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REPRESENTATIVE BASIN STUDIES IN MALAPRABHA AND GHATAPRABHA BASINS

PART I

NATIONAL INSTITUTE OF HYDROLOGY
HARD ROCK REGIONAL CENTRE
BELGAUM

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PREFACE

Representative basins are basins which are selected as representative of a hydrological region within which hydrological similarity is presumed. They are used for intensive investigations of specific problems of the hydrological cycle. A representative basin takes the more specific role representing a broad area to which the data can be transferred.

Nearly 65% of the total land of India is covered by hard rocks (igneous and metamorphic) which consists of cryatalline rocks , such as granites , charnockites , gneisses, schists etc. Due to complex nature of the hard rock region, it is quite essential to have a thorough study of the hydrological problems existing in this part of the continent. However , it is impossible to cover whole area at a stretch , therefore it is decided to select two representative basins in the region for extensive research. In this regard , the regional centre , in consultation with the state and other Central government departments selected two catchments as representative basins , viz. , (i) Malprabha catchment upto Khanapur , (ii) Ghataprabha catchment upto Daddi. In these catchments State and Central government organisations have conducted some preliminary studies. The rgional centre has already completed studies on Geomorphology , Hydrologic data year book and Land use mapping .

The present study , provides an introduction to the concept of representative basin studies and gives a detailed account of current status of the representative basins of the hard rock region, viz., Malaprabha and Ghataprabha comprising basin characteristics (i.e., soil, geology, landuse pattern , geomorphology) ,basin input and output parameters.

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1.Ø INTRODUCTION

1.1 Why Representative Basin Studies ?

With the growing demand on revealing all available water resources and analysis of hydrological conditions in a comprehensive way, a landmark appears in the science of hydrology, that is the contents and interrelation of hydrological activities under go a radical change . A new means of research is being established in a growing number and within the scope of comprehensive investigations extending to large regions the network of representative areas is formed (Szesztay, 1965). Thus, the aim of hydrological research is not only the collection of data, but rather than an interpretation of these data for use in solution of various management problems such as:

- Flood forecasting and management of floods;
- prediction and estimation of surface water;
- prediction and estimation of groundwater;
- understanding the system of hydrological cycle and the water balance nature under different regions;
- how does the variability of topography, soil, vegetation, geology and climate etc. influence the hydrological cycle within different region ? and
- how a small change within a system can effect the entire hydrological system of a region ? etc.

The newly emerged concept of representative basin study is being widely recognised to solve various management problems because:

* principal objectives of hydrological research in representative basin are the prediction and quantitative estimation of various components of the hydrological cycle;

* representative basin studies are used for detailed studies of the hydrological cycle and provide an insight into the characteristics of the area which they represent

* a representative basin takes the more specific role of representing a broad area to which the data can be transformed;

* it is the representative basin study by which a holistic model of hydrological system could be developed which defines that how a small change in one hydrological parameter can effect the other parameters of the system individually and the entire hydrological system as a whole;

* a holistic model derived from a representative basin study helps in the prediction of various hydrological parameters such as overland flow, sub-surface flow, channel run-off, evaporation, infiltration, groundwater storage, flooding, sheetwash erosion, channel erosion and sedimentation etc.

* prediction of estimation of various hydrological parameters based on a representative studies help planners, decision makers, farmers and engineers to formulate their plans and to execute their plans for different purposes;

*last but not the least the representative basin study is the most useful in reducing time and effort required for studies of large areas, and it permits the formulation of rapid approximations and because time is saved it enables more detailed observation to be made and a greater number of variable to be considered.

1.2 Scope of the Present Study

India has a complete physiographical and hydrological environment Hydrologically it is divisible into as many as eight district hydrological regions having significantly different hydrological system. The present report is aimed at providing an introduction of the concept of representative basin studies and case studies of the representative basins (i.e., the Malaprabha and Ghataprabha , Fig.1) of the largest hydrological domain of India, viz., the Deccan Hard Rock Region which were established in 1987.

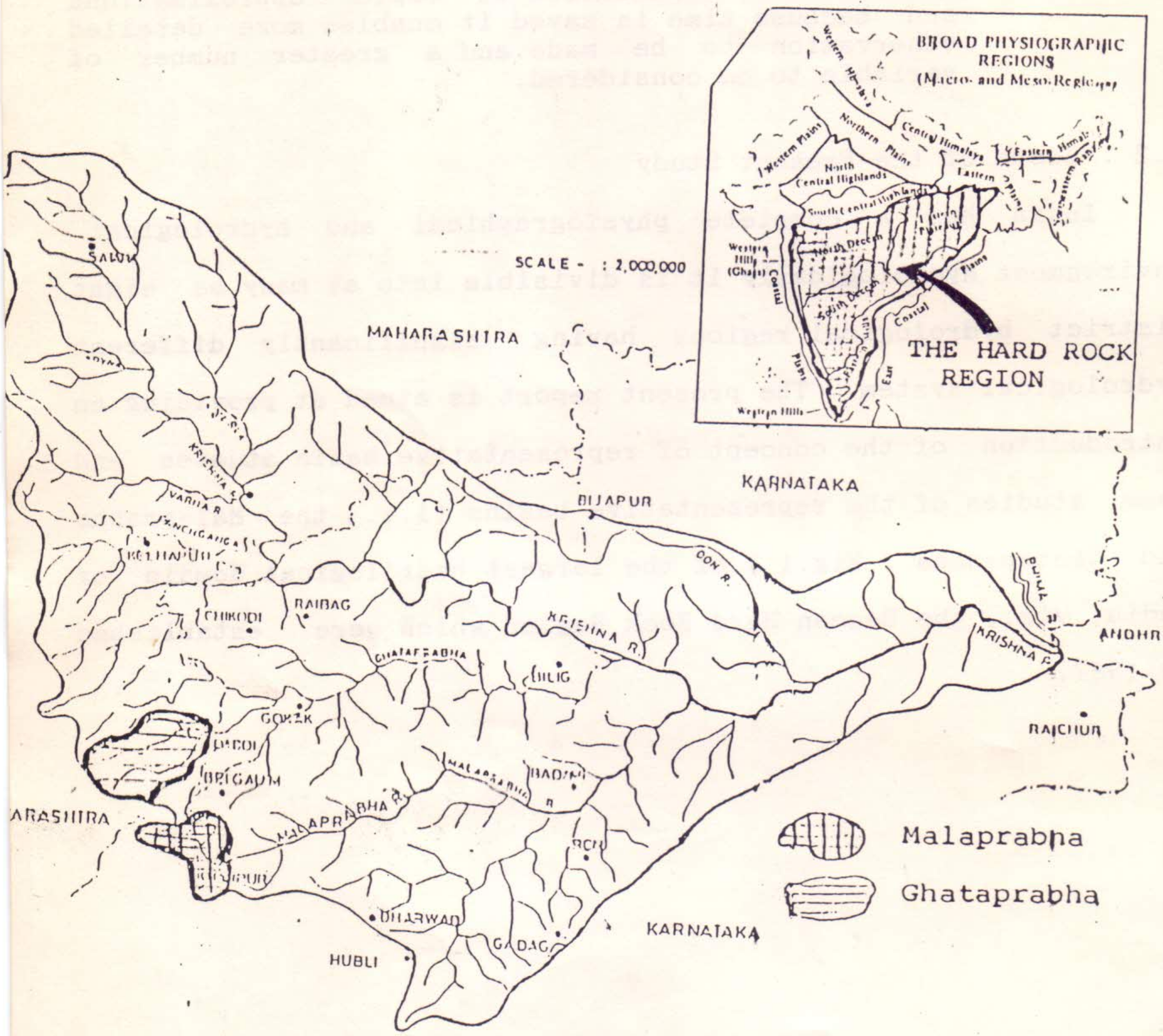

Fig.1 Location Map of the Malaprabha and Ghataprabha Representative Basin.

2.0 DEFINITION SCOPE AND VARIANTS OF REPRESENTATIVE BASIN STUDIES

2.1 Definition

Several analytical framework, for, or approach to organization of hydrological studies have been suggested in recent years and the term representative basin experimental basin and other associated nomenclature such as benchmark basins, vigil basins, barometer basins and paired catchments and multiple catchments (Fig.2) etc.

According to the Australian Water Resource Council (1969) a representative basin (Fig.2) which contains within its boundaries a complex of landforms, geology, landuse and vegetation which can be recognized in many other catchments of a similar size throughout a particular region. Recently Toebes and Ouryvaeu (1970) have defined the representative basins as follows.

"Representative basins are basins which are selected as representative of a hydrological region, i.e., region within which hydrological similarity is presumed. They are used for intensive investigations of specific problems of the hydrological cycle (or part thereof) under relatively stable, natural conditions. Thus a sparse network of representative basins may reflect general hydrological features of a given

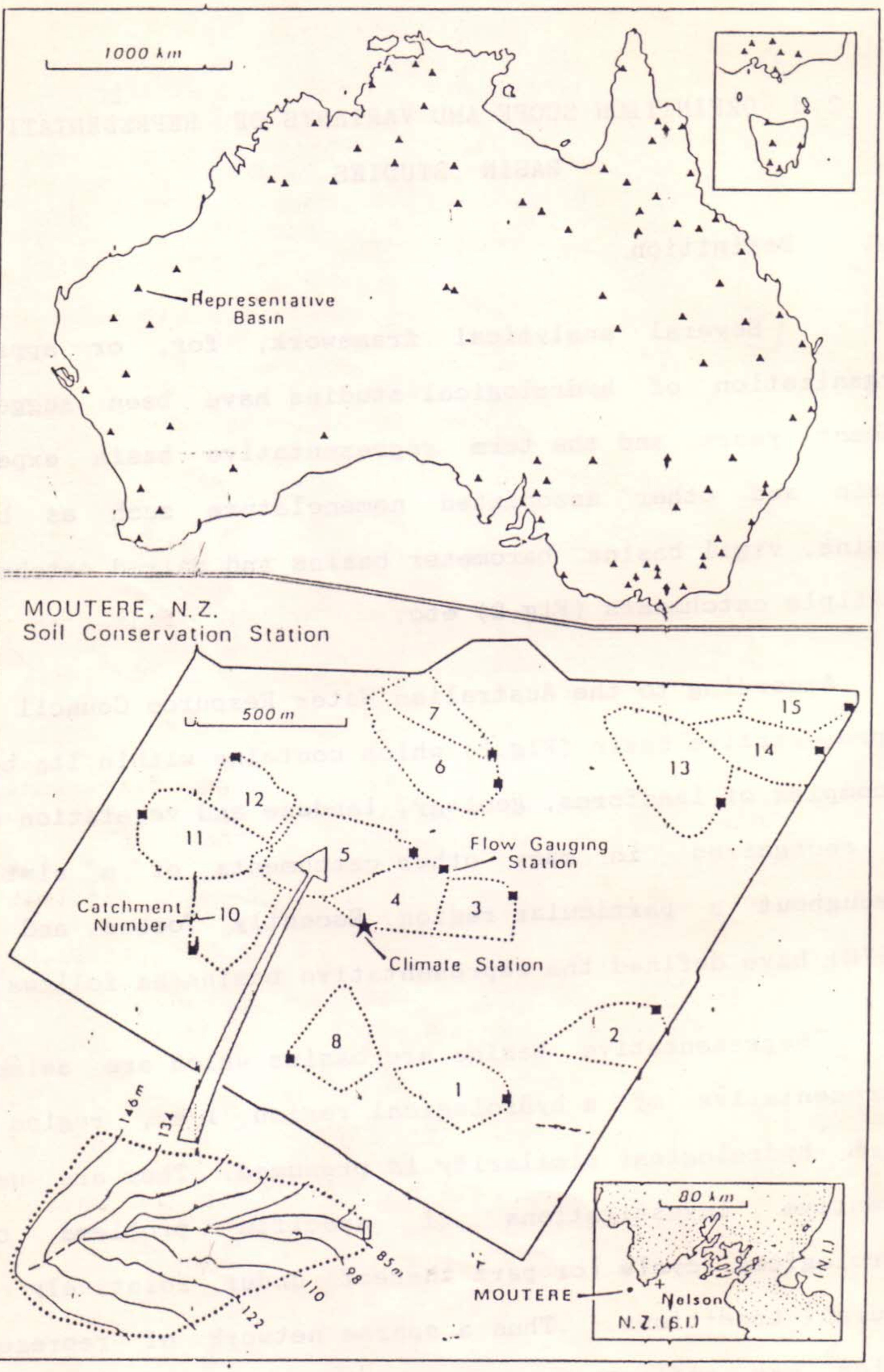

Fig. 2 Series of Representative Basins selected for a coverage of Australia (above) and multiple watershed experiments (below).

region and their variations over large natural zones.

2.2 Scope

Studies in representative basins are primarily observational. Observations should be on long term basis and combined with the study of climatic, pedological, geological, geomorphological and hydrogeological characteristics. These studies should be oriented to

* fundamental hydrological research,
* the determination of the effect of natural changes of the hydrological regimen;
* hydrological prediction,
* the formation of a basic network of stations to which short term records from the temporary stations can be correlated, and estimation and prediction can be made for ungauged stations.

2.3 Specific Variants

Within the wider definition of a representative basin, several specific variants have been distinguished as follows.

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* experimental basins,
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* benchmark basins,

* Vigil basins,
* barometric basins,
* Paired catchments,
* Multiple catchments etc.

The main difference between "representative" and "experimental basins" is that the former should have the minimum natural or artificial change during the study period and should be selected as representative of a hydrological region, whereas, in the later, one or more of the catchment characteristics is deliberately modified. The representative basins are therefore, used for detailed studies of hydrological cycle and to provide on insight characteristics of the area which they represent, while experimental basins are used principally to study the effects of cultural changes on hydrological system.

"Benchmark basins" were conceived within the IHD as representative basins which are still in their natural state and which have soil and vegetation conditions that are not expected to change for a long time. Benchmark basins study provides the interrelationships of climatic and hydrologic variables uninfluenced by the effects of human activities.

The concept of "vigil basins" originally developed by the U.S.G.S. (Leopold, 1962) has also been incorporated in IHD to denote a type of representative basin similar to benchmark basins, but not protected from artificial change.

In order to represent the broad climatic-physiographic regions and to provide an inventory of hydrological data for use in assessing the effects of watershed management techniques, "barometric basins" are used for this purpose. United States Forest Service has established a series of "barometric basins" ranging from 200-600 Km in area.

"The paired catchment" are used in comparative basin control procedure. It involves the use of an untreated control catchments with similar characteristics of the experimental catchment which is to be treated. The two basins are initially calibrated for a period of years so that the behaviour of one can be predicted from the response of the other, and subsequent to calibration one is treated and other is left as control. The effects of treatment are measured as departure from the predicted behaviour of the treated basin.

"The multiple catchments" study involves the use of a group of similar catchments which, being within a small area, are subject to similar climatic conditions. These catchments are subject to several types of treatment, usually involving replications, and by comparison with control basins and by statistical analysis, the influence of individual treatments can be assessed.

3.0 WHY BASIN AS A UNIT FOR REPRESENTATIVE BASIN STUDIES ?

The hydrological parameters (or responses/outputs) are the functions of energy inputs provided by the climate above the surface and the endogenic processes below the earth surface (Fig.3). To understand the hydrological cycle in general and hydrological system, in particular, in different hydrological regions, the relationships among the energy inputs and hydrological outputs is required. A drainage basin is excellent example of open system wherein the input-output relationships can be obtained most precisely. It is widely recognised as a fundamental unit in the hydrological milieu because;

* A drainage basin may be defined as the area which contributes water to a particular stream or set of streams (Leopold, et.al., 1964).

* It is a limited, convenient usually clearly defined and unambiguous topographic unit available in a nested hierarchy of sizes on the basis of stream ordering (Horton, 1932, 1945 ; Chorley, 1969).

* It is possible to quantify the amount of energy inputs and basin responses within certain natural boundaries (Fig.3), and therefore, it is easier to develop the relationship' between input-output parameters and to

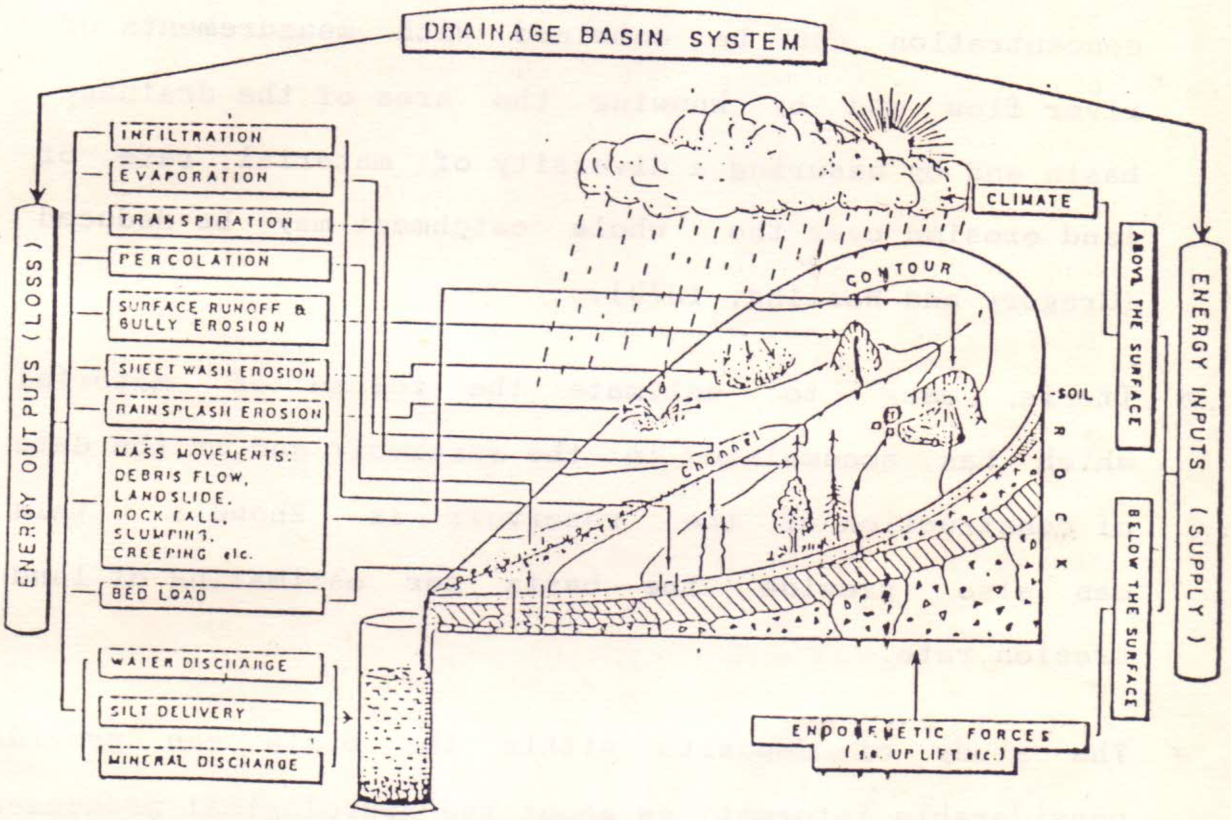


Fig.3 A Model of Basin system showing the Energy inputs and outputs or Basin Responses (after Rawat, 1987)

define the amount of water capacity, balance and storage within the basin.

