THE SOUTH ASIATIC MONSOON AND FLOOD HAZARDS IN THE INDUS RIVER BASIN, PAKISTAN

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Abstract

Flood is the most common of all environmental hazards. Each year floods claim over 20,000 lives adversely affect around 75 million people . The reason lies because of the widespread geographical distribution of rivers basins from mountainous terrain to flood plains, the low lying coasts and deltas. Pakistan is also a country which faces flood hazard periodically. The Indus river basin is the main flood prone area which occupies two-third area of Pakistan. The recent flood which occurred between 29th July and 26th August 2010 was the worst flood in the history of Pakistan. It affected four provinces, the Khyber Pakhtoon Khwa (NWFP), Punjab, Balochistan and Sindh. Out of 143 districts, 67 districts of Pakistan were severely affected. It is estimated that about 20 million people were directly affected, killed 3000, destroyed 1 million houses, displaced 10 millions, and millions were affected by water-borne diseases, lack of food, drinking water and shelter. It is estimated that about 130 million hectare of croplands had been inundated. The present study is an attempt to present a historical analysis of the relationship of south Asiatic monsoon and occurrence of severe floods in the Indus River basin. The study examines the nature of south Asiatic monsoon which caused catastrophic flood of 2010 in the Indus River basin. and also probe out anthropogenic causes of flood hazard and problems of flood water and flood plain management.

Keywords: Flood, Indus River, cropland.

INTRODUCTION

Floods are natural disasters which effect human life, property and infrastructure. Floods are generally linked with abnormal occurrence of rainfall or melting of snow. However abnormal discharge of water from water reservoirs due to any natural and anthropogenic factors may cause flooding. Flood occurs when surface runoff exceeds the capacity of natural drainage. The geographical area where floods occur are identified by different names like water shed, catchments area, drainage basin etc. Flooding is the most common of all environmental hazards. Each year floods claim over 20,000 lives adversely affect around 75 million people all over the world (Smith, 2000). The reason lies because of the widespread geographical distribution of rivers basins from mountainous terrain to flood plains, the low lying coasts and deltas. The worst river floods occur in parts of Asia where monsoon climate ensures 70 to 90 percent of annual rainfall. Bangladesh is by far the most flood-prone country in the world. The flood of 1970 in Bangladesh caused deaths of 55,000 people. China also badly suffers with flood hazard. In 1998 floods in China caused deaths of 3000 people (Smith,2000).

Floods in the Indus River Basin

Pakistan is also a country which faces flood hazard periodically. The Indus river basin is the main flood prone area which occupies two-third area of Pakistan (Fig 1). The Indus River originates in the northern slope of the Himalayas, and passes through the snow-capped Himalayan region of Indian Kashmir. It travels toward the north-eastern snow covered mountainous region of Pakistan where Shyok River and Gilgit River add snow-melted water. Traveling towards south, the Kabul River and the Swat River, the main western rivers of Khyber PakhtoonKhwa (N.W.F.P.) join River Indus. Entering into the Indus Plain, it widens to a kilometer. The volume of water flow in the Indus River is intensified by its major eastern tributaries the Jhelum River, the Chenab River, the Ravi River and the Sutlej River which originate from the Himalayan region of Indian Kashmir. They join each other at Punjnad and join the River Indus at Mithan Kot (Southern Punjab) from where it enters into the plains of Sindh and finally drains into the Arabian Sea at Keti Bunder (Thatta) .

The Indus River Basin is the most vulnerable region of flood hazard in Pakistan(Ahmed, 1956). The mountainous region of north and west are often affected by flash floods while the broad flood plains of Indus plains and low lying deltaic region are affected by rivers flood. The scale of loss as a result of river flood in the Indus River Basin is unbearable for the country like Pakistan where about 60 percent of the population live below the poverty line. The Indus River Basin constitutes about 75 percent of the total area of Pakistan, while about 95 percent population of the country live in this region. It is the most thickly populated region of the country. Major urban and industrial centres are located in this region. The Indus River basin is the

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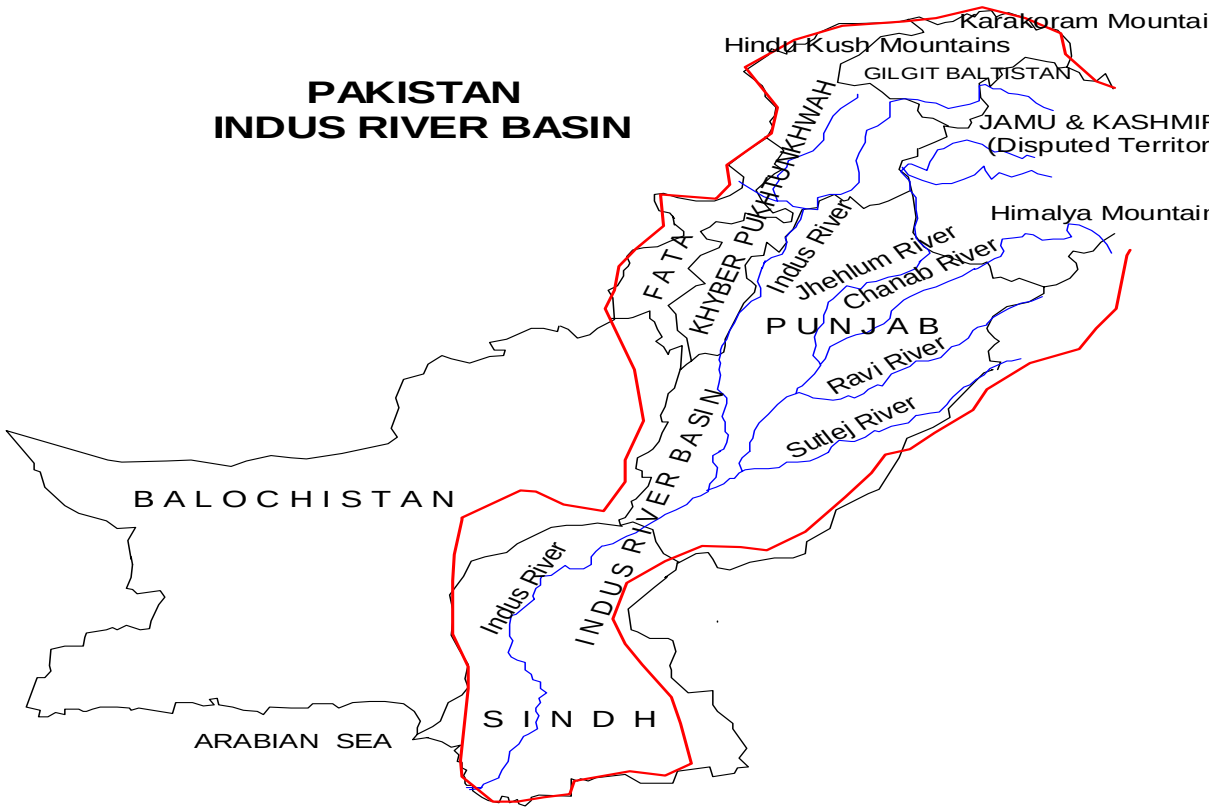


Fig. 1. Indus River Basin

backbone of agriculture in Pakistan. About 90 percent of crops lands are located here. The Indus plain is the food basket of the country. About 96 percent of Wheat,100 percent of rice, cotton, maize, pulses grow in this region.

