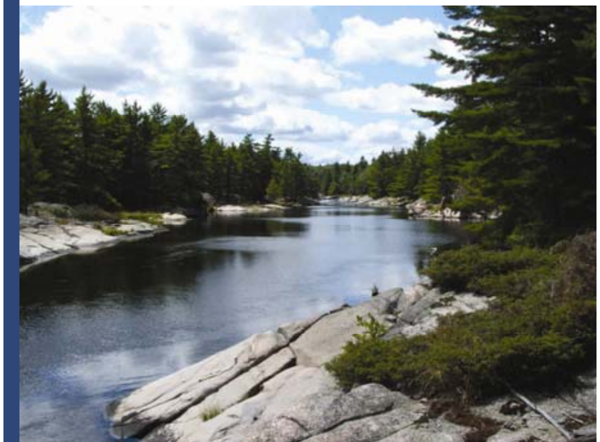

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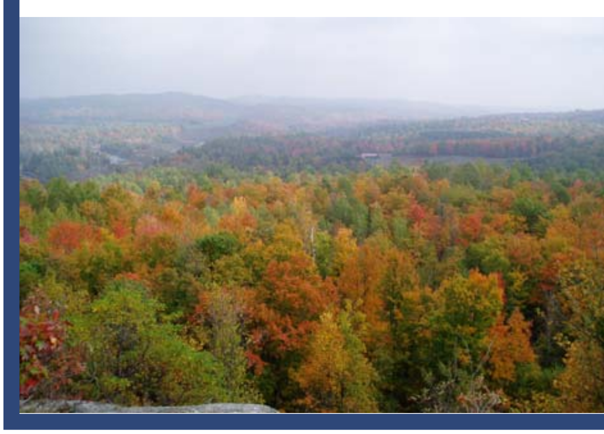


Mississippi Watershed In a Changing Climate

Paul Egginton and Beth Lavender

2008

Forward

It is my pleasure to introduce *From Impacts Towards Adaptation: Mississippi watershed in a changing climate.* The report has been authored by Paul Egginton and Beth Lavender who took up this challenge because they are both residents and or users of the Mississippi Valley. The report is based in part on their broad experience in addressing climate change impacts and adaptation issues and on a stakeholder workshop held in the fall of 2007 in the Town of Almonte, Ontario co-sponsored by Mississippi Valley Conservation (MVC) and Mississippi Valley Field Naturalists (MFVN).

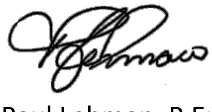
Beth Lavender has worked on climate change impacts and adaptation issues since 1994. Beth was a lead author of the Ontario Chapter of the Canada Country Study, the first national assessment report dealing with the impacts of climate change on Canada. She also co-led the development of the adaptation chapters for Canada's 3rd and 4th National Reports to the UN Framework Convention on Climate Change (UNFCCC). Between 2000 and 2007, while with Natural Resources Canada, Beth was responsible for overseeing more than 70 research projects related to the impacts of climate change on water resources, human health, fisheries and tourism and recreation. She was the co-lead author of the Ontario chapter on the recently completed (2008) national assessment of the impacts of climate change on Canada. In September 2007 Beth began working with Canada's Department of Foreign Affairs and International Trade, dealing with international climate change adaptation issues.

Paul Egginton is a member of Ontario Nature. He was the Executive Director responsible for Canada's Climate Change Impacts and Adaptation Program from its inception until his retirement in 2005. He has worked in a number of positions at the Geological Survey of Canada (GSC) since 1975, first as a researcher, then as a science manager including the Director of Terrain Sciences Division, GSC, Natural Resources Canada. For a number of years Mr. Egginton represented Canada at meetings of the Intergovernmental Panel on Climate Change (IPCC) and he was a chapter co- lead (Chapter 2) on the recently completed (2008) national assessment.

From attending these workshops and reviewing the extensive literature available on climate change impacts, it is evident to me that the Mississippi Valley has and will continue to be affected in many ways, both directly and indirectly by climate change. Extensive published research expects southern Ontario to warm by 3.5°C or more by the year 2050. While warmer temperatures, particularly in the dead of winter may not register as a significant concern, shifts in average annual conditions will be accompanied by changes in climate variability and the frequency of extreme weather and climate events. Adapting and responding to these changes will present both challenges and opportunities.

Establishing effective dialogue at the local level will be important as the impact of changes in our climate will affect all sectors of society and the response by one sector can have significant implications for other sectors. We will have much to consider.

I would urge you to review the impacts and opportunities which are summarized in the report and consider how these may be relevant to your particular interests and responsibilities. MVC along with the Community Stewardship Council of Lanark County are pleased to publish this report, it is a significant contribution to our community.



Paul Lehman, P.Eng., General Manager
Mississippi Valley Conservation
2008

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From Impacts Towards Adaptation: Mississippi Watershed

Summary

The impacts of a changing climate are already visible globally and in Canada. However, as recently as 2005 there was little local information readily available to the public that was specific to Mississippi Watershed; as result, few residents/users of the watershed were aware that climate is already changing here.

Warming of the climate system is unequivocal and recent warming is very likely due to humans. Climate is and will continue to change irrespective of initiatives to reduce greenhouse gas emissions: even if global emissions could be capped tomorrow at 2000 levels an additional global warming of 0.6°C would still occur. The best estimates of projected increases in global mean annual temperatures by 2100 range from 1.8 to 4.0°C. The Intergovernmental Panel on Climate Change (IPCC 2007) indicates that we need to both reduce emissions (to stop or slow down the rate of climate change) and adapt to the changes that are now occurring and will occur in future. Adaptation is not an option but a necessity.

In the Mississippi watershed and much of eastern Ontario mean annual temperatures can be expected to increase above 1960 -1990 values by about 1.5°C by 2020, 3.5°C by 2050 and 5.0°C by 2080.

Climate Change is often cited as a key environmental issue. Indeed it is, however; such a formulation misses the fact that it is also a key social and economic issue. There will be impacts to all sectors of the local economy. Such impacts can be minimized and opportunities maximized by pro-active adaptation. Local strategies for action need to be developed.

For this to occur the public, local agencies, and municipal governments need to begin a discussion of the implications of climate change for the watershed as a whole. With this in mind, Mississippi Valley Field Naturalists and Mississippi Valley Conservation in September 2007 convened a two day workshop, "*Weathering the Change*", in Almonte, Ontario. About 150 people attended. Ten speakers, all with sectoral and climate change expertise, gave overview talks and helped to animate the discussions in sector breakout sessions.

The main goals of the workshop were:

1. to engage the public and experts in a discussion of climate change and to identify some of the key impacts on the region.
2. to start a discussion of potential adaptation options—including water and fish management issues[1].
3. to recognize the limitations of adaptation.
4. to explore some of the barriers to taking action and start to raise awareness of the tradeoffs involved.
5. to capture key issues and concerns for our region as a point of departure for future discussions and actions.

The discussions in and around the workshop were rich with information. This publication attempts to capture the key points raised, and to provide additional data on these issues. The results, although focused upon Mississippi watershed, apply generally to eastern Ontario.

Key Results

1) Participants concluded that:
   - climate, ice cover, water temperature, river flows, local ecosystems and fisheries are changing in Mississippi watershed and will continue to do so.
   - there are now and will be future impacts on agriculture, tourism, forestry, fisheries and other sectors.
   - impacts will be both positive and negative.
   - some but not all of the impacts can be reduced through adaptation.
   - there are barriers to taking action—tradeoffs will be necessary.
   - climate change must be incorporated into all aspects of our planning processes (e.g. health care, fisheries management, infrastructure design, water management etc).
   - guidelines and tool-kits are needed to help at the local level; participants look to all levels of government to provide these.
   - there is a continued need to raise awareness of this issue.

2) The release of the Almonte Communiqué (see Attachment 1) expresses the 150 participants call for action to governments and residents to adapt to a changing climate.

3) There is a need for follow-up meetings and discussions around the sectors identified in the report to provide vertical integration amongst various levels of government and the public. There is a need for the establishment of a process for horizontal integration (e.g. using one or more regional co-ordination committees or existing bodies) to develop local adaptation strategies.

[1] "*Weathering the Change*" also served as a stakeholders outreach and science transfer workshop for the project "*Fish, fisheries and water resources: Adapting to Ontario's changing climate*" (for details see Casselman, http://www.mvc.on.ca/program/workshops.html)

Introduction

Many programs have been developed that begin to tackle the challenges of climate change. To date, most of these have focused on curbing green house gas emissions. While this is critically important, there is an increasing awareness that climate is already changing in Canada and Ontario and will continue to change for the foreseeable future. Ontario is promoting the development of local adaptation strategies to manage the impacts of our changing climate. Local strategies are necessary because one size will not fit all. There are local geographical and socio-economic realities that need to be considered in the development of adaptation responses.

The Mississippi watershed, its flora, fauna and human occupants will respond to climate change in a variety of ways. They will begin to adapt. Informed adaptation actions taken before severe impacts are experienced have the greatest chance for success both to reduce the negative impacts, and to take advantage of new opportunities that may be presented. Such adjustments will be reflected in future management plans as climate change is "mainstreamed" into programs, policies and practices at all levels and in all sectors (e.g. health, agriculture, forestry, water etc.). The longer we wait to take adaptive actions, the more likely we are to experience strongly negative impacts to our economy and well-being. As an initial step in moving climate change adaptation forward locally, Mississippi Valley Conservation Authority (MVC) and Mississippi Valley Field Naturalists (MFVN) hosted a workshop "*Weathering the Change: Adapting to Climate Change in the Mississippi Valley*". The workshop ran for two consecutive Saturdays, September 15 and 22, 2007, at R. Tait Mackenzie Public School in Almonte, Ontario.

Ten sectoral and climate change experts provided overview talks (see Attachment 2) that were followed by breakout sessions. Each breakout focused specifically on the Mississippi watershed and a particular sector, identifying the observed and expected impacts resulting from climate change and potential adaptive actions that might be taken. Facilitators helped workshop participants put a local face on the issues. Breakout group results were shared with plenary each day.

The workshop presentations and discussions were rich with information, and form the foundation of this report. This is supplemented by additional information. "*From Impacts Towards Adaptation*" is structured to first introduce current and future climate change in the watershed, and to then discuss the implications for each sector. To be succinct, and to allow for quick comparisons between sectors, the main body of the report is organized around a series of sector tables with a short discussion for each.

This report represents an early step in beginning to manage climate change in this watershed. It is hoped that it will help stimulate further discussion, and provide a basis for follow-up workshops and analysis.

