A COMPARISON OF FLOODING IN MICHIGAN AND ONTARIO: 'SOFT' DATA TO SUPPORT 'SOFT' WATER MANAGEMENT APPROACHES

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Abstract

The months of August and September 1986 produced four unique and extreme rainfall events. Average values of precipitation for each event ranged between 50 and 180 mm for 24-hour and 48-hour periods respectively. The heavy precipitation caused extensive flooding and damage in Michigan ($500 million US for the two months), while little flooding or damage occurred in Ontario (under $500, 000). The paper examines the soils, watersheds and flood management practices in Michigan and Ontario to determine if they are comparable. Next, the climatological events are described for the months of August and September. Analysis of each event for individual watersheds is performed using observed hydrograph characteristics such as volumes of runoff, flood yields, flood hydrographs and stream discharges. Flood damages are then tabulated and compared for each site, and a documentation of each respective site's floodplain management policies is provided. It was concluded that although Michigan sustained extreme damages and suffered loss of life, Ontario had higher flood yields for September. Even though Ontario's yields were higher, the province recorded only a small fraction of Michigan's damages. The study also identifies the need for establishing procedures for quantifying benefits that are accrued from implementing sound floodplain management, and in reducing otherwise intangible floodplain mapping benefits.

Résumé

Les mois d'août et de septembre 1986 furent témoins de quatre événements uniques et extrêmes en fait de précipitations. Les valeurs moyennes des précipitations pour chaque événement varient entre 50 mm et 180 mm pour des périodes de 24 heures et de 48 heures respectivement. Les fortes précipitations causèrent des inondations et des dommages considérables au Michigan (500 millions de dollars US pour les deux mois), alors que peu d'inondations ou de dommages se produisirent en Ontario (moins de 500 000 $). Le document examine les sols, les bassins hydrographiques et les pratiques de gestion des inondations au Michigan et en Ontario pour déterminer s'ils sont compatibles. Ensuite, les événements climatologiques sont décrits pour les mois d'août et de septembre. Une analyse de chaque événement pour les bassins hydrographiques individuels est menée à l'aide de caractéristiques hydrographiques observées comme les volumes de ruissellement, les produits de l'inondation, les hydrogrammes de l'inondation et les débits de cours d'eau. Les dommages causés par l'inondation sont ensuite mis sous forme de tableaux et comparés pour chaque site et une documentation est

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fournie à l'égard des politiques de gestion des zones inondables pour chaque site respectif. Il fut conclu que même si les inondations du Michigan avaient causé des dégâts extrêmes et fait des victimes, l'Ontario avait connu des débits d'inondation plus élevés pour septembre. Malgré cela, l'Ontario n'a subi qu'une infime fraction des dégâts que le Michigan a connus. L'étude révèle également le besoin d'établir une procédure pour quantifier les avantages qui découlent de la mise en oeuvre de saines pratiques de gestion des zones inondables et de la réduction des avantages autrement intangibles de la cartographie des zones inondables.

Introduction

Over the past twenty years two trends have become evident in flood plain management in Canada. First there has been a movement away from an almost exclusive reliance on structural measures (dykes, dams, and channelization) toward more emphasis on non-structural 'soft' approaches, such as land use and building restrictions in hazard areas, financial disincentives to developing hazard areas (Bruce, 1976). The other trend has been a greater interest on the part of government agencies in looking at the costs and benefits of water management projects (Public Accounts Committee, 1979; Treasury Board Secretariat, 1976).

Clear procedures have been developed for determining the benefits and costs of structural flood control benefits (Paragon, 1984; Book and Princic, 1975). These procedures generally relate capital measures for reducing damages at specific sites, and the determination of a frequency distribution for flood levels for the areas being protected; and the development of stage-damage curves based either on past damages or the use of existing damage functions for different types and values of structures. These two functions are then combined to derive an average annual damage, and a present value of damages is determined using several discount rates. The costs of structural flood control measures are the estimated capital costs plus the present value of anticipated annual maintenance costs. The net benefits of a capital project are the present value of flood damages prevented, less the present value of the capital cost. The amount of damage prevented is generally based on existing flood plain development, as most federal and provincial agencies do not accept the inclusion of additional benefits that might accrue from additional development in the protected area (Environment Canada, 1979).

It has been much more difficult to determine the costs and benefits of non-structural approaches. Several studies have been conducted at specific sites that were mapped under the FDR Programme (Millerd *et al.*, 1991; Weiss, 1987) The general approach in these studies has been to estimate the amount of flood vulnerable development that had been prevented in areas mapped under the Flood Damage Reduction Programme for a specific water course and then look at the damages that would be prevented. These estimates of damages prevented were then compared to the costs of mapping and the administrative costs of implementing and managing flood plain development restrictions. The estimate of damages prevented can be based on some actual flood events, or an average annual damage determined from flood level frequency relationships.

The benefits derived in these studies have been uncertain as they are based on known short-term development plans, or on guesses or predictions of what development might have occurred in flood vulnerable areas in the absence of flood risk mapping and flood plain controls.

The two studies noted above showed quantifiable, but somewhat modest, net benefits from the application of mapping and flood plain development restrictions to several specific areas. The short-term benefits found in these small site studies may not fairly represent the full potential of the non-structural approach, as land use

planning and development restrictions have a slow but progressive impact on flood vulnerability. A different picture may emerge if we could evaluate the damages prevented through the application of flood plain development restrictions over a longer period of time and over a wider area.

The intensive rainstorms that tracked across Michigan and southern Ontario in August-September of 1986 provide a good opportunity to compare damages in a province and adjacent state with very different approaches to flood plain management. Ontario has had an ongoing programme of flood plain management since the mid 1950s following the disastrous flooding from Hurricane Hazel. The programme has been province-wide and supported by provincial legislation (Conservation Authorities Act, Planning Act) and local implementation by conservation authorities and municipalities. The Ontario programme was broadened in 1978 to include the participation of the federal government through the Canada-Ontario Flood Damage Reduction Programme. Therefore the damages that occurred from the 1986 floods were affected by 30 years of legislative floodplain management by different levels of government.

