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URBAN INFRASTRUCTURE FLOODS IN SOUTHERN ONTARIO: A METHODOLOGY TO DETERMINE CAUSALITY (PART ONE)

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Article abstract

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Factors that need to be considered include the current extreme precipitation regime for southern Ontario, which is determined through literature reviews and through considering the annual maximum precipitation. The second factor that is considered is changes in land use from permeable to more impermeable surfaces, measured using aerial photos and a planimeter. The hydrological impacts of the change in land use from pervious to less pervious in the watersheds was considered through the literature. Precipitation data for southern Ontario do not follow the same trend as those in the U.S or the expected future trends for Canada. The role of climate change, sewage networks, insurers and communication between stakeholders are also considered. The main contribution of this work is the establishment of a methodology to determine causality of urban infrastructure floods, and the obstacles that exist to this type of research.

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by Tanuja Kulkarni

ABSTRACT

Urban flooding can be described as floods that occur outside of floodplains and are enhanced by the extreme impermeability of city surfaces. The Supreme Court of Canada's Thunder Bay decision that in some instances municipalities are liable for urban flood damage addresses the importance of paving in a watershed.

Factors that need to be considered include the current extreme precipitation regime for southern Ontario, which is determined through literature reviews and through considering the annual maximum precipitation. The second factor that is considered is changes in land use from permeable to more impermeable surfaces, measured using aerial photos and a planimeter. The hydrological impacts of the change in land use from pervious to less pervious in the watersheds was considered through the literature. Precipitation data for southern Ontario do not follow the same trend as those in the U.S or the expected future trends for Canada. The role of climate change, sewage networks, insurers and communication between stakeholders are also considered. The main contribution of this work is the establishment of a methodology to determine causality of urban infrastructure floods, and the obstacles that exist to this type of research.

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RÉSUMÉ

Le phénomène de l'inondation urbaine peut être défini comme toute inondation survenant hors des plaines inondables, rehaussées par l'extrême imperméabilité des surfaces urbaines. L'auteure se réfère à l'affaire Thunder Bay rendue par la Cour suprême du Canada concluant que les municipalités sont responsables, dans certains cas, des dommages consécutifs aux inondations urbaines ; cette décision témoigne de l'importance du pavement dans les zones délimitant la ligne des eaux.

Les facteurs qui doivent être considérés comprennent, d'abord, les précipitations extrêmes qui se produisent couramment dans le sud de l'Ontario, dont on peut mesurer l'ampleur dans la littérature au regard des précipitations maximum annuelles. Un second facteur à examiner réside dans les changements d'utilisation de terrain, c'est-à-dire des utilisations à l'origine dans les surfaces perméables jusqu'à celles beaucoup plus imperméables, ce qui peut être mesuré soit par des photographies aériennes soit par un planimètre. La littérature examine également les impacts hydrologiques des changements d'utilisation des sols, des altérations perverses à moins perverses, au niveau de la ligne de partage des eaux. Les données sur les précipitations dans le sud de l'Ontario ne suivent pas les mêmes tendances que celles existantes aux États-Unis ou les tendances à venir qui sont estimées comme probables au Canada. Sont également considérés le rôle joué par les changements climatiques, les réseaux d'égouts, les impacts dans l'industrie de l'assurance et la communication entre les principaux intervenants. La principale contribution de cette recherche est d'établir une méthodologie dans le but de déterminer les causes des inondations au niveau des structures urbaines et les obstacles qui existent dans ce type de recherche.

1.0 INTRODUCTION AND PROBLEM DEFINITION

Urban infrastructure floods can be characterized as flood events from rainstorms or snowmelt that supply a large amount of water, and are enhanced by the extreme impermeability of city surfaces (Lawford et al. 1995). Urban infrastructure flooding can occur outside of floodplains, contrary to natural flooding processes.

If there is an increase of urban flooding in southern Ontario, it is important for stakeholders to recognize the impacts and attempt to mitigate them. Urban infrastructure floods can cause damage to property. Furthermore, complex insurance issues have left some homeowners who experienced urban flooding with inadequate redress. One of the main problems with compensation is the question of causality; determining if floods in urban areas were a result of overland flow, sewer back-up or a combination of the two is of pivotal importance when establishing insurance status. Sewer back-up can be insured against, but incidences of overland flow floods are not. The 1997 Supreme Court of Canada ruling found the City of Thunder Bay negligent, and required them to compensate homeowners who were flooded. This case addressed part of the causality issue, but the complexity of issues surrounding urban infrastructure flooding is still problematic for municipalities, insurers and property owners alike, as no group has primary responsibility for collecting flood information.

