ENVIRONMENTAL RESOURCES ASSESSMENT OF COCHIN

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ENVIRONMENTAL PLANNING

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MARCH 1998

CERTIFICATE

This is to certify that this thesis is a bonafide record of research carried out by Sri.P.V.Benjamin M.L.Arch., under our guidance, in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** of the Cochin University of Science and Technology.

Cochin – 682 016
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DECLARATION

I hereby declare that this thesis entitled, "Environmental Resources Assessment of Cochin is an authentic record of the research carried out by me under the supervision of Prof (Retd.) Dr. K.P.Balakrishnan and Dr.M.V.Harindranathan Nair, Lecturer, School of Environmental Studies, Cochin University of Science and Technology, and that no part of it has previously formed the basis of award of any degree, diploma, associateship, fellowship or other similar title or recognition.

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PREFACE

In the present global circumstances, no individual or country can remain immune to the environmental impact of economic development and to the man-made consequences of fast urbanisation. As a sequel to the interaction between the population growth, technological advancement and scientific discovery, the world of the historical past cannot persist into the changing condition of the future. The overall conditions of the earth's environment have therefore deteriorated and global risks have become more acute. This beckons the necessity for a change in the perspective from the concept of growth at all cost to the idea of a sustainable development.

Urbanisation is a fast-growing tendency in the developing countries, whereas in the developed countries, it has more or less stabilised. All human activities have an impact on the urban environment. These impacts can be categorised as those resulting from (1) the extraction of environmental resources, (2) the release of residuals to the environment and (3) the modification of environmental regimes.

In the case of urban centres of the developing countries, corrective measures for the environmental consequences of spontaneous or wrongly planned developments are often prohibitively costly. Hence environmentally planned development alone appears to be the solution for which, a compre-hensive assessment of all the resources is an essential pre-requisite. An under-standing of the prevailing environmental conditions is essential for the effective management and execution of programmes for sustainable development.

The present work is a modest attempt at assessing the environmental resources of Cochin, the industrial and business capital of Kerala and a fast developing metropolis.

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Chapter-1

Introduction

1.1 The Urban Scenario

The term *'environment'* can be defined as the whole complex of physical, social, cultural, economic and aesthetic factors which affect individuals and communities and ultimately determine their form, character, relationship and survival (Rau John, G. 1980). Natural environment undergoes continuous change. This may be on a time scale of hundreds of millions of years, as in the case of continental drift, mountain formation or sea level changes (during ice ages); or hundreds of years as in the case of the natural siltation and eutrophication of shallow lakes. Some of these are irreversible and some cyclic. Superimposed on these natural processes are those produced by man.

Even as a primitive hunter-gatherer, man's use of fire must have changed some natural environments. The effect of man's action on environment became widespread with the domestication of animals and the introduction of agriculture. Man's impact on environment became very serious with the development of industry when muscle power was replaced by fossil fuel energy. In recent years, it has further worsened with the fast increase of population and their concentration in a few cities along with a higher per capita consumption of energy as well as other natural resources.

With the advent of modern technology, man's impact on environment increased enormously which created conflict between human goals and natural processes. In order to achieve greater short-term benefits, man deflects the natural flow of energy, bypasses natural processes, severes food chains, simplifies ecosystems and uses large energy subsidies to maintain a delicate and artificial ecological equilibrium. This often results in irreversible environmental degradation.

Another aspect of serious concern is the greenhouse effect and its impact on the human settlements. The greenhouse effect is due to trapping of an increasing quantity of infra-red terrestrial radiation by a variety of gases being released into the atmosphere in continuously increasing quantities emanating from millions of industrial smoke stacks, motor vehicles, waste dumps and other sources. The important green house gases are CO_2, methane, nitrous oxide and ozone. In nature, there was balance between CO_2 production during respiration and absorption during photosynthesis. This equilibrium got disturbed since the industrial revolution and widespread use of fossil fuels. The atmospheric CO_2 rose from 275 ppm in 1860 to 346 ppm in 1986, an increase of 26%. At the current rate of increase the CO_2 concentration is expected to reach 550 ppm by the year 2050 which will hike the global thermostat by 4 °C (Oliver and Owen, 1989). An increase in the average global temperature would result in a thermal expansion of warmed up seawater and melting of the glaciers such as the polar ice caps and a consequent rise in sea level.

Melting of glaciers has already begun as evidenced by the slab of ice of size 25 x 99 miles that broke off from Antarctic ice field in 1987 and splashed into Rose Sea. A one-meter rise in ocean levels induced by greenhouse warming by 2035 AD as predicted, if occurs, would cause the sea to move 30 meters farther inland along the American coast (Oliver and Owen, 1989). Under such circumstances, the case of India also will not be much different. It is reported that there is already an increase of 2.2 mm annual rise in sea level in Cochin which will amount to 22 cms in the next 100 years (Harish, 1993). When it happens, millions of people would be forced to relocate; human stress, anxiety and discomfort would be severe. International Panel for Climatic change (IPCC), has predicted a 31 cm rise (lower scenario) by the year 2100 (IPCC, 1990).

There is a rapid social change in developing countries from a rural agricultural nature to urban industrial society during the past few decades. Cities in the developing countries have grown almost double the rate as that of developed countries.

In India, the proportion of urban population went up from 19% of the total population in 1965 to 27 % in 1990. The average annual urban population growth rate was 3.7% in India (World Bank report, 1992) And 32% of the total urban population is concentrated in metropolitan cities of India. At the beginning of this century, India had just one metropolitan city i.e., Calcutta with 5.8% of the total urban population. This extreme polarisation resulted in the increased density of population and increased economic activities in metropolitan cities.

The growth of cities and towns has not been uniform. While cities are growing bigger and bigger, the small and medium size towns are showing negative trends (Kalyan, 1991). This led to over-concentration of population and economic activities in all metros.

This unprecedented demographic growth together with persistent financial stringency faced by the government has brought in its wake, a serious inadequacy in social and economic infrastructure leading to fast environmental degradation and deterioration of the quality of life for the masses in all our metropolitan cities. The scene of Cochin is also not so different from that of Bombay and other metropolitan cities, though comparatively on a lesser scale in every aspect.

1.2. Need for Environmental Resources Assessment in Urban Planning.

A great deal of damage has been done in the past, simply because environmental planning was non-existent and/or because planners did not appreciate the interplay of natural processes that affects their schemes.

National Environmental Policy Act (NEPA) was passed in USA in 1969 making it obligatory to prepare Environmental statement for activities that are likely to affect environmental quality (Rau and Wooten, 1980). India is also having several laws to ensure environmental quality while specific developments take place, such as Water (Prevention and Control of Pollution) Act, 1974; the Air (Prevention and Control of Pollution) Act, 1974; the Forest (Conservation) Act, 1980; the Wild Life (protection) amendment Act, 1986. These laws are for ensuring specific environmental qualities. The Indian Parliament passed the Environment (protection) Act in 1986, which makes it obligatory to prepare an Environmental Impact Assessment (EIA) report before embarking on major development programmes.

The existing environmental laws are found to be inadequate in protecting the urban environment, since the laws are activity-specific. Each kind of industrial development envisages only its specific impact on the environment in the EIA studies. Hence, a comprehensive environmental assessment-based planning (taking into account the already existing highly urbanised areas as well as the suburban and rural fringes where future urbanisation is imminent) is essential to streamline the growth of fast-developing cities particularly in the developing countries where expensive corrective measures are often not economically viable.

Due to lack of proper environmental resources assessment, the development plans often failed to give proper consideration to environmental aspects. Short term economic goals for 5-10 years or even a slightly longer period, which is considered a long period by economists but, environmentally and ecologically a very short and negligible time, is the root cause for all the current environmental problems. In such short term economic benefit-based planning, usually environmental aspects go unnoticed. (For example, slow soil deterioration, depletion of aquifers, accelerated eutrophication of large lakes, adverse effects of air and water pollution on animals, plants and man and the deterioration of scenic quality of the environment etc.). This state of affairs is due to the lack of proper awareness about the environmental parameters amongst the economic planners and physical planners.

Hence, this study is aimed at an assessment of the environmental resources of a fast-developing metropolis - Cochin - with an aim to provide a probable guideline for specific urban development in environmentally compatible areas.

It is very difficult to find an urban settlement with all the environmental parameters. If the settlement is totally in a coastal plain, parameters of hilly areas will be lacking and if the settlement is totally in a hill tract, the coastal parameters will be absent. Hence, a coastal city with deep sediment strata and adjoining hill tracts and associated features will be the most suited site for such a study. Cochin is such a coastal settlement interspersed with backwater system and fringed on the eastern side by laterite-capped low hills from which a number of streams originate and drain into the backwater system. The ridge line of the eastern low hills gives a more or less well-defined water shed delimiting Cochin basin which help to confine the environmental parameters within a physical limit which is very advantageous in such a study. Hence Cochin basin covering an area of approximately 535 km^2 is selected for this study for the environmental status assessment.

1.3. Need for the Study

Compared to many other parts of the country, Cochin enjoys an atmosphere of communal harmony and social security. The availability of necessary infrastructure facilities added to the amiable social scenario has started luring large-scale investments in various activities from people throughout India. This recent phenomenon has resulted in a rapid growth boom, which is likely to go beyond the carrying capacity of the present urban fabric resulting in various environmental problems.

Due to the improper siting of industries and settlements, Cochin, the fast-developing metropolis of Kerala, is likely to face severe environmental problems such as water and air pollution from industries, drainage problems due to settlements developed in filled-up low-lying marshlands, sinking of buildings due to unstable sub-surface conditions, contamination of ground-water etc. Therefore, Cochin needs a careful environmental planning for ameliorating the environmental problems inherited from the past as well as for preventing unsound future developments.

This study aims at assessing various environmental resources of Cochin, which may enable the physical planners to suggest appropriate areas for long-term develop mental activities which are environmentally feasible.

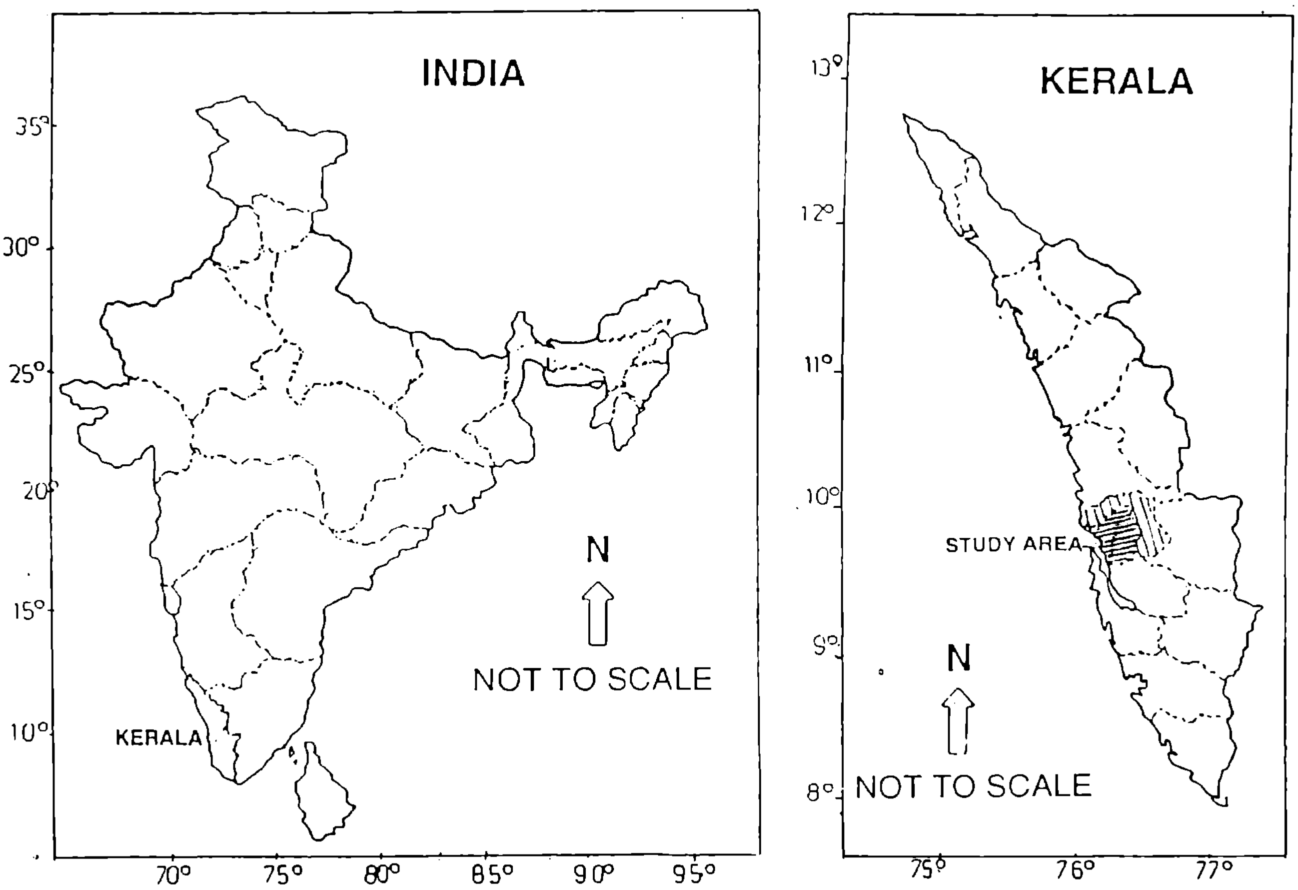
1.4 The Study Area

The study area is the Cochin basin lying between 9^0 49' N to $10^0$14' N and 76^0 10' E to 76^0 31' E along the south western coast of India (Fig. 1.1). It includes the Cochin City (the erstwhile municipalities of Ernakulam, Mattanchery and Fort Kochi), kalamassery and Tripunithura municipalities and the adjoining panchayats (Fig. 1.2).

Cochin City, the business and industrial capital of the state, is the nerve centre of a large urban agglomeration consisting of Alwaye, Parur, Perumbavoor, Thrikkakkara, Tripunithura, Kalamassery and Eloor lying around it. Cochin Port has trade connections with the countries all over the world. At present, the city has an air port on Willingdon Island, which facilitates business and tourist connections with all parts of the world. Now the construction of an International Air port at Nedumbassery in the suburb of Cochin is nearing completion.

1.5 Limitations of the study

The environmental problems of any industrial city are very vast and complex especially when located in a very low lying area with unstable geological substrata. The Cochin City has an area of 94.88 Km^2 and a population of 5,64,589 (Census - 1991). The central city area (Fig. 1.3) as envisaged in the Structure Plan for 2001 proposed by Greater Cochin Development Authority (GCDA) covers an area of 275.85 Km^2 and the GCDA covers an area of 732.00 Km^2 (encompassing definitive administative areas) whereas this study pertains to the entire Cochin basin,



LIES BETWEEN

9° 49' N to 10° 14' N and

76° 10' E to 76° 31' E

BOUNDARIES
West- Laccadives sea
East -Muvattupuzha river basin
South - Muvattupuzha river basin
North -Periyar river basin

TOTAL AREA - 535 km²

Fig-1.1. LOCATION MAP

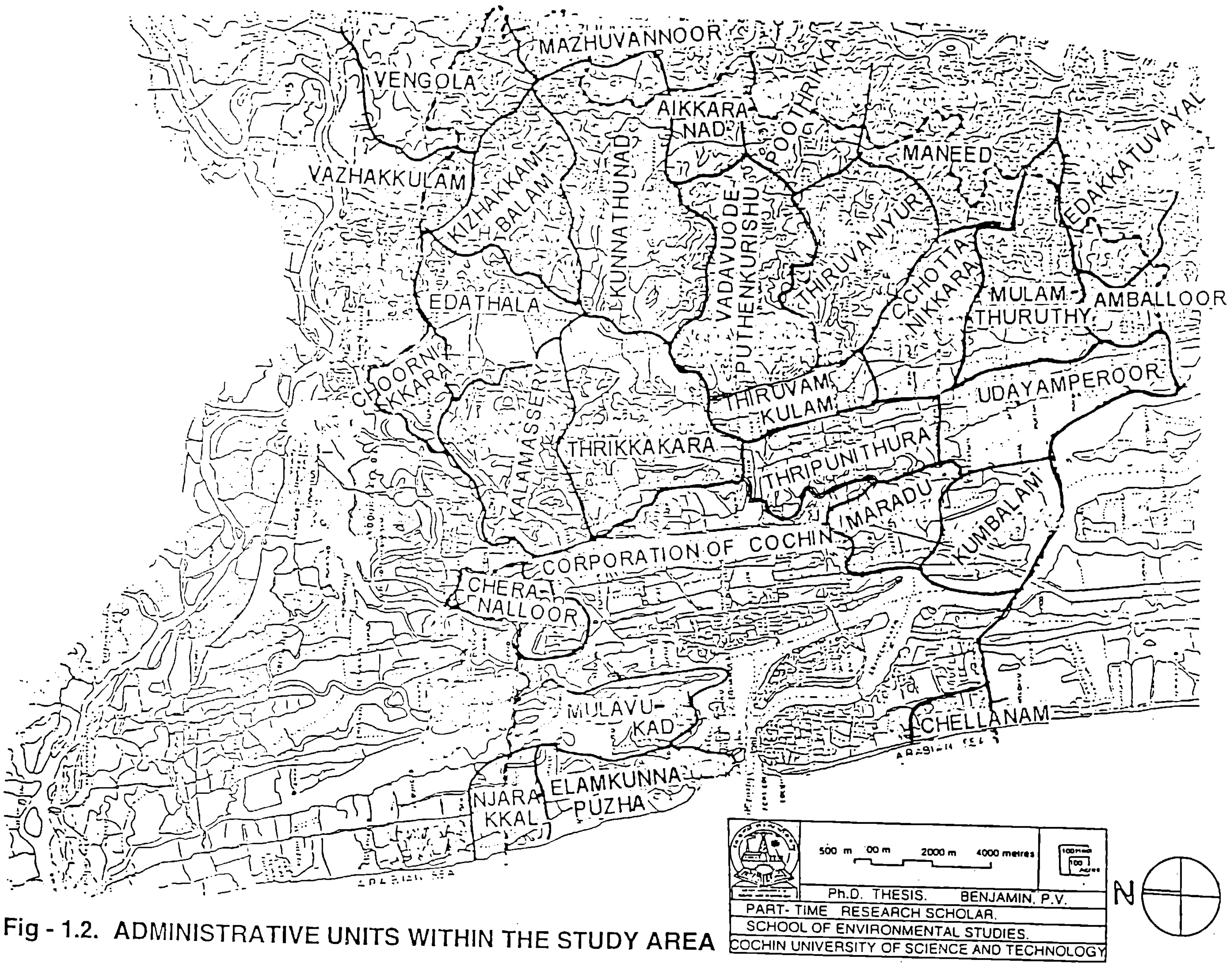


Fig - 1.2. ADMINISTRATIVE UNITS WITHIN THE STUDY AREA

ADMINISTRATIVE UNITS WITHIN THE STUDY AREA (COCHIN BASIN)

CITY CORPORATION

CORPORATION OF COCHIN

MUNICIPALITIES

KALAMASSERY
TRIPOONITHURA

PANCHAYATS

VENGOLA (PART)
VAZHAKKULAM (PART)
KIZHAKKAMBALAM
CHOORNIKKARA(PART)
EDATHALA
CERANALLOOR
THRIKKAKARA
MULAVUKAD
NJARACKAL(PART)
ELAMKUNNAPUZHA
CHELLANAM(PART)
MARADU
KUMBALAM
UDAYAMPEROOR
MULAMTHURUTHY(PART)
THIRUVANKULAM
CHOTTANIKKARA
EDAKKATTUVAYAL(PART)
AMBALLOOR(PART)
POOTHRIKA(PART)
THIRUVANIYUR
VADAVUKODU- PUTHENCRUZ
MAZHUVANNOOR(PART)
AIKKARANADU(PART)
KUNNATHUNADU
MANEED(PART)

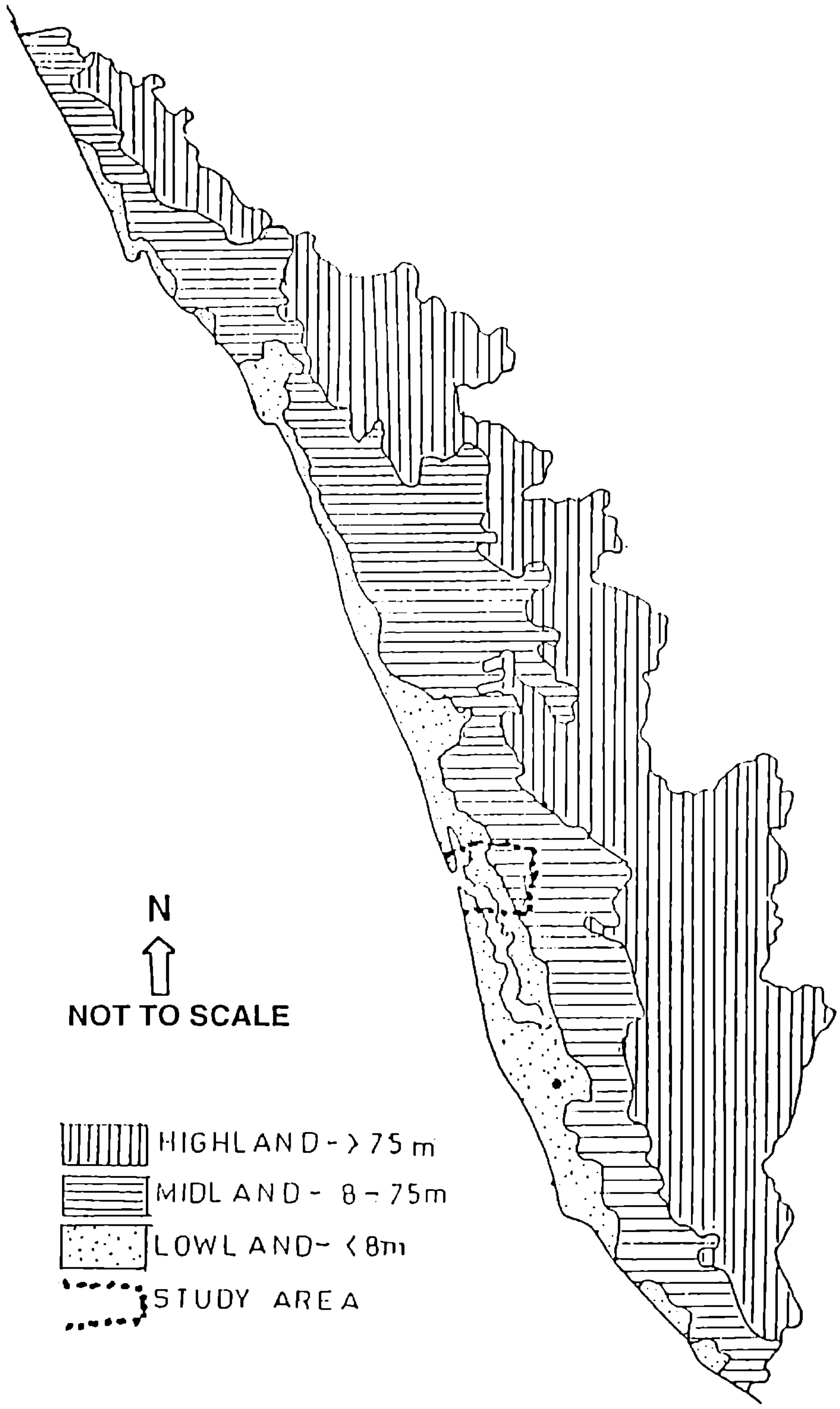


Fig - 2 . 1 PHYSIOGRAPHY OF KERALA

Fig-1.3 THE CENTRAL CITY AREA PROPOSED BY GCDA IN THE STRUCTURE PLAN FOR 2001 well defined by natural boundaries, covering an area of 535 Km^2. Due to vastness of the study area as well as multitude of environmental parameters, secondary data collected from National Environmental Engineering Research Institute, Nagpur, Kerala State Pollution Control Board, Trivandrum, the various departments of Cochin University of Science & Technology and Kerala Agricultural University, Trissur, National Institute of Oceanography,Cochin , etc. as well as various project reports and environmental assessment (E I A) reports prepared for specific projects of various agencies like Fertilizers and Chemicals Travancore Ltd. Cochin Refineries Ltd. , Cochin Port Trust, Greater Cochin Development Authority and Corporation of Cochin were also consulted. Bore logs of deep bore wells and those of foundation of buildings and bridges within the study area prepared by foundation engineers were also used as secondary data.

1.6 Historical Background.

Prior to 14^{th} century A D, the port of Musiris (present Kodungalloor) on the north of Cochin was the main centre of commercial activities of Kerala, which had trade connections with ancient Rome and Greece. In the year 1341 A D, a heavy flood silted up the Musiris harbour and formed a natural harbour at Cochin by opening a passage to the sea at Cochin (Logan, 1901). This caused the shifting of harbour activities and associated trades to Cochin from Musiris resulting in the sudden urbanization of Mattancherry on the west bank of the back water system.

The new town of Ernakulam in the main land began to develop on the east bank some where in 17^{th} century, even though the famous Ernakulam temple was there much before that and the place got the name after the temple.

However, the urban evolution of Ernakulam can be traced back only up to 1673 when Fr. Mathew got permission from the Dutch Governor to build a church at Chathiath – a place in erstwhile Ernakulam town - the first in Malabar, that the Carmelites ever built (Ernakulam Dist.Gazetteer, 1965)

Huzur court with appellate jurisdiction was set up in Ernakulam by Col. Monroe in 1812 AD. Survey and settlement of wetlands known as the 'Kandezhuthu' were done in the year 1821 AD (996 Malayalam Era) during the time of Dewan Nanjappayya.

Survey and settlement records of garden land were done during the period 1837-1838 AD.

An English school and an Allopathy hospital were commissioned during the period 1840-1858, which later developed into the present day Maharaja's College and General hospital respectively.

Roads were macadamized during the time of Thottakattu Sankunni Menon (1860-79).

Extensive reclamation of the backwater started during the period 1879-1889 when the Ernakulam foreshore was greatly improved in terms of recreation and road facilities.

Railway came to Ernakulam in 1905. Mattancherry became a Municipality in 1912. Ernakulam was upgraded to the status of a

Municipality in 1913, during the period of Diwan A.R.Banerji (1907-1914). Piped water supply was provided for the public at Ernakulam by Diwan Banerjee.

The aerodrome at Venduruthy was constructed during the period of Diwan Sri. Shanmugham Shetty (1935-1941). He was also responsible for the beautification and improvement of Ernakulam town and the foreshore area and their electrification. The Rammohan Palace (the present Kerala High Court building) was constructed in 1938.

Ernakulam thus gradually started to develop as an administrative town, with the establishment of the Huzur Court and connected buildings.

Dry land was very scarce in the vicinity of the Huzur Court (former Collectorate building) - the Administrative Secretariat of the Kingdom of Cochin - which resulted in the need of either reclaiming land from the lake or filling up the marshlands and canals for building purpose. This conversion continued and large-scale transformation of wetlands into dry area went on unabated along with the dredging and deepening of the channel and the sand bar at the channel mouth for opening of Cochin as a major port in 1940. The dredged material was added to the existing island to transform it into the present Wellington Island.

The commissioning of Cochin Port as an year-round port was responsible for the fast development of Ernakulam and suburban areas. With the road connection to the mainland on the west and road and rail connection to the east from the Island, the mainland on both sides began to develop fast in commercial activities. Along with this, the commissioning of Pallivassal Hydro Electric Project almost at the same time resulted in the rapid industrialisation and commercialisation of Cochin. The unplanned and haphazard development resulted in rapid degradation of the natural environment, which relentlessly continues.

The first step towards a planned development of Cochin was the preparation of interim development plan for Cochin by the Town Planning Department in the year 1966, which was further modified in 1968.

Cochin Town Planning Trust was formed in 1968 to implement the plan. In order to satisfy the basic environmental requirements of the people of the area, a Municipal Corporation was established in the year 1967 amalgamating three Municipalities of Fort Cochin, Mattancherry and Ernakulam. In 1976, in order to co-ordinate the development of the region, the Greater Cochin Development Authority was constituted. Ever since, at least some balance is maintained between development and environment.

1.7 General Methodology

This study is carried out in the following stages: -

(1) Identification and evaluation of various environmental resources of Cochin.

(2) Identification of areas suitable for various kinds of developments on the basis of each of the resources, individually.

The methodology of assessment of individual resources is given in the respective chapters on each resource. The environmental resources are assessed under the following headings.

1. Physiography
2. Geology and groundwater
3. Surface hydrology and backwater system
4. Climate
5. Vegetation
6 Socio-economic environment and Basic amenities and services

Broad environmental planning recommendations based on environmental suitability of the different zones within the study area in relation to the various resources individually and collectively are also given.

Chapter - 2

Physiography (Landform)

2.1. Introduction

Land is the basic resource available to mankind for his habitat, which unfortunately is limited. Hence, there is need for striking a balance between the competing claims on land use. An appropriate land use should ensure sustainability of land resources and optimum utilization. To achieve this goal, a study of the physiography of the area including drainage pattern, shape of the micro-watersheds within the area, land slope and drainage density is a pre-requisite. Development proposal of any area is to be compatible with the characteristics of its landform. Landform is an important determinant in the form and growth of a settlement and the distribution of population. Besides, it also influences the drainage, transport, climate and pollutant dispersion.

In steep slopes, poor grading and drainage practices aggravate landslide problems. Artificial fills placed on impermeable substrata are often rendered unstable by the build up of water pressure. Diversion of storm water on to slopes has a similar effect. Undercutting of hillsides for roads and houselots triggers landslides.

Another aim of physiographic studies is to limit occupancy of flood-prone areas (valley floors) by activities such as open spaces and gardens which are compatible with natural flood storage. However, flood plains in urban areas are usually occupied by slums or by housing colonies due to the fact that information regarding chances of flood are suppressed by unscrupulous land developers or others with various vested interests or lack of information.

2.2. Methodology

The physiographical study was conducted with the help of contour maps along with physical investigation of the study area. Relief map was then prepared to locate the hills and valleys and geographical boundaries of the study area (Cochin major basin) - lying in between Laccadives sea in the west and the ridge line of Muvattupuzha river in the east & south and the ridge line of Periyar in the north - the area which forms the catchment of Cochin major basin. The micro-catchments of individual streams and the ridgeline of the Cochin major basin were then marked. This also helped to fix the physical boundary line of the study area. Microclimatic zones are also identified from this physiographical study of the area extending over 535 km^2 Waterbodies were also located from the physiographical study. Drainage patterns of individual microcatchments and drainage density of the eastern lowhills were also assessed to find out the flood probability and other difficulties in infrastructure development.

2.3. Discussion

Cochin is a coastal settlement interspersed with backwater system and fringed on the eastern side by laterite-capped lowhills from which a number of streams originate and drain into the backwater system. The western part of the study area is a flat coastal zone, which forms a part of the coastal plains of Kerala, and the eastern lowhills are part of the midland region (Fig.2.1)

Evaluation of the physiography enabled to understand the various characteristics of the drainage basin, which is very important in urban planning. In the present study, with the help of contour maps, the boundary of the Cochin major basin is identified. Since each drainage basin is independent in many of the environmental characteristics, assessment of the environmental resources is done within this framework. In the case of Cochin major basin, the area is divisible into two major zones with entirely different landforms (Fig.2.2). They are the eastern lowhills, a zone, which is further divisible into minor watersheds (sub-basins) and the western flatland, which is further divisible into many independent drainage planning areas (Fig.2.3 & 2.4)

2.3.1. EASTERN LOW HILLS.

This area comes within the midland region of Kerala (CESS Atlas, 88) and is characterised by low hills and valleys. The area is geomorphologically an etched plain characterised by laterite-capped low hills with streams in the valleys draining into tidal canals, which lie at the junction between the two zones. The eastern low hills are running mostly in a north-south direction.

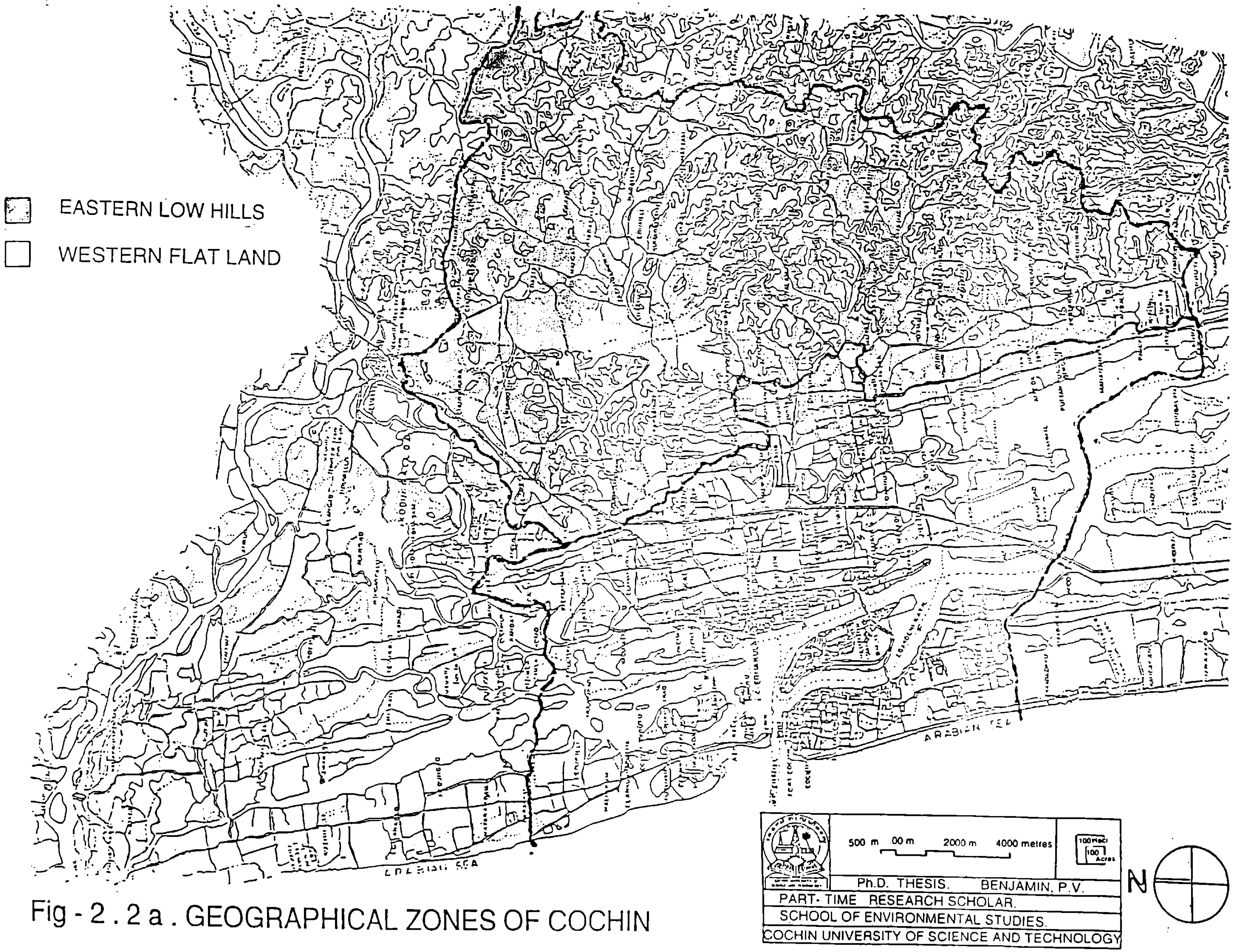


Fig - 2 . 2 a . GEOGRAPHICAL ZONES OF COCHIN

REFER ANNEXURE 2.1 FOR DETAILS

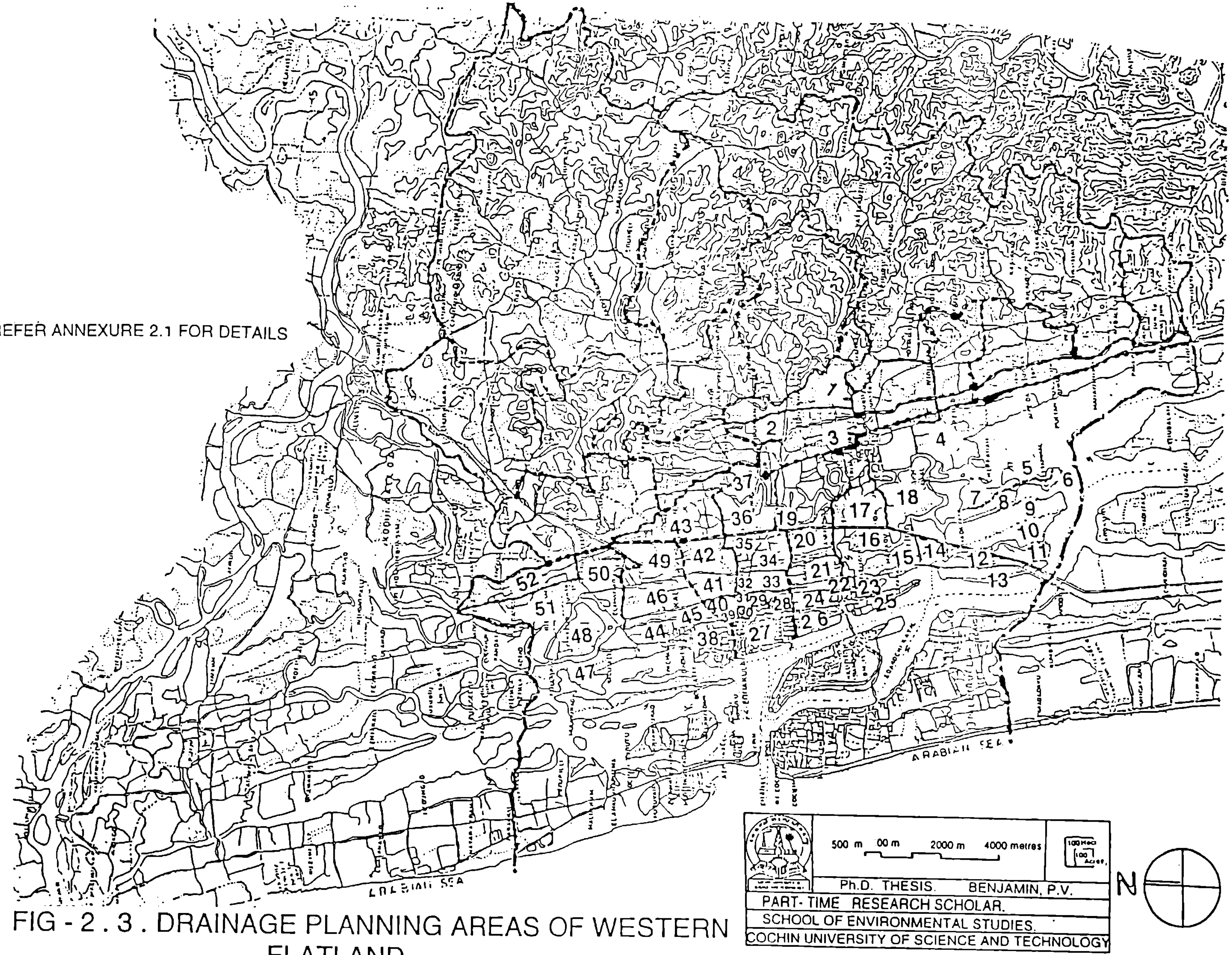


FIG - 2 . 3 . DRAINAGE PLANNING AREAS OF WESTERN FLATLAND

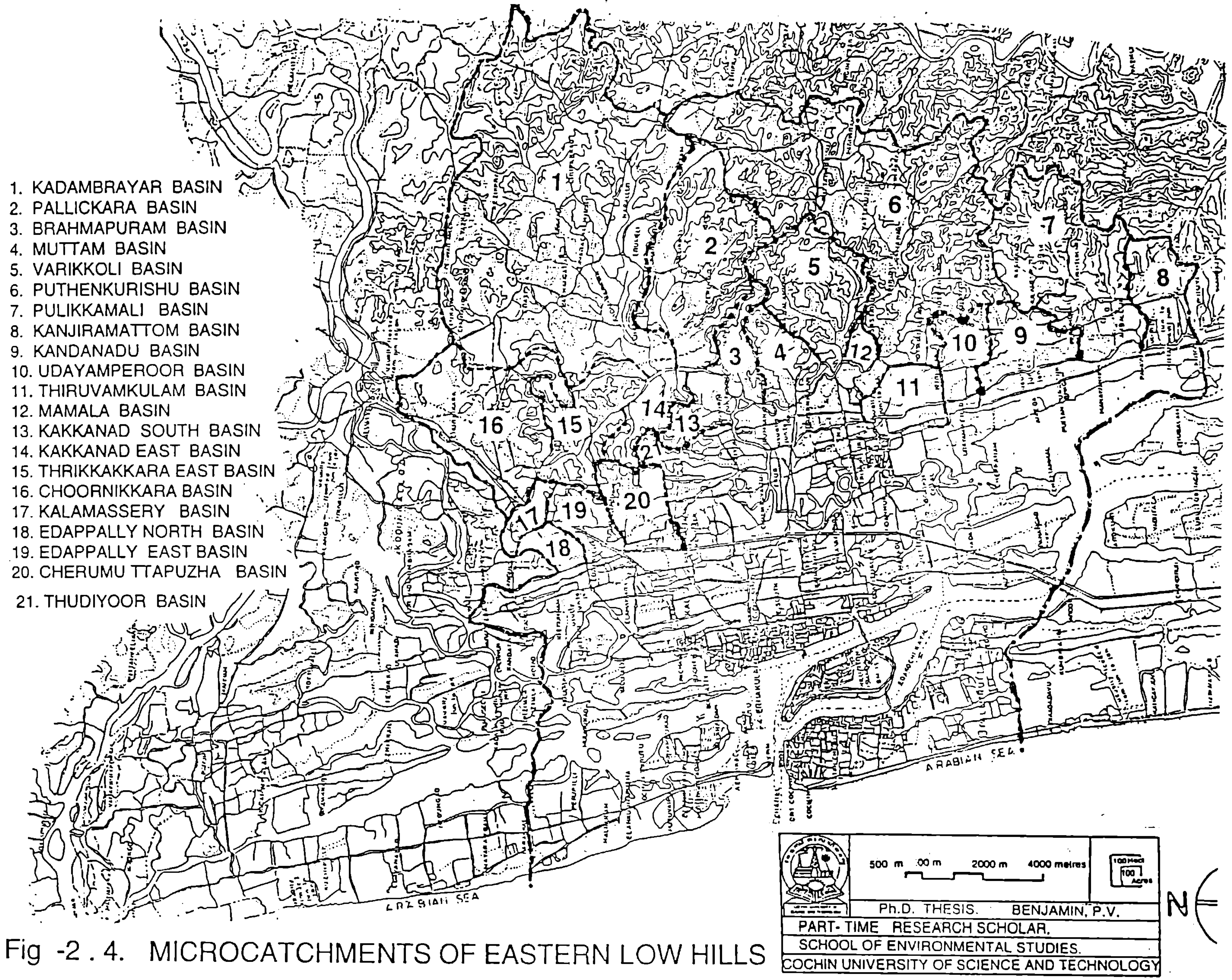


Fig -2 . 4. MICROCATCHMENTS OF EASTERN LOW HILLS

This zone, which covers an area of 291 km^2 , is comprised of the 21 stream basins (Fig 2.4), or microcatchments, each with independent watershed area. The 21 major streams (vide Annexure 2-I) originate from the eastern low hills, running mostly in westward direction in between these lowhills, drain into the tidal canals which also run in a north-south direction with linkage to the backwater system. These drainage basins have laterite or lateritic soil with occasional rock outcrops. The tidal water channels of Chitrapuzha, Eroor puzha, Poothotta thodu, Thudiyur puzha and Edappally thodu separate this sloped lateritic land from the western flat land. Such a peculiar physiographic nature makes the development planning for the eastern part very intricate because the characteristics of a drainage basin are very important in urban planning.

