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**MANGLA DAM PROJECT - A
PROPOSAL FOR FLOOD
MITIGATION BY 4.5 FT RAISING
OF DAM**

BY

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A PROPOSAL FOR FLOOD MITIGATION BY 4.5 FEET RAISING OF DAM

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ABSTRACT

Mangla reservoir operation criteria, when water level reaches at or near conservation, as given in Operation & Maintenance (O&M) manual, is that the outflows should match the inflows once the flood arrives. It means no flood mitigation at conservation level. The role of Mangla dam as a flood relief project was conceived during design stage but not provided. During September 1992 Flood, the damage to property, apart from hundred of lives, were reported to be billions of Rupees. A repetition would be just unacceptable. An attempt has therefore been made in this paper to propose modifications in the existing flood operating criteria.

Raising of embankment dam by constructing the parapit wall on the crest is a common practice now-a-days. The proposal describes, that how much raising of embankment is required if the downstream releases are restricted to 400,000 cfs for flood mitigation purposes. Different scenarios have been studied for this purpose. The study indicate that raising of dam crest by about 4.5 ft is required for flood mitigation to keep provision for future sedimentation.

GENERAL

Mangla Dam, an earthfill structure, was built across the river Jhelum in 1967 to create a reservoir of 5.88 MAF. It is a multipurpose project and is designed to conserve the flood waters of river Jhelum. The project comprises main dam, a subsidiary dam at Jari and a Dyke at Sukian located on left side of the reservoir. The crest of the dam is at 1234 ft. with conservation level at 1202 ft. The large capacity above conservation level was provided to handle and route the probable maximum flood (PMF) with reservoir level rising to 1228 ft leaving 6 ft for wave action.

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Provision was kept in the design for second stage raising of embankments to allow raising of maximum conservation level by about 50 ft. All the structures have been designed and constructed to cater for additional head.

RESERVOIR OPERATION

Jhelum river at Mangla has the history that rate of rise in flood hydrograph can be extremely rapid, the maximum increase in flow in one hour in 1929 flood being about 250,000 cusecs. Overtopping of the dams during a flood would be catastrophic hence the PMF was used as the design flood. Since its completion in 1967, the Mangla reservoir has been operated to regulate the seasonal flows of Jhelum river and to supply irrigation water to the downstream canal system.

The reservoir operation criteria when water reaches at or near conservation level, as given in Operation & Maintenance (O&M) manual, is that the outflows should match the inflows once the flood arrives. This criteria is simple and successful for most of the cases, as far as safety of the project is concerned, because it does not involve any decision making.

The history of reservoir operation indicate that the maximum reservoir elevation exceeded 1202 ft only four times - 2 days in 1975, (1203.75 ft) 11 days in 1988, (1202.67 ft) 31 days from August 10 to September 10, 1990 (1204 ft intentional storage for power generation) and 3 days in 1992 (1207.83 ft).

NEED FOR REVIEW OF OPERATIONAL CRITERIA

The dam under present operational criteria is safe for the critical situation of PMF (i.e 2600,000 cfs) which may or may not arrive during life span of the project however it may not be desired to operate the reservoir on critical path under all conditions.

The role of Mangla dam as a flood relief project was conceived but not provided during design stage. It was considered that the reservoir will be filled to conservation level only at the end of monsoon season in late August hence almost all floods generated during filling period shall automatically be absorbed in the reservoir. Flood peaks occurring in September would however pass down without any attenuation.

Past 28 years history indicate that a cushion for flood absorption below conservation level remained available except during September, 1992 flood. The resultant damages to property, apart from hundreds of lives, were reported to be of the order of billions of Rupees. A repetition would be just unacceptable. An attempt has therefore been made in this paper to propose modifications in the existing flood operating criteria to the extent possible, to include flood mitigation as a permanent role of Mangla reservoir.

FLOOD MITIGATION

The extent of flood mitigation possible under present conditions for flood of record or PMF conditions, assuring safety of the project, shall have to be established. If the storage capacity for effective flood mitigation is not available then it would be recommended either to increase the outflow capacity by providing additional outlet or to increase the surcharge storage capacity by raising the dam crest.

Raising of embankment dams by constructing a parapit wall, on the crest, is not uncommon. Recently the capacity of McClure reservoir in the state of New Mexico, USA has been increased by some 17 percent by constructing a concrete parapit wall on embankment and installation of Hydroplus Fuse Gates on the crest of original (ungated) Spillway. The final work was completed in April, 1995. Similar arrangements are possible at Mangla.

AVAILABLE STORAGE FOR FLOOD MITIGATION

From elevation 1202 to 1228 feet (the maximum permissible flood surcharge elevation) no sedimentation has taken place as indicated by the current storage capacity data even after the 1992 flood. Available storage between these elevations is about 1.8 MAF, same as estimated in 1965. It includes 0.3 MAF reserved for future sedimentation in the surcharge zone. In addition 0.05 MAF extra water shall be discharged through irrigation outlets during PMF routing. It means that 0.35 MAF extra storage is available for flood mitigation.

The power house expansion remained under construction, for several years therefore these outlets were not available and were not considered for flood routing. At present irrigation/power house releases are the most reliable with 10 power units in operation round the clock and must be considered for flood routing. Harza Engineering Company, USA in their February, 1992 study included power house

releases for routing floods. It is notable that these outlets remained operative during 1992 super flood.

