PAPER NO. 557

A PROPOSAL RAISE MAXIMUM CAPACITY LEVEL (MCL) OF MANGLA RESERVOIR BASED UPON DOWNWARD REVISION OF MANGLA PMF AND IMPROVED FLOOD FORECASTING AND WARNING FACILITIES

BY

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1.0 INTRODUCTION

Major consideration in fixing the level of 1202 SPD as the Maximum Capacity Level (MCL) for Mangla is the PMF of 26 lac cusecs as computed by the foreign Consultants (Binnie and Partners) in 1959. Since then a considerably large data series for the Dam site has become available. The highest value of Mangla inflow recorded during the past about 100 years stands at around 12 lac cusecs. A fleeing that 26 lac cusecs is perhaps much on the higher side (even as a PMF value) has agitated many minds linked with the problem. On the other hand however the foreign Consultants who originally computed this large value called it a conservative estimate and also warned against any attempt to raise the Maximum Capacity Level (MCL) in future. Despite this, however, the need to review the PMP/PMF gathered enough weight that the study got awarded to M / S Harza Engineering Company Limited for this purpose. Unfortunately it seems that M/ S Harza being one of the active partners with Binnie's were not in a position to contradict their earlier study and consequently the second study too did not produce any substantial change in the overall picture of the PMF (PMF value was brought down to 24 lac cusecs but the duration of the peak and thus the critical volume was increased). The two studies are based upon some what different assumptions. However, over maximization of the storm precipitation remains to be the common feature between them, resulting in the over estimation of the PMF value in both the cases.

The author having critically gone through the two studies is of the firm opinion that the PMF has been over estimated. A study of 1992 flood (which stands out as one of the most important land mark in the history of Mangla catchment) also confirms this impression. This Factor alone constitutes sufficient reason to raise the MCL suitability (depending upon the most realistic value of PMF). However additionally now the system of flood forecasting has been brought to a level that it can be conveniently relied upon as a means of early warning to permit the pre-flood releases. In the light of the above two factors , this proposal to raise the MCL for Mangla by at least 4 feet is presented.

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2.0 COMMENTS ON THE PMP/PMF STUDIES OF MANGLA CATCHMENT

First study upon which the present Mangla system is based was the one conducted by M/ S Binnie and Partners in 1959. A PMF amounting to 26 lac cusecs was computed. Subsequently a revised study was conducted by M/ S Harza Engineering Company Limited which resulted in the PMF of about 24 lac cusecs.

However, before furnishing comments on the two studies it seems appropriate to indicate the standard procedure of PMP/PMF computations, to enable the reader to understand the deviations in the two studies.

2.1 Steps Involved in the PMP/PMF Computation

i) Selection of storm / storms which have produced the highest rainfall in this or the adjacent catchment.

ii) Transposition of the storm from the adjacent catchment (only if considered necessary).

iii) Development of the storm isohyetal maps by using the isopercental technique based upon the use of normal seasonal precipitation map.

iv) Construction of the mass curves for stations in or around the basin to help develop depth-area duration curves of all the storms considered critical.

v) To maximize the rainfall values obtained in step (iv) by multiplying with the maximization factor based upon the ratios of the maximum precipitable water to the representatives storm precipitable water.

vi) To pick up maximum precipitation values for different six hourly time intervals in respect of various areas.

vii) To develop unit hydrographs for all the sub-basins. This may include development of synthetic unit hydrographs for those tributaries where actual discharge / storm data is inadequate.

viii) To develop the series of the flood hydrographs using PMP values with the respective unit hydrographs developed in step (vii).

ix) To Route the flood routing methods or models and adding all the routed hydrographs together with proper time sequence to obtain the PMF hydrograph.

The above steps constitute universally accepted and thus most commonly adopted procedure for PMF computations.

3.0 COMMENTS ON THE ORIGINAL (1959) PMF STUDY

3.1 General Comments

The study encompasses all the necessary hydrometeorlogical and physiographic aspects of the catchment and is therefore apparently quite comprehensive, yet however; due to the lack of adequate knowledge and experience of the Authors with regard to the climate and weather of this country, the study suffers from some of the serious technical errors.

3.2 Specific Comments

3.2.1Major Points

i) Concept of an antecedent storm which shall occur three days prior to the occurrence of a major storm from the Bay of Bengal has been included in the study. Consequently storm of August 1958 has been chosen to represent this antecedent flood which has been used to create the base flow upon which the major storm run-off hydrograph is superimposed after catering for the necessary time lag. Inclusion of such an antecedent storm is technically incorrect for the following reasons.

Recurrence interval of three days between the two successive storms is technically not supported by the PMD's studies. A minimum of 5 days between the occurrence of the two successive storms (associated with the Monsoon depressions) is the actual period.

In order to support the occurrence of the two successive storms within a short period of three days it has been indicated that the antecedent storm shall arrive in the Mangla catchment from the Arabian Sea (instead of from the Bay of Bengal). That this is contrary to Meteorological facts is brought out by the following consideration.

Firstly an extremely few storms originate in the Arabian Sea and secondly no such storm can penetrate sufficiently inlanded to reach the Mangla catchment. There is no storm on record (in the recorded history of the Meteorological Department) which has moved inland from the Arabian Sea. The Arabian Sea storms may just touch the narrow coastal belt but cannot move inland because of the opposing Meteorological factors.

It is however possible that a particular Monsoon depression having originated in the Bay of Bengal moves across India and then enters the Arabian Sea along the Gujrat coast and then moves inland again in the

North/ northeast direction and eventually arrives in or around Mangla catchment. However in case this happens it would be termed as Bay of Bengal depression and not the Arabian Sea depression. The time interval between this and the subsequent depression shall be at least five days and not three days.

Consequently use of the 1958 flood hydrograph as an antecedent flood is not justified.

ii) It is indicated in the study that the transposition of the storm from the adjacent catchment is technically incorrect due to unique nature of the Mangla Catchment. Consequently no transposition of 1929 storm to Mangla catchment (From Tarbela Catchment) has been attempted in the case. This hypothesis is not correct since there is nothing unique or strange about Mangla catchment. Strangely enough in their subsequent (Revised study) Harza has over-ruled this concept and transposed the 1929 storm from Tarbela to Mangla catchment.

iii) The study uses two maximization factors for maximizing the catchment precipitation. These are moisture and wind factors respectively. Moisture has been maximized by adopting the maximum dew point value of 85°F as the highest 12 hours persisting due point for the Mangla catchment. The value of the precipitable water for this dew point is 4.36 inches. This is divided by actual storm precipitable water to obtain the moisture index. Actually this was the only maximization required to be done; while M/s Binnie's have enhanced this maximizing factor by multiplying it with another maximization factor called the wind factor. This enhanced factor is by far the most important element in the entire study in raising the PMF to such an unrealistically high value. The concept of the wind factor is that the low level wind is the source of the moisture in the catchment and thus higher the wind the greater would be the moisture incursion. Even though the concept has the valid technical basis yet, it is not applicable to such inland catchments as Mangla. The concept is essentially valid for the coastal catchments only. Most of the investigators have regarded wind factor as unrealistic causing undue maximization and have therefore abandoned its use. This factor (which is actually not applicable to Mangla catchment) has been applied to the catchment in the following manner :

A maximum wind at 2,000 feet level has been taken to be 28.5 Knots (PMD study). This wind has been divided by the representative storm wind at 2,000 feet. The resulting factor is the wind factor. This wind factor has been multiplied by the moisture factor as computed earlier. The product of the two is the (final) maximization factor as given on page 25 of the study. The fact that the maximization factor is too high at least in respect of 1956

flood is borne out by its value which stands at 4.20. This simply means that the actual storm precipitation has been multiplied by at least a factor of 4 to obtain the final value of the catchment precipitation in the process of PMP computations.

The storm of 31st July to 3rd August 1956 has been used for PMP computations for Punch and Lower Jhelum catchments. These two sub-catchments are the major contributions to the PMF with the result that the PMF as computed in the study has been raised to such an unrealistic high value of 26 lac cusecs.

iv) Creager value provide the rough check to the computed PMF values. It is only dependent upon the catchment Area and is obtained from the following equation.

$$Qp = C*A'^{(0.894A'-0.048)}$$

Where A' = 0.39A, A is the catchment area in Square Kilometres.

