Climate Change Adaption: Ontario's Resilient Greenbelt

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Introduction

1.1 Research Question

This report examines the potential impacts, both positive and negative, of climate change on the long-term viability of the Greenbelt and proposes a suite of measures to adapt to these changes. The main focus is on climate change impacts on the Greenbelt Plan's main areas of concern: natural heritage, agriculture, recreation, and infrastructure. This report does not address climate change mitigation; the Friends of the Greenbelt Foundation has commissioned a separate report on that topic.

While there is a great deal of uncertainty about the exact nature and extent of future climate change, there appears to be a consensus in terms of the direction in which the climate is changing in Southern Ontario: longer summers with more major storms and droughts and warmer, shorter winters with greater levels of snowfall. Research conducted over the last decade suggests that natural systems in Southern Ontario – including water resources, habitat and wildlife – will be subject to significant climate change impacts. Climate change is also expected to have an impact on human activities, including agriculture and recreation. The natural and human systems impacted by climate change are highly complex and their interaction with climate remains poorly understood. Some changes in climate might be abrupt while others might be incremental; the consequential effects on natural and human systems are likely to be non-linear.

Despite the consensus that the climate is changing and that impacts, some potentially very serious, are likely to occur in the long-term, neither the Growth Plan nor the Greenbelt Plan explicitly addresses climate change. Together, these plans work to shield natural heritage, agriculture, and recreational opportunities in the Greenbelt from impacts related to the ongoing urbanization of the GGH. Yet, urbanization is not the only potential threat to these systems; policy directions on how to enhance the adaptive capacity of these systems in order to retain their valued qualities in the face of a changing climate should be provided, especially within the Greenbelt Plan. Policies are required to guide the implementation of adaptation measures that seek to minimize threats to the viability of natural and human systems in the Greenbelt due to climate change, but also to make the most of any positive impacts that may occur.

1.2 Methodology

This report combines research from primary and secondary sources, relying more heavily on the latter. In terms of primary sources, a number of interviews were conducted with academics, climate scientists, and other individuals with expertise on climate change, its various impacts, and adaptation activities. In terms of secondary sources, from which the bulk of the information present below was obtained, a variety of academic research papers and scientific and policy reports commissioned by the federal and provincial ministries of natural resources as well as other government department and non-governmental agencies were consulted.

1.3 Overview

The report first describes the currently accepted predictions for climate changes in the GGH. Second, the report examines impacts on the natural environment, infrastructure, agriculture, and recreational activities in the Greenbelt. This is followed by a brief discussion of the Greenbelt's role in helping the GGH adapt to climate change. The report then reviews current adaptation activities relevant to the Greenbelt and concludes with recommendations for further adaptation initiatives.

2

Expected Climate Changes in the Greenbelt

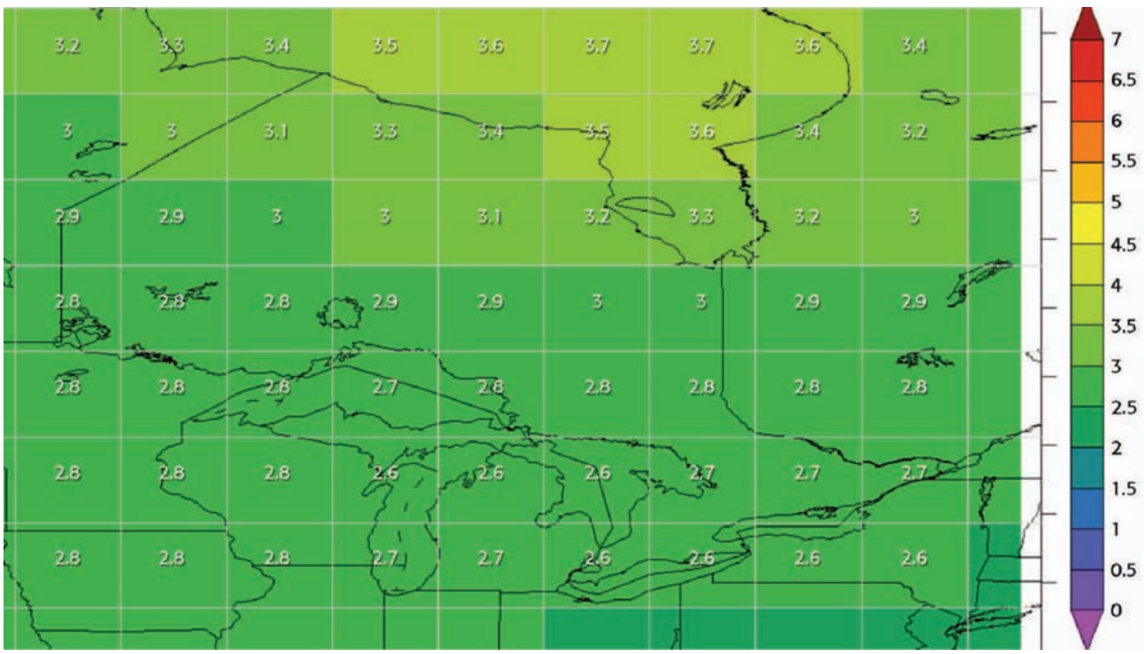
Climate changes in the GGH, as for any other region in the world, are fraught with uncertainty. There are numerous, competing climate models that produce divergent climate predictions. Predictions made by any one model can also vary, depending on the assumptions made concerning future atmospheric concentrations of CO_2 and other greenhouses gasses. In the face of this uncertainty, planning and policymaking for climate change is challenging.

As a basis for discussion in this report, we rely on recent projections adopted by the Ontario Expert Panel on Climate Change Adaptation (EPCCA). In a report to the Ontario Minister of the Environment, the EPCCA (2009) provided climate projections for mid-century (2040-2070) Ontario that were derived from models developed by 24 international climate modeling centres. Environment Canada scientists combined the 24 projections to generate a single set of projections for Ontario. This is known as an "ensemble approach" and is believed to provide more reliable projections of seasonal temperature and precipitation than any single climate model (EPCCA, 2009).

2.1 Temperature

Using "middle-of-the road" assumptions regarding GHG emission rates between now and the middle of the century,[1] the ensemble model predicts an average annual temperature increase of about 2.7°C in the GGH in 2050s compared to the 1961-1990 period (Figure 1). The average temperature increase is predicted to be slightly greater in the winter (~3.0°C) than in the summer (~2.5°C). Even with the smaller increase, the number of very hot summer days, with temperatures exceeding 30°C, could double by mid century (Hengeveld and Whitewood, 2005).

Figure 1. Projected increase in average annual temperature (°C) in 2050 compared to 1961-1990 under moderate GHG emissions scenario



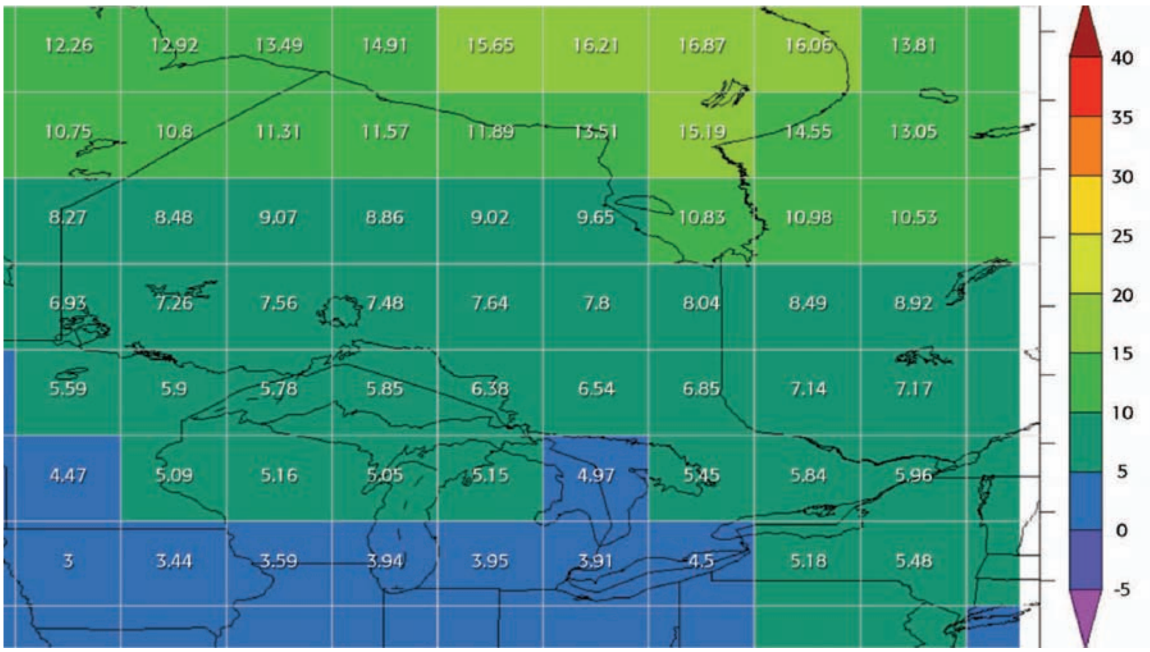
Source: EPCCA, 2009

2.2 Precipitation

Again using "middle-of-the road" assumptions regarding future GHG emissions, the ensemble model predicts an average annual increase in precipitation of about 5% for the GGH, compared to the 1961-1990 period (Figure 2). The changes will be especially significant during winter, with average winter precipitation rates rising between 9% and 11% in the GGH. Average summer precipitation rates are expected to remain at current levels.

1 This assumes that GHG emissions will continue to evolve according to present trends—i.e., there will be neither a rise nor a sharp decline in emissions.

Figure 2. Projected percent change in average annual precipitation in 2050 compared to 1961-1990 under moderate GHG emissions



Source: EPCCA, 2009

It is noted in the EPCCA report that these projections are made on the basis of global models that do not factor in certain geographic features that can influence local climates, such as large inland bodies of water. Therefore the ensemble model's predictions ignore the well-documented "lake effect"—the distinctive temperature and precipitation patterns affecting areas surrounding the Great Lakes, including the GGH. The EPCCA report suggests that increased evaporation from the Great Lakes due to rising temperatures is likely to increase lake-effect summer and winter precipitation above the levels predicted by the ensemble model, as reported above. Researchers who have studied the Great Lakes region in more detail believe that lake-effect snow is likely to increase in the short to medium term (Kunkel et al., 2002; Burnett et al., 2003). By mid-century, they predict that winter lake temperatures will rise and allow for more evaporation while air temperatures will still be cool enough to produce snow. However, snowfall may decrease and possibly be replaced by heavy lake-effect rainfall later in the century.

Aside from overall changes in seasonal precipitation rates, the frequency and intensity of individual precipitation events is set to change. Extreme rainfall events are predicted to become more frequent and more intense (Hengeveld and Whitewood, 2005; NRCan, 2006). Data collected over recent years have not yet shown an increase in the frequency of extreme events in Ontario. However, such increases have been observed elsewhere and the EPCAA expects that they will eventually be observed in Ontario as well (EPCCA, 2009).

