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The Temporal and Spatial Impacts of Road Salt on Streams Draining the Greater Toronto Area

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Abstract

The Ontario Ministry of Environment (MOE) and the Geological Survey of Canada (GSC) are working in collaboration to identify the importance of groundwater discharges to surface watercourses in the Greater Toronto Area (GTA). Background surface water chloride concentrations range from 10 to 25 mg/l in the GTA whereas in the urbanized Don River, concentrations exceeding 1,000 mg/l have been reported during snowmelt conditions, with median chloride concentrations of approximately 100 mg/l. Chloride concentrations in streams correlate well with reported degradation in the chemistry, physical features and biological health of watercourses. Since the laboratory analysis of chloride is both reliable and affordable, it may be an effective indicator parameter in environmental monitoring programs.

Introduction

The Ontario Ministry of Environment and the Geological Survey of Canada are working in collaboration to identify the importance of groundwater discharges to watercourses in the Greater Toronto Area (Hinton, 1996; Hinton *et al.*, 1998). Baseflow water quality surveys were undertaken to characterize regional differences in stream and groundwater chemistry. These surveys can be used to illustrate the influence of chemical point and non-point sources of pollution. These data have been examined in conjunction with historical data from the MOE Provincial Water Quality Monitoring Network and compared to various measures of surface water quality conditions, and ecological function of watercourses in the GTA.

Chloride is a highly soluble, and mobile ion which does not biodegrade, volatilize, easily precipitate, nor does it significantly absorb onto mineral surfaces. It travels readily through soils, enters groundwater and eventually discharges into surface waters. Increased chloride levels in surface and groundwater are a function of highway density, percentage of urban areas as streets, population density, traffic patterns, and road salting practices. Howard and Hayes (1997) provide an excellent account of the contamination of surface and groundwater by de-icing chemicals in the GTA. They report that more than 100,000 tonnes (t) of road salt (NaCl) are applied to Metropolitan Toronto roads and highways each year. Much of this salt is washed out each winter as snowmelt; however, a significant proportion (45-55%) enters the groundwater and eventually is discharged to streams as baseflow.

Study Area

The Greater Toronto Area of southern Ontario is Canada's largest metropolis, with a population of over 4 million. Our investigation of chlorides has focused on watercourses administered by the Toronto and Region Conservation Authority (TRCA). Headwaters for several of

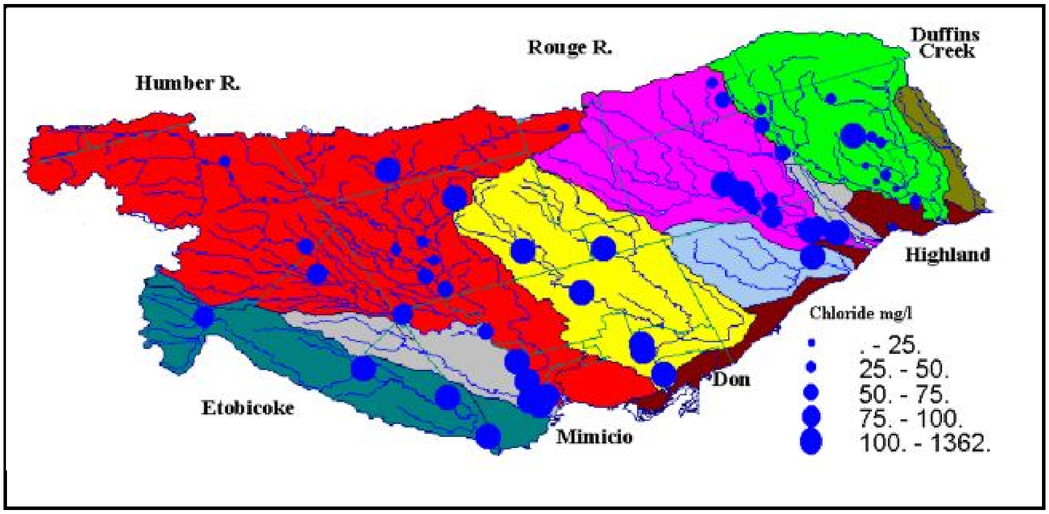

Figure 1: Chloride Concentrations in GTA Watersheds

these watercourses arise on the Oak Ridges Moraine (ORM) which has been the subject of intensive work by the GSC (Sharpe *et al.,* 1997). Detailed stream baseflow surveys were carried out in 1995 and 1996 in the Humber River and Duffins Creek watersheds. In 1997, surveys of the Rouge River and Little Rouge Creek were undertaken.

