Chapter 7

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7 Climate Change

Introduction

This chapter summarizes information that is currently available on climate change at global, regional, and local scales. General information on potential climate change impacts is provided along with discussion on more specific local impacts in eastern Ontario and more specifically within the Mississippi-Rideau Source Protection Region (MRSPR). Information is available for impacts on water quantity, which is discussed in Chapter 3 in the water budget, and on water quality, which is discussed in Chapters 5 and 6 for groundwater and surface water respectively.

The Technical Rules require the inclusion of climate change considerations in two ways:

- through documenting current climate change information available for the region for the next 25 years; and
- by considering how climate change may affect results found in the Assessment Report.

It should be noted that available projection information is based on thirty year intervals, both locally and provincially, and that timeline has been used in the following discussions.

Summary of Key Findings

Weather patterns are changing in the MRSPR and climate change projections show that they will continue to change. Trend data for the region indicates that some changes in temperature and precipitation patterns have already occurred over the past fifty years. Temperature and precipitation patterns are projected to continue to change in the MRSPR during the next thirty years.

The following highlights some key points:

- A rise in air temperatures in both warm and cold seasons in the range of 0-2^{o}C by 2040 is projected for eastern Ontario;
- Minimum temperatures are projected to increase at a faster rate than maximum temperatures;
- Monthly precipitation patterns and amounts are projected to change;
- Evapotranspiration (ET) is projected to increase. Approximately 60% of water is currently lost through ET, the remainder leaving as surface water flow; and

- Weather variability is projected to increase, with increased frequency of weather extremes and events.

The impacts of changes in temperature and precipitation may impact groundwater and surface water quality and quantity to varying degrees in the MRSPR. This may, in turn, affect delineation of:

- Intake Protection Zones;
- Significant Groundwater Recharge Areas; and
- Wellhead Protection Areas.

Other changes which may affect source water protection:

- The importance of transport pathways on vulnerability scoring may change; and
- Stresses on some subwatersheds within the region may increase.

Further study is required to determine the magnitude of specific impacts in the region and their importance to Source Protection Planning.

Technical Study

One background report was completed for the climate change chapter, titled “Review of Known Information about Climate Change in the Mississippi-Rideau Source Protection Region”, authored by consultant Jacqueline A. Oblak.

Peer Review

The Climate Change Report was reviewed by William D. Hogg M. Sc. Mr. Hogg is a hydrometeorologist with Reach Consulting.

Data gaps for this and other chapters may be found in Chapter 8. For further information on climate change knowledge in the MRSPR see the Climate Change Report, listed in the Technical Studies in Appendix A-1.

7.1 Review of Climate Change Knowledge

Source Protection Planning includes consideration of changing factors which may affect our water resources over time, and changing weather patterns are an important part. Studies indicate that climate change will bring warmer temperatures to the Eastern Ontario region in the next thirty years (and beyond), more so in some seasons than others. This may have a number of implications for the MRSPR.

It is difficult to find specific information at a scale which is useful in developing comprehensive local adaptation strategies. Of the thousands of climate change studies which have been completed in the past two decades, most documents project changes and impacts at a global scale, fewer quantify regional changes and impacts, and very few provide quantitative information on local changes and impacts. Fortunately some local research has been completed which provides quantitative projections and that information has been included in this review.

Table 7-1 provides historic information on temperature, precipitation, and evapotranspiration (ET) from two stations in the region, one located in the MVSPA and the other in the RVSPA. This is the basis for the following discussion.

7.1.1 Global

The International Panel on Climate Change (IPCC) Technical Paper on Climate Change and Water (2008) states that globally:

"Climate warming observed over the past several decades is consistently associated with changes in a number of components of the hydrological cycle and hydrological systems such as: changing precipitation patterns, intensity and extremes; widespread melting of snow and ice; increasing atmospheric water vapour; increasing evaporation; and changes in soil moisture and runoff. There is significant natural variability – on interannual to decadal time-scales – in all components of the hydrological cycle, often masking long-term trends."

Projected changes in global temperatures vary depending on scenarios of high and low atmospheric carbon dioxide concentrations. "The best estimate [of projected annual temperatures] for the low scenario (B1) is 1.8°C (likely range is 1.1°C to 2.9°C), and the best estimate for the high scenario (A1FI) is 4.0°C (likely range is 2.4°C to 6.4°C)" (Bates et. al 2007).