In Michigan, the approach to flood plain management has been different, and could be characterized as being more reactive and less comprehensive in the application of land use and development controls. A major part of this approach has been reactive through participation in the U.S. National Flood Insurance Program (NFIP). State regulatory controls on flood plain development have not been uniformly applied. The focus of flood plain regulation has been to flood proof or elevate new development rather than keeping development out of the floodplain.

Since the areas affected by the 1986 floods appeared to be comparable in certain

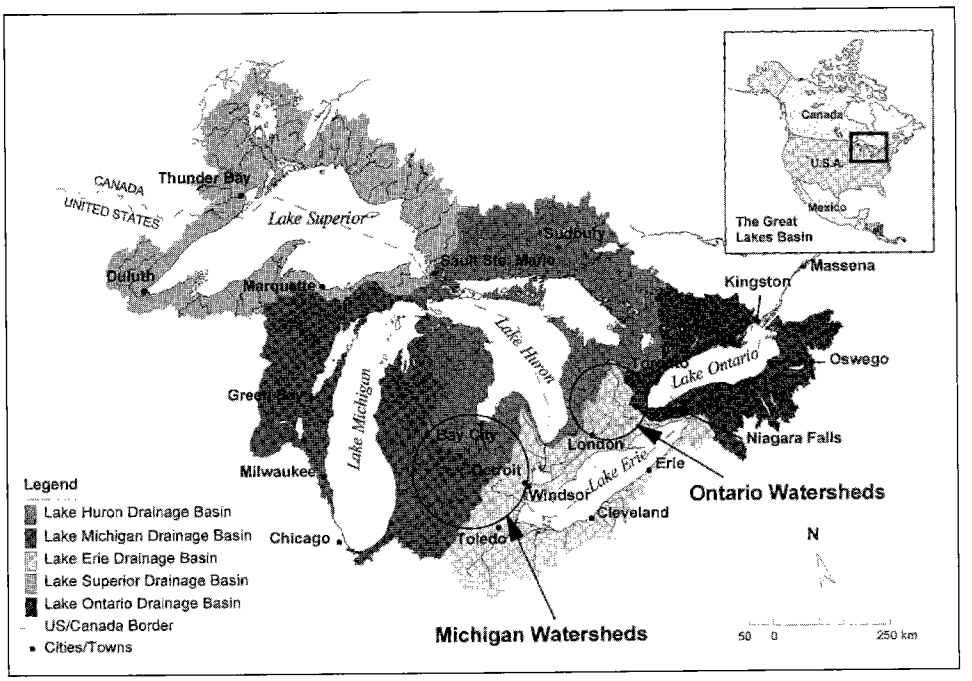

Figure 1: Location Map Showing the Great Lakes in North American Context and Michigan and Ontario Watersheds

respects (population, urban development, physiography, rainfall and runoff volumes and frequencies), a comparison of actual flood damages in these two jurisdictions appeared to be an excellent opportunity to compare two long-term approaches to flood plain management. In essence, Michigan would serve as a control and Ontario as the example of comprehensive flood plain management applied over a longer-term and to a large area.

Objectives of Study

The large disparity in damages between the two jurisdictions warranted further analysis. This study compares the phsiography, land-use, floodplain development and floodplain policies, rainfall and runoff to indicate what factors were most important in explaining the large differences in damages.

Land Use, Climate and Hydrology

To properly compare the floodplain management policies, it is necessary to determine if the two study areas are similar. Four variables are chosen to determine whether a comparison is justified: land use, climate, soil and hydrology, as below.

Land Use

The promise of agricultural land drew many immigrants to the Great Lakes basin in the 19th century. By the mid-1800s, most of the region where farming was possible was settled: 400,000 people in Michigan and 500,000 in what was known as Upper Canada. As population grew, dairying and meat production for local consumption began to dominate agriculture, and speciality crops such as fruits, vegetables, and tobacco became increasingly important. The rapid large-scale clearing of the land changed the lower basin's ecosystem. Greater surface runoff led to increased seasonal fluctuation in water levels and the creation of more flood-prone lands along waterways. Nearly all the settlements that grew into cities in the region were established on the waterways that transported people, raw materials and goods, eg. Detroit in Michigan and Hamilton in Ontario.

In the study area in Michigan, the most prevalent land use today is intensive general farming, with some specialized field crops such as fruits and tobacco. The largest urban centre is the region of Metropolitan Detroit with a population of approximately seven million; there are seven cities with populations of 100,000 – 200,000. The study area in Ontario is more dependent upon specialized dairying as well as specialized field crops, with intensive general farming in the more southwestern regions. There are fewer urban centres of 100,000 – 200,000 than in Michigan. The largest urban centre in Ontario is the Toronto-Hamilton corridor with approximately five million people. Overall, for the purposes of this paper, land use in the two study areas is similar.

Soil

The physiography and surficial deposits of both the Ontario and Michigan watersheds are the result of the last phase of the Wisconsin glaciation. The soils consist mainly of Podzolics and Gleysolics (Foth and Schafer, 1980). The fine-textured and well-drained Podzolic soils occur in the heartland of southwestern and southcentral Ontario, and in the northern portion of Michigan. Although Podzolics are the dominant soils in some counties in Ontario, Gleysolics can also occur. Podzolic soils have a lower natural fertility than do the Gleysolics, are high in water infiltration, but low in water retention for the soil as a whole. In the more gently rolling areas, the soils are more susceptible to erosion, but can support a variety of agricultural activities such as livestock, cereal grains, hay and pasture, and cash crops.

Gleysolic soils occur extensively in the central and southeastern portion of Michigan and in some counties in Ontario. Gleysolic soils are poorly drained because

normal development has been restricted by naturally high water tables. They are high in organic matter, and consist of at least 40% clay. Consequently, tile drains and open ditches are used extensively to alleviate flooding and to improve soil fertility.