FLOOD MITIGATION REQUIRED

The 1992 experience of flood routing has indicated that flood mitigation is required for flows exceeding about 500,000 cfs i.e. discharge when water enters the city of Jhelum. However, contribution from downstream nullahs can also be considerable to cause flooding of adjoining low lying areas and has to be duly regarded. Table-1 gives the annual maximum flood peaks at Mangla since 1922. A study of historic floods at Mangla has indicated that maximum volume of flood water required to be absorbed in the reservoir if outflows are restricted to 400,000 and 500,000 cfs is 0.647 and 0.404 MAF respectively. Summary of this study is as given below.

Year	Volume of Flood	VOLUME ABOVE	
		500,000 cfs	400,000 cfs
1929	2.24 MAF	0.285 MAF	0.437
1959	3.02 MAF	0.224 MAF	0.457
1992	2.70 MAF	0.404 MAF	0.647
PMF	7.65 MAF	--	--

It is, therefore, proposed that volume between elevation 1202 & 1208 ft which is about 0.4 MAF should be reserved for flood mitigation of historic floods. The 1208 ft is the present top level of erodible bund upstream of emergency spillway.

In case incoming flood exceeds all historic floods, no further mitigation shall be provided and the gates of main spillway shall be opened gradually to full capacity. If inflows persist for sufficient time or increase further, emergency spillway shall come into operation automatically.

SUCCESS OF FLOOD MITIGATION

Flood mitigation is normally required above a certain specified outflow so that downstream damages could be minimized. The available storage being limited, only a part of critical inflows can be absorbed in the reservoir and released later when inflows reduce below the specified limit.

The success of flood mitigation depends upon how effectively the available storage is utilized by the operator. The following can be two extreme options.

- a) Maintain the reservoir at conservation level till inflows exceed some specified limit of outflow (i.e 400,000 or 500,000 cfs in our case) and then start impounding under controlled releases.
- b) Start impounding at the beginning of the flood and occupy all the storage available for flood mitigation (i.e between 1202 and 1208 ft.) before releasing any water in the downstream channel.

In option (a) no mitigation is available below the specified limit of outflow, whereas in option (b) no mitigation is possible above the specified limit of outflow. It means option (a) is best for floods of record and PMF and option (b) is good for only small flood peaks and volumes.

If a reliable qualitative/quantitative forecast is available that the expected volume of flood and resulting peak is going to be significantly high, one can follow option (a) and if the forecast is otherwise one can follow option (b). In the absence of any forecast and to be on the safer side one should not go for option (b).

The operator of the reservoir should very clearly know the consequences of initial impounding which can result in no mitigation at the end. In the Mangla case mitigation is required especially when inflows exceed 400,000 cfs i.e discharge above which inundation of certain populated areas of Jhelum city starts.

When the reservoir is nearly full say within 5 ft of conservation and there is a forecast for a major flood it should not be considered necessary to wait for the attainment of 1202 ft level. Advantage of additional space available for mitigation of flood peak should be taken.

ROUTING SCENARIOS

To assess proper flood mitigation and to assure safety of the project the following four cases have been studied with flood of record (September, 1992) expanded and converted into PMF.

Case A: Without Sedimentation in surcharge zone and with Power House Discharge available i.e present condition.

- i) Initial Outflows restricted to 500,000 Cfs until water level rises to 1208 ft.
- ii) Initial Outflows restricted to 400,000 Cfs until water level rises to 1208 ft.

Case B: With Sedimentation in surcharge zone and with Power House Discharge available.

- i) Initial Outflows restricted to 500,000 Cfs until water level rises to 1208 ft.
- ii) Initial Outflows restricted to 400,000 Cfs until water level rises to 1208 ft.

Case C: Without Sedimentation in surcharge zone and without Power House Discharge available.

- i) Initial Outflows restricted to 500,000 Cfs until water level rises to 1208 ft.
- ii) Initial Outflows restricted to 400,000 Cfs until water level rises to 1208 ft.

Case D: With Sedimentation in surcharge zone and without Power House Discharge available.

- i) Initial Outflows restricted to 500,000 Cfs until water level rises to 1208 ft.
- ii) Initial Outflows restricted to 400,000 Cfs until water level rises to 1208 ft.

Figure-1 gives the hydrographs of historic floods for Mangla reservoir. Computer Model ROUTE prepared by Harza Engineering Company, Chicago, USA has been used for this study. After preliminary computer runs it was confirmed that 1992 flood converted into PMF is the most critical. No routings have therefore been considered for other historic floods in this study. Figures 2 to 5 give inflow, outflow and reservoir level for different cases for initial outflows restricted to 400,000 cfs.

One more case was analyzed to know the highest flood level, in case flood of record is not converted into PMF under existing conditions and emergency spillway not operated as given here-under:

Case E: Without Sedimentation in surcharge zone and with Power House Discharge available

- i) Initial outflows restricted to 500,000 cfs until water level rises to 1208 ft.
- ii) Initial outflows restricted to 400,000 cfs until water level rises to 1208 ft.

The maximum water level reached in case of flood of record i.e September, 1992 super flood for outflows restricted to 400,000 and 500,000 cfs respectively is 1210.63 and 1208.15 ft. figures 6 & 7 gives inflow, outflow and reservoir level for Case-E (i) & (ii) respectively.

ROUTING RESULTS

Table-2 gives the summary results and height of splash wall required in different cases to maintain 6 ft freeboard above the maximum flood level.

