review. The conservation authority is formally linked to municipalities by its board of directors, which is composed of municipal appointees. Communication between CVC, municipalities, and local water users from a variety of economic sectors, was initiated by the workshop described above (Credit Valley Conservation, 1999a). CVC also serves as the first point of contact for many local public interest groups concerned about water levels (e.g., Trout Unlimited, etc.) (Kuehnbaum, 2001, Pers. Comm.; Warrian, 2001, Pers. Comm.). At present, the authority has not formed a standing committee to address low water issues (as outlined in the *Ontario Water Response 2000*) (Worte, 2001, Pers. Comm.).

Cooperation and data sharing with other agencies has been a component of a number of studies initiated by local municipalities. For instance, the Town of Orangeville intends to work closely with, and share data with, adjacent municipalities throughout its groundwater management study (Town of Orangeville Public Works Department, 2000b). In developing aggregate resource management policies, the Town of Caledon and Region of Peel retained consultants who cooperated with CVC, taking preliminary

findings from its subwatershed 16/18 study into consideration (Planning & Engineering Initiatives Ltd. *et al*., 1999).

In the same spirit of cooperation, the Region of Peel is leading the Peel Children's Water Festival in 2001, in partnership with area municipalities, CVC, local school boards, and Environment Canada (Region of Peel, 2001a). Other community outreach activities include open houses, school presentations, representation at fairs, and presentations to local groups (Region of Peel, 2000d). The Region of Peel also maintains an Internet site with a "current collection of more than 2,000 documents [which] are accessed approximately 40,000 times per month" (Region of Peel 2000d, 8). In fact, with respect to water management, and especially water taking permits, the Region has an official plan policy to coordinate with other municipalities, OMOE, conservation authorities, and other relevant agencies (Regional Municipality of Peel, 1998).

Public involvement

Public involvement in water management decision making and implementation of activities will help to ensure compliance with adaptation activities. Public participation in local water management occurs primarily through representation on steering committees of water-related studies. For instance, the steering committee for the Town of Orangeville's groundwater resource and contamination assessment studies is to include representatives from the town council, OMOE, CVC, neighboring municipalities, the commercial/business sector, the agricultural sector, public interest groups, and the general public (Town of Orangeville Public Works Department, 2000b). As part of the studies, two public information sessions will be held, and information will be distributed to the general public through presentations and booths in public areas (Town of Orangeville Public Works Department, 2000b). In 1996, the Town of Caledon and Region of Peel retained consultants to conduct a study to develop an aggregate resource management strategy (Planning & Engineering Initiatives Ltd. *et al*., 1999). As part of the study, an ongoing Community Advisory Group was established, composed of representatives from the public, as well as aggregate producers, the Aggregate Producers' Association of Ontario, local businesses, the Ministry of Municipal Affairs and Housing, and local government (Planning & Engineering Initiatives Ltd. *et al*., 1999). There have been public information and involvement components to CVC's subwatershed studies, water management plan, and fisheries management plan (Credit Valley Conservation, 1997; Credit Valley Conservation *et al*., 1997; Credit Valley Conservation, 2000c; Dickison, 2001, Pers. Comm.; Whiting, 2001, Pers. Comm.; Worte, 2001, Pers. Comm.). In addition to involvement in CVC and municipal studies, members of the general public participate in low water level management through involvement with local interest groups, such as Trout Unlimited and Izaak Walton Fly Fishing Club, and the Coalition of Concerned Citizens of Caledon (Thompson, 2001, Pers. Comm.; Whiting, 2001, Pers. Comm.).

4.4 Community resources

A community's resources affect its ability to adapt to water shortages. In order to successfully respond to low water levels, a community needs secure financial resources,

adequate and appropriately trained staff, and accessible, high quality data on which to base decision-making.

Financial, human, and information resources

The upper Credit River watershed is a relatively affluent area of Ontario. Average total incomes of persons employed in 1996 in the towns of Orangeville and Caledon, and the former Township of Erin and Village of Erin, are well above provincial averages (Table 3).

Table 3: Average total income of persons reporting income in 1996 in upper Credit River municipalities

Location	Average total income ($)
Ontario	27,309
Town of Orangeville	27,424
Town of Caledon	34,652
Township of Erin	34,646
Village of Erin	30,243

Sources: Statistics Canada, 2001a; 2001b; 2001c; 2001d.