Urban floods and the impacts of their damage are problems that should not persist. Appropriate watershed planning, watercourse engineering and appropriate insurance application should be effective to prevent homeowner losses due to flooding.

Lawford et al. (1995) state that "urban floods are a special case of rainstorm floods because the flood from a rainstorm supplying a large amount of precipitation is enhanced by the extreme impermeability of the city surface". Although there is no established methodology for this type of study, two variables are being explored in this paper. The first is increases in extreme rainfall as a contributing factor to urban infrastructure floods. The second is changes in land use that reduces permeability.

☐ 1.1 Goals of the Paper

The main goal of this work is to establish a methodology for studying the causality of urban floods. A number of issues are noted. First, to determine if urban floods are the result of increased precipitation. Regional rainfall literature from the United States and Canada were examined to determine if increases in extreme precipitation events have occurred in Southern Ontario. The role of global climate change and the response of the stormwater systems for handling increased volume are also addressed. The sewage systems themselves need to be considered when studying urban floods, as the increasing growth of the sewer network relative to urban development may be a key concern. The sewershed that the flooded area lies in is important to define, and its characteristics, including capacity and density need to be determined. Changes in land use are also analyzed to determine the contribution of permeable surfaces urban floods.

The final goal of this research is to determine what obstacles exist to the collection of relevant data for the study of urban floods.

1.2 Variables of Consideration

1.2.1 Precipitation

Changing precipitation patterns in Southern Ontario will change the flood regime. Increased incidence of extreme precipitation events will cause an increase in non floodplain, urban infrastructure floods. Bruce (1997) argues that "there is increasing evidence that future rain may come more in heavy bursts, with higher percentages of the rain running off, and with significant portions of the basin being paved, (more research is) require(d)". Increased rainfall in short periods, combined with the traditional infrastructure idea of "get the water off the land as quickly as possible" may have contributed to increased urban flood frequency. (Kinkead 1997).

1.2.2 Land Use Change

Changes in local land use from permeable to impermeable will increase urban flood frequencies. For example, permeable land that surrounds a housing development that is converted to an impermeable surface will affect how water flows around that housing development. The water will be delivered to the sewer systems faster, and will contribute to urban infrastructure flooding.

2.0 METHODOLOGY

Many cities experience significant urban flood events, all with similar impacts (e.g. homeowners incurring large costs, inconsistent insurance reactions, undefined causality). Although local newspapers identify areas affected by floods, few are reported in newspapers with regional or national circulation, yet urban flood events have been reported from British Columbia, Ontario, and Quebec. This paper will focus on southern Ontario, as there have been a number of incidences reported in this area in local newspapers.

Insurance archives were searched to determine incidences of urban floods, how urban flood information is archived, and where urban flooding occurs, and how it is defined according to insurers.

Global climate change may be a driving factor for increases in extreme events. Precipitation data and current literature were used to determine if a measurable increase in extreme precipitation in southern Ontario has occurred. Sewage system data, land use data, local street maps, soil maps and aerial photos were collected for each of the three case cities to determine if land use in the area immediately surrounding flood events has changed over the last twenty years.

Current sewer networks were investigated through interviews with Municipal Works Department personnel, sewage maps and news reports.

☐ 2.1 Communication

Barriers to this type of research were discovered and documented. Phone interviews and personal meetings with water resources personnel at the appropriate Conservation Authorities were conducted, as well as with the Toronto and Region Conservation Authority. Engineers and water services personnel at the city hall of each of the case study cities and at the city of Toronto were interviewed (Appendix 1). The extent of communication and collaboration between municipal governments, insurers and Conservation Authorities was determined.

