Paper No. 277

RE-EXAMINING FLOOD MANAGEMENT MEASURES FOR SINDH

Iqtidar H. Siddiqui

RE-EXAMINING FLOOD MANAGEMENT MEASURES FOR SINDH

Iqtidar H. Siddiqui[1]

SYNOPSIS

Floods in Indus River system are every year's occurrences. It is feared that due to expected climate change, there will be serious negative impacts on future floods regarding their intensity and duration.

2010 floods in Indus River system was a super flood which was triggered due to heavy rainfall on 28th July 2010 in the basin of Kabul – Swat - Chitral river system. Flood waters of the system could not be stored and put to any use in Khyber Pakhtoonkhwa itself because there is no storage reservoir available anywhere across the rivers in the province where this water could have been stored and later put to use. This water if it was stored could have been used to irrigate areas in KP like lift areas of Chashma Right Bank Canal (CRBC). However, because of absence of reservoirs, it escaped the province and later was drained to the sea.

Between 23rd July and 15th October 2010, due to continued heavy rainfall in Indus River Basin, as much as 52.9 MAF of flood water entered Sindh through the Lower Indus River. This flood water was the property of Sindh and should also have been stored in Sindh or elsewhere in the country and used during water short periods. However, this precious water could also not be stored which ultimately escaped to the sea.

Pakistan Meteorological Department (PMD) which is mandated by the government to collect weather data from all over the country, issues weather forecasts and warning bulletin daily during flood season. These bulletins are sent to all concerned departments.

The current flood control strategy in Sindh, which was adopted during the 19th century is based on safe disposal of Indus Basin flood waters to the sea through flood protection bunds, after diversion of a part of these flood waters to the irrigated areas for irrigation of land with the help of three existing barrages namely Guddu, Sukkur and Kotri. The strategy was evolved when there were no barrage controlled canals. Moreover, at that time the area irrigated by those canals was also far less than the present area.

During the past several years, the river channel has been encroached by Jagirdars by constructing illegal bunds around their Kacha lands to protect them from floods. This encroachment has reduced the water way of the river which has consequently increased the height of flood waters against the bunds. The reduced water way slows down the flow of water to the sea. These illegal bunds which are called Keiti locally are the cause of inundation of large areas. These illegal bunds should be removed forthwith before the next flood season.

Although the present flood control strategy is working well, yet 2010 super flood has exposed the short comings of the present measures and forced the flood managers in the country to re-examine the strategy and improve it to handle super floods. Most effective option of flood control measures are creation of storages, before the flood waters enter Sindh, by constructing multi purpose reservoirs where flood waters can be stored; bypassing of flood flows from the upper Sindh and thence ensuring safe passage of remaining flood waters to the sea as fast as possible. Water stored in these reservoirs should be used to generate power and provide irrigation water for all the provinces including Sindh as per WAA.

---

[1] Former Regional Advisor on Water Resources for Asia and Pacific Region, UN-ESCAP, Bangkok.

Conclusions and recommendations given in the Article are important and need to be studied. Due considerations should also be given to them.

The Indus River:

The Indus River is one of the mightiest and longest rivers of the world. The 2,000 statute mile long Indus River originates in a spring called Singikahad near Manasarwer lake in the North of Kailas Parbat in Tibet range of the great Himalayas at an altitude about 18,000 feet above mean sea level. It is also called Abasin in the North and Sindhu in the South. In its upper most reaches, the Indus flows generally in the North-West direction for several hundred miles. However, near the town of Gilgit the river takes a nearly 90 degree turn on the left and starts flowing almost in the middle of Pakistan generally in North-South direction.

In its long run to the sea, the Indus River meets two major tributaries; The Kabul River with its four tributaries which join Indus on the right in its northern reach and the Punjnad river with its five major tributaries which join it on the left almost in the lower middle reach of the river. In all River Indus has 27 tributaries which join it on both sides of it during its long journey to the sea. In addition there are five big hill torrents which also join the river on the right. The Kabul River and its four tributaries have their catchments spread partly in Afghanistan. Whereas the Indus River and its major tributary, the Punjnad River with its five tributaries drain the snowmelts of mountains and glaciers and the rainfall in their catchments which are spread in China, Jammu and Kashmir and India.

Indus River from Punjab-Sindh border to the sea is called Sindhu or the lower Indus River. This reach of the river is 370 miles in length, although, the actual length of the river channel, if measured along the meanders of the river in the province is 460 miles. In this reach there is no major tributary inflow except flows from hill torrents from Kirthar and Suleiman ranges, which find their ways to the main Indus. The discharge of the lower Indus is the combine discharge of the upper Indus reach along with all its tributaries. The combined flood discharges of these rivers passing through lower Indus River occasionally makes the discharge of lower Indus very high which become high flood or even super flood discharges.

The flow of the Lower Indus River is highly variable from year to year and is seasonal in cycle. During non flood season which is winter, the discharge of the river becomes very low as compared to flood discharges in summer or abkalani season of 1st July to 15th October, which rises to about 40 to 50 times the low discharges. The suspended sediment concentrations vary from less than 100 ppm at low flows to over 5,000 ppm at high flows. Suspended sediment size in the water is found to be smaller and smaller as it nears the sea.

The lower Indus River is a very wide alluvial river. The active flood plain of the river is about 5 to 15 miles wide. Various reaches of the river have very flat slopes, which are less than half a foot per mile. In alluvial plain where the valley is unconfined, the river channel tends to adopt sinusoidal course. Silt in excess of the carrying capacity of the discharge is dropped down in its bed and the flow skirts round it which is the starting point of the meander. The river takes sinusoidal course and the meander length increases. The river channel meanders freely. The meander length is independent of the grade of the bed and bank materials in the flood plain. The meander width is greater in finer material.