The computer runs indicate that a very effective flood mitigation is possible even under present conditions (Case-A) perhaps without even raising the embankment.

It seems logical to consider releases through irrigation/power house outlets (as is the case at Tarbela reservoir) and keep the provision for future sedimentation. However in the initial years, the reservoir level can be kept higher to take advantage of no sedimentation in the flood storage zone. In fact storage at present above conservation level might have increased due to land slides along the periphery of Mangla reservoir.

The Highest Flood Level (HFL) attained in any case is 1229.05 and 1233.12 ft. without sedimentation (Case-C (ii)) and with sedimentation (Case-D (ii)) respectively, for initial outflows restricted to 400,000 cfs. If releases through irrigation/power house outlets are considered, the HFL comes out to be 1228.27 and 1232.22 ft. without sedimentation (Case-A (ii)) and with sedimentation (Case-B (ii)) respectively, for initial outflows restricted to 400,000 cfs. It will be noted that the worst case is D-(ii) but in our opinion it assumes unrealistic conditions.

With the known situation that power house release capacity is available it is logical to accept that the worst case is B-(ii) where the maximum level rises to 1232.22 i.e 4.22 ft above the permissible surcharge level. This would require raising of dam by about 4.5 feet.

CONCLUSIONS AND RECOMMENDATIONS

- The results of routing cases indicate that height of splash wall required for initial outflows restricted to 400,000 cfs considering irrigation/power house releases and future sedimentation in the flood storage zone is 4.5 ft. A high wall will obstruct the view. It is, therefore, recommended to raise the dam crest by 2 feet and construct only a 2.5 ft high wall on upstream side of embankment all along the periphery.
- Till such time that a raised crest is provided the following procedure is recommended for flood mitigation.
- Try to maintain the reservoir level between 1202 - 1203 ft until the inflows exceed 400,000 cfs. Start impounding inflows exceeding 400,000 cfs till the water level reaches 1208 ft. If inflows still rising increase the outflows gradually to full capacity and let the emergency spillway to operate.

TABLE - 1
JEHELUM RIVER AT MANGLA ANNUAL MAXIMUM FLOOD PEAK (CFS)

YEAR	FLOW	YEAR	FLOW
1922	102950	1959	830000
1923	84120	1960	150500
1924	155600	1961	157000
1925	107000	1962	155000
1926	147600	1963	80150
1927	165200	1964	85186
1928	600000	1965	88190
1929	1050000	1966	89115
1930	290000	1967	160868
1931	355000	1968	267976
1932	270000	1969	217320
1933	216000	1970	263154
1934	190936	1971	222020
1935	152000	1972	375016
1936	151217	1973	331379
1937	104704	1974	366342
1938	148000	1975	455495
1939	115806	1976	588501
1940	118676	1977	226520
1941	165726	1978	396460
1942	134694	1979	188110
1943	182762	1980	245751
1944	206610	1981	201434
1945	144406	1982	242784
1946	231315	1983	357715

TABLE -2
MANGLA RESERVOIR
Summary of Flood Routing Studies with Mitigation Element

	Maximum Water Surface Elevation (ft.)	Splash Wall Height in (ft.)
Case A : Without Sedimentation and With Power House Discharges.		
i) Initial Outflows 500,000 cfs upto 1208 ft. level.	1227.42	Nil
ii) Initial Outflows 400,000 cfs upto 1208 ft. level.	1228.27	Nil
Case B : With Sedimentation and With Power House Discharges.		
i) Initial Outflows 500,000 cfs upto 1208 ft. level.	1231.43	3.50
ii) Initial Outflows 400,000 cfs upto 1208 ft. level.	1232.22	4.50
Case C : Without Sedimentation and Without Power House Discharges.		
i) Initial Outflows 500,000 cfs upto 1208 ft. level.	1228.12	Nil
ii) Initial Outflows 400,000 cfs upto 1208 ft. level.	1229.05	1
Case D : With Sedimentation and Without Power House Discharges.		
i) Initial Outflows 500,000 cfs upto 1208 ft. level.	1232.31	4.50
ii) Initial Outflows 400,000 cfs upto 1208 ft. level.	1228.27	5.50

Note : In each case of the above study the flood of record (September 1992 flood) was assumed to have been converted into Probable Maximum Flood.