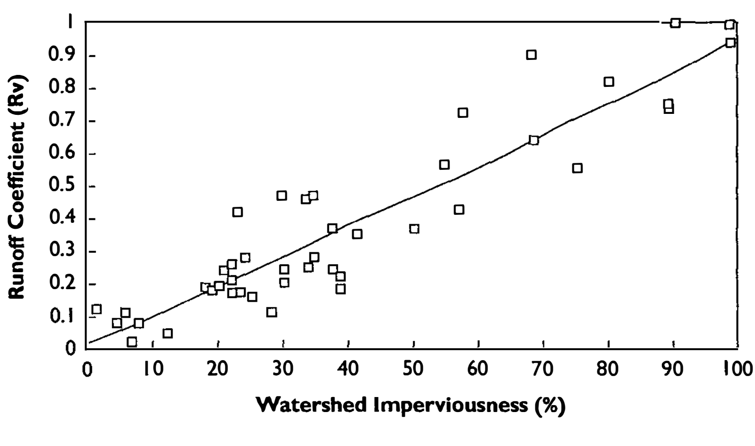
■ 3.0 IMPLICATIONS OF URBANIZATION FOR THE HYDROLOGICAL CYCLE

Urbanization causes changes to the terrestrial phase of the hydrologic cycle. Impermeable surfaces render urban areas more vulnerable to flooding, and promote rapid runoff rates that result in large quantities of water reaching urban drainage networks (Brun 1997). There is a decrease in infiltration due to hardening of surfaces, decreased amount of depression storage available due to regrading, reduced evapotranspiration due to vegetative cover removal, and faster travel time to the receiving body of water as a result of sewer system construction. All of these changes combine to increase the volume of runoff. Pipes may replace small streams, while open channels, after urbanizing, may be dry between storm events (Snodgrass et al.1997).

Traditionally, Canadian floods are the result of heavy rainfall events; ice jams; or snowmelt. In urban areas, floods are also the result of low drainage capacity mixed with combined systems[1] inadequate rainwater removal and land cover change from vegetated to impermeable surfaces. In Canada these urban floods are most common in southern Ontario, Quebec and southern B.C. (Brun 1997).

Imperviousness is the portion of the total catchment area covered by the sum of roads, parking lots, sidewalks, rooftops and other impermeable surfaces of the urban landscape. For mature urban areas, it can be defined as the fraction of watershed that remains unvegetated (Snodgrass et al. 1997). Land development almost always involves increasing the imperviousness of the landscape. Imperviousness is a useful indicator for measuring the impacts of land development on receiving waters and their aquatic environments because the intensity of the impacts is typically a function of urbanization (Snodgrass et al. 1997). Figure 1 describes the relationship between stormwater runoff and imperviousness in a watershed, illustrating how, in highly urbanized systems, there is higher runoff. This coefficient closely tracks the percent imperviousness except at low levels, where soils and slope factors play a larger role. The runoff coefficient characterizes variables including antecedent precipitation, soil moisture, infiltration, slope, ground cover, surface and depression storage, the shape of the drainage area and overland flow velocity (Belore 1976).

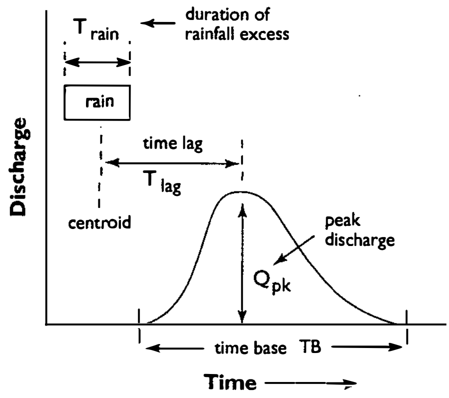
FIGURE 1
IMPERVIOUSNESS AND STORWATER RUNOFF IN A WATERSHED



Runoff coefficient (Rv) is a function of site imperviousness. Once acre parking lot is Rv = 0.95, while one acre of meadow is Rv = 0.06. (Snodgrass et al. 1997)

The hydraulic regime of urban sewer floods differs from natural streams in three basic areas. There is an increase in the magnitude and frequency of severe flood events; more of the annual flow is delivered as surface storm runoff (vs. baseflow or interflow); and the velocity of the flow during storm events increases. Urbanization increases peak flow, decreases the duration to peak and changes the volume of runoff (Figure 2).