A catchment is drained by a hierarchical network of channels. It is actually these channels which sculpture the valley in which they lie and are therefore responsible for the overall orientation of the valleys and hill slopes in an area (Ordway, 1971). The drainage pattern is the distribution of streams or channels in an area, which is influenced by the slope of the land, lithology and structure. The distribution and attitude of the rock system and their arrangements also control the drainage pattern (Zumberg, 1961). A study of the drainage patterns and drainage texture is helpful in the interpretation of geomorphic features and understanding landform evolution and such information is crucial in the location of appropriate land uses.

Fine drainage texture of dendritic pattern indicates that rock formations are impervious and the permeability is low (Tideman, 1996). Soil formed in such areas is deep, heavy and slowly permeable. They are subject to severe erosion hazards forming gullies at several places and are less suitable for urban development. Such areas are scarce in the eastern hill tracts of the study area. Medium textured drainage patterns of radial, braided and pinnate types, which are characteristics of rock formations with fractures and joints, are also absent. In the eastern lowhills of the study area, drainage pattern is angulate, Rectangular and angulate drainage pattern is normally associated with coarse drainage texture. In such cases, hydraulic conductivity is high. The soils are generally shallow and coarse in texture. Erosion hazards may be mostly due to steep slopes. In general, coarser the drainage texture the higher the conductivity, which is comparatively safer than the pinnate form in which simultaneous flooding of the tributary valley occurs. Being angulate, chances of simultaneous flooding of the valley of the eastern lowhills are less.

The dissection of the terrain is measured in terms of density of channels. The drainage density is defined as the length of all channels in the drainage basin divided by the basin area. The drainage density of individual micro-catchment of the eastern lowhills region of the study area is given in Table 2.1.

Areas with high drainage density are associated with high flood peak, high sediment production, steep hill slopes, general difficulty of access,

TABLE - 2 .1 STREAM BASINS (EASTERN LOW HILLS)

			Discharge			Runoff							
Sl.No	Drainage Plng. Areas	Drainage Intensity	Cross Sect Area (m2)	Velocit m/s	Discharg m /s	Area km	Length km	Height m	Co-effici	Timeof Concn.	Rainfall Intensity	Peak Run off m /s	Efficiency
1	Kadambrayar	0.781	62.61	1.17	73.32	81.072	16.75	115	0.4	3.84	48	434.53	0.1687
2	Pallikkara	0.689	15.01	2.12	31.78	21.321	8.25	70	0.4	2.05	65	154.14	0.2061
3	Brahmapuram	0.515	40.01	3.23	129.26	3.881	4.51	40	0.4	1.26	68	37.96	3.4052
4	Muttam	0.745	22.51	1.32	29.75	6.037	4.51	40	0.4	1.26	88	59.01	0.5043
5	Varikkoli	0.845	30.01	1.63	46.93	14.496	6.51	60	0.4	1.65	75	120.89	0.4047
6	Puthenkurishu	0.696	30.01	1.11	30.08	57.773	16.51	80	0.4	4.34	33	212.01	0.1418
7	Pulikkamali	0.845	16.51	1.88	19.61	22.491	9.01	67	0.4	2.31	58	145.01	0.1351
8	Kanjiramattom	1.259	74.01	2.24	165.46	6.989	5.01	20	0.4	1.86	70	54.41	3.0401
9	Kandanad	0.193	20.01	1.91	38.24	5.952	2.75	20	0.4	0.94	103	68.17	0.5609
10	Udayamperoor	0.769	20.01	1.01	20.29	4.617	3.25	20	0.3	1.14	92	35.42	0.5727
11	Thiruvankulam	0.031	12.01	1.4	16.99	3.861	3.01	20	0.4	1.04	96	41.21	0.4121
12	Mamala	1.553	30.01	3.82	114.64	0.966	1.51	20	0.4	0.47	137	14.71	7.7498
13	Kakkanad South	1.076	18.01	1.59	26.58	3.854	3.25	20	0.4	1.14	92	39.42	0.7251
14	Kakkanad East	0.672	Drained by	Four	Streams	5.947	2.51	20	0.4	0.84	104	68.78	--
15	Thrikkakara Ea:	0.454	20.01	1.42	28.32	10.458	3.75	20	0.4	1.34	87	101.18	0.2779
16	Choornikkara	0.519	18.01	1.588	28.59	20.701	9.01	40	0.4	2.81	50	115.11	0.2481
17	Kalamasserry	0.463	15.01	2.12	31.79	2.481	3.75	20	0.4	1.34	87	24.01	1.3231
18	Edappally Nort	0.462	15.01	2.12	31.79	2.163	1.01	20	0.4	0.29	85	20.44	1.5501
19	Edappally East	1.257	18.01	1.59	28.59	4.175	4.51	20	0.4	1.65	75	34.82	0.8201
20	Cherumuttapuzh.	0.137	12.09	1.41	16.97	5.475	3.01	20	0.4	1.04	96	58.45	0.2903
21	Thudiyoor	1.343	Drained by	Three	Streams	6.327	3.75	20	0.4	1.21	87	61.21	--

(1) Calculations are made using Rational Runoff Method

(2) The Runoff is calculated on the assumption that a rainfall of uniform intensity cover the whole baisn

REFER ANNEXURE 2.1. FOR DETAILS

Tide data for Cochin

Lower low water springs near solstices	Mean Lower low Water	Mean Higher Low water	Mean sea level	Mean Lower high water	Mean higher high water	Higher high water Springs near solstices
+0.20 m	+0.29 m	+0.56 m	+0.64 m	+0.79 m	+0.92 m	+1.05 m

Source: Tide table 1993. Surveyor General of India.

TABLE - 2.2. DRAINAGE PLANNING AREAS (WESTERN FLATLAND)

Sl.No	Drainage Planning Areas	Area Km	North Boundary	South Boundary	East Boundary	West Boundary	General Slo (Towards)
1	Thiruvankulam East	4.165	Thudiyoor Puzha	TPRA-MVPA Road	Chitrapuzha	KGCRA - IRPNM Rd.	
2	Irumpanam West	2.861	Thudiyoor Puzha	TPRA-MVPA Road	TDYR - TVKM Rd	Eroor Puzha	
3	Eroor-Poothotta Rd East	12.206	Eroor Bridge	Poothotta Puzha	Eroor-Poothotta thod	Eroor-Poothota Rd	East
4	Eroor-Poothotta Rd West	17.555	Eroor Bridge	Poothotta Puzha	Eroor-Poothotta Rd	Kandakadavu Puzha	West
5	Chathamma East	0.571	Vembanad Kayal	Vembanad Kayal	Vembanad Kayal	Local Rd	East
6	Chathamma West	0.326	Tidal Canal	Vembanad Kayal	Local Rd	Tidal Canal	West
7	Cheppanam East	0.616	Tidal Canal	Tidal Canal	Vembanad Kayal	Local Rd	East
8	Panangad East	2.965	Tidal Canal	Vembanad Kayal	Tidal Canal	Local Rd & NH-47	East
9	Panangad West	1.681	Tidal Canal	Vembanad Kayal	Local Rd & NH-47	Tidal Canal	West
10	Kumbalam East	0.857	Tidal Canal	Vembanad Kayal	Tidal Canal	NH-47	East
11	Kumbalam Central	0.801	Tidal Canal	Vembanad Kayal	NH-47	Coastal Rlwy Line	
12	Kumbalam West	1.399	Tidal Canal	Vembanad Kayal	Coastal Rlwy Line	Vembanad Kayal	West
13	Nettoor South	1.271	Tidal Canal	Tidal Canal	Tidal Canal	Tidal Canal	West
14	Nettoor North	1.901	Tidal Canal	Tidal Canal	Tidal Canal	Tidal Canal	East
15	Kundannoor West	1.614	Local Rd	Tidal Canal	NH-47	Tidal Canal	West
16	Kundannoor East	2.904	Local Rd	Local Rd	Tidal Canal	Local Rd	East
17	Maradu	2.669	Local Rd	Tidal Canal	Tidal Canal	Tidal Canal	North
18	Vyttila East	1.125	Rlwy Line	Champakkara Canal	Champakkara Canal	NH-47	East
19	Vyttila West	1.777	S.A. Road	Tidal Canal	NH-47	Tidal Canal	West& South
20	Chilavannoor	0.998	S.A. Road	Tidal Canal	Tidal Canal	KP Vallon Rd	-
21	Kadavanthara	0.773	S.A.Rd	Local Rd	KP Vallon Rd	TP Canal	East
22	Konthuruthy	0.751	Tidal Canal	Tidal Canal	Tidal Canal	Tidal Canal	South
23	Panampilly Nagar	1.992	S A Road	Tidal Canal	Tidal Canal	Rlwy Line	-
24	Thevara	1.405	MG Rd & Rlwy Line	Tidal Canal	Tidal Canal	Vembanad Kayal	East
25	Ravipuram	1.439	CL Road	MG Road	MG Road	Vembanad Kayal	West
26	Ernakulam CBD Area	3.101	Banerjy Road	CL & SA Roads	Rlwy Line	Vembanad Kayal	West
27	Gandhinagar West	0.617	Rlwy Line	S A Road	TP Canal	Rlwy Line	-
28	Gandhinagar East	0.971	Rlwy Line	S A Road	Kaloor-KDRA Road	TP Canal	-
29	Pulleppady	0.066	KTKDV-PLPDY Road	Rlwy Line	TP Canal	Rlwy Line	East
30	Kathrukkadavu West	0.162	TMNM - PLPDY Road	Rlwy Line	Kaloor-KDRA Road	TP Canal	West
31	Kathrukkadavu East	0.293	TMNM - PLPDY Road	Rlwy Line	TP Canal	Kaloor-KDRA Road	East
32	Asan Nagar & JawaharNagar	1.161	Rlwy Line	S A Road	Tidal Canal	Kaloor-KDRA Road	West
33	Ponnurunny	1.666	Rlwy Line	S A Road	NH-47	Tidal Canal	West
34	Thammanam	1.286	TMNM - PLPDY Road	Rlwy Line	NH-47	Tidal Canal	West
35	Chalikkavattom	2.339	TMNM-ARKDV Road	Rlwy Line&TidalCanal	Tidal Canal	NH-47	East& South
36	Arkka Kadavu	1.191	Tidal Canal	Tidal Canal	Tidal Canal	Tidal Canal	West
37	Thrikanarvattom- Pachalam	2.897	Local Rd	Banerjy Road	Rlwy Line	Ernakulam Kayal	West
38	Kaloor-Indira Nagar	0.319	NH-47	TMNM - PLPDY Road	TP Canal	Rlwy Line	-
39	Kathrukkadavu-Kaloor West	0.506	NH-47	TMNM - PLPDY Road	Kaloor-KDRA Road	TP Canal	West
40	Kathrukkadavu-Kaloor East	1.436	NH-47	TMNM - PLPDY Road	Tidal Canal	Kaloor-KDRA Road	East
41	Palarivattom South	2.233	PLVTM - Kaloor Road	TMNM - PLPDY Road	NH-47	Tidal Canal	West
42	Vennala	2.907	PLVTM-Kakkanad Road	TMNM-Arkakadavu Road	Tidal Canal	NH-47	East
43	Kaloor-Sivaramamenon Area	1.691	Rlwy Line	NH-47	TP Canal	Rlwy Line	East
44	Perandoor Road West	0.788	Rlwy Line	NH-47	Perandoor Road	TP Canal	West
45	Perandoor Road East	4.004	TidalCanal&Rlwy Line	NH-47	Tidal Canal	Perandoor Road	East& North
46	Vaduthala	3.201	Tidal Canal	Rlwy Line	Tidal Canal	Ernakulam Kayal	East& West
47	Chittoor	2.504	Tidal Canal	Tidal Canal	Tidal Canal	Tidal Canal	-
48	Edappally South	2.685	Local Rd	PLVTM - Kaloor Road	NH-47	Tidal Canal	West
49	Edappally North	2.393	Rlwy Line	Local Rd	Tidal Canal & Road	Tidal Canal	East & West
50	Cheranalloor West	4.517	Tidal Canal	Rlwy Line	Varapuzha Ferry Road	Tidal Canal & Roa	West
51	Cheranalloor East	0.321	Tidal Canal	Rlwy Line	Tidal Canal	Local Rd	East

REFER ANNEXURE 2.2. FOR DETAILS

relatively low suitability for agriculture and high development costs for the construction of buildings and the installation of bridges, roads and other facilities. Steep slopes with intricate drainage pattern may render most of the areas in a drainage basin inaccessible with roads, which will be limited to drainage divides only. Further, such areas are unsuitable for urban development not only due to difficulties encountered in waste disposal but also due to the reason that soil in such steep slopes are unsuitable for septic tanks. Steep slopes cause landslides, particularly when disturbed. Such locations in the study area are identified and presented in Fig.2.5.

In lands with gentle topography, construction of buildings will be easy. But if the gently sloped or level ground is at the valley floor, the area may get flooded during monsoon season (Fig.2.6). Not only that, the valley floors width, hill slope gradient, channel density, discharge capacity etc, have significant role in the generation of flood. Flood-prone areas of this region, identified with the help of hydrological calculations are presented in Chapter IV on Surface hydrology .

The lower the location in a drainage basin, the more likely are the problems posed by upstream water use. The terrain tends to be more flat and uninteresting also. But water supply and trafficability will be more as well as construction difficulties will be comparatively less. Upstream is often constrained by limited water supplies, steep terraces etc. Based on the

FIG 2.5 . SLOPE ANALYSIS

FIG -2 . 6. VALLEY FLOORS (EASTERN LOW HILLS) above aspects, areas suitable for various developments in the eastern lowhills of the study area are considered.

Another physiographic feature, which should be taken into account in the landuse proposal, is the shape of the watersheds. Long and narrow watersheds are likely to have longer time of concentration resulting in lower runoff rates than more square water sheds of the same size which have a number of tributaries discharging into the main channel near one point resulting in flood at that point. This time of concentration also affects the amount of water, which will infiltrate into the soil within the watershed. The longer it takes to leave the watershed, the greater will be the infiltration into the ground. This aspect is considered in detail for the flood computation and locating flood-prone areas in the chapter on surface hydrology.

An important physiographic feature of concern is land-slope, which has a major role to play in landuse. According to law of falling bodies, velocity varies as a square root of the vertical drop. Hence, if land-slope increases 4 times, the water-flow velocity on the slope doubles. If the velocity is doubled, the kinetic energy and consequently the erosive (or cutting) capacity increases 4 times, i.e., the erosive capacity of the runoff varies in direct proportion with land-slope. Also, when the velocity is doubled, the quantity of the material that can be carried is increased by about 32 times and the size of the particles that can be transported by pushing or rolling is increased by 64 times (Tideman, 1996). Thus the degree of slope sets limit on land use, both urban and agriculture.

A slope analysis of the eastern region of the study area has led to the following categorisation depending on slope.

Areas with less than 5% slope is ideal for the development of play fields and building construction. Areas with 5 - 20% slope is good for building purposes, since construction is easy on these stable slope, chances for erosion are very less and drainage will be efficient. Areas with 20 - 30% slope are less suitable for construction activities. Areas with above 30% slope is least suitable for construction activities. Eventhough, usual standard is 10% slope for building purposes, slopes up to 30% are considered suitable in the eastern hills of Cochin since the subsurface is very stable. Such areas are identified and located in the Fig 2.6.

2.3.2.. WESTERN FLAT LAND

The western flatland (Coastal Plain) comprises of 52 drainage units covering an area of 115 km^2 (Annexure-2.2) and islands in the backwater system with a total land area of 56.4 km^2. The backwater system extending to an area of 72.6 km^2 also comes within this zone.

This zone lies between the sea and the low hills. Two distinct areas can be identified in it. They are: -

a) Flatland interspersed with tidal canals: -

This strip is only about 1 Km wide in the southern tip and about 6 kms in the other areas and lies in a north-south direction more or less parallel to the coastline. The Edakochi Kayal and Ernakulam Kayal separate this flatland from the western sandbars, which are branches of the Vembanad estuary. This flatland zone covers a total area of 115 km^2 as calculated from the maps.

In this area no drainage basins could be identified since the land is flat with criss-cross roads and drains. However, there are distinct identifiable drainage planning areas bounded by natural tidal canals or man-made features like roads and railway lines which form independent drainage areas in physiographical as well as from the drainage point of view. 51 drainage-planning areas are distinguishable in this area (Fig.2.3).

The paddy fields in the flatland are being filled up for building purposes. Hence the drainage direction is under constant change. The eastern fringe of this flatland is rather high and sandy in nature, whereas western part is covered with low paddy fields (most of them drying up in summer), interspersed with land area 1-2m above MSL.

b) Backwater Islands and Coastal Sandbars

To the west of the flatland, interspersed with tidal canals, is the island zone in the backwaters and the sandbars bordering the Laccadives Sea, which is separated from the flatland by the Edakochi Kayal and Ernakulam Kayal (Fig 4.2). The sandbar and islands have a north-south orientation, parallel to the Laccadives Sea. The area, from Andikadavu in the south to Njarakkal in the north, comes within the study area. The total land area in the Backwater island zone comes to 56.407 km^2.

Six sub zones are distinguishable in this zone. They are: -

1) Area from Andikkadavu to Edakochi in the south and Fort Cochin and Mattancherry in the north - This is a coastal landstrip running parallel to the Laccadives Sea and separated from the main land by the Edakochi Kayal. Its total area is 24.897 km^2 . Its uplands are sandy and low lands are clayey paddy fields interspersed by tidal canals.

2) Vypin strip from Njarakkal to Vypin - Its boundaries are the ship channel in the south, local road in the north, Ernakulam backwaters on the east and Laccadives sea in the west. It covers a total area of 17.097 km^2

3) Willingdon Island - It covers an area of 6.556 km^2 surrounded by backwater.

4) Panambukad-Vallarpadam Island - This Island lies in the Ernakulam Kayal and covers an area of 2.984 km^2

5) Bolghatty-Mulavukad Island - This covers an area of 2.357 km^2 and lies in the Ernakulam kayal.

6) Small Islands - Behind the above-mentioned large islands there are a few islets lying in the backwaters whose total area is about 2.516 km^2

2.4. Summary and Conclusion

The study area, which is limited to the Cochin major basin, extending over 535 km^2 in area, is composed of:-

(a) 21 stream catchments (sub basins) in the eastern hill tracts with a total area of 291 km^2 ,

(b) the flatland interspersed by tidal canals covering an area of 115 km^2,

(c) the islands in the backwater system and the land strip along the sea coast together covering an area of 56.41 km^2, and

(d) the water sheets with an extent of 72.59 km^2.

The height of the flatland in the western part of the study area is only about 1m above MSL at Cochin. This portion comes within the coastal plains of Kerala. The eastern low hill tract, which comes within the midland region of Kerala, suddenly rises from about 1m to 20-40m above MSL with occasional peaks of 60m and above. The maximum height is 115m above MSL near Arakkapady in the northeastern corner of the study area, near Perumbavoor. This creates drastic difference in the drainage pattern between the two areas. In the eastern low hills, surface drainage is easy due to the steepness while in the western part, surface drainage is difficult due to the flatness of the area. This difference in the drainage pattern makes the two areas hydrologically distinct.

In the eastern lowhills of the study area drainage pattern is angulate. Angulate drainage pattern is normally associated with coarse drainage texture. In such cases, hydraulic conductivity is high. The soils are generally shallow and coarse in texture. The coarser the drainage texture, the higher the conductivity. Erosion hazards may be mostly due to steep slopes. Being angulate, chances of simultaneous flooding of the valley of the eastern lowhills are less.

In the eastern part of the study area, the hill tracts do not have a continuous high ridgeline and through the gaps at several places, sea breeze penetrates eastwards into the interior. However, the Puthencruz basin (57.77 km^2), lies in a more or less north-south direction between the two ridge lines which converges at Arakkapady in the north and diverges out in the southward direction. This peculiar shape of the basin makes it free from the influence of direct sea breeze. Besides this, there are several smaller basins also with similar conditions. The presence of these kinds of independent basins or depressions has a profound influence on the microclimatic conditions and dispersion dynamics of pollutants from the industrial areas of Ambalamugal and Udyogamandal areas.

The western flatland is interspersed with tidal canals and backwater system. These make the road transport difficult wherever they are not linked with the mainland by bridges. This keeps many islands within the highly urbanised areas underdeveloped, though within the immediate proximity of the highly developed areas. This situation has serious economic and socio-logical implications.

However, the abundance of waterbodies facilitates easy water transport and livelihood to many, by way of fishing. These waterbodies in the western part are degraded due to siltation, eutrophication and disuse in many areas, which are to be improved by proper widening and deepening of canals wherever necessary. Rejuvenated canals facilitate water transport and drainage efficiency. Not only that, the abundant water sheets and paddy fields within the urban structure provide easy availability of space for recreational facilities and parks by filling shallow waterbodies wherever required after thorough investigation of the ecological impact of such filling.

As stated earlier, landforms decide the urbanistion pattern. In the study area, waterbodies decide the settlement pattern in the western parts and the ridgelines of hills and floodzone of the streams decide the settlement pattern in the eastern upland.

Chapter- 3

Geology and Groundwater

3.1. Introduction

Geology (including soil) decides the dynamics of an ecosystem, which forms the base on which physical planning is executed. Hence, the influence of geological environment on man and viceversa has to be observed and assessed properly before any physical planning is done. However, geology is usually neglected in planning either due to ignorance or due to lack of sufficient information.

Geomorphology is the study of surface forms on the earth. Planning without the knowledge of geomorphic processes can lead to a series of omissions and commissions. Even if the planner is not an expert in geomorphic subjects, an awareness of natural processes can be of great assistance.

Good site planning and architecture that takes advantage of the natural features of the site rather than obliterating them will reduce soil loss. Soil is defined as the surface layer of earth supporting plant life. Land characteristics that favour soil erosion under various kinds of development can be recognised early in the planning process. Such information can be used to plan land use including drainage planning that is compatible with natural limitations and potentials of each area. Onsite sewage disposal is the usual norm in suburbs. Bad design or failure to anticipate the site limitations can lead to septic tank failure, aesthetic problem where sewage appear on the ground surface or in cut banks and ditches and even public health dangers. Planners can avoid committing themselves to sites that have such limitations, if they understand the soil condition.

Knowledge of runoff generation of various locations is also very useful in planning processes. It allows one to recognise those parts of a landscape that are likely to be major contributors of either storm runoff or ground water recharge. Precautions may have to be taken to avoid this zone for developmental activities or to detain water generated upon them. Zones that allow ground water recharge and therefore augment the stream flow during dry weather should be conserved so that they might continue their primary function instead of being paved or polluted (Mc. Harg, 1969).

Groundwater, besides being a resource, which has to be exploited judiciously, has profound influence on the geological stability. Excess withdrawal of groundwater may result in seawater intrusion as well as cause land subsidence in a coastal sedimentary area like Cochin.

3.2. Methodology

The study area was first investigated for geomorphological characteristics with the help of contour maps and field observations. This was then studied in relation to bore-hole logs obtained from the foundation engineers to arrive at conclusions regarding geomorphological characteristics. These bore-hole logs also revealed the litho-stratigraphy of the study area. The various geological strata are studied in the order they occur - one layer over the other - as revealed by bore hole logs.

Soil sample test results from 500 points in the study area co llected from soil testing laboratory, Vytila, were utilized for evaluating the general status of soil of the study area. For that, the whole study area was divided in to 4 types, viz. 1. Eastern hilly dry land, 2. Eastern wet land (valleys) , 3. Western dry land , and 4. Western wet land. The parameters selected are soil pH and macro nutrient status from nitrogen (as percentage of organic carbon), available phosphorous and potassium values.

Bore hole logs from Foundation Engineers (F S Engineers, Cochin, Jain Associates, Cochin and School of Technology, Cochin University of Science & Technology), deep bore well data from Kerala Water Authority and data from Central Ground Water Board were utilized for the study of ground water regime.

3.3 Discussion

3.3.1. Geology and Geomorphology.

As revealed in the physiographical study, the Cochin basin is having two physiographically and geomorphologically distinct zones running in a north - South direction, viz ; the hilly eastern up lands and the western flat terrain which forms part of the mid land region and coastal plains of Kerala respectively.

The Eastern part of the Cochin basin in as eroding area with mostly lateritic low hills and their valleys formed by differential erosion and the western part is a deposition area with the characteristic flat land form with meandering streams and shallow watersheets. The lateritic nature of the eastern low hills ensures their survival because of low erodibilty. On a local scale, laterite formations, which may have originated beneath lower slopes of valleys, are now found as summit copings, forming ridges, plateau or small mesas because of its low erodibility (Thomas, 1974). Wherever morphological changes have taken place and continue within the laterite terrain, it is clear that surfaces unprotected by the laterite duricrust are lowered more rapidly, unless they form bare rock hills (Thomas, 1974). This kind of differential erosion has given rise to the present 'etched plain' of low laterite hills in the eastern part of the study area. This proves that laterite-covered areas are erosion resistant and stable.

The 'valleys' of such 'etched plain' are highly erodible and these valleys are formed originally due to high erodibility. Human action further aggravate the erodibility by mechanical loosening of such areas or by removing vegetation cover resulting in the formation of gullies in such areas not protected by laterite duricrust (Thomas, 1974)

The western flatland portion is basically a deposition area. These sediments were brought from the eastern hills by the streams in the study area as well as from far off places by Periyar, Muvattupuzha, Pamba, Manimala, Meenachil and Achankoil rivers which drain into the Vembanad lake to which the flatland area is closely linked.

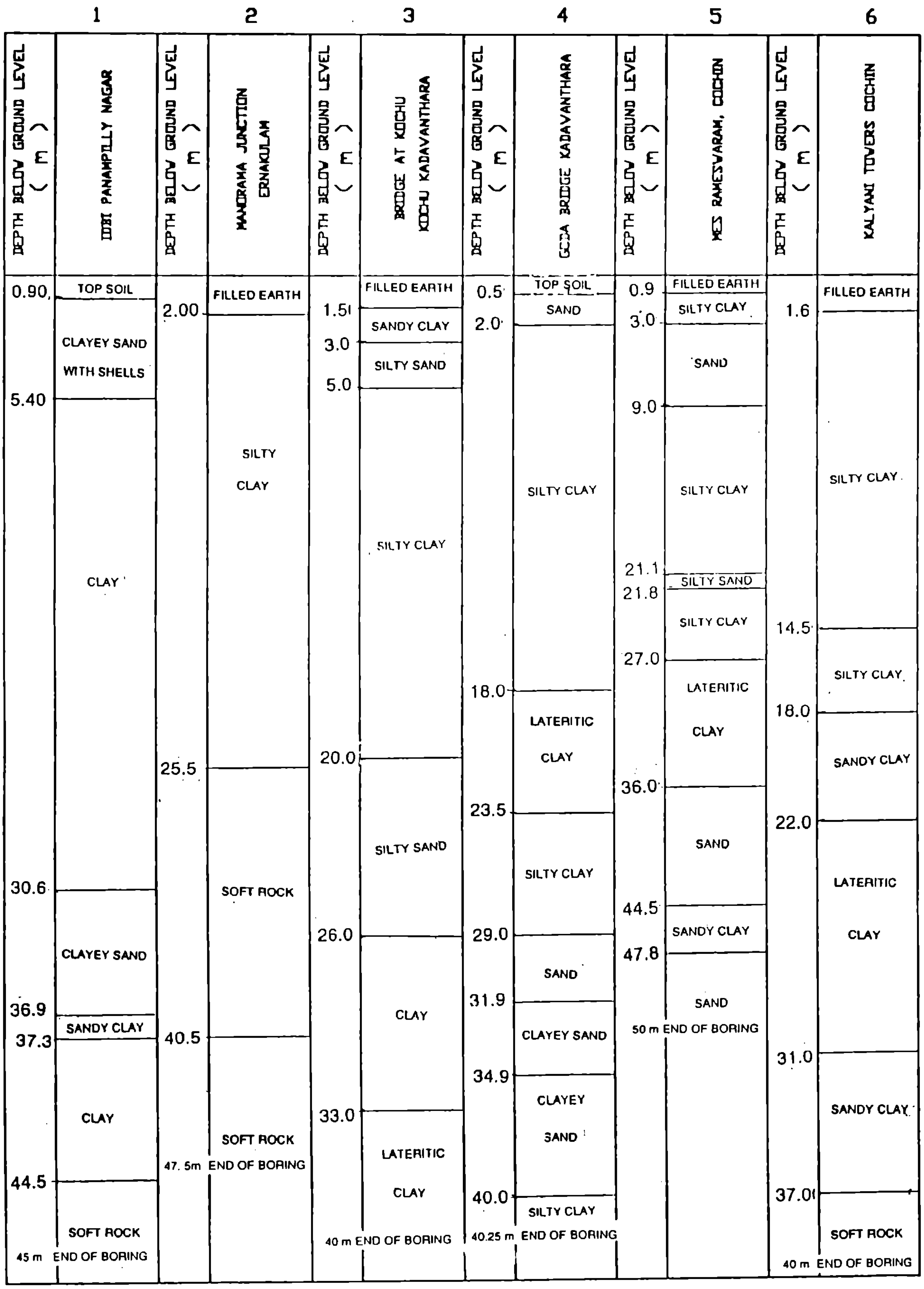
In litho-stratigraphy, the various geological strata are studied in the order of their occurrence - one layer over another. This assessment is based on bore-hole logs obtained from foundation Engineers and Geophysicists. The data from the foundation engineers reach up to a depth of about 50 m (Chart 3.1) while those of deep bore wells go up to a depth of about 100 m or more (Fig.3.2).

Bore-hole data from 50 bore holes (Fig 3.1.a & Table 3.1) distributed mainly in the western part of the study area reveals a laterite layer, several meters in thickness, at about a depth of 14 to 42 m. Over this laterite layer, sediments of several meters in depth are seen which might have been deposited over a long period. Below this laterite layer also, the material is sediment itself.

Two distinct kind of geological strata exist in the study area. In the western parts, the geological strata is that of sediments in layers of sand, clay, clayey sand or sandy clay with a band of laterite at varying thickness and varying sequences. The depth of these sediment layers go up to a depth of 115 m in the Ernakulam M.G.Road area as revealed by various bore hole logs. Any one of these layers forms the uppermost layer of the soil. The strata of sediments in the western part bear close resemblance to the general litho-stratigraphy of coastal belt of Kerala.

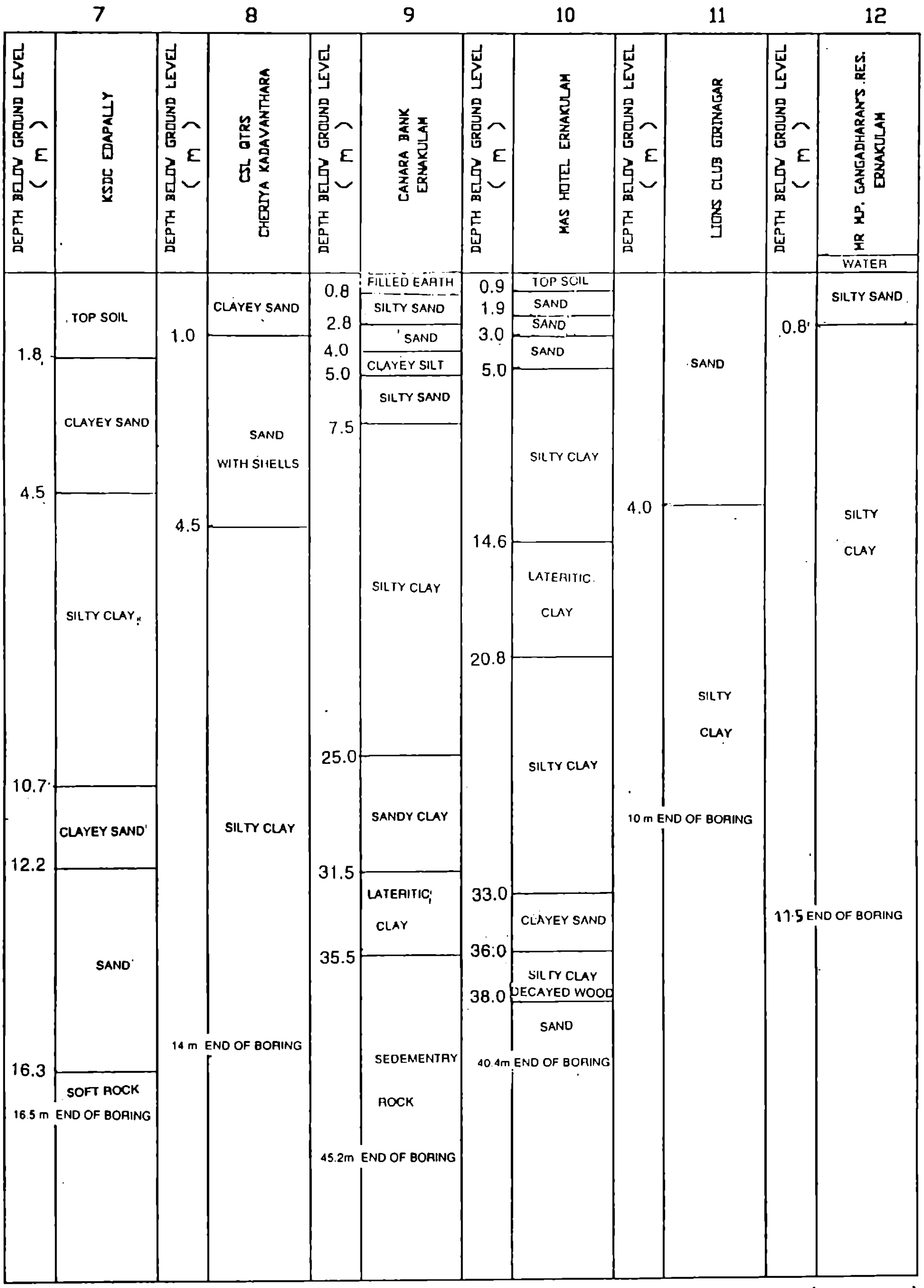
The litho-stratigraphic classification of the coastal sediment deposits of Kerala was worked out by Raha and Rajendran (1983). The coastal sediment of Kerala (including Cochin area) consists of Vembanad formation (3-60m) with various kinds of sediment layers with an unconformity at its bottom marked by laterite. Below this is the Ambalapuzha formation (3-140m)

CHART – 3.1. BORE LOGS



(continued)

CHART – 3.1. BORE LOGS (continued)



(CONTD....)

CHART – 3.1. BORE LOGS (continued)

13 — CSL CRANE TRACK

DEPTH BELOW GROUND LEVEL (m)	CSL CRANE TRACK
	TOP SOIL
1.5	SILTY SAND
5.0	SILTY CLAY
6.5	SILTY SAND
9.0	SILTY CLAY
30.5	LATERITIC CLAY
35.0	CLAYEY SAND
42.5	SILTY CLAY
46.0	SAND
	50 m END OF BORING

14 — HARBOUR CRUST ERNAKULAM

DEPTH BELOW GROUND LEVEL (m)	HARBOUR CRUST ERNAKULAM
	SAND
2.0	SILTY CLAY
3.0	SILTY SAND
8.0	SILTY CLAY
27.0	SILTY CLAY
29.0	LATERITIC CLAY
39.0	SILTY SAND
41.5	SAND
	42.05 m END OF BORING

15 — P.T QTRS. THEVARA

DEPTH BELOW GROUND LEVEL (m)	P.T QTRS. THEVARA
	SAND
8.7	SILTY CLAY
17.5	SILTY CLAY
30.0	LATERITIC CLAY
41.8	DISINTEGRATED ROCK
	48.8 m END OF BORING

16 — SBI, PALARIVATTOM

DEPTH BELOW GROUND LEVEL (m)	SBI, PALARIVATTOM
	SILTY SAND
3.0	SAND
4.5	SILTY CLAY
19.5	CLAYEY SAND
24.0	CLAYEY SAND
30.0	DISINTEGRATED ROCK
	35m END OF BORING

17 — BELLA GROUP COMPLEX PADIVATTOM

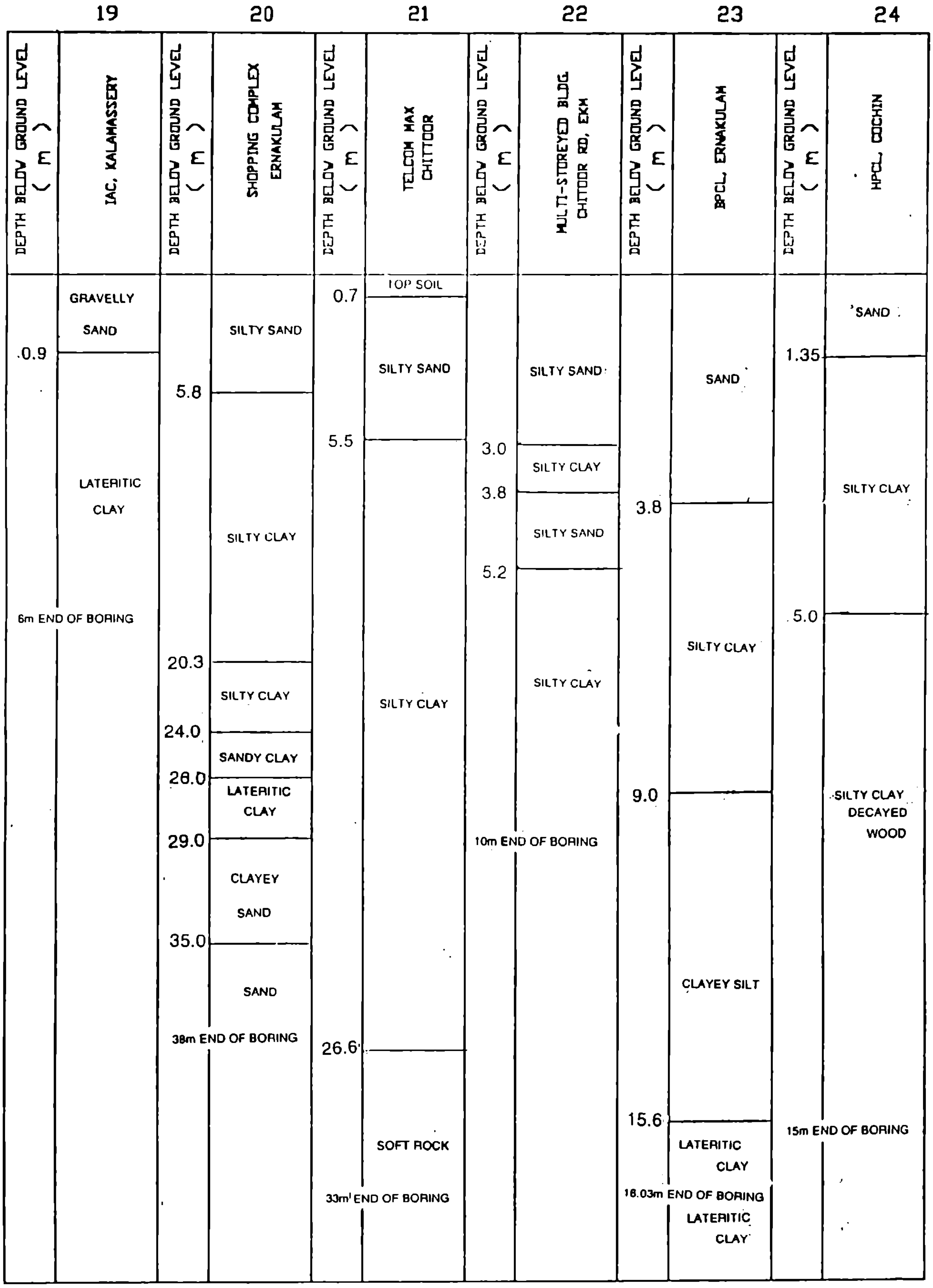
DEPTH BELOW GROUND LEVEL (m)	BELLA GROUP COMPLEX PADIVATTOM
	TOP SOIL
0.8	SAND
5.6	SILTY CLAY
8.6	CLAYEY SAND
11.5	LATERITIC CLAY
21.0	SOFT ROCK
	26m END OF BORING

18 — AMMONIA STORAGE TANK FLOOR

DEPTH BELOW GROUND LEVEL (m)	AMMONIA STORAGE TANK FLOOR
	FILLED EARTH
2.5	LATERITIC CLAY
6.0	LATERITIC CLAY
11.0	DISINTEGRATED ROCK
15.0	DISINTEGRATED ROCK
	33m END OF BORING

(CONTD....)

CHART – 3.1. BORE LOGS (continued)



(CONTD....)

CHART – 3.1. BORE LOGS (continued).

25 — JIS ELECTRICALS, EKM.

DEPTH BELOW GROUND LEVEL (m)	
	TOP SOIL
0.4	
4.5	SAND
5.6	SILTY CLAY
15.6	SILTY CLAY DECAYED WOOD
18.8	LATERITIC CLAY
28.8	SANDY CLAY
33.9	CLAYEY SAND
39.9	SILTY CLAY
40.5m	END OF BORING

26 — CRL, AMBALAMUKAL

DEPTH BELOW GROUND LEVEL (m)	
	FILLED EARTH
2.0	LATERITIC CLAY
3.5	CLAYEY SAND
5.0	SOFT ROCK
6.0	SOFT ROCK
9.0	HARD ROCK
12m	END OF BORING

27 — BPCL, IRIMPANAM

DEPTH BELOW GROUND LEVEL (m)	
	TOP SOIL
0.3	SILTY CLAY DECAYED WOOD
9.0	SILTY CLAY
12.5	SILTY CLAY
16.0	DISINTEGRATED ROCK
18.0	HARD ROCK
18.9m	END OF BORING

28 — KITEX GARMENTS KIZHAKKAMBALAM

DEPTH BELOW GROUND LEVEL (m)	
	LATERITE
0.3	BOULDER
0.6	DISINTEGRATED ROCK
3.0	HARD ROCK
3.65m	END OF BORING

29 — NH BRIDGE, VARAPUZHA

DEPTH BELOW GROUND LEVEL (m)	
	TOP SOIL
1.0	SANDY CLAY
8.0	CLAY WITH WOOD
16.5	LATERITIC CLAY
23.5	SOFT ROCK
26.8	HARD ROCK
27.8m	END OF BORING

30 — RAILWAY CROSSING, AROOR

DEPTH BELOW GROUND LEVEL (m)	
	SAND
1.0	SAND
6.5	SAND WITH SHELL
14.5	CLAY
20m	END OF BORING

(CONTD....)

CHART – 3.1. BORE LOGS (continued)

Depth below ground level (m) is given in the left column of each bore log.

31 – FEDO, ELOOR

Depth below ground level (m)	Layer
0 – 2.0	LATERITE
2.0 – 6.8	LATERITE
6.8 – 9.5	LATERITIC CLAY
9.5 – 18.7	LATERITIC CLAY
18.7 – 23.5	DISINTEGRATED ROCK

23.5m END OF BORING

32 – PROPYLENE PROJ., AMBALAMUKAL

Depth below ground level (m)	Layer
0 – 0.9	CLAYEY GRAVEL
0.9 – 10.5	LATERITE
10.5 – 15.0	LATERITI
15.0 – 17.3	SOFT ROCK

17.3m END OF BORING

33 – FISHERIES COLLEGE, PANANGAD

Depth below ground level (m)	Layer
0 – 3.0	FINE SAND
3.0 – 5.0	CLAYEY SAND
5.0 – 7.0	SAND
7.0 – 31.0	SILTY CLAY
31.0 – 36.5	SANDY CLAY
36.5 – 41.0	SEDEMENTRY ROCK

41m END OF BORING

34 – GOTHURUTHU BRIDGE KURIAPALLY

Depth below ground level (m)	Layer
0 – 4.0	SAND
4.0 – 8.8	COARSE SAND
8.8 – 19.3	SAND
19.3 – 24.4	SILTY SAND
24.4 – 30.3	CLAY
30.3 – 56.4	SEDEMENTRY ROCK

57.4m END OF BORING

35 – MBR MEDICAL TRUST, EKM.

