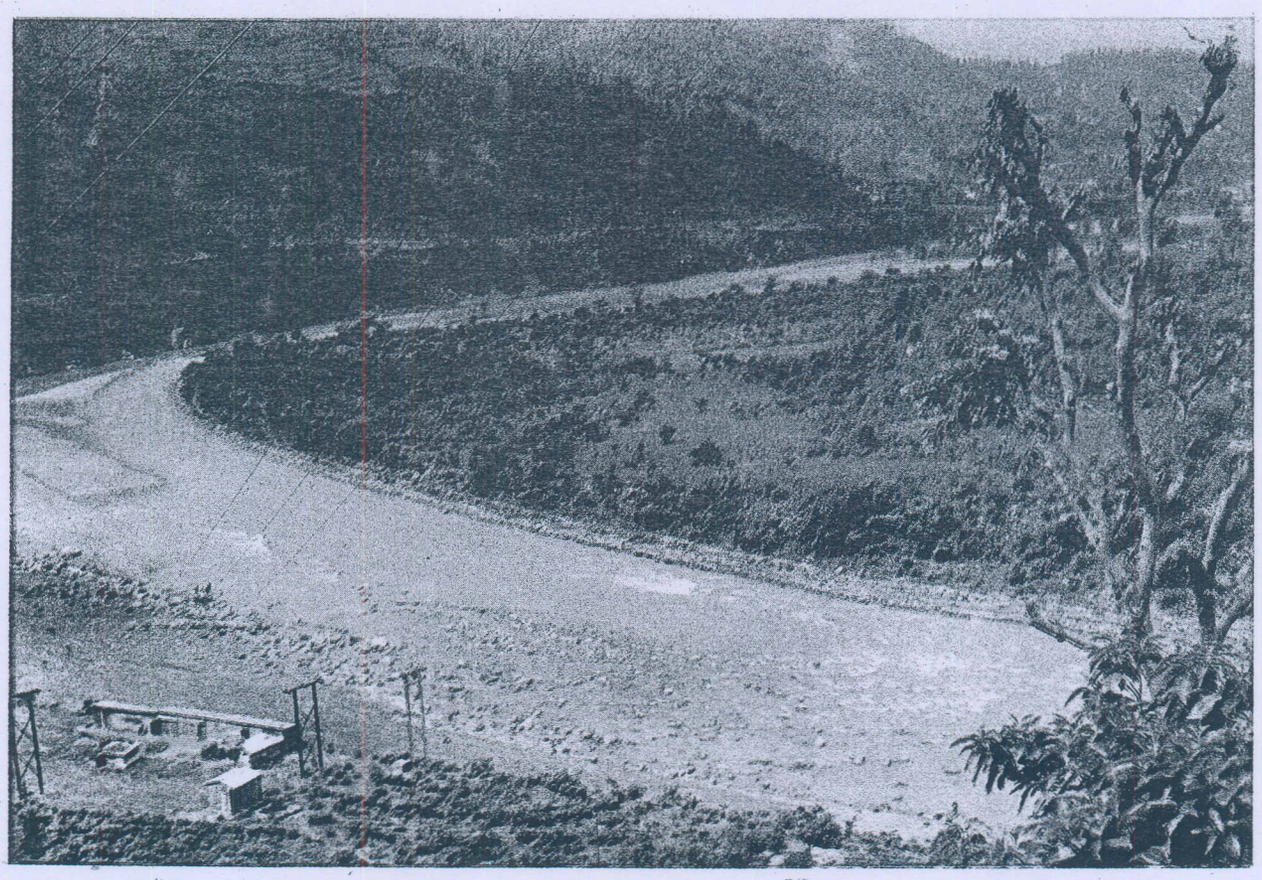
नदी आकारिकी रिपोर्ट तैयार करने हेतु सामान्य मार्ग दर्शिकायें

GENERAL GUIDELINES FOR PREPARING RIVER MORPHOLOGICAL REPORTS



भारत सरकार
GOVERNMENT OF INDIA
जल संसाधन मंत्रालय
MINISTRY OF WATER RESOURCES
केन्द्रीय जल आयोग
CENTRAL WATER COMMISSION
नई दिल्ली
NEW DELHI

अप्रैल 1991
APRIL, 1991

GENERAL GUIDELINES FOR PREPARING

RIVER MORPHOLOGICAL REPORTS

APRIL 1991

GOVERNMENT OF INDIA
CENTRAL WATER COMMISSION

FOREWORD

Empirical or semi-empirical approaches guide, to a large extent, the country's process of planning, design and construction practices in respect of river management in general and river training and anti erosion works in particular. Instances are not uncommon of indiscriminate adoption of these methods without regard to the unique characteristics of a river resulting in performance deficiency/ ineffective performance. The situation leads to huge recurring expenditure year after year on the repairs and maintenance of these works. An urgent need thus exists for evolving more rational and scientific approach through detailed morphological study of each problematic river. The Rashtriya Barh Ayog also emphasises the need for such studies based on necessary scientific data.