FIGURE 2
UNIT HYDROGRAPH



Urban infrastructure flooding can result form excess precipitation entering the sewage system, but may also result from: damaged sections of the system, clogs or other barriers in the network, or repair work on one or more sections may increase the flow to other areas of the system. The hydrological cycle is important when trying to determine the causes of urban flooding, as the terrestrial and atmospheric interfaces play large roles upon incidence of urban floods. The potential of an area to "pond", that is, collect precipitation on the surface in depressions in the land is higher for area with more impermeable surfaces, is a function of the land cover and soil type. In some instances where the soil type is naturally impermeable (i.e. clay soils in Sarnia), ponding may occur naturally and frequently. Ponding also occurs in areas that are paved but not designed to drain. In Sarnia, the paving of the surface may have little effect on the drainage of the land, as it is naturally poorly drained. Urbanizing upon poorly drained land provides a more direct and faster conduit for ponded surface water to reach the sewage networks, as the area is usually designed to remove surface waters.

☐ 3.1 Thunder Bay Decision

Residents in the City of Thunder Bay experienced urban flooding, related to a rainstorm event in June of 1991, and took the City to court to establish if the City was negligent and therefore, responsible for damage repair. The residents won their cases over the City of Thunder Bay in the Ontario Court of Justice, the Ontario Court of Appeals, and the Supreme Court of Canada in the fall of 1997. Two claims were based on sewer back-up, and two related to waterpipe failures. The court actions surrounding the sewer back-up cases established that the paving of streets contributed to flooding. The Municipal Engineers had published a report in 1965 that stated that the City's paving program and expansion of City drainage area for new development eliminates absorptive soils and therefore increases the quantity of runoff water and accelerates its movement towards the sewers. The overloading of the sewers was a result of the increased number of new homes, the paving of roads and private lands, and drains constructed to direct surface water to sewers. The report recommended that downspouts of homes that were connected to the sewers be disconnected, reducing the volume of water that immediately reached the sewers. Thunder Bay continued to develop new areas, increasing the area of paved land. The City did not adopt the recommendation to change its development plans or to disconnect downspouts. It maintained the direct link from downspouts to the sewer systems, allowing rainwater to directly enter the to the sewage network. The City was thereby found to be negligent.

The Thunder Bay case determined that under these specific circumstances, the City was liable. The case also addressed the more general implications of paving. Paving patterns are not considered to be problematic from the engineering perspective, as the technology currently exists to mitigate the flooding (i.e. storm water management plans, detention ponds) but the problem persists because municipalities do not necessarily apply these techniques.

☐ 3.2 Insurance

The subject of flooding poses a particular challenge to the insurance industry. MunichRe (1996) and PartnerRe (1997) have published reports that address the problem of flooding from the insurance perspective.

The question of how damage is inflicted on a property as a result of floods in urban areas is often unclear, since overland flow and sewage back-up can occur almost simultaneously. One of the key areas of misunderstanding is in the difference between sewer back-up and overland flow. Sewer back-up occurs when the flow to the sewer system is so great that it is overloaded and the network of sewers backs up into basements. Overland flow is not covered by insurers, as damage done by this type of water inundation is by water flowing into homes through windows. Overland flow usually occurs in floodplains[2], when the river floods. Both types of floods can result from heavy precipitation, ice jams or snowmwelt, but only the damage caused by back-up is compensated for by insurers[3]. Policies can be extended to cover sewer back-up, but not for damages by surface water that entered from outside the sewage network.

The basic position of insurers is that they do not cover residential floods. They do, however, insure for the costs of sewage back-up, damage done to automobiles from floods and offer commercial flood coverage, which includes damage done to commercial property and business interruption.

Generally, the Winnipeg flood of 1997 had the industry following a concurrent causation principle, where insured property owners who were affected by sewer back-up and flood water damage were compensated (Canadian Insurance 1997). There were instances where some companies honoured all sewer back-p claims, and some did not, claiming that overland flow flood damage had occurred, and sewer back-up damage did not worsen the situation (Odam 1997).

Part of the problem may lie in the insurance industry's lack of understanding of the nature of flooding. They often use arguments that involve construction within the 100 year floodplain[4], while describing it as the area that is flooded once in 100 years (ODonnell 1997). Alternatively, they do not consider floods that occur in non floodplain areas as a separate type of claim. Sewage back-up in non floodplain claims are not a result of natural hydrological cycles, but may be the result of poor planning of neighborhoods and rapid urban growth.

