"Flood Disposal in West Pakistan"

By

* SARDAR ALLAH BAKHSH

The floods have always been employed by nature as a means for destruction. Nature's agents of destruction become active whenever human society is believe to be transgressing the limits defined by God. The earliest known floods came during the time of Noah and the continuity of life is believed to have been maintained by the rescue provided by Noah's Ark. It is hoped that we are not amongst the trangressors. However in the Indo Pakistan Sub Continent the floods have assumed an alarming position in the last one decade. High floods of unusual magnitude once in a period of 30 to 40 years were not unknown in this country but in the last decade the frequency of the visits of high floods has increased. The total volume of water brought down by the floods now is much more than before. Every year the floods come, our communications are disrupted, irrigation system is upset, thousands of houses collapse, crops of the value of millions of rupees are destroyed and millions of people become homeless. Disease and hunger take many lives and thousands of heads of cattles are lost. If such a catastrophe visits once in 30 or 40 years the patience of human beings may stand it, but if the catastrophe visits too frequently human beings neither have the patience nor have the means to bear it. The floods of the last decade have shattered our economy and something has got to be done to prevent the occurrence of floods or at least to lessen the ill-effects of the floods by their safe disposal into sea.

Scope of the Subject.

The causes of occurrence of floods, their prevention and the means required for flood control in the mountainous and sub mountainous regions have been separately dealt with by other writers in this symposium. This paper deals with the subject of "flood disposal". When the floods enter the plains there is no alternative but to receive them. We have to endeavour to conduct the avalanche to sea in such a way that it does no damage enroute. This paper deals with the methods employed to conduct safely the huge accummulations of water to sea through channels defined by nature or man made ones.

It is not within the scope of this paper to describe the causes which lead to the precepitation of heavy rainfall in the catchment areas of rivers and subsequent accummulatations of huge volumes of water

* Superintending Engineer, Upper Jhelum Canal, Jhelum.

which lead their way to the plains in the form of floods. There have been varied opinions regarding the factors causing floods. Some believe that due to atomic explosion there has been more radiation and thus more evaporation from surface of sea resulting in heavy rainfall in catchment areas; others believe that due to formation of zones of low pressure in the atmosphere there has been concentration of rainfall resulting in heavy floods. Some more believe that on account of deforestation process in the mountainous areas the rate of run off has gone high and that results in floods. Yet there are some who advocate that because of geological convulsions there has been considerable change in the catchment areas of rivers which results in floods. Whatever may be the causes of floods one thing is certain that they visit us more frequently than they did before and that their visits are highly undersirable. Therefore it is up to us now to devise ways and means to save human life and property from being destoyed and to be able to conduct the floods safely into sea. The following are the possible ways of achieving this objective.

1. To eliminate or reduce the chances of occurrence of floods.

2. To construct flood control works i.e. resevoirs, dams and artficial lakes etc. or resort to afforestation in the catchment areas.

Unfortunately we have not yet discovered exactly the causes of occurence of floods of unusual magnitude. As such, to think of eliminating or reducing the chances of their occurrence at this stage is not possible. In fact floods are no longer a problem for Pakistan alone. U. S. A., Ceylon, China, India and U. S. S. R. and many other countries of the world have also suffered from flood in the last one decade and this problem has now acquired international importance.

Countries like U. S. A. have the advantage of having flood control works like dams and resevoirs etc. In Pakistan unfortunately no such works exist. The catchment areas of our rivers lie in India, the construction of flood control works is not possible unless India co-operates and such works are then taken up as a joint enterprise. In Pakistan we will have to face the problem of floods for a long time to come till both India and Pakistan come to an agreement and decide to solve this problem jointly. As such for us now the most important aspect of the floods is **their safe disposal into sea**.

The following table gives an idea of the volumes of water passing down in rivers from 1942 to 1957.

