FLOODPLAIN MANAGEMENT

The following is an edited version of discussion and notes
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1. Objectives of floodplain management

In the wake of catastrophic floods, it has frequently been wondered why so many people continue to live on floodplains, despite the potential for enormous flood damage. There are several reasons for the popularity of floodplain occupancy. First, many historical civilizations were attracted to floodplains because of the fertile alluvial land that could support such civilizations. Agriculture continues to be a dominant factor for floodplain occupancy even in modern times. Second, the adjacent floodplain rivers provide many other amenities, such as river-based recreation opportunities and a transport corridor for commerce and industries. Third, many modern cities have been built on floodplains because of the convenience of construction on level land, which provides considerable freedom of location. Floodplain management strives to maximize the benefit of living on the floodplain by minimizing flood damage potential. Most of the floodplain management policies have, thus, centred around a double-barrel policy of :

(a) protecting the existing properties with structural measures, and

(b) minimizing flood damage by adopting a number of non-structural preventive measures that discourage occupancy of major flood-liable areas.

2. Structural measures

(a) Flood mitigation storages

These are essentially flood control reservoirs, some of which might be multi-purpose projects. Storages are constructed either to contain peak flows within the main channel reservoirs or to store excess flows in some designated parts of the floodplain, by diverting water from the river into the embanked floodplain. A comprehensive basin-wide flood protection may require more than one storage facilities.

(b) Channel modification

These are the channelization projects, involving deepening, widening and straightening channel reaches, for improving flow conveyance. The main limitation of this technique is that it is generally effective for smaller streams. Only minor improvements in the passage of flood flows are possible in the larger streams by this method.

(c) By-pass floodways

The bypass channels, also called floodways, such as the Red River floodway or the Assiniboine Diversion, provide artificial channels or outlets for diverting floodwater from an upstream area to a downstream area, thus protecting a flood-liable area immediately downstream of the structure.

(d) Levees and floodwalls

Levees and embankments are identical terms for artificial ridges along river banks, that are designed either to confine floodwater within the river channel or to regulate flood levels on the floodplain by allowing limited amounts of water through such hydraulic structures along the embankment as sluices and culverts. Floodwalls serve similar purposes, but may be of different construction designs. Some flood walls are vetical structures, which may be made of concrete walls, as the term implies; whereas others may be flexible steel structures that may be lowered during low flows but elevated during flood seasons to provide flood protection.

3. Nonstructural measures

One of the problems with structural measures is that despite an enormous sum of money spent on such measures in the past, flood losses have continued to increase. There are two major reasons for the overall ineffectiveness of structural measures. Firstly, engineering structures have design limitations. The magnitude of an exceptionally large flood may exceed the design flood of an existing structure, defeating the intended purpose of the structure. The Mississippi flood of 1993 is a good example of a catastrophic event that exceeded the design capacity of most of the structures built by the US Army Corps of Engineers. Secondly, engineering structures often lead to complacency, giving a false sense of security about the protected area that it

would never flood again. This results in further encroachment of flood liable areas. When an exceptionally large flood inundates such areas, major flood losses occur. Because of these limitations of structural measures, non-structural measures utilize approaches that do not have to rely on the efficacy of engineering facilities. Non-structural measures can be classified broadly into two categories : (a) measures intended to prevent floodplain occupancy, and (b) measures to minimize flood losses and distribute losses over time and area.

(a) Planning controls

Planning controls, such as building codes and zoning regulations, can minimize flood losses (a) by compelling prospective homeowners to comply with and meet certain construction standards or (b) by regulating development in certain areas subject to serious periodic flooding. Planning control may include *acquisition of land* within the floodplain for the purpose of controlling the development of an area. While this is an attractive proposition from the point of view of flood alleviation, it is not necessarily as straightforward as it might sound because of the enormous cost of buyout of land and the local resistance to such a scheme. Similarly, *relocation* of buildings could have a long-term economic, environmental and social advantages, but suffer the disadvantages of very high costs and local objections to disuption of communities, loss of business and interruption to normal social life.