The soils of the study watersheds in Ontario and Michigan have a mixture of well-drained Podzolics and poorly drained Gleysolics. The 14 watersheds are distributed throughout southwestern Ontario (drainage areas between 303 km^2 to 6770 km^2) and portions of Michigan (drainage areas 1764 km^2 and 12691 km^2) and include both types of soils. Each region has developed successful soil drainage networks, so neither region has the advantage of greater soil permeability.

Climate

During the summer and early fall of 1986, there were four unique rainfall events that occurred in both Ontario and Michigan, each lasting from 24 hours to almost 72 hours. The most intense precipitation occurred on August 15, August 26, September 10-11, and September 29.

In 1986, rainfall was above average throughout the first half of the year in Ontario. The month of August continued the trend of above-average precipitation from southern Lake Huron through Lake Simcoe, Toronto, and eastward to Ottawa. At Toronto, the rainfall for the month was 255% above normal (DOE, 1986). For the majority of the gauges in Michigan, August rainfalls were generally close to average,

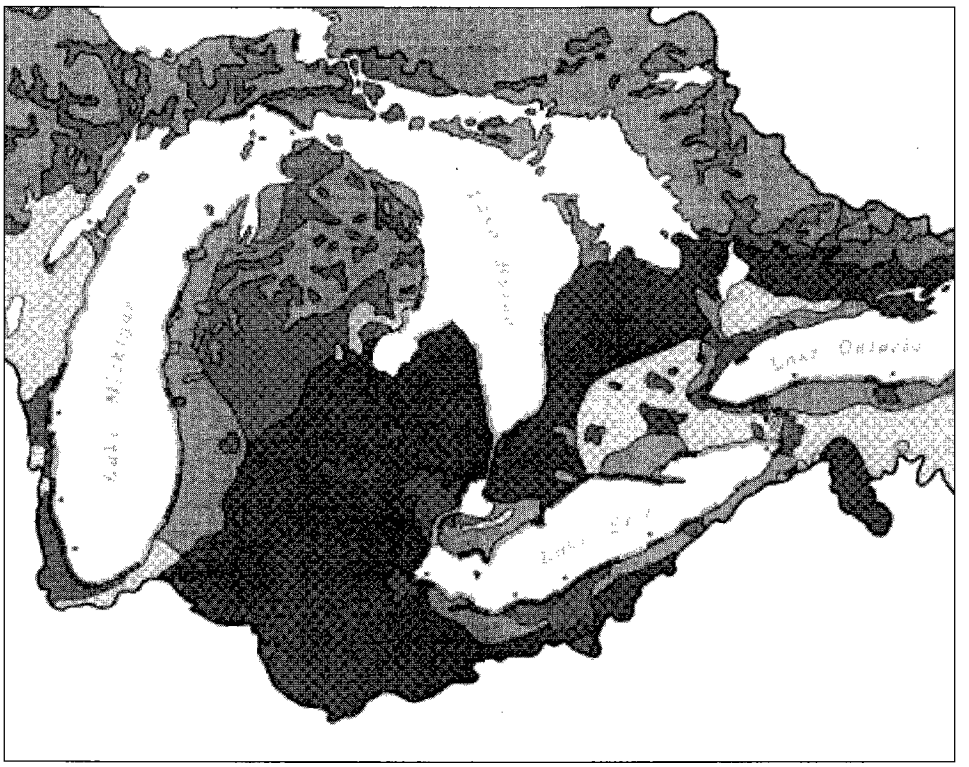

Figure 2: Land Use in Michigan and Ontario Watersheds. (Dark regions show heavy agriculture, lighter shade in Michigan is light agriculture, lighter shade on Ontario is dairy farming. From *The Great Lakes – An environmental Atlas and Resource Book, 1988.)*

indicating dryer conditions before and after the rainfall events.

Showers were almost a daily occurrence in Ontario and Michigan from August to early October. Rainstorms typically formed in large clusters and often intensified late at night. The August precipitation pattern was largely defined by the heavy rainfalls of August 15 and August 26 – 27. Both events recorded maxima of 60 – 90 mm of precipitation north of Toronto, and several monthly rainfall records were set in and around Toronto. On August 15, between 40 – 80 mm of rain fell on densely-populated areas of southern Ontario in 90 minutes. In Michigan for this date, precipitation was not as heavy; only four stations recorded more than 25 mm of rain with the majority of stations receiving only 10 mm.

On August 26, more widespread precipitation occurred, with a large portion of central Michigan inundated with 30 – 50 mm. The area of heaviest concentration was Detroit with 73.4 mm of rain. In Ontario, the highest recorded precipitation was at Elmira with 92.2 mm. At most sites, the rainfall occurred within a span of five to seven hours during the evening of the 26th. Both August events produced more rainfall in southwestern Ontario than in Michigan, with some regions in Michigan receiving below-normal amounts. On August 15, Ontario received twice the amount of precipitation than Michigan, and on August 26, Ontario recorded approximately three times that of Michigan.

The highest amount of precipitation during the study period occurred on September 10 – 11. Two thirds of southern Ontario received at least 50 mm of precipitation from this two-day event. Two-day totals reached 177 mm at Exeter (DOE, 1994). The storm area in Michigan measured approximately 290 km in an east-west direction and 100 km north-south.

