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NON-STRUCTURAL MEASURES FOR FLOOD MITIGATION AND SUSTAINABLE DEVELOPMENT OF A COUNTRY

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ABSTRACT

Flood causes enormous loss of life, throws normal life out of gear, leaves large scale destruction of property and crops, disrupts essential services and other developmental activities, creates hue and cry, chaos and loss in confidence in the people and thus costs the country's exchequer crores of rupees every year. The sustainable development of a country is adversely affected by the fury of floods. It is not possible in a developing country to ensure foolproof structural protection to the people owing to economical constraints. In such cases, non-structural flood control measures may be explored. Some of the non-structural measures are proper flood defence education, efficient drainage system and environmental hazard reduction, river control and monitoring of hydraulic structures, floodplain management, flood proofing, watershed management and anti-erosion strategies, flood relief management, flood forecasting and warning, setting up of flood control stations, flood insurance, economical strategies, etc. Computer-mediated communication systems, geographic information systems (GIS), remote sensing, electronic decision support systems (DSS) and risk-analysis techniques have developed substantially and show great promise for supporting sustainable flood mitigation. Deserted houses, inundated fields, disrupted services, damaged properties, crops and floating carcasses of dead animals show the devastation of floods which have catastrophic impact on country's sustainable development. Sustainable development is process-oriented and does not focus on a static world order. As such, flood management involves a constant search for ways to incorporate mitigative concepts into development decisions to reduce our vulnerability to natural hazards like floods for today and tomorrow.

***Keywords** : Flood defence education, floodplain management, flood forecasting and warning, disaster preparedness, flood mapping and damage assessment*

1. INTRODUCTION

The International Commission on Irrigation and Drainage (ICID) defines flood as "Flood is a relatively high flow or stage in a river, marked by higher than usual, also inundation of low land, which may result there from. A body of water, rising, swelling and overflowing land not usually covered. " Flood, caused by high rainfall and snowmelt and river and coastal erosion, are natural phenomena and processes. Flood control is an attempt to reduce the adverse effect on the inhabitants of river basin. Major causes of floods are inadequate capacity within the bank of the rivers to contain high flows within the river, synchronization of floods in the main and tributary rivers so that high flood flows occur in all the rivers at the same time, retardation of flow due to tidal and backwater effects resulting in stagnation of water, poor natural drainage in the flood prone area, landslides leading to obstruction to flow and change in river course, cyclone and associated heavy rainstorm / cloud bursts, snowmelt and glacial outbursts. Flooding duration wise flood may be Slow onset flood with prolong duration, Rapid onset flood with short duration or flash flood which occurs when the rate of infiltration is low and heavy rains occur over a short period of time. While locational classification of flood can be categorized as coastal flood, river flood and urban flood, flood in typical area may be single or combination of above types with its distinct characteristics. Floods wreak havoc

in one part or the other of our country every year. A map showing flood prone areas in India is annexed in Fig 1. A number of village houses collapse and properties and crops worth rupees crores are swept away by floods. Table 1 depicts flood affected area and flood damages in India. The huge money and other resources, which could have been utilized for country's development, go waste on anti-flood measures, rehabilitation and other flood relief operations every year. The sustainable development of a country is adversely affected by the fury of floods. This natural phenomenon will continue to occur and can not be eliminated entirely. However, losses can be reduced substantially by structural and non-structural flood control measures. It is not possible in a developing country to ensure foolproof structural protection to the people owing to economic compulsions. In such cases, non-structural flood control measures may be explored.