Results

The spatial pattern of chloride concentrations in surface waters of the GTA watersheds reflect traffic volumes and the distribution of highways, secondary and urban road networks (Paine, 1979; Ralston and Hamilton, 1979; Van Loon, 1972) (See Figure 1). Background concentrations of chlorides range from 10 to 25 mg/l whereas the more urbanized watercourses, such as the Don River and Highland Creek, experienced the highest chloride concentrations due to the denser and more heavily used highway and road transportation networks. In the Don River, chloride concentrations exceeding 1,000 mg/l have been reported during snowmelt conditions, with median concentrations of approximately 100 mg/l.

More detailed baseflow water chemistry surveys in Duffins Creek and the Humber River confirm that lower chloride concentrations occur predominantly in the rural portions of watersheds (Figures 2 and 3). These surveys also reveal that upstream areas within the ORM also are important groundwater discharge areas (Hinton, 1996; Hinton *et al.*, 1998) which dilute chloride concentrations (and other parameters) in downstream urban areas. Dilution of the effluent from the Stouffville Sewage Treatment Plant demonstrates this effect (Figure 2). Urbanization gradually will cause drainage areas to contribute rather than dilute chlorides. Small streams crossing the Lake Iroquois Shoreline in Duffins Creek have higher chloride levels because these streams do not originate on the ORM and have lower baseflow discharge which cannot dilute chloride sources.

Long-term monitoring locations show a gradual increase in chloride concentrations. In Highland Creek, a highly degraded urban watercourse, statistical trend analysis shows chloride concentrations increasing from 150 mg/l in 1972 to over 250 mg/l by 1995 (Figure 4). Increased chloride concentrations also are evident in Duffins Creek, with median values increasing from 10 to 20 mg/l to 30 to 40 mg/l (Figure 5). Howard and Hynes (1997) estimate that baseflow concentrations will reach 400 mg/l in urban watercourses (e.g., Highland Creek) within a 20 year time frame.

The pattern and chronology of water quality conditions in the Greater Toronto Area, as reported by Environment Canada *et al.* (1998), are related to changes in chloride. For example, the spatial pattern of total phosphorus (Figure 6) correlates well with the observed pattern of chloride (Figure