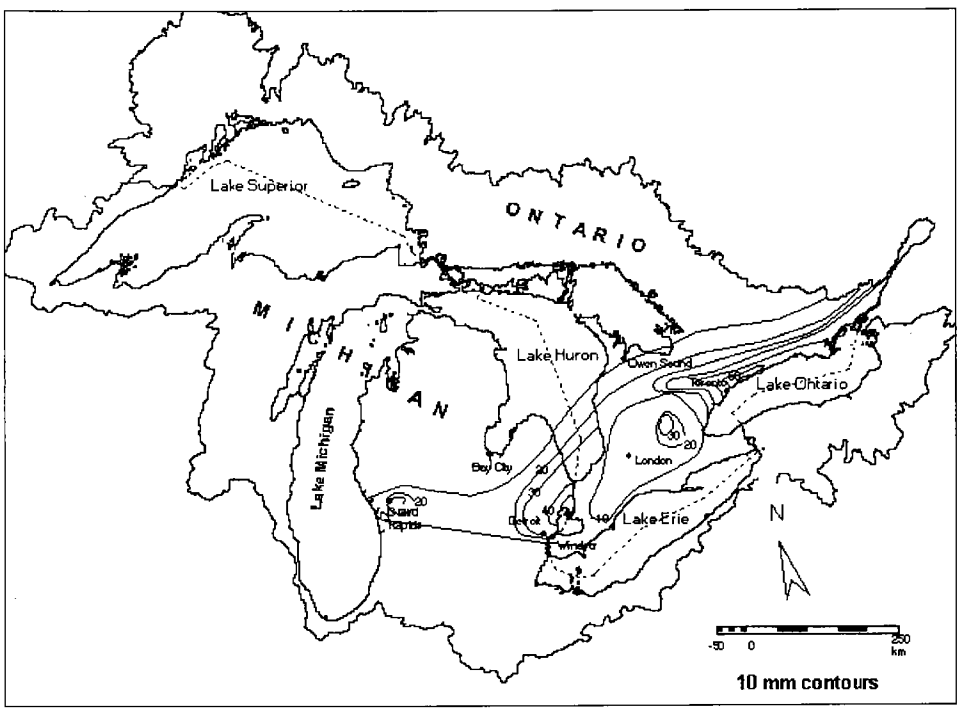

Figure 3: Precipitation in the Great Lakes Basin, August 15, 1986

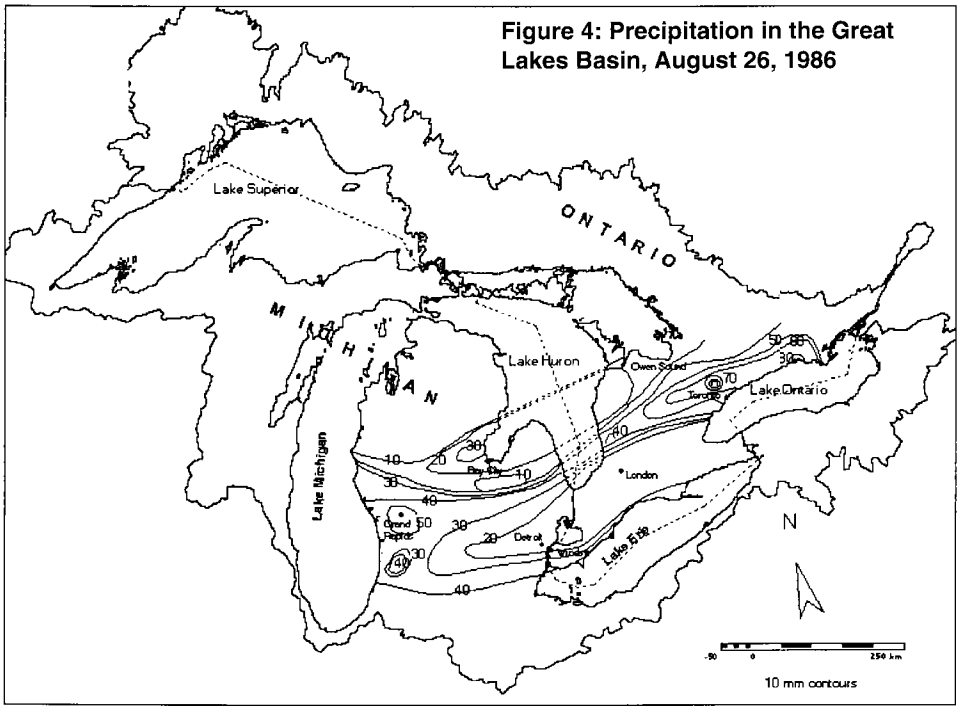

Figure 4: Precipitation in the Great Lakes Basin, August 26, 1986

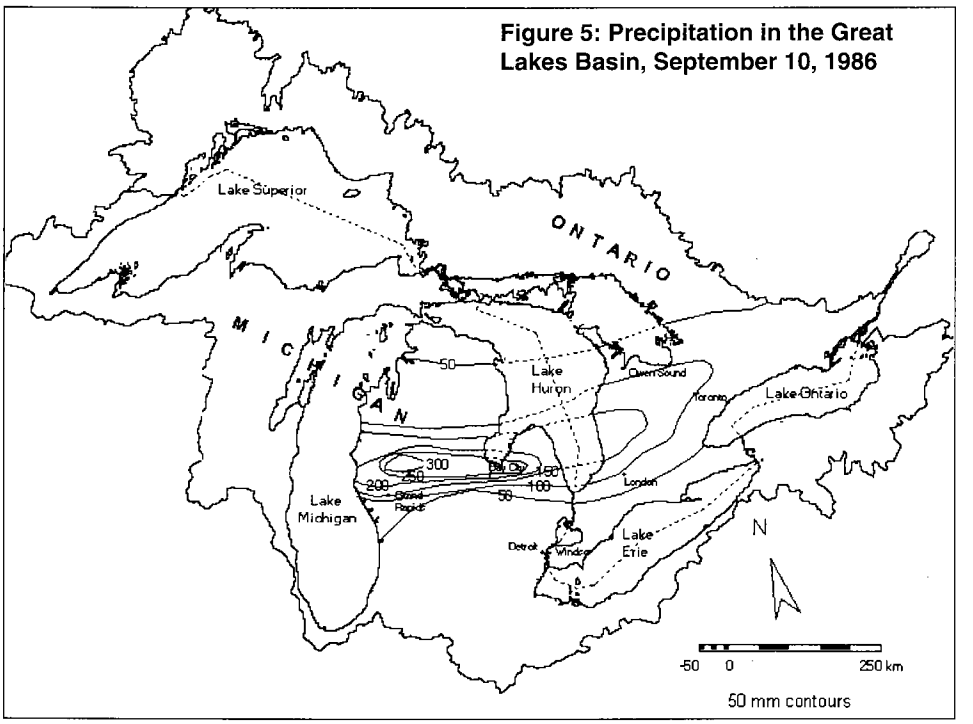

Figure 5: Precipitation in the Great Lakes Basin, September 10, 1986

Within this area, rainfall varied from 200 – 300 mm. Such precipitation rates were not seen in Ontario, although many precipitation records were set.

