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DAMS AND SOME RELATED ISSUES – THE CASE IN THE LOWER DAMODAR RIVER

KUMKUM BHATTACHARYYA

Abstract : River Damodar is one of the endemic flood-prone Lower Bengal rivers, which was heavily embanked in its lower sector to reduce flood disaster in the Rarh plain. The river was again selected first for the construction of sophisticated engineering structures such as barrage and reservoirs when the Damodar Valley Corporation (DVC) was first conceived after the Tennessee Valley Authority (TVS) of USA in 1948. Impacts of dams are noteworthy. Man induced hydrographs below control points show reduced monsoon discharge, increased discharge in winter and pre-monsoon period and reduced peak flow in the post dam period. In pre dam period return period of flood for bankful stage of 7080 cumec had a recurrence interval of 1.8 years. In the post dam period return period for the bankful stage has been increased to 14.81 years. Reduced discharge and consequent enhanced sedimentation below the major control structures have created a chain of sandbars locally known as *char* or *mana* which now forms the major resource base for the communities of the migrant popularly known as refugees whose position in the social space were distinctly different for obvious reason. These sandbars were perceived as infertile waste lands by the locals and were objective components of the landscape. The same sandbars are now preferred sites mostly for refugee settlements and crops range from paddy to mulberry including vegetables, oilseeds etc. Control structures in the Damodar have given rise to a set of landforms in the river bed and these fund resources are gradually replacing the flow resource of the Damodar. The Lower Damodar river is in the state of anthropogenic degradation.

PURPOSE AND OBJECTIVE

In ancient time prior to industrial revolution human being used to live within the ambit of hydraulic civilization particularly in the river basins of tropical countries. Archaeological excavations in the Nile and Indus valleys show that river control structures such as embankments, dams, canals etc., were an integral part of the drainage basins. Sadd-el-kafara dam in Egypt was probably built sometimes between 2950 BC and 2750 BC (Biswas, 1970). Ancient drainage ditches were discovered in the Indus valley also. It is also evident from various reports that there was an extensive canal system in the lower part of the undivided Bengal in India. According to many historians the Lower Bengal was inhabited by a very advanced people referred to as Gangaridi (Basu, 1989) and a network of canals were probably constructed by them. But from the very beginning such engineering devices on the river system have raised many questions on social, economic and political issues. These issues have a great significance in the contemporary world even today. In India there are several endemic flood prone rivers and many of them have been tamed with embankments, most of which were in existence prior to the British rule. The Damodar is one of such rivers which shows an extensive system of embankments in its lower catchment below its confluence with the Barakar River. The Damodar river basin is again selected for multipurpose development by construction of dams, barrage, sluice etc., by a high powered organization known as Damodar Valley Corporation. This is the river which had to face human interference in different forms and magnitudes at the various places in the historical past (Bhattacharyya, 1998).

Objectives of this paper are to address some issues emerging from construction of dams etc., and also to review the private initiative of the agrarian community through land use planning in the upper sector of the Lower Damodar river (Fig 1).

METHODOLOGY

The discharge data for the Damodar at different stations have been collected from the Irrigation and Waterways department, Government of West Bengal and also from Hydraulic Data Division, DVC, Maithon. Field survey includes interviewing people on location and field mapping to prepare landuse maps. Map analysis includes cadastral maps, topographical (SOI) maps and IRS geocoded imagery.

THE DAMODAR DEFINED

The Damodar river, a subsystem of the Ganga exhibits most of the characteristics of a seasonal tropical river. From its source to its union with Hugly, a distributary of the Ganga, the river runs a course of approximately 540 km while the total length of the Lower Damodar from the confluence of the Damodar with the Barakar, a tributary of the Damodar is 250.15 Km. The lower valley is entirely located in West Bengal in the plains of Bankura, Barddhaman, Hugly and Hoara. The volume of its water dwindles almost to a trickle during summer season while during monsoon at the time of cloudburst it lashes its fury causing devastating floods.

Damodar started its notoriety as a disastrous river from the early part of the eighteenth century. The first record of such flood dated back to 1730 and since then floods of varying intensity have occurred every 8 to 10 years. Record shows that in the last 100 years or so serious floods occurred in 1823, 1840, 1855, 1960, 1864, 1865, 1866, 1877, 1913, 1916, 1917, 1935, 1938, 1840, 1941, 1942, 1946, 1950, 1951, 1956, 1958, 1959, and 1978. The flood of 1823, 1840, 1913,1935, 1941, 1958, 1959 had peaks of more than 16,992 cumec. A peak flow about 18,678 cumec has been recorded thrice in August 1913, August 1935 and October 1941 (D.V.C. 1995, Bhattacharyya, 1998). Floods visited the Damodar river also in 1995 and 1999 with a peak flow of 8495 and 6192 cumec at Durgapur. The flood of 1978 can be taken as greatest disaster of the century.