TABLE SHOWING THE HIGHEST FLOOD DISCHARGES

	River Jhelum		*River Chenab*		
	Mangla	*Rasul*	*Marala*	*Khanki*	*Trimmu*
Designed capacity	—	9,50,000	7,00,000	7,50,000	6.40,000
Year					
1942	1,34,694	1,50,880	3,01,500	2,88,393	2,75,949
1943	1,83,880	1,56,756	2,56,900	2,20,574	2,47,238
1944	1,98,605	2,30,594	2,58,970	1,64,719	2,65,614
1945	1,44,400	1,50,000	2,07,650	1,80,106	2,70,687
1946	2,24,570	1,43,884	2,63,539	2,29,630	2,93,000
1947	1,30,801	69,968	2,81,000	2,36,583	2,27,935
1948	4,40,684	7,30,000	4,32,000	4,38,529	5,36,329
1949	1,55,412	1,65,000	2,51,965	2,24,949	2,10,600
1950	2,78,700	3,62,000	5,40,761	9,86,656	6,55,560
1951	1,20,500	2,75,000	1,93,847	2,17,868	1,97,570
1952	2,32,500	2,40,000	2,09,570	2,64,065	2,60,813
1953	2,86,500	3,75,000	3,16,198	3,15,330	2,56,584
1954	2,22,900	4,25,000	8,20,096	8,06,744	4,10,193
1955	1,75,000	2,10,000	3,44,090	2,30,490	2,85,700
1956	3,02,900	3,75.000	2,76,220	3,40,663	3,44,928
1957	1,20,500	1,75,000	4,93,385	10,86,416	5,59,575

	River Ravi		*River Sutlaj*		
	Balloki	*Sidhnai*	*Suleimanki*	*Pallah Islam*	*Panjnad*
Designed capacity	1,39,500	69,860	3,28,000	2,75,000	7,00,000
1942	1,55,500	62,200	3,31,026	2,84,000	4,34,688
1943	66,500	51,930	3,09,408	2,28,900	3,32,639
1944	53,300	29,662	2,05,000	1,04,145	2,83,764
1945	61,300	33,200	2,44,571	1,90,400	2,62,692
1946	61,000	34,000	2,09,960	1,35,825	2,48,500
1947	1,40,572	58,670	3,60,412	2,85,254	2,09,874
1948	1,00,840	69,286	1,70,350	1,84,742	4,89,634
1949	59,926	46,233	1,29,104	98,404	3,12,426
1950	2,25,540	85,985	3,32,102	2,70,800	6,76,722
1951	52,190	33,725	2,86,070	1,59,911	2,45,630
1952	61,370	51,625	2,62,043	1,42,001	3,34,108
1953	87,000	73,369	2,74,644	1,47,098	2,73,098
1954	1,90,950	91,355	2,33,782	1,80,207	3,81,636
1955	1,44,360	1,95,400	4,21,872	3,82,106	5,50 000
1956	74,774	57,718	1,14,455	1,60,473	3,86,891
1957	1,68,700	1,12,543	2,16,033	1,89,017	5,59,000

The above figures do not include the discharge passing through the breaches of the marginal bunds which in most cases gave way under the pressure of high floods.

A comparison of the highest flood with that of the designed capacity of the head works is given blow :-

Name of H/Works	Designed capacity	The maximum discharge reached at this point	Year
Mangla	—	8,05,000	1929
Rasul	9,50,000	8,75,000	1929
Marala	7,00,000	8,20,096	1954
Khanki	7,50,000	10,86,416	1955
Trimmu	6,40,000	6,55,560	1950
Balloki	1,39,500	2,25,540	1950
Sidhnai	69,860	1,95,400	1955
Sulemanki	3,28,000	4,21,872	1955
Islam	2,75,000	3,82,106	1955
Panjnad	7,00,000	5,59,000	1957

From the above it is evident that except for Panjnad and Rasul the Headworks are not capable of passing the floods that have now started visiting the headworks.

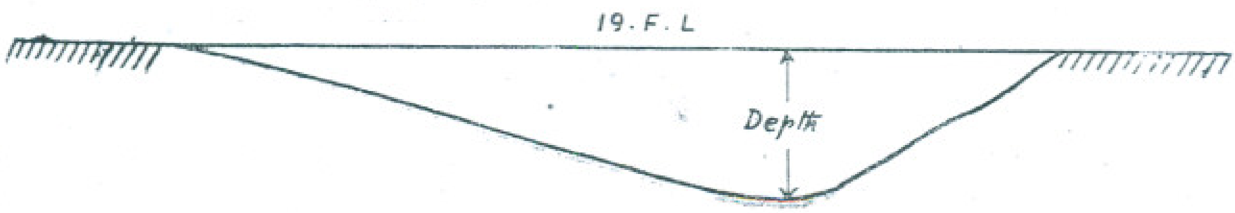
THE RIVER.