* Basin provide oppertunity to estimate the amount of erosion because measurements of the sediment concentration can be combined with measurements of river flow and by knowing the area of the drainage basin and by assuring a diversity of material, rate of land erosion over the whole catchment may be deduced (Gregory and Walling, 1979).

* It is easy to estimate the volume of material which has accumulated in the reservoir and if the date of construction of the reservoir is known, this can also provide the basis for estimating of land erosion rate.

* The study of deposits within the basin can provide considerable informations about the hydrological processes and about the chronology of the events which occurred in the past.

4.0 SELECTION OF REPRESENTATIVE BASIN

The selection of representative basins depends upon the purpose of the study. However ,Toebes and Ouryvaev (1970) have emphasised on the following points while selecting representative basins:

* Representativeness,
* Basin divide,
* Consistency of conditions,
* Deep percolation and channel infiltration,
* Quality of flow measuring stations,
* Access
* size of representative basin.

A brief account of these points based on Toebes and Ouryvaev (1970) is given below.

* The type and range of climate, vegetational, geomorpho logical, pedological and geological characteristics of the selected representative basin should be compared with those of the hydrological region.

* The water divide of the selected representative basin should be as distinct as possible for the exact determination of a basin boundary and area. If a basin is suitable in all aspects but the basin divide is not clear, an artificial divide can be constructed by means of small dams or walls.

* The cultural changes in land use, land management,

streamflow utilization etc. should be minimal during the period of study and, where they are inevitable, should be carefully recorded. The loss of subsurface flow by deep percolation, or the gain of this flow from neighboring basins, must be as small as possible.

It is essential that stage discharge relation is relatively constants. For this purpose, the site for a gauging station should have a natural control or, if this is not available, an artificial control should be constructed.

Access of the gauging station should be available for every stream flow condition. Access in the representative basin should be such that precipitation and other climatic observations can be carried out.

The size of the representative basin depends on the purpose for which the basin is being established. In general the representative basin should be so small that its sensitivity to high to high intensity rainfalls of short duration is not suppressed by channel characteristics.

5.Ø HOW TO STUDY ?

5.1 Perception of Basin System

For conducting representative basin studies the basic perception of the drainage basin system is necessary . A basin is an open system. Closed system are those which possess clearly defined boundaries, across which no import or export of materials or energy takes place. The open system requires a continuing energy supply and removal of energy . Therefore, a basin can be envisaged as receiving energy or inputs from the climate and its losing energy through the water and sediment lost to the basin, largely through the basin mouth (Fig.3). The advantage of the open system approach arise from the facts that it places emphasis upon adjustment and upon relationship between basin characteristics (morphology, geology, soil, vegetation etc.) and hydrological parameters, upon the multivariate character of the many hydrological phenomena, and upon the total hydrological environment. A basin has energy inputs provided by climate, it has different hydrological responses (or outputs) depending upon the characteristics of the basin. Thus, the representative basin study could be systematically divided into three different components. These are (Table-1) :

* Observations of basin input parameters ,
* Observations of basin output parameters
* Study of basin characteristics

Table - 1 Synoptic outline of representative basin study

Basin Energy input parameters	Basin Characteristics	Basin responses or outputs
Climate	Geology	At Basin Mouth
1) Precipitation	1) Rock types	1) Water discharge
2) Temperature	2) Structure	2) Sediment and mineral discharge
3) Humidity etc.	Vegetation	From basin surface
	2) Types	3) interception loss
	3) Density	
	Geomorphology	4) Evapotranspiration
		5) Infiltration
	4) Morphometry	6) Soil moisture storage
	5) Morphology	
	Soils	7) Overland flow
		8) Sub-surface flow
	6) Types	9) Groundwater
	7) Characteristics	1Ø) Erosion and Sedimentation
	Land use	
	8) Forest	
	9) Agriculture	
	1Ø) Barren etc.	

5.2 Observations of Basin Input Parameters

In view of the representative basin studies, precipitation is one of the most important basin energy inputs. Following observations are essential related to the precipitation in the representative basin.

* Determination of precipitation gauge network required for the basin.
* Determination of the type of precipitation, i.e., hail, snow, rainfall, dew etc.
* Determination of the amount of precipitation by continuous recording.
* Determination of spatial variability in precipitation.
* Determination of temporal variability in precipitation.
* Determination of intensity-duration relations.
* Determination of mean basin precipitation for periods of less than one day.

5.3 Observations of Basin Responses(or Outputs)

As soon as the basin receives energy in the form of precipitation, it is regularised through various pathways of the hydrological system within the basin and results in number of hydrological responses. Some of the important hydrological responses in view of the representative basin studies are listed in table 1 which reveals that these responses are divisible into two main groups (Fig.3).

* Hydrological responses from basin mouth
* Hydrological responses from basin surface

Thus , to define the hydrological response systems of a representative basin , observations of the following parameters are necessary.

* Interception
* Evapotranspiration
* Infiltration
* Overland flow
* Sub-surface flow
* Soil moisture storage
* Ground water storage
* Channel runoff
* Erosion
* Sedimentation

However , the number of the parameters for observation may increase as per need of the representative basin or purpose of the study . For example , in the high mountainous terrain observation of snowmelt becomes necessary . Details of observations of these parameters are described by Toebes and Ouryvoev (1970) and in case of the representative basins of the hard rock region of India these are discussed in section 7 and 8.

5.4 Mapping of Basin Characteristics

The regularisation of the energy input (precipitation) within the basin largely depends upon the characteristics of the basins . Under identical precipitation , the flow system within the basin may vary from one area to another having different geological (Fig.4 & 5), vegetational , pedological and landuse pattern. Hence , it is necessary define the basin characteristics by preparing the following maps.

* Topographic map ,
* Morphometric map ,
* Geological map ,
* Soil map ,
* Hydrological map ,
* Landuse map , etc.

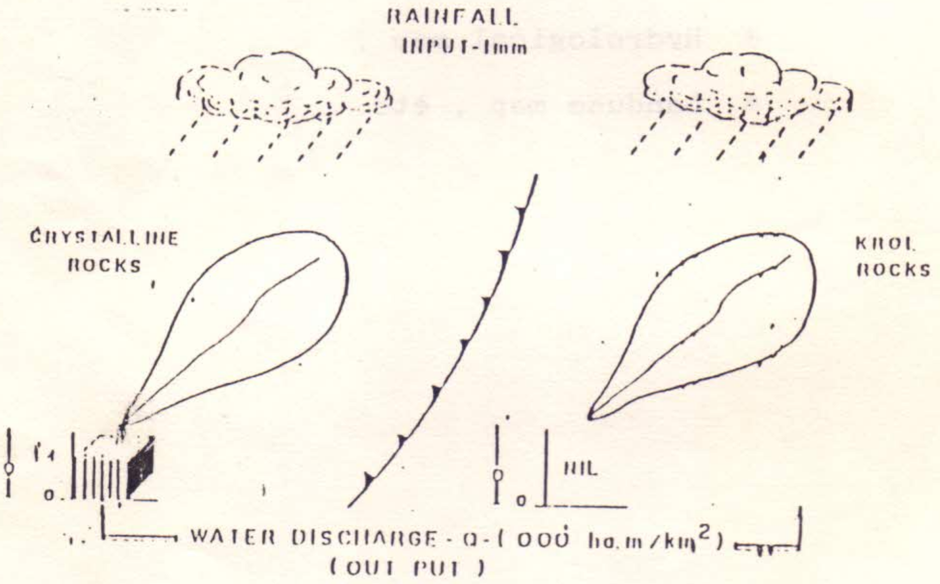


Fig.4 Spatial Variation in water discharge flow in the Central Himalayan drainage basins in identical scale and geomorphological conditions and rainfall (1 mm) input but different rocks (after Rawat 1987).

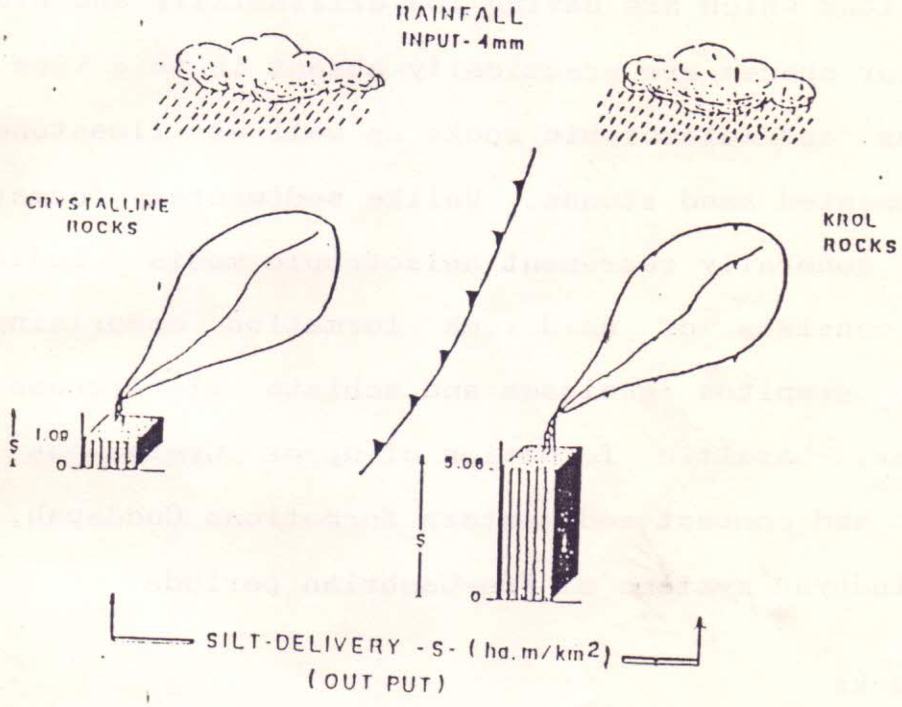


Fig. 5 Spatial Variations in silt-delivery in the Central Himalayan drainage basins on identical scale and geomorphological conditions, and rainfall input (4 mm) but different geological character. (after Rawat 1987)

6.Ø THE HARD ROCK REGION

6.1 Introduction

Eighteen percent of the continent is in the form of plateau constituted of hard rocks. The hard rocks are those geological formations which are having low drillability and also the inter-granular spaces are practically absent in this type of rocks i.e, igneous and metamorphic rocks as well as limestones, dolomites and cemented sand stones. Unlike sedimentary formation, the hard rocks generally represent anisotropic media. Indian sub continent consists of hard rock formation comprising crystalline rocks, granites gneisses and schists of Archaean crystalline complex, basaltic formation of upper Cretaceous to Oligocene period and compact sedimentary formations Cuddapah, Kurnool Delhi and Vindhyan systems of Pre-Cambrian periods.

6.2 Rocks

The major part (nearly 65%) of the Peninsular India is occupied by the hard rock region (Fig.1) made up of igneous and metamorphic rocks consisting of granite gneisses, khondalites, charnockites, schists, phyllites, limestones and some volcanic rocks (rhyolites). These rocks are devoid of primary porosity but have been rendered porous due to weathering and fracturing. The weathering zone is extensive within depths of 1Ø to 2Ø m but is localised down below with increase in fracture porosity. The calcareous members like clay gneisses and marbles have been subjected at places to solution.

The following differences summarise the main points of divergence between the hard rock region and other regions of the country (Wadia, 1979).

6.3 Stratigraphy and Structure

The first is "stratigraphic" , i.e., connected with the geological history of the area. Ever since the Cambrian period, the hard rock has been the land area, which since that epoch in earth history has never been submerged beneath the sea, except temporaily and locally . No marine sediments is deposited in the interior of this region.

The second difference is "geotectonic", i.e., pertaining to the geological structure. The hard rock region of India reveals quite different type of architecture from that of other regions. It is a segment of earths outer shell that is composed in great part of the most ancient complex of rock bed. The Indian hard rock region is , however, subject to one kind of structural disturbance, viz., fracturing of the crust in blocks and their radial and vertical movement due to tension and compression. Other regions of the country, on the contrary, are comparatively weak and flexible portions those have undergone a great deal of crumbling and deformation.

6.4 Physiography

The third difference is the specific "physiographic" setting of the hard rock region. In this region the mountains are mostly of the relict type, i.e., they are not mountain in the true sense of the term, but are more outstnding portions of the old plateau of the peninsula that have escaped for one region or another, the weathering of ages that has cut out all the surrounding parts of the land, they are the blocks of the old plateau or huge tors. Its streams and river have flat, shallow valleys, with low imperceptible gradients because of their channels having approached to the base level of erosion.

6.5 Hydrological Environment

The fourth difference is the distinct "hydrological environment" of the hard rock region having considerably different hydrological system i.e., apportionment of rain water through different pathways (overland flow, subsurface flow, channel flow, underground water storage, evaporation, transpiration etc.) in comparison to other regions. One very noticeable peculiarity in the drainage system of the hard rock region is the pronouncedly easterly trend of its main rivers, the western ghats in the western border of the hard rock region, being the watershed. The river that discharges in to the bay of Bengal thus have their sources and derive their head waters, almost within sight of the Arabian sea. This feature in land area of such antiquity as the Peninsula, where a complete hydrographic system has been in existence for a vast length of geologic time (Wadia, 1979). In the hard rock region the river system are all of great antiquity and consequently, by the ceaseless degradation by ages, their channels have approached the mature stage of river development geomorphologically known as mature stage geomorphic development or base levelling of a continent. Due to the broad and shallow valleys the vertical erosion has almost ceased and the lateral erosion is of greater moment.

6.6 Climate

Generally , the climate in the hard rock region is marked by a hot summer and a mild winter . The monsoon sets early in June and continues to the end of October. However in the eastern part of the Peninsular India , NE monsoon is active and this part continues to be hot during the remaining part of the year (States like , Andhrapradesh , Tamilnadu , parts of Madhya pradesh and Maharashtra). Usually December and April are the coldest and hottest months, respectively.

7.0 MALAPRABHA REPRESENTATIVE BASIN

7.1 . Location

The Malaprabha represntative basin lies in the extreme western part of the Krishna basin . It extends in between 74°20′ and 74°30′ E Longitudes, and 15°20′and 15°40′N Latitudes, and encompaasses an area of 540 Sq km of the Belgaum district in the Karnataka state (Fig.1). Two major roads run through the Malaprabha representative basin are Belgaum - Goa (NH 4A) and Belgaum - Mapusa state highway. This representative basin is the major source of water yield for the Naviluteerth Dam constructed at 35-45 km downstream of its mouth . This dam impounds about 1377 mcm water and provides water for irrigation approximately for 2.17 lakh ha land.

7.2 Hydrometeorological Network

There are five raingauge stations, and two hydrometeorological stations consisting of stevension screen (to record temperature and humidity), pan evaporimeter ,anemometer, windvane, self recording raingauge and ordinary raingauges at different places in the Malaprabha representative basin. Figure 6 depicts the distribution of hydrometeorological network of the Malaprabha representtive basin and details of these hydrometeorological stations are presented in table 2 .

The representative basin is gauged at its mouth,viz., Khanapur by WRDO Karnataka.

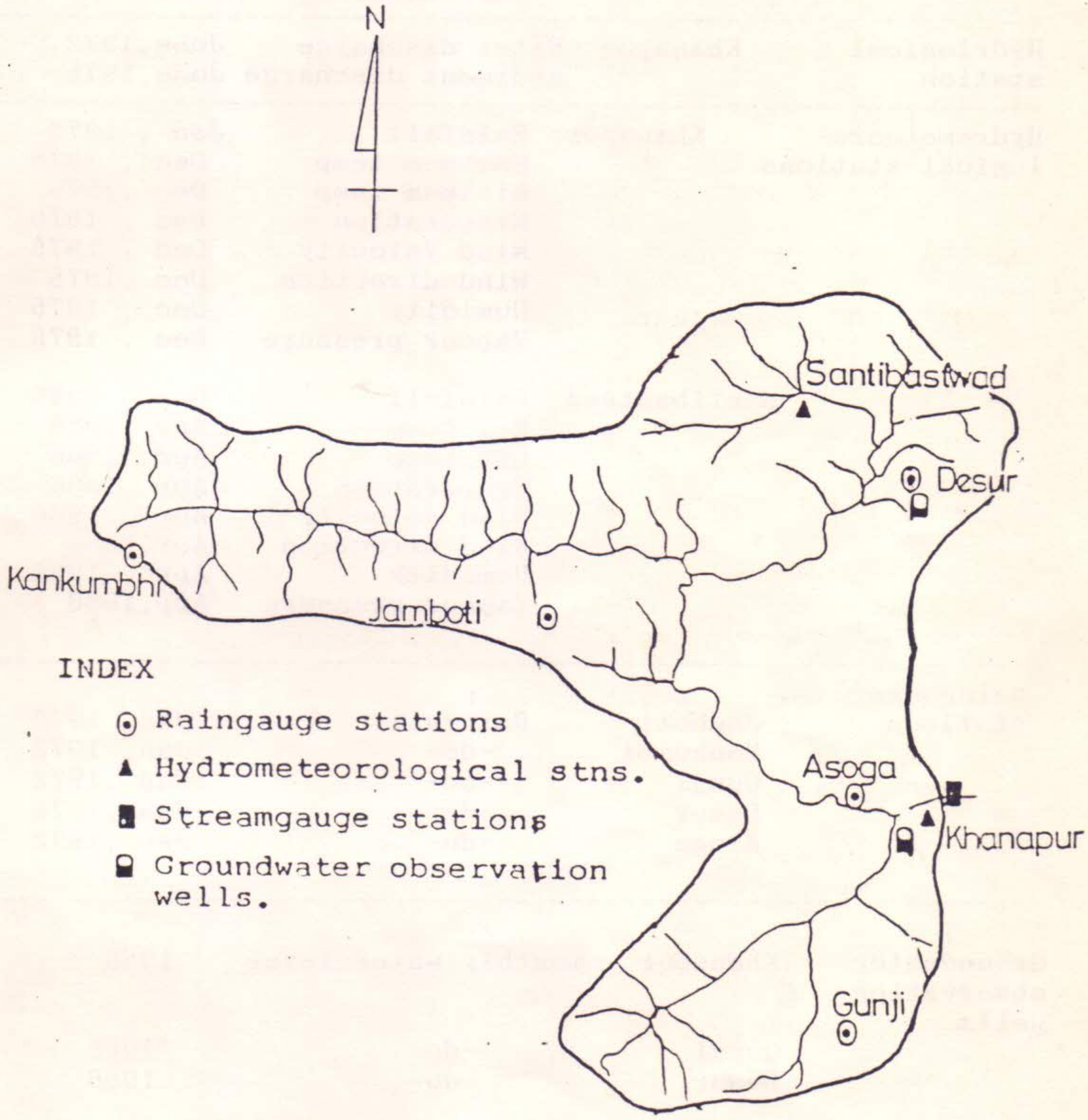


Fig.6 Hydrometeorological Network in the Malaprabha Representative Basin.

