Reducing Flood Disasters: the Need for Effective Local Planning

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Abstract

Flood disaster costs are increasing rapidly, stressing government resources and insurers' margins. This paper reviews Government flood response, showing that it continues to emphasize (possibly less efficient) expenditures on control structures rather than non-structural approaches. Local governments generally make the key land use decisions that effect watersheds, but they do not place much priority on floodplain management or flood mitigation, and repeated flood disasters result. This paper explores contributing issues: fragmentation of government responsibility and impacts of local land use decisions, excessive drainage, artificial landscapes, intense development design, development in the floodplain, and private sector development impacts. Key problems discussed are: inconsistencies in "Who Decides and Who Pays," and too much reliance on structural solutions to floods. The watershed as a system is considered in the context of government inaction and action that "stiffens" the watershed system leading to the loss of watershed system robustness, possible chaotic dynamics and increase in flood disasters. Maintaining or increasing watershed system capacitance is very important. The paper concludes by discussing a number of policy and practice matters that must be addressed by public planners, and requirements that senior governments must address to bring about institutional change to address government policy coordination at the watershed level and to reduce the reliance on physical flood control structures by emphasizing non-structural approaches.

1.0 Introduction

The increase in the number and severity of serious natural disasters continues apace. There is a long history of costly natural disasters shared by Canada, the United States, Australia, United Kingdom, and many other countries. This should stimulate major government planning initiatives to complete studies and develop and implement policies that would reduce the property, life and financial risks associated with natural disasters. While there are some cases of proactive planning to mitigate disasters, in large part governments seem to be preoccupied with a mainly reactive approach. This is not to say that governments have totally ignored investments and policy development required to reduce the effects of some major disasters. For example, there have been major investments in flood control structures. Rather, government action emphasis seems to have been misdirected in location, focus, and scale to large regional projects or more general policies ignoring potentially important actions at the local level, which could contribute to reducing disaster impacts.

Floods account for a very significant portion of natural disasters. Newkirk (1999 2000a) reported that in Canada, floods account for the highest per claim payment by the insurance industry. He suggested that local planners should place high priority on development and emergency planning that include mitigation provisions to reduce the impact of floods; he observed that already existing land use planning instruments (e.g., Official Plans, Site Plans, Zoning Bylaws) and development review processes could provide, over time, potentially effective local means to reduce the impact of floods. For more than the last century, the major government flood adaptation expenditures have been made by federal and provincial levels and primary emphasis has been on downstream remedial physical structures and upstream storage structures. This paper contends that governments need to direct more emphasis on local scale planning and less on a physical structure approach. This view shared by others is discussed further below. We begin with a brief characterization of some government policy response to floods. We then consider briefly institutional and structural approaches that have been used by government to deal with floods. This leads to some consideration of the systems implications of these government approaches. Finally this leads to some recommendations about initiatives that should be taken by planners and governments.

2.0 Natural Disaster Impacts and Government Policy Response

Newkirk (1999 2000) based on data published by the Institute for Catastrophic Loss Reduction and Emergency Preparedness Canada (1998a,b) notes that in Canada alone, disaster insurance claim payments doubled and government payments increased by more than an order of magnitude in just the last 10 years. The majority of these events were weather related. Canada suffered extensive loss of property and life in the 1996 Saguenay Flood, the Red River Flood in 1997 and the Ice Storm in Eastern Canada in 1998. It is also observed that these rapidly increasing and unanticipated disaster response expenditures have forced governments to divert funding from other priority programs and have pushed the property and casualty insurance industry to unsustainable low margins. The likely increase in insurance premiums and "risk management" insurance coverage exclusions will lead citizens and business to carry less insurance coverage. This, in turn, will potentially bring about even larger unanticipated disaster assistance expenditures by government.

It is remarkable that governments are not willing to take significant new policy and cost sharing approaches to mitigate the large disaster costs that are repeated with some regularity. For example, the United Kingdom continues to experience serious periodic flooding in West Country and yet local governments are not required in law to develop emergency plans and controls. Strong winds will continue to blow in from the west laden with moisture from the Gulf Stream occasionally bringing about extremely intensive rainfalls. Yet, after experiencing centuries of heavy rainfall impacts in the west, there was loss of life, heavy property damage and evacuations from floods in 1987 and 1990. (Parker 1992) In the United States there are recurring major floods in the Mississippi, Missouri, Ohio and many other watercourses. In Canada there is a regular cycle of flooding and property loss in the Great Lakes (Lawrence and Nelson 1999) and along Canada's many rivers and seacoasts. The main discussion in this paper relates to flooding in river basins; however, many of the aspects discussed apply also to issues related to coastal flooding.

