

Flood Management in Pakistan's Ecology

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Abstract: Flood management and control are essential to reduce economic and human life losses and to maintain the ecological condition. The intensity of occurrence of flood disasters constitutes a persistent and serious problem all round the world. Floods are growing in intensity and frequency year by year, producing adverse effects on the socioeconomic conditions of the country in question. This is particularly true for Pakistan since its birth. Serious scarcity of water in one season and disastrous floods in the other is a common observation. Vast rural and urban areas have to undergo a great disaster year by year. It seems that while some areas become less productive due to the deficiency of water. In the absence of any control measures a large amount of water is uselessly drained out in the sea. During the years when the river does not flow above the “fair irrigation level” for a sufficient time, canals are cut off from their water supply sooner and the entire irrigation system suffers. The arena of problems like correct assessment, proper storage, reliable control and judicious distribution of existing water masses among the provinces of Pakistan can be properly handled only by proper scientific research. For the prevention of major property damages and great agricultural losses, a detailed river flow study based on long-term predictions is very essential. For the study of uncertainty involved in real-time estimation and forecasting for the Pakistan's rivers this paper stressing on the role of local climatological parameters on the IRS flow as these parameter influence the river flow extreme events (floods) and their management and control. For this purpose this paper giving a plan to design an early warning system and flood management and control plan.

Keywords: Flood Management, Flood Control, Indus River, Climate Change

1 Introduction

Floods are growing in intensity and frequency year by year, producing adverse effects on the socioeconomic conditions of the country in question [1-2]. The intensity of flood disasters makes up a persistent and serious problem round the world [3]. Climate change, global warming, rapid urbanization, and socioeconomic disparity are making the world exposed to floods, particularly under developing countries like Pakistan (Table 1). The relationship between extreme floods and global warming or climate change may still unresolved problem. However, It is the fact that the catastrophic flood events are happening with remarkable property damages in the under developed nations as Pakistan [4-7]. The flood frequency is increasing in these countries due to climate change, to tackle these catastrophes few resources are available [4].

Serious scarcity of water, followed by disastrous floods in consecutive seasons has been the common observation in Pakistan since its birth. Massive rural and urban areas are facing a great disaster year by year, while some areas become less productive due to the deficiency of water. Due to lack of any control measures a large quantity of water is uselessly drained out into the sea [8]. Studying the global water cycle for assessment of the future hydrologic cycle, is important for planning, and flood estimation. Effective planning and flood management based on the long term flood forecasting, indication the of flood prone areas, may reduce the damages and preserving the water resources [5]. Flood management and control are essential to reduce economic and human life losses and to keep the ecological conditions (Fig.1) of the region.