Many State Government Departments and other agencies involved in river management have shown interest in pursuing such studies and some have already initiated action in this direction. In order to ensure that a rational pattern is adopted for preparation of river morphological reports by different agencies, it is considered necessary to formulate suitable guidelines. This publication forms an endeavor in that direction.

It should however be realised that, looking at the constraints and complexity of the problems, these guidelines cannot be comprehensive and universal. Specific river problems and river characteristics will obviously dictate the final contents of a morphological report. Despite the inherent limitations, I hope this publication will provide the river engineers an insight into the basic objectives and requirements of such reports.

(C.SUDHINDRA)
MEMBER(RM), CENTRAL WATER COMMISSION AND EX-OFFICIO ADDITIONAL SECRETARY TO THE GOVERNMENT OF INDIA

PREFACE

Since independence a large number of developmental and protective works have been taken up in different river basins all over the country. The developmental works include dams, barrages, weirs, bridges, etc. The protective works include flood embankments and anti-erosion works like spurs, revetments, bank pitching, bed bars etc. Most of the protective works have been taken up on rivers of the Ganga and Brahmaputra river systems where the problem of river instability and consequent bank erosion is particularly severe.

The design and construction practices in respect of various river training and anti-erosion works, at present in vogue, are based on empirical or semi-empirical formulae which were developed towards the turn of the century mainly for design of irrigation canals and head-works. The pioneering work done by the British engineers and scientists viz. Kennedy, Lacey, Lindley etc. came to acquire such high reputation that formulae and methods developed by them have been used rather indiscriminately in design of different types of hydraulic structures without much regard to the unique characteristics and behavior of the individual river. In many cases the likely effect of a structure on river regime is not evaluated before hand.

The experience of many of these works constructed so far has been that though, on one hand these have afforded the desired benefits, on the other hand, these appear to have adversely affected the stability of the rivers. Erosion of the banks on the river Satluj downstream of the Bhakra dam, on the river Ganga upstream and downstream of the Farakka Barrage and on both the banks of the river Kosi are just a few of the classic examples of this phenomenon. However, before carrying out detailed studies, it would be premature to attribute these problems to the different works. But it is being increasingly realised that these experiences should be properly documented and analysed and that the unique characteristics of each river should be understood so that the responses of the river due to any encroachment in the flood plain and more in the case of future man-made structures may be anticipated and preventive measures as considered necessary may be planned before hand.

The need for such an approach is all the more felt for finding solution to the serious problem of river bank erosion.

The Rashtriya Barh Ayog in its report has recommended that Scientific information should be obtained on river morphology and river response to various hydraulic structures and encroachments and efforts should be made to evolve mathematical models to remove empiricism and introduce better rationality in decision making process.

In order to ensure uniformity in scientific data collection and methodology for morphological studies, it is necessary that general guidelines are laid down. It is with this objective that this publication is being brought out.

The literature available on the subject is vast and varied and many concepts are either irrelevant to a river engineer or are too theoretical and complex to be of practical utility to him. Choice of the necessary material for a publication of this nature could therefore, be subjective. However, it is hoped that the publication would be of use to the agencies concerned in initiating the process of data collection and morphological studies.

Preparation of these guidelines would not have been possible but for the unstinted support and encouragement from Member(RM) CWC and the dedicated efforts of the team of officers and staff of River Morphology Directorate. A list of these officers and staff is appended.

