FLOOD HYDROLOGY

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INTRODUCTION

Floods have caused devastations and acute human suffering since time immemorial. Efforts to mitigate damages from floods originated from the basic human urge for self-preservation.

The losses from the devastations of floods are worse for a developing country like India, where out of the slender resources so badly needed for development work, large amounts have to be spent every year to provide flood relief and to repair public property.

The optimum exploitation of the land uses with proper management and control of water resources, so vitally needed to bring prosperity to the predominantely agriculture based economy of this densely populated country, cannot become technically feasible without effective flood management. Realising the importance of such an approach, Damodar Valley Project with multipurpose concept and Hirakud dam with substantial emphasis on flood control were taken up. However, not much importance was given to the flood management sector in the first Five Year Plan. The flood related activities were dealt with broadly as part of irrigation programme.

After the heavy floods in 1954, for the first time a national policy on the ''Floods in the Country'' was announced by the Govt. of India on Sept. 3, 1954, which provides the outline of the programme of flood control and protection measures. The collection of hydrological and other related data was given the highest priority. It was clearly indicated that the efforts of the various departments of the Central and State Governments should be directed to this end and that the data would be collected from Nepal, Sikkim and Bhutan also in respect of the rivers rising in those countries and running through India. Besides the States concerned, the central agencies such as Survey of India, Geological Survey of India, India Meteorological Department and Forest Department were also identified for active participation in the programme. Central Flood Control Board at the national level and State Flood Control Boards in the flood affected states were constituted with the idea of expediting the implementation of the programme and facilitating the formulation of policies. At the same time, the then Central Water and Power Commission (now Central Water Commission) was strengthened and a full fledged wing for the Flood and Drainage was established.

Thereafter, a number of studies and research activities have been taken up in the field of Flood Hydrology.

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FLOOD HYDROLOGY

Flood Hydrology encompasses all the studies related to the formation and propagation of the floods. The major applied problems refer to prediction and forecasting of flood magnitude and its time distribution to be used in planning and operation of the Water Resources Development projects including the Flood Management schemes. The following problems are very common:

a) Design flood estimation for various purposes and by different methods;

b) Studies related to flood regulation and flood moderation;

c) Flood routing problems;

d) Hydrological studies related to flood plain zoning;

e) Development of flood forecasting model; and

f) Studies related to post embankment changes in the riverflow regime.

Of course, the studies are to be carried out in such a way that the various objectives are achieved and the data from different sources are utilised for achieving the objectives set forth in systematic and scientific way.

It is well known that the studies related to water resources and floods will not be fully useful unless the objectives of such studies are well understood and properly defined. Moreover, the studies are very much inter-related. One simple example may be a case for watershed development. One of the objectives of the watershed development planning may be flood management but it is not essentially so. On the other hand any plan for watershed development needs a detailed flood study. Again, the flood studies will be required for the hydrologic design of the structures needed for watershed development and also for the overall choice of the different viable alternatives.

In other words, it can be summarised that the studies related to Flood Hydrology can not be looked at in an isolated way. It would be necessary to examine the requirements of the studies needed for various purposes and also their impact on future conditions. Some of the important related fields are:

1. watershed development;
2. remote sensing applications in hydrology;
3. socio-economic profile and its implication on flood management plans;and
4. modern techniques for data collection and processing.

Before the discussions on the progress made in India in the research & studies in the field of Flood Hydrology, it would be worthwhile to list out the various organisations/ institutes which are carrying out studies/ research in the field.

COUNTRY'S STATUS IN RESEARCH

Research activities have been accelerated in the post-independence era when the country launched a massive developlment programme. With a view to achieve optimal efficiency and economy in the planning, design, construction and operation of water resources projects, major research stations have been set up under the Irrigation department of the States, except Haryana, Himachal Pradesh, Jammu and Kashmir and some of the States/Union Territories in the north-eastern region.