The disaster causing components or elements are embedded in the river. Its source could be traced out in the laterite rich Khamarpat hills (1068 m) in the Chhotonagpur plateau of Bihar while its upper middle course traverses through quartz rich gneissic Archaeans and the upper part of the lower course travels through sandstone rich Gondwana sedimentaries of the coal measures with high rates of declivity. The region is subjected to incessant rainfall coupled with long intervening periods of dry weather, so the occurrence of sand rich sediment load truns out to be inevitable.

There are several phases of controls in the forms of embankments, sluices, weir, canals, barrage at Durgapur and dams at Maithon, Panchet, Tilaiya, Konar and Tenughat of which Maithon and Panchet (lower dams) constructed in the years 1957 and 1959 respectively need special mention.

DISCHARGE CHARACTERISTICS IN PRE AND POST DAM PERIOD

Base flow or the episodic flow is more important and significant in maintaining a fluvial landscape. Fundamentally, flow characteristics in the pre-dam and in the post-dam periods are analyzed so as to assess the effects of the major control structures on these.

Daily Monthly Mean and Annual Flow Characteristics

Based on a 10 year-record (1940-49) of the Damodar discharge at Rhondia it is revealed that about 62.6 per cent of the days experienced a flow of less than 283.2 cumec and 3.44 per cent of the days experienced a flow above 2266 cumec. The situation during the post-dam period (1993-95) has changed. About 66.40 per cent of the days experienced a flow less than 283 cumec, whereas only 1 percent of days experienced a flow above 2266 cumec. Under natural conditions on an average 229 days each year, the mean daily flow falls below 283 cumec. It is extended to 242 days between 1993 to 1995 whereas under natural condition 12 days on an average in a year experienced a flow above 2266 cumec but it has decreased to 4 days in an artificial condition (Bhattacharyya, 1998).

Time series analysis, showing variation of discharge of the Damodar at Rhondia in the period before the dam construction and after the dam construction has been done.

Here

$Y_c = a + bx$ where

Y_c = estimated discharge

a = value of y where x = 0

b = rate of change of y per unit of x

x = deviations of the actual discharge from the mean discharge.

The analysis produced trend lines of $Y_C = 3940.22 + \{(-11.05)\,x\}$ for the pre-dam period and $Y_C = 2803.13 + \{(-52.72)\,x\}$, for the post-dam period. It is expected that the discharge will vary on either side of the trend line. In both the cases the trend lines show a decreasing trend. From the figure 2 it is clear that discharge was increasing since 1935 when due to war, work in most of the industries had stopped and so reduced the demand for water in industrial sector and these enhanced the average discharge. The decreasing trend in the pre-dam period was due to extraction of water in the industries of the Damodar valley. The range of fluctuation has increased during the post-dam period, which can be determined by *standard error of estimate* or S_{YX} which is *1182.35* cumec for the pre-dam period and has increased to *1602.96* cumec for the post-dam period. An increase in the range of fluctuation in that period indicates that release below the Durgapur barrage corresponds to the demand of water for canal consumption and uncertainty in the rainfall situation. From the Rhondia weir water is also released to the Damodar main canal depending on the people's demand.

The river discharge of the Damodar at Rhondia has also been worked out for four climatologic seasons with respect to the total annual flow from 1934 to 1995 (Table No. 1).

TABLE NO. 1: DISCHARGE CHARACTERISTICS OF DAMODAR AT RHONDIA (% OF FLOW WITH RESPECT TO AVERAGE ANNUAL TOTAL).

Period	Parameter	Summer	Monsoon	Autumn	Winter	Average Annual Total (Cumec)
PRE-DAM	N	21	21	21	21	21
(1934–1956)	$\overline{X}$	1.4	83.70	12.2	2.7	4061
	s.d	1.3	6.9	6.3	1.5	1158
	c.v	92.86	8.2	51.64	55.55	28.52
POST-DAM	N	28	28	28	28	28
(1960–1995)	$\overline{X}$	5.40	76.36	13.97	3.91	2676
	s.d.	7.79	13.81	12.02	2.71	1576
	c.v.	144.3	18.09	86.04	69.3	58.89

N = No of years, $\overline{X}$ = Average % of Flow, s.d. = Standard Deviation, c.v. = Coefficient of Variation.

Nature of flow at Rhondia shows a sharp contrasting character from the pre-dam to the post-dam period. During summer season (March to May) the mean percentage of flow shows a significant increase from 1.4 per cent to 5.4 per cent but with a large standard deviation (7.79) and very high variability (144.3) during post-dam period. The mean autumn discharge shows a marginal increase but with large standard deviation and variability. The same is true for the winter discharge also. Regarding the total annual discharge the mean figure during pre-dam period was much higher than that in the post-dam period. But deviation and variability both have increased during the post-dam period. The most important characteristic is that there has been 34 per cent decrease in average annual discharge from the pre-dam to the post-dam period and more than 50 per cent increase in variability. There has been 34 per cent decrease of monsoon discharge during the post-dam period.