Governments appear to be reluctant or unwilling to force citizens to restrict their use of flood hazard lands (Day 1999). In the United States, the National Flood Insurance Program (NFIP) is plagued by repeated claims for individual properties or areas. Platt (1999) cites a study by the National Wildlife Federation (1998) that reports the following. Approximately 3,735,000 properties are insured under the federal program, of those 74,500 (or 2 percent) have accounted for 200,182 individual claims. [This represents an average of 2.7 claims for each of the repeat claim sites.] Platt (1999 p. 73) notes that one-third of the repetitive claim properties have actually been flooded more than three times with payments totaling $1.4 billion. These repeat claims also tend to be expensive. [In appears that approximately 24,800 repeat claim properties have each received an average of $56,500 payment.] One-third of the repetitive claims represent more than half of the repetitive loss payments. Two extreme cases are reported (Riley 1998) where one shorefront bar obtained NFIP payments in 1995 and 1996 totaling $752,000, and a nearby exclusive hotel received NFIP payments of $96,000 in 1991, $103,000 in 1992, $42,000 in 1993, and $250,000 in 1994 for a total of $491,000. The building was pulled down in 1994 after the last payment was received. Platt (1999 p.74) concludes:

> *"The repetitive loss problem reveals a major difference between governmental and private insurance plans. While the latter would either cancel coverage or raise premiums significantly after repetitive claims, the government is reluctant to offend anyone. Indeed, there is substantial lobbying by private property interests to protect availability of NFIP coverage at reasonable rates regardless of actual loss experience. Federal flood insurance thus is equivalent to an "entitlement" which property owners claim as a right, even when it is subsidized by taxpayers."*

Lawrence and Nelson (1999) review the lack of effective government policy and institutional action to deal with the impacts of recurring Lake Erie[1] floods in spite of many potentially useful assessments and policy studies. They report some flooding cost estimates for three recent periods of high water and flooding along the lake. In the 1951-55 period there were $89.2 million flooding impacts (of which $3.3 million were on the Canadian shore). In the 1972-73 period there were $196.5 million flooding impacts (of which $10.8 million were on the Canadian shore). In the 1985-86 there were even higher flooding costs. Total costs for that period were not available although it was known that the Canadian shore flooding impacts in 1985 alone were $26.3 million. They cite 10 reviews, studies and major policy reports that were produced during this period (especially in response to the 1985-86 experience). But they report that little substantive government policy or regulation change was effected.

> *"Public and government interest in more effective flood policies and responses tends to be very high after a major flood but declines thereafter in line with the Downs Issue Attention Model (Downs 1972). For example, public support and interest was initially very high for the 1986 International Joint Commission (IJC) Levels reference Study, but it fell thereafter. When the final IJC report was released almost ten years*

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[1] Lake Erie is one of the Great Lakes of North America. The international boundary between Canada and the United States passes though its centre. It and the other Great Lakes are studied and managed by the International Joint Commission (IJC) cooperatively established by Canada and the United States.

later, the results and recommendations received little public, government or media attention. By 1993, the Great Lakes water levels had declined and public and political concern had shifted to other issues." (Lawrence and Nelson 1999)

Much of this reluctance for governments to act is based on the fragmentation of responsibility between many governments, the uncoupled nature of "who decides and who pays," and undue reliance upon major structural engineering "solutions."

3.0 Government Institutional and Structural Response to Floods

3.1 Fragmentation of responsibility and local decision impacts

Most major floods take place in watersheds where there are usually numerous governments and agencies each involved with distinct or overlapping jurisdictions. In the United States and Europe, a watershed is likely to be the location of a large number of independently governed cities, villages, boroughs, and towns. Many of these make their own independent local development decisions on the basis of their own standards and objectives; such decisions of course, effect drainage and floodplain development and exposure to flood risk. Europe has a further complication: major watersheds often are shared by several independent countries, each with its own national interests, agencies, policies and procedures. Canada and Australia have somewhat fewer independent governments per watershed but a significant number are involved nonetheless. As an example of fragmentation, consider the Grand River Watershed in Southern Ontario Canada; it drains a watershed of 6,965 square kilometres along a watercourse of 300 kilometres (Boyd et al. 1999). This is a low relief watershed with its area predominately in rural land use but also with population of 787,000 in some concentrated urban settlements. This small watershed is divided into areas administered by 58 local and regional governments. There is a small amount of overlap in some jurisdictional spatial boundaries, and some watershed parts are administered by authorities whose geographic area of responsibility extend significantly outside the boarder of the watershed. A review of many watersheds reveals that the jurisdictional boundaries of governments effecting land use and development policy in a watershed or sub watershed usually do not conform to the natural (i.e., physical) watershed boundaries. Unless there are special institutional arrangements imposed (see section 5.0) development and land use control in the watershed (especially in the floodplain) will continue to be subject to uncoordinated independent decisions by local governments some of which perhaps have little interest in the watershed itself.