Creager value of C equal to one hundred has been considered quite large for the American Rivers. The value for the big storms of the Mangla catchment which occurred in 1893, 1928, 1958 and 1959 is given at page 43 as 86,61,53 and 74 respectively. Only in case of 1929 storm it is 107, while in case of 1992 storm it comes to around 110. This is quite normal since the rainfall intensity in such a tropical country like Pakistan has to be higher as compared to a river catchment in USA. Therefore the fact that the creager values of the largest Mangla historical floods are slightly greater than those of the largest USA floods, should not come as a surprise. Mangla catchment on account of its geo-graphical location is affected by an airmass which by virtue of its higher temp is capable of the holding and then precipitating greater amount of rain as compared to a catchment in USA. This however should not be construed to mean that the PMP/PMF would be un-proportionately higher in Mangla. Infact the ratio between the highest historical floods and PMF should be about the same any where in the world. A creager value ranging between 150-200 is considered reasonable for the PMF in Pakistani catchments. It is thus obvious that a creager value of 269 indicates a grossly over estimated PMF.

v) The Authors of the study have called Mangla catchment as an hydrologically abnormal catchment and have thus warned that the normal experience must not be allowed to influence the analysis carried out by them. In the same study while discussing the pattern of the PMF they have

indicated that the pattern of all Mangla floods is remarkably consistent. The fact is that there is nothing abnormal about Mangla catchment either hydrologically or Metrologically. The major Mangla floods are those of 1928,29,59 and 1992. Except for 1959 flood there is remarkable consistency in the amount of the peak as well as in the rising and falling pattern of the flood hydrographs. The meteorological consistency is even greater. Except for 1959 flood, all the three floods have occurred on account of the depressions which moved on a very similar track. As regards 1959 flood, there appears to be some discrepancy both in the rainfall as well as discharge measurements. On the meterological chart 1959 depression appears to have lost intensity while its centre was still over the central part of Sind Province. It's further movement is as monsoon low and not as a depression. As against this 1929 and 1992 depressions continue to move as deep depressions and the rainfall and discharge actually recorded is in agreement with the intensity of the depression. Therefore there is no hydrometeorlogical abnormality in the Mangla catchment and contrary to the Consultants impression, the behaviour of the catchment in producing the major floods is fully consistent with its physiographic and hydrometeorlogical characteristics. Consequently the applications of the past experience towards the future assessment is not only justifiable but is absolutely essential for any meaningful and realistic analysis.

3.2 Minor Points

i) While describing the climate and weather of the catchment, no mention is made of one of the most important weather systems responsible for the generation of Southwest monsoon current and source of category I floods in Mangla. This is the seasonal low which even though forms during the pre-monsoon period yet remains an important element during the entire monsoon season.

ii) The study (Page-17) indicates that the maximum elevation upto which the rainfall continues to increase within the Mangla catchment is between 8,000 and 9,000 feet. This is not correct, the increase in the rain (during monsoon) with elevation is limited to 5,000 feet only as has been established through a number of studies done by Pakistan Meteorological Department. This error has caused an unrealistic increase in the computed precipitation along the Pir Punjal range.

iii) The Authors have spent considerable time and effort in arriving at the conclusion that probable maximum storm (PMS) shall positively occur during Summer Monsoon period. In fact there was actually no need to waste this effort in computing the winter period PMF, since the fact that the PMS shall occur during the Summer Monsoon period only is much too obvious to merit any detailed study.

iv) The probable period of occurrence of the PMF has been indicated to be around first of August. This is technically incorrect. Actually the probable period of the occurrence of the event would be between 15th of August and 15tth of September. Out of this period the most probable time would be around 1st. of September within plus/minus one week. The Authors have however correctly indicated that the history of the PMS would also be very close to that of the 1929 flood. The technical reason for this is that the tendency for the Monsoon depressions to recurve north and northeastwards upon reaching Rajisthan becomes pronounced only after 15th of August.

4.0 COMMENTS ON THE REVISED PMF STUDY

4.1 General Comments

Revised PMF study even though essentially based upon the original study in as such as the selection of storm etc. is concerned yet differs widely in the basic approach. The concepts considered invalid in the original study have been accepted in this study have been abandoned in the revised study.

It was hypothesised in the original study that Mangla catchment being a unique catchment, it was not correct to transpose any storm from the adjacent catchment for the purpose of PMF computations. This hypothesis has been reviewed and the transposition adopted in the revised study. Similarly the wind maximisation factor adopted in the original study have been done away with for the fear of over maximization.

Lack of adequate knowledge of the authors is reflected in such phrases as " There are still many unknowns relative to the causes of the extreme rainfall". Such statements may be true for them but not far the PMD. As far as PMD is concerned there is absolutely no confusion in our understanding of the causes of the extreme rainfall in Mangla catchment. Extreme rainfall in Mangla shall always be caused by the meteorological conditions mentioned for the Cat III. Mangla floods i.e. under the combined effect of the strong westerly wave to the north and an intense monsoon depression to the South when on an extremely rare occasion the position of these two systems gets mutually juxtaposed along the north-south axis.

The second part of the statement that " Individual experience and judgement should guide the PMF analysis and the PMF values should always be considered as estimates which could vary with an increase in data base or with the judgement/experience of the investigator" is a factual expression, underlying the need for continuous updating of the PMF specially after some real big flood event such as that of 1992.

4.2 Specific Comment
Minor Points

i) The concept of antecedent storm as used in the original study has been retained and the hydrograph of 1958 has been used. This is technically wrong as already explained in the comment under para 3.2.1 (i).

ii) The time of occurrence of the PMF has been estimated as on or about 1st August as in the original study. This is again an incorrect assessment.

4.3 Major Points

i) The study is based upon the method of transposition of the storm from the adjacement i.e. Tarbela catchment and then maximising this storm by the standard moisture maximization procedure using the maximum 12 hours persisting dew points. However in the process an additional step has been introduced which amounts to double maximization.

Following is the storm transposition and the precipitation maximization procedure as adopted in the study.

a) The storm isohyetal map was prepared utilizing the normal July - September Isohyetal map.

b) The storm isohyetal map was transposed to Mangla catchment in such a way that the storm centre was located on the up slopes of the Swalik range to follow the general historic pattern.

c) Ratios of the storm rainfall depth to the significant storm locations were worked out and then transferred to their corresponding locations on the transposed isohyetal map of the Mangla Basin. These ratios were then multiplied by the normal July - September rainfall depth for Mangla catchment.

d) The storm depths derived in step (c) above were multiplied by the moisture maximization factor of 1.25.

The above steps resulted in the double maximization and caused the over estimation of the PMP and in turn that of the PMF.

Step (c) in the above process is an additional non standard step adopted by the authors. Moisture maximization of Mangla is meant to take care of the additional rainfall at Mangla catchment in relation to Tarbela catchment.

Actually all that was required was to transpose the storm isohyetal map from Tarbela to Mangla catchment (with due consideration to physiographic features of the Mangla catchment) and then multiply the rainfall depth with the moisture index factor of 1.25 or so as adopted by the authors. Instead the Authors have introduced a new maximization factor over and above the moisture maximizing factor.

5.0 CONCLUDING REMARKS ON THE TWO MANGLA PMF STUDIES

Major technical flaw in both the studies is the over maximization of the catchment precipitation. 1959 study includes (an additional) wind factor to be multiplied by the moisture maximization factor which is the ratio of the Mangla normal monsoon July-September rainfall to the Tarbela Normal monsoon July-September rainfall for the specific locations at Tarbela and the corresponding locations in Mangla (after the storm transposition). Thus both the studies use an additional maximization factor over and above the moisture maximization factor (based upon the ratios of the precipitable water corresponding to the highest 24 hours persisting dew point of the basin and the representative storm dew point.

The two (additional) maximization factors are the cause of raising the PMF to such high values.

Two other sources of the error adopted in the two studies are :

a) An antecedent storm persumed to emerge from the Arabian Sea three days prior to the major Bay of Bengal storm.

An elemination of this error shall result in the reduction in the base flow of the PMF hydrograph.

b) Time of occurance of PMF have been taken to be around 1st. of August. In case this is corrected to 1st of September then the already meager snow melt component shall further reduce to a negligible value.

In the light of the above analysis it can be safely concluded that the PMF of 23 lac or 26 lac is grossly over-estimated.

In order to find out the extent of over estimation and to assess the most realistic value of PMF, another PMP/PMF study is required. The study has even otherwise become necessary on account of 1992 Mangla flood event which had not occurred till then. However untill the new PMF Mangla study is ordered and the new value of the PMF is computed, a rough estimation of the PMF can be made as follows.