For quick and efficient disposal of floods the rivers play the most important role. Rivers are the natural drainages of a country. Nature itself has designed the rivers. The long section of a river generally runs along the lowest contour of the country it serves and the X-Section of a river in the plains is more or less cup-shaped i.e. deepest in the centre and shallow on ends. Nature's designs are perfect and a river's design, therefore, is supposed to cater for all time needs of a country as far as flood disposal is concerned. The carrying capacity of a river depends on the following factors :-

1. Shape of the X-Section of the river.
2. Slope.
3. Nature of the bed material.
4. Tortuosity.
5. Obstructions on the way.

Shape of X-Section of a River.

The general shape of the X-Section of a river in plains is cup shaped as shown in the Figure.



Maximum depth is some where in the centre or at a point where main current flows. The sides are shallow and slope upwards towards both banks till high ground is met. The position of the deep current keeps changing slightly from year to year and generally remains in the central portion of the X-Section of the river.

The carrying capacity of the river depends on the area of X-Section of tbe river.

Discharge = Area x Velocity.

Area = Breadth x Average depth

For the same breadth the carrying capacity of a deep river will be more. Therefore deep rivers are more efficient than shallow rivers.

Slope.

The slope of a river is important as the slope determines the velocity of the stream and also the highest flood level depends on slope. For the same discharge a river with steeper slope will acquire lower flood levels and more velocity. It will take less time to dispose of the flood. The slopes of West Pakistan rivers range from 3′ per mile in the sub-mountainous regions to about 0·5′ per mile in the delta areas. Therefore in the upper reaches the rivers have more capacity but the capacity decreases as the river enters the plains inspite of the fact that Khadir width increases as the river travels down and down.

Bed Material.

River beds in West Pakistan are made up of erodable alluvium. During rising flood stage when volume of water is more the bed as well as the sides are scoured and the carrying capacity of the river increases. While in the falling floods the sillt burden is again deposited in the bed or on the sides.

Tortuosity.

Tortuosity is an other important factor in river regime. Molly's theory of river regime explains the behaviour of an alluvial river in detail. The bends and cut offs are formed as the river flows down over an alluvium bed. A more tortuous river will have a more flat slope, shallow bed and low velocity where-as a straight river will have a steeper slope, deep bed and a high velocity. It is, therefore, clear that the flood disposal capacity of a straight river is much more that of a tortuous river. Tortuosity of rivers varies from river to river. In the sub mountainous regions the tortuosity varies from 3% to 8% while in delta areas the tortuosity increases to about 40% and this is one reason why the flood carrying capacity of a river in the sub mountainous regions is more than in the delta regions although the discharge in the delta regions decreases and Khadir widths increase.

Other Obstructions.

With the advance of civilization there has been more development of lands lying in the old river beds. Human habitations have sprung up, fields have been raised with various types of vegetation, railways and road bridges have been constructed, weirs have been made, syphons, aqueducts and other works of similar nature have been constructed. River training works like the protection bunds, marginal bunds, guide bunds, spurs, groynes, pitched islands have been constructed with a view to train our rivers. All these works having their own utility cause obstruction to the flow of water and result in swelling up of the water flow.

These obstructions are responsible for increased flood levels, reduction in the slope of the river and silting up of the beds. All these factors tend to reduce the flood disposal capacity of the rivers.

The following are the impor-tant obstructions in our rivers in West Pakistan.

River	Headworks sites	Railway Bridge sites	Road Bridge sites	Syphons and aqueducts	Other works
Jhelum	Mangla Rasul	Jhelum Malakwal Khushab.	Jhelum Khushab	Nil	-
Chenab	Marala Khanki Trimmu.	Wazirabad Chiniot Sher-Shah	Wazirabad Chiniot Sher-Shah	Nil	Marginal Bunds, Spurs etc.
Ravi	Madhopur Balloki Sidhnai	Lahore Abdul Hakim	Lahore Balloki Sidhnai	Batapur	-do-
Sutlej	Ferozepur Sulemanki Islam Pajnad	Ferozepur	Ferozepur Sulemanki Islam Pajnad	-	-do-
Indus	Kalabagh Kotri Sukkur	Attock Kalabagh Sukkur Hyderabad.	Attock Kalabagh Sukkur Hyderabad	-	-do- Weirs at Taunsa & Guddu are also under construction.