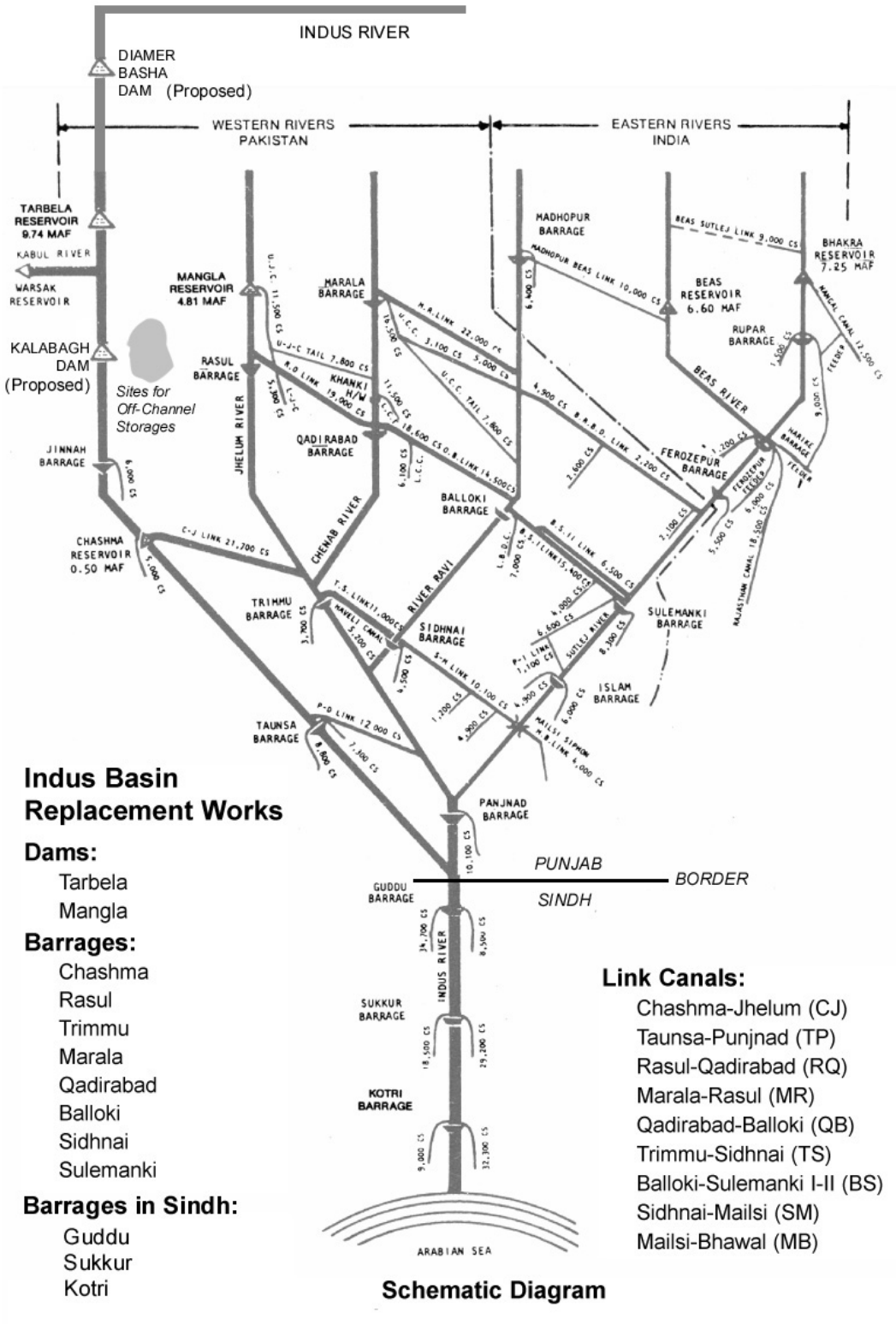

Fig: Indus River System

Source: Ministry of Water and Power, Publications, Pakistan

Thus in the lower reaches of the lower Indus plain there is more and more meanders as compared to that at the upper reaches. Meandering channels swing in a wide belt on both sides of the river axis. After construction of Sukkur Barrage it was observed that the river swing near Punjab-Sindh border which was about 4 miles increased significantly at the upstream of Sukkur Barrage. Due to meander, the river has a natural tendency of accretion of its bed which during thousands of years of its flow in the alluvium, has built up as a ridge on which the river channel now flows. In its course through Sindh, the Indus tries to run more or less on a ridge. This characteristic of the river has rendered whole of Sindh province vulnerable to flooding thus requiring the irrigated and inhabited areas along the active flood plain to be protected during flood season.

During its life of millions of years, the Indus River has many a times been affected by environmental forces, which have forced the river to change its course. Evidences are available that in the past, the river channel has shifted its course several times. Several ancient channels of river Indus have been identified, the most notable being that which has been converted into Nara canal during the beginning of the 20th century. Evidence of yet another river, which is called Rainee River is available which is now being converted into a big canal similar to Nara canal.

Floods in Indus River:

2010 Flood:

Pakistan was in the grip of a super flood from 23rd July to 15th September 2010. On 23rd July, River Kabul at Nowshera was in medium flood whereas River Indus at Tarbela, Kalabagh, Chashma, Taunsa and Guddu were in low floods. Starting from 28th July, due to fairly wide spread thunder showers, rains with heavy falls at isolated places in the province, River Kabul at Nowshera went into very high flood. At that time Indus River at Kalabagh was in medium flood. Simultaneously with fairly wide spread thunder showers and rains with heavy falls which continued at isolated places all over Northern part of the country for several weeks, flood situation worsened in all the rivers of Indus River system. River Indus, Jhelum at Mangla and Kabul at Nowshera went rising into very high to exceptionally high floods. Kabul at Nowshera was in exceptionally high flood on 29th July 2010. The floods over topped the gauge at Nowshera on 30th July 2010. The wave of flood waters of Kabul river system after creating havoc in Khyber Pakthonkhwa, joined Indus and jointly with Indus River flood waters entered the Lower Indus River.

Lower Indus went in exceptionally high to super flood stage. The 2010 flood was the greatest natural disaster in Pakistan's history which was greater than 2004 Tsunami, greater than Hurricane Katrina and greater than the earthquakes in Haiti, Kashmir and Sichuan Province (China).

Millions of people were affected by super flood waters. By one estimate Sindh was the hardest hit province with more than 2 million residents directly affected, 4,500 Sindh villages with more than 200,000 houses destroyed. 1,500 persons perished along with hundreds of thousands of cattle heads.

UN Chief Ban Ki-Moon is reported to have observed about the 2010 Pakistan including Sindh floods as follows:

"I will never forget the destruction and suffering I have witnessed today. In the past I have visited the scenes of many natural disasters around the world, but nothing like this."

Floods in Lower Indus River:

Flood flows in the Lower Indus River are the combined flows of Upper Indus, which consist of flood flows of Indus River main, the Kabul River with its four tributaries, which include the Swat, the Panjkora river and the Chitral rivers, and its left bank tributary, the Punjnad river. Punjnad river discharge is due to its five major tributaries namely Jhelum, Chenab, Ravi, Sutlej and Beas, resulting in floods in July to October every year. Main River Indus also carries the occasional discharges brought down by hill torrents on the west. Thus, the flood flow of lower Indus River has the combined flow characteristics of all the rivers of Indus River system and the hill torrents.

Floods in Jhelum River is due to early snowmelt run off from February reaching its peak in early June. High floods in the river, however, result from heavy rainfall in catchment areas during the monsoon season of July to September. Mangla Dam across Jhelum is an irrigation related reservoir. It does not have sufficient flood retention capacity and therefore it does not create much affect on the flood flows of Jhelum river.

Floods in Chenab River is mostly the result of heavy precipitation in its hilly catchment in lower Himalayas. Snowmelt is not a significant feature in Chenab river flows. Since, there is no storage reservoir across Chenab River except a small reservoir at Salal in India, there is no reduction of flood flows due to it.

Floods in Ravi River generally result from excessive rainfalls in the mountain catchments in India and submountaneous catchment in Pakistan. Snowmelts make no significant contribution in flood peaks in the Ravi river.

Contribution of flood flows of Beas and Sutlej rivers which are the result of heavy rainfalls in the catchment within India are generally altered and smoothened on account of two reservoirs, Pong dam and Bakhara dam, constructed by India during 1963-77 on this rivers.