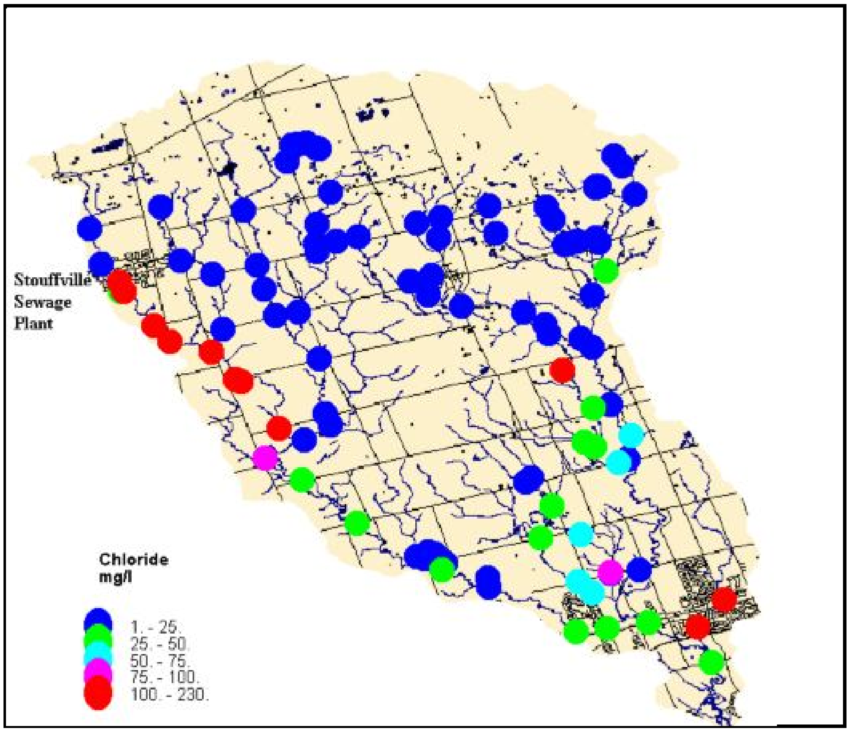

Figure 2: Summer Baseflow Chloride Concentrations in the Duffins Creek Watershed

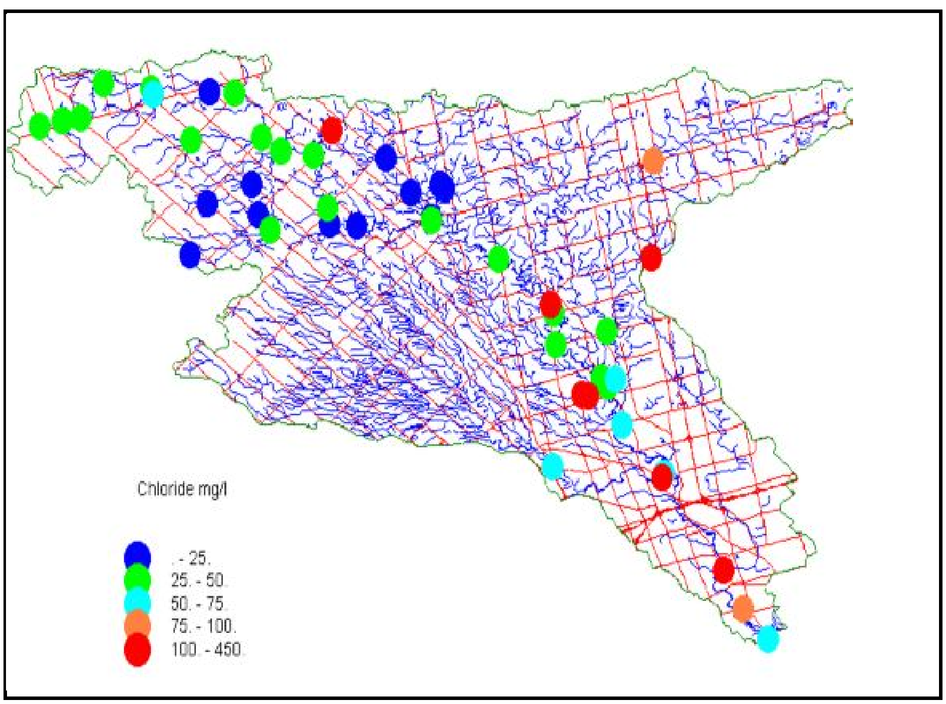

Figure 3: Summer Baseflow Chloride Concentrations in the Humber River Watershed

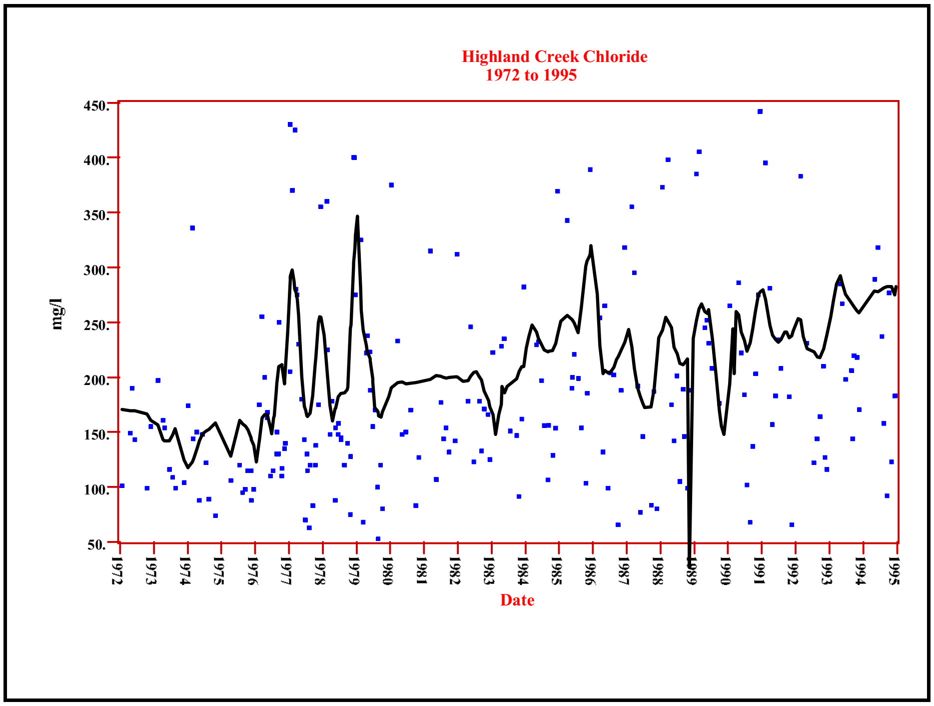

Figure 4: Long-term Chloride Trend in Highland Creek

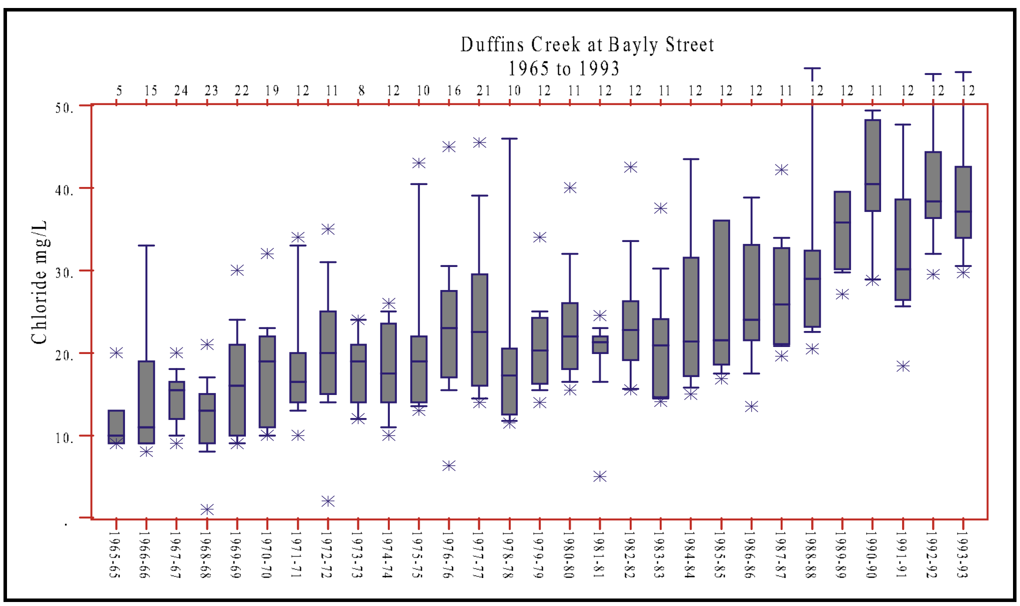

Figure 5: Long-term Chloride Trend in Duffins Creek

1). Monitoring data collected by the MOE and Toronto and Region Conservation Authority and Environment Canada over the past 30 years, has shown general deterioration in the quality of streams as a result of urbanization (Beak, 1988; D'Andrea and Anderton, 1996; MTRCA, 1994). Within the GTA, urban watercourses with the highest chloride concentrations such as the Don River, Highland Creek, Mimico Creek and Etobicoke Creek are more turbid, more heavily polluted with bacteria and frequently exceed Provincial Water Quality Objectives for several toxic substances. Conditions in these urban watercourses generally are not suitable for sustaining healthy