3

Impacts of Climate Change on the Greenbelt

3.1 Water

Changes in temperature, precipitation rates as well as the frequency of precipitation events are expected to have significant impacts on hydrological systems throughout the Great Lakes Basin, including the Greenbelt. The expected impacts are summarized in Table 1. The following sections provide details on the expected impacts on surface and groundwater resources, runoff and flooding, and ice and snow cover.

3.1.1 Surface and Groundwater

Shorter periods of ice cover, warmer summers, and stronger winds can conspire to increase evaporation and are predicted to result in falling surface water levels. It is likely that small rivers and streams flowing into and out of smaller lakes could dry up for weeks at a time during the summer (EPCCA, 2009). Lower surface water levels entail impacts on riparian and shore areas, as described in Section 3.2.2 below.

Table 1. Potential climate change impacts on water resources in the Great Lakes basin

Parameter	Projected Change
runoff	• decreased annual runoff, but increased winter runoff • earlier and lower spring freshet (the flow resulting from melting snow and ice) • lower summer and fall low flows • longer duration low flow periods • increased frequency of high flows due to extreme precipitation events
lake levels	• lower net basin supplies and declining levels due to increased evaporation and timing of precipitation • increased frequency of low water levels
groundwater recharge	• decreased groundwater recharge, with shallow aquifers being especially sensitive
groundwater discharge	• changes in amount and timing of baseflow to streams, lakes and wetlands
ice cover	• ice cover season reduced, or eliminated completely
snow cover	• reduced snow cover (depth, areas, and duration)
water temperature	• increased water temperatures in surface water bodies
soil moisture	• soil moisture may increase by as much as 80 percent during winter in the basin, but decrease by as much as 30 percent in the summer and fall

Source: Adapted from de Loë and Berg (2006)

Warmer summer temperatures are liable to lead to increases in water temperatures in lakes, especially in near-shore areas. Rising near-shore temperature have been documented around the Great Lakes since the 1920s. A number of researchers have found that the increases are most pronounced in the spring and fall and are positively correlated with increases in mean air temperature (Chiotti and Lavender, 2009). In lakes, warmer water temperatures in the spring and in the fall will extend the period during which lakes stratify into a warm upper layer and a cool lower layer. Oxygen in the cooler lower layer may be depleted before the mixing of layers occurs when water temperatures drop in the fall. Low oxygen levels can be fatal to aquatic wildlife that dwells in deeper water. The impacts of changing water temperatures on aquatic flora and fauna are described in further detail in Sections 3.2.2 and 3.3.1 respectively.

Summers with less frequent showers between major storms will result in longer continuously dry periods. This would lead to more reliance on irrigation agriculture at the expense of rain fed agriculture, adding to farm costs and increasing demand for irrigation water, perhaps most significantly in watersheds where the water is already fully allocated and ecological needs already sacrificed.

Combined with increased evaporation due to higher temperatures, longer dry periods could reduce the amount of water that infiltrates from the surface into groundwater aquifers, especially during the summer. In winter, this could be at least partly offset by increased infiltration, as the period during which the ground is frozen and impermeable could become shorter. Still, the net effect could be lower water tables toward the end of the summer. With lower tables, discharge to streams and rivers could be reduced, exacerbating the fall of surface water levels (EPCCA, 2009).

Lower water tables will affect communities and ecosystems in the Greenbelt that rely on groundwater resources. Seasonal water shortages resulting from extended periods of drought (and exacerbated by increased demand due to population growth) have already been documented across the GGH, including in Waterloo Region, Wellington County, Dufferin County and Peel Region, especially Caledon (de Loë et al., 2001; Ivey, 2001). Chiotti and Lavender (2008) point out that many of the areas identified by the Ontario Ministry of Natural Resources as susceptible to water shortages are within the Greenbelt. Lower surface water levels and groundwater tables have implications for water infrastructure, as described in Section 3.6.2.

3.1.2 Runoff and Flooding

If the ensemble climate predictions presented in Section 2 are accurate, it is likely that summer and fall runoff will decrease while spring runoff may increase. Summer and fall runoff is set to decline due to higher evaporation rates related to hotter weather, although rates of precipitation are to remain roughly the same. It is likely that summers will feature longer dry periods with low runoff and low soil moisture. Spring runoff on the other hand could increase as more winter snow and more spring rain are expected by mid-century (EPCCA, 2009).

While summer runoff is likely to decline, the risk of summer flooding could nevertheless increase. Both the frequency and intensity of major summer rain events are set to increase. In the GGH, recent trends suggest that the frequency of summer flood events is increasing. For example, York Region and Niagara Region have reported increases in basement and other types of localized flooding in recent years (Brûlé and McCormick, 2005). Between 1988 and 2008, there were eight heavy rainfall events resulting in flooding in the GGH, all of which were considered to have return periods greater than 25 years (D'Andrea, 2005). The most severe of these occurred on July 15th, 2004 in Peterborough and on August 19th, 2005 in Toronto. These floods caused extensive damage to infrastructure and properties, with insured losses estimated at $95 million and $500 million, respectively (Chiotti and Lavender, 2008).

Increased spring runoff could translate to an increased risk of spring flooding. Already, the majority of flood emergencies in Southern Ontario occur between January and May (Chiotti and Lavender, 2008). Most of these floods were the result of rain-on-snow conditions, during which little of the rainwater is absorbed into the soil and instead swells surface water bodies. However, some scientists suggest that more frequent winter thaws and an earlier spring freshet may actually reduce the risk of spring flooding (Hengeveld and Whitewood, 2005).

In the Greenbelt, the risk of flooding is lower than in the heavily urbanized portions of the GGH as there are fewer impermeable surfaces and more opportunities for natural retention and absorption of stormwater. Nevertheless, if flooding were to occur, it could cause damage to infrastructure, shoreline and riparian ecosystems, and low-lying agricultural lands.

3.1.3 Ice and Snow Cover

Warmer, shorter winters are predicted by mid-century, meaning that periods of ice and snow cover will be shorter and the thickness of both is likely to be reduced. In the Greenbelt, this has various important implications for natural heritage, agriculture, and recreational activities. For natural heritage, reduced ice cover is likely to result in greater loss of water through evaporation and more rapid shoreline erosion during winter storms. More evaporation can translate to more lake-effect snowfall in the GGH and other areas in the Great Lakes Basin (Mortsch et al., 2006) (see Section 3.2). For agriculture, a shorter period of snow cover could mean a longer growing season, potentially allowing for the planting of less hardy species (see Section 3.4). For recreation, a shorter period of snow cover means a shorter season for snow sports, such as snowshoeing and cross-country skiing. Thinner ice cover means that opportunities for safe ice fishing will be more limited and the season will be shorter. On the flipside, the season for summer aquatic sports may become longer (see Section 3.5).

3.2 Natural Features

3.2.1 Wetlands

According to Chiotti and Lavender (2008), wetlands are particularly sensitive to changes in the environment, including climate. Wetlands in Southern Ontario are already under stress due to urban development and excessive nutrient loading. Wetlands may not have sufficient resiliency to maintain their ecological integrity under the added stress of climate change (Easterling et al., 2004) and associated changes in conditions that may favour exotic invasive species over indigenous ones. Longer summers and warmer winters will most likely result in lower water levels and warmer water temperatures in the Great Lakes Basin, despite slightly higher annual precipitation rates. Further reductions in Great Lakes water levels as a result of climate change are likely to modify or destroy wetlands that presently maintain shoreline integrity and help prevent erosion, filter waterborne contaminants, absorb excess storm water, and provide habitat for fish, birds, and other wildlife (Mortsch, 1998; Branfireum et al., 1999; Devito et al., 1999; Mortsch et al., 2000; Lemmen and Warren, 2004). Though decomposition rates should increase with warmer temperatures, the combination of fluctuating water levels with warmer temperatures is likely to reduce the capacity of wetlands to assimilate nutrients and human and agricultural wastes (UCS and ESA, 2003).

3.2.2 Riparian and Shore Areas

Climate change is likely to affect riparian and shore areas through lower summer water levels, higher water temperatures, and increased runoff and flooding during extreme precipitation events.

Lower summer water levels will result in the isolation and fragmentation of riparian and lake shore wetland complexes. This will reduce the extent of riparian and near-lakeshore habitat. Falling water levels, particularly in rivers and streams, are also likely to disrupt migration corridors. Fish and amphibian reproductive cycles will most likely fail more often as a result of more frequent droughts (UCS and ESA, 2003).

Retreating shorelines will have impacts on near-shore infrastructure such as marinas, boat launches, and docks. While installations of this type are designed to tolerate some variation in water levels, extreme drops in water levels could in the best case render them temporarily useless until water levels return to the tolerated range. In the worst case, low water levels could damage boating installations and wet docked vessels. Either way, this would entail impacts on water-based recreational activities in the Greenbelt (see Section 3.5). Falling water levels can also have impacts on water infrastructure, specifically on near-shore water intakes. These impacts are described in Section 3.6.2.

Warmer water temperatures may have some benefits in terms of decomposition and nutrient cycling in streams. Microbes are likely to break down human and agricultural wastes faster, fueling the primary productivity of riparian areas. However, other climate change impacts may mitigate the extent of this benefit. In particular, during drought periods, low water flow may result in oxygen depletion, which will slow down rates of decomposition and reduce the waste processing capacity of riparian wetlands (UCS and ESA, 2003). Also, warmer waters can be more likely to host diseases (e.g. botulism) and be intolerable for cold-water species.

Increased runoff and flooding as a result of more frequent heavy rainfall events will cause lakeshore and riparian wetlands to periodically increase in extent. On one hand, this will enlarge the habitat for aquatic species. On the other hand, it may have adverse impacts on terrestrial species that reside in the same areas. In particular, ground-nesting birds are likely to be affected. Increased water flows in streams and rivers after major rainfall events will likely increase erosion in riparian areas. Increased volumes of runoff may also load more pollutants into lakes and other watercourses, with adverse effects on flora and fauna as well as on human users.

3.2.3 Forests

Forest ecosystems are sensitive to climate change. Not only are the growth and species composition of trees likely to be affected, other less conspicuous components of the ecosystem, such as micro-fauna, soil fungi, and bacteria will also be impinged.

Climate change can affect the duration of the tree growing season, when and how much photosynthesis and respiration can take place, and the availability of soil moisture—all of which are factors that can affect forest growth rates. As for species composition, climate affects the survival of existing trees in mature stands and their ability to reproduce. Flowering and seed production as well as the survival of germinated seedlings are sensitive to temperature and moisture (Colombo, 2008).

Climate change is likely to stress existing, mature trees. Prolonged periods of drought and more frequent flooding, both of which are predicted for the GGH, are important stressors for trees. As stressed trees are more susceptible to insect infestations and diseases, outbreaks of both are likely to become more frequent and more severe. Populations of certain micro-fauna, especially insects, may increase as a result of warmer winter weather and result in harmful infestations. In the past, cold winter weather has prevented certain insects from establishing themselves in Ontario. With warmer winters, insects that are currently established south of the Great Lakes may move in to wreak havoc on forests in Southern Ontario (Colombo, 2008), potentially including the Greenbelt.