Apart from the above permanent obstructions a lot of vegetation has over-grown on the natural beds of our rivers. Human habitations have sprung up even in the riverain areas. In fact nature had given us latitude in so far as no serious floods visited us for a long time. In this period of respite a number of canals were made in the riverain areas. People were settled on these canals and a civilization sprang up in these areas which were the flood basins of the rivers. The population of these areas is the most distressed population during floods. Construction of these canals was not based on sound economic conisderation. The mistakes committed in the past could be overlooked but some works have been undertaken recently inspite of the fact that the floods were hitting us badly every year. The examples of such badly planned works are 15R Disty : in Gujrat District and Ram Nagar Minor in Gujranwala District. Our experience with these works is unhappy. These works are vulnerable to floods even of a small magnitude. Their existence has reduced the disposal capacity of river basin and almost every year our economic losses are great. Without these works we could have been happier. It is recommended that development works in the flood basins should not be taken up in future.

Unfortunately our rivers have not been surveyed for a long time. Long Sections and cross-Sections of these rivers have not been prepared. No details of the habitations, nature of obstructions and over-growths are available to any degree of accuracy. Some records are maintained to show the conditions of river X-Sections a few miles U/S and D/S of the canal Headworks, but beyond that no data is available to estimate the capacity of a river. Probably this was not required in the past, but now it is essential to observe this data.

The bed material contains fertile silt, making growth of vegetation possible. Most of the land in the riverain tracts is over-grown by shrubs, bushes and trees. This increases the co-efficient of rugosity of river bed and thus reduces carrying capacity of the river. It is difficult for the river to erode this land quickly and widen its way during rising floods. During low supply seasons the tortuosity is appreciable and the main stream generally confines itself to the long and tortuous route having a flat slope. The adjoining soil being thickly overgrown by bushes and trees is difficult to erode. When a high flood sudden-ly comes all these factors stand against the quick passage of flood. The channel is restricted, the sides offer resistence, obstructions like weirs, bridges, etc. are insurmountable, therefore the flood water swells up and attains much higher levels than desirable. In most cases the bunds which have been designed for lower levels give way and flood water causes a havoc for the population.

In a flood the total volume of water is not so important as the level at which this volume passes down the river. What I mean to convey is that a discharge of 700,000 cusecs at Kalabagh may not be as dangerous as a discharge of 100,000 cusecs at Balloki, because at Kalabagh 700,000 cusecs pass at a low level causing no spill while at Balloki even 100,00 cusecs pass at a high level causing spill. The terms high and low levels are relative to the vicinity areas. A small discharge passing through a narrow and shallow channel assumes a high level and becomes dangerous while a huge discharge passing through wide and deep channel at a low level will do no harm. **Therefore for safe passage of floods the channel has to be clear of all obstructions, it should have wide and deep X-Section and an adequate slope.**

Before I attempt to describe any methods for disposal of our floods it is necessary to observe the main characteristics of our rivers.

It is important to know what is common in the behaviour of our rivers and in what characteristics they differ. A proper appreciation of these characteristics will guide us to take effective measures to disperse the floods. The following are the characteristics of our rivers.

Characteristscs of our Rivers.

1. All of them have their sources in the Himalayas. The catchment areas lie outside Pakistan.
2. Since the slope of the country is from North East to South West, all the rivers flow in that direction.
3. The Northern Banks of our rivers are higher than the Southern banks. With a few exceptions in certain reaches all of them have a tendency to spill towards the south.
4. All of them carry fertile silt load which is most useful for raising crops.
5. All the centres of our old civilization are located on river banks i.e. towns like Jhelum, Shahpur, Gujrat, Sialkot, Wazirabad, Jhang, Lahore, Multan etc. etc.
6. During monsoons the river discharges swell up to lacs of cusecs while in winter the rivers sometimes completely dry up. The variation between minimum and maximum discharges is extraordinarily high.
7. A number of weirs and barrages have been constructed on all the rivers. At the weir or barrage sites a certain pond level is to be maintained to feed the canal systems. Upstream of the barrages there is noticeable accretion while down stream of the barrages there is retrogression. Crest levels of the barrages are permanently fixed and flood water has to pass over them.
8. During high floods water spills out of the main channel, however, when the flood levels fall the spill water recedes back into the main channel and affords a quick relief to the flooded areas.

Ravi is however an exception. It is commonly believed that spill water of Ravi does not return to its main channel even when the floods recede in the main channel. This is probably due to the fact that in certain reaches river Ravi runs on a ridge instead of running on the deepest contour of the countryside. This is a novel aspect of this river and probably that is why this river inspite of its low discharge is more harmful than Jehlum and Chenab, which carry comparatively higher discharges.