S.S.Iyer

(S.S.IYER)
CHIEF ENGINEER

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DIRECTORATE ASSOCIATED WITH
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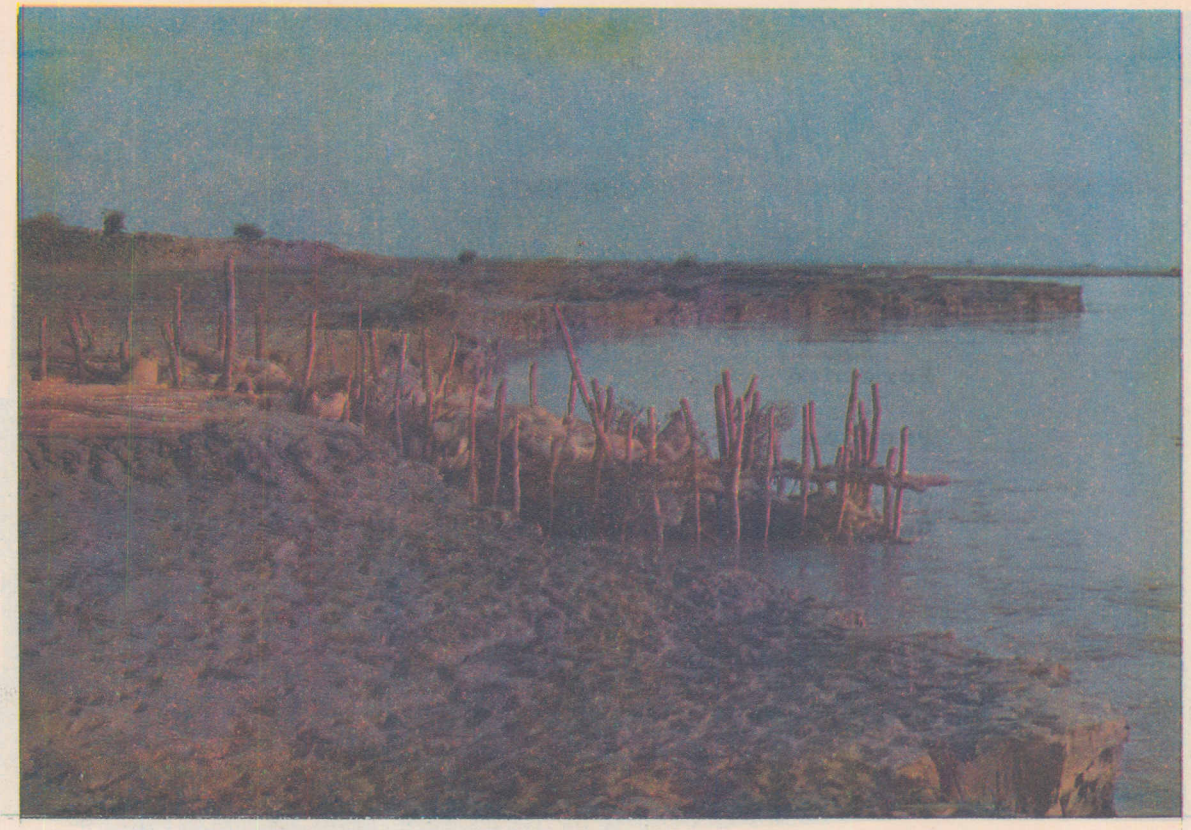
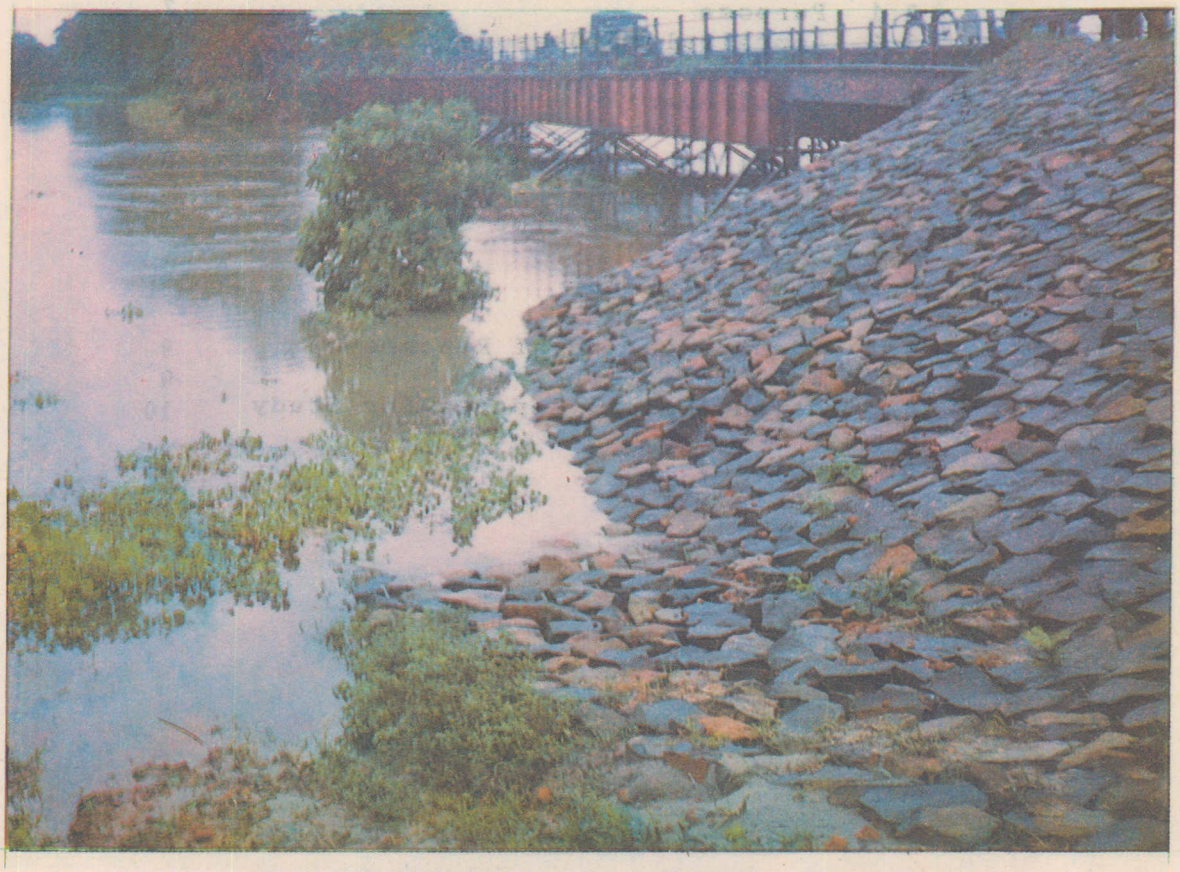


Erosion of Left Bank of The River Yamuna Near Village Yaqutpur (U.P.)