Often local jurisdictions perceive themselves to be in competition with neighbours for investment, resources, markets, etc. It is not surprising that the large number of semi autonomous jurisdictions in a watershed make it exceedingly difficult to obtain effective cooperation with regard to watershed land use and floodplain development, and the management of storm water. Some jurisdictions are just reluctant to share information or enter joint discussions; others on occasion actually approve actions that cause downstream problems. From the purview of a small local municipality, there is little natural inclination to consider downstream effects of storm water discharges. For example, in some provinces, notably in Quebec, existing provincial legislation indicates that it is the responsibility of the local municipality to "get rid of storm water"; there is no mention of an associated responsibility to minimize downstream effects. As long as a municipality's storm water is disposed of "adequately" by sending it outside a municipality, any extra management provisions to reduce outside impact is seen strictly as an unnecessary cost that can be avoided. In addition to the foregoing, individual local planning, environmental management, and engineering practices and policies followed by many local authorities across North America can exacerbate downstream storm water management problems. Some examples are: excessive drainage, artificial landscapes, intense urban design, development in the floodplain, and the private sector as driving force in development.

Excessive drainage: Most individual communities require all development site plans to ensure that surface storm water is removed quickly through engineered drainage swales or drains. Residents are required to ensure that drains and swales remain clear; by law, they may not be blocked or modified. Many municipalities extend this philosophy to their own sites and facilities (including playgrounds and even parks). City administrators and councilors receive pressure from citizens to ensure that there is little surface water left standing anywhere after rainfall events--particularly on roads, sidewalks, trails, and recreational facilities. As a consequence, most modern municipal storm water drainage is very efficient at dumping the results of a rainfall event into the nearby streams. In addition, rural governments have access to drainage laws that allow the government to force property owners to fund drainage projects for agricultural "improvement" purposes. The Ontario Drainage act has been used quite aggressively by some rural municipalities to eliminate wetlands, channelize small creeks and streams, and install tile drainage across extensive tracts of land. Excessive drainage can have substantial downstream impact on floods.

Artificial Landscapes: Perhaps as a leftover value from the manicured garden beautiful philosophy[2], many municipalities continue to drain damp areas and wetlands (large and small), avoid planting clumps of dense native vegetation, and some limit or discourage citizens from deviating from neat planting and manicured lawn residential site. Artificial landscapes discharge rainwater very quickly. Many "upscale" residential developments in the United States include title provisions to legally bind residents to maintain the manicured standard. An increasing landscaping practice for commercial sites and now some residential lots is to install a "low maintenance" landscape design where a site has an underlay of impervious plastic over which is placed stone or gravel; any vegetation is placed in pots or planters. In some cases artificial turf is installed over an impervious concrete or asphalt base. Artificial landscapes have very high runoff coefficients greatly increasing the storm water runoff from a site.

Intense development design: A recent residential development trend in North America includes a marked increase development density; this is particularly evident in the last half decade with increasing interest of planners and developers in the Neo-Traditional design approach[3]. While there are some environmental and economic benefits (e.g. reduced consumption of land, lower cost per unit for municipal services), there is significant decrease in the average site's ability to absorb rainfall. Building large homes with 2 or 3 car driveways on very small lots means that in some modern developments, as much as

[2] The manicured garden beautiful reached ascendancy in Europe and North America in the Victorian period. Although there was some decline through the middle 1900's, some aspects remained entrenched through to the 1990's. In the 1970s through the 1990's the manicured approach impact was exacerbated when private citizens began to make intensive use of fertilizer, pesticides and herbicides to maintain their outdoor planting. This has contributed to degradation of storm water quality as well increasing the volume of storm water runoff.

[3] The Neo Traditional approach is considered to have developed its main impetus from Dulane's work on the Seaside development in Florida.

80% of the total land surface is rendered impervious. Beyond the obvious impact of increasing storm water discharges, the reduced infiltration has serious effects on ground water tables.

Development in the floodplain: The floodplain is a naturally occurring part of a watershed. This area where the river occasionally expands to accommodate unusual volumes of floodwater also has served humans as a location for economic activity and residence. This is the area where disaster strikes in major floods and where governments make large disaster relief expenditures. It has not been easy to clearly define the floodplain or to limit development on it. The actual definition of a floodplain is a little elusive. Its boundaries are determined by basic landform, stream channel configurations, upstream land use change, and anticipated rainfall or runoff regimes. Once mapped, there is a continuing update problem; any significant upstream land use changes or new developments or the additional flood control structures require new evaluation of floodplain boundaries. Floodplain mapping is an expensive and very technical exercise (Boyd et al. 1999). The definition the floodplain is highly dependent on the reference "design storm," and the hydraulic modeling. Many jurisdictions do not yet have access to floodplain maps or even the detailed information required to develop such maps. In the United States the National Flood Insurance Program (NFIP) has initiated a $1 billion program to map flood prone areas at the level of a 100 year flood. This mapping will have some impact on floodplain development since it will determine areas where occupants will have to purchase flood insurance if they wish to qualify for loans from federally regulated institutions (i.e., federal banks and government agencies). The mapping will also be used to set different insurance rates for properties subject to more or less degree of flood risk. "*... it should be noted that NFIP maps have often been criticized for undue complexity and questionable accuracy in some cases. They however, have enjoyed a presumption of validity when challenged in court lawsuits." (Platt 1999: 72)* However, this initiative just involves federally associated funding and insurance; it still leaves local land development decision making (especially on the floodplain) in the hands of local authorities. For a short period, the federal government in Canada provided shared cost financing for floodplain mapping and some areas were mapped. But this program has been greatly reduced due to funding cut backs at all levels of government. (Boyd et al 1999, Day 1999, Newkirk 1998) Consequently, in many areas there is no clear designation of the flood hazard areas. This makes it very difficult for development control planners to limit building activity in the floodplain to which some people and activities have affinity.