According to an interviewed scientist at the Ontario Forest Research Institute, a likely consequence of climate change is periods of widespread forest dieback in the Greenbelt. More severe droughts but also more frequent flooding is likely to periodically weaken Greenbelt forests. Insects and disease, encouraged by overall warmer weather, may spread rapidly among the weakened trees and potentially lead to widespread tree deaths. Although the regeneration that occurs after dieback can provide an opportunity for new tree species to take hold, it is unlikely that this would occur in the Greenbelt. The forests of the Greenbelt are dominated by long-lived hardwood tree species whose seeds tend not to travel far. As the forest regenerates, even after a severe dieback, it will most likely be repopulated by the same tree species as before the dieback. The overall composition of the ecosystem is likely to remain stable.

Prolonged periods of summer drought will also increase the risk of forest fires. However, given the amount of infrastructure in the Greenbelt and the proximity to major population centres, fire response is very rapid and forest fires, though potentially more frequent, are likely to be contained quickly. Forest fires will be an issue of greater concern in Northern Ontario.

3.3 Fauna

3.3.1 Habitat and Migration Corridors

The habitats and migration corridors most liable to be impacted by climate change include wetlands, near-shore or shallow areas of lakes and rivers, and lakeshore and riparian areas—i.e., areas that will be directly affected by extreme fluctuations in water levels. On one hand, more frequent and severe flooding will affect vegetation and negatively impact near shore and riparian terrestrial habitats. Floods may also fragment terrestrial migration corridors. On the other hand, more frequent droughts will affect shallow water vegetation and impact near shore areas of lake habitat and shallow streams and river habitat. Low water levels during extended periods of drought may cause small streams to dry up and wetland areas to fragment, resulting in disruptions to aquatic migration corridors.

Climate change may also have longer-term impacts on the migration of species, both desirable and undesirable. Species and species communities are already moving and will likely continue to move gradually over time. Species such opossums, deer ticks, and armyworms, for example, whose ranges previously ended south of the Great Lakes, have gradually been shifting northward into Southern Ontario.

3.3.2 Terrestrial Wildlife

Terrestrial fauna, from tiny microfauna in the soil all the way up to large herbivores and predators, are liable to be affected by climate change in various ways. Factors that can affect terrestrial communities in the Greenbelt include: changes to habitat and migration corridors, as described in Section 3.3.1; tolerance, or lack thereof, for new climatic conditions; changes in populations of existing species and arrival of new species; and changes in the timing of ecological processes.

Changes in climatic conditions may promote the survival of some species while diminishing that of others due to varying abilities to tolerate related environmental changes. For example, milder winter temperatures may facilitate the survival of certain insect species and other microfauna that do not tolerate extreme cold, as is proving to be the case with deer ticks. Some species, such as moose, may have difficulty tolerating hotter summer temperatures, leading to their extirpation from the Greenbelt. The survival of certain insects and micorofauna may be affected by their tolerance for reduced soil moisture due to more frequent droughts, or excessive soil moisture after extreme precipitation events.

The viability of established species may be indirectly affected by climate change via changes in the population of other established species. Changes in the viability of one species due to intolerance to the new climatic parameters may affect all other interdependent species, regardless of their tolerances for the new conditions. The effect could be positive or negative, depending on whether the population of the first species increases or decreases and on what kind of relationship it has with related species. A decrease in the population of a prey may adversely impact the population of predators, while an increase in the population of prey could have the opposite effect. Conversely, increase in the number of predators could adversely impact the numbers of the prey, while a decrease in the number of predators could benefit the prey species. The arrival of new species is likely to upset the balance even more than changes in the populations of established species: the existing species may not be adapted to preying on or being preyed on by the new arrival. Because of interdependences between species, changes in the population of any species can ripple across the entire ecosystem.

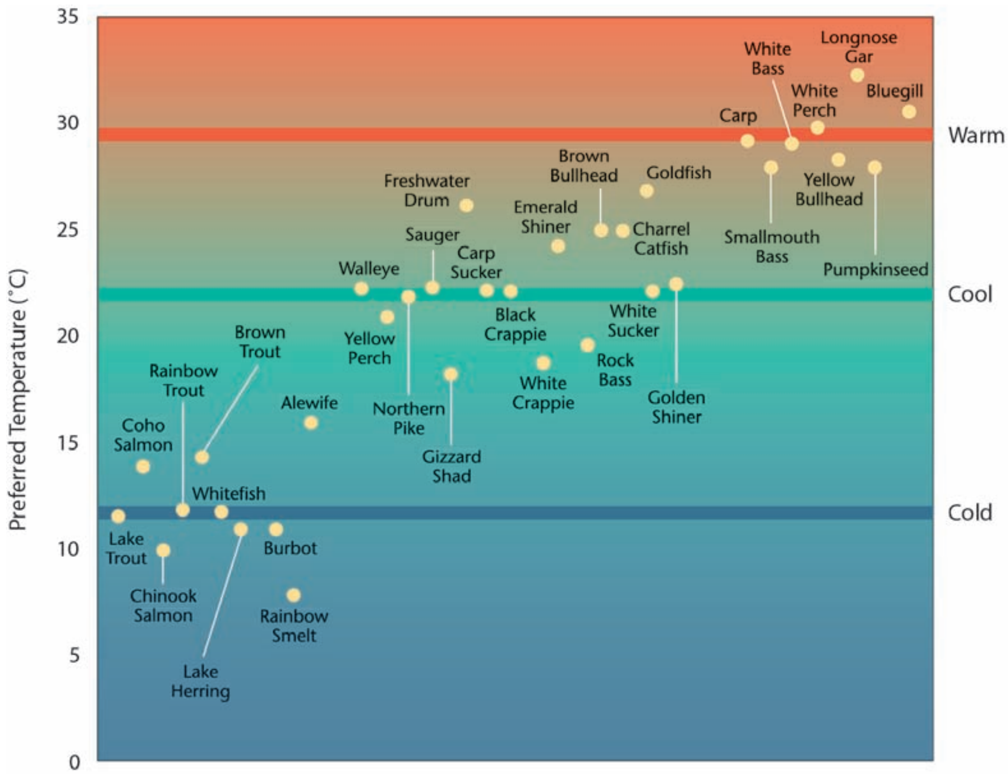
Some established species could also be affected by changes in the timing of various ecological processes that are crucial to their existence. For example, climate change may alter the timing of the blossoming of certain flowers and the emergence of the pollinator insects upon which they depend. If the two fall out of sync, the plant and insect populations may suffer as a result. Another example is the synchronization of the arrival of migratory bird species with the reproduction of certain insect species upon which the birds prey. If the insects emerge and reproduce earlier than before due to an earlier spring, the large numbers of larvae that the birds eat could die off before the birds arrive (Varrin et al., 2007).

3.3.3 Aquatic Wildlife

In wetlands, the ability of bird and fish communities to respond to climate change is likely to vary considerably across species. Mortsch et al. (2006) modeled the effects of different climate change scenarios on coastal wetland wildlife in the Great Lakes. Under all of the climate change scenarios, the abundance of species that nest in marshes decreased while the abundance of species that nest in trees and shrubs increased, largely due to destruction of marsh habitats linked to lower water levels. Not only does the average water level affect wetland wildlife, but so does the timing of annual cyclical changes in water levels. The models indicated that certain bird and fish species may be more affected by potential changes in the timing, duration, and depth of flooding of near-shore areas. Bird species that nest over water and fish species that require flooded vegetation for reproduction and the nursing of juveniles are likely to be the most vulnerable.

In lakes and rivers, increasing water temperatures will have impacts on the composition of fish communities, with the potential to affect both commercial and recreational fisheries in Great Lakes Basin (Chiotti and Lavender, 2008; UCS and ESA, 2003). The Great Lakes basin has a diversity of fish communities, with species that have differential preferences in terms of water temperature. The further warming of water bodies in the Great Lakes Basin will favour warm-water fish (thriving at 25°C and up) and negatively affect cool-water (thriving at 15-25°C) and cold-water species (thriving below 15°C) (see Figure 3). Such a shift has already been documented in Lake Ontario's Bay of Quinte. Certain warm-water species, such as bigmouth buffalo and flathead catfish, are already being seen more frequently in the Great Lakes basin (Chiotti and Lavender, 2008).

Figure 3. Temperature groupings of common fish



Source: UCS and ESA (2003)

Aside from higher water temperatures, climate change is also expected to increase the occurrence of "dead-zones" in lakes—pockets of oxygen-depleted water. Dead-zones occur when the water in a lake becomes stratified, with a warm layer on top and a colder one at the bottom. Lakes normally become stratified during the summer but mix in the early spring and late fall, when surface water temperatures equalize with the deeper water temperatures. If warmer temperatures come earlier in the spring and cooler temperatures arrive later in the fall, the period between spring and fall mixing is extended and the risk that the lower strata of water will be depleted of oxygen and unable to sustain life is increased. Certain cold water species may be extirpated from lakes where depletion of oxygen in the lower strata creates dead zones by the late summer or early fall. One species that is likely to be susceptible to this problem is lake trout, which inhabits the lower layers of lakes in the summer to avoid the warmer surface waters.

Amphibians are also likely to be affected by climate change. In particular, recent observations show that warmer spring temperature can allow certain species to emerge from hibernation (Gibbs and Breisch 2001) and breed earlier (Blaustein et al. 2001). Early reproduction can provide offspring with more time to grow before hibernating in the winter but is not necessarily beneficial for the parents (Carey and Alexander, 2003). Still, for some species, earlier reproduction may translate to greater reproductive success, in which case the population will increase and the species range may expand.

3.4 Agriculture

3.4.1 Growing Conditions

The relationship between climate and agriculture is complex. There is a range of climate parameters that influence crop and livestock production, including maximum and minimum temperatures, growing degree days, length of growing season, amount and timing of rainfall, extreme weather events, drought, snow cover and frost periods (Chiotti and Lavender, 2008). Climate change impacts agriculture directly and indirectly by altering these parameters. Shifts in climatic parameters affect the growth of certain crops and livestock species due their innate tolerance or intolerance for changes in temperature, solar exposure, moisture and so on. In some cases, the new climatic conditions may promote growth, while in other cases they may act as stressors and inhibit growth.

In terms of less direct impacts, climate change can affect the timing of the complex ecological processes upon which agriculture depends. For example, where crops are concerned, climate change can affect the coordination of soil moisture levels with germination schedules and the coordination of flowering with the presence of pollinators. Climate change can also interact other ecological factors that affect agriculture, such as the viability of various pests, invasive species, weeds and diseases (see Section 3.8.4). Climate change also interacts with air pollution, which is related to the occurrence of acid rain and smog. Both are known to affect crops, and the latter can affect livestock much in the same way that it affects humans (see Section 3.8.2).

Based on the expected average temperature increases, which will extend the growing season, climate changes in Southern Ontario is expected by some researchers to be beneficial for the production of many crops, including corn, sorghum, soybeans, maize and some forage crops, and could lead to a northward extension of crops not currently grown in the region (Chiotti and Lavender, 2008; Singh et al., 1998). Fruit production, an important agricultural activity in the Greenbelt, could also benefit from a longer growing season and seasonal heat accumulation in the soil, allowing for a longer frost-free period (Winkler et al., 2002), but would also be vulnerable to more extreme weather events.