Against the design capacity of Guddu Barrage of 1.2 million cusecs, maximum peak of 1.15 million cusecs was recorded on 9th August 2010.

Against the design capacity of Sukkur Barrage of 0.9 million cusecs a peak of 1.13 million cusecs was recorded on 10th August 2010.

Similarly, at Ghulam Mohammad Barrage, Kotri, against the design capacity of 0.85 million cusecs a peak discharge of 0.95 million cusecs was recorded on 28th August 2010. Kotri remained in high, medium and low floods upto 15th September 2010. The river channel, drained into the sea very slowly which was partly due to prevalent high sea levels.

All the barrages and river protection bunds remained greatly stressed due to high water pressure and mostly remained beyond their designed capacity during the flood period. Bund breaks occurred at two places, Tori Bund in upper Sindh and MS (Mool Chand Shah Bunder) Bund in lower Sindh which inundated vast irrigated and habitated areas of Sindh and Balochistan. The Commission specially formed by the government to investigate the causes of bund breaks during 2010 floods however, was limited to investigate causes of only two bund breaks i.e. Tori Bund and M.S. Bund. Other bund breaks were not assigned for investigation. The Commission concluded that those two bunds collapsed due to natural causes. These bund breaks inundated vast cultivated areas which destroyed houses and properties and government installations.

The tragedy of 2010 floods had been colossal. This loss was doubled when along with this tragedy, Pakistan and Sindh lost as much as 52.9 MAF of precious flood water in just three months which should have been stored in Sindh for its future use. This water escaped to the

sea. Not a single drop could be stored for future use. This water is in addition to 35.2 MAF of water which escapes to the sea unutilized on average annually.

Recording of flood discharges in the lower Indus Basin was first started in 1901 with the establishment of a river gauge at Kotri. Later, for planning of Sukkur (Lloyd's) barrage, a river gauge was setup in 1922 near the barrage site. Still later, for planning of Guddu Barrage, a river gauge was also setup at Guddu in 1945. Since the completion of Guddu Barrage in 1963 gauge heights are being recorded regularly. Later, for discharge measurements at all barrages, telemetry system was installed in 2000 by IRSA at each barrage of the country including the three barrages in lower Indus Basin.

Several major floods in the river basin during the 19th, 20th and the first decade of 21st century have been recorded in the past. These floods caused wide spread damages throughout the Indus River Basin.

Flood classification limits at the barrages as adopted by the Sindh Irrigation and Power Department are as follows:

Flood Classification

(Thousands of cusecs)

Gauge	Flood Limit				
	Low	Medium	High	Very High Danger Level	Exceptionally High
Guddu	200	350	500	700	900
Sukkur	200	350	500	700	900
Kotri	200	300	450	650	800

Out of the recorded discharge peaks in the past several were above very high limit and were in danger level limits. Notable high floods along Lower Indus River was recorded in 1874, 1942, 1973, 1976, 1978 and 1992.

High flood peaks recorded at Guddu, Sukkur and Kotri barrages are:

Flood Peaks

Barrages	Design Discharge	Recorded High Flood	Year
Guddu Barrage	1.2 million	1.15 million	2010
Lloyd's Barrage (Sukkur)	0.9 million	1.13 million	2010
Ghulam Mohammad Barrage (Kotri)	0.85 million	0.981 million	1956

Flood Frequency:

During the preparation of National Flood Protection Plan, theoretical flood frequency analyses was carried out for flood peak discharges at Guddu, Sukkur and Kotri barrages using the flood data upto 1976. Theoretical return period of 2010 flood in Lower Indus at various locations is expected to be between 25 and 50 years.

Results of these flood frequency analyses are given below.

Flood Frequency

Return Periods Year	Probability of Excedance, percent	Estimated Flood Peak Discharge		
		1) Guddu, Downstream	2) Sukkur, Downstream	3) Kotri, Downstream
2	50	550	620	460
5	20	770	790	600
10	10	920	930	690
25	4	1,100	1,120	810
50	2	1,240	1,260	890
100	1	1,370	1,390	980
200	0.5	1,500	1,530	1,060

1) Period of record is 1963-1978, prior years upto 1922 were developed from record at Sukkur. See Part II, Supporting Volume 1.

2) Period of record is 1922-1978.

3) Period of record is 1901-1978.

Environmental Threats to Water Resources:

Since the last quarter of the 20th century, scientists have recognized that the Greenhouse effect and depletion of ozone layer of stratospheres are serious environmental problem for earth and mankind. These are affecting water resources of the world including the subcontinent. Greenhouse gases include water vapors, carbon dioxide, methane, ozone and some minor gases. It has been concluded that greenhouse gases may result in global warming. Out of which carbon dioxide is going to be mostly responsible for about fifty percent of the mean temperature rise.

Climate change would create severe adverse affects on water resources, water resources management and agriculture in Lower Indus Basin. These changes may include disappearance of Himalayan glaciers including Siachen glaciers, which is the second biggest glacier of the world. Excessive and erratic rainfall, flash floods, increased occurrence of drought and dry spells are the direct effects of climate change. This will mean high and erratic weather and floods in Lower Indus River Basin. The country should be ready to face these changes. 2010 Pakistan super flood is the result of environmental changes. It has given a 'wakeup call' to the country.

Ban Ki Moon has warned that the world is accelerating towards a climate catastrophe. According to him 'more distant scenarios' as predicted by scientists have started 'happening now'. Scientists have been accused in the past for years of scaremongering. But according to the UN Chief the real scaremongers are those who say that they cannot afford actions in this regard as it would hold back their economic growth.

Flood Monitoring and Forecasting:

After the event of super flood of 1992, Pakistan Meteorological Department, established National Flood Forecasting Bureau (NFFB) at Lahore. It replaced the existing facility of floods forecasting unit at that time.

NFFB is a modern establishment. It uses weather data provided by various weather radars presently installed in the country. The radars installed at different places are of different sizes. Sizes of Lahore and Mangla radars are of 10 cm each. Sialkot, Islamabad, D. I. Khan, Rahim Yar Khan and Karachi radars are of the size of 5 cm each. In addition NFFB uses rainfall and discharge data from PMD, WAPDA, PIDs, data provided by Pakistan Commissioner for Indus Water (PCIWD) which also includes data provided by India. It also uses satellite pictures in predicting weather of the country. In addition to the already installed seven radars, PMD is following a big program of extension and modernization of its facilities. It is installing 8 more satellite stations at various locations in the Northern part of the country. This would fully cover the whole country. The PMD weather forecast would be much improved than what they are today.

During flood period of July upto October, NFFB issues daily two page weather bulletin at about 0900 hours. This bulletin is comprehensive and includes very useful data.