Depth below ground level (m)	Layer
0 – 4.0	SILTY SAND
4.0 – 4.8	CLAYEY SAND
4.8 – 14.0	SILTY CLAY
14.0 – 20.0	LATERITIC CLAY
20.0 – 23.0	CLAYEY SAND
23.0 – 27.8	SANDY CLAY
27.8 – 36.0	SILTY CLAY
36.0 – 42.0	SILTY CLAY
42.0 – 45.0	SAND

45m END OF BORING

36 – A RES. BLDG. MARADU

Depth below ground level (m)	Layer
0 – 1.5	SILTY SAND
1.5 – 15.0	SILTY CLAY
15.0 – 24.0	LATERITE
24.0 – 30.0	CEMENTED SAND

30m END OF BORING

(CONTD....)

CHART – 3.1. BORE LOGS (continued)

37 — PLT, THRIPUNITHURA

DEPTH BELOW GROUND LEVEL (m)	PLT, THRIPUNITHURA
	FINE SAND
7.0	CLAYEY SAND
9.5	SANDY CLAY WITH COAL
14.0	CLAYEY SAND GRAVEL AND SHELLS
20m	END OF BORING

38 — CSL QTRS., PANAMPILLY NAGAR

DEPTH BELOW GROUND LEVEL (m)	CSL QTRS., PANAMPILLY NAGAR
	SAND WITH SHELL
13.0	SANDY SILT
17.5	CLAY
30.6m	END OF BORING

39 — NON TECH. BLOCK T.E. BLDG., EKM.

DEPTH BELOW GROUND LEVEL (m)	NON TECH. BLOCK T.E. BLDG., EKM.
	SAND
6.8	SILTY CLAY
17.5	SANDY CLAY
21.8	LATERITIC CLAY
28.5	SANDY CLAY
31.2	SANDY CLAY WITH COAL
39.9	CLAYEY SAND
43.0	SANDY CLAY
47.5	SOFT ROCK
49.4m	END OF BORING

40 — INS GARUDA NAVAL BASE

DEPTH BELOW GROUND LEVEL (m)	INS GARUDA NAVAL BASE
	FILLED EARTH
0.5	SILTY CLAY
28.1	LATERITIC CLAY
30.8	CLAYEY SAND
33.7	SANDY CLAY WITH DECAYED WOOD
50m	END OF BORING

41 — SAIL, GANDHI NAGAR

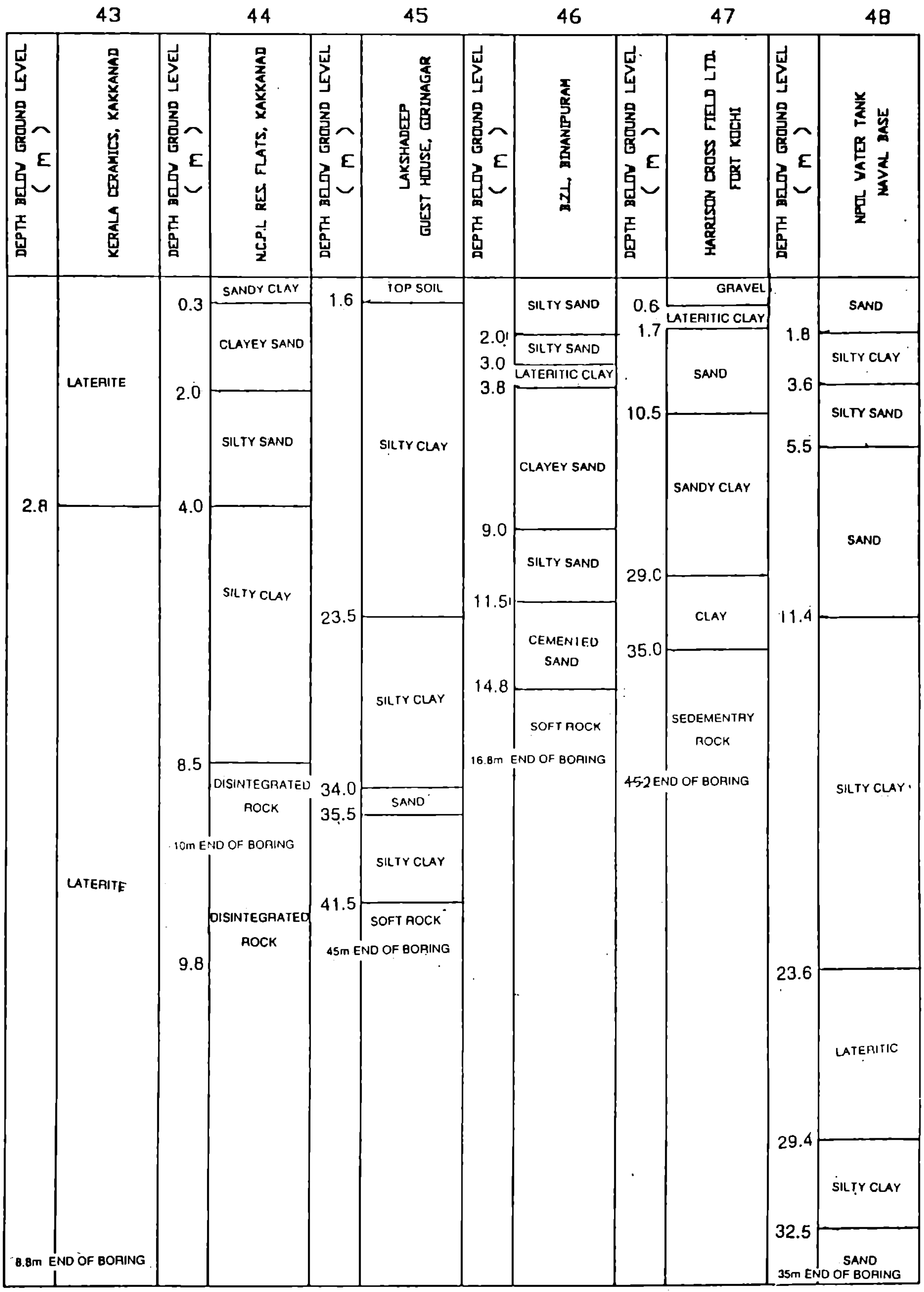
DEPTH BELOW GROUND LEVEL (m)	SAIL, GANDHI NAGAR
	TOP SOIL
1.5	SILTY CLAY
3.0	SAND
6.0	SILTY CLAY
9.5	SILTY SAND
10.2	SILTY CLAY
19.8	LATERITIC CLAY
25.0	CLAYEY SAND
29.0	SOFT ROCK
45.5m	END OF BORING

42 — WIRELESS STN., W. ISLAND

DEPTH BELOW GROUND LEVEL (m)	WIRELESS STN., W. ISLAND
	SILTY CLAY
12.0	SILTY CLAY
33.0	SILTY CLAY WITH WOOD
40.0	SILTY CLAY
50m	END OF BORING SAND

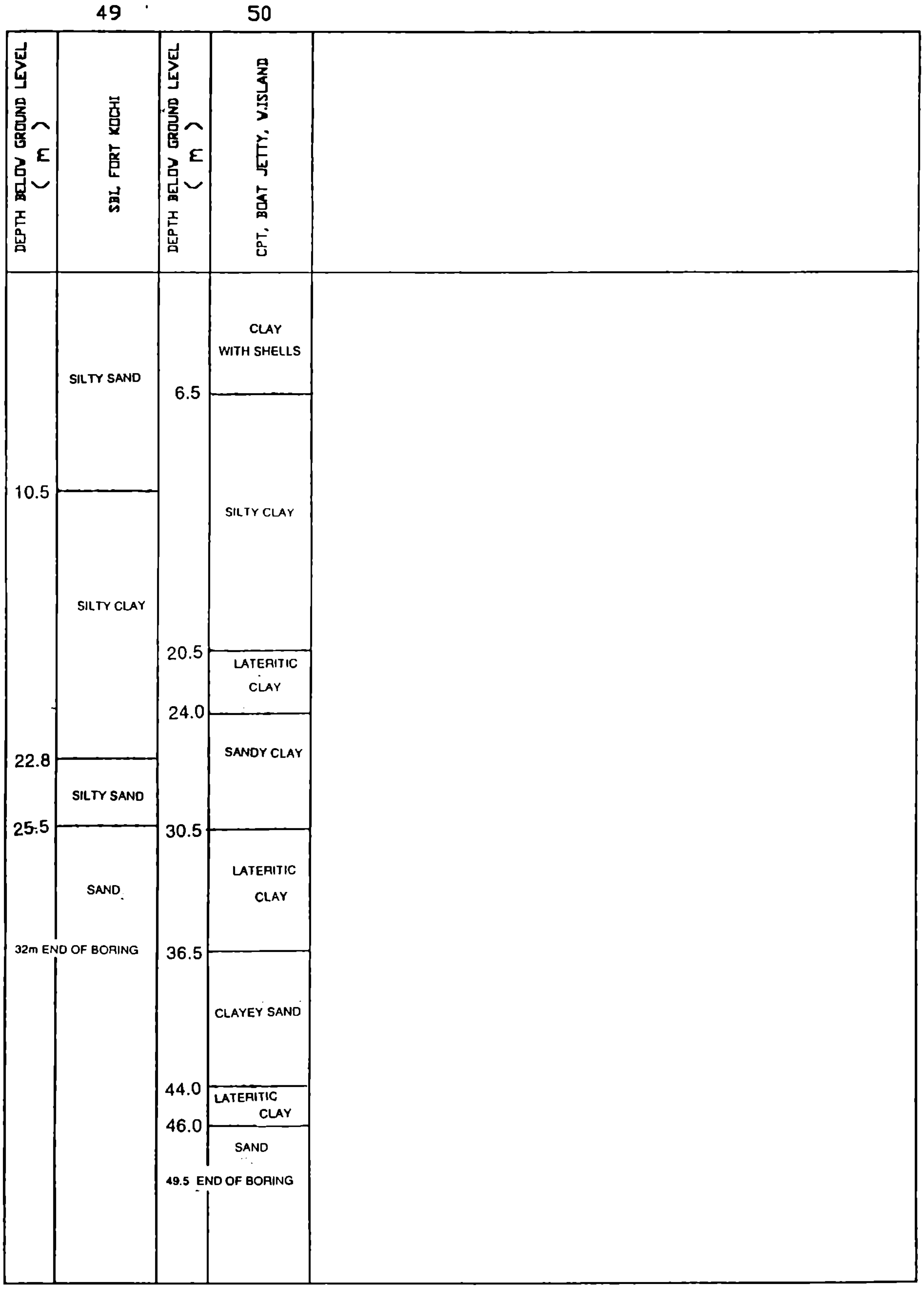
(CONTD....)

CHART – 3.1. BORE LOGS (continued)



(CONTD....)

CHART – 3.1. BORE LOGS (continued)



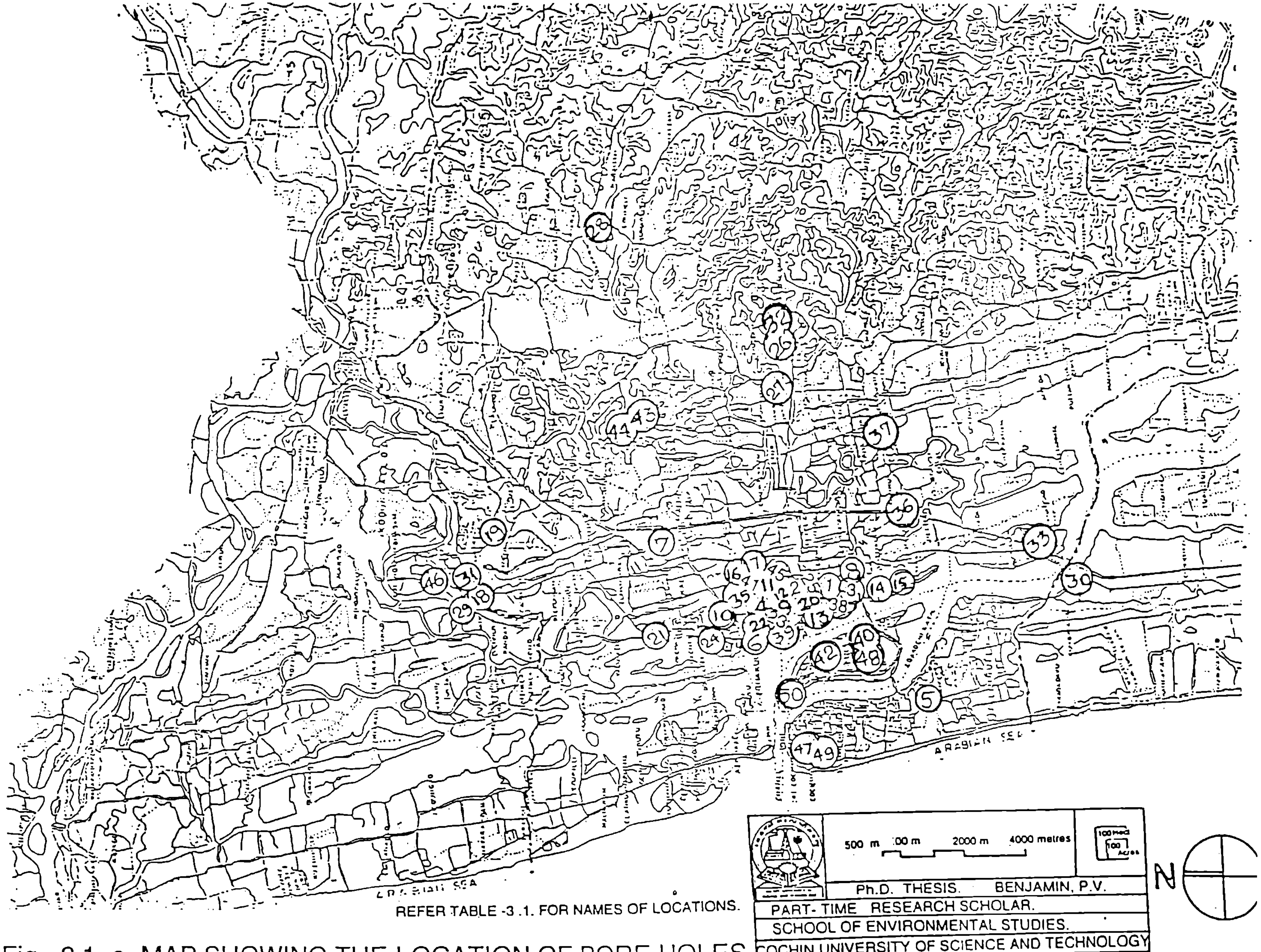
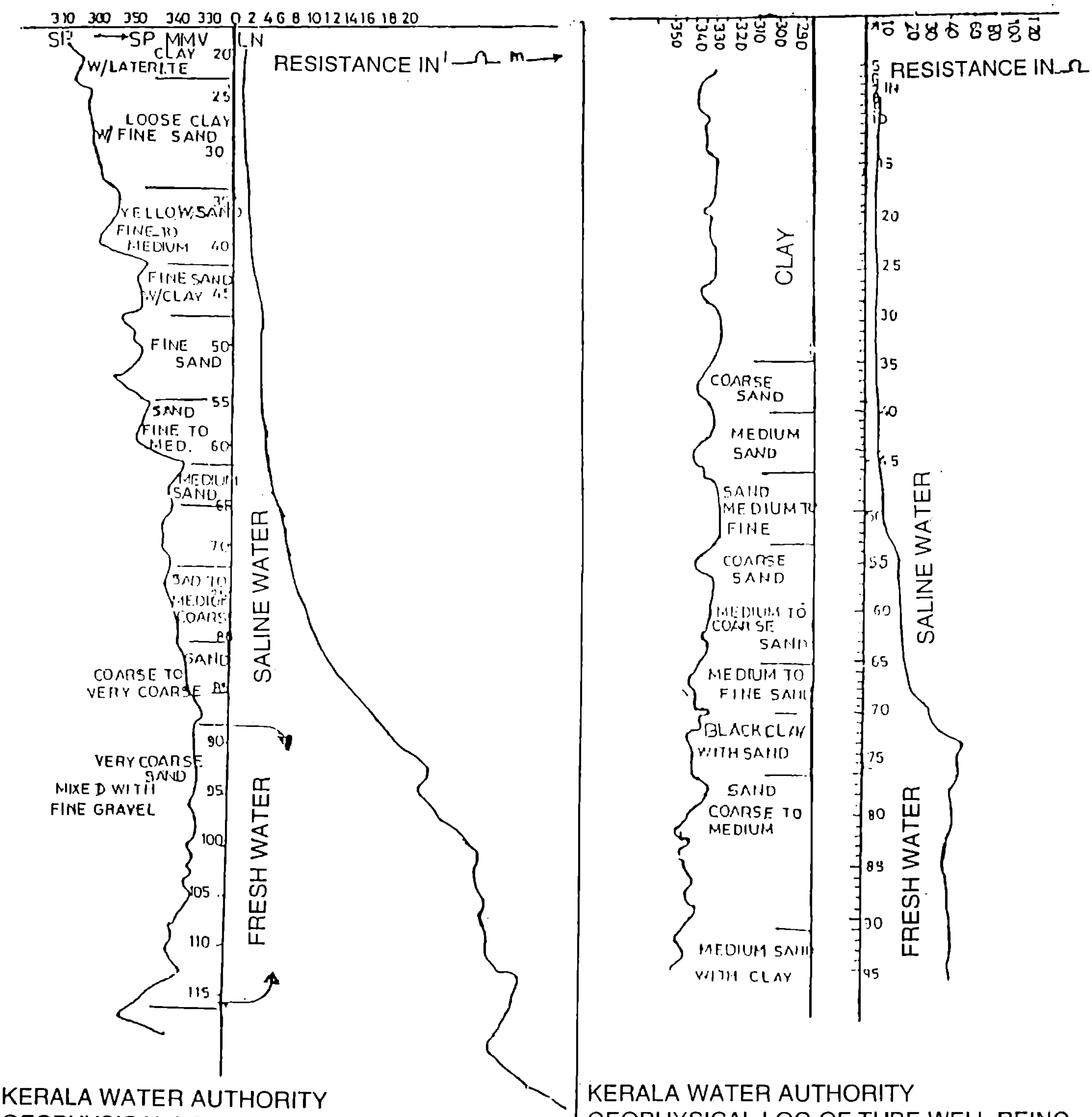


Fig - 3.1. a. MAP SHOWING THE LOCATION OF BORE HOLES



KERALA WATER AUTHORITY
GEOPHYSICAL LOG OF TUBE WELL BEING
DRILLED AT MEDICAL TURST HOSPITAL
PREMISES
PALLIMUKKU, KOCHI - 16
DATE - 30 - 03 - '93

KERALA WATER AUTHORITY
GEOPHYSICAL LOG OF TUBE WELL BEING
DRILLED AT THE LINK HEIGHTS
PANAMPILLY NAGAR KOCHI
DATE - 17 - 06 - '93

Fig - 3.2. FRESH GROUND WATER AVAILABILITY IN COCHIN SEDIMENTS

TABLE - 3.1 - BORE HOLES

SL.NO	LOCATION	DATE	DEPTH OF BORE HOLE BELOW GROUND LEVEL (m)	GROUND WATER LEVEL BELOW GROUND LEVEL (m)	TOP LAYER/ .DEPTH BELOW GROUND LEVEL (m)	LATERITE LAYER DEPTH BELOW GROUND LEVEL (m)	LAYER OF MAXIMUM PENETRATION RESISTANCE DEPTH BELOW GROUND LEVEL (m)
1	PNAMPILLY NAGAR. I. D.B.I.	17-12-'85	45	0.3	0.9 TOP SOIL	NIL	36. SANDY CLAY
2	MANORAMA JUNCTION	17-05-93	47.5	0.8	2 FILLED EARTH	NIL	40 SOFT ROCK
3	KOCHU KADAVANTHRA RLY. BRIDGE	10-02-82	40	0.1	1.5 FILLED EARTH	33 DOWN WARDS	40 LATERITE
4	GANDHI NAGAR R.C.C. BRIDGE	10-08-87	40.25	0.5	0.5 TOP SOIL	18 - 23.5	29 SAND
5	M.E.S. RES.COMPLEX RAMESWARAM	28-03-88	50	1.3	0.9 FILLED EARTH	27-36	4 SAND
6	KALYANY TOWERS ,MARINE DRIVE. COCHIN	30-09-89	40	0	1.6 FILLED EARTH	22-31	25 LATERITE
7	K.S.D.C ,EDAPPALLY	11-03-86	16.5	1.7	1.8 TOP SOIL	NIL	16.5 SOFT ROCK
8	C.S.L. QTRS	10-01-86	14	0.6	1 CLAYEI SAND	NIL	16.3 SOFT ROCK
9	CANARA BANK ERNAKULAM	24-10-87	45.2	1.2	0.8 FILLED EARTH	31.5-35.5	6 SILTY SAND
10	MAS HOTEL ERNAKULAM NORTH	29-04-87	40.4	1.4	0.9 TOP SOIL	14.62 - 20.80	2 SAND
11	LIONS COMMUNITY HALL GIRINAGAR	27-02-87	10	0.6	4 SAND	NIL	NO RESISTANCE
12	M.P .GANGADHARAN'S RES. ERNAKULAM	12-06-87	11.5	-0.2	1.1 SILTY SAND	NIL	NO RESISTANCE
13	C.S.L. CRANE TRACK	10-06-91	50	0.6	1.5 TOP SOIL	30.50 - 35	3.5 SAND
14	HARBOUR CRUST ERNAKULAM	09-12-88	42.05	0.8	2 SAND	29 - 39	6 SAND
15	P&T. QTRS. THEVARA	08-09-89	48.8	0.5	8.7 SAND	30-41.80	6 SAND
16	S B I QRTS . PALARIVATTOM	11-07-91	35	0.45	3 SILTY SAND	NIL	30 ROCK
17	LABELLA GROUP COMPLEX PADIVATTOM	06-12-85	26	1.5	0.8 TOP SOIL	11.50 - 21	4 SAND
18	AMMONIA STORAGE TANK ELOOR	03-09-92	33	1.8	2.5 FILLED EARTH	2 - 11	11 ROCK
19	I A C KALAMASSERY	05-10-88	6	.. -	0.9 GRAVELLY SAND	0.9 ONWARDS	0.2 LATERITE
20	SHOPPING COMPLEX , JOS JN. EKM	09-07-88	38	0.1	5.80 SILTY SAND	26 - 29	4 SAND
21	TELECOM MAX - 2 CHITTOOR	13-04-92	33	1.5	0.7 TOP SOIL	NIL	26 SOET ROCK
22	MULTYSTORIED BLDG. CHITTOOR RD.	05-02-88	10	2.1	3 SILTY SAND	NIL	2 SILTY SAND
23	BPCL , OLD RLY. STN. RD. EKM	06-05-88	16.03	1	3.80 SAND	15.60 DOWNWARDS	15.6 LATERITE
24	HPCL KOCHI	31-05-89	15	0	1.35 SAND	NIL	NO RESISTANCE
25	JOS ELECTRICALS, M G RD. EKM	01-07-87	40.5	0.3	0.4 TOP SOIL	18.8 - 28.80	36 CLAYEY SAND
26	C R L AMBALAMUGAL	28-12-92	12	2	2 FILLED EARTH	2 - 3.50	6 ROCK
27	B P C L IR MPANAM	26-02-91	18.9	0.35	0.3 TOP SOIL	NIL	16 ROCK
28	KITEX GARMENTS KIZHAKKAMBALAM	03-11-92	3.65	..	0.3 LATERITE	0 - 0.3	0.3 BOULDER
29	N H BRIDGE VARAPPUZHA	08-12-82	27.8	1.3	1 TOP SOIL	16.50 - 23.50	23.5 ROCK
30	RLY CROSSING AROOR	24-08-81	20	0.7	1 SAND	NIL	10 SAND
31	AMM. PLANT FEDO UDYOGAMANDAL	31-07-89	23.5	7.5	2 LATERITE	0 - 18.70	18.70 ROCK
32	PROPYL PROJECT H O C AMBALAMUGAL	23-09-83	17.3	7.4	0.9 CLAYEY GRAVEL	0.9 - 15	15 ROCK
33	FISHERIES COLLEGE PANANGAD	26-07-82	41	1	3 FINE SAND	NIL	36.50 ROCK
34	GOTHURUTHU BRIDGE KURIAPILLY	16-07-85	57.4	0.6	4 SAND	NIL	8.8 SAND
35	M B R MEDICAL TRUST EKM	15-05-87	45	0.9	4 SILTY SAND	14 - 20	20 SAND
36	RES. BLDG. OF K V THARU MARADU	29-05-92	30	0.6	1.5 SILTY SAND	15 - 24	30 LATERITE
37	P & T TRIPUNITURA	01-12-81	20	2	7 FINE SAND	NIL	5 SAND
38	CSL QTRS PANAMPILLY NAGAR	18-06-80	30.6	0	13 SAND WITH SHELL	NIL	8.50 SAND
39	NON - TECH TEL. EXCHANGE EKM	23-09-89	49.4	0.6	6.8 SAND	21.80 - 28.50	47.50 ROCK
40	INS GARUDA NAVAL BASE	05-05-88	50	0.7	0.5 FILLED EARTH	28.10 - 30.80	30.80 CLAYEY SAND
41	SAIL GANDHI NAGAR	08-12-87	45.5	1	1.5 TOP SOIL	19.80 - 25	29 SEDEMENTARY ROCK
42	WIRE STN W / ISLAND	29-01-88	50	1.8	12 SILTY CLAY	NIL	50 SAND
43	KERALA CERAMICS KAKKANAD	27-09-90	8.8	..	2.8 LATERITE	0 DOWNWARDS	0 LATERITE
44	NCPL RES. FLATS KAKKANAD	11-07-88	10	..	0.3 SANDY CLAY	NIL	8.50 ROCK
45	LAKSHADWEEP G. HOUSE GIRI NAGAR	10-08-93	45	0.8	1.60 TOP SOIL	NIL	41.50 ROCK
46	B Z L BINANIPURAM	20-07-92	16.8	3.7	2 SILTY SAND	3 - 3.80	14.80 ROCK
47	HAR. CROOS FLD LTD. FORT KOCHI	25-06-85	45.2	1.2	0.6 GRAVEL	0.6 - 1.70	2.80 SAND
48	NPOL WATER TANK NAVAL BASE	03-09-87	35	1	1.8 SAND	23.60 - 29.40	23.60 LATERITE
49	SBI FORT KOCHI	14-03-87	32	2.2	10.5 SILTY SAND	NIL	25.50 SAND
50	CPT BOAT JETTY W / ISLAND	25-01-80	49.5	-1	6.5 CLAY WITH SHELLS	20.50 24 , 13.50 - 36.5 44 - 46	46 SAND

with various kinds of sediment layers. Below this is the Quilon formation (0.5-130m) consisting of limestone, sandstone, clay, lignite etc. This is followed by unconformity (Gneiss, Charnockite, Leptinites etc.)

The basin is tectonically controlled with the development of a sequence of terrigenous, fluviolacustrine and marine sediments. Palaentological evidences indicate that the initiation of this basin had taken place in the Late Eocene (55 million years before present [MYBP]) or Oligocene (35-25 MYBP) time. The development of laterite and pebble bed beneath the sediments in this area indicates a break in sedimentation and regression of the area, a feature that exposed the sediments to weathering and caused the formation of laterite.

This was followed by a transgression accompanying the Holocene (10,000 years before present) rise of sea level. This rise of sea level submerging the platform formed an embayment, which developed a transitional clay peat horizon of marshy facies followed by an accumulation of alluvial and deltaic estuarine sediments that accompanied the formation of sand bars and dunes. This resulted in the development of the lagoon such as the Vembanad lake and the Ashthamudikayal and several smaller ones along the coastal tract (Raha and Rajendran, 1983).

Laterite can form only above the level of permanent water table in areas where there is oscillatory (vertical) movement of the groundwater (Thomas, 1974). Later, this laterite layer might have sunk below the sea level, above which fresh sedimentation continued. Thus, the occurrence of a laterite layer in between two sediment layers may be due to any one or both of the following causes: -

1. tectonic instability causing upheaval & sinking of the area
2. rise & fall in sea level during the period of the last ice age (Pleistocene - 600,000-1,200,000 years B.P) followed by the warming phase.

The sea level fluctuated with the advance and retreat of great continental glaciers during the Pleistocene period. Sea level dropped as low as 100 m during the last advance of glaciers, when large amount of water was trapped in continental glaciers and rose again when ice melted (Fairbridge, 1960).

In the western part of the study area, the upper layers are clayey and/or silty clay and extend to more than 10 m in most of the areas. Even for normal residential buildings appropriate pile or raft foundations are required with consequent high construction costs. Even with such types of foundation, there is chance for the building to sink (E.g. Hotel Queen Mary, High court junction, Ernakulam).

The various geological studies and observation on the western part of the study area clearly indicate geological instability with every possibility for aggravation by human activities. In an area of loose clayey and alluvial soil deposits of upto 150 m and more, even a slight earth quake can be disastrous since the buildings may sink due to its own weight during an earthquake.

Earthquakes (Reservoir Induced Seismicity) in many cases are associated with sudden build up of load at a place as in Koyna dam in Maharashtra. Idukki dam area in Kerala also felt tremors several times after the dam was built. It may be because the equilibrium was disturbed due to the weight of huge quantity of water, which was collected in the dam (Gupta, 1992).

Records during the time of the construction of the Cochin Port show indications regarding the geological instability of Cochin. Earthquake was reported in Cochin on 15th January 1934 at 2.15 pm which resulted in the subsidence of buildings on Willingdon Island (Bristow, 1934). This earthquake can be attributed to the crustal imbalance brought about by the weight of an enormous quantity of uniformly spread sediments dredged from the backwaters and deposited to a single area to form the Willingdon Island.

Hence, the possibilities of the occurrence of earthquakes/tremors in future can not be ruled out since millions of tonnes of earth is being brought from the eastern lowhills to reclaim marshy areas of western flatland region of Cochin for extensive construction activities. When the load on the crustal plate exceeds the threshold level, it has to be relieved by an earthquake. In Cochin with plastic calyey subsoil, such an occurrence can be disastrous. The present trend of filling up of marshlands and backwaters may be hazardous from a geological point of view.

Even though no geological catastrophe occurred in Cochin in the recent past, we cannot consider Cochin to be geologically stable and free from such a chance. However, historical evidence clearly indicates geological instability in the recorded past.

The Malabar Coast (of which Cochin is a part) was the scene of severe earthquake in 1341, as a consequence of which Waypi (Vypin) Island was raised above the sea level (de Bellore, 1904).

Yet another earthquake occurred on 26th July 1953 with a magnitude of 5.0 in Reichter scale (Kusala Rajendran, 1982).

Also, it is alarming that recently the adjacent districts of Trichur and Palghat experienced several tremors, which show that the Kerala region is not immune to seismic activity.

These reports of seismic phenomena, or of subsidence and/or of considerable rise and fall in the sea level along the Kerala coast necessitated an assessment of the litho-stratigraphy and geomorphology of the study area so as to enable one to locate geologically stable areas suitable for urban development.

In the eastern part, the profile is that of lateritic soil followed by laterite, which lies over the crystalline parent rock. Often the surface layer itself is of laterite or is close to the surface. This laterite lying just above the crystalline parent rock can bear very high amount of load. Hence the eastern upland has considerable advantage over western flatland as far as construction cost and geologic stability of multi-storied buildings is considered. This is of particular significance in view of the seismological history of Cochin.

The sedimentary nature of the litho-stratigraphic structure of Cochin may also be contributed by periodic subsidence and depostion of sediments through ages (Bristow, 1938). Moreover, the geological section from the litho-stratigraphical study indicates gradual sinking of the western part as indicated by the gradual inclination towards the sea where the basin is sinking.

3.3.2. Soil types of the Study Area.

The soil of the region can be broadly classified into sandy soil (in area coming under Cochin Taluk and the area in northwestern part of Parur taluk). Peaty or Kari soil (occurs as a small belt on the western part of Kanayannoor Taluk) and lateritic soil on the eastern part of the region. The sandy soil varies from pure sand to sandy loam.

The basic characteristic of the soil of the study area is that, the soil throughout is invariably acidic. In the eastern lateritic area, the pH varies from 4.5 to 6 in the case of wetlands (paddy fields) and 5.2 to 6.3 in the case of drylands. In the western flat land area, the pH is as low as 4.2 in many places and vary from 4.2 to 6 in wetland and varies from 4.9 to 6.5 in drylands.

Macro nutrients

a). Nitrogen (expressed as % organic carbon)

In the eastern lateritic land the percentage of the organic carbon varies from 0.1 to 0.71% in the case of dry land and 0.08 to 1.12% in the case of wetlands (paddy fields). In the western flatland area, the percentage organic carbon varies from 0.17 to 0.69 %in the case of dryland and 0.13 to 0.85% in the case of wetland. The assessment shows more or less uniform fertility status between highland and flatlands as far as percentage of the carbon is concerned. Udayamperoor area shows very low organic carbon content due to the loose sandy nature of the soil.

b) Phosphorous

In the northern part of the eastern highlands, the value of available phosphorus is mostly above 32 mg/kg, while in the southern part of the eastern highlands it is mostly between 10 to 32 mg/kg. The value of available phosphorus in the south-eastern part of the flatland is as low as 3 to 4 mg/kg in most of the places, while in its south-western parts it is mostly higher than 32 mg/kg, though there are sporadic lower values. In the northern half of the western flatland also, the value is mostly higher than 32 mg/kg.

However, the Eroor area in the flatland lying near the Ambalamughal industrial belt shows exceptionally high values as high as 108 mg/kg which may be due to the effluents from the FACT.

c). Potassium.

In the case of potassium, the dryland in the eastern upland shows 106 to 459 mg/kg in the northern part and 108 to 145 mg/kg in the southern part. The value for wetland is 238 to 560 mg/kg in the northern part and 117 to 1122 mg/kg in the southern part.

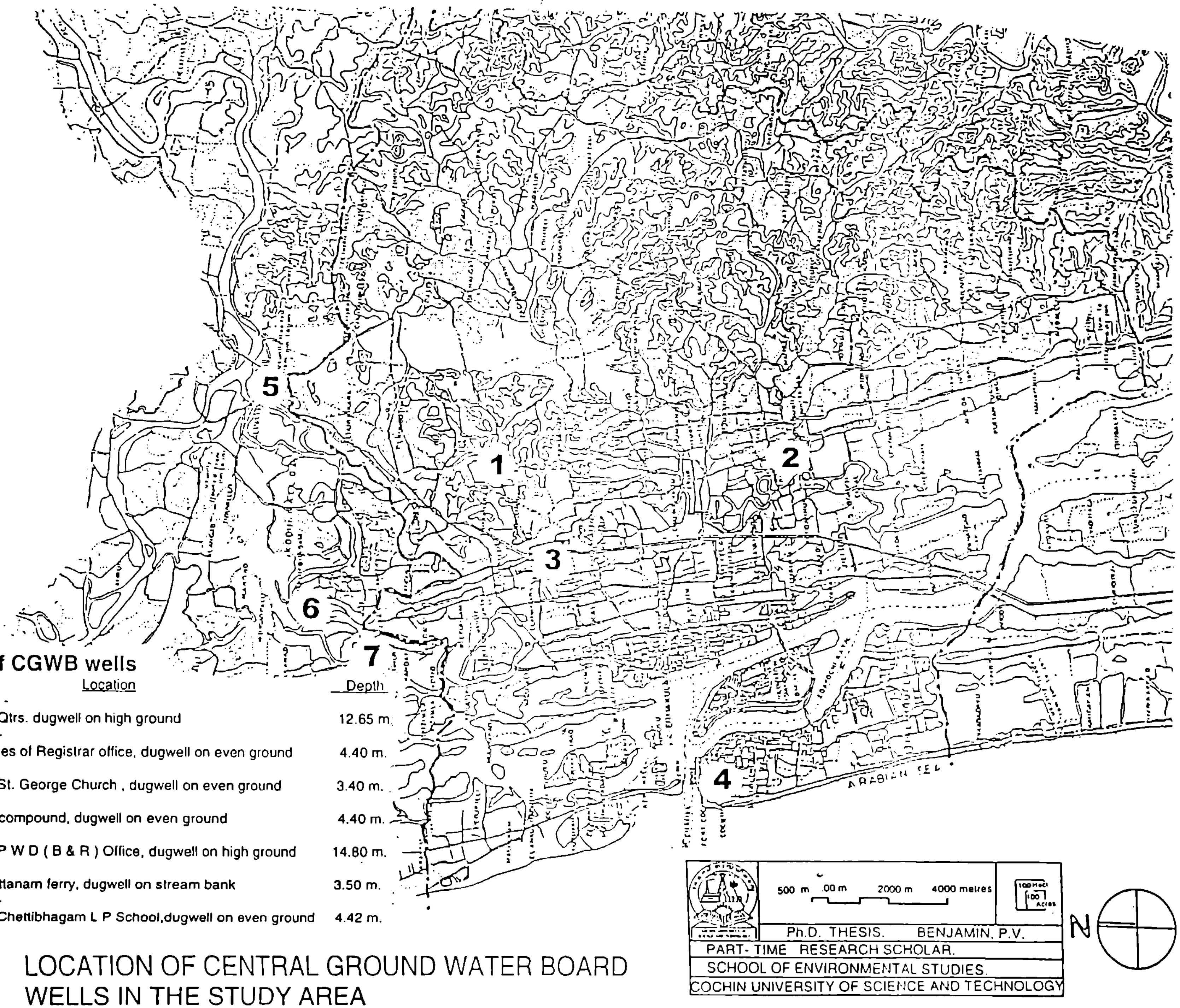
In the flatland area, the value for potassium is 156 to 560 mg/kg in the northern part of the dryland and 190 to 257 mg/kg in the southern part of the dry land. The value of wetland is 291 to 347 mg/kg in the north and 168 to 392 mg/kg in the south.

Unusually high values of phosphorus seen in the Eroor area can be attributed to effluents from FACT flowing into the Champakara canal.

If the soil does not allow water to drain away freely, the soil becomes saturated and unsuitable for construction, farming or recreation without artificial drains. Information on soil drainage is extremely useful for zoning land as suitable or unsuitable for certain kinds of uses.

3.3.3. Groundwater

In order to analyse at groundwater level and availability, data from 50 bore-logs of foundation engineers and data of groundwater from 7 wells (Fig3.4) of Central Ground water Board are alluded to.



Location of CGWB wells

I No.	Location	Depth
1.	Thrikkakkara - Near N G O Qtrs. dugwell on high ground	12.65 m.
2.	Tripunithura - In the premises of Registrar office, dugwell on even ground	4.40 m.
3.	Edappally - Premises of St. George Church , dugwell on even ground	3.40 m.
4.	Fort Kochi - Thaluk office compound, dugwell on even ground	4.40 m.
5.	Alwaye - Premises of P W D (B & R) Office, dugwell on high ground	14.80 m.
6.	Eloor North - South of Mettanam ferry, dugwell on stream bank	3.50 m.
7.	Varappuzha - Premises of Chettibhagam L P School,dugwell on even ground	4.42 m.

Fig - 3.4. LOCATION OF CENTRAL GROUND WATER BOARD WELLS IN THE STUDY AREA

It is seen that during summer months, the water table goes as low as 10 –12 m below ground level in the eastern lowhills whereas in the western flatland area even in summer the water table is only 1.5 to 3 m below ground level (Table 3.3).

In the eastern uplands, the large-scale groundwater exploitation is likely to cause the following problems: -

a) Drying up of nearby streams, open wells and ecosystem,
b) If the aquifer is too porous, toxic materials and germs from overland-polluted rivers may pass into the ground water system (Fig 3.5.a).

Another aspect of serious concern is overexploitation of ground water far above safe yield limit. In order to keep the withdrawal within the safe yield limit, the rate of pumping should be adjusted so that over a period of years (allowing for fluctuation of weather) the change in storage is zero and the source is not depleted.

When water is pumped from a bore well, a cone of depression is formed at the end of the suction pump and equilibrium is reached so long as the recharge of the aquifer is sufficient to supply the pumpage. If it is not, the cone of depression will continue to steepen and thus necessitating a continuous deepening of the well, thereby increasing the cost of pumping. When several bore wells are installed in close proximity, the cone of depression of different wells intersect and only the deepest well among them will get water. This will compel the neighboring wells to go deeper and this competition in unplanned withdrawal of water may end up in legal battle

Table - 3.3. DATA OF GROUND WATER LEVELS IN KOCHI (CGWB WELLS)

Year - 1986

W No	JAN Dt/LVL	FEB Dt/LVL	MAR Dt/LVL	APR Dt/LVL	MAY Dt/LVL	JUN Dt/LVL	JUL Dt/LVL	AUG Dt/LVL	SEPT Dt/LVL	OCT Dt/LVL	NOV Dt/LVL	DEC Dt/LVL
1	- -	(12) 9.96	- -	(6) 10.20	- -	- -	- -	(23) 9.70	- -	- -	(11) 9.45	- -
2	- -	(11) 2.93	- -	(4) 3.55	- -	- -	- -	(29) 2.09	- -	- -	(10) 2 05	- -
3	- -	(12) 2.09	- -	(6) 7.05	- -	- -	- -	(23) 1.09	- -	- -	(11) 0.85	- -
4	- -	(12) 1.30	- -	(10) 3.12	- -	- -	- -	(22) 2.60	- -	- -	(9) 2.10	- -
5	- -	(12) 7 55	- -	(6) 12.61	- -	- -	- -	23)10 75	- -	- -	(5) 12.91	- -
6	- -	(12) 2.34	- -	(6) 2.91	- -	- -	- -	(23) 2.67	- -	- -	(11) 2.44	- -
7	- -	(12) 3 04	- -	(10) 3.50	- -	- -	- -	(27)2.02	- -	- -	(9) 1.50	- -

W No. - Well Number ; Dt. - Date; LVL. - Level; All levels are in metres below ground level.

Year - 1987

W No	JAN Dt/LVL	FEB Dt/LVL	MAR Dt/LVL	APR Dt/LVL	MAY Dt/LVL	JUN Dt/LVL	JUL Dt/LVL	AUG Dt/LVL	SEPT Dt/LVL	OCT Dt/LVL	NOV Dt/LVL	DEC Dt/LVL
1	(8) 10.10	- -	- -	(4) 10.30	- -	- -	- -	(19) 7.60	- -	- -	(4) 9,92	- -
2	(7) 2.92	- -	- -	(4) 3.60	- -	- -	- -	(26) 0.77	- -	- -	(4) 2.19	- -
3	(7) 1.50	- -	- -	(4) 2.10	- -	- -	- -	(20) 1.35	- -	- -	(4) 1.64	- -
4	(7) 3.01	- -	- -	(3) 3.38	- -	- -	- -	(19) 1.70	- -	- -	(8) 2.57	- -
5	(8) 12.20	- -	- -	(5) 12.91	- -	- -	- -	(20) 4 57	- -	- -	(4) 11.81	- -
6	(7) 2.93	- -	- -	(5) 3 13	- -	- -	- -	(20) 1.40	- -	- -	(4) 2.65	- -
7	(7) 2.83	- -	- -	(5) 3.68	- -	- -	- -	(20) 1.44	- -	- -	(4) 2.37	- -

W No. - Well Number ; Dt. - Date; LVL. - Level; All levels are in metres below ground level.

Year - 1988

W No	JAN Dt/LVL	FEB Dt/LVL	MAR Dt/LVL	APR Dt/LVL	MAY Dt/LVL	JUN Dt/LVL	JUL Dt/LVL	AUG Dt/LVL	SEPT Dt/LVL	OCT Dt/LVL	NOV Dt/LVL	DEC Dt/LVL
1	- -	(6) 10.13	- -	- -	(25) 13.5	- -	- -	(17) 8.10	- -	- -	(7) 12.90	- -
2	- -	(5) 2.90	- -	- -	(26)3.17	- -	(24) 1.37	(18) 1.38	- -	- -	(8) 2.38	- -
3	- -	(6) 2.30	- -	- -	(31) 2.28	- -	(28) 1.54	(17) 1.36	- -	- -	(7) 1.88	- -
4	- -	(5) 3.14	- -	- -	(31) 3.06	- -	(20) 2.10	(15) 2.24	- -	- -	(8) 2.84	- -
5	- -	(6) 12.46	- -	- -	25)13.01	- -	(28) 9.16	(18) 8.94	- -	- -	(7) 11.53	- -
6	- -	(6) 2.84	- -	- -	(25) 3.06	- -	- -	(17) 2.24	- -	- -	(7) 2.83	- -
7	- -	(6) 3.09	- -	- -	(28) 3.62	- -	- -	(15) 1.64	- -	- -	(8) 2.30	- -

W No. - Well Number ; Dt. - Date; LVL. - Level; All levels are in metres below ground level.