Threat To The Bridge on Taib River (Bihar)

GENERAL GUIDELINES FOR PREPARING RIVER MORPHOLOGICAL REPORTS

1.0 INTRODUCTION

Most alluvial rivers in the country especially those of the Ganga and Brahamaputra river systems have erratic behaviour both during the lean and the flood seasons. While during the lean season the shoals in the low water channels cause problems in navigation, during flood season the deep channels swing laterally and erode the banks posing threat of serious damage to valuable property, lines of communication, towns and villages.

The planning, design and construction practices in respect of river training and anti-erosion works at present in vogue in the country are based on empirical or semi-empirical formulae developed towards the end of the last century. Most of these formulae were evolved in connection with the design of irrigation head works and canals. Indiscriminate use of such formulae, without regard to the unique characteristics of a river, sometimes lead to an anomalous situation where the benefits from a river training work are to some extent off set by its ill effects on the river regime.

For a scientific and rational approach to different river problems and proper planning and design of water resources projects, an understanding of the morphology and behaviour of the river is a prerequisite. In recent years there has been a growing awareness about the need for taking up morphological study of rivers in the country especially with particular reference to their unique problems. In order to assist the engineers of the departments concerned of States/Union territories and other agencies, an attempt has been made to formulate broad guidelines for preparation of river morphological reports.

2.0 GENERAL APPROACH

2.1 OBJECTIVES

The objectives of a river Morphological report are:

(i) To identify the problems-location specific and morphological, works taken up and their performance.

(ii) Interpretation of factors responsible for different types of problems, causes of failures of the measures taken and the corrective measures necessary.

(iii) Understanding of river mechanics to facilitate mathematical modeling.

(iv) Identify further studies to be carried out.

(v) Identify additional data required.

(vi) Evolve criteria for planning and design of structures for efficient river management.

2.2 CONTENTS

The contents of a morphological report are as given in Annexure I. The specfic information to be included in each Chapter is given in Annexure II.

3.0 APPRAISAL OF THE PROBLEMS

3.1 PURPOSE

3.1.1 A detailed description of the problem, both location specific, reach specific or over entire system is a basic requirement as this would lead to a choice of the proper methodology for study and the identification of the requisite data. The typical problems which are normally encountered in river management are those arising out of natural causes or those caused by man made structures or encroachments into the river bed. These may be one or more

of the following:-

(a) NATURAL PROBLEMS

(i) Frequent changes in river course.

(ii) Avulsion of one river into another (beheading).

(iii) Heavy shoal formation (as in Brahamaputra basin) causing diversion of the main current towards the banks.

(iv) Development of natural cut-off in meandering rivers. This sometimes changes the meandering pattern.

(V) Heavy land slides in the catchment causing sudden and steep rise in silt load. This causes instability, as was witnessed in the river Kosi in 1934.

(vi) Heavy aggradation of the river bed. This raises high flood levels resulting in overtopping of banks/embankments even during floods of relatively moderate intensity.

(vii) Heavy erosion of banks by hill streams due to flash floods (as in West Bengal where large tracts of tea gardens are affected).

(viii) River instability due to changes in bed slopes as a result of seismic activity (as in many rivers in Assam).

(ix) Changes in river channels due to changes in rainfall pattern.

(x) Erratic behaviour of rivers in deltaic areas where they have numerous spill channels.

(xi) Erratic behaviour of braided rivers.

(xii) Navigational problems due to shoal formations.

(xiii) Formation of sand bars at river out-falls into sea, due to reduction in upland discharges as in Hoogly river.

(xiv) Morphological changes in a river due to changes in its base level i.e. the levels of the out-fall into another river or sea.

(b) MAN MADE PROBLEMS

(i) Degradation of river bed downstream of a dam or a barrage.

(ii) Effects of constriction of river width due to Barrage/bridge construction.

(iii) Effects of flood embankment on the regime of rivers.

(iv) Effects of extraction of sand and boulders from the river beds and banks.

(v) Effects of spurs and bed bars of different types on river behaviour.

(vi) Effects of inter-basin transfers of water on the regime of rivers.

(vii) Effects of river bed cultivation and construction by farmers in a river reach.

(viii) Effects of dredging/chanalisation of river bed. (This is usually done near big cities to keep the deep channel near Power House or Water Works).

(ix) Effects of Pucca bathing ghats in big cities and places of pilgrimage.

(x) Effects of heavy urbanisation along the river banks.

3.2 APPRAISAL OF MEASURES TAKEN:

A detailed account of the different measures, alongwith sketches/drawings of structures constructed, design criteria and design conditions considered etc. is given. Performance of the existing works is given with details of the extent and type of failure if any noticed from time to time. These details are likely to lead to an understanding of the possible causes of malfunctioning/failure of the work which, in turn, would dictate the choice of morphological parameters to be studied in detail.

4.0 DATA REQUIREMENT

The data requirement would depend primarily on the

morphological parameters that are to be studied for a particular river. However, following minimum data is required.

(i) Topographical data such as topographical maps, aerial photographs satellite imageries etc.