Table 4 gives a snapshot of municipal financial resources for the year 1994. The range of total expenditures reflects the large differences in population in the municipalities. The absolute amount of money devoted to planning and environmental services is significant, in particular for the Region of Peel and Town of Orangeville. It is from these programs that a wide variety of studies and projects have been funded. As an example, in the past five years, the Town of Orangeville has commissioned:

- a Water Efficiency Study, funded by a $90,000 allocation in 1997 (Town of Orangeville Public Works Department, 2000b), estimated to cost $640,101 to implement between 1998 and 2015 (REIC Consulting Ltd. *et al*., 1998),
- a Phase 1 Class Environmental Assessment report to develop new water sources (Town of Orangeville Public Works Department, 2000b),
- a Groundwater Management Plan, funded initially by a $100,000 allocation approved in 1997 (Town of Orangeville Public Works Department, 2000b), and
- a Groundwater Resource and Contamination Assessment Study, estimated to cost $200,000, 25.97% of which will be funded by the Provincial Water Protection Fund (Town of Orangeville Public Works Department, 2000b).

Table 4: Revenues and expenditures of upper Credit River municipalities (1994) data

Measure	Town of Orangeville	Region of Peel	Township of Erin and Village of Erin
Revenue			
Total revenue	$14,345,000	$498,967,000	$3,978,000
Proportion from property taxes	64%	59.5%	53.6%
Proportion from Ontario grants	12%	35.5%	17.8%
Expenditures			
Total expenditures	$14,379,000	$500,364,000	$3,969,000
Proportion for general administration	14.9%	5.0%	20%
Proportion for planning	3.2%	0.6%	2%
Proportion for environmental services[1]	26.5%	26.7%	15.8%
Proportion for other expenditures[2]	55.4%	67.7%	62%

Notes: 1) includes water supply, wastewater treatment, and solid waste collection, 2) includes policing, transportation, health and social services, and recreation.
Source: Ontario Ministry of Municipal Affairs and Housing, 1996.

In 2000, the Region of Peel budgeted $800,000 for pumping station expansions, $100,000 for water quality and conservation studies, $15,000 for a groundwater monitoring program, and $150,000 for CVC's water monitoring program, as well as additional funds for CVC's subwatershed studies and water quality strategy (Region of Peel, 2000a). In order to address water supply concerns, the Region of Peel undertook a study to determine the feasibility of interconnecting municipal water systems in the Town of Caledon (Region of Peel, 1997).

CVC ranks among the more affluent conservation authorities with 1999 revenues of $3,241,965, 68% of which was generated by municipal levies (KPMG LLP Chartered Accountants, 2000). Despite the relative affluence of CVC, engaging in future drought management activities may place a strain on its financial resources. For example, OMOE will provide funding to instrument monitoring wells and to pay for two years worth of water quality monitoring under the new provincial groundwater monitoring network (Warbick, 2001, Pers. Comm.). However, OMOE will not provide funding for installation of monitoring wells, well maintenance, and staff time to collect and manage monitoring data (Warbick, 2001, Pers. Comm.). These additional costs will be the responsibility of local conservation authorities and their member municipalities.

In order to manage water resources in times of drought, local agencies need access to staff with training in hydrology and hydrogeology. The Region of Peel has a consultant on retainer in order to address hydrologic and hydrogeologic concerns, but is considering hiring a full-time hydrologist (Schiller, 2001, Pers. Comm.). The Town of Orangeville has typically hired consultants to conduct water-related studies (Tupling, 2001, Pers. Comm.). CVC has a hydrogeologist, and a water resources engineer on staff (Worte, 2001, Pers. Comm.).

Good quality, accessible data is a requirement for decision-making. There are a number of information resources that may be available to local agencies in Ontario, including the PTTW database (OMOE), well water records (OMOE), local hydrological or hydrogeological studies, and monitoring records (conservation authorities, municipalities, OMOE). The Region of Peel, for instance, conducts its own groundwater monitoring, and has access to CVC's surface water monitoring data (Schiller, 2001, Pers. Comm.). In addition, Peel has incomplete copies of OMOE's PTTW and well water record databases (Schiller, 2001, Pers. Comm.). The Town of Orangeville's monitoring regime involves collection of groundwater and surface water data, in accordance with conditions on their PTTWs (Tupling, 2001, Pers. Comm.). Orangeville has fairly comprehensive groundwater level data back to about 1985 (Tupling, 2001, Pers. Comm.). At present, Credit Valley Conservation has access to fairly comprehensive hydrological and hydrogeological studies covering most of the upper Credit River watershed, current versions of OMOE's PTTW and well water record databases, and municipal monitoring data (Worte, 2001, Pers. Comm.). During an interview, a CVC official stated that the authority needed more water temperature data to manage fishery resources (Morris, 2001, Pers. Comm.). CVC has also initiated a water budget study for the express purpose of gathering more information for water quantity management (Worte, 2001, Pers. Comm.). CVC staff also receive anecdotal information regarding water levels and impacts on natural and human systems from direct contact with members of the general public (e.g., telephone calls, concerns, complaints) (Worte, 2001, Pers. Comm.). Access to data by local agencies may improve in the future, as a result of the development of OMNR's Land Information Ontario initiative to integrate existing land and water data (Warbick, 2001, Pers. Comm.).