The construction of the storage reservoirs and barrage on the Damodar disrupts its equilibrium and lead to a series of changes in fluvial system. In such a reservoir channel, water is stored behind a dam and its gradual release results in marked reduction in magnitude and frequency of peak stream flow and also the entire flow regime. This is attenuation of peak flow which moderates the flood down the valley. The average peak discharge at Rhondia in the pre-dam period (1933-1956) was 9606 cumec which has been decreased to 3500 cumec in the post dam period (1959-1999).

Flood Behaviour of the Damodar River in Pre and Post Dam Period

The impact of dam closure on the flow regime of the Damodar river has been analyzed (Gumbel, 1941., Linsley et al. 1958) by statistical comparisons of the data. The result of the analysis and Chow's KT frequency factor (Chow, 1951) have been shown in the Table 2.

TABLE NO. 2: FLOOD FREQUENCY ANALYSIS

Period	$\overline{X}$ (cumec)	SD	Recurrence interval in years for discharge (cumec) values of :				q 1.58	q 2.33 (cumec)
			7,000	7080	10,000	20,000		
1934-58	8230.4	3747	1.74	1.8	3.78	99.98	6424.54	8087.99
1959-95	3477.67	2218	14.15	14.81	77.20	–	2471.73	3546.44

Under the natural flow conditions of the catchment the mean annual flood ($q^{2.33}$) and the most probable annual flood ($q^{1.58}$) are of the order of *8087.99* cumec and *6424.54* cumec respectively whereas *7000* cumec has a recurrence interval of only 1.74 years. The bankful stage of *7080* cumec has a recurrence interval of 1.8 years. This analysis clearly suggests that the Damodar at the hydrometric station was subjected to inescapable frequent floods in and around Rhondia and in the entire Trans–Damodar catchment.

Under the artificial condition of the catchment, the mean annual flood and most probable annual flood are of the order of *3546.44* and *2471.73* cumec respectively which have been depleted to well below the bankful stage at Rhondia. The return period for the bankful stage of *7080* cumec has been increased to 14.81 years. Stated in probabilistic terms a 14.81 years flood means 1 in 14.81 chance of its occurring in any given year. So it is evident from the above that probability of occurrence of flood has been reduced during post-dam period. The return period of flood of *10000* cumec has been increased from 3.78 year in the pre-dam to 77.20 year in the post-dam period and shows the definite effect of flood moderation capacity of the D.V.C. dams (Bhattacharyya, 1998).

According to data available the peak flow of floods exceeding *10,000* cumec. at Rhondia occurred five times before the dam closure (1933-1956). After the dam closure (1958-1996) combined peak inflow of *10,000* cumec in the D.V.C. dams (Maithon the Panchet) occurred ten times. Magnitude of design flood from the Panchet and Maithon has been reduced by about 57 per cent (Bhattacharyya, 1998). When considering the magnitude of floods of different recurrence intervals before and after the dam construction, it is clear that dams have much less effect on rare events of high magnitudes (Petts and Lewin, 1979). In spite of flood moderation by the D.V.C. dams, floods have occurred in 1959, 1978, 1995 and 1999. These floods clearly suggest that the lower valley is still exposed to sudden floods. Mr. Voorduin's project provided for the full control of a 'design' flood of *28,321* cumec resulting from a rainstorm of 50.8 cm in the upper catchment, the controlled flood is to be limited to the assumed channel capacity of *7,080* cumec at Rhondia, for this purpose all the dams together provided for a total flood reserve of 3595.6 million cu.m. (Voorduin, 1947). Four dams i.e., the Tilaiya, the Maithon, the Panchet and the Konar provide a total flood reserves of 1,292 million cu.m. Land acquisition for the Maithon and the Panchet reservoirs upto the top of gates is yet to be completed. When this will be done the flood reserve will be 1863 million cu.m. This is slightly more than half of what is required for the control of the 'design' flood (D.V.C. 1995).

The primary consideration in the flood control aspect of the D.V.C. dams is to provide adequate protection to the left bank embankment along the Damodar River, as it protects the mining, industrial area and important towns as well as railways and roadways. But the rural and undeveloped lower reaches of the valley covering about 780 sq. km. were neglected (Bhattacharyya, 1973, Bhattacharyya, 1998). The inadequate capacity of the Maithon and Panchet reservoirs has necessitated high water release during high rainfall condition (Sen, 1985) and the uncontrolled run-off in the catchment below dams may augment this discharge at Durgapur and Rhondia by more than *2832* cumec. In the Trans-Damodar distributary channels, the subsurface water yield is very high in case of excessive rainfall. There are other contributory factors like spilling of the Dwarakeswar river, flood in the Rupnarayan and also conditions of the Hugli river including the temporary factor as the occurrence of a high tide coming up from the Bay of Bengal (Bhattacharyya, 1973., Sen 1985., Bhattacharyya, 1998). At present whenever there is any discharge from Durgapur barrage exceeding *1400* cumec the lower part of the LowerDamodar gets waterlogged. So before the dam closure floods of the order of *10,000* cumec used to come in every 3.78 years and were tolerated but after the dam closure a flood of the order of *2471.73 to 3546.44* cumec creates all the problems in the lower part of the lower reaches (Bhattacharyya, 1998).