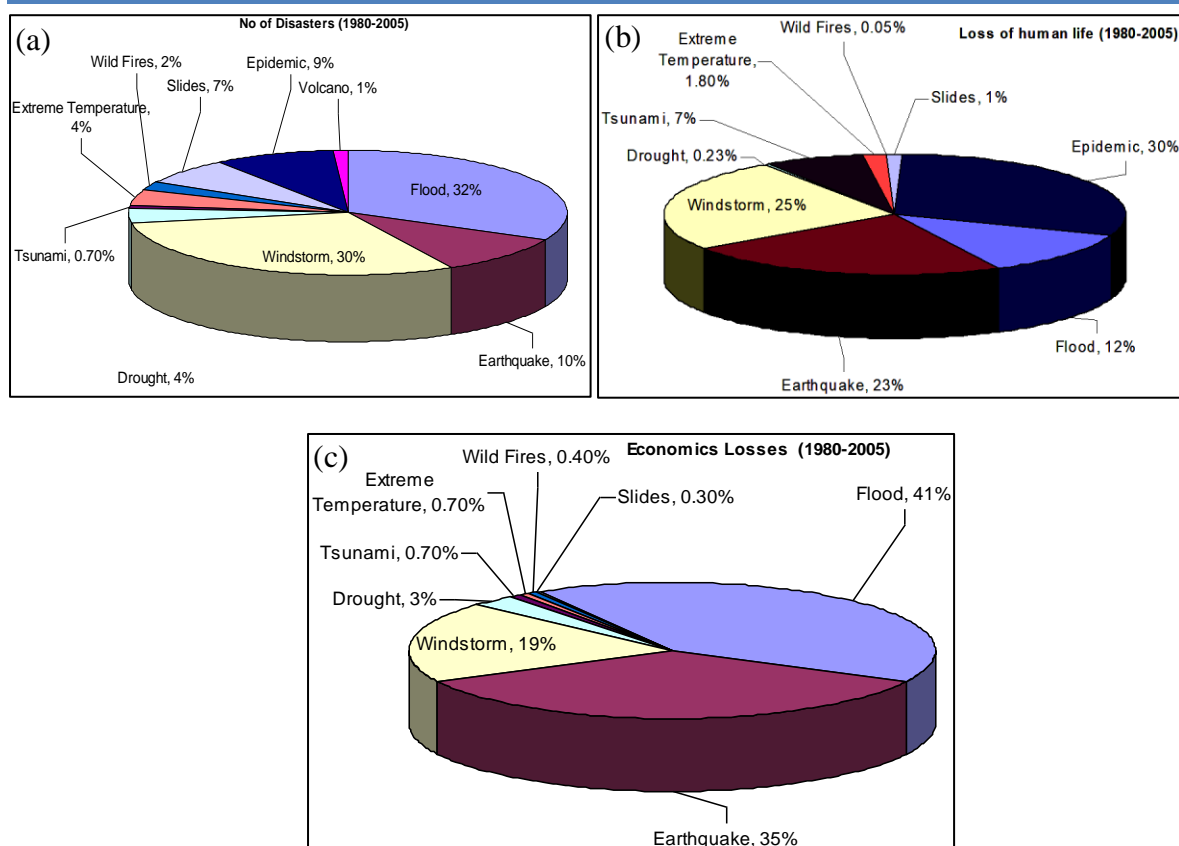


Fig. 1 World disasters (1980-2005): (a) Percentage of arrival of different world disasters, (b) Loss of human life, and (c) Economics losses. (Source: EM-DAT: The OFDA/CRED International disaster database- <http://www.emdat.be>)

Table 1 Major Flood events in Pakistan (1950-2003).

• represent Number of person affected

Year	Lives lost	Villages affected
1950	2910	10000
1955	679	6945
1956	160	11609
1973	474	9719
1975	126	8628
1976	425	9150
1978	393	9199
1988	508	1000
1992	1008	13208
1995	591	6852
1998	47	161
2001	201	0.4 million*
2003	230	1.266 million*

During the years when the river does not flow above the “fair irrigation level” for an enough time, canals are cut off from their water supply sooner and the entire irrigation system suffers. The associated main problems are correct assessment, proper storage, reliable control and judicious distribution of existing water masses among the provinces of Pakistan. This can be appropriately handled by proper scientific research based on mathematical analyses and modelling. To prevent of major property damages and great agricultural losses, a detailed river flow study based on long-term predictions is important. For the study of uncertainty involved in real-time estimation and forecasting for the Pakistan’s rivers, this paper stresses on the role of local climatological parameters on the Indus River system (IRS) flow as these influences the river flow extreme events (floods) and their management and control. This paper gives a plan to design an early warning & flood forecast system using the methods of real time river flow forecast system (existing) combine with Climatic dependant river flow forecast system (CDF) to form Hybrid river flow forecast system (HYF) based Early warning system (EWS) developed in [9]. In addition, for the flood management and control

this paper will designed a flood suppressing mechanism based on dam filling capacity.

1.1 Basis of flood

There are two flood mechanisms observed in Pakistan, the normal flood and the flash flood. Normally the flood appears every year in which majority of the rivers flow varies between high to exceptionally high limits (Table 2). In such situations sometime they overflow their banks from vulnerable areas. Sometime these potential river flows are suppressed by the dam filling capacity of the reservoir. In Pakistan the severity of the normal flooding situation is noticeable by every 7 to 8 years [10]. The flash floods appear in the monsoon seasons, because of short duration heavy rainfalls or by melting of ice bridges and/or glacier snouts due to rainfall and/or increase of local temperature or a combination of both, whatever most influential. In such conditions large destruction in the urban areas and plain regions is observed.

