Paper No. 181

FLOODS IN INDUS BASIN THEIR CONTROL AND MANAGEMENT

by

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SUMMARY

Reliable discharge data at most control points is available for 71 years. Their occurrence and frequency is scrutinized. There is no way to predict them on long term basis. The events for 1992 floods are recorded giving over-view of the development of this flood. The total losses due to flood damages have been considered and it transpires that during the last half century Pakistan has suffered direct losses of over Rs. 150 billion; various intangible losses are above these. Various methods of prevention and control of floods are discussed; channelization i.e. dredging of rivers or widening of Barrages are not supported. The present system of management of flood is discussed and improvements suggested. Pertinent and concise conclusions drawn by the author are listed on the last pages.

The observations and discussions in this paper are for the main rivers of the whole of the Indus basin, however pertinent data and dates are mainly given for Punjab in the northern part of which the floods first enter the plains.

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FLOODS IN INDUS BASIN THEIR CONTROL AND MANAGEMENT

INDUS BASIN

River Indus is the main artery of the Indus Basin System of rivers. The five major eastern tributaries of river Indus are; the Jhelum, the Chenab, the Ravi and the Sutlej (with the Beas in India). In addition numerous smaller tributaries and sub-tributaries including Nullahs and torrents join the river Indus directly or indirectly. The major eastern rivers group together and the combined River Panjnad (also called River Chenab) join the river Indus near Mithankot about 60 miles upstream of Guddu Headworks. Mithankot to Kotri is about 420 miles, Kotri to delta 134 miles along the river. Mithankot is situated about the middle of the Indus plains between the foot-hills of the Himalayas and River Indus delta.

On the western side of river Indus there are a number of hill torrents which are generally non-perennial, but bring in flashy floods. Some notable rivers on the western side are the Karam, the Kohat and the Kabul (with Swat). In fact the Indus plain owes its existence to these rivers, built up over billions of geological years. The classic pattern of rivers and tributaries is shown in the map at Annexure A.

The main rivers/tributaries have their source in the Himalayan range of mountains. Most of their hilly catchments lie outside Pakistan namely in China, India, Jammu and Kashmir (Disputed territory) and Afghanistan. The total hilly catchment is of the order of 176,000 sq. miles. About 2/3rd of the total catchment feeds river Indus, while Sutlej has 17%, Jhelum and Chenab have 7% each and Ravi 2%.

HISTORICAL OCCURRENCE OF FLOODS

All the main rivers are perennial but their water discharges vary from a few hundreds in the winter season to hundreds of thousands of cubic feet per second during the flood season. This trait of these rivers amongst other things, makes it almost impossible to rigidly control and harness them. Further due to limited valley storages in the upper catchment there is rapid build up of flood peaks.

Although freshets have occurred in early March especially in river Chenab, the flood period is mainly from June to September/early October in all these rivers. The floods are

thus a normal feature of these rivers and occur almost every year to varying extent. Since reliable river gauge observations started, in approximately 10% of years the floods have occurred in June and September each and 40% of the time in July and August each. During less than 1% of the years the floods have occurred in early October.

Based on the catchment areas of the rivers, their average flows and regime capacities within the Khadir, Committees of Experts have over the years categorized the floods into 5 types viz; Low, Medium, High, Very High and Exceptionally High (or Super) Flood. At Annexure B is given a statement showing the flood limits and design capacities of various Barrage sites. The river Ravi having the lowest catchment, has the lowest flood limits and exceptionally high flood is over 1.8 lac cusecs only. Super floods which are the most devastating however do not occur every year. Salient data of main rivers and years of occurrence of exceptionally high floods is given at Annexure C.

Discharge data is available from 1922 onwards for river Ravi, Chenab and Jhelum and from 1928 onwards for rivers Sutlej and Indus. (Data for river Indus at Attock Bridge site is available from 1868 onwards but in any case, before the construction of the Barrages and the Headworks to supply water to irrigation system no super flood i.e. above 8.0 lac cusecs was reported at Attock from 1868 to 1927. During that period the highest recorded was 6.89 lac cusecs in 1924. At Annexure D is given the history of occurrence of super floods in all the main five rivers. It will be noticed that super-floods occurred mainly in August and September in all the rivers with exceptions in 1942, 1959 and 1960 when the super-floods occurred in July, and 1955 and 1988 when they occurred in October.

During the 71 years since the discharge data is available at some Barrages continuously, super-floods occurred only 15 times (i.e. during 15 years) generally in 2 or 3 rivers the same year, except in 1950 when all the rivers had passed super-floods; Jhelum and Indus in August, and Sutlej, Ravi and Chenab in September. Fortunately due to the topographical divisions of the catchment area in between the various mountain aretes, the floods in the rivers did not synchronize. If this ever happens that will be 'the deluge'. Due to non-synchronization alongwith the larger capacity of river Indus valley storage super-floods downstream of Mithankot occurred only 5 times against 15 times upstream of Mithankot. For example the 1988 flood characterised by the fact that it affected only the rivers Chenab, Ravi and Sutlej was mainly confined to Punjab where it caused very heavy damages. The pattern repeated itself in 1992 also, although lower Indus had rain damages.

The worst hitting rivers which also pass through the most heavily populated areas and intensive agricultural cropped lands in Pakistan are rivers Chenab and Ravi which passed super - floods 12 times and 9 times respectively during the 71 year period.

Super-floods mentioned above do not represent the historic maximum discharges, which are given below for each river:-

River	Site	Year	Historic Max. flood (cusecs)	Return period (years)	Remarks
Indus	Kalabagh	14-7-42	9,50,000	55	Pre-Tarbela
Jhelum	Rasul	5-7-59	8,76,000	30	Pre-Mangla
	Rasul	10-9-92	9,52,170 + 50,000*	P.M.F. (Mangla)	Post-Mangla
Chenab	Marala	26-8-57	11,00,000	100	
Ravi	Shahdara	27-9-88	5,76,000	175	
Sutlej	Sulimanki	9-10-55	5,98,872	120	Pre-Bhakra

(*The additional 50,000 cusecs shown at Rasul is estimated through Breaches on the left flank).

FLOOD FREQUENCY

The records show that generally 'dry periods' in Indus Basin occurred between 1930 and 1941 (12 years) and again between 1977 to 1987 (10 years) while 'wet cycle period' was experienced between 1947 to 1960 (14 years). Seven out of 15 years when super-flood occurred over a period of 71 years were in that wet cycle period. Obviously no definite pattern of wet and dry periods is discernable in the rather short span of 71 years. The yearly peak discharges of 5 rivers are plotted at Annexures E-1 to E-5.

Experts have worked out probability curves for the 5 rivers. The probable periods of the historic maximum floods that occurred are given in the table in the last section, notwithstanding the probability of occurrences of super-flood in terms of years. Successive super-floods can occur even in consecutive two years. The probability of occurrence/return period of various rivers at Barrages is given at Annexure-F. Some Experts maintain that these tables can be modified, but that does not have much bearing on the practical aspects of flood control and their management.

THE 1992 FLOOD

The occurrence of floods in the year 1992 in chronological order as recorded at the Barrages/Headworks in Punjab is given here-below indicating how they developed to cause massive destruction over a large area:-

30-8-1992 River Sutlej started rising at Ganda Singh Wala and was in very high flood, which eventually passed Islam Headworks on 7-9-1992.

9-9-1992 At 0600 hours Mangla Dam reservoir level on River Jhelum was 1202.73 and outflow was 32700 Cs. only. Although the discharge in river Ponch had risen in the early hours to 1,85,060 cs. and further shooting up, yet the out-flow from Mangla was increased after six hours to 1,83,780 Cs. at 12.00 house. A hydrograph of hourly inflows and outflows at Mangla Dam for 9th and 10th September, 1992 is given at Annexure-G.

10-9-1992 By 0400 hours outflow from Mangla increased to 9,32,700 Cs. and remained at this level till about 1100 hours. By that time the discharge at Rasul had already crossed very high flood limit of 4,25,000 Cs. and rapidly rose to over 9,00,000 Cs. by 1200 hours. Breaching Section was operated at 1100 hours but the "explosives" failed and as a consequence L.M.B. breached. The peak of 9,52,170 Cs. at Rasul occurred at 1800 hours with additional 50,000 Cs. passing through the breaches. River Indus at Kalabagh also rose to very high flood peak of 8,46,040 Cs. at about midnight.

10-9-1992 During the night between 9-9-92 and 10-9-92 river Chenab had also started rising and it crossed very high flood limit. At 0600 hours river Chenab at Marala was 5,71,990 Cs. which rose to a peak discharge of 8,39,940 Cs. at

1100 hours. The peak of 9,10,512 Cs. at Khanki Headworks occurred at 2200 hours the same day.

11-9-1992 The peak flood of 9,48,530 Cs. passed Qadirabad Headworks at 0600 hours on 11-9-92. Although the peak at Khanki and at Qadirabad were about 50,000 Cs. to 60,000 Cs. above their designed capacities, the floods were passed without operating any breaching sections. River Indus at Chashma rose to very high flood peak of 6,65,236 Cs.

12-9-1992 River Chenab started rising at Trimmu, and River Indus started rising at Taunsa.

13-9-1992 River Chenab at Trimmu had crossed the very high flood limit during the preceding night and was 5,31,989 Cs. at 0600 hours. At 0900 hours breaches in Right Marginal Bund of Trimmu Headworks were activated when the critical level was attained and the discharge was 6,11,526 Cs. By 1200 hours river Ravi was also in high flood of 1,02,157 Cs. at Balloki.

14-9-1992 River Chenab attained the peak flood of 8,88,117 Cs. at Trimmu Headworks at 0700 hours out of which 2,05,000 Cs. was passing through the breaches. River Indus at Taunsa also attained a peak, very high flood discharge of 6,55,079 Cs. at 1300 hours.

