MFN-575

LAND UNITS AND LANDUSE IN CHHOTA TAWA RIVER BASIN: AN EXPLORATORY GEOMORPHOLOGICAL ANALYSIS

Thesis submitted to the Jawaharlal Nehru University in fulfilment of the requirements for the award of the Degree of

DOCTOR OF PHILOSOPHY

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CERTIFICATE

Certified that the thesis entitled "**LAND UNITS AND LAND USE IN CHHOTA TAWA RIVER BASIN : AN EXPLORATORY GEOMORPHOLOGICAL ANA**[illegible]ted by Ambadas Shripatrao Jadhav for the degree [illegible]sophy is a bonafide work to the best of our kn[illegible] be placed before the examiners for their consideration.

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to my parents

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(A.S. JADHAV)

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CHAPTER-I

INTRODUCTION

Geomorphological processes play a very important role in moulding surface materiel, ecology, landuse and human activities in a region. It is more so in steep and rugged terrain where extent of river terraces, alluvial basins, the degree of slope and the present altitude determine the landuse and human activities. The lay of land and the pattern of valleys and ridges control the routes through and along them and thus, influence the overall development of the area. In any agricultural planning, it becomes necessary to have the knowledge of the character of land and land capability. Geomorphological map, thus, is the best tool to give insight into configurations of surface, land character, land capability, over lying material and processes operating over an area. The geomorphological map has proved more suitable for illustrating the physical environment, the relief and the processes interacting therein. A detailed geomorphological map depicts morphological, morphogenetic, morphographic, morpho-chronological and morphometric aspects of relief and it also indicates its evolution over time.

In the above context and with a view to understand the application of the geomorphological processes in the identification of land units and their relationship with the landuse, Chhota Tawa river basin has been selected as a case study. Chhota Tawa forms a sub-basin on the left bank of Narmada river. This basin has witnessed a variety of processes acting and producing a variety of landforms which, in turn, has resulted in variations in the landuse patterns.

I.1 Overview of Literature

A few geomorphological and geological studies have been carried out in parts of Central India but a geomorphological and landuse study in the Chhota Tawa river basin using remote sensing techniques has so far not been attempted.

Geomorphological studies and mapping based on sound scientific principles are fairly well developed in many parts of Europe especially in Hungary[1], France, Poland, Belgium, Russia, The Netherlands, Italy[2] and Germany[3].

In India, in recent years considerable amount of work has been done by several scientists in geomorphological mapping using remote sensing technique. Among these scientists a special mention may be made of Vaidyanathan, Vidyanath, Scientists of

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[1] Pecsi M (Ed) (1985) *'Environmental and Dynamic Geomorphology'* Akademia : Kiado, Budapest.

[2] Geografia Fisica E Geomorphologia (1985), *Italian Research on Physical Geography and Geomorphology : An Overview*, Italy.

[3] Barsch D, H. Liedtke, K. Maller and G. Stablein (1985) *'Geomorphological Mapping in the Federal Republic of Germany'* Berlin, FRG.

CAZRI, NRSA, Indian Institute of Remote Sensing, Anna Institute of Remote Sensing and Various State and Central Governments' Departments like ONGC, Ground Water Departments, Soil Survey and landuse planning departments.

The development of geomorphic studies has quite a long history in our country. The Indian geomorphology has its roots mainly in the studies conducted by geographers and geologists. The geomorphological studies in Central India, however, did not attract too many geomorphologists and the Individual studies were carried out by professional geologists who surveyed this part of the country and described the landforms, while presenting the reports of their geological surveys. Among these geologists a special mention may be made of Mallet, Medlicott, Oldham, Auden and Ahmad who studied the Central Part of India.

A. B. Pithawala's (1939)[4] Classification of the physiographic region of India was based on geography and topography as controlled by the internal and external agencies working on them and subsequently he reviewed it taking into account the structural and erosional characteristics of the seventeen physiographic provinces of India.

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4 Pithawala, A.B. (1939) 'Need of Uniformity in the Physiographic Divisions of India, *Jour. Mad. Geol.*, Vol. 14, No. 3.

S.P. Chatterjee (1962)[5] has suggested a classification of physiographic divisions of India on the million scale. His division is based on the structural and topographic characteristics.

S.P. Chatterjee and B. Basu (1944)[6] have divided the greater part of Madhya Pradesh into nine physiographic regions on the same basis and regional geomorphological studies of the Sagar-Damoh plateau, the Murwara basin, the Narmada valley, the Northern foot hill zone of Satpura hills, the Purana valley, the Southern plain, the Balaghat-Bhandara hills, the Ajanta plateau, the Bundelkhand plateau and Vindhyan country, have been done.

The geomorphology of the region under study has not been studied in detail in the past. In different parts of the adjacent areas of the basin a large number of studies have been done. The geomorphic interest in the area forming the Central Indian territory developed after the studies of different areas by many geologists and geographers.

F.R. Mallet (1869)[7] has done work on Eastern Parts of

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5 Chatterjee, S.P. (1962), Physiographic Divisions of India, *Proc. of Summer School of Geography*, Calcutta.

6 Chatterjee S.P. and Basu (1944) Physiography and Economic Bases in Central Provinces and Berar, *Cal. Geog. R.*, Vol. 6, No. 1.

7 Mallet, F.R., (1869) 'On the Vindhyan Series as Exhibited in the North West and Central Provinces of India', *Mem. Geol. Sur. Ind.*, Vol. 7.

Vindhyan basin and published his observations in the Memoirs of the Geological survey of India. The work done by Mallet is extensive and does not deal with the details of the geology, but his work is an outstanding and pioneering contribution on the Vindhyan System.

R.D. Oldham (1901)[8] has surveyed the son valley area and published his observations on the geology of the son valley in Rewa state in the Memoirs of Geological Survey of India.

D.W. Johnson (1939)[9] has studied the fault scarps and fault line scarps in the central provinces of India.

E.H. Pascoe (1950)[10] worked on geology and stratigraphy of India and has given an account of some geomorphic features in a Mannual of Geology of India.

S.M. Mathur (1960)[11] (1962)[12] has done work on the Bijawar and Vindhyan system at Panna area. He has given an account of

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8 Oldham, R.D. (1901) Geology of the Son Valley in Rewa State and Parts of Jabalpur and Mirzapur *Mem. Geol. Sur. Ind.*, Vol. 31, Part 1.

9 Johnson, W.D. (1939) 'Fault Scarp and Fault Line Scarp', *Jour. Geomorph*, Vol. 2.

10 pascoe, E.H., (1950), *A Mannual of Geology of India*, Govt. of India Publication.

11 Mathur, S.M., (1960) 'A Note on Bijwar Series in Eastern Parts of the Type Area Chhatrapur Dist. M.P., *Rec. Geol. Sur. Ind.* Vol. 86, Parts 31.

12 ______________________ (1962) Geology of the Panna Diamond Deposits', *Rec. Geol. Sur.* Ind. Vol. 87.

geology of Bijawar and Vindhyan system as well as geomorphic information regarding major features of these two systems.

W.D. West (1962)[13] has attracted the attention of scientists to the differences in stratigraphy on either side of the line of the Narmada-Son valley.

W.D. West and V.D. Chaubey (1964)[14] have studied the Erosion surfaces at various altitudes in Sagar Katangi area. They explained the origin of erosion surfaces in the context of geomorphology.

R.S. Dubey (1965)[15] (1968)[16] has also worked on erosion surfaces and some aspects of the geomorphology of Rewa Plateau.

M.F. Siddiqui (1966)[17] has done physiographic studies and attempted physiographic divisions of Bundelkhand.

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13 West. W.D. (1962) The Line of the Narmada-Son Valley', *Curr. Science*, Vol. 3.

14 West, W.D. and Chaubey V.D. (1964), 'The Geomorphology of the Country Around Sagar and katanfi, M.P. *Jour. Geol. Soc. India*, Vol. 5.

15 Dubey, R.S. (1965) 'Some Aspects of the Geomorphology of the Rewa Plateau in M.P., *Jour. of the Univ. of Sagar*, Vol. 14-16, Part-IIIrd, Section B.

16 ____________________ (1968) 'Erosion Surfaces of Rewa Plateau, M.P. India, *21st Int. Geog. Cong. Sci. Papers* Vol. 1.

17 Siddiqui, M.F. (1966) Physiographic Divisions of Bundelkhand, *The Geographer*, Vol. 13.

F. Dixey (1971)[18] has attempted to construct the geological successions of Madhya Pradesh and has attempted to investigate into geomorphological features by taking a few traverses and field work in Madhya Pradesh.

M.R. Shaha (1972)[19] has attempted to study the geomorphology and structure of Vindhyan and Deccan trap and investigated into the origin of these litho units. He has identified Vindhyan escarpments, outliers, water falls, cascades, caves as geomorphic features on Vindhyans and Deccan traps. He has also attempted to give explanations to the origin of relief of Vindhyan, trap and sedimentary structures.

H.S. Sharma (1970)[20] has identified three meso and eight micro level geomorphic regions of lower Chambal valley on the basis of structure, lithology, relief features and degree of dissection, slope and terrain peculiarity.

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18 Dixey Frank (1971) Geomorphology of Madhya Pradesh, India, *In Studies in Earth Sciences West Volume* (Ed.) T.V.V.G.R.R. Murty and Rao S.R., Today and Tomorrow's Printers and Publishers, New Delhi.

19 Shaha, M.R. (1972) Geology of the Rocks Around Rohatgarh Dist. Sagar, Unpublished Ph.D. Thesis, University of Sagar, Sagar.

20 Sharma, H.S. (1970) Micro-Geomorphic Regions of the Lower Chambal Valley, *Ind. Geog. Jour.* Vol. 45, Nos. 1 & 2.

V. Subramanyan (1975)[21] has studied the evolution of the landscape around sagar with the help of geomorphic analysis. He has identified different landforms in the study area.

V. Subramanyan (1978)[22] has carried out land system studies for resources evaluation around Sagar, Madhya Pradesh. He has studied fourteen thousand square kilometre tract around Sagar employing the methodology of the Commonwealth Scientific and Industrial Research Organization (CSIRO) Australia, using remote sensing technique and recognized the Vindhyan land system and Deccan Trap land system consisting of a number of small units like top, scarp, debris slope, pediments, gap, tors, hills, plains and valleys.

R.L. Singh and S.B. Singh (1979)[23] have done the comparative geomorphic study between Simla-Nainital and Jabalpur, Mirzapur applying various morphometric attributes viz. relative relief, dissection index, drainage texture and average slope in identifying different landforms covered under

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21 Subramanyan, V. (1975) Evolution of Landscape Around Sagar, M.P., *Proceedings of the Indian National Science Academy*, Vol. 41, Part A, No. 6.

22 Subramanyan, V. (1978) Land System Studies for Resources Evaluation - A Demonstration Around Sagar Madhya Pradesh, PHOTONIRVACHAK, *Jour. Ind. Soc. Photo-Int.* Vol. VI, No. 1.

23 Singh R.L. and Singh, S.B. (1979) Morphometric Evaluation of Terrain and morphometric Mapping in Different terrain Type Area of India, *Nat. Geog. Jour. India*, Vol. 25, Part 3 & 4.

different environments. The maps of these attributes have been superimposed on a single frame to demarcate morpho-units in the hierarchical order. They have, concluded that three attributes viz., relative relief, dissection index and average slope are helpful in identifying the major landforms in the young Himalayan terrain.

R.S. Murthy, S.N. Deshmukh, Raj Kumar and R.K. Saxena (1980)[24] have studied the soil physiographic relationship using aerial photographs and identified different physiographic units and sub-units and their associated soils in Chhatarapur district, Bundelkhand region of Madhya Pradesh.

Salean Santhosh Kumar (1982)[25] has studied landsat imagery for deriving geomorphic indicators of ground water in parts of Central India. He has worked out different litho-units, lineaments, drainage density, major soil categories, major landuse categories and ground water potential for pediplain province consisting of residual hills, linear quartzitic reefs, piedmont zone, shallow buried pediment under black soils and

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24 Murthy R.S. et al (1980) Soil Physiographic Relationship Studies by Using Aerial Photographs in Chhatarpur District, Bundelkhand Region, Madhya Pradesh, *Proceedings of Seminar on "Application of Photo-Interpretation and Remote Sensing for natural Resource Survey and Environmental Analysis"*, IPI, Dehradun.

25 Salean Santhosh Kumar (1982) Land Sat Image Derived Geomorphic Indicators of Ground Water in part of Central India, PHOTONIRVACHAK, *Jour. ind. Soc. Photo-Int. & Remote Sensing*, Vol. 10, No. 2.

buried pediments, under valley fills.

Sita Ram, Pofali, and Swaminathan, (1982)[26] have studied sedimentary, metamorphic and basaltic formations for land resources appraisal of East Nimar district, Madhya Pradesh. They have delineated the landforms on the respective formations.

The hilly terrain of basaltic origin located in comparatively low rainfall zone having sufficient water and soil resources potential could be utilized for agricultural development of the inter hilly basin, and undulating plains also have good potential for forestry and silviculture. The basaltic undulating plains have potentiality for the development of social forestry, pasture activity and agriculture.

Ashok Arunachalam (1983)[27] has studied the structural landforms, slopes , drainages, processes and evolution of the Deccan trap using landsat imagery. The study reveals that basalts are horizontally deposited through most of the provinces but attain dips at places. The entire volcanic province represent four major geomorphic units namely plateaus, hill

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[26] Sita Ram, Pofali R.M. and Swaminathan M. (1982) "Photographic Interpretation of Sedimentary, Metamorphic and Basaltic Formations for land Resources Appraisal of East Nimar District, M.P." *Proceedings of Symposium on Resources Survey, Land use Planning and Environmental Conservation*, IPI, Dehra Dun.

[27] Arunachalam Ashok (1983) 'Geomorphology of the Deccan Trap Provinces', *Unpublished Ph.D. thesis*, Indian Institute of Technology, Bombay.

ranges, river alluvial plains and coastal plains. Dendritic, trellis, rectangular, radial, annular and deranged patterns are developed over the area. The evolution of the volcanic province has been traced.

A. Bhattacharya (1983)[28] has demonstrated that the distinctive landform is the result of lithology, structure and climate, which subsequently give rise to a particular type of landuse pattern. A marked influence of geology and geomorphology in controlling the landuse pattern has also been noticed.

A.M. Rakshit (1983)[29] has mapped Vindhyan and Deccan trap terrain using Photo-interpretation techniques. The structural hill comprising linear strike ridge with alternating valleys of sand stone and intervening shale and lime stone; low mounds, hummock and arcuate hills of folded beds; plateaus of horizontally disposed sand stone; denudational hills comprising of plateaus, benches and steps of horizontally bedded trap flows; lobate conical and rounded hills of vesicular lavas; and low lying surfaces with shallow depressions comprising of undulating plains on sedimentary rocks; undulating plains on

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[28] Bhattacharya, A. (1983) "Geologic and Geomorphic Controls in Landuse Pattern-Examples Using Remote Sensing Techniques", 'PHOTONIRVACHAK', *Jour. Ind. Soc. Photo-Int. and Remote Sensing*, Vol. 11, No. 3.

[29] Rakshit A.M. (1983) "Capability of Photo-interpretation Methods for Mapping of Vindhyan and Deccan trap Terrain - A case study from Jhalanawar Area, Rajasthan", 'PHOTONIRVACHAK', *Jour. Ind. Soc. Photo-Int. and Remote Sensing*, Vol. 11, No. 2.

Deccan traps and fluvial depositional surfaces comprising of flood plains, slope wash deposits are the landforms identified with the help of photographs in Vindhyan and Deccan trap country.

V.R. Rao et al (1983)[30] have made attempt to use remote sensing techniques in forecasting and assessing the damage due to different disasters in India.

L.R.A. Narayana et al (1986)[31] have devised a scheme of waste land mapping in India. They studied 190 land sat False Colour Diapositives Covering entire country of the period 1980-82, on 1 : 1 million scale based on image characteristics supplemented with sample ground check and topographic maps. The different types of waste lands thus, identified and delineated were transferred into 18 separate state maps (on 1:1 million scale) and finally all India map on 1:3.5 million scale.

R. Satyanarayan Rao (1986)[32] has studied ground water resources evaluation in Chambal river basin using Salyut-7 photographs. He has delineated geological, geomorphological

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30 Rao V.R. et al (1983) *Disasters in India : Can Remote Sensing Do Something*, ISRO, Bangalore.

31 NNRMS Bulletin, ISRO, Banglore.

32 R. Satyanarayan Rao (1986) 'Ground Water Resources Evaluation in Chambal River basin using SALYUT-7 Photographs' *Results from the joint Indo-Soviet Remote Sensing Experiment TERRA Onboard Salyut-7*, ISRO, Banglore.

units and structures using different band composition. He has also identified wind blown sand, river alluvium, older alluvium, sand stone, shale, quartzite, schists and granites as litho units; and fractures, faults, trend lines and folds as structural forms. The study area has been divided into a number of provinces such as Aravali hill province, Vindhyan Plateau, Fluvial plain, Fluvio-aeolian and aeolian provinces. He has also identified a number of landforms like strike ridges, inter ridge valleys, Pediment, Relict hill, Dissected plateau, Rocky exposures, Flood plains and aeolian plain etc. and recommended that TERRA data can be used for evaluation of ground water and geomorphology like any other remotely sensed data.

K.S. Meera (1988)[33] has mapped landforms and geomorphic processes in kalimachak river basin a tributary of Chhota Tawa river, using remote sensing technique to demonstrate the structural control on landforms and processes. She has identified and mapped different structural landforms, lineament and general landuse in the basin.

Surendra Singh (1992)[34] has studied geomorphology of

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33 Meera, K.S. (1988) "Application of Remote Sensing Techniques in Identifying the Structurally Controlled Landforms and Geomorphic Processes of Kalimachak River basin (Sub-Basin of Narmada)", *M.Phil dissertation (Unpublished)* Jawaharlal Nehru University, New Delhi.

34 Surendra Singh (1992) *Geomorphology and Remote Sensing in Environmental Management*, Scientific Publishers, Jodhpur.

Jodhpur district using remote sensing technique. He has attempted the survey of natural resources including landforms, soils, vegetation, water resources and landuse. Environmental problems of Jodhpur district have been investigated and suggestions have been made to over come natural hazards. Potential landuse of different landforms has been suggested along with the management and assessment of natural resources.

I.2 Geographical Personality of the Study Area :

In the study area, land units, landforms, processes and landuse are influenced by physical setting of the Chhota Tawa river basin. The main factors of physical setting which control, determine and influence the development and formation of land units, and landforms are physiography, relief, climate, soil, flora and fauna. The same factors also control and influence landuse pattern. It is imperative to study these factors for the proper understanding of geomorphological processes, landforms, land units, material and landuse pattern in the study area.

I.2.1 The Study Area - Location and Extent :

The study area, Chhota Tawa river basin, a left bank sub-basin of Narmada, spreads over 5051 square kilometre. It is located between 75° 50′ and 77° 15′ E longitudes and, 21° 25′ and 22° 19′ N latitudes spreading over 15 survey of India topographical sheets on scale 1 : 50,000 (Fig. I.1). The study area comprises of parts of Harsud, Khandwa and Burhanpur tahsils

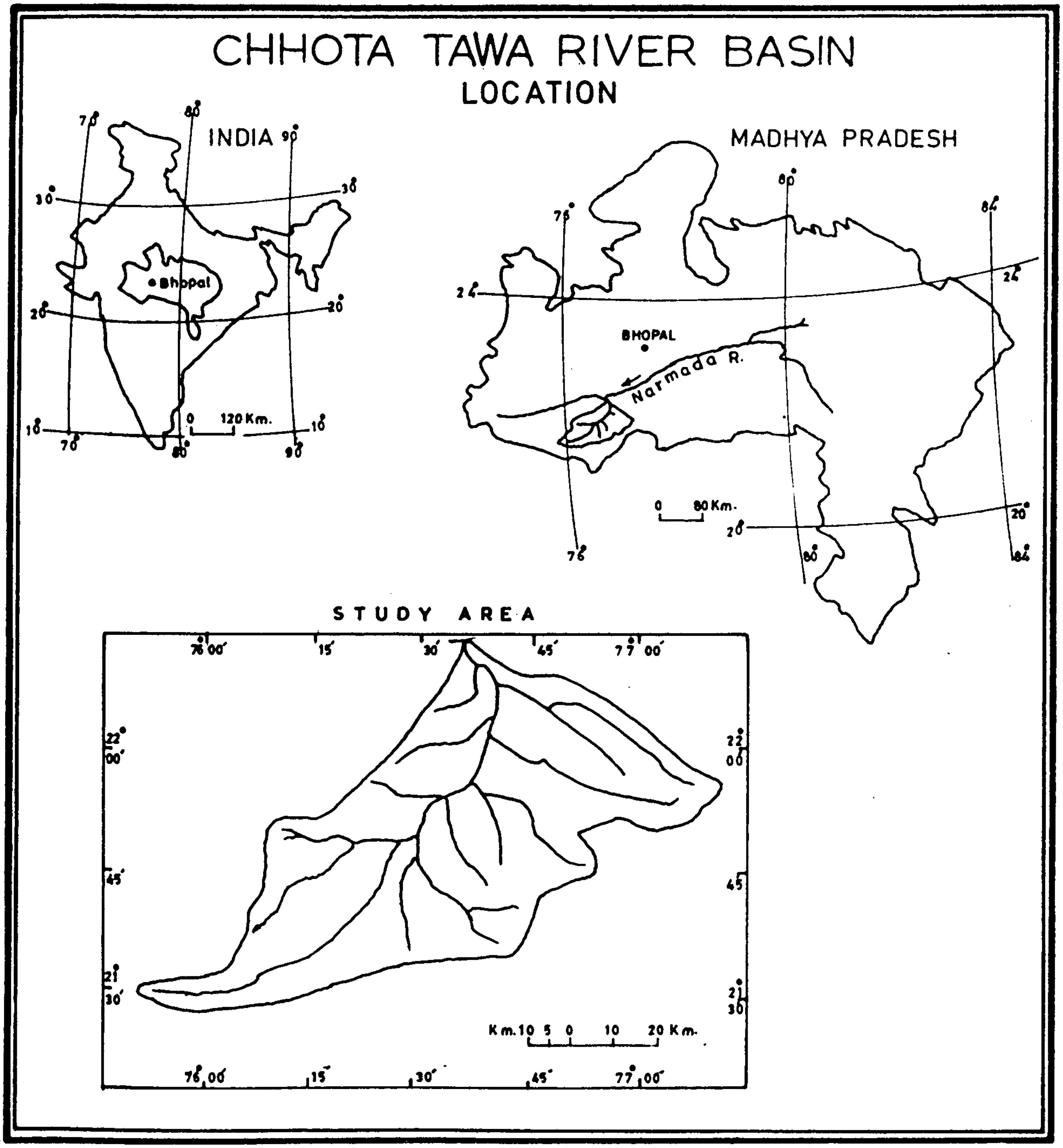

CHHOTA TAWA RIVER BASIN
LOCATION
INDIA
Bhopal
0 120 Km.
MADHYA PRADESH
BHOPAL
Narmada R.
0 80 Km.
STUDY AREA
Km.10 5 0 10 20 Km.

Fig. I-1

of West Nimar district; Bhikangon tahsil of East Nimar district and Harda tahsil of Hoshangabad district.

The aerial photographic coverage of an area along Central Railway tract in the central part of the basin was not available. The boundaries of land units and landuse classes are extrapolated with the help of topographical maps of 1 : 50,000 scale. At places it was not possible to infere the boundaries of land unit and landuse, so these areas have not been extended on the base map.

I.2.2 Physiography and Relief :

In the present section an attempt has been made to study the physiography and relief of the Chhota Tawa river basin, in brief, which could be useful to comprehend the processes, land units and landuse pattern.

The Chhota Tawa river basin has triangular shape with apex to confluence and base to source and occupies 505,1 square kilometre area on the northern slope of Satpura. This river is formed by the confluence of the three streams of Abna, Sukta and Bhan near Bhamgarh and joins the Narmada after a course of 51.5 kilometres, flowing south to north through the Harsud tahsil. The Chhota Tawa rises in the Satpura range in the West Nimar district of Madhya Pradesh near Kakora village at an elevation of 800 metres at the junction of 20° 30′ N. latitude and 75° 52′ E longitude. It flows for a total length of 169 kilometres in northerly direction to join the Narmada from the left, north of Purni village. Tawa signifies the flat bed of the river like a iron pan on which bread (chapati) is cooked. The tributaries of the river are the Agni, the Pipar, the Gangapat, and the Kala Machak on the right bank and Kharkhari and another Pipar on the left bank (Fig. I.2).

Abna river originates from Rajpura in the south west of the Khandwa Tahsil. It flows in an easterly direction through the Khandwa tahsil, passing within 1.6 kilometre of Khandwa town. The railway line of central railway crosses the river.

Sukta rises in the Satpura and enters the Burhanpur tahsil at its north-western boundary. After traversing for about 24.1 kilometres it enters the Khandwa tahsil near Kalana and turns to the north. It is joined by Abna near Kupasthal, and thence flowing north east falls into the Chhota Tawa near Selda.

The western half of the upper Chhota Tawa valley around Khandwa is a plain country with very fertile soils (Fig. I.3 & I.4). Once the streams leaves the chain of hills fringing in the south, west and north, it passes through an open country without any significant hills, though the surface is undulating. Minor rivers with banks covered with natural vegetation alternate with broad divides in this part.

The eastern half of the upper Chhota Tawa valley is bordered by the Satpuras in the southwest which in this part

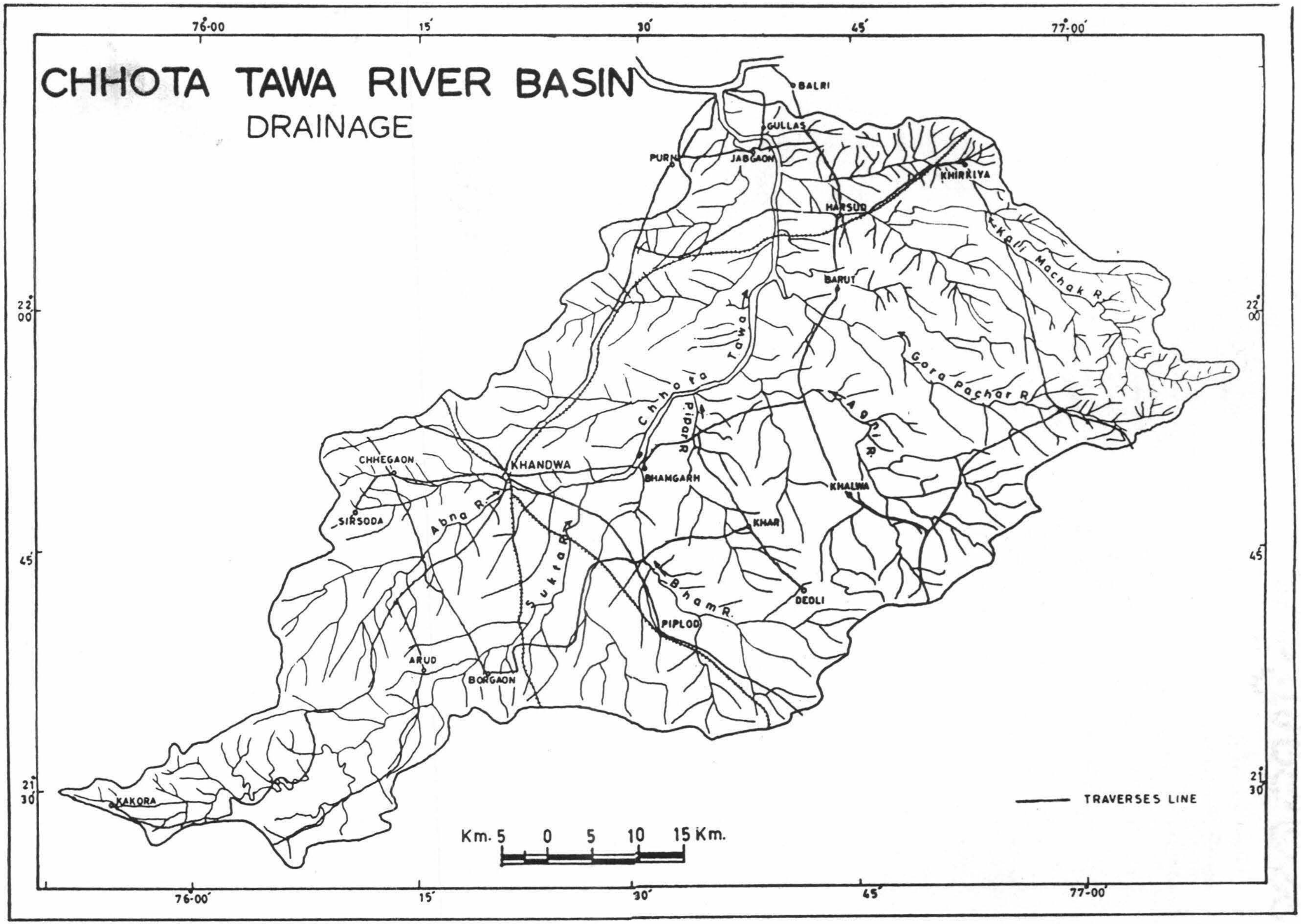
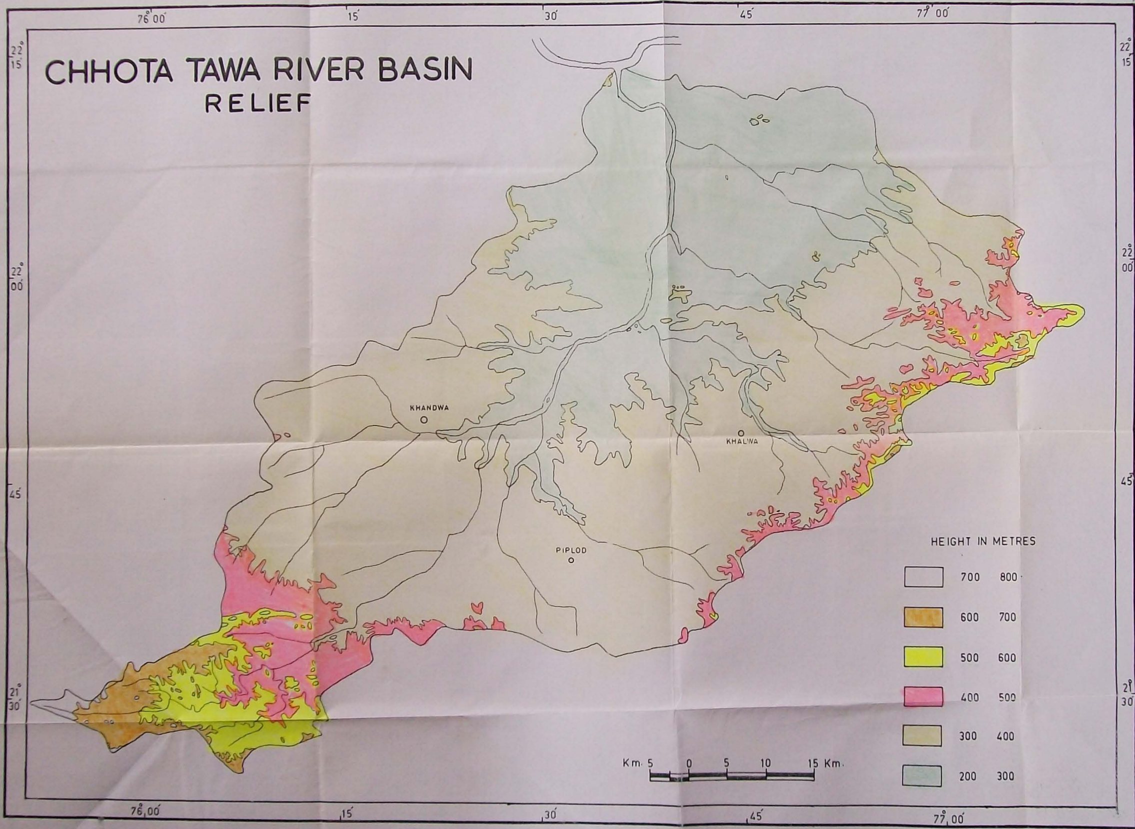

CHHOTA TAWA RIVER BASIN
DRAINAGE
76°00'
15'
30'
45'
77°00'
22° 00'
45'
21° 30'
BALRI
GULLAS
PURNI
JABGAON
KHIRKIYA
HARSUD
BARUT
Kali Machak R.
Gora Pachar R.
Chhota Tawa
Pipar R.
Agni R.
CHHEGAON
KHANDWA
BHAMGARH
SIRSODA
Abna R.
Suktar R.
KHALWA
KHAR
Bham R.
DEOLI
PIPLOD
ARUD
BORGAON
KAKORA
TRAVERSES LINE
Km. 5 0 5 10 15 Km.