6.0 A ROUGH ESTIMATE OF THE MANGLA PMF

6.1 In Relation to 1992 Flood Event

Floods in river Jhelum and Chenab on 9th and 10th September, 1992 were caused by the joint action of a monsoon depression and active western disturbance. The western disturbance moving across Russian Turkistan and North Afghanistan was extremely active and forced the monsoon depression to recurve in a northerly direction when it was lying over Rajputana adjacent to Pakistan border area. The monsoon depression which had become weaker was accentuated due to the approach of the westerly wave and made to move in a general northerly direction untill it finally fizzled out upon reaching East of Gujar Khan. Consequently Mangla catchment was directly affected resulting in the generation of historic precipitation and flood in the catchment. The inflow Hydrograph of Jhelum at Mangla (Exhibit-I) indicates two peaks of nearly 10 lac and 11 lac cusecs on the evening of 9th and early morning of 10th respectively. In between the river discharge fell to about 6 lac cusecs. It can be seen by adding together the run-off volumes of the two peaks as a maximization step that the resultant peak could have touched the 12 lac cusecs mark at the most. Previous records shows that river Jhelum at Mangla rose to a level of 11 lac cusecs in 1929 gave PMP studies conducted uptill now show that the storm of 1929 gave the highest values for different depth area durations. PMP study will be conducted for 1992 storm and it is expected that DAD values for shorter spells may exceed the 1929 values. Thus need to review PMP/PMF at Mangla has now positively arisen. However since this activity is likely to take considerable time, the alternate approach of maximising the peak by a factor based upon the maximisation of the dew points. (Pertaining to 1992 flood) could be used to get some rough, yet realistic idea of the PMF. Using this approach a factor of 1.24 has been computed. Now multiplying the highest recorded peak of 12 lac cusecs with this factor, a maximized peak of 14.88 lac is obtained. Additionally a maximized aggregate flow due to snow melt, ground water and base flow amounting to 90,000 cusecs could also be added to this. This yields a value of around 16 lac cusecs. This is the approximate value of PMF as based upon the 1992 flood event.

Contribution due to the antecedent flood (as included in the PMF study by Binnie's) is not considered, since it is not meteorologically possible to have two major depression within a short period of three days. Thus the contribution due to one depression only has been taken into account.

6.2 PMF Estimate Based Upon 100 Year Flood

100 year flood is usually considered equivalent to the standard project flood (SPF) in many countries including India. SPF is determined by the unit hydrograph and standard project storm (SPS). SPS is the largest recorded storm which in case of Mangla is 1992 storm. Consequently the flood of 1992 can be considered as the

100 years flood with the enhanced value of 12 lac cusecs based upon the consideration of double peak as explained earlier. In the revised study the M/s Harza have indicated two values for the 100 year flood (page-43), one based upon the data for the period of 1972-90 and the other for the data upto 1966 only. The two values are about 10 lac and 13 lac cusecs respectively. Taking the higher value of 13 lac for 100 year flood and multiplying this with the moisture maximization factor of 1.24 the rough estimate of Mangla PMF comes out to be between 16 and 17 lac cusecs.

6.3 Indian Assessment of the Design Flood

Mr. S.R. Sherma in his book titled " Test Book on Hydrology" has indicated that one of the methods of estimating the design flood is by the application of suitable factor of safety to the observed maximum flood. A value of 1.5 has been adopted by him as the factor in respect of the up land catchments of North Indian rivers and 1.35 for the low land catchments of the central India. North Indian rivers have been taken to include Indus, Jhelum, Chenab, Ravi, Bias, Sutlej and Ganges. Thus applying the factor of 1.5 to the maximum observed flood of Mangla a value of around 17 lac cusecs is obtained for the design flood as applicable to Mangla. Even though the design flood may not be the same as the PMF (PMF may be equal or exceed the design flood) yet it must cover all possible risks to the safety of the Dam and thus may be considered equivalent to PMF in case of major Dams.

7.0 PROPOSED PMF HYDROGRAPH AND ITS ROUTING THROUGH MANGLA RESERVOIR

A hydrograph conforming to the pattern of 1992 flood hydrograph but with an enhanced peak of 17 lac cusecs was constructed to represent the roughly estimated PMF hydrograph (Exhibit-II). Along with this an out flow hydrograph as taken from Exhibit-B of the revised study is appended. Additionally the proposed outflow hydrograph for routing the (proposed) PMF of 17 lac cusecs is drawn.

Thus depicted at Exhibit-II are the following three hydrographs.

i) Proposed PMF hydrograph of 17 lac cusecs (cloured red).
ii) A proposed out flow hydrograph for the safe routing of the PMF of 17 lac cusecs (cloured green).
iii) An elevation curve indicating the rise of the reservoir level.

Routing of the proposed (17 lac cusecs) PMF by using the out flow hydrograph proposed by M/ S Harza shall result in the increase in pond level by 7.8 feet only. Thus if the LCL is at 1206 SPD the lake level shall rise to 1213.8 feet. However this shall entail releases to the tune of 12 lac cusecs which shall cause damaging flood conditions downstream and thus needs to be avoided.

Routing of the proposed (17 lac cusecs) PMF hydrograph with outflow restricted to 5 lac cusecs as per the proposed outflow hydrograph shall result in 22 feet rise of reservoir elevation. Therefore if the MCL is kept at 1206 SPD the maximum pool level shall reach an elevation of 1228 feet SPDS. However since in the case of PMF there shall be enough warning and thus a draw-down to a level of 1202 SPD in advance of the flood peak would have been carried out, so the maximum lake level shall stand at 1224 feet pass the proposed PMF without much adverse effects downstream.

Therefore, if the MCL is raised to 1206 SPD and the PMF of 17 lac cusecs occurs it could be passed through safely by restricting the releases upto 5 lac cusecs only.

8.0 A COMPARISON OF THE PROPOSED PMF HYDROGRAPH WITH THE PMF COMPUTED BY THE CONSULTANTS

PMF is indicated in terms of its peak discharge value and not the volume. Volume is indeed important in assigning the Dam Operating procedure during PMF. In order to judge the values of the three PMF hydrographs all the three were plotted together (at the same scale) and volume for the crucial period of 52 hours was computed as shown at Exhibit-VII. The three volumes are 4.88 MAF, 5.08 MAF and 3.30 MAF in respect of PMF hydrographs computed by M/ S Binni's and Partners, M/ S Harza and the Director, National Flood Forecasting Bureau (NFFB) respectively.

9.0 IMPROVED FLOOD FORECASTING AND WARNING SYSTEM FOR MANGLA

9.1 Meteorological Conditions

A major element forming the basis for the improved warning in Mangla is the improved understanding of the meteorological weather systems responsible for the generation of floods in Mangla catchment.

Three basic Meteorological conditions have been identified and accordingly Mangla floods have been classified into three categories as detailed below:

9.1.1 Catchment - I Mangla Floods

Meteorological condition under which Catchment - I floods occur in Mangla is depicted in Exhibit - III.

This is the condition when seasonal low accentuated resulting in the generation of South Westerly wind flow from Arabian Sea right up to the catchment areas of rivers Sutlej, Ravi, Chenab and Jhelum. However it is the rivers Chenab and

Jhelum which get highest moisture incursion and consequently the maximum rainfall. Amount of rainfall shall depend upon the intensification of seasonal low , which shall in turn be indicated by the thickness of the moist layer as indicated by the vertical extent of the Southwesterly air current, which may extend up to the height of ten thousand feet under extreme conditions. Quite often in addition to this some South East incursion from Bay of Bengal may also be present.

Under this condition, the clouds start forming due to condensation brought about by the Orographic lifting of the moist air mass. Rains start in the afternoon / evening and may continue till the next morning. Heavy rains shall normally occur during morning due to nocturnal cooling. Peaks usually develop during morning hours. Such peaks are short lived but may be repeated every day as long as this meteorological situation persists. About 80% of the peaks shall be confined to below 2 lac cusecs. About 15% may range between 2-4 lac cusecs while only 5% may cross 4 lac cusecs. Under an exceptionally rare case when the South-East monsoon current is exceptionally strong and deep, a peak of upto 6 lac cusecs could occur. Generally speaking no serious floods problem is encountered under Catchment - I condition in Mangla catchment.

9.1.2 Catchment - II Floods

Second condition (Exhibit-IV) under which floods in Mangla catchment occur is when a monsoon low / depression approaches from East / South - East transversing across Sutlej, Ravi and Chenab catchments. Under this situation the rain producing capacity of the depression is considerably reduced (by the time it reaches Mangla catchment) due to extensive moisture shedding (in the form of heavy rains) over sutlej, Ravi and Chenab catchments.

Consequently the floods under this condition shall generally range within 3-6 lac cusecs. Only in extremely rare case however when the depression happens to be extremely intense, a peak ranging from 6-8 lac cusecs may occur. Again no serious flood management problem shall arise in this case.

9.1.3 Catchment-III Floods

Third and most critical situation is (Exhibit-V) when the depression takes a straight northerly path from its position in Rajishtan and enters Pakistan along Lahore Division and then continues to move towards Rawalpindi Division skipping the catchments of Sutlej and Ravi to the east. Under this condition Chenab and Jhelum catchments shall come under the direct effect because firstly it is the North East sector of the depression which gets the heaviest precipitation and secondly because the depression reaches the vicinity of Mangla catchment (along the plains) with most of its intensity still in tact. Additionally , since the northwards movement of the depression is caused by the presence of a strong

westerly wave to the north, heavy rains shall always extend further North to cover lower part of Tarbela catchment, Hazara Division and whole of Kashmir. Heaviest floods on record are caused under this situation (1928, 1929 and 1992 flood situations).