15-9-1992 At 1100 hours the water level at Sher Shah Railway Bridge on River Chenab had already crossed the safe limit level of 392.60 ft, AMSL and its left guide bund was breached at 11.30 hours at a level of 392.80 ft.

16-9-1992 At 1200 hours River Chenab at Panjnad had crossed the very high flood limit of 4,56,631 Cs. and water continued rising.

18-9-1992 During the preceding night the flood at Panjnad had risen much above its designed capacity of 7,00,000 Cs. and R.M.B. had to be breached at 0400 hours. The river still continued rising and reached the peak of 8,12,152 Cs. at 1800 hours out of which 70,000 Cs. were passing through the breaches. However, Peak discharge of 10,69,268 Cs. at Guddu Barrage had passed at 1200 hours (Noon).

20-9-1992 Peak discharge of 10,25,937 Cs. passed at Sukkur Barrage at 1800 hours.

Rasul and Khanki Headworks are about the same distance around 170 miles upstream of Trimmu Headworks. There was a time lag of about 6 hours between the peaks in the two rivers (Jhelum and Chenab). The peaks did not synchronize at Trimmu Headworks, otherwise the intensity of flood and devastation could have been much more.

Strangely in 1992 the worst super-floods occurred in river Jhelum although estimated flood peak at Rasul (Post-Mangla) is only 3,57,000 Cs. against 10,52,000 Cs. (Pre-Mangla) for a return period of 50 years. Even in 100 years in Post-Mangla era flood should not be more than 3.35 lac. Cs. at Mangla and 4.08 lac. Cs. at Rasul. However, the cause of this unthinkable happening is not the subject of this paper and for the future ways and means should be devised to control such floods at Mangla which can handle a maximum probable flood of 26 lac cusecs with surcharge storage at R.L. 1228 against embankment top at R.L. 1234'.

The tropical storm which caused extremely heavy floods in the rivers Chenab, Jhelum and Indus was caused by inter-action of intense monsoon depression with an active westerly wave. The monsoon low depression was first located over Orissa Coast, Bay of Bengal on Ist of September, 1992. The depression moved in the north-west direction and reached Rajisthan on 6th September from where it recurved in the north-westerly direction and then rapidly moved north-wards under the influence of the westerly wave, which had by then moved east-wards from Afghanistan and was lying over northern part of the country. The north-wards movement was very rapid and due to influence of the westerly wave the monsoon depression by-passed the Sutlej and Ravi catchments. This pattern was also experienced before in years 1928, 1929, 1959 when the combined effect of the monsoon depression and westerly wave caused heavy floods. Tracks of monsoon low/depression movement from Bay of Bengal over India and into Pakistan are given in the map at Annexure-H for some significant years.

FLOOD DAMAGES

In addition to the misery of millions of people and loss of human life, tremendous damage to public and private property occur during major floods. Crops are lost not only during the year of floods but also for the following seasons. It is impossible to estimate exactly the total direct and indirect losses. At Annexure-I are given the total losses estimated by independent sources that occurred during the years of significant damages by floods since 1950.

During the floods of 1992, over 7.6 million inhabitants were affected and about a million houses were demolished or severely damaged including over 10% pacca houses. In addition to loss of live-stock, over 1300 people are reported to have died. Province-wise details of the private sector losses are given at Annexure I.1. The public sector losses have been estimated by various agencies and a summary is given at Annexure I.2. The total damages in Pakistan for both private and public sector were estimated at Rs.60.00 billion (US $2.4 billion). Amongst its after effects, the 1992 floods alone may reduce the projected gross domestic product growth from 6.2% to 4.7%.

The country has suffered since the 1950 flood direct loss alone of US $5.06 billion (over Rs. 90 billion) at 1988 price level upto and inclusive of the 1988 floods, and another US $ 2.4 billion (over Rs. 60 billion) during the 1992 floods.

PREVENTION AND CONTROL OF FLOODS

There are various methods of prevention and control of floods which are amply given in the Text Books. Broadly speaking the controls can be in the catchment areas such as building of reservoirs, water-shed management, including growing more forests, rotating grazing areas, application of soil erosion sciences etc. After the rivers enter the plains they can be controlled by formation of levees/bunds, channel improvement and training of rivers by constructing spurs, diversion channels etc.

In Pakistan the very effective control by construction of reservoirs etc. in the hills is not possible on the three major eastern rivers viz; Sutlej, Ravi and Chenab because their main hilly catchments do not lie in Pakistan. However such methods can be applied to the other two rivers i.e. Jhelum and Indus.

For control in the plains a system of bunds and spurs is being used. In Sind, double integrated embankments have been built since 1890's and the super-floods of 1992 passed through the barrages and in between the double embankments of River Indus without very high damages to the adjoining areas. In Punjab total length of major rivers is about 1950 miles and most of the areas are very intensively populated and/or cultivated. A system of bunds and spurs has been built along vulnerable points. The total length of flood embankments in Punjab is 1671 miles, along rivers and nullahs. In all less than 30% of the

river banks and riverain areas are protected. The system of levees/bunds and spurs in Punjab is far from sufficient even now as was observed in the 1988 floods and again in the 1992 floods.

Such flood control works are "risk projects" and may not have immediate and direct benefits as compared to other development projects. Therefore, they are not popular with the planners, economists and administrators. Under Flood Protection Sector Project in Pakistan, the Government is constructing more bunds and spurs but although this project was started in 1988 with about 80% loan from Donors, the planning and execution has been slow and their impact although very good has been only in restricted areas where the works have been done. Most of such embankments were subjected to and withstood the ultimate stress conditions.

Suggestions have been made for control of floods by the following methods :-

i) Dredging, Channelization and Straightening of the entire reaches of reivers. An example is often quoted of the river Mississippi in U.S.A.
ii) Division Canals, Increasing Capacity of the Headworks, Bridges, Spill-ways.

As stated earlier about 1950 miles of the main rivers pass through Punjab. All these rivers alongwith additional Nullahs in the 'doabas' traverse the plains where the natural slope is very flat. Channelizing of these braided/meandering rivers shall not only be exorbitantly expensive but also liable to be silted up again typical to the problems faced in the biggest link canal in Pakistan designed for 22500 Cs. linking one river with the other which are obvious. It silts up and meanders eroding away either right bank or the left bank and now cannot pass the designed discharge.

In addition to a number of railway and road bridges on the rivers in Pakistan, there are 6 Barrages on river Indus (3 in Sind), one Barrage on River Jhelum, 5 Barrages on river Chenab, 2 Barrages and a Syphon each on river Ravi and Sutlej. "Breaching Sections" at specified sites have been provided for operation in an emergency on all the major Barrages and Bridges. Critical levels of flood water have been determined for all barrages and bridges, where the breaches are to be operated by joint agreement and decision of the concerned Engineering Department, Civil Administrations and Army Authorities. This

however requires that breaching sections are kept in working order and no inhabitation or permanent structures are built in the spill water-ways areas. The Breaching Sections act as spill-ways when operated.

All the Barrages are designed for a return period of about 20 to 25 years with minimum for Trimmu Barrage of 10 years (except Kotri Barrage which is designed for return period of 44 years). Widening of the Barrages/Bridges for higher capacities shall be exorbitantly expensive as the historic maximum floods as shown earlier have a return period of between 55 and 175 years excluding Rasul, (under Pre-Mangla conditions, the 1992 flood at Rasul was also a 50 year flood).

Over 30 Canal Systems off-take from the 16 Barrages. Nearly half of the annual flow of the rivers is diverted through canal withdrawals in Punjab and Sind. With the high variations in the river flows between the winter lows and summer highs, silt free in-take of water into the canals is maintained at present by careful regulation and ponding upstream of the Barrages. This will be impossible to adhere to if Barrages are widened as per proposals and arguments given by certain quarters. In case of Sukkur Barrage, 6 bays were closed and an island formed with the result that regulation and silt entry into the off-taking canals were improved. Further, most of the rail and road bridges will also have to be widened if the Barrages are widened.

Again due to the high seasonal variation of flows and silty nature of water, additional hydraulic problems shall arise as cross-currents shall develop posing danger to some spans of the structures, while choking some other spans over the years thereby nullifying the usefulness of widening the water-way. This hydraulic problem will be in addition to the high capital cost of widening structures and their increasing maintenance. Somewhat similar examples can be quoted in the case of Alexandra, Shahdara and other Railway Bridges which were originally built very wide and later some spans were permanently closed. When the colossal cost of widening Barrages and Bridges and their increased cost of maintenance is also taken into consideration it should become obvious that the general proposal of widening Barrages and Bridges is neither feasible technically nor financially. Providing permanent by-pass channels for such cases as Trimmu Panjnad Barrages can however be considered after model tests and Feasibility Studies are carried out.

MANAGEMENT OF FLOODS

In a broader sense management could mean the whole passage and disposal of floods as well as their prediction, relief measures and shifting of affected people etc. However, this section is restricted to institutional matters while some other aspects have been dealt in the sections given before.

Over the years the Federal Government had set-up a Federal Flood Commission in the Ministry of Water & Power which sets the policies, coordinates planning and arranges the funds for the new development works. After completion, the maintenance of the flood control works are the responsibility of the Provincial Governments. The Tarbela and Mangla Dams and Chashma Barrage which are the major storage sites on main rivers are however under the control of WAPDA.

In addition to the collection of rainfall and discharge data by the Provinces at various sites, WAPDA has a telemetric system in the hilly catchment of the rivers comprising of 33 stations from where rainfall and/or river discharge data are transmitted. Unfortunately not all of the telemetric stations were working in 1992 and a number of the gauge sites especially in the river Jhelum catchment were over-topped. Further-more WAPDA has the organization with a working Flood Forecasting System, where the floods can be computed.