Apart from the strengthening and expansion of Central Water and Power Research Station, Pune, which is functioning under the Central Government since 1937, the following Institutes were established after the independence.

i) Hirakud Research Station, Hirakud, Orissa was established in 1947 during planning of Hirakud Dam. In 1960,it got transferred alongwith the dam to the Govt. of Orissa which has since expanded its research activities to meet the needs of the state.

ii) The Land Reclamation, Irrigation and Power Research Institutes, Amritsar, Punjab came into being in 1947.

iii) The Uttar Pradesh Irrigation Research Institute, Roorkee was established in 1947. This Institute got further expanded in 1955 and it is carrying out both basic and applied research in various fields of hydrology and hydraulics.

iv) The Central Soil and Material Research Station, New Delhi was established in 1953-54. It carries out field and laboratory investigations for soil and material testing. Studies are also conducted on various related problems of water resources.

v) The Water Resources Development Training Centre, Roorkee was established in 1955 in cooperation with US Technical Cooperation Mission and UN Technical assistance.

vi) Irrigation Research Institute, Khagaul (Patna), Bihar was established in 1956. It has undertaken research works related to soil, concrete and other construction material, sedimentation survey of reservoirs and ground water problems.

vii) The Maharashtra Engineering Research Institute, Nasik was set up in 1959 with a view to achieve efficiency and economy in the large water development projects. It carries out investigations on soil mechanics, material testing, hydrodynamic problems etc.

viii) Kerala Engineering Research Institute, Peechi (Kerala) was set up in 1960. It carries out studies especially on the problems of sea erosion and has evolved cheaper design of sea walls for protecting the coast.

ix) Gujarat Engineering Research Institute, Vadodara came into existance on the bifurcation of the erstwhile Bombay state. The research set up assumed its present name in 1960.

x) In 1964, the Irrigation Research Directorate, Bhopal, Madhya Pradesh was established.

xi) The Department of Hydrology, University of Roorkee was established in 1972 as School of Hydrology and was jointly sponsored by the Govt. of India, Ministry of

Education and UNESCO. It offers the International Post Graduate Course in Hydrology and caters to the needs of developing countries in Asia and Africa.

xii) The Irrigation Research Station, Tamil Nadu was expanded and became a full fledged Institute of Hydraulics and Hydrology in 1973. Its activities include research on ground water hydrology, hydrology of river basins and flood prediction, hydrological modelling, instrumentation and watershed management schemes.

xiii) The Material Testing Centre, Krishnaraj Sagar, Karnataka was strengthened and renamed as Karnataka Engineering Research Station in 1974.

xiv) The National Institute of Hydrology, Roorkee, was set up in 1978. The Institute has eighteen scientific divisions and covers research on almost all the topics of hydrology. It has a full fledged division on Flood Studies.

xv) The Centre for Water Resources Development and Management, Calicut, Kerala has been estbalished in 1978 and is meant to serve as the technical wing of all the Departments in the State concerned with water resources.

xvi) The Water Resources Studies Programme has also been set up in 1977-78 at the Bihar College of Engineering, Patna. One of the major objectives is to carry out research on the flood problems of Bihar.

In addition, there are five Indian Institutes of Technology which were established by the Govt. of India with the specific objective of providing engineering and technological education at par with international standards of excellence. Their Civil Engineering Department are doing commendable job in the field of research, education and training in hydrology and water resources including the flood problems.

There has been considerable awareness towards the flood problems since indepence and accordingly considerable weightage has been given to this problem. This is evident from the establishment of various departments/organisations to deal with the flood problems. A number of departments have also been re-organised and properly strengthened to tackle the problem more effectively.

ORGANISATIONAL SET UP IN THE COUNTRY

The programme of flood management has to be evolved and implemented keeping in view the aim of optimum utilisation of water resources of the country. For achieving this goal, adequate organisational set ups are needed at the centre and in the states.

A continuous effort has been made from time to time for evolving the most appropriate organisational set up for the flood management programme.

The Central Flood Control Board was set up in 1954 to draw up a comprehensive plan of flood control with the following functions:

i) To lay down general principles and policies in connection with flood control measures;

ii) To consider and approve master plans for flood control submitted by the various state governments/river commissions; and

iii) To arrange for necessary assistance in connection with planning and execution of flood control works.

As a decision of the Central Flood Control Board in 1954, a flood wing was added to the then CW & PC. The flood wing also served as the secretariat of the Central Flood Control Board. In 1977, it was decided to merge the CFCB with the Conference of State Ministers of Irrigation.