It is widely accepted that winter and night-time temperatures are increasing more than summer and day-time temperatures because of the increases in greenhouse gases which reduce radiative cooling. Globally, minimum temperatures over land are increasing at three times the rate of maximum temperatures. This is being attributed to the increasing possibility of cloud cover which contributes to night time heat retention (Zhang et al. 2000).

7.1.2 Ontario and Southern Canada

Ontario Ministry of Natural Resources (MNR) temperature projections for Ontario as a whole forecast a rise of 3-8ºC over the next century. This may be seen at the MNR website; http://www.web2.mnr.gov.on.ca/mnr/ccmapbrowser/climate.html. This information is from study titled "Climate Change Projections for Ontario: Practical Information for Policymakers and Planners" (Colombo et. al 2007) and is referred to as the MNR study in this report.

Mean annual temperature ranges (MTR) across southern Canada (south of 60ºN) have decreased between 1900 and 1998 by a range of 0.5-2.0ºC (Zhang et al. 2000). This is consistent with minimum temperatures increasing at a faster rate than maximum temperatures.

The MNR website also shows projected changes in precipitation over the next 30 years, with much of the province showing marked reductions in precipitation amounts over the cold months from October through March.

7.1.3 Eastern Ontario and the Mississippi Rideau Source Protection Region

Temperature and precipitation forecasting for the 2011-2040 period has been carried out by MNR as part of a province-wide study. Maps from this study may be found on the MNR website for this time period, with the MRSPR partially falling under the Kemptville and Peterborough districts. Separate climate change studies have been conducted by Mississippi Valley Conservation (MVC) titled “Fish, Fisheries, and Water Resources: Adapting to Ontario’s Changing Climate. Subproject 4: Water Management Responses to Climate Change” (Kunjikutty and Lehman 2008) for the MVSPA. The Mississippi watershed study includes projections for the thirty year period of 2010-2039. This report is referred to as the MVC report in this chapter. For further information on temperature and precipitation changes please see the Climate Change Technical Report (see Appendix A-1).

Temperature Trends

Recent temperature data indicates that Ottawa has experienced an increase in temperatures in the past 50 years. Average winter temperatures have increased approximately 1.5ºC, spring temperatures have increased approximately 1.0ºC and summer temperatures have increased 0.5-0.7ºC (Egginton and Lavender 2009). Fall temperatures were the exception, not showing any significant change (Egginton and Lavender 2009). These changes should be generally applicable to the MRSPR and provide an indication of the magnitude of change although as indicated above there will be some variation throughout the region.

A number of local temperature trends have also been identified by Environment Canada. Significant trends are related to whether the changes over time are statistically relevant. Non-significant trends indicate that there is some change, but during the period measured it is not definitive and could be attributable to other factors. Both are important as they show how weather patterns are, or may be, changing so both are included in this discussion.

Historical trends in the number of cold nights in the region show a statistically significant decrease in Ottawa at both the airport and the Experimental Farm (CDA) between 1950 and 2003 as well as outside the region at Haliburton and Belleville (Environment Canada 2005). It appears that this trend will continue as suggested by MVC minimum temperature projections, which are discussed under the following heading titled Temperature Projections.

Trends in the frequency of cold spells indicate a statistically significant decrease in the “number of 'waves' or 3 consecutive days with minimum temperature < 10th percentile” for the same period in Haliburton (-4.5 days annually) which is located just outside the north-western edge of the region and therefore may be indicative of what is occurring in that area of the region. This refers to periods of three days or more that experience lower than normal temperatures: these occur less often.

There was a non-significant decrease in frequency of cold spells in the Ottawa area for that period. “The “cold wave frequency index” was defined as the number of “waves” or times during the year when there were three consecutive days with minimum temperature less than the 10th percentile for that particular time of the year” (Environment Canada 2005).

The “days with minimum temperature > 20^{o}C” category also indicates a significant trend, showing increases in the period 1950-2003 in Ottawa and surrounding climate stations outside the region (Environment Canada 2005). This means there are an increasing number of warm nights each year which remain above 20^{o}C.

