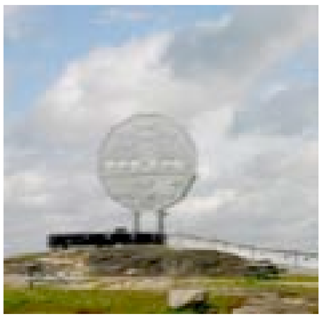
1 City of Greater Sudbury – Roads and Associated Structures Assessment

1.1 Background

Within the First National Engineering Vulnerability Assessment, the Public Infrastructure Engineering Vulnerability Committee (PIEVC) identifies roads and associated structures among the four priority classes of infrastructure to assess for vulnerability and adaptability to climate change.



The City of Greater Sudbury was selected as a case study in the roads and associated structures category. Dennis Consultants and Hydro-Com Technologies, divisions of R.V. Anderson Associates, conducted the case study. The consultants used the Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment and various information sources (including City of Sudbury personnel, climate models and a stakeholders workshop).

Figure A-15 City of Greater Sudbury

1.2 Where, What and How

The City of Sudbury, population approximately 158,000, operates and maintains about 3,500 km of roads. The city covers an area of about 3,600 sq. km, and is located on the Canadian Shield, about 340 km northwest of Toronto and 425 km west of Ottawa. An unusual feature of the area is that, due to recent amalgamations, Greater Sudbury has 330 lakes within its boundaries, more than any other municipality in Canada. They include Lake Wanapitea, the largest lake in the world completely contained within the boundaries of one city. The diverse soil conditions of the area can range from Precambrian Shield Rock to swamp within a few metres, creating road design and construction challenges.

Northern Ontario climate conditions, such as snowfall, sleet and particularly freeze/thaw cycles, pose infrastructure challenges. Daily temperatures in winter can drop as low as -40°C and as high as the upper +30°s C in summer. Although Sudbury is one of Ontario's sunniest communities, frost penetrates almost two metres into the ground on average and can reach three metres depending on freeze-thaw cycles. Mid-winter thaws now appear regularly in January and February and contribute to maintenance costs. Snowfall accumulations ranged from 256 cm to 286 cm between 2003 and 2006.

Increased variation in climatic conditions over the winter makes it difficult to forecast maintenance expenses. (The City maintains a "bare pavement" standard.) Winter control maintenance is the most significant (and rising) contributing factor to road-infrastructure costs.

The case study considers urban, rural, arterial and collector roads, with traffic volumes of up to 30,000 a day on major roads, and related components including:

- Above-Ground Components (e.g., the surface and surface treatment, curbs, sidewalks, bike paths, bridges and related structures, traffic signals, street lighting, municipal signage, etc.);
- Below-Ground Components (e.g., road sub-base, storm sewer systems, distribution systems, collection systems and underground utilities); and
- Miscellaneous: administration/personnel, surface maintenance (markings, crack sealing), winter maintenance (plowing, salting, etc.) and record-keeping.

The expected lifespan of roads and associated structures in the Sudbury area is about 30 years. This lifespan depends on interim rehabilitation being done when needed.

Data on climate change effects on ice accretion or ice storms that would have been of interest to this case study was not available. Interviews with city staff responsible for road maintenance did yield helpful information on what components might be more vulnerable to climate change. OURANOS, however, is able to make the following projects about the following types of climatic conditions the case-study region will experience by 2020 and to a greater extent by 2050 and 2080:

- a general warming trend, with hotter summers and warmer, shorter winters;
- slightly increased rainfall, with more frequent and intense precipitation, and more frequent and severe storms (but no change in total rainfall in summer);
- a decrease in the amount of snow, with a reduction in the number of minor storms, and an increase in major storms and “rain on snow” events; and
- a shorter frost season and a decrease in the number of freeze/thaw events.

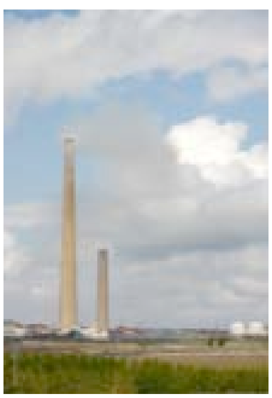


Figure A-16 Sudbury industries

A sizeable portion of the City’s nearly $500 million annual budget goes toward road operation and maintenance. In recent years, the amount of capital spending on roads has not kept pace with maintenance requirement and this has led to higher repair costs.