The final rainfall event for the study period occurred on September 29. The precipitation was clustered in western Michigan with values ranging from 20 – 40 mm, with a small pocket of greater than 50 mm. The heaviest precipitation fell in a small area near London (89.1 mm) with a heavy band of 50 – 70 mm occurring from Toronto to Blyth. In comparison, areas near Windsor received very little precipitation. Amounts were not as substantial as for the three previous rainfall events, but a large area east of Lake Huron received more than 25 mm. The last rainfall event brought similar amounts of precipitation to both regions, but the distribution pattern was erratic. There were isolated pockets of heavy rain in both Ontario and Michigan. As a summary for the month, rainfall totals exceeded 480 mm at several Michigan recording stations, with a mean rainfall for the month exceeding 355 mm for central Michigan.

Hydrology

A total of fourteen watersheds were selected in Ontario and Michigan to examine the hydrologic and hydraulic impacts of the four rainfall events. The forms of analysis used were flood yields and volumes of runoff. The drainage areas in Ontario were the Maitland, Grand, North Thames, Saugeen, Sydenham, Don and Humber rivers; in Michigan, the Pere Marquette, Muskegon, Grand, Tittabawassee, Shiawassee, Flint, and Cass rivers. These watersheds were chosen after the approximate extent of rainfall in August and September was mapped.

Flood yields are volumetric measurements that permit streams of differing drainage areas to be compared on the basis of flows. The equation

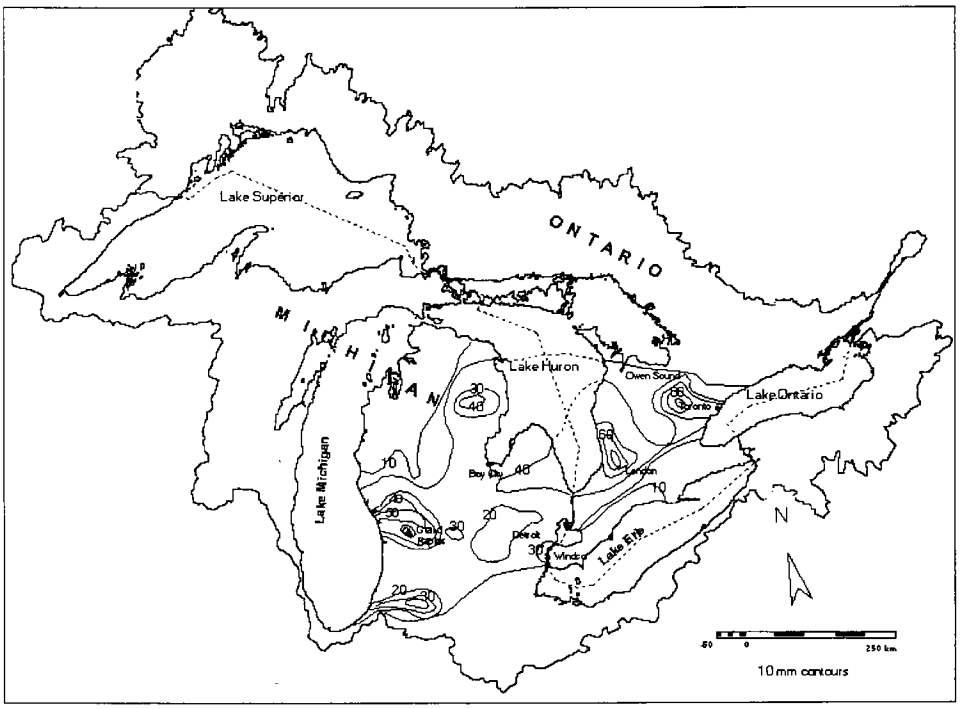

Figure 6: Precipitation in the Great Lakes Basin, September 29, 1986

$$Q_s = Q/A \quad (1)$$

was used, where:

Q_s = Flood Yield ($m^3/s/km^2$),
Q = Maximum Instantaneous Discharge (m^3/s), and
A = Drainage Area (km^2).

The maximum instantaneous discharge (Q) in each of the 14 watershed areas (A) was plotted against the respective drainage areas (A). The plotted results normalizes the flows on a per unit basis and allows for the comparison of flows to watersheds of varying sizes. When the logarithm of the flood yield (Qs) is plotted against the logarithm of the drainage area, a linear relationship is obtained.

Using the calculated maximum instantaneous discharge, the flood yields in August in Ontario are higher than in Michigan with calculated slopes of -0.37 and -0.50 (Figure 7). These results show typical watershed responses as both precipitation events produced higher amounts of precipitation in Ontario than in Michigan.

For September, the flood yields were plotted against drainage areas, and slopes were calculated at -0.23 and -0.29 for Ontario and Michigan respectively (Figure 8). Again, the slope of the regression line is less steep in Ontario although in September, more rain was recorded in Michigan and more flow records were set. In summary, streams had a higher maximum instantaneous discharge in Ontario per drainage area.