Year - 1989

W No	JAN Dt/LVL	FEB Dt/LVL	MAR Dt/LVL	APR Dt/LVL	MAY Dt/LVL	JUN Dt/LVL	JUL Dt/LVL	AUG Dt/LVL	SEPT Dt/LVL	OCT Dt/LVL	NOV Dt/LVL	DEC Dt/LVL
1	13)10.17	- -	- -	- -	(28) 10.4	- -	- -	- -	(2) 7.55	- -	(4) 9.32	- -
2	(14) 2.90	- -	- -	- -	(29) 3.03	- -	- -	- -	(1)1.88	- -	(6) 1.65	- -
3	(13) 2.32	- -	- -	- -	(28) 2.67	- -	- -	- -	(2) 1.61	- -	(4) 1.32	- -
4	(12)3.05	- -	- -	- -	(29) 2.03	- -	- -	- -	(1) 2.47	- -	(6) 2.05	- -
5	13)12.38	- -	- -	- -	28)12.94	- -	- -	- -	(2) 11.06	- -	(4) 10.82	- -
6	(13) 2.69	- -	- -	- -	(28) 2.28	- -	- -	- -	(2) 2.92	- -	(4) 2.25	- -
7	(13) 3.01	- -	- -	- -	(28) 3.24	- -	- -	- -	(2) 1.96	- -	(4)1.55	- -

W No. - Well Number ; Dt. - Date; LVL. - Level; All levels are in metres below ground level.

(contd..)

(contd..)

Table - 3.3. DATA OF GROUND WATER LEVELS IN KOCHI (CGWB WELLS)

Year - 1990

W No	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
	Dt/LVL	Dt/LVL	Dt/LVL	Dt/LVL	Dt/LVL	Dt/LVL	Dt/LVL	Dt/LVL	Dt/LVL	Dt/LVL	Dt/LVL	Dt/LVL
1	(9)10 08	- -	- -	- -	(25) 9.08	- -	- -	(25) 9.30	- -	- -	(13) 9.47	- -
2	(9) 2.79	- -	- -	- -	(29) 2 61	- -	- -	(25) 1.80	- -	- -	(12)1.85	- -
3	- -	- -	- -	- -	(25) 1.72	- -	- -	(24) 1.40	- -	- -	(13) 1.47	- -
4	- -	- -	- -	- -	(25)1.98	- -	- -	(24) 2.42	- -	- -	(14) 2.50	- -
5	(9) 12.28	- -	- -	- -	25)12.38	- -	- -	(24) 7.13	- -	- -	13)10.95	- -
6	- -	- -	- -	- -	(25) 2.58	- -	- -	(24) 2.43	- -	- -	(13) 2.42	- -
7	- -	- -	- -	- -	(25) 3.15	- -	- -	(24) 1.60	- -	- -	(14) 1.90	- -

W No. - Well Number ; Dt. - Date; LVL. - Level; All levels are in metres below ground level.

Source :- Cenral Ground Water Board

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Location of CGWB wells

Well No.	Location	Depth
1.	Thrikkara - near N G O Qtrs. dugwell on high ground	12.65 m.
2.	Tripunithura- in the premises of Registrar office, dugwell on even ground	4.40 m.
3.	Edappally - premises of St. George Church , dugwell on even ground	3.40 m.
4.	Fort Kochi - Thaluk office compound, dugwell on even ground	4.40 m.
5.	Alwaye - premises of P W D (B & R) Office, dugwell on high ground	14.80 m.
6.	Eloor North - south of Mettanam ferry, dugwell on stream bank	3.50 m.
7.	Varappuzha - premises of Chettibhagam L P School,dugwell on even ground	4.42 m.

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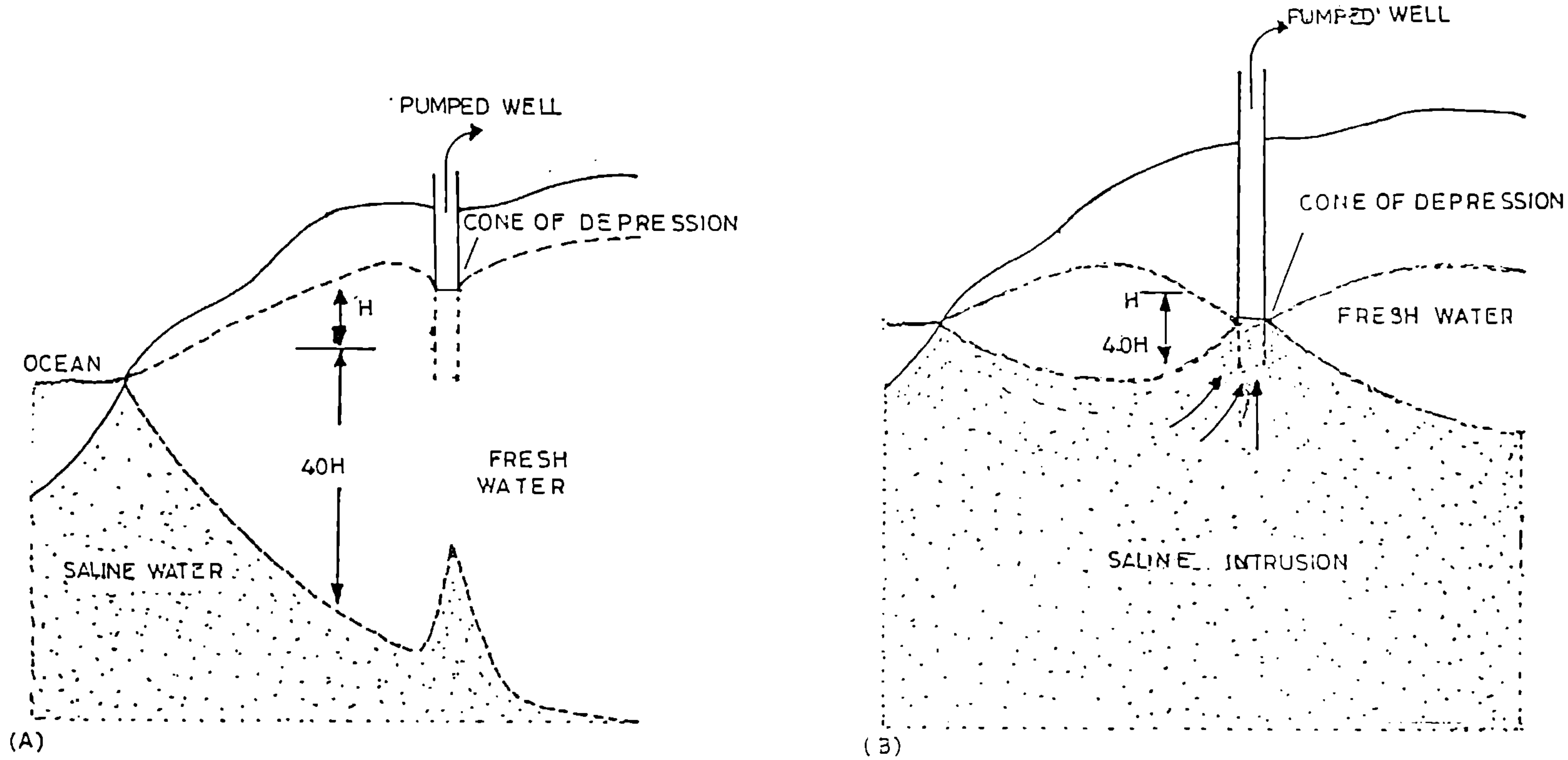


Fig - 3.5. SEA WATER INTRUSION DUE TO HEAVY PUMPING OF THE GROUND WATER between neighboring well owners, as in the case of several American states (Dunne and Leopold, 1978). Hence, it is necessary to define the safe yield of major aquifers and to control pumping rates on the basis of quantitative prediction by geophysicists on how a new withdrawal will affect the whole ground water system.

Drastic alteration of ground surface can reduce infiltration and thereby cause a reduction of ground water recharge and of dry weather stream flow. When the land is paved in urban areas serious reduction of summer stream flow results (Franke and Mc. Clymonds, 1972). Land use plans should take account of such deleterious effects of urbanisation.

In the western sedimentary area of Cochin basin, the aquifers are confined and lie between layers of aquicludes of thick organic clay. In such cases, withdrawal of large quantities of ground water may lead to reduction in pressure and thereby compaction of aquifers resulting in irreversible subsidence.

The withdrawal of water from storage where it is being replaced only at a slow rate or not at all is called "Groundwater mining". It can provide small supplies over a very long time, but if the source is over-exploited its useful life is limited.

Compaction of the upper layer of soil when the piezometric level is lowered is a serious problem throughout the world. It is more serious in clayey or silty soil because these materials have low permeability. They release water very slowly, so that, decrease of head and the resulting subsidence often take place over many years even after pumping is curtailed. The damage resulting from subsidence and the compaction throughout the world now amounts to 100s of millions of dollars (Dunne and Leopold, 1978). Differential settling disrupts canals, drains and river gradients, there by reducing their conveyance capacities or at times increases their velocities resulting in bank erosion. Differential settling can also cause fracturing of drain pipes, well casing etc. or can crack buildings, bridges and even roads as has happened in Mexico City (Loehnberg, 1958).

In Mexico City heavy groundwater pumping for Municipal supply accompanying the growth of city has lowered the piezometric surface by upto 2 m per year. This lowering of the piezometric pressure has caused the overlying 50 m sediment material to subside at a rate of upto 30 cm/year by 1950, and by that time has lowered the central city upto 5-7 m (Loehnberg, 1958).

In Tokyo, Japan, the total local subsidence because of deep bore well pumping of water exceeded 4 meters since 1892 and in order to retard subsidence, rigid controls over ground water pumping for industrial and domestic purposes were introduced in 1961 and 1963.

A more complicated situation exists in Venice, Italy, where the land is sinking slowly as the Earth's crust buckles under the combined effects of aquifer compaction as well as weight of enormous quantity of sediments brought from the Alps by rivers. Venice and its neighboring main lands are interconnected parts of the recent geologic sequence of unconsolidated sand, silt and clay. The ground water, contained in the sediments, is pumped from wells in Venice and neighbouring mainland. In the early 20th century, rapid industrialisation led to heavy withdrawal of ground water from these aquifers and thus lowering the water pressure in the underlying sediments, which supported part of the weight of the overlying sediments. This lowering of pressure led to compaction of the aquifer resulting in the subsidence of ground surface. Measurement of subsidence for the period 1952-1969 was about 10 cm in Venice and about 14 cm at the centre of the Marghera Wellfields in the mainland (Dunne and Leopold, 1978).

Yet another aspect of concern is excessive reclamation by dredging of backwaters which will have serious repercussions not only in the ecology of the backwater system but also in the groundwater quality. In Venice, partial filling of lagoons and dredging of deep shipping channels compounded the land subsidence problem by containing the high tides gathered by strong winds which allowed the tides to penetrate farther inland posing threat to the very existence of Venice. The proposed Vallarpadam super tanker trans-shipment terminal and Gosris island development project in Cochin have to be viewed in the light of what has happened in Venice.

In higher level confined aquifers (which is only a few m below the ground surface), a lack of aquifer recharging and drying up of the surface aquiclude, may result in the cracking of the upper layer of the earth causing splitting of the buildings as has happened a few years back in Parur in Kerala in a severe summer.

The subsurface condition of Cochin is more or less similar to those cases mentioned above. The depth of sediment in the western part of Cochin is even more than 230 m. Recently, fresh water was struck at about 75 to 95 m below the ground level at several places very close to the backwater system in the western flat sedimentary areas overlaid by impervious clay layers. Medical Trust Hospital, located in this area, is meeting most of its requirements by regularly pumping large quantities of ground water. This finding has led to a series of borings at several places in the central city by various large scale housing agencies, since pipe water is scarce and costlier than bore wells in the long run. Unless this trend is checked immediately, the tragedy of Venice may repeat in Cochin, perhaps at a greater magnitude.

Such a subsidence, even at a smaller scale, can disrupt canals, drains and river flows as well as cause fracture, warping and cracking of buildings, roads, bridges, rails etc. Since, the western flatland portion of the study area lies at an elevation of about 1.5 m above MSL, the consequences of a subsidence to a depth of few meters will be tragic, to say the least.

In coastal areas the seawater may extend about 1 km landwards. In unconfined aquifers in coastal areas, fresh groundwater occurs as a lens over the heavier seawater. The depth of this fresh water below sea level is approximately equal to 40 times the height of water table above sea level (Dunn and Leopold, 1978). Such a balance is due to the density difference between fresh and saline waters. Hence, each meter decline of the water table will cause a 40-m rise of the lower boundary of the fresh water lens to maintain the balance referred to before. Heavy pumping therefore can produce such a large cone of depression that saline water will eventually invade the well from below (Fig.3.5.b). Saltwater intrusion is a serious problem since paving of ground during urbanisation further worsen the problem by reducing ground water recharge seriously.

Another aspect regarding modification of water table is filling up of marshlands and paddy fields for construction purposes, which will result in a rise in the water table in the vicinity. This may lead to root suffocation or death of existing vegetation due to exosmosis from the roots if the ground water is saline. Further, a rise in water table will jeopardise the drainage system also.

Also, the discharge of untreated municipal and industrial effluents often contaminates the groundwater system altering its chemical and physical properties. Intrusion of saltwater is not only injurious to plant life but also affects construction activities. The chemistry of groundwater in saline area is of importance to foundation engineers where corrosive salty ground water is present. Special ingredients are to be used in foundation piles in such areas, thus adding to the cost.

3.4. Summary and Conclusion

The study area comprises of two distinct geological regions. The western part is a sedimentary area with all the characteristic features of Tertiary sediment deposit areas of the coastal belt of Kerala and the depth of the sediments go beyond 100 to 150 m near the sea. This area is not ideal for urban development from the geological point of view, as the sub strata are not stable. The clayey soil in most of the places has already caused buildings and roads to sink either due to self-weight or because of vibration due to traffic or construction activities of the adjacent buildings.

Future urban developments in the western part should be restricted taking into consideration the following findings of this study: -

1. Litho-stratigraphical evidence indicates periodic sinking and upheaval and/or transgression and regression of the sea.
2. This area has a history of seismic activity,
3. Large scale filling of low lying areas can induce crustal imbalance leading to tremors.
4. This area lies very near to sea level and hence a sea level rise induced by global warming can inundate a large portion of this area depending on the intensity of the global warming.
5. This area has a sedimentary origin with clay as the major component which increases the foundation cost

6. Large scale reclamation and dredging of backwater system will induce not only geological instability but also increased wave activity and intrusion of tidal water further inland.
7. In most of this area the groundwater in the upper strata is not potable and unsuitable for construction purposes either due to salinity or high organic content
8. Recently potable groundwater is being exploited on a large scale from a depth of 70 to 90 m. With the recent government ruling that treated public water supply scheme will not cater to the needs of multistoried residential complexes, excessive ground water mining is bound to increase. This may lead to land subsidence and salt water intrusion in the near future.
9. Drainage is difficult being a flat terrain.

The eastern highland area of the study area falls within the midland region of the state of Kerala. This eastern lowhills are geologically more stable since the composition is either laterite or lateritic soil forming a coping over a laterite layer, which in turn lies over crystalline parent rock. This kind of litho-stratigraphy is very stable and hence good for urban developments. It is found that the most urbanised western part is geologically not very good for urban developments while the less urbanised eastern upland is good for urban developments because of the following reasons: -

1. The sub strata are geologically stable in most of the areas, and hence the foundation cost will be less,

2. Also, onsite quarried laterite blocks / granite can be utilised thus reducing construction costs,
3. Potable ground water is available,
4. There is adequate slope for efficient drainage.

However, in the eastern uplands the valley floors and steep slopes should be avoided for building purposes.

The soil in the study area is of two distinct natures. Lateritic soil in the eastern upland and sedimentary soils in the western parts with sandy soil varying from pure sand to sandy loam and clay in varying proportions. Paddy fields contain peaty soil which is extremely acidic. Udayamperur area has sandy soil with extremely low organic content. Eroor area has a remarkably phosphorous rich soil, which can be attributed to the pollution from a fertilizer factory.

Chapter - 4

Surface Hydrology and Backwater System

1. Introduction

Many of the environmental problems of Cochin are hydrologic in origin; like water-logging/floods, sedimentation and pollution in the water bodies as well as shoreline erosion.

Hydrology involves the study of water over and under land surfaces. Several aspects of the hydrologic cycle get drastically modified during urbanisation, which in turn influences the whole urban environment. The detailed knowledge about the runoff in an area enables the planner to recognize the constraints and opportunities from which the prediction of the nature and consequences of any form of land development is possible. Also, information about runoff producing areas is an essential input in formulating zoning regulations.

The drainage basin in which some designs or planning is done often forms a portion of a larger drainage basin whose downstream portion may suffer from the effects of the design unless they are carefully planned. Also, in some landscapes topographic limit of the drainage basin may not coincide with boundary between subsurface drainage systems. Sometimes, inter basin linkages are also established in the lower reaches of the stream during floods. The drainage basin is a convenient unit for the understanding of hydrologic and geomorphic processes and for analysing the spatial linkages between different areas that can affect both regional and site planning.

Deforestation, road and building construction or the spreading of wastes and sewage effluents etc. lead to poor soil drainage and thus will increase storm runoff. Zones that produce storm runoff also yield sediments, nutrients, pathogens as well as other biological and chemical pollutants. Thus, a detailed understanding of storm runoff production will shed light on the pollutant load of various streams which will in turn enable the planner to formulate the management techniques to minimise the pollution levels of the surface water.

Drainage basin is the land that drains water, sediment and dissolved materials through a common outlet at some point along a stream channel. The term is synonymous with 'watershed' in American usage and 'catchment' or 'sub basin' in most other countries. The boundary of a drainage basin is known as 'drainage divide' in USA and as 'watershed' in other countries (Dunn and Leopold, 1978). Thus the word can mean an area or a line. In this study, the nomenclature "drainage basin" is used. The study area is a major drainage basin, which is separated by ridgelines from the Muvattupuzha river valley and Periyar river valley. The term "micro-catchment" or "sub basin" is used for the drainage areas of small drains and streams within it.

The rainwater, after interception reaches the ground and a part of it, which infiltrates into the soil, is available to recharge the groundwater storage. When a storm exceeds the infiltration capacity, water spills and flows down the slope as overland flow. When it reaches a stream channel, it is called as storm runoff or direct runoff. If this exceeds the capacity of the stream, there will be flooding.

The lower the infiltration capacity of the ground, the higher will be the runoff and chances for flood hazard in the lower reaches of the stream. On terrains with low permeability, the flood occurrence will be simultaneous to heavy rains as in urban areas where the percentage of paved areas is very high. Increase in magnitude and frequency of flooding is typical results of urbanisation. These effects are greatest immediately downstream of the urbanised area but decreases or fades away with the distance downstream. The infiltration capacity of the urban areas is often lowered to zero, due to the covering of parts of the drain catchments with impervious roofs, side walks, roadways and parking lots. Also, the areas, which remain soil-covered, are trampled to almost an impervious state, so that the volume and rate of the overland flow is increased. Filling and/or covering as well as clogging of natural drainage channels also contribute to floods and water-logging problems, with ensuing health hazards.

Gutters, drains and storm sewers are laid in the urbanised area to convey the runoff rapidly to stream channels. Natural channels are often straightened, deepened or lined with concrete to make them hydraulically smoother. Each of these increases the drainage efficiency. However, the trapping of waste materials by water supply and telephone conduits which cross these drains, often result in floods. Moreover, during torrential rains, the increased drainage flow is curtailed at the constrictions offered by culverts and bridges.

A major aspect to be considered by planners is the flood possibility of an area, which very much depends on the land use pattern. A typical example is the incident of 1981, when a building of Jaipur University was carried away and another crumbled as the earth beneath was washed away by flood waters. This happened because the building was constructed at a natural outlet of water, which was filled up assuming that such a large waterway was unnecessary in a dry area like Jaipur. However, in 1981, the floodwater from an unusually torrential rain took its natural course through the filled up channel carrying away the buildings along with it. In many places, buildings are being constructed in the floodway of rivers and rivulets after filling up. Such floodways may deceptively appear unnecessary in normal floods, but in case of unusually heavy floods the water will clear its way through the filled up area. This can be very devastating near the outlets of valleys or watersheds.

Another influence of urbanisation on the hydrologic cycle is in the ground water recharge. Due to the artificial imperviousness of the surface soil layer in cities, the water falling over the land is wasted as surface runoff rather than being availed for recharging the groundwater. Such a reduced groundwater recharge, supplemented by increased exploitation, will result in either a drastic lowering of groundwater table or saltwater intrusion in the case of coastal cities. Another problem to be envisaged is the water erosion associated with urbanisation of hill slopes. There are not yet any quantitative estimates of the contribution of rill and gully erosion on urban construction sites, road cuts or mined areas and spoil heaps, all of which favour severe erosion. The total cost of such accelerated soil erosion, both in monetary terms and in human suffering, will be very high. Hence, it has become imperative for planners to study the expected impact of the proposed land use on hydrologic cycle and runoff process.

Cochin, is not only a coastal city, but also is interspersed with an extensive backwater system and tidal canals forming a part of the Vembanad Estuary which receives freshwater from several rivers and salt water from Laccadives sea. It not only sustains a rich aquatic fauna and flora but also provides navigational facility including shipping.

4.2. Methodology

Individual microcatchments and drainage planning areas of Cochin were identified with the help of contour and land use maps supplemented by field investigations.

In the present study, run-off from the 21 catchments in the eastern portion of the study area is calculated in relation to rainfall intensity, water shed area and time of concentration. This run-off is compared to the calculated discharge capacity of the corresponding streams, to find out, whether the area is flood-prone. Such an analysis enables to identify the critical areas to be preserved in order to avoid future flooding problems.

From the available records of annual peak rainfall data and hourly tabulation, the annual series was formed for durations of 15 minutes, 30 minutes, 1 hr, 3 hrs, 6 hrs 12 hrs, and 24 hrs as given below (Unit mm /hr).

TABLE 4.1

ANNUAL SERIES OF RAINFALL DATA OF COCHIN

Duration / Year	15 min	30 min	1hr	3hr	6hr	12hr	24hr
1976	84.80	68.00	49.50	26.50	10.30	6.80	5.70
1977	120.00	84.00	56.00	24.80	11.60	11.30	8.10
1978	200.00	140.00	53.00	35.90	16.30	25.30	12.70
1979	136.00	94.00	48.30	23.00	16.20	7.20	5.60
1980	120.00	120.00	92.00	32.80	10.90	6.30	4.10
1981	120.00	120.00	100.00	20.90	13.20	7.70	6.60
1982	80.00	80.00	59.50	27.50	24.20	12.20	7.00
1983	140.00	90.00	50.00	16.40	10.30	5.00	4.60
1984	130.00	80.00	39.50	17.90	9.20	6.00	4.10
1985	96.00	88.00	73.00	41.60	13.80	7.10	5.40
1986	104.00	92.00	40.50	20.20	10.30	6.00	4.90
1987	88.00	82.00	36.20	18.90	21.80	12.20	6.30
1988	120.00	89.00	50.00	21.50	13.00	8.60	5.30
1989	120.00	120.00	100.00	48.20	13.00	8.00	6.30
1990	120.00	100.00	70.50	29.80	16.50	8.70	5.80

(Source: KUDP Report, 1992)

To quantify the flooding problems in the eastern upland area, where clear-cut identification of each microcatchment is possible, the maximum intensity of rainfall (mm /hr) for 15 minutes, 30 minutes, 1 hr, 3 hrs, 6 hrs, 12 hrs and 24 hrs, derived from the rainfall data for a 15 years period (1976-1990), were used to calculate the run off (Horton Overland Flow) from each catchment. But in the western flatland area, definite slope of individual area is not perceptible due to flat nature of land and criss-cross nature of roadside drains. Hence this part of the study area is not considered for detailed drainage calculations. The most accepted method of rainfall-runoff analysis is the Rational runoff Method (Dunn and Leopold, 1978). This method predicts peak runoff rates from data on rainfall intensity and drainage basin characteristics.

Runoff will increase as water from more and more distant parts of the catchment reaches the outlet. When the whole drainage basin is contributing, the discharge becomes a steady state flow (Q), the quantity of which depends on the catchment terrain characteristics and precipitation intensity (I) as described below

$$Q_{pk} = 0.278\ CIA$$

Where, Q_{pk} is the peak rate of runoff (m^3/s), 'I' is the rainfall intensity in mm/hr, 'A' is the drainage area (km^2) and C is the rational runoff co-efficient, which is taken as 0.4 since the eastern upland portion of the study area is mainly cultivated rural land. The value of C is usually assumed to remain approximately constant during and between large storms for a given basin.

The maximum intensity of rainfall (I) during a certain time interval (15, 30, 60 minutes etc.) for each catchment is chosen to calculate the above peak runoff (Q_{pk}) depending upon the time of concentration (T_c) for that particular catchment. If Q_{pk} is calculated with an intensity for duration less than the Tc the expected runoff will be an overestimate. Hence the selection of appropriate rainfall intensity depends on the calculation of T_c as given below (U.S.Soil Conservation Service, '72).-

$$T_c = \frac{L^{1.15}}{7700\ H^{0.38}}$$

where T_c is the time of concentration (hr), L is the length of catchment along the main stream from the basin outlet to the most distant ridge (ft) and H is the difference in elevation between the basin outlet and the most distant ridge (ft).

If the discharge capacity of a channel is less than the runoff of the catchment, it will result in flood.

In natural watercourses such as streams and rivers uniform flow seldom occurs. Despite this deviation, friction flow formula for computing discharges in natural streams assuming uniform flow conditions has been in wide use (Dunn and Leopold, 1978) and is given below.

Thus the discharge, Q which stand for quantity expressed in m^3/s, is the product of cross sectional area, time and velocity

Q = AU = WdU, where Q = discharge in m^3 /s, A = Cross sectional area in m^2 .

U = Velocity in m/s., W = Width in meters and d = Depth in meters

The velocity U depends on depth, slope (water surface gradient) and is inversely proportional to the boundary resistance and is calculated using Manning's formula (Dunn and Leopold, 1978), which is the most widely used formula to obtain the flow through open channels.

The equation is written as: -

$$U = \frac{1}{n} R^{2/3} S^{1/2}$$

U = Velocity in m/s

R = Hydraulic radius in m, i.e., the ratio of cross sectional area of flowing water to wetted perimeters,

(In the calculation of stream capacity, cross sectional area of the stream and perimeter of the stream in water filled condition are taken for the calculation of 'R ')

S = slope of energy line (the energy gradient) and is approximately the slope of the water surface.

n = Manning's coefficient of roughness which depends mainly upon the width and surface roughness of channel, which for the present study area, is taken as 0.050 - the value given for minor sluggish streams with weed growth and variable cross section (Dunne and Leopold '78).

4.3. Discussion

4.3.1. Land Drainage.

The study area encompassing 535 km^2 is divided into two geographically distinct zones: the eastern upland (291 km^2) comprising of 21 microcatchements (Fig.4.1) draining into the backwater system through streams and the western lowland covering 244 km^2 including the backwater system (72.59 km^2) as shown in figure.4.2.

The western flatland (Coastal Plain) comprises of 51 drainage units covering an area of 115 km^2 and islands in the backwater system with a total land area of 56.4 km^2

Due to the difference in topography, these two regions have distinctive surface hydrological features and hence experience flood problems due to different reasons. At the junction of eastern upland and the tidal canals, flood may become a serious problem in the near future due to the following reason. In the case of several catchments, such as Kadambrayar basin (81 km^2), Pallikkara basin (21 km^2), Puthencruz basin (57 km^2) and Pulikkamali basin (22 km^2), storm water from a very vast area gets collected at the exit point of each stream and escapes into tidal canals through topographical constrictions. The stream width is very narrow in those regions with the floodway only a few hundred meters in width (Fig.4.3).

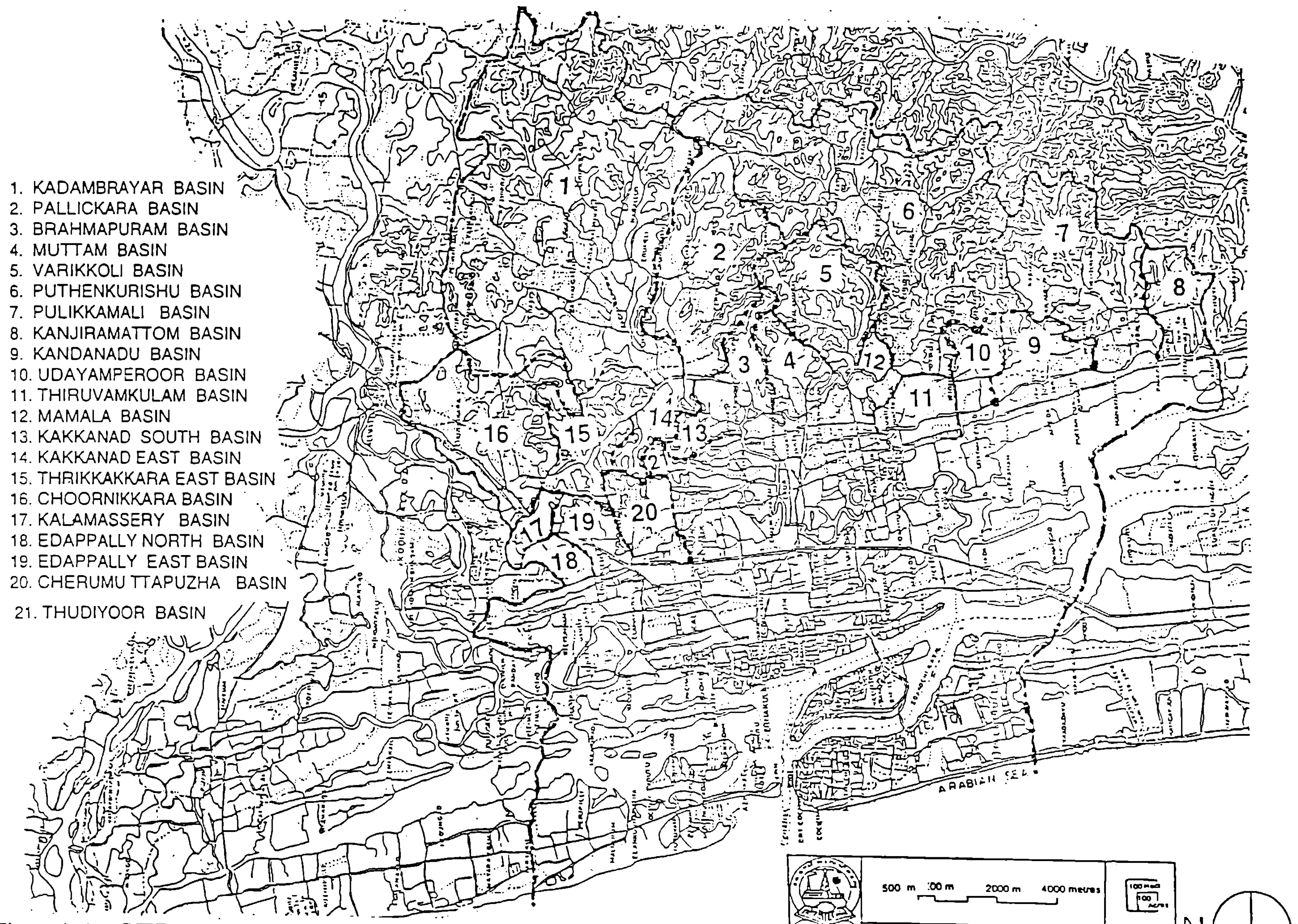


Fig - 4.1. STREAM BASINS IN THE EASTERN HILL TRACTS OF THE STUDY AREA

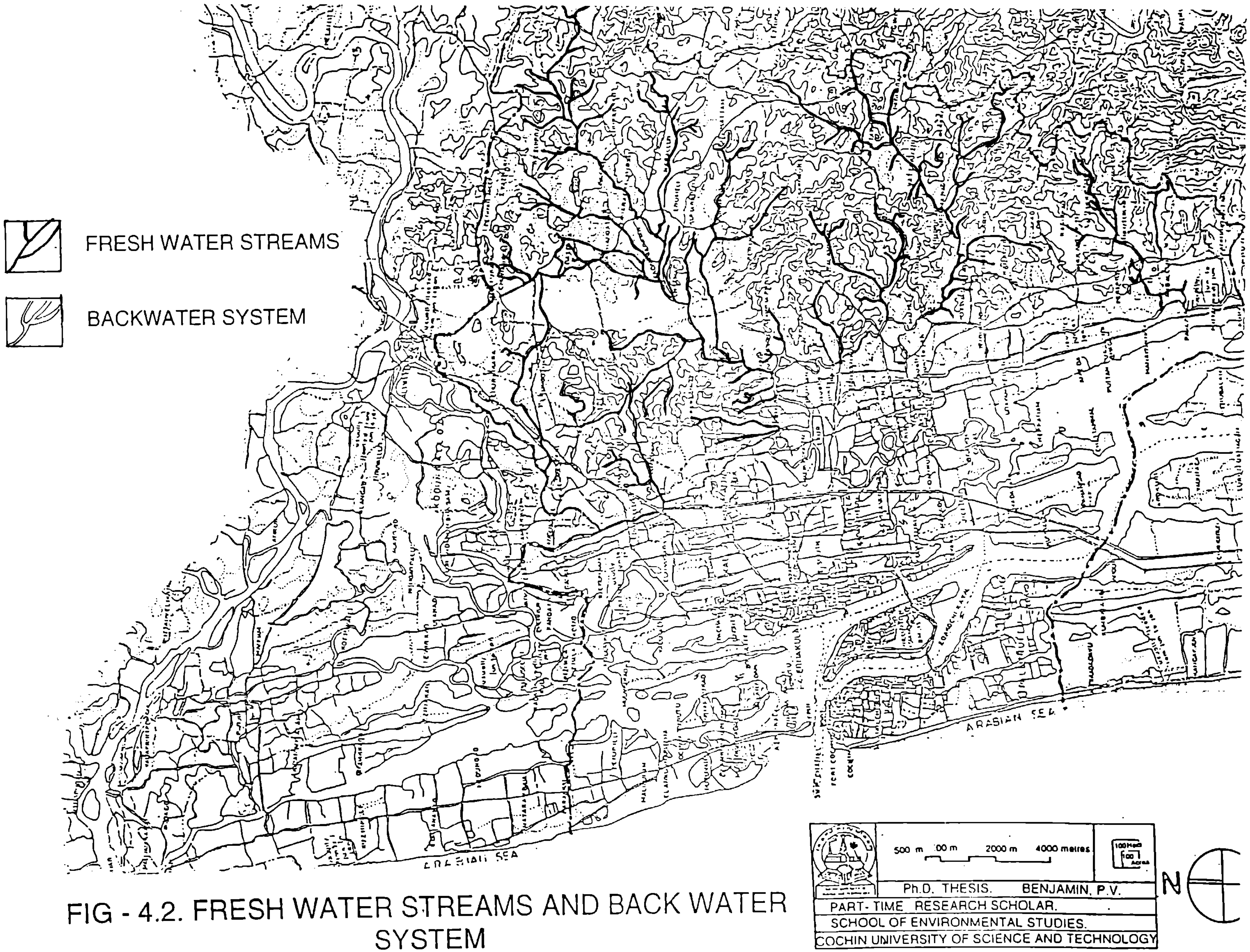


FIG - 4.2. FRESH WATER STREAMS AND BACK WATER SYSTEM

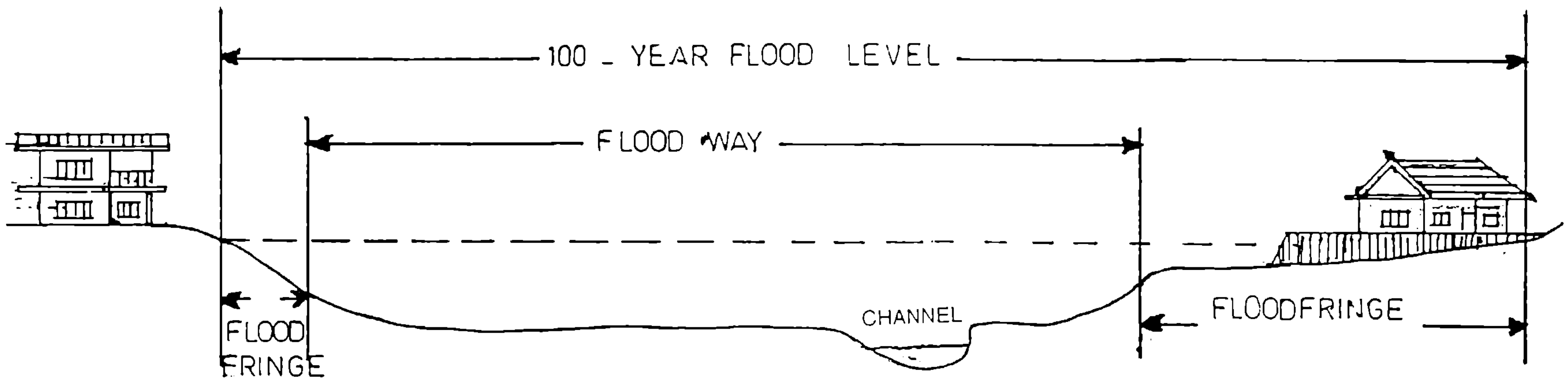


Fig - 4. 3 SCHEMATIC SECTION OF KADAMBRAYAR BASIN.

Changes made on the landscape alter the timing and amount of the waterflow especially peak (flood) flow. Over a long time, this affects the channel shape and stability. Channel stability changes are often delayed but abrupt and may have unwanted and often costly results. Also, land-use modifications in the upstream areas of hilly terrains increase the flood frequency in the downhill regions, which were originally outside the flood prone areas, due to reduction in the capacity of the streams because of siltation and increase in peak flow.

Presently, the floodwater from the 21 stream sub-basins of the Cochin major basin overflows to fill up the flood zone, which are mostly paddy fields, on either side before reaching the tidal canals. The large-scale filling going on in these paddy fields near these outlets for construction or plantation purposes is sure to eliminate this flood zone. During heavy rains, this filled up land acts as a dam causing severe flood in the immediate upstream area. When the flood water exceeds the holding capacity of these unintentional 'dams', the surging water is likely to carry away the filled up earth along with the buildings creating flash flood in downstream areas, a situation similar to that occurred in Jaipur as mentioned earlier.

In order to prevent such a disaster, those buffer zones are to be declared as "filling-free zone", so that, during very heavy rains, vast drainage basins of the streams such as Kadambrayar (84 km^2), Puthencruz basin (54 km^2) can easily drain their flood-waters into the backwater system through their flood zones.

In the U S A, flood prone areas are partitioned into two zones; the flood fringe and floodway. The former is the area that would be inundated by the 100-year discharge. In this area new buildings must be flood proofed whose lower floors must be at a level that will provide protection against immersion and against damage from floating debris. In the floodway, building or filling is usually forbidden and the area is maintained as green space. In USA, Federal Development Loans are not available for floodway land (Leopold and Dunn, 1978). Development controls similar to that of U S A may be adopted here also.

In the western parts, flood problem is local and it needs engineering solution while in the eastern parts, the flood expected is of a regional scale, which can cause wide damage if planning is not done in anticipation.

Flooding problem in the western part is in fact waterlogging caused individually or as a net effect of the following reasons: -

1. Absence of sufficiently wide drains with adequate slope connected to tidal canals.

2. Improper location of housing colonies and commercial centers in swampy areas after filling up.

3. Land originally above flood hazard becomes prone to frequent flooding due to filling up of the surrounding low-lying areas to comparatively higher levels for construction purposes, from where, during rains, water drains into the originally high lands causing floods.

In a recent study of the runoff of catchments and discharge rates of the drains of Kathrukadavu - Pulleppady area it is seen that the average efficiency of the drain is 43.31%. Out of the 34 catchments studied in the area 12 have less than 25% efficiency, 25 have less than 50% efficiency and 25 have less than 75% efficiency and only one has 100% drainage efficiency (Alex et al 1997). The above study is a typical example of the general situation in all highly urbanised parts of the western flatland of the study area.

This water-logging problem can be easily remedied by engineering solutions (linking the road side drains to the nearest tidal canals), since, no part in this area is more than 2 or 3 kms away from a major tidal canal and the maximum extent of each catchment is only a few hectares. In this part, tidal canals are of several meters in width and run in a north-south direction more or less parallel to each other. Constructing roadside drains and linking them to the tidal canals or backwater system at the nearest point is sure to solve the waterlogging problem to a great extent in these parts where flood is very frequent due to local depressions. Also, local authorities should ensure the periodic maintenance of the drains.

In the highly urbanised western area of Cochin, plinth height of each building in the catchment must be of the same level, which will prevent the runoff from one plot of land flowing into another plot.

4.3.2. The Backwater System

The Cochin backwater system (about 72 km^2 in area) is a part of the Vembanad lake which spreads out in the 4 districts of Trichur, Ernakulam, Kottayam and Alapuzha and covers an area of about 210 km^2 . Studies of lime shell deposits suggest that this backwater system formed a part of the Laccadives sea until the upliftment of the coastal regions of Ernakulam and Alapuzha districts in the year 1341 AD (Rasalam and Sebastian, 1976).

The Vembanad lake receives most of its fresh water supply through a network of rivers: the Pampa, Achankoil, Meenachil and Muvattupuzha rivers in the south and Periyar in the north. These rivers also bring sediments, plant nutrients and toxic pollutants.

About 7,200 ha of the Vembanad lake come within the study area. It is comparatively deeper in navigation channels where the depth varies from 8 to 12 meters, whereas in other parts, it is 0.75 to 5 meters. The width of the backwater system varies from 100 m to 9 kms. The backwater system is fringed with wetlands, a good part of which has been already reclaimed. The extent of the backwater is continuously reduced by siltation and land reclamation. The backwater system has two permanent openings to the sea, one at Cochin and the other at Azhikod, through which seawater enter the estuary system.

In the study area, the backwater system is connected to the Laccadives Sea (Arabian sea) with a 450 m - wide channel which provides a gateway to the tidal currents as well as ships to the Cochin harbour. The

In the study area, the backwater system is connected to the Laccadives Sea (Arabian sea) with a 450 m - wide channel which provides a gateway to the tidal currents as well as ships to the Cochin harbour. The tide is mixed diurnal/semi diurnal. The amplitude of spring tide is of the order of 1.6 m. The larger area of the Cochin backwater results in large tidal flow through the gut. The flow rate averaged over the tide through the gut is 4000 m^3 /s during spring tide and 2000 m^3 /s during mean tide (personal communication from Cochin Port). The mean sea level at Cochin is 0.64 m above chart datum as given in Tide Table '93 (Table 2.1).

At present, the wave action in the backwaters is insignificant. However, the proposed deepening and widening of the ship channel to suit the needs of the proposed *Cochin-Vallarpadam Container Trans-shipment Terminal Project* may considerably increase the wave action in the backwaters which may lead to serious erosion problems along the shore-lines of the islands and Cochin Marine drive as has happened in the case of Piazza San Marco of Venice, Italy.

The main freshwater inflow to the backwater is during monsoon period when Periyar in the north supplies about 350 m^3 /s while, in the south Achankoil, Pampa, Manimala, Meenachil and Muvattupuzha rivers together supply about 900 m^3 /s (Kerala Water Authority). This fresh water inflow into the Cochin backwaters causes a very high flushing rate during monsoon months. Given a total backwater area of approximately 300 km^2 (including other parts of Vembanad lake) and an average depth of 1-2 M, complete

Along with the freshwater, sediments are also transported through the streams and rivers, which are deposited either in the flood plains or in the backwaters where new landforms are being created. This is the process by which mudflats and islands are created in the Cochin backwaters. Thus geologic processes are closely linked with hydrologic cycles.