GOVERNMENT OF PAKISTAN
PAKISTAN METEORLOGICAL DEPARTMENT
FLOOD FORECASTING DIVISION

Dated:- 19th Aug, 2010

46-JAIL ROAD LAHORE-54000 **Time:- 09 : 55 hours (PST)**

BULLETIN No. A-066

1. Federal Minister, Water & Power, Islamabad.
2. Governor (All Provinces).
3. Chairman NDMA, Islamabad.
4. Chief Minister (All Provinces).
5. Secretary, Ministry of Defence, Rawalpindi.
6. Secretary, Ministry of Water & Power, Islamabad.
7. Secretary, Ministry of Information, Islamabad. Islamabad.
8. Chairman NHA, Islamabad.
9. Chief Secretary (All Provinces & AJK).
10. PDMA'S (D.G'S, All Provinces & AJK).
11. Administrator & Chief Secretary, Gilgit-Baltistan).
12. Chairman, Indus River System Authority, Islamabad.
13. Chairman, Federal Flood Commission, Islamabad.
14. Commissioner for Indus Waters, Lahore.
15. Relief Commissioner, (All Provinces & A.J.K.).
16. The Secretary General, Pakistan Red Crescent Society, Islamabad.
17. Secretary, Irrigation Department, (All Provinces).
18. D.G. Relief, (All Provinces).
19. D.G. Emergency Relief Cell, Cabinet Division,
20. Chief Engineer, Managla/Tarbela/Chashma.
21. Chief Engineer, Irrigation (All Provinces).
22. Chief Engineer, (All Barrages).
23. Chief Engineer, C.D.O. (Muzaffarabad).
24. All concerned D. C. Os.

SUBJECT :- FLOOD SITUATION AND WEATHER FORECAST FOR NEXT 24 HOURS:

I. FLOOD SITUATION:

River Indus at Guddu & Sukkur is in Exceptionally High Flood. River Indus at Taunsa, Kotri is in High Flood. River Indus at Kalabagh, Chashma, River Kabul at Nowshera are in Medium Flood. River Indus at Tarbela, River Chenab at Marala,Trimmu & Punjnad are in Low Flood.

II. HYDRO METEOROLOGICAL FEATURES:

(a) Seasonal low lies over north Balochistan and adjoining area.
(b) Weak Southwest Monsoon current from Arabian Sea is penetrating into Sub-mountain areas of Punjab and Kashmir upto 5000 feet.
(c) Shallow trough of westerly wave is moving across northeast Afghanistan and adjoining areas.

III. FORECAST:

Scattered thunderstorm/rain is expected over North Punjab, Khyber Pakhtunkhwa and Kashmir. Isolated thunderstorm/rain is also expected over south Punjab, Northeast Balochistan and Gilgit-Baltistan.

IV. RAINFALL RECORDED DURING PAST 24 HRS (UPTO 0800 OST)l:

Palku=27, Dir=25, Sialkot(Cantt=22, Airport=08), Ganda Singh Walla=18, Kund=17, Mangla=10, Ura=08, Islamabad(Sadipur)=07, Alexandra Bridge=06, Kotli & D.G. Khan=05(each) Dratian & Daulatnagar=04(each), Parachinar & Lahore(Jail Road)=03(each), Jassar, Zafarwal & Chakdara=02(each), Mandibahauddin & Muree=01(each), Jehlum=Trace.

V. WEATHER OUTLOOK FOR NEXT 48-HOURS:

No Change.

Web Site Address:-
www.pakmet.com.pk **(Flood Update)**
Duty Officer 24 hrs. Phone: LHR 99200139
99201244, 99205159,
99205160

(M. AKRAM ANJUM)
Chief Meteorologist
Ph. Office: 042-99200208
Fax: 042-99200209

Fig: Flood Bulletin Page 1 (19th August 2010)

GOVERNMENT OF PAKISTAN
PAKISTAN METEORLOGICAL DEPARTMENT
FLOOD FORECASTING DIVISION
46-JAIL ROAD LAHORE-54000

Dated:- 19th Aug, 2010
Time:- 09 : 50 hours (PST)

BULLETIN No. B-066

WEATHER/RAINFALL FORECAST FOR NEXT 24 HRS:

RIVERS	Upper Catchments (Above Rim Stations	Lower Catchments (|Below Rim Stations)
INDUS	Scattered thunderstorm rain	Scattered thunderstorm rain (Rawalpindi Division)
JHELUM	-do-	-do- (Sargodha Division)
CHENAB	-do-	-do- (Gujranwala Division)
RAVI	-do-	-do- (Lahore Division)
SUTLEJ	-do-	Isolated thunderstorm rain (D.G. Khan & B.Pur Division)

FLOOD FORECAT OF GAUGING STATIONS (IN THOUSANDS OF CUSECS)

RIVERS	Stations	Design Capacity	**Actual Observations at 0,500 PST**		Computerized Forecast for Net 24 hrs (Inflow)	Forecasted Flood Leval (Inflow)	Danger Level (Very High Flood)
			Inflow	Outflow			
INDUS	Tarbela	1500	341.0	336.5	320-350	Low	650
	Kalabagh	950	380.6	370.8	370-400	Low to Medium	650
	Chashma	950	440.1	440.1	400-440	Medium	650
	Taunsa	1000	565.9	545.9	550-570	High	650
	Guddu	1200	993.4	992.4	980 F 900	Exceptionally High	700
	Sukkur	900	1001.7	951.1	1000F 950	-do-	700
	Kotri	850	454.4	426.3	460 R 600	High	650
KABUL	Nowshera	-	90.8	90.8	70-90	Medium	200
JHELUM	Mangla	1060	61.7	67.0	60-90	Low	225
	Rasul	850	60.3	57.8	60-80	-do-	225
CHENAB	Marala	1100	118.5	88.9	150-200	Medium to High	400
	Khanki	800	73.3	68.5	130-170	Medium	400
	Qadirabad	807	55.9	40.9	70-150	Low to Medium	400
	Trimmu	645	174.7	170.5	150-170	Low	450
	Punjnad	700	195.8	192.8	150-190	-do-	450
RAVI	Jassar	275	4.1	4.1	No significant change	Below Low	150
	Shahdara	250	21.4	21.4	-do-	-do-	135
	Balliki	225	37.8	9.9	-do-	-do-	135
	Sidhnal	150	13.9	4.8	-do-	-do-	90
SUTLEJ	G.S. Wala	-	12.5 (FEET)	(Gauge only)	12-13	-do-	25.3 (Feet)
	Sulemanki	325	22.4	10.4	No significant change	-do-	175
	Islam	300	5.4	4.2	-do-	-do-	175

Isolated=20 to 30% of area
Scattered= 30 to 50% of area
Widespread= 90 to 100% of area
R= Rising
F= Falling

www.pakmet.com.pk **(Flood Update)**
Duty Officer 24 hrs. Phone: LHR 99200139
99201244, 99205159,
99205160

(M. AKRAM ANJUM)
Chief Meteorologist
Ph. Office: 042-99200208
Fax: 042-99200209

Fig: Flood Bulletin Page 2 (19th August 2010)

Present Flood Control Measures in Sindh:

Since river Indus is a seasonal river, it receives flood discharges during monsoon. In this period its discharge rises several times to that of the low flow discharge of non monsoon season. It is usual of Lower Indus River that its flood discharges rise by 40 to 50 times of the low flow discharges. High discharges overflow the river banks and inundated large areas along the river. Since irrigated areas and villages, towns and cities are mostly situated along the river, the flood waters inundated these areas occasionally. During the third quarter of the 19th century, when Sindh was a part of Bombay presidency and there was no arrangement from the government for flood protection, it was usual for the *jagirdars* and *zamidars* of Sindh to protect their lands from inundation by constructing crude earthen bunds around their lands. They were built by manual labour. In those early days there was no input of engineering principles in designing or constructing these bunds. The government realizing efficacy of flood protection bunds, adopted this practice as its strategy for flood protection of irrigated and inhabited areas. The government took over all *jagirdara* and *zamidara* bunds and converted them as proper flood control bunds with the help of engineering input.