Acknowledgements

The speakers gave freely of their time and contributed greatly to the success of the workshop. The authors have drawn heavily on the speakers' presentations and their publications. Many have contributed directly to this report. John Cassleman in particular is thanked for his encouragement and support throughout the process. The co-sponsors of the workshop, Mississippi Valley Field Naturalists (MVFN) and Mississippi Valley Conservation (MVC) organized and conducted the events. Thanks to Mike McPhail and Paul Lehman and their members /employees (see Attachment 3 for a list of the organizing committee members). Without the input of MVFN and numerous local volunteers, the workshop would not have been possible. Most importantly, thanks to the 150 people who attended the workshop and whose enthusiastic input provided the ground-truthing for this report. The authors would like also like to acknowledge the efforts of Don Lemmen who edited this document and Suzanne McFarlane who provided the layout design.

Historical Climate Trends

The most recent synthesis of global data by the IPCC (2007) shows that the earth's surface air temperatures, ocean temperatures, and atmospheric temperatures are all rising, and that global precipitation patterns are shifting. But, as a resident of the Mississippi watershed, it is difficult to assess what these global changes mean locally. How are air surface temperatures changing in Mississippi watershed, and how do they compare to Canada as a whole?

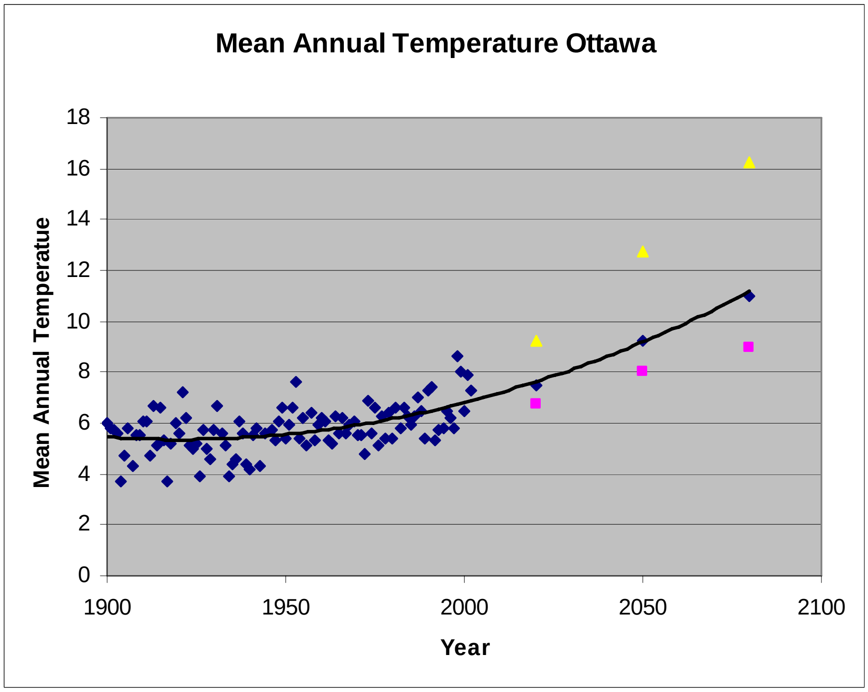
Global surface air temperatures have increased by about 0.7°C over the last 100 years, with much of that happening since 1960. However, the warming has not been uniform over the globe. Canada, with its temperate to polar location, has warmed as a whole about twice as much as the global average or about 1.3°C since 1948. This relative disparity can be expected to continue into the future: Canada as a whole will experience more than average global warming.

Environment Canada has compiled surface temperature data for all regions of Canada showing trends over the past 50 years or so. This data shows that far more warming has occurred in northern and western Canada than in eastern Ontario. However, distinctive changes have occurred in Ontario as well. Of particular interest is that in eastern and southern Ontario, most change has occurred in winter, with present average winter temperatures now about 1.5^{o}C higher than they were 50 years ago. Summer temperatures are about 0.5 to 0.7^{o}C higher and spring temperatures have increased by about 1^{o}C, while autumn temperatures do not exhibit any strong trend. This data suggest that we should expect to find similar seasonal impacts to changing climate conditions across much of eastern and southern Ontario.

Future Climate

Ottawa weather station data provide a long term record of climate that is generally applicable to Mississippi watershed. In Figure 1 historical mean annual temperature and precipitation data are plotted along with the high, low and mid-point values from the outputs from a suite of Global Circulation Models (GCMs) used in a recently completed national-scale assessment. These outputs provide a range of scenarios of future climate.

Current rates of change in annual temperatures (top panel, Figure 1) in Ottawa are roughly consistent with the future mid-range rates of change (trend line) suggested by the climate models. Precipitation data (bottom panel, Figure 1) are more variable, but annual historical values have increased from the 1960's. Most scenarios suggest that annual precipitation will continue to increase into the future.



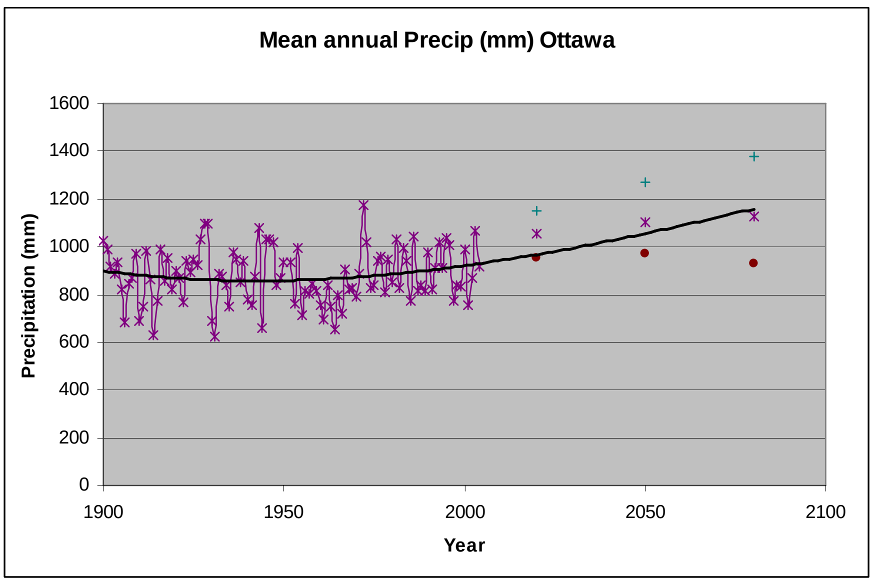


Figure 1: Mean Temperatures

Observed and projected mean annual temperatures and precipitation for the period 1900 to 2100 (projections as mean values for 30 year periods). High, low and midpoint projected values from the ensemble are shown. Recent trends are consistent with the direction and magnitude of change suggested by climate models.

The same GCM outputs were used to generate a range of future seasonal temperatures and precipitation, averaged over 30 years centered on 2020, 2050, 2080. The data are presented as box and whisker plots (Figure 2). This type of plot is a means of presenting summary data about a large data sample. The whiskers represent the maximum and minimum data values while the box (height) encloses 50% of the data values. For comparison, actual historical data for Ottawa averaged over 30 years (1961 to 1990) is also included in the figure. The plots suggest that we can expect to experience significant changes in mean temperatures in all seasons, while changes in precipitation may be more variable with the largest changes likely in winter and summer months.

Figure 2: Scenarios of future seasonal temperature and precipitation (courtesy of Elaine Barrow) compared to averages for 1960-1990 at Ottawa. See text for explanation of plots.

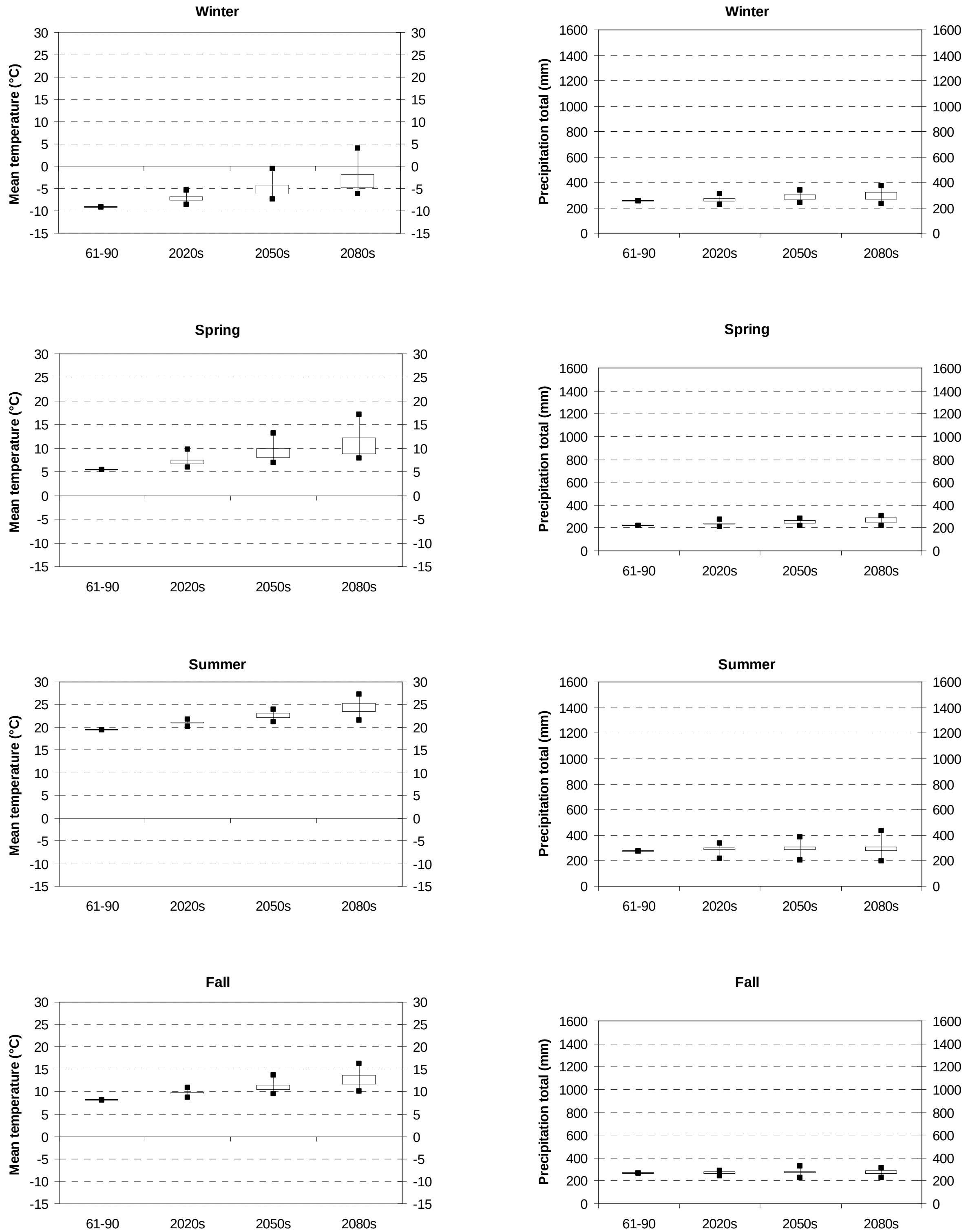


Table 1:#Historical trends and projected future changes in Mississippi watershed#