Table 2 : Details of the hydrometeorological stations in the Malaprabha representative basin

Type of station	Location	Parameters recording	Data recorded since	Maintained by
Hydrlogical station	Khanapur	Water discharge	June,1972	WRDO
		sediment discharge	June,1975	WRDO
Hydrometeoro-logical stations	Khanapur	Rainfall	Jan , 1975	WRDO
		Maximum temp	Dec , 1975	WRDO
		Minimum temp.	Dec ,1975	WRDO
		Evaporation	Dec , 1975	WRDO
		Wind Velocity	Dec , 1975	WRDO
		Wind direction	Dec ,1975	WRDO
		Humidity	Dec , 1975	WRDO
		Vapour pressure	Dec , 1975	WRDO
	Santibastwad	Rainfall	Oct , 1985	WRDO
		Max.temp	Apr ,1986	WRDO
		Min.temp	Apr, 1986	WRDO
		Evaporation	Apr ,1986	WRDO
		Wind velocity	Apr , 1986	WRDO
		Wind direction	Apr,1986	WRDO
		Humidity	Apr , 1986	WRDO
		Vapour pressure	Apr,1986	WRDO
Raingauge stations	Jamboti	Rainfall	Jan, 1972	WRDO
	Kankumbi	-do-	Jan, 1972	WRDO
	Gunji	-do-	Jan ,1972	WRDO
	Desur	-do-	Jan ,1972	WRDO
	Asoga	-do-	Jan ,1972	WRDO
Groundwater observation wells	Khanapur	monthly water level	1986	GWD, Karnataka
	Gunji	-do-	1986	-do-
	Desur	-do-	1986	-do-

7.3 Basin Characteristics

A brief description of the Malaprabha representative basin characteristics, i.e., geology. soils, land use pattern and geomorphological parameters are given below.

7.3.1 Geology : Geologically the Malaprabha representative basin comprises of two main geological formations (1) Tertiary basalts,(ii)sedimentary formations of Pre-Cambrian age (Table 3).

7.3.1.1 : Tertiary basalts : As shown in figure 7, a major part (96%) , of the representative basin is covered by Tertiary basalts. The hydrology of basalt is different from that other type of hard rocks. One of the main differences is that the various basalt flow units can form a multi-aquifer system some what similar to a sedimentary rock sequence, having alternate pervious and impervious horizons.

7.3.1.2 : Sedimentary Rocks : The sedimentary formation is of Pre-Cambrian age . This type of rocks are confined in the south eastern part of the study area. Sedimentary rock generally acts as a good aquifer if it is not interrupted by intertrappean clays and other impermeable rocks.

7.3.2 Soils : Pedologically speaking, the basin rocks are covered by thin (0.5m) to thick (10 m) layer of soils which are divisble into two major groups (Fig. 8). These are red loamy soils and medium black soils (Table 4).

Table 3: Distribution of area under different rock formations in the Malaprabha representative basin

Rock formation	Area in sq.km	Area in %
1. Tertiary Basalts	518.4	96.Ø
2. Sedimentary rocks	21.6	4.Ø
	54Ø.ØØ	1ØØ.ØØ

Table 4 : Distribution of area under different soil groups in the Malaprabha representative basin

Soil groups	Area in sq.km	Area in %
1. Red loamy soil	432.Ø	8Ø.Ø
2. Medium black soil	1Ø8.Ø	2Ø.Ø
Total	54Ø.ØØ	1ØØ.ØØ

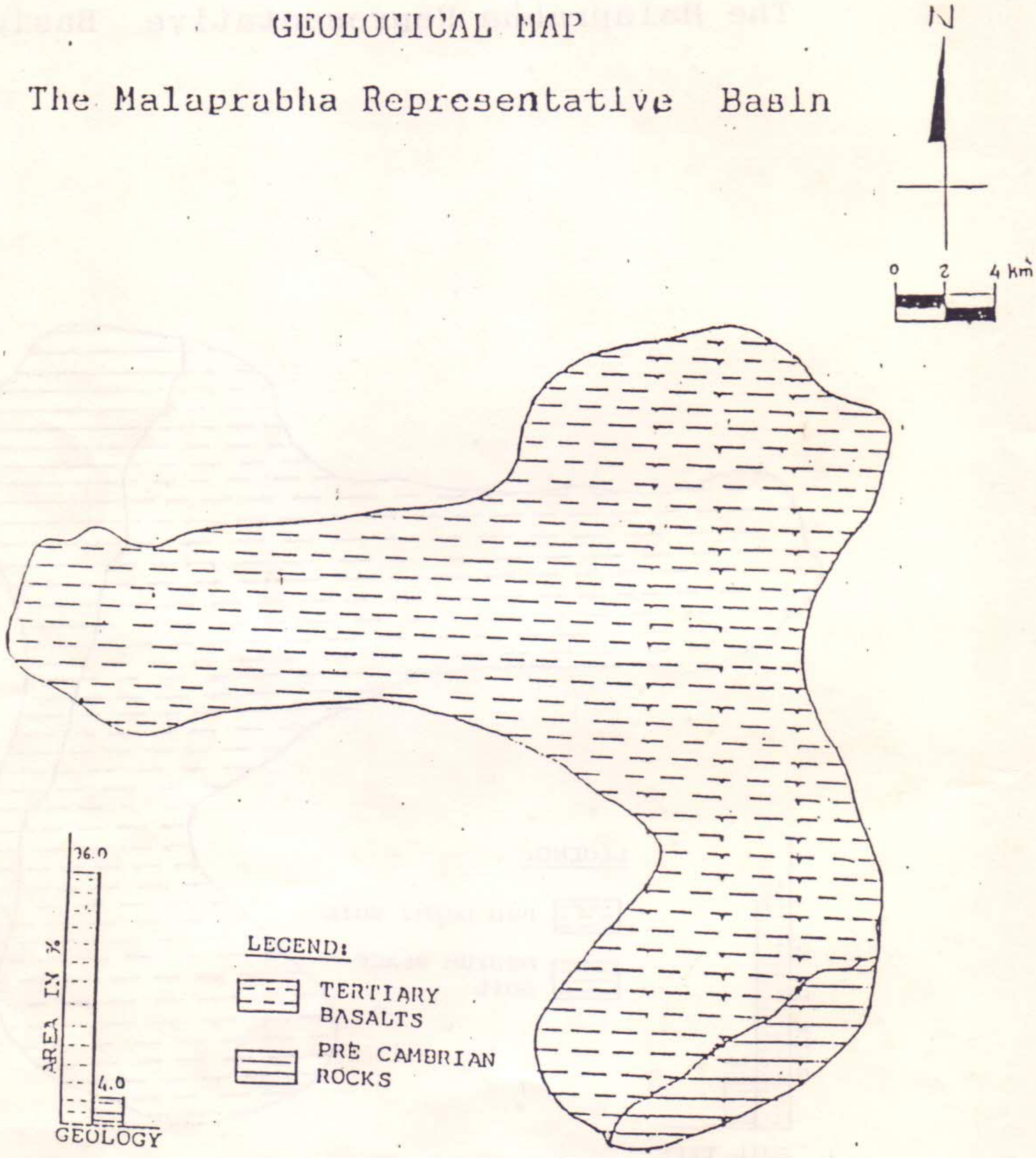


Fig.7 Geological Map of the Malaprabha Representative Basin.

SOIL MAP.

The Malaprabha Representative Basin

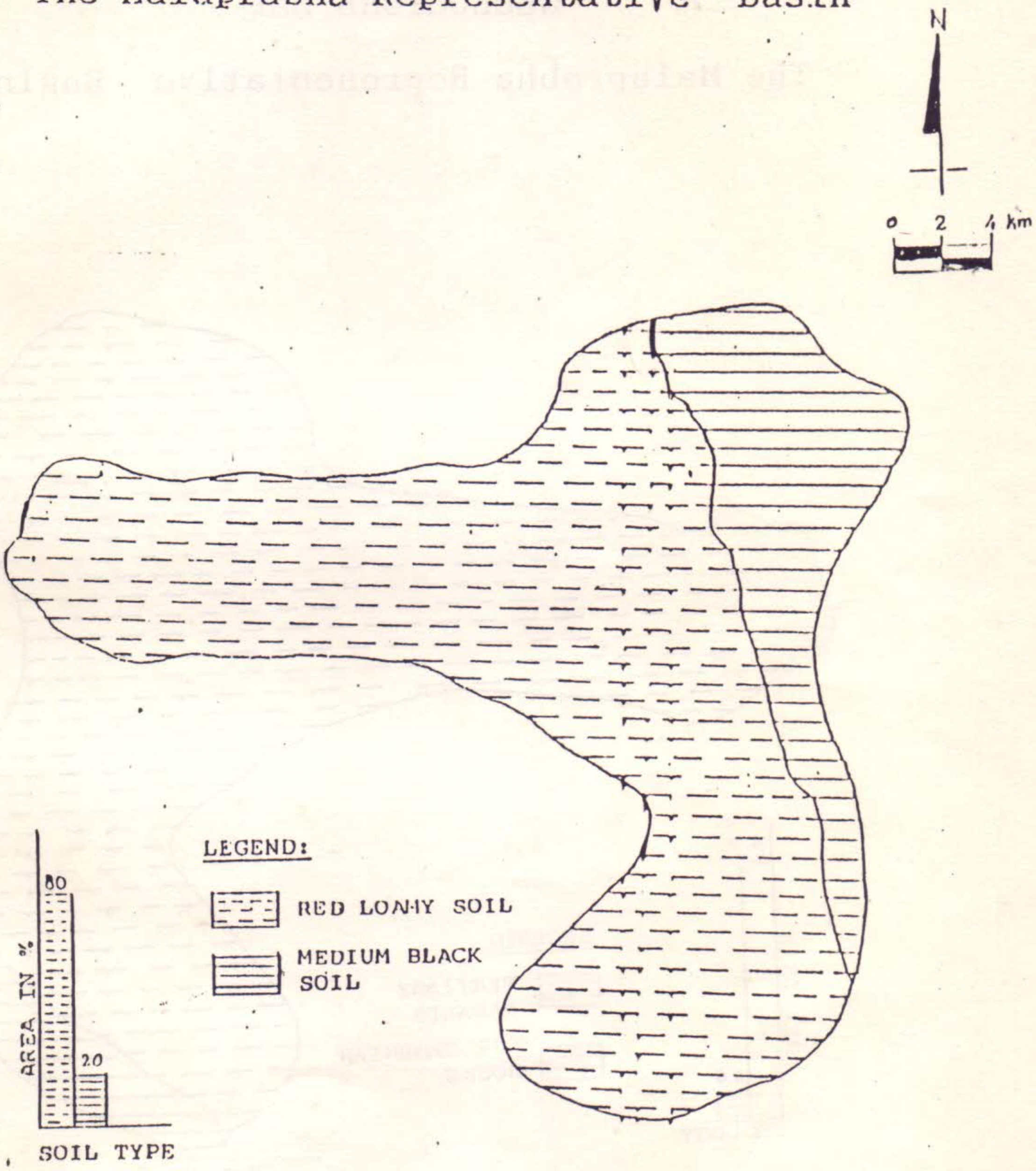


Fig.8 Spatial distribution Map of different types of soils in the Malaprabha Representative Basin.

Table 5 : Distribution of area under different land use type in the Malaprabha representative basin

Sl.No	Land use type	Area in sq.km	Area in %
1.	Forests	338.58	62.65
2.	Shrubs	104.22	19.35
3.	Agriculture	90.99	16.85
4.	Barren	6.21	1.15
	Total	540.0	100.0

7.3.2.1. Red Loamy Soils - The upper reaches of the basin, i.e., on crest and gently sloping mid-crest regions, viz., pediplains are characterised by red loamy soils. The top soil texture varies between sandy loam to clay loam underlain by gravel and sandy loam , sub-soil horizon. About 80% area of the Malaprabha representative basin is covered by red loamy soils.

7.3.2.2. Medium black soils: This type of soils occur extensively in parts of Khanapur taluk. Soils are moderately deep to very dark greyish brown, dark reddish brown or black in colour, usually calcareous cracking and clayey. These are moderately well drained with low permeability.

7.3.3. Landuse Pattern : Land use pattern of the Malaprabha representative basin is very complex comprising of forest, agriculture, shrubs and barren land (Fig. 9). Area under different category of land is presented in table 5 and a brief description of the different land use based on IRS-1A-LISS-II imageries and subsequent field check is presented below.

7.3.3.1. Forests : About 62.65 percent of the Malaprabha representative basin in Kankumbi, Jamboti and Gunji areas are covered by dry tropical forests . The major species are covered by teak wood, rosewood, jack wood, Bamboo etc. The ground of these forests is covered by shrubs (2-4 m high) and grasses.

7.3.3.2 Shrubs :The eastern facing watersheds of the area having steeper slope (20°-30°) are covered by shrubs and small

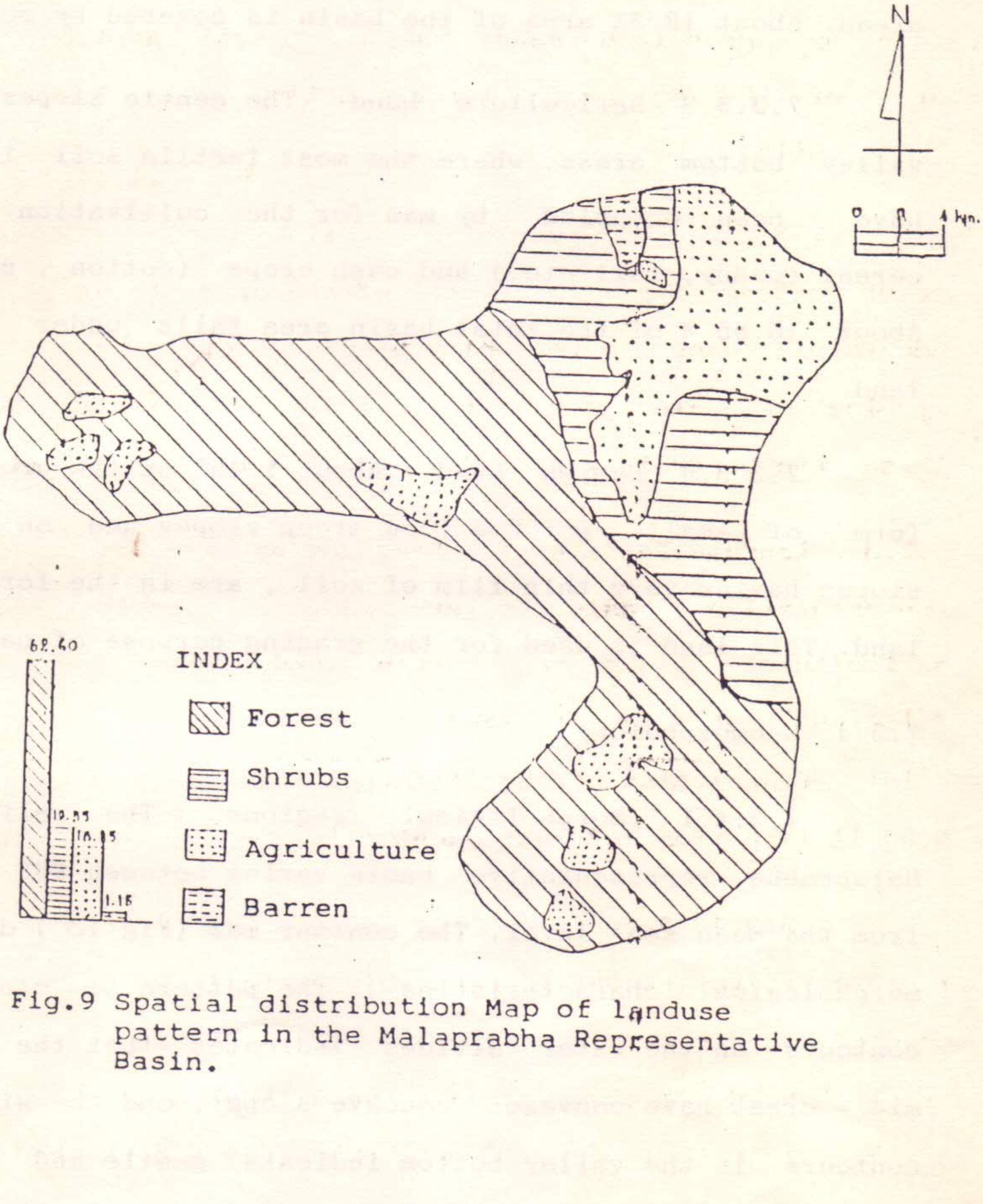


Fig.9 Spatial distribution Map of landuse pattern in the Malaprabha Representative Basin.

trees and bushes (3-5 m high). The most important feature of this class of land is that these are relatively shallow soil areas. About 19.3% area of the basin is covered by shrubs.

7.3.3.3 Agriculture Land: The gentle slopes and level valley bottom areas, where the most fertile soil is confined, have been occupied by man for the cultivation of various cereal (paddy, ragi etc.) and cash crops (cotton , sugarcane) . About 16.85 % of the total basin area falls under agricultural land.

7.3.3.4 Barren Land : About 1.15% of the area is in the form of small patches , on steep slopes and on the gentle slopes having very thin film of soil , are in the form of barren land. This land is used for the grazing purpose of cattles.

7.3.4. Geomorphology

7.3.4.1 Morphological regions : The relief of the Malaprabha representative basin varies between 668 and 1038 m from the mean sea level. The contour map (Fig 10) depicts the morphological characteristics . The pattern of closely spaced contours on the water divides indicates that the crests and mid - crest have convexo- concave slope , and the widely spaced contours in the valley bottom indicate gentle and flat valley bottoms. Thus, the basin is divisible into three distinct morphological zones.

CONTOUR MAP

The Malaprabha Representative Basin

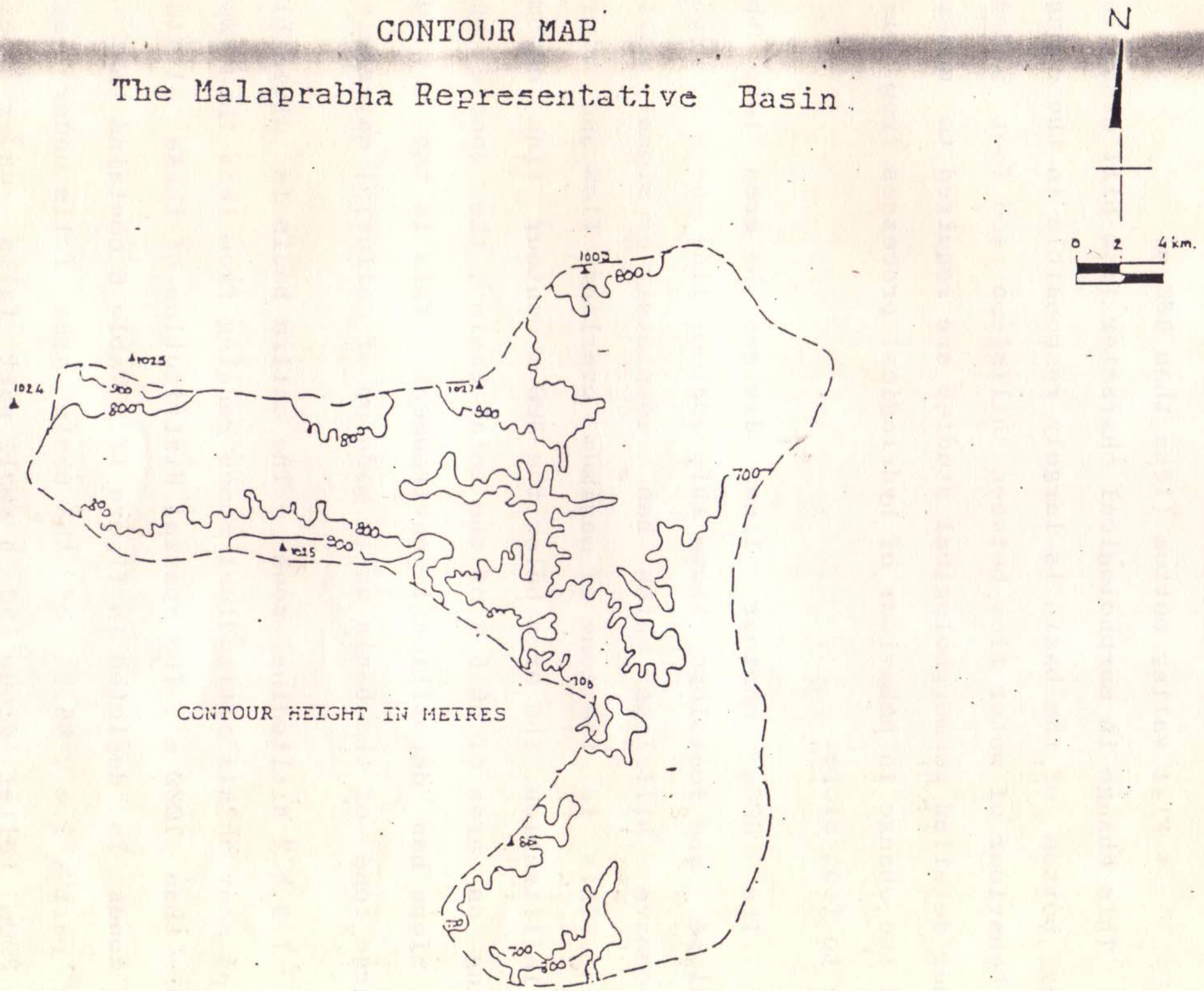


Fig: 10. Contour Map of the Malaprabha representative basin.