After the devastating floods in Sindh in 1874 which inundated a large part of Jacobabad district and about 80 towns near it, the government actually started to pursue its flood control policy by constructing Kashmore Kundkot Bund project. In the first few years 48 miles of bunds were constructed from head of Bagari Canal northwards to Kashmore and then connecting it to the rising ground in Sindh-Punjab border. On the downstream, the Sukkur Bagari bund running north from Sukkur on the right bank of Indus to the Begri Canal Headworks has always been a bund of great importance since 1878. After 1878 the activity of bund construction went on feverishly and every year several miles of bunds were added. By 1932, when Sukkur (Lloyd's) Barrage came into operation, a continuous line of bund, about 600 miles in length had already been constructed on the right bank of Indus from Sindh-Punjab border upto delta, however, with some gaps in its lengths. On the left bank again though not continuous, 337 miles of bund was constructed during this period.

In Sindh, bunds of three types have been developed and are being constructed namely:

The main bunds or front bund;

The loop bunds and

Cross bunds

The main bund is the first line of defence, whereas the loop bund which is usually constructed as an arc, is the second line of defence. The loop bund forms a compartment with the main bund. When the area between the main bund and the loop bund becomes too big, cross bunds are constructed to keep the area within manageable limit.

All cross bunds constructed for any purpose whatsoever should, therefore, be of standard bund section. They should also be provided higher free board to take care of pocketing effect.