A milder winter and longer, warmer growing season are not necessarily advantageous for all crops. One type of crop that might be negatively impacted is grapes used for the production of ice wine on the Niagara Peninsula. The production of ice wine depends crucially on the timing and frequency of cold spells in the fall and early winter, which could be affected by climate change. Some other over-wintering perennial crops could be negatively impacted by reduced snow cover in the winter. A certain amount of snow cover can act as insulation, protecting plants from injury during extreme cold temperatures (Chiotti and Lavender, 2008).

Overall, despite the apparent benefit of a longer growing season on average, agriculture in the Greenbelt and elsewhere in Southern Ontario is likely to remain vulnerable to year-to-year climatic variability and extreme climatic events, such as more frequent and severe heat waves; more frequent and severe summer droughts; and more frequent extreme precipitation events (C-CIARN Agriculture, 2002). Farmers are generally more concerned with more extreme weather variability within and across years than they are with changes in average temperatures and precipitation rates (Bryant et al., 2002). The increased frequency and severity of droughts is one of the greatest concerns for agriculture as it could increase windblown soil loss, make rain-fed farming less profitable, lower water tables and perhaps eliminate well-water sources.

Where livestock production is concerned, there is a potential for negative climate-related impacts due to environmental stress and animal diseases. Research shows that increases in heat stress can reduce weight gains in beef cattle and lower milk production in dairy cattle. Poultry production can also be affected through lower conception rates and lower egg production rates. Climate change can affect the spread of animal diseases by creating more favourable conditions for disease vectors, such as mosquitoes and ticks. Milder winters could help parasites living in and on animals survive, though they might reduce the occurrence of common ailments such as pneumonia.

3.4.2 Food Security

According to several interviewees, climate change is likely to have mostly beneficial effects on the food production in the Greenbelt and in Southern Ontario as a whole. Therefore, climate change is unlikely to disrupt agricultural markets and food systems directly in the GGH. However, some researchers believe that climate change impacts on food production elsewhere in the world and disruptions to global distribution systems are likely to occur and will affect agricultural markets and food systems in the GGH. In the event that long-distance food supply chains are compromised due to climate change and other factors, such as increased energy and transportation costs, the GGH may be forced to rely more fully on its own, local food production systems.

3.5 Recreation and Tourism

Climate change entails a mix of positive and negative impacts on recreation and tourism in the Greenbelt. Overall, warmer weather and longer snow- and ice-free periods are expected to lengthen the season for most warm-weather, outdoor recreational activities, such as camping, boating, and fishing. Conversely, the season for the main cold weather activities, such as skiing and ice fishing, is likely to become shorter. As a result, participation in warm weather recreational activities is predicted to grow while participation in cold weather activities is expected to decline (Browne and Hunt, 2007).

3.5.1 Boating

While the later onset of cold weather in the fall and earlier onset of warm weather in the spring should be beneficial for warm weather activities, climate change may nevertheless entail some negative impacts. In particular, water-based recreational activities are liable to be affected by lower water levels in lakes and rivers in the Greenbelt, as it has been the case elsewhere (Thorp and Stone, 2000). Retreating shorelines are likely to damage or reduce the utility of near-shore installations, such as marinas and docks, which are essential to boating and other water-based activities.

3.5.2 Fishing

Fishing in the Greenbelt is likely to be affected by both falling water levels and rising water temperatures. Falling water levels are likely to affect near-shore infrastructure used by anglers and may limit boat access to certain fishing areas. Lower water levels may also destroy fish habitat, displacing fish to other areas and affecting species composition of the lakes and rivers in the Greenbelt. As noted in Section 3.3.2, the composition of fish communities will also be affected by changing water temperatures. The relative share of warm-water species is likely to increase while that of moderate- and cold-water species will decline. Cold-water species prized by anglers, such as lake trout, may become more difficult to catch. Meanwhile, invasive warm-water species such as goby and Asian carp, neither of which is attractive to anglers, may spread through the Greenbelt, to the detriment of established species that are desirable to anglers. These threats to recreational fishing imply an important challenge for future fisheries management in the Greenbelt.

3.5.3 Skiing

Skiing in the Greenbelt is likely to be negatively affected by the decreased duration of snow cover. Not only is the average duration of snow cover set to decrease, but the quality of snow cover may be compromised by more variable winter weather, including more frequent winter thaws that could thin the snow cover despite higher overall winter precipitation levels. Under more pessimistic climate change projections, which assume that GHG emissions will continue to be produced at present rates, the current 94-day average cross-country ski season in southern Ontario could be completely wiped out by 2050, as the required snowpack might be prevented from forming (David Suzuki Foundation, 2009). Even if climate change is less severe, the duration of the ski season can still be expected to decline considerably.

3.5.4 Ice Fishing

Like the ski season, the duration of the ice-fishing season is set to decline. Warmer winters are expected to shorten the period during which ice cover on lakes and rivers is sufficient to allow ice fishing to be safely practiced. If atmospheric CO_2 levels double, the ice fishing season in Ontario's Lakeland (the regions immediately north and east of the Greenbelt) could be reduced by as much as half (David Suzuki Foundation, 2009).

3.6 Infrastructure

The literature on climate change impacts on infrastructure focuses overwhelmingly on two types of infrastructure: roads and water. However, some attention has been devoted to energy infrastructure, which is also vulnerable to extreme climatic events.

3.6.1 Roads

Roads are likely to be subject to more rapid temperature-related decay as the expected climatic trends unfold. An increase in the number and severity of hot days in southern Ontario will increase the formation of ruts and may cause asphalt to bleed out from older pavements.[2] Increased temperature variability in the winter, with more frequent freezes and thaws, will also cause ongoing minor damage to pavements and is likely to impact other road infrastructure, such as bridges and culverts,. Accelerated degradation of pavements at best entails a decline in ride quality for vehicles and at worst entails a decline in road safety. Road maintenance costs are likely to increase, as more frequent repairs and resurfacing will be required (Mills and Andrey, 2002). Aside from ongoing, cumulative damage due to hotter summer weather and more variable winter weather, roads will most likely be subject to more frequent and potentially more severe damage due to extreme precipitation events and subsequent flooding.

The small, predominantly rural communities in the Greenbelt are strongly dependent on roads for personal transportation as well as for the movement of goods. Deterioration and damage to roads in the Greenbelt is especially likely to affect the agricultural sector, which relies on trucking to supply materials and move its products to the market. Negative impacts on recreational activities in the Greenbelt can also be expected if accessibility to recreational areas is affected by poor road conditions.

3.6.2 Water

Climate change will affect water infrastructure in the Greenbelt primarily by causing a decline in both surface and groundwater levels. Lower surface water levels will affect near-shore water intakes whereas lower groundwater levels will affect shallower wells. The effects of climate change on water infrastructure have important implications for settlements and agricultural areas in the Greenbelt, as most of them rely on local water resources rather than water from the Great Lakes.

The increased potential for extreme precipitation events also has ramifications on water infrastructure in the Greenbelt. Precipitation events that exceed the current designed capacity of drainage infrastructure are likely to occur more often, damaging the drainage infrastructure itself and leading to floods and damage to other natural and human systems, including other types of infrastructure. Runoff not captured by drainage systems in human settlements in and around the Greenbelt may also cause erosion and carry sediments and pollutants into wetlands and watercourses, with consequences for aquatic habitats and life forms.

Climate change could also impact water infrastructure indirectly through changing water temperatures. Higher temperatures are likely to promote algal and bacterial growth, particularly in shallow water. This can affect the safety or at least the odour and taste of water supplies (Mortsch et al., 2000; Bruce et al., 2003; UCS and ESA, 2003). A further complication is lower oxygen levels, due to reduced or delayed spring and fall mixing, which can further promote microbial decomposition and subsequent release of nutrients from bottom sediments. Phosphorus release would be increased and mercury release and uptake by organisms in the

2 Most roads are paved with asphalt concrete, composed of gravel (aggregate) held together by asphalt (bitumen), a highly viscous petroleum byproduct. The viscosity of asphalt decreases when it is heated. If heated sufficiently, it can liquefy and bleed out from between the gravel in a pavement.

lake would also be likely to increase. Other contaminants, particularly some heavy metals, would be likely to respond in a similar fashion, as they tend to become more soluble in the absence of oxygen.[3] These changes in water quality could necessitate the relocation of lake water intakes and increase reliance on filtration.

There are also important implications for water infrastructure used by the agricultural sector. A reliable water supply is crucial for the viability of agriculture in the Greenbelt, for irrigation of crops and for feeding livestock. In response to more frequent and longer periods of drought expected in the future, the agricultural sector's reliance on irrigation is likely to increase. The additional demand could further lower surface water levels or groundwater tables during periods of drought. As noted in Section 3.1.1, some areas of the GGH are already known to experience periodic summer water shortages and many of the most vulnerable areas are within the Greenbelt. Stronger management of water resources in agricultural communities in the Greenbelt will be a priority for adaptation to climate change.

3.6.3 Energy

Another key type of infrastructure that could be subject to climate change impacts is energy infrastructure, specifically long-distance transmission lines and local distribution systems. The Greenbelt contains long-distance power transmission lines that are of vital importance to communities both inside and outside the Greenbelt. These, as well as local distribution networks that supply towns and farms with power, may be compromised by more frequent extreme weather events. A particular threat to power transmission systems is more frequent and severe episodes of freezing rain (Chiotti and Lavender, 2008), a likely consequence of winter temperatures oscillating more often above and below freezing temperatures. As demonstrated by the 1998 ice storm that affected Eastern Ontario and Western Quebec, the consequences of prolonged freezing rain events on power transmission infrastructure can be catastrophic. The prolonged loss of electrical power had especially devastating effect on rural farming communities in the affected regions, leading to very significant losses of livestock in particular.

3.7 Land Values

Given the wide range of climate change impacts on the Greenbelt's eco- and agro-systems, it would not be surprising to find secondary impacts on land values. For example, more extreme weather events could require municipal investment in climate-adapted infrastructure and add to the costs of infrastructure maintenance. This could raise municipal tax levels, which in turn might affect land values. More extreme weather events (e.g., snow storms) might discourage long-distance commuting and reduce land values in areas of the Greenbelt furthest from urban job centres.

Increased flooding risks may expand areas where development is constrained through planning regulations. Where those lands are already built upon there would likely be higher insurance costs (or a complete withdrawal of insurance coverage) and outlays to reinforce structures against flooding. Where the lands are in agricultural production, an increased risk of flooding may also expose farmers to economic losses. All of these factors would tend to

3 Oxygen binds with these elements to form insoluble compounds that sink to the bottom.

diminish the value of such lands.

Outside of flood-prone areas, the impact of climate change on farmland values is difficult to predict. On the one hand, a longer growing season and warmer weather could raise farm incomes and buoy up the value of farmland in the Greenbelt.[4] On the other hand, if climate change is associated with longer dry spells, it could increase windblown soil loss, make rain-fed farming less profitable, lower water tables and perhaps eliminate well-water sources. More extreme weather events could also increase erosion, stress drainage infrastructure, and disturb the water balance in sensitive areas such as the Holland Marsh. These impacts would tend to depress farmland values.