1.2 Normal flood

In Pakistan, the normal flooding is created because of the two reasons because the excess of monsoon rainfall in summer season (15 June-to-15 October) and secondly due to the excess precipitation through

western disturbance during winter season (15 December-to-15 March). During summer monsoon seasons depressions arriving from the Bay of Bengal traversing Indian landmass enter the Pakistan territory usually in the three directions (Fig. 2) to reach Pakistan (i) moving straight west causing heavy rainfall in Sind and southern Balochistan regions (ii) turning in to northeast direction, causing heavy rains and floods on both sides of the Indo-Pak border, especially Sutlej, Ravi, and Chenab River catchments (iii) moving north easterly direction affecting Mangla and Tarbela catchments [11]. Annually they vary in intensity and causing rainfall and flooding affecting the middle and upper-middle portions of Pakistan. They produce summer monsoon rainfalls in the large area from northeast (Jhelum, Chenab, Ravi and Sutlej areas) to northwest (the UIB areas) respectively [12-14]. The eastern part of Indus plains receive most of their rainfall from the three monsoon months, July, August, and September (as a part of annual rainfall of 100 to 750 mm). This normally happens each year, but in certain years, it causes severe flooding in the lower plain area of the Indus River and in the eastern tributaries (Jhelum, Chenab, Ravi and Sutlej) of the IRS. When it has higher intensity it penetrates the UIB region, causing flooding in the Indus River. Some serious floods occurred in 1973, 1974, 1978, 1992, and 1998.

Table 2 Flood limits of each stations of the main rivers of IRS

River	Site Barrage or Bridge	Designed Capacity	Flood limits (Above)				
			Low	Medium	High	V. High	Exceptionally high
Indus	Attock Bridge	---	7079	10619	14159	18406	22654
	Kalabagh Barrage	26901	7079	10619	14159	18406	22654
	Chashma Barrage	28317	7079	10619	14159	18406	22654
	Taunsa Barrage	28317	7079	10619	14159	18406	22654
	Guddu Barrage	33980	5663	9911	14159	19822	25485
	Sukkur Barrage	25485	5663	12743	15574	19822	25485
	Kotri Barrage	24777	7079	11327	15574	18406	22654
Jhelum	Kohala Bridge	---	2832	4248	5663	8495	11327
	Mangla Dam	25485 + 6003	2124	3115	4248	6371	8495
	Rasul Barrage	24069	2124	3115	4248	6371	8495
Chenab	Marala Barrage	31149	2832	4248	5663	11327	16990
	Khanki Headworks	24069	2832	4248	5663	11327	16990

	Qadirabad Barrage	25485	2832	4248	5663	11327	16990
	Trimmu Barrage	18406	4248	5663	8495	12743	16990
	Panjnad Barrage	19822	4248	5663	8495	12743	16990
Ravi	Jassar Bridge	7787	1416	2124	2832	4248	5663
	Shahdra Bridge	7079	1133	1841	2549	3823	5097
	Balloki Headworks	6371	1133	1841	2549	3823	5097
	Sidhani Headworks	4955	850	1274	1699	2549	3398
Sutlej	Suleimanki Headworks	9203	1416	2265	3398	4955	6371
	Islam Headworks	8495	1416	2265	3398	4955	6371
	Mallasi Headworks	11327	2124	3115	4248	6371	---

In the winter and spring (February-to-May) or pre-monsoon seasons the western disturbance arrives from the Atlantic Ocean producing precipitation in the UIB and western parts of the Indus plain regions of the Pakistan [13]. The western monsoon produces short duration rainfall of 1 to 6 day period and it is the main source of snow mass in these areas. These rainfalls do not produce disastrous flooding in these areas except annual overflows that are observed in the Chitral River up to normal flooding level. However, a severe flooding was reported in the year 2005 causing great disaster in these regions (Table 3 & 4) when the sum of 7,000,450 people was affected. Insert more data Related to "severe flooding was reported in the year 2005"

Table 3 Top 10 Natural Disasters in Pakistan for the period 1900 to 2010 sorted by numbers of total affected people. (Source: "EM-DAT: The OFDA/CRED International Disaster Database - <http://www.emdat.be>)

Disaster	Date	No Total Affected
Flood	9-Feb-05	7,000,450
Flood	8-Sep-92	6,655,450
Flood	15-Jul-92	6,184,418
Flood	2-Aug-76	5,566,000
Earthquake (seismic activity)	8-Oct-05	5,128,000
Flood	Aug-73	4,800,000
Flood	Jul-78	2,246,000
Drought	Nov-99	2,200,000
Storm	26-Jun-07	1,650,000
Flood	19-Aug-96	1,300,000