Pakistan Mett: Department also has a Flood Forecasting and Warning Centre at Lahore with facilities of information from the weather satellite received directly or through India, Quantitative Precipitation Measurement (Q.P.M.) Radar of 5.36 cm wave length at Sialkot, up-to-date weather information and computer facilities for flood forecasting. The Federal Flood Commission is making efforts to modernise the telemetric system as well as Flood Forecasting System by negotiating with Donor Organizations. In Punjab, Flood Warning Centre is set-up every year from 15th June to 30th September/15th October. Flood Warning Centre is under the control of Relief Commissioner Punjab who is Member of the Board of Revenue Punjab, Lahore and heads a committee with representatives from concerned Departments.

Flood Bulletins are broadcast from Jammu Radio Station by India, and also telegraphic and telephone information is received by the Indus Waters Commissioner, Lahore. Dedicated vigilance is required in receiving or hearing and transmitting the information from India.

The Duty Officers assigned to the Flood Warning Centre, not below the rank of Executive Engineer are provided by Irrigation and Power, C & W Departments and WAPDA. The Centre works round the clock. The representatives from the Information Department and Railways Department are also required to be present through-out. The Police Telecommunication Department provides telecommunication facilities and V.H.F./Mobile Stations to the District Headquarters, Barrages and other important stations and Government functionaries. A Hot-Line is provided between the Flood Warning Centre, Lahore and the Army 4-Corps Engineers Headquarters Lahore from where the information is further transmitted to other Corps Engineers Headquarters.

The representative of the Information Department is responsible to pass on timely and correct information to the media i.e. the Newspapers, the T.V. and Radio.

After the building of Bhakra Dam (1962) and Pong Dam (1974) on River Sutlej and its tributary, the flow of water in this River in Pakistan has been very much reduced in quantity and duration. The river channel has not only deteriorated but there is large scale encroachment of river bed for the purpose of agriculture and other uses. Therefore although the 1988 Flood in River Sutlej was less than the historic maximum flood of 1955, the devastation in 1988 was more.

In addition to the natural factors, we ourselves have added to the risks by the increasing population and search for low-cost land which has forced people to live in flood prone areas of major river systems which could not have been considered as habitable previously. Not only people have settled and built permanent structures in the areas specified for overspill; from the breaching sections of the Barrages but also in the areas very near to the river banks in the flood plain between the flood embankments, such as next to Mahmood Booti Bund upstream Shahdara on River Ravi. The general effects can be devastating.

Provisions were long since made in the Canal and Drainage Act No. VII of 1873, Part-VII, Section 55 and 56 giving powers to prohibit installations, or order for their removal if any river system drainage or channel is obstructed. At Annexure - J are excerpts from the Canal Act.

In many countries legislation provides powers and rules for "disaster management". Provisions of Canal Act as quoted above are sufficient to control the influx of population in the spill areas of Breaching Sections or the areas between Flood Embankments etc. if properly applied.

CONCLUSIONS AND RECOMMENDATIONS

1. Reservoirs are required for flood control in addition to their other multiple-purpose. The proposal of Kalabagh Dam is well-known, where the final decision is required. Chiniot Barrage on River Chenab is the only topographic possibility on the eastern rivers where some storage can be provided, after a detailed feasibility study is done.

2. Emphasis and attention should be given to Flood Protection Bunds for not only their construction where necessary, but also their later maintenance. As Punjab, in the upper Indus Basin down to the confluence at Mithankot and beyond, has over 70% of its riverain area unprotected and is the worst hit, special consideraion/extra funds should be provided to protect riverain areas along all the major rivers.

3. River Training by bunds and spurs is necessary so that the rivers can meander within the acceptable limits.

4. Forest and range management of the water-shed on rivers Jhelum and Indus and their tributaries which lie in Pakistan should be carried on continuously.

5. "Breaching Sections" on the marginal bunds of Barrages and Bridges to be kept in working order for operation in any emergency. Their design should be re-examined from time to time according to the latest flood conditions. Simultaneously with that the water-ways should be kept clear and property marked downstream of the breaching sections even by imposing Administrative action under the Canal Act or new Legislation where necessary. Deliberate cutting such as of the Mahmood Booti Bund, Lahore at various places to provide access to private buildings and factories built inside the river Ravi plain during the recent years should be severely punished and such cuttings restored at the cost the offenders.

6. It was stated that for Mangla Dam, "in case of occurrence of a maximum possible flood of 26 lac cusecs at the maximum pool, the two spill-ways and Power Station outlets can handle it with surcharge storage upto R.L. 1228 still leaving a free-board of 6 feet to the top of embankment level 1234". During 1992, the level was not raised beyond R.L. 1207.83 and over 9 lac cusecs was passed downstream for many hours. Technical studies on flood routing as well as the safety of Dam and/or change of administrative set-up as appropriate may be carried out so that the happenings of 1992 flood are not repeated.

7. Weather and Flood Forecasting System as well as timely warning systems should be modernized and co-ordination of all Departments stressed which has been rather lacking during the 1992 flood. Perfect coordination and rapid transmission of messages to the right Government functionaries is a pre-requisite for the proper management of the floods and mitigation of misery and losses.

   In addition to modernizing and extending the present telecommunication system, tele-fax machines could be provided at the Flood Warning Centre and District Headquarters etc. to provide alternate facility.

8. At times it is experienced that the general public do not heed the warnings given by the administration. It is, therefore, necessary that not only the warnings are given after proper check and consultation from the Flood Warning Centre but also the general population is educated. Some International Experts have suggested that rehearsals should be carried out under simulated conditions in May/June. This could however create unnecessary panic, and the devastating flood may not occur on the year of rehearsal.

9. Q.P.M. Radar of 10 cm wave-length to cover Rivers Ravi, Sutlej and their catchments as proposed by Meteorological Department should be installed before the commencement of the next flood season.

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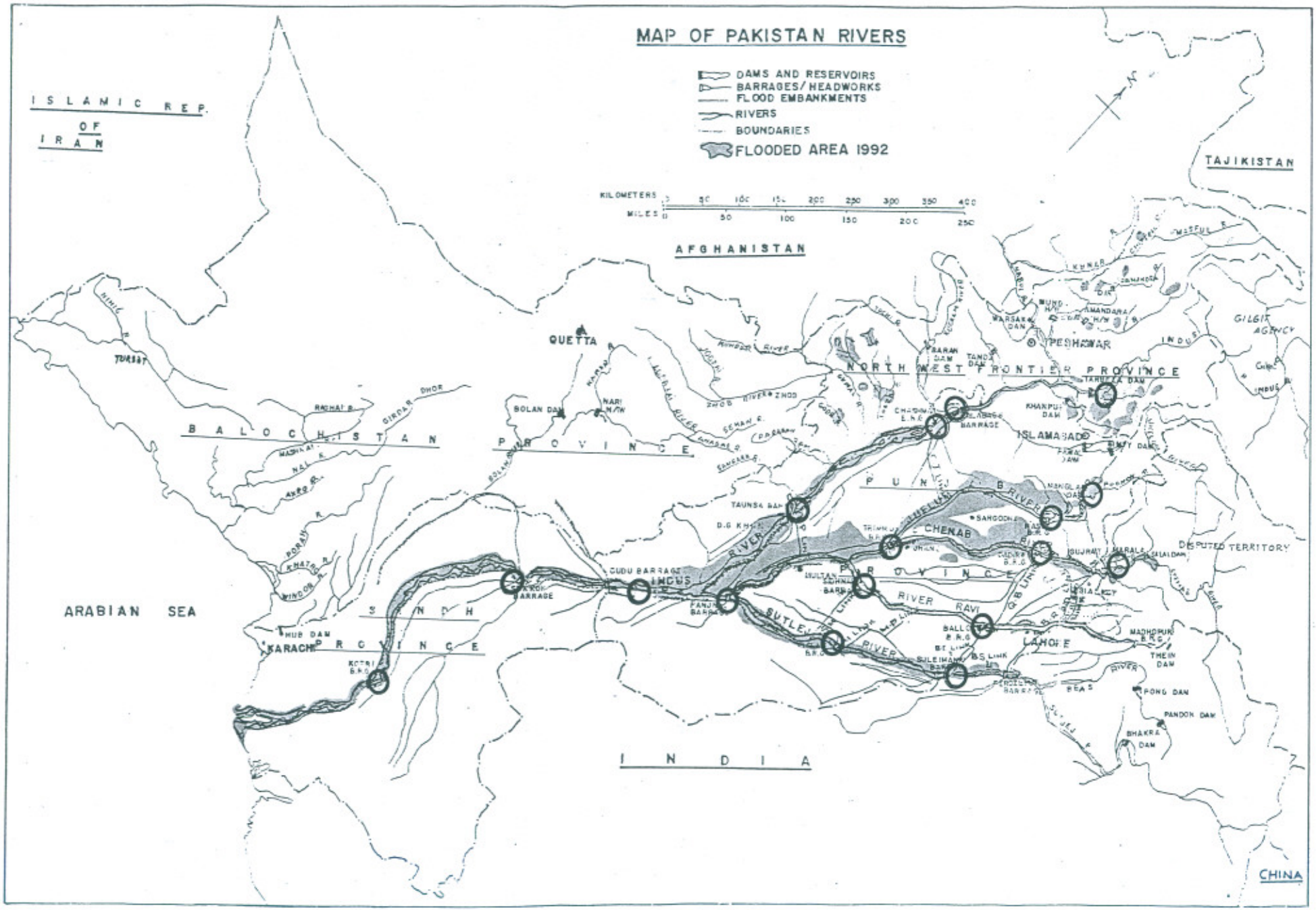
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13. Records of Flood Warning Centre, Punjab, from 15th June 1992 to 30th September, 1993.

