Chapter II

INTRODUCTION

2.1. OBJECTIVES

Objectives of the present study are to assess the impacts of river control measures on selected hydro-geomorphological parameters of a tropical alluvial river in its low gradient sector and to review the socio-economic significance of such control measures and consequent anthropogenic changes in the riverbed itself.

The river that has been selected is the Lower Damodar, which was once notorious for its flood havoc in undivided Bengal. Embankments were, thus the first control structures to tame this river. Therefore, it is imperative to trace:

i. the flood characteristics and flood history of the Lower Damodar.

ii. the phases of control measures in the said section chronologically and chorologically.

iii. the consequent changes in discharge, sedimentation and channel characteristics.

Such changes, it is admitted, are of great hydro-geomorphic significance. The objective, however, is to focus on them from resource and hazard perspectives. This part of the objectives perhaps needs a clarification.

Throughout tropical Asia pressure of population has forced socially and economically marginalized sectors of the society to occupy floodwise sensitive tracts. In that sense, river beds are the most vulnerable tracts. But these river beds are put to extensive and intensive agricultural uses particularly where rivers are highly seasonal and channel deposit consists of finer materials. So almost everywhere in tropical Asia, farmers get busy exploring the exposed fine grained channel deposits with the lowering of flood level and decreasing discharge. This is the scenario in Indian subcontinent and particularly in India and Bangladesh. Migration, exposure and submergence of channel deposits become sensitive socio-economic and political issues near the district-state and International boundaries. These issues have also been dealt in the present study, though tangentially.

What is to be mentioned here is that in the study area channel deposits are not only agriculturally used but most of the channel bars have settlements and the settlers are mostly Bengali refugees. Therefore, the channel deposits and channel discharge in the study are socio-economically significant.

The objectives in this section are to trace:

i. the socio-economic and socio-political history of colonization in the river bed.

ii. the impact of control measures and consequent changes on the perception of the river-bed occupiers.

iii. the history and characteristics of land use in the river bed.
So, the four fold objectives are to review:

i. the flood characteristics and flood history of the lower Damodar and flood control measures.

ii. the impact of flood control measures on discharge, sedimentation characteristics and channel behaviour.

iii. the history of colonization in the river-bed.

iv. the land use characteristics and emergent landscape in the channel bars.

Apart from these primary objectives, there is a secondary objective. Three questions have been addressed which are relevant in the present study.

i. Do excessive river control measures serve the expected socio-economic purpose?

ii. Should we encourage indiscriminate use of a river bed?

iii. Does a channel deteriorate due to rapid anthropogenic stabilization of the channel bars?

These questions have significance at national level and can demand justifiably a separate research endeavour for a reasoned answer. These questions are just touched as corollary to the primary objectives.

2.2 THE LOWER DAMODAR, THE STUDIED RIVER.

Since 1947 almost all major rivers of India have gone through extensive river training programmes. A pertinent question may, therefore, be raised at the very beginning why the Lower Damodar has been selected for this specific study. Prior to answering that question the Lower Damodar should be defined geomorphologically as through out this present treatise, the stretch between the Panchet reservoir and the Falta point has been referred to as ‘Lower Damodar’ (Fig.-2.1).

Schumm's classical division of fluvial system refers to Zone I as the source of sediment and water, Zone II as the zone of transfer of water and sediments and Zone III as a zone of distribution and deposition (Schumm, 1977). If Schumm’s classification is to be followed then the Lower Damodar should be taken from the off-take point of the Khari to the Falta point as the Khari is the first important distributary of the Damodar. But at present Khari no longer looks like a distributary, instead, it looks like an independent river. Though, there are historical evidences that once the Khari, Banka, Behula and Gangur etc., were distributaries in the old Damodar delta. All these distributaries have been severed from the main river most probably due to the construction of the south-eastern railway line and other roads. Therefore, I am not delimiting the Lower Damodar from the Khari off-take point.

If the Schumm’s scheme can slightly be modified then the stretch below Jamalpur from where distributaries are more important, should be defined as the Lower Damodar. Distributaries now appear on the map as the Kana Damodar, Kananadi, Kunti etc. The biggest or the largest distributary is the Mundeswari which is for various reasons treated
LOCATION OF THE STUDIED PART OF DAMODAR

REFERENCES
State boundary
District boundary
River
Canal
Reservoir
Railway line

INDIA

Fig. 2.1
as an independent river. But geographers like S.C. Bose (1948), S.P. Chatterjee (1969) had never mentioned this stretch as the Lower Damodar. From the old maps and reports and from the field survey, off-take point of the Mundeswari appears to be an anthropogenic landform which will be discussed later in details. Therefore, in the present study, the Lower Damodar has not been demarcated from the off-take point of the Mundeswari.