4.5 Summary

Rural communities in the upper Credit River watershed face challenges in balancing human uses of water with ecosystem protection. Development pressures, coupled with existing hydrologic variability, and possible complications resulting from increased variability due to climate change, combine to create a high potential for water-related conflicts among stakeholders. Concerns specific to subwatersheds 16/18 and 19 relate to the impacts of residential development and aggregate mining on wetlands, stream baseflows, and cold-water aquatic communities. Recent drought conditions during 1998 and 1999 have exacerbated the already delicate balance between human and ecological water needs.

In order to address conflict between human and ecological water needs during times of low water levels, the local conservation authority, CVC, and its municipal partners have engaged in a variety of planning, demand and supply management, data

management, and public involvement activities (Tables 5-9, in Appendix B). CVC has focused on water-related monitoring and research, planning activities, and providing information to, and soliciting input from, the public regarding low water levels in the watershed. Most recently, the conservation authority is developing a formal water budget for the watershed in order to provide necessary background information for water allocation decisions. The towns of Orangeville and Caledon, and the Region of Peel, make use of low water level management tools from every major category listed in Box 1. In addition to official plan policies relating to water conservation, and involvement in CVC's watershed and subwatershed planning initiatives, local municipalities have made particular use of demand, supply, and data management tools and activities. Local approaches to managing limited water supplies include modifying well pumping rates to minimize impacts on aquatic communities (Town of Orangeville), supplementing natural flows (Town of Orangeville), banning water suppliers from groundwater-based systems (Region of Peel), and interconnecting rural water supplies across watershed boundaries (Region of Peel). Notably, no local agency has explicitly addressed its vulnerability to climate change and identified response options. Furthermore, neither CVC, nor any of the local municipalities, have developed a drought contingency plan, either on its own, or in response to the OMNR's *Ontario Water Response*.

A number of factors have facilitated the upper Credit River community's response to low water levels. Perhaps chief among the factors is the relative affluence of the rural communities in the upper Credit River area. As much of the Credit River watershed is urban, and many of its rural communities serve as "bedroom communities" to the City of Toronto, the local conservation authority and municipalities have significant financial, human, and technical resources available to them. For instance, public water supplies for the rural northwestern portion of the Town of Caledon are the responsibility of the Region of Peel, which draws a portion of its income from the large urban populations of Brampton and Mississauga. CVC is among the ten highest revenue-generating CAs, and is one of the few authorities with a hydrogeologist on staff. In this fashion, the upper Credit River communities are perhaps not representative of rural Ontario communities as a whole.

Furthermore, the Region of Peel and CVC's workshop for watershed PTTW holders demonstrated that area water users are by-and-large aware of, and concerned about, the impacts of human water uses on ecological systems. This cognizance about water quantity issues on the part of water users may lead to greater support for proactive low water level management. The involvement of a number of public interest groups, such as Trout Unlimited, the Izaak Walton Fly Fishers' Club, and the Peel Federation of Agriculture, also strengthens the community's ability to respond to water shortages and conflict with ecological systems. These groups can play important roles in distributing information to, and guiding the actions of, their members.

However, a number of factors also constrain the ability of local agencies to manage low water levels and to balance human and ecological water needs. While the release of the *Ontario Water Response* demonstrates some commitment to local drought management on the part of the provincial government, concerns exist regarding communities' capacity to carry out the assigned tasks of the water response teams. Significantly, conservation authorities and municipalities have little influence over water

allocation in their watersheds. While, in some cases, the OMOE may circulate PTTW applications to local agencies for comment, neither CAs, nor municipalities, have the authority to curtail water withdrawals by large private water users during low flows, or when withdrawals are impacting natural systems. Furthermore, in the absence of formal water budget research, neither the OMOE, nor local agencies, have the necessary data to determine whether the Credit River and its tributaries are presently over- or under-allocated, or to assess the impacts of water takings on ecological systems. While the Provincial Water Protection Fund may assist some rural Ontario communities to engage in some basic water research and planning, little in the way of financial and technical support for actual low water level management by local agencies appears to be forthcoming. Moreover, the division of drought management from flood management and water quality management results in complex and changing responsibilities for water management among local and provincial agencies.