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ANNEXURE


MAP OF PAKISTAN RIVERS
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BARRAGES/ HEADWORKS
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RIVERS
BOUNDARIES
FLOODED AREA 1992
KILOMETERS
MILES
ISLAMIC REP. OF IRAN
AFGHANISTAN
TAJIKISTAN
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INDUS
JHELUM
CHENAB
RIVER RAVI
SUTLEJ RIVER
BEAS
KOTRI BARRAGE
GUDU BARRAGE
SUKKUR BARRAGE
TAUNSA BARRAGE
CHASHMA BARRAGE
TARBELA DAM
MANGLA DAM
SULEMANKI BARRAGE
BALLOKI BARRAGE
MADHOPUR BARRAGE
HUB DAM
SOLAN DAM
KHANPUR DAM
WARSAK DAM
KHUNAR
MUND DAM
AMANDARA
TANDA DAM
BARAN DAM
PONG DAM
PANDOH DAM
BHAKRA DAM
THEIN DAM
MANGLA DAM
RACHNA B.
GIDAR B.
DHOR
NAL R.
ANBO R.
PORALI R.
KHATAR R.
WINDOR R.
NIMIC
ZHOB RIVER
SEMAN R.
SANGSAR R.
KHARAN R.
NARI R/W
BOLAN R.
KACHHI CANAL
D.G KHAN CANAL
TRIMMU BARRAGE
JHANG
SARGODHA
SIALKOT
QADIRABAD BARRAGE
RASUL BARRAGE
MARALA
SIALDAM
QB LINK
BS LINK
BT LINK
MANGLA DAM
PANJNAD BARRAGE
SULEIMANKI BARRAGE
KABUL RIVER
SWAT R.
PANJKORA R.
CHITRAL R.
GOMAL R.
KURRAM R.

Annex : B

STATEMENT SHOWING FLOOD LIMITS OF MAIN RIVERS OF INDUS BASIN.

(In Lacs Cusecs)

River	Site Barrage or Bridge	Designed Capacity	Flood Limits (Above)				
			Low	Medium	High	V. High	Excep-tionally High.
Indus	Attock Bridge	--	2.50	3.75	5.00	6.50	8.00
	Kalabagh Barrage	9.50	2.50	3.75	5.00	6.50	8.00
	Chashma Barrage	10.00	2.50	3.75	5.00	6.50	8.00
	Taunsa Barrage	10.00	2.50	3.75	5.00	6.50	8.00
	Guddu Barrage	12.00	2.00	3.50	5.00	7.00	9.00
	Sukkur Barrage	9.00	2.00	4.50	5.50	7.00	9.00
	Kotri Barrage	8.75	2.50	4.00	5.50	6.50	8.00
Jhelum	Kohala Bridge	--	1.00	1.50	2.00	3.00	4.00
	Mangla Dam	9.00+ 2.12	0.75	1.10	1.50	2.25	3.00
	Rasul Barrage	8.50	0.75	1.10	1.50	2.25	3.00
Chenab	Marala Barrage	11.00	1.00	1.50	2.00	4.00	6.00
	Khanki Headworks	8.50	1.00	1.50	2.00	4.00	6.00
	Qadirabad Barrage	9.00	1.00	1.50	2.00	4.00	6.00
	Trimmu Barrage	6.50	1.50	2.00	3.00	4.50	6.00
	Punjnad Barrage	7.00	1.50	2.00	3.00	4.50	6.00
Ravi	Jassar Bridge	2.75	0.50	0.75	1.00	1.50	2.00
	Shahdara Bridge	2.5	0.40	0.65	0.90	1.35	1.80
	Balloki Headworks	2.25	0.40	0.65	0.90	1.35	1.80
	Sidhnai Headworks	1.75	0.30	0.45	0.60	0.90	1.20
Sutlej	Suleimanki H/works	3.25	0.50	0.80	1.20	1.75	2.25
	Islam Headworks	3.00	0.50	0.80	1.20	1.75	2.25
	Mailsi Syphon	4.00	0.75	1.10	1.50	2.25	

Note :- 1. Figures given for Mangla (outflow) and Rasul on River Jhelum are post-Mangla Dam.

2. Original designed capacity of Sukkur Barrage was 15 lacs, but after the formation of island and closure of 6 bays, it is considered as 9 to 10 lacs.

Annexure B-1

DEFINITIONS OF FLOOD LIMITS

Low Flood limits correspond to bankful stage of the river.

High Flood is about twice the discharge of the low flood and about 4 ft. higher than the bankful stage.

Exceptionally High Flood limits were fixed taking into consideration historical flooding and the designed capacity of the structures. The exceptionally high flood limits are from over one-and-half times to 3 times high flood limits.

Medium Flood is in between low and high flood.

Very High Flood limit is kept in between high and exceptionally high flood.

Annexure - C

SALIENT DATA OF MAIN RIVERS - OCCURRENCE OF SUPER-FLOODS.

River	Catchment Area in the mountains (Sq.miles)	Approx. total length (Miles)	Exceptionally High Flood		Observation started since year.
			Limit above	Years of occurrence	
Indus Main	1,18,400	1958	8 lac	1929, 42, 50. Post Tarbela - 1992	1928 (Kala bagh)
Jhelum	12,445	528	3 lac Post-Mangla	1928, 50, 54, 59, 60. Post Mangla, 92.	1922 (Rasul)
Chenab	11,399	807	6 lacs	1928, 29, 50, 54, 57, 59, 60, 66, 73, 76, 88, 92.	1922 (Khanki)
Ravi	3,562	626	1.8/2 lac	1947, 50, 55, 57, 59, 66, 73, 76, 88.	1922 (Balloki)
Sutlej (including Beas)	30,550	964	2.25 lac.	1942, 47, 50, 55, 88.	1928 (Sulei-manki).

Note : 1. Attock bridge on River Indus since 1868, but no super-flood from 1868 to 1928 recorded.

2. The recorded discharges for the years of occurrence are given in Annexure-D.

Annexure - D

HISTORY OF EXCEPTIONALLY HIGH FLOODS IN PUNJAB PROVINCE.

(Discharge in Cusecs)

Year	No. of rivers	River	Observation point.	Discharge	Date
1.	2.	3.	4.	5.	6.
1928	(2 Rivers)				
		Chenab	Marala	6.83,960	2-9-1928
			Khanki	6,96,286	2-9-1928
		Jhelum	Rasul	6,63,000	2-9-1928
1929	(3 Rivers)				
		Chenab	Khanki	7,42,293	29-8-1929
		Jhelum	Mangla	11,00,000	29-8-1929
			Rasul	8,75,000	29-8-1929
		Indus	Kalabagh	8,90,000	29-8-1929
1942	(2 Rivers)				
		Sutlej	Suleimanki	3,24,708	24-8-1942
		Indus	Kalabagh	9,50,000	(14-7-42)
1947	(2 Rivers)				
		Sutlej	Suleimanki	3,60,412	20-9-1947
		Ravi	Shahdara	2,25,000	28-9-1947
1950	(5 Rivers)				
		Sutlej	Suleimanki	3,32,102	22-9-1950
		Ravi	Balloki	2,75,000	22-9-1950
		Chenab	Khanki	9,86,656	20-9-1950
			Trimmu	7,15,560	27-9-1950
			Panjnad	6,50,000	27-9-1950

1.	2.	3.	4.	5.	6.
		Jhelum	Rasul	3,50,000	1-8-1950
		Indus	Kalabagh	7,43,757	2-8-1950
1954	(2 Rivers)				
		Chenab	Marala	8,17,228	26-9-1954
			Khanki	8,06,774	26-9-1954
		Jhelum	Rasul	4,25,000	5-9-1954
1955	(2 Rivers)				
		Sutlej	Suleimanki	5,98,872	(8-10-55)
			Islam	4,92,581	(11-10-55)
		Ravi	Jassar	6,80,000	4-10-1955
			Shahdara	5,42,000	6-10-1955
1957	(2 Rivers)				
		Ravi	Jassar	3,25,000	27-8-1957
		Chenab	Marala	11,00,000	(26-8-57)
			Khanki	10,86,416	(27-8-1957)
1959	(3 Rivers)				
		Ravi	Shahdara	2,00,000	7-7-1959
		Chenab	Marala	8,70,595	5-7-1959
			Khanki	10,21,019	5-7-1959
			Trimmu	9,43,225	(8-7-59)
		Jhelum	Rasul	8,76,000	(5-7-59)
1960	(2 Rivers)				
		Chenab	Khanki	7,09,524	12-7-1960
			Trimmu	6,05,132	15-7-1960
		Jhelum	Rasul	8,60,000	11-7-1960
1966	(2 Rivers)				
		Ravi	Jassar	3,21,000	9-9-1966
		Chenab	Marala	6,16,338	9-6-1966
			Khanki	6,51,670	10-9-1966

1.	2.	3.	4.	5.	6.
1973	(2 Rivers)				
		Ravi	Balloki	2,43,905	12-8-1973
			Sidhnai	2,10,000	18-81-973
		Chenab	Marala	7,69,650	9-8-1973
			Khanki	10,00,496	10-8-1973
			Trimmu	6,98,000	13-8-1973
			Panjnad	8,02,570	(17-8-73)
1976	(2 Rivers)				
		Ravi	Balloki	2,34,474	11-8-1976
			Sidhnai	2,44,348	15-8-1976
		Chenab	Khanki	6,15,043	11-8-1976
			Trimmu	7,06,443	10-8-1976
			Panjnad	7,02,000	12-8-1976
1988	(3 Rivers)				
		Sutlej	Suleimanki	3,99,453	30-9-1988
			Islam	3,06,425	4-10-1988
		Ravi	Shahdara	5,76,000	(27-9-88)
			Balloki	3,99,356	(27-9-88)
			Sidhnai	3,25,042	(2-10-88)
		Chenab	Marala	7,43,580	25-9-1888
			Khanki	8,64,220	26-9-1988
			Qadirabad	8,92,299	26-9-1988
1992	(3 Rivers)				
		Chenab	Marala	7,92,765	10-9-1992
			Khanki	9,10,512	10-9-1992
			Qadirabad	9,48,520	(11-9-1992)
			Trimmu	6,83,117	13-9-1992
			Panjnad	7,44,152	18-9-1992
		Jhelum	Mangla	9,32,700	10-9-1992
			Rasul	10,52,170	(10-9-92)
		Indus	Kalabagh	8,46,040	10-9-1992

Note : Dates of Historic Maximum Discharges at various points of observations are given in brackets.