10.0 CAPABILITIES AND LIMITATION OF THE FLOOD FORECASTING SYSTEM IN FORECASTING FLOODS OF THE MANGLA CATCHMENTS

Meteorological causes of floods in Mangla are illustrated in para 8 while describing the three categories of Mangla Floods. Bigger floods are easier to forecast since they are associated with intense weather systems. Catchment-I floods in Mangla are therefore, most difficult to forecast since the weaker weather systems with which they are associated cause rainfall with tremendous variability in space and time. Fortunately however catchment -I floods are relatively unimportant and shall pose no flood management problem. Catchment-I flood situation should mean that repeated peaks of short duration mostly confined to below 2 lac cusecs but a few ranging within 2-4 lac cusecs may occur. Most of the time rain shall occur in early morning and peak shall arrive during the early hours of the day.

Under the extreme intensification of the catchment-I condition a peak may range to within 4-6 lac cusecs. However in case this is expected another special information indicating such an intensification shall most probably be issued. Thus generally speaking catchment-I situation shall mean that there is no cause of worry and that all flood peaks are within manageable limits. In the presence of such qualitative information even if a particular peak is not properly forecast (due to lack of rainfall data etc.) it should not be a cause of concern.

Forecasting of catchment-II floods is easier than the catchment-I floods situation the movement of the monsoon depression as it starts moving out of the Bay of Bengal shall be monitored and communicated to Mangla. A blue Alert shall be issued indication the arrival of the depression at Rajisthan . In case the depression recurves North-Eastward and starts moving towards Sutlej catchment, a yellow Alert is issued which is followed by "Red Alert" when the depression starts to shed rain in the catchment under its direct effect. Thus catchment-II floods shall be easier to forecast. Possible error on the safer side i.e. in terms of the over warning is possible. However since under this category of floods there shall be no need for the pre-flood releases, an element of over warning shall have no serious repercussions.

Catchment-III flood forecasting shall be the easiest but most crucial of all since the condition under which a catchment-III flood shall occur are the presence of an intense monsoon depression which shall move northwards from Rajisthan under

effect of an abnormally depression to the south (Rajishtan) an almost equally strong westerly wave need be present to the North i.e. over Afghanistan or over the North-West Pakistan. Detection of these two intense weather systems should not pose any problem using meteorological maps and the satellite pictures. Further more an extremely good record of 1992 storm is available to provide a comparison of the intensity of the depression in terms of pressure gradient and the resulting rainfall / run-off.

Therefore capability of forecasting the most serious i.e. catchment-III floods in Mangla is to the extent that complete reliance can be placed on the forecasting system for early warning at-least in the qualitative terms. Capability of making the quantitative forecasts has also been developed to a satisfactory extent during the post 1992 flood period through extensive in-depth study of meteorological parameters of the 1992 flood event. Thus in future it should be quite possible to issue a quantitative forecast as well; indicating the range within which the peak in Mangla shall be expected. Quantitative forecast based upon the recorded rain and discharge data of Mangla catchment shall be limited to a maximum of about 10 hours (but often much less) due to the fast speed of the flood wave. In order therefore, to increase the lead time reliance on the meteorological parameters relating to the movement and intensity of the weather systems shall have perforce to be mad. In depth study of the 1992 flood event has provided good indicators on the basis of which a quantitative forecast indicating a narrow range within which the flood peak is expected can be made. Further studies to improve the methodology to a satisfactory level is urgently required.

11.0 CAPABILITY TO FORECAST PMF

PMF shall occur on account of the PMS caused by most intense catchment-III flood condition. As indicated earlier it shall occur on an extremely rare occasion when the positions of westerly wave and the monsoon depressions get mutually jaxtaposed along a North--South axis. Additionally the intensity of the monsoon depression in terms of the low pressure value shall be about twice that of 1992 depression. This shall mean that the isobaric structures of the depression may appear similar to the one given at Exhibit-VI. To detect such a deep depression should pose absolutely no problem for any experienced meteorologist. Consequently capability in forecasting of PMF in Yes/No terms is 100%. All that is required is to ensure the reception of meteorological data from New Dehli and Karachi. The state data reception is likely to improve with time in view of the better communication facilities planned in future. State of PMF forecast therefore, is that of complete satisfaction provided a proper co-ordination between WAPDA and NFFB is ensured and concerned WAPDA officers understand the conditions under which PMF occurs so that they are able to interpret the flood forecast without any confusion or misunderstanding. Further more it must be made a part of the procedure that in case some confusion occurs with regards to the

interpretation of the flood forecast/warning, it must be got clarified through the personal contact with the Director , National Flood Forecasting Bureau (NFFB).

In addition to all this the reservoir may be draw-down to a level of 1202 SPD in advance of catchment-III flood as an extreme measure of Dam Safety.

12.0 USE OF MANGLA RESERVOIR AS A SOURCE OF FLOOD MITIGATION

Presently little or no consideration is being given to use Mangla reservoir as a source of flood mitigation. Pattern of releases from Mangla during flood season indicate that upon reaching the MCL, the only consideration in operating the reservoir is to match the outflows so as to maintain the MCL.

It is indeed true that no flood storage as such exists in Mangla one the MCL has been reached. This however should not be construed to mean that the reservoir looses all its flood mitigation capabilities upon reaching the MCL. One the contrary a very effective flood mitigation function can be performed by Mangla reservoir if operated intelligently. In order to illustrate as to how it can be done the following facts need to be brought out to provide the necessary back-ground information.

The geographic and physiographic features of Mangla and Marala catchments are such that the significant rainfall in Mangla shall always be caused by the moisture laden winds from the Bay of Bengal and Arabian Sea which must reach Mangla catchment along the upper catchment of river Chenab. River Chenab can account of its typical physiographic features is the most flood prone channel of the Indus river system. One such significant feature is the Pir Punjal range which provided an excellent physical barrier and thus an effective source for orographic lifting for both the South West and South East air-masses originating in the Arabian Sea and Bay of Bengal respectively. Therefore the intensity and frequency of rainfall and consequently the floods in Chenab catchment far exceeds that of all the other rivers.

Therefore Significant Floods in Mangla catchment cannot occur in isolation because the monsoon air current associated with or without a monsoon low depression must travel across Chenab catchment before reaching the Mangla catchment. In case of Catchment-I and II Mangla floods, Bulk of moisture shall be shed out within the Chenab catchment leaving a relatively smaller share for the Mangla catchment. However under the Catchment-III flood situation since the depression as such shall mot move into the Chenab catchment the rainfall in Mangla catchment could equal or even exceed that of Chenab catchment. Even in this case the flood must simultaneously occur in both the catchments. Thus whenever significant flood occurs in Mangla catchment a flood of about twice that

size must occur in Chenab catchment.

The above fact is adequately confirmed by the flood data of the two rivers. Not only this but also the time of concentration of the flood peaks at Mangla and Marala is very similar and thus the peaks occur at the two rim stations at about the same time. In addition to this the strange coincidence is that the time of travel of the two peaks to Trimmu is about the same. Mangla-Trimmu time ranges from 66-80 hours while Marala-Trimmu time is limited to within 60-80 hours.

Consequently there shall always be a strong possibility that two peaks of the rivers Jhelum and Chenab shall completely or at least partially coincide at Trimmu creating a damaging flood peak at Trimmu and further down in the river Chenab. Cases are not uncommon when Mangla releases have positively aggravated the flood situation at Trimmu and downstream. This situation can be either completely or atleast partially averted if the releases from Mangla are held back at least for one day. This should be of catchment-III floods, the answer lies in resorting to pre-flood releases on the basis of the qualitative flood forecast with some indication of the range within which the flood peak is likely to be confined.

13.0 FINAL RECOMMENDATIONS

13.1 Maximum Capacity Level (MCL) - may be raised from 1202 SPD to 1206 SPD.

This recommendation is based upon the reduced PMF value of about 17 lac cusecs as against 26 lac cusecs provided for in the existing set up. The reduced value of PMF shall result in the reduction in the PMF volume to the extent that proposed raising shall not jeopardize the safety of the dam against floods.

13.2 A close liaison with Director National Flood Forecasting Bureau, Lahore should be maintained by Chief Engineer Mangla Dam during the flood season specially after a monsoon depression arrives at Rajisthan state of India.

13.3 In case of Catchment - I and Catchment-II situation all significant flood peaks (exceeding 2 lac cusecs) should be held back by at least one day and absolutely no fears in respect of dam safety be entertained on this account (even if the lake level rises beyond 1208 SPD).

This step is necessary to avoid complete or partial coincidence of Chenab and Jhelum peaks at Trimmu.

13.4 In case Catchment-III flood is forecast by Director, National Flood Forecasting Bureau (which shall be an extremely rare occurrence) the reservoir be drawn-down to 1202 SPD as quickly as practicable.

13.5 In case of Catchment-III flood situation , Director , National Flood Forecasting Bureau must give out a forecast of PMF in Yes/No. terms.