MANGLA DAM PROJECT
HYDROGRAPHS OF HISTORIC FLOODS AT MANGLA

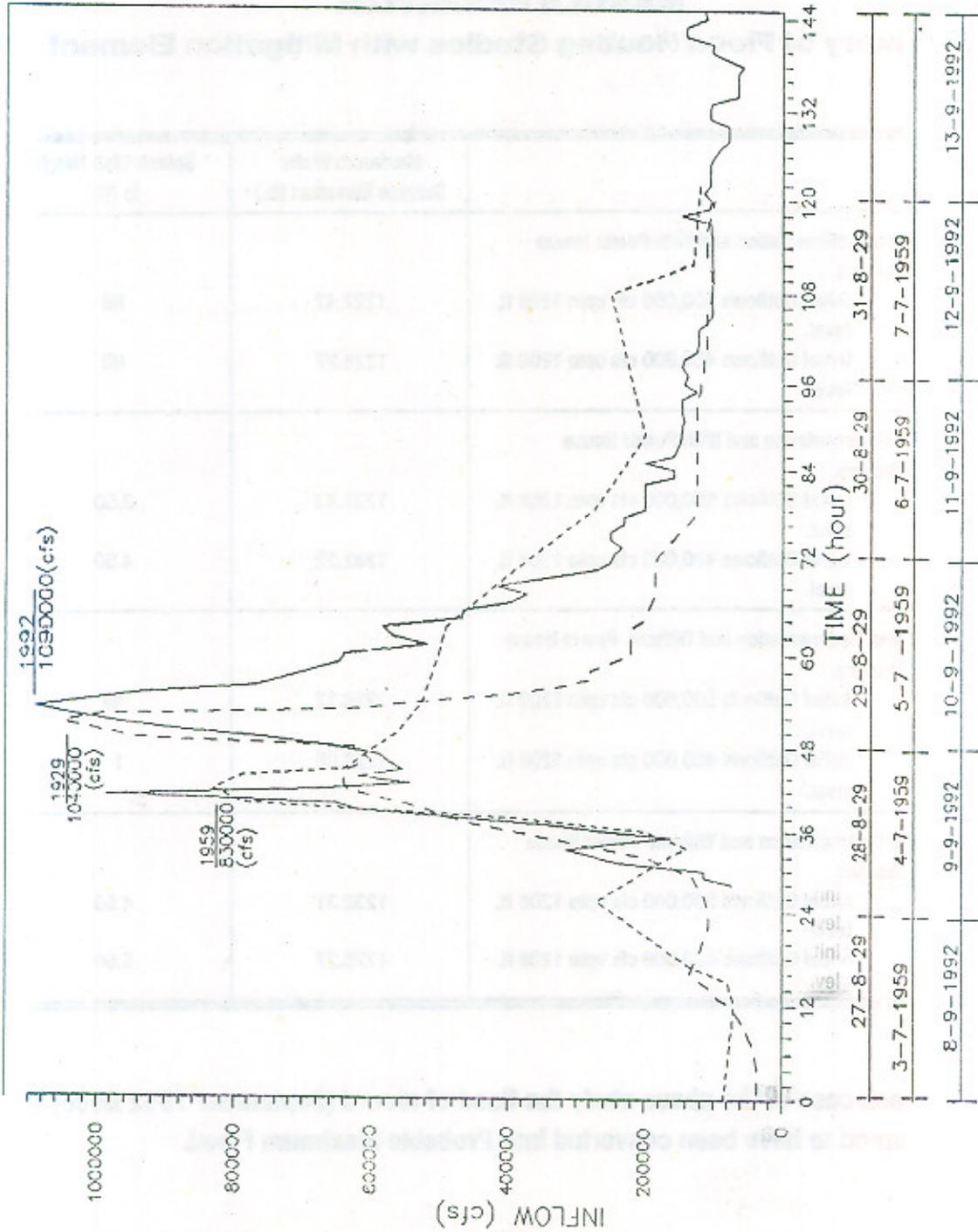