Recent changes (last 40-60 years)	Projected changes (within next 50 years)
Air Temperature	
1°C increase in average winter, summer and spring temperatures	Approximately 3.5°C increase in all seasonal average temperatures
15 day increase in length of growing season	Further 15 day increase in length of growing season
Increase in number of hot summer days	Doubling of number of summer days over 30°C
Fewer days below 0.0 °C and fewer extreme cold winter days	Shorter winter season and extreme cold days become very rare
Precipitation	
Increase in total annual precipitation	Increase in total annual precipitation likely, (10 – 20% range) but with more and longer dry conditions during summer between rain events More heavy precipitation events and associated winds
Greater winter precipitation, but more falling as rain	Increase in winter precipitation, more rain; snow cover duration significantly reduced (may be 70% reduction), fewer but heavier winter storms likely
Evapotranspiration	
6% increase in annual evapotranspiration	Continues to increase with temperature
Water Temperature	
Increase in seasonal temperatures of at least 1°C	Continues to increase (order of 3.5°C,) notably in summer.
Ice cover duration more highly variable but up to 20 days shorter than in the past	Ice cover quite variable, shorter duration (order of 40% reduction) and unreliable
River Flows	
Increase in total annual discharge	Possible decrease in annual runoff, but more frequent extreme rainfall events may produce high peak discharge events.
Peak spring flows occurring earlier	Peak spring flows occur earlier (2- 3 weeks), also lower spring flows due to reduced snow accumulation in winter
Summer flows generally lower	Summer flows can be extremely low
Fall flows sometimes higher	Fall and winter flows may double in response to more frequent extreme events
Winter flows higher	
Annual flooding can occur in any season	Annual flooding can occur in any season
Lake Levels	
Variable, but lower in some years	Decrease in annual levels likely
	More frequent and longer periods of low water levels in summer possible

Some of the key changes observed in the watershed over the past 40-50 years, and those changes projected by 2050 on the basis of climate model output, are elaborated in Table 1. Of particular importance is the fact that evaporation is currently increasing in the Great Lakes region as a whole at a rate of about 6% for a 1°C rise in air temperature. Future annual evaporation rates will likely continue to increase as temperatures rise. Transpiration rates (water lost through plant tissues) are also linked to air temperatures as well as to the length of the growing season. It appears future increases in annual future evaporation and transpiration will overwhelm any small increases in precipitation. The implication is that soil moisture levels, water levels and river discharge could decrease during the snow-free season.

Table 1 highlights, in summary form, that in future we can expect more of the sorts of change that are already underway in the watershed. The following pages identify the likely impacts from changing conditions in the watershed, and outline some possible adaptation options. Note that many future impacts will result from the interplay of a number of variables, but for simplicity here they are linked to one key climate variable.

Tourism and Recreation

Tourism and recreation are an important part of the overall economy of the Mississippi watershed, particularly so in areas away from the larger centres. Almost all residents take in local attractions, boat on lakes or simply enjoy a variety of day use activities. Many others who live outside of the watershed use or own cottages within in it. They purchase a range of supplies, employ local builders, and use local services. Others use a range of facilities, from Provincial Parks to ski-hills, on a weekend-use basis. All contribute to the local economy. Changing climate will affect how, when and where tourist dollars are spent, creating opportunities and causing changes in the nature of the tourist industry.

Overall, demand and use of the tourist and recreation facilities may increase because of an ameliorating climate. With longer summers and less harsh winters, Canadians indicate that they will travel more within Canada (28% less airline departures by 2050) and foreigners will find Canada a more desirable destination (40% increase in arrivals by 2050). Mississippi watershed may attract some small part of that increase. In addition, it is likely that more traditional users will want to make more use of the watershed. Beach and swimming pool use will likely increase significantly during hotter summers, as will Provincial Park use. Because warm season tourist activities are largely tied to water use, there will be increased demand for high water levels and high water quality in lakes and rivers for both swimming and fishing. This may be challenging, as low summer flows are now occurring three times as frequently as 40 years ago (see Water). It is likely that a reduction in the numbers of cold water fish species, such as lake trout, will result in some fishers choosing to leave the basin and moving their recreational activities further north (see Fisheries).

Warmer spring and fall seasons in the watershed may become much more attractive for tourists and recreational users. If current rates of seasonal change prevail, the shoulder seasons could extend the total season by about 6 weeks by 2050.

Changes in winter climate will also affect tourism and recreation, Snow cover and ice cover will deteriorate significantly. The skating season on the nearby Rideau Canal may be reduced by 44% by 2050, and in some years it may not be viable at all. What have been good snowmobile or cross-country ski river-crossing points in the past may not be safe in the future, and conditions are already changing. Workshop participants pointed out that the dates of annual winter ice-fishing events, for example on Clayton Lake, have changed because of persistent strong early January thaws and poor ice conditions.

Warmer winters may be associated with increased precipitation, however a higher percentage will be falling as rain and melt will be higher, such that snow cover can be expected to be reduced. Snowmobile (and associated ski and snow-shoe) trails may be reduced in length of use by 70% by 2050. Alpine ski areas with snowmaking equipment may fair better, but could still suffer about a 14% reduction in the length of the season.

In response, the timing of many events that attract tourists throughout the year will likely change, including hunting and fishing seasons, maple syrup season, and others.

An ongoing study of climate change and variability is monitoring tulips in 11 communities in eastern Ontario, including Almonte and Carleton Place ("Albert's Gardens"). Early results suggest that a warming of 2-2.5°C will shift bloom dates (earlier) by about two weeks, and also result in a much shorter bloom season. The phenology of other domestic flowers and wildflowers, including orchids at the Purdon Conservation area, a significant local tourist attraction, will also shift.

Significant changes for the tourist industry and associated service industries in Mississippi watershed are virtually certain, and adaptive responses will be needed.

Table 2: Sensitivities, impacts and concerns—Tourism in the Mississippi Watershed

Variable	Impacts/Implications	Possible Adaptation
Air Temperature Higher seasonal temperatures More heat waves Longer growing season	– Expect both more tourists and a longer "warm weather" tourist season. – On the basis of climate alone, expect more tourist arrivals by air in Canada (16% by 2025, 40% by 2050). – On the basis of climate alone, expect less air departures (15% by 2025, 28% by 2050). – Expect beach use to increase by 12% by 2020, 21% by 2050. – Expect Provincial Park use to increase by 30% by 2020, 50% by 2050. – Golf season: expect rounds played to increase (13% by 2020, 23% by 2050). – More "warm weather" boating/fishing use of lakes & rivers (growth in associated industries). – Greater demand for trails, hiking, biking, trail- riding, eco-tourism etc. – Greater demand/use of ATVs (trail damage). – Change in timing of special events (Tulip Festival, sugaring season, Purdon Orchids). – Expect more "off season" tourism & also a shift in demographics, increase in day use.	– Raise awareness that conditions are changing, plan for it, need to consider the whole mix of activities, not just one activity at a time. – Need to maintain wilderness areas/opportunities in the watershed. – Opportunity for shared involvement of all parties (government , naturalists, cottagers, business, farmers etc.) in developing a plan. – Beach development, opportunities for beach side patio restaurants etc – balance against water quality challenges - other options include waterslides, swimming pools etc. – Provincial Park planning must include climate change, may need more parks, more venues etc. – Growth in associated industries. – Further develop eco-tourism, trail maps, canoe routes. – Review/assess potential future impacts of ATVs, sustainable trails – local workshop? – The warmer seasons may open the door for new events, be the first area to react. – Hunting, fishing seasons will need to change. – Tourist venues will need to be open longer and to be targeted more to shoulder season clients.

Table 2: Sensitivities, impacts and concerns—Tourism in the Mississippi Watershed

Variable	Impacts/Implications	Possible Adaptation
Precipitation More rain in winter Longer dry periods More heavy rain events – flash rains and surface runoff more common	– Less water available with potential water quality issues in some years (summers) and areas, with a negative impact on tourism. – Some extreme bad weather days and damage. – Alpine skiing season (with snow making) down 10% by 2020, 14% by 2050. – Snowmobiling season, down 40% by 2020, 70% by 2050, similar for snow-shoeing and cross-country skiing.	– Promote source water protection. – Promote better manure/fertilizer management plans, erosion control. – Raise awareness of possible restrictions to release of treated sewage water. – Special one day events are risky – assess/consider cleanup issues. – Diversify tourism activities, link opportunities to conferences, weddings: become a four season destination.
Evapotranspiration Actual evapotranspiration rates have increased about 6% for a 1°C increase in air temperature, likely to continue to increase	– Greater demand for water for golf courses etc. (plant and soil water-loss will increase).	– Raise awareness of a need for water conservation. – Plan for/consider implications of increased water withdrawals (i.e. farms, golf courses).
Water Temperature Increasing throughout the seasons Longer open-water periods/shorter ice-cover periods	– Ice cover not as safe as in past, winter recreational activities at risk; – Skating season (Rideau Canal) down 23% by 2020, 44% by 2050. – Poor ice conditions may limit snow-mobiling, cross-country skiing etc. – More limited winter fishery. – Loss of cool/cold-water fish in some lakes. – Potential for less winter cottage use (around lakes); loss of winter fishers. – Loss of associated revenue, from supplies, gas, equipment, food.	– Raise awareness of changing conditions (ice monitoring for safety, ice huts pulled earlier). – Use regulations, length of season etc. to protect desirable fish. – Use hatchery reared cool/cold-water fish. – Promote use/value of warm water fish such as bass. – Diversify tourist opportunities: develop all season hiking trails, winter horse riding, hay and sleigh rides, etc. to specific points of interest not just straight concession lines.
River Flows and Lake and Well Levels All lower in some seasons/years more frequent extreme flooding events	– Extended use of open water, demand for higher water levels. – Loss of use of docks/marina's, water access; shoreline ownership and use of exposed lands. – Increase in low water hazards – rocks etc. – Flooding damage may occur in any season.	– Determine to what extent river management can balance the change in flow regime. – Reduce other water demands through awareness. – Use floating not fixed docks. – Examine trade-offs and options, "new" floodplain mapping and land-use zoning may open up opportunities for tourism.