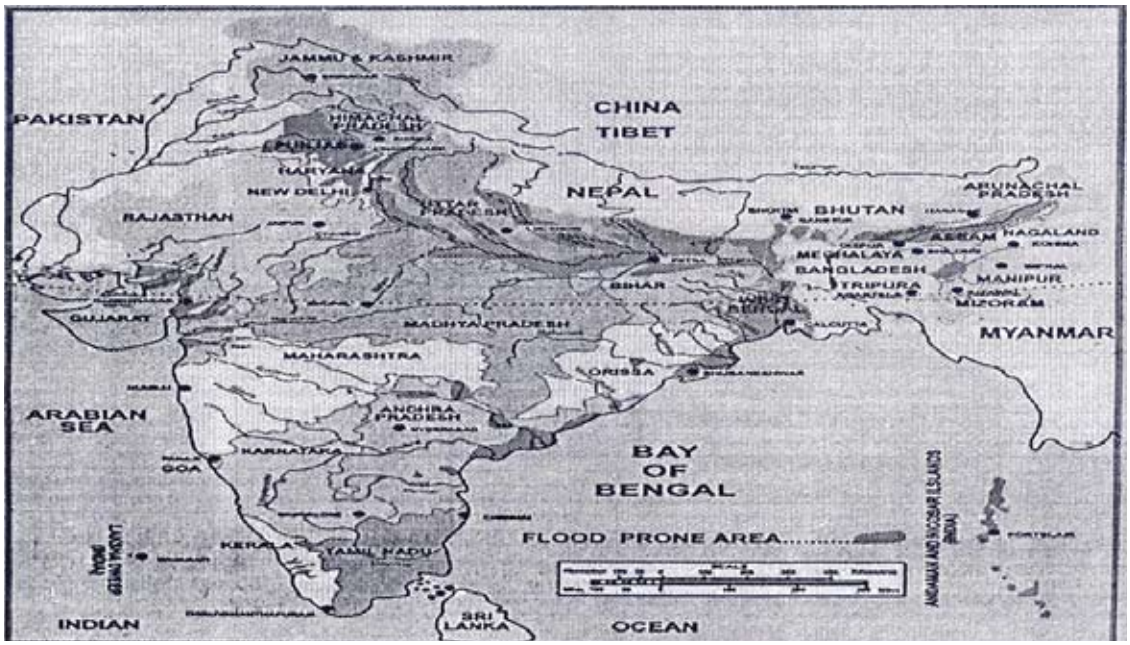

Fig. 1 : Flood Prone Areas in India (Source: Central Water Commission)

Table 1 : Flood Affected Area and Flood Damages in India (period 1953 to 2010)

Sl No.	Item	Unit	Average Annual Flood Damages	Maximum Damage	
				Extent	Year
1	Area affected	M.ha	7.57	17.50	1978
2	Population affected	Million	3.19	7.045	1978
3	Human lives lost	Nos.	1,612	11,316	1977
4	Cattle lost	Nos.	89,345	6,18,248	1979
5	Cropped area affected	M.ha	3.679	15.18	2005
6	Value of damaged crops	Rs. Crores	693.866	4,246.622	2000
7	Houses damaged	Million	1.22	3.51	1978
8	Value of damaged houses	Rs. Crores	275.481	1,307.89	1995
9	Value of damages to Public Utilities	Rs. Crores	814.596	5,604.46	2001
10	Total damages to Crops, Houses, Public Utilities, etc.	Rs. Crores	1804.419	8864.54	2000

(*Source* : Report of Working Group on Flood Management and Region specific Issues for XII Plan)

2.0 LITERATURE REVIEW

Johnson and K.William (1) discussed regarding physical and economical feasibility of non-structural flood plain management measures. Mohd. Jamil and Mubeen Beg (2) reported about flood control by non-structural strategies. A.S. Patel and A.K. Trivedi (3) discussed about the devastating flood in Vadodara City in the state of Gujarat in the year 2005 and suggested

some preventive measures against flood. Shah and Patel (4) reported about evaluation of decision support system (DSS) for sustainable planning and management of flood disaster. Md. Hossain and Bhattacharya (5) discussed about flood management in Bangladesh by non-structural methods.