Fig. I-2



CHHOTA TAWA RIVER BASIN
RELIEF
76°00'
15'
30'
45'
77°00'
22° 15'
22° 00'
45'
21° 30'
KHANDWA
KHALWA
PIPLOD
HEIGHT IN METRES
700 800
600 700
500 600
400 500
300 400
200 300
Km 5 0 5 10 15 Km.

Fig. I-3

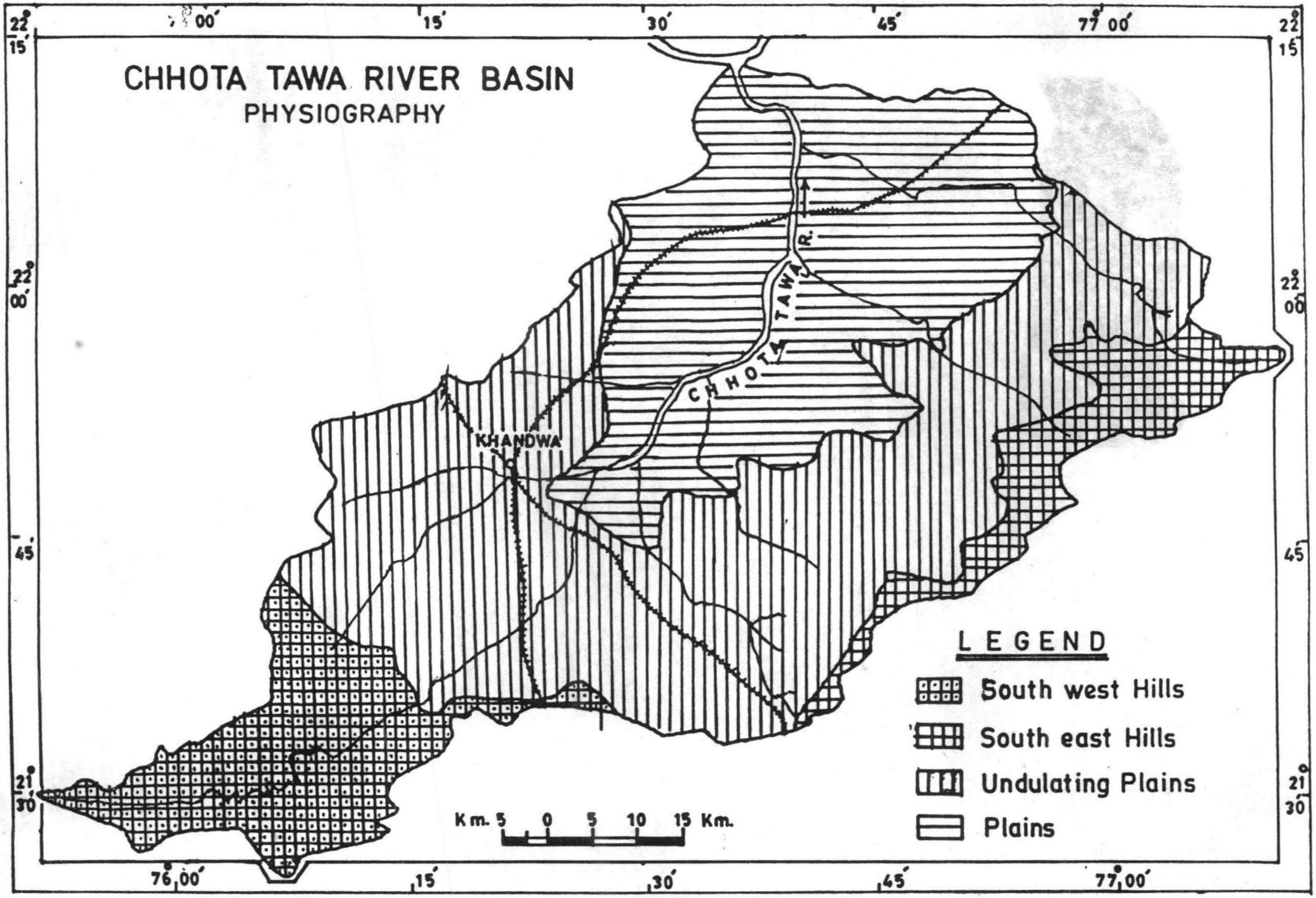

CHHOTA TAWA RIVER BASIN
PHYSIOGRAPHY
CHHOTA TAWA R.
KHANDWA
LEGEND
South west Hills
South east Hills
Undulating Plains
Plains
Km. 5 0 5 10 15 Km.
76°00′
15′
30′
45′
77°00′
22°15′
22°00′
45
21°30′

Fig. I-4

extend roughly in the direction from southwest to northeast. This area, south and east of Chhanera upto foot hills is hilly and much cut up by the channels of the meandering rivers and streams. Spurs of the Satpura extend towards the north west and gradually lose height between the streams. This part is mostly rocky with thin soils in the depressions. The thick forests cover the slope of the Satpuras, the foot hills and the lower valley of the Agni river. Forests with less economic value abound throughout the area. Some patches in the forest have been cleared for cultivation and have given rise to interspersed villages.

The lower Chhota Tawa valley is not a level plain through out since spurs and out-crops of the Satpura appear right upto the confluence of Chhota Tawa with Narmada. The hills and forests abound in most parts of the western bank of the Chhota Tawa river (Fig. I.4). East of Chhota Tawa river, the area around Harsud and khandwa is undulating and is covered with black soils of uneven thickness. Stretches of deep soil deposits in the depressions make good wheat lands. As one proceeds from here towards the Hoshangabad district boundary in the east, the relief becomes sharper and accentuated and soils poorer and lighter.

The general geology of the area is represented by traps, Vindhyans and alluvial deposits. Deccan trap covers the largest portion of the catchment area of Chhota Tawa river. At the

THESIS
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TH-5030

confluence of Chhota Tawa with Narmada, upper Vindhyans are found. Thus, there are three main geological formations viz; Deccan trap, Upper Vindhyan and Bijawar systems, which are found in the basin of Chhota Tawa river. Alluvial deposits are found wherever there is a stream. The surface soils are usually described as black cotton soil or regur. The soils covering high lands are so shallow that these are incapable of bearing crops or any thing better than the growth of scrub vegetation which is generally found on it. In low lying lands along the beds of stream, the soil reaches a fair depth while a few stretches of cultivated land occur on the Khandwa plain.

I.2.3 Climate :

Relief depends upon climates almost as much as on lithology. Climate exerts profound impact on geomorphic processes. Under a certain set of climatic conditions particular geomorphic processes dominate and give rise to landscape of an area which are different in their characteristics from those landscapes developed under different climatic conditions. climatic parameters of rainfall, temperature, wind velocity and moisture exercise profound influence on landform assemblage of an area through processes which shape them. Climate also affects the development of agriculture and choice of landuse either directly or indirectly through the influence on soil and groundwater. Climate is the most potent factor in arid and semi arid region. It would, therefore, be worthwhile to analyse the important climatic variables which control the processes, landform, land unit and landuse. Where moisture is deficient, a different balance exists in the process of denudation and landform which are characteristics of arid areas. The transition from humid to arid climates is not sudden, on the other hand there exists many intermediate stages. The area under investigation falls under one such intermediate stage and can be classified to have semi arid tropical climate.

As mentioned above, the area experiences semi arid climate characterised by extreme climatic conditions during summer and winter months with appreciable differences in diurnal temperatures. It is marked by high temperatures throughout the year and exhibits a wet and dry season annually. The wet season in semi-arid climate is much shorter in duration; the rains are higher and often irregular. During the greater part of the year, the weather is hot, dry and often dusty. The rains during the wet season occur in the form of the sudden heavy thunder showers, interspersed with short spell of fair weather. The essential feature of these types of climates is that potential evapotranspiration from soil and vegetation exceeds the average annual precipitation. As a result of rainfall deficiency there is no surplus of water with which to maintain a constant ground water supply. There are no permanent stream within such areas. It may be possible, however, for stream to cross them, provided they have their source in more humid areas. In such climatic zone, increasing aridity is marked by a gradual deterioration in the vegetation cover from poor grass land and scrubs with some patches of rock or soil through a wide variety of semiarid plant communities. The year may be conveniently divided into the following three principal seasons :

1. November to February - Cold Weather Season
2. April to June - Hot Weather Season
3. June to August - Rainy Season

The cold weather season commences in December and continues till the end of February. It is characterised by bright cloudless days and clear night and piercing winds. Frost is known to occur occasionally, hail too is uncommon. There is slight precipitation in the basin during these seasons.

The hot weather starts in March and continues upto middle of June. May is usually the hottest month. This season is generally dry except for occasional thunder storms.

The south-west monsoon sets in by the middle of June and withdraws by the first week of October. June to September are the rainiest months. During this season, the weather is somewhat sultry and opperessive especially in October. Therefore, the weather clears up and dry pleasant weather prevails through out the valley.

(i) Temperature : The Khandwa observatory records the month of May as the hottest months with ever recorded Maximum of 47.2°c[1].

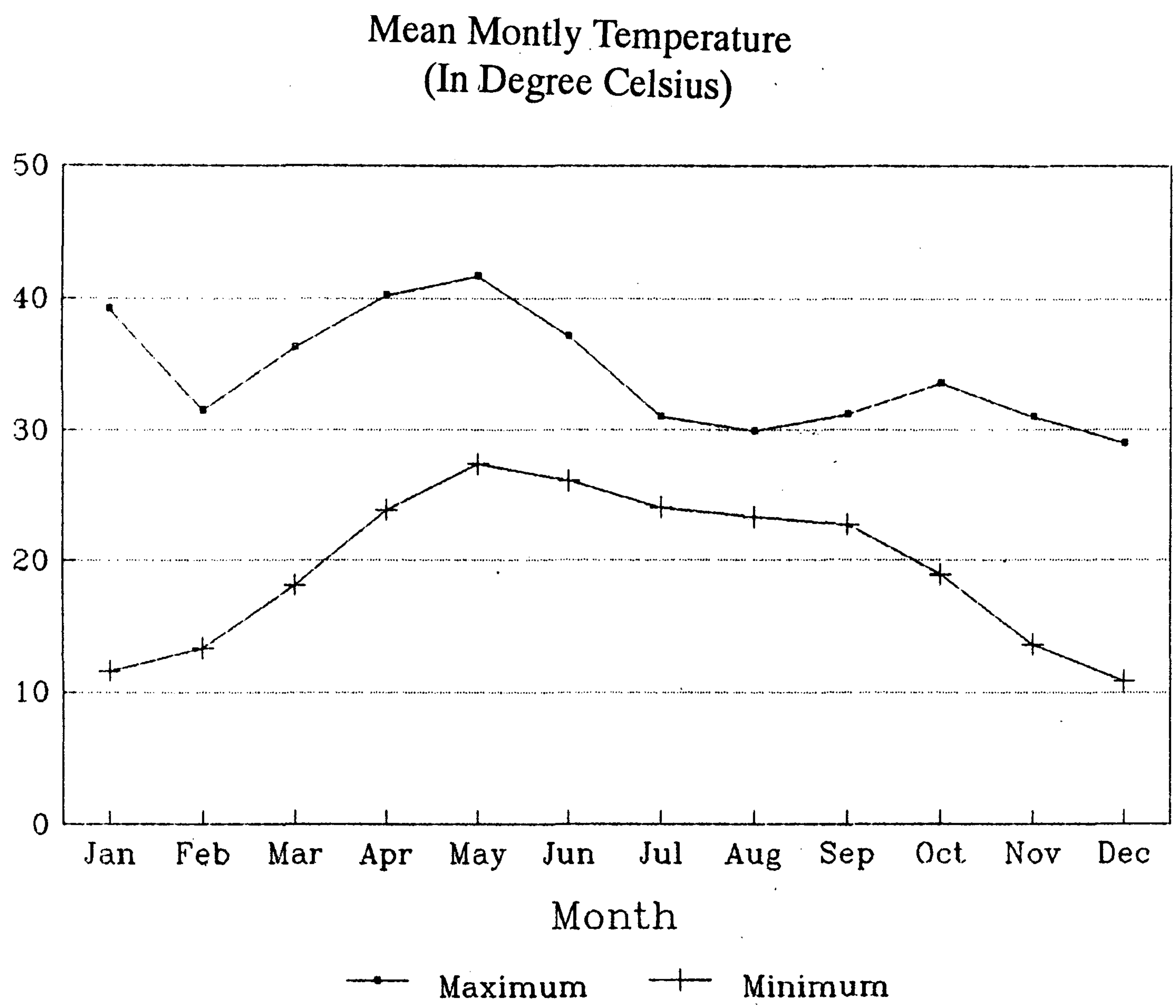
TABLE-I.1

MEAN MONTHLY TEMPERATURE

Month	Mean Monthly Maximum Temperature (in degrees Celsius)	Mean Monthly Minimum Temperature (in degrees Celsius)
1	2	3
January	39.2	11.6
February	31.5	13.3
March	36.3	18.1
April	40.2	23.8
May	41.7	27.4
June	37.2	26.1
July	31.0	24.0
August	29.9	23.3
September	31.2	22.7
October	33.6	18.0
November	31.0	13.6
December	29.0	10.9
Annual	33.5	19.5

Source: Gazetteer of District East Nimar of M.P. 1969.

It is evident from Table I.1 that the December is the coldest month of the year and the lowest fall recorded up to 6°c[2]. The average temperature in May is 34.6°c and in December 19.9°c. The range of day and night temperatures is low during the winter season and high during the rainy season. The graph in fig I.5 shows the


Mean Montly Temperature
(In Degree Celsius)
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Maximum
Minimum

trend of temperature in a year. Since the study area falls in tropical semi-arid climate marked by extremes of temperature, the winter is quite cold on the other hand, the heat during the summer is intense and scorching. Owing to the dryness of the atmosphere and the nature of the soil and lack of vegetation, the change of temperature from day to night is sudden. Details of the temperatures are given in Table I.1.

(ii) Rainfall : There are five rainguage stations in the study area. Data for five stations has been collected and presented in Table I.2. It is seen from the Table I.2 that the annual rainfall in the region varies from 818 to 987 mm.

It is obvious that the rainfall is very unevenly distributed over time. About 60 to 75 per cent of the rainfall occurs during the rainy season. It is seen from Fig. I.6 that the trend of the rainfall is almost the same for all the five stations. Hot and cold weather seasons receive very little rainfall. There are large fluctuations in the rainfall during hot and cold weather seasons. July is the rainiest month with the highest number of rainy days. the monsoon advances into the study basin around 10th of June and withdraws by the beginning of the October.

TABLE-I.2

NORMAL RAINFALL (in mm)

Month	Khandwa-I	Burhanpur	Harsud	Khandwa-II	E. Nimar (District)
1	2	3	4	5	6
January	8.6	9.7	9.9	7.1	8.8
February	5.6	6.1	5.3	4.1	5.3
March	4.8	3.5	5.3	2.3	4.0
April	2.0	1.5	1.3	1.0	1.5
May	8.1	8.9	9.1	11.2	9.3
June	135.4	148.8	136.4	131.8	138.2
July	267.5	231.9	338.6	292.3	282.6
August	116.4	162.1	235.7	222.3	196.6
September	147.3	185.4	179.1	168.8	168.6
October	38.3	32.3	34.3	31.7	33.9
November	27.2	22.9	23.9	18.0	23.0
December	7.4	10.9	7.9	6.3	8.1
Annual	818.6	824.1	987.3	889.9	880.0

Source : Gazetteer of District East Nimar, M.P. 1969.

(iii) Mean Relative Humidity : Data pertaining to mean relative humidly is available for Khandwa station only. The mean relative humidity at Khandwa at 8:30 and 17:30 IST is given in Table I.3. It is evident from Table I.3 that mean relative humidity is lower at 17:30 than 8:30.

Normal Rainfall
(In mm)

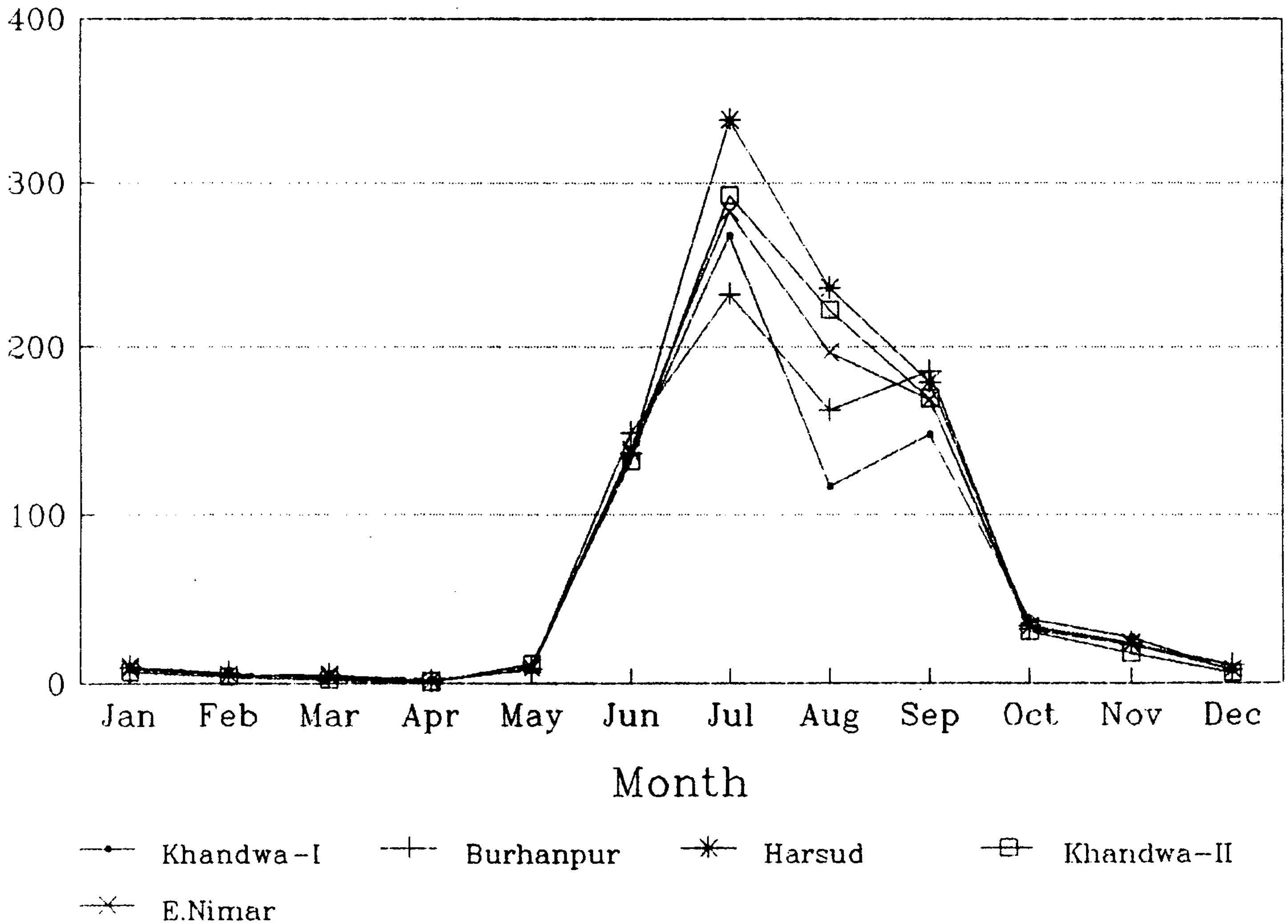


TABLE-I.3

MEAN RELATIVE HUMIDITY
(IN %)

Month	0830	1730
1	2	3
January	57	32
February	45	23
March	33	15
April	28	14
May	40	18
June	65	45
July	81	73
August	83	72
September	81	67
October	62	39
November	58	32
December	60	31
Average	58	38

Source : Gazetteer of District East Nimar, M.P. 1969.

It is evident from the Table I.3 that the relative humidity during dry months, i.e. April to June is about 48 per cent while during monsoon period it is about 81 per cent. Fig. I.7 shows considerable fluctuations in the relative humidly over time. Except rainy season the relative humidity is generally low. In summer months it is as low as 10 per cent.

(iv) Wind Velocity: The mean wind velocity is being recorded at Khandwa observatory. It is given in Table I.4.

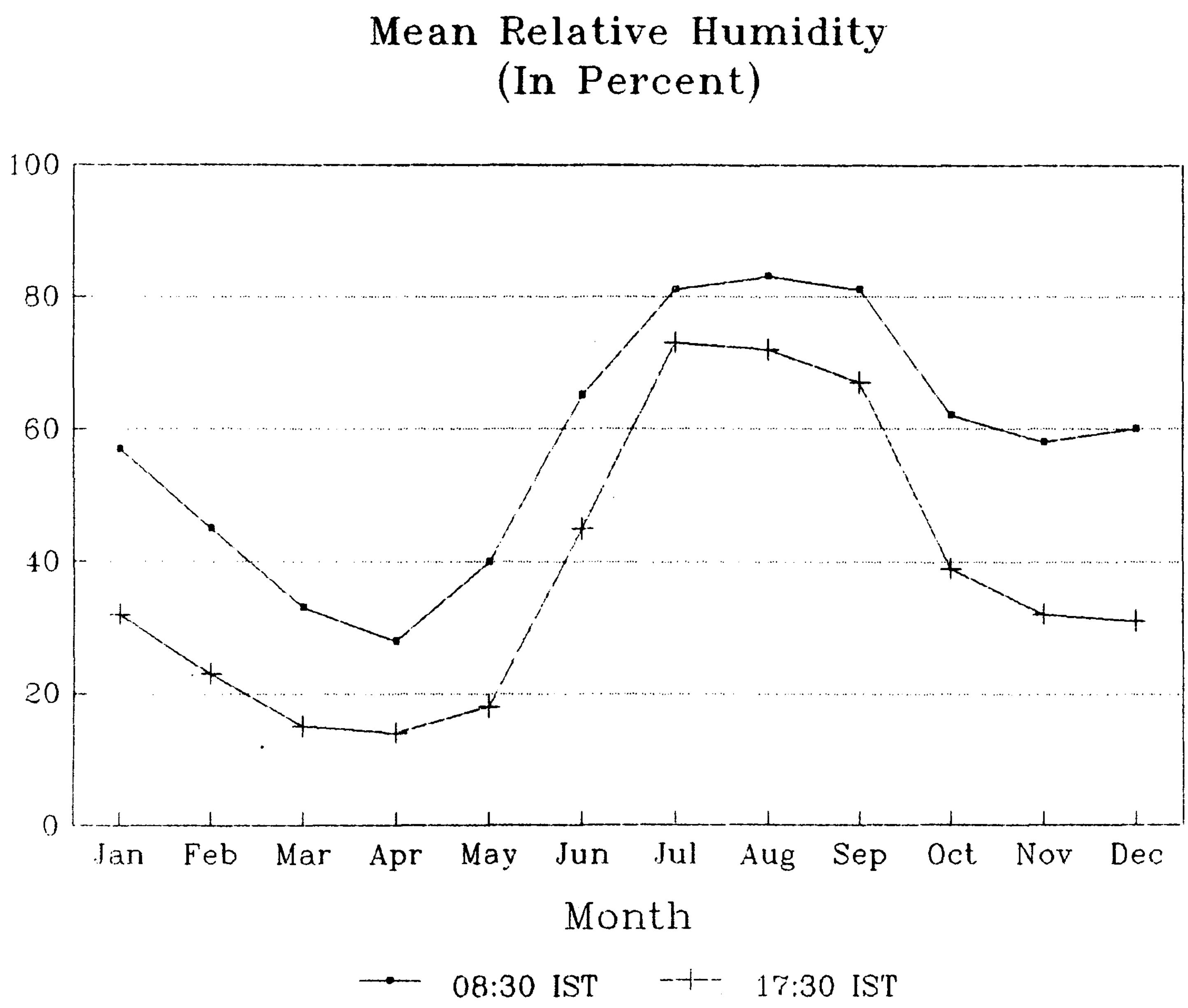

Mean Relative Humidity
(In Percent)
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
08:30 IST
17:30 IST

TABLE-I.4

MEAN WIND VELOCITY

Month	Mean wind velocity
1	2
January	4.5
February	5.6
March	6.6
April	8.6
May	13.0
June	13.4
July	12.1
August	11.1
September	8.2
October	4.3
November	3.7
December	3.7
Average	7.9

Source : Gazetteer of District East Nimar, M.P. 1969.

The mean wind velocity is 13.4 kilometres/hour. The highest is recorded in June while the lowest in November and December. Hot winds, which strengthen with the advance of the summer season, blow steadily from directions between west and north-west. During the monsoon season the winds blow from SW and NE.

I.2.4 Soils :

The character of the country varies considerably from place to place. In Harsud it is more broken than the rest parts and the soil is generally shallower. In Khandwa tahsil, the surface is generally undulating but there are stretches of excellent soils in the depressions. Generally speaking, the disintegrated trap forms the parent material of all soils in the area. The surface soil lies over trap rocks and varies in depth from a few centimetres on the top of ridges to 1 to 1.5 metres and some times even 4 metres in the valleys. The soils are regur. The soil covering on high land is very shallow. On the higher lands it often has a sprinkling of boulders over its surface. As a rule, this surface soil lies directly over the trap rock but in some of the larger valleys there are deposits of yellow sandy alluvium between them. In some of the smaller valleys, th yellow sub-soil is not found at all, but wherever it exists, it varies from a few centimetres on the higher ground to from 100 to 125 centimetres at the bottom of the largest valleys and is sometimes itself the surface soil near the banks of large rivers. As it lies over rock or a sandy sub-soils surface soil is well drained. the alluvial deposits are to be found almost every where there is a stream.

I.2.5 Flora and Fauna :

The Chhota Tawa river basin is densely covered by natural vegetation at places. The forests found in the basin belong to the southern Dry Deciduous types of the Indo-African botanical divisions. In addition, there are small patches of forest scattered all over the basin in the village area. The areas devoid of natural vegetation of big tree species are the Khandwa plain owing to a heavy impact of human influence through the clearance of vegetation for agricultural purposes and for meeting domestic needs. On the hill ranges of Satpura and the sandstone hill at the confluence, there are forests of teak, sal, salai and mixed. Vindhyan soils are mostly sandy and arenaceous with the result that Vindhyan terrain at places is mostly barren and devoid of vegetation. Only some skeletal trees and xerophytic types of plants and bushes are seen over the Vindhyans. On the contrary, since the deccan, trap soil is very fertile, it holds up water and supports good luxuriant vegetation. Teak and sal trees with their abundant green-brown leaves forming a canopy 7 to 8 mtere above the ground are characteristic of Deccan trap terrain resulting in thick forest in the Chhota Tawa river basin (Photo No. 17).

The area is not of much interest with regard to wild life. The fauna comprises mostly of deers, jackals, monkies, hyena, and pigs etc.

I.3 Objectives :

The main objective of the present study is to identify and delineate geomorphic units and examine the relationships between the land units and landuse pattern. On the basis of such understanding, it is further aimed to suggest the potential landuse for sustainable development in the study area. This has been viewed in the light of the following specific objectives:

i) to obtain the basic information from aerial photographs, Landsat Images, toposheets and supplemented with field work on different aspects of geology, geomorphology, soil, current landuse, their capabilities and management of land resources in the study area,

ii) to get better insight into nature of landforms, drainage, slope and processes that have developed present terrain in the Chhota Tawa river basin,

iii) to delineate land units and landforms which are the results of processes,

iv) to map the terrain of the study region geomorphologically and to find variations in land units, as well as in their morphology and surface materials,

v) to identify different elements of geomorphic processes which, through their variations, make land units different from one another,

vi) to attempt the geomorphic evaluation of the study area on the basis of the data so collected,

vii) to identify the different natural hazards on the basis of the intensity of the processes,

viii) to delineate and map different landuse classes,

ix) to identify the regional problems resulting from the anthropogenic interaction with the environment,

x) to prepare a zonal map for landuse planning according to the developmental policies,

xi) to correlate geomorphic units and processes with landuse.

xii) to suggest the optimum landuse for each defined land unit for future taking into account both physical and socio-economic considerations of environmental resources.

I.4 Data Base

Both secondary and primary data was collected and used in the present study.

I) Secondary Sources of Data :

Aerial photographs, toposheets and Landsat images were chief tools used as secondary sources for this study besides the geological reports.

(a) The following topographical sheets of survey of India have been used,

Toposheets	Scale
46 O, 55 B, C, F, & G	1 : 250,00
46 O/14,15;	1 : 50,000
55 B/8,12, & 16,	1 : 50,000
55 C/1,2,3,5,6,9,10,13,14	1 : 50,000
55 F/4, 55G/2	1 : 50,000

(b) Black and white aerial photographs numbering 200 on an approximately 1 : 50,000 scale,

(c) Landsat images on band 5 and 7 (black and white) and False Colour Composite (FCC) on scale 1 : 250,000,

(d) Geological Survey of India's report, Geological Memoirs; Soil Reports and climatic data collected from gazetteer of the East Nimar, West Nimar and Hoshangbad districts of Madhya Pradesh.

II) Primary Sources :

The primary data was collected through field traverses in the study area to make note of landuse, land units, processes, materials, hazards and problems.

I.5 Methodology :

All aerial photographs numbering 200 on an approximate scale of 1 : 50,000, 15 topographical sheets of Survey of India, on the same scale and Landsat imagery (black and white in band 5 and 7 and FCC on 1 : 250,000 scale) were systematically studied and interpreted for the collection of basic information regarding land units, landforms, surficial material slope and landuse. The study was carried out in three stages as described below :

I.5.1 Prefield Investigation :

Prefield investigation commenced with the consultation of available literature and scanning of aerial photographs. Land classification system slightly modified from one, described by Commonwealth Industrial and Scientific Research Organization (CSIRO), Australia, was applied to identify land units/landforms in Chhota Tawa river basin. CSIRO employed hierarchical spatial classification but in the present study a detailed qualitative non-hierarchical classification has been employed. In the classification, landscape approach combined with parametric approach was employed to give a comprehensive insight into the nature of terrain. Landunits have been described using the form process approach. The forms have been explained through the processes and so the processes operating in the study area are analysed and understood. The study area has been divided into different landunits and different mappable landforms have been identified and mapped.

The aerial photographs, toposheets of scale 1 : 50,000 and Landsat images (black and white and FCC) covering the area were examined and attempt was made to demarcate the boundries of various land units, landforms and landuse patterns.

An uncontrolled mosaic of alternate aerial photographs of study area was laid down on the table. Annotations with the help of Survey of India topographical maps were carried out on the photographs. The boundaries of major geomorphological and geological units and structural details had been demarcated in different convenient colours and line symbols by scanning the photographs under mirror stereoscope on the tracing paper. On completion of this task, the different strips of tracing paper pertaining to different runs were converted into mosaic and all the details were transferred onto a sheet of tracing paper. The legend of map using ITC symbols was also prepared. Light prints of the transparent negative was obtained and nineteen geomorphic units were demarcated and shown in colours and shades. Geological details like lithounits and structural features such as fault, folds, dip and strikes, were obtained by studying aerial photographs and imagery on Image Analyser and were transferred onto the geomorphological map. Thus, first base map depicting land units, lithounits and structural features was ready for the field check to incorporate the correction and addition of data.

The major landuse categories were demarcated in convenient colours and shades by scanning the aerial photographs under mirror stereoscope, and aerial photographs and imagery on Image Analyser by attempting the density slicing technique in which areas of identical reflectance were classified and grouped into twenty classes on another tracing sheet and a separate landuse map was obtained by similar method adopted for obtaining the geomorphological map. Thus, the landuse map was also ready for the field verification and checks to incorporate the corrections and additions of information obtained from field. The description and identification of soils were done based on tonal variation in photographs and images on Image Analyser taking into account the association of landforms, processes, lithounits with soils.

I.5.2 Field Work :

Observations through the field work play an important role in the geomorphological study of a region. Observations are made to check the results obtained in the pre-field interpretation in laboratory with the help of aerial photographs, images or toposheets and other material on the ground. In some cases a deviation between the interpreted results in pre-fields and observed results in field can lead to a modification in the pre-field results and a closer approximation to the actual conditions which the field represents.

The pre-field was followed by field work in area under investigation with an objective to check interpreted details and to incorporate additional information as suggested in pre-field work. The field investigation consisting of traverse lines was carried out in study area twice during the study period. Fig. I.2 shows traverses taken during field work. It also included general recconnaitory survey in the area, demarcation, confirmation and correction of land units, lithounits and landuse boundries. The selective field checks at ninty key areas were made and modifications were incorporated where ever necessary. In order to have an overall idea of ground water regime in the study area, well observations at selective points were made. In order to build up the overall structure of area, data on dips and (Fig. land unit map) strikes was collected at places. Brief notes were recorded regarding the details of the observations points like association of geomorphic features, lithology, depth and nature of weathering, dip and strike of beds, landuse and anthropogenic intervention. The geomorphic processes of weathering, mass wasting and erosion were studied in the field. The field data was compiled on the base map so as to bring out a coherent picture of geomorphological units and landuse pattern in the study area.