P.K. Sen (1991) in his study has delimited the Lower Damodar basin from the confluence of the Damodar and the Barakar near Damodar bridge site near Barakar immediately below the confluence of the Damodar with the Barakar respectively. Below the Damodar-Barakar confluence, there are a few insignificant tributaries like the Sali, Nunia, Tamlanala etc. In fact the Damodar does not show a noticeably middle stretch or Zone II if Schurnn’s scheme is accepted.

J. Choudhury (1990) divides the Damodar into three sections. Section one is from the source region to the Damodar-Barakar confluence, section two is from the Damodar-Barakar confluence to Barsul-Chanchai village where the river takes a turn towards south, section three is from Barsul-Chanchai to the confluence of the Damodar with the Hugli (Fig.- 2.1). It is this Barsul-Chanchai section which has thrown maximum number of distributaries in the historical past. So the debate on the definition of the Lower Damodar focuses on the four important issues:

i. The Khari off-take point is the beginning of the Lower Damodar if Schurnn’s classification is to be followed.

ii. The Mundeswari off-take point should be taken to define the Lower Damodar.

iii. The southerly stretch of the Damodar below the Barsul-Chanchai is the actual Lower Damodar.

iv. Finally, the stretch below the Damodar-Barkar confluence is the actual Lower Damodar.

The scheme proposed by P.K. Sen (1991) has been slightly modified here. The stretch below the Panchet reservoir, the most important control structure, is defined as the Lower Damodar. For this problem of definitions, in this research project the term Lower Damodar has not been used in the title of the thesis but the term Lower Damodar has been used for convenience while discussing the stretch between the Panchet reservoir and the Falta point (Fig. 2.1).

This part of the Damodar was notorious for floods and the recorded flood history dates back to 1730 (Voorduin, 1947) and the last flood was in 1995. While justifying the research theme it has been stated that flood is an issue from time immemorial i.e., from the dawn of civilization to the present era despite tremendous improvement in engineering technology. Therefore, a river has been selected which still creates flood havoc despite several flood control measures. Secondly, the Lower Damodar is one of the innumerable South Bengal rivers which was chained by embankments and most of these embankments predate the British Period. These embankments, constructed to control flood were the first control measures. Thirdly, this is the river which was selected first in independent
India for the multipurpose river valley development project according to the Tennessee valley Authority model of USA. This project is known as the Damodar valley Corporation (D.V.C.). In the studied section lies the Panchet reservoir, constructed in 1959. The Durgapur barrage (1958), and the Ulughata sluice (1982), are other two important transverse control structures. This section also contains the pre-independent control structures such as the Jujuti sluice (1881) and the Rhondia weir (1933). There are small control structures which have been constructed not by the Government but by the locals such as Rangamatia dyke or dam at Rangamatia sandbar in the Bankura district.

Fourth, the riverbed itself below the Panchet reservoir up to the Falta point is extensively used for agriculture. The crops, vegetables and trees grown vary from inferior type of cucumber (*Cucumis Sativus*) and bottle gourd (*Lagenaria Siceraria*) to mulberry plant.

Finally, there are several sandbars which are permanently settled by Bengalee refugees. Therefore, the factors behind selection of the Lower Damodar as the study area are as follows:

i. Flood propensity of the Lower Damodar.

ii. Presence of series of control structures from embankments to reservoir.

iii. Agricultural utilization of the riverbed.

iv. The presence of sandbars with settlements.

2.3 LOCATIONAL REFERENCE OF THE STUDY AREA

The study area from the Panchet reservoir to the confluence of the Damodar with the Hugli (previous Hooghly) river at Falta is a part of the Damodar drainage basin. The area roughly extends from 22°13' N to 23°40' N and from 86°46' E to 88°5' E. The total length of the Lower Damodar is approximately 250.15 Km.

The study area comes under the districts of Purulia, Bankura, Barddhaman, Hugli and Haora of West Bengal. Major portion lies within the districts of Bankura, Barddhaman, Haora and Hugli. Important towns near the study area are Asansol, Ranigunj, Durgapur, Barddhaman and Uluberia. Calcutta, one of the four metropolitan cities of India is not far away from the study area. The area comes under the police stations of Saltora of the Purulia district, Mejdia, Barjora, Sonamukhi, Patrasair, Indus of the Bankura district, Galsi, Khandaghosh, Barddhaman, Memari, Jamalpur of the Barddhaman district, Tarakeswar, Jangipara, Dhaniakhali and Pursurah of the Hugli district and Udainarayanpur, Anta, Bagnan, Uluberia and Sharmpur of the Haora district. The south-eastern railway line passes through the left bank. The Grand Trunk road runs almost parallel to the railway line. Finally, the area is a part of the Rarh, the Ranigunj Coalfield, the Durgapur, Asansol urban industrial complex, the industrial urban Barddhaman and agriculturally prosperous Barddhaman-Hugli plains (Fig.- 2.1).