Table 4 Summarized table of flood disasters in Pakistan from 1900 to 2010 (Source: "EM-DAT: The OFDA/CRED International Disaster Database - <http://www.emdat.be>)

Flood / Cause	# of Events	Killed	Total Affected	Damage (000 US\$)
Unspecified	26	7284	20671883	1170030
Average per event		280.2	795072.4	45001.2
Flash flood	11	949	1734229	573118
Average per event		86.3	157657.2	52101.6
General flood	30	4520	19883171	1225030
Average per event		150.7	662772.4	40834.3
Total	67	12753	42289283	2968178
Average per event		190.3	631183.3	44301.2
Average per year during 1900 to 2010 (111 years)	0.604	115	380985	26740

1.3 Flash flooding

During the regular spells of monsoon rains a flash flooding builds up due to short duration heavy rainfall. It causes great disaster in the urban areas and in the plain regions, particularly the area closest to the mountains which all dangerously affected by hill torrents. This is unpredictable, causing great damage to the human life, animals, agriculture, and buildings. Another type of flash flood produced because of catastrophic/avalanche abrupt melting of ice bridges and/or glacier snouts. This can cause unpredictable rise in the river flows in a fraction of hours. Such increase in the river flow data series frequently occurs in the UIB region.

For example, in 1941 collapsing of Ice Bridge in Shoyk River caused an increase in the water level of the Indus River 100 feet higher than that of the usual level [15-16]. In 1926, 1929, and 1932 collapsing of snout (about 400 ft long) of Chong Kundun glaciers across the valley of Shyok River caused an increase of water level up to 28 feet in forty (40) minutes across the valley [17-18]. In 1841 collapsing of Ice Bridge in Shoyk river (Skardu) produced abrupt 30 feet high wave [15-16], later produced an increase in the water level of 100 feet higher than that of the usual in the Indus River. Another flood in 1958 was caused by temporary impounding of water. On release it produced a rise in the Indus river water more than 70 feet at Attock. The severity can be

understood by the fact that it caused the Kabul tributary to reverse itself westward at the rate of 10 knots (10 nautical miles per hour; 1 nautical mile equals to 6,080 feet).

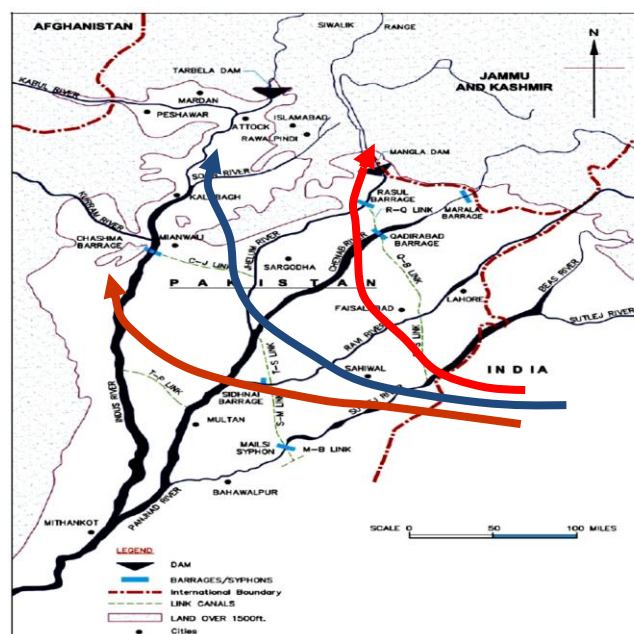


Fig. 2 Historical Monsoon Tracks Direction (1905-2013) from Bay of Bengal to Indus River & its tributaries and affected areas (a) Straight West: Sind

and Southern Balochistan, (b) Turning in to North-East: Indo-Pak border especially Sutlej, Ravi, and Chenab Rivers catchments, and (c) Moving North-Easterly: Mangla and Tarbela catchments

2 Methodology

2.1 Management of floods

In the context of the flood management plan, several studies [19-24] presented related to Pakistan and other regions of the world. These could not deliver any solution about management and control based on climate dependent long-term flood forecast. Usually the goal of the flood control is to suppress the dangerous rise in the river flow level by upholding the dam filling capacity before the flood. These measures are based on time to time issuance of the early warnings and flood forecast. With the help of these warning and forecast levels, it should take the preliminary flood risk assessment, flood risk maps, flood risk management plans, time schedule and flood directives. These measures can help to save the dam, embankments, bridges, roads, etc.