I.5.3 Post Field Interpretation :

In the post-field stage, re-examination and re-interpretation of aerial photographs was carried out with the background of observations made in the field. The corrections, modifications and additional informations collected during the field work were incorporated in the final land unit and landuse maps. All the finalized details were, then, transferred on to controlled base map on 1:50,000 scale prepared on Survey of India topographical sheets and reproduced on scale 1:100,000.

A few topographical cross sections, drainage pattern, and other relevant plates were prepared to be incorporated in the thesis. Climatic information was tabulated and represented diagrammatically to appreciate the variations in climatic conditions at a glance.

Measurements of area on map were computed by using centimetre graph along with electronic digital planimeter to calculate areas under different landuse categories, land units and litho units. Broad landuse categories have been analysed, omitting crops because of limitations of identification of individual crops types on photographs and imagery. A quantitative and qualitative land unit and landuse analysis was carried out on all media detailed above. Lineament map was prepared. Slope analysis was carried out on the scale of 1 : 50,000 for selected areas chosen to represent the different parts, covering the areal and profile aspects. A qualitative comparison between different land units and landuse categories have been attempted to infere the influence of the land units and processes on landuse.

Drainage analysis was carried out by studying river system, the drainage pattern, and the morphometric attributes of selected basins.

The attempt was made to trace the evolution of the geomorphic units from the evidences offered by topographical profiles, altimetric frequency curve analysis and accordance of summit level.

I.6 Organization of Study :

The entire work has been organised into six chapters.

The first chapter is introductory in nature which spells out the scope of study, its objectives, data base and methodology. It also makes an appraisal of the geographical personality of the study area including physiography and relief, climate, soil, and flora and fauna.

The second chapter describes stratigraphy, lithology and structure of study area, processes operating in the study area and drainage characteristics and evolution.

The third chapter is devoted to identification and delineation of land units.

The fourth chapter describes land utilization units suggested by various organizations and suggest land utilization units for Chhota Tawa river basin. In addition, land utilization units have been identified and delineated. Landuse problems of the study area have also been highlighted in the same chapter.

In the fifth chapter an attempt has been made to compare land units and land utilization units, and assess the impact of geomorphic processes over landuse.

The sixth chapter presents a brief summery and conclusions with viable and meaningful suggestions in the present context.

CHAPTER-II

GEOLOGY AND PROCESSES

II.1 Introduction

The landforms are strongly controlled by the structure and the composition of rocks. In fact, there is significant relationship between morphological parametres and lithology. Geological conditions form the basis of evolution of landforms in a region. In fact, geological characteristics constitute one of the three fundamental factors in the development of landforms - the structure, processes and stage. The nature and the arrangement of the rocks are fundamental in the development of land units. The structure of the rocks affects the general pattern of the relief, while the lithology of individual beds influences the relief and land units. It, therefore, appears essential to examine the detailed geological characteristics of the region in order to obtain full understanding of the land units developed there upon.

In the present chapter attempt has been made to identify and map different litho units. The identification of different litho units is based on photo characteristics, for instance, tone, texture, pattern, shadow, shape, and geotechnical element like drainage and erosion patterns, landforms and landuse. The field traverses helped to observe in detail the characteristics of different rock types. An attempt has been made to identify the stratigraphy and structure of the basin.

II.2 Stratigraphy

The Chhota Tawa river basin is covered by sediments and metasediments of Vindhyan, Bijawar system and traps. The general stratigraphic succession of the rock formation in the basin is as follow :

1.	Quaternaries (Recent to Sub-recent)		Alluvium & Soil cover
2.	Eocene	Deccan Trap	Dark grey to dark greenish grey basalt. Hard, tough, compact and medium to fine grained non vesicular basalt. Soft, friable vesicular basalt.
3.	Pre-cambrian	The Vindhyan	Arenaceous & argillaceous, massive thick bedded sand stone, shale, conglomerate, hard compact, fine grained purpulish thin bedded sand stone, well jointed fine to coarse grained cemented with silica.
4.	Archaean	The Bijawar	Quartzite, horn stone breccia, phyllite, chert, banded limestone Ferruginous Quartzite, medium grained quartzitic sand stone. Lime stone banded with chert or horn stone, breccia consisting of a horn stone or jasper, milky white Quartz.

II.3 Lithology

II.3.1 Bijawar System

Previous literature on Bijawar series is meagre. H.B. Medlicott (1860)[1] proposed the name Bijawar for the sediments found above the Bundelkhand granites and below the lower Vindhyans. He remarked, "The Bijawar formation is too confused to allow the safe or ready determination of sub divisions, although there is a large variety of rocks'. He has given a generalized lithological descriptions of the various rocks types and their description in the field and has divided the series into lower and upper Bijawars.

A note published by S.M. Mathur (1954)[2] gives an account of earlier work of W.L. Wilson who had mapped this area during 1873-77 and classified the Bijawar rocks as follows :

Upper Bijawar
Volcanic beds
Bijawar Lime Stone
Lower Bijawar

Mathur (1954)[3] has described the lithology of the Bijawar

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1 H.B. Medlicott (1860), "On the Vindhyan Rocks and their Associates in Bundelkhand", *Mem. Geo. Surv. Ind.*, Vol. 2, Part-1.

2 S.M. Mathur (1954), A Note on the Bijawar series in the Eastern part of the type Area, Chhaterpur District, M.P.", *Rec. Geol. Surv. Ind.*, Vol. 86.

3 Ibid.

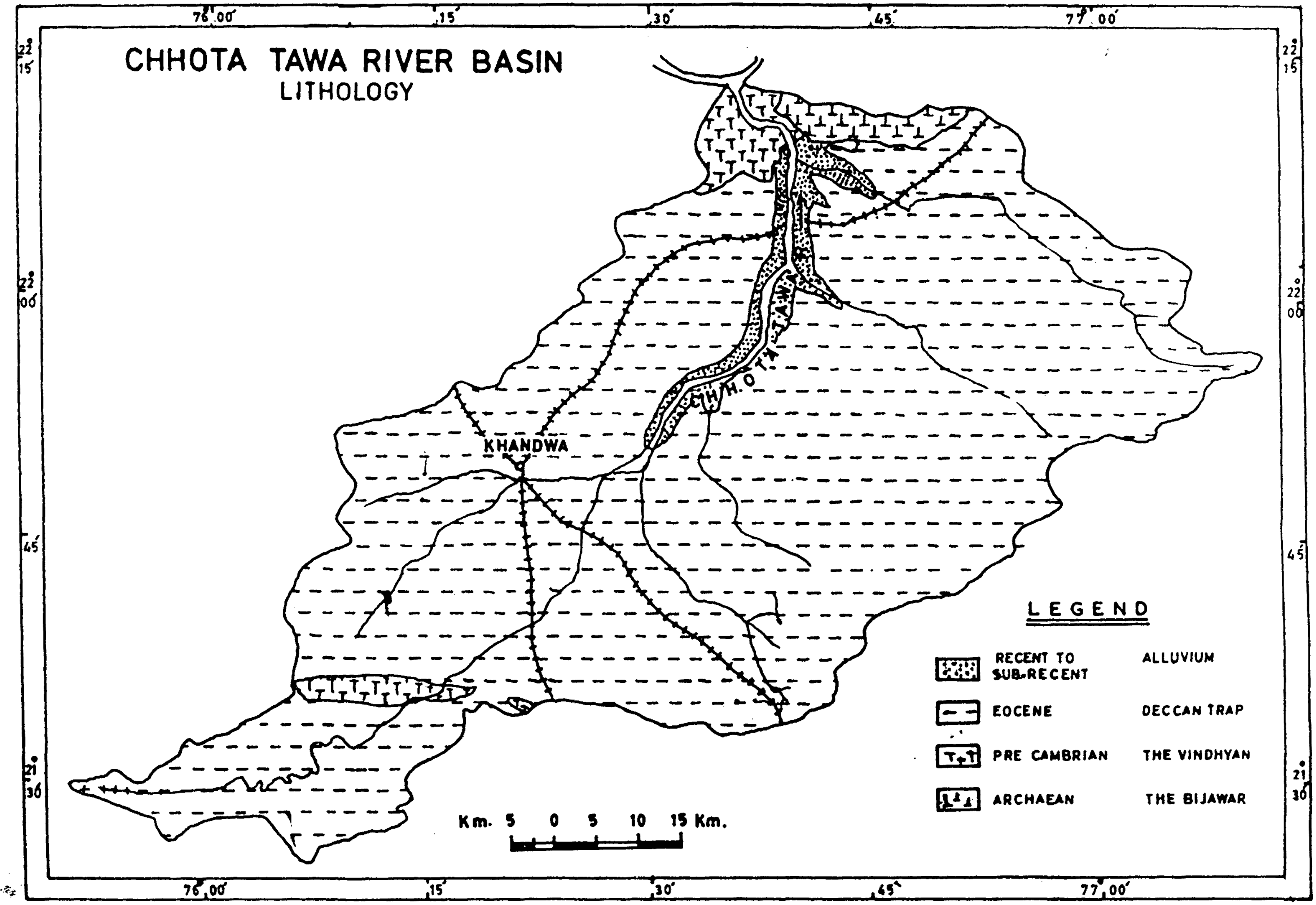
CHHOTA TAWA RIVER BASIN
LITHOLOGY
76°00′
15′
30′
45′
77°00′
22°15′
22°00′
45′
21°30′
KHANDWA
CHHOTA TAWA
LEGEND
RECENT TO SUB-RECENT
ALLUVIUM
EOCENE
DECCAN TRAP
PRE CAMBRIAN
THE VINDHYAN
ARCHAEAN
THE BIJAWAR
Km. 5 0 5 10 15 Km.

Fig. II-1

series and worked out its relationship with the overlying and underlying formations. He has also presented the following tentative table of the stratigraphic succession.

Upper Bijawar	Crushed Quartzite, chocate shales including tillite. Ferruginous conglomerate
-------------	Slight unconformity
Lower Bijawar	Quartzite Jasphere, Cherts limestone and sand, Trap flow, Basal Chert breccia and conglomerate.

In the past, several attempts have been made to work the exact lithologic sequence of the Bijawar rocks but most of them failed. It remained a controversial problem.

In Chhota Tawa river basin, Bijawar rocks occur in northern parts in Harsud tahsil. The Bijawar formations consist of quartzite, horn stone, breccia, phyllite, chert banded lime stone, ferruginous Quartzite. The rocks are very much disturbed. The Quartzite range from Quartzitic sand stone in which Quartz grains are readily distinguishable by naked eye, to soft, unaltered sandstones which are sometimes conglomeratic. The limestone is banded with chert or horn stone. Another important constituent of Bijawar is a massive breccia, yellow or yellowish brown in colour consisting of a horn stone or jasphere matrix in which fragments of milky white quartz are disseminated.

At the junction of Chhota Tawa river with the Narmada, the Bijawar presents a peculiar concentric structure with a alternating layers or bounds of siliceous and calcareous materials (Photo No. 1). Many of the concentric masses, further south, comprise of purplish jasphere with angular fragments of quartzite.

The Bijawar rocks are all covered with the thick vegetation. This limits the possibility of photo-interpretation. However, it is often possible to distinguish various rock types on aerial photographs. This is mainly done on the basis of topography. Cherty quartzites and ferruginous quartzite stand as conspicuous bold ridges, while phyllite and dolomitic limestone give rise to flat and elongated valleys. This differential erosion makes the interpretation of landforms easier and helps in the recognition of its general structures which ultimately leads to the identification of Bijawar and delineation of Bijawar unit (Fig. II.1).

II.3.2 Upper Vindhyan :

Originally the term Vindhyan was suggested by T. Oldham in 1876[4], after the name of Vindhyan mountain which divides north from south India.

The Vindhyan system is divided into lower, which is mainly calcareous and marine, and the upper, which is mainly arenaceous and argillaceous.

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[4] E.H. Pascoe (1950), *A Mannual of the Geology of India and Burma*, Govt. of India Publication, Calcutta.

Upper Vindhyans are found in Chhota Tawa river basin. They consist of massive thick bedded sandstones, shale and conglomerates and these are faulted against Bijawar along the east-west line marked by breccia. The prominent rock is one intermediate between sandstone and quartzite and is of a deep red or purpulish colour. The most common constituents of this formation is hard, compact, fine grained purpulish rather thin bedded sandstone. The bedding is well marked but the separate beds could not be mapped on photographs as they are of too small thickness to be identified and mapped separately.

The Vindhyan sandstone in the valley form the strike, ridges and plateaus. The sandstone are massive, well jointed and fine to coarse grained. The cementing material is silica. The silica is durable and resistant to both chemical and physical weathering. Hence, only physical weathering predominates on sandstones due to the daily range of temperature. Well developed joints and faults have appeared and heavy growth of plants along these joints and faults has further widened them. It has lead to physical destruction of the rocks.

Vegetation, an important characteristic of the formation, becomes of secondary importance though in the identification of Vindhyan sandstone. The sandstone beds can easily be recognised on aerial photographs by their bold geomorphic expressions and the development of slope asymmetrically in low dipping beds. The joints are extremely clear owing to the subsequent streams and alignments of vegetation along them. The sand stone covered with leafless trees and with grass impart a light tone and medium texture to photographs. Different vegetation bands corresponding to different lithologies can easily be recognised. For instance, upper Vindhyan sandstone can easily be distinguished from the Khandwa Deccan trap by dark tone, low topography or hummocky topography and scanty vegetation.

Vindhyan Sandstone-quartzite appears on landsat image in MSS band 7 with a lighter tone than the deep grey of the basalt. On the topographical maps, the contours representing the Vindhyan sand ridges show fewer indentations. This is because they have not been as heavily attacked by erosion being much harder than the basalts.

II.3.3 Deccan Trap :

The term, Deccan Trap[5], was first used by W.H. Sykes in 1833. Towards the end of the mesozoic or the beginning of the Tertiary period, there was an enormous outpouring of lavas covering the most part of the Peninsular India. These lava flows are known as the Deccan Trap which, at present, encompasses an area of about 520,000 square kilometre.

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5 E.H. Pascoe (1950), *A Mannual of Geology of India and Burma*, Govt. of India Publication, New Delhi.

During the recent years, West (1959)[6], while considering the source of the Deccan Trap flows, mentioned two, possible sources of its flows. Either they have been welled out through craters which have become buried beneath the later flow, which he considered unlikely, as they would be seen where the trap has been deeply dissected. The only alternative possibility is that they have been extruded through the fissures. By studying the distribution of the dykes, either within the trap area or on the margins of it, he came to the conclusion that the flows were issued from fissures which are now seen as dykes.

A large part of the Chhota Tawa river basin is occupied by Deccan Trap. The plain country around Khandwa seems to be formed of lower traps consisting of trap beds associated with inter trappean sedimentary rocks. The Deccan Trap belongs to the type called **'plateau basalt'** and are uniform in composition corresponding to dolerite or basalt. The basalt, found in study area are dark grey to dark greenish grey in colour. These traps are distinguished into vesicular and non vesicular varieties. The nonvesicular variety is hard, tough, compact, medium to fine grained and breaks with conchoidal fractures. The vesicular types are comparatively soft and friable and break more easily. Numerous ash beds are common in the upper portions. Thickness of trap may be 1200 meters.

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[6] W.D. West (1959) "The Source of the Deccan Trap Flows" *Journal of Geological Society of India*, Vol. 1, pp. 44-52.

Generally, the trap rocks appear to be horizontal in the study area except perceptible dip around Khandwa Plain. The dip around Khandwa plain is 2 to 3 degrees. At the water divide of Chhota Tawa river basin on Satpura strong southerly dip, in places amounting to as much as 10 to 15 degrees has been recorded.

Basalts are recognized on the imagery in MSS band 7 by their dark grey tone which represents contrast with the lighter tone of the other rock types in the background. On aerial Photograph Deccan Trap exhibits hummocky topography with dark tone and fine texture. On the toposheets on a scale of 1 : 50,000 the basalt can be recognized from their topographical expressions. The contours within the basaltic region have a characteristic pattern. They are irregular with a large number of indentations. The relief on the basalt also indicates the boundary where the elevation increases with their advent.

II.3.4 Alluvial Deposit :

The recent and sub-recent deposits comprising alluvium, cover a considerable portion of Chhota Tawa river basin. The undulating plain occupying the vast area has thick alluvial cover which mostly comprises of regur and loamy soils. Recent alluvial deposits are found along the course of stream. The foot hills and steep slope of hill tracts are mostly covered by rock boulders, derived from typical weathered conditions, under desiccating climate. Residual soil is very thin and at places washed away during rainy season exposing the bed rock to further processes of disintegration and erosion. The hill slopes are, generally, covered with coarse materials of talus and scree.

The alluvium is occupied by crops. On aerial photograph this alluvium is recognized by a lighter tone, smooth texture with dark field lines which are usually square or rectangular in shape. However, it displays a darker tone and a fine texture wherever the moisture content is high.

II.4 Structure

The study area is structurally very complex with large number of folds. A few faults of local and regional nature have been inferred on photographs, images and confirmed at places in the field.

II.4.1 Depositional Structure :

This type of structure observed in different litho units in Chhota Tawa river basin is described below :

(a) **Bedding** : Primary structural features like bedding and jointing are exhibited by Vindhyan quartzite and sandstone, and Bijawar sediments although former can be distinguishably seen only at very few places. From the aerial photographs and images, it is very easy to trace the trend lines in Vindhyan and Bijawars series for several Kilometres. But on the ground the bedding can, of course, be obscured but can be conspicuously seen at river banks and road cuttings. It is clear from photograph no.1 that the bedding at places is very nicely exhibited whereas, in other areas, it is obscured. The general strike is in SW - NE and dip with 5 to 40 degrees in both the directions. However, variations in the dip and strike are found due to the intense folding to which these formations have been subjected. Bedding in highly jointed and fractured Bijawar and Vindhyans is difficult to decipher. Beddings are found in Satpura trap also. The dip due north in trap varies between 3 to 30 degrees.

(b) **Current Beddings** : Current beddings are well developed in Vindhyans and Bijawars at places.

(c) **Ripple Marks** : Ripple marks are well developed on the shales and finer sandstone and indicate that the rocks are shallow water deposits.

II.4.2 Deformational Structure :

The deformational structure observed in the study area is described below :

(a) **Foliation** : It is the most planner structure, next to bedding, developed in the area. The foliation is well developed in argillaceous sediments of the Vindhyan system. It is represented by flaky minerals.

(b) **Joints** : Joints are well developed in all the formations with general three to four sets of joints. Most common of these are beddings and dip joints. The photograph no.16 shows the jointing pattern.

(c) **Folds** : The area has suffered with the intensive tectonic movements resulting into numerous folds and faults. The folds observed in fields and marked on photographs are macro anticlines and synclines. A number of upward and down ward folds, are shown in land unit map.

(d) **Dome** : Sandstone formed domes/inselberg are found in the study area. The trap also exhibits domal structure at places (Photo No.2). As the Vindhyans approache Narmada valley, they are first folded into a gentle dome, then closely folded into sharp anticlines, parallel with valley and finally faulted against the Bijawar (Photo No.3).

The study area comprises wide spread group of residual ridges and hills of more or less flat lying Vindhyan sandstones and quartzite that were completely over seen by the Deccan Trap and have since been largely reexposed to view, leaving remnants of trap at lower levels and as tables standing locally higher than the sand ridges.

The eastern Satpura range has resulted from the erosion of an elongated dome. The constituent rocks comprise of sediments, which had been peneplaned together with the surrounding Vindhyan rocks in pre-trap time. The basalt has been removed from the upper levels forming the domes except for a few remaining outliers. These are important from the structural point of view. These outliers surround the dome on all sides except for parts on the southern side and intermittently along the northern side where pre cambrian rocks crop out.

To sum up, the folding and faulting of the Vindhyan sediment is confined to the margin of the Vindhyan basin where it impinges on the old Bijawar massif.

(e) **Faults :** A few faults, as evident from displacement in litho-units, development of fault breccia, presence of crushed material, shift of crest line, displacement and abrupt truncation of rocks, straightness of the scarp line, straightness of the river courses and alignment of springs and break in slope, have been mapped. On aerial photographs, these faults could be easily picked up on the basis of shift of crest line.

A number of faults over trap were picked up. Apart from these, a number of minor cross faults have been marked, with the help of aerial photographs mainly on the basis of shift in crest line and break in slope.

The stratigraphy of the area during pre-field interpretation could not be worked out in detail due to lack of literature and limitations of interpretation. In the post-field map, after field checks stratigraphy has been worked out with the help of existing literature and field observations. The structures marked out in the pre-field maps tallied with the field observations. Faults with clear breccia, perennial springs, crushed material and shifting of strikes could be confirmed in the field and tallied with the pre-field interpretation.

II.5 Processes :

The term process refers to the dynamic action in geomorphological systems which involve the application of force over gradient. These refer to the events and actions of physical and chemical changes which affect a modification of the earth's surface forms. The landforms found on the Earth's surface are the results of complex interaction between the endogenetic and exogenetic forces. The landforms developed in Chhota Tawa river basin bear the testimony of the processes and these have been formed by different processes.

External physical processes include different modes of weathering, mass wasting and erosion that affect the rock differently to give rise to characteristic land unit types.

Geomorphological processes are gradational processes which include degradational and aggradational processes. The form and intensity of these processes are affected by relief, soil, rock type and landuse. Processes, landform and landuse are inter related and affect each other. In Chhota Tawa river basin, three main types of processes are important and responsible for the development of present day landforms. These are aggradation by fluvial action, degradation by weathering, erosion and mass wasting.

The following is the out line of the processes which are responsible for shaping and developing the present day landforms in the Chhota Tawa river basin :

1. Exogenetic Processes
   Gradation
   (I) Aggradation Processes
      (a) Fluvial Process

   (II) Degradational Processes
      (a) Weathering
      (b) Erosion
      (c) Mass Wasting

2. Endogenetic Processes

   (I) Orogenesis
   (II) Volcanic Erruption

The above out lined processes acting in the study area are discussed below :

1. Exogenetic Processes :

Erogenic Processes have played a very important role in the evolution of the landforms in the study area. These processes derive their energy primarily from the sun and have their origin in the earth's atmosphere and are guided by the force of gravity and hence, these are also known as sub-aerial processes.

Gradation

Gradation is the main sub aerial process operating in the study area. It comprises of aggradation and degradation.

(I) Aggradation :

The aggradational processes comprises of mainly fluvial process :

(a) Fluvial Process :

In the study area, fluvial aggradational processes have been identified through the analysis of some landforms like river built plains along lower Chhota Tawa, Abna and Sukta and valley-fill deposits in intermontane valleys evolved in Satpura high lands. Different types of terraces identified in the study area also suggest the operation of fluvial aggradational processes (Photo No. 4). The process of aggradation is also active at foot hills of Satpura, Vindhya and narrow river built plains bordering Chhota Tawa, Sukta, Abna, Kalimachak and Agni rivers. Aggradation by running water is a dominant process over these places, which works in conjunction with other processes.

(II) Degradational processes :

The degradational processes are also dominant and wide spread in Chhota Tawa river basin. These are as under :

(a) Weathering :

Weathering, the decomposition and disintegration of rocks in situ, is a static process. It involves a group of processes which act together at and near the earth's surface and reduces solid rock masses by physical disintegration and/or chemical decomposition to the clastic state. The product of weathering tend to accumulate in soft surface layer, called regolith, unsorted material, which covers the bed rock (Photo No. 5). In Chhota Tawa river basin weathering is ubiquitous.

The rate of weathering process in Chhota Tawa river basin could be identified with the help of aerial photographs by studying the Characteristics of landform resultant of weathering. It varies from place to place according to the parent material, topography and vegetation. The basin consists of sandstone, shale, quartzite and basalt. The sandstone is relatively resistant to weathering because of the strength of its cementing agent. Therefore, it produces a massive bold topography with steep slopes in Vindhyan range.

The spheroidal weathering is the most commonly observed weathering type of the basaltic terrain in the study area.

Layers of lose friable material ranging from 0.5 to 2 cm. in thickness form concentric rings around and unweathered core of basalt which may be varying from 15 cm to more than a metre in diameter can be discerned. Spheroidal weathering is seen on Satpura ranges in study area. This weathering is conveniently attributed to alternate heating and cooling of rocks due to diurnal and seasonal variations in temperatures, but due to its poor thermal conductivity the interior of the rock does not get heated. Weak planes are formed close to the surface due to expansion of surface. Fractures formed on this surface facilitate the breaking up of the outer surface. This is further subjected to chemical weathering. On the disintegration of outer surface, the inner surface comes under the influence of the heating an coaling effects and the process is renewed. It leads finally to a smaller core, with many weathered layers around it. Due to spheroidal shape of the fresh rock at the core, process is termed as spheroidal weathering. Photograph No. 5 provides an example of spheroidal weathering in Chhota Tawa river basin.

The weathering process is seen at places over the undulating and plain areas of Chhota Tawa river basin. The weathered material is not removed by transporting agencies as fast as it is produced. This results in the thick mantle of the regolith over pediment and the landforms, thus, produced are termed as buried pediments. These features are found every where over large area. These areas are under cultivation and are plain but their location, away from river, does not allow their origin to be attributed to flood plain.

Weathering on the cliffs and scarps also takes place but the material, thus, produced is brought down the slope under the influence of gravity and transportation agencies. Therefore, it has been discussed under erosion and mass wasting.

(b) Erosional Processes :

Erosion by fluvial processes is the dominant process observed in the parts of the study area. These include degradational, transportational and depositional processes. Since depositional process has been dealt with elsewhere in preceding pages, it is proposed to cover only erosional processes in this section. In the study area, erosion is caused by torrential spell of rainfall and becomes mere severe due to the lack of vegetation.

(i) Soil Erosion :

The rocks of the study area consist of predominantly traps and sandstone. The infiltration of rain water is less. Hence, the surface flow is higher. This process is responsible for the removal of soil in the study area. The basin lies in semiarid climatic tract and experiences torrential rainfall that induces splash erosion, and helps in the removal of soils. There are evidences of all forms of soil erosion taking place in the study area.

Splash and Sheet Erosion :

The process starts with the impact of the rain drop, which splashes the fine particles in all direction specially down slope, and breaks the structural elements into parts and tears off fine particles. The effect of this type of erosion on unprotected soils can be considerable. The small loose particles are washed away from the surface or they are deposited elsewhere and lead to a sealing of surface. Sheet erosion works over a large part of study area and generally causes most of the soil loss. In the Chhota Tawa river basin, sheet erosion resulted into the formation of bare rocks surfaces, pediment, and bare rocky slopes.

Rill Erosion :

The sheet erosion can change into rill erosion Rill erosion is dominant process of the South Eastern part of the Satpura hills and rolling plains adjoining the ranges. Here, rills originate from high lands where the soils are easily erodible in nature. Absence of vegetation and slope of these areas accelerate the erosion process.

The narrow ridges located in eastern parts, sloping flanks of intermontane valleys, and rivers banks of Sukta, Abna, Kalimachak and Agni are badly eroded by rills in the Chhota Tawa river basin. Even over buried pediments rills are observed. Rill erosion is indicated by very narrow strips of tone ranging from dark grey to black on black and white photographs and greenish blue colour on False Colour Composites.

Gully Erosion

Gully erosion is more vigourous in the northern parts of Satpura. The streams originate from high lands, erode the cuesta scarp and come to comparatively levelled area. Gully erosion has removed much of the soils and the resultant feature is a large ravenous and undulating topography. The river banks of tributaries of Chhota Tawa river, foot hills of Satpura and intermontane valley fills located on Satpura range are severely eroded by gullies. It has been reducing the area under cultivation by encroaching upon fertile lands. In study area, rills are enlarged into gullies and remove the soils and form many linear valleys. Headward erosion is very much dangerous for agricultural landuse as it has been continuing and increasing the amounts of the gully erosion.

(ii) Channel Erosion :

Channel erosion includes vertical and lateral erosion. In study area, the vertical erosion takes place in and along the central part comprising of Satpura high lands and flanking area. The areas that experience vertical erosion are very irregular with considerable variation in relative relief. In this part, because of the steep gradient and presence of sandstone intercalations with shale, vertical cutting is vigorous.

The steep scarps of the plateaus are eroded very deeply and resultant landforms are deep valleys and gorges that are most dominantly found in the flanking area of Satpura and Vindhya. Though these areas are thickly vegetated at places, the erosional processes are Vigorous because of the gradient and rock types. The courses of streams are eroded till the bed rocks are encountered (Photo No. 6). Bare rocks present in stream courses could be easily identified with the help of aerial photographs. Chhota Tawa river after flowing over areas with 340 metres and above height enters the plain region where velocity of the stream and down cutting gets reduced. In upland denudational hills, almost all the streams are engaged in bed deepening.

Thirty per cent of the study area lies over gently sloping topography between 240 to 340 metre height (Fig. I.3). In this part, the lateral erosion is caused by major streams. In short, in Chhota Tawa river basin lateral erosion becomes relatively important. Meandering pattern of rivers is mainly due to bank erosion that results into the formation of point bars but, at the same time, the role of neo-tectonic movement can not be completely ruled out.

The intensity of the bank erosion is more along the concave banks where river flows rapidly and hits the bank than that of convex where the depositional processes are the most dominant one. The concave banks found in north and north East flanks of

Satpura high lands are eroded by lateral erosion and the process is accelerated by presence of non-cohesive material. It is also important to note that not all the concave banks are affected by lateral erosion in major rivers. Bank vegetation exerts a strong control over bank stability and it also has influence on channel form. Bank vegetation is almost completely absent in the study area, except along a few river where control exerted by vegetation over lateral erosion is less (Photo No. 7). The banks that are affected by lateral erosion are shown in the geomorphic land unit map. The banks are eroded and the materials are deposited inside the channels leading to the formation of channel bars (Fig. III.1). These depositional features could be easily identified on aerial photographs. These features reflect tonal variations.

(iii) Differential Erosion :

The differential erosion is another important process that operates over the basaltic terrain in the study area. Differential erosion of the lava flows has led to formation of multiple scarps, separated by benches and debris slope. Differential erosion is most active in the basalt of Central India represented by narrow stud or butte or is altogether absent. Differential erosion is aided by vertical joints in the study area and caused scarp retreat in the upper flows. The differential erosion is brought about by the variable resistance offered by the different flows. The erosion is concentrated along the joint plane, leading to their widening. It causes the breaking off blocks. These blocks, are removed subsequently leading to retreat of scarp. This has been evident by presence of a number of scarps in the Satpura high lands in the study area.

(c) Mass Wasting

The bulk of masses of rock debris moves down the slope due to the direct influence of gravity. This is called masswasting or mass movement. It is accelerated by the presence of water but the water here is not in such an amount as to be categorised a transporting agency. Gravitation produces the mass movement of weathered material from higher slopes to the lower land. The mass wasting depends upon the lithologic, stratigraphic, structure, topographic and orogenic factors of the region. Soil creep, talus/scree creep and debris fall are the out come of the mass movements.

In the study area, coarse materials, and boulders are found accumulated at the break of slope indicating that mass wasting is in operation at places. The bending standing trees on the debris slope also provides clue to identify the soil creep area. All along both the sides of Satpura range, mass movements were observed in the field at the time of traverses.

Mass wasting in the study area could be identified on aerial photograph by studying the landforms that are resulted from mass wasting. Mass movements in the study area are very slow. Usually mass wasting occurs only when the disturbing forces over come the resistance of slope.

The study area consisting of basalt is more susceptible to weathering and mass wasting at relatively higher gradient. These weathered material consist of boulders, which gives coarse texture and light tone shade on aerial photographs.

The mass wasting occurs almost every where, wherever the high lands, steep scarp, residual and conical hills, and plateaux are present. The areas of headward erosion are important for the accumulation of colluvial materials.

Soil creep has been identified almost all over the study area except the plain areas and areas which have alluvium, thick colluvium and regoliths. The characteristics of soil creep on aerial photograph is its lighter tone with concave slope. The main source of soil creep is parental rocks on slopes that are comparatively devoid of vegetation except at some places where scree material covered with shrubs. The deformation of slope material is continuous where the hill slopes are affected by weathering and force of gravity.

2. Endogenetic Processes

Endogenetic processes are defined as the processes that originate below the earth's surface and are responsible for shaping the landforms. In the study area, orogenic and volcanic processes are classified as internal processes.

(I) Orogenic Processes :

Vindhyan system in the study area is believed to be formed by orogenesis. It has played a major role in the formation and building up of these mountain ranges.

(II) Volcanic Erruption :

This process has played a dominant role in building up of the landscape in southern parts of the study area. It is considered that high lands of Satpura are the products of volcanic erruption. Prof. W.D. West (1959)[7]believed that the Deccan trap is formed due to fissure erruption of lava and hence, it can be said that, since the trap occupies most of the part, the landscape, to great extent, has evolved by volcanic fissure erruption.