The flood history of the Damodar during the period 1857 to 1917 can be traced from the E.L. Glass report submitted to the then Bengal Government as observed at Raniganj, a few kms upstream of Durgapur (Sen, 1962). Data for the period between 1935 and 1956 and 1958 and 1999 at Rhondia have been collected from different sources and calculated for the present analysis.

During the period of 1857-1917 the number of normal floods (between 5664-8496 cumec) was 33 (55 per cent of the total occurrences) (Sen, 1962) which was reduced in later periods (1933-1956) to 11 and 2 in the post-dam period (1959-1999). In the post-dam period only 2 abnormal floods (above 8496 cumec) have occurred, one in October 1959 and the other in September 1978. Where as number of subnormal floods (between 2472 - 5664 cumec) in pre-dam days in between 1857-1917 was 15 and in between 1933-1956 was 3 which has been increased to 22 in post-dam days between 1959-1999. It can be stated that after dam closure a reasonable flood protection has been achieved in the upper part of the Lower Damodar Valley (Bhattacharyya, 1998).

SEDIMENT LOAD CHARACTERISTICS

The Damodar gets enormous quantity of eroded materials from the uncontrolled catchment below dams. There is a substantial growth of coal mining in the Ranigunj Coalfield. The coal mining based industries, coal washeries, refractories and significantly developed iron and steel industries in Burnpur and Durgapur have changed the whole landscape of the Lower Damodar basin into one of industrial smokes and coal spoils etc, all over the area.

In case of the Damodar, the sediments are non-compact sand and the quantity of sediment introduced from non-regulated sources exceeds the regulated capacity, therefore aggradation occurs. The trapping of sediment and the lack of flushing have inevitably transformed the Lower Damodar area into an ecologically disbalanced area (Sen, 1985., Bhattacharyya, 1998).

The contemporary river bed of the Lower Damodar is choked with sediments below major control points. A series of sandbars are now the characteristics of the lower Damodar. Transient bars are in a process of stabilization. But much of the sediments have been contributed by overland flows from embankment free mining industrial urban areas (Bhattacharyya, 1998).

SILTING OF THE RESERVOIRS

Deposition of stream-borne sediment causes reduction of storage capacity of reservoirs. As land management and vegetal cover is poor in the upper catchment, the rate of sediment production is far in excess of the rate assumed at the time of planning (DVC 1995). In the Panchet Hill reservoir 55.5 per cent of the dead storage space have been filled up by sediment. At the same time 36 per cent of the live storage space and 2.6 per cent of the flood storage space have also been lost during the past 36 years upto 1995. In Maithon reservoir 54 per cent of the dead storage space and 22.4 per cent of the live storage space and 4.3 per cent of the flood storage space have also been lost upto 1994. The capacity has also been depleted in these reservoirs both in dead storage and life storage space. Silting of Panchet and Maithon reservoirs (Table No. 3) has significant consequences below reservoirs (Bhattacharyya 1998). Estimated life of Maithon reservoir is 246 years and Panchet reservoir is 75 years (DVC, 1995).

PEOPLE'S LIFE IN THE DAMODAR RIVER BED

The sandbars in the Damodar would have remained as uncultivable waste land had there been no population transfer between India and erstwhile East Pakistan (presently Bangladesh) between 1947 and 1971 following Independence and Bangladesh war respectively. These sand bars locally known as *char* or *mana* were settled by the Bengalee migrant community popularly known as refugees. The migrant community discovered this place as there was no competition for these sandbars and here they could have an independent existence. They started to colonize these snadbars whose resource potentialities were not identified by the local people (Basu and Bhattacharyya, 1992., Bhattacharyya, 1998). These were treated as objective components of the landscape. These people with their sense of vulnerability responded positively to analyze the physical space in the river bed more objectively and rationally and looked at it as a challenge to their independent existence (Bhattacharyya 1995, 1997, 1998). From a series of mid-channel and marginal sandbars, some portion of Bara *mana* has been selected to explain my observation in the river bed.

Landuse Planning in River-Bed, Examples from Bara mana

Bara *Mana,* the largest alluvial sand bar in the culturally defined Lower Damodar, is sited below the Durgapur barrage. Bara *Mana* comes under eleven mouzas (villages) such as Bamandihi, Purakonda, Tajpur, Pakhanna Bhairabpur, Pakhanna, Radhakantapur, Gopalpur under Barjora Police Station and Palashdanga, Jaynagar, Alampur and Dihipara under Sonamukhi police station of the Bankura district. The latitudinal and longitudinal extension are from 23^{0} 24' 30" N to 23^{0}27' N and from 87^{0} 20' E to 87^{0} 25' 30"E. Total area of Bara *Mana* is 7 sq. km. (approx). Durgapur and Panagarh are the nearest towns and railway stations towards Barddhaman side. Bara *Mana* is approachable by ferry service from Pakhanna in the district of Bankura.