2.3.1 Problem of Area Demarcation

The study area is small part of the Damodar drainage basin mentioned above. Therefore, selection of indicators to define the study area, has posed many problems. As the study
is on a controlled river, one of the control structures, has been taken for demarcation. The embankments, the primary control structures on the Damodar demarcate the study area mostly on the left and right banks. But the problem is that the embankment does not exist beyond Silna on the left bank excepting few places upstream of the Durgapur barrage and above Paikpara on the right bank. In the absence of embankments, the natural levees which have been protected in some places by artificial means have been taken as the limits of the actual study area. In absence of prominent natural levees, river bank has been taken as the demarcation line. Area demarcation poses a serious problem where riverine alluvial bars have almost been merged with the main land. In such a situation, previous channel boundary has been taken as a limit of the study area (Fig.-2.2).

The western most boundary is the Panchet reservoir, the most important control structure on the Damodar. The south-eastern most limit is the opposite of the Falta point. Though the Damodar delta geomorphologically extends below the Falta point but the present study does not include the extended delta of the Damodar into the Bay of Bengal. Bahir Aima is the last settlement in the study area.

So, following are the selected indicators to demarcate the study area:

i. Embankments.
ii. Levees.
iii. River bank.
iv. Old channel of the present Damodar.
v. Reservoir.

2.4 BACKGROUND OF THE DAMODAR

2.4.1 River System

The Damodar river or the Deonad nadi as it is known in its upstream sector, is a subsystem of the Ganges river system of India. In the Matsya Purana (6th Century B.C.), the Damodar is named as ‘Mahagauri’ and has been described as a rocky river (Antasira) and a river which is difficult to encounter i.e., a ‘Durgama’ river (Ali, 1966). This description probably refers to the upstream bedrock controlled Damodar. Ptolemy, has mentioned this river as Dharmadaya (Majumder Sastri, 1927; Sen, 1962). Ancient cartographers, travellers and explorers have also mentioned this river in different names but there is no reference of this river in our epics, the Ramayana and the Mahabharata. Local meaning of the Damodar is a womb or ‘Udar’ which is full of fire. This implies that the Damodar flows through a coal rich area.

The river rises in the Chhotanagpur watershed at 23°37' N and 84°41' E. The entire drainage basin resembles a tadpole. In its upper sector, the Damodar flows through quartz rich Archean gneiss. In its middle stretch lies the Raniganj coal field, i.e., the Damodar flows through the sandstone rich Gondwana sedimentaries near Asansol Raniganj (Fig.-2.3).

The main tributaries are the Barakar, Tilaiya, Konar etc. Below the confluence of the Barakar there are a few insignificant tributaries such as the Nunia, Sali etc. Once the main distributaries were the Khari, Banka, Behula, Gangur etc., but now they look like
SELECTED INDICATORS FOR DEMARCATING THE STUDY AREA

Fig. 2.2
independent rivers. Near Barsul-Chanchai the river takes a sharp southerly bend. Similar characteristics are to be observed in some other tributaries of the Ganges such as Mayurakshi, Khari-Banka etc. These sharp bend and deferred confluence with the Ganges are explained as reflection of structural hinges (Sengupta, 1972; Agarwal and Mitra, 1991). Below Jamalpur, the river bifurcates into the Kanki-Mundeswari and the Amta channel and joins the Hugli at Falta some 48.3 Kms south of Calcutta. Old maps of Jao De Barros (1550), Blaev (1645), Vanden Broueke (1660), Rennel (1779-81) and other maps and charts of unknown cartographers show the changing courses of the Damodar below Barddhaman (Sen 1962). This part is referred to as the Damodar para-delta (Bagchi, 1944) which is older than the Ganga Brahmaputra delta.

2.4.2 Physiographic Divisions

Damodar Valley region can be divided into four physiographical regions (Fig.-2.4).

i. Eastern low alluvial plains.

ii. Central rolling plains.

iii. Central uplands.

iv. Western plateau and plateau fringe (referred to as ‘Rarh’ plateau in West Bengal).

The eastern alluvial plain is also referred to as ‘Rarh’ plain. It extends between the Bhagirathi Hugli in the east and 60m contour line in the west. The Banka-Damodar plain lies within this physiographic division.

The soil ranges from skeletal plateau soil, laterites to alluvial soil in its lower region. Near the Falta outfall the soil is slightly saline.

2.4.3. Tropicality Of The Lower Damodar Environment.

The Damodar is referred to as a tropical river as it flows through a tropical environment. Tropicality of environment is assessed in terms of specific conditions and not by mere latitudinal location. The tropicality of environment is primarily a product of thermal criteria. Further classification is based on amount and seasonality of precipitation.