It is to be noted that the processes discussed above do not work independently but they work together, so it becomes very difficult to attribute the origin of a particular landform to any one single process. It can be said that the present day landforms are the results of more than one process.

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7 W.D. West (1959) 'The Sourse of Deccan Trap Flows' *Journal of Geological Society of India* Vol. 1, pp.44-52.

II.6 Drainage Characteristics

The spatial relationship, trend and behaviour of the streams and their tributaries reflect the control exerted by micro relief climate and geological structure in the evolution of the drainage pattern. Most of the rivers in the study area except lower Chhota Tawa, are seasonal. The drainage patterns are well developed and integrated. The low precipitation coupled with high rate of evapotranspiration has not favoured development of perennial drainage system, consequently; majority of the streams are ephemeral in their upper catchments (land unit map).

The drainage patterns prominently found in the study area are dendritic, sub-parallel, sub-annular, trellis and fault controlled.

Dendritic drainage pattern is the most commonly occurring pattern in the area (Fig. II.2). It indicates uniform rock type in central part of the study area. On Satpura high land, Vindhyan sand stone and Bijawar. The same pattern is observed all over the area except zones of Weaknesses and Mesa/Butte.

A physiographic control over the development of a drainage pattern is very clear in the study area. A physiographic control is responsible for forming centripetal and sub-annular drainage pattern over Satpura. Fig. III.3 shows that streams circumvent

CHHOTA TAWA RIVER BASIN
(AN EXAMPLE OF DENDRITIC DRAINAG PATTERN)

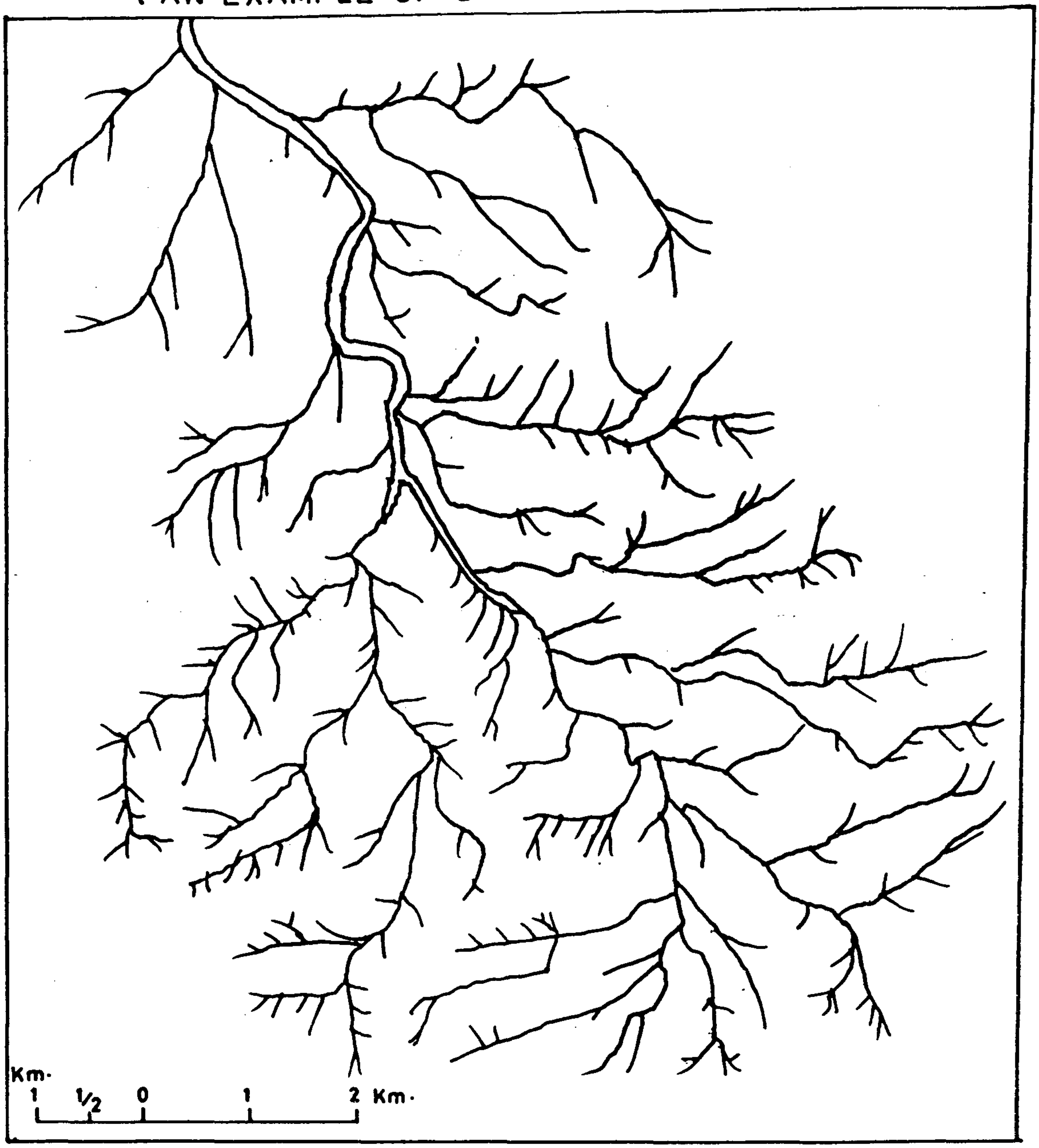

Fig. II-2

CHHOTA TAWA RIVER BASIN

(AN EXAMPEL OF SUB-RADIAL DRAINAGE PATTERN)

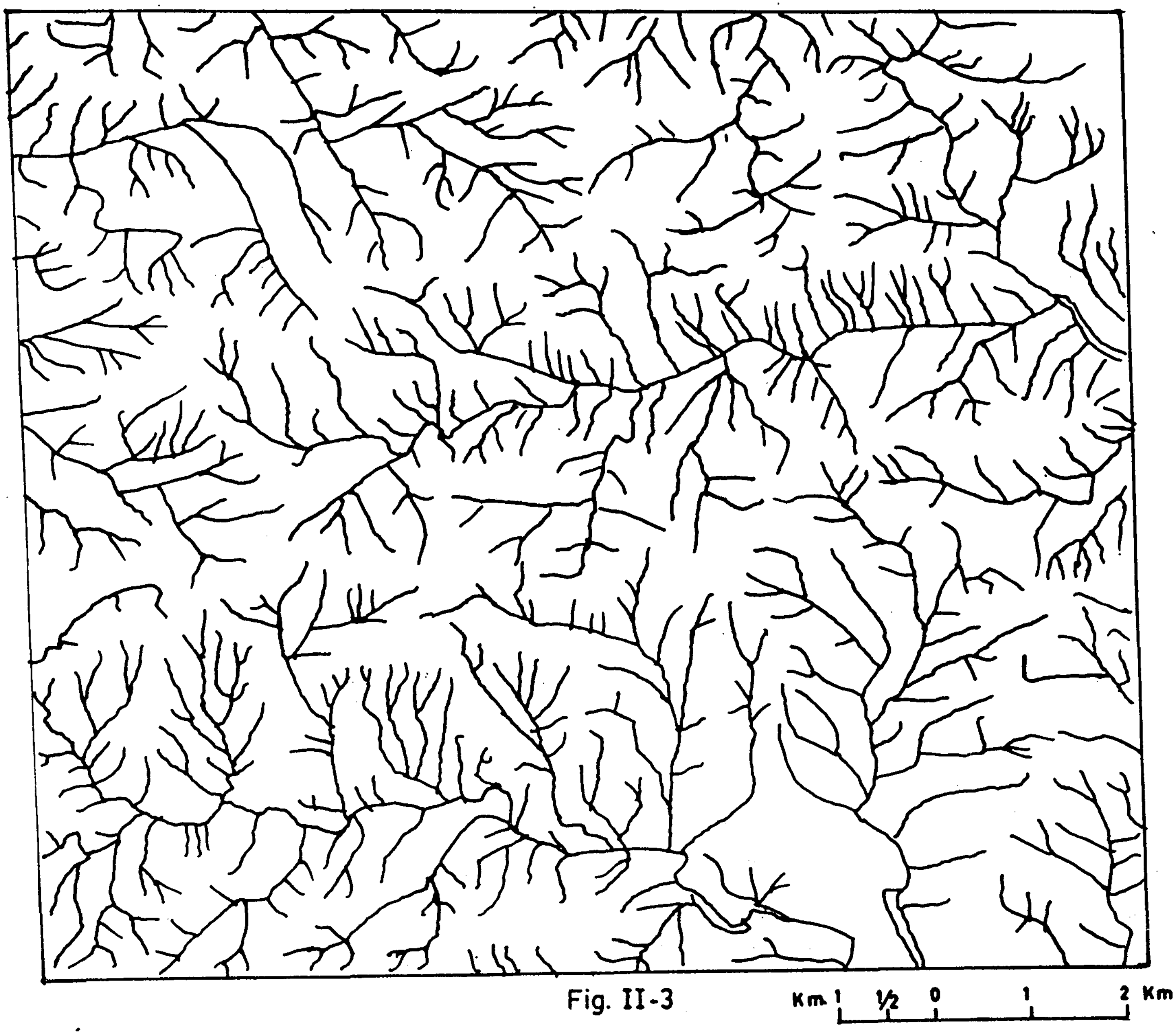

Fig. II-3

CHHOTA TAWA RIVER BASIN
(AN EXAMPLE OF SUB PARALLEL DRAINAGE PATTERN)

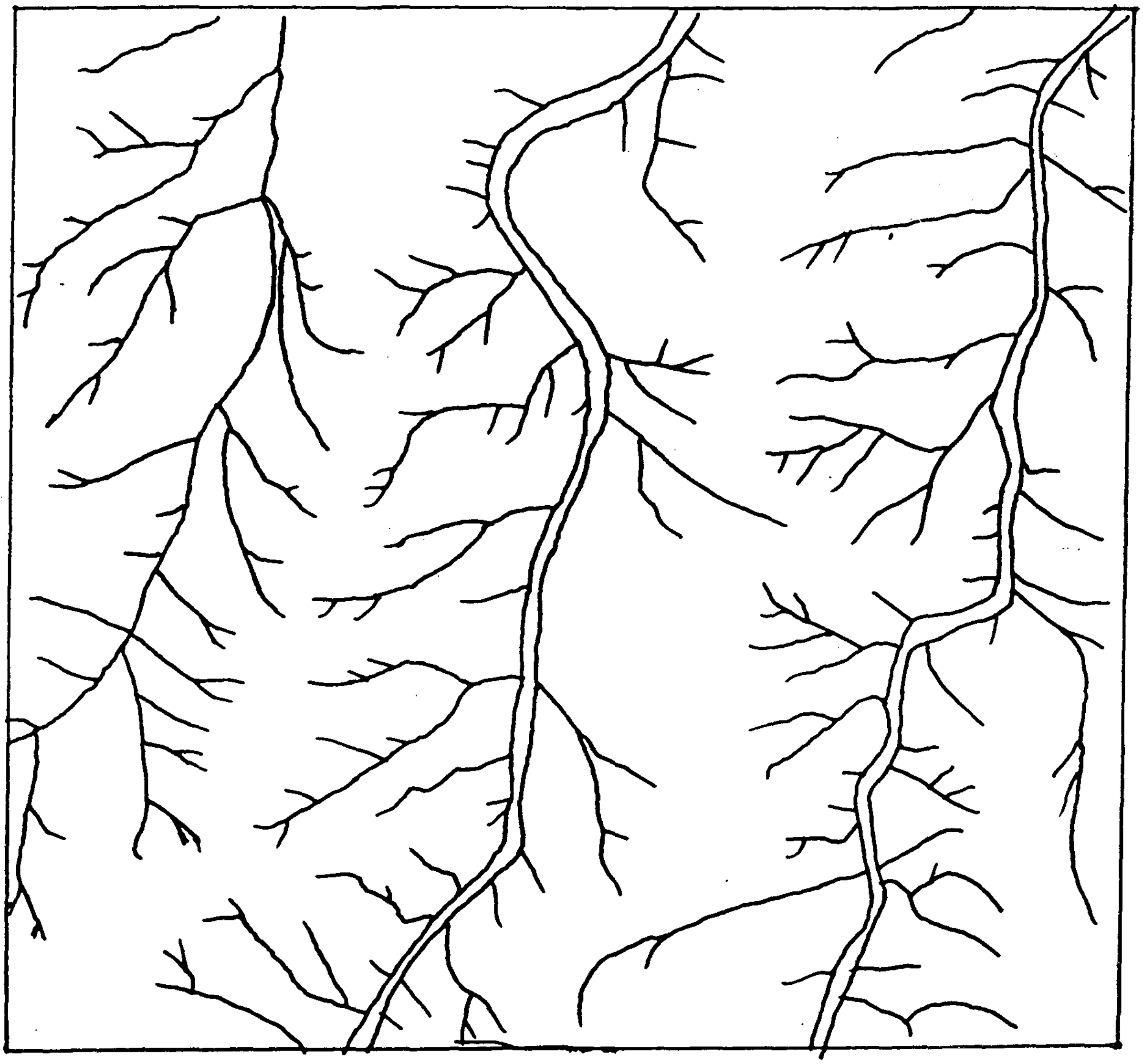

Fig. II-4 Km. 1 ½ 0 1 2 Km.

the mesa and butte. Over the top of them, streams are not developed, since tops are quite flat but when run off descends down the scarp it forms streams ultimately assume sub-annular sub-radial pattern. This type of drainage pattern helped to identify mesa/butte in the study area.

A little further from the hill where slope uniformly starts decreasing over rolling plain, sub-parallel drainage pattern develops (Fig. II.4). The figure II.4 exhibits three main streams parallel to one another over rolling colluvial plain. The streams leave inlier and approach the plain area where the sub-parallel drainage pattern developed on either sides of the inlier (Fig. II.7). The sub-parallel pattern indicates the rolling nature of the land.

A joint controlled drainage is seen on hills with prominent joints followed by streams (Fig. II.5) but typical trellis pattern is not observed in the study area.

The drainage pattern is well adopted to the structure and flow along the zones of weaknesses in the underlying bed rocks. The straight segments between curves of the river, as well as the arms of curves appear parallel in pattern and are controlled by structure. A fig. II.6 shows that streams take turn and flow straight for a few kilometres and again take right angle turn. Each straight sector of the rivers represent a fault. In fig. II.6 there are 7 parallel faults treading approximately North-

CHHOTA TAWA RIVER BASIN

(AN EXAMPLE OF SUB-TRELLIS DRAINAGE PATTERN)

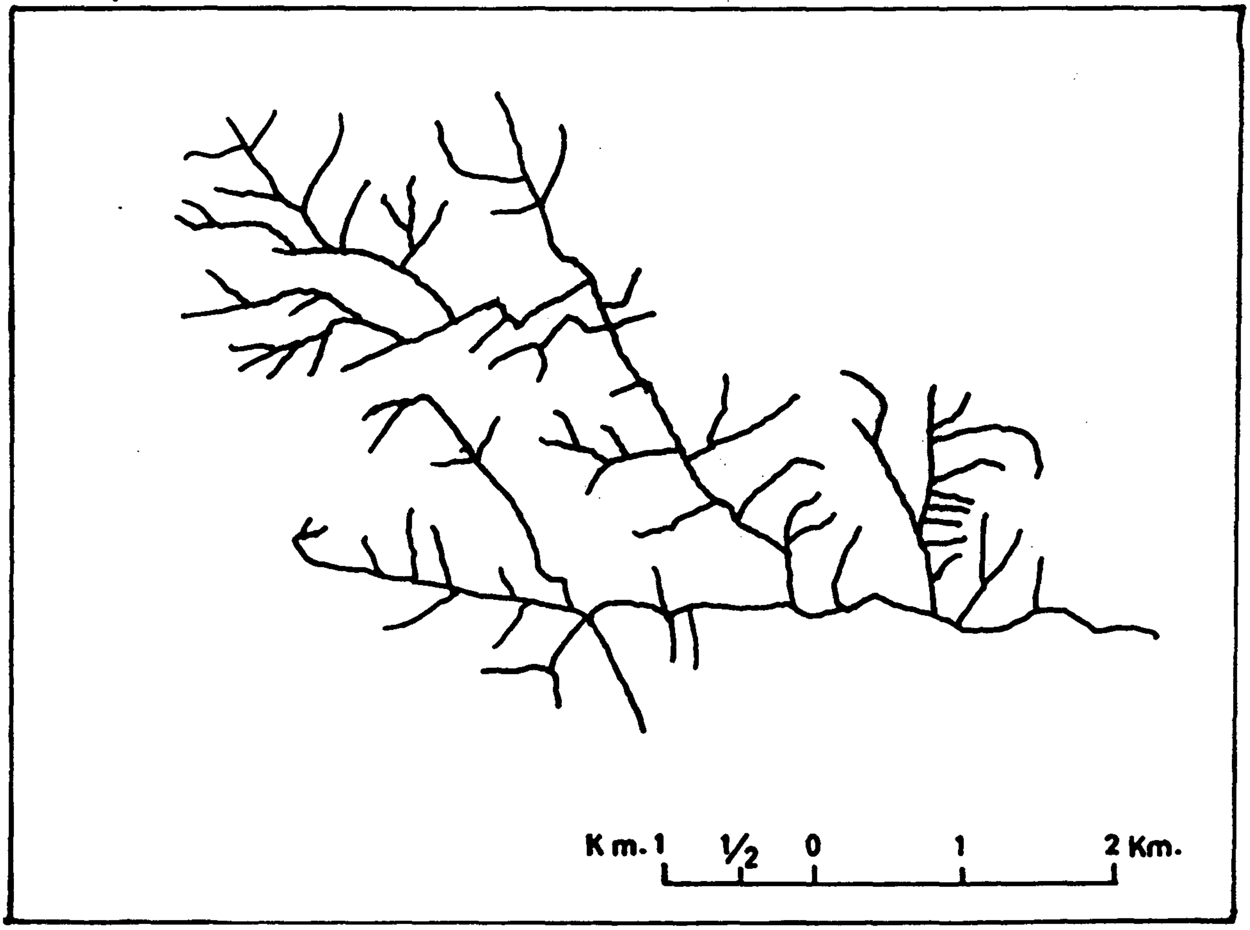

Fig. II-5

CHHOTA TAWA RIVER BASIN
(AN EXAMPLE OF FAULT CONTROLLED DRAINAGE PATTERN)

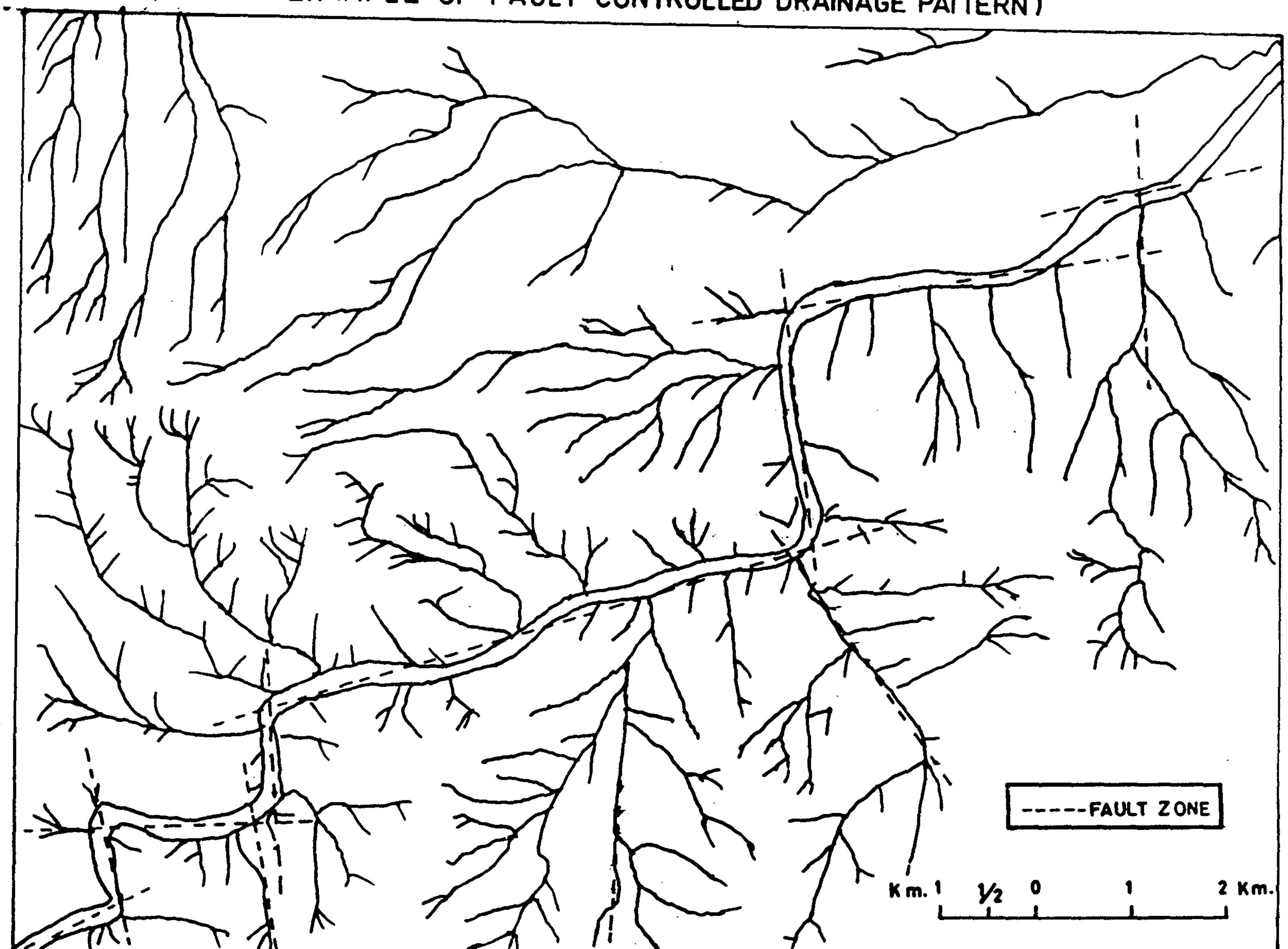

Fig. II-6

CHHOTA TAWA RIVER BASIN
(AN EXAMPLE OF SUB-PARALLEL DRAINAGE PATTERN)

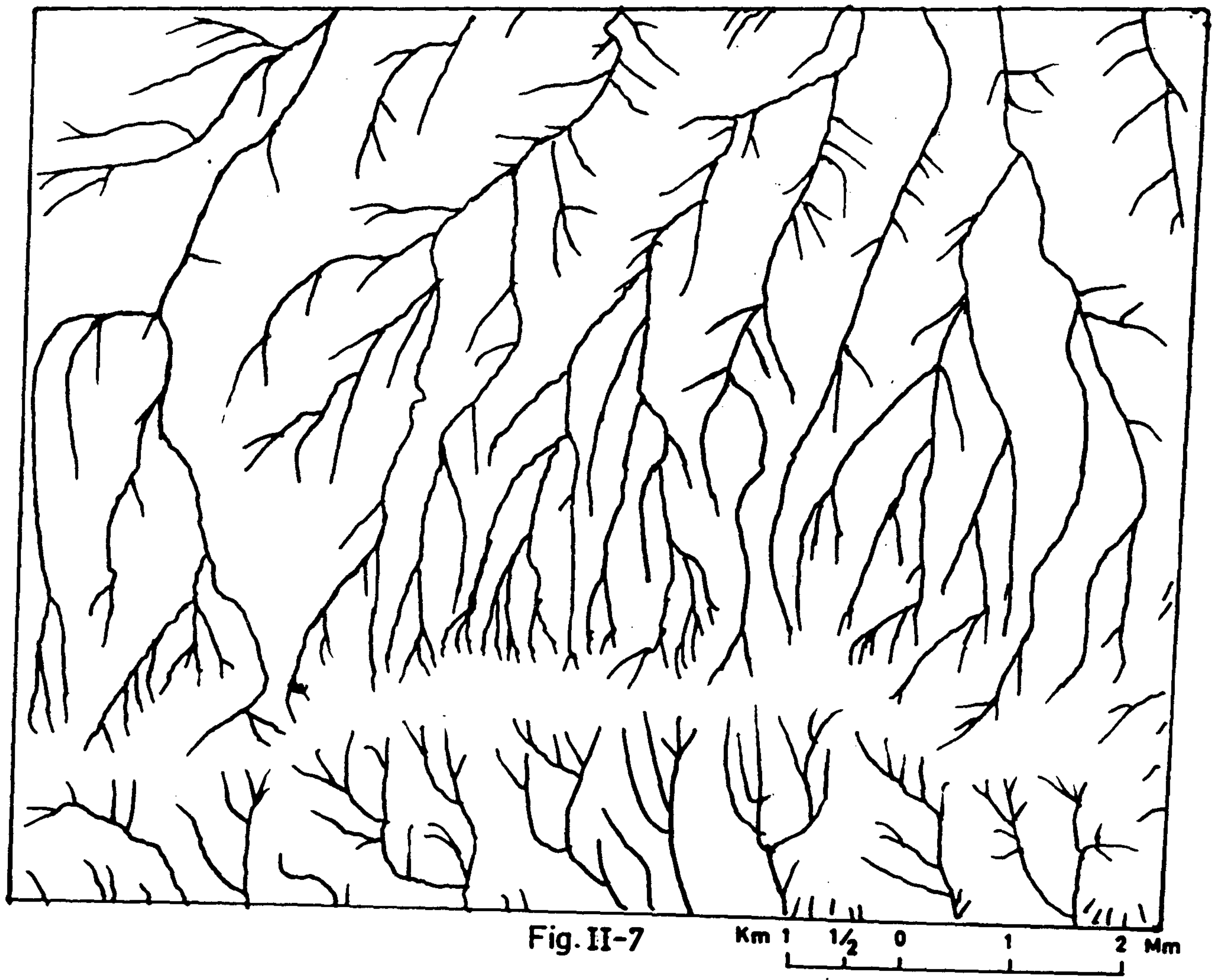

Fig. II-7

South and other set of 5 faults treading about west-east it shows very strong control of fault over drainage pattern and well adopted drainage pattern.

In short, faulted zones are occupied by streams and major joint directions have had considerable influence in determining the drainage pattern of streams. Thus, it is seen that there is a close correspondence between the drainage pattern, the landform and the geological structure which is the chief controlling factor in the evolution of topographic forms and associated drainage pattern.

About 10 km upstream from the confluence of Chhota Tawa with Narmada, such inter relationship between physiography and structure on one hand and drainage pattern on other hand does not exist. The river can be said to be inconsequent. The ten kilometre long lower course of Chhota Tawa river shows, in part, discordant relation to the structure and cut across the resistant ridge of Vindhyan sandstone. The river flowing over easily eroded basalt, cut across the ridge. had it continued for a short distance from Gullas Village further north, instead of taking east-west course, it could have avoided the ridge, altogether. It is very clear that the pattern of the drainage of this river course bears no relation to the geological structure of the rocks over which it is imposed. Johnson

(1931)[8] explained the discordant drainage pattern by the mechanism of super imposition theory. As a theory it is plausible in the explanation of the discordant of drainage in the present study area. The main essence of the theory is that the covering mass (younger) rests on an older land surface and any drainage system freshly initiated upon it will confirm to the disposition of the surface of the covering mass. In passage of time fresh mass initiated by the stream will cut into underlying basement of the older rock, but as soon as the old surface is reached the streams are firmly established in their courses and can maintain them independently of the structural feature of the underlying old basement rock mass.

Chhota Tawa river crosses the Vindhyan ridge after flowing over a plain area. This peculiar course can be explained by taking the help of the theory of superimposition. It has been confirmed by scholars that the Deccan Trap Lava flows buried the old vindhyan topography completely before the erruption ceased. The present discordant river is the descendent of the stream which developed upon the volcanic lava flows; and the present anomalous relationships between the transverse river and encountered geological structure and physiography are nicely explained by postulating that the stream have been let down onto the underlying structure which they cross. The presence of Trap

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[8] D.W. Johnson (1931), *Stream Sculpture on the Atlantic Slope*, Columbia University Press, New York, P. 142.

flows and remnants of Vindhyan beds at widely separated localities but similar height is strong evidence that lava flows once covered the whole area.

The conclusion is, therefore, drawn that at the close of the cretaceous already mature and old Vindhyan topography was buried beneath the volcanic lavas of the trap, which must have completely covered the Vindhyan hills. The original areas covered by lava must have been considerably more extensive than it is observed at present. In the centre of the study area, there is a huge inlier of the Vindhyans which is also exhumed to view by denudation processes. When the erruption of the trap fully ceased, a new drainage would have developed on the surface of the last flow. As denudation proceeded and upper flow was removed, the underlying Vindhyan topography would have been exposed to view once more. The new drainage, however, would have no relation to the old, Pre-Deccan trap drainage which had carved the Vindhyans into hills and valleys seen in the study area. The more powerful of the new stream would have continued to erode in the courses they were flowing on the Deccan Trap, but the weaker streams would tend to adopt their courses to the old vindhyan topography and avoided more resistant rocks as much possible as in the case of river flowing almost parallel to inlier in the study area. This reconstruction of the drainage history of the area if correct, explains the anomalies existing at present in Chhota Tawa river basin.

The drainage density in highlands, low lands and plain areas varies depending upon the composition of the material it is draining through, and the slope. Vegetation also plays a vital role. The drainage density over Satpura range is very high (fig. II.2). It is also high over sedimentary exposed inlier (Fig. II.7).

According to Leopold and Wilman (1957)[9] the channel pattern refers to limited reaches of the river that can be defined as straight, sinuous, meandering and braided. When dealing with the channel pattern due consideration should be given to river shape which means the shape of the river corss-section and also to the changes in the shape from the small rills to ultimate master stream. The shape varies depending upon whether river over flows or flows at low flow and also upon the action of the water on the material it is cutting through at various stages of flow. The pattern is also closely related to the amount and character of the available sediments and to the quality of variability of discharge. In study area straight streams could be observed (Fig. II.6). here, by straight means that the channel should be straight for a distance exceeding ten times its width. In study area, straight streams area controlled by lineaments and beddings and restricted to the structural hill land unit and table land unit. A braided channel develops due

9 Leopold L.B. and Wilman M.G. (1957) River Chhanel Patterns- Braided, Meandering and Straight", *USGS, Professional Paper* 228-B, pp. 39-73.

to the unloading of material, further deposition round which results in channel bar that subsequently grow into a sand bar or island dividing the main channel into two, and so on. Chhota Tawa river shows a development of sand bar making the channel braided (fig. land unit map). all along the upper courses of rivers, rock masses are expose showing very hard rock underlying (photo No. 7). The rivers are meandering in the Satpura hill tract. This is evident in the land unit map. Chhota Tawa river in the lower course shows steep and very high banks ranging between 6 meter to 14 metre in height and bed of the river is very flat (Photo No. 6). The term Tawa (in Hindi) signifies the flatness of the river bed like **tawa**. Smaller and narrower gullies show steeper banks which attain height varying from a metre to 5 metres over intermontane valley fill land unit and on the bank of Chhota Tawa. This has resulted into badland topography. Bank erosion is also observed. The Chhota Tawa river basin has, thus the drainage pattern and characteristics of river channel of varied nature controlled by present day topography.

CHAPTER - III

LAND UNITS

III.1 Introduction

In this chapter an attempt has been made to divide the study area into a number of land units in terms of a broad set of properties. The classifactory systems are evolved in response to the need for the classification of land required to help in solving the landuse planning problems (FAO 1974). Land classification has usually been done by two systematic approaches namely landscape approach and parametric approach. Land scape approach mainly categories the land into land units and then attempts to measure their properties quantitatively and relates them to landuse. It separates the landscape into natural units based on origin, processes and forms. Under this approach, one proceeds from the whole to the part. The land units are first identified and then their properties are determined. The under lying principle is to consider the close relation between land type and soil and to treat soil as a product of interaction of five basic genetic factors - parent material, climate, vegetation, relief and age in addition to origin, processes and forms. In its present form, the approach makes use of the external characteristics of the land scape and the internal characteristics of the soil horizons. The landscape approach is being used by CSIRO Division of Land Research, Soil Conservation

Authority of Victoria, Oxford MEXE (Military Engineering Experimental Establishment, now known as MVEE [Military Vehicle Experimental Establishment]), United States Department of Agriculture, All India Soil and Landuse Survey, The National Bureau of Soil and Landuse Planning, Ministry of Defence, (Terrain Evaluation cell) etc.