These are :

* Convex hill summit (more than 900 m)
* Concave and gentle mid-crest and (800 - 900m)
* Flat valley bottom (less than 800 m)

This change in morphological character from hill crest to valley bottom of the basin is largely responsible in the change in behaviour of water flow between hillslope and foot slope. Further detailed geomorphological studies are required to understand the change in behaviour of hydrlogical processes from hill slope to foot slope.

The 800m contour line divides the area into the hillslope and footslope. Above this contour line there is convexo-conave hillslope which has completely erosional environment. This is the zone of maximum overland flow and minimum infiltration. The area below the 800 m contour line encompassing an area of 86.5 % of the total basin , the gentle and flat slope has depositional environment . This is the maximum recharge zone of the basin as is made up of colluvial materials.

7.3.4.2 Altitudinal zone : The entire basin is divisible into as many as six altitudinal zones ranging from less than 700m to more than 1000 m . The spatial distribution of these altitudinal zones is depicted in figure 11. Table 6 contains that a large part , i.e., 86.5% of the basin area falls under less than 800m relief group and a small part falls under more than 1000 m . Area under other altitudinal zones , i.e., between

RELIEF MAP

The Malaprabha Representative Basin

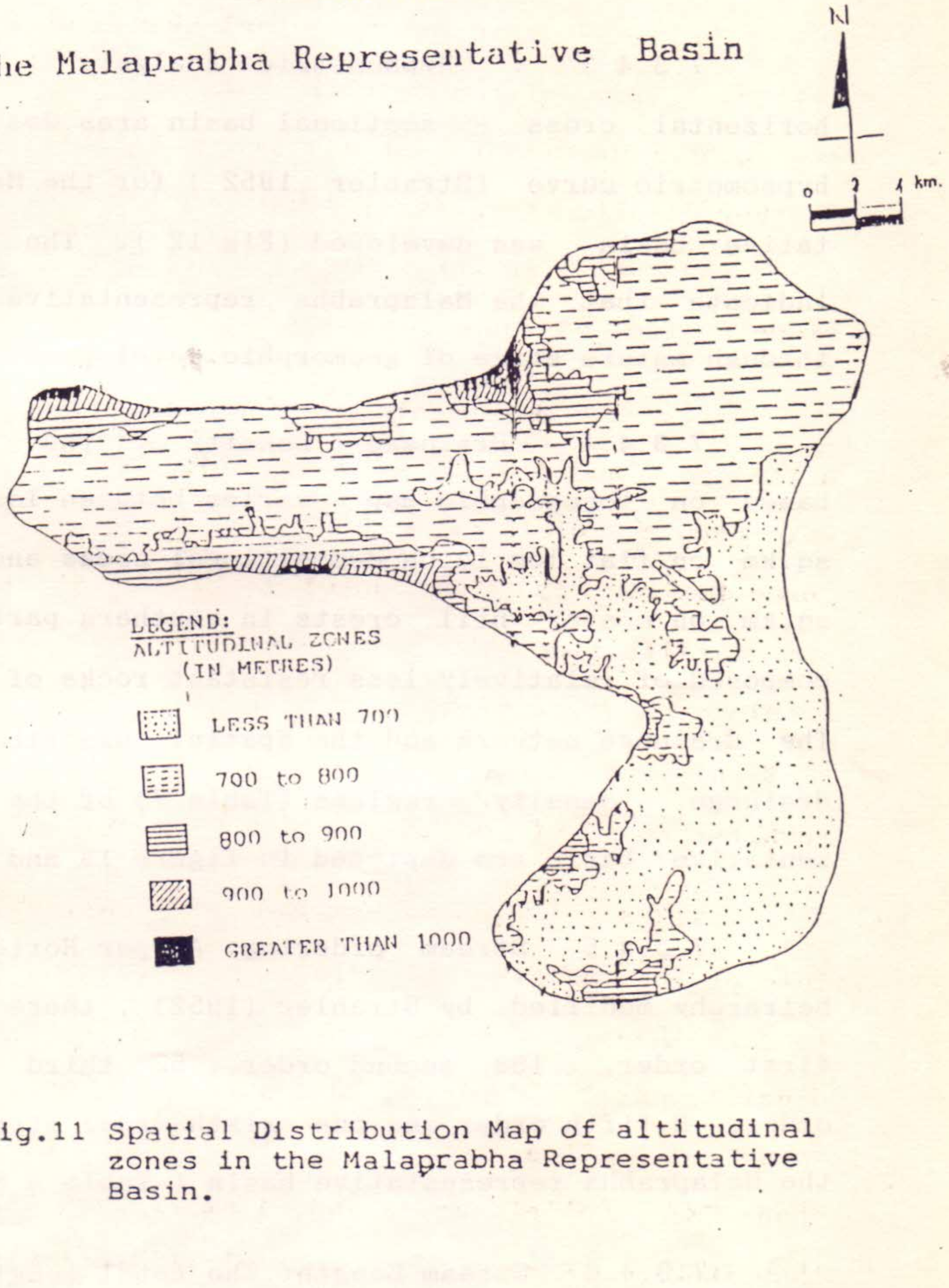


Fig.11 Spatial Distribution Map of altitudinal zones in the Malaprabha Representative Basin.

800m and 900m and 900m to 1000m stands at 12% and 1.5% , respectively.

7.3.4.3 : Hypsometric Analysis : Relationship of horizontal cross - sectional basin area was obtained and the hypsometric curve (Strahler ,1952) for the Malaprabha representative basin was developed (Fig 12). The hypsometric curve indicate that the Malaprabha representative basin is passing through mature stage of geomorphic development.

7.3.4.4 Drainage Density : The drainage density based on topographic map varies between less than 0.5 km / sq.km on flat low lying depositional areas and more than 2.5 km/ sq.km on convex hill crests in southern part of the basin , composed of relatively less resistant rocks of Pre-Cambrian age. The drainage network and the spatial distribution of different drainage density regions (Table 7) of the Malaprabha representative basin are depicted in figure 13 and 14, respectively .

7.3.4.5 Stream ordering: As per Horton (1932) stream heirarchy modified by Strahler (1952) , there are as many as 784 first order, 198 second order , 50 third order, 8 fourth order, 2 fifth order and one sixth order streams are there in the Malaprabha representative basin (Table - 8).

7.3.4.6 Stream Length: The total length of the drainage network of Malaprabha stands at 1186.03km. The distribution of this total length under different stream order segment is presented in the table 8 , which reveals that a large part of

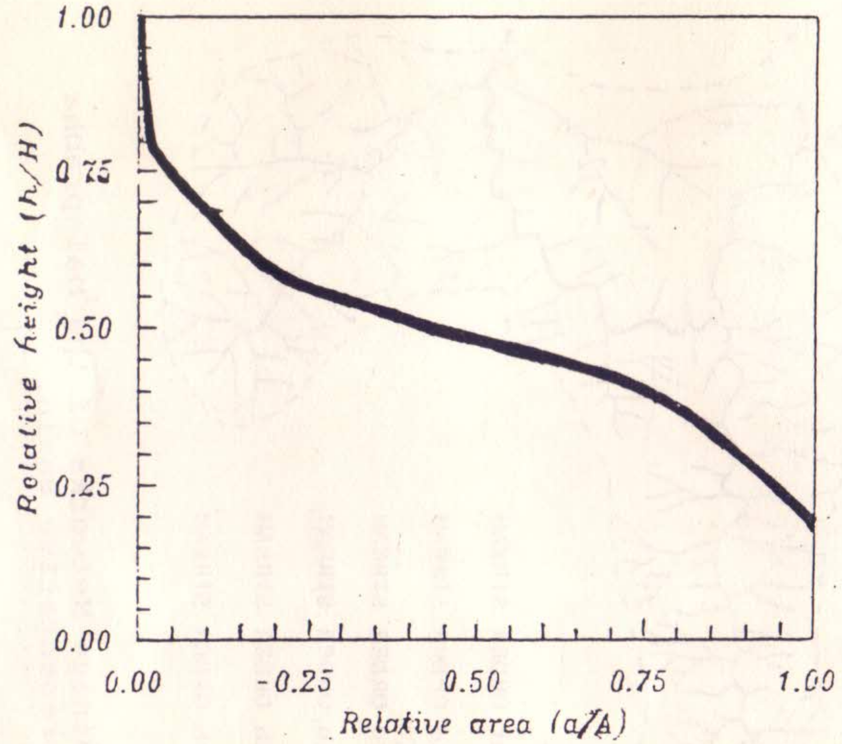


Fig.12 Hypsometric curve of the Malaprabha representative basin.

DRAINAGE NETWORKS

The Malaprabha Representative Basin

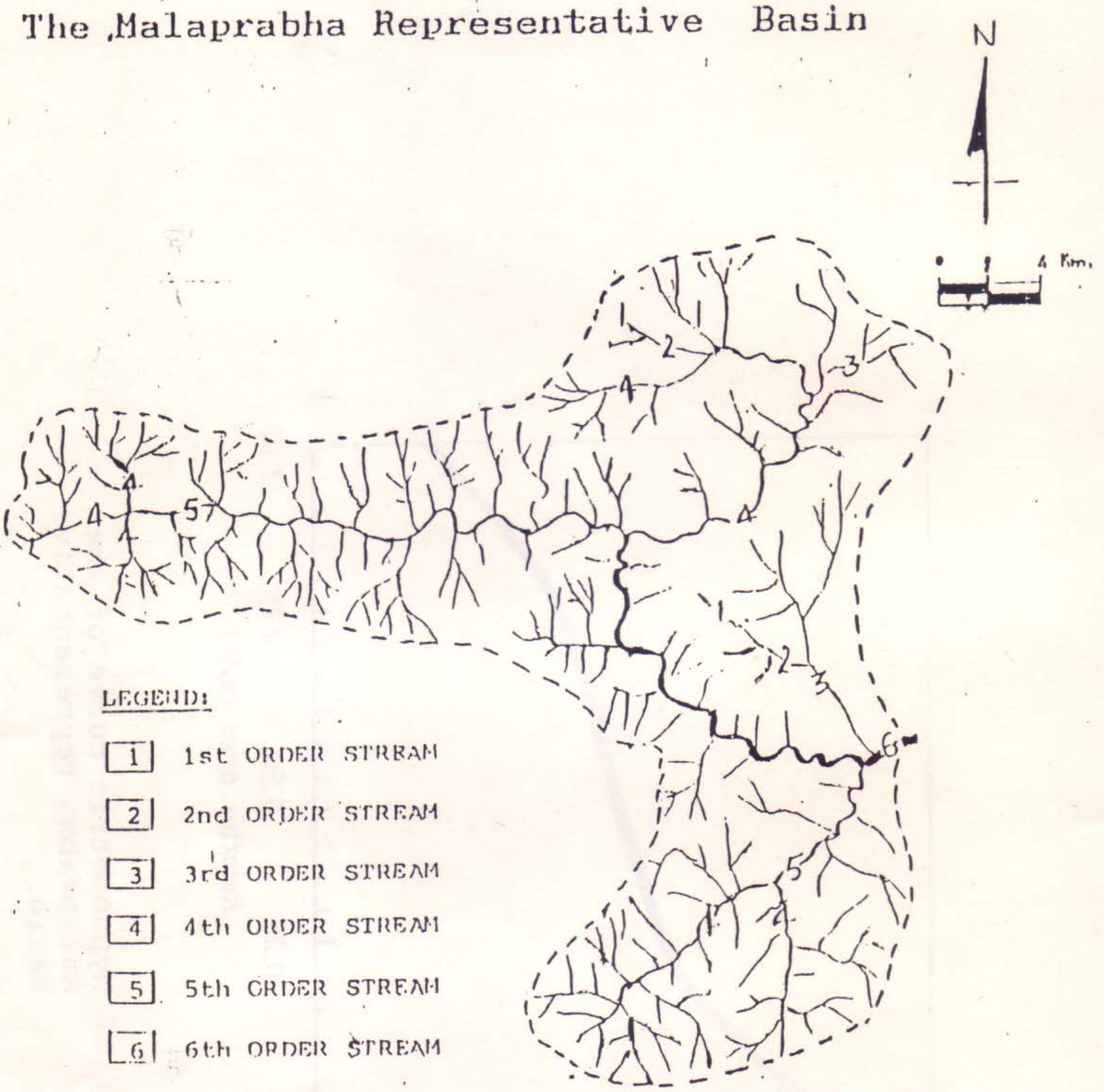


Fig.13 Drainage Networks of the Malaprabha Representative Basin.

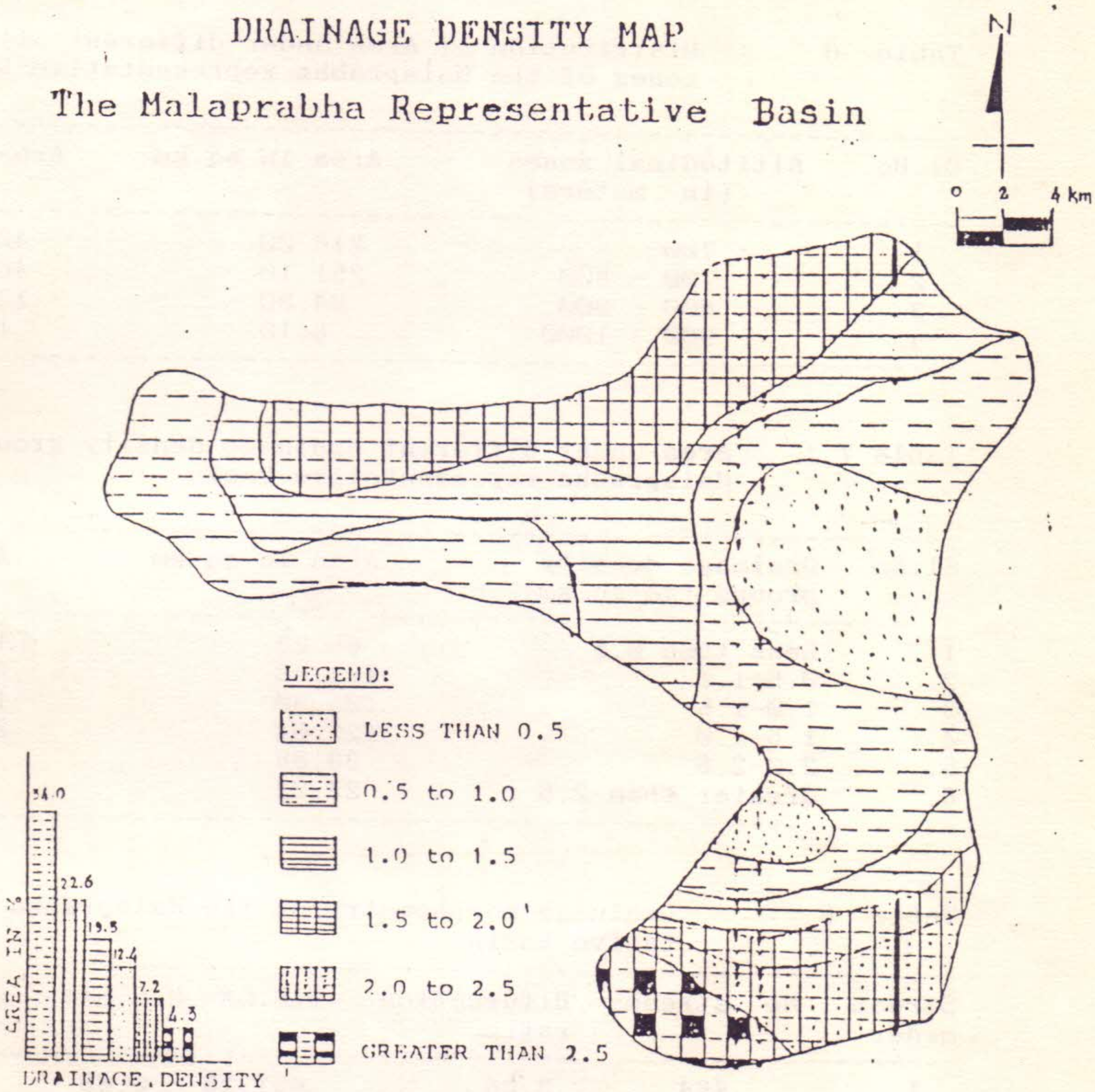


Fig.14 Spatial distribution Map of Drainage Density in the Malaprabha Representative Basin,

Table 6 : Distribution of Area under different altitudinal zones of the Malaprabha representative basin

Sl.No.	Altitudinal zones (in meters)	Area in sq.km	Area in %
1	< 700	216.00	40
2	700 - 800	251.10	46.5
3	800 - 900	64.80	12.0
4	900 - 1000	8.10	1.5

Table 7 : Area under different drainage density groups in the Malaprabha representative basin

Sl.No	Drainage density groups (km/sq.km)	Area in sq.km	Area in %
1 .	Less than 0.5	65.88	12.0
2.	0.5-1.0	184.68	34.2
3.	1.0-1.5	105.30	19.5
4.	1.5-2.0	122.04	22.6
5.	2.0-2.5	38.88	7.2
6.	Greater than 2.5	23.22	4.3

Table 8 : Drainage morphometry of the Malaprabha represen tative basin

Stream order	No. streams	Bifurcation ratio.	T.S.L*	M.S.L**	S.L.R***
1	784	3.96	651.16	0.83	-
2	198	3.96	329.3	1.66	2.0
3	50	6.25	97.46	1.95	1.17
4	8	4.0	58.14	7.27	3.73
5	2	2.0	47.62	23.81	3.27
6	1	-	2.35	2.35	0.10

* T.S.L - Total stream length in km
** M.S.L. - Mean stream length in km
*** S.L.R - Stream length ratio

stream length (82.7 %) is covered by the first and second order streams and a small part (4.3%) by the large streams , i.e., fifth (4.Ø1%) and sixth order stream(Ø.2 %). The remaining part is covered by medium size streams , i.e., third (8.2 %) and fourth (4.9%) order streams.