2.4.3.1. Climatic tropicality

The basic tropical climatic characteristics of the drainage basin are:

i. Temperature of the coolest month (Dec.) is 19.15°C and 19.85°C at Asansol and Barddhaman (Table 2.1, 2.2).

ii. The average seasonal ranges are 13.95°C (May and December) and 11.85°C (May and December) for Asansol and Barddhaman respectively.

iii. The average daily range of temperature is greater than seasonal range of temperature.

iv. Monthly rainfall varies from 2.5mm (December) to 344.4mm (July) and 4.3mm (December) to 314.4mm (July) and 3.2mm (December) to 331.9mm (August) for Asansol, Burdhaman and Hugli respectively (2.1, 2.2).

v. There is a definite dry period from November to May.
### Climatological Table of Asansol

**Table 2.1** (Based on observation from 1931–1960)

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature in °C</th>
<th>Wet Bulb Temperature in mm.</th>
<th>Relative Humidity</th>
<th>Total Rainfall</th>
<th>No. of Rainy days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Highest</td>
<td>Lowest</td>
<td>Mean in °C</td>
<td>in °F</td>
<td></td>
</tr>
<tr>
<td>Jan</td>
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<td>27.00</td>
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<tr>
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<td>18.9</td>
<td>30.85</td>
<td>21.85</td>
<td>71.33</td>
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<td>21.7</td>
<td>33.10</td>
<td>24.95</td>
<td>76.91</td>
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<tr>
<td>June</td>
<td>35.3</td>
<td>22.9</td>
<td>32.75</td>
<td>25.80</td>
<td>78.44</td>
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<tr>
<td>July</td>
<td>34.4</td>
<td>23.7</td>
<td>29.45</td>
<td>26.40</td>
<td>79.52</td>
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<tr>
<td>Aug</td>
<td>34.7</td>
<td>23.1</td>
<td>29.05</td>
<td>26.35</td>
<td>79.43</td>
</tr>
<tr>
<td>Sep</td>
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<td>17.6</td>
<td>25.85</td>
<td>23.50</td>
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</tr>
<tr>
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<td>31.7</td>
<td>12.1</td>
<td>21.90</td>
<td>18.10</td>
<td>64.58</td>
</tr>
<tr>
<td>Nov</td>
<td>29.2</td>
<td>9.1</td>
<td>19.15</td>
<td>14.90</td>
<td>58.82</td>
</tr>
</tbody>
</table>

Source: IMD Climatological Tables of Observatories in India. (1931–1960)

### Climatological Table of Barddhaman

**Table 2.2** (Based on observation from 1931–1960)

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature in °C</th>
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<th>Relative Humidity</th>
<th>Total Rainfall</th>
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<tr>
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<td>Mean in °C</td>
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<tr>
<td>Jan</td>
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<td>19.85</td>
<td>14.90</td>
<td>58.82</td>
</tr>
</tbody>
</table>

Source: IMD Climatological Tables of Observatories in India. (1931–1960)
vi. There are five rainy months from June to October which account for more than 80 per cent of the total annual rainfall.

vii. Relative humidity is more than 80 per cent in July, August, September and only 50 per cent or less than 40 per cent in March and April.

viii. Number of rainy days increases from June to August.

ix. The annual rainfall is variable, the co-efficient of variability being 106.07 per cent.

The above conditions confirm to the requisite conditions for a tropical climate as defined by Thornthwaite in 1931, 1933, 1948, Koppen in 1931, 1936 and also by Trewartha (1968), Barry and Chorley (1978) and Niéwolt (1977) et al.

The monsoon tropicality of the environment is reflected on the hydrographs (Fig-2.5). The hydrograph is leptokartic in nature. Peak discharge is generally found in the month of July to September. Discharge is low between January and May and again between November and December. Mainly on the basis of discharge characteristics the adjective tropical has been used for the Damodar.

2.4.3.2. Tropical floristic composition:

The tropicality of the Lower Damodar basin can also be assessed from the floristic composition. Original climax vegetation was tropical deciduous with sal (Shorea robusta) predominating. Extension of coal mining activity, construction of roads, railways, barrage and reservoir, growth and development of urban industrial towns in the upper part of the Lower Damodar have necessitated removal of this climax vegetation. Mostly open forests with coppiced sal are to be found now (Dhara and Basu, 1988). By virtue of its position the rest of the Lower Damodar basin must have been forested in the historical past, but for the extension of agriculture, forests have been cleared long ago. Expensive afforestation scheme has been taken under territorial forestry and social forestry schemes. Almost everywhere tropical energy plant species like Akashmoni (Acacia monilisormis) subabul (Leucaena leucocephala) etc. have been planted.

2.4.3.3. Tropicality of soil

The tropicality of the environment can be recognized from soil characteristics also which has been mentioned above.

2.4.3.4. Tropicality of economic activities and transport

Tropicality of the environment is also reflected in economic activities of the region. In the entire Damodar drainage basin, human occupation varies from rock quarrying, forestry, mining, agriculture to industrial urban activities. Agricultural land use characteristics are closely associated or adjusted with flood-prone micro-environment. Crop selection and crop calendar strictly follow the tropical climatic regime that will be discussed in later chapters. Economic activities like open-pit mining, sand quarrying are greatly affected by heavy rain during monsoon. Transport facilities in the Lower Damodar valley area are most inadequate. The Grand Trunk Road which links Calcutta with Upper India is the only important all-weather long distance road in the valley. The village roads are
seasonal and almost impassable during monsoon period using any modern conveyance. Unmetalled roads are motorable only in dry season i.e., from November to May. Seasonal rivers are fordable during dry season because ferry service is rendered during monsoon period. There are state and district high ways but surface conditions deteriorate during rainy season. All these activities, however, are not controlled by tropical environment but to some extent are influenced by the climatic characteristics. Jarrett (1977) also refers to human background of tropics while defining the tropical region.