A comparison of volumetric runoff in the 14 watersheds was also made to permit a comparison of runoff from watershed to watershed, acknowledging that the drainage basins differed in area. To calculate the volume of runoff, the trapezoidal rule was used. The first rainfall event in August did not produce significant volumes

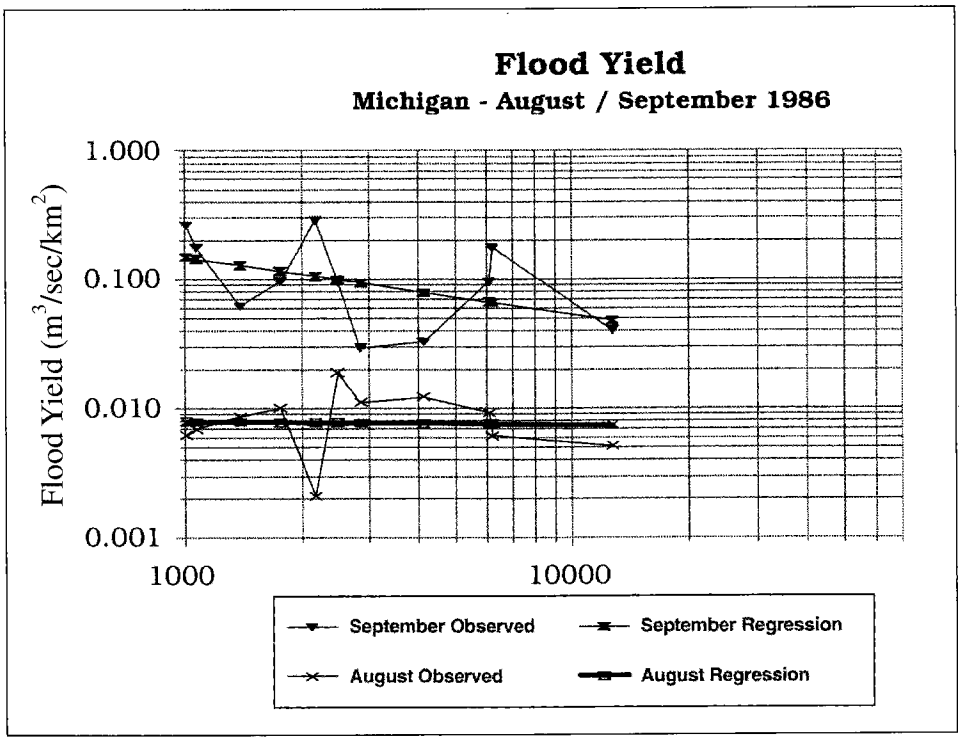

Figure 7: Flood Yields for the Michigan Watersheds, August/September 1986

of runoff. The highest runoff of 21.54 mm was calculated in one of the Toronto tributary watersheds and the lowest volume of runoff calculated was a tributary in the eastern region of Michigan. With the outliers removed, the mean volume of runoff in Ontario watersheds was only 3.09 mm and the volume was comparable in Michigan with 4.14 mm.

The rainfall on August 26 produced more runoff in Michigan than the previous month, but in Ontario the mean was almost 10 mm higher than the mean for the August 15 event at 12.60 mm. A tributary in the Toronto region recorded the highest runoff at 41.07 mm and the lowest recorded was the tributary in Michigan mentioned above at 1.18 mm. The volume of runoff was fairly uniform in Michigan and ranged from 1.18 mm to 8.34 mm. In Ontario the volumes were more diversified and ranged from 2.40 mm to 41.07 mm.

For the September 10 – 11 event, a higher total of precipitation was recorded in Michigan than in Ontario. With the outliers removed the mean volume of runoff in Ontario was 54.74 mm, almost 10 mm more than the mean for Michigan (45.09 mm). Most watersheds in the area affected by heavy rainfall had at least 40 – 60 mm of runoff. The highest calculated runoff volume in Ontario was 71.10 mm.

The final event in September again produced large volumes of runoff, although not as much precipitation was recorded. Presumably, this was because the soils were saturated from the previous rains. With the outliers removed, Ontario had, for the third time, a higher volume of runoff at 53.87 mm, compared to Michigan's 47.88 mm. The volumes in Ontario ranged from 29 mm to 74.40 mm.

With the exception of the event of August 15, the seven Ontario watersheds produced larger mean volumes of runoff, but the mean values were never greater than 10 mm. Although Michigan sustained larger amounts of precipitation, Ontario's watersheds produced more runoff.

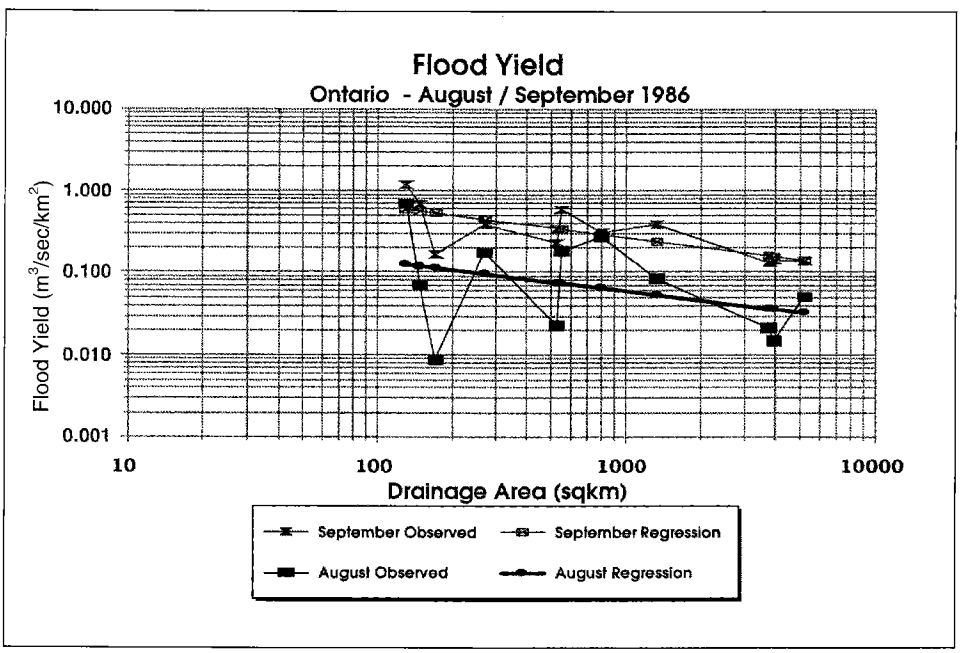

Figure 8: Flood Yields for the Ontario Watersheds, August/September 1986

Regulations and Floodplain Management

From the previous section, it was evident that the climatological and watershed responses of Michigan and Ontario basins were similar. The flood damages in the two jurisdictions were, however, substantially different. Some of the anomalies in the difference of flood damages can be traced to the age of settlement in the watershed (and by extension, settlement in the floodplain), density of settlement, floodplain management practice, etc. In this section, two different floodplain management models are examined: the Ontario floodplain regulations and the floodplain management styles in Michigan.