In the past, individuals, cities, villages, and towns located close alongside rivers for transportation and access to water and waterpower. To this day, the floodplain offers humans a number of positive attributes: the land tends to be flat, easy to dig and build upon, it is often easy and less costly to service, it may offer some building materials (stone, gravel, and sand), the land cost may be low (a market adaptation to periodic flooding), it is often fertile, and it provides recreation potential. It is somewhat natural that individuals might be willing to tempt fate and locate residences and economic activities in a floodplain. It is generally recognized that individuals who live in close proximity to a hazard often downplay the danger due to familiarity. In addition, with a somewhat long cycle to some major flood events, individuals may not have sufficient experience or information to understand the potentials for local flood impact. Further, structural adaptations (e.g., levees, dikes, dams) may give individuals a false sense of security from floods (White 1945, Day 1999, Plat 1999). Day (1999) notes how ready large numbers of individuals were to locate behind dikes in the lower Fraser River Valley--essentially as quickly as the diking took place. Another favorite adaptation in the floodplain is to fill around buildings, transportation facilities, and other structures. Filled areas can be overtopped in serious floods, and the washout of filled areas is possible in extreme flood situations. Washouts can significantly exacerbate down stream flood volumes. Filling has the tendency, over time, to reduce the size of the floodplain and correspondingly increasing the height of floods. In spite of these risks, diking and filling give residents a sense of security. Accordingly there is no shortage of individuals desiring to locate residences and businesses in the floodplain. Senior governments generally have been reluctant to force local authorities to forbid floodplain development, leaving control in the hands of local authorities who have demonstrated over the years a strong inclination not to worry too much about floodplain development.

In the following example reported by Hunt (1999), it is clear that Tulsa, Oklahoma, USA was reluctant to attend to floodplain management problems. Tulsa had experienced floods regularly that devastated this city of 375,000; the city had the US Army Corps of Engineers construct in 1964, a dam 16 miles upriver.

> *"Largely because the dam provided ... a sense of security, Tulsa continued to allow the construction of new buildings in the floodplain. Following the construction of the dam, ... Tulsa experienced floods every two to four years. The City's response ... included emergency assistance to flood victims, reconstruction of floodplain buildings as quickly as possible, and denial that the floods could reoccur. ... A major flood [then] occurred in 1984 that killed 14 people, damaged or destroyed nearly 7,000 buildings [and] left $180 million in damage ..." (Hunt 1999: 107)*

Following this last experience, Tulsa finally began to take a variety of steps to regulate risk in the floodplain, including regulating floodplain uses. All through this experience, the state and federal governments were called upon to provide disaster assistance. It appears that there is good reason for senior state, provincial or federal governments to impose statutory requirements on local municipalities to manage floodplains to minimize floods.

The private sector as driving force in development

In most cases, it is private citizens or firms who assemble land parcels, initiate, plan and finance land development projects. Market demand and profit considerations are key. Developers wish to minimize development costs. Unless required by regulation, developers pay little attention to changing surface runoff volumes and impacts. With rare exceptions, the only consideration of storm water in the initial design and review of a proposed development or redevelopment of an area is whether or not the storm water flows generated can be adequately discharged outside the community. Thus, with the overview of local municipal planners, private sector led land development proceeds with projects that substantially increase the amount of impervious land in a watershed. These and other factors under the control of local governments yield new urban areas with very decreased ability to absorb rainwater, and increased capability to dump storm water rapidly into the watercourses of the watershed. It is obvious that these local actions will increase the risk of downstream flooding bringing about possible assistance costs for provincial and national governments. One reason this situation exists is the inconsistency between who decides and who pays.