River floods in the summer season are common phenomena in the Indus River Basin. There are two hydro-climatic factors which cause occurrences of floods in the Indus River Basin. The first factor is the melting of snow which accumulates in the mountainous north of Pakistan during winter. This snow cover starts melting in March-April, and reaches its maximum in July. Since 1868 the annual maximum snowmelt flows in the Indus River ranges between 150,000 cusec (cubic feet per second) and 500,000 cusec. The second most important factor is the occurrence of south-west monsoon rain during the summer season, which falls over the whole Indus River Basin. The two factors coincides each other. Therefore, the Indus and its tributaries swell, and almost every year they overflow their banks. The most severe rain floods in the Indus occurred between 26 and 30 August, 1929 – with an estimated peak flow of 11,00,000 cusec. The second severe rain flood occurred between July 31st and August 3, 1976, when peak flow reached up to 10,00,000 cusec.

The Meteorological Department of Pakistan classifies floods intensity on the basis of water discharge in rivers. Discharge of water below 200,000 cusecs is categorized as low level flood, between 200,000 and 400,000 cusec is categorized as medium level flood, and between 4,00,000 and 6,00,000 cusec is considered as high level flood. Discharges of water over 6,00,000 cusec is categorized as exceptional flood. The maximum discharge in the Indus River had been ever recorded during 100 years of flood history is about 11,00,000 cusec.

Historical Analysis of Severe Floods in the Indus River Basin

Flood in the Indus River Basin is not severe every year (Khan, 2009). This is because of the climatic characteristics of the region. About 90 percent of the region lies in the arid and semi-arid climatic region. About 60% of the Indus River Basin receives less than 250 mm annual rainfall. Out of the total annual rainfall in the Indus River Basin, about 70 percent rainfall occurs through South Asiatic summer monsoon which is usually not strong every year because the monsoon winds usually enters Pakistan in July, after crossing India(Mubashir, 1960). The remaining 30 percent rainfall takes place through western wind system in winter and thunder storm

Table 1. Severe Floods in t he Indus River Basin since 1947.

River	Site	1			2			3		
		Cusecs	Date	Flood level	Cusecs	Date	Flood level	Cusecs	Date	Flood level
Indus	Tarbela	510000	31.7.89	High	500000	10.9.92	High	480000	26.7.95	Medium
	Attock	670000	1958	VH	653000	1966	VH	623000	1964	
	Kalabagh	862000	2.8.76	EH	849245	10.9.92	EH	776000	7.58	
	Chashma	786600	8.76	VH	689100	29.8.83	VH	668336	11.9.92	
	Taunsa	789000	1958	VH	675233	7.8.76	VH	655079	14.9.92	
	Guddu	1199672	15.8.76	EH	1172292	13.8.86	EH	1162653	31.7.88	
	Sukkur	1166574	15.8.86	EH	1161000	1976	EH	1118856	31.7.88	
	Kotri	980329	14.8.56	EH	826369	25.8.94	EH	799447	18.8.95	
Jhelum	Mangla	1090000	10.9.92	EH	1045000	4.7.59	EH	730000	6.8.58	
	Rasul	952170	10.9.92	EH	876000	5.7.59	EH	860000	11.7.60	
Chenab	Marala	1100000	26.8.57	EH	870795	5.7.59	EH	845090	10.9.92	
	Khanki	1086410	27.8.59	EH	1021018	5.7.59	EH	1000496	10.8.73	
	Qadirabad	948530	11.9.92	EH	878719	26.9.88	EH	873442	28.8.97	
	Trimmu	943225	8.7.59	EH	888117	14.9.92	EH	706433	6.8.76	
	Panjand	802516	17.8.73	EH	744152	18.9.92	EH	676722	27.9.50	
Ravi	Jassar	680000	4.10.55	EH	Overflow	25.9.88	EH	328000	27.8.57	
	Shahdara	576000	27.9.88	EH	542000	6.10.55	EH	225000	28.9.47	
	Balloki	389845	28.9.88	EH	275000	22.9.50	EH	275000	8.10.55	
	Sidhnai	330210	2.10.88	EH	244348	15.8.76	EH	212340	12.9.95	
Sutlej	Sulemanki	598872	8.10.55	EH	399453	30.9.88	EH	360412	30.9.47	
	Islam	492581	11.10.55	EH	308425	4.10.88	EH	285254	4.10.47	

Source: Pakistan Meteorological Department

wind and tropical cyclonic wind in April to June and October. Therefore, due to variable summer monsoon, the risk of severe flood (exceptional flood) is usually once in 7 to 8 years (Khan, 2009). During the last 4 decades severe flood occurred in 1973, 1976, 1978 and 1992 (Table 1). The flood of 1976 inundated 3.6 million hectares cropland, killed 1600 people and demolished 3 million houses. Before the July-August 2010 super exceptional flood, Pakistan had experienced two historic super floods. The first one occurred in 1929 and the second one in 1976. The super flood of August 1929 occurred as a result of three main factors: (a) snow-melting which caused flow up-to 5,00,000 cusec, (b) failure of Shyok glacier dam caused flow of 4,00,000 cusec and (c) the occurrence of strong monsoon over the catchment area caused huge surface runoff with peak-flow of 11,00,000 cusec.

Rainfall and River inflow Relationship

Rainfall is the main cause of flash as well as river floods (White, 1945). To examine the relationship of rainfall occurrence and severe floods in the Indus River Rainfall data and river inflow during severe floods since creation of Pakistan were collected (Table 2). These data were graphically and statistically analysed. The graph clearly shows that when amount of rainfall in the catchment areas of the Indus River increases the amount of inflow in the Indus River also increases.

In the summer monsoon season the highest maximum river inflow was in 2010 and this was the period when highest rainfall in the catchment area was recorded (Fig. 2).

Table 2. Indus River Maximum inflow and Mean Rainfall during summer monsoon season.