It is noted that the Sudbury region has major mines (Xstrata and Vale Inco) and these operations contribute to the overall economy. However, in terms of covering costs related to roadways, they City has limited powers to tax these resource operations.

1.3 Technical Summary

Climate Modeling

The Greater Sudbury case study of infrastructure vulnerability and adaptability to climate change draws on climate modeling by OURANOS and uses the Canadian Regional Climate Model. The years 2020, 2050 and 2080 were selected as the bases for analysis.
It should be noted that OURANOS was unable to model expected changes in ice build-up and accretion due to insufficient data. The Sudbury PIEVC workshop identified this potential climate event as being important in assessing possible impacts of climate change on roads.

However, OURANOS can make the following general projections about changes in temperature, rainfall, snowfall, wind and frost that are likely to affect the case study region:

1) Temperature

A warming trend is predicted, with higher average maximum and minimum temperatures on both a monthly and annual basis. This is in line with the general warming trend predicted worldwide (hotter summers and warmer, shorter winters).

2) Rainfall

Rainfall is expected to increase slightly. This follows general trends for Ontario and Eastern Canada that suggest somewhat more precipitation will fall as rain, and more frequent severe storms will occur. Little change in rainfall amounts is expected during the summer months (June, July and August).

3) Snowfall

Snowfall is expected to decrease overall, with fewer minor snow storms (less than 20 cm) and more large snow storms (20 cm or more). An increase in the occurrence and severity of “rain on snow” events is also suggested.

3) Wind

No changes are suggested.

4) Frost

A shorter frost season and a decrease in freeze-thaw cycles are suggested.

5) Cumulative Effects

No significant impacts are expected on infrastructure as a result of the cumulative effects of climate factors.

Probability Scales

The case study employs two probability scales (Method A – Climate Probability Scale Factors and Method E – Response Severity Scale Factors) from the Protocol for Climate Change Infrastructure Vulnerability Assessment to gauge vulnerability of Vancouver Sewage Area infrastructure to climate change.

Scale	**Method A** **Climate Probability Scale Factors**	**Method E** **Response Severity Scale Factors**
0	Negligible or not applicable	Negligible or not applicable
1	Improbable/highly unlikely	Very low/Unlikely/Rare Measurable change
2	Remote	Low/Seldom/Marginal Change in Serviceability
3	Occasional	Occasional Loss some capacity
4	Moderate/possible	Moderate Loss of some capacity
5	Often	Likely Regular Loss of Capacity and Loss of Some Function
6	Probable	Major/Likely/Critical Loss of Function
7	Certain/Highly probable	Extreme/Frequent/ Continuous Loss of Asset

The climate change effects that were considered include average daily high temperature, average daily low temperature, extreme temperature range, rainfall and snowfall frequency and intensity, freeze/thaw cycles, and wind.

Climate Change Impacts

Based on the data provided, none of the infrastructure components assessed was considered to be highly vulnerable to climate change effects. However, the study pointed to some potential vulnerability related to the effects of rainfall on drainage infrastructure and gravel road surfaces.

It should also be noted that lack of detailed information made it difficult to evaluate the capacity of Sudbury's drainage infrastructure in the event of heavy rainfall or snowfall. The development of a database with more information on conveyance capacity and design flows, including type, size, age and location, would be helpful. This gap is significant, in light of the fact that predicted rainfall events are large enough to affect structural integrity and other aspects of the infrastructure. Although the City of Sudbury is equipped to deal with heavy snow events, and vulnerabilities are not expected to arise, there is a lack of data to substantiate this belief.

High Temperatures

Roads – Asphalt road surfaces could lose their rigidity due to extremely high temperatures, impacting the structural integrity and functionality of the roadway.

Intense Rain

Drainage System (includes bridges and related structures, storm sewer systems, catch basins, culverts and ditches) – Intense rain events could cause overloading of the drainage infrastructure, overflowing private property with insurance and economic ramifications. As well, overloading of the combined sewers could impact public health, and contaminants and sediments could be washed into watercourses, affecting the environment.

*Road*s – Rain could pool on road surfaces, affecting emergency responses. Gravel surfaces may be eroded, resulting in ruts and depressions, requiring more maintenance and in some cases making roads impassable.

Embankment – The structural integrity of embankments may be affected, raising the possibility of washouts, more repair work and loss of sediment to watercourses, affecting the environment. Falling rock and soil material could also cause vehicle accidents and personal injury.

Intense Snow

Roads – Intense snow would greatly affect functionality of the road system, impact emergency response and public safety and require greater maintenance.