There is a non-significant trend in the number of hot days for Ottawa, defined as “days with maximum temperature above thirty degrees” C for the period 1950-2003. The number of hot days has increased slightly.

There are also non-significant trends in both the number of very warm days, defined as “days with the maximum temperature greater than the 19 percentile” (Environment Canada 2005) and the duration of warm spells (maximum number of consecutive days with maximum temperature > 5°C above normal maximum temperature) for the same period.

When considered as a whole, the trend information indicates that changes in temperature patterns have been measured throughout the year.

Temperature Projections

Although there is some variation in specific temperature increases projected, both the MNR and MVC studies project a rise in temperatures in both warm and cold seasons in the range of 0-2^{o}C by 2039/2040. Minimum temperatures are forecast to increase at a faster rate than maximum temperatures.

The following table shows the projected maximum (tmax) and minimum (tmin) seasonal temperatures for the period 2010-2039 from the base period 1984-2003, as calculated by MVC.

Projected Temperature Changes For the period 2010-2039 (0C/30yr)					
Summer	**tmax**	**tmin**	**Fall**	**tmax**	**tmin**
June	0.9	0.9	September	0.9	0.6
July	1.2	1.5	October	0	0.3
August	0.9	0.9	November	1.2	0.3
average	**1**	**1.1**	**average**	**0.7**	**0.4**
Winter	**tmax**	**tmin**	**Spring**	**tmax**	**tmin**
December	0.6	1.2	March	0.3	1.5
January	2.4	5.1	April	0.6	1.5
February	0.9	1.8	May	2.1	1.2
average	**1.3**	**2.7**	**average**	**1**	**1.4**

Table 7-i. Mississippi Watershed Projected Temperature Increases by end of period 2010-2039. Source: Compiled from data from Kunjikutty and Lehman 2008**.**

Precipitation Trends

Trend data for Ottawa indicates a statistically significant increase in the number of days with heavy rain (greater or equal to 95 percentile rainfall) with other stations immediately surrounding the region having non-significant increases in the 1950-2003 period (Environment Canada 2005).

The trend in “highest five day rainfalls”, the amount of rain which falls in a five day period, for the same period has a statistically significant increase of 20.5 mm in Ottawa (Environment Canada 2005).

Although there is no strong indication of trend at this time, the percentage of precipitation which falls as winter rain or occurs as freezing rain may rise as winter temperatures increase. The trend in the number of freezing rain hours per year shows a small but steady increase (Environment Canada 2005).

Precipitation Projections

Changes in precipitation patterns and amounts may affect the water budget (Chapter 3) and may have a number of implications for the quality and quantity of surface and groundwater. Precipitation is more difficult to predict than temperature and projections have a higher degree of uncertainty. It is interesting to note that the variability of what is projected to occur means that projections sometimes appears to be contradictory, since in some instances there are projections of slight increases in one study and slight decreases in another.

The following projections are for changes in precipitation amounts and do not consider the type of precipitation (i.e. rain, snow, or freezing rain). The MNR data is presented as cold weather (October through March) and warm weather (April through September). The MVC data has been presented here for the same time frame for comparison purposes, in addition to having been broken down seasonally into three month periods.

Fall

The MVC study indicates that fall (September, October, and November) precipitation will increase by 2039.

Winter

Cold weather (October through March) precipitation in the MNR study for the region is forecast to decrease only slightly during the period, between 0 and 10% for most of the region with an area in the north-western section of the region facing a decrease of 10 to 20% (Colombo et al. 2007). The MVC study's data for the same six month period forecasts an average increase in the range of 6-9%.

The MVC study shows winter (December, January, and February) precipitation will decrease in December, with increases in January and February.

Spring

The MVC study indicates that spring (March, April, and May) precipitation will show no change in April and decreases in March and May by 2039.

Summer

In the MNR study, precipitation projection maps indicate that warm weather precipitation (April through September) will decrease by 0 to 10% in most of the region with increases from 0 to 10% in the area immediately east of Ottawa and for the Perth area. MVC precipitation forecasts are for average increases of 2.0 mm for the same period, in the range of 2-3%.

The MVC study shows summer (June, July and August) average precipitation projections by 2039 indicate an increase in June and July with a decrease in August.