Year	Mean Rainfall(July to September) in the catchment areas of Indus River(mm)	Indus River Maximum Inflow During July to September at Guddu Barrage (Cusecs)
1950	289	620000
1955	310	680000
1957	559	1125321
1958	376	820000
1959	495	1086410
1966	320	753000
1973	324	802516
1976	579	1199672
1978	328	850000
1983	350	789100
1986	568	1172292
1989	298	650000
1992	465	1048321
1994	410	926369
2010	593	1228623

Source: Pakistan Meteorological Department

The scatter graph clearly indicates a strong positive relationship between rainfall and the river inflow (Fig. 3). The computed results of product moment correlation and regression analysis confirm strong positive relationship. The regression equation and regression graph also reveal a strong positive linear relationship between amount of rainfall and water discharge in the Indus River (Fig. 4).

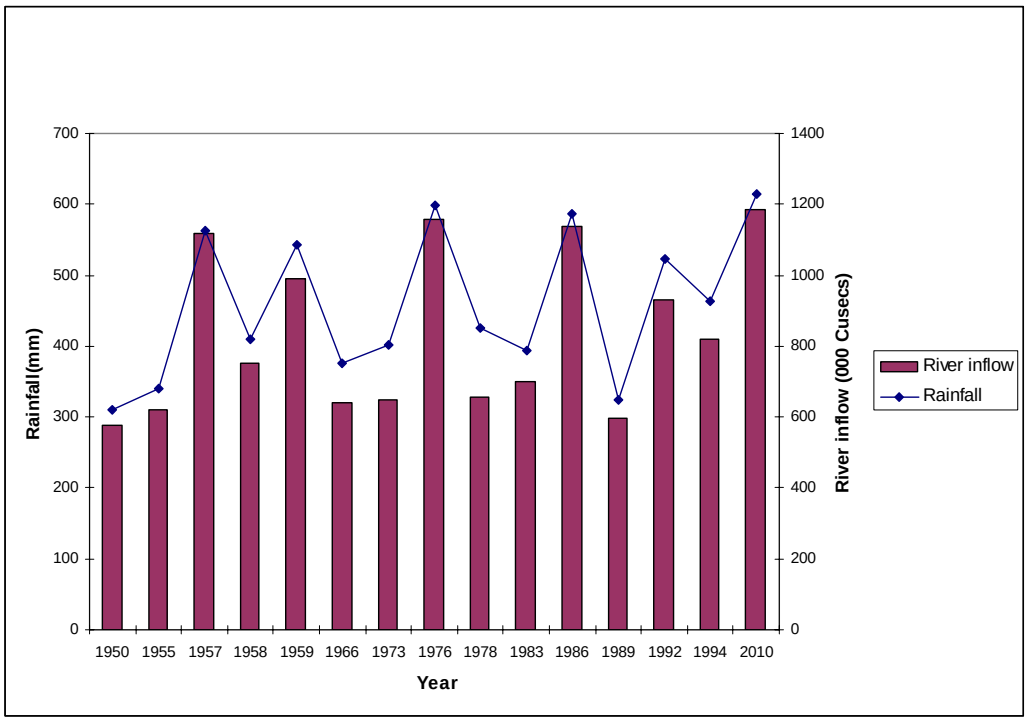
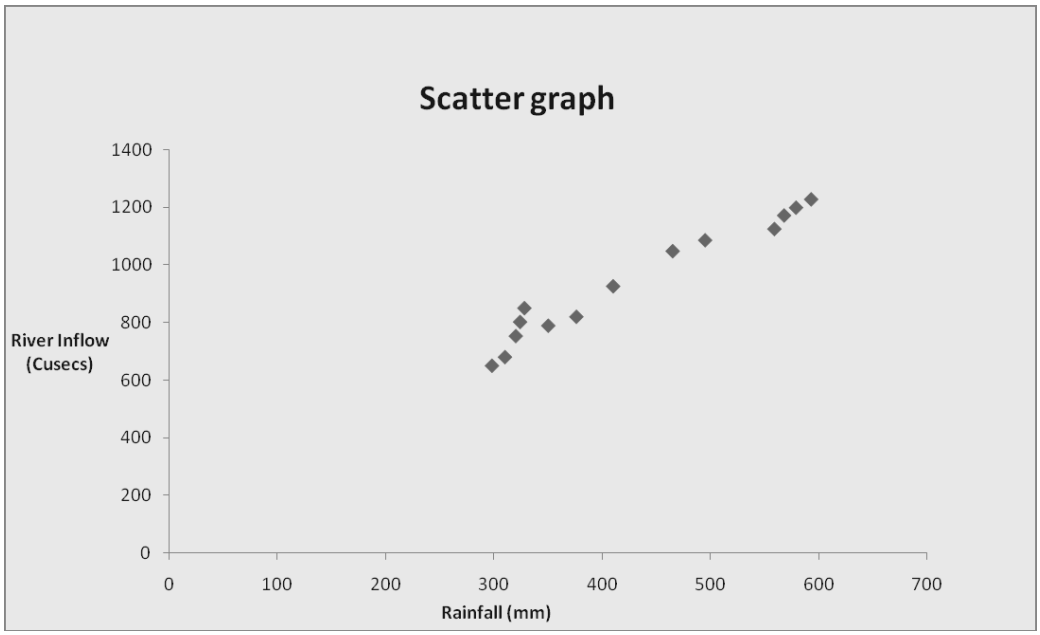


Fig. 2. Mean rainfall in the catchment area in summer mansoon and maximum inflow in the Indus River.



Product Moment Correlation r = 0.97

Fig 3. Scatter graph showing relationship between rainfall and river inflow.

Flood Frequency

Hydrologist study flood frequency on the basis of recurrence interval, or return period (APWA, 1981). To calculate the recurrence interval of flooding for a river, the annual peak discharges are collected and ranked according to size. The largest annual peak discharge is assigned a rank(m) of one, the second a two and so on. The recurrence interval **R** of each annual peak discharge is then calculated by adding one to the number of years of record(n) and dividing by its rank (m).