5.0 Capacity building

Rural communities in the upper Credit River watershed have responded to low water levels, and conflict between competing uses of water, in a number of ways. Key tools have included subwatershed planning, modifying water takings to minimize environmental impacts, interconnecting rural water supply systems, and managing temporary water suppliers (e.g., water hauling). Each of these activities can be characterized by many of the attributes of successful adaptation responses presented in Table 1 (Section 2.0). For instance, subwatershed planning is anticipatory and responsive, in that it provides useful information and structure for current and future water and land use planning, and aims to identify and integrate a variety of community goals and objectives (i.e., human and ecological goals). Modifying well pumping rates to protect aquatic habitat is flexible and responsive, because it seeks to balance both human and environmental water needs, under a variety of current, and possible future, hydrologic conditions. Interconnecting water supply systems across watershed boundaries is anticipatory and flexible, as it helps to ensure provision of domestic and other water supplies under variable hydrologic conditions. Finally, managing the activities of water haulers is flexible because it reduces the likelihood of insufficient water supplies, now and in the future, due to low water conditions or increased development. These activities can be considered “no regrets” because they have been justified under existing pressures of hydrologic variability and development, without explicit consideration of future climatic conditions, and because they do not limit future adaptation. Each of these activities has garnered sufficient political, financial, technical, and community support, as to make them “implementable” within the Credit River watershed.

These adaptation tools and activities, those found in Box 1, and those identified at the workshop, are potentially applicable to rural communities across Canada. However, different adaptation measures will be appropriate for different rural communities, in accordance with local problems, concerns, values, and resources. For successful implementation, each measure will require specific human, financial, and technical resources. However, some lessons can be drawn from the upper Credit River case study

for application to rural communities in other areas of Ontario and Canada, regardless of the specific approach adopted by the community.

An important part of developing and enhancing local capacity for water management and planning is the identification of human activities and ecological functions that are dependent on water and sensitive to variations in its availability. Beyond this it is important to understand the interconnectedness of human and environmental systems. Thus, there is a requirement for accurate environmental information. Research can and should play a role in satisfying this need.

Effective water management depends, in part, on clearly and comprehensively defined roles and responsibilities. While the function of a given type of agency (e.g., CA, or municipality) may vary from location to location, according to local conditions and capacities, each individual organization must be aware of its role, and the roles of others, in water management. Furthermore, water management is enhanced by networking among the various agencies involved in water management in a watershed. While the Water Response Teams suggested by the province's *Ontario Water Response* are a step towards coordination of activities, networking is required in advance of crisis situations, and is required for flood and water quality management, as well as for drought management.

The capacity building literature, key informant interviews, and workshop discussions, all highlighted the importance of the involvement of public interest groups in local water management. Non-governmental organizations can serve to educate and involve members of the public, or industry, in water conservation and management. Furthermore, they may act as an additional source of financial resources and technical expertise available to the community. Some groups may perform specific tasks, such as monitoring, on a formal, or informal, basis. In the upper Credit River watershed, one of the activities most favoured for reducing water-related conflict is habitat restoration (e.g., riparian plantings), a project most actively pursued by local non-governmental organizations (e.g., Trout Unlimited, Izaak Walton Fly Fishers' Club).

The tools and activities of adaptation presented in Box 1 are already available to many rural communities across Canada. In other words, the legal authority to undertake many of these activities is in place. In order to improve local drought management and adaptation to future climatic variability, rural communities need encouragement to apply existing tools and approaches to better adapt to present and future climatic conditions. In order to adapt, communities need information on both existing and probable future hydrologic conditions. Reliance on data based on historical patterns of hydrologic variability constrains water managers' capacity to choose adaptation options appropriate for dealing with conditions resulting from climatic change (Lauermann, 1985; Riebsame, 1988; Burton, 1996; Frederick, 1997; de Loë and Kreutzwiser, 2000).

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Appendix A

Interview Questions

General questions

When was the last water shortage in the subwatershed?
Was the problem due to insufficient supply, or insufficient water distribution capacity?
How were human water needs affected?
How were ecological systems affected?
What was done to respond to the shortage?
What has been done to prepare for future water shortages?
What would be done in the event of another water shortage?