13.6 In case of PMF releases must be increased to 5 lac cusecs as quickly as practicable and kept at this amount untill the inflow drops substantially below this amount, after which the releases may be gradually reduced and the reservoir brought back to MCL.

13.7 In case it is not the PMF but a catchment-III flood only, then the releases must be increased to 3 lac cusecs as quickly as practicable and maintained at the level till such time that the inflow drops substantially below this amount after which the releases may be gradually reduced till the MCL is reached (Exhibit-VIII).

13.8 Emergency spillway being a safety valve for the reservoir, should be kept operative and the lake level permitted to rise beyond 1208 SPD in case of Catchment-III floods. Consequently the run off channel be cleared of all obstructions and its capacity to pass the maximum design discharge through it fully restored.

13.9 Basically there shall be one major peak only which shall correspond to the north-most position of the depression. However a small scale peak can occur essentially due to the poonch catchment flows in advance of the major peak at the time when the depression is still moving northwards along Lahore Division. This shall be a short lived peak and Director National Flood Forecasting Bureau (NFFB) by monitoring the movement of the depression should be able to indicate the period of major peak which shall occur only when the depression arrives in the immediate vicinity of the Mangla Catchment. The new Quantitative Precepited Measurement (QPM) Doppler Weather Radar at Lahore shall be a finetuning the flood forecast.

13.10 A fresh PMP/PMF study needs to be carried out in view of the fact that the highest (historic) flood occurred in 1992 (subsequent to the revised study) and also because 1992 flood is the best recorded flood in term of hydrometeorlogical data.

14.0 ACKNOWLEDGMENTS

The author gratefully acknowledges the useful discussions held with Director Raees-ur-Rehman and Xen Saleem-ud-Din of D.S.O. (WAPDA).

Mr. S.M. Muzzam the Rtd. Director, flood Forecasting and Warning Centre, Lahore, provided valuable hints based upon his long standing experience in hydrometeorology. Mr. Tajdar Hussain, Meteorologist was helpful in the computational work. The author is deeply indebted to Mr. Muhammad Yasin, Senior Observer who not only keyed in the manuscript but also did a lot of technical work as well. Finally, the author is extremely grateful to Mr. Saadat Ali Chairman IRSA, who reviewed the study and gave useful suggestions.

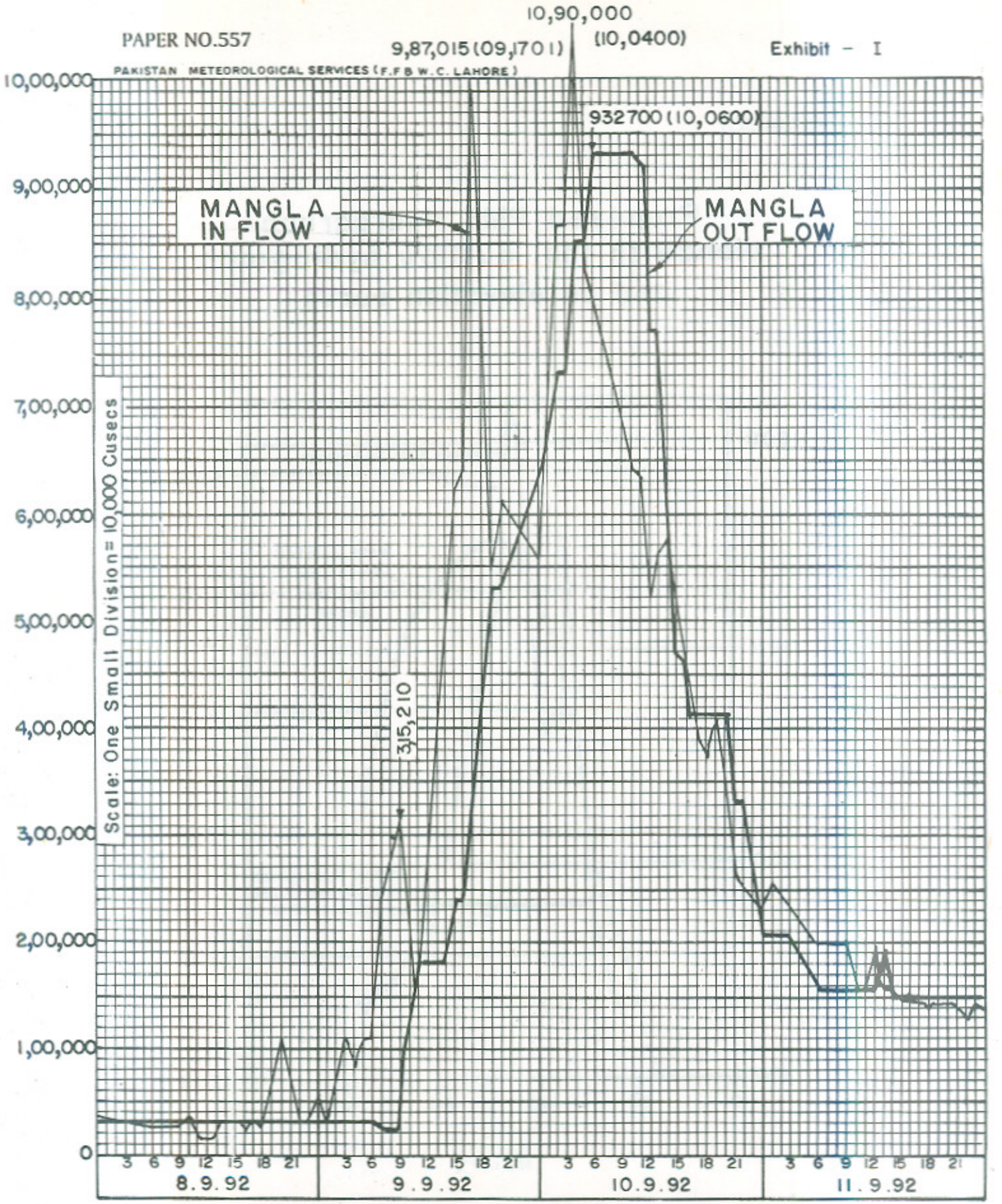
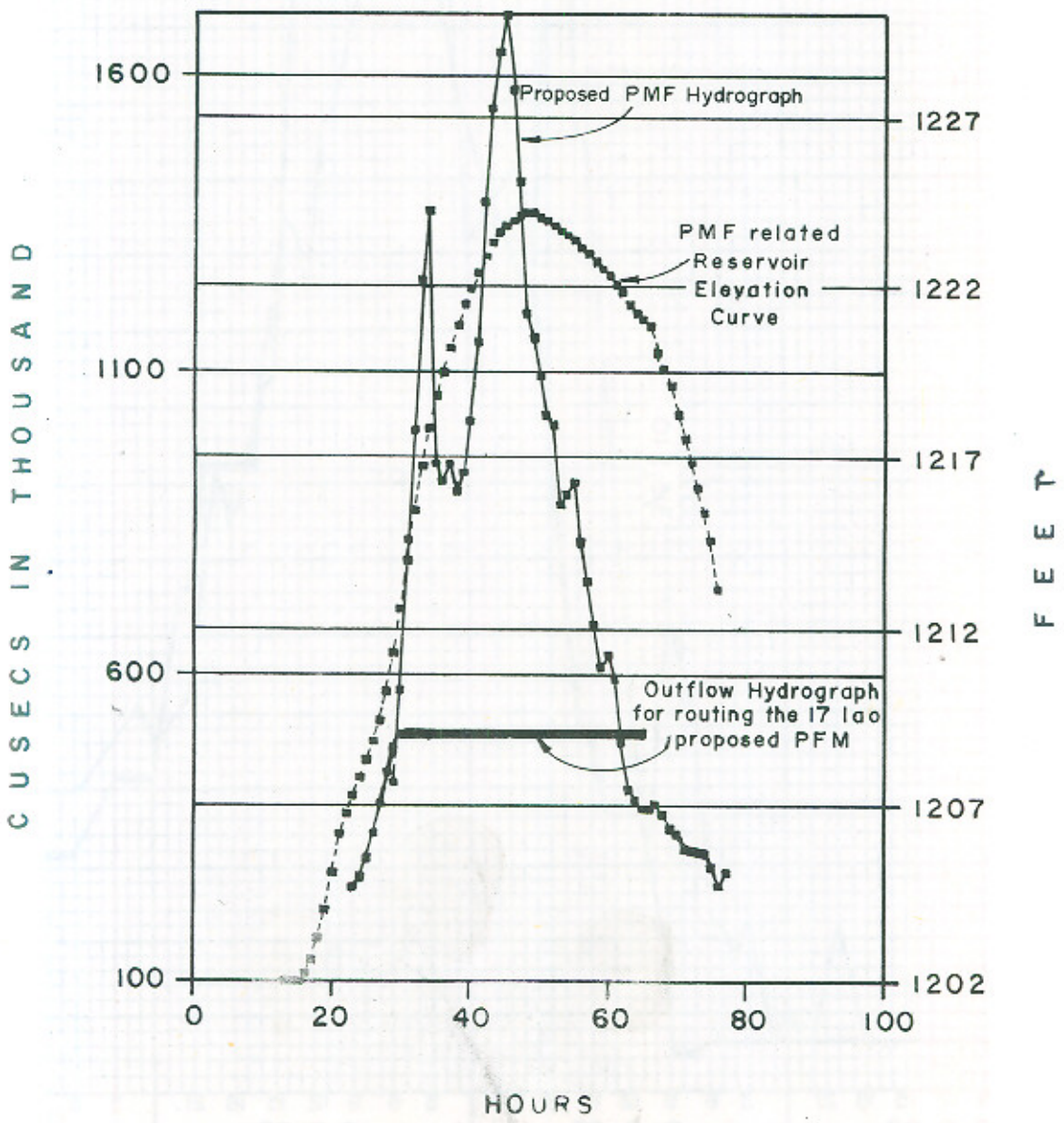