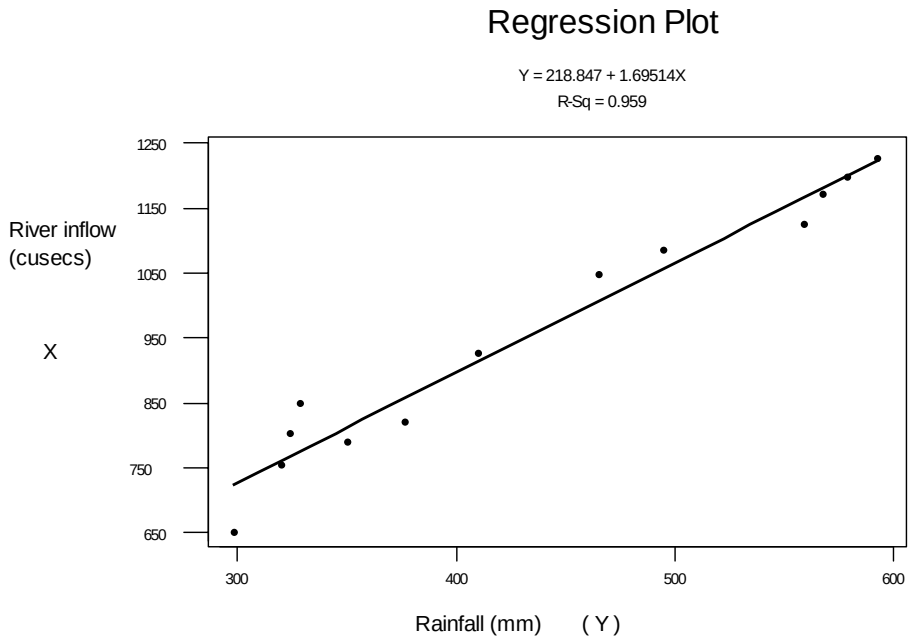


Fig. 4. Regression line explaining relationship between river inflow and rainfall'

The regression equation is y = 219 + 1.70 x

Predictor	Coef	StDev	T	P
Constant	218.85	47.63	4.59	0.000
X	1.6951	0.1061	15.97	0.000

S = 41.15 R-Sq = 95.9% R-Sq(adj) = 95.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	432039	432039	255.14	0.000
Error	11	18627	1693		
Total	12	450665			

Table 3. Recurrence intervals in rank order of the Indus River

Year	Annual Peak Indus River inflow at Guddu Barrage (Cusecs)	Magnitude Rank (m)	Recurrence Interval (years)	Chance of occurrence each year (percent)
2010	1228623	1	63.0	1.0
1976	1199672	2	31.5	3.2
1986	1172292	3	21.0	4.7
1957	1125321	4	15.7	6.3
1959	1086410	5	12.6	7.9
1992	1048321	6	10.5	9.5
1994	926369	7	9.0	11.1
1983	850000	8	7.8	12.8
1978	850000	9	7.0	14.2
1958	820000	10	6.3	15.8
1973	789100	11	5.7	17.5
1966	753000	12	5.2	19.2
1955	680000	13	4.8	20.8
1989	650000	14	4.5	22.2
1950	620000	15	4.2	23.8

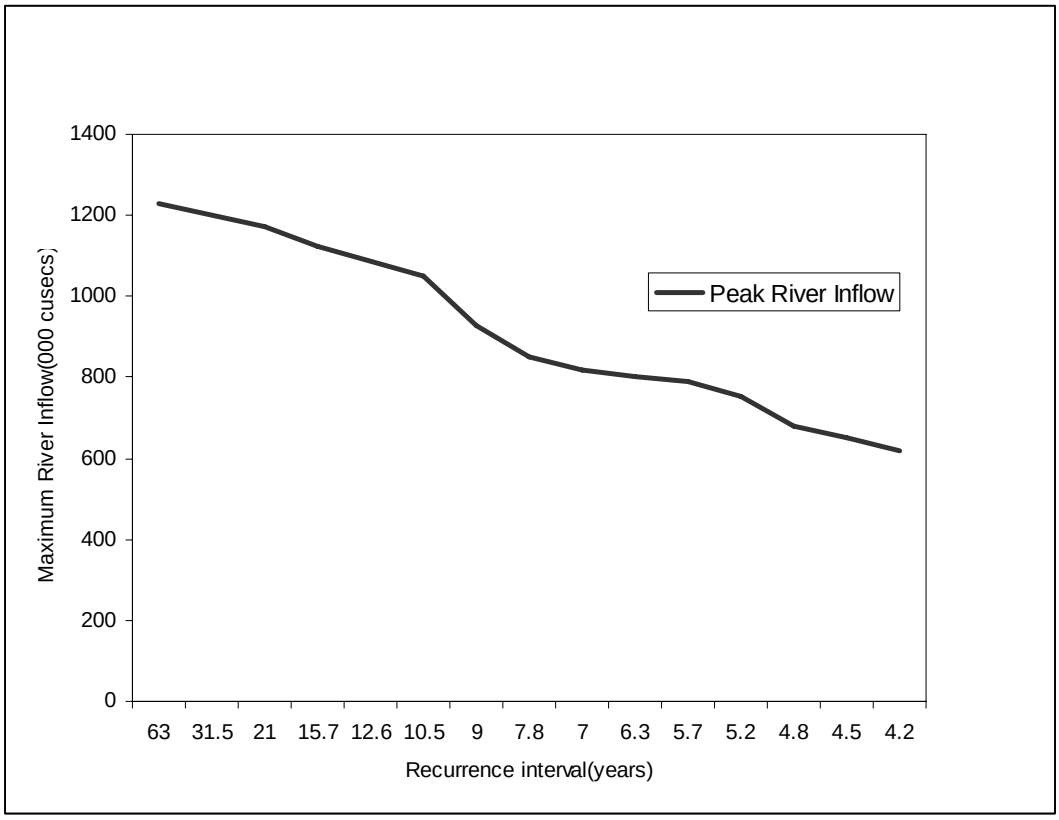


Fig 5. Flood frequency curve for the Indus River.

It comes out that the highest peak discharge in the Indus River caused catastrophic flood was in 2010. Its recurrence interval is 63 years while its chance of occurrence is about 1 percent each year. Similarly the second peak discharge was in 1976 and its chance of occurrence in each year is 3 percent while recurrence interval is 31 years (Table 3 and Fig. 5).

The Super Exceptional Flood of July-August, 2010

The recent flood which occurred between 29th July and 26th August 2010 was the worst flood in the history of Pakistan. It affected four provinces, the Khyber Pakhtoonkhwa, Punjab, Balochistan and Sindh. Out of 143 districts, 67 districts of Pakistan were severely affected (Fig 6). It is estimated that about 20 million people were directly affected, killed 3000, destroyed 1 million houses, displaced 10 millions, and millions were affected by water-borne diseases, lack of food, drinking water and shelter (Photo 1).

It is estimated that that about 130 million hectare of croplands had been inundated, destroyed 80 percent of cotton crops and 30 percent of sugarcane and rice. The flood destroyed million of tons of wheat which were kept in government storages and farmers' houses. The scale of devastation is so vast and the U.N Secretary General called it bigger than tsunami (Photo 2).