To review the changes in generalized land use characteristics and landscapes, Bara *Mana* has been divided into six sections and two sections have been shown which are self-explanatory (Fig. 3). The grass-covered land over decades have turned into agricultural fields. From the cadastral maps of 1957, some unauthorized agricultural fields are found, permanent settlements have come up after 1957 after the completion of Durgapur barrage and Maithon and Panchet reservoirs as flow in the main channel has been reduced after the construction of these control structures.

To examine the land use characteristics, Bara *Mana* has been divided into six sections. One section has been shown here.

Section–2 (Fig. 4) comprising Purakonda mouza shows some interesting landuse characteristics. Findings are noted below.

Scrub and grass covered area is found to the north east of this section.

The river bed of the D_2 and unauthorized land in north are intensively cultivated.

Cocoon rearing mulberry cultivation is observed on the highest part of the bar (above 62m).

Multiple cropping is practiced on higher land above inundation level.

Clay deposits in the dried up channel D_6 is used for mainly rice culture.

Settlements are sited on the highest elevation and individual houses as usual have been constructed on higher plinth above usual inundation level.

Wet rice and jute were introduced first as a major cereal and cash crop. Both the crops are part and parcel of agriculture in Bengal delta. Jute was not an important cash crop in this part of Bankura. Bengalee refugees have introduced this cash crop here. With the application of fertilizers, nutrient status of these sand bars has improved. Together with rice and jute, wheat and potato are grown as spring crops. In the higher ground (above 60m) cocoon rearing mulberry cultivation and perennial tree crops have been introduced. On the highest part of the bar settlements are also found. The next zone is used for cereals, vegetables and cash crops. In the decaying channel beds of D2 and D6, clay deposits accrued from vertical accretion are used for double cropping and the crop selected is the clay loving wet rice. In the inundation prone peripheral area jute is grown. Jute sticks provide building materials of their house. The area to be inundated almost every year is devoted to rice culture of H.Y.V. in non-monsoon period. On the margin of the sandbar quick growing vegetables and fruits like cucumber, water melons are grown with the lowering of river level. These are mainly cultivated in dry river bed from November to April when there remains just a trickle of water and maximum discharge is passed through irrigation canal from the Durgapur barrage. Due to such an endeavor the area is getting stabilized through trapping of sediments and in course of time there will be no flow of water and the entire area along with Bara *mana* will be merged with the land. By suitable gate operation of Durgapur barrage the main flow is always maintained at the southern side to protect the mid-channel bar.

The bar is still exposed to hydrological floods if discharge from the barrage is above 5664 cumec. During 1978, 1995 and 1999 floods with a peak flow of 9345, 8495 and 6162 cumec at Durgapur the sand bar was submerged but the settlements were not totally washed away as the individual huts are on higher plinth and bamboo structure, deeply imbedded on surface can withstand flood currents. Even, inside individual rooms there are shelves where they can keep their valuables.

They have planted branching perennial tree crops like mangoes and jackfruits for twin purposes. Fruits are consumed or sold at local markets. Secondly they can take shelter on trees in the face of flood calamity. Unlike deltaic rivers, the flood slopes of the Chhotanagpur rivers are high and boating becomes hazardous (Basu, 1988). The islanders had to face this problem during 1978 floods. So these trees have been planted with a definite purpose after the 1978 floods. In the floods of 1995 and 1999 the sandbar was submerged barring a few places. People took shelter on these trees or temporarily deserted the area inundated.

They follow the announcement and can calculate which part will be inundated and which will remain above it so they have organized their space accordingly. They get drinking water from tube well and irrigation water from shallow pumping machine. They are also equipped with boat (Bhattacharyya, 1998).

These people with their specific political status initially had rejected the dole-sustained government sponsored settlements and opted for self sought settlements in these barren sandbars. They were rather forced to live within a closed system but this system perhaps enabled them to access the physical parameters of flood more objectively and rationally and to adopt innovative measures to reduce hazard loss. Every available space in the sandbars is now utilized judiciously and the concept of flood zoning has been applied at micro level. They have accepted short-term risk in order to gain long term benefits from the riverbed.

CONCLUSION

The control structures have profound influences on the flood behavior and riverbed sedimentation of the Damodar River but these control structures have given rise to a set of geomorphic features, which have very high resource potentialities under specific socio-economic environment.

Bara *mana* is just one example of cultivated settled sandbar in the Lower Damodar. It is quite natural for a migrant community to modify and fortify the fragile tract to reduce vulnerability of these sandbars from inundation, natural or artificial. But the fact is that most of the sandbars are getting stabilized. Previously the refugees did not have legal rights on these lands but recently they have been given 'patta' or legal rights. They have taken the river bed as their own. A kind of allegiance has developed among the refugees.