The saline water inlet into this backwater system is through guts at Cochin and Azhikod, as mentioned earlier. The salinity in the backwater is a function of the distance from the sea and of fresh water flow from the rivers. The highest salinity value is recorded during pre-monsoon season (Vasudevan, 1992). The large riverine freshwater inflow during the south-west monsoon season (June-September) drives out the entire saline wedge during ebbflow. In between the haline (salt) and freshwater conditions, there is an intermediate mesohaline condition. During June and July there is very low surface salinity whereas below 2 m depth mesohaline condition exists. A further lowering of salinity values is noticed during August and September. A monthly distribution of salinity is shown in Fig.4.4.

The vegetation and animal types of the backwater system show considerable seasonal changes due to the salinity variation. During the pre-monsoon season (January to April), vegetation adapted to salt condition alone thrives and the migration of marine fishes and prawns also occur. During monsoon (June to September), when saltwater gets flushed out, the vegetation and animals adapted to freshwater proliferate and a luxuriant growth of vascular plants like Water Hyacinth (*Eichhornia crassipes*), the

Month		Stations 1	2	3	4	5	6	7	8
Apr'90	s	2.54	13.53	22.24	24.82	17.54	6.88	0.33	0.00
	b	10.76	16.78	24.45	25.96	25.13	16.02	0.17	0.00
May'90	s	0.08	0.89	2.47	3.42	0.56	0.83	0.00	0.00
	b	0.11	1.64	3.75	8.85	0.83	0.17	0.08	0.00
Jun'90	s	0.06	0.16	0.24	0.43	0.23	0.83	0.03	0.03
	b	0.06	0.16	0.24	0.51	0.32	0.08	0.03	0.03
Jul'90	s	0.00	0.08	0.30	0.67	0.08	0.00	0.00	0.00
	b	0.00	0.14	0.40	0.67	0.03	0.00	0.00	0.00
Aug'90	s	0.40	0.16	1.46	2.45	0.61	0.14	0.14	0.11
	b	0.04	0.19	1.73	4.07	0.51	0.08	0.08	0.09
Sep'90	s	0.14	1.50	9.80	9.91	7.25	0.35	0.00	0.00
	b	0.24	4.28	10.86	10.97	16.39	1.20	0.00	0.00
Oct'90	s	0.35	3.90	6.62	15.96	12.03	2.37	0.00	0.00
	b	0.03	7.04	9.70	22.33	24.03	2.90	0.00	0.00
Nov'90	s	0.16	3.57	10.65	15.13	10.27	1.05	0.00	0.00
	b	0.80	15.00	17.18	25.11	30.10	4.13	0.00	0.00
Dec'90	s	10.54	12.83	2.51	35.86	23.70	15.39	4.64	0.93
	b	11.93	20.51	23.06	39.06	35.06	25.62	13.98	5.41
Jan'91	s	1.95	21.78	23.70	26.90	20.47	6.68	0.80	0.00
	b	14.23	11.02	24.34	20.18	26.90	15.62	0.00	0.00
Feb'91	s	4.38	16.66	28.45	30.10	19.87	7.07	0.93	0.00
	b	4.64	21.14	29.46	31.00	21.14	10.90	1.31	0.00
Mar'91	s	0.54	11.04	22.42	21.70	16.00	3.23	0.67	0.19
	b	11.68	19.99	21.79	25.62	21.79	19.20	6.68	0.93

s: surface b: bottom

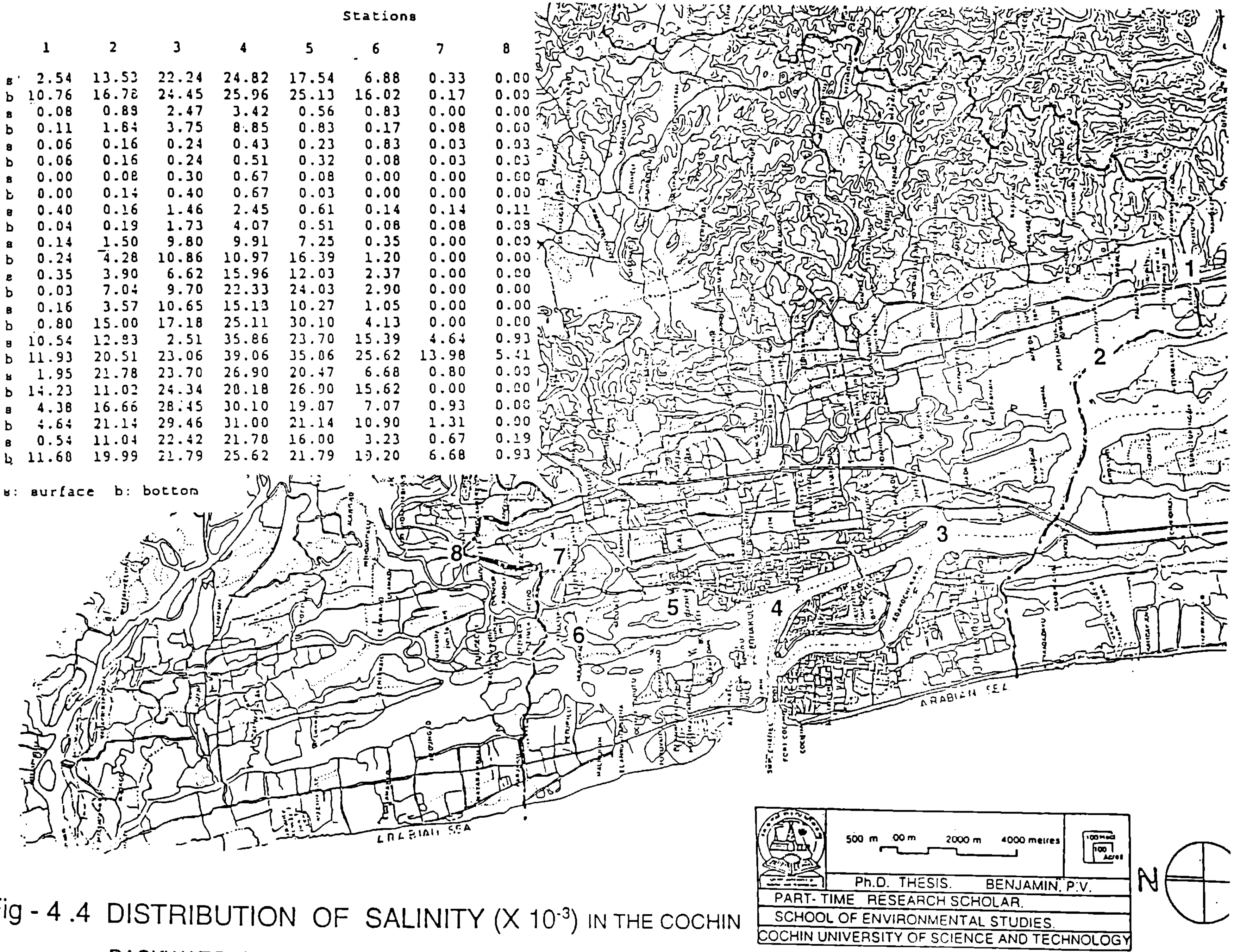


Fig - 4 .4 DISTRIBUTION OF SALINITY (X 10^{-3}) IN THE COCHIN BACKWATERS

During monsoon (June to September), when saltwater gets flushed out, the vegetation and animals adapted to freshwater proliferate and a luxuriant growth of vascular plants like Water Hyacinth (*Eichhornia crassipes*), the African Payal (*Salvinia auriculata*) occurs. These plants often obstruct water transport particularly in tidal canals. These weeds die and sink to the bottom as soon as the estuarine water becomes saline. Some animals and plants can survive in both the conditions and such organisms exist throughout.

The high primary productivity and rich production of phytoplankton and zooplankton in the backwater system sustain a rich fishery. This is because, most of the fish larvae are voracious feeders of the plankton found abundantly in the backwaters. Maximum fishery occurs during the inter-monsoon months of October to April (Silas and Pillai, 1975).

The Vembanad lake sustains 150 species belonging to 100 genera and 56 families of fishes (Kurup, 1982). Among them, the commercially important fish species are *Metapenaeus dobsoni, Penaeus indicus, Meta-penaeus manoceros,* Grey mullets (Mugil sp), *Daysciaena albida, Sead bass* (Lates calcarifer), Marine Catfish (Tachysurus sp), Half beak (Hyporhampus sp), Tarpon (*Megalops cyprinoides*), Perch (Lutjanus), Pearl spot (*Etroplus suratensis*), Penaeid prawns, Palaemonid prawns (Macrobrachium), Edible crab (*Scylla serrata*), Black clam (*Villorita siprinoides*) and *Penaeus monodon.*

Besides, there is seasonal pisciculture of prawns alternating with paddy cultivation in bunds extending over an area of 6000 hectares in the

The clam *Villorita cyprinoides* var. 'Cochinensis' form extensive beds in the Cochin backwaters, which is a cheap protein source for a large section of the people and a raw material for the manufacture of cement and lime (Nair, '75). Oysters of the species *Crassostrea madrasensis* are abundant in the Cochin backwaters throughout the year, especially in some places near the harbor.

The backwater system is subject to serious pollution from many sources. The industrial wastes from various factories in and around Cochin ultimately reach the backwater through the various rivers and drains. Also, the residues of pesticides used in Ernakulam, Idukki, Kottayam and Alapuzha districts ultimately reach the backwaters to pollute it. The nutrients or chemicals may be beneficial for aquatic animals and plants (since rich in nutrients) or may be toxic and detrimental to their growth (if it contains industrial / domestic effluents and agricultural residuals including pesticides).

Large quantities of effluents are being discharged from various industries. The main sources of pollution in the southern side are Travancore Sugars and Chemicals - Thiruvalla, Hindustan Paper Corporation-Velloor; and Mc. Dowell Company - Cherthala. The main sources of pollution in the north are the industries located at the Alwaye, Kalamassery - Ambalamugal industrial belt. At the downstream of Alwaye, the industries in the Eloor area cause pollution by the toxic substances like mercury and insecticides. The main polluting industries in the catchment of the backwaters are those of Rayons, Aluminium, Chemicals, Fertilizers, Rare Earths, Insecticides, Zinc and catalysts (Table - 4 . 3.). Traces of these waste discharges are found in water samples and are also found to accumulate in the sediments and in living organisms in the backwaters (Table-4.2)

The concentration of trace metals in the water, sediments and biota of Cochin backwaters (KWBSP Repot, 89) is as follows, (ranges of highest concentration encountered) concentration is expressed in ppm ie μg/litre and μg/g dry weight in biota.

Table 4.2

	Water	Sediment	Biota *Crassostrea madrasensis*(Oyster) *Villorita cyprinoids* (Clam)
Cadmium (Cd)			8.0 - 10.5
Copper (Cu)	1.0-1.2	4.8-5.6	32.5 - 38.5
Iron (Fe)	7.2-7.7	72-93	1900 - 2400
Lead (Pb)			7.0 - 7.5
Manganese (Mn)			5.2 - 7.6
Zinc (Zn)	3.5-4.0	3.1-3.2	960 - 1400
Mercury (Hg)			0 .05 - 0.07

Significant concentration of organochlorine pesticides was reported in the black clam and fish from the Vembanad Lake with a still higher concentration near agricultural areas. Although DDT has been banned internationally, the same and its derivatives DDE and DDD were found in the black clams from the backwaters and channels. Low concentration of Dieldrin, Endrin and Endosulphan were also detected in the clam samples (KWBSP, 1989). Many parts of the backwater system, which are tradi-

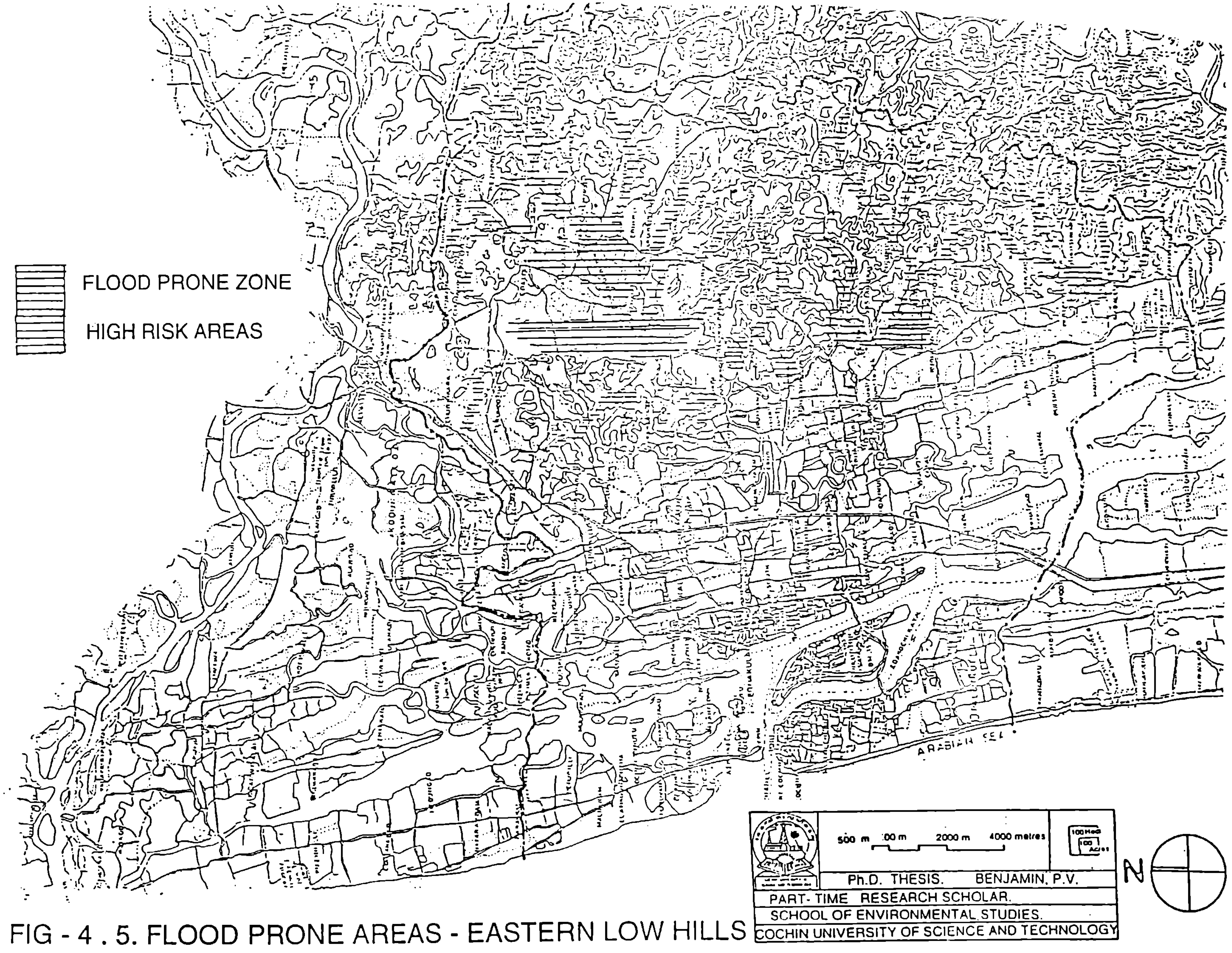


FIG - 4 . 5. FLOOD PRONE AREAS - EASTERN LOW HILLS tionally used for coconut husk retting, are characterised with anoxic condition, putrid smell, high turbidity, presence of phenolic compounds and Hydrogen Sulphide. Most of the fishes and other aquatic animals desert the vicinity of retting grounds (KWBSP, 1989).

Also, it is reported that excessive sedimentation within the stream channel can ruin the spawning habitats of fishes. The deposits of eroded materials can reduce the conveyance capacity of the channel, especially from urban drains. The mulching of small areas cleared for urban construction in the hilly areas can effectively prevent erosion from such areas which adds to the sedimentation in the water bodies (Wischmeir and Meyer, 1973). Another method of soil erosion control is terracing of hilly areas.

The backwaters also receive large amount of sewage effluents from the urban and semi-urban settlements along its coast, such as Cochin Corporation, Tripunithura, Kalamassery, Alapuzha, Alwaye, Perumbavoor and Kottayam. This leads to a high concentration of coliform and other faecal bacteria in water, sediments and shorelines (Samy etal, 1981).

The high concentration of faecal bacteria in the backwaters may make fish, shrimps and clams to be unsuitable for human consumption. High concentration of coliform bacteria was detected in fishes and bivalves collected from Cochin backwaters (Quasim and Madhupratap, 1979) rendering them unsuitable for human consumption.

4.4 Summary and Conclusion

The various aspects of hydrology applicable to the land surface of the study area i.e., the rainfall-runoff relationship and the drainage efficiency of streams is calculated. Various environmental implications arising out of these observations are dealt with in this chapter. The salient features of the backwater system are also assessed.

The study area (535 km^2) is divisible into 3 regions with distinct surface hydrology characteristics.

(1) The eastern upland (291 km^2) with the highest point 115 m above MSL and comprising of 21 sub-basins or micro-catchments draining into the backwater system through streams.

(2) The western flatland (115 km^2) interspersed with tidal canals and the islands in the backwater system (56.4 km^2).

(3) The backwater system (72.59 km^2).

The eastern upland area, being a sloped terrain generates a fast runoff and is hence prone to erosion. In this area, physiographical study reveals the presence of 21 sub-basins drained by a stream except a few which are having basins shared by 2 or 3 streams with interbasin linkage. In this study, the runoff that would have generated in these sub-basins when rainfall intensity (maximum in 15 years) corresponding to the time of concentration of each sub-basin is calculated using the rainfall data from 1976-1990. Thus the discharge capacity of the sub-basin exit points (the point at which these streams drain into the tidal canals) was calculated. If the discharge capacity of a channel is less than the runoff of a catchment, it will result in flood. Such flood-prone areas within the study area are located and marked in the plan (Fig.4.5). Such areas are not suitable for urban development, since these areas, if reclaimed and buildings constructed, are liable to be washed away by the surging floodwater (Fig.4.6). Also, such reclaimed areas act as unintentional earthen dams breaking free flow of flood water and cause damage to agriculture and rural settlements in upstream areas by frequent floods though they are at present free from flood hazard. Such areas are marked in the plan as filling-free zone or areas where only regulated development is permitted.

The western flatland (115 km^2) interspersed with tidal canals is having a different hydrologic character. Being a flat terrain, interlinked throughout by urban drains and tidal canals, definite sub-basins are not distinguishable in this highly urbanised area. In these areas, the only hydrologic problem is waterlogging either due to closure of drains or due to improper location of drains. This problem can be solved by engineering solution linking roadside drains to the nearby natural tidal canals.

The islands in the backwater system are rural in nature and hence sufficient natural channels are present to meet the current drainage requirements. In future, when urbanisation takes place, drains are to be laid up with proper slope and hierarchy and are to be linked to the backwater system at the nearest point.

TABLE -4 .3. MAIN WATER POLLUTING INDUSTRIES IN THE STUDY AREA

NAME OF INDUSTRY	LOCATION	QUANTITY OF DIS-CHARGE (litres per day)	MAIN POLLUTANTS	DISCHARGE INTO
FERTILIZERS & CHEMICALS TRAVANCORE Ltd.	UDYOGA-MANDAL	70400000	pH,BOD,COD,SS,DS,CHLORIDES,FLUORIDES,PHOS-PHATES, FREE AMMONA,AMMONIACAL NITROGEN, HEXAVALENTCHROMIUM,ARSENIC,VANADIUM, NITRATES,OIL&GREASE-	PERIYAR
FERTILIZERS & CHEMICALS TRAVANCORE Ltd.	AMBALA-MUGAL	31,400,000	pH,BOD,COD,SS,DS,CHLORIDES,FLUORIDES,PHOSPHA TES,FREEAMMONA,AMMONIACAL NITROGEN,HEXA VALENTCHROMIUM,ARSENIC,VANADIUM,NITRATES, OIL&GREASE	CHITRA-PUZHA
COCHIN REFINERIES	AMBALA-MUGAL	7,800,000	pH,BOD,COD,SS,SULPHIDES,OIL&GREASE	CHITRA-PUZHA
INDIAN RARE EARTHS Ltd	UDYOGA-MANDAL	3,000,000	pH,,COD,SS,DS,CHLORIDES,FLUORIDES,PHOSPHATES, AMMONIACALNITROGEN,LEAD,ZINC,SU .PHIDES, SULPHATES,a-Emitters,b-Emitters	PERIYAR
HINDUSTAN INSECTICIDES Ltd.	UDYOGA-MANDAL	2,044,000	pH,BOD,COD,SS,DS,SULPHIDES,CHLORIDES, FLUORIDES,PHOSPHATES,SULPHATRS,PHENOLIC, COMPOUNDS.,ENDOSULPHAN,D.D.T.,B.H.C.,ZINC, OIL&GREASE.	UNTHI-THODE
CRL-BALMER LAWRIE Ltd.	AMBALA-MUGAL	35,000	pH,BOD,COD,SS,OIL&GREASE,PHENOLIC COM-POUNDS,SULPHIDES, CYANIDE,FLUORIDES,CHROMIUM.	CHITRA-PUZHA
tTRAVANCORE COCHIN CHEMICALS Ltd.	UDYOGA-MANDAL	7,800,000	pH,SS,,OIL&GREASE,OIL&GREASE, MERCURY, RESIDUAL CHLORINE.	PERIYAR
HINDUSTAN ORGANIC CHEMICALS Ltd.	AMBALA-MUGAL	1,200,000	pH,BOD,OIL&GREASE,PHENOLIC COMPOUNDS, CYANIDES,FLUORIDES,CHROMIUM,SULPHIDES.	CHITRA-PUZHA
INDIAN ALUMINIUM Co Ltd.	UDYOGA-MANDAL	3,650,000	pH,SS,BOD,OIL&GREASE,FREE AMMONIA,AMMONIACAL NITROGEN,NICKEL, CHROMIUM, LEAD, ZINC, COPPER.	PERIYAR
COMINCO BINANI ZINC Ltd.	EDAYAR	550,000	pH,SS,DS.ZINC,SULPHIDES,SULPHATES,COPPER,FLUO RIDES,MERCURY,CADMIUM.	PERIYAR
HINDUSTAN LEVER Ltd.	ERNA-KULAM	12,657	pH,BOD,COD,SS,DS,,OIL&GREASE,PHENOLICCOMPOU NDS, SULPHIDES,NICKEL, FLUORIDE,NITROGEN.	BACK-WATERS
CARBORUNDU M UNIVERSAL Ltd.	EDA-PPALLY	1,156,000	pH,BOD,SS,DS,OIL&GREASE	MUTTAR
TRAVANCOREC HEMICALS&MA NUFACTURING Co.Ltd.	UDYOGA-MANDAL	721,500	pH,SS,PHENOLICCOMPOUNDS,OIL&GREASE,COPPER, CHLORIDES,FLUORIDES,CHROMIUM,LEAD.	PERIYAR
TRAVANCORE RAYONS Ltd.	PERUM-BAVOOR	46,000,000	pH,BOD,COD,SS,DS,OIL&GREASE, AMMONIACAL NITROGEN,SULPHIDES,ZINC.	PERIYAR
PERIYAR CHEMICALS Ltd.	EDAYAR	33,000	pH,BOD,COD,SS,DS,,OIL&GREASE	PERIYAR
UNITED CATALYSTS Ltd.	EDAYAR	537,000	pH,SS,OIL&GREASE , COPPER,NICKEL,ZINC, FREE AMMONIA,AMMONIACAL NITROGEN,CHROMIUM.	PERIYAR
COCHIN MINERALES & RUTILES	UDYOGA-MANDAL	60,000	pH,BOD,OIL&GREASE,MANGANESE, NICKEL, TITANIUM, COPPER, ZINC, CADMIUM, MERCURY, LEAD, CYANIDES, CHROMIUM.	PERIYAR
MERCHEM L td	ELOOR	150,000	pH,BOD,SS,OIL&GREASE,ZINC, PHENOLIC COMPOUNDS,SULPHIDES.	PERIYAR

SOURCE:- KERALA STATE POLLUTION CONTRO L BOARD

ABBREVIATIONS:- pH - NEGATIVE LOGARITHM OF THE HYDROGEN ION CONCENTRATION. BOD - BIOLOGICAL OXYGEN DEMAND. COD - CHEMICAL OXYGEN DEMAND. SS - SUSPENDED SOLIDS. DS - DISSOLVED SOLIDS

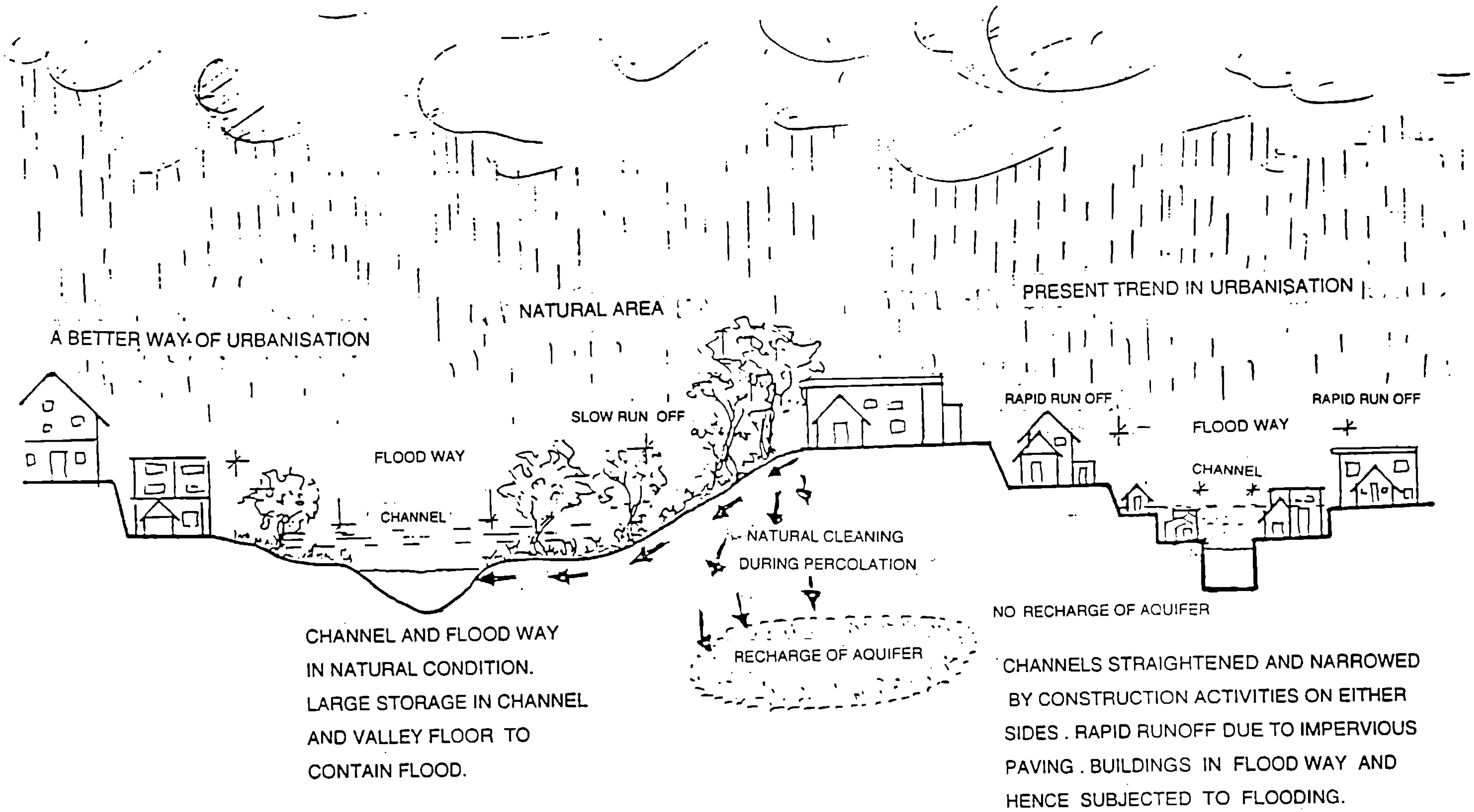


Fig - 4 .6 SCHEMATIC REPRESENTATION OF THE FLOOD PROBLEM ACCOMPANYING URBANISATION.

The Cochin backwater system is a part of the Vembanad Lake, which covers a total area of 21,050 hectares. About 7,200 ha of this area lies in the study area. The width of the backwater system varies from 100 m to 9 kms and a depth of about 0.75 to 5 meters. The ship navigation channel within the backwater system is 8-12 m deep. The backwater system is open to sea at Cochin and Azhikod. The water is saline during summer months, which is flushed out during rainy season. After the monsoons, the salt-water intrusion takes place gradually inwards through these guts. This periodic (seasonal and tide induced) variation in salinity and nutrient supply supports a rich aquatic fauna and flora in the backwater system. Extensive land reclamation and increasing pollution (industrial and urban) has already started to take its toll in the fishery resources.

The following environmental planning guidelines are suggested based on this study.

Many of the environmental problems of Cochin are hydrologic in origin because hydrologic cycle gets drastically modified during urbanisation. The drainage basins, on which some modifications are done, often form a portion of a larger drainage basin and hence these modifications may inadvertently affect also other areas of the drainage basin as well, unless they are carefully planned. Hence, drainage basin dynamics give a better understanding of hydrologic and geomorphic processes for analysing the spatial linkages between different areas that can affect both regional and site planning

In order to avoid floods, it is necessary to assess the possibilities of flood hazard in an area and to provide adequate drain size for peak discharge in any storm. Peak discharge must be estimated from the size of expected rainstorm and from the characteristics of the catchment. Unlike water supply or sewerage facilities, storm water drainage system offers little scope of subsequent improvement essentially because, the system is gravity dependent.

In the land area of the western low-lying region, the main hydrologic problem is waterlogging due to absence of slope. Hence water gets logged in the depressions and in the areas where there are no drains or where the drains are blocked by various reasons. Waterlogging also occurs due to inadequacy of drain size and/or due to unnecessary meandering of drains through low-lying areas. Another serious problem is that land originally above waterlogging levels becomes prone to frequent waterlogging due to filling up of surrounding low-lying areas to comparatively higher levels for construction activities.

The waterlogging problem in the western flatland can be easily remedied by engineering solutions (linking the road-side drains to the nearby tidal canals), since no part of the area is more than 2 or 3 kms away from a major tidal canal and the maximum extent of a catchment is only a few hectares. Proper drainage planning in all the drainage planning areas will solve the problems if executed along with proper maintenance system.

Chapter-- 5.

Climate

5.1. Introduction

Climate plays a decisive role in the evolution of all human settlements. It determines the hydrology, ecology, socio-economic development as well as urban evolution. Thus climate deserves due weightage in land use planning and industrial location. Any planning without proper assessment of the meteorological aspects may lead to wrong location of various land uses resulting in avoidable environmental degradation.

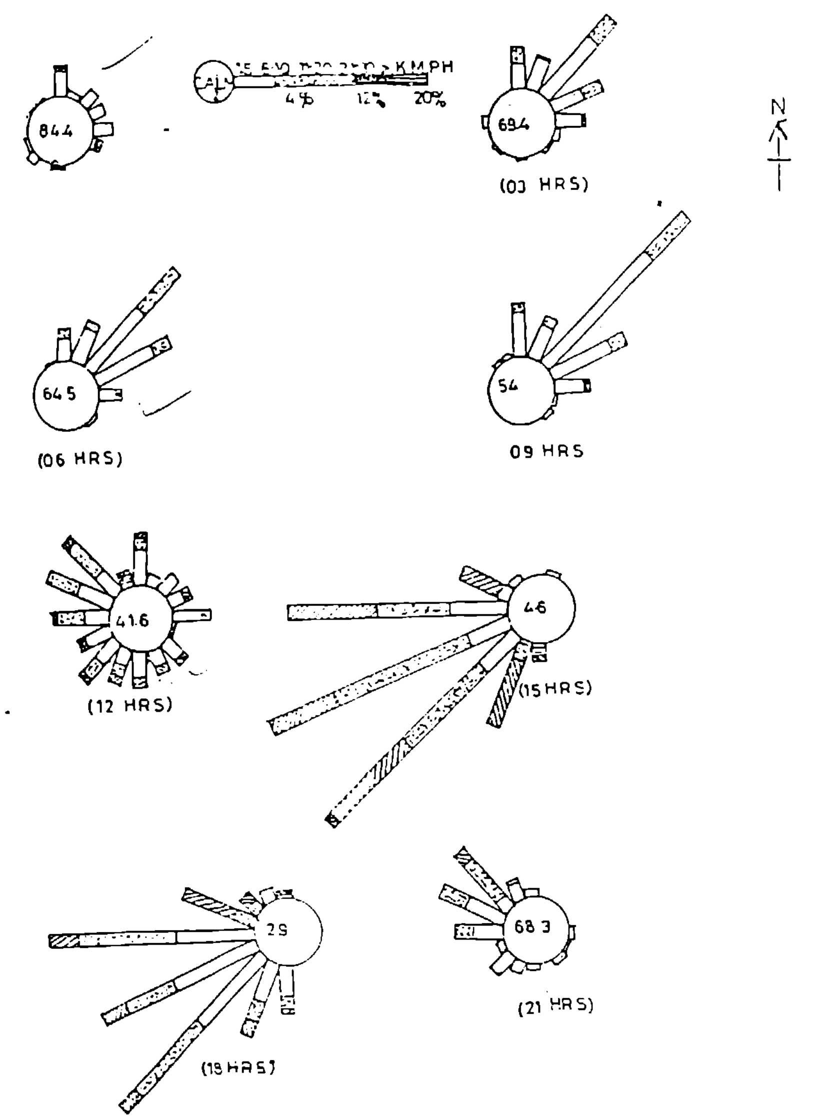
Climate of an area has an important bearing on its ambient air quality. Meteorological aspects along with physiography play a crucial role in determining the concentration of pollutants, which depends on dispersion or dilution of pollutants. The general dispersion pattern and direction of movement of air pollutants can be understood from the wind climatology and relating it with physiography. Improper location of industries without considering the meteorological aspects may result in severe air pollution in sensitive areas.

Sources of Air Pollution can be natural or man-made. Methane and hydrogen sulphide emissions from marshlands are the main natural source of air pollution in Cochin, but it is not yet quantified. Man-made pollutants are:- (1) Oxides of Sulphur and Nitrogen, (2) Carbon compounds (3) Particulate matter. Also, there are photochemical compounds (also called secondary pollutants because in the presence of reactive hydrocarbon, solar energy is absorbed by NO_2 to form photochemicals).

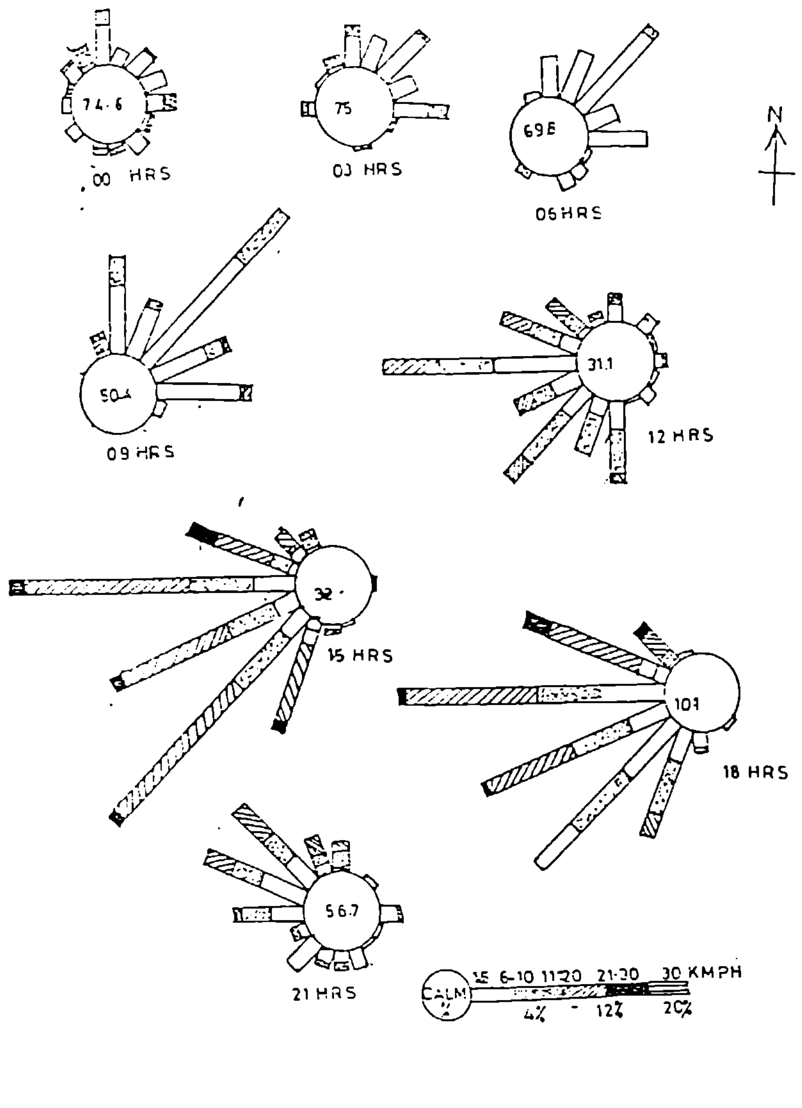
Atmospheric stability, which is determined mainly by the vertical thermal profile over a place, is indicative of the wind status, particularly in the vertical, which in turn, governs the pollutant's dispersal. Highly unstable conditions, characteristic of a steep vertical decline in temperature, result in thorough mixing and hence dilution of pollutants. Stable conditions, on the other hand, are characterised either by a vertically isothermal layer or one with an increasing temperature (inversions) which results in low mixing and poor dispersal of pollutants.

Depending on the height at which the inversion occurs, the ground level pollutant concentration can vary. If the base of the inversion is above the effective stack height (H), that base line virtually act as a lid below which a rapid build up of pollutants takes place. If the top of the inversion lies below the effective stack height, the pollutants will not reach the ground and consequent build up take place only at higher elevations. However, once the inversion breaks, a sudden high doze of pollutants is likely to reach the ground. If the inversion base is below but its top is above the stack height, the dispersion is completely inhibited. However, in such conditions also, high ground concentrations are likely to occur when the inversion breaks after sunrise. Usually inversions are found during night and early mornings.

Atmospheric dispersion of pollutants from stacks depends upon many interrelated factors. They include the physical and chemical nature of the



WIND ROSES OVER COCHIN FOR JANUARY



WIND ROSES OVER COCHIN FOR FEBRUARY.