The role of uncertainty is critical for the insurance industry, since weather patterns largely affect it. Changes in weather patterns (i.e. increased extreme precipitation) will change the expected return periods of floods, thereby changing the distribution of risk. Insurance industry risk assessment is based on historical data (White and Etkin 1997), not on regional predictions of future weather events in the context of climate change. When increased extreme weather events occur, the payout for insurers increases. Historical data can be misleading when the future trends of climate change are difficult to detect (Nutter 1997). The industry recognizes that climate change and continued urbanization will influence future trends, as the Insurance Council of Canada stated, (1998) "... losses (are) exacerbated by population growth, urbanization, economic expansion and climate change". More frequent extreme events may be an indication of climate change, but there has been no research on the impacts of increases in extreme precipitation on urban areas.

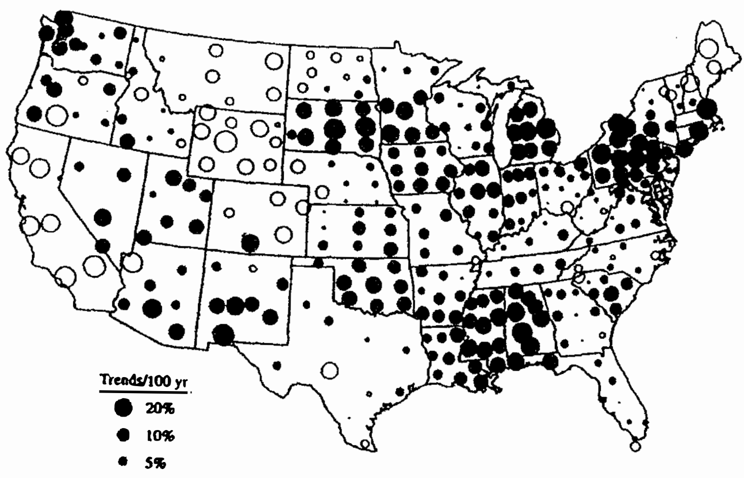
The problem is often misunderstood by victims who believe that they should be compensated for their losses through insurance or through government assistance in a timely and comprehensive manner. Households and businesses may be insured, but when the causality of the events is unclear, the redress, if any, may not cover costs, and may not be from the insurance companies.

■ 4.0 PRECIPITATION TRENDS IN SOUTHERN ONTARIO

The Canada Country Study is a national assessment of the social, biological and economic impacts of climate change for Canada (Mayer and Avis 1998). It determined that "an increase in flooding events is expected due to more intense rainfall and snowfall over localized areas in some regions..." However, existing meteorological definitions of flooding are narrow in scope, and cannot necessarily be applied to predict local urban flood events. For example, they do not consider the functions of soil permeability, topology or land use.

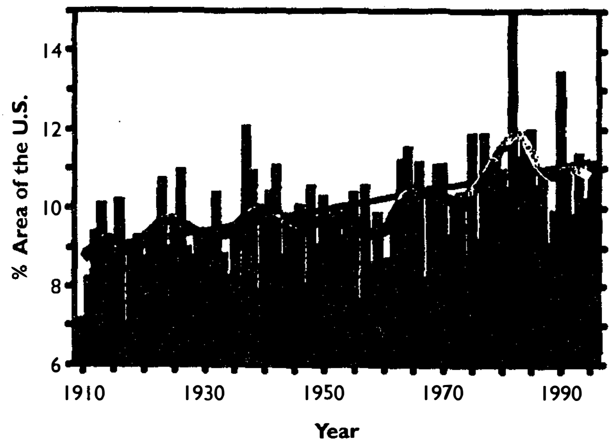
One determinant of infrastructure flooding, to be evaluated this study is increased extreme precipitation in the region. Karl et al. (1996) have measured an increasing trend in annual precipitation in the United States over the last century (Figure 3). Karl et al. (1996) defined extreme precipitation as an event where two or more inches (50.8 mm) of precipitation fall over one day. Their study shows that since 1970, the precipitation trend has remained above the 20th century mean, and averaged more than 5% greater than the previous seventy years (Karl et al. 1996). Karl et al. (1995, 1996) state that there is a clear increase in the areas of the United States affected by extreme precipitation (Figure 4). The increase in extreme precipitation occurs in all seasons in all regions of the continental United States, except for the west and southeast. This increase is equivalent to one additional extreme precipitation event occurring every two years. The National Ocean and Atmospheric Administration (NOAA) has stated, with 90% probability, that the United States is experiencing more extreme weather events (Nutter 1997). Shriner et al. (1998) stated that, "annual precipitation amounts from 1901 to 1995 over North America *as a whole* show evidence of a gradual increase since the 1920's, reaching their highest levels in the past few decades".