Stabilization and over utilization of sandbars have become detrimental to the river itself as fund resources in the control sector are gradually replacing the flow resources. The Damodar river is in the state of anthropogenic degradation.

It is not possible to bring the Damodar in its natural state any more. But the flow in the river can be regulated in order to even out seasonal peaks and to produce a more uniform annual discharge pattern to maintain a perennial channel, which has a tendency to shrink owing to complete cutoff of high floods. At the same time further encroachment on the active riverbed should be prevented at the Government level. In the settled sandbars man should learn to live in harmony with his environment during his interaction with the river bed.

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TABLE NO. 3 : SEDIMENTATION DATA OF MAITHON RESERVOIR (BASED ON 1994 SURVEY)

	Original Capacity (1000 hm)	Present Capacity (1000 hm)	Loss of Capacity (1000 hm)	Loss of Capacity (%)	Rate of Sedimentation
Dead storage Upto EL 119 m	20.66	9.49	11.17	54.0	1280 m^3/sqkm/year
Live storage EL 119 m - 125 m	55.81	47.11	13.64	22.4	
Flood storage EL 125 m - 136 m	38.23	36.58	1.64	4.3	
Over all upto EL 136 m	119.64	93.19	26.44	22.1	

SEDIMENTATION DATA OF PANCHET RESERVOIR (BASED ON 1995 SURVEY)

	Original Capacity (1000 hm)	Present Capacity (1000 hm)	Loss of Capacity (1000 hm)	Loss of Capacity (%)	Rate of Sedimentation
Dead storage Upto EL 119 m	23.63	10.50	13.13	55.5	
Live storage EL 119 m - 125 m	25.24	16.12	9.12	36	617 m^3/sqkm/year
Flood storage EL 125 m - 136 m	109.30	106.38	2.91	2.6	
Over all upto EL 136 m	158.16	132.99	25.17	15.9	

Source : After DVC : 1995, Bhattacharyya, K., 1998.

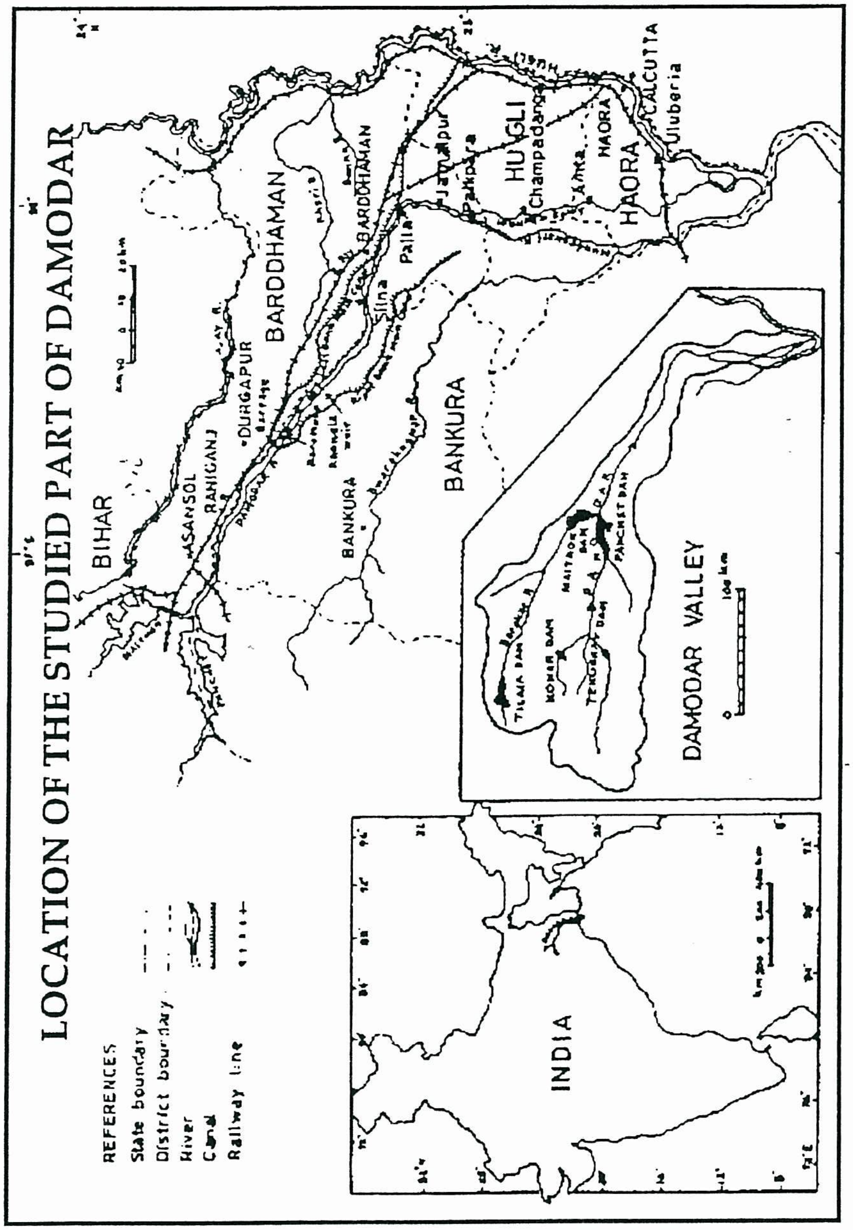
LOCATION OF THE STUDIED PART OF DAMODAR
REFERENCES
State boundary
District boundary
River
Canal
Railway line
BIHAR
ASANSOL
RANIGANJ
DURGAPUR
BARDDHAMAN
BARDDHAMAN
BANKURA
BANKURA
Silna
Palla
Jamalpur
Paikpara
HUGLI
Champadanga
Amta
HAORA
HAORA
CALCUTTA
Uluberia
INDIA
DAMODAR VALLEY
TILAIA DAM
KONAR DAM
TENUGHAT DAM
MAITHON DAM
PANCHET DAM