Forestry

Our forests and woodlots provide many benefits including: wood products, employment, areas for recreation and many ecosystem services such as water retention and erosion control. Some small communities rely heavily on forestry for their economic well-being. All of these benefits may be affected as forests change.

A mean annual warming of about $3.5^{o}C$ is anticipated by 2050. This will allow trees from much more southerly locations to grow in the watershed. However, the fact is that this rate of warming is about 10 times faster than the natural migration rate of most trees. Changing climate will, favour some species and disadvantage others. As a result, our forests are likely to look different in 50 to 100 years. Human intervention using focused planting programs, and perhaps modified trees, may be needed to manage the change (see Ecosystems).

Temperate deciduous tree species, such as hickories and oaks, are going to fare better than those boreal softwood conifers which are currently near the southern limit of their range in Mississippi watershed. In time, and within limitations presented by soils and bedrock, the present mixed woodland landscape will become increasingly temperate and deciduous and more typical of the Carolinian Forest.

In the short term, longer growing seasons, higher heat-units, and elevated CO_2 levels are likely to increase growth rates (timber production) as long as summer soil-moisture content and nutrient levels are adequate. The importance of summer soil-moisture to tree health was noted by workshop participants: trees on shallow bedrock soils in the watershed during late summer 2007 were commonly experiencing significant leaf-drop (marking tree stress). Susceptibility to disease is enhanced by stress, particularly water stress. Increasing evapotranspiration rates will exceed any moderate increase in precipitation in the watershed. Water stress will be most common in trees on shallow-bedrock soils or on soils with poor water retention.

Many insect pests are currently limited by climate; typically by extreme winter temperatures. As climate warms, new invasive species may become established and native pest species may expand their range. Forest tent caterpillars and gypsy moths, which already occur in the area, are likely to expand northward while the emerald ash borer is likely to arrive in numbers soon. As climatic conditions become more favourable populations, of exotic pest species that lack natural predators, parasites, or disease controls may expand rapidly. Many forest trees will be stressed and more susceptible to insect borers, leaf-eaters and diseases alike. Significantly warmer summer temperatures will lead to drier forest floors and an increased length of the fire season, likely leading to more frequent and severe forest fires. There will be a need to enhance forest fire fighting capacity and, in critical areas, manage forests to reduce fire risk.

In terms of forest management, current planning processes typically do not yet factor in climate change. The length of the winter harvest season will shorten significantly in future, and it is clear that assumptions about growth rates, harvest dates, possible levels of disturbance, suitability of sites, suitability of seedlings and seed stock need to be reconsidered. Salvage harvesting will become very important in the watershed as time progresses.

Some woodlots in the watershed are managed for maple syrup production. Sap flow is very much related to weather and climate, but in complex ways. In addition to recognizing that the timing of the season will shift, coming earlier in the year, there are concerns about the overall length of the future season and about syrup quantity and quality.

Table 3: Sensitivities, impacts and concerns—Forestry (woodlots) in the Mississippi Watershed

Variable	Impact/Implications	Possible Adaptation
Air Temperature Higher seasonal temperatures More heat waves Longer growing season	– As long as there is adequate moisture, growth rates should increase for many species of trees. – Less winter temperature damage and winter kill of sensitive trees (i.e. trees in current hardiness zones 5 and 6). – New opportunities for valuable species—such as black walnut—and invasive “weed” species. – Species composition of "natural forests" are changing; rate of climate change is expected to occur faster than species can grow /reproduce/re-establish. – Changes in forest ecosystems are expected. – Timing and length of sap flow season will change (especially important for maple syrup production). – Warmer winters will lead to less winter-kill of pests (spruce budworm, jack pine budworm etc.). – New pests are showing up and surviving (e.g. emerald ash borer, asian long-horned beetle).	– Raise awareness that conditions are changing, and the need to plan for it. – Because growth rates will vary with climate on a species by species basis update forest management and harvest plans; need flexible harvests - cull poor performers and harvest immediately to remove infected trees; manage forest structure - forests with different tree types and different ages will be more resilient. – Consider climate change in all future planting strategies—plant trees resistant to known threats. – Because forests have greater value than just as a wood source diversify woodlot activities, consider eco-tourism, trail walks etc. – Enhance trails and road allowances manage shrub plantings, consider pests and visual impacts of defoliation. – Develop monitoring programs for pests, adjust harvest plan or spray/control as needed. – Salvaged wood is likely to become an important wood source. – Underplant or replant later where needed.

Table 3: Sensitivities, impacts and concerns—Forestry (woodlots) in the Mississippi Watershed

Variable	Impact/Implications	Possible Adaptation
Precipitation More rain in winter Longer dry periods More heavy rain events – flash rains and surface runoff more common	– Less water available in some years and some seasons perhaps slowing growth. – With climate change, more marginal land will come out of agricultural use but will still be useful for forests, carbon storage etc. – More extreme wind and ice storm damage associated with seasonal storms. – Ice-rain will be harder on some species than others (e.g. poplar and birch). – Less favourable and shorter harvest season. – Potential for more damage by skidders, greater soil erosion because of less snow cover.	– Alter/update harvest and planting schedules identify thresholds for intervention. – Take advantage of "new land" for such things as carbon sequestration, source water protection etc. – Harvest (some) mature or overly mature trees; protect forest edges with shrub plantings to reduce wind damage. – Take into account shorter harvest season (snow cover) and the need for more selective harvests to remove none performers. – Safe-guard the soil in shallow soil areas, to protect against loss of any potential future harvest.
Evapotranspiration Actual evapotranspiration rates are currently increasing by about 6% for a 1 ^{o}C increase in air temperature – likely to continue to increase.	– Soil moisture lower, some early tree die-offs will occur in shallow bedrock areas. – Risk of forest fires is and will increase in area because of drier conditions, more lightening strikes, longer fire season, dieback from insect/microbial damage, more wood litter on forest floor, poor shape of many trees/woodlots and the fact that we historically fight all forest fires – litter accumulates if not burnt-off. – Increased fires puts property loss at risk, potential loss of employment, loss of related activities (e.g. tourism, maple syrup facilities), loss of historic sites, and in the extreme homes and towns.	– Decide which areas and trees most at risk selectively harvest and replant appropriately. – Consider other conservation needs (shelter/food supply, old growth forests etc.). – Raise awareness of risk, and need for caution to prevent forest fires. – Remove or clean deadfall in some areas, consider benefits of prescribed burns. – Be "firesmart" have firebreaks around homes and buildings and forest based communities, thinning may substantially reduce the risk. – Promote the use of local trees/products so that forests are used and maintained appropriately.

Fisheries

Fish in Mississippi watershed, as elsewhere, can be grouped into distinctive guilds (cold, cool and warm water) depending upon species preferences and needs for both recruitment and growth. All guilds can exist in a dynamic balance in a given water body. However, Mississippi Watershed is located near the southern range for some cold water species such as lake trout and the northern limit for some warm water species such as bass. This in itself suggests that major changes in local fisheries can be expected as lakes warm. Water temperatures are indeed on the rise; a long water-temperature record is available from Bay of Quinte. Recent work in eastern Ontario has begun to quantify what changes are occurring and will occur with future warming. A temperature rise of only a few degrees can cause very large shifts (15 times or more) in recruitment success of the warm water guilds and similar declines in the cold water guilds. In addition, as temperatures rise, growth rates of mature fish may decrease for cool and cold water fish but increase for warm water species. Apart from these direct climate impacts, warming conditions also favour the rapid expansion of what some consider less favourable competitors that can have negative impacts on existing fisheries (e.g. rock bass eat prey used by lake trout while crappies devour walleye fry).

In addition, climate induced water level fluctuations at critical periods in the growth cycle can also be crucial to the successful recruitment of many species (e.g. pike). Water flow and discharge patterns are shifting in Mississippi Watershed (see Water) and in some cases there may be negative impacts on the fish. It is complex but participants and fish biologists at the Weathering Climate Change workshop report that change is underway: i) only remnant lake trout populations are now found in Silver Lake; ii) Mississippi Lake has largely switched from a walleye fishery to a warm-water fishery; iii) the annual spring walleye run, Mississippi River, at Innisville, is very much reduced since the 1960s; iv) some deep, headwater-lakes in the western part of the basin have over the past 30 years lost cold water fish species such as white fish and burbot. A report to be released by Casselman et al in 2008 shows that recruitment rates in lakes studied in the watershed are indeed shifting and that such change will continue.

Management (adaptation) options to deal with both current and future changes in fisheries will be lake and species specific. Fisheries management options could involve specific stock interventions including for example put and take programs and/ or replacing stocks. It could also involve water management (e.g. manipulating or maintaining suitable lake temperatures, river flow, water levels) and maintaining water quality to reduce stress on fish. It may be possible through ongoing selective fishing or commercial fishing to reduce numbers of warm water competitors. However, in the long run fishers may simply have to adjust to the changing species composition in lakes and value and utilize the whole resource. In this regard continued warming winter conditions mean that the winter fisheries will become more limited and the summer fisheries more dominant.

In summary, both control of expanding warmer water fish-stocks and actions to enhance survival of cool and cold-water species may be required. Such actions may be expensive and justifiable only in the most suitable lakes or river reaches where such interventions have the greatest chance of success. To be sure, crappie and bass fishers are every bit as passionate about their choice of species for sport as are other species-specific fishers who seek cold-water fish such as lake trout. Users will need to value all fisheries and utilize them for the sport and food that they provide. If possible, it is desirable to maintain diverse fish communities in the watershed. Participants at the Weathering Climate Change workshop felt that there was a strong need to raise awareness of the fisheries issues, encourage the use of all fish stocks, and make fish part of our 100 mile diet.

Table 4: Sensitivities, impacts and concerns—Fisheries in the Mississippi Watershed

Variables	Impacts/Implications	Possible Adaptation
Air Temperature Higher seasonal temperatures More heat waves Longer growing season	– Recreational patterns change, spring and fall more amenable to on water activities. – Switch in fishing pressure, less in winter more in summer. – Demand for higher summer lake levels and flows. – Increased aquatic plant growth.	– Start to promote summer fisheries. – Promote warm water fish use.
Precipitation More rain in winter Longer dry periods More heavy rain events – flash rains and surface runoff more common	– Water quantity and quality in some years and areas poor, impact on fish quality. – Potential for pollutants to be washed into river system during extreme events. – Water level fluctuation may be too extreme for some species. – Increased sedimentation, particulate matter in water column, and scouring.	– Monitor fish quality. – Source water protection. – Improve quality of urban effluent. – Encourage manure/fertilizer management plans; – Develop riparian buffer zones. – Wetland protection and maintenance. – Encourage re-vegetation/ naturalization of shorelines).
Evaporation and Evapotranspiration Actual evapotranspiration rates are currently increasing by about 6% for a 1^{o}C increase in air temperature, likely to continue to increase.	– Greater surface water loss, less inflow from shallow ground-water sources. – Streams may become ephemeral and/or warmer. – Increase in emergent aquatic vegetation, leading to water loss (transpiration).	– Encourage reforestation where possible (helps to maintain summer groundwater inflow into lakes and mines to reduce the magnitude of spring floods).