(ii) River cross sections upto the highest recorded water level for different years at/in:

- existing gauge discharge sites (Premonsoon and post monsoon)

- The reaches affected by bank erosion and/or erratic river behaviour.

(iii) Daily discharge data for the existing discharge sites.

(iv) Daily gauge data for the existing sites as well as for the study reaches.

(v) Daily sediment load data for the existing sites.

(vi) Grain size distribution of the bed material for existing sites as well as for study reaches.

(vii) Grain size distribution of the suspended and bed load.

(viii) Hydrographic charts in the vicinity of existing sites and in the study reaches (refer para 6.1).

(ix) Vertical velocity and sediment load distribution at the existing sites.

(x) Dimensions of the dunes and/or ripples.

(xi) Geomorphological map of the basin with particular reference to the flood plain.

5.0 HISTORICAL PERSPECTIVE

5.1 MORPHOLOGICAL TIME SCALE:

Various flow and channel parameters are interdependent. Identification of independent and dependent variables is an important step in a scientific study of river morphology.

Viewed in a geological time scale of millions of years, a river is an open system undergoing continuous change and there are no definite relations between different parameters as they change with time. On the other hand, over a small time scale of a few days or weeks a river may be in a "steady state" in which no significant changes in channel characteristics occur. The cause effect relationship in the two cases may be quite different, which if documented quantitatively may be a source of serious error in the interpretation of the mechanics of river flow and thereby in the understanding of the river behaviour.

In the graded time span, arbitrarily defined as a few hundred years, a graded condition or dynamic equilibrium exists. During this time span the variables which appear as constantly changing in geologic time and as static in "steady time" appear to fluctuate in a cyclic manner. Geology, hydrology, initial relief and valley dimensions may be considered " independent variables" and the channel morphology as " dependent variable". It is this time span which is of relevance to the river engineer. In river morphological studies, therefore, these interdependencies have to be kept in view.

Since the river channel is the result of flowing water, magnitude and frequency of run-off events are a major factor in determining the character of a river channel. It is therefore, possible to show qualitative relationships between river flow on one hand and different aspects of channel morphology like channel dimensions, shape, gradient etc. on the other.

For a short term (steady-time) evaluation of changes in river parameters, the variables are considered as follows:-

Water discharge - Dependent variable
Sediment discharge - Dependent variable
Hydraulics of flow - Dependent variable
Channel morphology - Independent variable

For the evaluation of parameters in the graded time scale, the variables are as follows:-

Hydrology (mean discharge of water and sediment) - Independent variable
Hydraulics of flow - Indeterminate
Channel morphology - Dependent variable

Erosion of Left Bank of The River Yamuna Near Village Tilwara (U.P.)

6.0 MORPHOLOGICAL STUDY

6.1 IDENTIFICATION OF REACHES

After a detailed appraisal of the problems, the river reaches to be studied are identified and sub divided into a number of study reaches such that a precise profile of the energy line may be established for study. A rigid criteria for the length of a reach obviously can not be laid down, but as a general rule a length of about 10 KM is considered adequate. In meandering reaches, the study reaches are so demarcated as to identify the curved and straight portions. Braided reaches of a river are sub divided in such a way that all major and minor channels separated by shoals and bars are covered for study. Divided flow(twin channels) and long straight reaches are included in separate study-reaches.

6.1.1 DEMARCATION OF CROSS SECTION LINES

In each study reach cross section lines are laid out normal to the general direction flow at an interval of about 5 km. distance being measured along the center line of the main channel.

6.2 DATA COLLECTION

While para 4.0 gives the general data requirement, following data is necessary for specfic morphological studies. Some of the data is, therefore common.

(i) Daily gauge, discharge and sediment, data are collected for each G&D site in accordance with the procedures laid down in the relevant codes of the Bureau of Indian Standards. Daily gauges are observed for each study reach. For morphological study, sediment samples are taken from each segment used in discharge measurements.

(ii) Cross sections of the river at the identified locations are taken every year before and after the monsoon season.

(iii) Hydrographic survey of each study reach is done separately for different river stages. The survey charts are used for bed form studies.

(iv) Measurements of the dimensions of the dunes in different parts of the river bed are also made for sediment transport modeling.

(v) Grain size distribution of the suspended sediment load is determined.

(vi) Grain size distribution of the bed material is determined.

(vii) Vertical velocity distribution and vertical sediment distribution at significant river stages are observed for each G&D site.

(viii) Engineering properties of the bank material are determined especially for locations susceptible to river bank erosion/collapse.

(ix) Geomorphological map of the entire basin covering the flood plain and showing important features like point bars, alternate bars, middle bars, ox-bow lakes, palaeo channels, channel plugs etc.

6.3 MORPHOLOGICAL ASPECTS FOR STUDY

6.3.1 RIVER FLOW ANALYSIS

The main objectives of river flow information are, (a) the study and description of river morphology, (b) investigation of river bed forms, (c) study and prediction of sediment transport and (d) analysis of aggradation and degradation. These groups of river mechanics problems are mutually inter-related processes dependent on river flow processes. Therefore river flow data is analysed, described and presented in such a way as to provide the best insight into effects on various dependent processes.