PAPER NO.557
Exhibit – I
PAKISTAN METEOROLOGICAL SERVICES (F.F.B W.C. LAHORE)
10,90,000
(10,0400)
9,87,015 (09,1701)
932700 (10,0600)
MANGLA IN FLOW
MANGLA OUT FLOW
315,210
Scale: One Small Division = 10,000 Cusecs
10,00,000
9,00,000
8,00,000
7,00,000
6,00,000
5,00,000
4,00,000
3,00,000
2,00,000
1,00,000
0
3 6 9 12 15 18 21
8.9.92
9.9.92
10.9.92
11.9.92

Exhibit – II

Proposed PMF Hydrograph alongwith the outflow hydrograph and an elevation curve



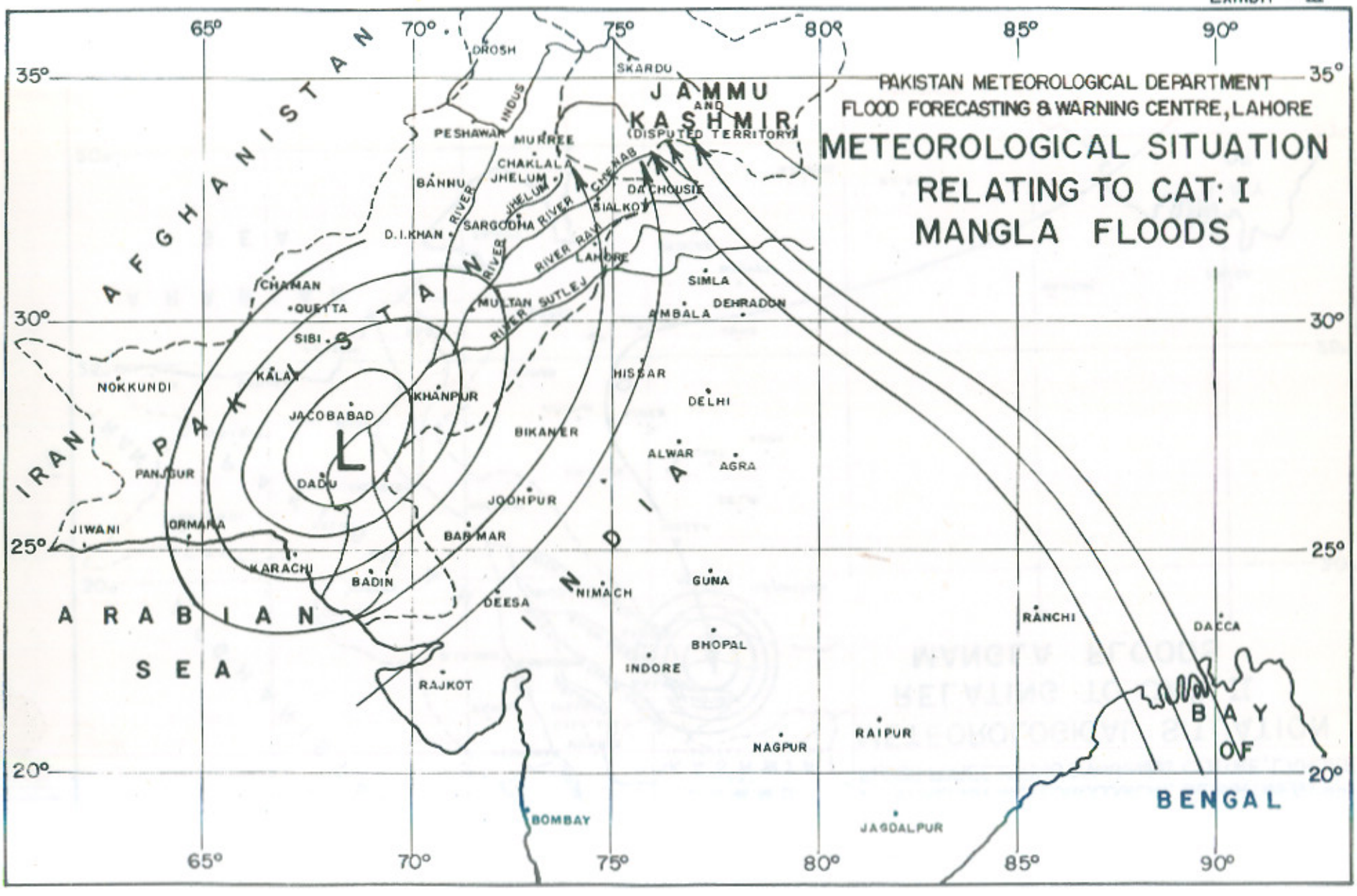
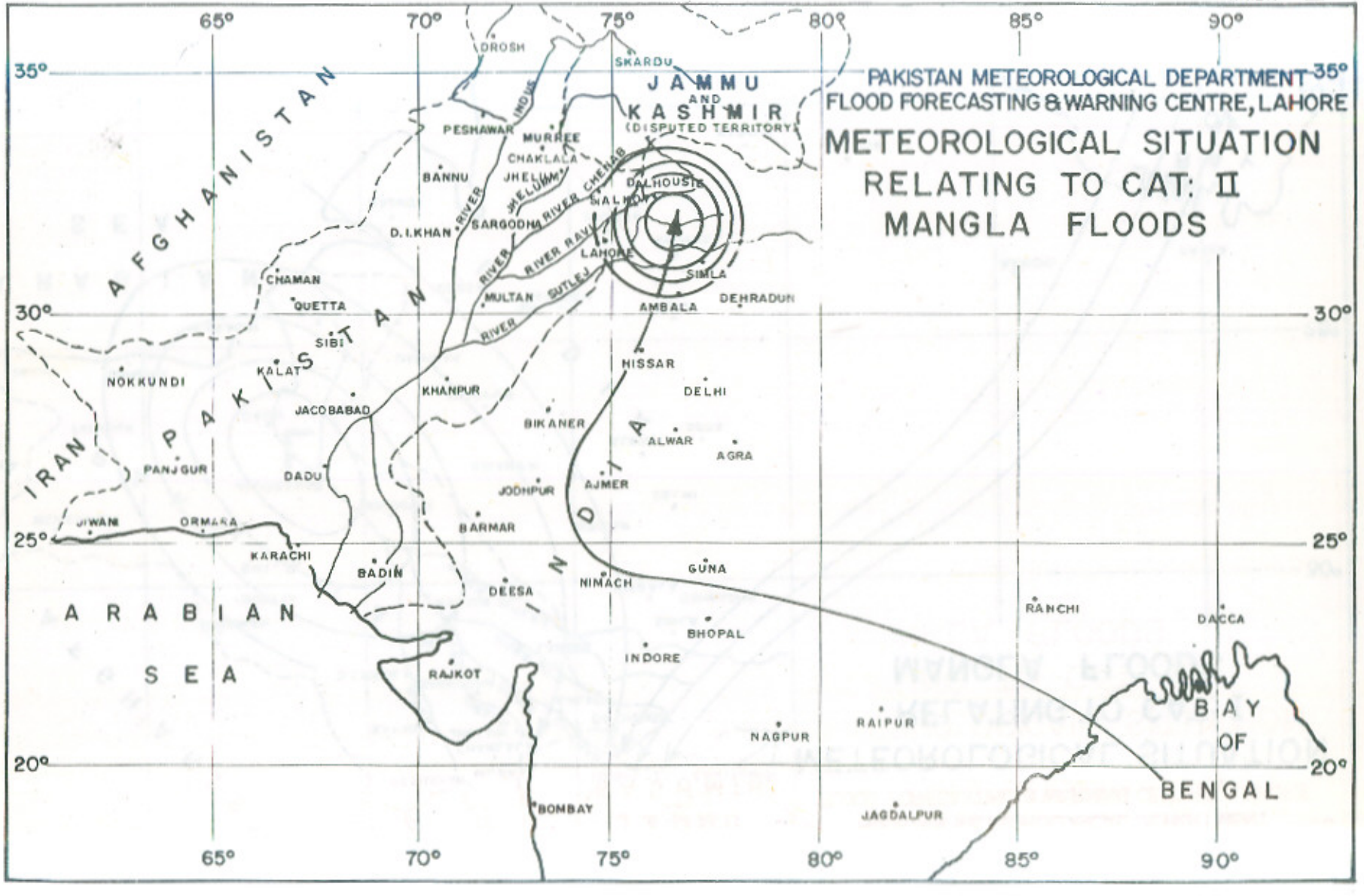
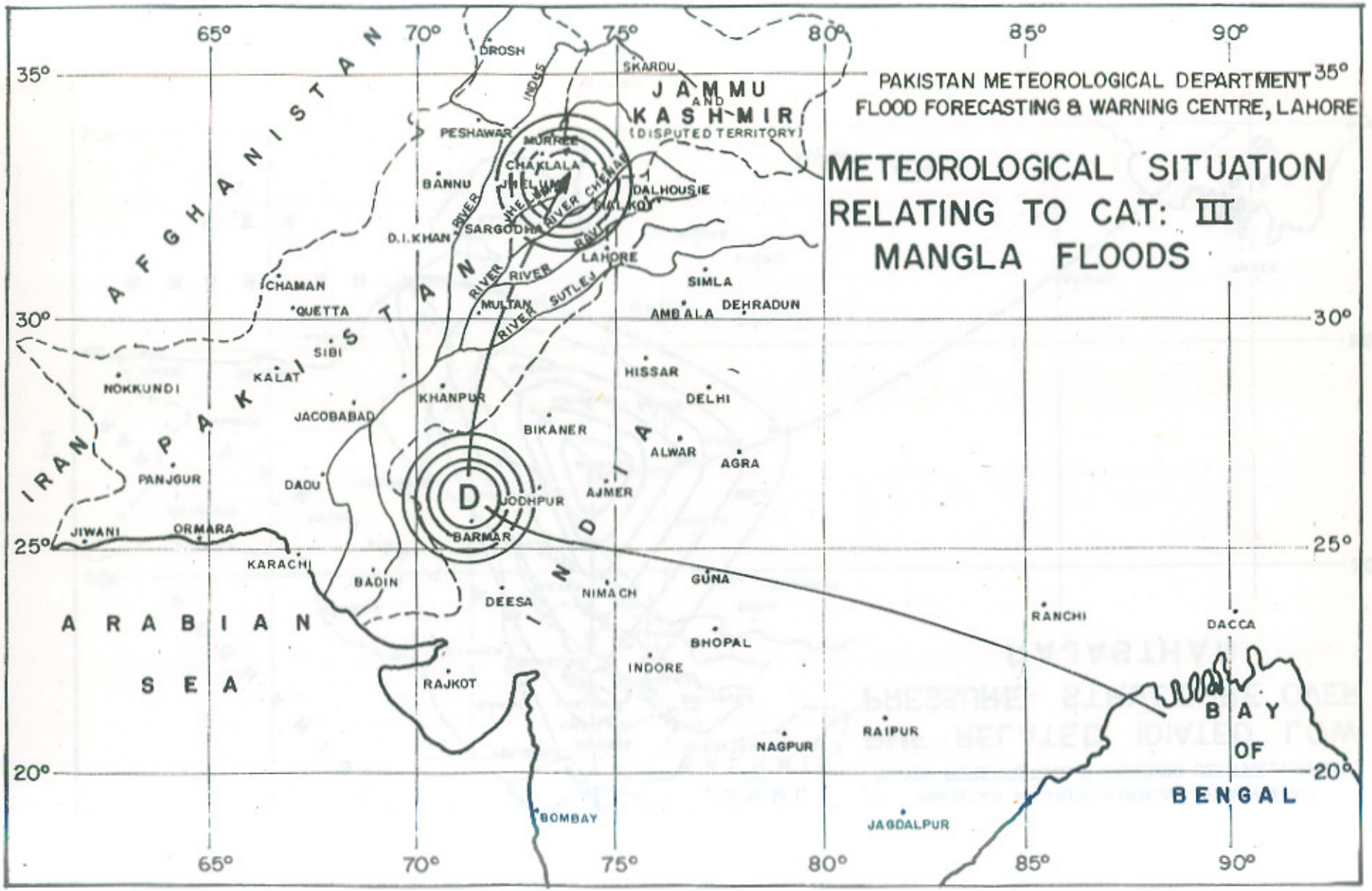
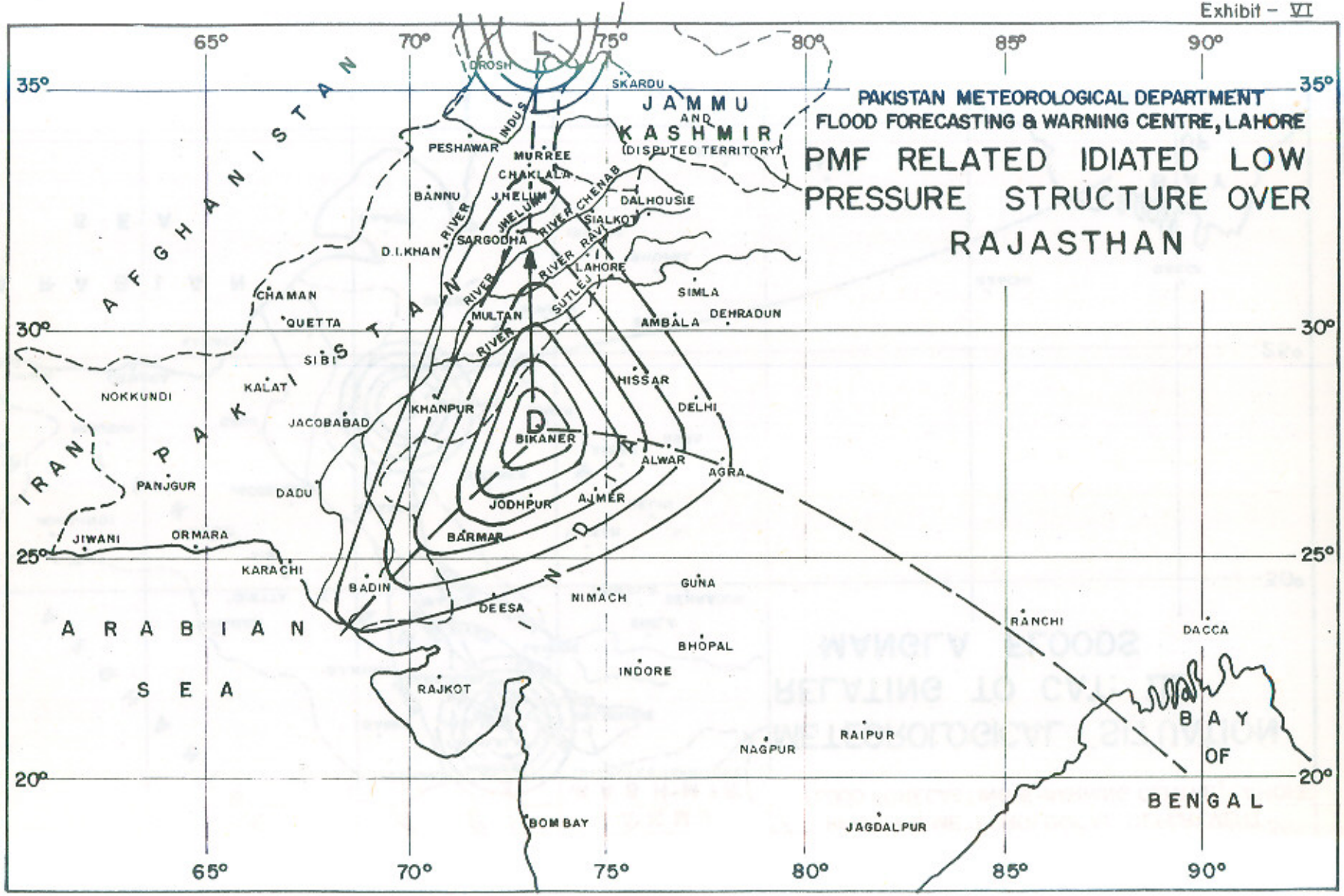