Following is a summary of precipitation changes for the period 2010-2039 from the base period 1984-2003, as forecast by the MVC study.

Season	Month	Precipitation Change (mm) from Base Period 1984-2003
Winter	January	7.8
Winter	February	3
Spring	March	-7.8
Spring	April	0
Spring	May	-0.3
Summer	June	2.4
Summer	July	2.4
Summer	August	-3.3
Fall	September	10.8
Fall	October	10.8
Fall	November	20.7
Winter	December	-4.8

Table 7-ii. Mississippi Watershed Projected Precipitation Changes by end of period 2010-2039. Source: Compiled from data from Kunjikutty and Lehman 2008**.**

Changes in Related Factors

Changes in temperature are the basis of other changes in the weather. Increased heating contributes to more intense upward movement of air and when adequate water vapour is present results in cloud formation and rain or sometimes in intense, often localized storms which can include high winds.

Higher temperatures and increased winds may increase potential evapotranspiration (ET), increasing humidity and making water vapour readily available for cloud formation and precipitation.

Surface water temperatures are also influenced by changes in air temperatures, winds, precipitation amounts, and the availability of solar radiation. Increases in air temperature and solar radiation generally contribute to higher water temperatures.

7.1.4 Examples of Potential Impacts of Projected Changes

Seasonal shifts are forecast under climate change scenarios, with spring conditions beginning earlier and summer conditions extending into spring and fall. Under these scenarios shorter winters will begin later and end earlier.

Increased variability in weather patterns is also projected. Extreme events are forecast to occur more frequently. Extreme events include intense rainfalls and thunderstorms with high winds, ice storms, and extended periods of high summer temperatures and drought.

The region as a whole has a large number of surface water bodies which can make large volumes of water available for ET under the right conditions. Increased potential ET is projected to accompany increases in temperature and this may lower surface water levels and reduce flows in some waterways in the region, especially wide shallow water bodies.

7.2 Potential Impacts on Water Quality and Quantity

Water quantity and quality in the region may be affected under current climate projections. It should be noted that quality and quantity changes, while being discussed separately here, are often related. Changes in quantity will affect contaminant and bacterial concentrations. When contaminants are present in water the quality decreases when water quantity decreases, assuming all other factors remain the same.

7.2.1 Water Quantity

> *Mean annual* precipitation and temperatures only tell part of the story. Distribution of precipitation amounts and types vary significantly daily, monthly and annually with short term changes in the amount of overland runoff, surface infiltration, groundwater recharge, ET and streamflow. In the long term, changes in precipitation distribution coupled with increased temperatures can potentially affect surface and groundwater availability, especially in the traditional summer dry season.

Some surface water features, especially smaller rivers and lakes, are more susceptible to changes in precipitation amounts and patterns. This is especially true where precipitation is the primary source of new water and baseflow is minimal for all or part of the year. These lakes and rivers may also be affected by increased ET as temperatures and winds increase. If average ice-free days increase in the region then this allows increased water flow in non-traditional times (i.e. January and February) and increases potential ET.

Spring freshet (traditionally occurring sometime in the March through May period) is dependent on a combination of snowmelt and rain. Freshet may be reduced in parts of the region and/or may occur earlier as a greater percentage of winter precipitation falls as rain, rather than snow, due to average temperature increases. Increasing temperatures may also increase both the frequency and the duration of winter melting periods.

High water and flooding in off-seasons may also occur in some lakes and rivers due to changes in precipitation and snowmelt patterns. Increases in winter and early spring runoff, summer flooding from summer thunderstorms and intense rain events may be an increasing flood risk over time both in traditionally-susceptible areas such as floodplains and in areas where flooding has not historically occurred.