2.5 BACKGROUND OF THE POPULATION GROUP

The studied section of the controlled Lower Damodar is inhabited by three distinct communities,

i. Local Bengalee and migrated Bengalees.

ii. Migrated people from Bihar.

iii. Bengalee Hindu refugees and Bihari and U.P. people with refugee status.

Biharis came from the Chhotanagpur plateau to work in coal mines of the Ranigunj coal fields. The labour freed from disused collieries was absorbed later in agricultural sector. People from Uttarpradesh were originally fishermen or boatmen. Prior to independence they used to ply from U.P. to the present Bangladesh. Most probably they left the erstwhile East Pakistan after 1947. The Bengalee Hindus came to India after 1947 and again after 1970. There was step migration from East Pakistan or Bangladesh. They came to the districts Nadia and 24 Parganas first and from there they shifted to the Barddhaman and Bankura districts. Biharis and local Bengalees include Muslims. The Bangalee refugees, it to be mentioned here, are mostly scheduled caste. Approximately total population in the studied section is about forty thousand. All these groups are undifferentiated in one characteristic, the level of education is very low everywhere.

2.6 RESEARCH PARADIGM

There has been a marked paradigm shift in geomorphology from structural geomorphology to applied and environmental geomorphology. Prior to mid 1880's geomorphology was an amorphous concept. The term geomorphology was yet to be coined. In that period Hutton, Playfair, Smith, Lyell, Agusses, Powell and Gilbert contributed to the concept. In 1889 Davis proposed the historical concept of landform evolution and Davisian school has reigned the discipline of geomorphology till 1960 which was approximate year for the end of the concept of erosion cycle and denudation chronology (Hart, 1991). 1960 is a landmark in geography when the term applied geography was first used by L.D. Stamp in 1960 (Frazier, 1972). In 1962 Chorley introduced the concept of system theory and Kuhn used the term 'paradigm' (Chorley, 1962; Kuhn, 1962). But way back in 1954 Thornbury introduced the term 'Applied Geomorphology' and devoted a separate chapter on Applied geomorphology in his book. He also gave a precise definition of the term by stating that 'Applied geomorphology' is the application of geomorphic knowledge in planning and management (Thornbury, 1954). But Cooke and Drookamp (1974, 1990) are treated as father figures in applied geomorphology who roughly defined 'Applied geomorphology' as a deliberate attempt to concentrate on geomorphological expertise in
PHYSIOGRAPHY AND DRAINAGE OF DAMODAR VALLEY REGION

REFERENCES
- Aggradational flat plains
- Degradational and dissected uplands
- Plateaus
- Hills
- Ghats
the solution of practical problems. From 1970 applied study began to multiply noticeably. 1980 is the beginning of the man-environmental studies and 'Applied geomorphology' from 1980 has taken a new name as 'Environmental geomorphology'. During the past twenty years 'Environmental Impact Assessment' has been adopted in many countries in order to assess and mitigate the environmental effects of large scale engineering projects such as electrical power plants, chemical works, railways, river valley projects etc. Among these effects the natural component must be examined in terms of geomorphological hazards, which may endanger a project or other geomorphological assets. (Cavallin et al., 1994).

Structural geomorphological perspective is still popular in geomorphological research where there are noticeable structural variations at regional scale, and lithological variations at local scale. In the study area, there is practically no structural variations. Lithological variations are also negligible and there is no correspondence between landforms and structures and lithology. For example, the exposure of the Gondwana sandstone and shale in the Ranigunj coal field, west of Durgapur and newer alluvium in the east does not make any relief variation (Fig.-2.3). Therefore, this structural perspective or approach in this research has no significance.

Application of Davis' historical or diachronic perspective is still very common among Indian geomorphologists. But it has been stated that Davisian perspective has lost its significance since 1960. It is because of the fact that Davis deals with a physical environment which does not include man or anthropogenic processes. The study begins with controlled structures which are anthropogenic landforms in a historical environment. Secondly, application of Davisian approach requires an extensive spatial scale and extended time horizon. Here, the study area is too small for Davisian paradigm. Compared to the Davisian time scale which is about 15 million years, the time scale in the present study is only from 1730 to 1996, i.e., 266 years. Though Davis is respected as a father figure in geomorphology, objective of present study cannot be fulfilled with Davisian concept.