Fig 5.1(a)

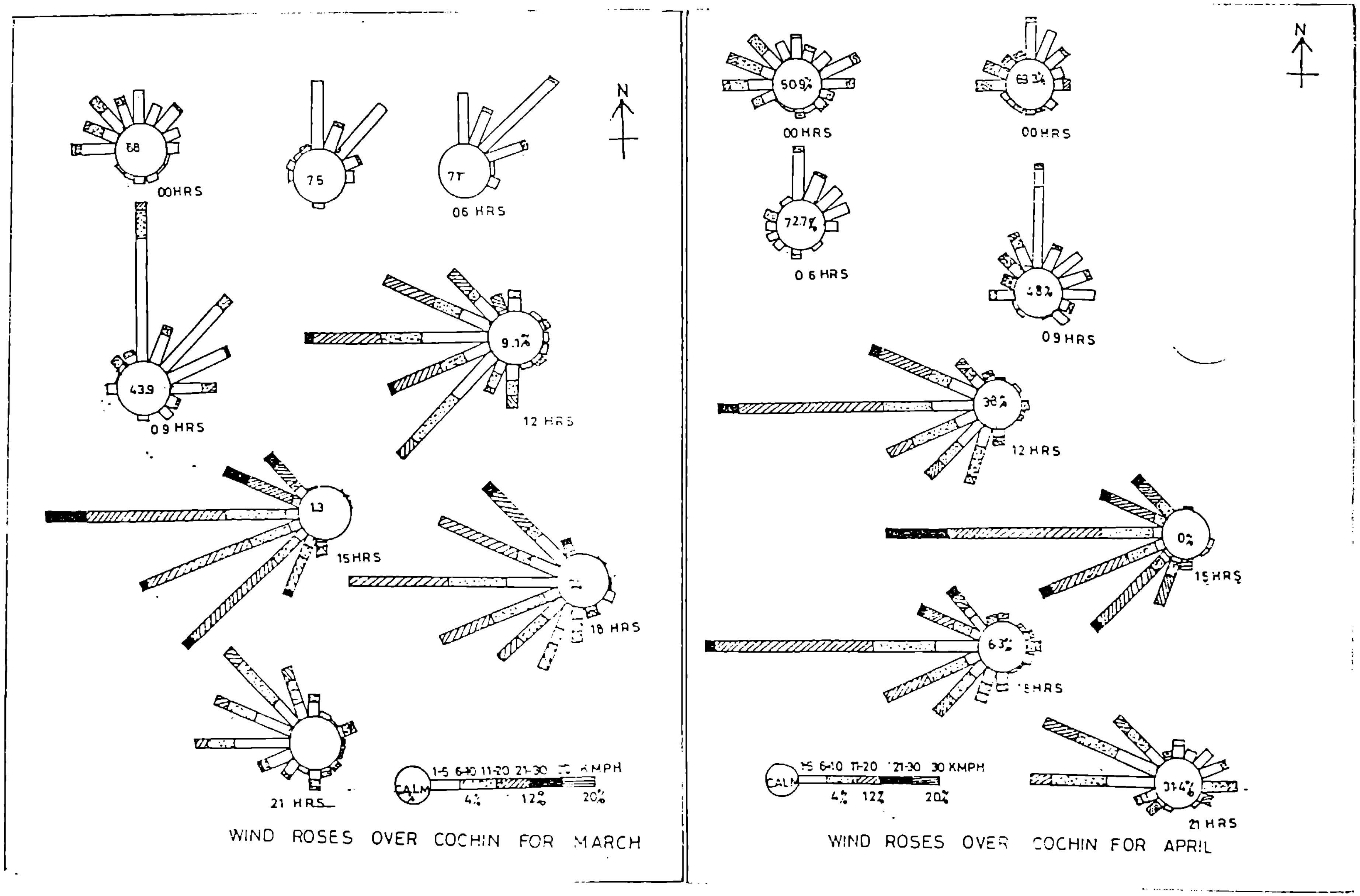
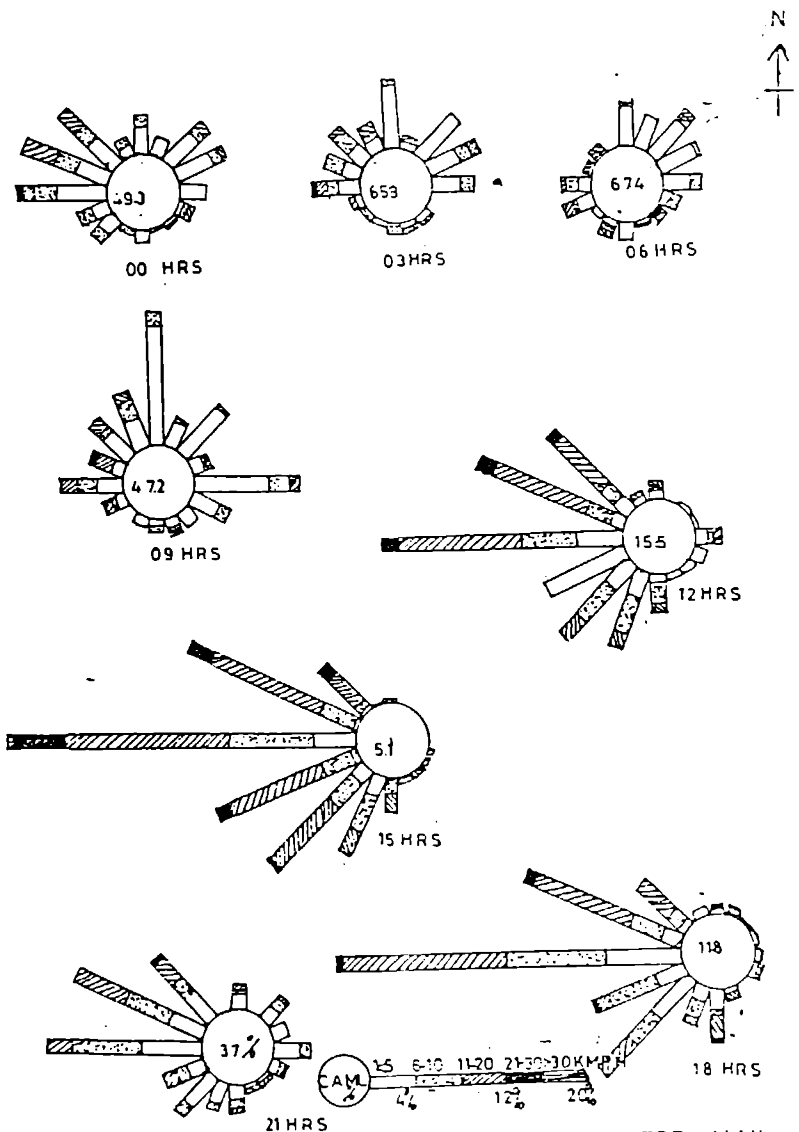
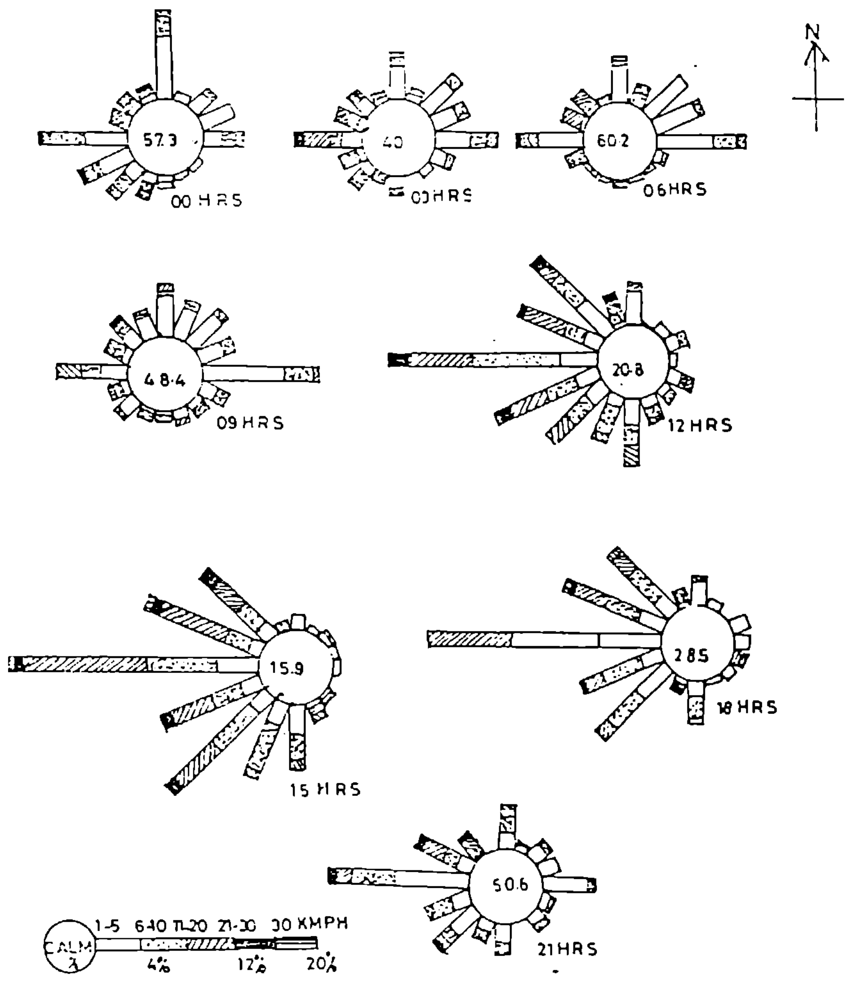

N
00HRS
06 HRS
09 HRS
12 HRS
15HRS
18 HRS
21 HRS
1-5 6-10 11-20 21-30 KMPH
CALM
4% 12% 20%
WIND ROSES OVER COCHIN FOR MARCH
00 HRS
0 6 HRS
09 HRS
12 HRS
15 HRS
21 HRS
1-5 6-10 11-20 21-30 30 KMPH
4% 12% 20%
WIND ROSES OVER COCHIN FOR APRIL

Fig 5.1(b)

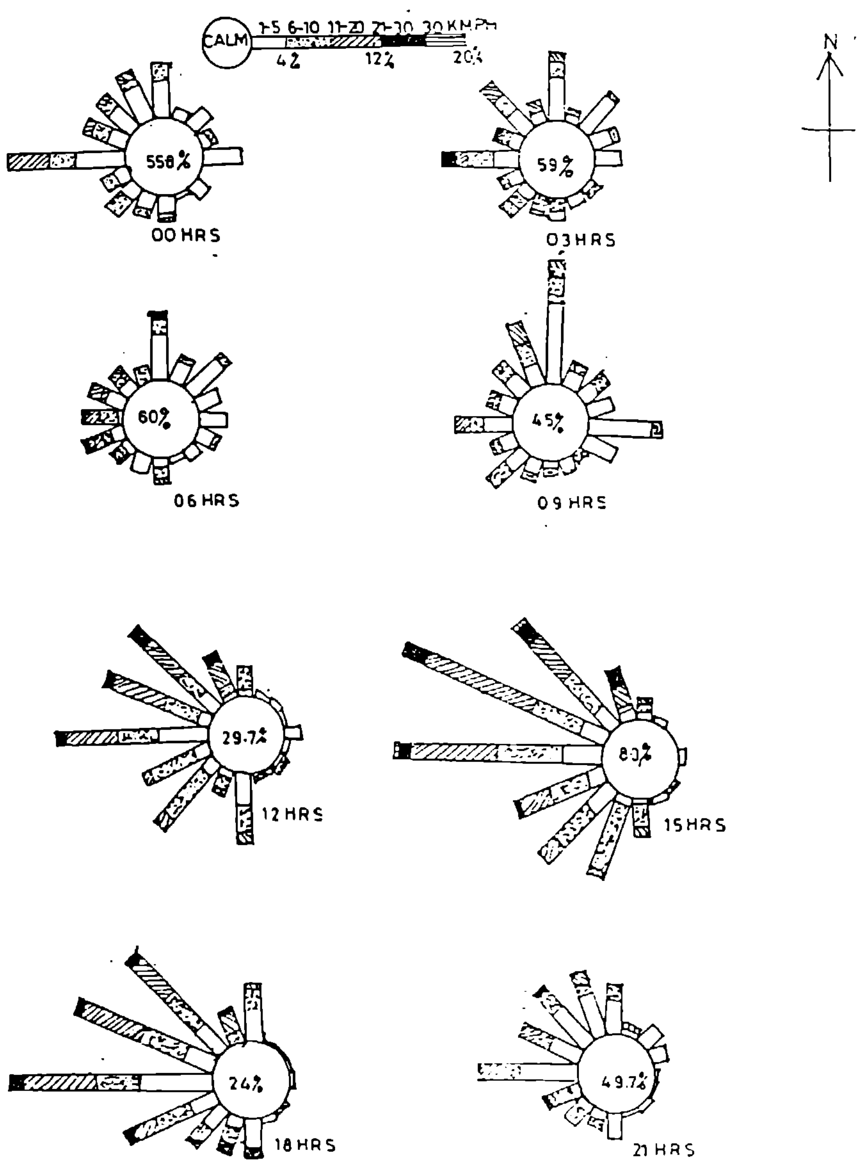


WIND ROSES OVER COCHIN FOR MAY.

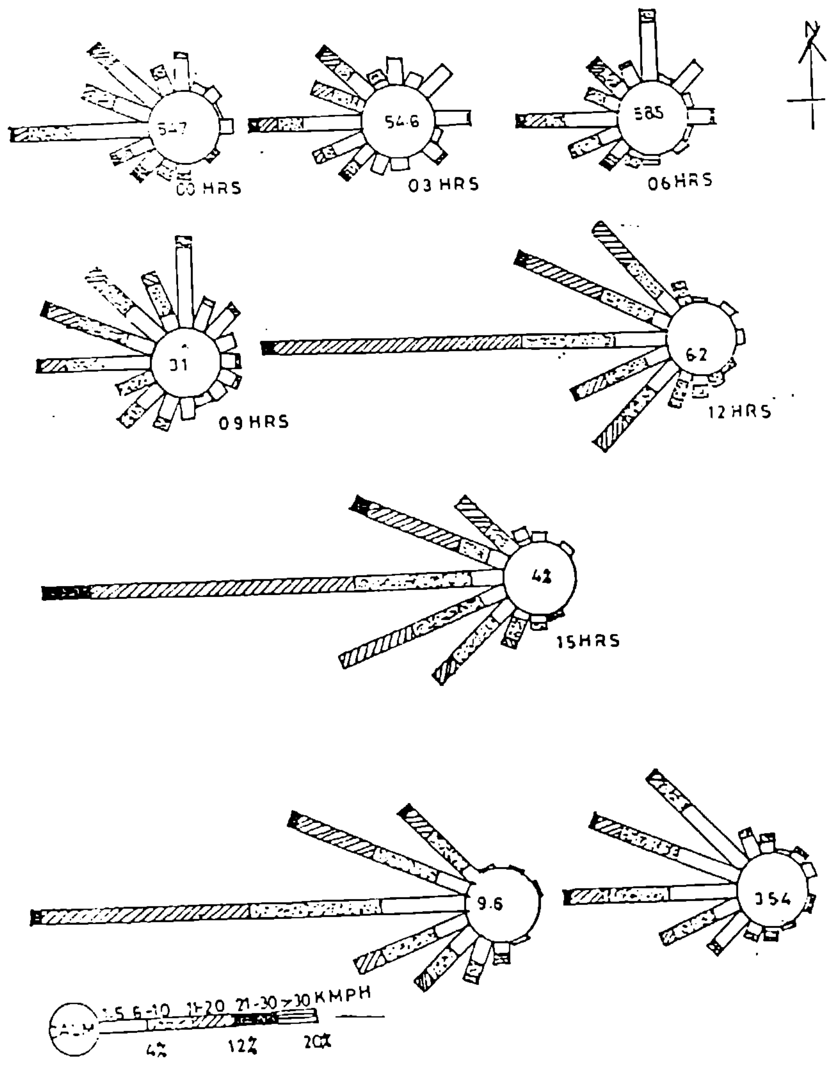


WIND ROSES OVER COCHIN FOR JUNE.

Fig-5.1 (c)

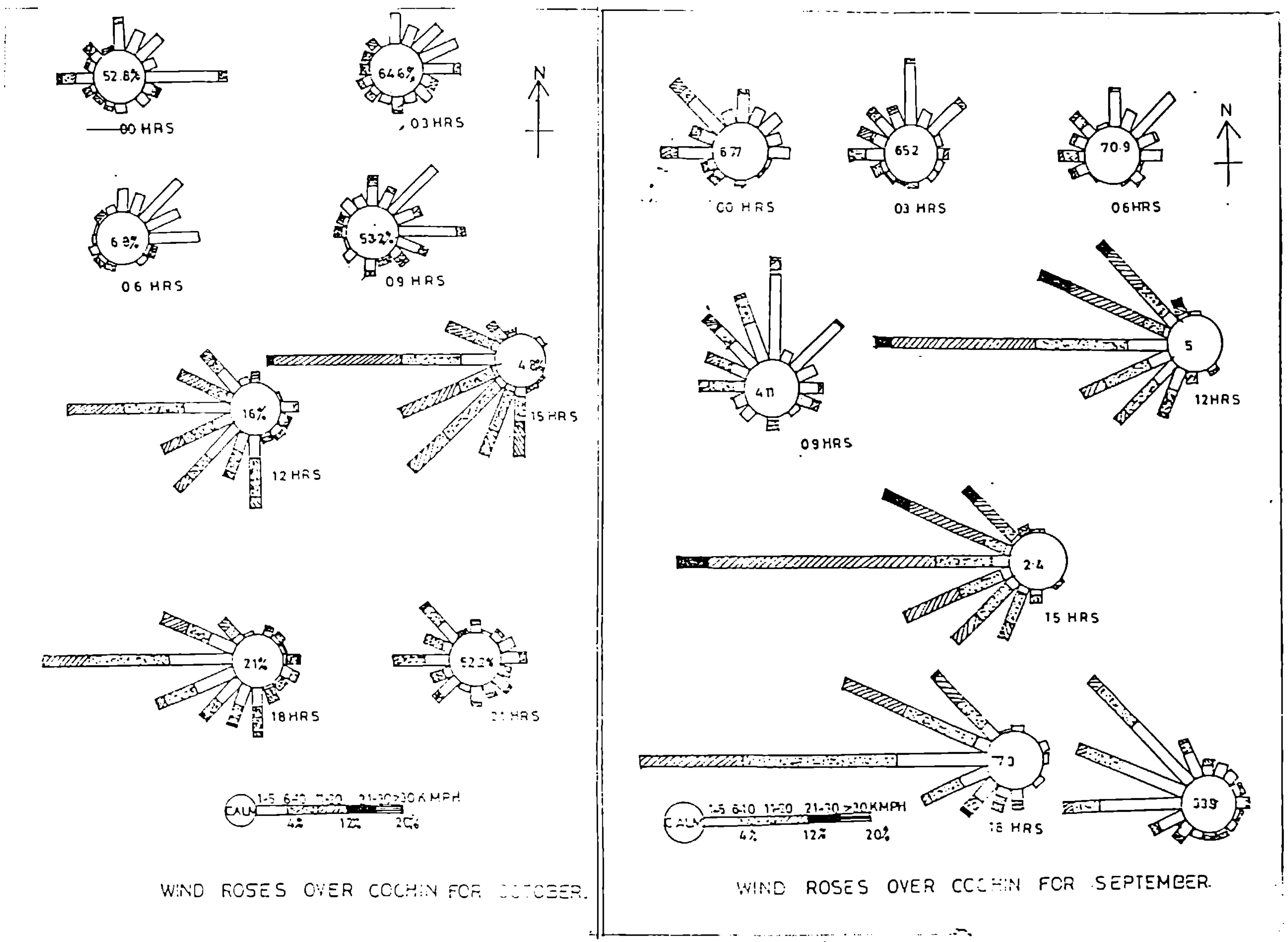


WIND ROSES OVER COCHIN FOR



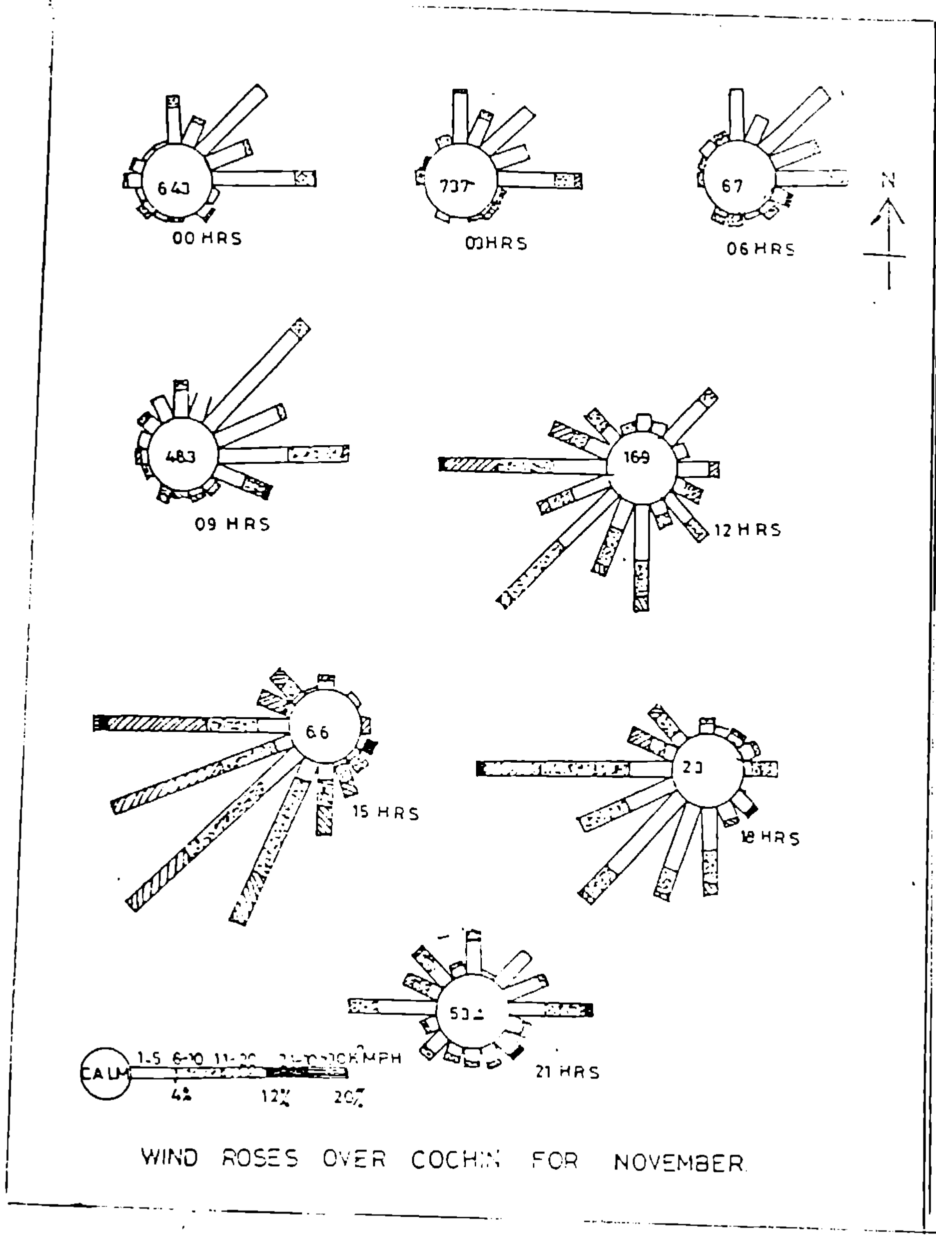
WIND ROSES OVER COCHIN FOR AUGUST.

Fig. 51(d)

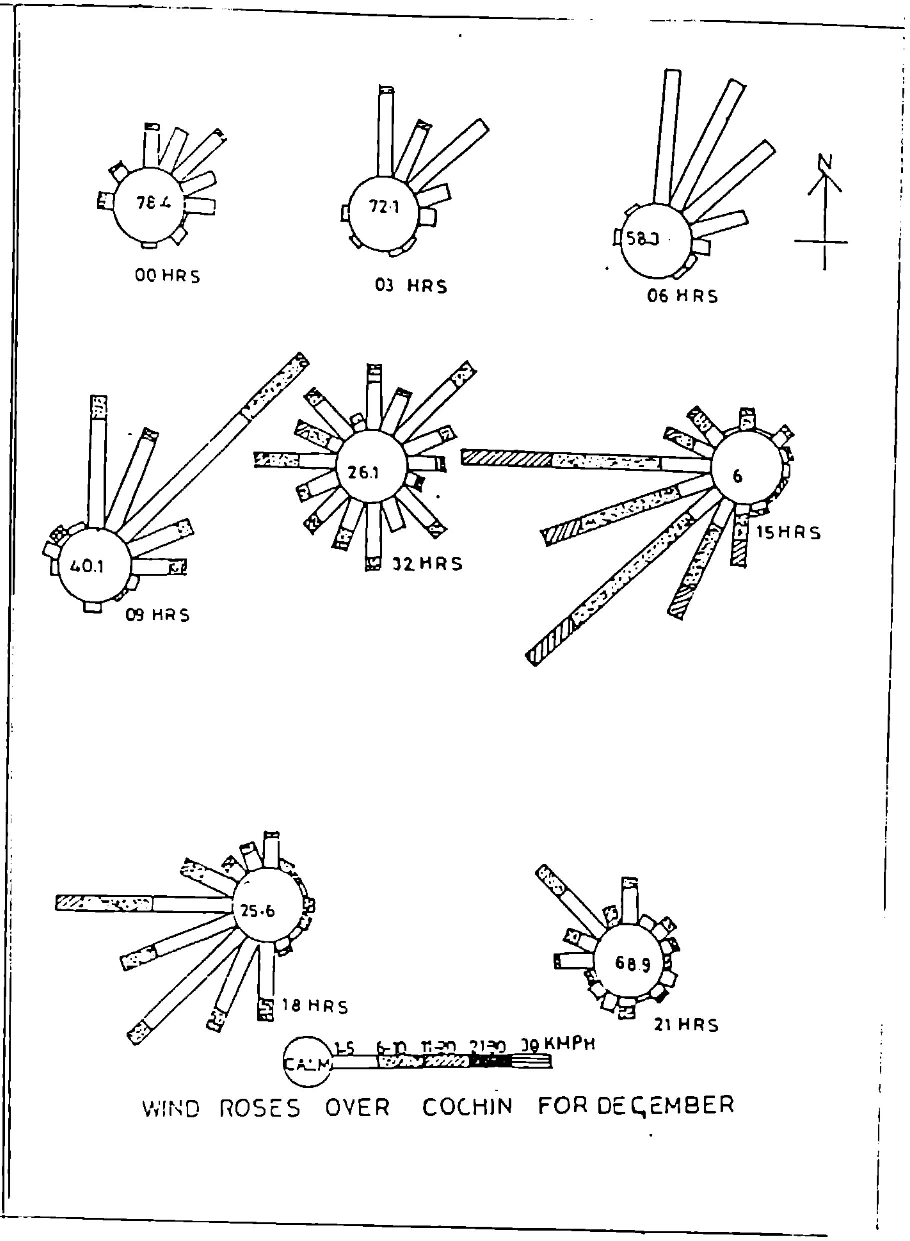


52.8%
00 HRS
64.6%
03 HRS
6.9%
06 HRS
53.2%
09 HRS
16%
12 HRS
15 HRS
21%
18 HRS
21 HRS
N
CALM
1-5 6-10 11-20 21-30 ≥30 KMPH
4% 12% 20%
WIND ROSES OVER COCHIN FOR OCTOBER.
6.77
00 HRS
652
03 HRS
70.9
06HRS
4.11
09HRS
5
12HRS
2.4
15 HRS
18 HRS
33.9
WIND ROSES OVER COCHIN FOR SEPTEMBER.

Fig-5.1(e)



64.3
00 HRS
73.7
03 HRS
67
06 HRS
N
48.3
09 HRS
16.9
12 HRS
6.6
15 HRS
23
18 HRS
21 HRS
CALM
1-5
6-10
4%
12%
20%
KMPH
WIND ROSES OVER COCHIN FOR NOVEMBER



78.4
00 HRS
72.1
03 HRS
58.3
06 HRS
N
40.1
09 HRS
26.1
12 HRS
6
15 HRS
25.6
18 HRS
68.9
21 HRS
CALM
1-5
6-10
11-20
21-30
30 KMPH
WIND ROSES OVER COCHIN FOR DECEMBER

Fig-5.1(f)

TABLE 5.1. CLIMATOLOGICAL TABLE OF KOCHI.

(LATITUDE 9° 58' N & 76° 14' E)

MONTH	STATION LEVEL PRESSURE (m b)		AIR TEMPARATURE (0 C)						RELATIVE HUMIDITY (%)		RAIN FALL (mm)						WEATHER PHENOMENA (NO OF DAYS WITH)					
	0830 IST	1730 IST	DAILY MAX	DAILY MIN.	HIGHEST & DATE		LOWEST & DATE		0830 IST	1730 IST	MONTHLY TOTAL	NO. OF RAINY DAILY	TOTAL IN WETTEST MONTH (YEAR)		HEAVIEST FALL IN 24 Hr. (DT.)		RAIN 03 MM	HAIL	THUNDER	FOG	DUST STORM	SQUALL
JANUARY	1,012.9	1,008.9	30.6	23.2	33.3	10-1-55	17.8	4-1-29	68	64	9.6	0.6	211.3	1,921	133.3	16-1-21	1.5	0	0.9	0	0	0
FEBRUARY	1,012.4	1,008.3	30.7	24.3	34	27-2-60	19.4	1-2-32	72	68	34.2	1.6	169.2	1,928	105.4	8-2-1899	3	0	1.8	0	0	0
MARCH	1,011.5	1,007.5	31.3	25.8	34.4	21-3-59	21.1	19-3-54	74	70	50	2.6	245.2	1,960	125.8	11-3-60	5	0	6	0	0	0
APRIL	1,010.5	1,006.8	31.4	26	34.1	3-4-59	21.7	7-4-43	75	74	139.5	7.5	372.6	1,839	160.5	29-4-56	12	0	1.8	0	0	0
MAY	1,008.8	1,006	30.9	25.7	34.6	2-5-59	21.1	15-5-39	81	78	364.5	12.8	1,077.5	1,933	253.2	28-5-33	18	0	12	0	0	0
JUNE	1,009.2	1,007	29	24.1	32.7	12-6-58	20.6	17-6-35	88	84	755.9	25	1,216.4	1,912	185.4	24-6-1900	28	0	5	0	0	1
JULY	1,009.7	1,007.6	28.1	23.7	31.7	1-7-53	21.1	8-7-43	89	87	571.9	23.9	1,258.1	1,924	213.9	24-7-10	27	0	1.8	0	0	0.6
AUGUST	1,009.9	1,007.4	28.1	24	32.2	15-8-29	21.1	8-8-50	85	86	385.7	19.3	1,172.2	1,931	155.7	16-8-47	25	0	1.2	0	0	0
SEPTEMBER	1,010.7	1,007.7	28.3	24.2	31.1	23-9-55	21.1	5-9-50	84	84	234.8	14.1	534.9	1,897	111.8	26-9-36	20	0	3	0	0	0
OCTOBER.	1,011.1	1,007.9	29.2	24.2	32.2	19-10-30	21.1	13-10-43	83	80	332.7	14.3	905.8	1,932	236.2	17-11-1884	19	0	8	0	0	0
NOVEMBER	1,011.6	1,008.4	29.8	24.1	32.8	24-11-57	19.4	29-11-44	78	74	183.7	8.9	440.9	1,943	121.4	24-12-20	12	0	8	0	0	0
DECEMBER	1,012.5	1,008.9	30.5	23.5	32.8	12-12-57	19.4	14-12-45	71	66	36.8	2.1	203.7	1,946	154.7	8-12-46	3	0	1.8	0	0	0
ANNUAL TOTAL / MEAN	1,010.9	1,007.7	29.8	24.4	34.6	--	17.8	–	79	76	3,099.1	132.7	4,215.4	1,924	253.2	--	173	0	63	0	0	1.6
NO. OF PERIODS	30	23	30	30	35	—	35	..	30	23	30	30	80	..	80	...	21	21	21	21	21	21

SOURCE : MENON & RAJAN, 1989

ALL TIMES RECORDS ;

DAILY MAXIMUM TEMPERATURE - 56.0° C ON 27-3-1977
DAILY MINIMUM TEMPERATURE - 16.0°C ON3-2-1967
MAXIMUM MONTHLY RAINFALL - 1258.1 mm ON JULY 1924
MAXIMUM RANFALL IN 24 HOURS - 253.2 mm ON 28-5-1933

TABLE - 5.2 PERCENT FREQUENCY OF OCCURRENCE OF INVERSIONS AND ISOTHERMAL CONDITONS OVER COCHIN

PARAMETERS	%FREQUENCY	MONTH											
	FROM —— TO	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
SURFACE BASED INVERSION	0 - 2	7.1	4.1	2.6	3.7	0.6	1.3	1.3	0.3	1.0	0.3	2.0	4.0
	2 - 4	00	00	00	00	00	00	00	0.3	00	00	00	00
	4 - 6	00	00	00	00	00	00	00	00	00	00	00	00
ELEVATED INVERSION	0 - 2	1.3	00	0.6	0.3	0.3	0.3	1.0	0.6	1.0	00	00	1.3
	2 - 4	0.3	0.7	00	0.6	00	0.7	00	00	00	0.3	00	00
	4 - 6	0.6	0.7	00	0.3	00	00	00	00	00	00	00	00
ISOTHERMAL CONDITION	SURFACE BASED	28.1	16.9	21	23.5	21.9	22	31.3	23.9	19.7	25.2	29.3	25.2
	ELEVATED	1.0	3.1	4.2	4.2	4.5	4	4.8	2.6	2.3	4.2	4.7	3.2

SOURCE :- ANILKUMAR 1986

effluents, the meteorological characteristics of the environment, the location of the stack, and the nature of the terrain down wind from the stack. High wind speed increases the diluting action of the atmosphere. Hence low ground level concentrations downwind from the stack.

5.2.. Methodology

The climate of Cochin is studied on macro (regional) and micro (local) levels to assess the way it influences the general living conditions. For that, average monthly mean data on rainfall, temperature and humidity data for the period 1931 to 1960 (Table 5.1), 3-hourly wind rose data for one year (Fig.5.1) are used.

To obtain the pollution scenario of the study area, monthly mean concentrations of different air pollutants from 16 stations during 1990 (NEERI-Report, 1991), mixing height data (Anilkumar, 1986) for 12 months from 9 stations (Fig.5.6) are utilised. This data interpreted in relation to physiographical aspects and urbanisation pattern of the study area facilitates the demarcation of different zones based on pollution climatology.

5.3. Discussion

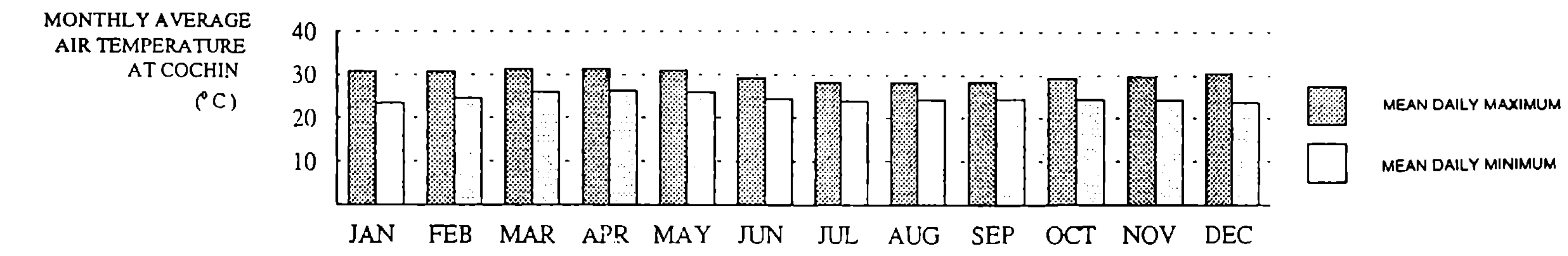
5.3.1. Macroclimate

Macroclimate is the general climate of the area. Cochin enjoys a tropical climate with intense radiation during the months of December to May. The relative humidity is very high due to the proximity of the sea and the interspersal of water bodies. This makes the life uncomfortable particularly in summer months during night time between 8 P.M.to midnight and early morning hours (the lull between land and sea breezes) when the wind velocity is very low (Fig.5.1). This kind of climate necessitates the area to have human settlements with its own characteristic orientation & ventilation.

There are two rainy seasons 1. The southwest monsoon during June, July and September, and 2. a weaker northeast monsoon (also considered as the retreating phase of the southwest monsoon (during the months of October and November) with a brief dry spell between the two during early October (Fig.5.2). The yearly average rainfall is about 300 cms. Since the rainy season extends to about 6 months, drainage is very important particularly when urban settlements are developed. Not only that, since there is continuous rain during rainy season any modification of the land surface without due consideration to the rainfall climatology, is likely to cause denudation in the eastern sloped terrain due to erosion and water logging in the flat areas.

The driest month is January followed by February, December, March, April and November respectively. These months are the most ideal for construction activities as the number of man-days lost due to heavy rains will be minimum.

The hottest months (November to April) coincide with the time when the sun is positioned below of 9° N latitude (Fig.5.3)). So, during a year, south-faced slopes are more exposed to the sun making it very



AVERAGE MONTHLY RAINY DAYS & DAYS OF THUNDER

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
NO. OF RAINY DAYS	0.6	1.6	2.6	7.5	12.8	25	23.9	19.3	14.1	14.3	8.9	2.1
DAYS OF THUNDER	0.9	1.8	6	13	12	5	1.8	1.2	3	8	8	1.8

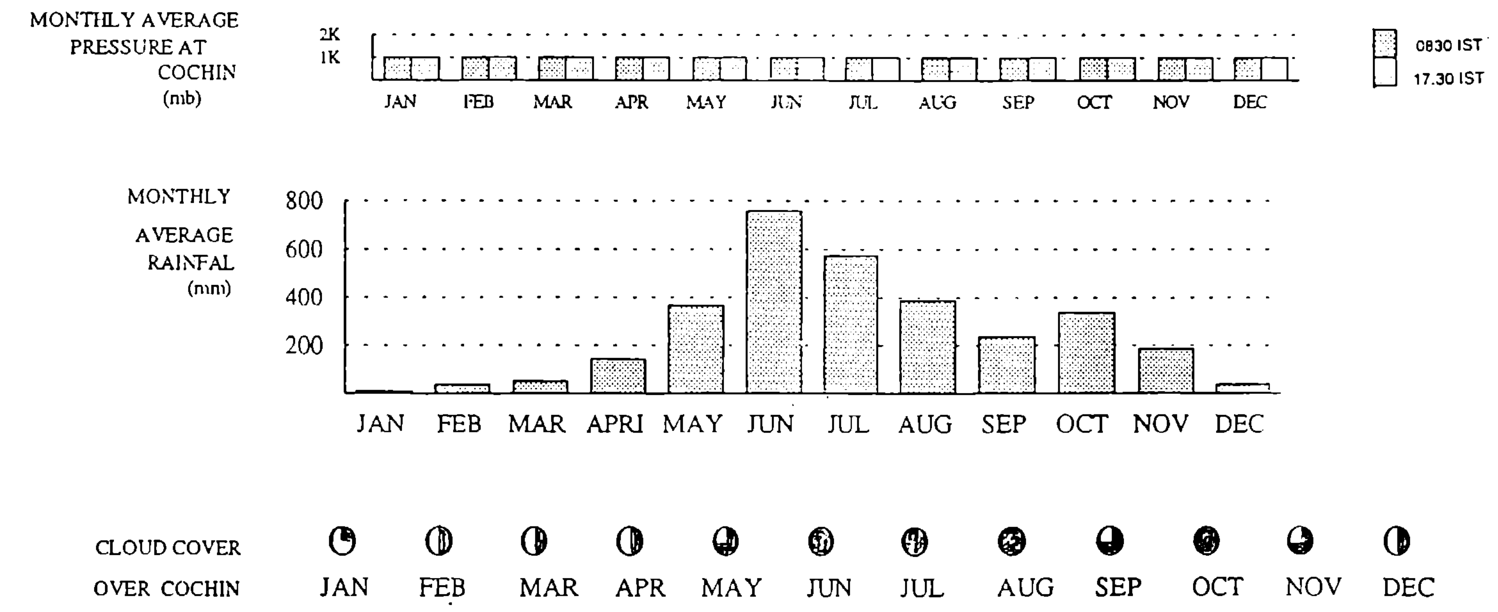


FIG - 5.2. CLIMOGRAM OF COCHIN

SOLAR CHART

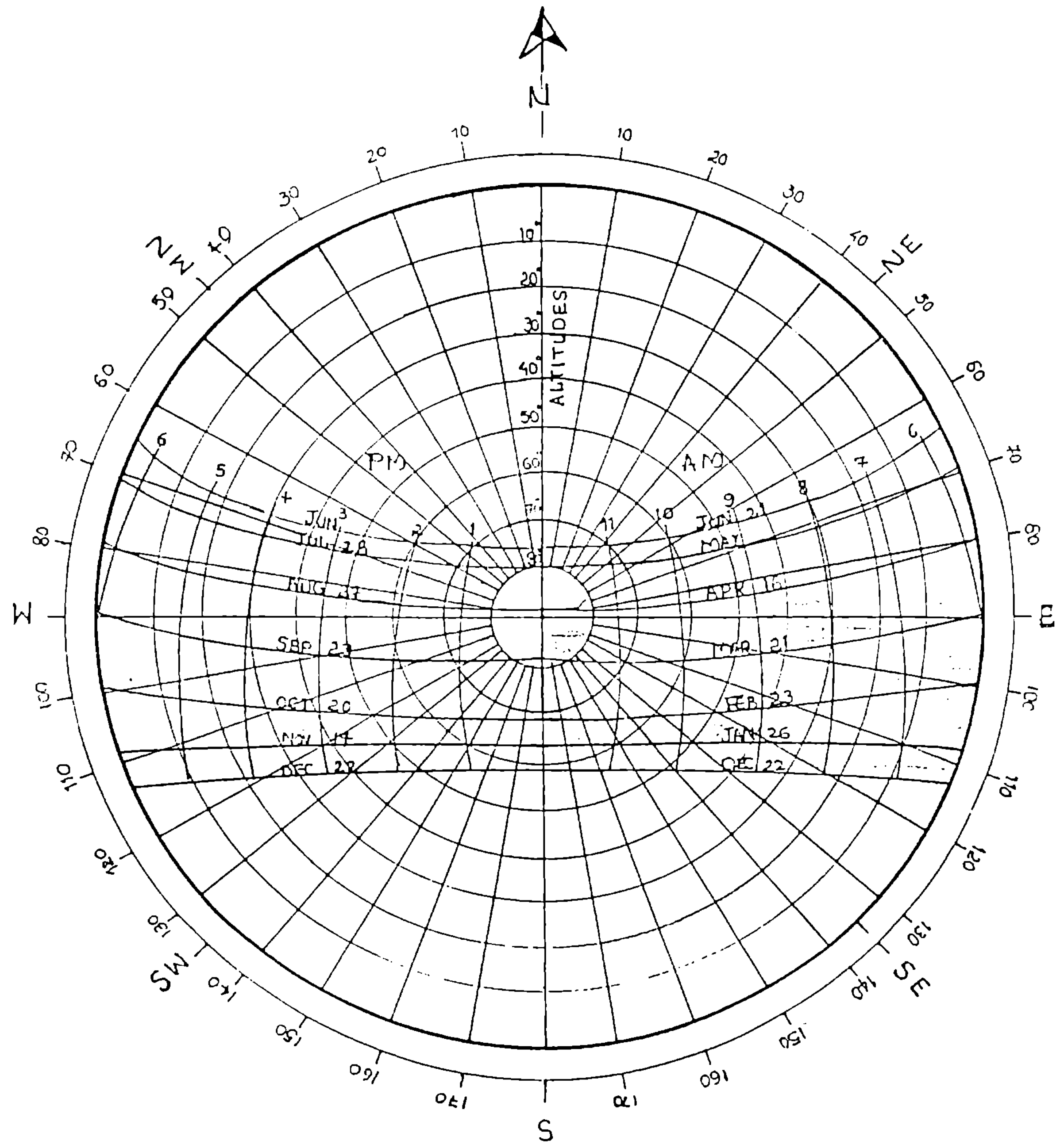


FIG - 5 .3. SOLAR CHART FOR (COCHIN) LATITUDE 9° NORTH uncomfortable, particularly since the humidity is very high. Hence, southward slopes in a hilly terrain as in the eastern lowhills of the study area are less suitable for human occupation being exposed to the sun for about 8 months annually (Kukreja, 1978).

The relative humidity, which is a major determinant of human comfort, is minimum during January followed by December, February, March, April and November with about 68%, 71%, 72%, 74 %, 75 % and 78% respectively (Table 5.1). Maximum humidity is observed during July, August and June with about 89%, 88% and 88% respectively. The hottest months of the year is April with a daily maximum of 31.4 ° C with a diurnal variation of about 6° C and coolest month of the year is July with maximum 28.1 ° C and minimum 23.7 ° C (Menon and Rajan, 1989). It can be said that the study area is free from winter season and has only rainy season and summer season.

Since the relative humidity is very high, maximum ventilation is to be ensured while urban colonies are designed. The buildings are to be oriented so as to obtain maximum ventilation in relation to wind direction during the most humid and hottest months. Also, buildings are to be designed with minimum incidence of sunrays on the south sidewalls or appropriate shade trees are to be planted on the southern side of buildings.

5.3.2. Microclimate

Microclimate is the precise climatic condition in a locality, i.e., it refers to the more immediate climate experienced by specific areas within the region. The various localised conditions, which affect microclimate, are identified as follows (Fig.5.4).

The study area has a seashore of 17.5 kms. This shoreline is continuously exposed to (1) salt sprays from the sea, (2) a high albedo from the white sand and water surface and (3) very high daytime temperatures radiated from the hot sand. Also, the atmosphere is extremely humid. All these make the zone microclimatically distinct resulting in a characteristic ecosystem.

The coastal plain lies to the east of the shoreline. It has a micro-climate characteristic of such areas with the presence of direct sea breeze, high humidity and very low diurnal variation in temperature and humidity, but with lesser albedo and atmospheric salt content compared to the seashore area.

The hill tract lies along the eastern parts of the study area. The four distinct characteristics of the hill tract have profound influence on the microclimate.

(i). Relief.

The higher elevations are more exposed to wind action. Since the hills are very low and the ridge line is not continuous, most of these regions get either direct or indirect sea breeze except the upper (northern) reaches

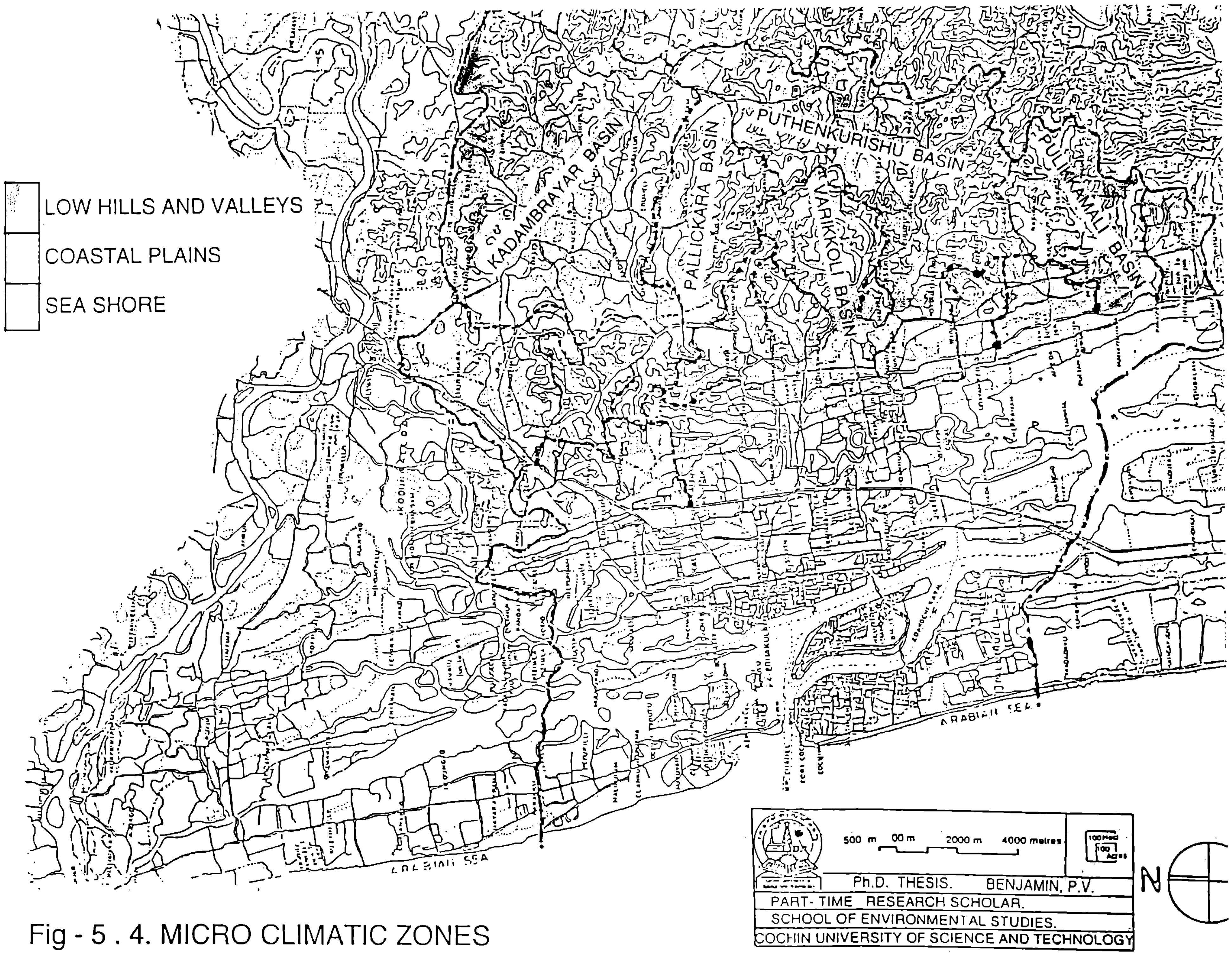


Fig - 5 . 4. MICRO CLIMATIC ZONES

of the Puthencruz basin which is sheltered on the west from the sea breeze by the continuous (about 15 kms long) hill tract from Arakkapady to Sasthammugal (Fig.5.4). This hill tract runs in a north-south direction with an opening at the southern end (Sasthammugal) only. Such a sheltered condition from sea breeze as well as absence of waterbodies provides this area with a sharp diurnal variation in temperature in non-monsoon months. Also, such a physiographic condition prevents to a certain extent the polluted air from Ambalamugal-Karimugal industrial area, lying on its west, from entering this sheltered area during daytime. During the nighttime the wind direction is mostly towards south, southwest and west and hence the area remains comparatively free from pollution though very close to the Industrial belt. Hence, this part of study area is better suited for future expansions of urban settlements, with other economic and infrastructural considerations due.