After knowing the characteristics of our rivers we are now in a position to proceed to examine the carrying capacity of our rivers and lay out a programme for the disposal of the floods. The following methods of flood disposal are discused and recommended for future.

METHODS OF FLOOD DISPOSAL

1. An efficient system of sending out flood warnings to be set up.
2. A detailed survey of each river should be done. Long sections and X-Sections at every 5 miles should be observed for each river.
3. Devices to lower the H.F.L. be introduced. Weirs barrages, bridges and other works to be tested and redesigned to meet the new challenge of the floods.
4. Diversion channels to be provided in the reaches where disposal capacity of the section is inadequate.
5. To introduce devices to give time-lag and break the synchronisation of floods.
6. River basin to act as a dead storage reservoir.
7. The existing bunds and spurs to be tested and re-designed to suit the new requirements.
8. A well-thought plan to be laid out for an efficient disposal of floods of great magnitude in each river.

Flood warning.

The most important item for proper disposal of floods is a timely and accurate warning. Prior to 1950 flood warnings were issued from the canal headworks to all the canal and civil officers of the concerned districts likely to be inundated by such floods. These warnings were issued by postal or canal telegrams. In many cases the warnings remained undelivered and if delivered these were not taken notice of by the concerned officials. 1950 floods shook everyone. For Chenab the warning used to be received from Jammu. In 1950 no warning was received from Jammu as Jammu was under Indian occuuation. For Ravi warning used to be received from Madhopur, no warning was received from Madhopur as this formed part of India after Independence. We were caught unawares by the unprecederted floods in Ravi and Chenab in 1950 and the consequences suffered by us form part of an unfortunate history of this country. The importance of the flood warnings was therefore realized by the Government and a system of wireless sets was brought into operation. These wireless sets now work during flood season and continuously send out warning to all the concerned officers on headworks and and in the districts. This system has proved very useful and needs to be further improved and strengthened on proper scientific lines. It will be better if the Irrigation Department whose primary duty it is to look after the floods should have its own system of wireless sets installed at all Head Works and Circle headquarters.

2. River surveys.

In 1951 M/s M. A. Rahim, I. A. Zafar and Sadiq M. Niaz worked out the average rate of accretion of our rivers at certain sites. This data although insufficient is reproduced below to give and idea to the reader :—

River	Site	Average rate of accretion per year
Indus	Kalabagh	0·054 feet
	Milton	0·195 ,,
	Kotri	0·065 ,,
	Sukkur	0·154 ,,
Jehlum	Jehlum Bridge	0·020 ,,
	Trimmu	0·192 ,,
Chenab	Rivaz Bridge	0·136 ,,
	Alexandera Bridge	0·066 ,,
Ravi	Shahdara	0·050 ,,
	Sidhnai	0·082 ,,
Sutlej	Islam	0·440 ,,

The above table gives an idea of accretion mostly on the railway bridge sites where heading up is low as compared with the heading up caused at weirs. Unfortunately no sueh data has been worked out for weirs in the Punjab. To form an accurate idea regarding the extent of silting up the data at every Headworks will have to be collected and examined in detail.

The silting up of the bed of a river reduces the area of flow. The carrying capacity of a river is expressed in the simple equation.

$$Q = A \times V$$

Where Q=Discharge

A=Area of X-Section.

V=Average velocity of stream.

In a flood we cannot reduce Q. To be able to pass flood in the river course at convenient flood levels the only factors to be adjusted are A and V.

Area of Section $= B \times D$ where

B =Breadth or Khadir width.

D =Average depth over the X-Section.

Most of the Khadir widths of rivers are overgrown with jungle and are also silted up. Therefore to effect an improvement in the area of X-Section it is necessary to remove heavy jungle growth and to lessen the silt burden. Velocity is a function of slope. Therefore to increase velocity the slope will have to be increased and this will automatically increase depth. Also velocity can be improved by keeping the X-Section clear of obstructions like the jungle etc. as this will reduce co-efficient of rugosity. To effect a quick disposal of flood discharge Q, all tnat is necessary is to keep B clear and devise ways and means to increase velocity. Nature has defined the limits beyond which B can not be increased. Increase in B means more flooded areas. However to improve the carrying capacity of the X-Section we can do the following :—

(i) To keep the whole width of the X-Section clear from undesirsble types of bushes, shrubs and jungle which cause an obstruction to the flow.