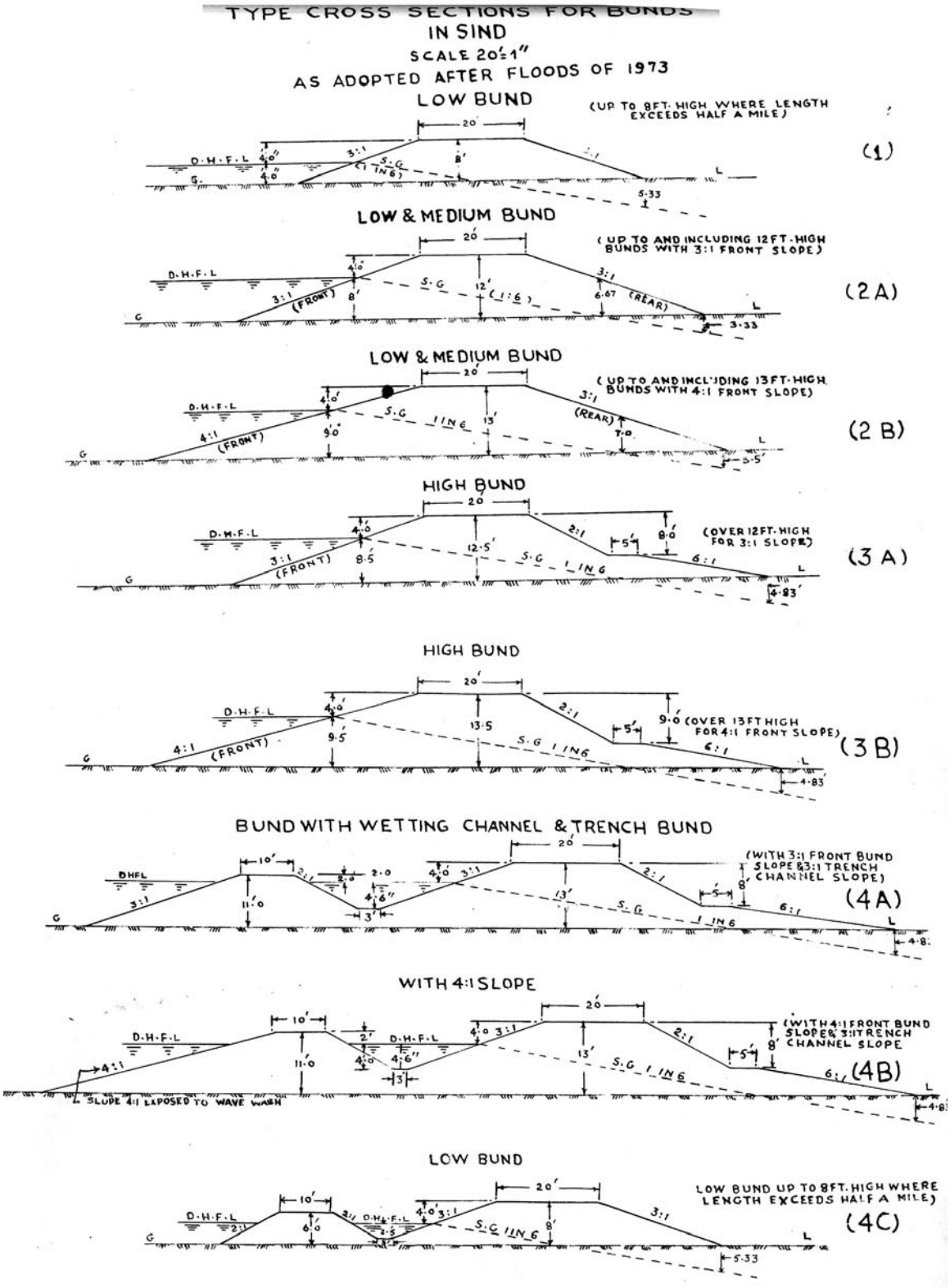

Fig: Type Sections of Bund

Source: Bund Manual, Sindh Irrigation and Power Department

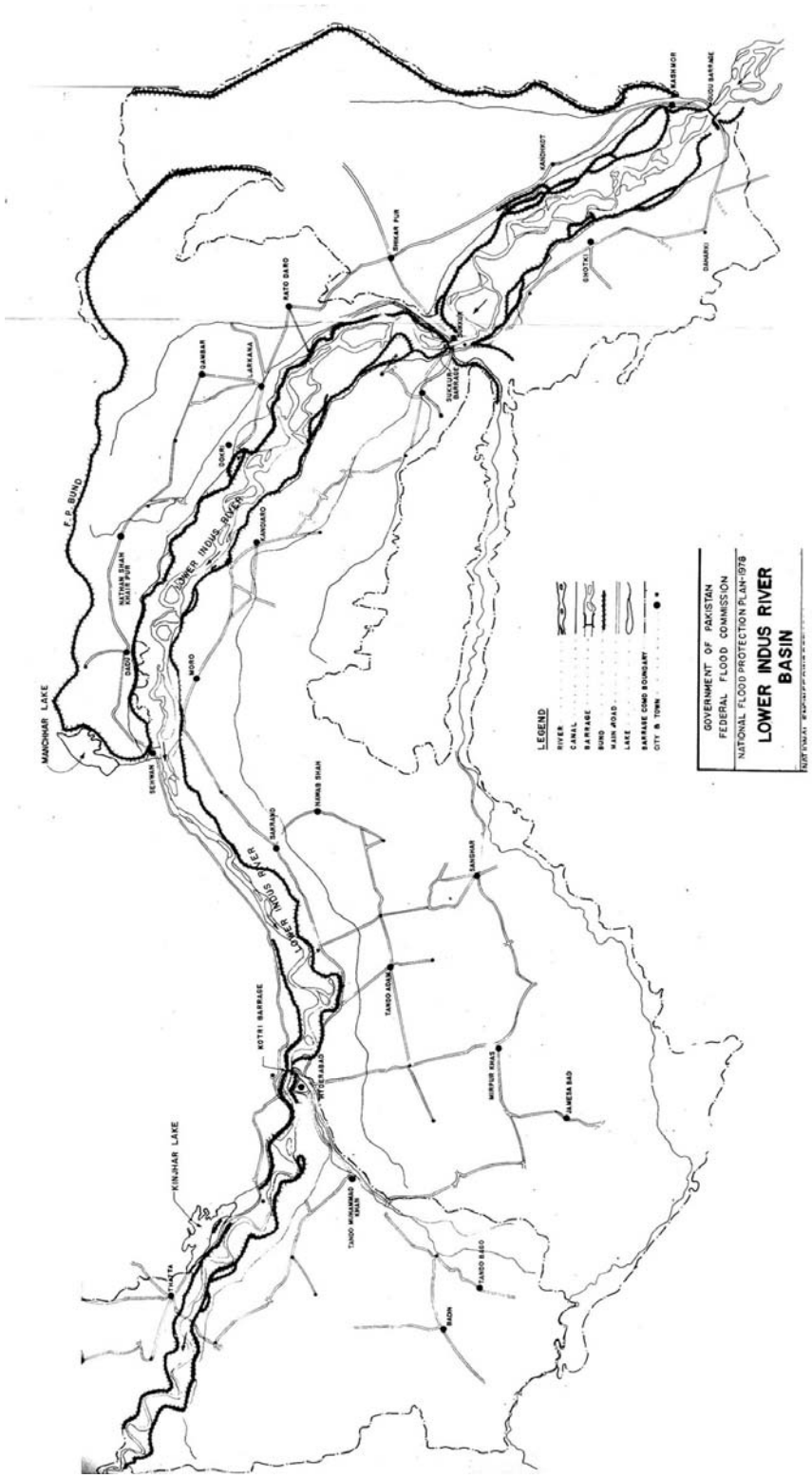

Fig: Bunds in Sindh

Source: National Flood Protection Plan, 1976

Since, Indus River is an alluvial stream, its bed is continuously changing through the process of retrogression and accretion, therefore, the river stages also change due to river bed conditions. Flood stage is directly related to discharge. Bigger the discharge, higher would be the river stage. Since, Indus River is a wide alluvial channel, even with large increase of discharge, the corresponding affects on the stage may be small. For the safety of flood protection works, river stage is more important than discharge, as the stage directly indicates the availability of free board against the bunds and training works. The stage is also affected by withdrawal of large amount of river water for irrigation through canals. The fetch of the river, which is the span of water in front of the bund, wind direction and velocity, would have very prominent affect on the stage. At bankfull stage and with high winds pocketing affect on the bunds would be very significant, which means that stage would increase significantly. High winds may start wave wash, which is detrimental to the safety of the bund. Moreover, splashes due to high winds may start over topping the bund, if free board is insufficient.

Since Indus River is a meandering channel, the alignment of the main bund is kept along the high bank so that it is situated as far away as possible from the river course. Because of the occasional meander, the river channel may come close to the bund and may threaten its safety by eroding it. In worst case it may completely erode the bund. In view of it every year, during non abkalani season, river channel survey is carried out. Erosion ordinates are set out, with bunds as the base line, upto the edge of the nearest river channel. Sufficient numbers of ordinates are set out and the river course is plotted. River channel survey is an important exercise, which is done every year to plot the river course in the flood plain. The survey helps to plan a new bund and also to propose a loop bund, which is the second line of defence. According to Sindh government policy, when the river channel approaches 3,000 ft from the main bund, a loop bund becomes necessary and is planned. At places the compartment formed by the main bund and the loop bund is filled with flood water by allowing river water to enter the compartment through a specially designed river sluice of adequate capacity. The level of the water in the compartment is kept at the same level on both sides of the main bunds.

Bunds are designed against assumed river water levels which are higher than the actual highest recorded flood levels. The top of the bund is kept at a sufficiently high level, after allowing an adequate free board. This will provide sufficient factor of safety for sudden unforeseen rise of water level.

To monitor the river level against a bund, bund gauges are fixed at every mile. Also to monitor the availability of free board, special free board gauges are also fixed on the bund gauges. They enable the inspecting officials to monitor water level of the river and simultaneously the availability of free board at a glance.

For filling of compartments formed by the front bund and the loop bund, sluices of adequate sizes are provided. They are usually double acting sluices.

Proper maintenance of bunds is an important function which should be performed regularly by the maintenance staff during pre-flood period. During this period the bund is kept ready to perform its functions during flood season. The maintenance includes ensuring the height of the bund by allowing adequate free board, repairing of slopes, closing of holes, dug out by borrowing animals and closing leaks, jungle cutting etc.

Common Causes of Failure of Bunds:

1) Erosion of main and loop bunds by the river.
2) Over topping the bund.
3) Development of leaks into breaches.
4) Inadequate cover over the saturation line.
5) Inadequate maintenance.

Need for Upgrading Flood Control Strategy:

The current flood control strategy which was adopted in the past in Sindh during the 19th century is based on the use of flood protection bunds along with the barrages. This strategy has worked very well up till now. The three barrages in Sindh namely, Guddu, Sukkur and Kotri are mainly for diversion of irrigation supplies through a large number of canals which off take the river upstream of these barrages. In flood season, diversion of flows through these canals provides much needed relief to the downstream river channel. Although, the present flood control strategy is working well yet 2010 super flood has forced the country to re-examine its present strategy and improve it, if necessary.

Flood Control Measures:

To adopt an improved strategy for flood control in Lower Indus River Basin, use of different types of river flood control measures, which are used all over in the world either singly or in combination have been examined. These measures are:

Multi purpose storage dams and reservoirs;

Diversion dams or barrages;

Embankments, bunds and leeves;

Dredging of river channel;

River training works; and

Flood bypass channel

Multi Purpose Storage Dams and Reservoirs:

Multi purpose storage dams and reservoirs are used extensively all over the world as flood control dams and reservoirs. They impound flood water in the reservoirs which results mainly in reduction of flood peaks to non damaging rates downstream of the dam. The hydrograph of flood water emerging from a flood control reservoir is always different from the hydrograph of the flood which enters the reservoir. The peaks of the emerging hydrograph is always much lower than the hydrograph of the incoming flood. Bigger the reservoir, greater would be its damping and smoothing affects of the flood peaks.