(ii). Aspect.

Aspect is the orientation of the slopes of a hill. The aspect of the ground and its angle of slope have an important bearing on the amount of sun's radiation it receives at different seasons and hence the microclimate.

(1) South slope: - Since Cochin lies at about 9° N, for about 8 months in a year, the sun will be towards the south (Fig.5.3) and hence, the southern slopes of hills receive more concentrated solar rays for most part of the year and thereby becoming warmer than flat terrain.

(2) North slope:- Coldest slope for most of the year

(3) East slope: - Warm and sultry mornings and mild afternoons

(4) West slope: - Cold mornings and hot and windy afternoons.

Northwest, north, northeast and east aspects are the most ideal for residential development in the eastern low hills region of the study area, from the solar radiation point of view.

(iii). Altitude.

Increase in the altitude results in the reduction of temperature by about 0.6° C for every 100m. This will have considerable ecological effect. In the study area, the maximum level difference is only about 115 m above MSL and hence, altitude is not an important climatic element.

(iv). Vegetation.

Vegetation has profound influence on the microclimate at a local level when small areas are considered. But in the study area, covered more or less uniformly with vegetation, zoning based on vegetation cover is not possible and hence excluded.

5.3.3. Air Pollution Climatology

The following meteorological parameters were considered in the assessment of air pollution distribution pattern in the study area. The direction and speed of the transport of air pollutants as well as its dilution are mainly governed by the wind. Based on wind data (Fig.5.1) and mixing height characteristics mainly within the Cochin corporation area (Anilkumar, 1986), and monthly mean concentrations of different air pollutants from 16 stations (Fig.5.5 & Table 5.2) during 1990 (NEERI-Report, 1991) the air pollution scenario for the study area is worked out.

Road traffic and industries are the major pollution sources in the study area. Automobiles are significantly contributing to the air pollution; about one hundred thousand vehicles are said to be scooting in and around Cochin daily.

The major industries in Cochin are located in 2 clusters (Fig.5.7) - one at Ambalamugal - Karimugal area and the other at the Udyogamandal - Kalamasserry - Edayar area. The main industries in the first cluster are – Hindustan Organic Chemicals, Fertilizers & Chemicals Travancore Ltd., Milma Dairy Ltd, Carbon & Chemicals Ltd., Traco Cables Ltd., Cochin refineries Ltd. and Brahmapuram thermal power plant. The main industries in cluster 2 are Hindustan Insecticides Ltd., Indian Rare Earths Ltd., Travancore Cochin Chemicals Ltd., Premier Tyres Ltd., Chackolas Spinning & Weaving mills, Carborundum Universal Ltd., Travancore chemical Manufacturing Co.Ltd., Kerala Acids & Chemicals Ltd., Sreechitra Mills, Indian Aluminium Co.Ltd., Periyar Chemicals Ltd., United catalyst India Ltd., Cominco Binani Zinc Ltd., Fertilizers & Chemicals Travancore Ltd and Hindustan Machine Tools Ltd.

Some of these industries release large quantities of air pollutants and their dispersion is a function of the following aspects.

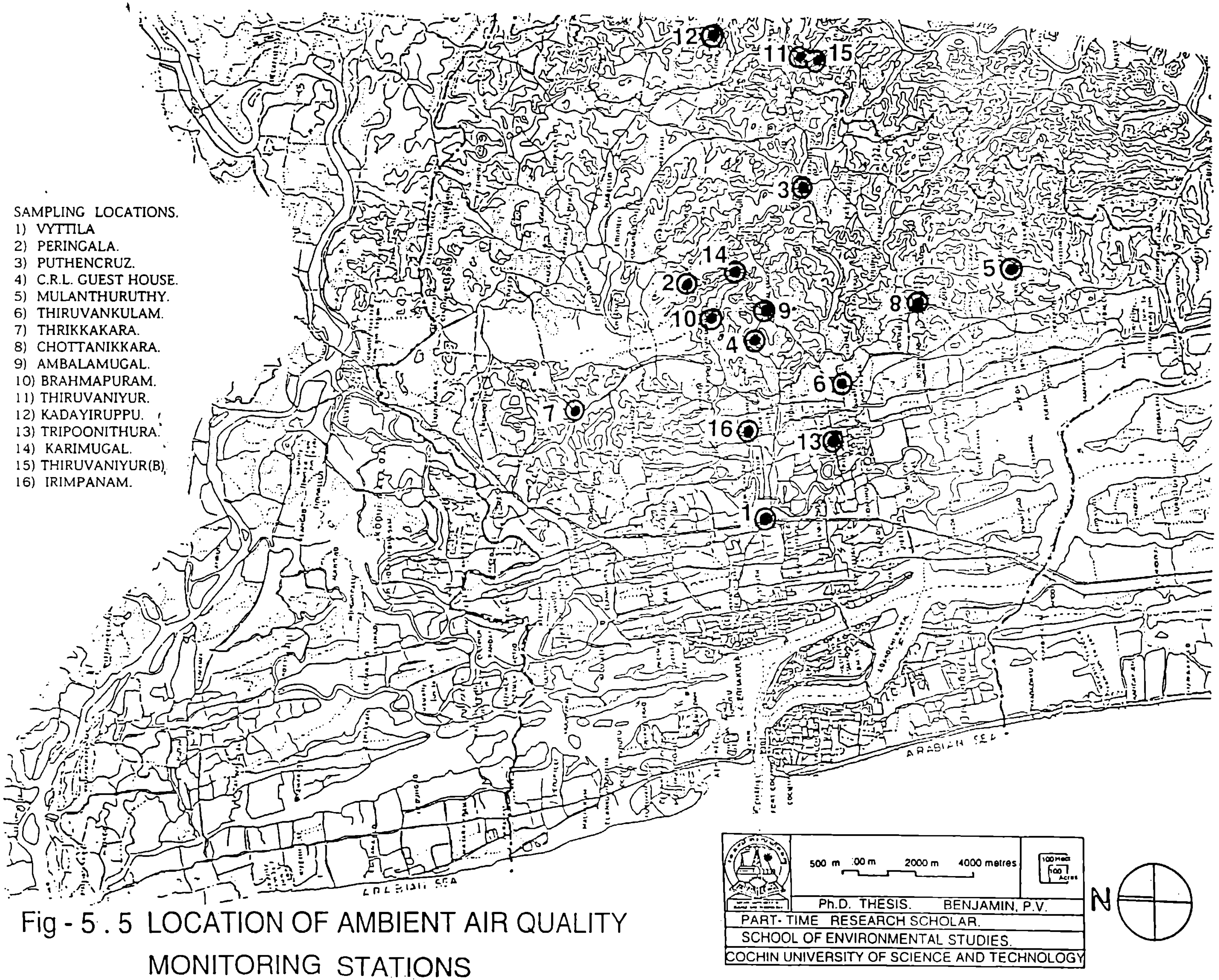


Fig - 5 . 5 LOCATION OF AMBIENT AIR QUALITY MONITORING STATIONS

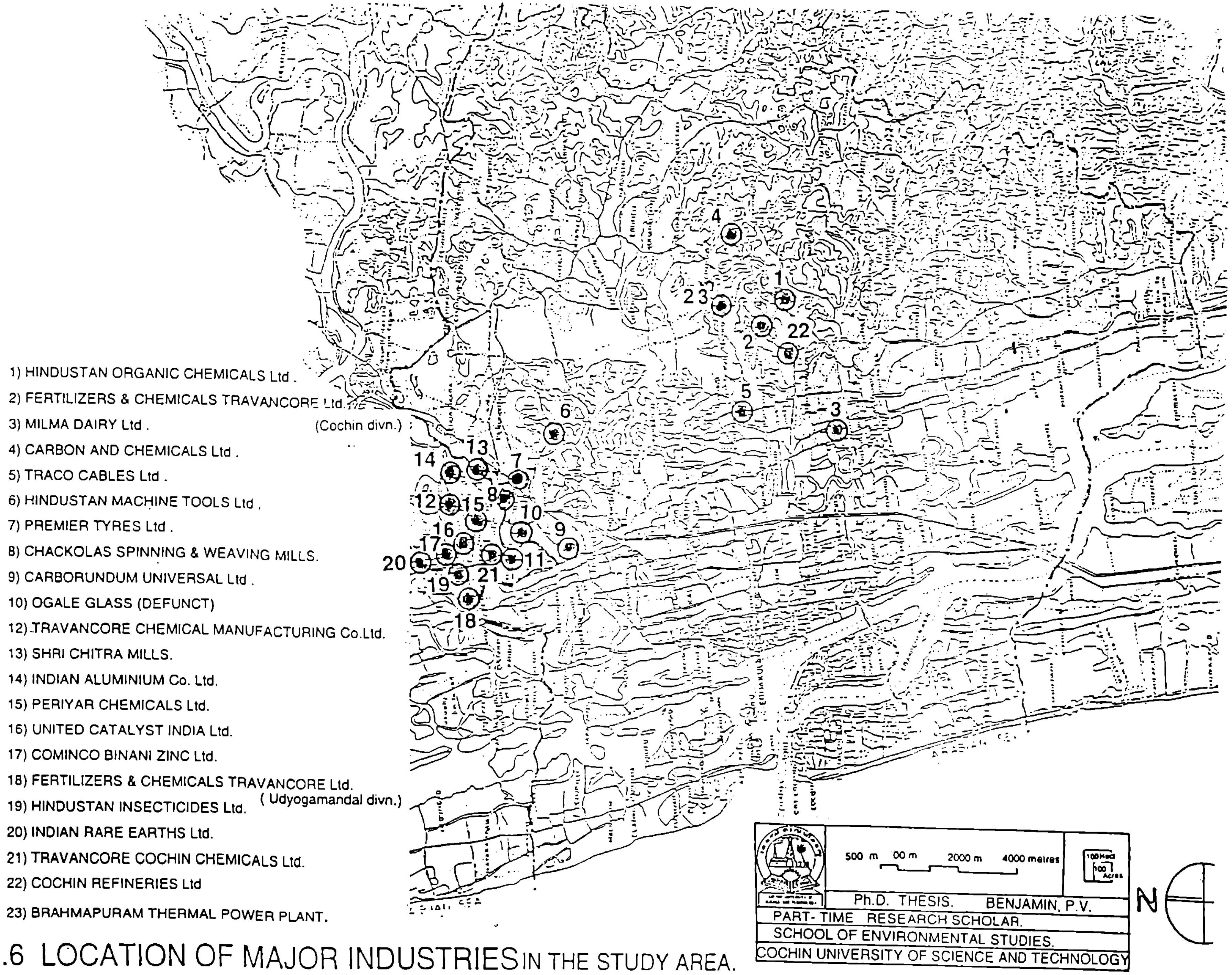


Fig - 5 .6 LOCATION OF MAJOR INDUSTRIES IN THE STUDY AREA.

TABLE 5.3 (a) DIURNAL VARIATION OF SO_2, NO_2, AND NH_3. 8 hr. Avg. Unit $\mu g/M^3$.

WINTER

SL. NO	SAMPLING LOCATION	TIME PERIOD (hr.)								
		1000 - 1800			1800 - 0200			0200 - 1000		
		SO_2	NO_2	NH_3	SO_2	NO_2	NH_3	SO_2	NO_2	NH_3
1	VYTTILA	8	5.5	30.7	9.5	15.7	26.2	8.7	4.5	19.2
2	PERINGALA	6	3.7	5.2	6	6	34.5	6	5.5	25
3	PUTHEN CRUZ	7	4.7	29.7	6	6.5	50.7	6	17	118.3
4	C.R.L. GUEST HOUSE	7.7	3.2	252.7	6	4.5	63.7	6	3.7	29.5
5	MULANTHURUTHY	6.3	3	10.3	6	5.7	20.7	6	3.7	6.7
6	THIRUVAMKULAM	10.2	7.7	29.7	6.5	11.2	40	7.7	6	60.2
7	THRIKKAKARA	7.5	4.2	30	6	5.7	15	6	4.2	21.5
8	CHOTTANIKKARA	6.7	3	23.5	6	3	8.7	6.5	5	11.2
9	AMBALAMUGAL	11.7	3.2	23	7.5	4	32.7	7.3	5	23.5
10	BRAHMAPURAM	8.5	3	50	6	9	47.6	6	12.3	37.5
11	THIRUVANIYUR	6	3	45	6	6	32.5	7	5.5	18.2
12	KADAYIRUPPU	7	4	5	5.7	3.3	5.3	6	7.6	23.6
13	THRIPUNITHURA	7	3	33.7	5.7	15.7	45	6	43.7	43.5
14	KARIMUGAL	15.5	4.5	63.7	32.5	5	32.3	6.2	5	19.7
15	THIRUVANIYUR (B)	10.2	6	39	6.2	8.6	40	6	6	27.5
16	IRIMPANAM	7.5	4.2	11	6	5.7	23.7	6.7	4.7	27.5

TABLE 5.3 (b) DIURNAL VARIATION OF SO_2, NO_2, AND NH_3. 8 hr. Avg. Unit $\mu g/M^3$

SUMMER

SL. NO	SAMPLING LOCATION	TIME PERIOD (hr.)								
		1000 - 1800			1800 - 0200			0200 - 1000		
		SO_2	NO_2	NH_3	SO_2	NO_2	NH_3	SO_2	NO_2	NH_3
1	VYTTILA	6	10	94	8	10	82	12	11	80
2	PERINGALA	7	6	64	8	8	70	13	10	101
3	PUTHEN CRUZ	6	6	42	8	9	50	7	13	56
4	C.R.L. GUEST HOUSE	14	6	145	16	9	102	20	10	67
5	MULANTHURUTHY	7	6	55	9	8	48	9	11	42
6	THIRUVAMKULAM	8	7	51	12	8	44	16	10	82
7	THRIKKAKARA	8	6	67	10	7	50	14	8	32
8	CHOTTANIKKARA	6	6	67	6	8	56	6	12	45
9	AMBALAMUGAL	9	7	64	20	8	82	15	9	44
10	BRAHMAPURAM	6	6	55	6	7	32	6	8	42
11	THIRUVANIYUR	7	6	42	12	8	53	14	8	31
12	KADAYIRUPPU	6	7	16	6	8	11	6	10	18
13	THRIPUNITHURA	8	8	34	18	12	29	25	18	73
14	KARIMUGAL	7	6	39	16	7	44	22	8	16
15	THIRUVANIYUR (B)	7	7	18	8	9	24	8	16	25
16	IRIMPANAM	7	7	15	9	8	36	12	12	39

TABLE 5.3 (c) DIURNAL VARIATION OF SO_2, NO_2, AND NH_3. 8 hr. Avg. Unit $\mu g/M^3$

POST MONSOON

SL. NO	SAMPLING LOCATION	TIME PERIOD (hr.)								
		1000 - 1800			1800 - 0200			0200 - 1000		
		SO_2	NO_2	NH_3	SO_2	NO_2	NH_3	SO_2	NO_2	NH_3
1	VYTTILA	6.75	7.9	21	7	10.5	41.5	6	15.7	24.3
2	PERINGALA	6	3	17.7	6	4.5	10.2	6	3.5	23
3	PUTHEN CRUZ	6.05	4.75	29.55	6	4.25	11.55	6	4	27.7
4	C.R.L. GUEST HOUSE	10	5.5	65	6	3.75	50.05	6	5.25	50.2
5	MULANTHURUTHY	6	5.3	66.6	6	8.3	36.6	6	4.5	45
6	THIRUVAMKULAM	6.16	5.5	66.6	6	3.25	48.75	6	5.5	73.3
7	THRIKKAKARA	6	4	24	6	4.3	12.6	6	3.3	8
8	CHOTTANIKKARA	6	4.5	77.7	6	5.5	44	6	5.5	60
9	AMBALAMUGAL	6	3	46.5	6	4.5	38.5	6	3	23.7
10	BRAHMAPURAM	6	3.75	64.25	6	5	49.2	6	5.5	42.2
11	THIRUVANIYUR	6	3	71.7	6	3.5	52.2	6	3	17.5
12	KADAYIRUPPU	6	3	34.6	6	4	16	6	3	17.6
13	THRIPUNITHURA	6.5	4	23.5	6	8.6	24.6	6	6.6	20.3
14	KARIMUGAL	19.5	4	33.7	6	6	30.8	6	4.25	18.4
15	THIRUVANIYUR (B)	6	4.75	31.75	6	8.25	40.2	6	3	33
16	IRIMPANAM	6	3	21	6	3.75	57	6	3.5	59.2

1. General Climatological Factors
2. Physiographical aspects which influence the wind pattern and hence the distribution pattern.
3. Controlling factors at the source such as measures taken to control pollutant emissions and stack height of chimneys.

The pattern of pollutant distribution is assessed in relation to wind climatology and physiography of the area. An important factor in the pollution climatology is the direction of the wind when the speed is minimum i.e., during night and early morning hours.

The winds are mostly from west (westerlies) during daytime and carry pollutants towards east or southeast during daytime (Fig.5.1). The night time winds are either absent or very weak north-easterlies (Figs.5.1 & 5.8) and hence pollutants are not transported to long distances resulting in the accumulation of pollutants in the vicinity of source. Although during South-west monsoon months the day as well as night time winds are towards east, the pollution levels are low due to the scrubbing effect of the rains.

The continuous unidirectional (mostly westerlies) wind during day-time results in the dispersion of pollutants in mostly in an easterly direction only. This could have created serious air pollution in the localities east of the industrial clusters.

However, due to the unique physiographical feature of the hill tract running in a more or less north-south direction perpendicular to the direction of the day wind, there is continuous upward thrust for the wind when it

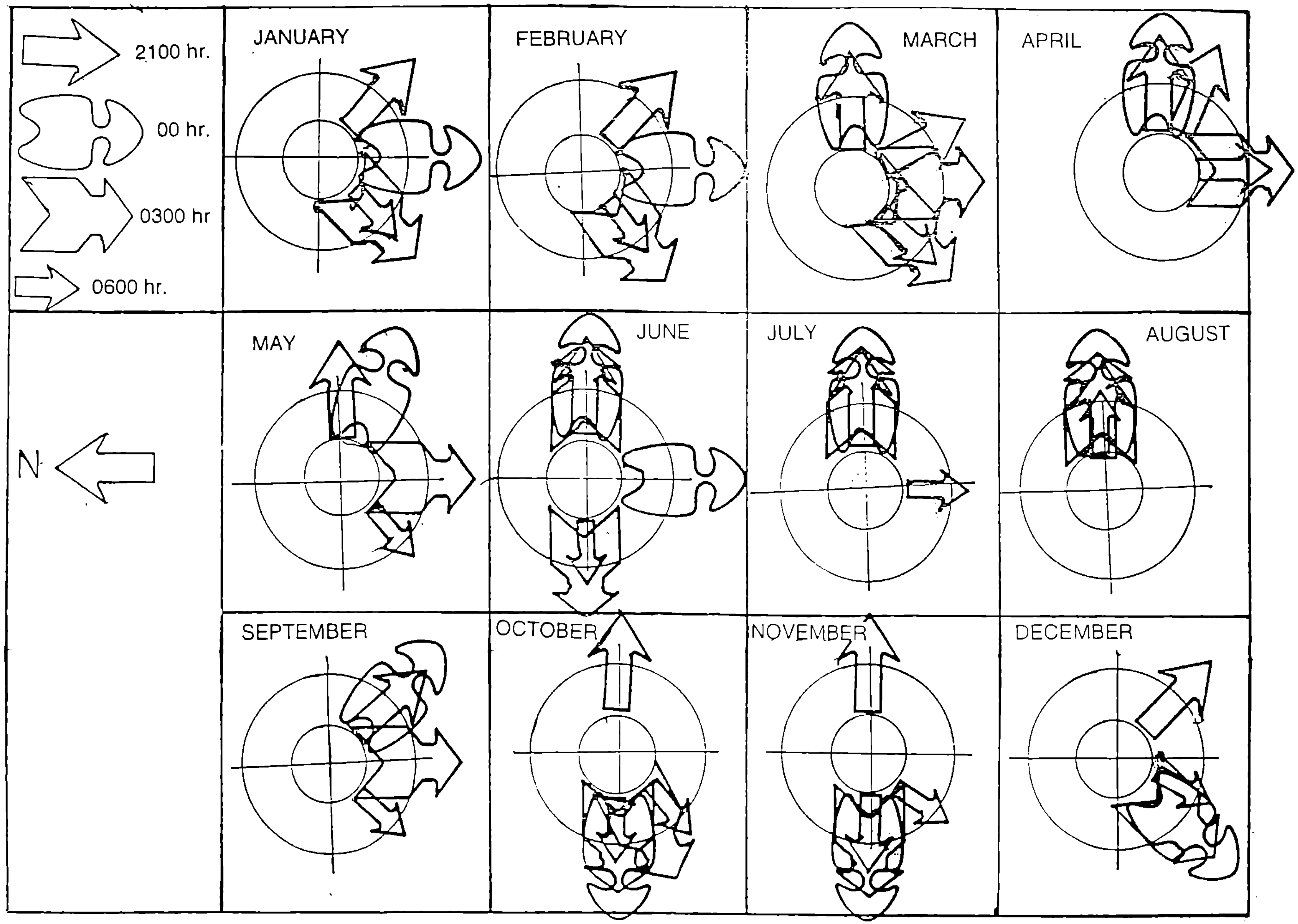


FIG - 5 . 7 . PREDOMINANT NIGHT WIND DIRECTIONS comes close to the ridges. This together with the high wind velocity keeps the polluted air from reaching the ground level, protecting the human population in the valleys of the hill tracts during daytime. Further the high wind velocity facilitate the fast dilution of the pollutants.

During night-time, winds are either absent or blow weakly towards S and SW direction during Jan- Feb; SE, S and SW during September; E, SE, S & SW during Mar & May; E, SE & S during April; E, S & W during June, October & November; E during July, August and SW during December.

Pollution hazard will be maximum during inversions or isothermal conditions which inhibits the dispersion of pollutants resulting in high ground level concentrations. In Cochin, such conditions are maximum during December, January and February (Anilkumar, 1986). Thus the areas in the direction of night wind during these months in relation to the major industrial pollution sources Ambalamugal Karimugal area and Eloor-Kalamassery area - will have considerable increase in atmospheric pollution. Hence, most of the densely populated areas in the western flatland in the proximity of pollution sources are high-risk areas both in the case of normal industrial pollution or during a disaster (as happened in Bhopal). The consequences of an industrial disaster can be severe particularly during the calm nights of winter months when dispersion of pollutants is minimum and ground level concentrations maximum. Such zones lie in South and Southwest side of both the industrial areas.

This study reveals that the place most safe from pollution is the upper reaches of Kadambrayar, Puthencruz, Churnikkara and Pallikkara basins (Fig.5.4). Also, during daytime, when strong winds blow towards east, these areas will have lesser pollution, which is due to following reasons. (1) There will be thorough mixing and hence dilution when winds are strong and (2) during daytime when winds blow towards east, these areas will be on the leeward side of the ridge hills which separates them from the pollution sources. Kanjiramattom, Pulikkamaly, Churnikkara and Thrikakkara East basin are also safer when compared to western flatland area. From a pollution point of view, the Panchayats lying in these sub-basins suitable for urban development are Vengola, Kizhakkambalam, Edathala, Churnikkara, Kunnathunadu, Thrikkakara, Aikkaranadu, Poonithura, Maneed, Edakkattu-vayal, Amballoor, Mulamthuruthy, Chottanikkara and part of Vadavukodu-Puthencruz. However, some parts of these Panchayats lying in the south of Ambalamugal-Karimugal industrial cluster may be subjected to occasional pollution problems since the night-time wind direction is towards that side.

Besides these, some areas far off from the pollution sources such as Udayamperoor, Kumbalam and Chellanam Panchayats and Cochin taluk areas of Cochin Corporation as well as the areas free from the night-time wind direction such as Nayarambalam, Kadamakkudy and Elamkunnapuzha panchayats may also be free from air pollution from major industries within the study area.

5.4. Summary and Conclusion

Cochin is a fast-developing industrial metropolis lying in central Kerala, the southern state of India. Being a tropical coastal settlement, the annual and diurnal variation in temperature and humidity is not very significant. It can be said that the study area is free from winter season and has only rainy season and summer season.

The study area enjoys a vigorous Southwest monsoon season and a mild North-east monsoon with an yearly average rainfall of about 300 cms. Since the rainy season extends to about 6 months, drainage is very important particularly when urban settlements are developed. Not only that, since there is continuous rain during rainy season any modification of the land surface without due consideration to the rainfall climatology, is likely to cause denudation in the eastern sloped terrain due to erosion and waterlogging in the flat areas.

Since Cochin lies at about 9° N, for about 8 months in a year, the sun will be towards the south and hence, the southern slopes of hills receive more concentrated solar rays for most part of the year and thereby becoming warmer than flat terrain. Hence, south slopes in a hilly terrain as in the eastern lowhills of the study area are less suitable for human occupation. Northwest, north, northeast and east aspects are the most ideal for residential development in this region from the solar radiation point of view.

The relative humidity also is very high making it necessary to have human settlements with appropriate orientation and ventilation so as to obtain maximum ventilation in relation to wind direction particularly during the most humid and hottest months. Also, buildings are to be designed with minimum incidence of sunrays on the southside walls without which appropriate shade trees should be planted.

Cochin is the industrial capital of Kerala. The major industries are located in 2 clusters in the study area - one at Ambalamugal - Karimugal area and the other at the Udyogamandal - Kalamasserry - Edayar area. Some of these industries release large quantities of air pollutants and their dispersion is a function of meteorological and physiographical aspects. An important factor in the pollution climatology is the direction of the wind when the speed is minimum i.e., during night and early morning hours particularly during winter season. Rainfall also is a major determinant in the quality of the ambient air due to the scrubbing effect of rains, which reduces the concentration of atmospheric pollutants.

The winds are mostly from west (westerlies) during daytime and carry pollutants towards east or southeast. During nighttime, winds are either absent or very weak north-easterlies and hence pollutants are not transported to long distances resulting in the accumulation of pollutants in the vicinity of source.

Pollution hazard will be maximum when inversions or isothermal conditions occur, since such a condition blocks the dispersion of pollutants and results in high ground level concentration. Such conditions are found to be maximum during December, January and February in Cochin. Hence the areas in the direction of night wind during these months in relation to the major industrial zones will have considerable increase in atmospheric pollution. Thus most of the densely populated areas in the western flatland are high-risk areas both in the case of normal atmospheric pollution or during a disaster (as has happened in Bhopal).

As far as the location of the existing industries is concerned, the ideal place would have been the extreme south west portion of the study area so that the interior of the city and all the densely populated areas would have been relatively free from pollution. In such a case most of the spread of the pollutants would have been over the ocean.

This study reveals that the places most safe from pollution is the upper reaches of Kadambrayar, Puthencruz, Churnikkara, Pallikkara Kanjiramattom, Pulikkamaly, ~~Churnikkara~~ and Thrikakkara East basins. Also, during daytime, when strong winds blow towards east, these areas will have lesser pollution, which is due to physiographical peculiarities. Besides these, some areas far off from the pollution sources such as Udayamperoor, Kumbalam and Chellanam Panchayats and Cochin taluk areas of Cochin Corporation and the areas free from the night time wind direction such as Nayarambalam, Kadamakkudy and Elamkunnapuzha panchayats may also be free from air pollution from major industries within the study area.

Chapter- 6

Vegetation

6.1. Introduction

Plants have an important role in the preservation of soil as well as moisture conservation. Extensive root system of the vegetation binds the soil particles while the canopy intercepts the rain and thereby reduces the force of falling water. Moreover, abundance of leaf litters results in higher infiltration rates thereby reducing the runoff. A reduction in runoff reduces the siltation in water bodies and thereby conserves its storage capacity resulting in a reduced flood frequency and intensity.

Vegetation has a prominent role in ameliorating microclimate. This is attained by directing the wind, shading the incoming radiation and by evapo-transpiration from the trees. It has been recorded (Federer, 1971) that a single isolated tree by evaporating 400 litres of water per day accounts for about 2,30,000 kilocalories of energy, the equivalent of cooling of five average room air conditioners (each 2,500 kcal/hr) running 24 hours a day. The air conditioners while only shift heat from indoors to outdoor, the evaporation from the trees actually reduces the heat.

Also, vegetation is found to be efficient in noise reduction. In many areas of the metropolitan cities noise levels exceed 120 dB which is the pain threshold level. Even short-term exposure to noise at 150 dB leads to contraction of blood circulation, body exhaustion and nervousness, dilatoriness of the eye, stomach and intestines (Gupta, 1979). A vegetation belt of 130m or more gives significant reduction of noise level (Smith, 1970). Nevertheless, even a relatively narrow strip of plant material in urban areas holds a major potential for noise reduction.

Vegetation plays an important role in pollution reduction by active stomatal absorption of polluting gases as well as providing vast areas of leaves for settling of suspended particulate matter. Decrease in atmospheric turbidity by vegetation has been recorded (Gupta, 1979).

Vegetation can be utilised for economic returns also. Urban forests can be planted in wastelands for timber yield as well as for firewood. Firewood is the source of energy for more than one third of the world population and for many people the real energy crisis is the daily scramble to find wood they need to cook their food.

Besides the above environmental and economic functions, the plants also serve various physical and aesthetic functions like defining boundaries, creating enclosures, making barriers, directing views, providing color in the environment, emphasizing texture of the building walls, providing shade to building, relating buildings to surrounding landscape, giving scale to the building, forming background to structures, creating visual interests in the form of focal points, etc.

Vegetation of any area is determined by different combinations of edaphic, climatic and biotic factors.

Each plant needs a particular soil pH for its best growth and most of the plants prefer neutral to slightly alkaline condition.

Another decisive factor is the water table. If the water table is very high, it will adversely affect the growth of plants by devoiding plants of the necessary soil aeration, which may make the plants, stunted and in extreme cases may lead to the death of the plants. Further, the roots of plants usually never grow below the level of water table. Such a shallow root system can result in uprooting of large trees during strong winds.

Many shrubs and herbs are very susceptible to damage due to flooding. Even two or three days of flooding may cause damage to plants due to water logging and lack of soil aeration while mangrove vegetation needs rhythmic diurnal tidal flooding for its survival. Mangroves are unique plant species by the fact that they are established in the ecotone zone between terrestrial ecosystem and estuarine ecosystem. They are very tolerant to periodic salinity variations and tide-induced root submergence and exposure.

Salinity of the soil, if very high, causes physical dryness in the soil by causing exosmosis from the roots resulting in the death of the plant. Further, near the seashore, salt spray can scorch the leaves of plants. However, there are lots of plants like coconut trees, which are resistant to high soil salinity and sea-salt sprays.

Each climatic condition is best suited for a particular kind of vegetation. Some plants prefer full sun, some prefer semi-shade and some others full-shade conditions. Some plants are adapted to high altitudes while some others prefer low altitudes.

6.2. Methodology

The study of the vegetation was carried out to identify trees, shrubs and climbers of aesthetic and/or economic value to provide information on the germplasm. A field survey in the study area was conducted, herbarium prepared and the plants were identified according to the system of classification followed by George Bentham and Joseph Dalton Hooker in their work GENERA PLANTARUM. Rather than a detailed taxonomic survey, an ecological / environmental planning approach was taken in this study of environmental resources assessment. Hence, only trees, perennial shrubs and perennial climbers are included, since they only have profound influence on the environment.

The plants were morphologically identified by comparing the characteristics with descriptions given in books (Annexure 6.1), being the best and the most convenient method because morphological characters are easily observable in the field itself with a hand lens or dissection microscope or light microscope in the laboratory. Not only that, there is a well-knit terminology to describe morphological variations for differentiating innumerable morphological variations for the identification of species.

Floral characteristics such as inflorescence, type, position, flower symmetry, ovary position, number, size, shape and union of floral leaves in each whorl, their modification and various other associated features and the characters of bracts, bracteoles, and pedicels were used in the identification of species. The characters of fruits and seeds as well as vegetative characteristics also helped in the taxonomic identification of trees, shrubs and climbers of economic, aesthetic or medicinal value.

6.3. Discussion

Natural vegetation of the study area exists in its pristine form in small sacred groves (Sarpakavu) which are religiously retained in old Hindu house compounds and in the mangrove stands on the shorelines of the backwater system. This natural vegetation in the study area coincides with the characters of tropical rainforests (Pandya etal, 1989). According to him, tropical rainforests are characterised by tall, dense, evergreen, broad-leaved trees, lianas and vascular epiphytes and is much stratified. The number of trees is very high.

The vegetation of the area can be classified basically into two types –

1. General vegetation of the area without specifying ecological adaptation,
2. Eco-specific vegetation such as mangroves and beach vegetation.

6.3.1. General Vegetation

In Cochin, altitude-based vegetation difference is negligible since the altitude variation in the study area is less than 115 meters and hence the mesophytic vegetation is more or less uniform throughout the study area even though localised luxuriant or stunted growth is observed depending on edaphic variations. In the eastern lowhills (with lateritic soil, low water table and easy drainage), even though the plants seen in the western flatland also grow, the nature of the growth varies to that extent as dictated by the edaphic difference.

The western flatland, mostly about 1 m above MSL, shows a distinct edaphic condition of clayey / sandy-clay / sandy soil with a very high water table. In this area, the predominant mesophytic vegetation is *Cocos nucifera* (Coconut), *Areca catechu* (Arecanut), *Samadera indica* (Karingotta), *Dipterocarpus indicus* (Pine), *Hydnocarpus wightiana* (Marotty) and bamboo thickets. Most other native mesophytic trees, shrubs and climbers, though identified in the study area, occur very scantily and that too mostly as individual plants. A list of ecologically significant plants (trees, shrubs, and woody climbers) are given in Annexure 6.1.

A large prevalence of exotic trees is observed both in the eastern lowhills and western coastal plain (Annexure 6.2). Natural regeneration seems to be very low for the native plants as young plants and seedlings of native trees are rarely met with during field reconnaissance survey, except for a few species. If this trend continues, the alien species are likely to replace the native species from the scene as they now occur only as isolated patches or individually with very low regeneration capacity. This is environmentally very undesirable since birds and animals in the area are ecologically adapted to the native vegetation and this kind of transformation to alien vegetation is sure to upset the food chain and thereby the ecosystem, though the quantification of the damage is not possible. Hence, it is suggested that, as far as possible, the planting of native species must be recommended in urban aesthetic planting schemes instead of going for the ephemeral beautiful flowers of the alien species with due consideration to aesthetic appeal.

6.3.2. .Shoreline vegetation

A zone-wise study was attempted along the shoreline since the nature of vegetation is found to change even within a few meters away from the backwater as well as the sea.

The shoreline of Cochin can be broadly divided into seashore and shorelines of the backwaters including tidal canals. These shorelines differ in their exposure to furies of nature and hence develop different kinds of vegetation.

6.3.2.1... Vegetation of the backwater shores (Mangrove and associated vegetation)

This exists in patches in the shorelines of the backwater system, particularly, in the intertidal areas (Fig.6.1). These plants, that once relentlessly protected the shores, are now being destroyed to residual remnant stands.

The plants are found to reveal remarkable zonation even within few tens of meters from the backwater system. In the waterward and landward edges of intertidal areas (Zone I), vegetation is found to be exclusively mangrove species, whereas in the areas above the high tide level (Zone II)

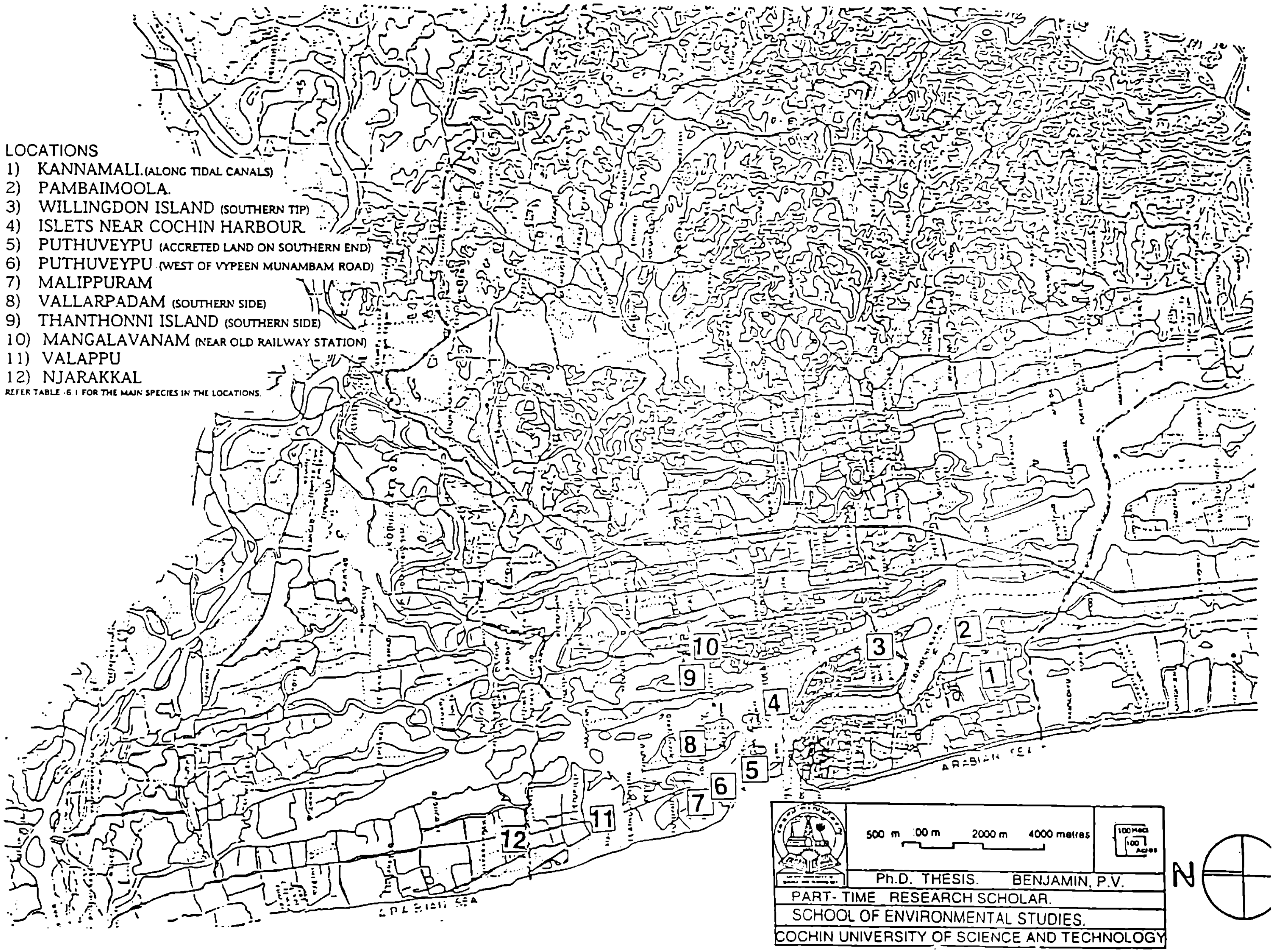


Fig - 6 .1. LOCATION OF MANGROVES IN THE STUDY AREA.

remnants of mangrove species along with mesophytic vegetation are found to co-exist.

Zone I Intertidal areas.(Mangrove Vegetation)

1. *Bruguiera cylindrica* - tree.
2. *Bruguiera gymnorhaza* - *tree*
3. *Rhizophora mucronata* - tree.
4. *Acanthes ilicifolius* - Shrub
5. *Avicennia officinalis* - Tree
6. *Candelia cylindrica* - Tree
7. *Carallia integerrima* - Tree
8. *Excoecaria agallocha* - Tree
9. *Pandanus spp* - Tree
10. *Sonneratia caseolaris* - Tree
11. *Clerodendron inerme* - Shrub

Zone II Land just above high tide level

1. *Acanthes ilicifolius* - Shrub
2. *Adenanthera pavonia* - Tree
3. *Ailanthus malabaricum* - Tree
4. *Anacardium occidentale* - Tree
5. *Artocarpus heterophylla* - Tree
6. *Artocarpus Integrifolia* - Tree
7. *Artocarpus hirsuta* - Tree
8. *Bambusa* spp. - Tree
9. *Barringtonia recemosa* - Tree
10. *Calophyllum ionophyllum* - Tree
11. *Cerbera odollum* - Tree
12. *Cocos nucifera* - Tree

13. *Dendrocalamus* spp. - Climber
14. *Eugenia jambolana* - Tree
15. *Hibiscus tiliaceous* - Tree
16. *Hydnocarpus wightiana* - Tree
17. *Mangifera indica* - Tree
18. *Nerium odorum* - Shrub
19. *Odina wodier* - Tree
20. *Oroxylum* spp. - Tree
21. *Pithecolobium saman* - Tree
22. *Sapindus laurifollius* - Tree
23. *Spondias mangifera* - Tree
24. *Terminalia catapa* - Tree
25. *Thespesia populnea* - Tree
26. *Thevetia nerifolia* - Shrub
27. *Vateria indica* - Tree
28. *Vatica* spp. - Tree
29. *Vitex negundo* - Shrub

Not only the mangrove trees prevent soil erosion, but they also aid in the building up of land in the following way. Some early successional species of the waterward side extend even to a depth of about one meter into the water. The intermeshing of proproots of these trees along with the pneumatophores (breathing roots) collect suspended particles in water and result in the gradual formation of land. The thick mesh of roots prevents any chances of erosion also.

Also, the shallow water protected by the intertwining prop roots of the mangrove trees forms an ideal fish breeding areas (Liberero, 1984). Mangrove trees have a significant role in the production of food for fishes in coastal waters. It is estimated that (Odum, .1976) mangrove trees produce about one metric ton of dry organic matter / hectare / year in the form of leaves which fall into the water and slowly disintegrate to form food for small fishes and other small aquatic animals, which in turn form food for large fishes. Also, the mangrove ecosystem forms ecotone with edge effect resulting in the maximum productivity of aquatic life and species diversity. Mangrove forests form a protective zone in the shallow areas in the backwaters, which is an ecological edge.

Removal of this protective zone for developmental purposes, as was done in most of the backwater shorelines of Cochin, has caused serious erosion problems and might have contributed substantially to the decline of fish productivity. It is reported that destruction of mangrove forests lead to the reduction in production of food for aquatic life (Odum, 1976).

Also, these stands of mangrove trees, with their proproots protect coastal area from severe storm. The mangrove trees also provide firewood if selective cutting is done without upsetting the system.