(ii) Increase D and thus improve carrying capacity. In view of the limitation already described under the heading "Characteristics of our rivers" it is not an easy task to increase average depth of our rivers. The following steps have to be taken to achieve it.

(a) **To observe the L-Section and X-Section of the river**.

Before a comprehensive plan for a flood disposal scheme of a certain river is prepared it is essential that a long section of the river be prepared and at every 5 miles interval along the L-Section, X-Section should be observed. An examination of the L-Section and X-Section will clearly give the existing carrying capacity of the river at each point and at various heights. The whole length of the river is to be tested in this way to examine whether the river can pass the flood at desirable levels. In case the river section needs improvement at certain places this has to be done by clearing the jungle or removing other obstructions or if necessary by digging local cunettes. Dredging of our rivers has not been done so far. This is a more sure method of increasing the depth of the river. This has not been tried for the evident reason that it is expensive. Also there being no navigation in our rivers, dredging of these rivers has not been considered necessary. But now a serious thought is to be given to this problem as to why dredging should not be tried to improve the capacity of our rivers particularly the Ravi in which case even nature's design appears to have been exceeded.

(b) The silt burden upstream of weirs can be washed by careful manipulation of the weir bays or undersluice gates during winter freshets of January. A provision in the regulation rules of each Head Works needs to be made to make use of the winter freshets in January or to make use of the rising river discharges in May and June to wash all silt burden above the weir bays and keep the whole weir breadth ready for disposal of floods. These washing operations will automatically improve D to a certain extent particulariy if the washing is done through the under sluice gates at a low pond level. With this much care the X-Sections of the river will be clear of all obstructions and ready to receive the flood.

3. Devices for Lowering the H.F.L.

Amongst our rivers Jhelum has been quiet since 1929. Chenab, Ravi and Sutlej have been furious and have far exceeded the discharges for which the weirs on these rivers were designed and constructed. The new challenge has been repeated more than once. Since 1942 we have been avoiding to redesign our weirs to meet the new challenge. All that has been done is to raise our marginal bunds, extend them to meet yet higher ground and force the floods to pass over the same weir crests at much higher levels. For protection of affected lands and towns we have constructed protection bunds and thus afforded them relief from suffering. Experience also shows that the subsequent floods have risen to still higher levels and in many cases have broken the defences provided by us. The course of raising and strengthening the bunds therefore is not at all advisable as this induces further accretion and further rise in flood levels takes place. The strengthened bunds under the new conditions again become unsafe in a few years time. This arrangement is therefore unsatisfactory. We must therefore re-examine our weirs, bridges and syphons and improve them with a view to pass the last known maximum flood discharge with due factor of safety for future. The improvement should be effected in such a way that the H.F.L. is lowered and the depth of the river upstream and down stream of the works is increased. This can be done by the following devices :—

1. To lower the crest of the shutter type weirs where possible.
2. To convert the shutter type weirs into barrages with low crest.
3. To provide under-sluice bays in the centre of the weirs.

With the introduction of the above devices the disposal capacity of the weirs will improve and also such disposal will be effected at a desirable flood level. The protection bunds and marginal bunds will remain more safe against the risk of breaches.

4. Construction of Spill Channels or Diversions.

In some reaches of rivers where the X-Section of the river cannot be improved or the weir or barrage cannot be remodelled or improved to take care of the total increased flood discharge the answer lies in constructing the spill channels. The idea of spill channels or diversions is not new. The diversion of river Ravi was done in Moghal time. This was necessitated by the fact of river Ravi threatening the safety of the important town of Multan. The old Ravi used to flow near Multan Fort in the area still known as Rava. This diversion was probably planned by an Iranian Engineer. The levels were favourable and Ravi was joined with Chenab by cutting a straight 11 miles cunette known as the Sidhnai i.e. the straight river. Another spill channel is under construction at the same site i.e. about 10 miles above Sidhnai weir. The old diversion channel served us efficiciently for about a couple of centuries but due to the construction of Sidhnai weir the capacity of the diversion has been restricted creating new problems and necessitating another diversion. The spill channel will dispose off 30,000 cusec flood discharge and will relieve pressure on the Sidhnai Head Works. The flood levels that increase due to heading up caused by in adequate disposal at Sidhnai will also be lowered and thus provide a great relief to the left and right marginal bunds which have been breacning frequently.