Annexure - D-1.

PEAK DISCHARGES AT GUDDU & SUKKUR DURING SUPER FLOODS IN PUNJAB ON 15 YEARS.

Year	Sukkur Barrage Disch: 9 Lacs.			Guddu Barrage Disch: 12 Lacs		
	Discharge U/S.	Discharge D/S.	Date	Discharge U/S.	Discharge D/S.	Date
1928		447000				
1929		702000				
1942		574000				
1947		359000				
1950		776000				
1954	457261	416975	5-10-54			
1955	804760	765578	30-8-55			
1957	707260	661230	4-8-57			
1959	972122	928927	15-7-59			
1960	795218	755598	25-7-60	Guddu Barrage Completed in 1962		
1966	665029	518240	18-8-66	613188	589138	16-8-66
1973	1117246	1065712	21-8-73	1044359	1023713	18-8-73
1976	1197252	1157972	16-8-76	1189256	1168725	16-8-76
1988	1118856	1069426	31-7-88	1162653	1138676	31-7-88
1992		1025937	20-9-92		1069268	18-9-92

Source : Information collected for 1954 onwards from W.T.C. Irri: & Power Department, Lahore.

Note : Exceptionally High (Super) Floods were experienced in Sind on 5 years i.e. 1959, 1973, 1976, 1988 & 1992 as underlined. Historic maximum floods are underlined.

Annexure - F

FLOOD FREQUENCIES

RIVER INDUS

Return Period	Probability of Exceedance (%)	Estimated Flood Peak Discharge (1,000 Cusecs)			
		Attock Bridge	Kalabagh Barrage	Chashma Barrage	Taunsa Barrage
2	50	510	527	499	455
5	20	572	647	614	561
10	10	618	741	705	647
25	4	677	858	819	756
50	2	720	946	904	837
100	1	763	1033	988	916
200	0.5	806	1119	1072	996

RIVER JHELUM

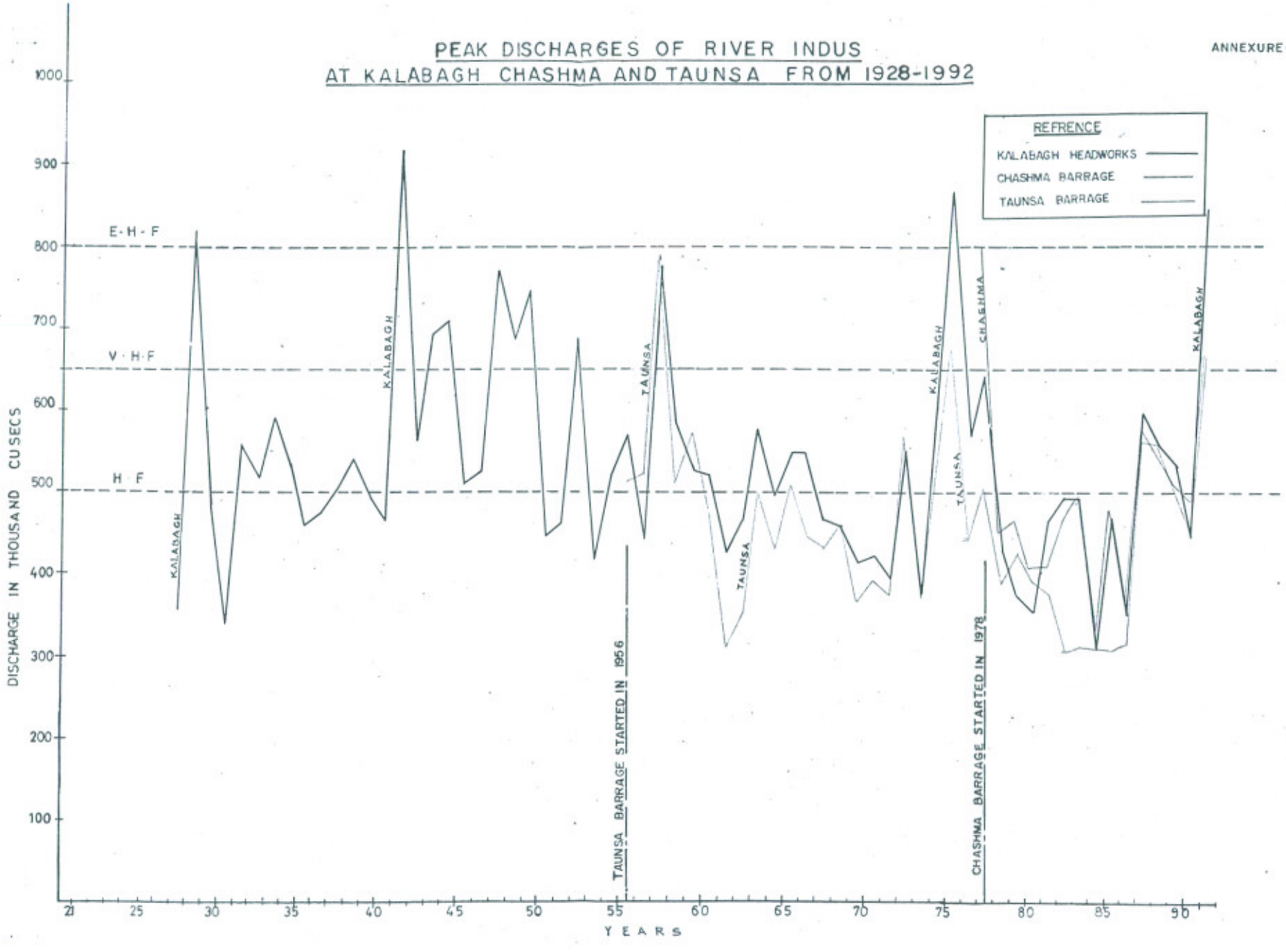
Return Period Years	Probability of Exceedance, Percent	Estimated Flood Peak Discharge, 1,000 Cs					
		at Manga			At Rasul		
		Pre-Mangla[1]	Post-Mangla[2]	Percent Reduction	Pre-Mangla[1]	Post-Mangla[2]	Percent Reduction
2	50.0	140	88	37	165	101	39
5	20.0	247	154	38	395	183	54
10	10.0	510	198	61	600	238	60
25	4.0	848	253	70	860	306	64
50	2.0	1100	294	73	1052	357	66
100	1.0	1350	335	75	1242	408	67
200	0.5	1600	376	77	1435	458	68