It is neither possible nor intended to store the entire volume of flood water of Indus River in a single reservoir. However, even for storing only a part of its flood volume a reservoir of sufficiently large size would be required. However, for its own safety flood control reservoir would require spillway of much bigger size along with an emergency spillway. Low level sluices are also required for release of water in the river downstream during water short periods.

For effective functioning of a flood control reservoir, its reservoirs level is kept depleted as far down as possible before the onslaught of the new flood season, so as to keep maximum storage capacity readily available for storing flood waters in the reservoir.

Flood flows impounded in a reservoir provide additional irrigation supplies, which would otherwise be wasted to the sea. In other words with the impoundment of flood flows, availability of irrigation supplies is optimized.

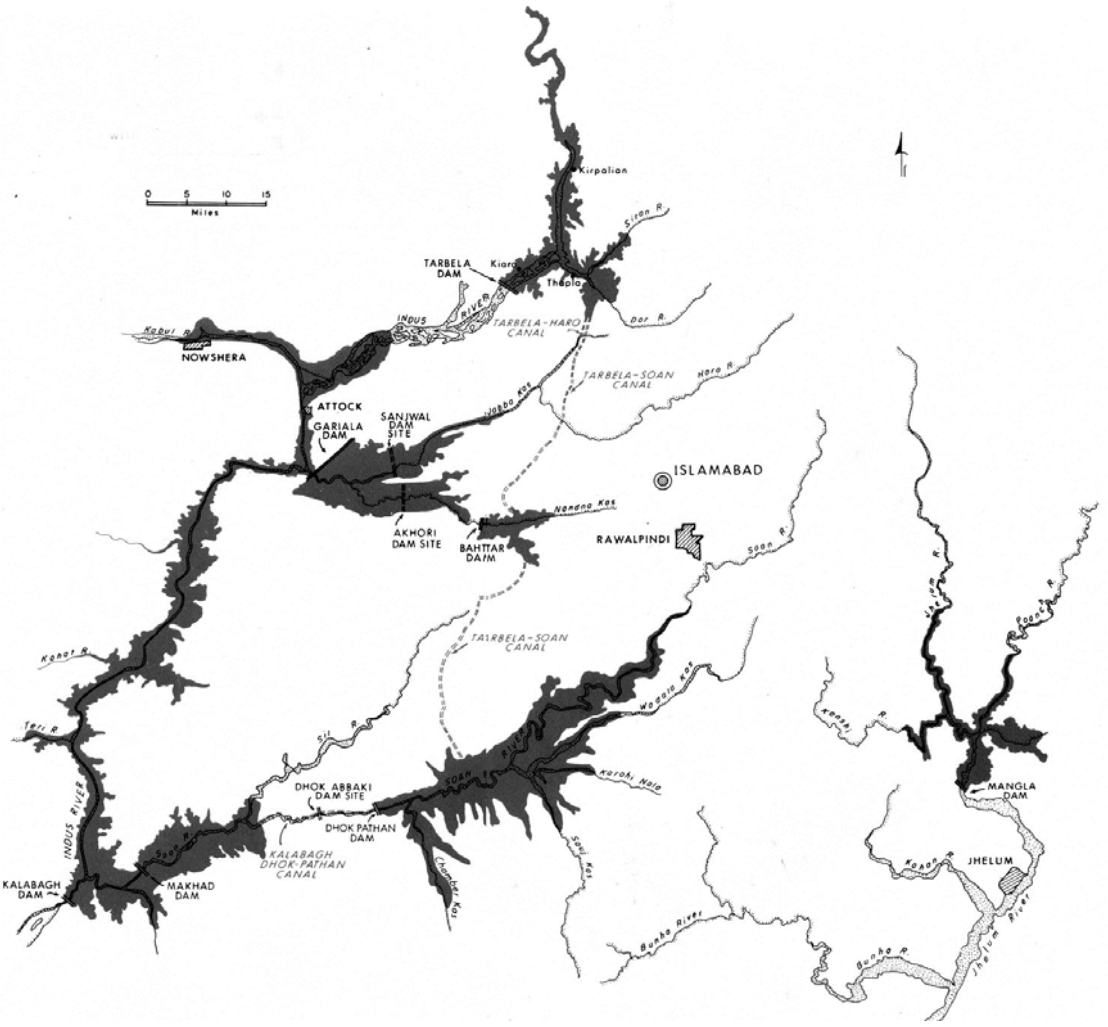

Fig: Location of Tarbela Reservoir, Kalabagh Reservoir and Off Channel Storages

Source: Pieter Lieftnick, A Study in Water Sector Planning, The World Bank, 1968

Sindh is a vast plain, where there are no depressions anywhere. Even hills situated on the western periphery also do not have big valleys which can be used as a reservoir to conserve flood flows which enter Sindh. Volume of flood water entering Sindh is so huge that only a part of this water can be stored in big reservoirs which can provide relief as a flood control reservoir. Therefore, Sindh should take advantage of reservoir sites available on the upstream of Sindh provincial boundaries. Any reservoir above Tarbela reservoir will not be helpful to provide flood control facility. For flood control, the reservoir should be big and located below the confluence of Kabul river with Indus river. These reservoirs will capture the flood flows of Kabul, which along with Khyber Paktoonkhwa's own share of water can be used to irrigate the Chashma Right Bank Canal (CRBC) lift areas. This would give great help to the province.

Unfortunately, for the last 40 years, a strong lobby is opposing creation of any big reservoirs on River Indus. This has resulted colossal loss to the country's economy.

The first big reservoir has been identified as Kalabagh reservoir. In its close proximity, several big off channel reservoirs sites like Dhok Pathan, Dhok Abhaki, Gariala, Sanjwal Akhori, etc, have been identified. If these off channel reservoirs are developed along with Kalabagh

reservoir, the flood peak of Indus River would be greatly altered, lowered and smoothened. These reservoirs can cumulatively give much needed relief to Sindh of its flood woes.

Low Diversion Dams or Barrages:

Barrages or low diversion dams are used to divert river waters. In Pakistan including Lower Indus River, barrages are used solely for diversion of river waters for irrigation purposes. Since, they can divert large quantity of water from river channel they reduce volumes of flood flows downstream in the river channel to a significant level. They act as a flood control work. However, the flumed length of the barrages are mostly only 1 mile in length as against the flood plain of 5 to 15 miles. Fluming creates afflux which is hazardous for the safety of barrages and the operational staff remains under great stress during the flood season. Because of this fluming, the afflux or rise of river level upstream of the barrage is about 3.0 to 3.5 ft at each barrage. This rise in the flood level against the bunds puts great stress on the river protection bunds also.