This paper introduces a flood management plan (Fig. 4) based on early warning and flood forecasting system (Fig. 3). It explores the causes and information about forming regional flooding earlier. The method comprises linear and nonlinear techniques based long and short-term river flow forecast [18] and its climatic propagation at each station of the network [9]. The results will use for early warning to the vulnerable areas and to the flood management plan (Fig. 3). This will help with earlier evacuation of the people from these areas and to the flood management plan. The majority of the time this plan will to suppress the flood peak by dam filling capacity, kept by the early warning and long term flood forecast system. The volume of the dam is maintained by supplies more water to the downstream and by relieving larger volume of water to the adjacent rain-fed irrigation dam (Fig. 4; proposed in this study).

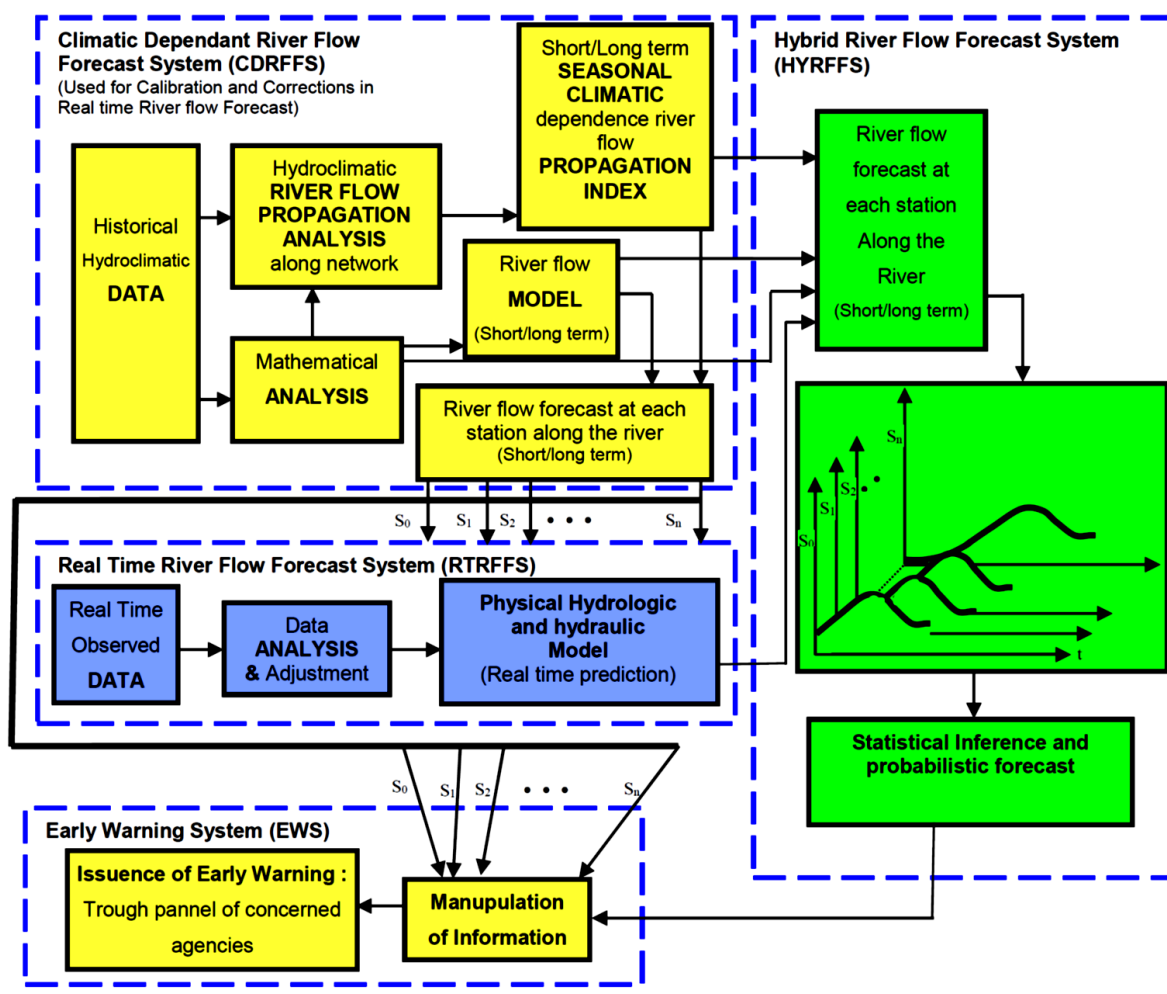


Fig. 3 Plan for the early warning and flood forecast system

2.2 Early warning & flood forecast system

The above stated flood control techniques receive benefit of flood arrival using the proposed flood management plan. Early information about the flood and the dam filling techniques will give enough amount of water in the region during drought period. It also recharges the rain-fed dam and their irrigation areas regularly. The proposed early warning and flood forecast system depicted in Fig. 3. It comprises four major blocks (i) Climate Dependent River Flow Forecast System (CDF), (ii) Real Time River Flow Forecast System (RTF), (iii) Hybrid River Flow Forecast System (HRF), and in the last advice issuing through (iv) Early Warning System (EWS).