In the research theme, the adjective 'tropical' has been used for the river Damodar to indicate the tropicality of the river, particularly the flood habits and of the over-all environment, the Lower Damodar falls within the tropical monsoon climate. Table 2.1 and 2.2 gives some idea of tropicality of climate and focuses on tropical rainfall characteristics specifically. From the climatological tables of Asansol, Barddhaman it is observed that there is no marked variation in temperature in the Lower Damodar region. There is very little hydric variation also. It is admitted that over-all agricultural practices follow tropical system. Open-pit mining in the Raniganj coal field is affected by monsoon, and several man-days are lost during rainy days. The Lower Damodar is in many parts fordable during dry season and unmetalled roads are motorable in dry seasons only. Originally an extensive part of the Lower Damodar region, west of Durgapur was densely forested with Sal (Shorea Robusta) a tropical species (Dhara and Basu, 1988). For these reasons mentioned above, the term tropical river has been used in this research theme but my approach is not climatic geomorphological approach as there is generally an absence of morphogenetic landforms even at micro level.
Chorley and Kennedy's system approach (1971) is gaining popularity all over the world particularly in assessment of hydro-geomorphological consequences of reservoirs but they have certain limitations also. They have not touched upon social aspects in geomorphological investigation. Secondly, Chorley's system approach requires a large set of quantified data and analysis of complex relationships between different phenomena in a system. Due to paucity of complete data it was not possible to apply Chorley's system approach. Though, Chorley's approach is of paramount significance in modern geomorphological research.

Considering all these factors the applied geomorphological approach has been adhered to by taking the definition of Thornbury (1954), later modified by Coates (1971, 1972–74), Cooke and Doornkamp (1974, 1990) i.e., geomorphological information can be applied to solve practical problems, arising out of geomorphological or hydro-geomorphological phenomena like floods and geomorphological expertise can be used for geomorphological hazard and resource identification and hazard reduction and resource utilization.

The applied perspective in the present study has two levels. At the first level geomorphological knowledge is utilised for constructing control structure on the Damodar. Engineers, hydrologists, geomorphologists and planners have used their knowledge at national and regional levels. The embankments, sluices weirs, barrages, reservoirs are outcome of planning at this level. At the second level it is the village folk who uses geomorphological knowledge (though they are not aware of the term geomorphology) to identify and explore resources for sustainance in the bed of a controlled river.

This applied perspective has to be distinguished from environmental geomorphic perspective. The term 'environment' has been used in the present study, but the term environmental geomorphology has a wider connotation whereas the term applied geomorphology has a restricted meaning as it has been stated while defining the term. The emphasis is on the necessity and impacts of control structures on the river discharge, sedimentation, channel behaviour and the land use characteristics in a controlled river-bed. Application of hydro-geomorphological knowledge is of paramount significance in land use under specific socio-economic situation. The paradigm selected is thus, 'applied geomorphology'.

2.7 APPLIED GEOMORPHOLOGICAL ISSUES

Applied geomorphological issues are location specific, time specific and culture specific as well. Soil erosion may be a problem in one area. Excessive sedimentation in the river-bed may create problems somewhere else. Avulsion may be a problem in X region, neck cut off may create problems in Y region. Landslides may pose serious problems in some area whereas collapse of river bank may become hazardous somewhere else. Thus, applied geomorphological issues vary from place to place. Bank erosion may be a problem now. Excessive riverbed sedimentation may pose problems tomorrow. So, there are temporal variations in applied issues. Flooding and creation of water logged bodies may be menace to cultivators but fishing folk may welcome that. Thus, applied issues are also culture specific.
Significance of applied issues also varies according to local, regional, national and international levels. Rising of sea level and consequent flooding of coastal areas in certain parts of the tropics due to global warming are international issues. Sharing of river water between adjacent countries and related problems have great significance at national and international level, but shifting bank lines and bank erosion in a particular area affect the locals. They are primarily of local significance but ultimately may become significant at international level. Taking all these factors into consideration issues have been selected which may appear of local significance but ultimately the issues have regional and national significance too. These issues often touch international level.

The primary issue is the Lower Damodar flood and flood control measures, second the impacts of flood control measures on the river discharge, sedimentation and on the river behavior, third, the impacts of flood control measures on the communities utilizing the controlled river-bed as their resource base. The issue that has been touched peripherally is the gradual deterioration of the riverbed of the Lower Damodar due to anthropogenic stabilization of alluvial bars.

2.8 MODELS AND METHODS

Here the paradigm is applied geomorphology. But there are no specific models which can be duplicated in the present research. Though D.V.C was formulated after the T.V.A model of the U.S.A. but no systematic study has been done to review the post D.V.C. situation. There are several official papers and documents highlighting the positive impacts of the D.V.C. in general but no attempt has been made to assess other aspects of the said project. There are several research articles published from various countries which focus on discharge and sedimentation pattern below major control points (Gregory and Park, 1974; Park, 1976; Petts, 1977, 1979, 1984; William and Wolman 1984; Chein 1985). But the social relevance of control structures at local level has not been mentioned. As the present research endeavour focuses on socio-economic issues emerging partly from control structures there is no a priori model which would have helped in the present study.