To cater for super floods in the river usually a place is earmarked along the marginal bund of each barrage which can be dynamited and a breach is created for allowing floods to bypass a barrage. However, it is suggested that a permanent emergency spillway at the same place may be constructed which may come into operation when super flood passes the river.

Embankments, Bunds and Leeves:

River embankments, bunds or leeves are used to protect irrigated and inhabited areas around the flood plain from flood damages. They act like banks of the river channel to carry flood waters safely down to the sea. Since bunds do not permit heavy silt laden flood water to spill over lands around the river, the flood water is forced to deposit its silt contents in the river channel itself, which has risen with time its bed, which has formed a ridge within the bunds. The Indus River in Sindh therefore, flows on this ridge. This has risen the flood levels and requires raising of river embankments periodically.

Dredging of River Channel:

Dredging is the process of excavating material from bed of a water channel and depositing the excavated material sufficiently away from the watercourse. Dredging has been practiced since thousands of years. Egyptians, Chinese and Romans used dredging through crude implements. However, in the modern days United States has been using this practice for the last about 200 years. It has modernized the practice in the early 19th century by use of specially developed machinery. In USA, US Corp of Engineers has been using this practice since 1825 on various American rivers mostly for removing snags in Mississippi & Ohio rivers. Progressively it has started using this practice extensively on many of other US rivers for making these river channels navigable.

At least seven different types of plants based on mechanical and hydraulic principles have been developed of which three types are mostly used. These are cutter head type, bucket type and dipper type. Special purpose type dredgers have also been developed for specific purpose.

Different methods are being used to dispose of the excavated material. The excavated material can be dumped at the assigned places such as for construction of new bunds or raising of existing bunds.

Dredging in rivers is mostly used for either widening, deepening or for improving the river channel length like removal of the neck of the meander, straightening of the channel or for improving its discharge capability. Dredging of river channel can be used as a flood protection measure. Since, it is used to increase river channel dimensions and flow capacities and

capabilities. US Corp of Engineers has been using dredging extensively since long but specially since 1970 in US rivers for improving the river channel dimensions mainly for inland navigation purposes. Dredging can however be used in Pakistan as well, both as a flood protection measure and for inland navigation.

This practice has not been used in Pakistan on rivers but is recommended to be tried in the Lower Indus River specially in its lower reaches.

This will open a new avenue of inland navigation for small ocean going crafts. Ocean going crafts can reach upto Hyderabad.

River Training Works:

Spurs and cutoffs at the neck of river meanders are helpful to train the river, keep the main channel in the required area and to reduce the affects of flood water concentration along the bunds. Concentration creates pocketing affects at some place along the bund which may mean raising of water stage against the bund, which may result in over topping the bund and causing its failure.

Flood Bypass Channels:

Flood bypass is used to divert flood flows away from towns and irrigated areas. The entire area of Sindh province is a vast plain and is intensively cultivated and more or less thickly populated. Therefore, no big capacity channel can be constructed for diverting flood flows. The only possibility is below Punjab-Sindh border where an old abundant bye river on the left of Guddu Barrage, which is called the “Rainee” river exists. Without disturbing the already canal network, if Rainee river is developed as a bypass channel, it will provide the much needed relief to the whole of Sindh. It can be developed to carry large amount of discharge, which can be spread in the desert areas on the left of Dharki. This natural facility should be used to the maximum capacity. The channel may be designed for a sufficiently large discharge which may provide significant relief to the Sindh.

Conclusions and Recommendations:

Conclusions:

1) Between 23rd July and 15th October 2010, as much as 52.9 MAF of flood waters entered Sindh. However, this precious water escaped to the sea, because it could not be stored for use in future water short periods.

2) Flood waters of Kabul River system which escaped to Indus River could also not be stored because there is no reservoir below the confluence of Kabul and Indus Rivers in the system. This water, if stored, could have been used for CRBC lift areas of KP.

3) Expected climate change is going to have serious negative impacts on flood intensity, occurrence and duration.

4) During flood seasons, Pakistan Meteorological Department (PMD) and National Flood Forecasting Bureau (NFFB) issue a comprehensive and adequate bulletin daily which gives flood situation in the rivers and weather forecast on data collected from weather radars. PMD is conducting an improvement programme of its infrastructure. When PMD’s improvement programme for establishment of additional weather radars is completed, PMD would be in a much better position to give better forecasts.

5) Present flood control measures being practiced in Sindh comprises of barrages and bunds. Though, these measures are adequate to handle normal floods, yet, they need to be improved to handle super floods.

6) Illegal bunds or Keiti's constructed by jargirdars and zamindars around their kacha land in the flood plain obstruct flow of flood waters to the sea. This obstruction raises flood levels against the bunds and was the cause of bund breaches and flooding of large rural areas.

7) High sea levels also delayed discharge of river Indus flood waters to the sea.

Recommendations:

Indus discharge above Tarbela is mostly due to snowmelt, whereas, flood discharges in Indus below Tarbela are mainly due to monsoon rains in the catchments. Reservoirs above Tarbela would therefore, not create the desired flood control affect. In view of several options available for flood protection, it is proposed that all the options should be examined. Most viable options of flood fighting are construction of multi purpose reservoirs; bypassing the flood flows from the upper Sindh and thence ensuring safe passage of water to the sea through bunds.

1) There are a number of reservoir sites which can be developed as multi purpose reservoirs. They can be operated singly or in combination with off channel storage reservoirs. These are:

   Main river Reservoir

   Kalabagh

   Off channel storage Reservoirs

   Dhok Pathan

   Dhok Abaki

   Garihila

   Sanjwal Akhori

   Water stored in these reservoirs would be used as irrigation water for all the provinces including Sindh as per Water Apportionment Accord.

2) Bypass through Rainee River is also a very attractive and viable option. Through this bypass a large flood discharge can be diverted to lands in Sindh which can be developed as irrigated areas.

3) Bunds would continue to remain the back bone of Sindh flood control measures. However, their designs have to be examined specially regarding DHFL and provision of adequate free board to minimize the chances of over topping.

4) All illegal bunds or Keiti's as they are called locally which have been constructed in flood plain by Jagirdars to protect their private kacha areas should be removed before the next flood season.

5) All barrages would continue to divert flood flows and would provide relief as flood control measure. However, permanent emergency spillway at each barrage should be constructed at marginal bund.

6) Dredging of lower reaches of Indus would improve the discharging capability of Indus to the sea. It would also open a new avenue of inland navigation from Arabian sea upto Hyderabad.

7) River Indus has prominent place in the economy of the country and specially in Sindh. This requires that the flow of River Indus should be managed both in low flow and in flood seasons, in the best way it could be done by adopting modern management

methods. This requires that the engineers should be given relevant knowledge at the university level. Unfortunately, no university in the country teaches river engineering as well as hydrology as separate courses.

It is recommended that to improve the knowledge and understanding of engineers in I&P Departments, courses in river engineering and hydrology may be introduced as separate courses at under graduate levels. Similarly, a post graduate diploma course be introduced at all those engineering universities and colleges where irrigation engineering is being taught.

Epilogue

Conclusions and recommendations may be studied and due considerations to them may be given.