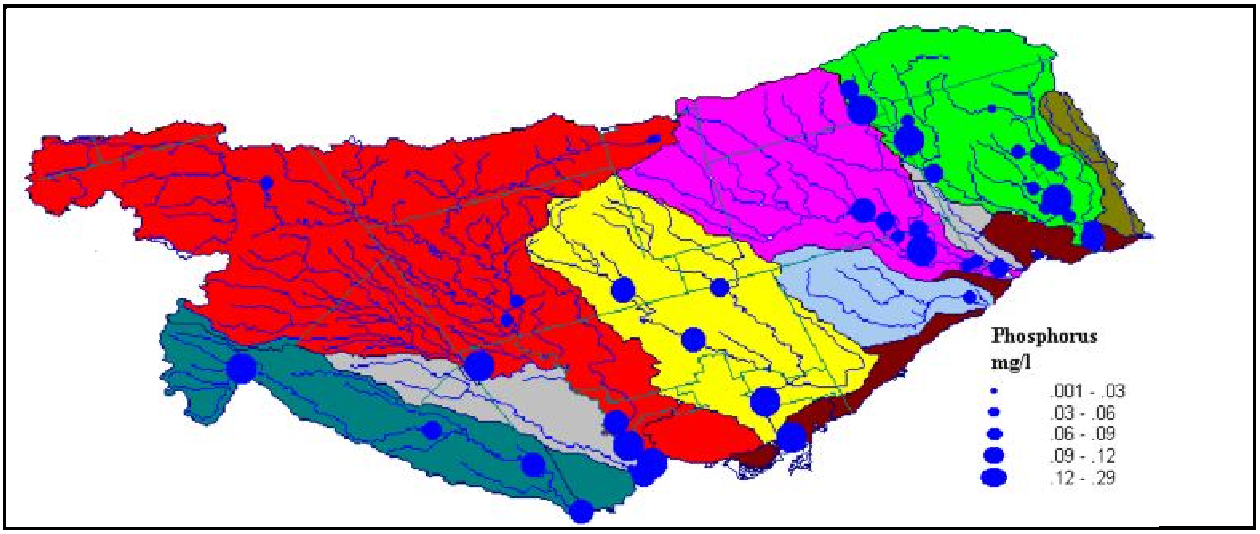

Figure 6: Total Phosphorous Concentrations in GTA Watersheds

fish populations due to habitat alterations (Environment Canada *et al.*, 1988) and are subject to frequent flooding and erosion problems.

Stream baseflow provides an integrated measure of groundwater discharge. Therefore, summer baseflow chloride concentrations reflect chloride transport to the stream via groundwater, direct surface water sources, or surface water impoundments. Our baseflow investigations have shown watercourses with low chloride concentrations generally to be associated with unpolluted streams, which have stable stream channels and healthy fisheries. These observations are consistent with the findings of an intensive study of the relationships of land use and stream health which demonstrated that measures of urban development and measures of the degree to which riparian forest was present, were associated with stream health in Toronto area watersheds (Steedman, 1987). Furthermore, watershed health as measured through the Index of Biotic Integrity (Figure 7) is related to the patterns of stream chloride (Figure 1). Small watersheds without headwaters in the ORM were predominately of poor quality, as were sites in the mid to lower Don and Humber River watersheds. The highest proportion of good to excellent sites were found in Duffins Creek where chloride concentrations are low.

Discussion and Conclusions

Chloride concentrations in streams appear to correlate well with reported degradation in the chemistry, physical features and biological health of urban watercourses. While the relationships reported here are strictly qualitative, they warrant further investigation and quantification. The value of this correlation is that stream baseflow chloride concentrations may serve as a preliminary indicator parameter in environmental monitoring programs. In the GTA, chloride concentrations also are strongly correlated with stream electrical conductivity. Therefore, very simple and inexpensive baseflow surveys of stream chloride or conductivity potentially could indicate the relative degradation of different stream segments or document long-term watershed degradation related to gradual urbanization.

An obvious benefit of chloride as an indicator of watershed health is that it primarily shows the effects of urbanization. Therefore, it also can provide some indirect measure of other effects that are not directly related to road salting but often are associated with urbanization (e.g., erosion). However, chloride would not serve as an indicator for effects related to agriculture that also can greatly affect stream water quality and ecological integrity. Consequently, chloride cannot serve as a universal indicator of stream health but may