3.0 NON-STRUCTURAL FLOOD CONTROL MEASURES FOR SUSTAINABLE DEVELOPMENT

Providing absolute protection to all flood prone areas against all magnitude of floods is neither practically possible nor economically viable. Such an attempt would involve stupendously high cost for construction and maintenance. Hence a pragmatic approach in flood control is to provide a reasonable degree of protection against flood damages at economic cost through non-structural measures. The total flood damages reported by the States in India from 1953 to 2011 have been projected as Rs.812500 crore approximately based on 2010 price index. On an average (1953 to 2010), the floods resulted in an annual damage of more than Rs.1800 crore besides the loss of precious human lives and cattle. Fig 2 to Fig 5 show destruction of properties due to flood and sufferings of the flood affected people. Several non-structural flood control measures are discussed below.

3.1 Flood defense education

Flood defense education of the people from school level may reduce the flood damages considerably. It has been observed that there starts hue and cry, panic and confusion on the occurrence of floods due to lack of flood defense education. The people do not know how to respond to this natural event. Flood defense strategies, which the people may use in flood crisis, should be the part of education curriculum as a compulsory subject taught particularly to the people living in more potentially flood prone areas. If the people are such trained they can seek appropriate solution to the flood problem themselves and thus major flood damage can be minimized, if not prevented, resulting in saving of country's exchequer which otherwise might be expended on flood relief and rehabilitation measures. Flood proofing measures consisted of raising a few villages in the flood prone areas above pre-determined flood levels and connecting them to nearby roads or high lands. Building houses on high and raised grounds was an age-old system in rural India. Other method of flood proofing like use of aluminum / steel bulkhead in doors and closure of low-level windows and other opening, etc are commonly used.

Fig. 2 : A large number of structures including hotels, commercial and residential buildings close to river Alaknanda caved in like a pack of cards in Rudraprayag district in Uttarakhand as observed on 17 June 2013. (Source Google Search)

Fig. 3 : Flood in Rishikesh in Uttarakhand as observed on 24 June 2013. (Source : Google Search)

Fig. 4 : A two-storied house was washed away due to floods following heavy rainfall in Junbadia village in Bankura district of West Bengal, India as observed on 6.8.2018. (Source : Anandabazar Patrika dated 7.8.2018 published from Kolkata, West Bengal, India.)

Fig. 5 : Commuters wade through flooded streets in Kozhikode district, about 385 km north of Trivandrum, in the south Indian state of Kerala, on August 17, 2018 (Source : www.insider.com)

3.2 Floodplain management

This concept recognizes the basic fact that the flood plain of a river is essentially its domain and any intrusion into or developmental activity therein must recognize the river's 'right of way'. Flood-plain zoning is a concept central to flood plain management. Flood-plain zoning measures aim at demarcating zones or areas likely to be affected by floods of different magnitudes or frequencies and probability levels, and specify the types of permissible developments in these zones, so that whenever floods actually occur, the damage can be minimized, if not avoided. Unfortunately, while all in principle generally endorse this approach, scant attention is given to it in actual practice, leading to increased flood damages. Flood plain zoning requires careful delineation of flood risk zones. This is possible if maps, with close contours 0.3 m to 0.5 m interval, are available. These maps, when used with GIS by storing non-spatial and other data, can be a very effective tool to devise right steps to reduce flood damages.

3.3 Environmental hazard reduction and drainage system

There is a negative impact of floods on the environment. The people are directly affected by environmental hazards caused by the floods. The unprecedented duration and intensity of floods contaminates local resources of drinking water. Poor quality of drinking water becomes a major cause of morbidity and mortality. The outbreak of an epidemic looms large over the dirty, flood ravaged localities. Huge quantity of mud and slush are piled up on the streets and carcasses of dead animals begin to rot and the stench in the towns reaches to nauseating levels. People dump the garbage in the drainage facilities and the drains are choked causing obstacle in smooth and quick disposal of waters from flooded localities. Choked drains cause the sewage to spill on to the streets and chronic water borne diseases like dysentery, gastroenteritis and Japanese encephalitis often outbreak. Many people die due to these diseases and the government has to bear unwanted financial loss for life and property compensation on humanitarian ground. The solution of this health hazard lies in the quick disposal of floodwaters

from inhabited areas. The drainage facilities should be cleaned before monsoon. In this scenario, everybody has its role to play. The municipal staff should swiftly clean the piled up mud and slush. The medical personnel should voluntarily be available for the service of the nation and the mankind. Adequate chlorine tablets should be made available to disinfect the water for drinking. Adequate potable water should be preserved apprehending the arrival of floods so that the people may get safe drinking water in flood situation. These precautionary measures may prevent the panic among the flood-affected people and may save so many lives.