Fig. 1

TREND OF ANNUAL MEAN DISCHARGE OF DAMODAR AT RHONDIA IN PRE-DAM AND POST-DAM PERIOD

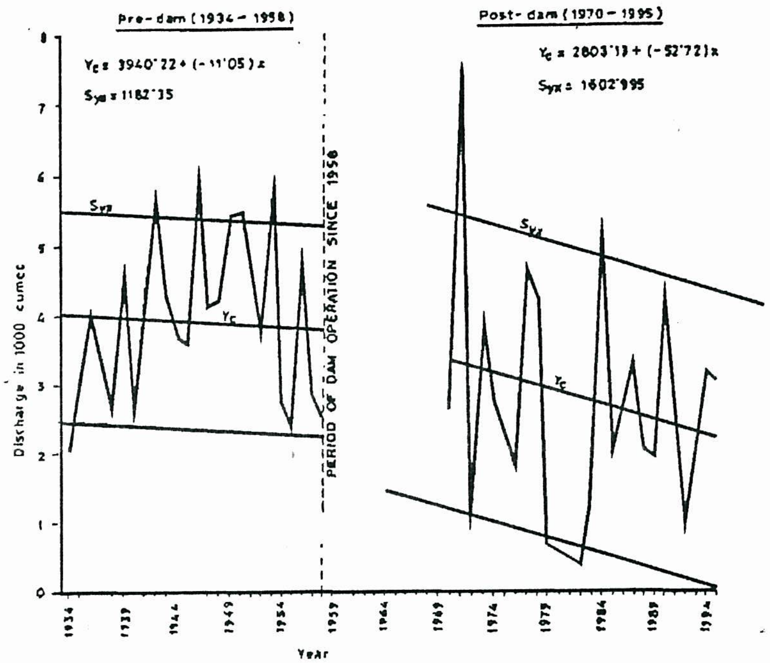

Fig. 2

BARA MANA (Section - 1 and 2)
CHANGES IN GENERALISED LANDUSE AND LANDSCAPE
BAMANDIHI AND PURAKONDA MOUZA

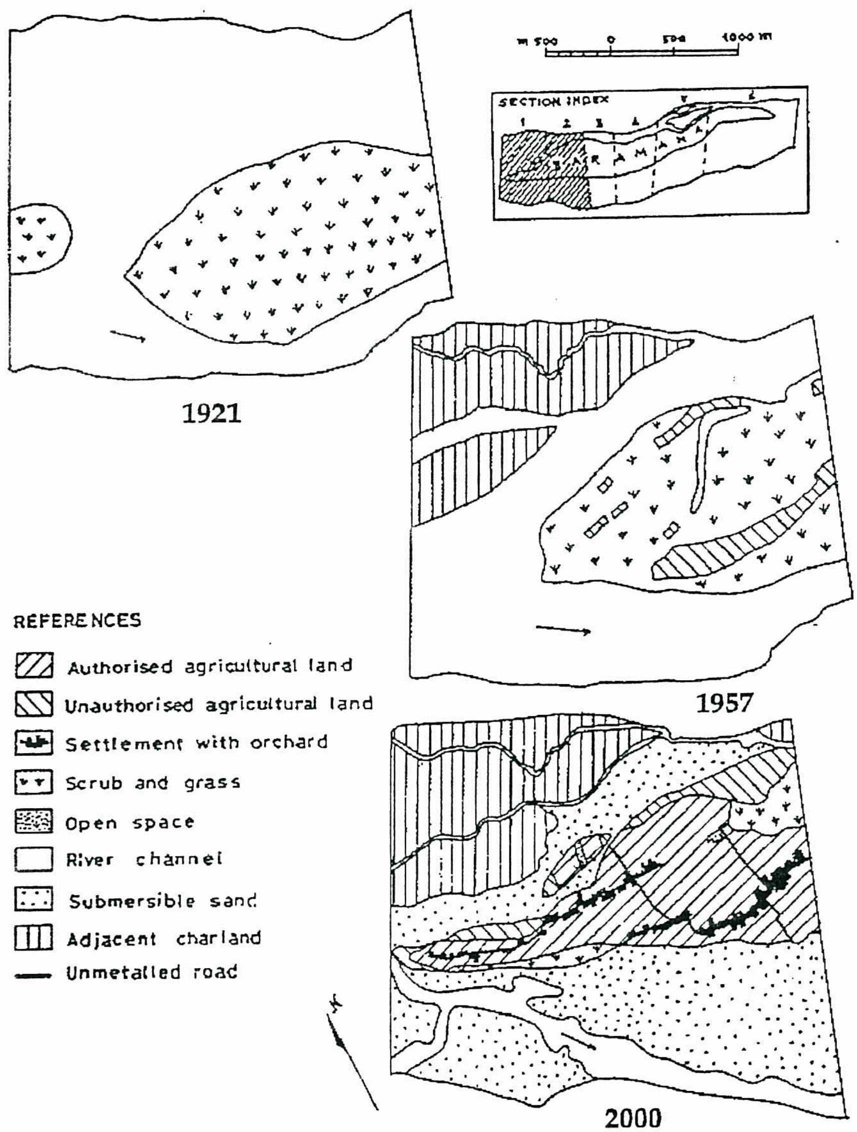

Fig. 3

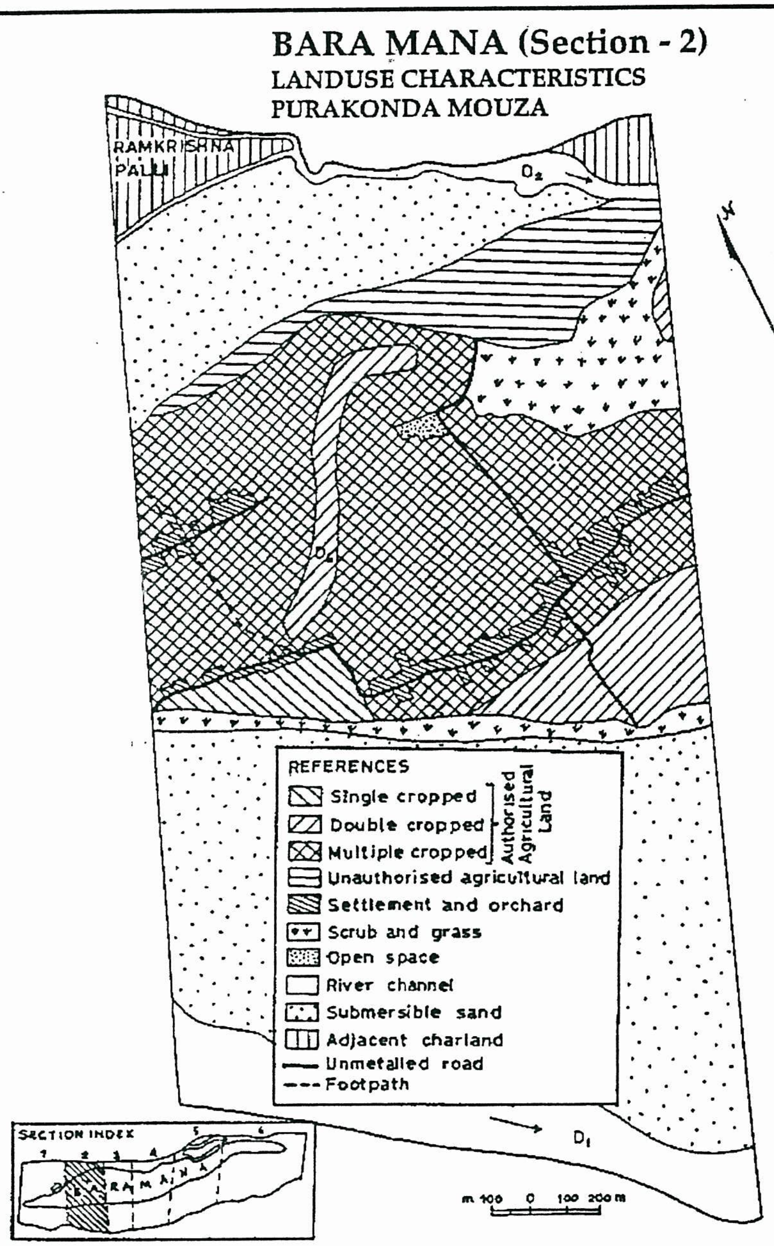
BARA MANA (Section - 2)
LANDUSE CHARACTERISTICS
PURAKONDA MOUZA
RAMKRISHNA PALLI
D2
D1
REFERENCES
Single cropped
Double cropped
Multiple cropped
Authorised Agricultural Land
Unauthorised agricultural land
Settlement and orchard
Scrub and grass
Open space
River channel
Submersible sand
Adjacent charland
Unmetalled road
Footpath
SECTION INDEX
m 100 0 100 200 m

Fig. 4