The second approach is known as parametric approach wherein classification of land is based on the values of the selected attribute. Under this approach, one proceed from the part to the whole. The property variations are first ascertained and the spatial units are then demarcated by extrapolation or super imposition. The property characterization is done with the help of different parameters depending upon the purpose of terrain study. It involves measurement of landscape properties like altitude, slope, relative relief, soil depth, process, drainage pattern, dominant geological formations, material texture, colour, NPK, status and hydrological conditions. The accuracy depends upon the number of attributes measured. No doubt, this approach is more precise than landscape approach. It is quantifiable and thus, computer compatible and allows numerical comparison but it is difficult to map all the attributes to give a composite picture and draw a precise and exact boundary from super imposition of different thematic maps. The second disadvantage is that the spatial units are demarcate by extrapolation and super imposition and boundaries can not be demarcated with precision.

Hence, the landscape approach slightly different from one developed by Common Wealth Scientific and Industrial Research Organization (CSIRO) is adopted here to classify the land units of Chhota Tawa river basin.

As mentioned above, there are a number of organizations that employ land scape approach for land classifications with slight variations in methodology of investigation, nomenclatures used for the divisions of different orders and mode of presentation of results. A brief account of nomenclatures is given in Appendix no III.1. Geomorphologist have devised hierarchical and non-hierarchical spatial classification of landscapes. In the present investigation a detailed, qualitative non-hierarchical classification on 1 : 50,000 scale has been attempted and results have been presented by adopting ITC method. The nomenclature to the units has been assigned keeping into view the origin and morphology of the unit.

A geomorphological investigation of land units of study area has revealed that present landforms represent the result of interaction of endogenetic and exogenetic processes as mentioned in the preceding chapter and present and past constructional and denudational processes occurring on pre-existing endogenetic forms. The rate and intensity of these processes might not have been uniform causing uneven nature of topography. The geomorphology of the area has been continually evolving for a long period, as the rocks and materials from the pre-cambrian era to quaternary era occur in the study region.

The faithful observation of various landforms their shapes, extension and pattern with the help of photographic image recognition elements and geotechnical elements helped identifying land units in study area. The photo image recognition elements taken into consideration while identifying objects have been as under :

1.	Tone	5.	Shadow
2.	Texture	6.	Pattern
3.	Size	7.	Location
4.	Shape	8.	Situation or Association of Features.

The following geotechnical elements helped in identifying the land units in study area :

1. Topographic expressions including

   i) Relief
   ii) Altitude/height
   iii) Slope

2. Inter relationship of different morphological units present in study area

3. Drainage including its

   i) Pattern
   ii) Texture
   iii) Frequency
   iv) Dissection index

4. Presence or absence and abundance or paucity of particular features

5. Antiquity and state of preservation of landforms

6. Nature of soil formation including

   i) Colour
   ii) Nature
   iii) Extension

7. Lithology including its

   i) Type
   ii) Extension

8. The stability or rate of change of landforms

9. Processes generating landforms

10. Biotic variables

    i) Vegetation its type and
    ii) Density of vegetation

11. Human influence specially

    i) Settlements
    ii) Roads
    iii) Cultivated area.

It would be appropriate to understand the concept of land unit and its properties before analysing and describing the land units identified in the study area.

Land unit is a single physiographic feature of geomorphic significance, fairly uniform in its physical properties with fairly high degree of uniformity in landforms, parent material, soil, climate, vegetation, morphology, configuration, slope, surface and sub-surface conditions. It means land unit is a tract of land containing similar landform properties. The land units tend to have relatively little internal variation in their geomorphological properties, though they may be quite different from each other neighbouring units. Land units are homogeneous in terms of their physical properties. They have a simple form and usually occur on a single rock type or superficial deposits, and have the soils which if not the same across the whole unit, at least vary in a constant manner across the land units. Some land units show local deviation in one property or the other from general character of the unit. These local deviations are isolated as variants and are not easy to distinguish upon aerial photograph of small scale and thus, their identification requires field observations.

In short, it can be defined as a mappable unit of area reasonably homogeneous and fairly distinct in geomorphic properties from the surrounding terrain.

III.2 An Out line of Land Units

The following land units could be identified with the help of photo image recognition elements and geotechnical elements in the Chhota Tawa river basin :

A land Units of Fluvial Origin

I Land Units Created by the Accumulative Action of Flowing Water:

1. Active Flood Plains
2. Old Alluvial Plains
3. Bajada
4. Alluvial Fans

II Land Units Created by the destructive Action of Flowing Water coupled with Denudative Processes Possessing an Accumulative Bottom :

5. Intermontane Valley Fill (undissected)
6. Intermontane Valley Fill (Dissected)

B Land Units of Denudational Origin

I Land Units Created by Constructive Action of Denudation Factors :

7. Buried Pediment

   i) Flat Buried Pediment

   ii) Undulating Buried pediments

II Land Units Created by destructive Action of Denudative Factors :

8. Pediments

   i) Flat Pediments
   ii) Undulating Pediments
   iii) Rolling Pediments

9. Denudational Hills
10. Inliers
11. Residual Hills

C Land Units of Orogenic Origin

I Land Units Created by Constructive Action of Endogenetic Movement and Sculptured by Destructive Action of Denudative Factors :

12. Structural Hills

D Land Units of Volcanic Origin

I Land Units Created by Fissure Eruption and Sculptured by Destructive Action of Denudative Factors :

13. Balastic Table Land

    i) Undiessected Basaltic Table Land
    ii) Dissected Basaltic Table Land

14. Mesa/Butte

15. Plateau Step

The above mentioned are the main land units; in addition the under mentioned geomorphic features are also identified in the study area :

i) **Water Fall**
ii) **Spring**
iii) **Crest**
iv) **Bluff**
v) **Escarpment**
vi) **Hogback**
vii) **River Terrace**
viii) **Alluvial Cone**

Since these features are very small in dimension and are found on the units which are already identified, they have not been considered as units.

III.3 The Main Characteristics of the Land Units :

The main characteristics of the land units have been summarised in Appendix III.2 and described below :

A Land Units of Fluvial Origin :

The land units resulting from fluvial processes belong to constructional as well as destructional phases. In Chhota Tawa river basin land units of fluvial origin have been found as follows.

I Land Units Created by Accumulative Action of Flowing Water:

1. Active Flood Plain :

In the present investigation the term, active flood plain, has been applied to the plains bordering Chhota Tawa river, Sukta river, Abana river and Kalimachak river, which are under frequent spell of flood. These depositional plains are confined to Chhota Tawa river besides other minor rivers. The maximum width of the active flood plain is about 3 kilometres on either side of Sukta river and minimum is 0.5 kilometre. Active flood plain is composed of unconsolidated unsorted depositional materials derived from sediments transported by these rivers form Vindhyan and Satpura.

The limit of the active flood plain is marked by the presence of micro irregularities due to periodical flooding causing deposition and erosion in the plain. The unit is characterised by a flat topography, proximity to river courses and very high grey tone on aerial photographs.

Since the unit is traversed by many rivers, the eroded material transported by these rivers is deposited over active flood plains and the material found over the unit is brown to black alluvium which is very fertile. This unit consists of deep to very deep soils and it is devoted to cultivation.

Active flood plain has been demarcated on aerial photograph with the help of grey to dark tone along river courses supplemented with profiles (Fig.No. III.1). The unit displays bluish to red colour on FCC as it is under cultivation. It is also easily demarcated on black and white imagery as it exhibits darker grey tone owing to cultivation.

The stereoscopic scanning of the photographs of this land unit permitted recognition of a few fluvial forms such as :

1. Present River Courses
2. Channel Bars
3. Bluffs
4. River Terraces

The channels of Chhota Tawa and its tributaries flow mostly in northern direction. The river courses are sinuous at present which can be seen from (Fig. No. III). River courses at places are braided and indicate the quality of load being carried. The height of the banks ranges upto 6 metre.

Channel bars are noticed in river courses of Chhota Tawa, Sukla, and Gorapachra rivers. These are of varying sizes and shapes picked up on photograph and confirmed in the field. These variations are due to the fluctuation in discharges and low gradient resulting into low capabilities of rivers to carry the load. These are mainly sandy deposits. Tone, location and texture help in identify these features. The tone of sand bar is lighter than that of surrounded water in the courses.

The steep to vertical slope of a river bank or a steep under cut slope formed by the lateral erosion of a stream is termed a river bluff or cliff. The two major rivers of Abna and Sukta besides a few minor streams exhibit a fairly well developed river bluffs. Normally the height of bluff is not more than 5 to 8 metres, above the stream beds (Photo No. 6 and Fig. No.III.1). The river bluff observed in the study area have fairly uniform composition of fine to coarse textured sandy silty clay but in a few bluffs sections of the Sukta river a thin layer is noticed. The formation of the bluff of river Chhota Tawa in lower part possibly indicates the superimposed river over Vindhyan System.

River terraces represent former flood plains over valley floor, and are later incised by stream (Quinn, 1957)[1], (Howard

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[1] Quinn J.W. (1957) "Terraces, Fluvial-Introduction" in Fairbridge (ed) *Encyclopedia of Geomorphology*, Reinhold Book Co., New York.

1959)[2], (Leopold, Wolman and Miller 1964)[3]. The terraces formed by Sukta and Chhota Tawa rivers were spotted on aerial photograph at a few places near west side of Kohdar village at the junction of Gangapat river with Agni river and near Ashapur. They are relatively flat at places, but mostly gently inclined towards the river bed (Photo No. 4). These are discontinuous and occur at two different levels above the present river beds. The higher or first terrace located at junction of Gangapat river with Agni river is about 5 and 10 metres from the river bed and the lower or second terrace is at Ashapur about 2 metres from the river bed. The higher terrace is little below the present bank levels. These terraces are single and isolated, and absence of paired or unpaired terraces rule out the element of upliftment or rejuvenation in this area in the past. McGee in Fairbridge, 1958[4] has been given to these fill cut terraces the names of erosional terraces as distinct from depositional type. Erosional terraces are formed by the lateral cutting of the earlier fill by meandering river that implies the equilibrium stage of the river (absence of down cutting), tectonic or

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2 Howard A.D. and Spock L.E. (1940) "Classifiation of Landforms", *Jour. Geomorph*, Vol. 3, pp. 332-345.

3 Leopold L.B., Wolman M.G. and J.P. Miller (1964) *Fluvial Processes in Geomorphology*, W.H. Freeman & Co., Sanfrascisco.

4 Mc Gee (1968) " River Terraces" in Fairbridge R.W. (ed) *Encylopedia of Geomorphology*, Reinhold Book Co., New York.

climatic stability (Cotton 1940)[5] and (Fairbridge 1968)[6]. Thus, the formation of terraces on the slip of slope and the occurrence of river bluffs on the undercut slope possibly indicate lateral planation by river followed by lowering of base level.

2 Old Alluvial Plain :

A narrow elongated strip bordering active flood plain on either sides of the rivers have been demarcated as old alluvial plain. This unit is level to gently sloping located between active flood plain on one side and pediment and/or colluvial plain/buried pediment on the other. The boundaries are very sharp and are clearly seen on the side of pediment, buried pediment on aerial photograph as old alluvial plain is covered under deep soil, whereas on other side, exposed rocks are seen at places, it is difficult to infere the boundary between active flood plain and old alluvial plain, but it can be attempted with the help of the nature of sediments deposited. Active flood plains consist of heterogenous assorted sediments whereas old alluvial plains exhibit development of profile. This unit is covered by fertile soil which supports intensive cultivation. On aerial photograph it gives a medium grey to dark grey tone

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[5] C.A. Cotton (1940) "Classification and Correlation of River Terraces", *Jour. Geomorph.*, Vol.3, pp. 27-37.

[6] R.W. Fairbridge (1968) *Encyclopedia of Geomorphology*, Reinhold Book Co. New York.

which also suggests good ground water potential besides intensive cultivation (Photo No. 8). No vestiges of flood plain are found in this unit as these might have been obliterated in the past. It can be said that some times during very high waters or deluge, water spreads over this unit but it is not frequently subjected to flooding.

3 Alluvial Fan :

This type of land unit is of mappable size and found in isolation at the foothills of Vindhyan and at some places in intermontane valleys. The rivers descending from high lands through constricted valley and debouching in the plain below or valley bottoms, owing to break in slope and decrease in gradient, speed and capacity, cannot carry the load brought down from high land and starts depositing coarse material first and finer mater later on. The deposited materials assume fan shape. It is clear from Fig. III.1. that the fans in the study area are found at so many places. The material found over the fan is coarse at apex and the size of material decreases out ward. It is unsorted material. Some old fans are under intensive cultivation. These are favourable sites for ground water exploration.

On the aerial photographs, alluvial fans are identified with the help of their location at foothill, proximity to river or across the river courses and their fan shape that can be appreciated if photographs are viewed under stereoscope. With the help of above mentioned image elements fan can be identified and located on landsat imagery also.

4 Bajada :

A term bajada, derived from Spanish language to describe the gentle, sloping surfaces leading down from a mountain front to an inland basin, in an arid and semiarid region.

In the present study area, bajada has been used to describe a broad, continuous alluvial or colluvial slope or gently inclined detrital surface extending for long and from the base of a mountain range out into and around inland basin or plain formed by the lateral coalescence of a series of separate but confluent alluvial fans, and having an undulating character due to the convexities of the component fans. The gradient of this unit passes imperceptibly out into the plain.

In this area bajada is found at the slope of Satpura, and Vindhyan denudational and structural hills (Fig. No. III.1). It is composed of unconsolidated material, such as sand, gravel and angular scree material, which together cover the underlying rock cut pediments. The material is essentially colluvium (Sandy-silty-gravel as that of colluvial plain). The form, the occurrence in relation to the mountain slope and, the association and non association of stream are the four important criteria that have been taken into consideration in drawing distinction between bajada and colluvial plain, even though the material is identical over both land units. The inter fan areas, depressions, are filled with colluvium. This land unit is irregular in shape and size and the total thickness also varies from place to place. The formation of bajada indicates that the area experiences semi arid climatic conditions and torrential rains. The run-off during the torrential rain brings the eroded material scoured from soft rocks and deposits the same when the speed decrease due to change in slope.

This land unit presents geological conditions that are excellent for obtaining ground water from wells sunk into their permeable material as water infiltrates readily in the coarse materials at the heads of the fans and moves down the bajada under the hydrostatic head.

II Land Units Created By Destructive Action of Flowing Water in Conjunction with Denudational processes Possessing an Accumulative Bottom :

These are the land units produced by the fluvial erosion process with the cooperation of denudational processes like weathering and aggradation or accumulation of material brought down from highlands. The valleys, primarily carved out by river and at present, filled with detritus, have also been included in this unit.

5 Intermountane Valley Fill (Un-dissected) :

The term intermontane is referred to intermont, which describes the location of feature between two uplands. Inter montane valley fill implies that the intervening area between two uplands, is filled with unconsolidated debris brought down by denuding agencies. Soil and rock fragments may be transported down the slope in such quantities that the stream (in valley bottom) is not capable of transporting the entire load into the lowest part of the basin. In these circumstances, debris accumulates and fills up the valley. the intermontane valley fill can be recognised on aerial photographs by their flat bottom and the absence of pronounced run off channels.

This land unit shows that unconsolidated material is deposited in valleys and these valleys are partially filled. At present valleys can be seen clearly but the flat bottom of the valleys suggest that these are partially filled with colluvium. Owing to flat to gently sloping nature of the unit, it is under cultivation at places. These land units are found over the high lands between parallel ridges and these units are flanked by intermontane valley fill (dissected).

6 Inter Montane Valley Fill (Dissected) :

The valley fills located on uplands are narrow stretching for 4 to 5 km in length. The gullies and rills have been developing over this area. Intensive gully erosion is active.

This unit is not under cultivation and even forest and shrubs are not found. The running water coming down the crest erodes and takes away the sediment already deposited by denudational actions. It exhibits darker tone with intercalately developed rills exhibiting coarse texture and banded dark tone. This unit can be termed as badland, which means an extremely dissected land scape difficult to cross on horse back and agriculturally useless. They are characterised by a very fine drainage net-work and short steep sided slopes with narrow interfluve. These are developed along the front of steep sided ridges in high lands of Satpura and Vindhyans (Fig. III.1).

B Land Units of Denudational Origin :

The land units of denudational origin have resulted from the denudational processes of weathering, mass wasting and erosion. These land units can be either destructional or constructional. These are grouped into classes namely land units created by the constructive action of denuding factors and land units created by destructive action of denuding factors.

I Land Units Created by the Constructive Action of Denuding Factors :

These are the land units produced by constructive action of denudation encompassing the fluvio-denudational processes of gravity and weathering. Buried pediment plain is the only land unit belonging to this category.

7. Buried Pediments :

Buried pediments refer to the pediments buried under in situ unsorted material produced by pedimentation processes. In the present investigation, detritus is referred to colluvium, a part of regolith i.e. the surficial mantle of unconsolidated and unassorted rock debris and soil. This material is deposited at the foothills near piedmont zone (bajada) and laterally spreads over the gently undulating slope by gravity and sheet wash by running water into a pediment surface which gets buried under colluvium and forms buried pediment or colluvial plain. The material is essentially derived by the disintegration of the basalt and sandstone in this area. It essentially consists of sandy silty gravel in different proportions. Below the sheet of colluvium, lies the decomposed weathered rock of 2 to 3 metres thickness followed by bed rock which is normally encountered between 8 to 10 metres depth (Photo No. 10). This plain has a gentle slope of 4 to 5 degrees. The colluvial plain slowly merges with the adjacent pediment and the zone of contact between the two is often found to be a transition zone.

These land units are found on both the sides of Satpura upland and Vindhyan upland. The lower boundary, (since it is transitional zone) is conjured and drawn with the help of rock cut surface. The upper boundary of the land unit is bordered by the uplands and debris slopes. The material found over buried pediments/colluvial plain is partially brought down by running water and partially by material produce by weathering at a place. The soil profiles are well developed. This land unit is devoid of vegetation and is put under intensive cultivation.

It is registered in darker tone on aerial photograph indicating deep weathered profile with more soil moisture as compared to the surrounding area. The land unit map shows that these land units are scattered in patches all over the study area. There are two types of buried pediments in the study area.

(i) Flat Buried Pediment :

This land unit occurs through out the study area except over Satpura and Vindhyan highlands. The unit, flanking the rocky or gravelly pediment, is covered with 1 to 4 metres deep sediments that are mainly transported by stream, rain wash from adjoining hills and pediment surfaces and partly developed in Situ. The slope of this unit is less than 2 degrees and drainage channels are only a few in numbers. The area is under intensive cultivation (Photo No. 10) and has good agriculture and ground water potentials.

(ii) Undulating Buried Pediment :

These pediments occur around flat buried pediment and undulating pediments. The mode of formation is similar to that of the flat buried pediment but the only difference is that the slope is irregular and varies from 2 to 5 degrees. This unit appears like having hummocky topography on aerial photographs and even in field also small Knolls or low broad hummocks can be noticed. Since it is undulating, the depressions are occupied by river courses and perceptible slope can be noticed.

II Land Units Created by Destructive Action of Denuding Factors :

These are the land units produced by the destructional processes of weathering, mass wasting and erosion. Pediments, denudational hills and inlier are the only land units that belong to this subdivision.

8 Pediments :

Pediments are plains of eroded bed rocks (which may or may not be covered by a thin veneer of deteritus) in an arid or semi-arid region developed between mountain and basin area. It is a gently slopping rock cut surface covered under deteritus at places. In the present study, pediments refer to a broad, concave or gently sloping rock floor/erosion surface of low relief, extending from periphery of the debris slope of the Satpura and Vindhyan hills to its meeting point with the next geomorphic unit. Pediments are found to the north of Satpura upland. These are of complex surfaces, comprising of the patches of bed rock in the form of basalt, sandstone, shale and old alluvium exposed to atmosphere (Photo No. 11, 12 & 13) and at places capped by thin veneer of weathered/ transported material or soil. The extensive patches of bed-rock and small patches of colluvium might have resulted partly because of some material might be temporarily in transit across the surface and partly from the incompleted removal of formerly more exclusive colluvial covers.

Some inferences about the origin of the pediments in Chhota Tawa river basin can be drawn on the basis of existing literature and field observations. The present climatic conditions and past and present processes acting over may give an important clue to reconstruct the evolutional history of the area.

"Gilbert (1877) suggested that lateral planation of stream is dominant process in shaping the pediment but Brayan maintains that in many areas lateral planation is dominant, particularly in early stages of the cycle, but that is considerably less effective as the cycle progresses and may be subordinated to weathering, rain wash and rill wash in later stages. Lawson holds weathering and rain wash more important than lateral planation. Davis (1930, 33, 36, 38) favours the process of back wearing (Weathering, rainwash, and rill wash) added by down wearing (down cutting by stream) of the mountain back as the more significant factors in pedimentation, the relative efficiency of 'back wearing and down cutting depends upon the initial form and stage of the cycle. Rice (1935) favours wasting (weathering and transportation) and sheet washing as the most essential factors in pedimentation. It is generally agreed that pediments are typical of arid and semi-arid lands but King (1969) and others considered that all plains moulded by running water are also of this type. Many workers like Twidle (1960), King (1967) Garner (1974) Weise (1978) now consider that a complex of processes-weathering, rill wash, sheet wash and sheet flow are responsible for the formation of the pediments".[7]

It can be said that pediments in the study area are sculptured by wasting and sheet erosion. Weathering, rain wash, rill wash and sheet erosion are most effective processes in the study area. A few streams are perennial and it has semi-arid climate where rainfall is concentrated in rainy season with torrential rain during May.

In study area, pediments are grouped into three categories:

(i) Flat pediments : Over these pediments slope cannot be perceived either on ground or on aerial photograph (Photo No. 11).

(ii) Undulating Pediments : These are small rock cut surfaces surrounded by depressions(Photo no. 12).

(iii) Rolling Pediments : These are pediments with uniform slope in particular direction. They are sloping rock cut surfaces (Photo No. 13).

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[7] Robert P. Sharp (1980) "Geomorphology of the Rubby-East Humboldt Range Nevada", *Bull. Geol. Soc. of America*, Vol. 51, pp. 338-339, 361-69, 70-71.

On aerial photographs these are very easily picked up with the help of light tone as compared to surrounding dark tone colluvial plains, coarse texture due to erosion and base rough rocks, and proximity to undulating plains and buried pediments. This land unit is completely devoid of vegetation and agriculture.

9 Denudational Hills :

The denudational hills may be narrow or wide but have conical summits or rounded summits. They range from 300 to 350 metres in altitude. These hills are denuded by denudational agencies like weathering, erosion and mass wasting. These hills are resultant of collective action of all denudational factors with dominence of erosion. At the lower part of the basin, continuous stretch of a few Kilometres is occupied by number of denudational hills composed of Vindhyan quartzite and sandstone intercalated with Shale (Fig. III.1, Photo No. 14). On aerial photographs, these land units are picked up with the help of height and shape supplemented with sparse vegetation and absence of cultivated areas, which exhibit lighter grey tone. These hills are off shoots of Vindhyan and gradually merge with high lands.

10 Inliers :

Inliers are an area or group of rocks surrounded by out crops of younger rocks or a limited area of older rocks completely surrounded by younger rock. It may be produced by erosion, faulting or folding or a combination of any two or all three of these agencies.

In the study area a huge inlier is found (Fig. III.1). As stated above it should have been produced by erosion combined with folding or faulting or combination of any two or all of three, but in the study area it has been exposed to view due to intensive erosion. Inlier comprising of sandstone and shale of precambrian age is surrounded by Deccan trap of Eocene age. It means younger rocks have surround the older rock. Pre-cambrian rocks, sandstone and shale were buried under the lava due to the erruption of lava during Eocene age. It can be presumed that whole land mass was covered under lava. Denudation of upper surface of lava was so intensive that the buried rocks were exhumed, and since buried rocks were harder than overlying rocks, upon exposure, new and less resistant rocks started eroding faster than those of old and more resistant ones. Consequently, the older hard rocks formed bold uplands and new softer rocks were eroded to form plains. Fig.III.1 reveals that the elongated hill/upland is surrounded by pediments and colluvial plains. At present inlier is under the attack of denudation, though these appear like denudational hill but its situation and the fact that it is surrounded by new rocks, suggests that these denudational hills are inliers. Inlier is composed of hard, resistant and massive sandstone. Debris and soils are not well developed which can support plant life hence this land unit is devoid of vegetation.

11. Residual Hills :

The term residual hill is used as synonym to inselbergs and Bornhardts as suggested by King (1948)[8]. These are the resistant isolated steep sided, usually smoothened and rounded hills or rock out crops of circumdenudation rising abruptly from and surrounded by an extensive and nearly level plains in tropical regions (Magaret Gary et al 1972)[9].

In the study area, all the rock outcrops and hills with an elevation of 240 to 600 metres above the mean sea level have been described as residual hills. These usually occur in pediments and colluvial plain land units (Photo 15, Fig. III.1). These land units exhibit conical to rounded summits with steep to very steep debris slope. The possible sharp piedmont angle between the pediment/colluvial plain and the basal slope of the residual hills could not be discerned in the field due to the overlying cover of debris (Photo No. 15). King (1948) held that these are formed due to scarp retreat and pediplanation processes. The surrounding land units (pediment/ colluvial

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[8] L.C. King (1948) "Theory of Bornhardts", *Geog.Jour.*, Vol. 112, pp. 83-87.

[9] Margarat Gary et. al. (1972) Fairbridge (1968) Encyclopedia of Geomorphology.

plain) is the testimony to the fact stated by Fairbridge (1968) that residual hills or inselberg commonly occur in areas of deep chemical weathering. This process is now regarded by many authors as fundamental to dome formation; more susceptible of closely fractured rocks becoming weathered to depth in excess of 350 metres while resistant and massive rocks become etched into relief as dome, smaller resistant massive rocks become tors. King (1953)[10] claimed that residual hills/inselbergs were recorded from every climatic environment on earth. They also occur in variety of rock types. In the study area, residual hills are found over igneous rocks (basalt) and sedimentary formations in semiarid region. There is an increasing tendency to restrict these land units to arid and semiarid climatic conditions and granitic gneiss rock type but as stated above, in study area, the term residual hill used to connote a "isolated hill abruptly rising from surrounding plain in any climatic conditions and over any type of rock (King). This unit is bare one. The height and location of the unit are the main clue to identify residual hills over photographs in the study area.

C Land Units of orogenic Origin :

orogenic process (orogenesis) has played a dominant role in the lower part of the Chhota Tawa basin in building up of the

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10 L.C. King (1953) Canons of Landscape Evaluation" *Bull Geol. Soc. America*, Vol 64, pp. 721-752.

land unit. Orogenesis includes folding, faulting and throwing up, often as a result of crustal movement, during which sediments within geosynclines are buckled and deformed as they are compressed into long, linear mountain chains. The origin of Vindhyan system has been ascribed to orogenesis and hence the land unit covering Vindhyan system has been included in this sub unit. There is a increasing tendency to describe the landforms that result from crustal movement as neo-tectonic but in present analysis these are ascribed to orogenesis. In fact as a process, it is very difficult to draw a distinction between orogenesis and neotectonic as both are related to crustal deformation. But the term neo tectonic is restricted to land units that are largely the result of Quaternary or of late Cenozoic earth movment. Since the Vindhyan folding, faulting and warping has not taken place during Quaternary or late Cenozoic period, the term orogenesis is preferred to neotectonic movements.

In the study area, land units comprising of structural and denudational hills and inselberg/residual hill are formed over Vindhyan mountain range but only structural hill are included in this category as other land units are so thoroughly denuded that the initial form of the upheaved mass can be restored only by guess work. The residual hill/inselberg and denudational hills are sufficiently worn down by denudation and the shape of the deformed surfaces can not be discerned. These land units can no longer be recognised as such on geomorphic evidences as they are worn down. Therefore, the term orogenic land unit is reserved for those land units on which sufficiently large areas of an upheave surface have escaped erosion to allow the identification of anticlines, synclines, faults, dips and strikes.

I Land Units Created by Constructive Action of Endogenetic Movements and Sculptured by Destructive Action of Denuding Factors :

These are the land unit created by internal forces in the past and at present being denuded. The structural hill land unit is included in this category.

12 Structured Hills :

The structured hills are orogenic land units found in study area. The term structured hill is restricted to those land units that have been developed by erosion under the control of internal structure of the terrain. Twidale (1968)[11] defined structural landform as "Landform which are due to the exploitation by weathering and erosion of weaknesses in the crust, to the differential wearing away of rocks which leave some areas greatly worn down and other areas upstanding". In study area, structural hills experience differential erosion owing to structure of internal rocks like warping and fracturing (Photo No. 16). Hills ranging from narrow, rocky, broad crest

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[11] C.R. Twidale (1968), "Analysis of Landform".

to sharp conical to rounded summits are present in the area under investigation. Two main types of structural hills have been demarcated on the basis of the lithology viz. Vindhyan System and Bijawar System. They show sharp crest, steep back slope, and joint controlled drainage (Fig. No. III.1). The area under study has been subjected to crustal deformation in the geological past as is evident from the structural features like folds, faults, fractures, and joints. The general trend of the hills is east to west. A few isolated hills, far from the main range but prominently exhibiting the structural control over topography, have been included in structural hills. For example west side hills at the junctions of Chhota Tawa with Narmada river near Purni village are such type of hills.

The present land unit is the second highest topographic unit next to mesa/butte in the area reaching to a maximum height of 360 metres above the mean sea level. The structural hills are characterised by folding, faulting, dragging, jointing, hogback, cuesta, escarpment and over turning of beds subsequently modified by erosional agencies. The hills are being eroded by denuding agents. Deep valleys and gorges are found. Debris and rock falls have been noticed.

The observation on the aerial photographs of this land unit permitted the recognition of a few structural landforms within the unit. These are folds, cuesta and faults/joints. The area has suffered crustal movements resulting into numerous folds, cuesta and faults/joints. The folds observed in the fields and marked on aerial photographs are macro anticlines, synclines and over turns (Fig. No. III.1). A synclinal ridge has been observed. A number of alternate and separate anticlines/synclines are found in study area.

The ridges formed by anticline/syncline have low dipping beds. These rideges with low dips are termed as cuesta and marked (Fig. No. III.1). However, before giving any final view on different pattern of folds and episodes of folding found in the area, a thorough study of structural elements is necessary. The present observations over fold can only lead to the conclusion that the area was under upheaval/or orogenesis for sometimes in geological past.

Joints, faults and fractures are prominent zones of weaknesses which are worn off easily than surrounding areas that are more resistant. Any linear alignment which is structurally controlled can be called a lineament. These represent the lithological horizons or beddings, faults, joints, unconformities, rock boundaries, vein and mineral banding. Lineaments which are formed due to faults can be identified through difference in elevation, straightness of scarp. A few faults, as is evident from displacement in litho units, development of faults crest lines, straightness of scarp and difference in elevation have been mapped on aerial photograph, These faults could easily be picked up on the basis of shift of crest line, change in strike of bed, straight scarp and dark tone of fault. The study area consists of fault scarp (Photo No. 3). This is the scarp which is produced directly by fault and fault line scarp which is the erosion affected fault scarp consisting of varying resistance. The fault scarp which is found in this area is young as indicated through the steep scarp except in the cases of some scarps which are denuded. A long fault scarp is shown in Photo No. 3 which is very prominent, abrupt with imposing front face and linear base that indicates a fairly high resistance to erosion. Faults are found every where over the study area. A valley formed along a fault line is called fault line valley (Robert 1980)[12]. This valley is developed by headward erosion in the soft, crushed, relatively weak material along a fault zone. Fault line valleys are found prominently in structural hill land unit (Photo No. 3).

D. Land Units of Volcanic Origin :

A vast area is covered under lava represents the land units of volcanic origin. It is known that the Satpura uplands and associated land units are the products of fissure eruption which resulted into the accumulation of lava in the form of plateau, hence the origin of these land units is ascribed to volcanic processes. These landforms are mainly due to the erruption of

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[12] L. Robert et. al. (1980) "Glossary of Geology", *American Geological Institute*, Falls Church, Virginia.

lava and in course of time sculptured by destructive actions of denuding factors.

I Land Units Created by Fissure Eruption and Sculpture by Destructive Action of Denudational Factors :

These are the land units produced by destructive action of the denudation over pre-existing accumulation of lava through fissure erruption. Table land, Mesa/Butte, and structural terraces are the main land units of this category.

13. Basaltic Table Land

Basaltic hills are narrow elongated highlands, having flat tops like table, abruptly elevated from the surroundings. In fact, basaltic hills are produced due to denudational agencies but these are not included in denudational hill unit because its striking geomorphic characteristics is the formation of different levels which gives step like view. The flat topped weathered basaltic surfaces, mesa butte with relatively steep slope linking different flat levels give a trap like or step-like geomorphic aspect to this unit and other hills donot have the trap like appearance. No doubt, basaltic hills like other hills of the study area are denuded by denudational agencies like erosion, weathering and mass wasting, but what single out the basaltic hill is trap or step like nature of slope or abrupt breaks in the slopes of hills. The step like slope are partly due to the vertical (columnar an prismatic) jointing. The vertical fissures provide one line of weakness. Horizontal joints (whereever they might exist), the function of the successive flows provide horizontal line of weakness. These intersect rectangularly with the vertical fissures of columnar jointing and are responsible for the erosion of lava into hills of step like slopes.