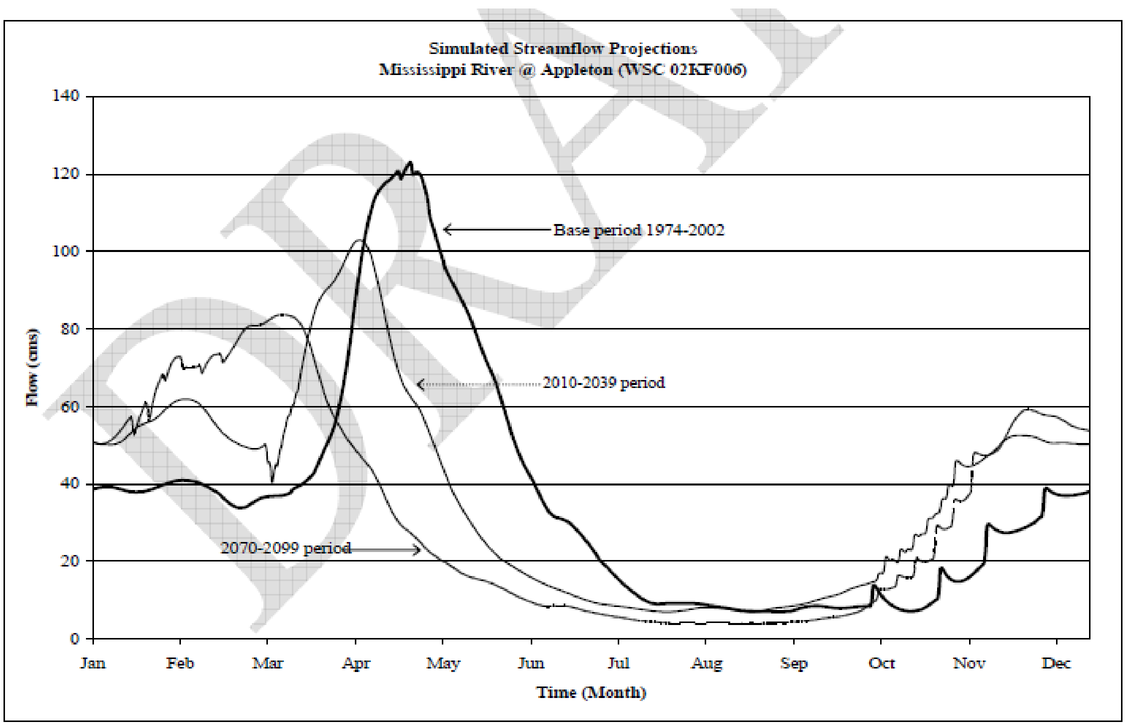

Figure 7-i. Simulated Streamflow Projections for the Mississippi River at Appleton Gauge for 2010-2039 and 2070-2099. Source: Kunjikutty and Lehman 2008.

The graph above shows projected changes in the water flow of the Mississippi River. It should be noted that this figure shows streamflows for two sets of projections: 2010-2039 and 2070-2099, as well as the base period of 1974-2002. Only the 2010-2039 information is being considered for this report.

The streamflow projections in the figure above for 2010-2039 for the Mississippi River illustrate an earlier, reduced spring freshet. From April through August flows are lower compared to the base period, then flows are above the base period from October through the winter months until the freshet peak in early April.

Changes in weather patterns may influence how the Mississippi and Rideau Rivers are managed in the future. The water levels in both rivers are affected by a series of dams, and in the Rideau system locks are also present in the Rideau Canal. How much water is released or held back at any given time is determined in part by using historic water level and streamflow data which is affected by precipitation and ET. Operating ranges are also determined using historical flow and water level data. As weather patterns change, management strategies may require alteration to ensure sufficient seasonal streamflow for municipal surface water intake needs.

Further information on water management in the Mississippi River may be found in the Mississippi River Water Management Plan (2005). Water management procedures for the Rideau Canal may be found in the Rideau Canal Water Management Study (1994).

Due to natural variability in weather patterns, the region already experiences events such as drought, ice storms, and flooding. What appears to be different under climate change projections is the *increased likelihood* that there will be drier hotter summers, an increased percentage of winter precipitation in the form of rain, and a higher chance of severe rainstorms, among other changes.

7.2.2 Water Quality

Similar to quantity issues, if there are currently water quality issues in certain rivers or lakes due to summer low flow conditions, then the frequency and/or severity of these conditions may increase. Increasing air temperatures will increase some surface water temperatures and may create favourable conditions for bacterial and algal growth. Low flow conditions and increased plant growth may decrease dissolved oxygen earlier in the summer season, exacerbated when vegetation dies back and uses oxygen during the aerobic decomposition process.