3.2 Inconsistency in "Who Decides and Who Pays"

We have seen that most of the key land use development decisions in a watershed are controlled by local planners and local or regional councils. These decisions are based on locally developed and enforced standards and normally do not consider external impacts. Most development and redevelopment is proposed by private sector builders or land developers with regard to local government standards and responding to the several trends discussed in the proceeding section. The developer is required to finance the installation of all physical services internal to the development. In turn, the municipality collects development fees or charges (paid either by the developer or the end purchaser) and provides trunk sewer and water infrastructure, connecting roads, and other services. In the long run, the municipality experiences net benefits from increased municipal revenue generated by the development. It appears that a municipality is in a very favourable position where its development charges offset its initial servicing cost for eventual recurring tax revenue from the development. Accordingly, many upstream local governments willingly approve development proposals that substantially increase storm water discharges, and many downstream local governments willingly approve continued use and even development in the floodplain.

Local governments have the first responsibility to deal with costs of floods (Boyd et al 1999 Day 1999). Small periodic floods can be often be managed locally since structure and facility damage is likely to be small (possibly covered by insurance) and evacuations minimal. However, when a flood disaster happens, the costs and physical response needs rapidly outstrip a local government's ability to cope. In Canada, the responsible provincial government immediately steps in. In large-scale disasters, the federal government is involved as well. In discussing flooding costs in the Fraser River Valley, Day (1999) reports an estimated $C426 million has been spent from 1948 to 1997 in compensation for floods in the Fraser Basin even though a major (100 year) flood was not experienced in that period. The burden of cost is instructive. He reports that the province[4] contributed roughly 96%, and the federal contribution, which exceeded $C 18 million, is not insignificant. He goes on to observe that the senior governments could face very substantial costs when the Fraser River basin experiences a 100-year flood. In this scenario, costs are estimated to exceed $C 1.8 billion. *"This level of disaster would constitute an enormous drain on both senior governments, but particularly the federal level, which [by legislation] covers 90% of eligible losses in excess of $C 20 million." (Day1999: 58).*

Local governments make decisions that can influence flood potential and impacts in a context that is net financially positive to them. At the same time, senior governments pay the largest portion of costs of the resulting flood disasters that result from decisions they have not made. Unless there is some external requirement placed on a local administration to restrict or remove development in a floodplain or to limit storm water output from upstream development, there is little incentive for the local authority to restrict or manage floodplain development. In most cases, senior governments have not imposed such requirements. As a consequence, there continue to be large populations and economic activities placed at risk of flood damage as a result of local government decisions.

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[4] British Columbia.

3.3 Reliance on Structural Solutions to Floods

Structural adaptation to floods has a history stretching well back into antiquity. Levees, dikes, dams, weirs, etc. have been engineering solutions for generations, and often provided the added bonus of improving transportation and economic activity. Sometimes there are situations where physical structures provide the only way of avoiding floods. Since one-third of the Netherlands is below sea level, the country must rely upon dikes to keep out the North Sea. In 1953, a serious breaching of the dikes in Zeeland led to approximately 2,000 deaths. Under global warming sea rise scenarios, the Netherlands will have to spend between 2,600 million to 17,500 million Dutch guilders to raise and strengthen dikes. (Penning-Rowsell 1999). It appears that the country has no other choice but to make these costly major structural investments to protect its citizens and their property. However, it is not always clear that investments in flood control structures in other cases are the best way of mitigating all potential flood situations.

The preferred solutions to floods have been upstream control structures and downstream levees, in spite of some questions about their overall effectiveness. Consider the "flood proofing" of the lower Fraser River Basin in British Columbia, Canada. The basin covers about 240,000 square kilometers with population of 2.4 million concentrated primarily in the lower alluvial plain. The upper reaches rise in the glacial interior mountains, and the river rushes seaward with flows that run from 450 to 20,000 m^3/second (averaging 3,972 m^3/second). Its mainstream length is 1,400 km, with the lower reaches now containing approximately 250 km of dikes, 84 km of bank protection, and more than 100 flood control structures (Day 1999: 51). Much diking followed a serious flood in 1948 after which the federal government paid 75% of dike improvements. The public responded (with local government approval) by continuing to move into the perceived "safe" floodplain. Day (1999: 55) quotes a Sewell report:

> *As in many other areas, these new protection works were undertaken without any land use restrictions and induced "encroachment into the floodplain ... at an extremely rapid pace. Population ... almost doubled and in some parts it ... almost tripled in the lower Fraser Valley" (Sewell 1964: 22).*

The United States Congress, in 1825, authorized the Army Board of Engineers to undertake waterway improvements on the Mississippi River. By 1861, the Board began a system of levees in the lower river. In 1889, the US Congress established the Mississippi River Commission that still manages the River to this day. By the 1930s, control dams were being built, and dam construction, channelizing, and levee work continues to this day (Platt 1999). Throughout this lengthy period and in spite of active flood structure construction, there continued to be many disastrous floods that caused substantial property damage and loss of life and required expensive repair and rebuilding of flood control structures.