Regarding methods of enquiry the traditional text books on geomorphology by Wooldridge and Morgan, (1959). Thornbury (1954), Sparks (1972) et al. are rather reticent about methods of enquiry in geomorphological research. Traditional text books do not contain a separate chapter on applied geomorphology. Thornbury’s book is an exception. Thornbury has devoted a separate chapter on applied geomorphology (1954) but he does not mention about method of enquiry. King in (1967) in his introductory chapter has dealt with the methods of study. He has mentioned about four research methods i.e., theoretical, observational, experimental and empirical. According to King, observation in field plays an important part in geomorphological work (King 1967). Following King, it may be stated that the method is observational method to a great extent but these observational method does not necessarily mean a descriptive method. Pitty in his book entitled ‘The Nature of Geomorphology’ has stated clearly that in applied geomorphological research the method has to be ideographic (Pitty, 1982) as applied problems are location and culture specific.
HYDROGRAPHS OF THE DAMODAR AT RHONDIA

Fig 2.5
King distinguishes research method from methods of analysis. He states — "One of the methods used in the development of the geomorphological argument is inductive method. By this means a series of facts is arranged in a logical order. So that one leads to another and then to the final conclusion, which follows a reasonable and accepted way from the data set fourth. In this method observations are used to draw conclusions as the argument is built up" (King, 1967: 25) This inductive method requires a large number of case studies on a single theme for identification of similar phenomena, comparison of findings and ultimately formulation of a theory (Beaujeu-Garnier, 1976). Following King, Beaujeu-Garnier and Pitty, it may be stated that the method of analysis is ideographic or inductive. Nomothetic method has also been used partly.

2.9 SPATIAL SCALE AND TIME SCALE

The scale of geomorphological enquiry is linked with paradigms, models and methods on the one hand and with the cost of research on the other. Researchers and authors in applied geomorphology have not spelt out the spatial scale to be followed in such researches. But from their works (Douglas, 1971; Gregory and Park, 1974; Bird, 1980) it appears that they have taken part of a drainage basin as their study area. They have concentrated on extremely local issues and time scale selected by them is the graded time (Cooke and Droonkamp, 1974, 1990; Chien, 1985; Brunsden, 1981: Xu Jiongin, 1992, 1996). Even Coates (1972-74), Verstappen (1983), and Cooke and Droonkamp (1974, 1990) have not specified the time or spatial scale. As applied issues are location and time specific study area has to be a small area so that problems can be intensively studied.

Here, space is the Lowar Damodar river in between control structures though references have been made on the adjacent areas tangentially to fortify some of the arguments. The time scale is from 1730 to 1997.

This time bound research project has been funded by the University of Burdwan and the fund is meagre to carry on such research, based on field surveys over an extensive areas for a long period.

2.10 TECHNIQUE AND TOOLS

Selection of techniques and tools varies with research perspective, method of analysis and spatio-temporal scale but sometimes it so happens that a researcher is forced to use some of the out dated techniques due to non-availability of required tools.

Wooldridge and Morgan says that Geomorphology must begin at home if the student is to cultivate the "eye for country" which alone can make him a master of his medium and free from the limitations of book knowledge. (Wooldridge and Morgan, 1959). The statement is relevant in theoretical research but more important in applied geomorphology. Even King (1967) has devoted a special chapter on "Field Techniques". Despite improvement in techniques and tools field survey techniques have been focused on by almost all researchers or authors in geomorphology. Field techniques have been given emphasis to fulfil two fold purposes. Firstly, for observation of micro-relief forms as these forms are not observable in generalised toposheets or other maps. Second, these
micro landforms are so much dynamic that they required field visits several times within stipulated time of this research project. Third, due to non-availability of or inaccessibility to air-photographs and Landsat Imagery field survey techniques became imperative to collect active data from repeated field visits. Fourth, data on land use in the river bed are not available in Government institutions. Therefore, frequent field visit has been done to collect data on land use characteristics as land use is one of the important applied issues.

Land use to a great extent is the reflection of one’s perception about the given environment, which is physical as well as the socio-economic environment. Clayton in 1971 and Craik in 1970 have pointed out this perception concept in their articles “Reality in Conservation”, (1971) and Craik has given stress on man’s perception of the physical environment in 1970 respectively. So, perception survey is one of the techniques applied in the present study. Hortonian techniques have no relevance in applied geomorphological research. Therefore, Hortonian morphometric techniques have not been applied. While reviewing discharge characteristics of the Lower Damodar in pre-independence or in the post independence era statistical techniques have been widely used. Brunsden (1981), Verstappen (1983) and others have given emphasis on the interpretation of maps and utilization of map derived data to solve practical problems. In the present study that technique has also been applied.