1 - Period of Record 1922-1966

2 - Period of Record 1967-78

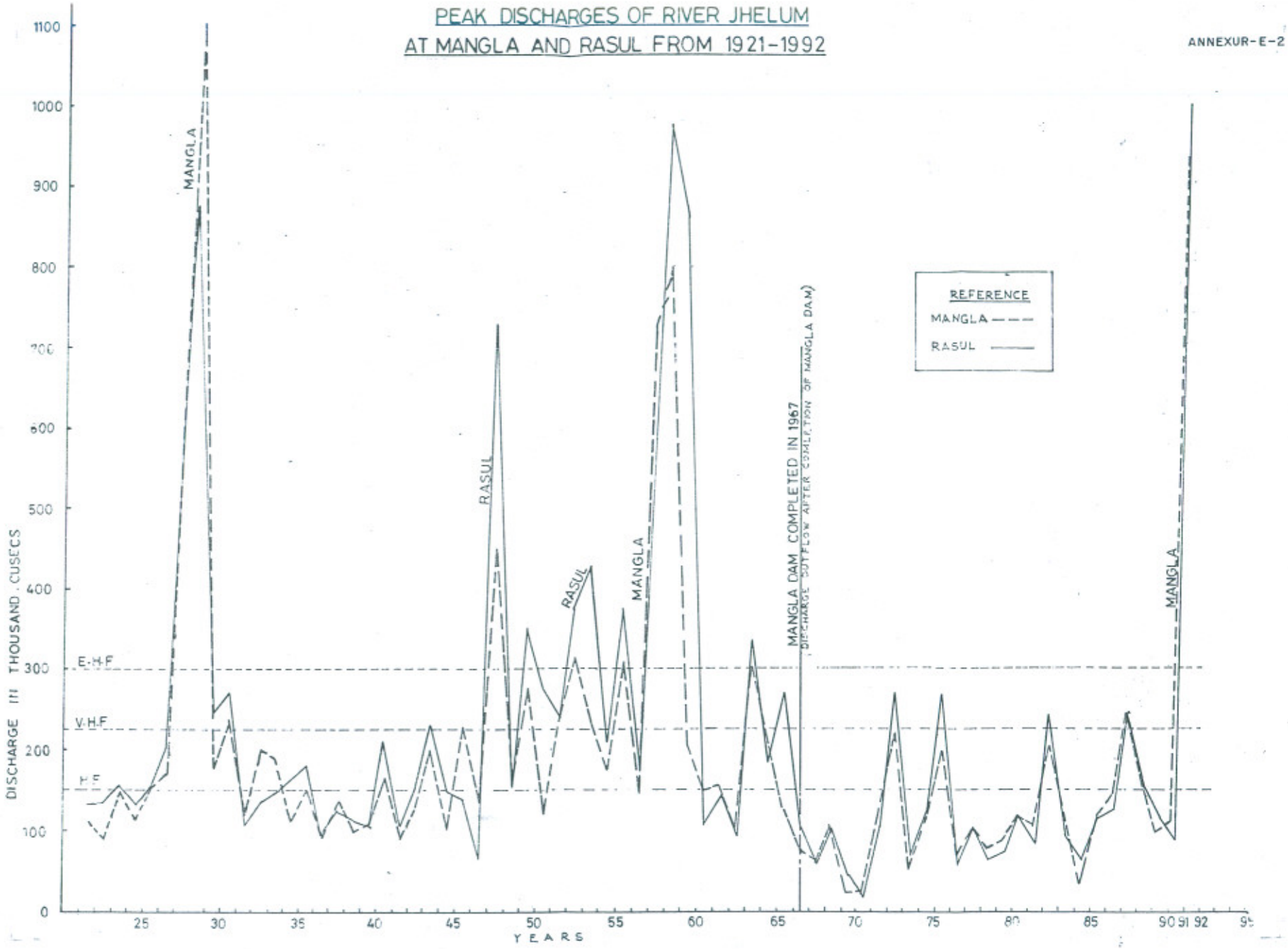
ANNEXURE-E-I

PEAK DISCHARGES OF RIVER INDUS AT KALABAGH CHASHMA AND TAUNSA FROM 1928-1992

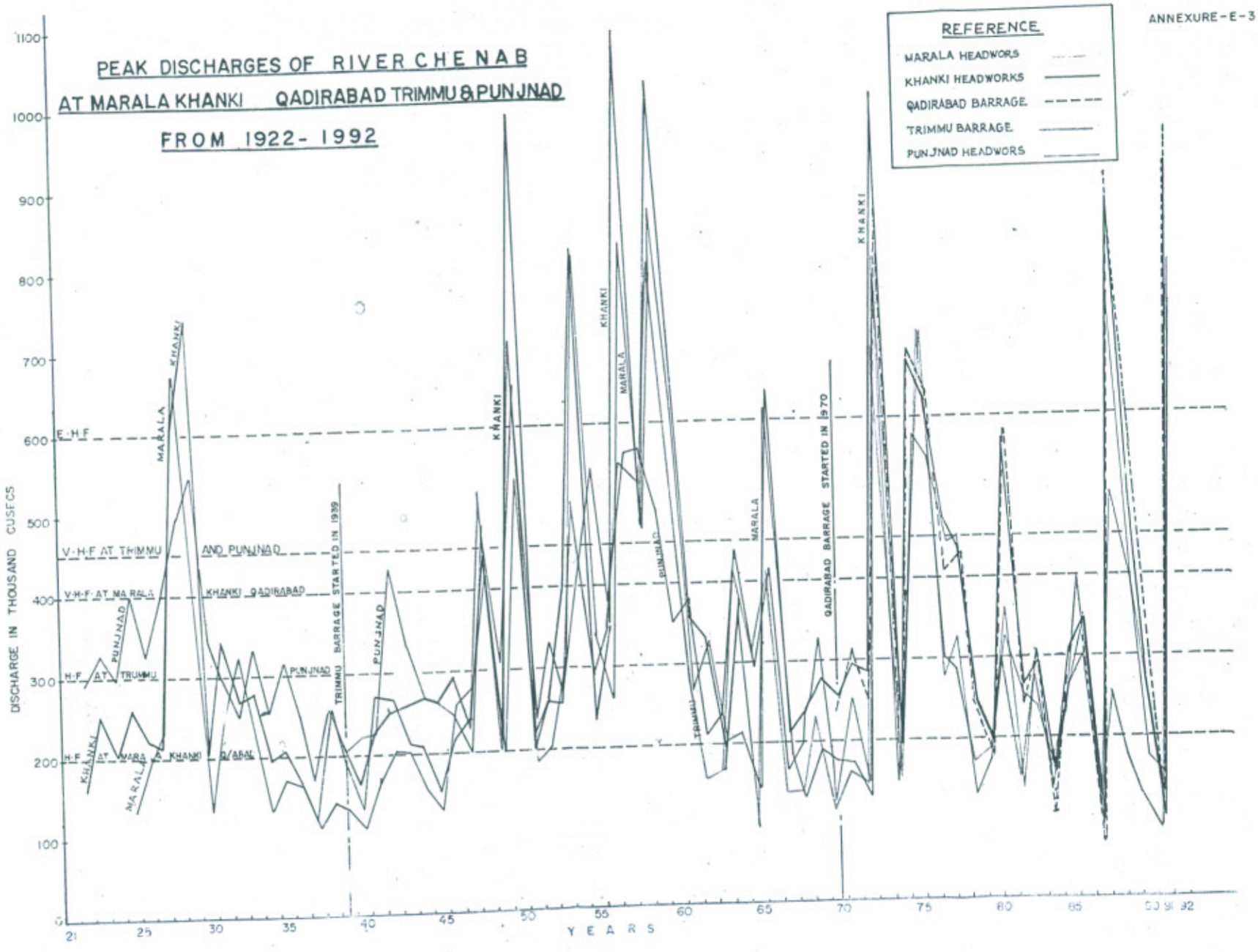


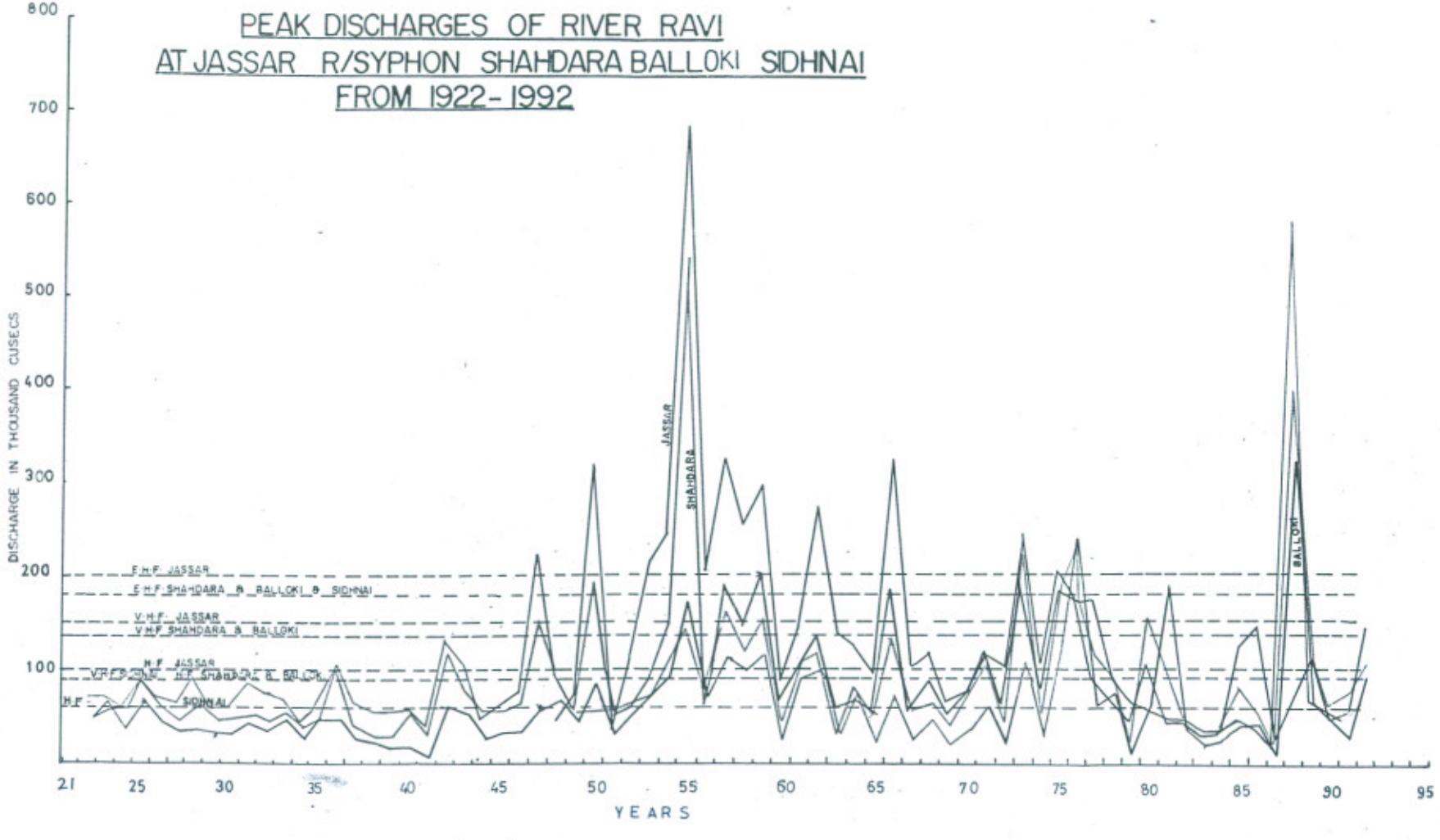
ANNEXUR-E-2

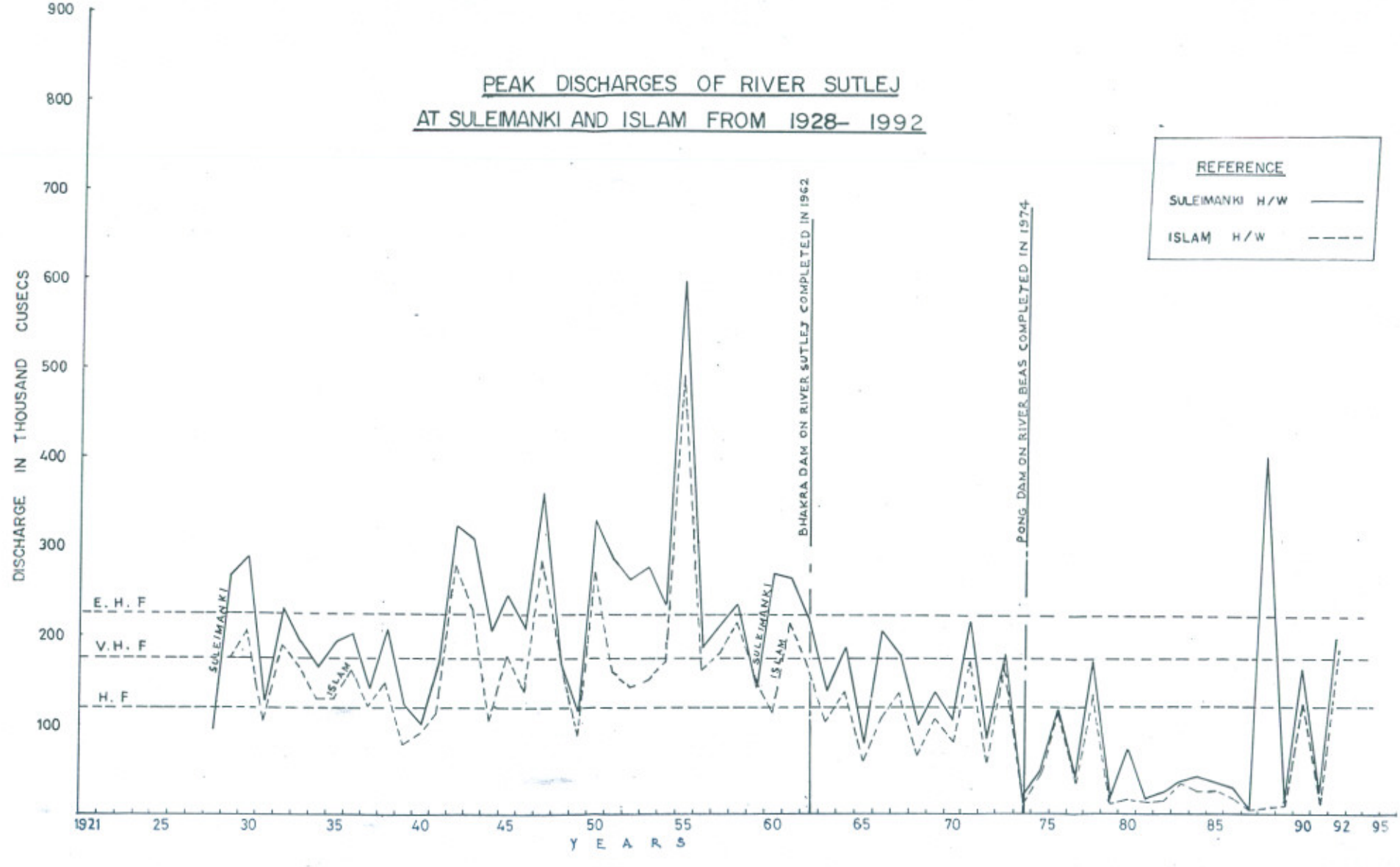
PEAK DISCHARGES OF RIVER JHELUM AT MANGLA AND RASUL FROM 1921-1992



ANNEXURE-E-3


PEAK DISCHARGES OF RIVER CHENAB
AT MARALA KHANKI QADIRABAD TRIMMU & PUNJNAD
FROM 1922- 1992
REFERENCE
MARALA HEADWORS
KHANKI HEADWORKS
QADIRABAD BARRAGE
TRIMMU BARRAGE
PUNJNAD HEADWORS
DISCHARGE IN THOUSAND CUSECS
YEARS
E.H.F
V.H.F AT TRIMMU AND PUNJNAD
V.H.F AT MARALA KHANKI QADIRABAD
H.F AT TRIMMU PUNJNAD
H.F AT KHANKI MARALA & KHANKI QABAL
TRIMMU BARRAGE STARTED IN 1939
QADIRABAD BARRAGE STARTED IN 1970


PEAK DISCHARGES OF RIVER RAVI
AT JASSAR R/SYPHON SHAHDARA BALLOKI SIDHNAI
FROM 1922-1992
DISCHARGE IN THOUSAND CUSECS
800
700
600
500
400
300
200
100
E.H.F. JASSAR
E.H.F. SHAHDARA & BALLOKI & SIDHNAI
V.H.F. JASSAR
V.H.F. SHAHDARA & BALLOKI
H.F. JASSAR
H.F. SIDHNAI
JASSAR
SHAHDARA
BALLOKI
21
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
YEARS


PEAK DISCHARGES OF RIVER SUTLEJ
AT SULEIMANKI AND ISLAM FROM 1928- 1992
REFERENCE
SULEIMANKI H/W
ISLAM H/W
BHAKRA DAM ON RIVER SUTLEJ COMPLETED IN 1962
PONG DAM ON RIVER BEAS COMPLETED IN 1974
DISCHARGE IN THOUSAND CUSECS
900
800
700
600
500
400
300
200
100
E.H.F
V.H.F
H.F
SULEIMANKI