7.4 Basin Input Parameters

A brief account of the basin input parameters, i.e., temperature, rainfall and humidity is presented below.

7.4.1 Air Temperature - Table 9 contains the average of 5 years (1987-1992) monthly characters of temperature recorded at Santibastwad in the Malaprabha representative basin. On the basis of these data followng salient characteristics of the air temperature of the Malaprabha basin may be deduced.

The maximum temperature in the Malaprabha representative basin varies between 35.Ø°C in the month of April , and 26.Ø °C in the month of July and August and the average maximum temperature stands at 29.5°C .

The average minimum temperature of the Malaprabha representative basin stands at 19.2°C which approaches maximum upto 21.5°C in the month of May and drops to 14.6°C in the month of January . The average annual temperature stands at 24.4°C which varies in between 35°C and 14.6°C . April is the hottest month and January , the coldest month of the year.

7.4.2 Rainfall - Table 1Ø contains the average monthly

Table 9 : Monthly average maximum and minimum temperature observed at Santibastwad (1987-1992) in the Malaprabha representative basin

Sl.no.	Months	Temperature °C Max	Min
1	January	28.5	14.6
2	February	31.0	15.7
3	March	32.6	18.9
4	April	35.0	21.0
5	May	34.5	21.5
6	June	28.7	21.0
7	July	26.0	20.8
8	August	26.0	20.7
9	September	27.6	21.0
10	October	29.0	20.6
11	November	28.5	18.1
12	December	27.4	16.3
	Annual mean	29.5	19.2

Table -10: Average monthly rainfall at 3 different stations in the Malaprabha representative basin

(Rain fall in mm)

Months	Stations			
	Khanapur †	Kankumbi ††	Jamboti †††	Average
1. Jun	367.9	1363.4	415.3	715.5
2. Jul	616.2	2115.9	898.3	1210.1
3. Aug	412.8	1709.2	598.4	904.8
4. Sep	127.7	439.4	198.0	255.0
5. Oct	69.1	175.7	65.5	44.4
6. Nov	44.4	45.4	39.7	43.2
7. Dec	4.5	0.0	0.0	1.6
8. Jan	0.0	0.0	0.0	0.0
9. Feb	0.3	0.0	0.0	0,1
10. Mar	3.2	2.4	6.9	4.2
11. Apr	24.8	23.0	20.1	22,6
12. May	58.8	62.4	48.9	56,7
Average	144.4	494.73	190.92	271,68

† Average of 12 years (1979-80 to 1991-92)

†† Average of 12 Years (1979-80 to 1991-92)

††† Average of 6 years (1981-1982,1986-87 to 1991-92)

rainfall data recorded at different localities of the Malaprabha representative basin.

The mean annual rainfall of three different stations is 1113 mm . The average total annual rainfall for the catchment is high often exceeding 3300 mm. The rainfall is not evenly distributed throughout the year as well as throughout the basin.

7.4.2.1. Monthly Budget : The basin receives maximum rain, i.e., 36.5 % of the total annual rainfall in the month July and 27.3% of the rainfall during August which is the second important month . 21.6 % of the rain is received during the early part of the southwest monsoon season , i.e., in June (Table 11).

7.4.3 Humidity: The mean relative humidity is high during the south west monsoon season and comparatively low during the non-monsoon period . In summer, the weather is dry and the humidity is low , (Table 12).

7.5. Basin Responses or Outputs

Among various basin response parameters of basin (Fig .3) observations are available only for water discharge (1979-92) and sediment flow (1987-88) recorded by WRDO . A brief account of these parameters is given below .

7.5.1 Water Discharge : Table 13 contains the year wise per day monthly water discharge of the Malaprabha stream

Table 11 : Monthly Budget of the Rainfall in the Malaprabha representative basin

Months	Rainfall in the Malaprabha representative basin	
	Rainfall in mm	in % of the Annual
JUN	715.2	21.6
JUL	1210.1	36.5
AUG	906.8	27.3
SEP	255.0	7.7
OCT	103.4	3.1
NOV	43.2	1.3
DEC	1.6	0.05
JAN	0.0	0.0
FEB	0.1	0.03
MAR	4.17	0.12
APR	22.61	0.70
MAY	56.68	1.70

Table 12 : Relative humidity observed at Santibastwad in the Malaprabha representative basin

Sl.no.	Months	Average relative humidity(%) (1987-1992)
1	January	84
2	February	88
3	March	91
4	April	90
5	May	91
6	June	91
7	July	92
8	August	92
9	September	91
10	October	92
11	November	90
12	December	88
	Average	90

Fig- 13: Monthly water discharge (in cumecs) at Khanapur in the Malaprabha representative basin.

YEAR	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
1979-80	743.9	1619.6	5831.9	632.2	247.9	236.2	-	-	-	-	-	-
1980-81	1616.4	6076.3	4580.7	816.0	105.6	-	-	-	-	-	-	-
1981-82	330.9	4259.5	4761.1	763.5	221.8	111.2	46.4	16.9	6.7	-	-	-
1982-83	615.5	3978.3	5805.1	764.2	236.0	124.3	-	-	-	-	-	-
1983-84	2075.2	3326.9	3727.8	938.6	272.6	87.6	-	-	-	-	-	-
1984-85	965.0	3929.3	2075.5	715.3	331.4	-	-	-	-	-	-	-
1985-86	555.3	1634.5	2854.0	320.2	611.9	100.1	-	-	-	-	-	-
1986-87	1093.8	2133.7	2818.8	274.9	120.4	-	-	-	-	-	-	-
1987-88	195.9	2252.3	1207.2	823.0	858.7	104.8	-	-	-	-	-	-
1988-89	171.7	3673.4	2204.2	1629.4	530.1	82.1	-	-	-	-	-	-
1989-90	1090.2	2036.6	1841.0	780.6	290.0	86.4	22.1	-	-	-	-	-
1990-91	350.7	3595.0	3229.4	1314.5	301.9	149.3	27.9	-	-	-	-	-
1991-92	582.6	3694.7	5028.4	1533.3	1013.0	159.2	24.2	-	-	-	-	-
Av	799.0	3246.9	3535.8	869.7	395.5	95.5	9.3	1.3	0.5	-	-	-

recorded at the mouth of the representative basin ,viz., Khanapur, reveals that

* 1) Malaprabha is a rainfed stream.
* 2) The stream flow is confined mainly to the rainy period
* 3) The stream has influent nature that is why it becomes dry during non rainy season.
* 4) The stream is not receiving water form its permanent ground water table throughout the basin area, hence it becomes dry during non-rainy season .

Hydrograph (Fig.15) based on 13 years data of the Malaprabha stream reveals the following salient characteristics.

1) June is the month of approaching segment of the water discharge,
2) July is the month which corresponds with rising segment of graph.
3) August is the month of peak water discharge,
4) September is the month of gradual recession segment.
5) October is the month of rapid recession segment.

7.5.1.1 Monthly Budget : Table 14 contains the month-wise budget of water discharge from the Malaprabha representative basin. It reveals that:

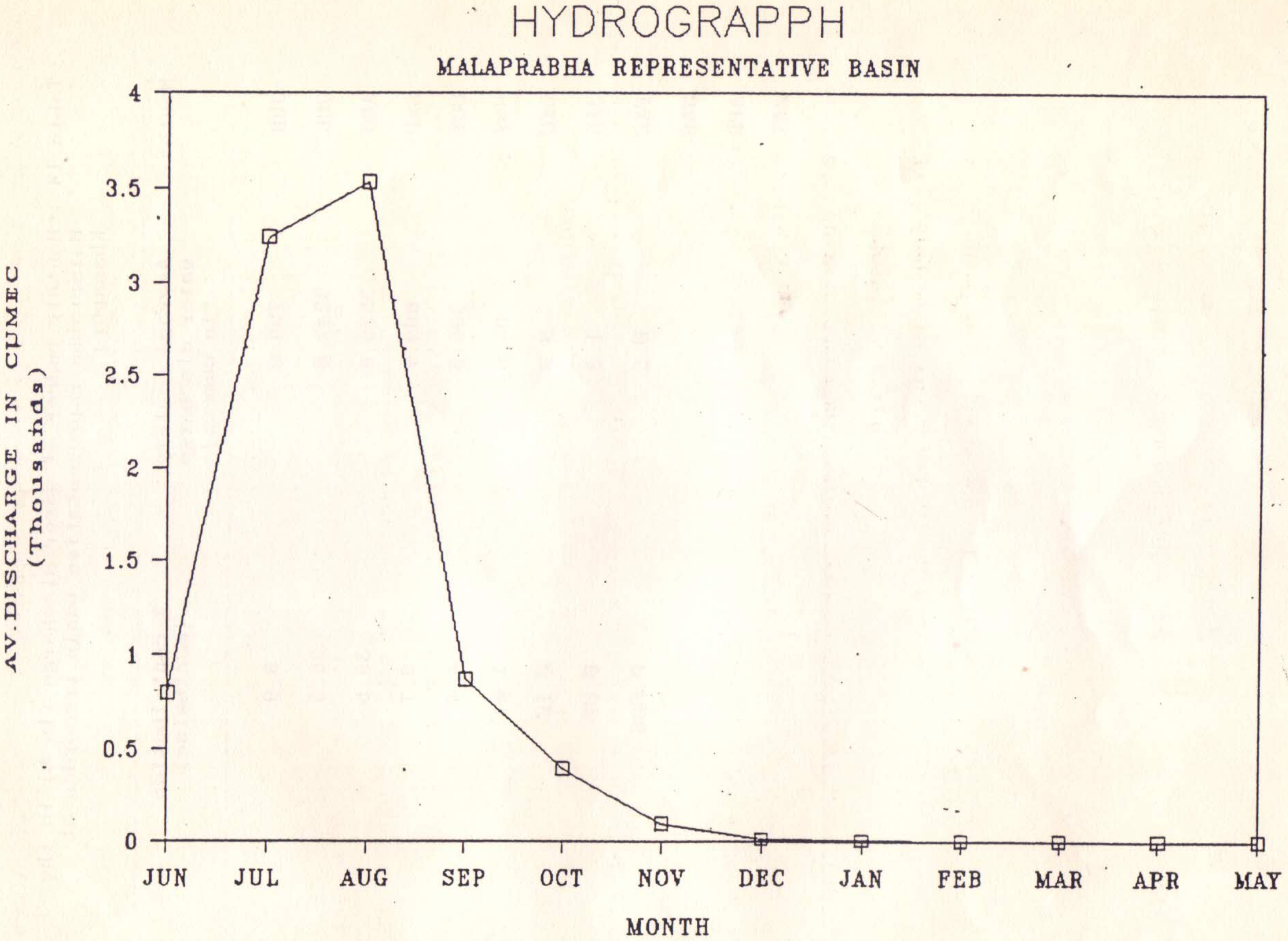


Fig.15 Hydrograph of the Malaprabha Representative Basin Recorded at Khanapur (1979 to 1992).

Table 14 : Monthly budget of water discharge (in %) in the Malaprabha representative basin (recorded at Khanapur)

Months	Average monthly water discharge (in cumecs)	% contribution (monthwise)
JUN	799.Ø	8.9
JUL	3247.Ø	36.3
AUG	3535.8	39.5
SEP	869.7	9.7
OCT	395.5	4.4
NOV	95.5	1.Ø7
DEC	9.3	Ø.1Ø
JAN	1.3	Ø.Ø2
FEB	Ø.5	Ø.ØØ6
MAR	-	-
APR	-	-
MAY	-	-

1) The highest water discharge flow amounting to 40 % of total annual and equivalent to a flow of 3536 cumecs flows in the month of August only.

2) July is the second most important month . 36.3 % of the total annual and equivalent to 3247 cumecs water is discharged from the basin during July.

3) September and June are other important months. 9.7% and 8.9% of the total annual flow is discharged from the basin respectively during these months.

4) In March, April and May the water discharge approached generally at zero and the flow of other months accounts 4.4% for October, 1.07 % for November , 0.1 % for December , 0.015 % for January and 0.006% for February.

7.5.1.2 Annual Budget : On an average (1979-92), the Malaprabha representative basin discharges 8953.4 cumecs water each year which approached upto 13194.9 cumecs in 1980-1981 and dropped to 5441.9 cumecs in 1987-1988.

7.5.1.3 Water Generating Capacity of Land to Stream : Based on the water discharge data (Table 13) water generating capacity of the Malaprabha representative basin to its streams were calculated which is presented in table 15 . The table reveals that:

1) On an average (1979-92), the water generating capacity of land to its streams stands at 1.38 cumec/sq.km/day.

Table 15 : Water generating capacity of land to channels in the Malaprabha representative basin

Sl.no	Months	Water generating capacity (cumec/sq.km/day)
1	JUN	1.5
2	JUL	6.Ø
3	AUG	6.55
4	SEP	1.61
5	OCT	Ø.73
6	NOV	Ø.17
7	DEC	Ø.Ø2
8	JAN	Ø.ØØ2
9	FEB	Ø.ØØ1
1Ø	MAR	-
11	APR	
12	MAY	-

Table 16 : Suspended sediment flow from the mouth of the Malaprabha representative basin

Months	Sediment flow in metric tonnes				
	Av/day	monthly total	max./day	min/day	sed.load in %
Jun'87	5Ø.63	1519	2Ø9	37	3.14
Jul'87	826.9Ø	25634	413Ø	86	53.Ø5
Aug'87	197.61	6126	1147	6	12.67
Sep'87	178.27	5348	963	1Ø	11.Ø6
Oct'87	312.77	9676	16ØØ	38	2Ø.Ø2
Nov'87	-	-	-	-	-
Dec'87	-	-	-	-	-
Jan'88	-	-	-	-	-
Feb'88	-	-	-	-	-
Mar'88	-	-	-	-	-
Apr'88	-	-	-	-	-
May'88	-	-	-	-	-

2) The water generating capacity of land to channels approaches upto 6.5 cumecs/sq.km/day in the month of August and drops almost zero in the months of March , April and May.

3) July is the second important month. For this month the water generating capacity of land to stream stands at 6 cumec/sq.km/day.

4) June and September are third important months when the water generating capacity of land to channel stand at 1.5 and 1.6 cum/sq.km/day, respectively.

5) In the months of October, November, December, January and February this capacity stand at 0.73 , 0.17, 0.01, 0.002 and 0.0009 cumec/sq.km/day respectively .

7.5.2 Sediment Flow -- Sediment flow recorded at Khanapur as presented in table 16 reveals the following salient characteristics,

1) In the Malaprabha channel erosion occurs during the months of June to October.

2) In other months of the year the channel erosion is negligible or approaches zero .

7.5.2.1 Monthly Budget : Table 16 contains the monthly budget of the sediment flow from the Malaprabha representative básin which reveals the following facts :

1) About 53 .05 % of the total annual sediment flow and equivalent to a flow of 826.9 metric tonnes/day flows in a

single month of the year ,i.e., July. The sediment flow rate approaches upto 4130 metric tonnes/day and drops to 86 metric tonnes/day in this month.

2) August, September and October are other important months when 12.67 % , 11.06 % and 20.02 % respectively, of the total annual sediment is discharged from the basin.

7.5.2.2 Annual Budget : The Malaprabha drainage network have a capacity to generate about 48,323 metric tonnes of annual sediment load at the average rate of 132.4 metric tonns/ sq.km/ day.

7.5.2.3 Rate of Erosion : Using the value of total annual sediment yield of the Malaprabha representative basin (i.e. 48323 metric tonnes), the rate of erosion may be extraspolated by using following formulae.

Rate of Denudation = Total load/Area (sq.km) X Sp.gr. mm/thousand yrs)

Using above formulae, it can be extrapolated that the rate of erosion in the Malaprabha representative basin stands at 0.026 mm / year .

8.Ø THE GHATAPRABHA REPRESENTATIVE BASIN

8.1 Location :

The study area of Ghataprabha is the watershed upto Daddi, which is the first gauge-discharge site on the stream. The catchment area of the sub basin lies between latitude 15°5Ø′ and 16°4Ø′, and longitude 74°Ø8′ and 74°3Ø′. A dam is constructed at Hidkal (which is about 2Ø - 25 km from Daddi) in Hukkeri taluk. A road connecting Belgaum - Vengurla passes through the catchment. The government has planned for irrigation to an extent of about 1Ø lakh acres to augment food production. The total command area of the reservoir is 3, 17, 43Ø hectares.

8.2 Hydrometeorological Network :

Various hydrological parameters like rainfall , temperature , evaporation, relative humidity , wind velocity , vapour pressure , soil temperature and soil moisture are observed at hydrometeorological observatories. There are two hydrometeorological stations within the reprsentative basin, i.e. one at Halkarni , maintained by NIH and one at Tarewadi maintained by irrigation department, Maharashtra (Table 17). Hydrometeorological stations and hydrological stations are shown in figure 16 . There are six raingauge stations maintained by State and Central organisations. There is a G & D site in Daddi maintained by Central Water Commission. The discharge data are computed on the basis of current meter reading taken at Ø.6 times the depth of flow from the water surface.