Causes

The heavy torrential monsoon rain in the catchment area of the Indus River is the immediate cause of this super flood. However the dynamics of this super flood are multi-dimensional. Let us examine the possible factors of this historic drastic super flood.

1. Up to mid-July, despite the flow of snowmelt water and commencement of normal monsoon rain, all the rivers flew normally, and in some rivers – like the Kabul River, Swat River and the Indus River – low flood levels were recorded. The canal-irrigated provinces of Sindh and Punjab had been facing shortage of water and conflicted over the share of water from Indus River System.
2. In June, the Meteorological Department forecasted normal monsoon rain and no threats of heavy monsoon rain and super flood. In the last week of July, 2010, the Meteorological Department indicated a new spell of monsoon rain all over the Indus River Basin with low to high level floods in the Indus River System. However it was not considered a serious threat by the Government and the people of the affected areas. On 29th of July 2010 heavy torrential rain took place over the catchment areas of River Swat, River Panjkora and River Kabul. About 250 mm rainfall occurred within twenty-four hours which

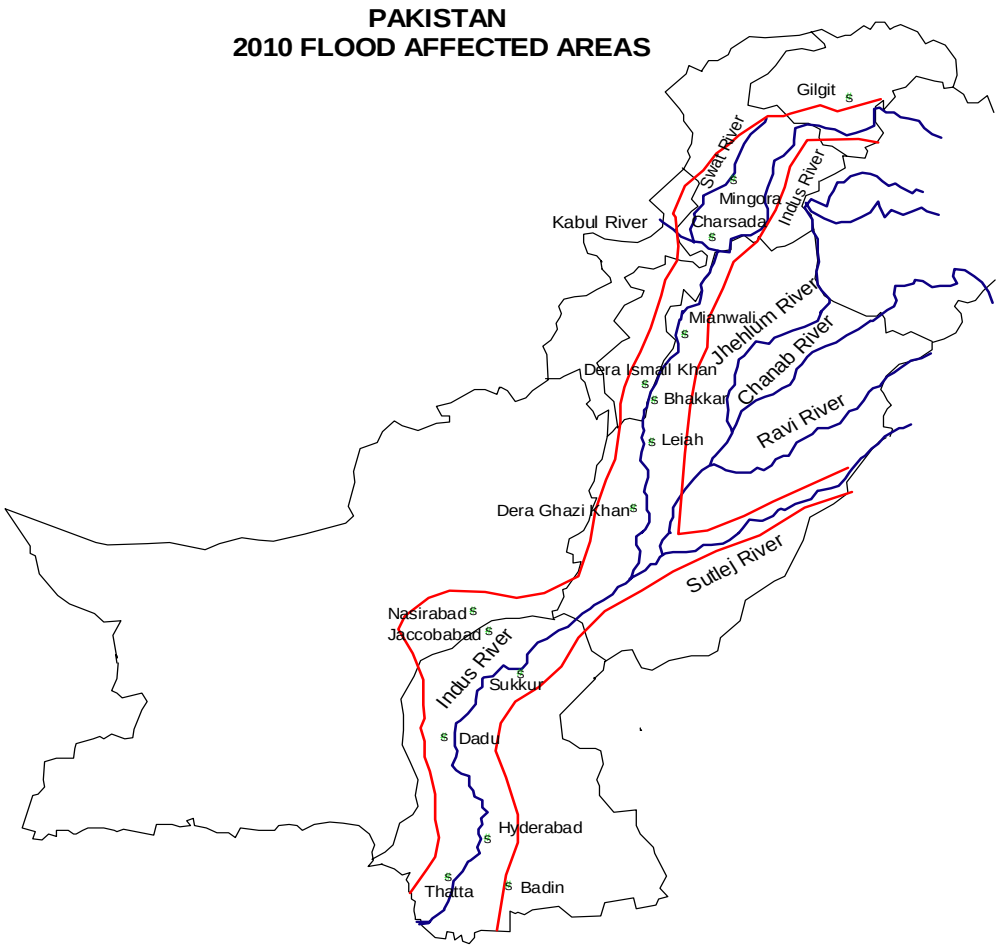


Fig. 6. 20I0 Flood Affected Areas in Pakistan.

created a flash flood in the mountainous districts of Upper Dir, Lower Dir, Swat, Kohistan, Shangla (Figs 7-8) and (Tables 4-5).

Batgram. Swat District was the first most affected district of this flood. Bridges, highways, roads,villages and crops were washed out. The flood water of the three main rivers – Kabul, Swat and Panjgora – reached the relatively low lying districts of Charsada and Nowshehra which were inundated in two days under 10 meters of flood water, which smashed these two districts. Flow of Indus River is also intensified due to heavy monsoon rainfall which was further intensified by flood water discharge of the Kabul River into the River Indus. As a result, at Kalabagh, where River Indus enters into the plains of Punjab, a historic massive flow of 12,00,000 cusec was recorded, which inundated the western districts of Mianwali, Layaha, Bhakkar, Dera Ghazi Khan, Rahim Yar Khan etc. of Punjab province. The hill torrents of the Sulaiman Mountain ranges also created flash flood in these districts. Similarly flash flood in Gomal and Zohb rivers smashed the District of Dera Ismail Khan. On the other hand the eastern tributaries of River Indus like River Chenab, the River Jhelum also recorded high flood due to monsoon rain (Figs 10 & 11).

Medium level flood also developed in the Indian controlled rivers of Ravi and Sutlej as a result of

Photo 1.Flash flood in Swat River, Khyber Pukhtunkhawah.