Many variables in river mechanics are power functions of discharge. Greater values of the exponent in the relationship indicate that high river flows are more important and neglecting the low flows is justified in the study of a particular river problem. Some variables depend upon the integrated effect of previous discharges, both low and high, so that all flows are relevant in the study, while some other variables depend not only on the discharge but also on the rate of its variation.

In order to understand the significance of different variables in river mechanics and to identify the different types mentioned above, structural analysis of the flow series is carried out.

6.3.2 FLUVIAL GEOMORPHOLOGY

For a proper understanding of the process of erosion and silting on which depend the morphology of the river basin, it is also necessary to view the fluvial land scape in a historical perspective. The variables influencing the river channels and river systems can be broadly categorised as (a)Structure, (b) Stage and (c) Process.

(a) STRUCTURE

The term structure as used in geomorphology implies not only the effects of various kind of rocks but also the differential erosional character of the rocks, the ;influence of various geologic factors like fractures, joints, faults and their distribution in a drainage basin.

(b) STAGE

The change of landform with time is referred to as stage of development of a land form. The progression of erosion in a given region is mark by "Competition" between river systems for drainage area. The most aggressive river with the steepest slope or greatest discharge or an advantage of lower altitude may capture the drainage area of another river system thereby changing the course of the later. A qualitative understanding of this aspect helps in undertaking detailed investigations of specfic problems of avulsion of one river into another.

Landform development is studied from a hypsometry curve for the basin drawn between h/H and a/A where h is the contour height above the base plane, H is total height, a is area enclosed by a given contour and A is the total area of the basin. A typical hypsometric curve shows the lines corresponding to different stages of development of a landform viz. youthful, mature and old stage. Relations between contour height and area and between contour height and percent area above the contour could also be developed.

These studies afford a preliminary knowledge of the basin which helps in deciding the further exploratory work in the field. For instance, it would be worthwhile looking for old courses (palaeo channels) of a river in a landform that has reached the old stage.

Drainage pattern of a basin gives a fair idea about the geology of the basin i.e the nature of rocks, faults, folds, joints, fractures, unconformities etc.

Drainage density, expressed as the length of drainage channels per unit area of the basin, helps in better interpretation of the hydrological data of a river. It also helps in identifying different categories of lands, for instance:-

	Drainage density
Sand stone areas	3 to 4
Fractured igneous rocks	15 to 25
Bad Lands	200 to 400

Other basin characteristics like form factor,circular ratio, elongation ratio, bifurcation ratio,stream order etc. are discussed.

(c) PROCESS

Distinctive characteristics of river flow are the "processes" which determine the character of a river channel. River flows in the form of daily discharge, gauge and sediment load being the most pertinent time series, should be analysed. This may be done by developing relationships between the three parameters and identifying the unique characteristics of the flow series. On the yellow river in china, it has been shown that channel shifting varies with fluctuations in discharge. A linear relation was found to exist between ratio between maximum discharge to bankfull discharge and the wandering intensity in meters/day of the Thalweg.

The "Structure", "Stage" and "Process" aspects of river morphology afford a qualitative understanding of the nature of a river and its behaviour.

6.3.3 CHANNEL CHARACTERISTICS

Lateral and vertical movement of the deepest river bed at different sites from year to year are described both in qualitative & quantitative terms from the study of river cross sections. The lateral/vertical movement of the river bed, where possible, are co-related with the problem of bank erosion, if any. A description of secondary channels especially those frequently shifting and causing significant changes in flow pattern near the banks are described.

(a) BANK FULL WIDTH

This is a subjective term. This is taken as the river width at water surface level corresponding to the mean discharge. Mean discharge is taken as the mean of daily discharge for 365 days of the year. This could also be decided by visual examination of the river cross sections & confirmed with the study of G&D Curve plotted on semi-log paper (the level at which the curve flattens out could be taken as the bank level).

Mean Depth (D) = Area of cross section at bankfull stage (A)/Bankfull Width (B)

Width Depth Ratio = B/D

It is also useful to study changes in channel parameters in the downstream direction for different frequencies of flow.

(b) REGIME STATUS

From the regime formulae of Lacey, width, depth, area and velocity, are worked out and these are compared with the observed values at different river stages. Such a study would indicate the applicability or otherwise of the regime formulae of Lacey.

(c) RIVER BED CHARACTERISTICS

i) The qualitative and quantitative description of lateral

slope of the flood plain are given from observed cross section for different years.

ii) Aggradation and degradation of the river bed in a reach are studied through a comparative study of river cross sections for different years. These cross sections for different years are superimposed and the area of each cross section below a reference line are worked out. An increase in the area from one year to another would indicate degradation while a decrease in area would indicate aggradation at the site.

Aggradation/degradation of the bed may also be reflected in a shift in the G-D Curve over a given period. For a meaningful study it would be desirable to draw G-D curves separately for rising and falling stages of the river.

The above study from cross sections and G-D curve would indicate aggradation/degradation at a particular cross section and not in a reach. However, such a trend between two sites could be broadly studied through a sediment balance study for the reach.