> *Floods have continued to challenge federal policy and to stimulate important changes in strategy for dealing with them. Between 1936 and 1952, [the US] Congress spent more than $11.1 billion for flood control, of which $10 billion was allocated to the Corps of Engineers*[5]. *By 1983, the cost of the Corps flood control projects on the lower Mississippi valley alone since 1928 was estimated at $10 billion. ... In*

[5] Author notes the figures are not adjusted for inflation.

> *the 1993 Midwest Flood along the upper Mississippi and lower Missouri, the Army Corps of Engineers estimated that its facilities saved $19.1 billion in flood losses. (Platt 1999)*

No doubt, through the various floods, there were some savings in life, property, and economy due to the investments in physical flood management structures. However, costs from floods continue to rise substantially in spite of flood control investments. In Canada, floods account for the highest per claim insurance settlements (three times the next most expensive natural hazard claim) (Newkirk 1999 2000a). Gilbert White (1942) studied the increasing costs of flood damage versus the effectiveness of building flood control structures. White (1942), Day (1999), Platt (1986 1999), and Hunt (1999) agree that non-structural approaches could be potentially more effective than physical structural approaches.

> *"[White concluded] ... single purpose structures such as dams and dikes seldom solve flood problems .... indeed they usually exacerbate the problem. In their place White urged a multiple adjustment approach based on the wise use of floodplains and avoidance of creating a false sense of security for activities better located in less hazardous areas. In addition to appropriate structural works, he suggested the adoption of forecasting and warning systems, evacuation planning, flood proofing of buildings that must be located in hazardous areas, land use planning and floodplain zoning, flood insurance, and public disaster relief." (Platt 1995: 243)*

White's conclusions in 1942 were widely disseminated and well received by academics and many resource managers. However, the engineering emphases on building flood control structures continued with enthusiasm across North America in large, medium and small watersheds. For example, Boyd et al. (1999) report that Grand River Watershed floods were first responded to in the 1900s to the 1930s with the construction of levees. This was followed in the early 1940s by the construction of the first large dam. Following the first dam, 7 more dams were built between 1952 and 1978. Channelizing and diking continued to 1995. *"The emphasis in [this] structural approach is to control or modify the natural systems ... rather than tackle the land use issues that cause the problems ... "* While flooding is somewhat reduced, these structural methods have certainly not eliminated the risk. *" ... in the Grand River Basin, all of the dike systems have failed except for the dikes built in the last 20 years ... "* (Boyd et al. 1999: 26). In spite of the flood control works in place, there was a serious flood in 1974 with significant property loss and evacuations.

Structural interventions have not removed flood threats. Their construction has allowed local municipalities to ignore the need to manage floodplain use and to ignore storm water discharge from development. The structures seem to have given people a false sense of security, encouraging them to continue to locate in floodplain areas. At the same time, these various government interventions and development decisions have altered the basic systems nature of watersheds reducing their ability to respond properly and safely to major rainfall events. Indeed, government actions have served to increase the instability of the watershed's basic systems response to rainfall events, increasing the possibility of serious flood effects.

4.0 Some Systems Implications of Government Structural Flood Response and Development Decisions

The various physical flood adaptations financed by governments have the express purpose of changing the system performance of a watershed (Boyd et al. 1999). Normally these structural interventions are valued for their perceived direct effects. For example, a levee is valued because its height is seen to protect properties from flooding; a dam is valued because it is seen to store excess water (to take the peak off a flood). However, these government structural interventions also introduce fundamental direct and indirect changes to a watershed's overall systems performance. Some important systems properties that can change include stability and robustness. In undisturbed natural state, most watersheds work smoothly to accommodate the possibly wide variation in precipitation loads; this means their systems exhibit performance stability. In addition they tend to possess a significant degree of system robustness. A robust system is able to tolerate a large range of stresses to the overall system or to components without loss of stability and throughput performance. The fact that many rivers have been able to tolerate sometimes-extensive structural interference with their systems indicates that most had (at least initially) intrinsically robust systems.

In attempting to control an apprehended flood problem by introducing special structural facilities, government intervention may actually degrade a watershed's system performance leading to increased tendency for degenerate behavior (floods). We now explore some general discussion of a watershed as a system so that we can consider some of the possible overall performance changes induced by government structural interventions. We begin with a simplified systems description of a watershed.

A watershed may be considered a feed forward[6] tree structure (sometimes called a feed forward network). The desired flow system in a watershed is one when, under various precipitation event loadings, there is sufficient network capacity to accommodate the necessary flows throughout the system without stressing individual components. A system's description of a feed forward flow tree network consists of a series of nodes connected by edges. The peripheral tree nodes represent the land as a receptor of precipitation. They may represent small local upstream areas or they may represent a range of "developed" rural and urban areas. The edges (i.e., links or arcs) that connect directly from the peripheral nodes represent first order (small) streams or drains. Edges connecting from lower order nodes join at higher order nodes that are internal to the tree structure. Edges that connect successively higher order nodes represent creeks, then small rivers and tributaries, and eventually main river watercourses. Eventually one reaches the trunk or root of the tree structure where the watershed output discharges into a large water body or, perhaps an even larger watershed. There may be some special internal network nodes that represent storage within the tree structure; these represent ponds, lakes, and reservoirs behind dams. There is a large literature (beyond discussion scope in this paper) that allows one to study detailed behavior of flows modeled by such trees as well as overall system performance. Many storm water modeling systems have affinity with this conceptual representation.

