Flood Mitigation Strategies Adopted in Sri Lanka A Review

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Abstract—Floods are repeatedly in the headlines of local, national and international media. The problem of floods and their computation is one of the main and most complex problems the hydrologists are facing now. The optimal development of water resources depends to a considerable extent on flood control, design and construction of structural measures and taking proper measures for flood mitigation including non-structural measures like flood plain zoning, flood forecasting and warning, etc. All such hydrologic analysis and design problems require accurate and reliable data for flood estimation using statistical and or deterministic methods. The estimation of design flood for safety of structures has also to take into consideration cost aspects and to avoid over design. This paper discuses issues related to the occurrence and its' management of floods based on several reviews.

Index Terms— Climatological factors, **F**lood mitigation**,** Meteorology, Water resource, Semiarid regions, Rainfall intensity, Erosion, Silting, Flood plain

1 INTRODUCTION

THE flow in a river varies from day-to-day and year to year. The volume of water carried is not the same every year due to complex meteorological factors and varying characteristics of the ground on which the rainfall occurs. The river is stated to be in flood when the flow exceeds the capacity within the banks. The magnitude of the floods depends upon the catchment characterises, the intensity of the rainfall, its duration and also the ground conditions when the heavy spell of rainfall occurs.

Arid and semiarid regions where the rainfall' is scanty and infrequent have poor drainage characteristics. Consequently, whenever there is a heavy spell of rainfall, such as a case of cloud burst, water:' accumulation and flooding occurs. Other factors which tend to increase the flooding are erosion and silting which lead to decrease in the capacity of river channels and increased meandering. Earthquakes and landslides, synchronization of the floods in the main tributary rivers and retardation of flood flow due to tidal effects and cyclones further aggravate the changes caused by floods.

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2 DEFINITION

2.1 Review Stage

Defining a flood is somewhat difficult, partly because floods are complex phenomena and partly because they are viewed differently by different people. A meaningful definition of flood should incorporate the notions of damage and inundation. Some typical definitions are as follows

- Flood is a relatively high flow which exceeds the natural channel capacity provided for the runoff
- Flood is a body of water which rises to overflow land which is not normally submerged
- Flood is any relatively high stream flow which overtops the natural or artificial banks of a stream.

The overtopping of the banks results in spreading of water over the flood plains which generally comes under conflict with man and his activities. It therefore necessary to study the characteristics of floods so that they could be controlled.

Generally the following situations could require flood mitigation measures

- Streams carrying flows in excess of the conveying-capacity within their banks, thus overflowing adjoining land
- Backing up of water in tributaries at their outfalls into the main river
- Heavy rainfall synchronising with river spills
- Ice jams or landslides blocking stream courses resulting in the backwater overflowing river banks
- Synchronisation of upland floods with high tides
- Heavy local rainfall
- Typhoons and cyclones
- Inadequate drainage to carry away surface water quickly

3 Occurrence of Flood

As defined in the above paragraph, from a number of basic causes as listed below may cause floods

- **Climatological**
  - (a)Rainfall (b) Snowmelt (c) Ice melt (d) Combined rainfall and snowmelt
- **Part climatological**
  - (a)Estuarine interactions between stream flow and tidal conditions (b) Coastal storm surges
- **Other natural factors**
  - (a)Earthquakes (b) Landslides
- **Failure of dams and other control works**

However, it is to be noted that the identical flood generating mechanisms, particularly those associated with climatological factors may result in very different floods from one catchment to another, or even within a given catchment from time to time. These differences are due to a number of flood intensifying factors which tend to speed up the movement of water within the catchment. Their effect is to reduce the time of concentration (which is defined as the time required for water falling on the most remote part of the catchment to contribute to stream flow at the outlet) either directly as a flow mechanism or indirectly as a push through mechanism of infiltrating water in the higher parts of the basin.

4 Flood Intensifying Conditions

The intensification of the flood condition depends on the characteristics of the basin/catchment, network of natural channels. These are elaborated below

- **Basin characteristics**
  - Stable - area, shape, slope and altitude
  - Variable interactions between climate, geology, soil type, vegetation cover, wild life, man's activities causing important differences in storage capacity of soil and bed rock, infiltration and transmissibilityof soil and bedrock of the basin.
- **Network characteristics**
  - Stable - pattern of network
  - Variable - surface storage, channel length or contribution or source area and under-drainage
- **Channel characteristics**
  - Stable -slope, flood control and river regulation works
  - Variable - roughness, load, shape and storage.

One of the most important of all flood producing conditions is the total area of interconnected water and water logged surface within the catchment where the effective infiltration capacity is zero and on which, therefore, all falling precipitation contributes directly to stream flow.