Ontario

In Ontario, the development of floodplain regulations can be traced to the early 1940s. In this period, floodplain regulations were closely tied to the conservation movement for soil erosion from agricultural watersheds. For management purposes, Conservation Authorities like the Grand River Conservation Authority were established, based on watershed boundaries as the administration unit and restricted to the urban areas in southern Ontario. The floodplain regulations followed the disaster of Hurricane Hazel in 1954. The mandate for floodplain management was enhanced in the late 1950s.

The floodplain management approach taken by Ontario Conservation Authorities was two pronged: damage prevention and flood protection. Flood damage prevention is attained by first identifying flood risk areas, and then regulating and controlling the development in such areas. Flood protection is achieved by construction of multipurpose reservoirs, dams, channelization, etc.

In Ontario, floodplains are regulated primarily under two Provincial Acts. The Planning Act provides the broad guidelines for developing planning documents, land-use planning and sustainability of various uses. The Conservation Authorities Act deals primarily with floodplain management aspects. This Act lies below the Planning Act, but covers the majority of urban and potential growth centres in the province. The Conservation Authorities Act spells out the mandate of an Authority in areas of compliance with land use, which is compatible with the floodplain. Generally, Conservation Authorities regulate any fill or construction in a corridor that envelops the floodplain. The delineation of such regulatory lines are usually based on slope stability criteria, and other physical separators like lot and concession lines, road alignment, etc.

The criteria used for identifying the limits of flood risk area in Southern Ontario are based on the maximum of Hurricane Hazel-generated flood flow, the 1-in-100 year flood flow or an observed historical flood. No return period is ascribed to Hurricane Hazel-generated flows, but for the size of watersheds in the Grand River watershed, for example, these may range from 200 to 300-year return period flood.

The Grand River Conservation Authority followed this approach in the late 1950s and 1960s. The first generation flood risk maps were produced to form the basis of planning, guiding flood-prone development away from flood risk areas and permitting floodplain compatible land use. In situations where development existed within an identified floodplain, flood protection measures were implemented where economically feasible. Several flood control structures were constructed using this approach. The 1970s saw a gradual shift to damage prevention approach. When the 1986 flood event occurred, flood plain management had been in effect for over 30 years.

On March 31, 1978, Canada and Ontario signed the Flood Damage Reduction Program Agreement. To lessen the amount of flood damages, the program discourages flood-vulnerable development within identified floodplains. The two main objectives of the program were to: identify flood risk areas, reduce flood damage and

risk to life by regulating new development in these areas; and to find feasible ways to reduce future flood damage to existing development.

Maps are produced displaying the area of flood risk for each watercourse identified in the program. The flood risk area in Ontario is the area which would be inundated by the Regulatory Flood, which is the 1-in-100 year flood, or the regional flood, whichever is greater. Within the flood risk area, certain government policies are applied. Communities may have flood risk areas that are considered to be a one-zone or two-zone flood risk area. (A two-zone area indicates the two separate areas of a floodway and a flood fringe, the area where water tends to be shallower and slower).

In a one-zone flood risk area, the following policies are in effect:

- no future federal or provincial government buildings or structures that are vulnerable to flood damage will be placed in the flood risk area,
- funds from government sources, such as the Canada Mortgage and Housing Corporation will no longer be available for new buildings or structures placed in the flood risk area and subject to flood damage,
- any buildings or structures vulnerable to flood damage placed in the flood risk area after designation will not be eligible for flood disaster assistance, and
- the two governments will encourage local municipalities to adopt Official Plan Policies and zoning restrictions on development in the flood risk area.

Where a two-zone approach is used, the above policies apply to the floodway zone only. Development is allowed within the flood fringe providing it is adequately protected from flood damage. However, any development that existed prior to the designation of the flood risk areas is eligible for government flood disaster assistance.

The designation of flood risk areas is not intended to stop all use in the floodplain, but land use such as greenbelts, parks and agriculture lowers the damage potential and does not aggravate flood conditions. Flooding in the river valleys was extensive in the Toronto area in August 1986, but property damages were negligible since few buildings are permitted in the floodplain.

Michigan

Floodplain regulations and flood insurance are the two non-structural approaches for adjusting to flood hazard in Michigan. To implement these approaches, land use regulations, development policies, floodproofing, disaster preparedness and response plans, flood forecasting and warning systems are used (FEMA,1986).

The Floodplain Regulatory Authority, which came into effect in 1968, falls under the broad heading of land use regulations. The Authority defines floodplains based on the Regulatory Flood which in Michigan is the 1-in-100 year flood. Development of any residential properties is prohibited in the floodway but other development is allowed if it can be proved that the new structure would not increase flood elevations or divert flows. However, new buildings can rarely meet these criteria.

The Subdivision Control Act guides the division of large parcels of land into smaller lots for the purpose of sale or building. The 1-in-100 year floodplain must be mapped, basements are not allowed in fill areas, and no openings lower than the flood elevations are permitted. Two similar Acts, the Condominium Act and the Mobile Homes Commission Act also restrict residential development in floodplains. The only stipulation to the Condominium Act is that the lowest floor of the structure must be built above the 1-in-100 year floodline. The Mobile Homes Commission Act allows for floodproofing, but no mobile homes can be located in a floodway. If pads are used, they must be above the Regulatory Flood level.