Table 17 : Details of hydrometeorological stations in the Ghataprabha representative basin

Type of station	Location	Parameter	Data recording since	Maintained by
Hydrological station	Daddi	water discharge	Dec ,1978	CWC
	Halkarni	Rainfall	June,1989	NIH
		Max temp	July, 1989	NIH
		Min.temp	Jan .1990	NIH
		Evaporation	Nov.1989	NIH
		Wind velocity	July ,1989	NIH
		Wind direction	July , 1989	NIH
		Humidity	July , 1989	NIH
		Soil temp.	Apr , 1991	NIH
Raingauge stations	Chandgad	Rainfall	Aug ,1990	NIH
	Nesari	-do-	Sep , 1990	NIH
	Mahagaon	-do-	Jun , 1990	NIH
	Daddi	-do-	Jan ,1975	WRDO

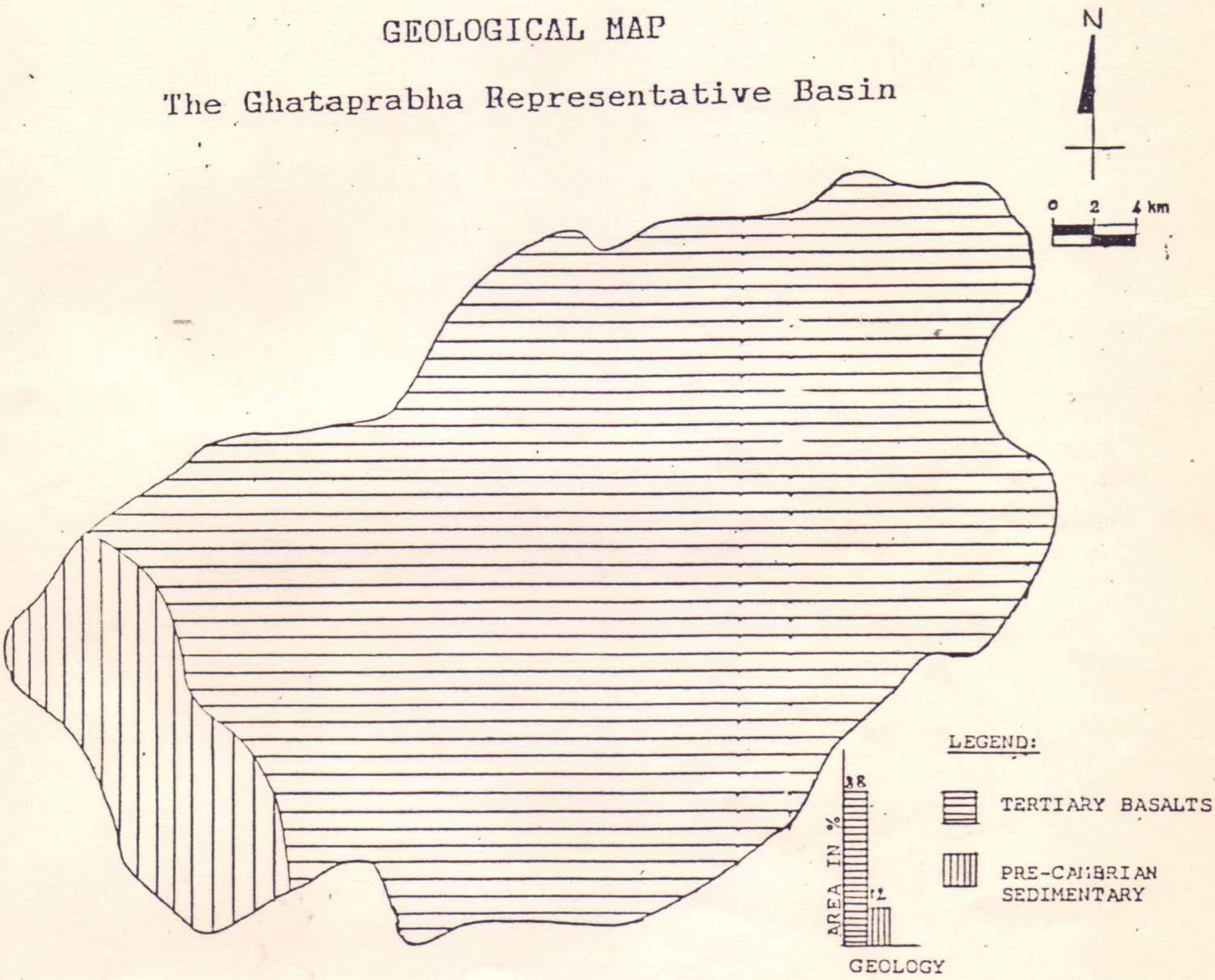


Fig No.17. Geological Map of the Ghataprabha Representative Basin.

GEOLOGICAL MAP

The Ghataprabha Representative Basin

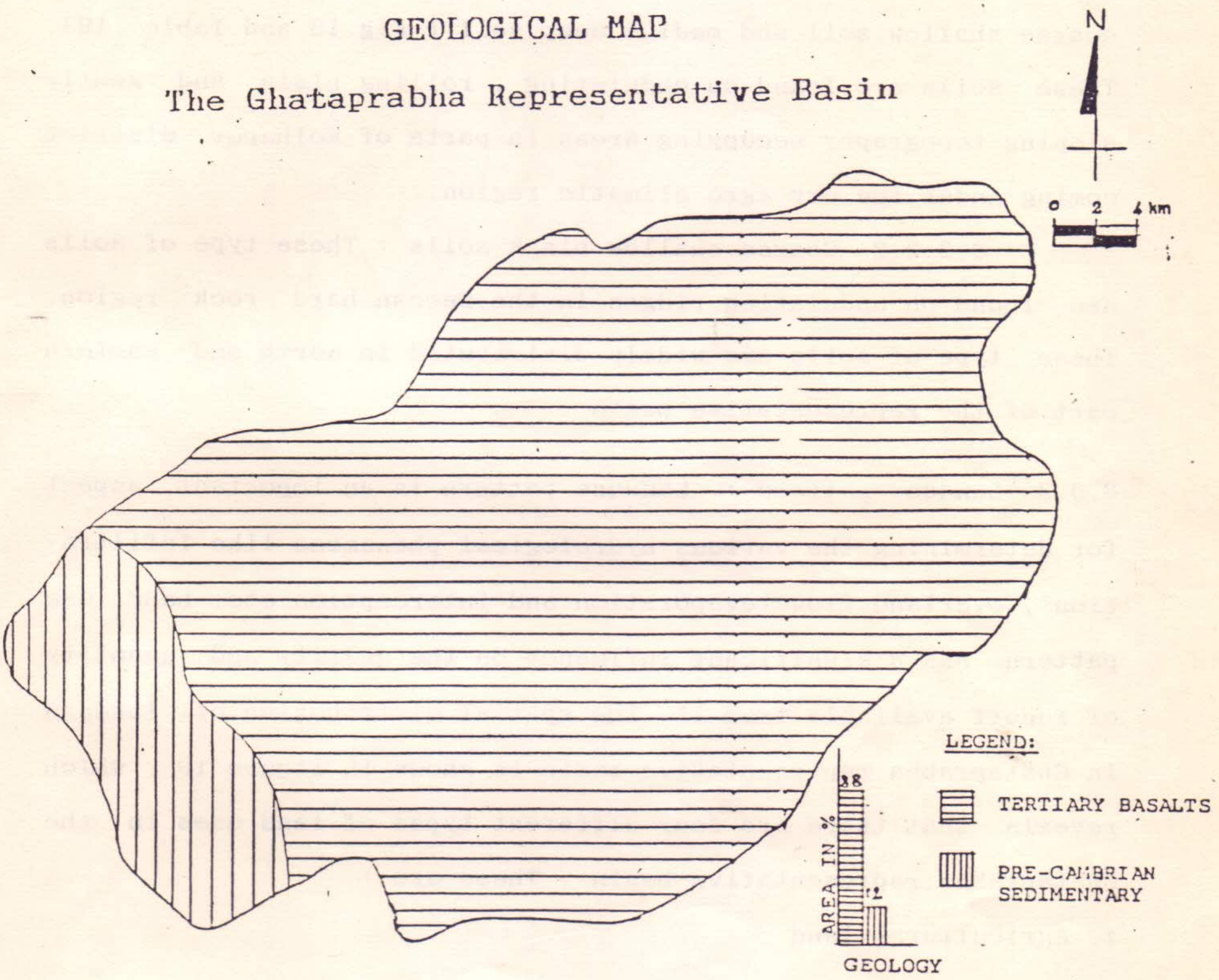


Fig No.17 Geological Map of the Ghataprapha Representative Basin.

(ii) lateritic medium deep soil (29 %) , and (iii) coarse shallow black soil (38%).

8.3.2.1 Lateritic soils : Lateritic soils include both coarse shallow soil and medium deep soil (Fig 18 and Table 19). These soils are found on undulating , rolling plain and gently sloping topography occupying areas in parts of Kolhapur district coming under the dry agro climatic region.

8.3.2.2 Coarse shallow black soils : These type of soils are found on undulating ridges in the Deccan hard rock region. These type of soils are widely distributed in north and eastern part of the representative basin .

8.3.3 Landuse pattern : Landuse pattern is an important aspect for determining the various hydrological phenomena like infiltration , overland flow ,evaporation and interception etc. Land use pattern has a significant influence on the quality and quantity of runoff available from it. The spatial distribution of landuse in Ghataprabha representative basin is shown in figure 19 , which reveals that there are four different types of land uses in the Ghataprabha representative basin . These are :

1. Agricultural land
2. Barren/Fallow land
3. Shrubs
4. Forests

8.3.3.1 Agriculture land : Agriculture land covers about 42.15 % of the total catchment. Generally , the type of land use is governed by social , and socio-economic and characteristics of

Table 18 : Distribution of area under different rock formations in the Ghataprabha representative basin

	Rock formation	Area in sq.km	Area in %
1.	Tertiary Basalts	928.4	88.00
2.	Pre-cambrian sedimentaries	126.6	12.00
	Total	1055 .00	100.00

Table 19 : Distribution of area under different soil groups in the Ghataprabha representative basin

	Soil groups	Area in sq.km	Area in %
1.	Coarse shallow black soil	400.90	38.0
2.	Medium deep soil	348.15	33.0
3.	Coarse shallow soil	305.95	29.0
	Total	1055 .00	100.00

Table 20 : Distribution of area under different land use type in the Ghatprabha representative basin

Sl.No	Land use type	Area in sq.km	Area in %
1.	Forests	145.6	13.8
2.	Shrubs	369.7	35.05
3.	Fallow lands	88.08	8.35
4.	Agriculture	451.56	42.80
	Total	1055	100.0

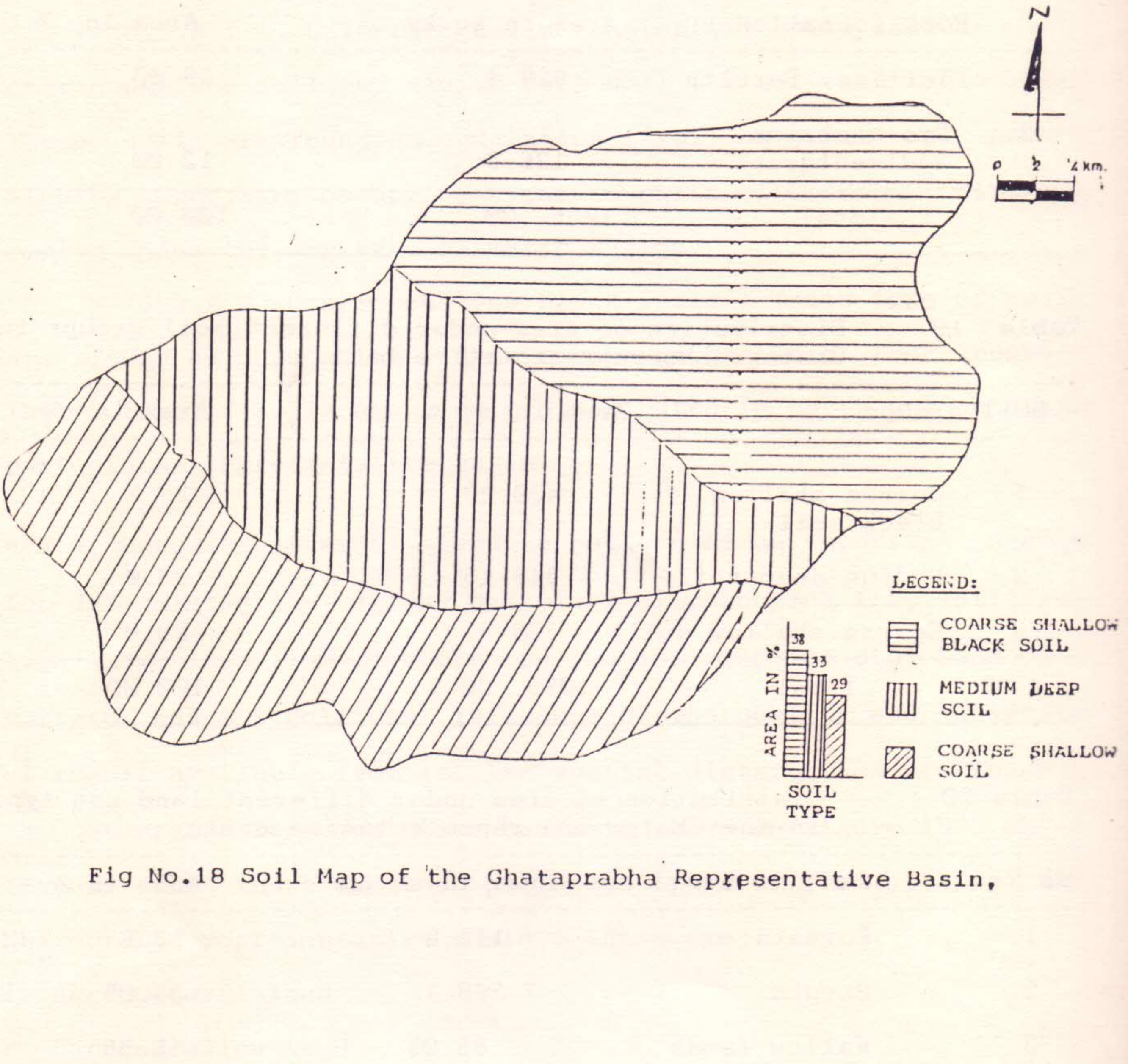


Fig No.18 Soil Map of the Ghataprabha Representative Basin,

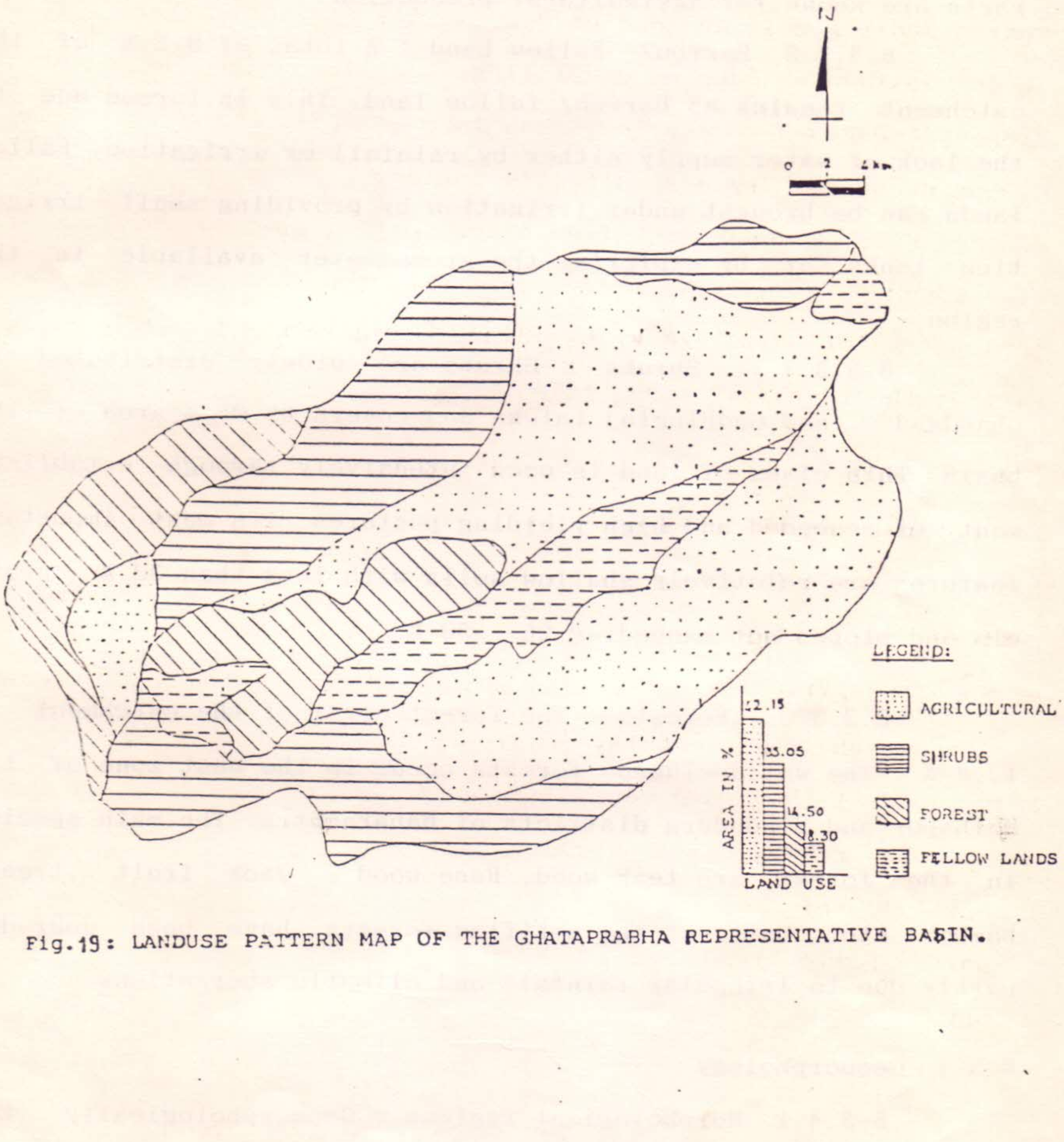


Fig.19: LANDUSE PATTERN MAP OF THE GHATAPRABHA REPRESENTATIVE BASIN.

the soil. Here except in the western part of the basin other parts are known for agricultural production.

8.3.3.2 Barren/ Fallow Land : A total of 8.3 % of the catchment remains as barren/ fallow land. This is formed due to the lack of water supply either by rainfall or irrigation. Fallow lands can be brought under irrigation by providing small irrigation tanks or by exploring the groundwater available in the region.

8.3.3.3 : Shrubs : Shrubs are widely distributed in Chandgad , and Gadhinglaj taluks and covers 35.05 % area of the basin. This class of land is used intensively through establishment of reseeded and high yielding pastures. Its most important features are relatively shallow soils with less than 30 % gravels and slopes not exceeding 25 - 30 %.

8.3.3.3 Forests : The forest cover of the catchment is 13.8 % . The wet deciduous forests occur in the west zone of the Kolhapur and Sindudurg districts of Maharashtra. The main species in the forest are teak wood, Rose wood , Jack fruit ,trees, bamboo etc. Most of the notified forests have been degraded partly due to irregular rainfall and climatic aberrations.

8.3.4 Geomorphology

8.3.4.1 Morphological regions : Geomorphologically the catchment is relatively flat and gently undulating with isolated hillocks intervened by valleys. The catchment is some what oval in shape. The relief of the basin varies between 682 m and 1039 m. Very steep contours (Fig 20) are observed towards the western side of the representative basin. The high basin relief observed in the Ghataprabha catchment is an indication of higher potential energy available to move water and sediment downstream regions ,i.e., the region in and around Daddi, however, in the northern part of the basin they are not as steep as in the south and western part of the basin. This part (southwestern part) may easily be subjected to erosion due to its higher relief.

8.3.4.2 Altitudinal Zones : The entire basin is divisible into as many as 5 divisions ranging from < 700 to > 1000 m. The spatial distribution of these zones are shown in figure 21 Table 21 shows the percentage distribution of different altitudinal zones. It is found that a total of 686.3 sq.km.(65.05 %) area is lying within 700-800 m contour line. A small part of the catchment falls under higher altitude groups (900 - 1000 m , 1.5 %) .

8.3.4.3 Hypsometric Analysis. The hypsometric analysis shows the various stages of geomorphological development. This is indicated in the figure 22 shows that Ghataprabha river has rached the mature stage of development. The field studies carried out in this region also gives a clearcut indication of its maturity.