5 Need for Flood Control Directives/ Policy

The need for flood control and management has been given increasing importance in evolving national water policy. The following are the policy guidelines suitable for the countries like Sri Lanka

- Sound watershed management through extensive soil conservation, catchment area treatment, preservation of forests and increasing the forest area and the construction of check dams
- Adequate flood cushion to be provided in water storage projects
- Establishment of an extensive forecasting network, along with regulation of settlement and economic activity in the flood plain zones.
- Use of structural measures like embankments and dykes as well as non-structural measures like flood forecasting and warning, flood plain zoning, etc. for the minimization of losses and reduction in expenditure on flood relief.

6 Need for Hydrological Study of Floods

There are several situations in which an estimate of future flood conditions is required by many different categories such as

- Individual
- Industry
- Government agency
- Other groups

Essentially, however, this information is needed for either design or forecasting purposes. In the design situation engineers and planners involved in the design of dams, spillways, river channel improvements, storm sewers, bridges and culverts need information on flood magnitude and frequency.

In the forecasting situation, local government agencies, industrialists, farmers, etc. require more immediate information on flood magnitude and timing so that on appropriate action may be taken.

In view of these, a thorough understanding through mathematical modeling of flood formation beginning from sub-basin routing, combining sub-basin floods in the main channel, routing along channel and establishing the flood at the required point is necessary. Therefore, detailed flood hydrology studies are essential for accurate flood forecasts and design flood predictions. Flood studies dealing with flood plain zoning and economic analysis for assessing the actual flood damages are useful for the planners and government agencies involved in flood relief and flood protection activities.

Dam Break Flood

Dam failures are often caused by over-topping of the bund due to inadequate spillway capacity during large inflow to the reservoir from heavy precipitation. Dam failures may also be caused by seepage or piping through the dam or along internal conduits, slope embankment slides, earthquake damage and liquefaction of earthen dams from earthquakes and land

slide generated waves in the reservoir.

Usually the response time available for warning is much shorter than for flood runoff. The protection of the public from the consequences of dam failures has taken on increasing importance as population have concentrated in areas vulnerable to dam break disasters.

One of the preventive measures in avoiding loss of life is by issuing a flood warning to the public living downstream of the dam under thread. However, it is quite difficult to conduct analysis and determine the warning time regarding the dam break flood at the time of disaster. The method used for such analysis gains more credibility of one can simulate the past dam break failure scenario using that method with reference to the failure mode and flood wave movement downstream of the dam.

7 Flood Plain Management

The general objectives of a flood plain management strategy can be broadly stated as the enhancement of economic efficiency, social well-being and environmental quality within the area. It aims at establishment of a framework for future decision making on land use and development within the floodplain and identification of necessary river management works and programme for their execution.

During the passage of significant floods certain areas of the floodplain which carry the major portion of flood flow are termed as"loodway". While, the remaining areas of the floodplain which get inundated, but contribute very little to the passage of the flood water, are termed as "flood fringe". It is possible to allow development on the flood fringe that would be unacceptable within the flood way.

It is generally seen in our country like in many other Asian countries that the flood affected areas and flood damages are on the increase despite massive investments made on flood control measures. Further, human activities in the catchments such as urbanization, construction of dams for utilization of water resources, flood control levees, etc. have increased the nature of flood hazard. In view of this fact there have been major attempts to improve knowledge of the flood hazard and of the possible responses to it. As a result it is being realized that total elimination of flood hazard is not possible and alternative approaches to reduce the flood hazard are necessary. The viability and appropriateness of alternate measures must be worked out in relation to the nature of hazards.

Floodplain management includes all planning and actions needed to determine, implement and revise plans for the best use of flood plains and their water resources for the welfare of the country. Its goal is to strike a balance between the benifits obtainable from the use of flood plains and the potential losses to individuals and society arising from such use.

The three general strategies for reducing flood losses will noe be defined as

A. Modifying the Flood

Under this category the following measures have been adopted in countries likev Sri Lanka

- Reservoirs
- Flood embankments
- Diversions
- Channel improvements
- River training works

Modifying the flood in order to keep flood water away from development and populated areas may be achieved through flood protection and flood abatement measures. Flood protection can be achieved through construction of flood levees, flood walls, channel improvements, diversion schemes, reservoirs, etc. These measures are also known as structural measures of flood control. Abatement of floods involves modifying the characteristics of the factors affecting runoff of the catchment in such a manner that runoff is delayed. As such it involves actions to be taken on the catchment. These actions may comprise of

- Afforestation
- Modifying the land use
- Regulating flow from urban areas, etc.

These actions may be combined and called as watershed management. While this strategy may be suitable for controlling runoff responses from small catchments, its effectiveness for large catchments seems to be small because the watershed management practices are not very much reflected in much of the downstream area of large catchments [2].