The use of economic instruments, such as *taxation and subsidies,* may also be considered as a planning tool. For example, levying of taxes to contribute to the cost of flood protection structures, such as embankments, could be a possible deterrent for prospective developers to select flood-prone areas for their activities.

(b) Flood insurance

Flood insurance is useful in spreading flood losses over time and area, but its main purpose is to ensure that the insured bears full cost of the decision to live in a flood-prone area. The main problem with flood insurance is with the premiums which, in theory, should be proportional to the risk, but in reality tend to be unacceptably high for many subscribers. That is why flood insurance has not been popular in either the United States or in Canada.

(c) Flood information

Flood information includes flood forecasting, flood warning, flood mapping, and a variety of public educational programs on disaster preparedness. These measures are, thus, intended to prepare floodplain residents for coping with flood disasters and minimizing flood damage.

(d) Flood adaptation

The term *flood adaptation* refers to those activities taken by communities before or during flood events to mitigate flood losses based on acceptance of the fact that flooding was an

inevitable and unavoidable event. Such activities include building homes on flood-free areas within the floodplain (for example on natural levees), elevating foundations of homes above certain designated flood levels, and engineering flood-proofing of homes.

Although flood proofing homes requires certain amount of engineering construction, it is normally considered as a non-structural or semi-structural flood alleviation measure.

4. Floodplain management in the United States

(a) Phases of floodplain management policies

Floodplain management in the United States has developed in three major phases. The first phase, which lasted until 1935, was characterized by the provision of structural measures on an *ad hoc* basis in response to specific problems as they arose. The passage of the Flood Control Act of 1936 usherd in a new era of greater and more coordinated Federal involvement. However, the emphasis was still on structural measures. The second phase started in the 1960s, when it became apparent that structural measures by themselves were ineffective in limiting, let alone reducing, the annual flood loss. Despite the expenditure of some $7 billion over the previous three decades, the annual flood loss bill in 1966 was estimated to be $1 billion. Two task forces enquired into floodplain management matters and found that a mix of structural and nonstructural measures was likely to be more successful than structural measures alone. Non-structural measures that were recommended included land use

regulations and flood insurance. These findings culminated in the establishment of the National Flood Insurance Program (NFIP) in 1968. This program provides subsidized insurance for existing properties at risk and was used as an instrument to enforce the adoption by state and local governments of land use development controls and regulations for flood prone areas.

The third phase is a very recent one that started in the wake of the Mississippi flood of 1993, when it became obvious that the nation's floodplain management policies were not working. The Federal government chartered an Interagency Floodplain Management Review Committee (IFMRC) to assess the nation's floodplain management policies and suggest new directions. The Committee made many recommendations for improving both structural and non-structural adjustments to floods. Revamping the NFIP is a major objective of the revised floodplain management policies.

(b) Zoning regulations

The enforcement of floodplain management policies is based on the principle of designating different portions of the floodplain into different flood hazard zones. *regulatory floodway* refers to area that must be kept open to carry floodwater. No building or fill is allowed within this zone. *Flood fringe* is the area not within the floodway. In this area construction may be permitted if protected by fill and/or floodproofing. *Standard project flood limit* is the area within

the maximum probable flood that may result from the heaviest rainfall and maximum runoff. This area may include certain public buildings, such as schools and churches, but private homes should be excluded.

5. Floodplain management in Canada

Floodplain management policies in Canada are very similar to that of the United States. Up until the mid-1970s, structural measures were the most important method of flood damage abatement. In 1975 the National Flood Damage Reduction Program (NFDRP) was established by the Federal Government in recognition of the ineffectiveness of structural measures. This program recognized that a mix of structural and nonstructural measures was required for effective flood damage reduction. The NFDRP is based upon a series of agreements between the Federal and provincial governments that encompass, amongst other things, the delineation and mapping of flood risk areas, the encouragement of provinces and municipalities to institute appropriate floodplain development controls, and the refusal of Federal housing loans and other grants for development in flood prone areas, or making of this financial assistance conditional upon adequate flood proofing or other damage reduction methods.