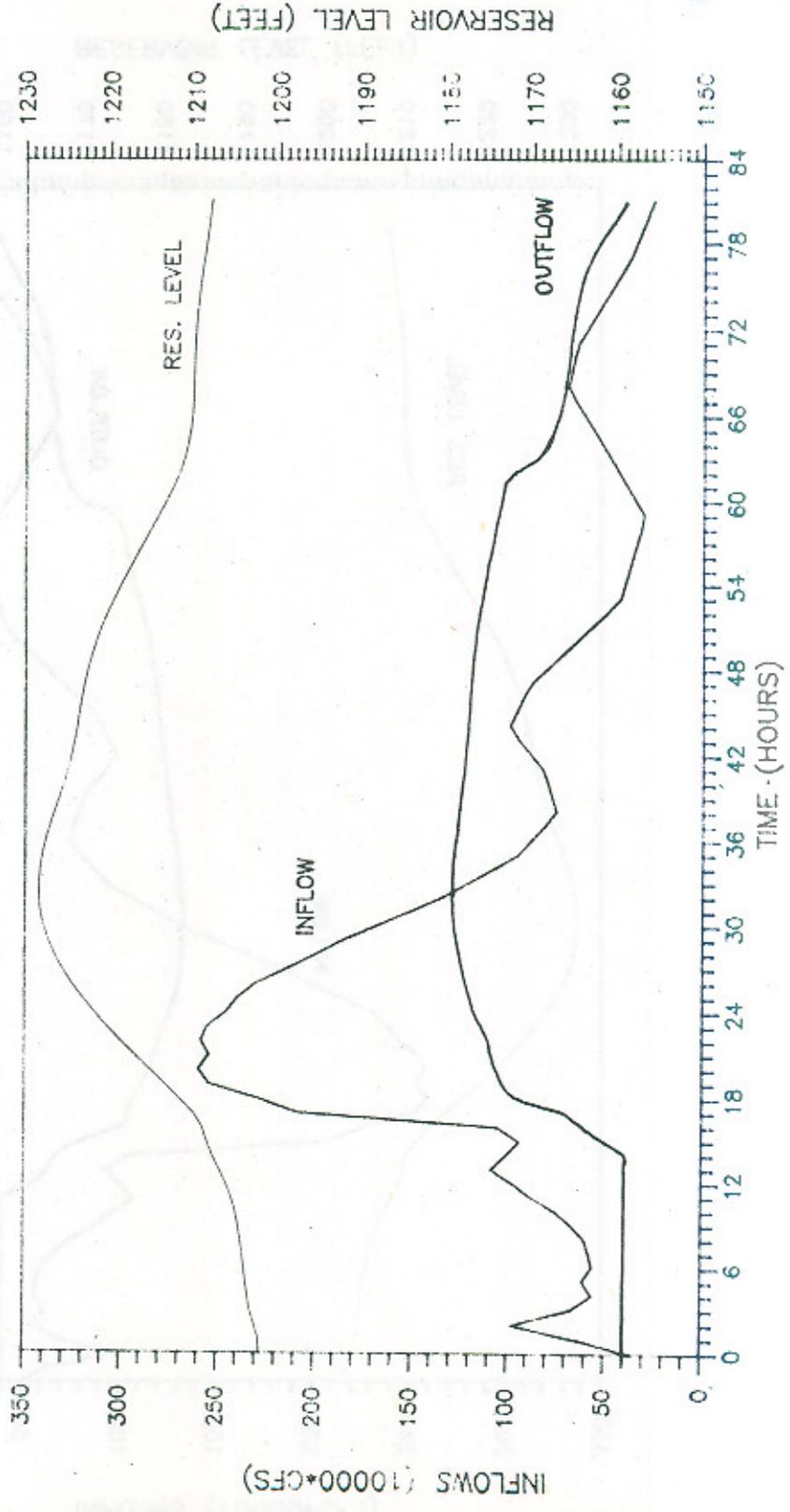
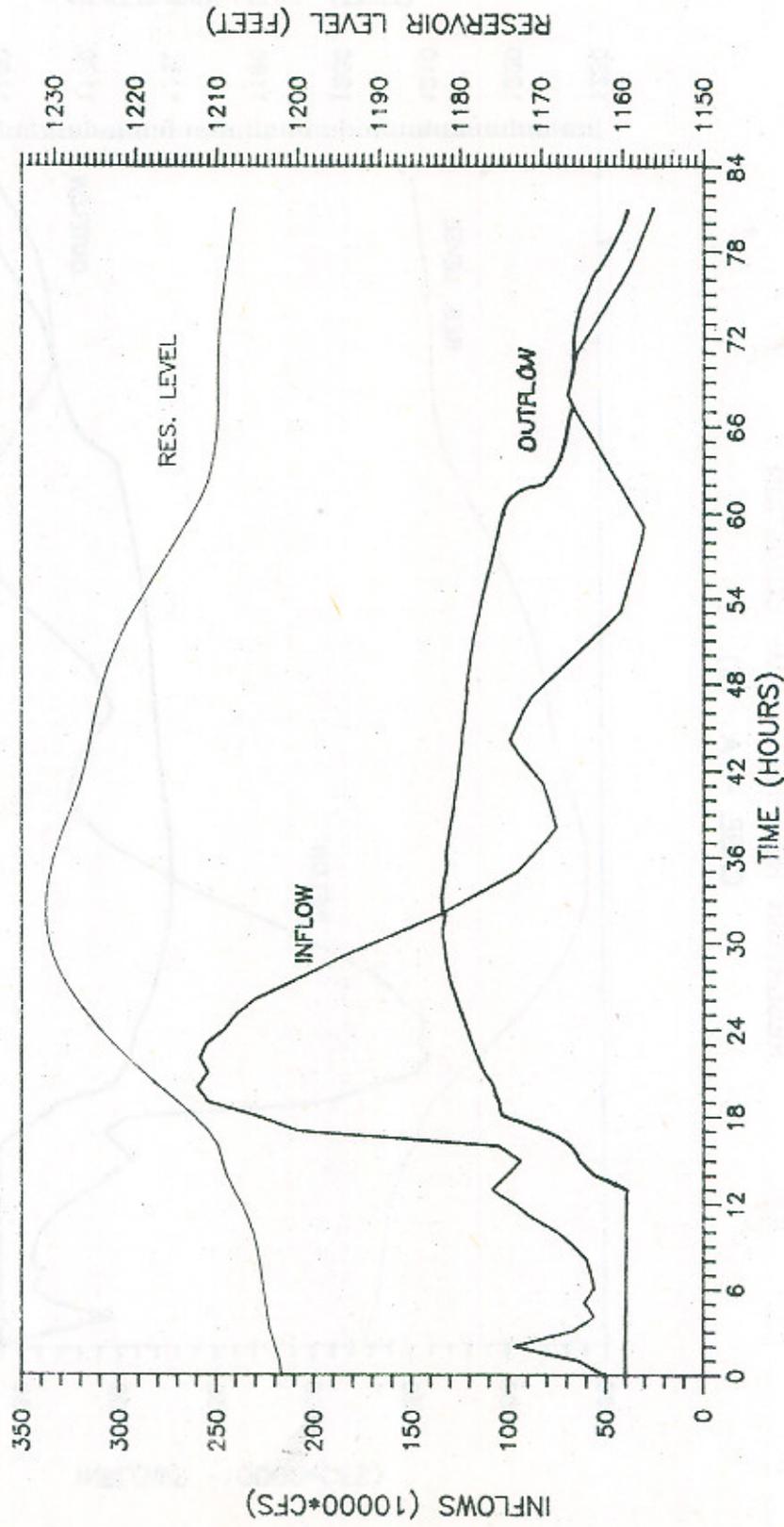