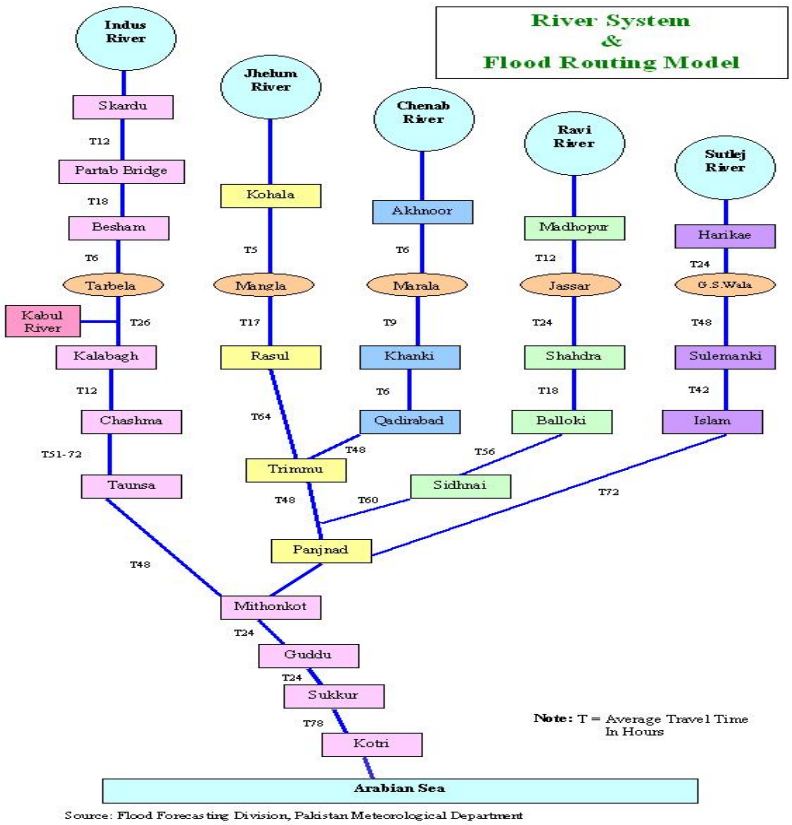


Fig. 7. River system and flood routing model in the Indus River System.

discharge of water. Due to the accumulation of massive flood water in the River Indus, all headworks and barrages over the River Indus and associated canals faced massive pressure of flood water. In many areas of Punjab, Sindh and Balochistan river embankments and canal embankments had breached either naturally or by the irrigation department to save major cities, oil refinery, natural gas plants and barrages. As a result of such

Satellite image of Indus River before flood 2010 at Guddu.

Satellite image of Indus River during flood 2010 at Guddu.

Photo 2: Satellite images of Indus River at Guddu Barrage before and after flood 20I0

breaches flood water inundated not only the flood plains but other low lying areas of Balochistan and Sindh provinces, which caused massive loss of crops, destruction of villages and influx of 10 million people to safe areas in Khyber Pakhtoon Khawa, Punjab, Sindh and Balochistan. To remove the pressure of flood water on the Kotri Barrage, the last barrage over the Indus River and save main cities of Hyderabad and Kotri embankments were breached. As a result, the low lying small cities like Sajawal, Thatta and villages of Indus delta region were inundated and massive influx of rural and urban population along their goods and livestock took place toward Karachi the largest populated and industrial city of Pakistan.

3. The changing path of summer monsoon and its intensity are also considered important factors which need to be examined. Generally strength of the South Asiatic summer monsoon is estimated by meteorologists in May on the basis of sea temperature in the Indian Ocean which is the source region of South-Asiatic summer monsoon. It enters into India and Bangladesh in early June, and reaches the eastern part of Pakistan in July. Its direction is usually determined by the existing low pressure areas. It is generally believed that the spell of 29th July, 2010, monsoon winds was very moist , changed their normal paths and extended over the north-western mountainous region of Pakistan where orographically lifted and caused heavy torrential

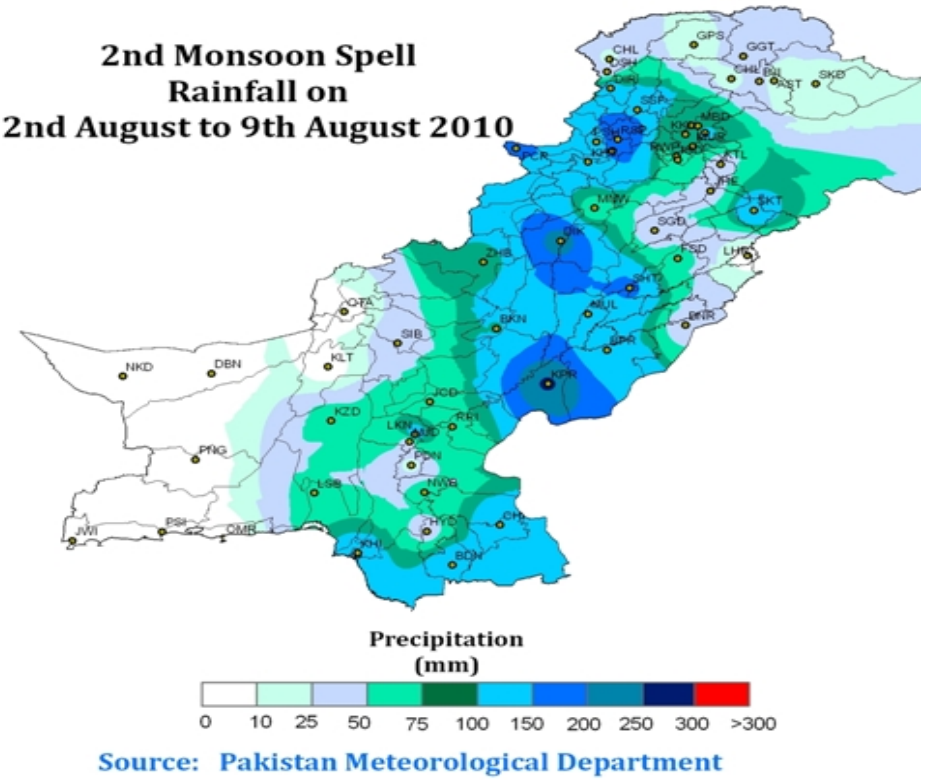


Fig. 8. Distribution of rainfall on 2nd August to 9th August 2010.

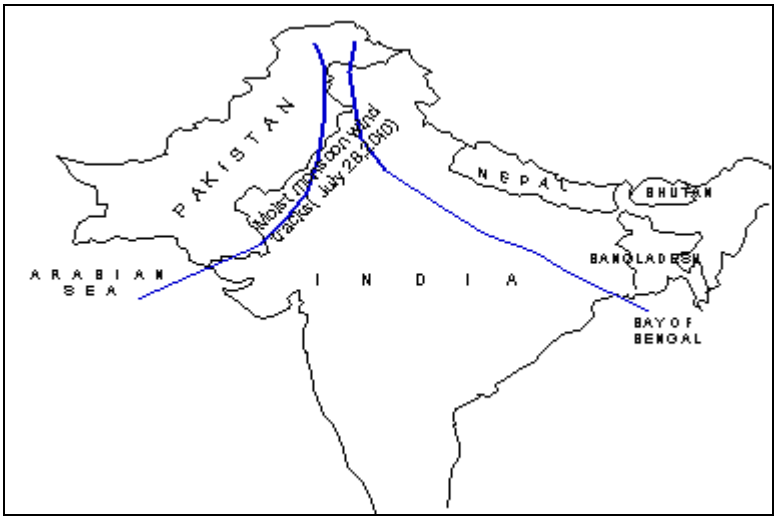


Fig. 9. Tracks of South Asiatic Monsoon July 28 –August 8,2010 caused catastrophic flood in the Indus River Basin, Pakistan.

rains over Upper Dir, Lower Dir, Swat, Kalam, Charsada, Batgram, Shangla etc. This monsoon torrential rains were followed by normal monsoon rain over plains of Punjab and Sindh provinces (Fig. 9).