The implications of sudden or unexpected shifts in property values can be substantial. Property comprises a significant element in many personal and corporate asset bases. A sudden fall in property values can cause breaching of banking covenants and considerable financial problems for an organization. Thus, climate change could increase personal and corporate bankruptcies and affect the overall economic stability and viability of farming and other economic activity in the Greenbelt. Changes in the value of the property base could also have implications for the stability of municipal revenues and taxation levels.

3.8 Interaction with Other Environmental Stressors

One somewhat overlooked topic related to climate change impacts in Southern Ontario is the potential interaction of climate change with other environmental stressors, such as water and air pollution, acid deposition, and pests and diseases. The following subsections provide a brief overview of the types of interactions that can be expected between climate change and other key environmental disturbances.

3.8.1 Water Pollution

Falling water levels entail increased risks of water pollution. Concentrations of dissolved and particulate contaminants discharged from municipal water treatment systems and from industrial sources as well as runoff from farms could become problematic during dry periods, when the volume and flow of the receiving body of water are reduced. One of the most problematic pollutants is likely to be phosphorous, which is loaded into watersheds from a variety of human sources, especially private septic systems. Phosphorous stimulates the growth of cyanobacteria (blue-green algae) and other nuisance algae in warmer, shallow lakes and slow moving rivers, creating a hazard for animals as well as for humans (EPCCA, 2009).

3.8.2 Air Pollution

Weather conditions are known to have a complex interaction with air pollution. Concentrations of several common, smog-producing air pollutants – such as nitrogen oxides (NOx), volatile organic compounds (VOCs) and particulate matter – are sensitive to temperature. There is a tendency for more VOCs to be released from human sources, such as solvent use, fuel tanks, and

4 Using a regression model that explained differences in land values based on differences in climatic conditions, Hauer et al (undated) concluded that climate change would have a positive effect on farmland values throughout Canada.

chemical plants when temperatures are high, due to increased volatility. High temperatures also tend to accelerate the release of VOCs from vegetation as well as the release of nitrogen compounds from soil bacteria. Thus, with an increased number of hot days in the summer, climate change will most likely increase the frequency of smog episodes in the GGH. Recent trends suggest that the frequency of smog episodes is already increasing. In the seven-year period from 1994 to 2000, there were 43 smog alert days in the City of Toronto; in the subsequent seven-year period, from 2001 to 2007, there were 152 smog alert days (EPCCA, 2009).[5]

Air pollution and smog are likely to have impacts on communities both inside and outside the Greenbelt. Both are known to have a variety of health impacts, including respiratory, cardiovascular, and reproductive effects. Long-term exposure to elevated levels of air pollution and smog are also believed to cause developmental problems in children and may contribute to the formation of certain forms of cancer (OCFP, 2005). Increased emissions of pollutants and increased occurrence of smog due to higher air temperatures is likely to exacerbate pollution related health impacts.

Air pollution compounded by climate change may also have an adverse effect on agricultural production. The combination of pollution and more frequent extreme weather events will stress both crops and livestock, potentially slowing rates of growth and increasing vulnerability to disease in both. Livestock in particular is subject to many of the same health issues related to air pollution and extreme temperatures as human populations.

3.8.3 Acidic Deposition

It is probable that atmospheric concentrations of acid-forming compounds will increase during the expected hotter summers and will lead to more acid deposition. Acid deposition is harmful especially to terrestrial vegetation as well as to all aquatic life forms, as it increases the acidity of watercourses. Increasing temperature accelerates the physical and chemical transformation rates of primary and secondary acidifying materials. Emissions of acid-forming sulphur and nitrogen compounds from power plants already tend to be highest in the summer and could increase due to growing demand for air conditioning. The use of air conditioning in automobiles contributes more of the same compounds. Furthermore, more hydrogen peroxide (H_2O_2), a strong oxidant and a catalyst for the production of sulphuric acid, is produced on hot days, creating conditions that favour acid formation and deposition.

Acid deposition in the GGH might also increase due to emissions of acid-forming compounds outside the GGH. Distant sources, including other highly urbanized and industrialized areas in the Great Lakes Region, could just as well lead to increased acid deposition within the GGH. Acid deposition depends on the circulation patterns of the atmosphere and on precipitation patterns. These are expected to change but it is unclear how they will affect acid deposition in the GGH. There is a dearth of research on acid deposition and climate change in Ontario in general and the Greenbelt in particular. More work is needed in order to better understand this problem.

Acid deposition may have a negative impact on numerous agricultural crops, acting as a further stressor and potential reducing productivity.

5 The eventual closure of the Ontario Power Generation coal stations should help alleviate smog in the GGH, but long distance transport from the US will remain a source or smog-forming air pollutants.

3.8.4 Pests and Diseases

Climate change can have indirect effects on agriculture and human health by favouring the spread of pests and diseases. In terms of agriculture, some researchers have noted that these indirect effects of climate change could offset gains in productivity related to higher temperatures and a longer growing season. According to Lipa (1999), the geographic distribution and size of insects and other pest population is likely to be influenced by climate change and can be expected to lead to crop losses (Lipa, 1999). Likewise, changes in the geographic distribution of plant diseases are likely to increase the risk of crop losses (Chakraborty et al., 2000). Other than recognizing that plant diseases are more sensitive to changes in precipitation rates than to temperature variations, there is not much relevant research on plant disease management in a changing climate (Chiotti and Lavender, 2008).

Changing precipitation patterns are also likely to affect the wellbeing of livestock. Run-off after extreme precipitation events could increase the risk of bacterial and parasitic contamination of water supplies, also helping to spread diseases to livestock. Between precipitation events, if intense drought conditions arise, there is a potential for water sources to become toxic due to increasing concentrations of sulphur and cyanobacteria (blue-green algae), with likely negative impacts on cattle production if appropriate mitigation measures are not taken (Prairie Farm Rehabilitation Administration, 2003).

In terms of human health, one of the main pests likely to become more prevalent in Southern Ontario as a result of climate change is the deer tick. Though it already occurs in parts of southern Ontario, tick populations are densest in the northeastern United States. As winter temperatures warm, tick populations are expected to increase in Southern Ontario. The establishment of deer ticks in the province will likely cause Lyme disease, which is carried by ticks, to become more prevalent. There are other insect- and arachnid-born diseases that may spread into or become more common in Ontario as a result of climate change. Examples include epidemic typhus and the West Nile virus. (Varrin et al., 2007).

3.8.5 Invasive Species

The warming of rivers and near-shore areas of lakes in Southern Ontario is believed to have facilitated invasions of non-native aquatic animal species. These include invertebrates such as spiny water fleas, zebra mussels, and quagga mussels as well as vertebrates such as round goby, various carp species, and the Eurasian ruffe (Great Lakes Information Network, 2010). Many of these were introduced through contaminated ballast water from transoceanic ships released into the Saint Lawrence Seaway or directly into the Great Lakes. Other species, such as rusty crayfish and white perch, have migrated from warmer parts of the continent via human-made watercourses, such as the Welland and Erie canals. With further warming projected, other species inadvertently introduced from warmer habitats are likely to find it easier to become established (Schindler, 2001; MacIsaac et al., 2004).

A variety of plant species have also invaded the Great Lakes Basin in recent decades. These include phragmites, purple loosestrife, and Eurasian water milfoil (UCS and ESA, 2003). The spread of these species is likely to be accelerated as climate change further stresses native species. Other species, whose spread is currently limited by cold winter temperatures, are likely to invade the GGH.

3.8.6 Other Habitat Stressors

Climate change can stress natural habitats through increased flooding and drought, frequent heat waves, extreme rainstorms, changes in water flow in rivers and streams, fluctuating surface water levels, and other impacts. However, climate change is more likely to have deleterious effects on plants and animals when combined with other stressors on habitat. Many of these stressors are human in origin, such as urban development, agricultural operations, introduction of invasive species, and recreational activities. These factors lead to degradation and fragmentation of habitat and reduce biodiversity. There is evidence that reductions in biodiversity limit ecosystem resilience, making it more difficult for natural areas to recover after the kind of disruptive events that are expected to be associated with climate change (UNEP, 2009).

4

The Role of the Greenbelt in Climate Change Adaptation

Climate change adaptation refers to any action that reduces the negative impact of climate change on local systems, both natural and human-made. The Greenbelt has three potential roles to play in a global climate change adaptation strategy for the GGH: (1) helping to protect biodiversity from local climate changes; (2) allowing agriculture and food systems to adapt to local and global climate changes; and (3) providing urban populations with a refuge from hotter cities.

We have seen that climate change interacts with other human-imposed stressors to amplify impacts on biodiversity. The Greenbelt can help protect biodiversity in the GGH in the context of a changing climate as it limits human stressors on the flora and fauna contained therein. In principle, natural heritage areas under Greenbelt protection should be free from many potential stress factors related to human activities, especially urban development. In the absence of these stress factors, plant and animal species in natural heritage areas should be more resilient to climate change than their counterparts in unprotected areas, especially in areas close to areas of concentrated human activities. Thus, the very existence of the Greenbelt is likely to help many resident plant and animal species cope with climate change, helping to maintain biodiversity in the GGH.

In addition to reducing stresses on resident species, the Greenbelt is also likely to help protect biodiversity both within and outside the Greenbelt by protecting migration corridors. This function will become more important as the climate changes and the distribution of plant and animal species changes. The Greenbelt provides terrestrial and aquatic corridors through which flora and fauna can migrate as it adapts to changing temperatures and precipitation patterns.

As for agriculture and food systems, the protected agricultural land in the Greenbelt may become an increasingly valuable resource in the future in the event that long-distance food supply chains are disrupted due to climate change. As discussed in Section 3.4.2, the GGH may be confronted with a situation in which it has to increase its reliance on local agricultural production. This points to the importance of protecting agricultural land in GGH as a means of ensuring regional food security.

Last but not least, the Greenbelt could play a role in hot-weather response strategies for the more intensely urbanized portions of the region. The Greenbelt, due to its size, has the potential to function as a refuge for humans during periods of extreme heat and poor air quality in urbanized areas, which are expected to become more frequent and severe in the future. Part of a hot-weather response strategy could be to provide a means for sensitive populations to access the Greenbelt.

5

Existing Adaptation Measures

The federal and provincial governments as well as non-governmental organizations have funded a considerable amount of research on climate change, its impacts and potential adaptation measures. Thus far, however, climate change adaptation has not been widely taken up by planning and policymaking at any level of government in Ontario. Rather, it appears that all three tiers of government are only beginning to develop climate change adaptation measures.

At the federal level, Natural Resources Canada has launched six Regional Adaptation Collaboratives (RACs), one of which targets Ontario (Ontario RAC). The goal of the Ontario RAC is to develop information resources and tools to help municipalities in the province adapt to climate change. The focus areas of the Ontario RAC include (NRCan, 2011):

Managing the risks of extreme weather:

- risk assessment and management tools for municipalities
- best practices for the construction of buildings
- decision-support tool for extreme heat events response.