Table 4: Sensitivities, impacts and concerns—Fisheries in the Mississippi Watershed

Variables	Impacts/Implications	Possible Adaptation
Water Temperature Increasing throughout the seasons Longer open-water periods/shorter ice-cover periods Greater thermal inertia in lakes	– Ice cover, not as safe as in past, shorter duration cover. – Winter sports fisheries at risk. – Potentially less fish winter- kill. – Aquatic plants and algae expand with longer aquatic growing season. – Changes in depth of thermocline and position of fish in water column. – Increased summer kill of fish. – Conditions move to favour warm water fish. – Expect average yearly recruitment to increase in warm water species (e.g. bass) to double by 2020, and increase 15 times by 2050; expect a decrease in cold water fish (e.g. lake trout) recruitment by similar amounts. – Conditions will be more conducive to invasive warm water species. – Expect outbreaks/fish deaths associated with toxic-producing strains of bacteria such as *Colmunaris.*	– Raise awareness of changing fishing conditions, & risk of invasive species, target schools, sports fishers, cottage associations, public, government etc. – Use stocking programs to minimize thermal bottlenecks for cold water fish (e.g. trout). – Take actions to maximize and promote potential and use of summer fishery and warm-water species. – Long term monitoring: changing water conditions and species with time, response will be species specific. – Consider viability of options such as only catch and release of valued species, change in start/end of season etc. – Protect key feeding/spawning areas. – Assess potential to use water management to flush river/lake system, moderate temperatures. – Promote full use of (removal of) warm water fish, in cool/cold water lakes through: catch and keep, derbies, commercial fishing. – Awareness—eating quality of fish is high. – Manage rivers and lakes to protect cold-water species recruitment. – Keep water quality high.
River Flows, Lake Levels, Ground Water All lower in some seasons/years More frequent extreme flooding events	– Low, or changing water levels and/or loss of wetlands, shallows will affect spawning. – Competition for remaining water flow in time of drought. – Flooding – peak floods may occur in any season and affect fry through increased scouring and flushing.	– Assess potential to use water management to regulate flow and water levels for fish. – Keep wetlands wet. – Assess the need for more water storage in the basin to moderate floods and to enhance flow during droughts. – Examine sector trade-offs and choices in maintaining sensitive species. – Reforest basin where possible.

Health and Well Being

The most significant health impacts associated with a changing climate are likely to relate to temperature stress; air pollution; extreme weather events; vector and water-borne diseases; and exposure to ultraviolet (UV) radiation.

If projected warming leads to an increase in outdoor activities, as seems likely, (see Tourism) then there is an associated risk of greater exposure to ultraviolet (UV) radiation. Related health impacts would include temporary skin damage (sunburn), eye damage (e.g. cataracts) and increased rates of skin cancer. However, through raising awareness and the use of sunscreen and proper sunglasses these risks can be minimized.

Although current cold related mortality numbers in the region are not high, warmer winter temperatures mean that these numbers could drop by perhaps as much as 45% by 2050. On the other hand, warmer summers will result in increased problems due to heat stress. During the summer of 1999 it is estimated that 41 excess deaths occurred from heat stress in Ottawa. Participants at the workshop noted that moderately hot days (over 25^{o}C) are more numerous now than in the past, an observation supported by Ottawa weather data. They also noted that air conditioners are now more commonly in use. Environment Canada issues an advisory when the temperature is forecast to reach 30°C or when the humidex reaches 40^{o}C, or at specific humidex readings for certain regions. Over the period 1960 to 2000, Ottawa averaged 8 days per year above 30^{o}C. That figure could double by 2050 and quadruple by 2080. These figures are averages; extreme years will have even more hot days. In addition, a critical consideration is overnight temperature. If nights are relatively cool then they give relief and are more conducive to sleep, even if the days are hot. Unfortunately, overnight temperatures are expected to rise faster than daily maximums. Heat stress is likely to be most severe in the elderly, those who feel compelled to work outside in spite of extreme heat, those that live or work in poorly insulated or non-air-conditioned buildings and/or in buildings surrounded by asphalt or concrete. Detailed alert systems, such as Toronto's Hot Weather Response Plan, are designed to reduce risks.

Thousands of Canadians die prematurely each year from short and long-term exposure to air pollution. The Ontario Medical Association has estimated that the air pollution in Ontario annually results in 5,800 premature deaths, more than 16,000 hospital admissions, almost 60,000 emergency room visits and 29 million minor illness days. These figures will go up as the population ages. Pollution and climate warming will cause more smog and poor air days, with perhaps a 15-25% increase in deaths by 2050 in larger Ontario cities like Ottawa. Some of this poor air will reach the Mississippi watershed. Local forest fires or burns (see Forestry), may also have local implications for air quality. In addition, warmer and longer summers will also increase pollen counts and days with high concentrations of pollen in the air with some adverse respiratory impacts.

Future changes in climate could lead to more favourable conditions for the establishment and re-emergence of vector-borne diseases, as evidenced by the recent spread of Lyme disease. The range of the tick vector is thought to be constrained by temperature, spring migratory bird densities and woodland habitats. Warmer winters and springs will allow populations to continue to expand northward and increase in density, increasing the risk of exposure in the watershed.

Extreme weather can have significant direct and indirect impacts on human health. For example the 1998 ice storm resulted in 28 deaths, an estimated 60,000 physical injuries and tens of thousands of individuals potentially affected by post–traumatic stress disorder in eastern Ontario, southern Quebec and parts of the Atlantic Provinces. Many additional deaths and injuries occur during or after extreme events as traffic accidents. Localized extreme rainfall events can cause sewers to back-up and basements to flood. This can lead to mold build-up in basements. Some estimates from climate model outputs suggest that, locally, what are now 20 year precipitation events will be more than twice as frequent by 2050.

The young, the elderly and people with impaired immune systems are particularly sensitive to water-borne gastrointestinal diseases. The incidence of enteric infections, such as caused by *Salmonella* and *Escherichia coli* (*E. coli*), is in part sensitive to heavy rainfall and high temperatures. As such, climate change could lead to an increased risk of such infections in residents in the watershed. As the Walkerton outbreak has shown, Ontario's water supply is vulnerable to water-borne disease outbreaks. Source-water protection represents an important step in reducing the risks of water-borne diseases.

Table 5: Sensitivities, impacts and concerns—Health and Well being in the Mississippi Watershed

Variables	Impacts/Implications	Possible Adaptation
Air temperature Higher seasonal temperatures More heat waves Longer growing season	– If more time is spent outdoors – UV radiation more of an issue, sunburn, skin cancer, eye damage. – Higher incidence of heat stress, deaths; – More smog, and resultant cardiovascular and respiratory disorders – possible deaths. – Pollen and spore production will likely increase, increasing allergies. – Diarrhea and food poisoning expected to increase with warmer temps (e.g. meat spoilage. – Less winter kill of pests (vectors) and longer disease transmission season resulting in introduction/spread of diseases (e.g. Lyme disease, West Nile virus). – Emergence of entirely new diseases. – Fewer cold-related injuries/illnesses.	– Raise awareness of UV issues, promote protection. – Heat and air quality alert systems. – Better insulation, green roofs, air conditioners, move sleep areas down stairs, adequate emergency shelters. – Use air filters. – Reduce activity when air quality poor. – Raise awareness of increased risks. – Raise awareness of ticks and protection against Lyme disease. – Protective action for mosquitoes in mid-summer (West Nile Virus). – Assess current local monitoring and early warning programs.
Precipitation More rain in winter Longer dry periods More heavy rain events – flash rains and surface runoff more common	– Water availability and quality in some years and areas poor. – Flash floods can move bacteria into water (e.g. Salmonella and Escherichia coli). – More forest fires, which affect air quality; – Potential mold issues. – Social disruptions and related issues resulting for example from local crop failures.	– Promote source water protection – Promote better manure/fertilizer, management plans. – Develop riparian buffer zones. – Deeper wells. – Need to ensure local water supply. – Promote air filters for molds and increase awareness. – Assess support systems.

Table 5: Sensitivities, impacts and concerns—Health and Well being in the Mississippi Watershed

Variables	Impacts/Implications	Possible Adaptation
Evapotranspiration Actual evapotranspiration rates are currently increasing by about 6% for a 1 C increase in air temperature – likely to continue to increase.	– Greater fluid loss in humans.	– Raise awareness of need to drink fluids to avoid dehydration.
Water Temperature Increasing throughout the seasons Longer open-water periods/shorter ice-cover periods Greater thermal inertia in lakes	– Ice cover not as safe as in past, winter recreational activities at risk. – Summer water quality and temperature issues, leading to outbreaks of parasites causing, for example, swimmers itch.	– Raise awareness of changing conditions. – Assess adequacy of lake-ice safety programs, and need for monitoring programs. – Assess adequacy of water-quality monitoring programs in rivers and lakes and wells.
River Flows and Lake and Well Levels All lower in some seasons/years More frequent extreme flooding events	– In some years and in some areas water marginally adequate for needs. – Peak floods may occur in any season.	– Assess capacity to ensure drinking water supply in drought years. – May need deeper wells. – Reduce water demand (conservation). – Review floodplain mapping and land use. – Assess infrastructure/people at risk. – Promote source water/well protection and reduction of pollutant loads in surface waters. – Promote emergency kits (72 hours supply).

Agriculture

The agricultural sector can be highly adaptive to climate change if information is available to the farming community and if opportunities and risks are well defined. Agriculture has continually adapted to changing conditions in the past, as reflected in land drainage, irrigation, hybrid crop development, tillage systems, and crop insurance activities, amongst others.

On the positive side, there are likely to be several benefits for agriculture. Warmer average temperatures, if all else is equal, will mean higher crop yields. The growing season has extended by 15 days in the past 50 years or so in eastern Ontario, and it is likely to extend by another 15 by mid-century. At that time, the growing season in Mississippi Mills will be more like that in Windsor today.

Future problems will most likely be related to the frequency of extreme events, including higher temperatures and drought. Summer drought-like conditions have become more common during the last 40 years, and this trend seems likely to continue into the future (see Water). Awareness, local early warning systems, and long term precipitation forecasts could help farmers immensely.