3.4 Flood forecasting and warning

Flood forecasting and warning has been one of the very effective measures of forewarning the people living in flood prone areas. It consists of observation and collection of hydro-meteorological data at base stations and transmitting them to forecasting centers, assimilation of data from various sources, formulation of forecasts and their dissemination. These forecasts of floods in advance, allow time for precautions and altering flood-fighting organizations so that timely and appropriate actions can be taken. The effectiveness of flood warning depends upon the effectiveness of their dissemination to the public, time available and the action taken in response. Police, fire and rescue squads and media need to be notified. In many cases, removal of goods and inhabitants are possible with sufficient warning. At present, the flood forecasting and warning network have covered almost all the interstate flood prone river basins.

3.4.1 *Flood control network stations*

From upper reach of the river to the tail end of the river, the travel of flood surge waves should be monitored by setting up flood control stations at important points which are vulnerable to flood failure. The flood surge levels likely to reach at critical locations and the areal extent up to which flood waters may spread, should be transmitted to the central flood control station from where the necessary and appropriate instructions may be transmitted to the local flood control cells to implement the decisions by taking the people into confidence. Once the people know the flood stage arriving to their area and when they know the extent of area in which floodwaters may spread, they can shift themselves to safer areas. At local level, flood control cells should be established to monitor the flood relief operations and to implement the instructions transmitted to the people from the central flood control station.

3.5 Disaster preparedness and response planning

To cope with the flood fury, the learning of swimming in flood prone areas should be made mandatory and the people should learn boating. Modern communication equipment like cellular phones and internet facilities should be available for fast communication between the affected people and flood control management. Often, the electricity supply is disrupted due to floods, which makes the flood scenario more horrible due to which the psychological fear and anxiety grows among the people. In the absence of electricity in the night, the flood affected people may become soft target of the anti-social elements taking advantage of the cover of darkness. In such situations, proper prior arrangement of generator sets should be made at strategic locations. Flood relief workers should be given night vision binoculars for effective round the clock relief and rescue operations. The government and other law enforcing agencies should be competent and honest to foil evil attempts and intension of anti-social elements. This may build up confidence in the flood affected people and thus the people feel secured. Figure 6 depicts relief and rescue operations during flood.

3.6 River Control

The river sedimentation which is a major flood causing factor should be prevented to preserve the river section at its maximum discharging capacity. This objective can be achieved by covering the catchments surface under vegetal cover for most of the time which prevents the soil erosion from the catchments surface by the run off. The cropping style should be such that the catchment surface remains under vegetal cover and may not be exposed to erosion for most of the time particularly during monsoon. All weaker parts of the river banks should be strengthened before arrival of monsoon and should be monitored during the entire period of monsoon particularly when there is heavy rainfall so that the high flood waves pass downstream quickly, smoothly and safely to the sea. The interference on the river course may lead to flood problem to new areas, which did not experience this national hazard for decades. This may happen when a new hydraulic structure is constructed across a river. It changes the river morphology and causes floods in new areas. This aspect should be taken into consideration while planning is done for construction of new hydraulic structure across the river.

Fig. 6 : National Disaster Response Force conducts a rescue operation at a flooded area of Tambve village in Karad in Satara district in Maharashtra in India on 2.10.2019. (Source : www.business-standard.com)