Managing water resources:

- web-based climate change adaptation guidance for local communities and its
- application to watershed management
- risk assessments and recommendations for source water protection
- network of practitioners to share knowledge and build capacity.

Integrating adaptation into community plans and policies:

- urban- and rural/northern-targeted information, tools and training.

All three of the focus areas address climate change impacts that are expected in the Greenbelt and outcomes are likely to be of value in guiding climate change adaptation in the Greenbelt. In a joint announcement (January 7, 2011), the governments of Ontario and Canada pledged $6.8 million in funding for the Ontario RAC for the next three years. In addition to the Ontario ministries of Environment, Natural Resources, and Municipal Affairs and Housing, project partners include two other actors in the GGH—the Clean Air Partnership (CAP) and Conservation Ontario, represented by the Toronto Regional Conservation Authority (TRCA).

At the provincial level, climate change adaptation measures are absent from the key policy documents that apply to the Greenbelt and urban development in the GGH as a whole—the Greenbelt Plan, the Growth Plan, and the Provincial Policy Statement. The Lake Simcoe Protection Plan (2009) is so far the only exception to this rule. The plan requires that an adaptation strategy be developed for the entire Lake Simcoe watershed, part of which is inside the Greenbelt.[6]

However, the province does appear to be inching forward on climate change adaptation. The Ministry of the Environment' Climate Change Action Plan Annual Report 2008-09 (MOE, 2009a) summarizes provincial undertakings with respect to climate change. Where adaptation is concerned, the government's most significant undertaking has been the creation of the Expert Panel on Climate Change Adaptation (EPCCA). The 11-member panel was appointed in 2007 and tasked with proposing broad policy directions for climate change adaptation. The panel's numerous recommendations (some of which are outlined in Section 0 below) were published in 2009 (EPCCA, 2009).

The province has also set up a multi-stakeholder Urban Flooding Working Group, which is tasked with investigating the development of a provincial strategy to address urban flooding, and another committee chaired by MOE, that is exploring methods to incorporate climate change issues into stormwater management efforts. Finally, the province is modifying capital planning funding criteria, requiring ministries and other government agencies to consider the impacts of climate change on infrastructure when seeking funding for projects (MOE, 2009a).

At the local level, Conservation Authorities are leading the effort to build capacity for climate change adaptation. The Toronto and Region Conservation Authority appears to be especially active in this regard (TRCA, undated). Its activities include:

- developing a climate change strategy that builds climate change adaptation into the agency's existing business areas
- participation on behalf of Conservation Ontario on the provincial urban flooding and stormwater management committees, mentioned above

6 MOE officials are currently working on this adaptation strategy.

- updating watershed plans to address climate change and better deal with the increased
- variability in water levels expected in the future
- updating flood forecasting and early warning systems and communicating updated
- state-of-risk information to partner municipalities
- helping to develop and test new stormwater and water balance technologies.
- working with regional and local municipal partners to develop municipal climate
- change strategies
- coordinating a Municipal Climate Group among Golden Horseshoe municipalities
- establishing a Regional Climate Consortium, including 12 universities, all levels of
- government and the private sector to provide one-window access to multi-disciplinary,
- multi-sectoral climate change expertise in Ontario.

At the municipal level, some of the upper- or single-tier municipalities in the GGH are beginning to develop climate changes adaptation strategies and plans, including the City of Toronto, Peel Region, and York Region. A climate change expert, who was on the Ontario Expert Panel on Climate Change Adaptation, described these local efforts as ad-hoc and noted that there was no evidence of program coordination.[7]

The Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) is a non-governmental organization that is working with communities to build capacity for climate change adaptation (the Community Adaptation Initiative). The centre is a university-based clearinghouse for information on climate change impacts and adaptation. In addition to providing information resources on municipal climate change adaptation efforts (such as videos and case studies), the OCCIAR will also be delivering capacity-building workshops to help communities identify their climate change vulnerabilities and devise appropriate adaptation plans. OCCIAR, with funding from the Ministry of the Environment, will partner with the Clean Air Partnership to deliver the workshops. Each two-day workshop will cover a specific theme, either public health, urban forestry, electricity, high-rise residential buildings, or emergency management/critical infrastructure. The workshops will be held in various cities across the province, including Toronto and Guelph, between May 2011 and January 2012.

The Clean Air Partnership will also be providing training sessions for municipal stakeholders, called the Intensive Municipal Adaptation Training Program. The initiative is organized under the auspices of the Ontario RAC and funding will therefore be coming from Ontario Ministry of the Environment and Natural Resources Canada. The program will address key considerations for municipal climate change adaptation; impacts of climate change on Ontario municipalities; assessment of community risks and vulnerabilities; key steps in planning for adaptation; and how municipalities can build on their strengths to integrate climate change adaptation measures into existing goals, plans and programs. Each session will include a train-the-trainer component, so that municipal officials who take the course can go back to their community and train others. The four-day workshops will take place from April to November 2011 in different locations across Ontario. The first session will take place within the Greenbelt (Richmond Hill).

7 However, a GTA-wide Climate Change group is currently trying to bring the people behind these initiatives together to improve information sharing.

6

Recommended Adaptation Measures

6.1 Policy Framework

As noted in Section 5, the planning policy framework that governs development in the Greenbelt and the GGH does not directly address climate change adaptation. Perhaps the most fundamental recommendation of this report, echoing recommendations made by the EPCCA (2009), is to integrate climate change adaptation into provincial policies that govern provincial and municipal planning processes, including the PPS, the Growth Plan, and the Greenbelt Plan. These policy documents could be amended to require municipalities to assess climate change related risks and to include appropriate climate change adaptation measures in their Official Plans. For example, municipalities can incorporate floodplain mapping in their Official Plans to identify areas where flood hazards exist.

6.2 General Measures

Climate change adaptation measures can be divided into two broad categories. One category includes proactive measures to prevent or at least minimize some of the possible negative outcomes of climate change. The other category includes reactive measures to respond to the negative outcomes of climate change if and when they occur. The measures proposed in this subsection are proactive and cross-cutting in nature in that they are intended to reduce climate change risks to multiple natural and human systems. Most of these measures are intended to decrease risks and increase resiliency by mitigating non-climatic factors that stress multiple natural and human systems. The less stress that is being exerted on these systems by non-climatic factors, the more resilient they will be to climate-related stresses. The following general measures are drawn from a report on the ecological and community impacts of climate change on the Great Lakes Basin by the Union of Concerned Scientists (UCS) and the Ecological Society of America (ESA) (2003) as well as from the recommendations of the EPCCA (2009).

6.2.1 Improved air quality management

Just as air pollution has negative impacts on human health, it also impacts plant and animal health. This applies to both natural settings as well as to agricultural settings. More aggressive provincial measures to reduce air pollution from industrial sources and the transportation sector would decrease stress on natural and agricultural systems in the Greenbelt, helping to make both more resilient to changing climatic parameters.

6.2.2 Water quality and supply/demand management

Poor water quality and limited water availability can stress entire ecosystems and make them more susceptible to climate change impacts. Improvements to water quality and supply/demand management should therefore be pursued at the municipal level as a part of a climate change adaptation strategy. Demand management would require that all types of human users—residential, commercial, industrial, and agricultural—undertake conservation efforts. Other improvements could include upgrades to sewer and septic systems, the reduction or containment of runoff from farmland and roads. In the case of sewage systems, those that release untreated sewage to surface water bodies should be replaced or upgraded. It will become increasingly urgent to perform such upgrades if extreme precipitation events are likely to become more frequent. In the case of roads, stormwater runoff, which tends to load large amounts of pollutants into surface water bodies, could be reduced through the use of permeable surfaces and lining roads with natural stormwater retention systems. As roads are a shared municipal and provincial jurisdiction, both levels of government would need to be involved in implementing such measures.

6.2.3 Growth management

Urban growth management is an important factor for reducing ecosystem stress. More compact growth should help prevent further habitat destruction and fragmentation in the GGH. Compact growth can indirectly reduce ecosystem stress by helping to reduce automobile dependence and, therefore, emissions of GHGs and pollutants that are harmful to humans as well as to plants and animals.

6.2.4 Habitat protection and restoration

The integrity of natural habitats is essential for the survival of resident species. The following measures should be undertaken to protect and restore habitat:

- rehabilitation of wooded riparian buffer strips
- restoration of floodplain forests
- wetland preservation and restoration
- reduction of impervious surfaces.

These measures would not only restore habitat and decrease environmental stresses on wildlife but also buttress ecological services such as water purification and flood control. Protection and restoration of natural habitats can also be important for maintaining and improving recreational opportunities in the Greenbelt. Such undertakings would have to be shared between the province, especially the Ministry of Environment and the Ministry of Natural Resources, municipalities and conservation authorities.

6.3 System-Specific Measures

The measures proposed in this subsection include both proactive and reactive adaptation measures for specific natural and human systems in the Greenbelt—i.e., measures to reduce climate change-related related risks to these systems and measures to respond to climate change impacts that cannot be prevented.

6.3.1 Water Resources and Aquatic Wildlife

To help maintain the Greenbelt's water resources and increase the resilience of aquatic ecosystems in the Greenbelt, vigorous protection of the riparian zones associated with rivers, wetlands, and headwater streams will be necessary. The protection and re-vegetation of riparian zones is particularly important to help maintain water quality and control flooding during high precipitation events. It is recommended that plant species and species communities that are native to riparian zones in the Greenbelt be evaluated by MNR for their capacity to withstand extreme hydrological conditions—i.e., droughts and floods—and warmer temperatures. The most robust species should be privileged in re-vegetation efforts.

To manage low-water level and drought risks, the EPCCA recommends that the Ministry of the Environment use water budgets that include the cumulative impacts of climate change at the watershed scale while reviewing the Permit to Take Water Program and introduce water conservation measures. It is also recommended that the Ministry of Natural Resources undertake a comprehensive review of the Ontario Low Water Response Program to adjust for projected drought conditions in areas determined to be vulnerable to extended dry periods, and should link this review to water use reporting and water conservation in the context of integrated watershed management.

On a broader scale, more attention needs to be given in the land use planning process to the overall carrying capacity of watersheds, from the sub-watershed level all the way up to the regional level. Carrying capacity calculations would need to involve attention not only to historical and prospective supply variations, but also to ecosystem requirements, precautionary cushion needs, and human supply possibilities in light of current and projected population levels as well as trends in per capita consumption levels. Some jurisdictions, such as Wellington County and Waterloo Region, which do not rely on the Great Lakes for their water supply and disposal of wastewater, are already considering the carrying capacity of local watersheds in their planning decisions. Wellington County in fact has asked the province to revise growth projection downwards on the basis that a local river would not be able to absorb the wastewater produced by the projected population growth (see Outer Ring Report). It is recommended that the Growth Plan and the Greenbelt Plan be modified to require carrying capacity consideration in the planning process. Carrying capacities should be addressed explicitly in municipal official plans inside as well as outside the Greenbelt.