Water management is likely to be key to successful adaptation. Possible actions include contour plowing and cropping, no till programs that will maintain soil-moisture and top-soil, use of ponds and dug-outs to store water for drought conditions, and more extensive use of irrigation systems. Management strategies should consider actions such as adjustments to the timing of planting, the use and/or need for irrigation waters and crop substitution when and where it makes sense. Support/insurance programs of one form or another can help to balance extreme bad years, but problems can develop if these programs support practices that will no longer be sustainable.

Ironically, at the same time that drier conditions will be a concern, precipitation events, when they do occur, are likely to be more intense than in the past (see Water). This has important implications for soil erosion, and leaching of potential contaminants (fertilizers, herbicides, manure and pesticides) from fields.

Farm infrastructure can be substantial, and costly to build and maintain. In future, heating needs will decline. Cold events that now occur once every 20 years will occur only very, very rarely by 2050, offering clear benefits for livestock farmers. Unfortunately, winters are also likely to be more damp than today, with more of the precipitation falling as rain and more melt during the winter months than in the past. By 2050, winter temperatures will likely be about 3.5°C warmer on average than those of 1960- 1990.

Increased summer heat is likely to be a problem for both farmers (see Health) and livestock. Barn cooling systems that were designed for historical conditions may become inadequate.

Higher summer temperatures could have adverse affects on farm animals resulting in lower weight gains in beef, lower milk production, and lower conception rates in poultry, rabbits, and other associated losses. In some cases, cooling or shading (shade-tree planting) will be justified.

Many of the social challenges facing farms and farmers today are likely to continue into the future, including; the need for farm size to increase to compete effectively, increases in operating costs, urban encroachment driving up land prices, and other urban/rural disconnects. There has been a general loss in agricultural services and increasing emergence of environmental regulation. Farming is no longer the dominant force that it once was in the watershed, and more people are abandoning farm life. This suggests that many farms lack the capacity that they once had to adapt to change. Climate change is going to exacerbate these problems. Participants at the workshop emphasized the need to support local farms, including using and promoting local produce and a 100 mile diet where possible. It may be necessary to promote other types of support programs, to facilitate change as well.

Table 6: Sensitivities, impacts and concerns—Agriculture in the Mississippi Watershed

Variable	Impact/Implication	Possible Adaptation
Air Temperature Higher seasonal temperatures More heat waves, longer growing season	– Potential for better crop yields, heat-units up, (e.g. corn, sorghum, soybeans). – Less winter kill of perennials. – Better conditions for invasive weeds – Current barn cooling systems may be inadequate. – Potential for adverse affects of heat on farm animals, lower weight gains in beef, lower milk production, and lower conception rates in poultry, rabbits. – Less winter kill of pests (insects/deer/rats mice/geese/ animal parasites) leading to more crop and/or animal losses.	– Choose crops carefully, but look to more drought resistant species. – Switch to longer maturing varieties or new crops. – Assess weed control program. – Flexibility is key; small to medium sized operations may be disadvantaged. – Re-assess cooling loads for barns etc. – Better pest control programs. – Monitor changes, local pest advisories may be needed. – Spraying/control as needed.
Precipitation More rain in winter Longer dry periods More heavy rain events - flash rains and surface runoff more common	– In dry summers – crop loss. – More soil erosion (e.g. a 10% increase in rain intensity may mean a 24% increase in erosion). – Higher winds blow down of crops. – Potential for ice rain, power loss; power critical for some operations. – Higher probability of well and water pollution from intense rain/more run-off. – During intense drought, potential for water to become toxic from sulfur and blue/green algae.	– Insurance programs will continue to be needed to offset the broad-based changes occurring. – No-till programs adjust timing of harvest and planting programs, alter tile drains. – Plant setbacks to decrease erosion and sedimentation along ditches and other waterways. – New improved crop varieties. – Many operations will need power back-up – Waste water and manure management plans. – Develop buffer zones around/wells/ lakes and rivers. – Protect ponds and monitor/ raise awareness that animals could be at risk.

Table 6: Sensitivities, impacts and concerns—Agriculture in the Mississippi Watershed

Variable	Impact/Implication	Possible Adaptation
Evapotranspiration Actual evapotranspiration rates are currently increasing by about 6% for a 1°C increase in air temperature – likely to continue to increase.	– Soil moisture regime is changing. – Greater water loss, plant stress. – Surface water loss.	– Retain soil moisture, snow fence—or "standing corn fence"—conservation tillage. – Grow more drought resistant crops. – Need to replenish livestock water containers more frequently, shading and wind protection. – Develop tools to predict soil moisture conditions. – Better, long range forecasts.
Water Temperature Increasing throughout the seasons Longer open-water periods/shorter ice-cover periods	– Surface water in summer may not be as good for stock as in past (too warm).	– Monitor for increased temperature and bacterial counts and contaminant levels. – Assess possibilities for other water sources.
River Flows, Lake and Well Levels All lower in some seasons/years More frequent extreme flooding events	– Groundwater – hard-water problem may develop as levels drop in wells. – Natural springs, shallow wells and creeks may only be marginally adequate for livestock/crop needs. – Flood peak could occur in any season.	– New water sources may be needed. – Ponds, dug–outs for summer. – Consider framework for participatory irrigation, advisory committee. – Evaluate farm infrastructure (bridges/drains) that may be at risk.

Ecosystems

Ecosystems are dynamic with both biological (plants, animals) and physical (soil, landscape, water) components. The concepts of ecozones and ecoreregions were developed based on historical relationships. Under a changing climate, the changing distribution of individual species will depend on a large number of factors, including migration rates, migratory pathways, presence of pollinator species (for some types of vegetation), and many others. Ecosystems will not move as a single unit. In Ontario, with a 1^{o}C increase in mean annual temperature over the last 50 years, 41% of 175 terrestrial species studied are showing recent range expansion or contraction. Together, this suggests that ecosystems in the future will undoubtedly look different than those of today.

Changing climate also has the potential to create significant changes in the demographics of populations. For example: successful over-wintering of many mature adults can result in rapid population expansion (e.g. black legged ticks, or ants); changes in the timing of life cycle events could result in two nestings instead of one during a longer summer season (e.g. bluebirds); genetic modification causing species to breed earlier (e.g. red squirrels in some areas) or later because conditions would otherwise be too warm (e.g. lake trout in some lakes).

There are currently more than 181 "*species at risk*" in Ontario, and that number is likely to increase as climate and habitats change. Species that currently have limited ranges, limited genetic variability and have southern range boundaries in or near the Mississippi watershed may disappear from the basin completely. Species with high productive rates, abilities to move long distances, rapidly colonize and live in proximity to humans are likely to do well under a changing climate. Complex predator/prey interactions and disease and parasites also need to be considered. For example, less snow on the ground means there will be less protective winter cover for voles and mice. The periodic loss of a white background during winter will also make hares more vulnerable to predators. Thus, there is a need to assess the utility of a range of human interventions to help species, such as; promoting/ developing dense brush or thickets; maintaining feeding stations; or even translocation of some species.

Climate change presents unique challenges to parks and conservation areas that now protect approximately 9% of Ontario. Currently, each park is designated to protect ecosystems representative of the natural region in which it occurs; this is written into each parks management plan. Unfortunately, these systems are currently on the move. Addressing this challenge is not simple. Should parks protect existing natural ecosystems by removing invasive species, including those originating just to the south of current park boundaries, or should they become areas where "natural" ecosystem change is allowed to occur? Should parks be linked to corridors that allow migration to occur more readily, and therefore accelerate such change (e.g. the Algonquin-Adirondack Conservation Initiative)?

With respect to management, virtually the entire Mississippi watershed is now managed in one form or another. For example, water flows and levels are managed, forests are managed and harvested, parks and conservation areas have management plans, there are strategies to decide whether or not to fight forest fires, etc. Ecosystem needs and changing climate should be considered as part of these specific planning strategies. Parks and conservation areas may represent one of the best means of managing climate change impacts, and may be where local ecosystem management strategies in the face of climate change will be first developed. Identifying and monitoring species most at risk is critical. Plans for translocation, including perhaps the need to develop suitable habitat through anticipatory planting, or creating new conservation areas, need public engagement. Without some type of significant management effort, provincially significant species will be lost.

Table 7: Sensitivities, impacts and concerns—Ecosystems in the Mississippi Watershed

Variable	Impact/Implications	Possible Adaptation
Air Temperature Higher seasonal temperatures More heat waves Longer growing season	– Better survival of many over-wintering species (e.g. deer, house mouse, house sparrow) including, predators. – Higher fall/winter temperatures, may lead to spoiled food hoards for some species leading to lower survival and breeding success. – Fragmented ecosystems - all species cannot migrate at the same rate. – "New" competition and displacement of less competitive species. – Expect significant movement of species through the watershed. – Local extinctions (at least) are likely. – Expect hybrids (e.g. species of chickadee).	– Encourage harvest and greater use of "new" arrivals (e.g. crappie) and some natives. – Evaluate impact of predators and manage. – Assess need for assistance (e.g. feeding areas etc.) for some species. – Land-use planning – keep critical parts of ecosystem intact; examine, mediate other stressors on environment. – Develop plans/methods for both new and more diverse plantings' of trees and shrubs – Assess the efficacy of developing a north south greenbelt to aid natural migration (e.g. use land trusts, "parks" etc.) – Assess risks and actions needed, including resettling (translocation) of some species
Precipitation More rain in winter Longer dry periods More heavy rain events – flash rains and surface runoff more common	– Expect water quantity and quality issues in some years, impacts on wildlife and fish. – Potential for pollutants to be washed into rivers and lakes during extreme events. – Water level fluctuation may be too extreme for some aquatic/ riparian species (e.g. fish, amphibians, etc.). – Less snow cover on ground, less winter protection for some species while feeding under snow (mice/voles) and loss of white background/camouflage (e.g. for hares). – Increased risk of ice covered ground – food sources periodically unavailable.	– Source water protection. – Improve quality of urban effluent. – Encourage manure/fertilizer management plans. – Develop riparian buffer zones. – Wetland protection and retention crucial to buffer water fluctuations, and maintain habitat and wildlife and water sources. – Assess utility of promoting/developing some dense brush/thickets of suitable species under for example hydro lines. – Assess, develop/expand feeding areas.