Verstappen is eloquent about the use of air-photographs and Landsat imagery in the analysis of dynamic landforms. Due to non-availability of air-photographs of recent years it could not be used as the basic tools. IRS Geocoded imagery of 1992 and satellite image of 1994 [IRS-IB LISS-2/FCC/ classified image (1: 100,000)] have been used for a very small section.

To trace the evolution of channel bars and bank lines I have used S.O.I. maps of 73M/7N.E., 73M/7N.W., 73M/7S.E. (1:25,000). 73I/10, 73I/14, 73M/2, 73M/6, 73M/7, 73M/11, 73M/12, 73M/15, 73M/16. 79A/4, 79N/13, 79N/14, 79N/15, 79/B2 and 79B/3. (1:63,360 ; 1:50,000 ). 73I, 73M, 73N (1:250,000). Dickens’s map surveyed in 1854 (1:126, 720) has also been used. More than 100 cadastral maps have been consulted.

Other maps like geological maps, D.V.C. maps, have been sparingly used. It is admitted that S.O.I maps are not geomorphological maps, therefore, there may be discrepancies in the data collected from these maps. The same statement is applicable to other archival maps of Barros, 1550; Gastaldi, 1561; Hondivs, 1614; Blaev, 1645; Cantelli Da Vignolla, 1683; Vanden Broucke, 1660; G. Delisle, 1720–40; Izzak Tirion, 1730; and Rennel, 1979–1781, et al. (Sen, 1962).

2. 11 SELECTION OF VARIABLES AND INDICATORS

Of four independent variables such as time, initial relief, geology and climate influencing two important hydro-geomorphic parameters such as discharge and sediment load, time and climate have been selected as variables in impact analysis of control structures. Other two variables have no significance in the present study. Variations in quantity as well as in type of sediments can be well observed within a graded time span. Seasonal changes
in climatic parameters are well reflected in discharge and sedimentation. To assess the impact of control structures the variables on which emphasis has been given are discharge and sedimentation. In assessing the river-bed land use characteristics agricultural crops, and settlements are the most important variables selected for the present study.

Verstappen (1977) mentions that cultural features like domesticated vegetation, settlement roads, cultivated fields etc. are effective geomorphic indicators in the analysis of dynamic landscape. Indicator investigation in erstwhile USSR entered new phase. Indicators are used to evaluate the prediction of indicated processes having different effects on landscape. Vegetation is often used as a direct indicator of depth and mineralization of shallow water (Abrosimov and Kleiner, 1973). Viktorov (1973) says that man-made indicators such as indicators that have come up due to man's activity are significant in the analysis of landscape. In examining the applied issues and interpreting river-bed landscape the man made indicators such as vegetation, crops settlements etc. have been considered as viable indicators in the present study.

2.12 DATA BASE AND DATA CONSTRAINT

Four sets of data form the basis of the present study. Archival data from old maps and Government reports and records have been profusely used to trace the changing course of the Lower Damodar and the flood history. Archival data has again been used to trace the history of embankments, the first control structure. In most cases this type of data, is a qualified data which is a constraint in the present study.

Quantified data on discharge, silt have been collected from various departments of the Damodar Valley Corporation (D.V.C.) and Irrigation and Waterways (I & W) departments of West Bengal Government, and Refugee, Relief and Rehabilitation department (RRRD), National Atlas and Thematic mapping organisation (NATMO), District Collectarates, Regional Remote Sensing Unit, Kharagpur etc. Different types of maps which have been used as tools have helped to generate data qualified as well as quantified. Finally, the largest set of data on socio-economic aspects has been generated from field survey.

Formidable constraint in the data base is that data are not necessarily geomorphological data. So, non-geomorphic information has been translated into geomorphic information.

2.13 CHAPTER ORGANIZATION

The first chapter clarifies the research theme and perspective. The second chapter deals with objectives and various methodological aspects. The third chapter makes a review of previous works on the DVC and literature relevant to research. Some of the concepts to be used in this study have been briefly discussed in this chapter. The chapter four traces the history of the Lower Damodar floods and phases of flood control measures. The fifth and six chapters focus on the impacts of lateral and transverse control structures on river discharge and sedimentation and channel behaviour. The seventh chapter concentrates on the history of colonization in the Lower Damodar river-bed. The chapter eight, nine and ten bring out the land use characteristics in the riverbed. The eleventh chapter is theses. The final chapter is conclusions and suggestions for further future investigation.
2.14. WORKING STEPS

The research began with the literature survey on the Damodar and a reconnaissance field survey in the study area. On the basis of this field survey, research theme was selected. The next step was the collection and collation of the different types of maps. The third step was to collect data from different Government Institutions. It was followed by an intensive field survey. Simultaneously literature has been reviewed on various aspects of applied geomorphology so as to organise thoughts and data to meet the objectives. The next working step was to prepare chart, tables, graphs and maps. Statistical analysis of data was a part of this step. The final step was to organise observations and thought in form of a research report. At all stages field survey and field checking were imperative.