Surface water quality may be reduced during high water and/or intense precipitation events if contaminants are washed into rivers and streams which contribute to municipal drinking water systems.

Groundwater quality may be affected if extreme events such as flooding carry contaminants to areas where they can enter the aquifer, potentially through natural features or human-made transport pathways (see Chapter 5).

7.3 Potential Impacts Related to Source Protection

Current stresses on source water, such as areas where there are issues or conditions, may be exacerbated by the increasing frequency of flooding, drought, and other related factors. Water systems which are currently experiencing low stress may show higher stress as temperature and precipitation patterns change.

The water budget (see Chapter 3) will change under climate change. Monthly precipitation may change as precipitation distribution patterns change, even if annual precipitation shows little change. If temperatures increase then annual actual ET will likely increase and may be a larger factor in times when ET has historically been relatively low, such as early spring. ET is currently the most significant loss factor in the water budget with water approximately 60% of annual precipitation leaving the watershed through ET and the remainder leaving the region as surface water flow. Increased water loss through ET in summer months could reduce future river flows and water levels.

Subwatersheds which have municipal drinking water systems currently have been assigned low stress. This may change over time under climate change scenarios, with small surface water systems and small shallow groundwater systems being most susceptible to changes. The water budget currently identifies one subwatershed which is assigned a moderate groundwater stress and three subwatersheds which are assigned moderate surface water stress levels, none of which have municipal drinking water systems.

7.3.1 Groundwater

Groundwater, with regard to Highly Vulnerable Aquifers, Significant Groundwater Recharge Areas, and Wellhead Protection Areas for the seven municipal wells in the region, is discussed in Chapter 5. Groundwater in many parts of the region is less likely to be impacted by changing air temperatures or amounts and patterns of precipitation in the time frame determined by the Technical Rules. This is especially true for the larger, deep regional aquifers. Regional aquifers are currently generally under little stress and a large percentage of the water in these aquifers may have been there for decades, or longer.

Water Quantity

Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas (SGRAs) are defined as areas where the annual groundwater recharge is greater that 55% of the average regional water surplus. Delineation of SGRAs is dependent then on snowmelt and precipitation amounts and patterns, both of which are forecast to change.

There is currently high uncertainty associated with SGRA delineation. As work continues to improve this, it is important to incorporate climate change projections for precipitation changes in volume and patterns. At some point in the future it may be necessary to revisit the SGRA definition.

SGRAs have a maximum assigned vulnerability score of 6 so changes in SGRA delineation due to incorporating climate change projections will not affect the number of significant threats.

As discussed in the water budget in Chapter 3, one subwatershed, "Rideau River at Ottawa", showed a moderate groundwater stress under current and future demand scenarios. This is based on historic data and is primarily due to commercial permits to take water. Further information is required to determine whether this stress will increase in the future under projected climate change scenarios.

Smaller, shallower aquifers, such as those used for private wells, which have a high dependency on regular annual precipitation and have little storage capacity are more susceptible in the shorter term to the projected changes of higher temperatures, increased ET (which may decrease soil moisture and reduce recharge), and increased risk of extended periods of drought.

Water Quality

If the frequency of heavy precipitation events increases as projected, the risk of contamination related to flooding of traditional and non-traditional areas and associated movement of contamination into shallow aquifers through infiltration also increases in some areas.

Highly Vulnerable Aquifers

Much of the region has been identified as Highly Vulnerable Aquifers (HVA) as the layer of soils in many parts of the region is shallow. HVAs may be affected as weather variability increases and high precipitation events become more common. During these events contaminants may be carried into the area where they could infiltrate the shallow soils and enter the groundwater.

Wellhead Protection Areas

The Wellhead Protection Area (WHPA) delineation is determined through Time of Travel, as discussed in Chapter 5. If precipitation patterns change they can affect groundwater in three key ways:

- Reduction of recharge due to projected reduction in summertime precipitation;
- Reduction of recharge due to increased percentage of precipitation occurring as overland flow, and decreased infiltration, during heavy rain events; and
- Increased risk of contamination in floodplains as flooding risk increases in these areas, if they are also aquifer recharge areas.

Decreased recharge could increase the area that supplies water to the municipal well, which in turn would require the increase of the WHPA.