FIG. 1

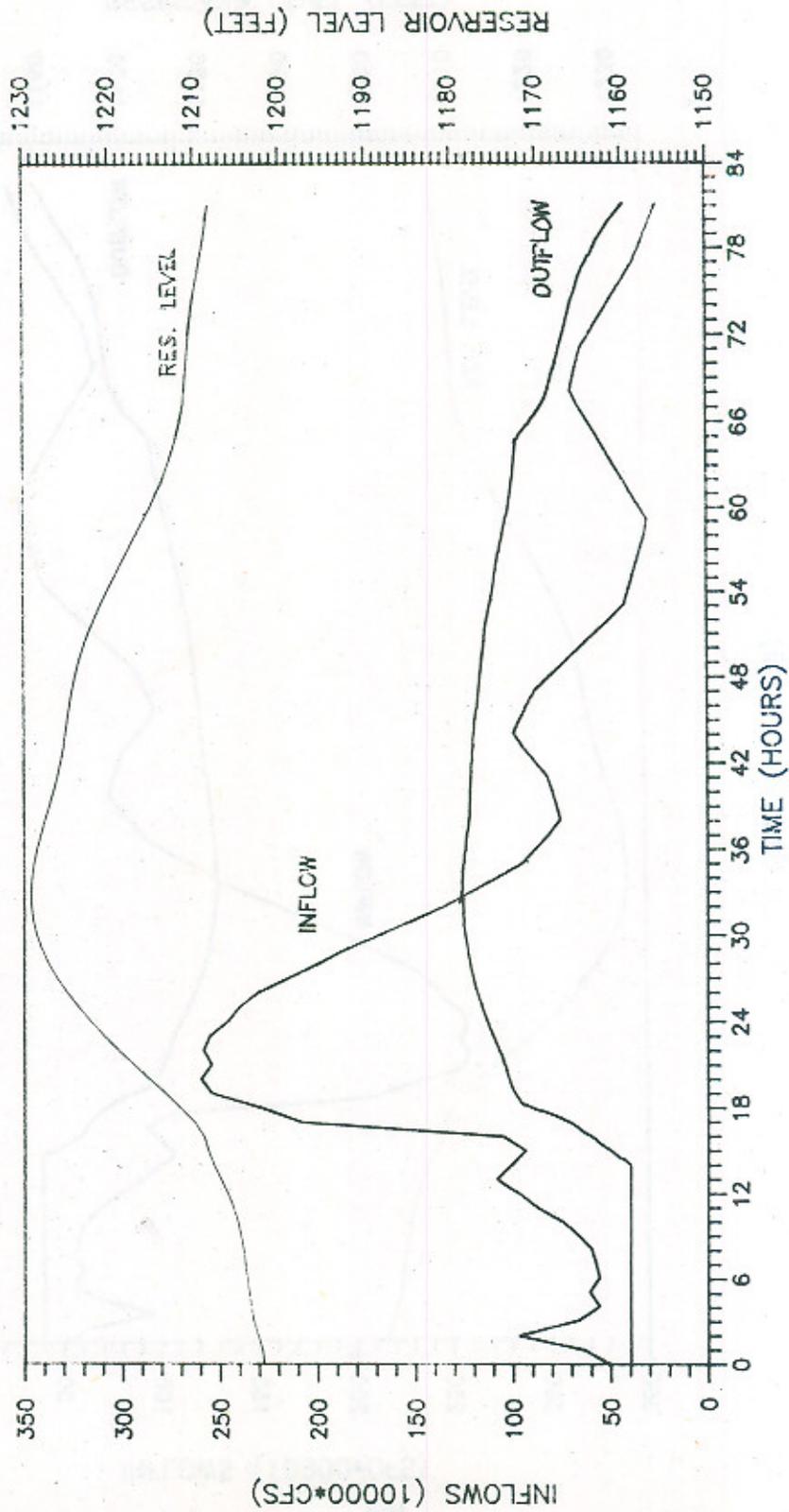
MANGLA DAM PROJECT
RESERVOIR ROUTING - PMF CONDITION
CASE - A (ii)