(d) SEDIMENT TRANSPORT

Though there are numerous sediment transport formulae developed by various investigators from time to time, none of these is considered suitable for all situations. Efforts, therefore, is made to develop relationships between observed values of sediment transport on one hand and different flow parameters on the other. The different flow parameters could be discharge, velocity and stream power.

(e) FLOW CHARACTERISTICS

Relations could be developed by plotting graphs on log-log scale between width, depth and velocity on one hand and discharge on the other. For low flows, critical velocity may be co-related with depth to develop an equation which will have the form of Kennedy's equation.

(f) PLAN FORM

Meandering and braiding reaches of the river are separately studied. For meandering reaches following relations may be developed on log-log scale:-

Meander length	Vs.	Bankfull width
Meander width	Vs.	Bankfull width
Radius of curvature	Vs.	Bankfull width

For braiding rivers/reaches there is very little literature available for any accurate study. However, different approaches as given in CBI&P Publication No.204 titled, "River Behaviour, Management and Training" Vol. I may be referred.

Tortuosity, Sinuosity etc. of the river may be studied.

Tortuosity = (Length of the river along the middle of main channel)/(Axial Length)
Sinuosity = (Length along thalweg)/(Axial Length)

(g) BARS AND SHOALS

Bars and shoals in the river bed may be identified as point bars, middle bars, alternate bars etc. The bars associated with meanders are mapped for consideration in correcting river alignments. Unwanted shoals are identified for removal.

(h) BED FORMS

There are several methods of bed form study. However, those by Engelund - Hansen and Garde - Raju could be used.

(i) BED AND ENERGY SLOPES

A comparative study of valley slope, bed slope, water surface and energy slope is made. Excessive energy loss in a reach is associated with significant shoal formations.

Valley slope could be taken from the Survey of India topo sheets. Bed slope, observed for reaches is given. Water surface slope in different reaches, if available, may be given otherwise the same at the G&D sites may be given. Energy slope is drawn with respect to the river bed taking into account the hydrostatic head (Depth) and velocity head(V*V/2*g).

(j) CHANNEL MIGRATION

Channel migration is believed to be dependent on the variation in discharge from season to season. High variation is usually associated with significant shift in the deepest channel while low variation is associated with comparatively stable channel. There may be some exceptions to this general observation. Relation may however be established between the ratio of maximum discharge to bankfull discharge on one hand and lateral channel shifting on the other. In some cases there is a very good relation between these two parameters.

The above morphological parameters are studied to explain the unique characteristics and behaviour of the river and their bearing on various problems. The channel parameters, which need to be corrected/modified to find solution to the problems, are identified and the extent to which such corrections/modifications are required, are spelt out.

7.0 SUMMARY

A Summary of various studies carried out, conclusions arrived at and recommendations for necessary remedial measures are given at the end of the report.

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ANNEXURE - I

FORMAT FOR MORPHOLOGICAL REPORTS OF RIVERS

Chapter No.

I INTRODUCTION

i) Introduction

ii) Scope

iii) Data used

iv) Limitations

v) Land use

THE RIVER

i) Catchment/Drainage

ii) Topography (This should include flood plains)

iii) Valley slope and bed slope

iv) Flood plain

v) Existing under construction and planned structures.

vi) Apparent effects of man made structures.

III CLIMATE

i) Rainfall

ii) Temperature

iii) Humidity

iv) Evaporation

IV SOILS

Soil Characteristics and erodability.

V WATER QUALITY AND UTILIZATION

Water quality, different uses of water including navigation.

VI GEOLOGY

i) Physiography

ii) Geomorphology

iii) Structure and tectonics.

iv) Earthquake/Seismicity etc.

v) Land slides

vi) Glaciation

VII HYDROLOGY

i) Description of lean season and flood season flows with figures of maximum, minimum & dependable flows and bankfull discharge.

ii) Water surface slope.

iii) Sediment Transport (during lean season and during floods with figures of coarse, medium and fine sediment).

VIII PROBLEMS

i) Flood problem: Flood damage, Threat to cities etc.

ii) Erosion

iii) Lateral shifting of the river

iv) Problem of city water front, if any.

v) Earlier Studies

IX MORPHOLOGICAL CHARACTERISTICS

i) Channel Characteristics

a) Cross section study for variation in area, deepest bed movement (lateral & vertical), description of secondary channels with reference to erosion problem, if any.

b) Bankfull width, mean depth, width depth ratio, etc.

Inter relationship between different parameters

c) Regime status

d) Lateral slope of river bed

ii) Aggaradation/Degradation of bed:

a) By cross section study

b) By G-D curve study

c) By sediment balance study

iii) Relation between sediment transport and different flow parameters including stream power.

iv) Flow characteristics (Relations between different flow parameters with reference to mean velocity and critical velocity).

v) Plan Form

a) Meander or braiding characteristics of the main river.

b) Changes in Thalweg (This should include meander, geometry tortuosity, sinuosity etc.)

vi) Bed Forms

a) Bars and shoals

b) Analysis of bed forms with reference to flow characteristics.

vii) Analysis of bed slope, water surface slope and energy slope with respect to valley slope.

viii) Channel Migration

Shifting of deepest channel with reference to the channel parameters like bankful width, maximum width etc.