FIGURE 3
ANNUAL PRECIPITATION TRENDS



Annual precipitation trends (1900-1994 converted to percent per century) centered within state climatic divisions are reflected by the diameter of the circle centered within each climatic division. Solid circles represent increases and open circles represent decreases. (Karl et al. 1996)

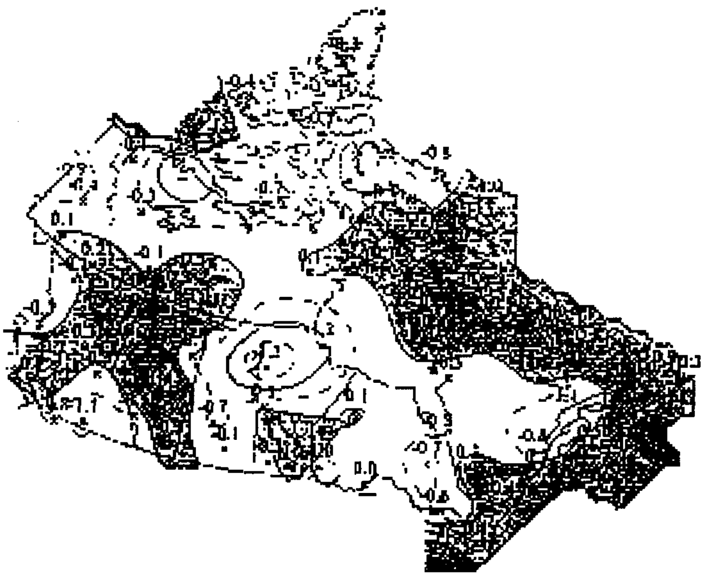
FIGURE 4
PERCENTAGE OF THE CONTERMINOUS U.S. AREA



Percentage of the conterminous U.S. area with a much above normal proportion of total annual precipitation from 1-day extreme events. (Karl et al. 1996)

If such a trend exists for extreme events in southern Ontario, increases in infrastructure flood events may occur. However, Hogg and Swail (1997) applied the methodology of Karl et al. (1996) to a Canadian study and came to a different conclusion. The Canadian extreme event was characterized as one half of the American extreme, (i.e., the American "heavy rainfall equivalent of 25 mm), but despite this reduction in threshold, there was no significant trend in Canada (Figure 5). In Canada, the 65 stations that were available for extreme value analysis were insufficient to determine the ratios of greater than normal values, so linear ratios were mapped. Hogg (1995) found no systematic increase in daily rainfall in Canada and no evidence of regional frequency increases of extreme rainfall. Hogg and Swail (1997) state that "The proportion of rain falling in events exceeding 25 mm has decreased, between 1910 and the present, at the majority of the 65 stations analysed. This doesn't mean that the area affected by above normal values is necessarily decreasing, but it certainly doesn't support Karl's finding in the United States". The regional trend for southern Ontario was a slight increase (0.1 mm), but was not statistically significant (Hengeveld pers. comm.).

FIGURE 5
MAP OF TREND



Map of trend of the fraction of annual precipitation falling in events greater than 25 mm/day. Units of trend are change/year 1000. Shaded area are increases, non-shaded areas are decreases. (Hogg 1997)

The precipitation literature supports different conclusions for extreme precipitation analysis. The international community (MunichRe 1997, Shriner et al. 1998) has suggested that the number of extreme precipitation events has been increasing. In addition, American studies have indeed measured an increase (Karl et al. 1996). However, Environment Canada (Hogg and Swail 1997) has not measured a change in extremes in Canada, and elsewhere it is reported that Canada expects to discover an increase in the future (Maxwell, Mayer and Street 1998, Francis and Hengeveld 1998).