4. All over the world where flood disaster takes place, flood management is an essential requirement to minimize flood loss. Large and medium size dams, reservoirs, lakes are considered good methods of flood water management which store flood water and utilize it in dry seasons. United States, China, India, Egypt, Turkey and many developed and developing countries have adopted this policy. The best example is the largest three gorge dams over the Yangtze River in China to control intensity of flood and generate hyro-electricity. The number of large water storages and dams is also important. The number of

Table 4. Distribution of Rainfall in the Indus River Basin in (Mean) July-August and July-August 2010.

Places	Annual Mean Total Rainfall (mm)	Mean Total July and August Rainfall (mm)	Total July and August Rainfall 2010 (mm)
Gilgit	129	31.1	112
Muzzafarabad	1526	576	758
Peshawar A/P			535
Saidu Sharif	1058	189	757
Risalpur			795
Kakul	1366	519	524
Cherat	630	187	618
Balakot	1671	650	528
Dir	1415	301	609
Lower Dir			448
D. I . Khan	268	110	282
Muree	1789	665	848
Faisalabad	367	204	468
Multan	186	93	222
Mianwali			703
Sibi	144	65	149
Jaccobabad	217	154	182
Sukkur	88.1	45	81

Source: Pakistan Meteorological Department.

Table 5. Distribution of Rainfall in the Indus River Basin in July(Normal(mean of rainfall in the last 30 years) and July 2010.

Places	Normal Total July Rainfall (mm)	Total July 2010 Rainfall (mm)	28 July	29th July	30th July
Gilgit	16.2	53	5	11	14
Muzzafarabad	359	359.4	91	59	103
Peshawar A/P	46	402	274	59	0
Saidu Sharif	152	471	44	187	103
Risalpur		433	5	280	121
Kakul	263	389	3	35	124
Cherat	93	388	33	257	81
Balakot	372	327	45	45	90
Dir	154	317	154	57	149
Lower Dir	56	295	6	0	192
Kalam		105	14	84	0
D. I . Khan	80	147	80.5	0	0
Muree	364	579	97	40	231
Faisalabad	117	244	1	12	3
Multan	60	55	3	12	0
Mianwali		528	0	190	31
Sibi	37	56	6	7	0
Jaccobabad	42	132	57	1	0
Sukkur		42	0	0	0

Source: Pakistan Meteorological Department

such dams in the United States is 3000, in China 2000, in India 400. Unfortunately Pakistan has only two large dams and only one dam on the Indus River. They were built about 40 years ago and do not work in their full capacity due to sedimentation. The total number of small and medium-size dams are about 100, mostly are small dams (Tables 6 and 7). The country has been facing acute shortage of water for its winter crops. The Water and Power Authority has pointed several locations and conducted studies through international experts for constructing large and medium size dams over the Indus River and its tributaries like Swat, Kabul, Panjkora, Hunza, Shyok, Gomal, Zhob etc. However the conflict between India

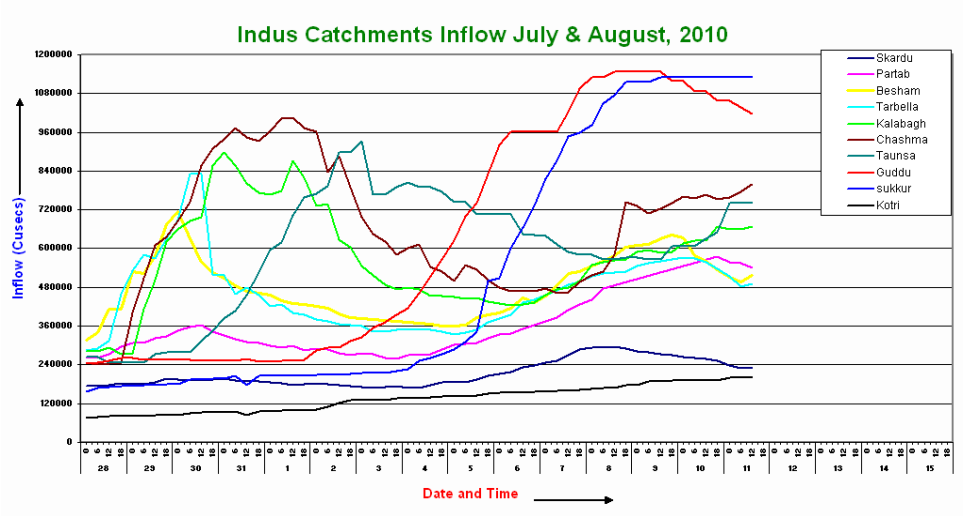
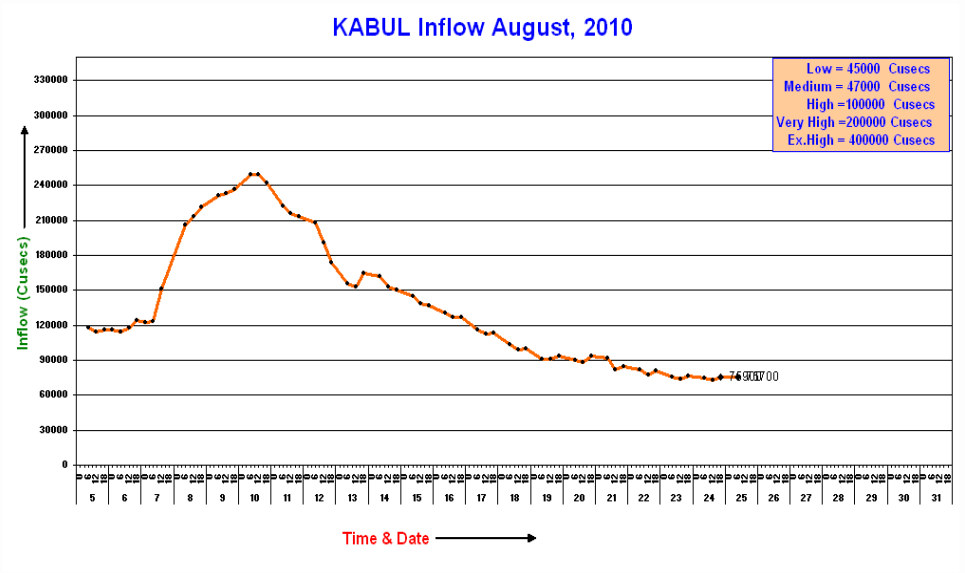