8.3.4.4 Drainage Density : Density of the drainage network varies widely between < 0.5 km/sq.km to > 2.5 km/sq.km . It is observed that (Fig. 23) the less resistant rocks confined in the western part of the catchment has higher values of drainage

CONTOUR MAP

The Ghataprabha Representative Basin

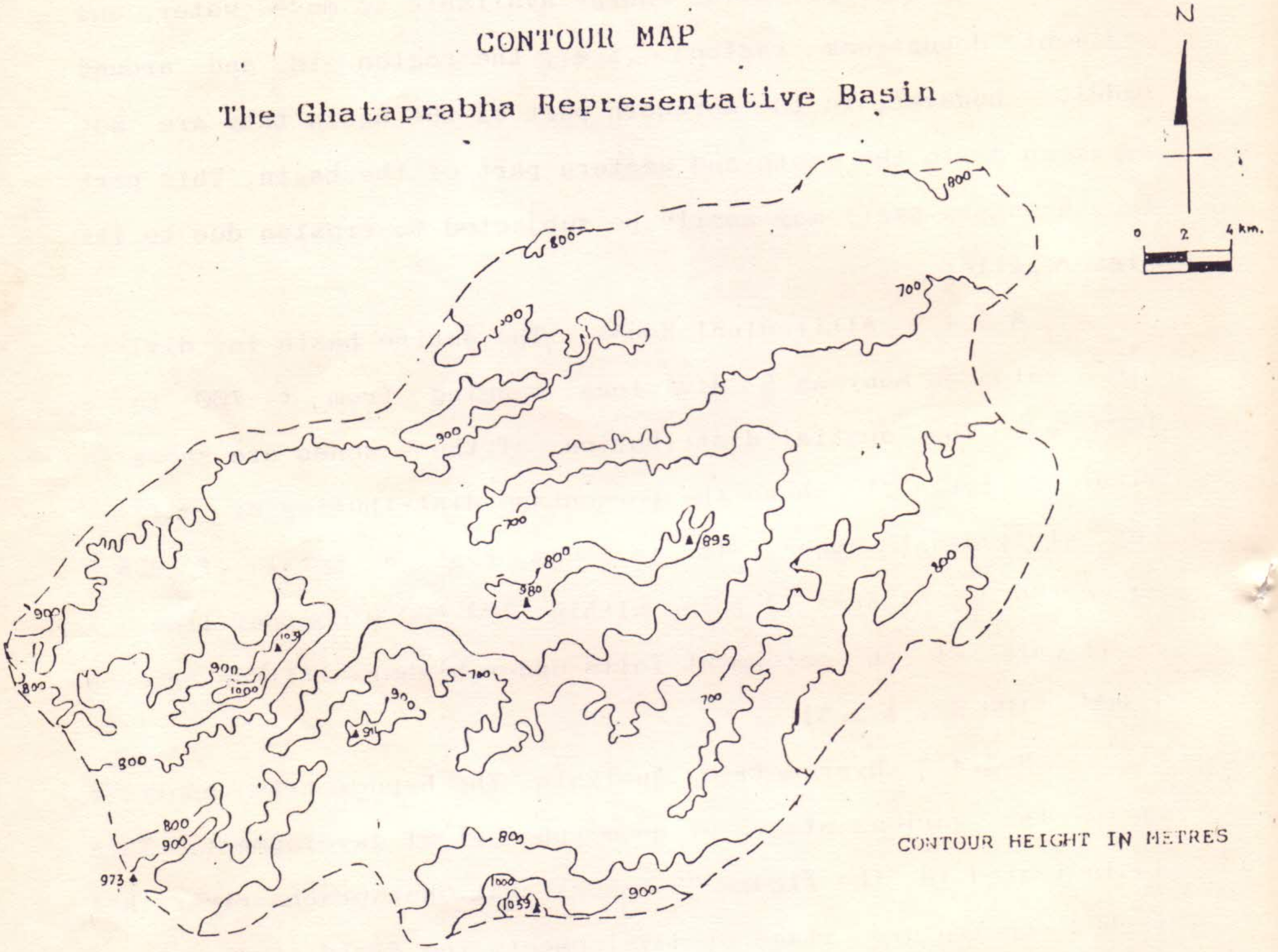


Fig No.20 Contour Map of the Ghataprapha Representative Basin.

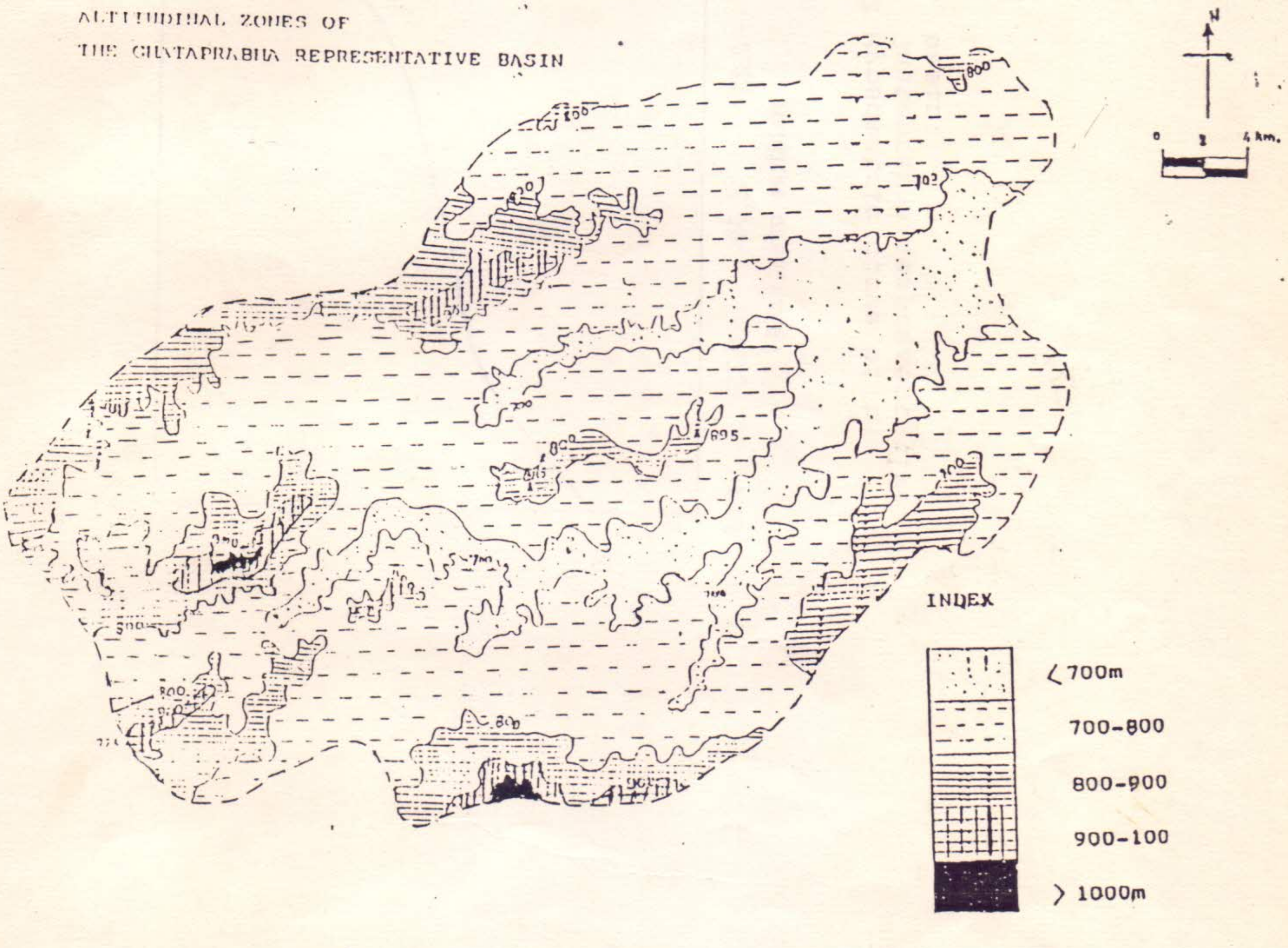


Fig. 21: Altitudinal zones of the Ghataprabha representative basin.

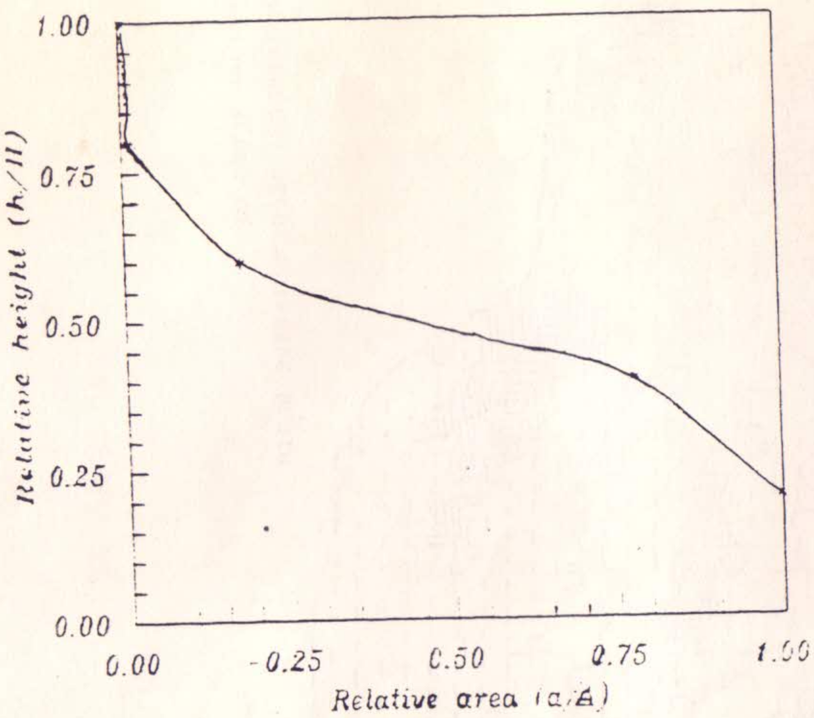


Fig.22 Hypsometric curve of the Ghataprabha respresentative basin.

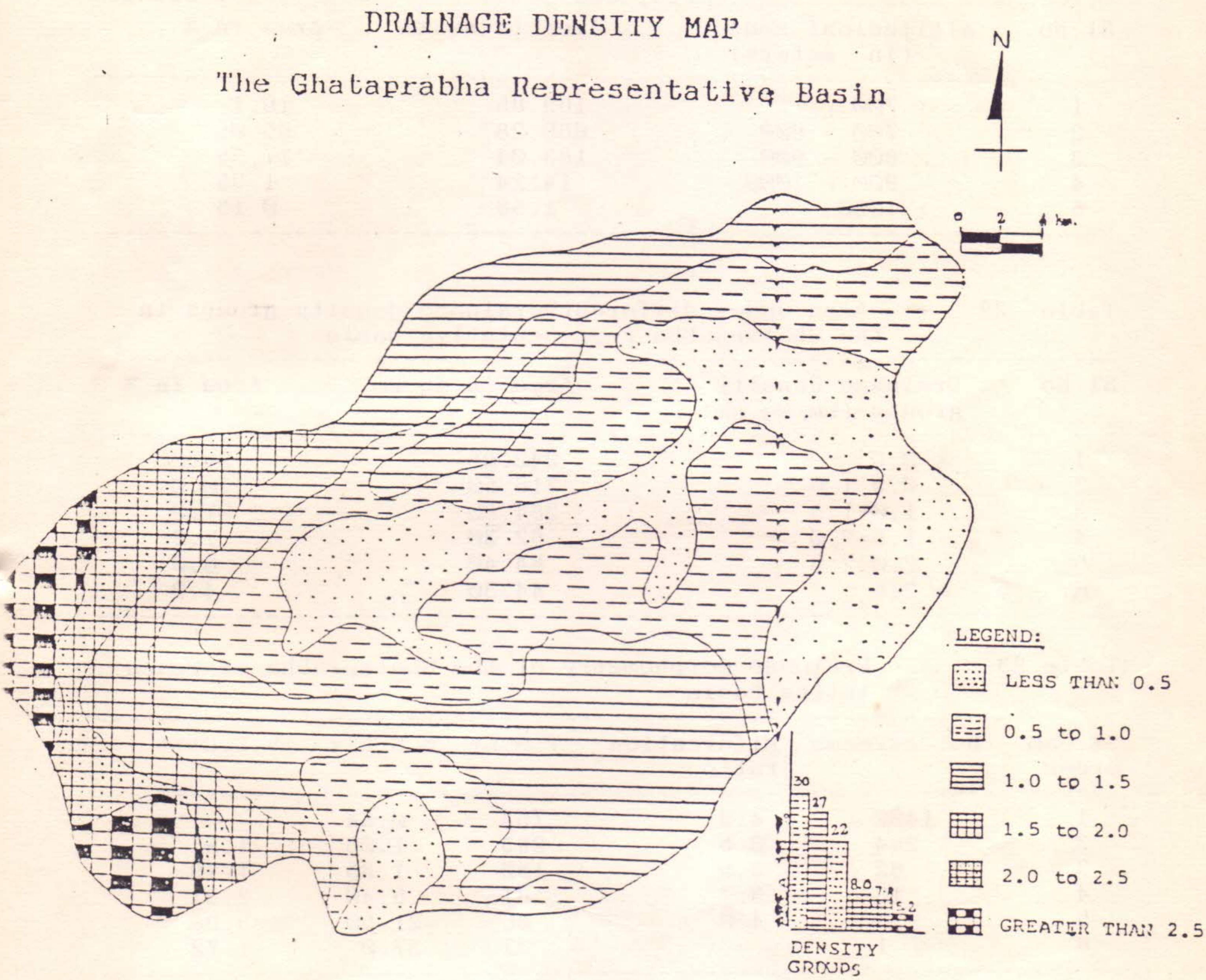


Fig No. 23 Spatial Distribution of Drainage Density in the Ghataprabha Representative Basin.

Table 21 : Distribution of Area under different altitudinal zones of the Ghataprabha representative basin

Sl.No.	Altitudinal zones (in meters)	Area in sq.km	Area in %
1	< 700	169.85	16.1
2	700 - 800	686.28	65.05
3	800 - 900	183.04	17.35
4	900 - 1000	14.24	1.35
5	> 1000	1.58	0.15

Table 22 : Area under different drainage density groups in the Ghataprabha representative basin

Sl.No	Drainage density groups (km/sq.km)	Area in sq.km	Area in.%
1.	< 0.5	242.65	23.0
2.	0.5-1.0	316.50	30.0
3.	1.0-1.5	284.85	27.0
4.	1.5-2.0	82.30	7.8
5.	2.0-2.5	84.40	8.0
6.	> 2.5	44.30	4.2

Table 23 : Drainage morphometry of the Ghataprabha representative basin

Stream order	No. streams	Bifurcation ratio	T.S.L*	M.S.L**	S.L.R***
1	1402	4.9	753	0.54	-
2	284	3.5	293	1.03	1.9
3	82	5.5	152	1.85	1.79
4	15	3.7	81	5.40	2.91
5	4	4.0	86	21.50	3.98
6	1	-	37	37.0	1.72

* Total stream length (km) , ** Mean stream length ,
*** Stream length ratio.

density than that of the flat areas in the central part. The areal distribution of various drainage density groups are given in table 22 .

8.3.4.5 Stream Ordering : Table 23 shows the various geomorphological parameters of the Ghataprabha representative basin . There are 1402 first order , 284 second order , 82 third order, 15 fourth order , 4 fifth order and one six order streams in the representative basin

8.3.4.6 Stream Length : The total stream length of the Ghataprabha representative basin is 1102 km . Stream lengths of covered by different order streams are given in table 23 . As in the case of Malaprabha , here also a large part of the stream length is covered by first and second order streams which is followed by third and fourth order streams. Only a very small percentage is covered by higher order streams (Table 23).

8.4 Basin Input Parameter

The available basin input parameters of the Ghataprabha representative basin are presented below.

8.4.1 Air Temperature : The data on temperature (average of 3 years) shows that April is the hottest month (34.4 C) and January is the coldest month 14 C. The average maximum temperature in the catchment is 34.4 C and average minimum temperaure is 18.6 C. With the onset of monsoon there is an appreciable drop in the day temperaure, but the nights are generally warm.

Table 24 : Monthly average maximum and minimum temperature observed at Halkarni in the Ghataprabha representative basin

Sl.no.	Months	Temperature (in°C) Max	Temperature (in°C) Min
1	January	30.2	14.0
2	February	31.9	14.7
3	March	33.9	17.3
4	April	34.4	20.0
5	May	32.3	20.8
6	June	26.8	20.6
7	July	24.7	20.5
8	August	24.5	22.1
9	September	27.0	19.9
10	October	28.3	19.4
11	November	28.8	19.1
12	December	28.2	15.2
	Annual mean	29.6	18.6

Table 25 : Average Monthly Rainfall in the Ghataprabha representative basin

Months	Chandgad	Halkarni	Daddi	Average
	STATIONS			
JUN	509	463.1	180.9	384.3
JUL	1286.0	499.3	245.0	723.4
AUG	749.0	385.9	189.8	441.6
SEP	216.0	106.6	129.5	150.7
OCT	117.0	71.2	52.5	80.2
NOV	45.0	9.9	21.6	25.5
DEC	6.0	0.1	2.2	2.8
JAN	0.0	0.1	4.4	0.1
FEB	2.0	0.0	0.6	0.9
MAR	8.0	-	13.8	7.3
APR	40.0	19.9	20.1	26.7
MAY	93.0	74.4	48.1	71.8
TOTAL	3011.0	1753.3	885.7	1916.70

8.4.2 Rainfall : The average monthly rainfall in the Ghataprabha representative basin , at stations Chandgad , Halkarni and Daddi are given in table 25 . It is observed that, the maximum rainfall occured in the month of July (37.7% of the total rainfall) and minimum is observed during February (0.05 %) (Table 26) , which is quite negligible. The average maximum rainfall is noted at Chandgad , 3011 mm and minimum is 885.7 mm recorded at Daddi.

8.4.3 Humidity : The relative humidity is high during the southwest monsoon period and low during the non-monsoon period. In summer the weather is dry and the humidity is low. The maximum relative humidity is noticed in the month July and minimum in the month of March (53.7%). the average relative humidity from 1989-1992 is 71% observed at Halkarni observatory (Table 27).

8.4.4 Wind Velocity : Maximum wind velocity is experienced during the month of July (15.3km/hr),(Table 28). During the south-west monsoon period , the wind blows mainly from south west and west. In November and December , it experiences NE-easterly wind. South westerlies and westerlies appear in January and generally from February onwards, the easterlies decrease in frequency . The average minimum wind speed is recorded in the month of October .

Table 26 : Monthly budget of the average rainfall in the Ghataprabha representative basin

Sl.no.	Months	Average monthly rainfall	% contribution
1.	JUN	322.0	23.5
2.	JUL	472.0	34.5
3.	AUG	287.9	21.0
4.	SEP	118.1	8.6
5.	OCT	61.8	4.5
6.	NOV	15.8	1.1
7.	DEC	1.1	0.08
8.	JAN	2.2	0.16
9.	FEB	0.3	0.02
10.	MAR	6.9	0.5
11.	APR	20.0	1.5
12.	MAY	61.2	4.5

C

Table 27 : Monthly average relative humidity data (1989-1992) of Halkarni observatory located in the Ghataprabha representative basin

Sl. No.	Months	Relative humidity
1	January	57.8
2	February	53.7
3	March	57.5
4	April	63.6
5	May	71.6
6	June	83.1
7	July	85.6
8	August	84.7
9	September	80.7
10	October	75.9
11	November	68.3
12	December	69.2
	Average	71.0

Table 28 : Average monthly wind speed observed at Halkarni observatory

Sl .no.	Month	Wind Speed (km/hr)
1.	JUN	6.0
2.	JUL	10.4
3.	AUG	9.0
4.	SEP	2.4
5.	OCT	2.4
6.	NOV	2.4
7.	DEC	3.6
8.	JAN	3.8
9.	FEB	1.9
10.	MAR	2.3
11.	APR	2.2
12	MAY	2.6

8.5 Basin Outputs:

8.5.1 Water Discharge : Table 29 shows the monthly water discharge of the Ghataprabha river recorded at the mouth of the represèntaive basin ., viz ., Daddi.