Under the apex body of the then Central Flood Control Board, four River commissions namely, the Ganga, the Brahmaputra, the North West & Central India and Deccan River Commissions were set up during the fifties, mainly with the purpose of preparation of integrated plans of the river basins and ancillary matters. These commissions have became non-functioning bodies now.

The Brahmaputra Flood Control Board was set up in 1970 under the chairmanship of the then Union Minister of Irrigation and Power. The Board is a high-powered policy making body which decides priorities in the implementation of various flood control schemes etc.

Following the floods of 1971, the Ganga Flood Control Board was set up in 1972 to deal with the flood problems of the states in the Ganga basin, with the Union Minister in charge of Irrigation as Chairman. Concurrently, the Govt. of India set up the Ganga Flood Control Commission.

The importance of the flood forecasting services was duly recongised and a Central Flood Forecasting Cell under the then Central Water and Power Commission was set up for the Yamuna river in 1959. The forecasts rendered by this unit were found to be extremely useful and helpful in giving timely warning of impending flood events; the work of flood forecasting was extended as a result of the review by the Minister's Committee on Flood Relief, in 1972. During 1975-76, the organisation was further strengthened by opening a Chief Engineer's office at Patna and the activities of various field formations were reorganised. By 1977, the Central Flood Forecasting Organisation comprised of 1 Chief Engineer's office,3 Circles and 11 Divisions.

The units of the Central Water Commission dealing with Flood Forecasting and Hydrological observations activities were reorganised. At present, there are about 145 forecasting stations located in 12 States/Union Territories of the country.

Apart from the above named organisations exclusively established for flood management, the other related agencies which were established by the Govt.of India from time to time are as follows:

1.	Damodar Valley Corporation	(1948)
2.	Bhakra Beas Management Board	(1963)
3.	Brahmaputra Board	(1979)
4.	Sone River Commission	(1980)
5.	National Water Development Agency	(1982)

The sone River Commission has since completed its report.

Set ups in the States

Water being a state subject, the states have to investigate, plan, construct, maintain and operate all flood works. In line with the central organisation, Flood Control Boards were concurrently set up in some of the states, later followed by some others. The functions of the State Flood Control Boards are to assess : (a) the flood problems in the states; (b) deal with questions of policy and oversee the planning; and (c) implementation of flood schemes.

Till recently, the works related to flood problems were under the Irrigation departmens. However, in view of the recommendations of the Minister's Committee on Flood Control (1964), a number of states have re-organised the departments and have established full fledged and independent units for flood control. For example, in Bihar two different departments namely, Irrigation Department and the Water Resources and Flood Control Department are established under the Ministry of Irrigation. Similarly, there is an independent department for Flood Control in Assam and some other states.

A REVIEW OF STUDIES & RESEARCH IN FLOOD HYDROLOGY

As mentioned earlier, considerable work has been done in this field and the same is briefly reported hereunder:

Design Flood Estimation

Correct estimation of the design flood is one of the most important aspect of the water resources development planning. Earlier practice for the design flood estimation was mainly restricted to the use of empirical formulae. Of course, the lack of sufficient data was a major hurdle in adoption of the different available techniques elsewhere.

With availability of more and more data after the independnece and growing awareness for the accuracy in design flood estimation, a number of studies were made and first effort in preparation of a manual was made in the year 1961. then Central Water and Power Commission published the manual on "Estimation of Design Flood - Recommended Procedures"

The criteria for design flood of dam and other hydrualic structure as recommended by the CW& PC and reported in the above mentioned manual are summarised below.

i) In the design of spillways for major and medium projects with storage more than 6167 Ha-m, the probable maximum flood which is the maximum flood for which there is a resonable chance of occuring at the site should be used.

ii) The probability method when applied to derive design floods for long recurrence intervals several times larger than the length of the data has many limitations. In certain cases, however, like that of very large catchments where unit hydrograph method is not applicable and where sufficient long term discharge data is available, the frequency method may be the only course possible. In such cases, the design flood to be adopted for major structures should have a frequency of not less than once

in 1,000 years. Where annual flood values of adequate length are available, they are to be analysed by the Gumbel's method, and where the data is short, either partial duration method or the regional frequency analysis technique is to be adopted as a tentative approach and the result verified and checked by hydrological approaches.