Fig. 10. Indus River flow during July and August, 2010



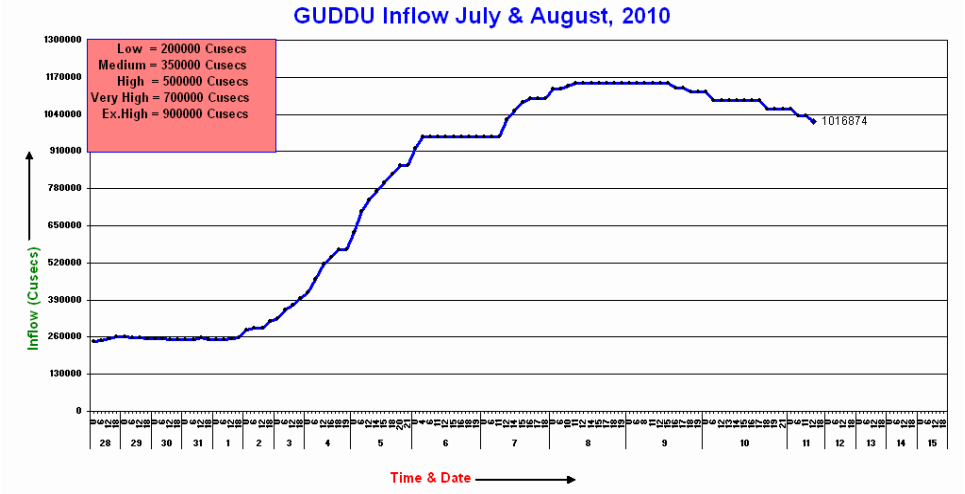


Fig. 11. Flood water inflow in the Kabul River and the Indus River at Guddu barrage.

Table 6. Existing Surface Storage Sites in the Indus River Basins

Sites	River	Storage capacity MAF
Tarbela(1976)	Indus	9.3
Mangla(1966)	Jhelum	4.8
Chasma(1971)	Indus	0.61
Warsak(1960)	Kabul	0.04
Baran Dam(1962)	Kurram	0.03
Khanpur(1984)	Haro	0.03
Tanda(1965)	Kohat Toi	0.06
Rawal(1962)	Kurang	0.04
Simly Dam(1972)	Soan	0.02
Manchar Lake	Indus	0.75
Kinjhar Lake	Indus	0.32
Chotiari Lake	Indus	0.78
Total		17.74

Source: WAPDA

Table 7. Proposed Surface Storage Sites in the Indus River Basins

Sites	River	Storage capacity MAF
Yougo	Syhok	4.82
Skardu	Indus	15.52
Basha	Indus	5.7
Kalabagh	Indus	6.1
Kalam	Swat	0.26
Munda	Swat	0.67
Khazana	Panjkora	0.56
Mir Khani	Chitral	0.58
Gomal Zam Dam	Gomal	1.13
Kurram Tangi	Kurram	1.2
Tank Zam Dam	Tank zam	0.3
Naran	Kunhar	0.25
Sukikinari	Kunhar	0.12
Patrind	Kunhar	0.1
Rohtas Dam	Jhelum	5.75
OFF CHANNEL STORAGES		
Sanjwal	Jabba Kas(Attock)	3.6
Akhori	Nsndna kas(Attock)	3.6
Dhok Pathan	Soan(Attock)	8.5
Thal Reservoir	Indus(Khushab)	8.3
Rohtas	Kahan(Jhelum)	5.75
Chiniot Reservoir	Chenab(Chiniot)	1.40
Total		61.4

Source: WAPDA

and Pakistan over the territory of Gilgit-Baltistan and inter-provincial political disputes work on large dams could not be started. Recently, the construction of Bhasha dam over River Indus has been stopped due to objection of India and World Bank which has stopped financial assistance. Similarly, construction of the Kalabagh Dam could not be started due to serious inter-provincial political conflict. Construction of dams over Swat River, Panjkora River, Gomal River has been delayed due to lack of financial resources.

5. Flood plain management is an essential element to coup flood hazard. Flow of water in the Indus River

and its tributaries vary seasonally and annually depending upon melting of snow and rainfall. The active flood plains of these rivers are the most vulnerable areas of flood hazard. However the old flood plains are also seriously affected by exceptional high flood. Due to high variability of monsoon rain in the region, exceptional floods are rare. Therefore due to the negligence of the government and explosive population growth, the beds of rivers and lands of active flood plains have been grabbed illegally for settlements and cropping. Usually the irrigation departments and local administration construct flood embankments in active flood plains and along canals. But due to the lack of maintenance they were either breached or their levels were not raised. Therefore, flood water crossed over them. In the active flood plains of the rivers, riverine forest existed which worked as natural barrier against flood water. Now in most of the areas they have been cut and are now utilized for cultivation of crops and construction of settlements. It was also observed in the August 2010 super flood that earth embankments along rivers and canals were breached by influential landlords and ministers of Sindh and Punjab provinces to save their villages and crops and divert water to towns and villages of general people.

Findings

1. The occurrence of the super flood was due to the unexpected torrential rain which caused due to change of path of the moist South Asiatic Summer monsoon winds over the north of Pakistan.

2. The occurrence of the recent super flood can be controlled through flood water management which was lacking. The country has not sufficient numbers of dams and flood water storages to minimize flood hazard by storing flood water and utilizing it during dry season.

3. The impacts of super flood could be minimized through flood plain management which includes i. restrictions on settlements, cropping and cutting of forests in the active flood plains ii construction of flood embankments and their maintenance.

CONCLUSION

Flood is a natural phenomenon however it becomes a hazard when it causes loss of human life ,destruction of human settlements, roads, bridges and crops. The factor of climatic change has been intensifying this hazard. Many countries of the world have minimized their impacts through flood management which include flood water management and flood plain management. United States, China, India, Turkey, Egypt, Japan, France, Germany Australia etc. are some examples where a sufficient number of flood control dams exist.

Pakistan is also a flood prone country where monsoon floods occur during July and mid- September. However, occurrence of severe floods is highly variable depending upon the strength of moisture content and tracks of monsoon wind towards Pakistan. The Indus River basin is the most vulnerable region of flood hazard. The flood of July-August 2010 was the super flood in terms of extent, intensity, duration and destruction in the history of Pakistan. On one hand Pakistan has a serious challenge of drought and water shortage and on the other hand the country has only two large dams and flood water storage.

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Received: 24-03-2011
Accepted: 09-05-2011