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[6] A feed forward structure contains no feedback components. While the absence of feedback in the structure provides a slightly more inherently stable system (feedback in a system can introduce instability and oscillations), feed forward watershed modeling is non trivial due to the asynchronous combinatorial complexities of such large systems.

In systems modeling, we refer to a network element's *capacitance* as its ability to accept a flow, absorb the flow as a stored quantity and its ability to release or discharge the flow, over time, into the tree or network. The functioning of a capacitance element in a flow tree is similar to the functioning of a capacitor in an electrical circuit. Such an element can act as a temporary storage device and is very useful in damping (i.e., slowing down) response in a system; it also has the benefit of smoothing out or reducing oscillations. Its effectiveness is dependent upon its size (i.e., its inherent storage capacity). In natural or undisturbed watersheds, there is usually a high degree of capacitance through the system. This means that, unless a watershed was already saturated from a number of recent intense rains, its capacitance could accommodate new heavy precipitation with correspondingly small immediate increases in stream flow. Capacitance has an additional benefit: it can provide a natural supply of base flow to streams during dry periods. In general feed forward systems, capacitance is a major contributor to system robustness and leads to system performance stability.

The edges (i.e., links) in the network transmit flow from one node to another. A flow property may be defined for the various specific edges to represent corresponding flow rates (i.e., flow volumes) over time. Edges may be assigned a variety of additional properties in a system depending upon the nature of the system being modeled. In a flow system, an edge may have some or no capacitance. An edge's flow and capacitance description is based on edge gradient, its hydraulic geometry and is form, shape, or configuration (in plan view). (Methods for developing these flow and capacitance estimates are beyond the scope of this discussion.) If an edge in a model represents a pipe, culvert, or a stream channelized by levees or with concrete bedding, it would have little or no capacitance and might have a relatively fast flow property. An edge that represented an undisturbed vegetated headwater stream could have some capacitance (due to wetlands and aquatic plants), and might have a lower flow rate.

A flood in an edge section of a river indicates this component is under stress from other upstream network flows and has exceeded its capacity. The flood can be thought of as a way for that edge to develop capacitance that it does not have in its intrinsic nature; as flood water overflows banks into the floodplain a certain amount of local storage in the floodplain area (temporary capacitance) ensues for that edge. Elements in a network are considered stiff if (a) they cannot readily adapt their performance to changing demands or (b) they have little or no capacitance. It is well understood in systems theory that a feed forward system's inherent stability is diminished if capacitance is reduced and/or stiff sections are added or created through structural modifications.

As a system has its capacitance reduced, basic system robustness declines. A low capacitance, stiff, feed forward flow network is likely to exhibit instabilities under heavy precipitation load, particularly in the downstream sections, as upstream sections download precipitation stress in a non linear combinatorial manner in the network. This can easily lead to performance oscillations that can overload the capacity of downstream edges. The consequence is flooding when a downstream edge overtops its (possibly stiff) channel. It is conjectured that capacitance reductions are the most critical in degrading a watershed's robustness and stability. Stiffening of edges (largely through construction of government-funded structural flood adaptations) also contributes to reducing robustness and stability. Government policy to limit watershed capacitance reductions and edge stiffening is important if flood threats are to be reduced.

Contributing factors – capacitance reductions: Agriculture reduces capacitance through vegetation clearing, improved field drainage, failure to follow contour plowing practices, installing large feed lots and extensive buildings and facilities for intensive poultry and pig farming, and draining wetlands. Resource based industries reduce capacitance through logging, mining and extraction practices and facilities. Urbanization in general reduces the capacitance of an area. Particular contributors are: expressways, roads, government commercial and industrial roofs, parking lots, residential roofs, land grading for rapid drainage and storm sewerage systems. Development of new subdivisions can substantially reduce capacitance unless special steps are taken with site design, drainage, and vegetation practices. Indeed, extensive tracts of urban areas have become "stiff" because all of their capacitance has been eliminated.

Contributing factors – stiffening system components: Construction of structures to constrain watercourse boundaries and control flow (levees, dikes, dams, weirs, etc.) all introduce significant system stiffness. The most extreme form of stiffening a watercourse is burying streams to pass them below grade through urban areas. Filling and construction of public or private facilities in the floodplain increases stiffness. Governments built structures in the floodplain to protect citizens and business from floods, ensure water supply, provide transportation, create recreational and electric power generation. Although it was not the government's intent to "stiffen" the watershed system, the watershed system dynamics were stiffened nonetheless.