(1) The stream is rainfed stream

(2) The stream is influent in nature

(3) The base flow is negligible

Hydrograph (Fig 24) based on 10 years data of the Daddi site explains the following facts

(1) Discharge paeak increase from June (8.9%) to August (39.5%) and decrease thereafter. From November onwards the discharges are negligible and March and April are seems to be the dry months . The pèrcentage contribution of discharge is shown in table 30 .

(2) The average discharge (1979- 1989) is 23034.8 cumecs each year which approached 30740.2 cumec in 1980-1981 and dropped to 123412.2 cumecs in 1987-1988.

8.5.2 Water generating capacity of land to stream : Based on the water discharge data (Table 29) water generation capacity of the Ghataprabha representative basin to its stream was calculated which is presented in table 30 . The table shows that

(1) On an average the water generating capacity of the catchment to its streams is 2.96 cumecs/sq.km/day.

Fig- 29: Monthly water discharge (in cumecs) recorded at Daddi in the Ghataprabha representative basin.

YEAR	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
1979-80	1070.8	6151.0	14167.0	1792.0	744.9	305.9	102.7	16.0	1.8	nil	nil	nil
1980-81	3691.0	12572.6	11261.3	2327.3	736.2	112.5	37.0	2.3	-	-	-	-
1981-82	1348.1	10454.7	12070.3	2337.6	556.4	159.2	36.2	-	-	-	-	68.8
1982-83	1359.8	10736.6	12454.4	1421.9	398.5	281.2	37.3	-	-	-	-	-
1983-84	4737.5	10132.2	10113.8	2932.0	714.8	162.3	51.3	-	-	-	-	-
1984-85	2130.8	11711.0	6417.1	1606.0	684.0	120.6	32.5	-	-	-	-	-
1985-86	3040.6	6765.7	NA	948.2	0.0	0.0	31.0	-	-	-	-	-
1986-87	2805.7	6863.0	7431.2	578.1	262.2	205.8	18.4	-	-	-	-	-
1987-88	486.0	5944.1	3159.2	1566.4	969.2	150.0	37.3	-	-	-	-	-
1988-89	835.1	12504.7	8571.9	4111.3	1095.3	56.9	-	-	-	-	-	-
Average	2232.5	9383.6	9605.1	1910.0	616.1	155.4	38.4	1.92	0.23	-	-	6.9

Table 30 : Water generating capacity of land to channels inthe Ghataprabha representative basin

Sl.no	Months	Water generating capacity (cumec/sq.km/day)
1	JUN	2.1
2	JUL	8.9
3	AUG	9.1
4	SEP	1.8
5	OCT	0.6
6	NOV	0.15
7	DEC	0.04
8	JAN	0.002
9	FEB	0.0002
10	MAR	
11	APR	-
12	MAY	-

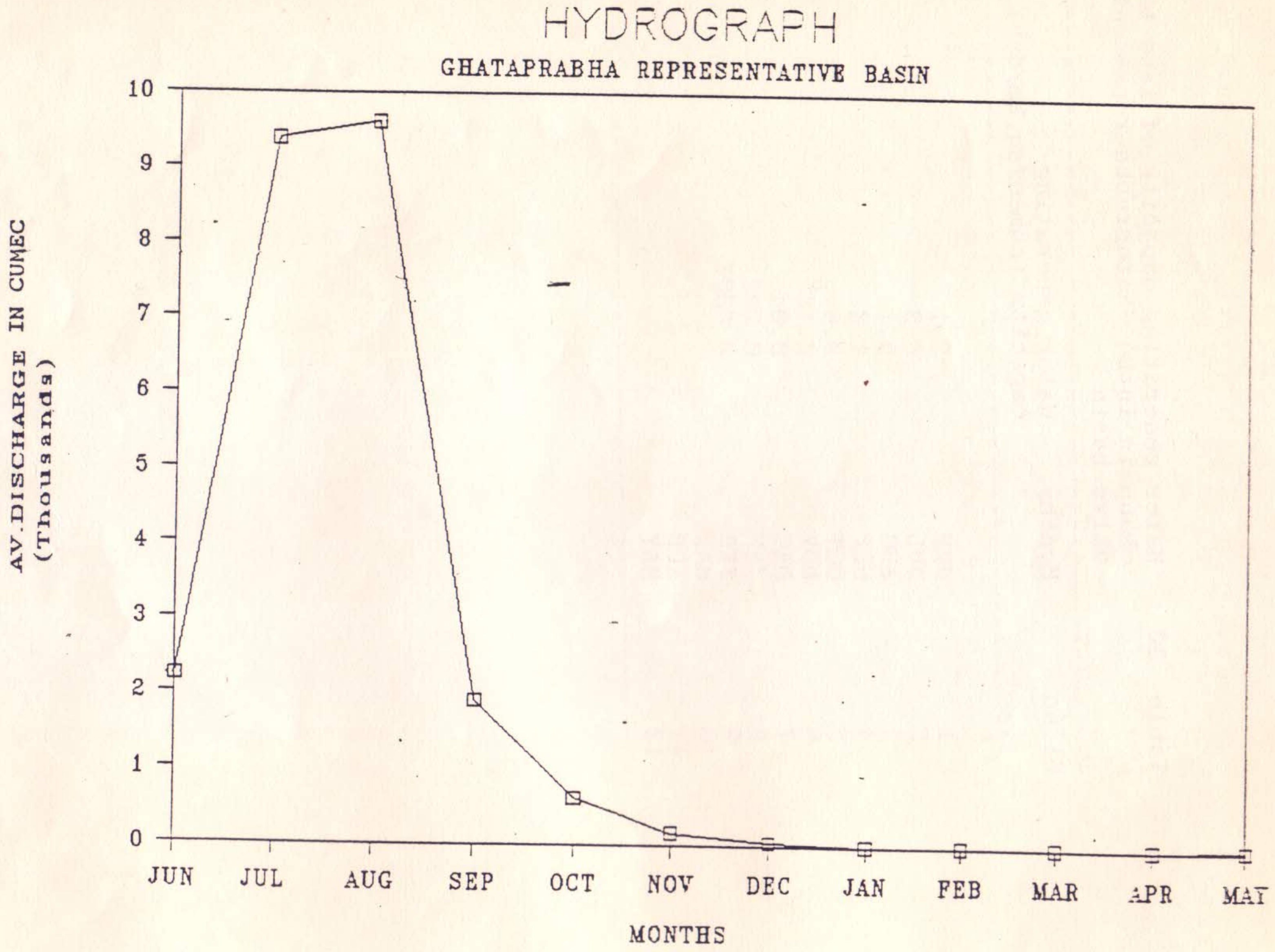


Fig.24 Hydrograph of the Ghataprabha Representative Basins Recorded at Daddi.(1979 to 1989)

(2) The maximum water generating capacity is observed during July and August months and it recedes slowly and approaches to zero during February , March and April months. The corresponding values are shown in table 3Ø.

9.0 CONCLUSIONS

9.1 General

To satisfy the short term and long term requirements for assessing water resources and solving various management problems, to define the relationship that express the internal laws of hydrological phenomena, and to provide a medium giving fundamental data for other hydrological problems, representative areas of different hydrological regions are needed. In view of the above matter a new concept, viz., representative basin studies has emerged in the hydrological studies which is developing very rapidly. The principal objectives of hydrological research in representative basin are :

- The prediction and quantitative estimation of various components of hydrological cycle and to provide an insight into the hydrological characteristics of the area which they represent.

- Studies in representative basins are primarily observational on long term basis and combined with the study of climatic, pedological, geological, geomorphological characteristics.

- The type of climate, vegetational, geomorphological, pedological and geological characteristics of the selected representative basin should be compared with those of the hydrological regions and the cultural changes in landuse, management, streamflow utilization etc. should be minimal during the period of study and where they are inevitable , should be carefully recorded.

· The representative basin study could be systematically, divided into three different components . These are :

(1) Observation of basin input (or energy) parameters

(2) Observation of basin output (or response) parameters

(3) Study of basin characteristics

A synoptic outline of the parameters related with these three components are presented in table 1 .

* some of the parameters are related with basin outputs may be observed on short term basis , i.e. , for one or two years only at selected sites as per the need of the basin. The parameters which could be observed on short term basis are :

(1) Overland flow

(2) Sub-surface flow

(3) Interception losses

(4) Soil moisture

(5) Infiltration

(6) Evapo transpiration

(7) Sheetwash erosion

(8) Channel erosion

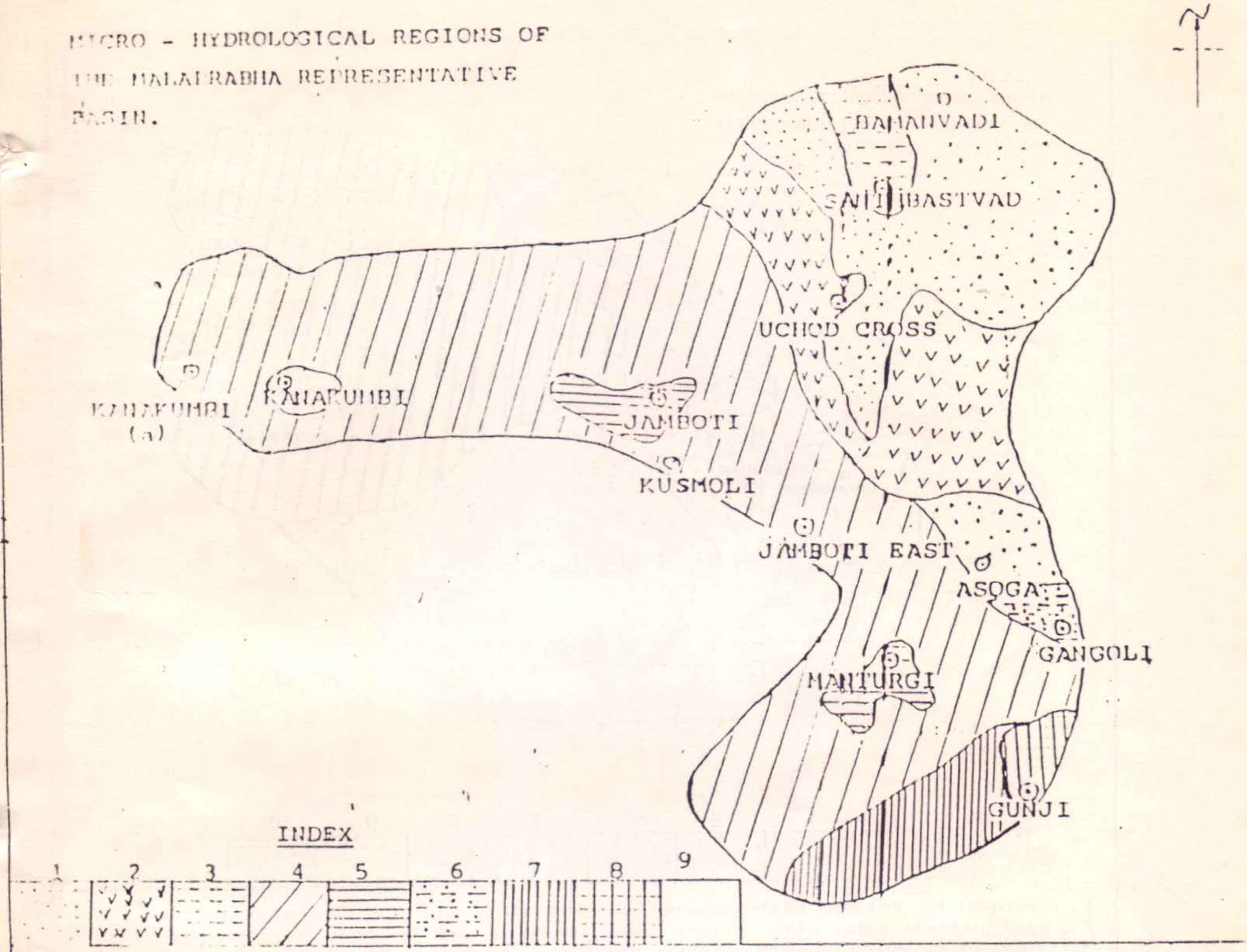
* For the selection of sample sites to study hydrological parameters , a thorough knowledge of the physical as well as the cultural environment of the representative basin is required. Under a complex environment (i.e having different rock types

soils, relief, conditions, vegetation cover and landuse pattern etc.) sample site selected based on one geographical factor cannot be ideal or unbiased. Hence, multistage stratification of the representative basin by using geological soil, landuse pattern, maps is needed to minimise variations in order to obtain the homogeneous , micro hydrological regions. The hydrological parameters should be observed in each micro hydrological region of the basin.

9.2. Case studies

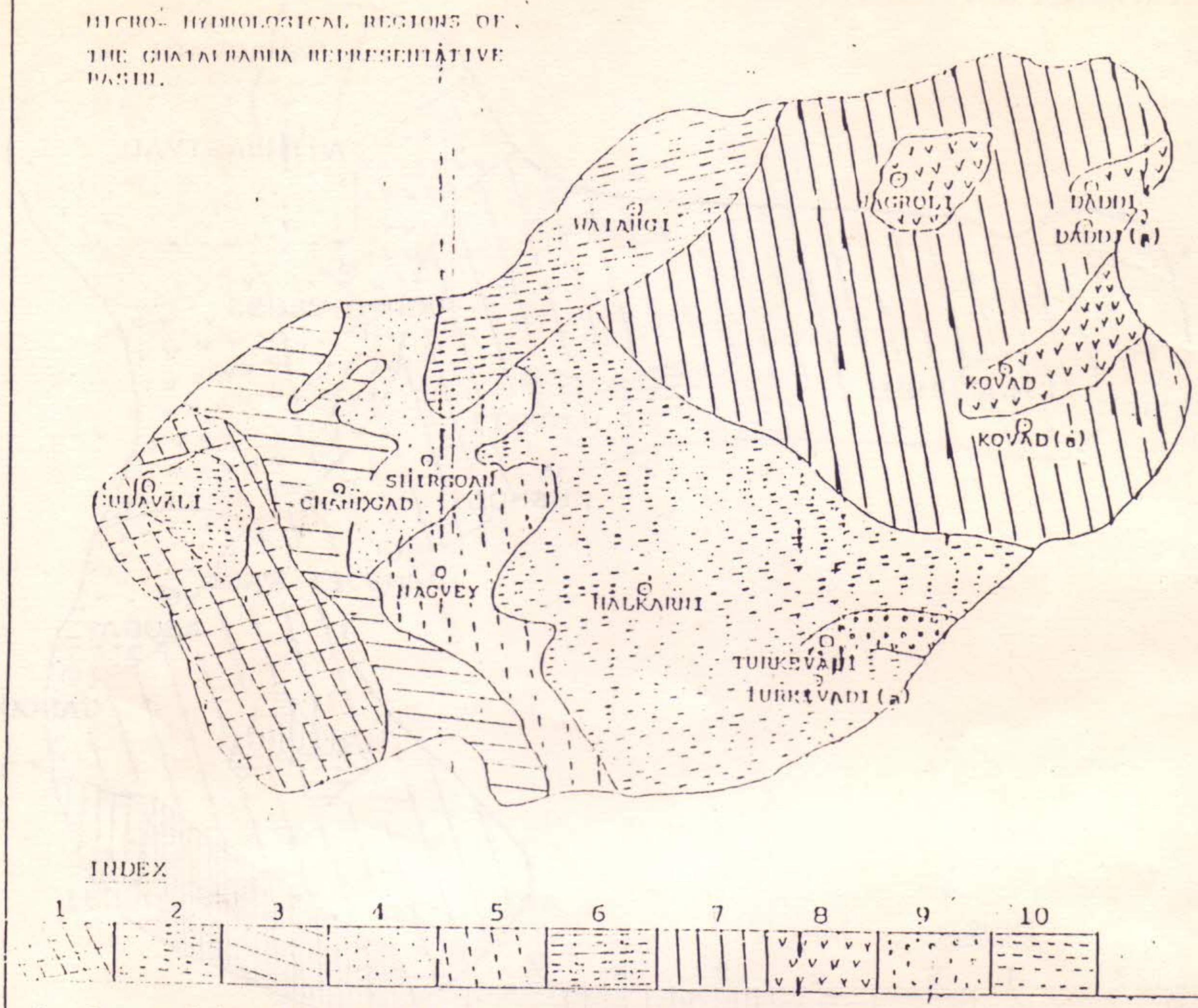
Representative basin studies in one of the major hydrological region of India, viz, the Deccan Hard Rock region was started in 1987. A summary of Hydrometeorological network, basin characteristics (geology, soils, landuse, geomorphology), basin input parameters and output parameters is presented in the report reveals that the representative basins have complex geographical environment.

Representative basins , viz., Malaprabha and Ghataprabha are divisible into as many as nine and ten micro hydrological regions respectively (Fig.25 and 26). Therefore , additional instrumentation is required for the observation of different parameters as follows.



1. Agriculture land having medium black soil underlain by terriary basalts.
2. Shrubs having medium black soil underlain by tertiary basalt.
3. Barren land having medium black soil underlain by tertiary basalts.
4. Forest region having Red loamy soil underlain by tertiary basalt,
5. Agriculture land having red loamy soil underlain by tertiary basalt,
6. Forest land having medium black soil underlain by tertiary basalt.
7. Forest land having Red loamy soil underlain by pre - cambrian sedimentary rocks.
8. Agriculture land having Red loamy soil underlain by pre - cambrian sedimentary rocks.
9. Barren land having Red loamy soil underlain by Basalts.

Fig. 25 Micro - hydrological regions of the Malaprabha Representative Basi



1. Covered by forest with coarse shallow soil and sedimentary rocks.
2. Agriculture land with coarse shallow soil and sedimentary rocks.
3. Covered by shrubs with medium deep soil and basalt rocks.
4. Agriculture land with medium deep soil and basalt rocks.
5. Covered by forest with medium deep soil and basalt rocks.
6. Covered by shrubs with coarse shallow soil and basalt rocks.
7. Agriculture land with coarse shallow black soil and basalt rocks.
8. Barren land with coarse shallow black soil and basalt rocks.
9. Barren land with medium deep soil and basalt rocks.
10. Agriculture land with medium deep soil and basalt rocks.

Fig.26: Micro - hydrological regions of the Ghataprabha representative basin.

Period	Parameters to be observed	No. of sites
Long-term	Water discharge	* At 3 sites representing forests, agriculture and barren land.
	Ground water	* At 6 sites representing 2 each in forest agricul ture and barren land.
Short term	*Overland flow * Sheetwash erosion * Sub-surface flow *Interception loss * Evapotranspiration * Soil moisture	* At 6 sites representing each micro hydrological region.
	* Channel erosion	* At 3 sites representing Forest , agriculture & and barren land.

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