2.2.1 Climatic dependent river flow forecast system (CDF)

This module uses the historical hydroclimatic data. It first analyses the river flow data and through

identification of the model it gives the river flow forecast at the rim stations. For the river flow modelling, the methods discussed in Hassan & Ansari (2010) are used because they show the significant forecast accuracy with long and short term forecast. Second, it analyses the climatic dependence of the river flow data at each station of the river and estimates the river flow propagation index about each unit change in the temperature and each event arrival of the rainfall in the proper catchment. To set up the river flow modelling techniques as discussed in [9]. Combining these two techniques will produce the long-term (monthly) and short-term (10daily and daily) forecast at each station along the river. Utilizing early forecast is twofold, one is producing early warnings and the other calibrates the RTF block.

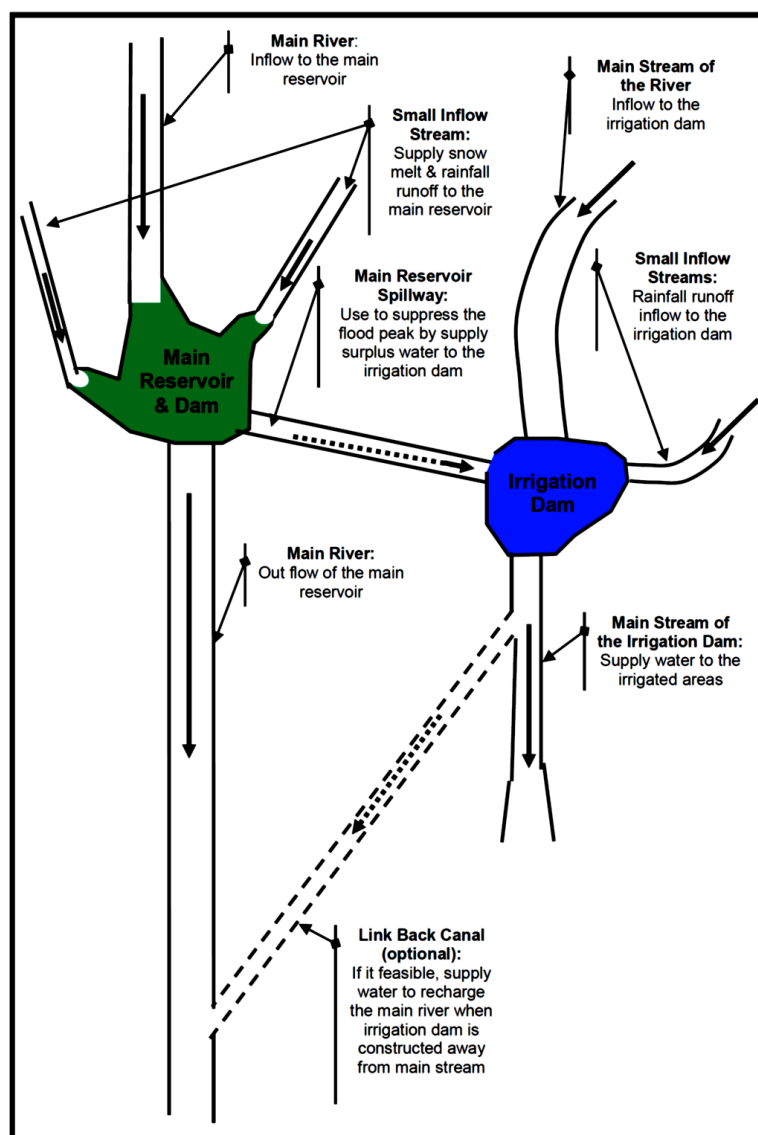


Fig. 4 The proposed flood management plan

2.2.2 Real time river flow forecast system (RTF)

This block works in the same way as the existing real time river flow forecast system is used in Pakistan. Now they equipped with CDF based calibration (correction factors) of each station.