The National Flood Insurance Program (NFIP) promotes a variety of non-structural means for flood and erosion damage reduction. While not a protective measure, flood insurance does require adoption of certain floodplain management measures and serves to mitigate the effects of flooding on individual policyholders. FEMA, which administers the NFIP, conducts Flood Insurance Studies (FIS) to develop flood risk data for communities which have chosen to participate in the program (Kehoe, 1989). In Michigan, approximately 600 of the 1776 communities participate in the NFIP. Using the results of an FIS, FEMA prepares a Flood Insurance Rate Map (FIRM) depicting Special Flood Hazard Areas within the community. The FIRMs however, do not contain any flood elevation information that would be helpful to a community for floodplain management. Special Flood Hazard Areas are areas which would be subject to flooding in the occurrence of a 100-year flood. Structures existing prior to the publication of a flood insurance rate map are eligible for insurance at a lower cost than those structures constructed subsequent to the publication of a FIRM Within the NFIP, floodproofing is also available to those structures that are non-residential.

In Michigan, communities have the option of adopting their own floodplain management policy. About 80% of communities follow the State Construction Code, which is an amendment to the Building Officials and Code Administrators (BOCA) National Building Code. The Amendment does not regulate the location or the type of development within the floodplain, but states that no basements can be built within a floodplain, and subgrades must be above the flood elevation. Only non-residential units can be floodproofed.

In total, 95% of Michigan's communities follow one form of non-structural floodplain management. The common regulation in the policies states that buildings must have at least their lowest floor above the Regulatory Flood. However, many of the local policies that may be adopted do not deter the development of residential units within floodplain but only restrict the height of the lowest floor.

In Michigan, the Department of Natural Resources (MDNR) regulates floodway occupancy. This occurs only when a building permit is involved. As building permits are required for new construction or substantial improvements, the adequacy of the State or County building code enforcement program becomes the definitive element of the regulatory process (FEMA, 1986). It was found by FEMA's Inter-agency Action Team that proper knowledge of State building codes, zoning, the NFIP, and overall the wise use of floodplain was lacking. It was also discovered that the enforcement of existing codes and regulations was lax. Since many of the regulations and codes were not adhered to, the residents of Michigan had a greater exposure to flood hazards.

Although in many communities the flood elevations exceeded the 100-year flood level, more appropriate use of the floodplain would have alleviated many physical and psychological damages. Instead of allowing communities to adopt their own floodplain management policies, more cohesion of floodplain regulations within the State is needed. Enforcement of existing policies would probably have minimized damages, but Michigan still pays millions of dollars in flood relief and rehabilitation annually.

Discussion

From the presentation of the two floodplain management models, it is obvious that the objectives of the two programs, reduction of future flood damages, are the same, but the methods of achieving these objectives and the success in implementing the floodplain management models are quite different. These are briefly discussed.

In Ontario, a Conservation Authority is formed by agreement of all participating municipalities and these are represented

in the administration of the Conservation Authorities Act. Further, the Conservation Authorities and municipalities work hand in hand in approving development proposals or alterations to properties within or close to floodplain. Also, in implementing the Conservation Authorities Act through the fill regulations, the CAs tend to retain a buffer of safety between the actual floodline and regulatory fill lines. While this may give an illusion of over-regulation, the difference in flood damages, as presented in Table 1, confirms the socio-economical benefits of such an approach.

In contrast, in Michigan, the Flood Insurance Program is not mandated to keep the development away from the floodplain. It requires different premiums for the various flood zones; inner zones carry higher premiums and vice-versa. Also, the participation in the program is voluntary with a significant number of municipalities not participating. The approach taken in Ontario, when interpreted from the insurance program perspective is that the premiums for developing within an identified floodplain are so high that people cannot afford them and hence there is incentive to move development away from the floodplain.

There were enormous differences in the damages that occurred in Ontario and Michigan from the August-September 1986 floods. The comparison between non-agricultural damages is particularly striking: less than $500,000 in Ontario, more than $200 million in Michigan, as seen in Table 1 (Nicolson, 1991). The non-agricultural sector is targeted by floodplain restrictions, as agricultural uses are generally permitted in flood-prone areas. Also, there is a high degree of uncertainty about the extent of agricultural losses that occurred in Ontario.

The large differences in non-agricultural flood damages cannot be accounted for by differences in the intensity or volume of rainfall; the volume or frequency of the runoff; differences in phsiography; or differences in population densities and amount of urban development. A major reason for the large differences in damages is in the large differences in the amount of flood plain development in the

Table 1: Estimated Flood Damages in Michigan and Ontario for August-September 1986 Floods

Sector	Ontario	Michigan
Public	480,300*	66,848,900
Private		136,417,990
Agricultural	0**	106,366,310
Total non-agricultural	480,300	203,266,890
Total	**480,300****	**309,633,200**

* Figure includes both public and private losses.

** A potential agricultural loss of $10,000,000 was oiriginally speculated by the Ontario Ministry of Natural Resources, (Toronto Star, 1986) but no measurable loss was actually realized. Some loss may have been incurred by the need to forego planting of winter wheat (which was replaced by alternative crops in the spring), but this can not be confirmed.

two jurisdictions as a result of two different long-term approaches to flood plain management.

Summary

Since the mid-1950s Ontario has had an ambitious and comprehensive flood-reduction program. This has not been the case in much of the affected area in Michigan where flood plain restrictions have been limited. The 1986 floods show that for large flood events, the benefits of long-term non-structural flood plain management strategies can be enormous, possibly in the hundreds of millions of dollars saved in one year.

The benefits of non-structural flood plain management measures are cumulative and increase over time. The full benefits of these approaches cannot be fully represented by studies based on shorter periods of flood plain development control. As a result, the full benefits of non-structural flood plain management approaches may be under-estimated by planners and resource managers.

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