ISLAM
SULEIMANKI
ISLAM
1921
25
30
35
40
45
50
55
60
65
70
75
80
85
90
92
95
YEARS

RIVER CHENAB.

Return Period years	Probability of Exceedance percent	Estimated Flood Peak Discharge, 1,000 Cs.								
		Marala	Alexan-Brdg:	Khanki	Qadir-Abad	Chiniot	Rivaz Brdg.	Trimmu	Sher Shah	Panj-nad.
2	50	255	213	269	276	303	328	341	246	314
5	20	482	358	534	532	525	537	516	388	451
10	10	632	564	838	728	688	651	632	523	553
25	4	822	823	997	976	893	816	778	694	681
50	2	963	1020	1190	1160	1050	940	887	821	776
100	1	1100	1210	1380	1340	1200	1060	994	947	870
200	0.5	1240	1400	1570	1520	1350	1150	1100	1070	964

RIVER RAVI

Return Period years.	Probability of exceedance percent	Estimated Flood Peak Discharge, 1000 Cusecs				
		Jassar	Ravi	Shahdara Syphon (Inter-polated)	Balloki	Sidhnai
2	50	141	90	72	62	46
5	20	270	163	126	126	88
10	10	375	248	204	172	128
25	4	506	354	302	229	179
50	2	604	434	375	272	217
100	1	700	513	448	314	255
200	0.5	797	591	520	355	292

RIVER SUTLEJ

Return Period Years	Probability of Exceedance percent	Estimated Flood Peak Discharge 1000 Cs.					
		Pre-[1] Bhakra period	Bhakra[2] Period	Percent Decrease period	Pre-[1] Bhakra period	Post-[2] Bhakra period	percent Decrease
2	50	212	111	48	150	85	43
5	20	294	177	40	210	136	35
10	10	358	221	38	280	170	39
25	4	437	276	37	370	213	42
50	2	510	317	38	437	245	44
100	1	573	358	38	500	277	45
200	0.5	647	399	38	573	308	46

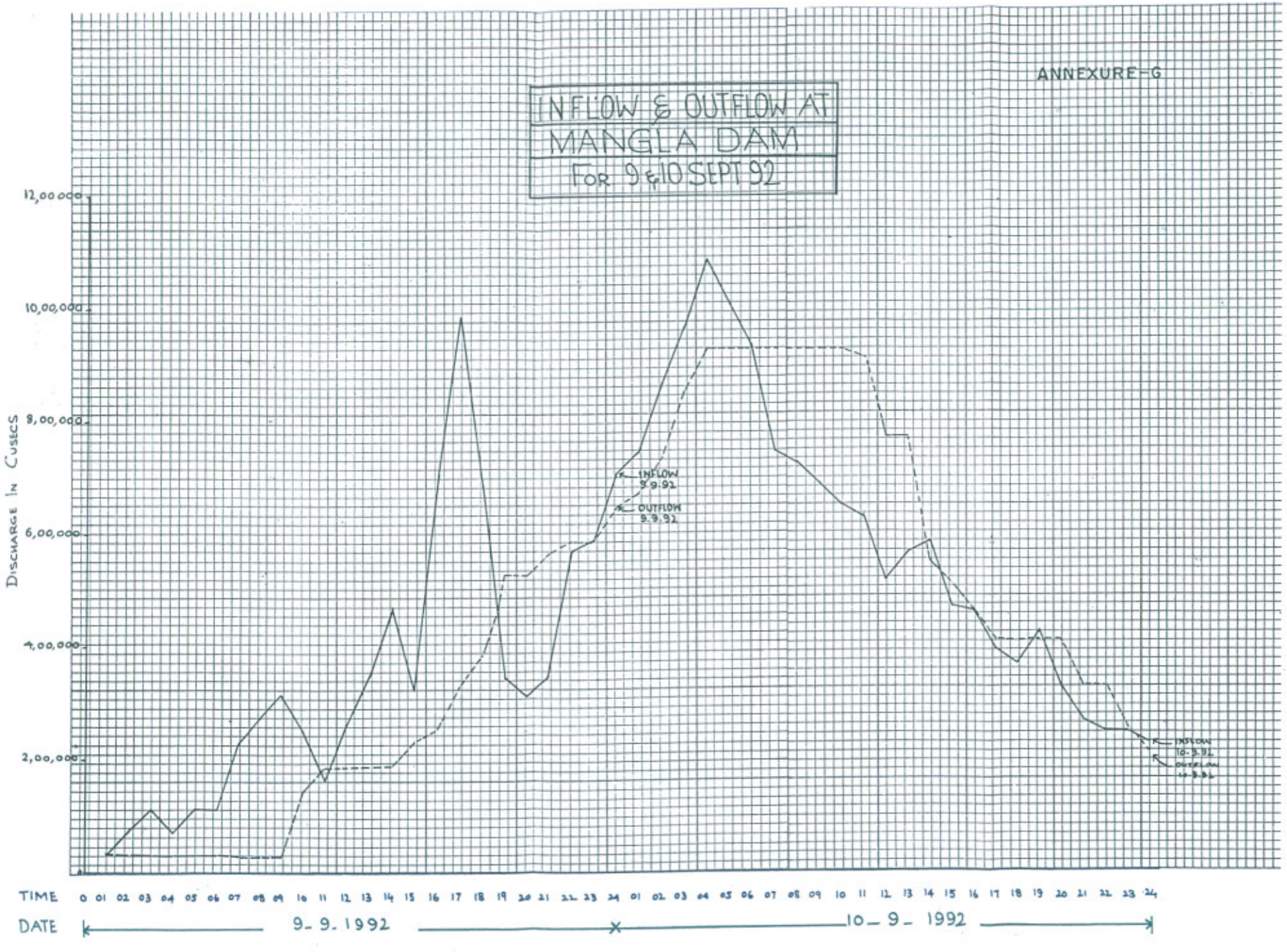
1 - Period of record 1928-1964.