6.3.2 Forests and Terrestrial Wildlife

The natural landscape of the Greenbelt is fragmented by human settlements, by agriculture-related land uses, and by linear infrastructure such as roads and power lines. To help sustain terrestrial migration corridors under the predicted climate changes, planning policies and development regulations in the Greenbelt should be designed to minimize landscape fragmentation. The Greenbelt Plan prescribes the protection of wildlife habitat, as defined by the 2005 Provincial Policy Statement (PPS). The PPS definition includes "areas that are important to migratory and non-migratory species". However, the Greenbelt Plan does not contain language explicitly directing planners to minimize fragmentation of wildlife habitat (whereas it does explicitly address the fragmentation of agricultural land). It is recommended that the relevant sections of Greenbelt Plan be amended to address explicitly the fragmentation, and not just the destruction, of wildlife habitat by human settlements, agricultural land uses, and infrastructure projects.

Beyond measures to minimize fragmentation, measures for encouraging habitat and corridor restoration and rehabilitation are needed. It is recommended that the province identify areas of the Greenbelt in which habitats and corridors have been subjected to fragmentation and deterioration and that these areas be monitored. Long-term restoration and rehabilitation programs should be undertaken, prioritizing habitats and corridors that have been compromised by human activity (i.e., urban development, infrastructure, resource extraction) as well as natural occurrences (i.e., flooding, droughts, fire), including those related to climate change.

6.3.3 Agriculture

Farming practices in the Greenbelt will have to adapt to the changing climatic conditions. The primary concerns for farmers are not changes in average temperatures and precipitation rates, but rather increased inter- and intra-annual variability in the climate (Bryant et al., 2000). Farmers are generally already prepared for dealing with some climate variability, but increasingly extreme conditions may exceed their "coping range" and require more dramatic changes in farming practices.

Farmers in Ontario have already observed changes in the climate in recent years and have adapted their practices accordingly. Responses have included (C-CIARN, 2002):

- changes in crops or crop varieties
- increased crop rotation
- alterations to tile drainage
- wider use of conservation tillage
- changes in the timing of planting
- installation of irrigation systems.

Large, well-capitalized farm operations in the Greenbelt are likely to be more resilient as they are in a better position to make the necessary changes than smaller farms (Chiotti and Lavender, 2008; UCS and ESA, 2003). They can afford and are more likely to proactively implement adaptive measures compared to smaller farms. The province could play a role in helping smaller farm operations in the Greenbelt by providing such farms with access to the expertise and capital needed to make the necessary anticipatory adjustments to their operations, including the types mentioned above.

According to agronomists at the University of Guelph (Wall and Smit, 2005), adapting agriculture to climate change overlaps with making agriculture more environmentally sustainable. They list a number of practices that can be used to achieve greater resiliency in the face of climate change while increasing sustainability. These include:

Diversifying Crops

- Growing more perennial crops (such as forages), which improve drought tolerance by enhancing soil quality and moisture retention.
- Reintroducing native grasses for pasturing, where possible (native grasses are drought resistant when rotational grazing is practiced on them).
- Growing a wide variety of new crops (e.g., pulses) that are more drought resistant.
- Growing a diversity of crop types and varieties in rotation and in different areas of farm properties, which helps spread the risk of losing an entire year's production since conditions can vary across small areas.
- Staggering seeding and harvesting dates by choosing a variety of crops that require a range of growing conditions so that crops are at different stages.

Diversify Enterprises Within One Farming Operation

- Including more livestock in their operations to make use of increased forage production and to add value on the farm.

Land Resource Management

- Using conservation tillage practices (reduces risks from drought and flooding by minimizing soil erosion and compaction and maximizing water retention).

- Adding new or enhancing existing shelterbelts[8], which reduce negative impacts from drought by maintaining water tables, increasing biomass in soil, and ensuring surface moisture is kept on the land.Cutting stubble at different heights to trap snow on field surfaces thereby enhancing spring moisture levels in the soil.

Water Resource Management

- Adopting newer, more water-efficient systems and timing for applications to avoid waste.
- Managing sloughs and ponds to ensure water is captured and protected as much as possible.

The EPCCA (2009) made three key recommendations with respect to adapting agriculture in Ontario, all of which are applicable to the Greenbelt. First, the panel urged the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) to conduct a province-wide climate change risk and opportunity assessment for the agricultural sector. The panel directed the Ministry to work with agricultural stakeholders, the research community, and other levels of government to develop local adaptation options, to engage the agricultural community in an ongoing assessment of the effectiveness of adaptation measures, and to facilitate the sharing of best practices.

Secondly, the panel advised OMAFRA to amend its policies relating to agricultural business risk management, income support, incentives and crop insurance in order to increase the climate resilience of the agricultural sector. The changes would facilitate an adaptive management approach that supports farmers' capacity to anticipate climate change in their operations rather than merely reacting to it.

Thirdly, the panel urged OMAFRA to work with the MNR and the Ministry of Health and Long Term Care to enhance the province's ability to anticipate, prepare for and prevent new or expanded animal and plant diseases and pests including:

- building on the Plant Diseases Act to improve provincial capacity to respond to plant and animal diseases
- improving monitoring and surveillance capacity to detect, prevent, and respond to new pests, and plant, livestock and zoonotic diseases
- seeking opportunities to collaborate with the federal government.

As already mentioned, ensuring regional food security under conditions of a changing climate may entail greater self-sufficiency in terms of food production. This has implications for agriculture in the GGH, both inside and outside the Greenbelt. Primary agricultural production (i.e., farming, horticulture, etc.) and secondary agricultural production (packaging, processing, etc.) would need to be expanded, intensified, and diversified if a larger share of the food consumed in the GGH were to be produced there. Greater local food self-sufficiency would also entail a restructuring of food distribution systems to bring food sourced in the GGH to local markets, complementing or substituting for the global food distribution network that the GGH currently relies on.

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8 Shelterbelts, also known as windbreaks, are plantations of one or more rows of trees or shrubs that provide shelter from the wind and to protect soil from erosion. They are commonly planted around the edges of fields on farms.

6.3.4 Infrastructure

Most infrastructure is physically designed to tolerate some degree of climate variability. If climate variability increases, with extreme conditions becoming both more frequent and more severe, the tolerances of some existing infrastructure could be exceeded (especially during droughts and floods), with potentially disastrous consequences.

To avoid water shortages in settlements and agricultural areas in the Greenbelt, municipalities will have to modify water infrastructure to tolerate more frequent and longer periods of drought. Water intakes in lakes and rivers will need to be moved deeper and further from shore. Likewise, where groundwater resources are used, deeper wells will be required to provide a more reliable water supply (presuming there is a deeper aquifer). Municipalities will need to increase water storage capacity to reduce the strain on water resources and to help communities in the Greenbelt weather periods of low flow or drought. Echoing the EPCCA (2009), it is recommended that the province update its stormwater management guidelines to this effect. Communities in the Greenbelt may also need to implement more stringent water conservation measures, again to help reduce the strain on water resources and to better weather periods of drought.

Shifts in storm intensity, duration, or frequency as a result of climate change could entail more frequent flooding and related hazards. Storms that exceed the drainage capacity of existing stormwater management systems will likely occur more frequently. In addition to property damage, excess run-off and flooding could introduce contaminants to surface and groundwater sources, affecting many Greenbelt communities' water supply. Municipalities should implement measures to monitor their water sources on an ongoing basis, with intensified testing after major storm events to ensure water sources have not been contaminated. As a contingency, municipalities should put in place rapid response plans for supplying potable water where local sources are deemed contaminated. Rapid access to potable water in the event of source contamination would be crucial for the wellbeing of humans as well as of livestock in agricultural communities. Municipalities should undertake a thorough mapping of flood plains to identify where flood hazards exist or are likely to develop. This would help prevent development in areas with elevated flood risks. It would also help municipalities to prioritize flood response contingency measures and improve their emergency preparedness.

Other infrastructure, especially transportation infrastructure, will have to be adapted to handle more frequent and severe flooding. It will also need to withstand faster rates of erosion due to a longer rain season (because of shorter winter) and more frequent extreme precipitation. This may entail some structural measures to reinforce and shield infrastructure from flooding. However, it may also include measures to manage stormwater and mitigate flooding in the first place. The implementation or expansion of natural stormwater retention and absorption features along roads and railways may help prevent catastrophic levels of flooding from occurring.

Roads in particular will be subject to more wear and tear from the more frequent winter thaw-and-freeze cycles expected in the future. More frequent replacement of road surfaces will be required, barring technological advancements in road surfacing materials.

The climate conditions expected in the future in Southern Ontario fall within the range of conditions already experienced in other locations in North America. Materials, construction, monitoring, and maintenance technologies for managing these conditions already exist (Mills et al., 2007). While the appropriate adaptations are likely to be rapidly implemented on primary road networks, they might not materialize soon enough on secondary and tertiary provincial or municipal roads in rural areas, leaving them vulnerable to climate change impacts. The EPCCA (2009) recommends that the Ministry of Energy and Infrastructure (now the Ministry of Infrastructure) develop a set of case studies to better understand the climate change risks to roads and other types of infrastructure at different locations across the province. The data that flow from this effort could be used to plan road upgrades, using the appropriate technology, in the Greenbelt.

To maintain the vitality of agricultural sector and to keep the more remote parts of the Greenbelt accessible for recreational purposes, the Greenbelt's road network should be monitored. Engineering standards for roads in the Greenbelt (as elsewhere) should be modified to provide better resiliency under more variable and extreme climatic conditions. When road maintenance or construction is carried out, roads in the Greenbelt should be brought up to standards consistent with the expected climate patterns.

6.3.5 Energy

Some adaptation measures will be required to make energy infrastructure in the Greenbelt more resilient to extreme weather events, especially prolonged freezing rain events. The most obvious measure is the modification and replacement of transmission and distribution infrastructure to allow it to withstand more violent winds and heavier loads of ice. Accordingly, we second the EPCCA (2009) recommendation that the Ministry of Energy and Infrastructure (now the Ministry of Energy) ask the province's Independent Electricity System Operator to complete a climate change risk assessment of the electricity grid and to propose adaptive actions.

A potential strategy for improving the resilience of the electricity grid is the development of more distributed, local generating capacity across the Greenbelt and the GGH as a whole. At present, the GGH relies heavily on electricity from remote sources (Chiotti and Lavender, 2008). Any failure of one of the main transmission lines would leave the region vulnerable to blackouts. Creating distributed, local power generation entails creating relatively small power generation systems across the region and reconfiguring the distribution system in order to allow these small generators to feed-in the power they create. The small generators can be based on alternative or clean power sources, such as wind, solar, or biomass. A local, distributed network of small power generators would be more resilient to extreme weather events. Furthermore, it would make the GGH more self-sufficient in terms of energy, increasing the region's energy security. The Ontario Power Authority already has a program, called the Feed-in Tariff (FIT) Program, to support the development of small, distributed power generators (FIT for projects over 10 kW and microFIT for projects under 10 kW, suitable for residential and small agricultural proponents). This program should be maintained and supporting measures to help Greenbelt residents and farmers obtain the required planning permits should be undertaken.