2.2.3 Hybrid river flow forecast system (HYF)

A hybrid of CDF and RTF modules produced real-time short-term forecast at each station along the river with more precision.

2.2.4 Early warning system (EWS)

This unit will issue early and real time warnings to stakeholders, including each river flow station. This will consist of the joint or individual directives to the agencies related to the river flow forecast system and their impact like water and power development authority (WAPDA), Pakistan Meteorological Department (PMD), National flood forecasting bureau (NFFB), Federal Flood Commission (FFD), Indus River System Authority (IRSA), National Disaster Management Commission (NDMC), etc. Moreover, some work also related to the EWS like, Hazard detection, flood hazard Risk Assessment, vulnerability analysis to more sensitive areas. EWS need some deep insight as formulation and dissemination of warning messages and the community response.

2.3 Working of flood management plan

The flood management plan (Fig. 4) is based on the early warning systems as discussed above. This plan is working as suppressing the flood peak in the mainstream by keeping the inventory of the water volume in the main reservoir up to the dam filling level. There are two methods of keeping the main reservoir level, first is by releasing more water to the downstream before the flood peak and the second is by releasing the excess water to the adjacent rain-fed irrigation dam through the spillway. The theme of the second method is to support the suffering big eastern agricultural land of the Pakistan due to the maximal utilization of their river (Chenab, Ravi, and Sutlej) water from India. These irrigation dams may be one of the proposed on the eastern tributaries (Chenab, Ravi, and Sutlej) of the Indus River. In normal situations the regular flow from these dams will support to fulfil the need of irrigation water of the region. This will also accomplish the requirement of freshwater for delta and coastal areas especially during drought periods.

When the irrigation dam is constructed away from the main river like an only rain-fed irrigation reservoir, it will be feasible to provide a link back canal from this reservoir to the main river stream. The water released from this link back canal (Fig. 4)

can recharge the main river when water scarcity conditions. This recharging method will keep the water tables of the region and manage the sustainable quantity of the fresh water requirement in the delta and coastal region. It will preserve the delta ecosystem in particular the mangrove forests in the coastal regions. In turn, they prevent flooding in the coastal region by the sea level rise and appearance of the tsunami.

3. Results and Discussions

3.1 Estimations of flood damages

Man has to plan for a large number of precautions and protective measures to rivers structures, people, and the ecological balance. However, the intensity and effect of natural disasters can reduce not vanished. In Pakistan, a disastrous flood appears after every 7 to 8 years and put great damages to the population and the ecological conditions especially in the riverine areas along the stream. To improve the future rehabilitation efforts and flood management plan the assessments of damages of property, agriculture, hydrological structures is necessary after each flood. These estimations will helpful for reconstruction work. The assessments can accomplish by local provincial and district government, army and media. It must include reason of the failures of early flood management efforts. These measures will support to improve the warning systems and levels and rescue operations in the future.

3.2 Rehabilitations and restoration work

The rehabilitation, restoration, and reconstruction should start it in flood and completed at earliest. Rebuilding roads and hydrological structures can complete through governmental reconstruction work. However, the agricultural losses affect locally, therefore, governmental and nongovernmental agencies should go together to rehabilitate the individuals by providing relief in the taxes, providing seed and fertilizers on subsidizing rates. Then the farmer can easily self-survive in a short period.

4. Conclusion

This paper proposed a flood management plan based on the information manipulated from the early warning & the flood forecast system. Consequently, active contribution towards the management of floods can be made to set the imbalance ecological conditions of Pakistan. The one main target is to use the potential floodwater in drought and during below fair irrigation levels river flows days. To further strengthen this proposed flood management system and to adapt the robustness in the flow it is suggested the study of large-scale circulation patterns and solar activities is essential.

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