Technical activities

Has the organization (or another in the subwatershed) engaged in the following activities?

- Watershed management
- Monitoring and data management: hydrological/hydrogeological studies, data on water levels, water use, water demand, present and future conditions (forecasting for future population growth), influence of water withdrawals on natural systems, etc.
- Contingency/emergency response planning: e.g., drought contingency plans, studies of responses (adaptations) to water shortages, long term water supply plans, responses to water contamination
- Supply management: rules for operating existing infrastructure (esp. during low flows), plans for new infrastructure, interbasin transfers, water allocation, groundwater-surface water integration, lawn watering by-laws, etc.
- Demand management: voluntary and mandatory water conservation, metering, pricing, standards, education, leak repairs
- Pollution control programs: point and non-point sources

Capacity-related questions

What organizations play a role in water quantity management in the watershed?
Who does what?
Responsibilities/jurisdictions (human vs. ecological water needs)?

How has [any organization] demonstrated its commitment to balancing human and ecological water needs in the subwatershed?

What [federal/provincial/municipal] policies or legislation/by-laws exist to deal with water shortages, and balancing human and ecological water needs?

Do you believe that climate change is likely to result in more frequent and severe droughts in the subwatershed?
Do you believe that the impacts of climate change on water levels are a short-term (<10 years) or long-term (>10 years) problem?
Should the amount of water allocated for human uses be subject to modification in order to protect ecological water uses?
Who is most responsible for balancing human and ecological water needs in the subwatershed?
Who should be most responsible?

What sort of existing information do you have relating to water quantity management, drought, or human/ecological water use conflicts?
How confident are you in the quality of the data?
Where do you go for information relating to water quantity management, drought, or human/ecological water use conflicts?
Where would you go?
Who have you shared this type of information with?
Who do you coordinate your activities with?

Who plays a coordinating role in water quantity management/drought management in the subwatershed?
Who plays a leadership role in water quantity management/drought management in the subwatershed?

Who tries to educate and inform the public about water quantity management in the subwatershed?
How do they do this?
Who tries to involve the public in water quantity management in the subwatershed?
How do they do this?

Are financial statements/budget documents available? (1999)
How much is spent on water quantity management?
Where does the money come from?
Any special projects?

Number of staff in “water department”?
Number of staff in “planning department”?
Any staff with expertise in water quantity management, drought, water needs of ecological systems?
What are their credentials?

Appendix B

Table 5: Planning activities for adapting to low water levels in the upper Credit River watershed

Adaptation activity	Credit Valley Conservation	Town of Orangeville	Region of Peel and Town of Caledon
Long term planning incorporating the possibility of climate change	• Water budget development[1,2]		
Assess vulnerability to climate change			
Inventory adaptation options			
Managing development and growth	• Review of development plans for impacts on fish habitat[3]	• Official Plan policies[4] • Holding Bylaw to delay development until additional water sources are secured[5]	• Region of Peel Official Plan policies[6] • Core Fishery Resource Area policies in Town of Caledon Official Plan[7] • Town of Caledon Official Plan policies to protect stream baseflow[7] • Town of Caledon Official Plan policy requiring proven private water supplies in agricultural areas/rural areas before issuance of a building permit[7]
Watershed planning and management	• Water Management Strategy for the entire Credit River watershed[8,9] • Studies of subwatersheds 15, 16, 18, and 19 completed or underway[10,11,12,13,14,15]	• Involvement in subwatershed 19 study[10] • Official Plan policies in support of watershed management principles[4] • Financial support for CVC studies	• Region of Peel Official Plan and Strategic Plan policies in support of watershed management principles[6,16] • Financial support for CVC studies
Drought contingency planning			

Table 6: Demand management activities for adapting to low water levels in the upper Credit River watershed

Adaptation activities	Credit Valley Conservation	Town of Orangeville	Region of Peel
Voluntary/mandatory water conservation		• Voluntary water use restrictions issued for summer 1999[17] • Lawn and garden watering Bylaw (#22-99)[18] • Official Plan policy to promote water conservation[4]	• Voluntary water use restrictions issued for Town of Caledon in late 1980s[19] • Voluntary water use restrictions issued for Bolton in summer 1999[19,20] • Bylaw restricting water used in fountains, garden hoses, sprinklers, air conditioners[21] • Official Plan policies to promote water conservation & to develop water efficiency strategy to reduce per capita water consumption by 10-15% over 20 years[6]
Water use metering		• Non-residential water users on public water supply are metered[22] • Metering required for new residential developments[22] • Water meter testing program[5]	• Some residential users metered and pay by volume, some flat rate[23]
Pricing structures			• Constant block charge of $0.39 per m^3 of water for residential, institutional, industrial, commercial water users[23]
Water conservation standards			