3.6.1 *Monitoring of hydraulic structures*

Due to heavy rains over the catchments, water level rises on upstream of the hydraulic structures causing closure of the highway and railway bridges constructed across the flooding river. Hundreds of vehicles remain stranded on the roads due to which the whole business is severely disrupted and essential commodities and assistance stop reaching to the needy people. In these circumstances, release of excess water from the hydraulic structures becomes inevitable to bring down the river water level to manageable level to make the communication routes operative. However, some time the flood is caused by sudden water release from a hydraulic structure like a dam to save it against its failure due to higher magnitude of flood discharge for which the structure was not designed. If the surplus water is not released in time, the structure may burst and it may bring severe devastation. Such flash floods are more disastrous as people have no time to prepare for the protection against sudden attack. Such damaging situations can be averted by constant monitoring of all hydraulic structures while flood surge waves resulted from heavy rainfall over the catchments in upper reaches of the river, pass through them. For this purpose, the gates of the hydraulic structures should be operated such that the flood waves pass smoothly through the hydraulic structures to downstream.

3.7 Watershed management and anti-erosion strategies

The land component of watershed management should be used for flood impact reduction. The flood plain can be compartmented and the compartments may be surrounded by the embankments. Quite a proportion of flood water filled in these compartments percolates down to reach the ground aquifers and good fertile soil brought by the flood waters settles down in these compartments and thus the productivity of the land increases. Small anicuts may be constructed to prevent excessive soil erosion from watershed surfaces. Overgrazing of pastures by cattle exposes the land to erosion. Sufficient fodder for the cattle should be produced. Barren lands should be reclaimed by employing soil conservation methods so that the land may be kept under vegetal cover by growing crops on them. In urban area, the rainwater from rooftops of buildings and other clean surfaces may be discharged into the underground reservoirs. Substantial floodwater from urban watersheds is thus prevented from going to inundate the urban areas and at the same time underground water levels are recharged.

3.8 Flood mapping and damage assessment

Hazard information is one of the pre-requisite for non-structural flood management. For major flood events occurred in the country, flood inundation information may be derived from satellite data and based on that, flood hazard map for any region may be prepared. The flood inundation information is integrated with the digital database for estimation of district-wise extent of flood inundation, marooned villages, crop area submerged and the transportation network in the affected area. This information is primarily used in the relief management by the local Governments.

4.0 NATIONAL AND INTERNATIONAL COOPERATION

Flood problem is more acute in the basins of interstate and international rivers. Each of the co-basin States prepares and implements its flood management programme in isolation, complicating the problems in lower riparian States. In case of co-basin countries, this problem becomes greater. The flood management programmes, therefore, need to be more coordinated, focused, result oriented and time bound. Flood control measures, adopted by the upper riparian States, greatly affect lower ones. Similarly drainage congestion in a lower riparian State on account of infrastructure development can lead to delayed evacuation of flood waters. Regional co-operation among the co-basin States is a necessity for effective management of

floods. For an interstate river, the political and social considerations of different States often cloud these issues. The basins of some of the major rivers in India are shared by more than one country. Co-operation among the co-basin countries is of vital importance for proper flood mitigation. The basin of Ganga is shared by Nepal, India and Bangladesh, that of Bramhaputra by China, Bhutan, India and Bangladesh while the basin of Indus is shared by China, India and Pakistan.

4.1 India-Bhutan Co-operation

A scheme titled "Comprehensive Scheme for Establishment of Hydro-meteorological and Flood Forecasting Network on rivers common to India and Bhutan" is in operation. The network consists of 35 hydro-meteorological / meteorological stations located in Bhutan and being maintained by the Royal Government of Bhutan with funding from India. The data received from these stations are utilized in India by the Central Water Commission for formulating flood forecasts. A Joint Expert Team (JET) consisting of officials from the Government of India and Royal Government of Bhutan reviews the progress and other requirements of the scheme.