iii) When data are inadequate for the frequency analysis or the estimation of probable maximum flood, the peak flood may be estimated by the following empirical formulae.

a) For Central & Northern India - Dicken's Formulae

b) For South India & Western Ghat - Ryves Formulae

c) For Maharashtra region - Inglis Formulae

iv) For permanent barrages and minor dams with less than 6167 Ha-m storage, the standard project flood or a 100-year return period flood, whichever is higher is to be adopted.

v) For pick-up weir, a flood of 50-100 years frequency should be adopted according to its importance and level conditions.

Waterways for canal aqueducts should be provided to pass a 50-100 years flood, but their foundations and free board should be designed for a flood of not less than 100 years return period.

In general, the above mentioned practice is followed for the design flood estimation for various purposes. However, a number of studies have been carried out for the estimation of design flood both by the frequency analysis method as well as by using the storm analysis.

Considerable work has been carried out at NIH and the Civil Engineering Department of the IIT on the regional flood frequency analysis. Works have also been carried out for regional analysis for the development of unit hydrograph. CWC published a number of reports for the different regions of the country and suggested empirical model for unit hydrograph. Some of the important references are cited in the Bibliography.

Flood Forecasting

As discussed earlier, there are 145 flood forecasting stations along the various rivers of the country. Data of nearly 380 hydrological and 500 hydro-meteorological stations are collected and used for the real time forecasting during the monsoon period.

There has been considerable improvement in the various phases of the flood forecasting services.

The land-line communications i.e. telephone/telegram was the earliest and very commonly used mode for data transmission in flood forecasting services till 1970. The communication system was improved with installation of VHF/HF wireless sets at the data collection sites, most of which are 100 W/15 W sets. With a view to improve the warning time and the accuracy of the forecast, it was considered necessary to adopt latest technology

for real time collection and transmission of hydrological and hydro-meteorological data. In order to achieve these objectives, a pilot project to establish fully automatic operational river and flood forecasting system in the country with the assistance of WMO/UNDP is under implementation in the Yamuna basin upto Delhi, the first phase of which is already completed. Once successfully tested and fully operational, the experience gained from this project will be applied to modernise other forecasting centres in the coiuntry. In the second phase of this project, the installed communication system is to be linked with satellite communication (INSAT-IB).

The forecast formulaltion started with the development of simple graphical correlation between the upstream & the downstream gauges. Subsequently co-axial graphs using the gauge/discharge data of forecasting & base stations and other parameters such as rainfall and gauge/discharge data of tributaries etc. were developed and were extensively used. An effort was made by CW&PRS Pune for development of an analogue model for a site on river Tapi. Serious efforts were made during 1975-76 to use the hourly rainfall data as well as the Quantitative Precipitation Forecasts (QPF) issued by IMD for the formulation of forecast. As a result, the techniques based on application of unit hydrograph theory were attempted. Around the same time, the flood routing models were also used for some specific reaches of different river systems.

Studies for development of suitable mathematical models were also taken up in 1976.

In view of the special features of the coastal rivers, studies were taken up for development of flood forecasting models for some of the coastal rivers of Orissa under the ESCAP Panel of the WMO. In 1978, a training seminar on "Intense Precipitation and Flood Forecasting" was organised by the CWC in Co-operation with World Meteorological Organisation. Subsequently, the Central Water Commission organised a few training seminars for the in-service engineers from the CWC as well as from the various State Governments.

Under the UNDP Project for the establishment of a fully automatic operational river and flood forecasting system in the country, a modified version of the SSARR model was developed for river Yamuna. The NAM model was calibrated and implemented for the flood forecasting in the Damodar river basin under another scheme called CWC-DHI (Central Water Commission, India and Danish Hydraulic Institute, Denmark) collaboration project.

During this period, a number of studies were also taken up in different research and educational institutions and different commonly used models such as TANK, NWSH, HBV etc. were applied to various river basins of India.

The work for development of a suitable flood forecasting model for river Yamuna was taken up at IIT, New Delhi as a sponsored scheme for CWC. The BHU, Varanasi in colloboration with CWC took up the work for development of a flood forecasting model under a CBIP project for river Gomti. At the same time, a study was taken up for development of a mathematical model for flood forecasting of river Punpun by CWC in consultation with Bihar College of Engineering, Patna.