6.3.6 Recreation and Tourism

In general, it appears the recreation and tourism industries in the GGH and elsewhere in Southern Ontario will need to invest more in warm-weather activities while preparing to rely less on winter snow- and ice-based activities. Aside from adapting to a longer season for warm-weather activities, provincial, municipal and private stakeholders will have to undertake measures to make activities more resilient to the more extreme variations in weather within each season, especially varying water levels. This entails the modification or replacement of near-shore infrastructure, such as boat docks and marinas, by their owners, whether private or municipal, to make them more tolerant of both higher and lower water levels than today.

The EPCCA (2009) recommends that the Ministry of Tourism work with communities, researchers, and tourism associations on an assessment of tourism vulnerabilities to climate change and on monitoring climate-related tourism trends. The panel suggested that, in the coming years, the Ministry should facilitate communication among stakeholders regarding the potential impacts, risks and opportunities that climate change entails for tourism as change occurs and emerging trends become more evident.

6.4 Hot Weather Response Measures

More frequent extreme hot-weather events are expected in Southern Ontario. In urbanized areas, such events are primarily a human health issue. Urban hot-weather response plans, such as the Toronto Hot Weather Response Plan, focus on helping sensitive populations, including the elderly and the chronically ill. In the Greenbelt, given that there are no large urban settlements likely to experience extreme air pollution and heat island effects, the mitigation of human health impacts of hot weather are a less urgent concern. Hot weather response programs for the Greenbelt should focus on protecting the agricultural sector, particularly livestock. Secondly, hot weather, particularly during a period of drought, may also entail increased risk of fire in the Greenbelt's forests. Forest fire response capacity may need to be increased to handle the increased levels of fire risk.

6.5 Enhancement Measures

Not all impacts of climate change are necessarily negative. There is a potential for positive impacts, particularly in agriculture, recreation and tourism.[9] Just as adaptive measures are required to mitigate the negative impacts of climate change, certain adaptive measures can be undertaken to maximize gains from the positive impacts of climate change.

In terms of agriculture, the main positive impact of climate change is an extended growing season. With earlier spring thaws and later autumn frosts, it might be possible to cultivate new types of crops in the Greenbelt—crops that are currently cultivated only in the warmer parts of the continent. To take advantage of the longer growing season, farmers in the Greenbelt will not

9 Other benefits from climate adaptation measures include local employment opportunities, spurs for innovations that may have broader markets, means of reducing inequities, WTO-compliant supports for agriculture, measures that also enhance ecological integrity and strengthen ecosystem services reliability, and so on. An analysis of these benefits are outside the scope of the current report.

only need to change what they plant but also when they plant and harvest their crops. Just as larger farming operations are likely to be in a better position to respond to the negative impacts of climate change, they are also in a better position to take advantage of the positive impacts of climate change. Smaller farming operations may lack the required technical and financial resources to respond to the positive impacts of climate change. Financial assistance from the public sector could help them make the necessary changes to their operations.

Ultimately, the availability of new types of locally grown crops could help Southern Ontario reduce its dependence on imported produce and improve local food security. Policies and programs that help bring locally grown produce onto the market, favouring local produce or imports, would help maximize this benefit.

In terms of recreation and tourism, climate change is likely to bring a longer season for warm-weather activities, including watersports, camping, hiking, mountain and cross-country cycling, and so on. Provincial and municipal recreational services will most likely need to adapt their seasonal schedules in order to accommodate increased demand for recreational services in the Greenbelt's warm months, especially in the early spring and the late fall. Private firms offering recreational and tourist services in the Greenbelt will likewise need to adapt their operations to be able to benefit from an extended season for warm weather activities.

7

Conclusions

The nature and extent of climate change in the GGH, as anywhere else in the world, is fraught with uncertainty. There are numerous, competing climate models that offer diverging predictions of the future climate, even under the same assumptions regarding future GHG emissions. Despite this uncertainty, a consensus is beginning to emerge about the nature and extent of climate change. As described in this report, for the GGH, the general prediction is that, by mid-century, the average temperature will be higher, potentially by a few degrees, while total precipitation rates will remain roughly the same. The overall warming trend aside, there appears to be a consensus that the climate will become considerably more variable than today. Extreme weather events, with unseasonal temperatures or unusually high volumes of precipitation, will become more common.

The majority of the negative climate change impacts directly on the Greenbelt area documented in this report are related to more frequent extreme weather conditions rather than to the overall warming trend. It is primarily extreme conditions such as extreme heat, drought, and floods that are likely to stress natural and human systems in the Greenbelt. Many of these negative impacts appear to be related to the effects of climate change on hydrological systems. Extreme variations in water levels related to droughts and flooding will directly affect terrestrial and aquatic ecosystems, agriculture, recreational activities, and infrastructure in the Greenbelt.

The overall warming trend also entails some negative impacts. Higher air and water temperatures and shorter periods of snow and ice cover entail disturbances of terrestrial and aquatic ecosystems. Plant and animal species that thrive in colder temperatures and that depend on either snow or ice cover could be affected negatively. Species better adapted for warmer temperatures, including some that are currently not found in the Greenbelt, may increase their presence in the Greenbelt. This applies to wild plants and animals (and fungi and bacteria, etc.) as it does to agricultural crops and livestock.

Shorter winters as a result of the overall warming trend could have some positive impacts. The most obvious of these is a longer growing season, which is likely to benefit agricultural production in the Greenbelt. It may become possible to plant crops that are currently confined to warmer parts of the continent. Warmer weather also entails benefits for recreation and tourism in the Greenbelt, as the period during which outdoor, warm-weather activities are practicable will be extended. Of course, agriculture as well as recreation and tourism will also be subject to negative impacts including those due to extreme weather conditions. Nevertheless, appropriate adaptation measures that minimize extreme weather stress on crops and livestock, as well as minimizing other environmental stressors, could allow farms in the Greenbelt to maintain or even increase their level of productivity, potentially benefitting from the expected longer growing season, all else being equal.

Climate change adaptation concerns are beginning to be integrated into policymaking and planning processes at the provincial level. The province has sponsored the Expert Panel on Climate Change Adaptation and has signed on to the Ontario Regional Adaptation Collaborative while it develops a Climate Change Action Plan. The inclusion of a requirement to develop a climate change adaptation plan in the Lake Simcoe protection plan is a good sign. Climate change considerations have yet to be introduced in the Greenbelt Plan and the policies that frame development in the GGH, namely the PPS and the Growth Plan. Addressing this lack is of fundamental importance to improving climate change readiness in the Greenbelt.

Climate change adaptation is far from being mainstreamed at the municipal level. Some GGH municipalities are beginning to develop climate change adaptation plans but there appears to be little coordination of their efforts. Conservation authorities are leading the charge locally with new generation watershed plans that incorporate climate change adaptation strategies and these are expected to eventually impact municipal Official Plans. In the hopes of further encouraging municipalities to undertake adaptation planning, the province is funding non-governmental agencies such as OCCIAR and CAP to provide municipalities and community stakeholders with workshops and information resources on adaptation. Until the province updates the policy framework to require climate change adaptation planning, municipal participation remains voluntary.

Climate change is expected to interact with a number of other environmental stressors, such as water and air pollution, acid deposition, pest infestations, and stressors related to urban development and other human activities. It is not climate change alone but rather climate change in combination with these other non-climatic stressors that is likely to produce the most serious negative impacts—i.e., the combination of these multiple climatic and non-climatic stressors may push certain natural and human systems beyond the limits of their tolerance.

In order to increase the resiliency of natural and human systems and help them adapt to a changing climate, it will be necessary to take a holistic planning and management approach that addresses these non-climatic stress factors.

Even if non-climatic stress factors are significantly reduced, some systems are still likely to be stressed beyond their tolerance and will be subject to climate change impacts. When climate change impacts are impossible to prevent, measures must be taken to adapt systems—especially human systems such as agriculture, infrastructure, and recreation and tourism—to withstand them. In particular, these systems need to be adapted to withstand more frequent extreme precipitation events and the resulting runoff and flooding, more frequent low-water periods and draughts, and longer and more intense heat waves.

At the same time, some systems, such as agriculture and recreation and tourism, stand to derive some benefit from a milder winter and longer period of warm weather. It should be emphasized that in both cases, adaptations will be required to maximize benefits and minimize the potential drawbacks of the new climatic conditions. Farmers will need to change what they plant, when they plant it, and when they harvest it. Crops that have heretofore been difficult to grow in the GGH may become feasible. In the recreation and tourism sector, provincially-, municipally- or privately-run establishments will need to change their annual operating timetables to take advantage of an earlier spring and later onset of winter. It may be necessary to redirect investment from infrastructure and services related to winter activities to those related to summer activities.

Many of the adaptation measures proposed in this report (such as the need for managing urban growth, curbing industrial and transportation pollution, and preserving vegetated areas) would also serve to reduce GHG concentrations in the atmosphere and mitigate climate change. Stressing these measures' capacity to prevent or least reduce the severity of certain climate change impacts—i.e., to mitigate climate change impacts—is likely to help build agency and public support for adaptation measures.

In many cases, there are other good reasons to pursue adaptation measures apart from their climate change impact mitigation or adaptation value. For example, there are clear public health imperatives for pursuing measures to control air pollution. Similarly, there are well-established social and economic imperatives for pursuing measures for containing urban sprawl—imperatives to which the public is increasingly attuned. Emphasizing these imperatives, in addition to the link with climate change, is another means of building public support for adaptation measures.

The Greenbelt Plan contributes positively to protecting natural and human systems in the Greenbelt from the negative impacts of climate change by limiting the scope for environmental stress through urban development and other human activities.[10] In order to strengthen the Greenbelt Plan's protection of natural heritage, agriculture, and recreation and tourism, policies that explicitly address climate change should be added. Climate change policies in the Greenbelt Plan should require that all land use and infrastructure planning processes explicitly consider climate change. Consideration should be given to how the proposed change in land use or the proposed new infrastructure will interact with climate change, specifically how it will affect the resiliency of natural and human systems in the long term.

10 However, insofar as the Greenbelt displaces these stresses elsewhere, the net gain over the broader region is questionable.

The science of climate change and its impacts is in its infancy. The research cited in this report has allowed us only to identify and broadly characterize a variety of potential impacts and systems that may be vulnerable to climate change. Further research is required to in order to better understand the nature and extent of potential climate change impacts highlighted by this report. Research is also required to evaluate the vulnerability of different systems in the Greenbelt—ecosystems, agriculture, infrastructure, recreation and tourism, and so on—to climate change. An assessment of the vulnerability of different systems would help with shaping and prioritizing mitigation and adaptation measures.

This report focuses strictly on how climate change will affect key systems in the Greenbelt and how policies should be modified to increase the adaptive capacities of these systems. It should nevertheless be acknowledged that climate change is a global phenomenon whose impacts are likely to be vast in scale and require the development of adaptive capacities that are far broader in scope than anything discussed in this report. Still, even local efforts to address climate change can be seen as contributing to the global effort. Other regions face challenges not unlike those being faced by the GGH. It is important to keep in mind that knowledge and resources developed to address climate change here could be of value to other regions, and vice versa.

8

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