2 - Period of record 1965-1978

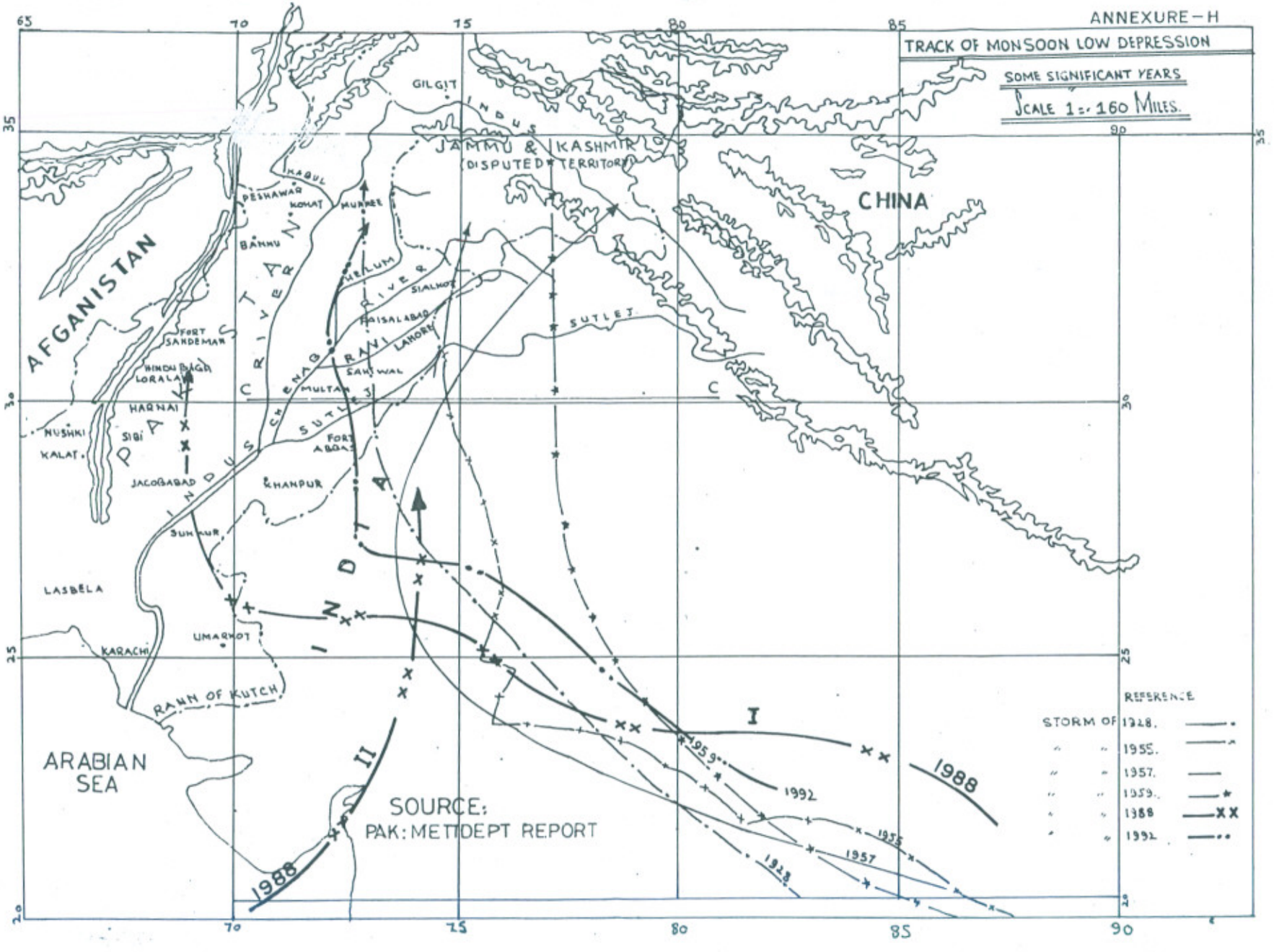
Source : National Flood Protection Plan - 1978.

ANNEXURE-G

INFLOW & OUTFLOW AT MANGLA DAM FOR 9 & 10 SEPT 92



ANNEXURE – H


TRACK OF MONSOON LOW DEPRESSION
SOME SIGNIFICANT YEARS
SCALE 1 :- 160 MILES.
AFGANISTAN
CHINA
JAMMU & KASHMIR
(DISPUTED TERRITORY)
INDIA
PAKISTAN
ARABIAN SEA
GILGIT
INDUS
KABUL
PESHAWAR
KOHAT
MURREE
BANNU
JHELUM
RIVER
SIALKOT
FAISALABAD
LAHORE
SUTLEJ
RAVI
CHENAB
SAHIWAL
MULTAN
FORT SANDEMAN
HINDU BAGH
LORALAI
HARNAI
SIBI
NUSHKI
KALAT
JACOBABAD
FORT ABBAS
KHANPUR
SUKKUR
LASBELA
UMARKOT
KARACHI
RANN OF KUTCH
SOURCE:
PAK: METDEPT REPORT
REFERENCE
STORM OF 1928.
1955.
1957.
1959.
1988
1992
1959
1992
1988
1955
1957
1928
1988
I
II
63
70
75
80
85
90
35
30
25
20

ANNEXURE-I

HISTORICAL FLOOD DAMAGES IN PAKISTAN

(Years during which Significant Damages occurred).

Year	Direct Losses ($ million) adjusted to 1988 price level	Intangible Losses		
		Lives lost	Village affected	Flooded area (square miles)
1950	162	2,910	10,000	7,000
1955	126	679	6,945	8,000
1956	106	160	11,609	29,065
1957	100	83	4,498	6,251
1958	35	90	2,459	6,863
1959	78	88	3,902	4,072
1973	1,706	474	9,719	16,200
1975	227	126	8,628	13,645
1976	1,158	425	18,390	32,000
1977	112	349	2,186	1,819
1978	740	214	9,199	11,952
1980	45	75	862	744
1981	99	82	2,071	1,637
1982	6	41	283	101
1983	45	39	643	735
1984	25	42	251	427
1985	5	30	171	89
1988	285	508	tbd	2,400

Source : Asian Development Bank Reports.

Annexure - I. 1

ESTIMATED PRIVATE SECTOR LOSSES OF 1992 FLOODS

Province/ Region	Villages affected	Persons affected (000)	Area affected (acres) (000)	Crops affected (acres) (000)	Houses damaged kacha/ pacca (000)	Houses Demolished/ kacha/ pacca (000)	Persons died.	Cattle Head lost (000)
Punjab	6577	4192	5743	2808	150/76	120/37	390	39
Sindh	5000	3233	3844	3845	251/00	276/-	223	85
N.W.F.P.	945	120	87	64	8/11	13/04	386	5
Balochistan	500	NA	NA	NA	NA	NA	NA	NA
Azad Kashmir	261	33	NA	NA	12/20	4/10	304	5
Northern Areas.	NA	43	15	14	6/00	9/00	37	26
Islamabad C.T.	--	2	1	--	0.4/.04	.03/.02	1	0.042
Total :	13208	7623	9690	6731	427/89	422/39	1341	160

Note : In addition 9603 cattle Shed destroyed, 830 fully and 42 shops partially damaged. 504 punchakis, 62 hotels, 3 petrol pumps, 18 poultry farms, 2 saw mills etc.

Source : - Provincial Relief Commissioners/Additional Relief Commissioner.

- NESPAK Project Report, November, 1988.

Annexure - I. 2

ESTIMATED PUBLIC SECTOR LOSSES - 1992 FLOODS

(Rs. in million)

Province/ Department	Description	Amount
1	2	3
Punjab	Roads, Bridges, irrigation works, water supply schemes, dams, public buildings, structures etc.	4874
Sindh	Road, bridges, irrigation works, buildings, Karachi local abadies.	1454
N.W.F.P.	Roads, Bridges, Irrigation Works and Buildings etc.	1100
A.J.K.	Roads, Bridges, Buildings etc.	582
Northern Areas.	Roads, Power installations, Bridges etc.	50
WAPDA	Grid stations, Transmission lines etc.	413
N.H.A.	Roads, Bridges etc.	1160
E.N.C.	Roads, Pind Dadan Khan	2360
Railways	Track and bridges Rehabilitation.	200
	Total :	12,193

Note : The amount of losses given above is generally based on reports given upto November, 1992 with updated information where available.

Source : Departmental Reports and NESPAK Project Report.

Annexure - J

EXCERPTS FROM CANAL & DRAINAGE ACT.
ACT NO. VIII OF 1973, PART VII

Section 55 Power to prohibit obstructions or order their removal.	Whenever it appears to the Local Government that injury to any land or the public health convenience has arisen or may arise from the obstruction of any river, stream or drainage channel, such Govt: may, by notification published in the official Gazette, prohibit, within limits to be defined in such notification, the formation of any obstruction or may, within such limits, order the removal or other modification of such obstruction There upon so much of the said river, stream, or drainage channel as is comprised within such limits, shall be held to be a drainage work as defined in section three.
Section 56 Power to remove obstructions after prohibition.	The Divisional Canal Officer, or other person authorised by the Local Government in that behalf, may, after such publication, issue an order to the person causing or having control over any such obstruction to remove or modify the same within a time to be fixed in the order. If within the time so fixed, such person does not comply with the order, the said Canal Officer may himself remove or modify the obstruction; and if the person to whom the order was issued does not, when called upon, pay the expenses involved in such removal or modification, such expenses shall be recoverable by the Collector from him or his representative in interest as an arrears of land revenue.