Table 7: Sensitivities, impacts and concerns—Ecosystems in the Mississippi Watershed

Variable	Impact/Implications	Possible Adaptation
Evapotranspiration Actual evapotranspiration rates are currently increasing by about 6% for a 1 °C increase in air temperature – likely to continue to increase.	– Greater surface water loss and less shallow ground-water inflow - ponds and wetlands and waterfowl, amphibians at risk. – Expect drought tolerant tree species to do better than those that are not tolerant. – Potential negative affect on a successful hatch for some species of birds (e.g. eggs may dry out as in case of grouse).	– Assess potential to control water levels on key wetlands. – Encourage land development to retain site functionality (infiltration, tree/woodlot retention where possible). – Encourage shading of streams, rivers and ponds or other natural habitats through retention or remediation. – Assess use of more drought tolerant tree species in plantings.
Water temperature Increasing throughout the seasons Longer open-water periods/shorter ice-cover periods	– Distribution of some aquatic plants and algae and invasive species will expand with longer and warmer aquatic growing seasons.	– Long-term monitoring needed; management response will be species and lake specific (see Fisheries).
River Flows, Lake and Well Levels All lower in some seasons/years More frequent extreme flooding events	– Low, or changing water levels and/or loss of wetlands. – Competition for water by all users in time of drought. – Flooding – peak floods may occur in any season affecting aquatic species.	– Assess potential to use water management to regulate flow and water levels. – Keep wetlands wet, revise various wetland blue prints and guidelines to include CC. – Assess the need and potential for more water storage in the basin to moderate floods and to enhance flow during droughts.

Communities

Municipalities in the Mississippi watershed supply essential services such as drinking water, sewage treatment, roads and recreational facilities. They are also responsible for maintaining important infrastructure, play a key role in land use and watershed management, and are vital players in emergency preparedness and response. Municipalities implement national and provincial policies and, for many residents, are the most important political actors.

Shifts in typical (mean) climatic conditions are important to all communities. For example, based upon current water usage trends, warmer summers and higher evaporation rates imply that there will be greater demand for water, even if community populations were to remain unchanged. This alone highlights the need to manage/plan for such change, a situation that is enhanced by the fact that these changes will not be smooth. They will be associated with changes in the frequency and severity of extreme weather events such as storms, floods, drought, hot weather days, and related disasters. There is evidence that such change is already occurring (Table 1) and that risk management plans are needed. Climate change needs to be factored into the municipal planning process and those of related agencies (e.g. Mississippi Valley Conservation Authority amongst others; see the opinion expressed by workshop participants in Attachment 1).

There will be costs for adaptative actions, but the costs from inaction are likely to be much higher. Furthermore, there are more options available today than there will be tomorrow: as development unfolds it will take away some adaptive options or make them more expensive. Many such actions including water conservation, source water protection, reduction of hard surfaces (to allow for water infiltration), encouraging shade tree plantings to relieve heat and the costs of cooling, periodically reviewing emergency response programs, reviewing flood plain mapping and many others make good sense in their own right today.

The news is not all bad. Longer growing seasons, warmer winters, the reduced need for winter heating, more warm days at the cottage and the beach, longer boating seasons will be positive changes for residents. Furthermore, although climate is changing rapidly, it is not particularly rapid compared to the rate at which decisions and changes can be made at the community level. There is time to develop strategies and to put in place adaptive actions, even those that may take years to fully mature, for example tree lined streets that provide shade and relief during extreme heat.

Some Ontario municipalities, such as Toronto, are already developing proactive and protective measures to prepare for changing climate. These experiences need to be shared. In the same light, many communities in Ontario and farther south already deal with warmer climates and extremes, similar to those the Mississippi watershed can anticipate in the future. They can offer important lessons to inform future approaches. There are also advantages in local communities (and agencies) acting and learning together. Workshop participants felt that some co-ordination may be required for this to happen efficiently.

Table 8: Sensitivities, impacts and concerns—Communities in the Mississippi Watershed

Variable	Impact/Implication	Possible Adaptation
Air Temperature Higher seasonal temperatures More heat waves Longer growing season	– More health impacts. – More demand for warmer weather recreational facilities. – More warm weather tourism. – Traditional cold weather tourism in jeopardy. – More pests survive (rats/mice etc.). – More damage to roads (more freeze-thaw cycles and more use of salt). – More forest fires – air quality, fire risk.	– Raise awareness that conditions are changing, plan for change: more heat and air quality alerts etc. – Assess adequacy of emergency responses – Promote trees (mixed varieties) for shade in communities. – Consider range of recreational activities. – Promote and take advantage of warmer shoulder seasons (spring and fall). – Consider adequacy of control measures for both new and old pests. – Review load restrictions and their timing. – Likely an increase in road repair frequency, allow for it in long term budget forecasts. – Assess/review need for fire breaks in land-use planning; capacity to fight (forest) fires.
Precipitation More rain in winter Longer dry periods More heavy rain events – flash rains and surface runoff more common	– Poor water availability and quality in some years and areas. – Possible restricted release of treated sewage water during low water events. – Crop failures – social –emotional disruptions/issues. – More frequent local flooding. – Snow removal costs likely to increase due to increased salting; plus intense winter storms (more intense snow removal effort required).	– Promote source water protection. – Promote manure/fertilizer management plans. – Develop/promote riparian buffer zones. – Consider implications of restrictions to release of effluent (adequacy of design). – Examine/create/expand community support. – Review adequacy of floodplain mapping and land use and infrastructure design. – Expand urban forests – to slow runoff. – Design developments to retain infiltration characteristics, reduce percentage of hard surfaces and introduced steep gradients. – Plan for more "salting", winter road maintenance costs likely to increase.

Table 8: Sensitivities, impacts and concerns—Communities in the Mississippi Watershed

Variable	Impact/Implication	Possible Adaptation
Evapotranspiration Actual evapotranspiration rates are currently increasing by about 6% for a 1 °C increase in air temperature – likely to continue to increase.	– Greater water demand for gardens, lawns etc. in spring summer and fall. – Urban trees already under stress may be vulnerable.	– Raise awareness, need for water conservation, review costing for water. – Promote drought resistant gardens, lawns, treed areas, timing of daily water access for same. – Promote porous surfaces.
Water Temperature Increasing throughout the seasons longer open-water periods/shorter ice-cover periods	– Ice cover not as safe as in past, winter recreational activities at risk. – Summer water quality issues in lakes and rivers. – More aquatic vegetation, algal blooms.	– Raise awareness of changing conditions. – Ice monitoring and awareness programs. – Assess monitoring /warning systems. – Consider cost effectiveness of swimming pools versus maintaining river beaches.
River Flows and Lake and Well Levels Down in some seasons/years More frequent flooding	– In some years and in some areas marginally adequate for needs. – Possible urban/rural conflict over water use. – Peak floods may occur in any season, frequency of extreme events will increase, (already evidence of increase in heavy one day events). – Flooding/runoff may spread contaminants and bacteria. – Municipal risks are higher.	– Deeper or multiple wells, expand supply. – Reduce water demand (water conservation). – Open discussions, advisory groups. – Identify where people are at most risk and take steps to reduce vulnerability. – Review (or change) floodplain zoning & land use. – Review infrastructure design (bridges, culverts etc.), replacement and maintenance timetables. – Source water/well protection needs to be promoted. – Review emergency response plans for remote communities, encourage 72 hour or even longer self sufficiency. – Include climate change adaptation in all planning activities especially long term plans.

Water

It is not surprising that water is the key cross-cutting issue in the watershed. Both mean seasonal conditions, and extremes (low flows and future flood flows), are important to all sectors and to residents and users of the watershed.

Rainfall has been increasing at a rate of about 1-3% per decade since 1970 in the area and climate models suggest that it will continue to increase, and likely will be of the order of 10 to 20% higher than today by 2050. However, it is also likely that much of this increase will fall in intense rainfall events; and that conditions will be drier between rainfall events. Models suggest that heavy rainfall events (those that occur 5% of time) will be between 23-57% more intense in the Great Lakes area than they are today by 2080 to 2100. High intensity precipitation events will wash soils and pollutants into the water system and cause shoreline/river bank erosion and even regional flooding. Major management options to deal with flooding include lowering river or lake level (cutting sills) or removing/modifying items at risk. An example of this is that fixed infrastructure such as docks are more at risk than floating ones.

At present, flooding can occur at any time in the year (e.g. not just during the spring melt). Low summer flows are now more common than in the past. Low flow events (less than $6m^3/s$) on Mississippi River over the past 40 years occurred about three times more frequently than they did in the previous four decades. Indications are that summer low-flow conditions in some years will be both lower than in the past and of longer duration. Manipulating forest cover and maintaining slow draining wetlands may help to maintain critical summer flows.

It can be argued that we have adapted well to the surface water and groundwater that we have. The major challenge in the water sector will be managing expectations for water flow, water levels, and water quality. This will be further challenged by the changes in the timing of flow events which are already occurring today. Winter discharge is now higher because winters have become warmer and more snow melt is occurring during the winter months. As a result less snowmelt is available for the spring freshet which is now occurring earlier than before. Water levels decline earlier in the year and every second or third year may remain low over the summer before increasing again with fall rains. It appears that such changes will be amplified in the future, punctuated by more frequent seasonal flood events, (e.g. what are now 20 year events will occur every 10 or even seven years by 2050).

Many of the flow control structures in the Mississippi watershed are aging and will need to be upgraded or replaced soon. This presents opportunities to enhance water management capacity including the ability to increase seasonal water storage capacity by increasing the present height of existing dams or by adding more dams. Clearly there are costs to taking such actions. Cost- benefit analyses are required.

Low flow events raise special concerns. As flows decrease the potential for adequate dilution from point-source pollution also decreases. However, lake and river water quality are demanded by most users. Adequate water flows are required for fisheries, cottagers/tourists using the river for transportation, hydro-electric generation, communities and potentially for future agricultural needs (irrigation etc.). Figure 3 highlights the challenges for the different sectors.

As has happened elsewhere in North America, if low flows and overall drier conditions become more common, both individuals and sectors will try to adapt and expect to use or control a higher proportion of the declining water resource for their particular needs. Some users may be affected twice, first by climate change, which causes lower water levels; and second by the adaptive actions of others, as they try to adjust to the lower water levels.

Conflicts will inevitably arise. Water management solutions must be informed by answering questions such as: what are the priorities for water use and allocation in the watershed? Participants at the workshop felt that there was a need for further discussion and identification of various positions around this issue. There is also a need for an assessment of how, when and where water is used within the watershed, modelling of how climate change is likely to affect water flow and levels and the degree to which such changes can be managed by current or future control structures. Participants felt that it is important to examine what can be achieved by water conservation and associated measures such as wetland preservation, integrated water management, source water protection and reforestation. In short, a watershed management plan is needed.