X SUMMARY

ANNEXURE-II

SPECIFIC INFORMATION TO BE GIVEN IN DIFFERENT CHAPTERS OF A MORPHOLOGICAL REPORT.

CHAPTER I

- Terms of reference if any.
- Brief introduction with statement of the problem
- Need for morphological studies.
- Specific objective and scope of the studies.
- Definitions (As per standard glossary of terms)
- Index map (Topo-sheet 1" = 40 miles)
- Data used.
- Limitations of the data and methodology.

CHAPTER II

- Description of the river and tributary system.
- Topography of the catchment, flood plains, deltaic reaches.
- Valley slope, bank slopes, bed slope.
- Description of flood plain with mention of Khadir limits, significant high and low areas.
- Brief description of various river valley projects-existing, under construction and planned with figures of water utilisation for different purposes.
- Observed ill effects, if any on the river regime/behavior during the post project period.

- Land use- significant changes from time to time with land use maps.

III CLIMATE

- Rainfall pattern, intensities, frequencies, duration etc.

- Temperature (Max., minimum, mean) in different parts of the basin.

- Humidity

- Evaporation (Observed)

IV SOILS

- Soil types found in different parts of the basin.

- Soil characteristics, composition.

- Erodability of bank material.

- Engineering properties of bank material.

- Soil map

V WATER QUALITY AND UTILISATION

- Quality of Surface water PH Value, mineral and metal content, BOD, dissolved oxygen.

- Geo-Hydrology with water quality.

- Different water uses including navigation.

VI GEOLOGY

-Physiography with detailed map of stream. Hypsometry curves.

- Drainage pattern (Horton's classification), drainage density.

- Geology with description of various lithofacies, rock types, erosional character of rocks, influences of factors like fractures, joints, faults on river shape and pattern. Structure, tectonics, earth- quakes, land slides and their effect on sediment load.

-Geomorphology with geo-morphological map showing flood plain features like point bars, alternate bars, middle bars, valley plugs, ox-bow lakes, palaeo channels etc. with their descriptions and their effect on river behavior.

VII HYDROLOGY

-Temporal and spatial distribution of rainfall, mean monthly and annual isohytes.

- Storm movement

- Rainfall intensities 1,2,3 days.

- Isohytal map and maximum intensities observed.

-Description of lean season and flood season flows with figures of maximum, minimum, mean and bankfull flows. flood flows of different return periods. Brief description of historical floods, 50%, 75%, 80%, 90% dependable lean season flows.

- Water surface slope.

-Sediment transport during lean and flood season with figures of coarse, medium and five sediments.

- Gauge and discharge hydrographs.

- Graphs showing typical variation of sediment load with discharge.

-Hydrological stations. Inventory of G&D sites with frequency of measurements.

- Network analysis of G&D sites.

-Sediment size distribution and concentration of suspended load along a vertical.

- Bed material size distribution (Samples to be

collected at 4 to 6 locations at every alternate cross-section from a depth of 30 cm. below the bed)

VIII PROBLEMS

- Flood damage, threat to cities, lines of communication, public utilities etc.

-Bank erosion posing threat to important towns, populated areas, roads, railways. Apparent causes of the problem.

-Significant lateral shifting of the river posing threat of out flanking of important structures like bridges, barrages, etc. besides bank erosion. Possibility of avulsion into another river and the possible consequences thereof etc.

- Significant shifting of the river away from important towns causing water shortage for drinking, industrial use, cooling water for thermal power stations etc. besides degradation of the city environment.

-Earlier studies by different agencies, remedial measures taken from time to time, performance/efficiency of the measures and need for further measures based on morphological studies.

IX MORPHOLOGICAL CHARACTERISTICS

- River flow analysis (refer para 6.3.1)

-Fluvial geomorphology (refer Para 6.3.2) and S.No. VI.

- Channel characteristics(refer para 6.3.3). These may include plan form changes if any, braiding characteristics and shoal formations, meandering characteristics and sub-meanders, physical constraints like hills and nodal points, bed forms in low medium and high stages with sonic soundings.

-Regime formulae applicability for width, depth, velocity, slope etc. Changes in Manning's 'n' values.

- Sediment load analysis with comments on transporting capacity.

- Historical information on aggradation and degradation in different reaches.

- Lateral migration from historical data.

-Khadir limit, determine extreme limits of coarse sand.

- Multipurpose reservoir and barrages and other structures with their effect on upstream and downstream.

-Low water channel characteristics in the context of navigation development.

- Catchment area treatment if any and its likely effect.

-Diagonosis of the problems of flood inundation and bank erosion. Scope and limitations of mathematical and physical models including review of available models and their choice.

- General approach and specific measures for a lasting solution to the problems.

- Further studies required, if any.

- Additional data to be collected in future.

SUMMARY

- Various parameters having a bearing on the river characteristics, behavior and problems.

- Basic approach to the problems in general and specific recommendations for a lasting solution to the problems.

- Further studies required, if any.

- Additional data required for such studies.