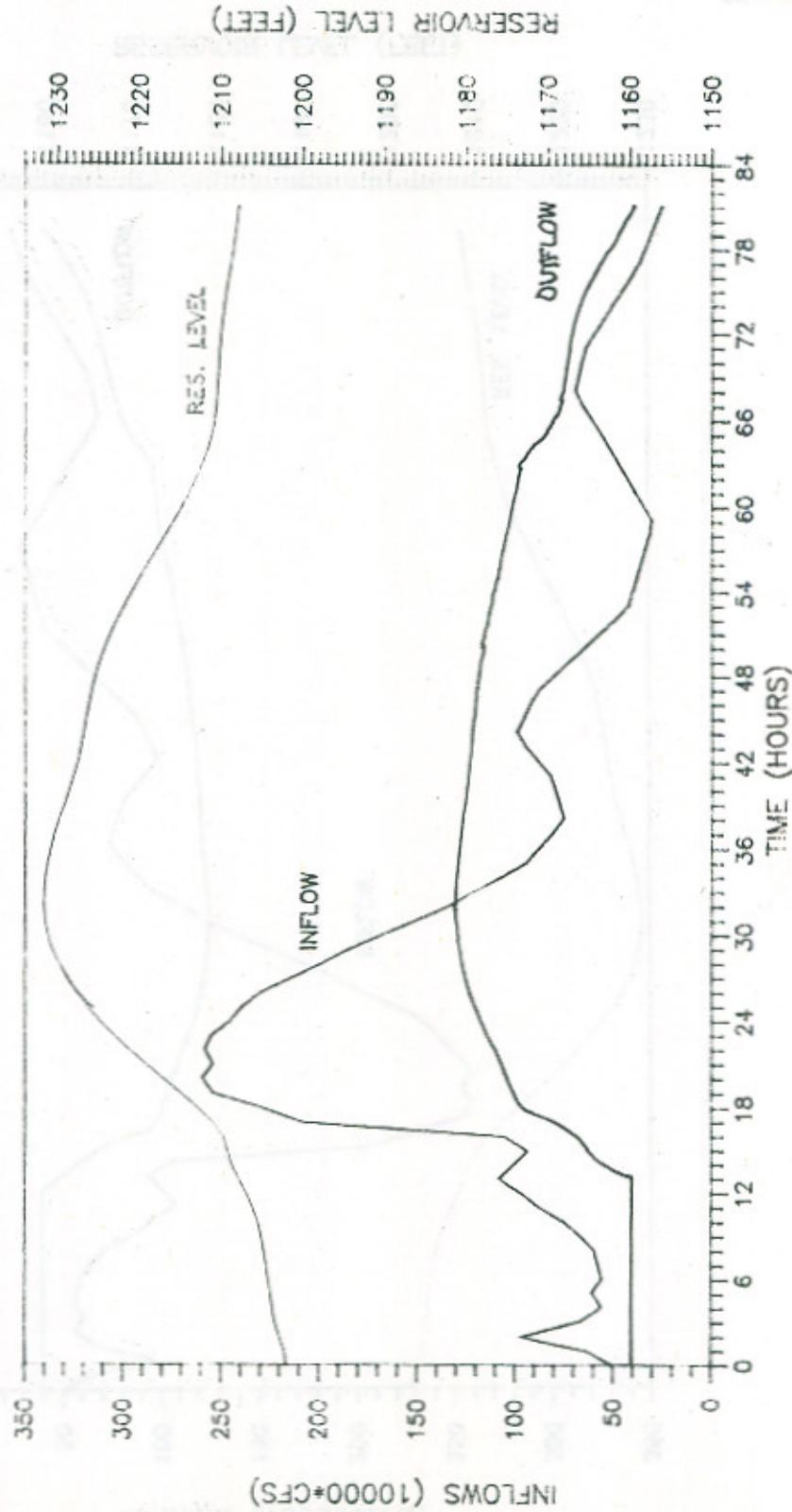
MANGLA DAM PROJECT
RESERVOIR ROUTING - PMF CONDITION
CASE -- B (ii)



MANGLA DAM PROJECT
RESERVOIR ROUTING - PMF CONDITION
CASE - C (ii)



MANGLA DAM PROJECT
RESERVOIR ROUTING - PMF CONDITION
CASE - D (ii)



MANGLA DAM PROJECT
RESERVOIR ROUTING - SEPTEMBER, 1992 FLOOD
CASE - E (i)

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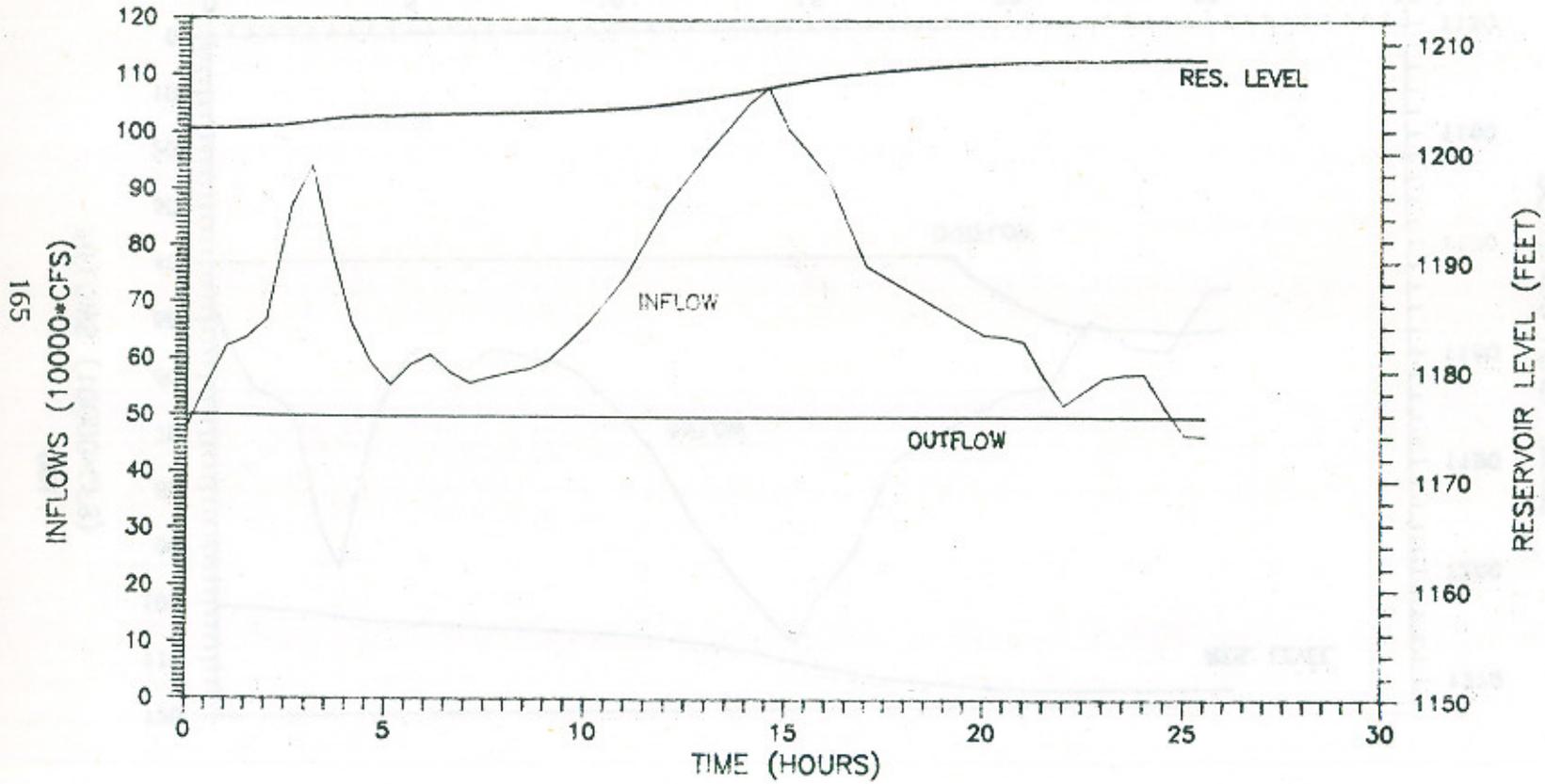