This spill channel has been undertaken because it was believed that the monolithic mass concrete of the crest of Sidhnai Head Works was not capable of being broken and thus crest level could no be lowered and secondly because there was no steel available to convert Sidhnai Weir into a barrage. I still believe that lowering of crest of Sidhnai is the real answer for proper disposal of flood at that site and that this will have to be done one day.

The reach of river Ravi from Bedian to Balloki is also not capable of disposing of the floods and therefore another spill channel in this reach may have to be constructed one day if the Balloki Barrage is not remodelled.

5. Time Lag.

Time-lag is an important factor in the disposal of floods. Before the occurrence of a flood there are continuous and heavy rains in the catchment areas of rivers. The accummulations of discharge travel down the hills and join each other. More nullahs and torrents join on the way and thus it becomes a wall of water. If the times of all these sources that contribute to make a flood synchronize with each other this becomes a huge avalanche travelling down in the form of a wall af water and the limited capacity of the river channel is unable to accommodate this avalanche. However if this synchronization can be broken by check dams and reservoirs the same river channel can dispose of this total volume of water over a longer period of time.

The West Pakistan rivers after leaving the hills travel some distance in the plains and then join another river and finally all join the Mighty Indus. Jhelum joins Chenab at Trimmu. Ravi joins them at Fazil Shah and Sutlej joins tbem at Panjnad and ultimately all fall into Indus below Panjnad. Synchronization of the floods of two rivers is a rare phenomenon. It is very seldom that Chenab and Jhelum being both in very high flood join at Trimmu at the same time or Ravi and Chenab both in high flood join at Fazal Shah at the same time. If natur schemes against us this can also happen.

The Time-lag factor is therefore very useful to disperse floods. Time-lag can also be created to a certain degree by working links, diversion channels and spill channels. This type of action can reduce the peak discharge of a flood on a point of attack down below. If one river is in flood a part of the discharge of this river could be diverted into the other river through a link or spill channel to reduce the intensity of discharge down below. The existing links being irrigation channels are not being used for this purpose for fear of their being silted up. It will be wrothwhile examining if under worst conditions these links could be used to creat time-lag. In case of Ravi a good relief could be afforded tc Sidhnai if B.S. Link takes off 15000 cusecs in addition to 30000 cusecs taken by the spill channel.

6. River Basin Acting as a Dead Storage Reservoir.

The river basin itself acts as a dead storage reservoir and consumes an appreciable discharge of the advancing flood. As the flood advances the low lying areas, local depressions, ravines etc. get filled up and consume a good volume of water all along hundreds of miles of length of a river. Therefore a big flood in Ravi doing considerable damage near Lahore may not be as dangerous near Sidhnai about 175 miles down below as quite a considerable part of the flood will be consumed enroute to fill up local depressions and river basin itself. The intensity of discharge will reduce as the flood travels downwards. At the same time if the first flood is followed by another one in quick succession, this may not be taken lightly simply because its predecessor being greater in magnitude had done no damage. This second flood of comparatively lesser magnitude may prove dangerous as this time the river basin's dead storage will have no effect. The basin is already full and therefore the full effect of the flood at Lahore will reach Sidhnai and will cause more damage than its great predecessor.

7. The existing bunds and spus etc. to be tested and redesigned to suit the new requirements.

The existing systems of bunds and spurs etc. need to be tested. It is possible that a certain spur or a bund may be causing unnecessary heading up and may have to be removed or retired. The shanks of the spurs particularly cause serious obstruction to the flow and consideration may be given to the necessity of keeping intact or doing away with such types of works. However these bunds and spurs which have to b e kept should be maintained with meticulous care. These bunds have to stand against the hydrostatic pressure of the flood water. They have to be free from cracks or rat holes. Apart from these a new danger has sprung up to these bunds since the visits of these unprecedented flo ods and this is from human interference. In certain cases doubts arose whether the bunds were not cut by the inhabitants of the village lying inside of the bunds on the river side which get drowned by the flood water. The only way these villagers can save themselves is to cut the bund and certain mischievous elements can always try such a thing without knowing the damage they are doing. Therefore in future care must always be taken to safeguard the bunds against the possibility of a cut by the interested villagers.

8. Need for proper planning.

The foregoing justifies the need of advance planning to receive and dispose of flood in each river. A Flood Control Organization has already been set up by the West Pakistan Government and it is hoped that this organization will prepare detailed schemes for proper disposal of floods which visit us in future.