Canadian weather stations are not as spatially concentrated as they are in the United States because the land mass is large, and the density of observation stations is low (Hogg et al. 1998). The spatially inhomogeneous nature of extreme events compounds the uncertainty in Canada. It is assumed that *changes* in extreme precipitation are "more spatially consistent than extreme precipitation itself, making it possible to describe changes in extreme precipitation conditions based on regionalized extreme indices or homogenous regions of extreme precipitation variation" (Hogg et al. 1998).

☐ 4.1 Climate Change

More frequent extreme weather events are predicted to accompany global warming, in part as a consequence of projected increases in convective activity (Shriner et al. 1998). More intense rainfall accompanying global warming is expected to increase the occurrence of floods in floodplains as well as the incidence of urban floods in non-floodplain areas.

The Canada Country Study (Maxwell, Mayer and Street 1998) considered how Canada will be affected by climate change and determined that "an increase in flooding events is expected due to more intense rainfall and snowfall over localized areas in some regions...".

There is a growing interest in softer approaches to stormwater management, including encouraging infiltration, and wet/dry ponds (Kinkead 1997). In the face of climate change, these soft approaches need to be more widespread in order to mitigate some impacts.

Francis and Hengeveld (1998) agree that weather extremes are becoming an increasingly serious problem, and that there is a reasonable possibility that climate change will intensify it. The extent of the exacerbation due to climate change is unclear at present, because the role of the natural fluctuations of extremes has not been determined. Severe weather as a feature of climate has not been adequately studied, and there are three key areas where further study is warranted: (i) there is a need for a better grasp of emerging trends, as the frequency of extreme weather needs to be more throughly examined; (ii) the use of historical records brings forth the questions of quality of the records and their comparability; and (iii) there needs to be a better understanding of natural variability. The extremes that are measured may or may not be part of the natural flux of climate and this should be further studied before policy can be made. The link between climate change and weather extremes is not clear because we lack complete understanding of the natural phenomenon (Francis and Hengeveld 1998). Global circulation models do not produce output at the appropriate scale to determine this relationship.

Extreme precipitation events are an indicator of climate change, and although the climate change—extreme events link is still emerging, if the trend can be determined for southern Ontario, urban infrastructure flooding may be partially explained. Once extreme precipitation trends for southern Ontario are resolved, than definitive policy decisions can be made, and appropriate mitigation and adaptation strategies can be developed.

4.2 The Intensity, Duration and Frequency of Rainfall Events

Stream flow information is not always available for all areas, so to determine sewage capacity needs, engineers turn to rainfall data to determine the peak flows over an area (Hogg and Carr 1989). The use of this data is based on the assumption that precipitation usually varies in a regular manner (Hogg and Carr 1989). The peak flow estimates can be determined using computer models, but the engineer must determine the maximum duration of the rainstorm that the system should be built to sustain and they must determine the frequency with which the capacity of the structure can be exceeded (or the return period of the storm) (Hogg and Carr 1989). Lawford et al. (1995) outlined that, "for a given rainfall amount, the runoff generated is dependent on the distribution of the city's permeable surfaces. Urban flood models can be calibrated for specific cities to account for this factor in infrastructure design. For most design applications, rainfall statistics are obtained from intensity, duration frequency curves using durations equal to or greater than the time for runoff from the farthest reaches of a river basin to reach the rivers mouth".

5.0 CONCLUSION

The phenomenon of urban infrastructure floods may be attributable to many factors. This paper considered the role of precipitation, land cover and to a lessor degree, sewage networks. Although the variables considered were simple, they could not be pursued to their fullest degree due to the limited data available. Single urban infrastructure flood events in a city do no indicate a pattern of floods, or establish the frequency of them, but this work considers the potential causes of flooding, rather than determining if a pattern exists. To determine if a pattern of urban infrastructure floods is emerging, a content analysis approach would be needed.

The detected extreme precipitation data in Canada is inconsistent with that measured in United States studies. The differences may lie in the different extreme value calculation, the different sample sizes or in latitude effects. The trends in the United States are not expected to be identical to those of Canada, but there should be a gradation of extreme precipitation over the border, not abrupt shifts (Hogg 1999 pers. comm.). The difference in the values over the border may be a latitude effect for the more western stations; the southern Ontario precipitation is expected to be similar to that of Michigan and New York.