Culverts – Large snowfalls could block culverts. The need for larger, more versatile equipment for snow clearing would increase.

Frost

Curbs, sidewalks and surface maintenance (repairing holes) – A shorter frost season and freeze/thaw cycles would reduce maintenance requirements of these infrastructure components.

1.4 Policy Makers Executive Summary

General Climate-Change Impact

The City of Greater Sudbury area can anticipate hotter summers and warmer, shorter winters as a result of climate change. Rainfall is expected to increase slightly, not only in frequency and amount but also in intensity. More frequent and severe storms are also likely, although relatively little change is anticipated in total rainfall during the summer months. Warmer winters will bring a decrease in snowfall and in the number of minor storms. However, an increase in the number of major snowstorms is predicted, as well as more “rain and snow” combination events. A shorter frost season is anticipated, along with a reduction in freeze/thaw cycles.

Climate-change effects upon Greater Sudbury roads and associated structures do not suggest high vulnerability of any of the components assessed. High temperatures and intense rain and snowfall events will, however, have an impact on road surfaces and could potentially cause overflow of the drainage system and related infrastructure, including embankments. This could pose public health, emergency response and environmental risks, as well as increasing maintenance costs.

It should be noted that lack of data on drainage capacity limited assessment of infrastructure vulnerability resulting from heavy rain and snowfall.

It must also be pointed out that, due to lack of data, this case study does not evaluate potential infrastructure vulnerabilities related to ice storms. This is a significant gap, particularly since this type of weather event could increase. In future, the availability of suitable data may lead to more information about potential vulnerabilities.

Specific Impacts on Sudbury Area Infrastructure

Some specific components of the Greater Sudbury roads and associated structures are expected to be impacted by climate changes, notably changes related to increases in intense rainfall and more severe snowstorms, along with more “rain on snow” events.

Drainage System (*including bridges and related structures, storm sewer systems, catch basins, culverts and ditches)*

The system’s capacity to deal with heavy rain and snowfall events requires further study and attention. Increased rain with higher flows and velocities could result in overflowing, which could affect private property, adding to insurance costs, and cause public health and environmental risks. There is also concern that heavy snowfalls could block culverts, resulting in further overflowing.

Roads (asphalt and gravel)

Extremely high temperatures, and a longer duration of high temperatures, could contribute to wear and tear on asphalt road surfaces, causing them to lose their rigidity. Intense rain could result in pooling, impeding emergency responses and causing surface contaminants to be washed into the drainage system and nearby water courses. On gravel surfaces, intense rain could hasten erosion, adding to maintenance costs, and even making roads impassable. Major snow events could significantly impact traffic flows as well as impede emergency response and cause public safety challenges.

Embankments

Intense rainfall could cause washouts, and result in falling rock, posing safety risks to vehicles and occupants. Soil material could also be carried away, increasing maintenance costs.

Curbs, sidewalks and surface maintenance (repairing holes)

A positive impact is that warmer winters and decreased freeze/thaw cycles will reduce the maintenance required for road surfaces, curbs and sidewalks.

Recommendations

Although this case study does not identify vulnerabilities for the components assessed, the consultant makes “medium-priority” recommendations for remedial action or further study. Key recommendations centre on stormwater management related to roads and drainage infrastructure, the impact of high temperatures on paved roads, mitigating the effects of rainfall (groundwater) on embankments, and further study of vulnerabilities related to ice events. They were presented in order of importance:

- Develop a database with hydraulic information for all culverts within Greater Sudbury.
- Perform a capacity evaluation of minor and major drainage systems within Greater Sudbury.
- Perform impact assessments of the functionality and environmental effects associated with increased rainfall intensity and frequency on gravel surfaced roads.
- In response to the lack of reliable information related to potential increases in ice accretion/ice storms, do a risk and criticality assessment of the roads and associated infrastructures, design standards, and operations and maintenance procedures that could be impacted by ice accretion and ice storms. (Specific attention should be paid to the suspected drastic impacts of ice, snow and the re-freezing of pooled water and slush on the functionality of sidewalks in general, and the priority that is assigned to the winter maintenance of sidewalks in particular).
- Evaluate the possibility as well as the lifecycle costs associated with changing the asphalt mixes used in Greater Sudbury to accommodate higher temperatures. Alternatively, consider the use of trees to provide shade on low-speed roads to reduce the urban “heat island effect.”
- Perform sensitivity analyses on the slope stability of large and “high risk” embankments/cuts within Greater Sudbury in response to increased groundwater levels.