This unit covers southern part of the study area where the river Chhota Tawa and its tributaries originate. The unit is conveniently sub divided into dissected and undissected units on the basis of the erosion.

(i) Undissected Basaltic Table Land :

The tops of such units are quite flat, covered with weathered material and having developed a good cover of soil, hence, this unit is extensively cultivated. Rainfed agriculture is practised over the land unit.

On aerial photograph, undissected basaltic table lands are identified on the basis of check board pattern exhibited by cultivated fields, banded tone, location, slope and height.

(ii) Dissected Basaltic Table Lnad :

Dissected basaltic table lands have flat tops covered with thick materials. The periodic and concentrated nature of rainfall favours the development of rills and gullies on the lose unconsolidated material found over basaltic table lands which results in the development of dissected flat tops. The unit is located on Satpura hills in the vicinity of undissected basaltic table land unit. The headward erosion of gullies and rills may encroach upon undissected basaltic table lands resulting in increasing of area under dissected basaltic table land unit.

On aerial photograph dissected basaltic table lands are delineated with the help of rills and gullies. It can be said that undissected basaltic table lands under cultivation are being encroached upon by gullies/rills and being transformed into dissected basaltic table lands. If this process continues and is not arrested in time, it will endanger the cultivated land and reduce its extent by developing rills/gullies over cultivated areas.

14. Mesa/Butte :

Mesa is a term of Spanish origin, widely adopted to describe a table land or isolated flat topped hillock, bounded on at least one side by steep slope or cliff. Butte is a French term for a conspicuous flat topped hill with steep sides and frequently capped by resistant layer of rocks and is thought to be a remnant of a partly dissected plateau surface. It is smaller in extent than a mesa which closely resembles in every other way. Mesa/Butte develop most easily in terrain with horizontally beded strata where a resistant layer may from a cap rock to the eminence.

In study area mesa/buttes are found located on high lands where horizontal lava layers are subject to differential erosion Dr. E. Ahmad (1985)[13] tried to explain the origin of mesa/butte on Indian basaltic plateau. According to him the upper surfaces of flat topped plateaux are not greatly affected by weathering and erosion because of the presence of the cap rock, and there is only negligible weathering of the upper surface. The principal means of reducing the areas of the plateau is by marginal attack. The scarp-slopes are weathered and worn back through mass movement of debris and rill and stream erosion. Caverns developed at the base of the bluff are instrumental in undermining and causing the collapse of the protective cap rock and joints are also exploited. Retreat of the bounding slopes causes a reduction in areas of each plateau, and with the headward extension of the drainage net work, the once extensive plateau is subdivided into a number of smaller plateaux. Though the point of transaction is subjective, plateaux of limited extent are called mesa.

Erosion of the escarpments continues, and when the maximum diametre of the top of a residual hill is less than its elevation above the adjacent plain, the mesa conveniently becomes a butte. At this stage, the boundary of the upper part of the bluff, which is of negligible significance on plateux and

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[13] E. Ahmad (1985) *Geomorphology*, kalyani Publishers, New Delhi, pp. 230.

mesas, becoms relatively important. The plateau tops give way to a rounded upper slope which may, in some areas, be so well developed that the flat, upper surface is virtually eliminated. Such forms are especially well displayed on thick beded formations.

These features are found on high lands. Since the areas covered by mesa/buttes is smaller in dimension, inspite of their flat topped surface these are not brought under cultivation. Thus, these units are devoid of agriculture and at places covered under grass and scanty vegetation.

On aerial photograph, they exhibit darker tone and fine texture. These are identified with the help of their height, location on table land and escarpment.

15 Plateau Step :

This unit refers to rock terrace formed due to unequal erosion of hard and soft underlying rocks. It is a terrace like unit controlled by the structure of the underlying rock, especially produced by the more rapid erosion of weaker strata lying on more resistant rocks in a formation with horizontal bedding. The terrace or step is a narrow, relatively level or gently inclined surface, generally less broad and bounded along one side by a steeper descending slope and along the other by a steeper ascending slope, a large bench or step like ledge breaking the continuity of the slope. In the study area, a land

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unit having terrace type appearance, located on high lands and breaking the continuity of slope is termed as plateau step. Essentially it refers to lava flows exposed due to the differential erosion and fast wearing back of the upper layers giving rise to terrace type appearance to the resistant lower layer because of not wearing back as fast as upper one.

The land unit is partially under cultivation and partially covered by vegetation. In the study area, the unit is identified with the help of steep ascending slope on one side and steep descending slope on the other side. Hence, escarpments and location helped in identifying this land unit on Satpura mountainous area.

The detailed interpretation of aerial photograph and Landsat image analysis helped in identifying geomorphic features over land units of volcanic origins such as :

(i) Scarp,
(ii) Faults,
(iii) Joints/Fractures, and
(iv) land Slides.

In study area, a number of escarpments have been identified and mapped in land unit map (Fig. III.1). These scarps are produced due to differential erosion of layers of lava with varying resistence. Scarps are ubiquitous in the study area. They surround one or more sides of mesa/butte, they border one or more sides of plateau terraces and can easily be identified on aerial photographs and satellite images with the help of dark tone due to Shadow cast by them and precipitous height observable under stereoscope on aerial photographs.

The lineaments traversing over volcanic land units have been identified and mapped (Fig. III.1). These lineaments have been identified mainly taking into account tonal contrast. Lineaments represent joints, fractures and faults. Faults with clear displacement in formation are also identified.

Owing to the steep slopes and scarp, these land unit produced by volcanic activities experience land slides. The size of the scree is too small to map on 1 : 50,000 scale but these are observed during the field work.

Thus, the form process approach combined with land scape approach of CSIRO and ITC coupled with parametric approaches have helped in identifying afore discussed 19 land units. Their origin, extension and disruption have helped in explaining variations in processes , forms and landuse in Chhota Tawa river basin.

CHAPTER-IV

LANDUSE : A SPATIAL ANALYSIS

IV.1 Introduction

An accurate information regarding the rate and kind of change in the use of land resources is essential for their proper planning and management. The information about existing landuse and trend of changes is essential if the nation is to tackle the problems associated with haphazard and uncontrolled growth. Landuse mapping concerns classification of land according to its use. For planning purposes, a landuse map should depict the distribution and extension of different land utilization categories of the study area. Assessment of use and misuse of land is the pre-requisite to plan the utilization of resources. Land utilization surveys and mapping is the obvious requirement to make such estimates.

The rapidly developing technology of remote sensing offers an efficient and timely approach to the mapping and collection of basic landuse and land cover data over large area. It has been found, in most of the cases, that data collected for some specific purpose were of little value or by the time data is collected, it is out dated because of the slow processes involved in the collection of such data. Remote sensing technique can be used effectively to complement surveys based on ground observations, and to provide an accurate inventory of the current use of the nations land resources.

Various departments in the central and state government, private sectors and university departments have been collecting data about land and its resources for the last many years, but their works are mostly independent and without coordination and result in certain amount of duplication of work.

At present there is no standard landuse classification system in India except adopted by the revenue departments. Very few organizations like National Atlas and Thematic Mapping Organization, All India Soil and Landuse Survey, Directorate of Economics and Statistics, Department of Agriculture, National Remote Sensing Agency, and Central Arid Zone Research Institute have developed their own classification schemes for landuse mapping and these are suitable to particular areas at particular scale and do not appear to fulfil the requirements of other sectors. Landuse classification schemes suggested by various organizations and individuals are given in appendix table IV.I.

An attempt has been made by N.C. Gautam and L.R.A. Narayana (1982)[1] to provide a standard landuse classification at the

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[1] N.C. Gautam and L.R.A. Naraynan (1982), *Suggested National Land Use, Land Cover Classification System for India Using Remote Sensing Techniques,* Pink Publishing House, Mathura,pp. 1-23.

national and state level A.K. Sen (1978)[2] attempted to provide a standard landuse classification system for arid areas based on aerial photo-interpretation.

Since Gautam et el and A.K. Sen's classification schemes do not fit to present study area and for the limited resources available at disposal, a new land classification system is developed to suit the needs of study area. The scheme is so designed that it contains all possible categories which might be encountered in the interpretation process in study ares. The scheme is fairly compatible with the classification developed by various departments, institutes and individual as mentioned above. The scheme presented below is designed for landuse mapping in Chhota Tawa river basin.

IV.2 Landuse Classification System For Chhota Tawa River Basin

1. **Forest**

   1.1 Dense Forest
   1.2 Open Forest
   1.3 Forest Blank

2. **Cultivated Land**

   2.1 Cropped Land
   2.2 Plantation
   2.3 Fallow Land

3. **Grazing or Range Land**

   3.1 Grass Land
   3.2 Scrubs

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[2] A.K. Sen (1978) *Landuse Classification System in Indian Arid Zone*, CAZRI Monograph, pp. 1-43.

4. **Waste Land**

(I) **Unculturable Waste**

4.1 Rocky Waste
4.2 Gullied Land
4.3 Gravelly Land

(II) **Culturable Waste**

4.4 With Scrub
4.5 With Out Scrubs

5. **Water Bodies**

5.1 River
5.2 Lake
5.3 Reservoir
5.4 Canal

6. **Built Up Land**

6.1 Urban
6.2 Rural
6.3 Road/Railway

The landuse map of Chhota Tawa river basin adopting the above mentioned classification scheme was prepared. It depicted the distribution and extent of different land utilization units. The aerial photographs, landsat images and toposheets were used to demarcate the boundaries of different landuse units. These units could be interpreted on photographs by studying the pattern and variations of the image characteristics of the object in the photographs. The correct interpretation is based on three basic considerations viz. (1978 A.K. Sen)[3].

(a) Similar landuse in photographs is likely to appear in

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[3] Ibid.

similar pattern. Any two landuse units arising due to different cultivated or due to grazing or waste lands derived from rocky, saline or sandy nature of terrain have similar characteristics and appear in photograph in similar pattern.

(b) Dissimilar landuse is likely to appear in dissimilar pattern.

(c) Once the photographic images are correlated with the type of landuse in field, the sequence of events which form a particular landuse unit can often be delineated by means of photo-interpretation and many important aspects of landuse like cropping pattern or type of waste land or types of settlement can be inferred.

Keeping above basic principles in view, the Chhota Tawa river basin landuse classification has been attempted on 1 : 50,000 scale using black and white photographs and Landsat imagery. All the elements of land are registered on the photographs. Their identification and interpretation is done on logical classification of images through the study of photo elements i.e. tone, texture, height, shadow, size, shape, pattern and associated features and correlation of texture and tone of the images or variations of tones. Certain aspects are identified directly from photograph and others are deduced by systematically studying and correlating photo-elements of the images. Many objects are inferred and identified by means of logical search and resorting to probabilities by studying and correlating photo-elements and existing knowledge.

Agricultural lands are distinguished by check board pattern of fields, which indicate the individual holdings. Similarly, check board pattern with wells or canals indicated irrigated crop lands, but attempt was not made to identity irrigated crop lands owning to small scale of photographs. Built up areas or settlement are distinguished from density pattern. Radial pattern of roads helped to identify trading or marketing centres. Waste lands are inferred on photographs as lands covering small or large areas in continuous or having irregular or diffused boundaries. Permanent pasture lands are often marked by a pattern having irregular or triangular boundaries. Urban areas are marked by patterns having sharp angular corners. In this way taking into account the photo-elements and field work, landuse map has been prepared.

IV.3 Present Landuse in Chhota Tawa River Basin

It has been observed that remote sensing technique in conjunction with ground truth and toposheet is very useful in identification, classification and mapping of the landuse units. The distribution and salient photographic and space image spectral characteristics of these landuse classes have been given, in brief, in Appendix IV.1 and discussed in detail below:

1. Forest Land :

Forest land is defined as a unit of vegelation which possesses characteristic in physiognomy and structure sufficiently pronounced to permit its differentiation from other vegetation unit. This category includes three sub-types:

1.1 Dense Forest,

1.2 Open Forest,

1.3 Forest Blanks.

1.1 Dense Forest :

A continuous stretch of forest with dense canopy has been defined as dense forest. On aerial photograph it has been identified with the help of dark tone and smooth texture owing to dense canopy. In this unit no individual tree crown is distinguishable easily, rather they form continuous stretch of dark tone on black and white aerial photograph. Dense forest appear on FCC in bright red to dark red in tone because of very dense canopy cover. They vary in size and shape and exhibit smooth texture and contiguous in spread but occasionally interspread with cultivated areas or forest blanks. These occupy high lands and slopes (Photo No. 17). It covers 90 per cent area of the denudational hills, 40 per cent inliers, 65 per cent table land, 20 per cent valley fill undissected and negligible area of alluvial fan, bagada and structural hills.

1.2 Open Forest :

Open forest is defined as a forest with sparse vegetation. In this forest, an individual trees can be picked up on aerial photographs. Open forests exhibit mottled or banded tone and coarse texture given by individual tree crown. Open forest appears light red to dark brown in tone on False colour composite. The spatial spread, vary in size with irregular and discontinuous shapes. The texture is coarse to mottled owing to sparse vegetation and exposure of terrain underneath. It is contiguous to limited extent but mostly non contiguous in total pattern giving rise to vast patches due to openings. It occurs on upland, slopes, hills and on soil of low fertility in Chhota Tawa river basin (Photo No. 26). 100 per cent area of mesa/butle comes under open forest and less than 5 per cent of bajada and alluvial fan and about 20 per cent area of valley hills.

1.3 Forest Blank :

Forest blanks are those opening, cleared forest patches which are amidst forest without any tree cover. These are of assorted size and shapes. On imagery forest blanks exhibit light yellow to light brown tone and coarse to mottle texture dispersed and scattered amidst forest on hill tops or slopes. On aerial photographs, forest banks are picked up with the help of coarse texture and medium dark tone to light tone. In Chhota Tawa river basin this occurs on the top and slope of Satpura and

Vindhyans but they are very small in size and are negligible as compared to the size of study area. It covers about 5 per cent area of undissected table lands.

2. Cultivated Land :

Cultivated lands are not necessarily cultivated each year and include all agricultural lands generally used for production of food crops and other cash crop, plantation and fallow land.

2.1 Crop Land :

Crop land includes land with standing crop. On aerial photograph crop lands are picked up with the help of check board grid pattern. Individual fields can be marked as boundaries which are clearly seen on aerial photographs. Current cultivated plots give medium to dark tone and coarse texture with sharp boundaries. On False Colour Composite, crop lands, exhibit bright red to red colour with smooth texture. Crop lands occur on the variety of terrain in Chhota Tawa river basin. Large part of study area is under cultivation (Photo Nos. 8,10 and 28). It covers 100 per cent area of flat buried pediment and old alluvial plain and 90 per cent area of active flood plain bajada and valley fill undissected, and negligible portion of rest of the units.

2.2 Plantations :

Plantation includes an area under agricultural tree-crops and orchards. On aerial photographs plantation are seen and identified with the help of aligned trees in field giving banded tone with coarse texture and occupying plain areas. On False Colour Composite, it exhibits bright red colour and coarse texture. In Chhota Tawa river basin mostly banana plantations and citrus fruit plantations are grown. In photo no. 18 banana plantation is seen. The size of plot are too small to map, hence no plantations could be mapped.

2.3 Fallow Lands :

Fallow land is defined as lands which were cultivated but at present left uncultivated for the recoupment of soil fertility. This is agricultural land but without crop. On the aerial photographs, fallow lands are recognized with the help of diffused boundaries and lighter tone with coarse texture either fringing crop land or surrounded by crop lands. At some places, they occur in isolated patches in discontinuous manner with irregular boundaries. It appears yellow to greenish blue in tone with medium to coarse textures in False Colour Composite. In Chhota Tawa river basins fallow land patches are ubiquitous. 2 per cent, 25 per cent, 15 per cent area of active flood plain, undulating pediments and rolling pediments are covered under this category respectively (Photo No. 19).

3. Grazing Land or Range Land :

Grazing land or range land includes two types i.e. grass land and scrub land.

3.1 Grass Land :

Grazing land or grass land are the lands where the potential natural vegetation are predominantly grasses or grass-like plants. On aerial photographs, grass lands are registered in medium grey to dark grey tone and coarse texture. Grass lands occur in contiguous, and at places in isolated patches. Grass lands on False Colour Composite appear in light red to light brown tone and coarse to mottled texture. It occurs on mountain tops, hill slope and on lands which are economically not viable for cultivation. In Chhota Tawa river basin grazing lands are found in patches in forested areas (Photo Nos. 22 & 23). Grass land covers 60 per cent area of inlier, 20 per cent valley fill and less than 5 per cent area of bajada and alluvial fans.

3.2 Scrubs Land :

Scrub land includes lands where scrubs are standing. In this landuse unit, area under dwarf trees and grasses is included. It mostly occupies hilly areas or range lands in Chhota Tawa river basin. On aerial photographs scrubs are identified with the help of light and medium dark grey tone with coarse texture. On FCC, scrubs exhibit dark brown colour (Photo No.s 27 & 29).

4. Waste Land :

Waste lands includes the land which is at present lying waste or unused due to unproductive nature of land or due to some other reasons. There are two main types of waste lands i.e. unculturable waste land and culturable waste land.

4.1 Unculturable Waste Land :

Unculturable waste land includes the land which is unfit for cultivation for instances rocky waste, riverine or gullied land, gravelly waste. These lands can not be brought under cultivation.

4.1.1 Rocky Waste :

Rocky waste land includes exposed rocks. It is identified on aerial photograph on the basis of lighter grey tone, mottled image structure, medium to coarse texture and specific photo pattern in large area covering in continuous manner interrupted by hills and rocky out crops, scattered trees and scrubs. Rocky wastes appear in greenish blue yellowish to brownish tone. The size varies from small patches to large one ranging from a few meters to a kilometres. In Chhota Tawa river basin rocky waste occur mostly in upper Northern catchment area. Vindhyans, Bijawar and traps are exposed by erosion on level to undulating terrains included in this categoring (Photo Nos. 11 & 12). It covers 100 per cent area of pediments, 75 per cent and 60 per cent of undulating and Rolling pediments respectively.

4.1.2 Gullied Land :

Gullied waste lands are developed on the river banks and at foot hills in Chhota Tawa river basin. The identification of gullied land is facilitated by the presence of gullies and hence it was very easy to delimit areas subjected to gully erosion on aerial photographs. On False Colour Composites, gullies are identified with the help of blue greenish tone. It occurs on valley fill (dissected) basaltic table land (dissected) and active flood plains and cover 100 per cent, 100 per cent and 5 per cent area respectively.

4.1.3 Gravelly Wastes :

Gravelly waste land includes the waste lands on which gravelles are so ubiquitous that it is not possible to bring the land under any use. In case of rocky waste rock surfaces are exposed, and on rocky surfaces, there is no soil where as on gravelly waste many gravels are studed on ground. Gravelly waste gives a specific photo pattern in large or small areas in continuous manner. The tone variation is medium to light. The presence of the gravels is marked by close arrangement of dots displaying coarse texture in photograph. On False Colour Composite, gravelly wastes show greenish brown tone. In Chhota Tawa river basin gravelly waste lands are found over all litho units on undulating terrain in negligible proportion.

4.2 Culturable Waste Land :

Culturable waste lands are those lands which are fit for cultivation or can be brought under cultivation if some measures are applied but at present lying waste. Culturable land with scrub and without scrubs are two main subtypes of culturable waste lands.

4.2.1 Culturable Waste Land with Scrub :

This unit is different from scrub of range land in that these lands are found in areas of low topography, basins and undulating plains where soil develops. This unit can be brought under cultivations. The tone and texture do not help much in differentiating scrub waste land and scrub range land as both having identical physiognomic characters resulting in similar tone and texture. This unit occurs on low topography or undulating plains and covers about 20 per cent areas of these land units.

4.2.2 Culturable Waste Land without Scrubs :

This unit also occurs on th same terrain as the preceding one but in this unit no trees are found and it is completely barren and occupies 25 per cent area of undulating pediments.

5. Water Bodies :

It includes river, tank or lakes, reservoirs and canals.

On aerial photographs, water bodies are demarcated with the help of darker tone than its surrounding area, smooth texture and location. On False Colour Composite, they exhibit bluish tone and fine texture. Main water bodies are marked on map. This unit has not been mapped owing to its small size. Only a few rivers for orientations of the map have been mapped.

6. Built Up Lands :

These are the lands used for non-agricultural purposes and covered by mostly building structures. It includes both urban and rural settlements. Parks and other open spaces within the built up areas are also included in this category. In addition, roads and railways are also included in built up lands. As built up area gives best three dimensional perception, it was easy to delineate built up areas on aerial photographs. Roads and railways were identified with the help of dark tone and its linear pattern. All built up lands are not marked on map as it could mask other details of agricultural landuse which are important for present study. Only a few major settlements roads and railways are shown on map for the orientation and location purpose.

IV.4 Natural Hazards and Landuse Problems

Land unit studies which are mainly concerned with the materials, forms and processes significantly contribute in the identification, assessment and evaluation of natural hazards and landuse problem in Chhota Tawa river basin. In view of the practical application of geomorphology in the environmental management and resources conservation and development, geomorphological investigation on the nature, magnitude and distribution of the hazards and landuse problems by employing remote sensing technique have been carried out in the present study area.

The hazards and landuse problems encountered in Chhota Tawa river basin are given below :

1. Flash and sheet erosion,
2. Rill erosion,
3. Gully erosion,
4. Rock out crops, thin and poor soil cover,
5. Low water table,
6. Steep slope,
7. Land slide and Rock fall,
8. Lack of perennial river,
9. Fallow lands,
10. Deforested land.

The above listed hazards and landuse problems are discussed below in brief :

In the study area flash and sheet erosion are very active. The mechanism of flash and sheet erosion has already been discussed in the section of processes. An attempt has been made here to show the spatial extension which also indicates the intensity and severity. This erosion has produced pediments which are unproductive waste lands. This process of erosion does not allow soils to settle and develop over rocky surfaces. As the data regarding rainfall show that rains are concentrated in short spells and cloud bursts which cause flash erosion that dislodges fine particles and make them loose. Subsequently these loose particles are washed off the down slope exposing the rock surfaces which are of no practical use. This process should be checked as it helps in increasing pediments, exposed bare rock surfaces, by removing thin veneer of colluvium, assorted material, essential for soil formation. If it is not checked it will render the productive land as rocky waste land. The intensity and severity of this hazard can be imagined by seeing the extension of pediments which are ubiquitous all over the study area. It is picked up on aerial photographs with its lighter tone and a coarse texture on False Colour Composite (FCC) it exhibits greenish brown colour. The suitable method of arresting the extension of pediments is to channelise sheet flow in controlled-manner. It should be noted that the rain drops dislodge fine particles every where and cause flash erosion but it is not serious problem in other areas as compared to the pediment where soil and weathered materials are very thin.

Rill erosion is another hazard faced by study area, though it is not much serious over agricultural land but it is quite serious over mountainous region. Due to torrential rainfall, run-off gets channelised and forms rill. Rills are small, maximum of 0.3 metres in depth. In agricultural fields, these are obliterated due to tillage practices but it causes soil loss. In Satpura high lands, the rills are not destroyed and they grow into gullies and ravines giving rise to badlands.

The land unit map shows that a large area is subjected to gully erosion in Chhota Tawa river basin. Gully formation takes place where run off is concentrated and channelised sufficiently. The mechanism and factors favourable for formation of gullies are discussed at length in the section of processes. The study area receives torrential rainfall in short spells. The water collected over table land and high lands rushes down and removes unconsolidated materials. the gullies are encroaching fertile cultivable lands on buried pediments, table land, intermontane valley fill and along river banks in the study area. These gullied areas are occupied by sparse thorny vegetation and grasses. Over-grazing and human activities have caused damage to natural vegetal cover and accelerated gully erosion. The gully erosion should be checked by plugging gullies and bringing the land under protected forest and grass.

As it can be observed from land unit map and photographs nos. 11 and 12, the rock out crops are ubiquitous in study area. This is one of the major problems of the study area. It has reduced the area under cultivation, forest and grasses. The origin of these out crops is ascribed to sheet erosion and processes of pedimentation in the land unit chapter.

Since the rock out crops, pediments, are ubiquitous in study region, the water table is very low in pediment and also on structural, denudational and residual hills. It is almost not possible to sink a bore in this region. Over such a vast stretch of land, low water table is a serious problem. Women have to walk kilometres together to fetch the water for domestic use. No doubt, in rest of the land units, water table is about 12 to 30 metre below surface. The ground water is harnessed and used for irrigation (Photo No. 8 shows irrigated farm and dug well with electric punset installation).

In the study area, as land unit map shows, over table land, and around mesa, butte and trap steps a very precipitous slope about 80 and 85 degrees is developed. And below and above these free faces, slope is quite steep measuring about 45 and 60 degrees and it has given rise to uncontrolled and unchecked run off descending down the slope and causing rampant rill and gully erosion. The problem of steep slope can not be over come but at least these slopes can be put under forest, grasses and off the grazing for some time so as to avoid further erosion.

At the bases of the free faces, scree materials were observed during field work. It provides ample clues to believe that in mountainous area land slides, debris slides and rock fall occur. These are too small to identify and delimit on aerial photograph. As these are small in proportion, they do not pose much problems but certainly disturb natural slope and causes damages to the vegetation below free face and over steep slopes.

The climatic data exhibits that the study region experiences semi-arid climate. The rainfall (about 80%) occurs in monsoon season and rest of the part of a year receives very meagre rainfall. Evapotranspiration exceeds precipitation and always results into water deficiency and aridity. The aridity is very serious problem of landuse in study area. The dwarf species of vegetation, extensive fallow land and bare exposed rock surfaces in central part of the study region, are the testimony to the fact that the region falls in semi-arid zone and has a acute problem of aridity.

Aridity owing to low rainfall, concentrated in short period and high temperatures (Table I.2 and I.1) has resulted into non-perennial rivers. In the preceding section about processes, it has been elaborated at large that except lower courses of Chhota Tawa and its tributaries (fig. land unit map) are ephemeral. The intermittent rivers are not a perennial source of the water in upper catchment areas. Hence the river waters could not be utilized or irrigation during rainfall decifiencey period. It is evidenced from the wide spread dry farming observed on photograph as well in the field too.

Aridity, lack of perennial source of water, low water table, thin soil cover and highly concentrated rainfall during monsoon season are, a few factors, responsible for fallow lands in the study area. The landuse map shows the proportion, extension and distribution of fallow lands in study area. Above listed factors force farmers to keep the land fallow for regaining fertility in one season or the other. It is one of the problems faced by study area and needs to be investigated in detail to over come the problem of fallow lands.

The forest resources are shrinking and depleting in study area because of various reasons known to all. These reasons need no mention. The deforestation is very serious problem resulting into erosion, aridity, depletion of ground water, its lowering down and land sides.

As a matter of fact, the above discussed hazards and problems are inter linked and cannot be separated from each other and studied in isolation. The change in one affects another and causes changes in others too. It is a delicate ecosystem. It needs a comprehensive survey regarding hazards and problems.

CHAPTER-V

RELATIONSHIP BETWEEN THE LAND UNITS AND Landuse

V.1 Introduction :

Land units and land utilization patterns are closely related. Geomorphology of an area, plays a dominant role in controlling and moulding landuses in any region. An attempt has been made to identify the relationships between land and cultural and natural factors of the environment. Chaturvedi has attempted a correlation between the landuse with physiography and drainage and classified lands according to capability. Raghwaswamy (1981)[1] identified the settlement pattern with land classes. Gautam and Narayana have attempted to establish relationship between agricultural lands and canals in U.P., Punjab and Haryana. Forestry with physiography have also been correlated. Murthy, Pofali and Saxena (1982)[2] have used remote sensing techniques in establishing the relationship between geomorphology and soils. Pandey, Ghose, Roy and Abichandani

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1 Raghwaswamy, V. (1981) "Landforms, Land systems and Geographical synthesis of Vishakhapatnam Tract in East Coast Plain of India", *Unpublished Ph.D thesis*, Andhra University, Waltair.

2 Murty, R.S., Pofali, R.M. and Saxena, R.K. (1982), "Remote sensing Techniques in establishing geomorphic-soil relationships", PHOTONIRVACHAK, *Jour. of Ind. Soc Photo-Int and Remote Sensing*, Vol. 10, No. 2, pp. 1-11.

(1967)[3] have attempted to recognise geomorphic influence on soil genesis in semi-arid and arid environment. Pandey, Ghose and Vats (1968)[4] have studied geomorphic influence on water resources. Sen and Singh (1972)[5] have studied significance of geomorphic factors on landuse planning and development in Bikaner district. Vats (1977)[6] has studied the influence of micro-geomorphic units on landuse and cropping pattern in Dundli village. Vats and Singh (1983)[7] have assessed the impact of geomorphology on land utilization in Nagaur district of Rajasthan. Jadhav (1986)[8] have investigated water resources

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3 Pandey, S., Ghose, B. Roy, B.B. and Abichandani, C.T. (1967), "Geomorphic Influence on Soil-genesis in Semi-arid and Arid Environments" , *Jour. Ind. Soc. Soil Sci.*, Vol. 15, No. 3, pp. 163-172.

4 Pandey, S., Ghose, B. and Vats, P.C. (1968) "Geomorphic Influence on Water Resourviors", *Ind. Jour. Geog*, Vol. 3, No. 1, pp. 45-55.

5 Sen, A.K. and Singh, S. (1977) "Significance of Geomorphic Factors on Land Use Planning and Development in Bikaner District", *Ann. Arid Zone*, Vol. 16, No.1, pp. 13-24.

6 Vats, P.C. (1977), "Influence of Micro-Geomorphic Units on Land Use and Crop Production - A Case Study of Sundli Village", *The Deccan Geographer*, Vol. 15, No. 2, pp. 317-326.

7 Vats, P.C. and Singh, S. (1983), "Impact of Geomorphology on the Land Utilization in Western Rajasthan - A Case Study of Nagaur District", *The Deccan Geographer*, Vol. 21, No. 3, pp. 441-448.

8 Jadhav, A.S. (1986), "Application of Remote Sensing in Hydromorphology for Third World Development : A Resource Development Study in Parts of Haryana (India), in M.C.J. Demen (eds.), *Remote sensing for Resource Development and Environmental Management*, A.A. Balkema, Amsterdam, pp. 721-725.

using remote sensing applications on hydrogeomorphology in parts of north India to demonstrate the relationship between landforms and ground water resources. Surendra Singh (1993)[9] has attempted to correlate lad use with natural resources unit. Datye and Gupta (1979)[10] have attemmpted to explain spatial variations in agricultural landuse through physical aspects especially slope and concluded that slope below 3 degrees offer maximum scope for cultivation, whereas the slope above 5 degrees imposes serious limitations to the cultivation of crops. Sharma and Sharma (1973)[11] have attempted the hydrological evaluation of morphological features of fluvial terrain in parts of Uttar Pradesh and concluded that abondoned river channels in the flood plains are expected to yield appreciable quantities of ground water. Prudhvi Raju and Vaidyanaathan (1977)[12] have studied

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9 Singh, S. (1993), *Geomorphology and Remote Sensing in Environemental Management*, Scientific Publishers, Jodhpur.

10 Datye, V.S. and Gupta, S.C. (1979) "Slope and Agricultural Land Use - An Analytical Studyy with Reference to Poona District (maharashtra)", TRANSACTION, *Jour. Int. Ind. Geog.*, Vol. 1, No. 1.

11 Sharma S.K. and Sharma S.C. (1973), "Hydrological Evaluation of Morphological Features of some parts of Hamirpur, Jhansi, Banda and Fatehpur Districts, U.P. using Air Photto-Interpretation Techniques", PHOTONIRVACHAK, *Jour. Ind. Soc. Photo-Int.*, Vol. 1, Nos. 1 & 2.

12 Prudhvi, Raju, K.N. andR. Vaidyanathan (1979), "Study of Land forms, Land use and Land Units of Parts of Krishna District from Aerial Photographs", PHOTONIRVACHAK, *Jour. Ind. Soc. Photo Int.*, Vol. 5, No. 2.

landforms, landuse and land capabilities and limitations in relation to geomorphology of Krishna district. Landforms and land units have been identified and their landuse has been studied. Chopra (1990)[13] has studied geology and geomorphology for the landuse appraisal and identified geological formations and geomorphic zones and exanmined existing landuse to suggest potential landuse to identified zones.

The present study attempts to identify the relationship between land units and landuse patterns.