5.0 APPLICATION OF NEW TECHNOLOGY

Computer-mediated communication systems, geographic information systems (GIS), remote sensing, digital elevation models (DEM), electronic decision support systems (DSS) and risk-analysis techniques have developed substantially and show great promise for supporting sustainable flood mitigation. For example, GIS models enable managers to consolidate information from a range of disciplines, including the natural and social sciences and engineering and to formulate plans accordingly. Remote sensing can be used to show changes over time, feed information to GIS models and gather information in the wake of floods. Flood extent study can be very much helpful in developing flood map with advanced geospatial technique for flood risk assessment analysis. Essential dataset for measuring and analyzing extent of flood in urban area includes the Highest Flood Level (H.F.L) of various urban regions, natural topography of such regions, soil conditions, pattern of urban growth, river carrying capacity, bank full stage and tidal situations in case of coastal areas. Close contour information is important in flood control for acquisition of very high resolution data using Digital Camera (DC) and also high resolution elevation data using Airborne Laser Terrain Mapper (ALTM) from aerial platform. Web based applications have been developed in GIS environment for identification of suitable sites for flood shelters. Finally, decision support systems (DSS) can fill a gap in flood management by analyzing information from core databases. The systems can then be asked "what-if" questions about future losses to inform today's decision making. Such systems are now constrained by the lack of comprehensive local data, but they will become more important as the process of evaluating and managing risk grows in complexity.

6.0 CONCLUSIONS

The following conclusions are drawn from the present study.

(i) Flood defense education is identified as a great anti-flood and pro-sustainable development measure. The people of an area going to be flood affected should be informed well in advance about the flood arrival time, flood stage magnitudes and floodwater spread on the area so that they can themselves shift to safer places in time.

(ii) Adequate and efficient drainage facilities, watershed management and anti-erosion measures are effective methods for flood damage control.

(iii) Sudden release of excess water from a hydraulic structure to save it against flood failure which may cause severe damage due to people unpreparedness should be avoided by constant monitoring and efficiently operating the gates of hydraulic structure built across a river so as the excess water is released gradually, smoothly and safely to the downstream. Weaker portions of river banks and sharp river bends should be strengthened before monsoon and the same should be constantly monitored. Interlinking of rivers is good solution of flood control as waters from flood ravaged river basins can be diverted to scarce water river basins.

(iv) Based on flood frequency in an area, there should be strong vigil on the floodplain encroachers. Flood control stations in flood prone areas in a river basin should be established and local flood control cells should be established in towns and villages to combat with flood situation.

(v) A Decision Support System (DSS) is envisaged as a non-structural tool for analyzing alternative mitigation and recovery strategies. A way of making flood planning and management process must be transparent and efficient in reducing future economic, environmental and social impacts of floods. Digital Elevation Models (DEM) along major river systems including area falling in the flood affected zone in the range of 0.5 m to 1 m should be prepared for all river basins. The work of preparation of basin-wise flood management models including ALTM technology based

Digital Elevation Models, Inundation Forecast Models, Bathymetric Surveys and Cubature Study Models may be undertaken.

(vi) The activities of preparation of flood hazard zonation maps, close contour information, river configuration and bank erosion studies, development of geo-spatial tools, flood mapping and flood damage assessment may be expanded to include more river basins.

(vii) There should be internal and international cooperation in providing technological, financial and material assistance in the event of a natural calamity.

REFERENCES

[1] Johnson and William, K. (1978)- Physical and Economic Feasibility of Non-Structural Flood Plain Management Measures, Hydrologic Engineering Center, Corps of Engineers, U.S.A.

[2] Jamil, Md. and Beg, Mubeen. (1998)- Flood Control by Non-structural Strategies, National Conference on Geo-Environment, M.N.R Engineering College, Allahabad.

[3] Patel, A.S. and Trivedi, A.K.- (2006)- "Flood in Vadodara City", Proc of the National Conference'HYDRO-2006', pp149-157, BVDUCOE, Pune, Maharastra, 8th to 9th December 2006.

[4] Shah, S. and Patel, J.N. (2006)- An Evaluation of DSS for Sustainable Planning and Management of Flood Disaster, Proc of the National Conference 'HYDRO-2006', pp 116- 123, BVDUCOE, Pune, Maharastra, 8th to 9th December 2006.

[5] Rahman, Md. Mizanur., Hossain, Md. Amirul. and Bhattacharya, A.K. (2014)- "An Analytical Study of Flood Management in Bangladesh", Journal 'River Behaviour & Control', Vol 34, pp 35-44, 2013-2014.