In circumstances where there is less recharge available for the area that supplies water to a municipal well, the well may need to draw water from a larger area to keep the same amount of water available. This could change WHPA delineations, increasing WHPA sizes.

Impervious Surfaces

Areas in the region where there are large percentages of impervious surfaces may affect groundwater due to the:

- potential to retard infiltration; and
- use of road salt to clear frozen surfaces.

Only the potential for impacts on water quality are addressed here. If salty water from road salt infiltrates the ground, it can decrease groundwater quality; if it runs off, surface water quality may decrease.

Under climate change projections, salt may be required more or less, depending on the specific set of circumstances. Climate change has the potential to decrease the use of road salt and other contaminants on HVAs, SGRAs, and WHPAs, seasonally, but that may be offset by increased use during events. Eastern Ontario is susceptible to freezing rain in winter months, and winter road salt usage may change in any given year as temperatures increase, approaching the freezing point. Periods of higher than freezing temperatures will reduce salt requirements at times, where temperatures around freezing increase risks of freezing rain and the associated need for increased salt application.

Transport pathways

Weather variability and the increase in events such as heavy rains may increase the importance of transport pathways. Some areas which are not currently considered transport pathways or would be transport pathways only under extreme conditions may have a changing status under climate change projections. The role of each transport pathway is somewhat unique and the level of risk should be considered using climate change projections.

The changing importance of transport pathways may be illustrated through considering specific examples, or scenarios. An example is an improperly sealed well casing. During periods of intense rainfall, water pools around the casing and runs along the casing into the aquifer, providing a pathway for surface contamination. Historically this may have occurred very infrequently, but under projections of increased frequency of extreme events such as intense rainfalls this could become a significant occurrence.

7.3.2 Surface Water

As discussed in Chapter 6 the region has five drinking water intakes, two in the Ottawa River and three in smaller inland waterways.

Water Quantity

IPZ delineation is based on Time of Travel (ToT). If seasonal changes occur in flow characteristics due to changing temperature and precipitation patterns which in turn affect ToT, IPZ delineation could increase or decrease accordingly.

As discussed, if surface water quantity is reduced in some seasons it can result in increases in contaminant concentration. Modifications to IPZ delineation may be required to ensure protection of the drinking water quality at the water intake. Low flows may also affect mixing in some waterways.

If an increased risk of severe flooding occurs and floodplain delineation is modified to address this, then the IPZ-2 will require similar delineation changes.

IPZ-3 delineation is event-based in the Ottawa River. If precipitation events become more severe and/or more frequent there may be a need to modify IPZ-3 delineation to address the increased areas that may feed contaminants into the waterways.

The IPZ-3 delineation uses the Boundary Approach for the Ottawa River municipal water intakes, using the assumptions that spring freshet is the most extreme annual event. As freshet duration and/or intensity is reduced and off season rainfall events occur on a more regular basis, this assumption may need to be revisited.

Water Quality

Earlier springs and warmer air and water temperatures, resulting in increased bacterial and aquatic plant growth, may decrease water quality to a greater extent than it does now.

Transport Pathways

Surface transport pathways which do not currently play a significant role in increasing water volumes or decreasing ToT may, in the future, become more important if precipitation patterns change. Following are some examples of changes in the role transport pathways may play.

- Transport pathways may serve to dilute contaminant concentrations in waterways during rain events as they decrease the ToT for precipitation to reach the waterways, increasing the volume of water and in some circumstances decreasing contaminant concentrations which may be present.
- Transport pathways may decrease the amount of water infiltrating into the soil and recharging groundwater as they encourage runoff. If contaminants are present, this may actually serve to reduce the amount of contaminant entering groundwater under certain circumstances.
- An increase in heavy rain events may flush contaminants from further distances into transport pathways which then would carry the contaminants into waterways.
- The large number of scenarios on the possible role of transport pathways which are possible illustrates the complexity of determining problems and priorities.

Impervious Surfaces

Areas with a high percentage of impervious surfaces will be affected by rapid snowmelt and rain events. These areas are designed to drain surfaces quickly and will increase the peak volume of water in local waterways in periods which may already be experiencing high water levels.

As discussed in Section 7.3.1, in certain circumstances impervious surfaces may also decrease water quality due to the use of road salt which then runs off into waterways.

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