B. Reducing the Susceptibility to Damage

Under this strategy, the following measures have been adopted generally in Asian countries

- Flood forecasting and warning
- Raising of Villages

Reduction in the susceptibility to damages can be achieved by keeping people and development away from flood hazard area. The important measures involved in this strategy are

- Floodplain regulations
- Development and re-development
- Flood forecasting and warning with an evacuation plan
- Flood proofing

C. Reducing the Impact of Flooding

This strategy is achieved in many countries through the following measures

- Flood fighting
- Redistribution of losses through disaster relief and tax remission

The strategy of reducing the impact of flooding is meant to reduce the distress of the individuals and communities at the time of flooding or after experiencing the flood problem, through emergency measures such as

- Evacuation,
- Flood fighting,
- Public health measures,
- Flood insurance
- Provision of relief
- Recovery

All these three strategies briefly mentioned herein are adopted in most of the Asian countries with more emphasis for the strategies of modifying the flood and reducing the impact of flooding. The strategy of reducing the susceptibility to damages is not very popular although it deserves more attention in the near future.

For developing appropriate flood management measures proper understanding of factors affecting hydrological aspects of floods with regard to intensity and duration of flood is necessary. In addition to the natural factors, increasing human activities over the catchment such as

- Deforestation
- Flood protection works
- Dams
- Urbanization

have profound influence on the hydrology of floods of the catchments.

8 Floodplain Zoning Strategy

Floodplain zoning means restricting any human activity in the flood plains of a river where the plains are created by overflow of water from the channels of rivers and streams.

Generally the term flood plain includes the water channel, flood channel and area of nearby low land susceptible to flooding by inundation. The activity of flood plain zoning has the short term objective of preventing more damage from flooding and in the long term to reduce and even eliminate such damage. The strategy for flood plain zoning should include the following aspects

- Creation of flood zoning authority and its power
- Surveys and delineation of flood plain area
- Notification of limits of flood plains
- Prohibition or restriction on the use of the flood plains
- Compensation
- Authority to remove constructions after prohibition

The application of remote sensing and hydrological analysis are involved in delineation of flood plain area and deciding about limits of flood plains. Surveys have to be carried out for determining the nature and extent of flood plains of rivers [1]. Such surveys form the basis of establishing flood plain zones. This includes delineation of the areas which are subject to flooding including classification of land with reference to relative risk of flood plain use intended to safeguard the health, safety and property of the general public.

9 Flood Forecasting

Flood forecasting is a process of estimating future stages of flows and their time sequence at selected places along a river during floods. The estimates or forecasts required generally are

- Maximum discharge and its time of occupancy (the crest of a flood hydrograph)
- The levels expected at various points of time during rising and falling stages of flood in a river above a specified water level or the warning level

Utility a forecast is very much dependent on its timeliness and accuracy. If the forecast is not available sufficiently before the event occurs, its value is nil.

The entire forecasting service has to be planned around a time factor. This time factor should be large enough so that efficient dissemination of the forecast is possible and adequate time to organize alleviation measures is available.

Real Time Flood Forecasting

Forecasting needs meteorological data from the catchment, river flow data in reaches or stretches of river at the analysis points at the earliest. A network of hydrometeorological stations to obtain such data at sufficiently fast sampling rates and on real time basis has to be organised to make it available for suitable computations. The data collection and transmission network and computational procedure have to meet the following requirements [3].

- Such a system of stations will need suitable sensing instruments that can cope with the highest and lowest observed variable or rates of variables with accuracy at sampling rates envisaged
- Data have to be transmitted to the analysis center with the least possible delay, i.e. system needs good telecommunication linkage
- Processing of such collected data to spot absurd values, errors in measurement and check continuity and consistency between meteorological and hydrological variables by using high speed computers through suitable software
- Computer (Hardware) facility to carry out speedy and accurate computations. Software options by way of mathematical packages can be used after duly adopting them to each situation
- Software packages (models) calibrated at one point of time are related to experience gained up to that time. They need improvement by way of updating as further data become available. For this work, a research and development section is needed continuously to update and

improve the procedures.

Summing up, a forecasting system should have a data network, an efficient transmission system, computational facilities and an analysis unit.

10 CONCLUSION

In most of the countries like Sri Lanka the systematic forecasting programme started in late eighties and the forecast issued by application of hydrological models such as SSARR, HEC-1F, NAM and Non-linear Cascade Model.

At present, in most of the river systems, the forecasts are formulated with the help of multiple correlation diagrams in which, the actual river stages at the base and the forecasting stations, the rainfall in the intervening catchment with appropriate antecedent precipitation index and the stages of the tributaries joining the river between base and the forecast stations are the parameters.

In the last two decades, significant progress in flood forecasting in most of the Asian countries has been made. All major inter-state/ inter Country Rivers in the countries like India, Thailand, Kampodiy, Veitnam and China have been covered by a flood forecasting programmes.

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