FIGURE-6

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MANGLA DAM PROJECT
RESERVOIR ROUTING - SEPTEMBER, 1992 FLOOD
CASE - E (ii)

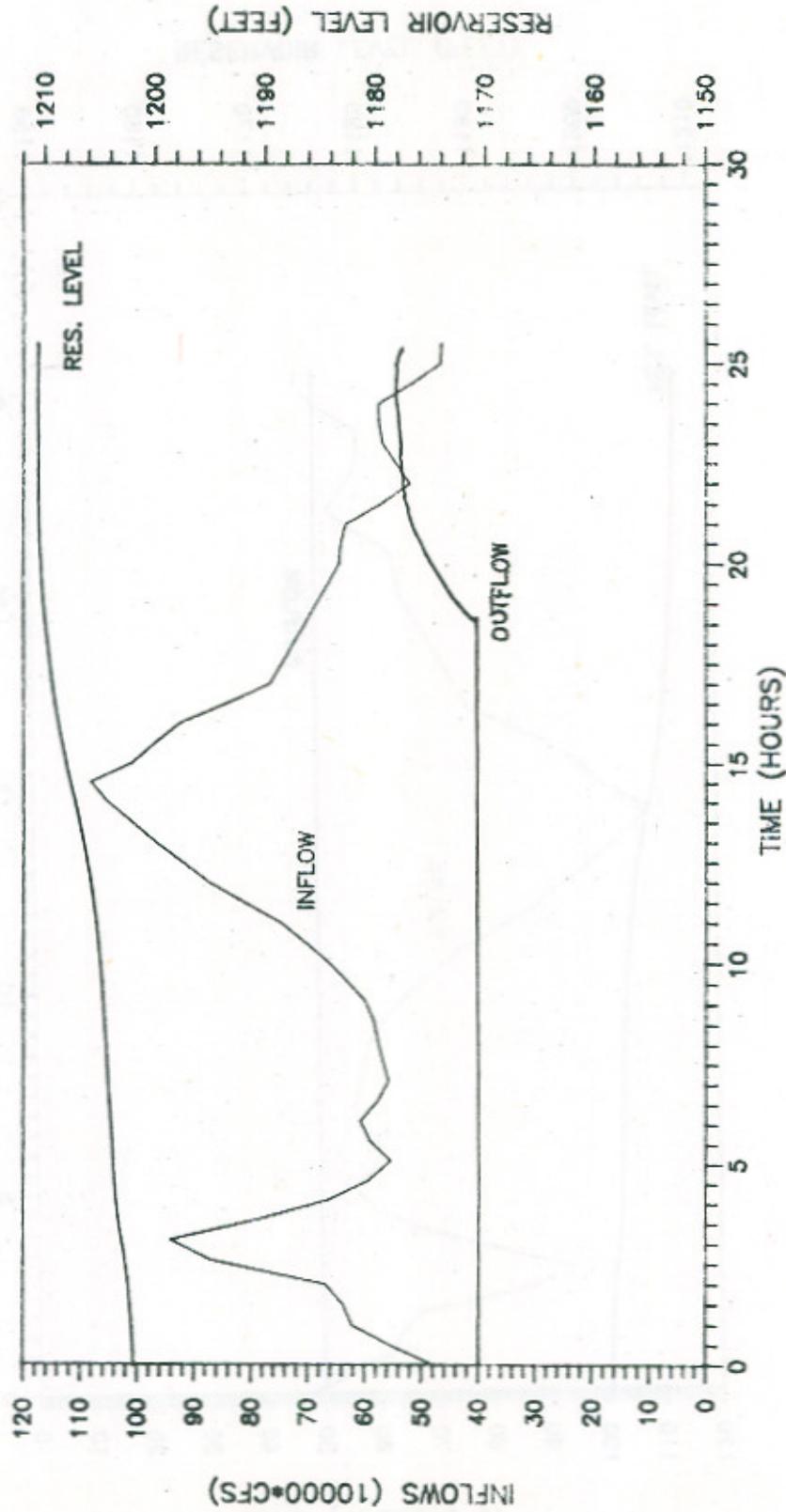


FIGURE-7