As it has already been stated in the methodology that the maps of land units and landuse are prepared and superimposed to explain the land utilization of all 15 major and 19 sub land units. In fact it was thought to correlate land units with landuse classes by statistical methods but owing to complexity of geomorphic processes, it could not be worked out. As Thornbury aptly states that, "Probably no one questions the need for more quantitative work in geomorphology. All science is becoming more quantitative and it is inevitable, as well as desirable, that this trend extends to geomorphology. It should be kept in mind, however, that the conclusions drawn from mathematical calculations are no better than the data and assumptions upon which they are based. Landform characteristics

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13 Chopra, S. (1990) "A Geological cum Geomorphological Framework of Haryana and Adjoining Area for Land Use Appraisal using Land Sat Imagenary", PHOTONIRVACHAK, *Jour. Ind. Soc. Remote Sensing*, Vol. 18, No. 1 & 2.

are influenced by many processes and control factors. Some of these processes and controls are not quantifiable and thus, cannot be subjected to rigorous statistical treatment. As Bauling (1950) has stated, "the laws of geomorphology are complex, relative and rarely susceptible to numerical expressions". This is not to suggest that we should not attempt to make geomorphology more quantitative, but it is to be hoped that increasing attention given to the mathematical approach does not detract from the roles played by such factors as lithology, stratigraphy structure, diastophic history and climatic variations in the development of landforms".[14] The land units and landforms are controlled by structure, diastrophic history, processes, material, lithology and stratigraphy, which indirectly control land utilization. Since land unit and landform controlling factors are not quantifiable, the explanations to varied landuses are given in the frame work of above mentioned factors qualitatively instead of quantifying them and trying to bring about mathematical relations and explanations.

There are fifteen main land units and nineteen sub units which have been identified in the present study area. Remote sensing has helped to recognise six main and twenty sub land utilization classes in the study area. In the present chapter

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14 W.D. Thornbury (1985), *Principles of Geomorphology*, John Wiley International, New York, p. 14.

attempt has been made to compare the land units and landuse classes to assess the extent of accordance between these two variables. Attempt has also been made to assess the impact of geomorphological processes on the land utilization in the study area.

The land units due to the significant variations in their geomorphic properties like surface configuration, slope, denudation including erosion, weathering and mass wasting; drainage characteristics and soils have different landuse patterns. Appreciating the importance of the geomorphic impact on landuse, the studies on relationship between land units and landuse categories were carried out and their results have been discussed below :

V.2 Landunits and Landuse :

1. Landuse in the Active Flood Plains :

The active flood plain unit, due to geomorphic factors like level slope and good quality alluvium observed during field work, is under intensive cultivation (Photo No. 28). Only at a few places along Sukta river, Gorapachar and Chhota Tawa in lower reaches gullied waste lands have been located. About 90 percent of the area covered by this land unit is under cultivation and 5 per cent under gulled waste lands. The rocky and gravelly wastes accounts for 3 per cent. These have been exposed near the river banks by floods which wash down soil cover and expose rock surfaces to view. The fallow lands cover only 2 per cent of the area of active flood plains.

2. Landuse on Old Alluvial Plains :

These land units border active flood plains and form narrow belts. The landuse of these units falls under the category of cultivated lands in general and cropped lands in particular. The tone and texture of the aerial photograph indicate that the soils are well developed and have good ground water potential, better drainage conditions and limited natural hazards and have less problems pertaining to landuse. This land is devoted to raising irrigated and rainfed crops (Photo No. 8).

3. Landuse of Bajada :

The bajada borders basaltic high terrain. When rivers come down to plains, their load carrying capacity is reduced and they start depositing the debris and form alluvial fans. When a number of alluvial fans coalesce together they form bajada. This unit has perceptible slope of 20 degrees, but it has a good and thick cove of materials brought down by rivers (inferred from photographs). The bajada has also been devoted to raising crops. The super imposition of landuse map over the land unit map shows that at places the land unit is under forest, open forest and range land, but the proportion of such uses is negligible and accounts for only 5 per cent of the area (Photo No. 21).

4. Landuse on Alluvial Fans :

The landuse on alluvial fans is identical to bajada. The figure IV.1 shows that at places, it is under cultivation. The interpretation of aerial photographs helped to deduce that this unit has good and thick cover of material brought down by rivers which has good water holding capacity. The area has forest particularily open forest and range land but these are of negligible proportions.

5. Landuse in the Intermontane Valley Fills (Dissected) :

This land unit occurs on Satpura high lands between ridges. The dominant processes found over this unit are the degradational fluvial processes. This unit has been severely denuded and gullies and ravines have developed, it is devoid of cultivation. This land unit lies under wastelands in general and gullied land particular. The entire area under gullied waste land has no cultivation. Rills have developed into gullies and have made the land unsuitable for cultivation. It can conveniently be concluded that in all the intermontane valley fills (dissected), the landuse will be gullied waste land. It is necessary to chanelise the run off and the land unit may be put under forest and grass cover so as to arrest the further growth of gullies over surrounding areas. It is inferred from the height of banks of gullies that the valley fills have very thick deposits of weathered materials and very fertile soils which could be put even under cultivation and controlled grazing but plugging of gullies and levelling of land would involve huge capital. If the run off of gullies is channelised, it would help in arresting the growth of pediments too where unchecked run off strips off soils and weathered materials.

6. Landuse of Intermontane Valley Fills (Undissected) :

This land unit is found bordering intermontane valley fill (dissected). In the Satpura range, this unit occurs at five places. Since units have thick deposits of material brought down by denudational agencies and soils are well developed (inferred with the help of darker tone and fin texture on aerial photograph), the land unit is under cultivation. Its location deters the sinking of tube wells and hence the farming is largely rainfed. About 80 per cent of the land is under cultivation and 20 per cent is under forest, open forest and range lands. The bottoms of valley fills are flat and flanks are sloping. More land can be brought under cultivations with proper terracing.

7. Landuse of Buried Pediments :

There are two types of buried pediments viz. flat buried pediments and undulating buried pediments identified in Chhota Tawa river basin.

The flat buried pediments are covered under deep, well drained, fine textured fertile soils. It is inferred from photographic tone and texture that the ground water potential is also very good (Photo No. 10) as compared to rest of the land units in the present study area. It does not suffer from any major landuse problems or natural hazards. The only problem occasionally encountered is rill erosion during torrential rainfall at places. These rills are obliterated due to tillage practices. The soils and nature of topography is very favourable for cultivations.

The present landuse of the flat buried pediments falls under the landuse category of cropped lands. The crops are irrigated by ground water at places (Photo No. 10). All the area under this land unit is under cultivations.

The undulating buried pediments have hummocky type of topography with well developed soils in depressions and shallow soils over tops of knolls. The depressions are intensively cultivated and tops have cultivation and fallow lands. About 75 per cent area is under cultivation and 25 per cent under fallow lands.

8. Landuse on pediments :

There are three types of pediments based on nature of the slope where the landuse on these three types of pediments differs.

The flat pediments are bare and levelled. The rock cut surfaces are visible (Photo No. 11). The slope varies from 3 to 5 degrees and no detritus is found over it and hence soils are not developed. These are mostly all waste lands and may be termed as rocky waste. All over the flat pediments no grass, vegetation or cultivation is noticed (Photo No. 11).

Undulating pediments present hummocky type of topography with depressions/hummocks or inter locked knolls. In the depressions shallow soils are developed. Hence, the knolls are formed of bare rocks and depressions have skeletal soils. These lie as rocky waste on hummocks and range land in general, and scrubs with grasses in particular in depressions. Rocky waste covers bout 75 per cent of the undulating pediments and 25 per cent is covered by scrubs with grasses (Photo No. 12).

The rolling pediments have a uniform slope variation. It is covered under thin veneer of detritus at places. The landuse of this land unit falls under four categories. Rocky waste land covers bout 60 per cent, grazing lands with scrubs cover about 20 per cent and cultivated area is found over 5 per cent. The proportion of fallow land due to thin soils and its low water retention capacity is about 15 per cent. Gravelly waste land is also observed in this unit but covers negligible area.

9. Landuse on Denudational Hills :

Owing to unfavourable conditions for farming like steep slope, ruggedness, lack of sources of water for irrigation, this land unit is poorly cultivated. About 90 per cent of the area of the unit is under forests and 10 per cent is under cultivation. The cultivated patches are found within the forests.

10. Landuse on Inliers :

The huge inlier, the older rock mass encompassed by younger formation, is identified in central part of Chhota Tawa river basin. It consists of Vindhyan sandstones of pre-cambrian age. Since Vindhyans are more resistant than basalt, the surrounding basalt has been denuded and inliers, Vindhyan sand stone, stand out boldly forming high lands. The inliers have steep slope varying from 40 to 60 degrees. The slope is the main constraint to cultivation.

The inliers are under forest and range lands. A few forest blanks are also noticed. About 40 per cent of the area is under forest and 60 per cent is range land with the dominance of scrubs and grasses.

11. Landuse on Residual Hills :

As the term implies that it is a remnant of huge hill and at present located in isolation or detached from high land/huge hill and small in dimension, almost all residual hills have open forests and rocky waste lands. At places where rocks are exposed to view on top of the hills, it is included in the waste land and gravelly barren.

12. Landuse on Structural Hills :

The structural hills have been located in north western part of Chhota Tawa river basin. The land unit is structurally controlled. It is covered by forests. Part of it is range land. A few patches are found where dry forming is carried on within the forest area.

13. Landuse on Basaltic Table Lands :

There are two sub units in the basaltic table lands viz. basaltic table land (dissected) and basaltic table land (undissected).

The essential characteristics of basaltic table land (dissected) is steep slope and gully erosion. This unit is severely dissected and does not support the healthy growth of the forest or grasses. The landuse of this sub unit falls under the landuse category of waste land in general, and gullied land in particular. A very scantly open forest is visible but this could not be ascribed to the dominant landuse and hence, it can be said that whole area is a gullied waste land.

The basaltic table lands (undissected) have vast flat tops. The use of this sub-unit is varied. 65 per cent of the basaltic table lands (undissected) are covered by forest, 20 per cent is under cultivation, 10 per cent is under open forest and 5 per cent is forest blank. It seems that the forest blanks may be due to the felling the forest for cultivation but at present, it is not used for cultivation and lying as unused land.

14. Landuse on Mesa/Butte :

A small flat topped hill surrounded by scarp at least on one side is termed as mesa/butte. On Satpura high lands a number of flat topped hills of small dimensions are termed as mesa/butte. The major landuse of mesa/butte falls under open forests. Though the hills have flat tops, these can not be cultivated due to thin soils, limited area and precipitous slopes on the sides. Almost 100 per cent area of the mesa/butte is covered by sparse forest and is included in the landuse category of open forests.

15. Landuse of Plateau Steps :

The plateau steps represent the plane of lava flow and lie almost horizontal or with a little slope ranging from 5 to 10 degrees. This land unit is largely under cultivation, and grasses and scrubs are also observed at places.

V.3 Geomorphic Processes And Landuse :

The landuse of a region is influenced by geomorphic processes. A detailed out line of the processes has already been presented and discussed in the second chapter. Here, an attempt has been made to discuss the impact of major geomorphic processes on landuse.

As it has been mentioned that fluvial process controls and influences landuse in the study area. An area where fluvial depositional process is dominant, for example, active flood plains, old flood plains, bajada and alluvial fans are devoted to cultivation. intensive cropping is generally practiced in those areas where water for irrigation is available.

Second important group of geomorphic processes pertain to denudation processes viz. weathering including spheroidal and chemical weathering, erosion, including sheet, rill, gully and channel erosion comprising of vertical and lateral erosion; and differential erosion and mass wasting. The land units created by these processes are of many types which have already been discussed in Chapter III. The area witnessing these processes have generally been classified as waste land comprising of gullied land, rocky waste land, forest and grass lands and limited cropped lands.

The volcanic processes particularly fissure eruption has deposited a huge mass of lava and formed Satpura range. The dominant landuse observed in such areas are cropped and fallow lands, waste lands especially gullied waste land, forest, open forest and forest blanks.

Vindhyan system found in the Chhota Tawa river basin have been witnessing denudational processes. The land under this system has been utilized for forest and range lands. Limited area has been used for cultivation also.

V.4 Suggested Potential Landuse :

In the present section potential use of land units has been suggested. The principal objective is to select the potential landuse for each defined land unit group, taking into account physical conditions and the consideration of environmental resources, for future use. In order to suggest the potential landuse of the land units the analysis of geomorphic conditions, the nature and extension of weathering of rocks and development of soil cover, slope conditions, the drainage net work has been attempted and natural hazard have been identified. Secondly, the present landuse and landuse problems have been identified and demarcated.

An attempt has been made to group 19 sub land units into five land unit groups for suggesting potential landuse. A few land unit groups are further differentiated into sub-land unit groups based on certain limitations.

1. Land Unit Group-I :

This group of land unit comprises of old flood plains and flat buried pediments. The soils over this land unit group (as inferred from aerial photographs) are well developed, well drained and deep with fine texture which has high water holding capacity. The slope is very gentle ranging up to about 4 degrees. The darker tone and cultivation indicate that the potential of ground water is good. It faces no natural hazards as such except aridity. The soils erosion specially sheet and flash erosions are experienced to some extent but it does not pose serious problem to soils. No gully erosion is observed. The soils have naturally determined fertility and are not affected by wetness, stoniness, salinity etc. At present the land is under intensive cultivation. This land unit group can be put under any use; from cultivation to forestry or wide life without giving any special treatment to soils or slopes. It is recommended that this group of land unit be put under cultivation to augment the crop production.

Land Unit Group-II :

This group of land units spread over active flood plains, undulating buried pediments, alluvial fans, bajada and intermontane valley fill (undissected). This group of unit is divided into two sub groups on the basis of the nature of topography mainly slope and ruggedness.

2. Land Unit Group-II(A) :

It comprises of active flood plains, situated along major streams as described in Chapter III. The slope of land is imperceptible and soils are also well developed, deep, well drained (inferred from aerial photographs) and capable of supporting cultivation. Soils are affected by gully erosion along the river banks. The wetness, salinity and stoniness is not observed. At present this group is under cultivation and small part is under waste lands especially gullied waste land. This has limitations that need moderate conservation practices. The ground water potential is good as indicated by its location and geotechnical characteristics. The lower reaches of the rivers may be harnessed for irrigating the lands.

The present landuse of this group is cropped land. Some proportion is gullied land. It requires some measures to be taken to arrest the expansion of gully erosion over fertile soils that are under cultivation. It would be better if gullies are plugged and land is brought under cultivation because gullied lands are situated along rivers and over flat tops where soils are fertile.

3. Land Unit Group-II(B)

This land unit group lies over undulating buried pediments, alluvial fans, intermontne valley fills (undissected) and bajada. This land unit group is developed by depositional processes. As it is deciphered from photographs, it had good cover of soils but it is not a plain. Slopes vary from 5 to 20 degrees. At present the land is under cultivation, fallow, forest and open forest.

TABLE-V.I

Land Unit Groups And Their Corresponding Land Units

Sr. No.	Land Unit Group	Corresponding Land Units
1.	Land Unit Group-I	Flood plains and buried pediments.
2.	Land Unit Group-II(A)	Active Flood plain.
3.	Land Unit Group-II(B)	Undulating buried pediment, alluvial fans, bajada, Intermontane valley fill (undissected).
4.	Land Unit Group-III	Denudational hills, Inlier, Residual hills, structural hills, plateau steps, undissected basaltic table lands.
5.	Land Unit Group-IV	Intermontane valley fill (dissected), dissected basaltic table lands.
6.	Land Unit Group-V	Mesa/butte, Rolling pediments, flat pediments, undulating pediments.

It is recommended that land pertaining to this unit may be managed with terracing and contour bunding. The land may be put under forest and grass lands. The controlled grazing may be allowed so that forest may not get damaged and people living in the vicinity may not find it difficult to rear cattle.

4. Land Unit Group-III :

This land unit group consists of denudational hills, residual hills, inliers, structural hills, undissected basaltic table land and plateau steps. Mostly this group covers high lands and hills. It has severe limitations that reduces the choice of landuse and requires special conservation practices. The main problem of landuse is the low ground water table. As it is stated in the preceding pages that it is not possible to sink a bore well or dug well over this unit.

At present, the existing landuse of the group falls under categories like forests, forest blanks, open forests. At places cropped lands occurs on undissected basaltic table lands, plateau steps, denudational and structural hills. The proportion of cropped land is negligible. Another problem faced by this group of land unit is high degree of slope over hilly areas as well as poor and thin soils cover which make land unsuitable for cultivation.

Taking into consideration its physical limitations, it is recommended that this group of land units may be brought under forest except existing cropped lands and the existing forests may be protected from grazing. Except existing cropped land, no land should be allowed to be brought under cultivation causing deforestation which would lead to uncontrolled run off causing the erosion down slope.

5. Land Unit Group-IV :

This group covers intermontane valley fills (dissected) and basaltic table lands (dissected). Located on high lands, it is highly dissected by gullies and ravines.

TABLE-V.II

Land Unit Groups , Their Physical Characteristics, Dominant Problems, Conservation Measures and Existing and Suggested Landuse

Sr. No.	Land Unit Group	Physical Characteristics	Dominant problem	Conservation measures	Existing land use	Suggested landuse
1	2	3	4	5	6	7
1.	I	Gently sloping to levelled plain well developed, drained, deep, good textured fertile soil with high water retiontion capacity	Slight-sheet and flash erosion but poses no problem	Sinking bore wells and dug wells	Cropped land	Cultivation with irrigations
2.	II(A)	Plain, unperciptible slope, deep, well developed, drained, five textured fertile soils	Gully erosions along river banks over small areas	Pluggig gullies	Cropped and gullied waste land	Cultivation using water available in lower reaches of main streams
3.	II(B)	Good cover of soils slope viries 5° to 20°	Slope	Teracing, contour bunding levelling	Cultivated land, forest, open forest rage land, fallow lands	Forest and grasses with controlled grazing
4.	III	High Lands, hills, steep slope except flat tops of basaltic table lands	Steep slope, low water table	Channelising run off and terracing	- " -	Forest and grasses with controlled grazing and cultivation on existing cropped lands
5.	IV	Slopping valley flanks and flat table tops	Severe gully erosion	Channelising uncontrolled run off and bunding	Gullied waste lands	Protected forest and grasses
6.	V	Rock cut surfaces covered with thin veneer of soil or bare rock cut surfaces	Severe sheet erosion	Stopping expansion of pediments by channelising uncontrolled water from other areas	Rocky waste lands	Quarrying

At present, the land is waste especially gullied waste land. Owing to slope, it is not possible to level it and bring it under cultivation and its location on highlands also does not favour cultivation. It is suggested that these lands be conserved by channelising run off properly and the lands after wards should be brought under forest and grass cover. It can be used as recreative site also.

6. Land Unit Group-V :

This group includes rolling, flat and undulating pediments and mesa/butte. The main problem of this group of land units is limited and thin soils cover. The flat buried, rolling and tops of undulating pediments are completely bare rocks cut surfaces without any cover of detritus or soils. These characteristics severely put limitations of its use. The depressions of undulating pediments and mesa/buttes have thin soil cover but the small areas of these units donot encourage any cultivations. This unit suffers permanent problems of no soil cover and deep water table which could not be over come.

At present, the group of unit falls under waste land category particularly rocky waste lands. This group is not suitable or any agricultural uses including forest and grazing. it is recommended that it should be used to quarrying building stone (Photo No. 11 & 12).

In short, these are the recommended landuses and controlling measures to be applied to overcome landuse problems based on physical properties assessed during the geomorphological analysis of Chhota Tawa river basin. The map V.1 gives synoptic view of the lands that could put under suitable uses. This classification provides broad generalization of lands based on soil property, physiographic properties, limitations in landuse and management problems in each group of land units. Each group can be further divided into ceratin land suitability and capability classes for specific type of landuse, crops or vegetation. This requires detailed soil survey information, irrigability and slope. These surveys can be carried out for the each group of land unit to study the land unit suitability for specific crops and plants.

CHAPTER-VI

SUMMARY AND CONCLUSIONS

Remote sensing, both conventional and satellite remote sensing, techniques have been used in the present study. The remotely sensed data was used to obtain information regarding lithology, strcture, landforms, land units, geomorphic processes, drainage characteristics and lnd use of the Chhota Tawa river basin. The available literatures, perticulars and data from other sources supplemented with field checks were obtained and incorporated with interpretated data. Based on the information thus obtained, here an attempt has been made to summeries the main findings of the study area to high light the broad generalisations emerging out of it and to suggest preventive measures to allievate and over come natural hazards and land use problems.

The investigation in the present study area was carried out in three stages i.e. pre-field investigation followed by field checks and post-field interpretation.

It is found that the geological formations of the study area consist of alluvium of recent to sub recent, Deccan trap of Eocene, Vindhyan System of pre-cambrian and Bijawar of archaean age.

The northern part of Harsud tahsil in Chhota Tawa river bsin is formed of Bijawar formations consisting of quartzite, horn stone, breccia, phyllite, chert, banded limestone and ferruginous quartzite. The quartzite range forms quartzitic sandstone in which quartz grains are readily distinguishable by necked eye to soft unaltered sandstone which are some times conglomeratic. The limestone is banded with chert or horn stone. Another component of Bijawar is a massive breccia, yellow or yellowish brown in colour consisting of a horn stone or jaspher matrix intercalated with milky white quartz. The quartzitic breccia comprising of purplish jaspher with angular fragments of quartzite is found in extreme north in the study area. At the junction, concentric structures with alternating layers of siliceous and calcareous material are also found.

Upper Vindhyans consisting of massive, thick beded sandstone, shale and conglomerates faulted against Bijawar along the East West line marked by breccia also occur in parts of the study area. The prominent rock is one intermediate between sandstone and quartzite which is deep red or purplish in colour. The most common constituent of this formation is hard, compact, fine grained purplish rather thin beded sand stone. The bedding is well marked. The formations form the strike ridges and plateaus. The sandstones are massive well jointed and fine to coarse grained. The cementing material is silica.

The rocks exposed in most of the area belong to plateau basalt represented by fine grained, vesicular and non vesicular type. The non-vesicular rock is hard, tough, compact and medium to fine grained, and in dark grey to dark greenish grey colour and break with a conchoidal fracture while vesicular types are comparatively soft and friable and break more easily. The thickness of bed may be 1200 metres. Generally trap rocks appear to be horizontal except perceptible dip around plains ranging between 2 to 5 degree and water divide as much as 10 to 15 degrees.

The recent to sub-recent deposits comprising of alluvium occur in the study area. Recent alluvium deposits are found along the courses of the streams. The foot hills and slope of hills are mostly covered by rock boulders.

The basaltic terrain is faulted and jointed. The Vindhyas have dips and are highly disturbed by tectonic activities which have resulted in folding, faulting and jointing. In the present study area, depositional structure consisting of beding, current beding and ripple marks; and deformational structures consisting of foliation, joints, fractures, fault, folds and domes are well developed.

The rock type identification key is prepared to facilitate to the rock identification and demarcation.

The processes responsible for shaping the present landforms and land units have been identified and studied. It is found that the present landforms and land units assemblages are due to the complex interaction of these processes. There are four main processes operating in the study area-aggradational fluvial process, degradational processes like weathering, erosion and mass wasting, volcanism and orogenesis. Though these processes do not work in isolation, the intensity and magnitude differ from place to place. In the central and southern parts which are made up of trap, volcanism has been the dominant process resulting into the formation of basaltic table land, plateau steps, mesa and butte. This process has been aided by fluvial processes particularly differential erosion and soil erosion resulting into the formation of small features on land units like scarps, rill and gullies. Along the streams the fluvial process is more dominant than that of the rest of the three processes. This has resulted in destructional and constructional land units. The area with Vindhyan formation is subjected to the denudational processes producing a number of characteristic denudational forms such as pediments and buried pediments. The orogenesis is responsible for the formation of the structural hills supplemented by other denudational processes.

The identified process are :

1 Exogenetic Processes
(Gradational Processes)

(i) Aggredational Processes

(a) Fluvial processes

(ii) Degradational Processes

(a) Weathering- Spheroidal & Chemical

(b) Erosion - Soil erosion consisting of sheet, rill and gully erosion; channel erosion comprising of vertical and lateral channel erosion; and differential erosion.

(c) Mass Wasting- Land slide, rock fall and soil creep.

2 Endogenetic Processes

(i) Volcanism

(ii) Orogenesis

The spatial relationship, trend and behaviour of the streams and their tributories helped in identifying dendritic, sub parallel, sub annular, trellis and fault controlled drainage patterns. It is observed that the physiographic control over the development of drainage pattern is very obvious in the Chhota Tawa river basin. The drainage lines are adjusted to the present physiography except at a few places. At a few places the drainage lines exhibit that the present day drainage is super imposed over pre trappean Vindhyan System. The channel characteristics observed in the study area are braided streams, meandering channels, straight segments and flat-beds with exposed bed rock and river terraces.

Geomorphologically, terrain of the Chhota Tawa river basin has been classified into 19 land units on the basis of photo recognition and geotechnical elements and processes responsible for moulding and shaping them. The form-process approach has been adopted to explain the origin, extension and distribution of land units in the study area. The classification of the land scape is mostly based on land scape approach of CSIRO and ITC owing to disadvantages of parametric approach regarding selection of parameters and demarcation of boundaries on the basis of the super imposition of certain thematic maps. The classification of terrain is non-hierarchical one and has been presented by adopting ITC method. The nomenclature to the units has been assigned keeping in view the origin and morphology of the unit. The following land units are identified in the Chhota Tawa river basin :

A. Land Units of Fluvial Origin

I Land Units Created by the Accumulative Action of Flowing Water :

1. Active Flood Plains
2. Old Alluvial Plains
3. Bajada
4. Alluvial Fans

II Land Units Created by the Destructive Action of Flowing Water in Conjunction with Denudational Processes Possessing an Accumulative base :

5. Intermontane Valley Fill (undissected)
6. Intermontane Valley Fill (dissected)

B. Land Units of Denudational Origin

I Land Units Created by Constructive Action of Denudational Factors :

7. Buried Pediments

   (i) Flat Buried Pediment
   (ii) Undulating Buried Pediment

II Land Units Created by Destructive Action of Denudational Factors :

8. Pediments

   (i) Flat Pediment
   (ii) Undulating Pediments
   (iii) Rolling Pediments

9. Denudational Hills

10. Inliers

11. Residual Hills

C. Land Units of Orogenic Origin

I Land Units Created by Constructive Action of Endogenetic Movements and Sculptured by Destructive Action of Denudational Factors :

12. Structural Hills

D. Land Units of Volcanic Origin

I Land Units Created by Fissure Erruption and Sculptured by Destructive Action of Denudational Factors :

13. Basaltic Table Land

   (i) Undissected Basaltic Table Lands
   (ii) Dissected Basaltic Table Lands

14. Mesa/Butte

15. Plateau Steps

In addition to the above major land units, the under mentioned geomorphic features have also been identified in the present study area :

(i) Water falls
(ii) Spring
(iii) Crest
(iv) Bluff
(v) Escarpment
(vi) Hogback
(vii) River Terraces
(viii) Alluvial Cones

The identification key and short characteristics of above mentioned land units have also been prepared for use to identify the land units of similar characteristics in other areas. This key can be used to recognize the similar land units in other parts of the region with identical climatic conditions.

An accurate information regarding spatial distribution, rates and types of changes in the landuse is pre-requisite for proper planning and management of landuse. In India, various departments in central and state governments, private sectors and university departments have been collecting data about land resources for the last many years, but their works are mostly independent and lack co-ordination. It has resulted in duplication of work in most of the cases. Twelve land utilization schemes employed in India have been presented in appendix IV-1. It is found that these schemes are suitable for a particular area at a particular scale and donot appear to fulfil the requirements of other sectors. Since no scheme out of these is suitable for the present study area, a new land utilization scheme has been developed to cater to the needs of Chhota Tawa river basin. The scheme is so designed that it contains all possible categories existing in the study area. The scheme is fairly compatible with the classifications developed by various departments, institutes and individuals. The scheme is presented as under :

1. Forest

1.1 Dense Forest
1.2 Open Forest
1.3 Forest Blanks

2. Cultivated Lands

2.1 Cropped Land
2.2 Plantations
2.3 Follow Lands

3. Grazing or Range Lands

3.1 Grass Land
3.2 Scrubs

4. Waste Lands

4.1 Rocky Waste
4.2 Gullied Land
4.3 Gravelly Waste
(ii) Culturable Waste Lands
4.4 With Scrubs
4.5 Without Scrubs

5. Water Bodies

5.1 River
5.2 Lake
5.3 Reservoirs
5.4 Canals

6. Built Up Area

6.1 Urban
6.2 Rural
6.3 Road/Railway

The landuse map of the Chhota Tawa river basin has been prepared and spatial distribution of these landuse categories have been demarcated. The key for identification and mapping of these land utilization units has been prepared taking into account photo-elements and geotechnical elements.

The problems of the area are manifold. It is found that most of the problems are due to climate, processes and human interventions. The problems of the study area which could be identified on the basis of geomorphological and climatological data and landuse investigations are as under :

1. Flash and Sheet Erosion
2. Rill Erosion
3. Gully Erosion
4. Aridity
5. Steep Slope
6. Land Slide and Rockfall
7. Rock outcrops, thin and Poor Soil Cover
8. Low Water Table
9. Deforestation
10. Fallow Land

It is found that flash and sheet erosion is very active in the study area and results into the formation of unproductive bare rocks surfaces known as pediments at places. This process of the erosion hampers the processes of pedogenesis by removing the detritus. The fine particles of the soils are made loose due to the impact of torrential rains and are dislodged making the rock surfaces bare.

In order to arrest the expansion of pediments, the sheet flow of water has to be controlled and channelised. This will help in making the soil settle over the rocky surfaces by encouraging the process of pedogenesis. It is also observed that rain drops dislodge fine particles every where and cause flash erosion but it is not a serious problem in other areas as compared to the pediments where the layer of soil and weathered material is very thin.

The rill erosion is also caused by the same factors which are responsible for the formation of gullies. It is not serious over agricultural fields as rills are obliterated by tillage practices whereas in mountainous areas, these are not disturbed and slowly these get enlarged into gullies and ravines resulting into bad land topography.

It is observed that large areas are subjected to gully erosion. Gully formation takes place where run off is concentrated and channelised sufficiently. As it is noticed that the study area receives torrential rainfall during short spells, the water collected over basaltic terrain and high land rushes down and removes unconsolidated materials. The gullies encroaching upon the fertile cultivable lands on buried pediments, basaltic terrain, active flood plains, intermontane valley fills and along river banks. It is noticed that over grazing and human activities have caused damage to natural vegetal cover and accelerated gully erosion. It is recommended that the gully erosion should be checked by plugging gullies and bringing the land under protected forest and grass with controlled grazing.

It is concluded from data regarding climatic parameters and landforms that the study area also faces the problem of aridity. It is needless to explain the causes of aridity as the area experiences semi-arid climate. The aridity is the major cause of water deficiency and poses problem to crops. It is observed that most of the rivers in the study area are ephemeral owing to the aridity, low rainfall concentrated in short period and high temperatures. The water from the rivers could not be utilized for irrigating crops during rainfall deficiency period due to their ephemeral nature.

Over the denudational, structural, residual hills and basaltic high lands and above and below free faces a very precipitous slope ranging from 80 to 85 degree is developed. Below and above, the free faces, slope is quite steep measuring about 45 to 60 degrees. It has given rise to uncontrolled and unchecked run off descending down the slope which has resulted in serious rill and gully erosions. The problem of steep slope can not be over come but atleast these slopes can be put under forest, grasses and grazing may be regulated so as to avoid further erosion.

It has been observed during the field work that in the mountainous areas, land slides, rock fall and debris fall occur below the free face zones. This is not much serious problem at present but certainly it disturbs the natural slope and causes damage to the vegetation below free face over steep slopes.

It is seen that rock out crops are ubiquitous in the study area. This is also one of the major problems experienced in this region. The formation and exposure of these out-crops have been reducing the area under cultivation, forest and grass lands. These exposures of out-crops are due to the sheet erosion and the pedimentation processes. In order to control the formation of pediments, the sheet erosion has to be controlled by taking corrective measures. Over a large part of rolling and undulating pediments, residual hills and mesa/butte, the soil cover is very thin which is not in a position to support crops or vegetations.

Another major problem of the study area is a low water table in pediment, structural hills, denudational hills, plateau steps and basaltic table land units. It is observed that it is almost impossible to sink a bore to such a depth over these land units.

The deforestation is very serious problem giving rise to erosion, accentuation of aridity, depletion of ground water, lowering down of water table and mass movements.

In the study area land is kept fallow for regaining fertility in one season or the other because of aridity, lack of perennial source of water, low water table, thin soil cover and highly concentrated rains during monsoon seasons. These factors force farmers to keep land fallow. The fallow lands can be reduced by using bio-chemical inputs provided water for irrigation is made available.