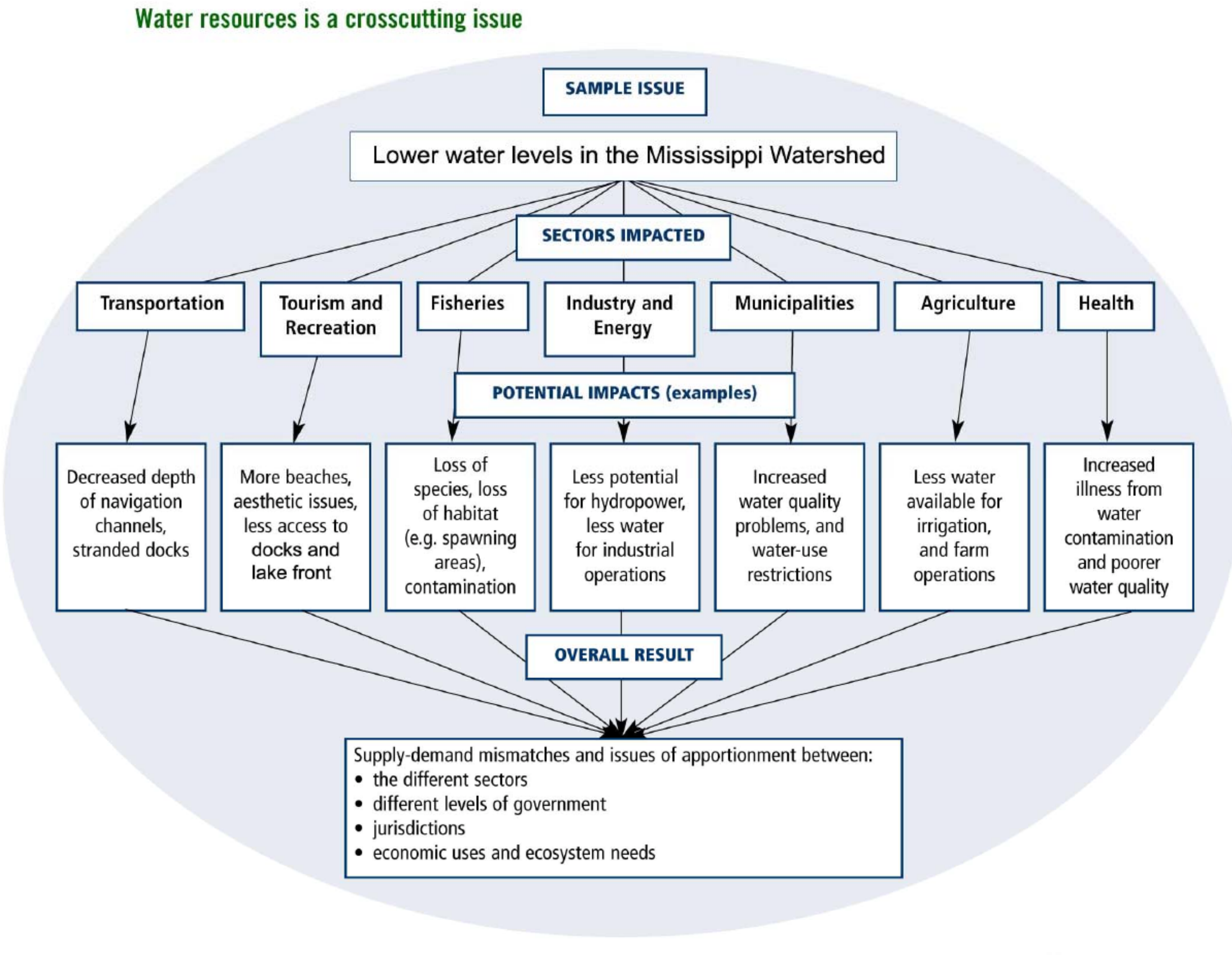


Figure 3 - How sectors in Mississippi Watershed are affected by lower water levels

Table 9: Sensitivities, impacts and concerns—Water in the Mississippi Watershed

Variable	Impact/Implications	Possible Adaptation
Air Temperature Higher seasonal temperatures More heat waves Longer growing season	– More warm weather boating/fishing use of lakes and rivers. – Greater demand for higher water levels in lakes/rivers during summer, spring and fall. – More salt use on roads in winter, which may leach into river system.	– Raise awareness that conditions are changing, plan for it. – Explore water management options. – Consider salt loading issue, promote alternatives.
Precipitation More rain in winter Longer dry periods More heavy rain events – flash rains and surface runoff more common	– Less water available and water quality (dilution) issues in some years and areas. – Possibility of limited release of treated sewage water during droughts. – Summer water quality issues, outbreaks of E.coli, Cryptosporidium, etc.	– Promote source water protection. – Promote manure/fertilizer management plans. – Promote erosion control on agricultural lands. – Develop/promote riparian buffer zones. – Raise awareness of possible restrictions to dumping treated sewage water. – Track occurrences, evaluate alert systems and needs.
Evapotranspiration Actual evapotranspiration rates are currently increasing by about 6% for a 1°C increase in air temperature – likely to continue to increase.	– Greater water demand in summer for gardens etc.	– Raise awareness of the need for water conservation. – Promote drought resistant gardens, lawns plan for/ consider implications of increased demand for water withdrawals (farmers etc). – Promote farm ponds/dug-outs.
Water Temperature Increasing throughout the seasons Longer open-water periods/shorter ice-cover periods Temperatures increasing	– Ice cover not as safe as in past, winter recreational activities at risk. – Longer open water seasons – greater annual shoreline and river bank erosion.	– Raise awareness of changing conditions – Ice monitoring and awareness programs. – Examine options; promote shoreline naturalization/stabilization programs.

Table 9: Sensitivities, impacts and concerns—Water in the Mississippi Watershed

Variable	Impact/Implications	Possible Adaptation
River Flows and Lake and Well Levels All lower in some seasons/years More frequent extreme flooding events	– Ground water supply marginally adequate for needs in some years and in some areas. – Conflicts will likely arise over water usage. – Flooding may occur in any season. – Flooding/runoff may spread land based contaminants and bacteria. – Tailing/settling ponds may not be adequate.	– Reduce water demand through awareness. – Determine to what extent river management can balance changes in flow regime. – Consider adding water storage capacity (higher or more dams) in watershed. – Manage to keep wetlands wet. – Examine trade-offs (conflicts) and options. – Review (or change) floodplain zoning. – Keep options open –floodplains free of development. – Identify where people are at most risk, not all of the watershed is equally at risk. – Consider river flow control at critical points in system (e.g. sills). – Protect wetlands from drying out via better riparian zones, preserving or replanting forests, or seasonal flooding of wetlands. – Promote source water/ headwater protection. – Raise awareness of trend to lower summer flows for longer periods and potential for inadequate dilution, possible curtailment of release of treated sewage water, negative role of leachate in watershed, and the need for: adequate manure pesticide/ herbicide/fertilizer planning. – Review or encourage review of infrastructure design (bridges, culverts tailing ponds etc.). – Include CC considerations in all watershed planning activities, develop a watershed management plan.

Conclusions

Long term changes in mean climate conditions in Mississippi watershed will offer both long term benefits for some sectors as well as negative impacts and costs. Extreme events by their nature are in general negative and are often associated with significant costs and losses. Such is the case today and it will remain so in the future. Pro-active adaptation can reduce some of these costs and the impacts.

This report provides a list of actions that may be taken to address some of the many potential impacts resulting from climate change. Some actions could be undertaken quickly by individuals, or groups, or governments. But, others require much more consideration and analysis. In all cases it is assumed that there will be follow-up meetings and discussions. This report provides a simple point of reference for moving forward on this important issue. From the perspective of the authors, there are obvious advantages for co-ordination at the watershed level.

1) Participants at the Almonte workshop concluded that:
   - climate, ice cover, water temperature, river flows, local ecosystems and fisheries are changing in Mississippi watershed and will continue to do so.
   - there are now and will be future impacts on agriculture, tourism, forestry, fisheries and other sectors.
   - impacts will be both positive and negative.
   - some, but not all, impacts can be reduced through adaptation.
   - there are barriers to taking action, and often tradeoffs will be necessary.
   - climate change should be incorporated into all aspects of our planning processes (e.g. health care, fisheries management, infrastructure design, water management etc).
   - guidelines and tool-kits are needed to help at the local level; participants look to all levels of government to provide these.
   - there is a continued need to raise awareness of this issue.

2) The release of the Almonte Communiqué (see Attachment 1) expresses the 150 participants call for action to governments and residents to adapt to a changing climate.

3) There is a need for follow-up meetings and discussions around the sectors identified in this report to provide vertical integration amongst various levels of government and the public. There is a need for the establishment of a process for horizontal integration (e.g. one or more regional co-ordination committees or the use of existing bodies) to develop local adaptation strategies.

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Attachment 1

Almonte Communiqué

The “Almonte Communiqué” was drafted and unanimously endorsed by participants of the “Weathering the Change: Adapting to Climate Change in the Mississippi Valley” workshop, hosted by Mississippi Valley Conservation and the Mississippi Valley Field Naturalists in fall 2007.

The Almonte Communiqué

“Many important economic and social decisions are being made today on long-term projects and activities in our watershed based on the assumption that past climate data are a reliable guide to the future. This is no longer a good assumption.

We believe that all levels of government are key players in this issue and must raise awareness and incorporate climate change into planning, decision making and leadership.”

Attachment 2

Speakers List
"Weathering the Change: Adapting to Climate Change in the Mississippi Valley"

Climate Sensitivity and Change in the Mississippi Watershed, by Paul Egginton, Resident
Global Warming: Implications for Ecodiversity and Biodiversity, by Paul Gray, Ministry of Natural Resources
Climate Change and Your Woodlot, by Bob Stewart, Retired Canadian Forest Service, Natural Resources Canada
Climate Change and Agriculture in Central Canada, by Mike Brklacich, Department of Geography and Environmental Studies, Carleton University
Fish and Fisheries: Sensitivity to Climate Change – Response and Adaptation , by John Casselman, Department of Biology, Biosciences Complex, Queen's University
Climate Change Impacts and Adaptation: Concerns for Ontario, by Beth Lavender, Natural Resources Canada
Climate Change and Water Resources, by James Bruce, Soil and Water Conservation Society
Local Adaptation to Climate Change, by Philippe Crabbé Professor Emeritus, University of Ottawa
Climate Change and Tourism in Eastern Ontario: Changing How We Play?, by Dr. Brenda Jones, University of Waterloo
Helping Canadians plan for the Health Impacts of Climate Change, by Steve Dolan

Attachment 3

Organizing Committee
"Weathering the Change: Adapting to Climate Change in the Mississippi Valley"

Paul Egginton
Paul Lehman
Mark Burnham
Jackie Oblak
Nicole Guthrie
Cliff Bennett
Mike MacPherson
Howard Robinson

2007