PAKISTAN METEOROLOGICAL DEPARTMENT
FLOOD FORECASTING & WARNING CENTRE, LAHORE
METEOROLOGICAL SITUATION
RELATING TO CAT: I
MANGLA FLOODS
AFGHANISTAN
IRAN
PAKISTAN
INDIA
ARABIAN SEA
BAY OF BENGAL
JAMMU AND KASHMIR (DISPUTED TERRITORY)
DROSH
SKARDU
PESHAWAR
MURREE
CHAKLALA
JHELUM
BANNU
DALHOUSIE
SIALKOT
D.I.KHAN
SARGODHA
LAHORE
CHAMAN
QUETTA
SIBI
MULTAN
SIMLA
AMBALA
DEHRADON
NOKKUNDI
KALAT
KHANPUR
JACOBABAD
HISSAR
DELHI
BIKANER
ALWAR
AGRA
PANJGUR
DADU
JODHPUR
JIWANI
ORMARA
BARMAR
KARACHI
BADIN
DEESA
NIMACH
GUNA
RANCHI
DACCA
BHOPAL
INDORE
RAJKOT
RAIPUR
NAGPUR
BOMBAY
JAGDALPUR
L
65°
70°
75°
80°
85°
90°
35°
30°
25°
20°

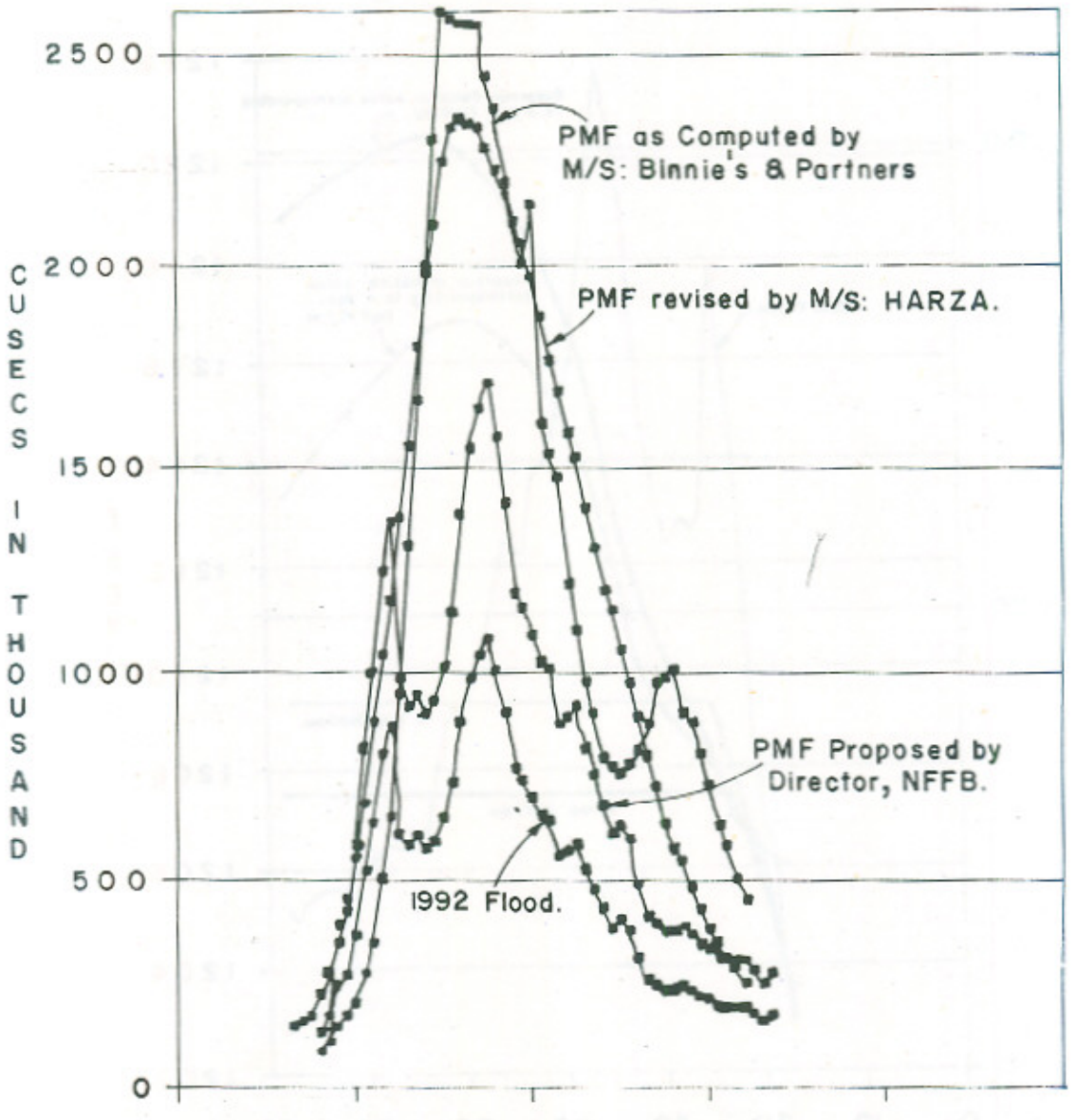
Exhibit – IV


PAKISTAN METEOROLOGICAL DEPARTMENT
FLOOD FORECASTING & WARNING CENTRE, LAHORE
METEOROLOGICAL SITUATION
RELATING TO CAT: II
MANGLA FLOODS
65°
70°
75°
80°
85°
90°
35°
30°
25°
20°
AFGHANISTAN
IRAN
PAKISTAN
INDIA
JAMMU AND KASHMIR
(DISPUTED TERRITORY)
ARABIAN SEA
BAY OF BENGAL
DROSH
SKARDU
PESHAWAR
MURREE
CHAKLALA
BANNU
JHELUM
INDUS RIVER
JHELUM RIVER
CHENAB RIVER
RAVI RIVER
SUTLEJ RIVER
DALHOUSIE
D.I.KHAN
SARGODHA
LAHORE
SIMLA
CHAMAN
QUETTA
MULTAN
AMBALA
DEHRADUN
SIBI
KALAT
NOKKUNDI
KHANPUR
HISSAR
DELHI
JACOBABAD
BIKANER
ALWAR
AGRA
PANJGUR
DADU
JODHPUR
AJMER
JIWANI
ORMARA
BARMAR
KARACHI
BADIN
DEESA
NIMACH
GUNA
RANCHI
DACCA
BHOPAL
INDORE
RAJKOT
NAGPUR
RAIPUR
BOMBAY
JAGDALPUR


PAKISTAN METEOROLOGICAL DEPARTMENT
FLOOD FORECASTING & WARNING CENTRE, LAHORE
METEOROLOGICAL SITUATION
RELATING TO CAT: III
MANGLA FLOODS
D
AFGHANISTAN
IRAN
PAKISTAN
INDIA
JAMMU AND KASHMIR
(DISPUTED TERRITORY)
ARABIAN SEA
BAY OF BENGAL
DROSH
SKARDU
PESHAWAR
MURREE
CHAKLALA
BANNU
DALHOUSIE
D.I.KHAN
SARGODHA
LAHORE
SIMLA
CHAMAN
QUETTA
MULTAN
AMBALA
DEHRADUN
SIBI
KALAT
NOKKUNDI
KHANPUR
HISSAR
DELHI
JACOBABAD
BIKANER
ALWAR
AGRA
PANJGUR
DADU
JODHPUR
AJMER
JIWANI
ORMARA
BARMAR
KARACHI
BADIN
DEESA
NIMACH
GUNA
RANCHI
DACCA
BHOPAL
INDORE
RAJKOT
NAGPUR
RAIPUR
BOMBAY
JAGDALPUR
INDUS
JHELUM
CHENAB
RAVI
SUTLEJ
RIVER
65°
70°
75°
80°
85°
90°
35°
30°
25°
20°


PAKISTAN METEOROLOGICAL DEPARTMENT
FLOOD FORECASTING & WARNING CENTRE, LAHORE
PMF RELATED IDIATED LOW PRESSURE STRUCTURE OVER RAJASTHAN
AFGHANISTAN
IRAN
PAKISTAN
INDIA
JAMMU AND KASHMIR (DISPUTED TERRITORY)
ARABIAN SEA
BAY OF BENGAL
D
DROSH
SKARDU
PESHAWAR
MURREE
CHAKLALA
BANNU
JHELUM
DALHOUSIE
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D.I.KHAN
SARGODHA
LAHORE
CHAMAN
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INDORE
RAJKOT
RAIPUR
NAGPUR
BOMBAY
JAGDALPUR
INDUS RIVER
JHELUM RIVER
CHENAB RIVER
RAVI RIVER
SUTLEJ RIVER
65°
70°
75°
80°
85°
90°
35°
30°
25°
20°

Comparison of Different PMF Hydrographs for a Critical Period of 52 hours.



1_Volume of PMF Computed by M/S Binnie & Partners. =4.88 maf (RED)
2_Volume of PMF Computed by M/S: Harza = 5.08 maf (YELLOW)
3_Volume of PMP as proposed by Dir: NFFB. = 3.30maf (BLUE)
4_Volume of 1992 Flood = 2.06 maf (GREEN)

Exhibit - VIII

PAPER NO.557

1992 Flood hydrograph alongwith Reservoir Elevation Curves for 3 lac & 4 lac outflow hydrographs