The precipitation literature has not laid out a clear picture of whether extreme precipitation in southern Ontario is increasing. A regional study done for southern Ontario does has different results than the national study for the northeastern U.S. (Hogg and Swail 1997, Karl et al. 1996). This could be the result of a number of factors, but the geographical limits to both studies indicates that political boundaries determined the limits of the analysis. For a more comprehensive analysis, a North American climate zones study may prove to be more useful and may indicate the true trend of extremes. If the studies were conducted from a continental perspective, one that included data stations from the U.S and Canada, perhaps more harmonious conclusions can be drawn.

Climate change has implications for urban flooding, as expected increases in volume of flow, due to increases in rainfall, in urban areas will be carried by the sewage networks. This increase in flow may decrease the return period for the sewage pipes, causing more frequent infrastructure back-up and damage to homes. This can be alleviated if sewers were designed for expected trends in volume, but to date, there are no plans to expand sewer services to include the expected impact of climate change.

The insurance issues can only be resolved when the causality of urban floods is determined. This paper outlines a potential methodology to begin the process of discovering the origin of urban floods, and as it is refined, the causality will emerge. Causality remains to be determined, only then can homeowners be fairly compensated.

Upstream and downstream land users should co-ordinate on drainage and land use issues, as the behaviour of upstream land users will directly impact those downstream.

One of the obstacles to obtaining complete data sets of the land cover, sewage networks, floodplain and precipitation data was the lack of communication among the stakeholders. There are two sets of non-communicating stakeholders; insurers, homeowners and municipal governments, who do not share information on urban floods; and municipal governments and conservation authorities, who do not coordinate efforts when confronted with urban flood events. There is clearly value in establishing communication lines for municipal engineers and conservation area managers, if only to collect the appropriate data sets for studying urban floods. This lack of communication may contribute to the lack of integrated watershed management and the lack of preventative approaches to planning. If communication between these stakeholders was more structured and information about land use was exchanged more readily, land use analysis and urban flood causality research could be more easily facilitated.

The gaps in the environmental management of Canadian cities have left no institution with primary responsibility for urban floods or their prediction. Urban floods need to be recognized as an important issue for insurers, municipalities and conservation authorities, because their impact can be massive. With proper planning and municipal responses, however, they should be avoidable.

The primary product of this paper is the development of the methodology and the determination of where gaps in resources exist. The next steps to further this research include filling the data gaps; which may take considerable resources, and further refinement of the methodology.

APPENDIX I
LIST OF INTERVIEWEES

Jeff Caden – Water Resources, St. Claire Conservation Authority

Barbara Gray – Regulations Officer, Rideau Valley Conservation Authority

Don Haley – Coordinator, Floodplain Management, Resource Science Section, Watershed Management Division, Toronto and Region Conservation Authority

Bill Hogg – Chief, Climate Monitoring and Data Interpretation Division, Climate Research Branch, Atmospheric Environment Service, Environment Canada

Grant Kelly – Institute for Catastrophic Loss Reduction

Chris Kocot – Atmospheric Environment Service, Environment Canada

Kevin Loughborough – Engineering, City of Toronto Public Works

Reg McMichael – Engineering Division, Works Department, City of Sarnia

Laurie Mennaman – Water Resources Planner, Ontanabee Conservation Authority

Don Poof-Engineering Department, City of Ottawa

Sandra Rakovac – Insurance Council of Canada

City of Peterborough Engineering Department, City Works

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☐ Notes

1. Combined sewage systems are those that carry both sanitary sewage and storm water. They were the first system to be used in Canada, and are slowly being replaced with separate sewer systems that carry the sanitary flow and the storm water in different pipes.

2. The relatively flat land stretching from either side of a river to the bottom of the valley walls. Floodplains are periodically inundated by the river water, and is defined by municipalities as the furthest extent of the one in one hundred year flood.

3. Compensation is only available to residential and commercial buildings in Ontario.

4. Municipally defined floodplains are areas which have a 1/100 probability of flooding, independent of flood events the previous year.