Floodplain management responsibilities of the three tiers of governments in Canada are similar to that of the United States and Australia. The Federal Government defines broad policies; the provincial governments define details of their

individual floodplain management programmes; responsibilities for the implementation of these programs are shared between provincial and local governments. In short, provinces and municipalities are the principal floodplain managers.

6. Floodplain management in Ontario

Ontario pioneered the move towards nonstructural measures following the devastation caused by Hurricane Hazel in 1954. In 1987 the province developed detailed technical guidelines for floodplain management. The cornerstone of the floodplain management policies in the province is the preparation of flood inundation maps. The technical guidelines specify the procedure for the preparation of such maps. The municipalities and the Conservation Authorities use these guidelines for enforcing floodplain regulations. Normally hydrotechnical consulting engineering firms use these guidelines as tools for preparing such maps.

(a) Regulatory floods

The regulatory flood in Ontario is event-based. The 100-year flood is the minimum acceptable standard for regulatory flood in Ontario. Besides the 100-year, there are three other regulatory floods which are larger than the 100-year event. These are based on past observations of exceptionally large floods and are labelled by the names of the events, as the following illustration indicates:

Regulatory floods in Ontario

(Source : OMNR n.d, B-2)

Hazel refers to the flood of the equivalent amount resulting from Hurricane Hazel in 1954 that affected mainly Southern Ontario. Adoption of this standard means that the regulatory flood for the given site or the area must be at least the 100-year flood or the Hazel flood, whichever is larger. *Timmins* flood occurred in August 1961 at Timmins due to a cloud burst from a thunderstorm. Similarly an *observed flood,* like Timmins or Hazel, must be larger than the 100-year flood. In Figure B-1 three regulatory flood zones have been delineated.

Regulatory flood zones in Ontario

(Source : OMNR n.d., Figure B-1)

In Zone 1 (i.e. in southern Ontario) Hazel is the regulatory flood. In Zone 2 in northeastern Ontario, including Ottawa,

the 100-year is the regulatory flood. The vast area of northwestern Ontario falls under Zone 3 of Timmins storm. Observed floods can be used in any of the specific project sites as the basis of the fourth regulatory flood.

(b) Flood magnitudes

The two main steps in mapping of a floodplain are to determine the desired flood magnitude and to delineate the area inundated by that flood.

Flood frequency analysis is the main technique of determining flood magnitudes. A single site flood frequency analysis for a stream in question is considered adequate only if the record is long and reliable. If the record is not of sufficient length or there is some doubt of its reliability, a regional flood frequency analysis is carried out in which case several single site analyses are combined. Whenever possible, maximum instantaneous discharges should be used. For practical purposes however, often the maximum daily flows are used because of their longer record. The flood data are ranked according to their magnitudes; their frequencies calculated by using the probability equation R = (n=1)/m and then plotted on one of the following four types of distribution graphs:

(i) Extreme Value Gumbel 1 distribution,
(ii) Lognormal distribution,
(iii) Three-parameter lognormal distribution and
(iv) log Pearson Type 3 distribution

(c) Hydraulic analysis

The next step in floodplain mapping involves converting the streamflow to a water surface elevation at a given location, generally downstream of the reach to be mapped, and computing the water surface profile for the reach. This is generally computed by using one of the backwater analysis procedures. HEC-2 is a well-known computer program for such analysis. The program requires the following set of data:

(i) Cross-sections of the flood channel, including the floodplain,
(ii) Critical flood depth at each cross-section
(iii) Velocity of flow at each cross-section
(iv) Data on friction losses due to roughness of the channel, using Manning's "n" factor.

Following the completion of the HEC-2 analysis flood risk maps are prepared. These show isolines (like contours) indicating flood boundaries and flood depths; thus defining areas within which construction is regulated.