Studies in respect of application of various models for river flow simulations were also taken up in different institutions from time to time. Goel (1980) applied the NWSRFS model to river Yamuna upto Lakhwar. Gosain and Chander (1984) applied the same model for river Yamuna upto Delhi. HBV model was applied to the river Baitarani upto Anandpur site by Haque (1983). Dutta & Seth (1986) applied the Tank model to the river Narmada. Unit hydrograph model was used by a number of researchers at different sites with encouraging results. Mukhopadhyaya (1984) used discrete model for the forecasting at the Dibrugarh site on river Brahmaputra. Studies were also carried out for application of various stochastic models for the flood forecasting purposes. Gosain & Chander (1984) used ARMAX model for forecasting of river Yamuna.

The very comprehensive models such as SHE model which simulates almost all the components of the hydrologic cycle has also been applied to the various sub-basin of Narmada and a few other rivers at NIH (1988, 1989). Although these models are not recommended for operational flood forecast, they are quite helpful in understanding the flow characteristics. The DAMBRK model and MIKE11 models have also been implemented at the Central Water Commission and the National Institute of Hydrology during 1988-90. These models are being used extensively for various studies etc.

The Central Water Commission published its first Manual on Flood Forecasting in the year 1980 for its field engineers associated with the flood forecasting activities. In view of the further development and use of modern techniques etc, a revised Manual on Flood Forecasting was published in the year 1989 by CWC. The National Seminar on Real Time Flood Forecasting was organised by CWC and CBIP in the year 1984. The proceeding of the seminar provides a good compilation of work done for Indian river basins.

Flood Routing

Generally, the Puls method for the flood routing through reservoirs and the Muskingum method for channel routing were used in the pre-independence period.

Considerable work has been reported in respect of use of latest technique for flood routing in India. Studies in respect of Muskingum Cunge and Kalinin-Milyukov methods of flood routing have been carried out using the data from Indian river basins. Studies have also been carried out at National Institute of Hydrology and elsewhere to evaluate the effects of changes in flood plains and channels etc. on the routing processes.

Flood Risk Mapping and Flood Plain Zoning

The importance of non-structural measures of flood management was duly recognised and the implementation of various non-structural measures such as flood forecasting and flood plain zoning etc. were encouraged. The Govt. of India drafted a Flood Plain Zoning Model Bill, 1975 and the same was forwarded to the various State Governments for necessary actions. Around the same time, actions were initiated by various departments for collection of necessary data for the preparation of the flood risk maps. Survey of India carried out necessary surveys for the flood prone areas. Aerial photographs of selected reaches of a few major river systems were exclusively taken with a view to prepare the flood risk maps. The ISRO also took up a few studies by using the Satellite Imageries

Studies have also been taken up at National Institute of Hydrology (1987, 1989) in respect of Flood Plain Mapping of selected reaches of a few river systems. National Institute of Hydrology (1989) also carried out a study on Flood Plain Zoning for the areas downstream of Machhu Dam-II. The DAMBRK model and MIKE 11 model have been implemented at Central Water Commission and National Institute of Hydrology and are also being used for flood risk mapping studies. The models are also being used by a number of other research and academic institutions in the country.

CONCLUSIONS

Considerable work has been done in the field of flood hydrology since independence, but the application of the findings of the studies & research to the various field problems is generally restricted to a few cases only. One of the major hurdle which has been reported time and again is the non availability of sufficient data of desired quality. This aspect was also considered by the Rashtriya Barh Ayog and the RBA have made specific recommendations for collection of various data by the different agencies. The recommendations in respect of establishment of Central Data Bank and the publishing of the data need to be properly implemented without any further delay. No doubt, considerable work has been carried out by the Central Water Commission towards the modernisation and strengthening of existing hydrological network, there is need for serious efforts to be made by the various state governments and other departments in this direction.

Further, more and more joint research projects are required to be taken up for specific field problems involving the research/academic institutions and the field organisations. This is very much essential to apply the modern techniques & technologies to the field problems for their best possible solutions.

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