Table 7: Supply management activities for adapting to low water levels in the upper Credit River watershed

Adaptation activities	Credit Valley Conservation	Town of Orangeville	Region of Peel
Changing operations protocols to increase efficiency	• Adjusted release volumes from Orangeville reservoir in summer of 1999 to meet sewage dilution objectives[24]	• Modifies well pumping rates to minimize impacts on fish habitat[5] • Supplements water flow to Monk Pond[5] • Reduced water pressure in summer 1999[17] • Official Plan policy to operate wells to protect groundwater and surface water quality and quantity[4] • Official Plan stormwater management policy[4]	• Banned water haulers from filling from groundwater-based public water supplies in Bolton[19] • Interconnected water supplies of villages of Caledon and Mono Mills[19,25]
Interbasin transfers			• Interconnected water supplies of villages of Caledon (Credit River watershed) and Mono Mills (Humber River watershed)[19,25]
Managing water allocation		• Required review of development applications requiring > 10 $m^3 day^{-1}$ as of 1998[5] • Present freeze on residential development until new supplies connected to system (use of Holding Bylaw)[5]	• Town of Caledon Official Plan policies recommending ecosystem approach and consideration of cumulative effects for new water takings[26]

Table 7: Continued

Adaptation activities	Credit Valley Conservation	Town of Orangeville	Region of Peel
Development of new or modification of existing infrastructure and water sources		• Class Environmental Assessment to develop new water sources[5] • Official Plan policy to replace undersized water supply pipes[4]	• Construction of Snelgrove water filling station for water haulers[19] • Interconnecting water supplies of villages of Caledon and Mono Mills[19,25] • New well for villages of Caledon and Mono Mills in near future[19]
Conflict resolution			
Artificial recharge of groundwater			
Conjunctive surface water-groundwater use			
Leak detection and repair			
Pollution control programs	• Developing a water quality strategy[27]	• Wellhead Protection Program[5] • Contamination assessment and prevention study[5] • Participation in provincial Drinking Water Surveillance Program	• Wellhead Protection Area Program[28,29,30] • Official Plan policy to develop groundwater protection strategy[6]

Table 8: Data management activities for adapting to low water levels in the upper Credit River watershed

Adaptation activities	Credit Valley Conservation	Town of Orangeville	Region of Peel
Existing and new data collection	• Surface, groundwater, fisheries, benthic monitoring[24,27]	• Groundwater quality and quantity monitoring[5] • Monitoring of well pumping impacts required by conditions on PTTWs[5]	• Groundwater quality and quantity monitoring[19]
Forecasting future demand and supply		• Has forecast water demand to 2031[17]	
Research		• Water efficiency study[22] • Groundwater Management Plan[5] • Groundwater Resource and Contamination Assessment Study[5] • Class EA for development of new water supplies[5] • Official Plan policy requiring hydrogeological studies for development permits[4]	• Water efficiency study[19] • Groundwater quantification study and flow model[28,29] • Water supply interconnection feasibility study[25] • Town of Caledon Official Plan policy requiring hydrogeological studies for development permits[7]

Table 9: Public information activities for adapting to low water levels in the upper Credit River watershed

Adaptation activities	Credit Valley Conservation	Town of Orangeville	Region of Peel
Development of literature and information/education initiatives for the general public and other water users	• 1999 media blitz calling attention to low water levels, and provincial Permit to Take Water Program[31,32] • Workshop for PTTW holders (1999) in partnership with regions of Peel and Halton[33,34]	• Water Care program promoting water efficient landscaping and lawn care (distribution of their own and others' literature)[35,36] • Distribution of water saving kits including low flow shower heads and faucet aerators[22] • Quarterly waterworks reports available[37] • Public awareness components in water efficiency study and groundwater resource and contamination assessment study	• Distribution of water conservation kits, news releases & pamphlets[38,39] • Children's Groundwater Festival[40] • Children's Water Awareness Week[40] • Public works staff presentations[41] • Community Advisory Group for Caledon Community Resources Study[42] • Caledon Environmental Advisory Committee[43] • Workshop for PTTW holders (1999) in partnership with CVC and Region of Halton[33]

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