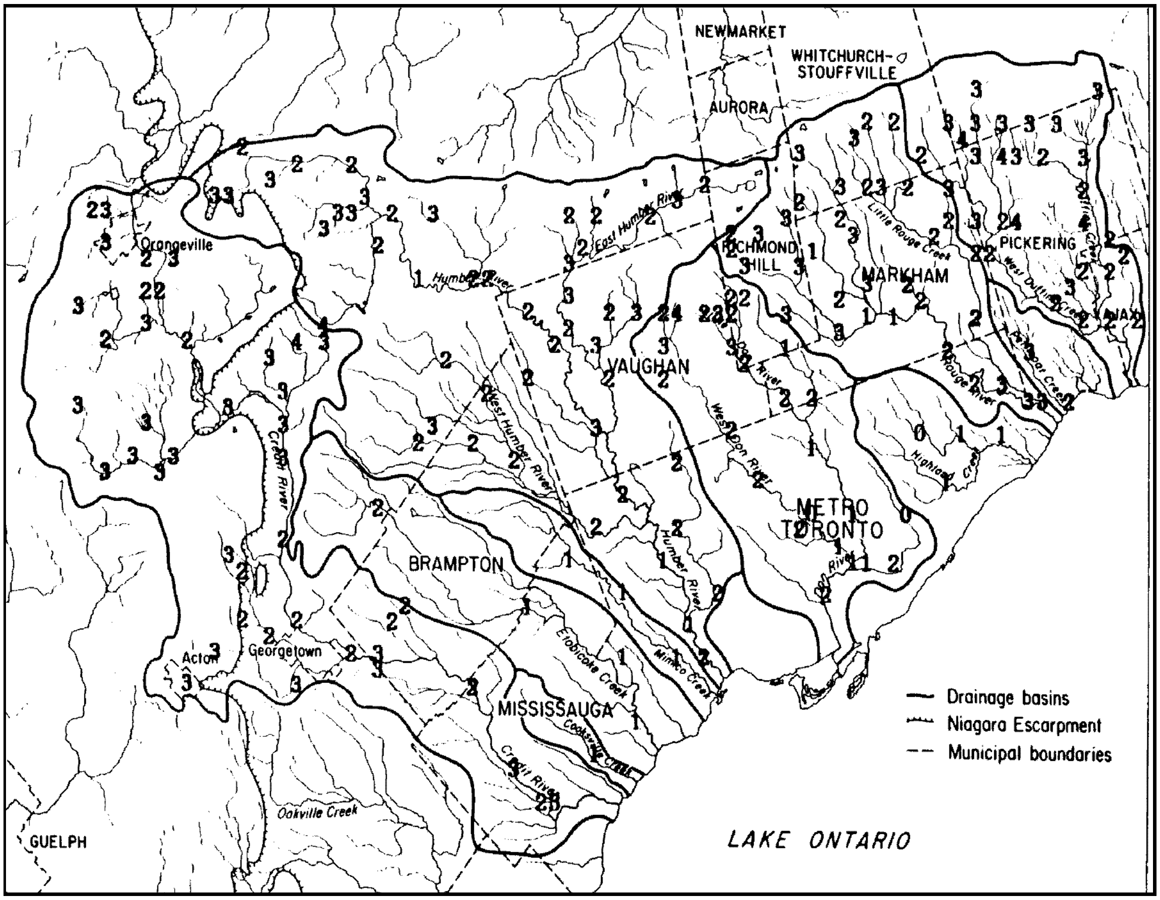

Figure 7: Index of Biotic Integrity in GTA Watersheds. 0 = Low Integrity, 4 = High Integrity (Steedman, 1987)

be one of a suite of indicators that could be used to monitor stream health.

These observations raise the question of whether a threshold chloride level can be defined as a warning for other kinds of degradation. Comparison of long term chloride trends (both peak and baseflow) in Duffins and Highland Creeks suggest that an intermediate value of approximately 50 to 100 mg/l may be appropriate (Figures 4 and 5). However, further analysis of observed relationships between stream health and chloride trends are needed to validate this estimate.

Even at the elevated levels reported for Highland Creek and the Don River, chlorides are not considered to be deleterious to aquatic biota. For drinking water purposes, chloride concentrations exceeding 250 mg/l in wells or surface water are likely to present taste problems. Environment Canada currently is reviewing the environmental implications of road salt on the environment and has established an Environmental Resources Group to develop an assessment approach and work plan for the review of road salt as a priority pollutant substance. Provincial agencies (MOE and Ministry of Transportation) actively are seeking ways to mitigate and safely reduce salt applications.

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