In overview, government action has stiffened watershed components and government inaction has allowed drastic reduction in capacitance; this leads to chaotic system dynamics in many watersheds. It appears that governments need to redirect focus to a more holistic watershed dynamics approach with more attention to the upstream (capacitance) components and less on downstream traditional structural works. This will require new ways of planning mitigation strategies for floods.

5.0 Planning Initiatives to Reduce Floods

The previous discussion has identified a number of factors that contribute to continuing and exacerbating flood disasters. A number relate to the institutional and legal context in which governments deal with watersheds and land use. Another group relates to more technical aspects of land development; these require changes of practice and policy at the local level. Still others relate to an unbalanced emphasis in the response to floods--i.e., too much attention on downstream structural work as opposed to dealing with inland and upstream development issues (White 1945, Day 1999, Hunt 1999, Platt 1999).

Public sector planners need to place more professional attention on developing plans that anticipate emergencies and include mitigation provisions and programs. Planners should revise Official Plans to include policies on enhancing area capacitance (eg., maintaining site capacitance in new developments, enhancing capacitance of public spaces), limiting floodplain use, and returning floodplains to their natural (non urban) function. They also need to take the lead in public and politician education about the real risks of natural hazards – including floods – so that interest in developing appropriate policy and regulation is sustained (Lawrence and Nelson 1999). It has been shown (Newkirk 1995 1996 1997) that alternative land development layouts (which still provide the same kind and number of units and facilities) can substantially reduce peak storm water discharges and attenuate flows over longer periods of time. New developments could at least be required to retain more of an area's capacitance simply through relocating structures and facilities in a development area. Further improvements could come from better site level vegetation practices and storm water flow attenuation. There are a number of other benefits of such a strategy (e.g., improving ground water resources) that are beyond discussion in this paper. Thus, public agencies should change their procedures for development approval requiring developers to include development project level storm water modeling of alternative layouts. Also, agencies should revise individual site level development standards to encourage better drainage and vegetation practices; this should include a full review and revision of storm drainage standards. They should limit a developer's ability to use artificial landscapes and should prohibit covenants attached to title that require owners to maintain such landscapes. Finally, they need to explore ways to reduce the storm water impacts of the new high density (e.g., Neo Traditional) development paradigms. Overall, planners need to review all practices with the view to maintaining or increasing area capacitance both for new and existing areas.

Senior governments need to change legislation to require local municipalities to develop plans that anticipate natural hazard and other emergencies and require them to include mitigation strategies. They also need to impose legal requirements upon local municipalities to restrict floodplain use; this should include long term programs to assist with the eventual removal of structures and activity incompatible with the floodplain. (The NFIP repeat claim problems and Tulsa experience discussed earlier demonstrate the importance of forcing local authorities to restrict and remove floodplain development.) They need to assist municipalities in this task by providing important resources such as floodplain mapping and shared cost program funding to improve land use control and rehabilitation of floodplains.

The imbalance between who decides and who pays has led to continued loss of robustness in watershed systems, leaving senior governments exposed to ever-increasing costs of flood disaster relief and construction of structural adaptations. The fragmentation of development and management authority within a watershed must be resolved if this problem is to be successfully addressed. The Province of Ontario, Canada, has shown that there can be effective coordination of planning at the watershed level through its legislation to establish Conservation Authorities that now have the ability to define watershed floodplains and can influence local authority policy on floodplain use. For example, in the Grand River basin, watershed planning activities that relate to areas under the mandate of 58 individual governments are now coordinated and supported by the professional staff of one conservation authority (Boyd et al 1999). Although this initiative is laudable, it remains only a partial solution since watershed level direct control of floodplain use is not exercised by Conservation Authorities nor are there funded watershed level programs to gradually remove uses that are incompatible with the floodplain. While the Conservation Authorities have made some positive contributions to watershed capacitance through upper watershed planting programs on both public and private lands (recently reduced due to government funding cuts), they still have little if any influence on individual municipality land development decisions that effect site capacitance. However, Conservation Authority watershed based planning and management for floods has significantly reduced the potential for flood damage (Boyd et al. 1999: 29). Other senior government jurisdictions, such as the Province of Quebec, that have no legislative framework for dealing with storm water management issues between communities let alone at the watershed level, should make a beginning by borrowing from Ontario's Conservation Authority experience. Until the necessary legal frameworks are established to enforce planning at the watershed level, there will be little progress in dealing with the many forces that continue to degrade watershed system performance and expose citizens to risk.

In summary, governments must cooperate at a watershed level toward intensifying the non-structural approaches to reducing the impacts of floods and rely far less on expensive structural adaptations; these, in reality, continue to leave citizens and economic activity exposed to risk from floods disasters.

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