As a matter of fact, the hazards and problems experienced in the study area are interlinked and can not be separated from each other and studied in isolation. It is very obvious that the change in one affects another and causes changes in others too. It is delicate system consisting of physical and human interactions and needs a comprehensive understanding of the system in order to combat hazards and problems.

There are fifteen major land units and nineteen sub-land units identified in the study area. These units have been grouped into five land unit groups for assessing landuse. The groups are based on geomorphic, geological, hydrological and soil conditions; erosion hazards, existing landuse pattern and their problems. On the basis of above factors the potential landuse of each land unit group has been suggested. The current landuse on these units have been assessed in order to find out alternative landuse for each land unit group. The identified groups are reproduced from Table V.1 and V.2 and are presented below in Table VI.1

Table VI.1

Summary of the Land Unit Groups

Sr. No.	Land Unit Group	Corresponding Land Units	Physical Characteristics	Dominant problem	Conservation measures	Existing landuse	Suggested landuse
1	2	3	4	5	6	7	8
1.	I	Old alluvial plains and buried pediments	**Gently sloping to levelled plain well developed, drained, deep, good textured fertile soil with high water retaintion capacity**	Slight-sheet and flash erosion but poses no problem	Sinking bore wells and dug wells	Cropped land	Cultivation with irrigations
2.	II(A)	Active flood plain	**Plain, unperciptible slope, deep, well developed, drained, fine textured fertile soils areas**	Gully erosions along river banks over small area	Plugging gullies	Cropped and gullied waste land	Cultivation using water available in lower reaches of main streams
3.	II(B)	Undulating buried pediment, alluvial fans, bajada, Intermontane valley fill (undissected)	Good cover of soils slope viries 5^0 to 20^0	Slope	Terracing, contour bunding levelling	Cultivated land, forest, open forest rage land, fallow lands	Forest and grasses with controlled grazing
4.	III	Denudational hills, Inlier Residual hills, structural hills, Plateau steps, undissected basaltic table lands	High Lands, hills, steep slope except flat tops of basaltic table lands	Steep slope low water table	Channelising run off and terracing	- " -	Forest and grasses with controlled grazing and cultivation on existing cropped lands

Contd......

Table VI.1 (Contd.)

Sr. No.	Land Unit Group	Corresponding Land Units	Physical Characteristics	Dominant problem	Conservation measures	Existing landuse	Suggested landuse
1	2	3	4	5	6	7	8
5.	IV	Intermontane valley fill (dissected) dissected basaltic table lands	Slopping valley flanks and flat table tops	Severe gully erosion	Channelising uncontrolled run off and bunding	Gullied waste lands	Protected forest and grasses
6.	V	Mesa/butte, Rolling pediments, flat pediments undulating pediments	Rock cut surfaces covered with thin veneer of soil or bare rock cut surfaces	Severe sheet erosion	Stopping expansion of pediments by channelising uncontrolled water from other areas	Rocky waste lands	Quarrying

Recommendations

Based on the geomorphological analysis of land units, processes operating in the study area, existing land use, the following recommendations can be made for development and proper use of land resources :

1. The flash and sheet erosion is very severe over pediments which makes land unproductive and devoid of soil and vegetation. It may be checked to arrest the growth of pediments by channelising run off over surrounding land units of pediments.

2. The gullies occur over active flood plain and basaltic high land units. These may be plugged and area may be brought under forest and grass cover. The grazing has to be controlled. The slopes, flanks of high land and hills may also be put under forest so as to cheek the erosion down the slope and arrest the growth of gullies on active flood plain, basaltic high lands and valley fills.

3. The ground water potential zones available in active flood plain, old alluvial plains, buried pediments and fracture zones can be developed for ground water exploration.

4. The fractures and faults lying in the hilly areas may be developed for extracting water.

5. It is recommended that as a long run policy, government

may launch a massive artificial ground recharge and adoption of non-conventional ground water recharge techniques such as construction of percolation tank, sub surface dyke, gabian bund, nallah bunding, fracture blasting and afforestation in the basaltic table land and valley fill to raise the ground water table.

6. There is a good scope for developing agro-based industries particularly dairying an cattle rearing over buried pediments and old alluvial plains. This industry can be encouraged by providing loan and bringing undulating pediment, rolling buried pediment, pediments and basaltic table land under grasses where controlled grazing may be allowed.

7. Land use practices based on the land capability in the area may be adhered to for improving the over all conditions in the area. The following land use practices are recommended in the study area :

   i) land unit group-I may be put under cultivation.

   ii) Land unit group-II(A) may be put under cultivation by giving moderate treatment like plugging of gullies and levelling.

   iii) Land unit group-II(B) may be given a treatment like terracing and contour bunding and to some extent it may be levelled and brought under forest and grasses.

The controlled grazing be allowed so that forests do not get damaged and people also donot face hardship in rearing animals.

iv) Land unit group-III may also be afforested except existing cropped lands and the existing forest be given protection with controlled grazing. No new land be allowed to bring under cultivation which causes deforestation resulting into lot many problems.

v) Land unit group-IV consists of gullied waste lands. It is recommended that the growth of these groups should be arrested by channelising run off properly and may be brought under forest and grass land which will also result into raising water table.

vi) Land unit group-V consists of rocky waste lands. It is recommended that it should be used for quarrying of building stones.

It is hoped that, this geomorphic and landuse analysis may help to provide a valuable information to the authorities in planning and development of the area through optional and rational utilization of available land resources.

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Appendix II. 1

Image and Geotechnical Characteristics of Litho Units (Litho Unit Identification Key)

Sr. No.	Litho Units	Tone	Colour	Texture	Location	Geomorphic Characteristics	Structure	Rock Type
1.	Bijawar	Light to medium dark grey	Yellowish to light red	Medium coarse	Hills	Conspicuous bold ridges and flat elongated valleys give basin range topography	Dip and strike Anticline and syncline, joints fracture, faults	Quartzite, horn stone breccia Phyllite, Chert Banded Limestone Ferruginous Quartzite, Medium grained quartzitic sandstone limestone banded with chert or horn stone breccia consisting of a horn stone or jaspe, white milky quartz
2.	Vindhyan	Light tone	Lighter tone on Black & White Images Yellowish colour on FCC	Medium coarse	Hills	Bold geomorphic expression asymmetric slope	Low dipping beds	Arenaceous and Argillaceous massive thick bedded sandstone, shale conglomarate, hard compact fine grained purplish thin bedded sandstone well jointed fine to coarse grained cemented with Sillica
3.	Deccan Trap	Dark grey	Greenish brown	Medium	Hills & Plains	Mesa/Butte, Plateau steps, escarpment Basaltic high lands	Low dipping to Horizontal beds	Dark grey to dark greenish grey basalt Hard, tough, compact and medium to fine grained non-vesicular basalt and soft friable vesicular basalt
4.	Alluvial	Lighter tone	Yellowish to Bluish green	Smooth texture	Along rivers	Plain lands		Alluvium and soil cover

Appendix III.1

NOMENCLATURE USED IN LANDSCAPE CLASSIFICATION

Hierarchical order	Fannman 1916	Bourne 1931	Unstead 1933	Linton/ wood ridge 1949	CSRID-LRRS Chritown and Stewart 1953	Wittesey 1954	Isacenko 1965	MEXE 1965	Grant & Aitchinson 1965	MEXE/CSRO Brink et al. 1966	CSIRO Christian Stewart 1968	Soil Conser-vation Autho-ring & vic torian	USSR method	Jhadav
		Site	Feature	Site/facet	Land unit		Facies	Land element	Land component	Land element	Land element	Land component		
Lower order		Regions	Stow	Stow	Sub-system	Locality	Urocise	Land facet	Terrain unit	Land facet	Land unit	Land unit	Fascia	Land unit
	District			Tract	Land system								Urochishcha	
			Tract			District	Meso zose	Recurring Land pattern	Terrain pattern	Lans system Land pattern	Land	Land system		
	Section			Section	Land region			Land region		Land region		Land zone		
			Sub-region			Province	Okrugunter proving		Province					
Higher order	Province			Province	Province					Land province				
			Minor region											
	Major division			Major division	Region	Realm		Land province		Land division				
			Major region	Continent				Land zone						

Appendix III.2

Image and Geotechnical Characteristics of Land Units (Land Unit Identification Key)

Litho Unit	Geomorphic Characteristics	Image Characteristics	Lithology	Dominant Landuse	Associated Features
Active Flood Plain	A unit of Relatively smooth topography nearly plain on sides of Chhota Tawa Sukta, Pipar, Abna and kalimachak river. It is constructed by material brought down by rivers	Grey to dark tone on aerial photograph bluish red colour on FCC smooth texture	Brown to black alluvium	Cultivation and gullied waste land	Rivers, channel bar bluff, river terraces
Old Alluvial Plain	Narrow elongated strip bordering active flood plain. Level to gently sloping	Medium grey to dark grey tone on photograph. Deep red colour on FCC owing to cultivation	Well developed profile of soil, soil and alluvium	Cultivation	Flanked by active flood plain and pediments and/or buried pediments
Alluvial Fan	River deposit at foot hills assuming fan shape	Fan shape, coarse texture, grey tone on photograph yellowish colour on FCC	Coarse material and soil brought down by rivers	Cultivation and open forest	Location of fan at foot hills proximity to river
Bajada	Continuous alluvial or colluvial slope or gently inclined detrital surface extending for long an form the base of a mountain range into and around plain formed by the lateral coalescence of a series of separate but confluent alluvial fans	Medium dark tone on photo. Light red colour on FCC coarse texture	Colluvial/alluvial material & coarse scree material	cultivation and range land	Proximity to hills and rivers
Intermontane valley fill (dissected)	Valley fills located on uplands. Gullies and hills developed. Intensive gully erosion	Coarse texture banded tone bluish to greenish colour on FCC	Alluvium and colluvium	Gullied waste land	Located on high lands in depression/ valley severely eroded bottoms

Contd....

Litho Unit	Geomorphic Characteristics	Image Characteristics	Lithology	Dominant Landuse	Associated Features
Undissected	Intervening depression on upland partially filled with unconsolidated brought down by denuding agencies	Dark tone, medium texture, medium red colour on FCC	Alluvium and colluvium	Cultivation at places open forest and range land	Located on high lands
Buried Pediment	Pediment-buried under the in situ material as well as unsorted colluvium two types of buried pediments, flat pediment and undulating pediments with Knolls and depressions	Dark tone, fine texture, red colour in FCC	Colluvium	Cultivation	Located in plain area plains and knows depression
Pediment	Broad concave or gently sloping rock floor/erosion surface of low relief covered with in situ detrital material at places	Grey tone, coarse texture brown colour on FCC	Deccan trap	Rocky waste land	
Denudational Hill	Hills denuded by denudational agencies like weathering, mass washing erosion	Coarse texture grey tone and yellowish to brownish colour on FCC	Sedimentaries	Forest, open forest range land	
Inliers	Area of rock surrounded by out crops of younger rocks old Vindhyan surrounded by new basalt out crop	Grey tone, coarse texture and yellowish to red tone on FCC	Vindhyan sand stone	Forest and range land	Surrounded by basaltic out crops
Residual Hills	Resistant isolated steep sided usually rounded rising abruptly from and by extensive and nearly plains	- do -	Deccan trap &	Forest and range	Located in plain and detached

Contd...

Litho Unit	Geomorphic Characteristics	Image Characteristics	Lithology	Dominant Landuse	Associated Features
Structural Hill	Hill denuded under the control of structure and exhibiting dip, strike, folds and faults	- do -	Sedimentaries	Forest and range land with	Anticline synclines dip, strike, hogback
Basaltic Table Land	High and rugged relief Satpura hills	Light grey to dark grey tone on photo coarse texture yellowish to red colour on FCC	Deccan trap	Forest, cultivation and open forest	Mesa/Butte, Escarpments, plateau steps
Mesa/Butte	Remnants of lava flows appearing like flat topped lad form on hilly terrain	On FCC yellowish to red colour surrounded by dark shadow of escarpment and on photograph lighter tone surrounded by darker tone of escarpment Shadow	- do -	Open forest	high lands
Plateau Steps	Almost flat plane of lava representing lava flows with steep slope on sides	Light grey uniform tone, relatively smooth texture on photograph. Few bands o yellow to red colours on FCC	Deccan Trap	Cultivation, forest range land	High table lands, Mesa, Butte

Appendix IV.1

Categories Used in Landuse Classification in India

1. **Land Utilization Scheme of National Atlas Organization 1957**

    1. Forest

        (a) Dense Forest
        (b) Open Forest

    2. Scrub Land

    3. Arable Land

    4. Arable Land with Trees

    5. Plantation Crops

    6. Pasture Lands

    7. Uncultivated Land

        (a) Rocky Waste
        (b) Sandy Waste

    8. Alpine Grass and Srub Lands

    9. Glaciated Region

2. **Land Utilization Scheme of Govt. of India Ministry of Agriculture 1957**

    1. Total Geographical Area

    2. Area Under Forest

    3. Area not available for cultivation

    4. Current Fallows

    5. Other Uncultivated Lands, Excluding Current Fallow

    6. Net Area Sown

3. **Land Utilization Scheme of Diagnostic Survey of Damodar Valley Region (DVA) 1960**

1. Field Crops
2. Orchards including smaller water features and land of non agricultural uses
3. Dense Forest
4. Light Forest
5. Non-Agricultural use of Land-mines and Quarries (working and abandend)
6. Unproductive Land
7. Water features/tanks
8. large villages with houses 300 and above
9. Agricultural waste - small
10. Agricultural waste - large
11. Small villages
12. Cities and Towns

    (a) Administrative, Commercial, Industrial
    (b) Residential
    (c) Industrial
    (d) Mining
    (e) Mining and Industrial
    (f) Agricultural and Administrative

4. **Land Utilization Scheme of All India Soil and Landuse Survey 1960**

Forest Areas

F1 thin forest
F2 moderately thin forest
F3 dense forest

Cultivated Lands

C1 single cropped
C2 double cropped
C3 triple croped
C4 occasionally cultivated

Waste Land

W1 waste land fit for cultivation
W2 unfit for cultivation

Pasture Land

P1 Plantation
T Thorns, Weeds and Scrubs

5. **Land Utilization Scheme of E. Ahmad**

1. Net Sown Area

   (a) Trriple cropped land
   (b) Double cropped land
   (c) Single cropped land

2. Fallow

3. Land Under groves and Orchard

4. Land Under Scrubs and Grasses

5. Land Permanently under water

6. Built upland (village building school, temple etc.)

7. Land Under Communication lines
   e.g. Railways, roads tracts

8. Bareen land
   e.g. snow, steep slope, Ravines, Salain, Sand, threshing ground, grain yeard etc.

9. Forest

   (a) Reserved Forest
   (b) Protected Forest
   (c) Village Waste

6. **Land Utilization Scheme of Central Arid Zone Research Institute Proposed for Aerial Photo Intepretation (A.K. Sen (1961-72)**

1. Forest

2. Settlement

3. Road and Railways

4. Land Not Available for Cultivation

   (i) Sandy waste
   (ii) Rocky waste
   (iii) Gravelly waste

5. Hills

6. Slopping hills sides

7. Fallow Land

8. Cultivated Lands

7. Land Utilization Scheme of All India Soil and Landuse Survey 1970

Forest Areas

F1 with no canopy
F2 thin forest
F3 moderately dense forest
F4 Dense forest and fully stocked for canopy

Cultivated Land

C1 single croped
C2 double croped
C3 Tripple croped
C4 occasional cultivated

Terraced Land

T1 poorly bunded land
T2 poor terracing measures
T3 bench terraces

Waste Land

W1 fit for cultivation
W2 unift for cultivation

Pasture Land

P pasture and grazing land
PH haylands where the grass is periodically cut
P1 with young scurbs
P2 with well grown scrubs
T thorny plants and heavy canopy scrubs, weeds

8. Land Utilizations Scheme of Govt. of India Directorate of Economics and Statistics (Land Utilizations Unit) 1978

1. Forest

2. Land not Available for cultivation

   (a) land put to non-agricultural use
   (b) barren and unclutivable land

3. Other Uncultivable Land excluding fallow land

   (a) permanent pasture and other grazing lands
   (b) land under miscellaneous tree crops and groves

4. Fallow Land

   (a) culturable waste
   (b) fallow land other than current fallow
   (c) current fallow

5. Cultivated Land

   (a) net sown area
   (b) area sown more than once

9. Land utilization Scheme of A.K. Sen 1978

1. Settlements

A. Rural *settlements*	*(a) Villages with compact settlement* *(b) Villages with scattered settlement* *(c) Linear villages* *(d) Temporary villages* *(e) Desterted villages*
B. Urban Area	*(a) Administrative* *(b) Residential* *(c) Mining and Industry* *(d) Agricultural* *(e) Religious*
2. Water Features	*(a) Rivers* *(b) Lakes* *(c) Wells* *(d) Tanks* *(d) Canal*

3. Forest

A. Natural	*(a) With no canopy*
B. Reserved	*(b) With canopy*
	(c) Dense forest

4. Cultivated Land *(a) Single cropped*
(b) Multiple cropped

5. Waste Land *(a) Fit for cultivation*
(b) Unfit for cultivation but suitable for pastures
(c) Unculturable waste

6. Pasture Land *(a) permanent pasture*
(b) Hay lands where the grass is periodically cut
(c) Thorny land covered by thorns, weeds and scrubs

7. Plantation

10. Land Utilization Scheme of National Atlas and thematic Mapping Organization 1980

1. Agricultural Land

1.1 Irrigated crop land
1.2 Unirrigated crop land
1.3 Plantations

2. Forest

2.1 Reserved forest
2.2 Protected forest
2.3 Unclassed forest

3. Non-Agricultural Land

3.1 City
3.2 Mines
3.3 Settlement with trees

4. Grazing Land

4.1 Grass land
4.2 Scrubs

5. Unproductive Land

5.1 Sand
5.2 Rocky
5.3 Saline
5.4 Bad land
5.5 Snow field

11. Land Utilization Scheme of N. Gautam and L.R. Narayan (For Land Sat Survey) 1982

Level I	Level II
1. Buit up land	1. Built up land
	1.1 Urban
	1.2 Rural
	1.3 Road & Railways
2. Agriculturl land	2. Agricultural land
	2.1 Croped land
	2.2 Fallow land
	2.3 Jhum/shifting and terraced cultivation
	2.4 Net land/fallow
	2.5 Plantation
3. Forest land	3. Forest land
	3.1 Ever green forest
	3.2 Deciduous forest
	3.3 Mixed forest
	3.4 Scrub land
4. Water bodies	4. Water bodies
	4.1 River/stream
	4.2 Lakel tank
	4.3 Reservoirs
	4.4 Lagoons
	4.5 Estnario
	4.6 Occan
5. Waste land	5. Waste land
	5.1 Sandy land
	5.2 Rocky out crops
	5.3 Culturable waste

6. Others	6. Others
	6.1 Grazing land *6.2 Snow area* *6.3 River sand*

12 Land Utilization Scheme of N.C. Gautam and L.R.A. Narayana (For Aerial Photo Interpretation) 1982

Level I	Level II	Level III
1. Built up/ urban land	A Residential	Single family multiple family Detached houses semi detaches houses mixed type
	B Commercial and service centre	Type of services
	C Industrial	Type of Industry
	D Transportation communication and utilities	Road, Railway, Footpath etc.
	E Recreational	Play ground, stadium Garden/Park,
	F Religious	Temple, Church, Mosque other
	G Open and other	Vacant
2. Agricultural land	A Crop land	Type of crop
	B Fallow land	Current fallow
	C Plantation	Orchards
	D Wet land	Other orticultural areas
	E Jhum/shifting cultivation	Size of field

3. Forest	A Ever green	Coniferous and others
	B Deciduous	Vegetation community
	C Mixed	Dry/moist deciduous sparce vegetation
4. Wet land	A River	Small stream
	B Lakes/Tank	Dry/wet tank
	C Reserviour	Canal
	D Bay	Nallah
	E Esturies	Dry channels
5. Range land	A Vegetation Community	Scattered vegetations with grasses
	B Scrubs/Bush/Range land	
	C Grazing land (Permanent)	
	D Mixed	
6. Waste land/ Barren land	A Bare exposed rock B Salt flat C Ravines D Strip mines/quaries E Beaches/River sand F Sandy area other than beaches G Transitional area H Other	
7. Snow Covered land	A Perment Ice covered B Temporary Ice covered	

13. Land Utilizations Scheme of NRSA, 1989

Level I	Level II
1. Buit-up land	1.1 Buit up land
2. Agricultural land	2.1 Crop land
	(i) Kharif *(ii) Rabi* *(iii) Kharif + Rabi*

	2.2 Fallow
	2.3 Plantation
3. Forest	3.1 Evergreen/semi evergreen forest
	3.2 Deciduous forest
	3.3 Degraded or scrub land
	3.4 Forest Blank
	3.5 Forest plantation
	3.6 Mangrove
4. Waste lands	4.1 Salt affected land
	4.2 Water logged land
	4.3 Marshy/ swampy land
	4.4 Gullied/Ravinous land
	4.5 Land with or without scrubs
	4.6 Sandy area
	4.7 Barren rocky/stony waste/ sheet rock area
5. Water bodies	5.1 River/stream
	5.2 Lake/Reservior/Tank/Canal
6. Others	6.1 Shifting cultivation
	6.2 Grass land/grazing land
	6.3 Snow covered/Glacial area

Appendix IV.2

Image an Geotechnical Characteristics of Landuse Categories (Landuse Identification Key)

Sr. No.	Landuse category	Tone on Black & White	Colour on FCC	Texture	Size	Shape	Pattern	Location
1.	Forest							
	1.1 Dense Forest	**Dark Tone because of dense canopy**	**Bright Red to Red because dense canopy**	**Smooth on FCC and medium on photo-graph**	**Varying size**	**Varying irregular**	**Continuous stretches on high lands and small non contiguous areas in other units**	**Denudational hills basaltic uplands inlier valleys hills Bajada and structural hills**
	1.2 Open Forest	Banded	B Light red to dark brown	Coarse texture given by Individual crown and sparse vegetation with exposition of terrain under neath	Varying in size	Irregular and discontinuous	Contiguous to non-contiguous and slopes	Basaltic table land Mesa/Butte hills, inliers

Contd....

Sr. No.	Landuse category	Tone on Black & White	Colour on FCC	Texture	Size	Shape	Pattern	Location
	1.3 Forest Blanks	Light to medium dark	Light to light brown	Coarse to mottled	Varying in size mostly small patches	Varying irregular	non contiguous dispersed scattered a midst forest	Top of the Basaltic higher lands and slopes structural residual and denudational hills
2.	Cultivated land							
	2.1 Crop Land	Medium to dark tone	Bright red to red	Medium to coarse texture	Varying in size	Check board	Check board grid pattern	Flat buried pediment old Alluvial plain active flood plain Bajada valley hill basaltic table land plateau steps
	2.2 Plantations	Medium to dark banded tone	Bright red to red	Medium to coarse texture	Varying in size	Check board	Check board grid pattern with aligned trees	Flat buried pediment old Alluvial plain active flood plain

Contd....

Sr. No.	Landuse category	Tone on Black & White	Colour on FCC	Texture	Size	Shape	Pattern	Location
	2.3 Fallow land	light tone	Yellow to greenish blue to coarse on FCC	Coarse texture to photo medium	Varying size	Irregular shape with differed irregular boundaries discontinuous	Fringing crop land or surrounded by crop land	Active flood plain undulating pediments rolling pediments basaltic high lands
3.	Grazing or Range Land							
	3.1 Grass land	Medium grey to dark grey on photo	Light red to light brown	Coarse texture	Varying in size	Irregular	Contiguous and isolated too	Hill slopes, slopes of Basaltic table land inlier valley fill Bajada and Alluvial Fans
	3.2 Scrub Land	Light and medium dark grey	Dark brown	Coarse texture	Varying size	Irregular	Discontiguous	Hilly Area
4.	Waste Land							
	4.1 Rocky Waste	Light grey	Greenish blue yellowish to brownish	Mottled medium to coarse texture	Small patches to large	Irregular	Contiguous	All the land units

Contd....

Sr. No.	Landuse category	Tone on Black & White	Colour on FCC	Texture	Size	Shape	Pattern	Location
	4.2 Gullied Land	Light grey to dark grey	Blue greenish colour	Coarse texture	Varying size	Discontiguous with 'V' shaped cross section	Discontiguous	River banks, foot hills, valley fill and basaltic table land
	4.2 Culturable 4.2.1 With Scrubs	Light and medium	Dark brown	Coarse texture	Varying size	Irregular	Discontiguous	Low topography undulating plains an basins
	4.2.2 Without scrubs	Lighter tone	Yellowish to brown	Medium coarse	Varying size	Irregular	Discontiguous	Undulating Pediments
5.	Water Body	Darker	Bluish colour	Smooth and fine	Small	Irregular		
6.	Built up land 6.1 Settlement	Dark	Dark bluish green	Coarse mottled	Small to large	Irregular with sharp boundary	Scattered houses compact houses	On all land units
	6.2 Road/Railway	Dark	Dark to dark bluish green, light yellow				Linear	On all land units

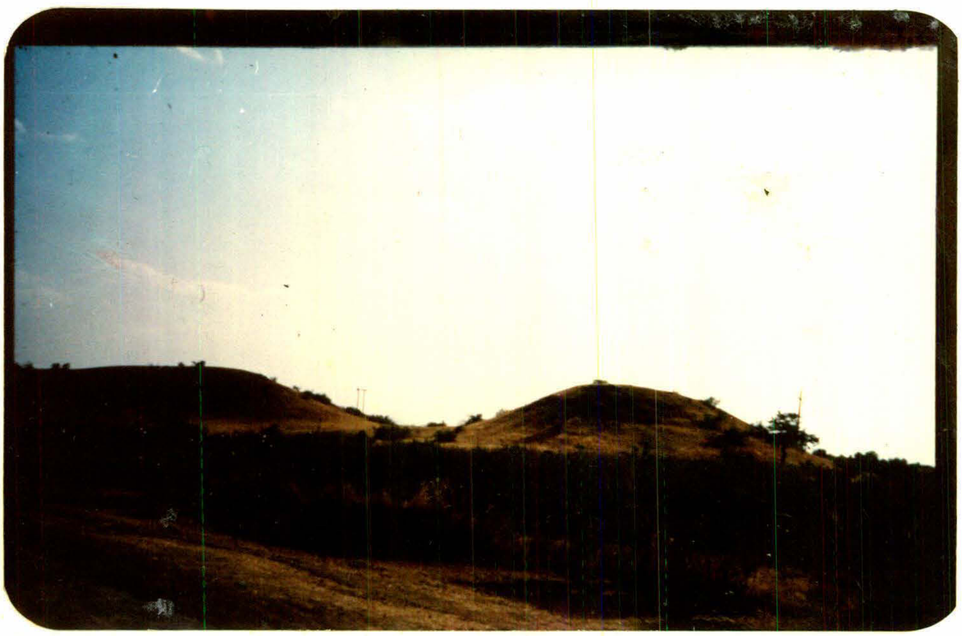
FIELD PHOTOGRAPHS

3. Vindhyans faulted against Bijawar. An abrupt scarp with imposong front face and linear base fairly high resistant young fault line valley.

4. River terraces

1. Bijawar displaying concentric structure with alternate layers, exhibiting bedding.

2. Trap domal structure and residual hill



5. Regolith, unsorted material showing weathering process spheroidal cores exhibits spheroidal weathering

6. Flat-bed of river with exposed bed rock at bottom, river bluff, steep river bank.

7. River banks devoid of vegetation, the river bed made of hard bed rock.

8. Old alluvial plain under intensive cultivation, exhibiting good ground water potential, cultivated land irrigated by dug well installed with electric pump set.

9. Vindhyan under forest.

10. Buried pediment covered under colluvium. Intensive cultivations exhibiting good ground water potential and cultivated land.

11. Flat pediment, rock out crops exhibiting rocky, waste land, with no grass, vegetation or cultivation

12. Undulating pediment, Rock out crops, Rocky waste land exhibiting rocky waste top and range land specially grass in depression.

13. Rolling pediment

14. Denudational hill under forest

15. Low residual hill devoid of forest/range land without grasses and scrubs

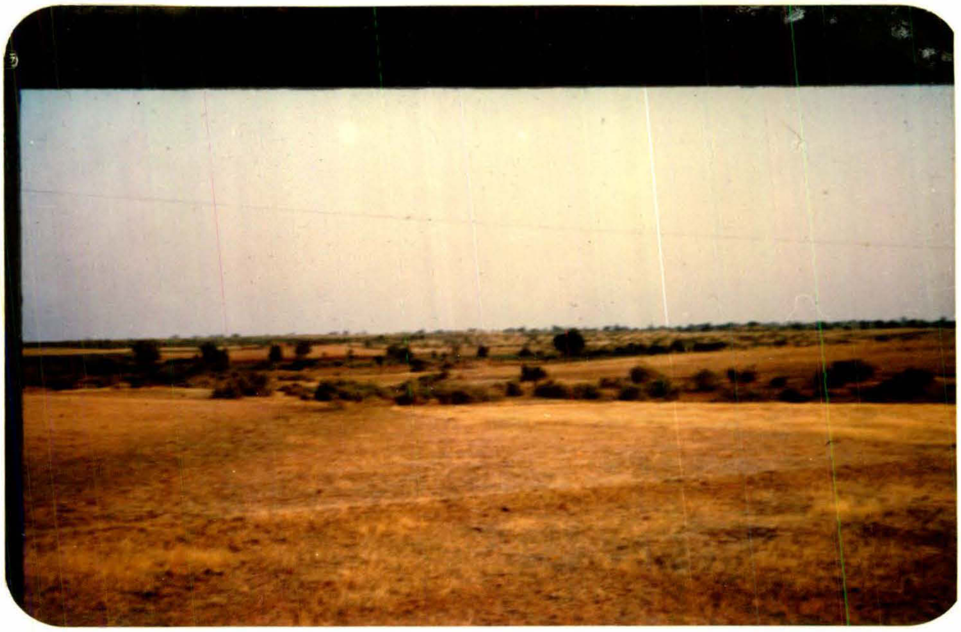
16. Joints/Fractures in beds and dip joint

17. Deccan trap under dense forest

18. Banana plantation

19. Fallow land

20. Undulating pediment



21. Bajada under cultivation and range land

22. Grasses on rolling burried pediment

23. Grasses on undulating burried pediment

24. Bijawar denudational hill under forest at the confluence of Chhota Tawa with Narmada river

25. Open forest

26. Open forest on tops of undulating burried pediment and grass and cultivation in depressions

27. Hill covered with scrubs

28. Intensive cultivation in Active flood plain/cultivated land

29 Hill covered with scrubs.

CHHOTA TAWA RIVER BASIN
SUGGESTED LAND USE

(Based on Photo-Interpretation and Selective Field Checks)

CHHOTA TAWA
Harsud
Chhanera
Agra
LANDUNITS
ACTIVE FLOOD PLAINS
OLD ALLUVIAL PLAINS
BAJADAS
ALLUVIAL FANS
INTERMONTANE VALLEY FILLS
UNDISSECTED
DISSECTED
BURIED PEDIMENTS
FLAT
UNDULATING
PEDIMENTS
FLAT
UNDULATING
ROLLING
DENUDATIONAL HILLS
INLIERS
RESIDUAL HILLS
STRUCTURAL HILLS
BASALTIC TABLE LAND
UNDISSECTED
DISSECTED
MESA/BUTTE
PLATAEU STEPS
OTHER FEATURES
ANTICLINE
BLUFF
DIP
ESCARPMENT
FRACTURE/FAULT
RIVER STREAM
SPRING
STRIKE
SYNCLINE
TERRACE
RIDGE CREST
ROAD
RAILWAY
SETTLEMENT
Km 2 1 0 1 2 3 4 5 6 Km

Fig. III-1

LANDUNITS
ACTIVE FLOOD PLAINS
OLD ALLUVIAL PLAINS
BAJADAS
ALLUVIAL FANS
INTERMONTANE VALLEY FILLS
UNDISSECTED
DISSECTED
BURIED PEDIMENTS
FLAT
UNDULATING
PEDIMENTS
FLAT
UNDULATING
ROLLING
DENUDATIONAL HILLS
INLIERS
RESIDUAL HILLS
STRUCTURAL HILLS
BASALTIC TABLE LAND
UNDISSECTED
DISSECTED
MESA/BUTTE
PLATAEU STEPS
OTHER FEATURES
ANTICLINE
BLUFF
DIP
ESCARPMENT
FRACTURE/FAULT
RIVER STREAM
SPRING
STRIKE
SYNCLINE
TERRACE
RIDGE CREST
ROAD
RAILWAY
SETTLEMENT
Km 2 1 0 1 2 3 4 5 6 Km
35'
40'
45'
50'
55'
77°0'
5'
10'
15'
10'
5'
22° 0'
55
50
45
40
35
21° 30'

Fig. III-1