7. Floodplain management in Thunder Bay

Enforcement of land use regulation within the flood boundaries is strictly a function of 39 conservation Authorities through the co-operation of the municipalities within their jurisdiction. Floodplain management in Thunder Bay is an ideal example of collaboration between the LRCA and the City of Thunder Bay for enforcing land use regulations on floodplains.

(a) Flood regulated areas

Five rivers flow through the City of Thunder Bay : The Kaministiquia is the largest and passes along the southern edge of the city. The remaining four are relatively small. Of them, the Neebing and the McIntyre have extensive floodplains. Both of these rivers used to experience frequent flooding. In 1981-82 the Neebing-McIntyre Floodway was constructed to alleviate this long-standing flood problem: consequently now the flood-liable areas have been minimized significantly.

(b) Fill, construction and alteration to waterways

Besides the delineation of actual flood lines, another component of floodplain mapping is the delineation of fill-control lines that define fringe areas beyond the regulatory flood lines within which other hazards, such as erosion and slope instability may exist. Fill line mapping in the Lakehead region is authorized under the Conservation Authorities Act *R.S.O. 1980: Fill, Construction and Alteration to Waterways*.

The location of fill line is determined with the assistance of topographic maps, aerial photography and field inspection. The criteria applied to most of the Lakehead region include:

(a) a minimum setback of 15 m for the floodline
(b) minimum setbacks based on potential slope failure and
(c) minimum setbacks based on predicted rates of river erosion. The basic objective of fill line mapping is to control construction of buildings and structures and/or the dumping of fill which will, by itself or cumulatively, limit channel capacity and increase flood heights.

(c) Flood warning and forecasting systems

There are three components of flood forecasting/warning systems for the City of Thunder Bay. Firstly, the LRCA maintains a flood warning system for alerting municipal representatives, media, local police, OPP, the MNR etc. The procedure for providing a flood warning is outlined in a LRCA draft manual. Secondly, the City of Thunder Bay has a flood contingency plan that lists allocation of tasks of the Emergency Operations Control Group, Police and Fire Departments, Public Works, Thunder Bay Hydro and many other departments. Thirdly, the MNR maintains a provincial flood Forecasting Centre through which the LRCA is notified of impending storms and floods. The LRCA may rely on the forecast issued by the provincial Flood Forecasting Centre or it may issue its own flood warning system using local data.

(d) Enforcement of flood and fill line regulations

The enforcement of flood and fill line regulations involve certain legal procedure. If a building site is near a water course, a permit is required to construct a structure, place fill or alter the existing channel of the water course. Before any construction can begin, the owner must apply to the LRCA for permission. All applications are reviewed by an LRCA committee. If an application is not approved, the decision may be appealed to the MNR who may dismiss the appeal or grant the permission.

Following their approval in 1974, the regulations were published in local newspapers and in the form of pamphlets, which were distributed to local construction firms, government agencies, real estate companies and other interested groups. Copies of the flood and fill line maps (photo mosaics) have been kept on file with the Registry Office, City Hall and the Lakehead Planning Board. Between 1978 and 1986 the LRCA received 171 applications for permission to build within the flood and fill lines. The majority of the applications dealt with additions to existing residential buildings, such as garages and basements. Following a review of the applications, approval was granted in most cases if it was found that the proposed structures would have no effect on the flood level.

(e) Municipal Zoning Regulation

Municipal zoning regulations, which restrict land uses for different purposes, also play an important role in controlling floodplain uses. In July 1983 the City of Thunder Bay passed By-Law Number 1977 to enact its zoning regulations.

8. Flood Alleviation in Thunder Bay and Duluth

How have the property owners within the designated areas reacted to these designations? I will examine this through a slide presentation on comparative study of flood alleviation in Thunder Bay and Duluth. You may read my co-authored paper with Tobin (Tobin and Rasid 1990) on this comparative study. For similar assessments of floodplain management policies, you may read the three papers for seminars, i.e. Schaeffer (1990), Kreutzwiser et al. (1994), and Shrubsole et al. (1995).

Geography 4411 : Water Resources Management

Topic : Floodplain Management

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