The shorelines of the inland waterways of Cochin are prone to erosion due to the removal of mangrove forests, which once protected the shorelines from erosion. The stabilization of the shore is important both to prevent loss of land by erosion and also for prevention of silting up of waterbodies, which affect water navigation particularly in the case of tidal canals.

The mangrove vegetation in the study area is under severe threat from firewood collectors and by extensive backwater reclamations by land developers and agriculturists. Hence, there should be not only legislative measures for the preservation of existing mangroves but also mangroves should be grown in low-lying wastelands adjoining backwaters. New mangrove plantations can be developed by the following inexpensive method.

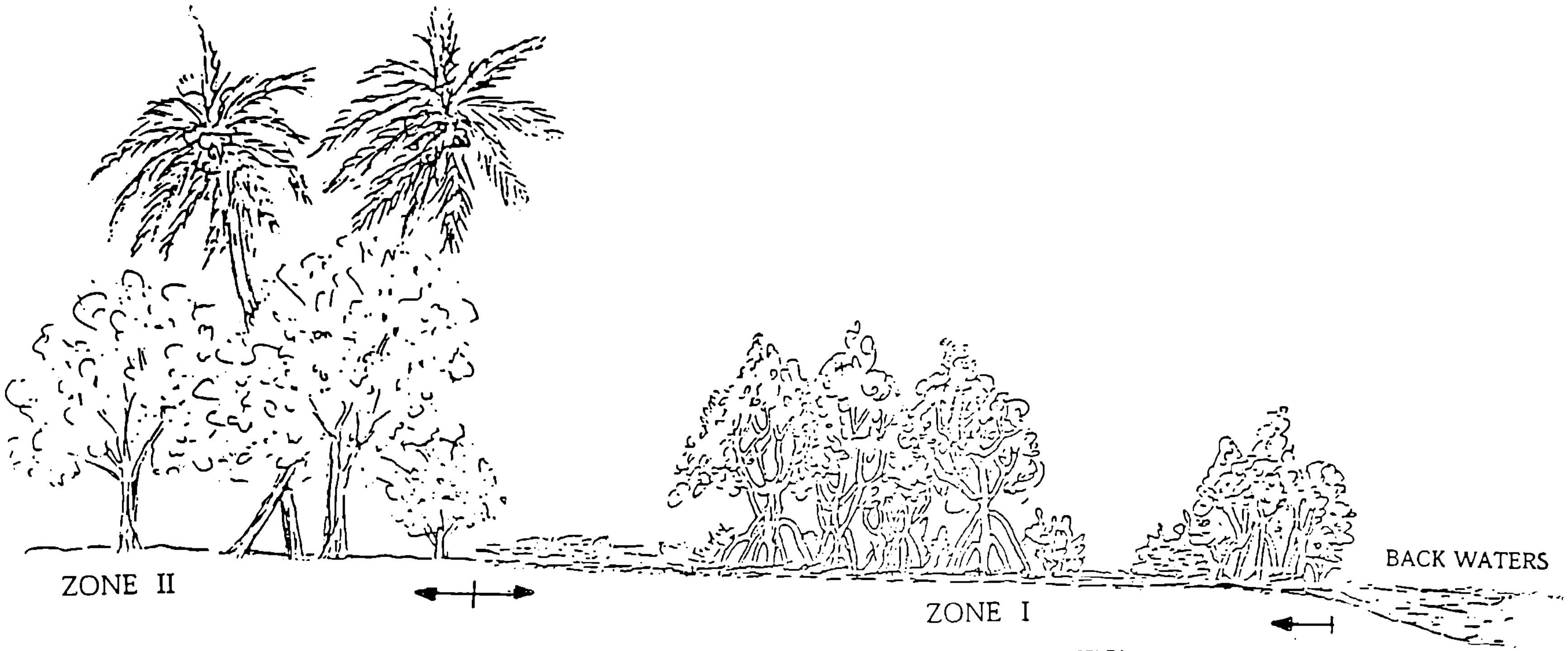
The seeds of viviparous mangrove trees germinate while on the tree itself and fall down after sprouting after developing anchoring roots. Such germinated seedlings collected without damage from mangrove forest areas should be preserved in estuarine water for sowing on mud flats exposed during low tides. The sowing is best done when the tides are at their lowest and water has drained off so that seedling do not drift away. The seedlings anchor in the mud flats and put forth supporting roots within one year and attain about 2 meters height in 2 years producing pneumatophores which bind the mud. The seedlings require no maintenance and no watering. In the estuarine regions of Cochin, *Rhizophora mucronata* and *Bruguiera roxburghiana* are the two species of mangrove vegetations suitable for this kind of propagation. Also, in planting programmes, selection of species conducive to the natural zones will ensure maximum survival of the plants.

6.3.2.2. Beach Vegetation.

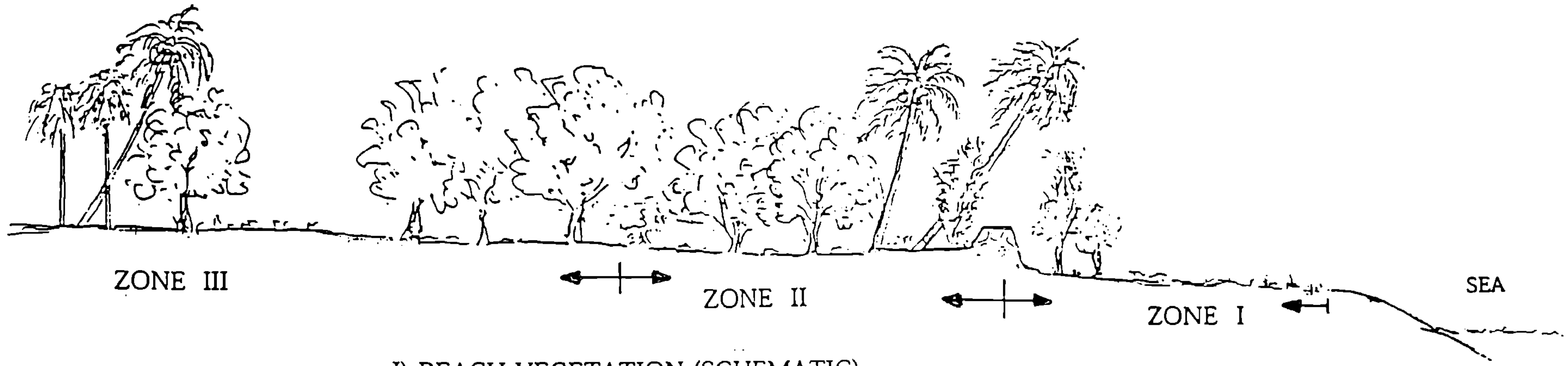
Field survey of the beach zone vegetation in the study area from Njarackal in the north to Chellanam (Fig.6.2) in the south was carried out.

TABLE - 6 . 1. MAIN LOCATIONS OF MANGROVES IN THE STUDY AREA

Sl.No	Location	Main species
1	KANNAMALI. (ALONG TIDAL CANALS)	Rhizophora mucronata, Acanthus ilicifolius, Avicennia officinalis, Bruguiera cylindrica, Bruguiera gymnorrhiza,Cerbera odallam,Thespesia populnea Excoecaria agallocha.
2	PAMBAI-MOOLA	Acanthus ilicifolius, Avicennia officinalis, Rhizophora mucronata, Thespesia populnea.
3	WILLINGDON ISLAND (SOUTHERN TIP)	Avicennia officinalis, Acanthus ilicifolius, Rhizophora mucronata.
4	ISLETS NEAR COCHIN HARBOUR	Rhizophora mucronata, Avicennia officinalis, Excoecaria agallocha, Clerodendron inerme, Acanthus ilicifolius, Pithecolobium saman, Ipomoea palmata.
5	PUTHUVEYPU (ACCRETED LAND ON SOUTHERN END)	Avicennia officinalis, Excoecaria agallocha, Clerodendron inerme, Acanthus ilicifolius,.
6	PUTHUVEYPU (WEST OF VYPEEN MUNAMBAM ROAD)	Acanthus ilicifolius, Excoecaria agallocha, Avicennia officinalis, Rhizophora mucronata, Bruguiera cylindrica, Bruguiera gymnorrhiza, Clerodendron inerme, Thespesia populnea,
7	MALIPPURAM	Acanthus ilicifolius, Clerodendron inerme, Bruguiera cylindrica, Excoecaria agallocha, Avicennia officinalis, Cerbera odollam, Thespesia populnea.
8	VALLAR-PADAM ISLAND (SOUTHERN SIDE)	Rhizophora mucronata, Avicennia officinalis, Acanthus ilicifolius, Sonneratia caseolaris, Thespesia populnea, Bruguiera gymnorhiza, Bruguiera cylindrica,Clerodendron inerme.
9	THANTHONNI ISLAND (SOUTHERN SIDE)	Avicennia officinalis, Acanthus ilicifolius, Rhizophora mucronata, Bruguiera cylindrica
10	MANGALA VANAM (NEAR OLD RAILWAY STATION)	Avicennia officinalis, Rhizophora mucronata,Acanthus ilicifolius, Pithecolobium saman.
11	VALAPPU	Rhizophora mucronata, Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha, Acanthus ilicifolius, Clerodendron inerme.
12	NJARAKKAL	Rhizophora mucronata, Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha, Acanthus ilicifolius,Clerodendron inerme,Thespesia populnea.



II) VEGETATION OF BACK WATER SHORES (SCHEMATIC)



I) BEACH VEGETATION (SCHEMATIC)

Fig - 6. 2. VEGETATION ALONG BEACH AND BACK WATER SHORES

The study revealed that vegetation in the area shows zoning pattern or the existence of plants in belts parallel to coastline. Roughly three belts are distinguishable.

Zone I

These are the front rows of plants inhabiting the highly saline soil of the coastal area, exposed to salt spray and sand blasting due to fierce winds. The following plants are found to grow successfully in this zone.

1. *Acacia auriculiformis* - Tree
2. *Adhathoda vasica* - Shrub
3. *Agave americana* - Shrub
4. *Agave victoria-reginae* - Shrub
5. *Arundodonax sp.* - Shrub
6. *Casuarina equisetifolia* - Tree
7. *Cocos nucifera* - Tree
8. *Dracaena fragrans* - Shrub
9. *Euphorbia tirucalli* - Tree
10. *Hibiscus tiliaceous* - Tree
11. *Ipomoea biloba* - Climber
12. *Morinda tinctoria* - Tree
13. *Muhlenbeckia* - Shrub
14. *Opuntia* spp. - Tree
15. *Pandanus utilis* - Shrub
16. *Solidago canadensis* - Shrub
17. *Spinifix littoralis* - Herb
18. *Vinca rosea* - Shrub
19. *Yuca aloifolia* - Herb

Zone II

This is an area which has plants protected from the flying sand and salt spray by the coastal plants of Zone-I or by natural barriers like sandbanks or sea walls. Plants in this belt tolerate a good deal of salt in the soil and in the air; only that, they require a barrier between them and the open sea. The lee side of the sea wall all along the coast from Njarackal to Chellanam forms the Zone-II. Many of the plants in Zone-I also thrive well in Zone-II. The following plants are found to grow in this zone

1. *Acalypha wilkesiana* - Shrub
2. *Achras sapota* - Tree
3. *Adinum obesum* - Shrub
4. *Alpinea* spp. - Herb
5. Asparagus *plumosus* - Climber
6. *Asparagus* spp. - Climber
7. *Bougainvillaea glabra* - Shrub
8. *Caesalpinia pulcherrima* - Shrub
9. *Callistemon lanceolatus* - Tree
10. *Calotropis gigantea* - Shrub
11. *Carissa carandas* - Shrub
12. *Casuarina equisetifolia* - Tree
13. *Cestrum diurnum* - Shrub
14. *Cocos nucifera* - Tree
15. *Cordyline* spp - Shrub
16. *Delonix regia* - Tree
17. *Dracaena* spp. - Shrub
18. *Elaeis guineensis* - Tree
19. *Erythrina indica* - Tree

20. *Eugenia jambolana* - Tree
21. *Ficus bengalensis* - Tree
22. *Ficus radicans* - Climber
23. *Gloriosa suporba* - Shrub
24. *Hibiscus rosa-sinensis* - Shrub
25. *Hibiscus syriacus* - Shrub
26. *Ipomoea biloba* - Climber
27. *Ixora coccinea* - Shrub
28. *Ixora parviflora* - Tree
29. *Lawsonia alba* - Shrub
30. *Malpighia coccigera* - Shrub
31. *Muntingia calabura* - Tree
32. *Nerium indicum* - Shrub
33. *Polyalthia longifolia* - Tree
34. *Pithecolobium dulce* - Tree
35. *Rhoeo discolor* - Herb
36. *Ricinus communis* - Shrub
37. *Sansevieria trifasciata* - Herb
38. *Terminalia catapa* - Tree
39. *Thespesia populnea* - Tree
40. *Thevetia nerifolia* - Shrub
41. *Vinca rosea* - Shrub
42. *Vitex negundo* - Shrub
43. *Zebrina pendula* - Herb

Zone-III

This Zone lies towards the eastern side of Zones I & II, and is occupied by plants which seems to tolerate mild soil salinity but do not stand the rigors of Zones I & II. Most of the mesophytic vegetation of the study area is found to grow in this zone. The following trees, shrubs and climbers were identified in the area.

1. *Acacia auriculiformis* -Tree
2. *Ailanthus malabarica* - Tree
3. *Allamanda violacea* - Climber
4. *Antigonon leptopus* - Climber
5. *Aralia* spp. - Shrub
6. *Areca catechu* - Tree
8. *Asystasia* spp. - Shrub
9. *Azadirachta indica* - Tree
10. *Bauhinia purpurea* - Tree
11. *Bougainvillea glabra* - Shrub
12. *Caesalpinia pulcherrima* - Shrub
13. *Caesalpinia coriaria* - Tree
14. *Calliandra haematocephala*. - Shrub
15. *Carica papaya* - Tree
16. *Cassia fistula* - Tree
17. *Cassia siamea* - Tree
18. *Ceiba pentandra* - Tree
19. *Clerodendron thomsonae* - Climber
20. *Coleus blumei* - Herb
21. *Eranthemum* spp. - Shrub
22. *Erythrina indica* - Tree
23. *Eucalyptus* spp. - Tree
24. *Ficus bengalensis* - Tree
25. *Ficus pumila* - Climber
26. *Ficus religiosa* - Tree
27. *Ficus retusa* - Tree
28. *Gardenia jasminoids* - Shrub

29. *Glyricidia maculata* - Tree
30. *Hibiscus rosa-sinensis* - Shrub
31. *Hydnocarpus wightianum* - Tree
32. *Ixora coccinea* - Shrub
33. *Jasminum* spp - Climber
34. *Lagerstroemia flos-reginae* - Tree
35. *Lagerstroemia indica* - Shrub
36. *Lawsonia alba* - Shrub
37. *Malpighia coccigera* - Shrub
38. *Mangifera indica* - Tree
39. *Michelia champaka* - Tree
40. *Millingtonia hortensis* - Tree
41. *Mimusops elenji* - Tree
42. *Morus alba* - Tree
43. *Muntingia calabura* - Tree
44. *Murraya exotica* - Shrub
45. *Nerium oleander* - Shrub
46. *Odina wodier* - Tree
47. *Peltophorum inerme* - Tree
48. *Petrea volubilis* - Climber
49. *Pithecolobium saman* - Tree
50. *Pithecolobium dulce* - Tree
51. *Plumbago capensis* - Shrub
52. *Plumeria acutifolia* - Tree
53. *Plumeria alba* - Tree
54. *Plumeria rubra* - Tree
55. *Pongamia glabra* - Tree
56. *Psidium guajava* - Tree
57. *Quisqualis indicus* - Climber
58. *Saraca indica* - Tree
59. *Spathodea campanulata* - Tree

60. *Spondias mangifera* - Tree
61. *Swietenia mahogany* - Tree
62. *Tabernaemontana coronaria* - Shrub
63. *Tamarindus indicus* - Tree
64. *Theobroma cacao* - Tree
65. *Thumbergia grandiflora* - Climber
66. *Vitex negundo* - Shrub
67. *Zizyphus jujuba* - Tree

During the monsoon months, strong winds from the west along with high water level increase the strength of waves, which erode a large extent of beach at Munambam and Chellanam areas causing considerable destruction to land and properties. This is a major environmental problem in the coastal zone of Cochin. Even though, sea walls were constructed all along the coast, in many places it failed to check the rage of the waves as is evident from the disappearance of sea wall at several places in Munambam and Chellanam area.

There are good many plants, both native and alien species that withstand the fury of the nature to a great extent in the coastal area. Vegetation will considerably solve the coastal management problems like beach protection by binding the soil particles with their roots in areas prone to water and wind erosion. The vegetative cover (trees) also provides windbreaks against strong winds which frequent the coastal areas. Only, man has to imitate the natural protection system by planting appropriate species in the respective zones.

6.4. Summary and Conclusion.

A comprehensive study of the species diversity of vegetation is an important pre-requisite for the assessment of environmental resource of any area. The vegetation of any place is determined by edaphic, climatic and biotic factors. Such a study will enable the authorities to propose appropriate planting materials from the trees, shrubs and climbers of economic, aesthetic and medicinal value which have proven capacity to grow success-fully in the various edaphic and microclimatic conditions of an area.

In the study area, edaphic and climatic zonation is clearly distinguishable with their own characteristic vegetation types due to its unique physiography. However, this vegetation, originally tropical rainforest, is drastically modified by biotic influence of urbanization and increased agricultural activities. The vegetation in its original form exists only in a few sacred groves and mangrove forest bits.

Alien species, which were once introduced for aesthetic planting or for agricultural purposes, are found in large numbers among the vegetative cover of the western flatland area, whereas, alien plantation and agricultural crops have significantly replaced the native vegetation in the eastern upland area.

In Cochin altitude-based vegetation difference is negligible since the altitude variation in the study area is less than 108 meters.

The western flatland shows a distinct edaphic condition of clayey or sandy-clay or sandy soil with a very high water table. The land is less than 1 meter above MSL at Cochin. In this area, the predominant mesophytic vegetation is *Cocos nucifera* (Coconut), *Areca catechu* (Arecanut), *Samadera indica* (Karingotta), *Dipterocarpus indicus* (Pine), *Hydnocarpus wightiana* (Marotty) and bamboo thickets. Most other native mesophytic trees, shrubs and climbers, though identified in the study area, occur very scantily and that too mostly as individual plants.

Natural regeneration seems to be very low for the native plants except for a few species like *Samadera indica, Dipterocarpus indicus, Thespesia populnea, Macranga indica, Alstonia scholaris* and a few species of *Eugenia* (all of which regenerate naturally only in isolated pockets), while alien species of *Pithocolobium saman, Peltophorum inormi, Dolonix regia, Muntingia calabura* and *Lucaena lucocephala* show vigorous regeneration in the western flatland area.

If this trend continues, the alien species are likely to replace the native species from the scene as they now occur only as isolated patches or individually with very low regeneration capacity. This is environmentally very undesirable since birds and animals in the area are ecologically adapted to the native vegetation and this kind of transformation to alien vegetation is sure to upset the food chain and thereby the ecosystem, though the quantification of the damage is not possible. Hence, it is suggested that, as far as possible, the planting of native species must be recommended in urban aesthetic planting schemes instead of going for the ephemeral beautiful flowers of the alien species with due consideration to aesthetic appeal. Also, the pollens of the alien species are likely to cause allergic and other health problems.

The shore line vegetation shows pronounced zoning - the species composition changes within a few tens of meters from the shore line - both near the sea as well as backwaters. In the case of backwater shores, the waterward edge of intertidal zone is predominantly occupied by mangrove species *of Bruguiera roxburghiana, Rhizophora mucronata* and *Accanthus ilicifolius*. Behind this, about 12 mangrove species occupy the landward edge of intertidal zone. The land just above the intertidal zone has about 36 species of trees and shrubs, which are the combination of mangrove and mesophytic vegetation.

This zoning is disturbed in many places either due to human intervention or due to acute steepness of the shoreline. If the land suddenly rises from the backwaters, only the second and/or the third zone will be present. In the study area fifteen major locations of mangrove vegetation are present besides the occasional existence of a few isolated mangrove species here and there along the backwater shorelines.

For the prevention of backwater shore erosion and fisheries protection, mangrove replanting should be done along with the conservation of existing patches.

A similar zonation parallel to shorelines is observed in the vegetation near the sea. The first layer of plants is that which can withstand the contact with waves of the sea with its salt. Nineteen species of trees, shrubs and other ground covers are found to grow in this zone successfully with regeneration. Protected either by the above-mentioned vegetation or by the sea wall is the second zone, where, 46 species of trees, shrubs or climbers are found to thrive. These plants can be ideally planted in this zone in future planting programmes. Behind the second zone of beach vegetation, there exists a region, which is not exposed to the direct impact of the sea, but with traces of salt in the soil. 66 species of trees, shrubs and climbers are identified in this zone which can be used for future planting schemes in the sand bars from Njarakal to Chellanam where these plants occur in natural condition or cultivated condition and found to survive.

Except the mangroves and beach vegetation in zones 1 and 2, almost all the species survive in the eastern upland where they can be best utilized for planting schemes depending upon the local edaphic and microclimatic conditions.

Chapter - 7

Socio-economic Environment & Basic Amenities

7.1. Introduction

Assessment of the socio-economic condition of an area is a pre-requisite for environmental planning. Comfort in urban life lies in the condition of basic amenities and services because they in turn decide the status of health & sanitation, commutation and recreational facilities etc. The urban boundaries of Cochin are expanding fast with a consequent over stretching of the existing fabric of basic amenities and services. The unique geographical settings of the study area are a further burden, which necessitate a proper evaluation of the present status of the socio-economic conditions.

The important basic amenities and services to be considered for environmental planning are (1) housing (2) water supply, (3) drainage, (4) transport facilities, (5) parks & playgrounds.

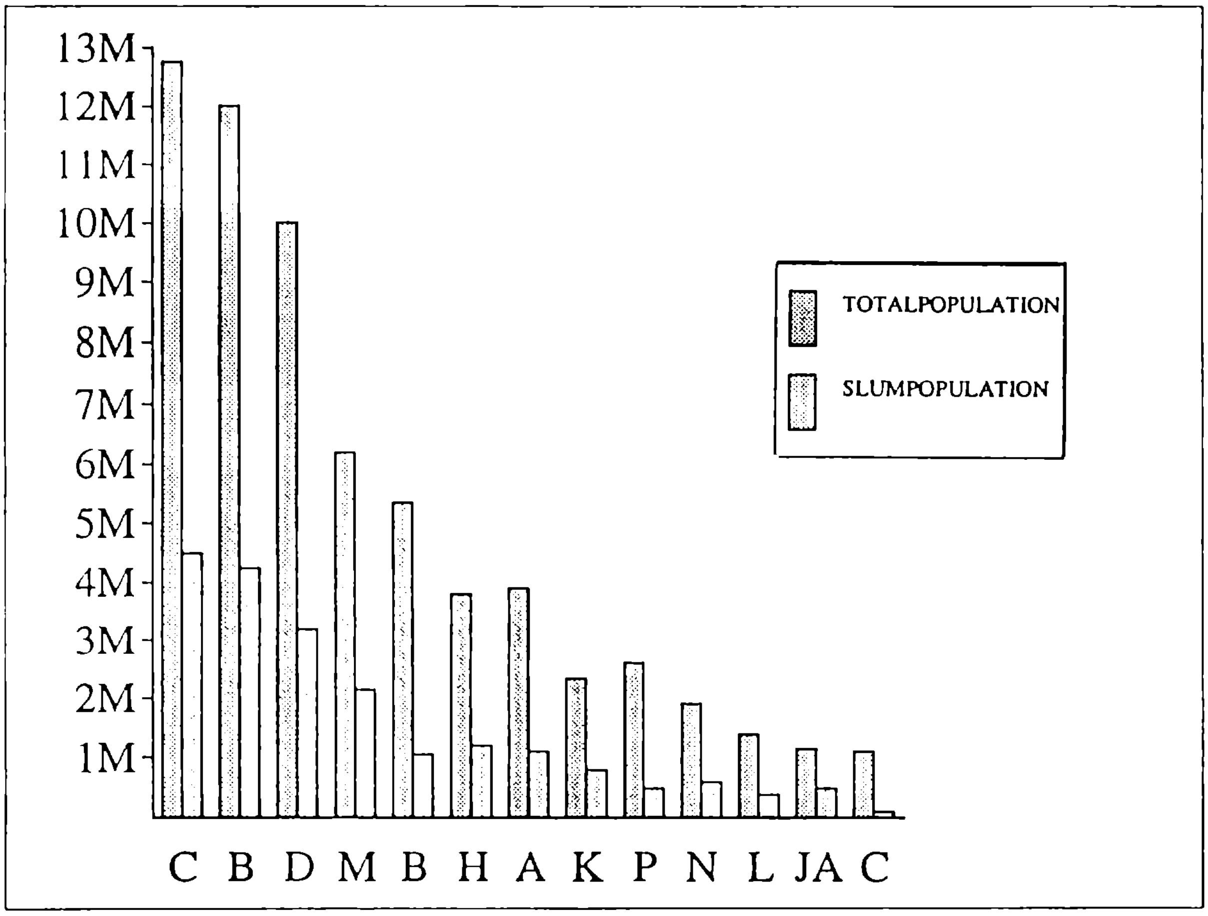
A projection of the future population and its sex-age structure helps in estimating future human and economic resources, expected school-going population and related requirements, future growth of the city and requirements of food, water, sanitation, housing and health services. The major concern of demography - the science of population - in socio-economic studies is to assess how the general social & cultural factors are related to population structure. The census report serves as a primary data source for administrative purposes as well as for economic & social research and planning. The census also contributes to our knowledge of the changes in the occupational and industrial composition, in its level of literacy & economic development and trends in population growth & distribution. Such a comprehensive outlook is essential in future urban planning.

Urbanisation leads to the transformation of agricultural land into built-up areas with the concomitant problems regarding water supply, drainage, garbage and sewage disposal etc. Out of about thirty infectious diseases communicated through environmental agents and vectors, at least twelve have been identified to be propagated through waste materials. Hence, the identification of problems associated with waste disposal and evolving solutions to these problems form an important part of any city planning work.

Social environment and economic environment cannot be segregated. Economic upgradation or degradation of an area brings about drastic changes in sociological aspects. Such a gradual socio-economic degeneration is clearly seen in the case of Mattancherry.

Throughout the world, the growth of cities has introduced a lot of socio-economic problems in which social justice is denied to a majority of its population - the slum dwellers, the pavement dwellers and squatters who live in abject poverty (Fig.7.1).

The traffic problem in urban areas is assuming serious proportions due to the inability of road expansion to catch up with the rapid increase in the vehicle population. This situation brought about by space and resource



C CALCUTTA , B BOMBAY , D DELHI , M MADRAS , B BANGALORE , H HYDERABAD , A AHMADABAD

K KANPUR , P PUNE , N NAGPUR , L LUCKNOW , JA JAIPUR , C COCHIN

Source: * Gupta ('92)
** Corporation of Cochin

Fig - 7 . 1 . ESTIMATED URBAN POPULATION AND SLUM POPULATION IN 12 METROPOLITAN CITIES FOR 1990* AND CORPORATION OF COCHIN*

constraints, not only increases the pollution load in the urban environment by idling of vehicles and frequent traffic jams, but also causes substantial loss to economy by increased fuel use and wastage of transit time. It also affects adversely the health, social and cultural life of the community, aesthetics of buildings & monuments etc. The loss and trauma induced by frequent accidents should also be considered in this context.

In Ernakulam town (the central part of the Cochin city), the population was only 14,038 in 1875, 15,467 in 1881, 17,870 in 1891 and 21,901 in 1901 (Menon, 1902) which has increased to 5.61 lakhs now (Fig 7.2). The opening of Cochin Port and the commissioning of Pallivasal Hydroelectric Project in 1930s resulted in fast industrialisation and commercialisation of Cochin with corresponding population explosion and consequent changes in the socio-economic scenario

7.2.. Methodology

For the socio-economic analyses, census reports provided the primary data. Also, data from various government departments and institutions relating to the 26 panchayats, 2 municipalities and the Cochin Corporation, which either fully or partially come within the study area, were also depended upon to obtain a comprehensive picture.

Published data as well as those obtained through personal communications with various institutions and governmental agencies like Kerala Water Authority, Kerala State P.W.D, Regional Transport Office, Police department, Cochin Port Trust, Corporation of Cochin, Greater

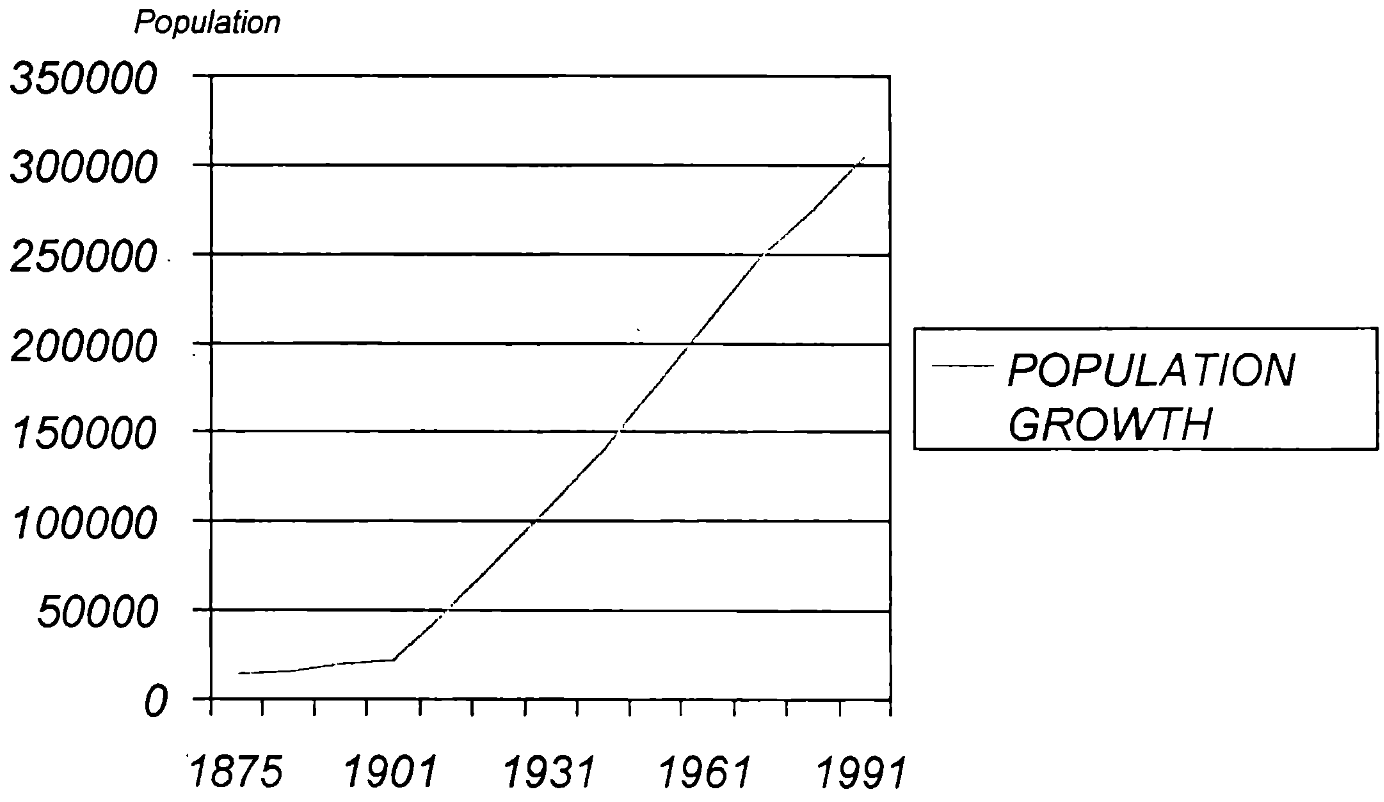


Fig 7.2 POPULATION GROWTH IN THE ERSTWHILE ERNAKULAM TOWN AND THE ERNAKULAM AREA OF PRESENT CORPORATION OF COCHIN

Cochin Development Authority etc, provided the basic information on which the existing status of the basic amenities and other infra-structure were assessed. Annexure 7.1)

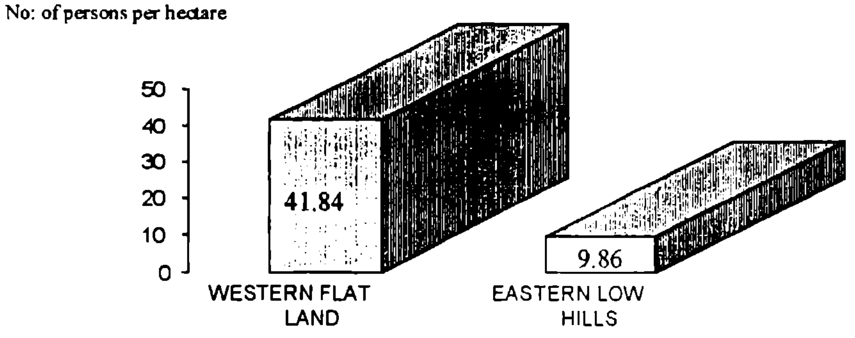
7.3. Discussion

The study area includes the most urbanised area of the most urbanised district in the state of Kerala (Census, 1991). The study area comprising of Cochin Corporation, 2 municipalities and 26 panchayats, either fully or partially, holds about 48% of the population of Ernakulam district while occupying only 29.63% of its area.

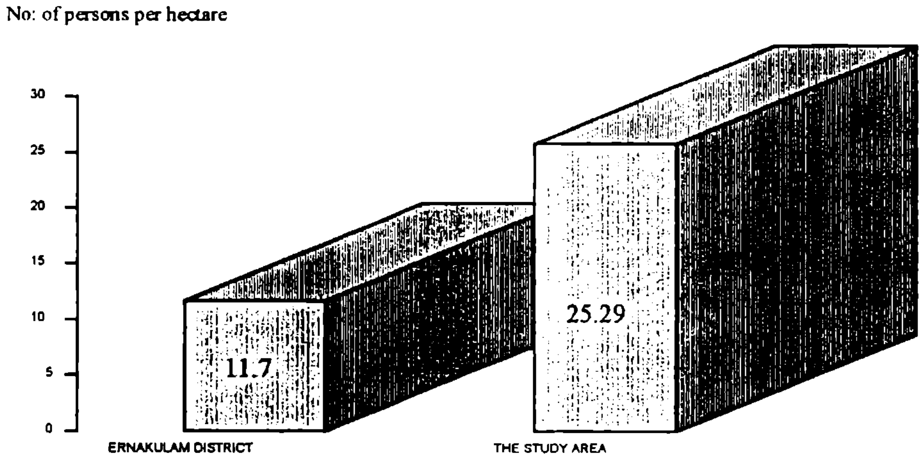
7.3.1. Population structure & distribution

The analysis of census data reveals the spatial variation of population density, which help in identifying certain characteristic problems of population distribution. It is found that the densities are high in the low-lying areas adjoining the water sheets (Fig.7.3). The population density in the western part excluding backwater area is 41.54 persons / hectare, while in the eastern part it is only 9.86 persons / hectare (Census, 1991) The variation is seen to be of lesser magnitude along the coastal axis, but is very prominent in the eastern axis. Ironically the most suitable land for urban expansion lies most unutilised.

This analysis gives an insight into the future population distribution. The rational approach to future population distribution will be to even out the density histogram. This will mean that the increase of the percentage of



POPULATION DENSITY DIFFERENCE BETWEEN WESTERN FLAT LAND AND EASTERN LOW HILLS



POPULATION DENSITY DIFFERENCE BETWEEN ERNAKULAM DISTRICT & THE STUDY AREA

Fig 7.3 POPULATION DENSITY

population in high-density areas will have to be kept marginal. This restriction will be justified considering the overcrowding and deficiency of services in these zones. At the same time, allocating larger percentage of population to low density areas may not be economically feasible. The rational approach will be to emphasize on the medium density zones.

a) Sex composition

In the study area, the sex composition by 1991 census is 50.16% male and 49.84 % female which is a rather balanced sex composition.

b) Literacy and family size

The 1991 census data reveals a literacy level of the population above 6 years age is 93.26 %. The literacy rate for males and females above 6 years is 96.25% and 90.27% respectively which is higher than the district level literacy. Higher level of literacy is reflected in the higher standard of living as well as the choice for smaller families (Fig 7.4). In 1971, the literacy rates of the central city area was 69.44% and the average family size was 6.33 persons (G.C.D.A Structure Plan, 1982) which further reduced to 5.81 by 1981 when the literacy rate increased to 79.5% (Census, 1981). With further increase in literacy rate, this value reduced to 5.08 percent by 1991 (Census, 1991) and is expected to be 5 or even less by 2001. The planning significance of the size of household is in areas such as housing where demand for smaller houses is expected to increase.

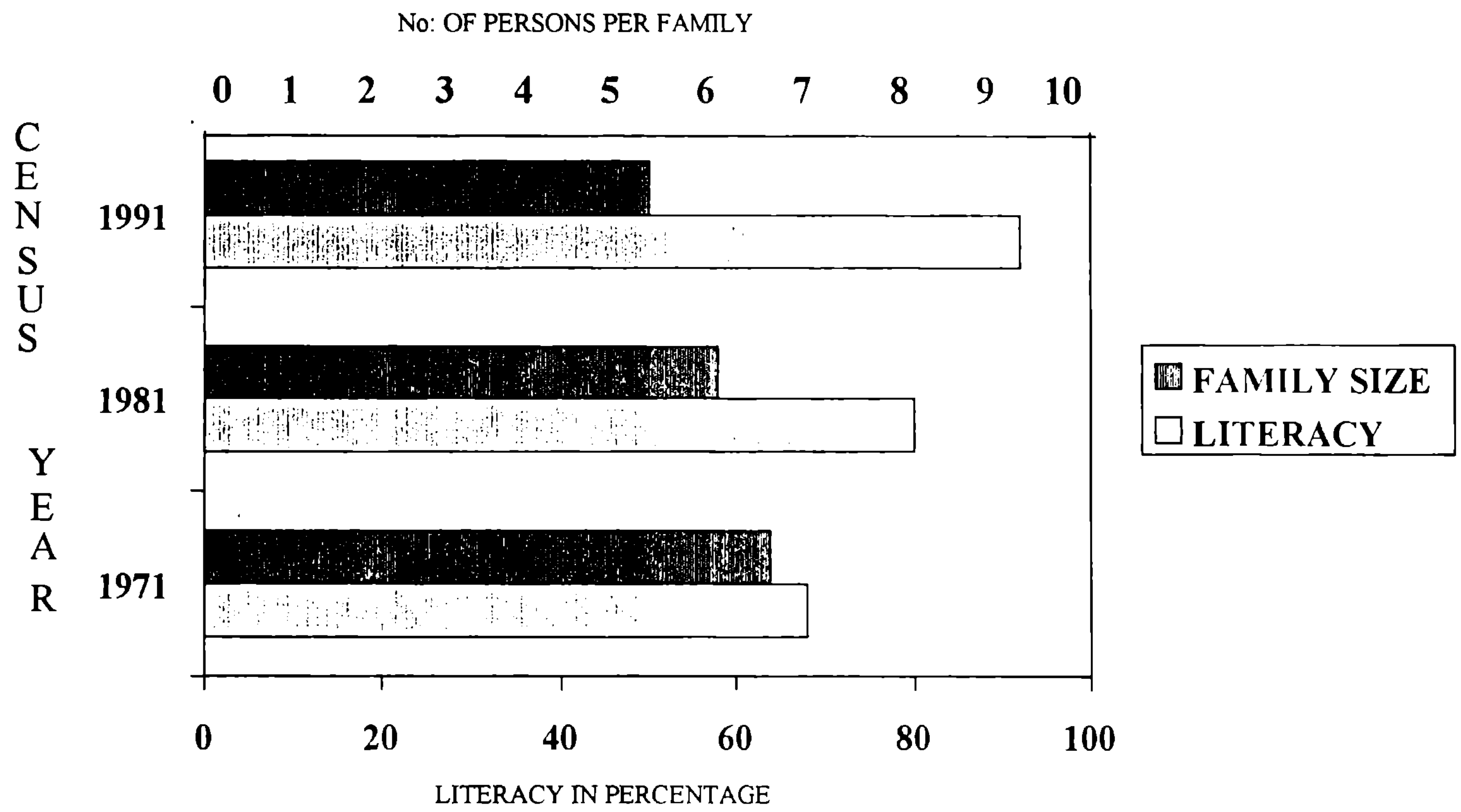


Fig 7.4 LITERACY AND FAMILY SIZE RELATION IN COCHIN

c) Employment and livelihood

The labour force can be divided into 3 categories - main workers, marginal workers and non-workers. In 1981, the percentage of main workers in the central city area was 25.82% and that of marginal workers (those who have worked for only a small part of the year) was 2.82%. Totaling the two together, the participation rate comes to 28.64%. By 1991, the study area had a working force of 6.46 Lakhs - 32% of the total population, against a projected 30.18% (GCDA Structure plan 2001) - comprising of 4.06 Lakh (30.2%) main workers and 2.4 Lakh (1.8%) marginal workers. Thus the working force rose by 3.36% compared to 1981 (Fig. 7.5). This increase in employment - much above the earlier projections - reveals an economic growth faster than the predicted rates - thus generating increased job opportunities.

The distribution of main workers in the Cochin City Corporation, Kalamasserry and Tripunithura municipalities and 26 Panchayats which come either fully or partially within the study area is as follows:- (Fig7.6)

1) Agricultural sector

This sector (cultivators and agricultural labourers) constitutes 15.06% of the working force of the study area in 1991. This sector is likely to weaken further with urban expansion.

2) Workers in other categories

a) Livestock, forestry, fishing and hunting

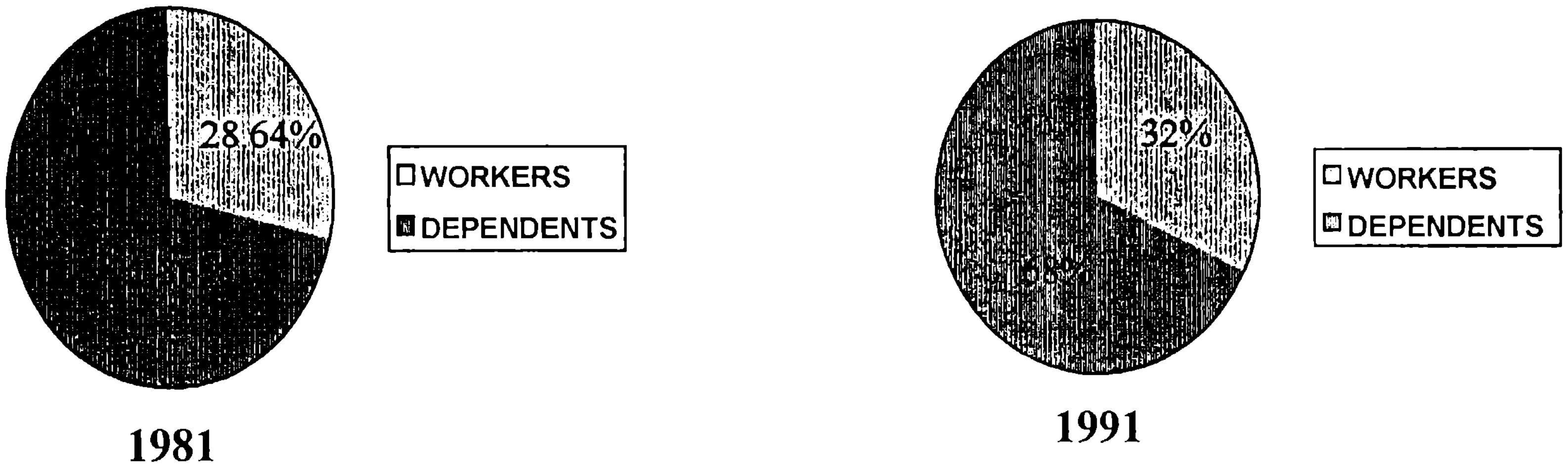


Fig 7.5 RATIO BETWEEN WORKERS & DEPENDENTS

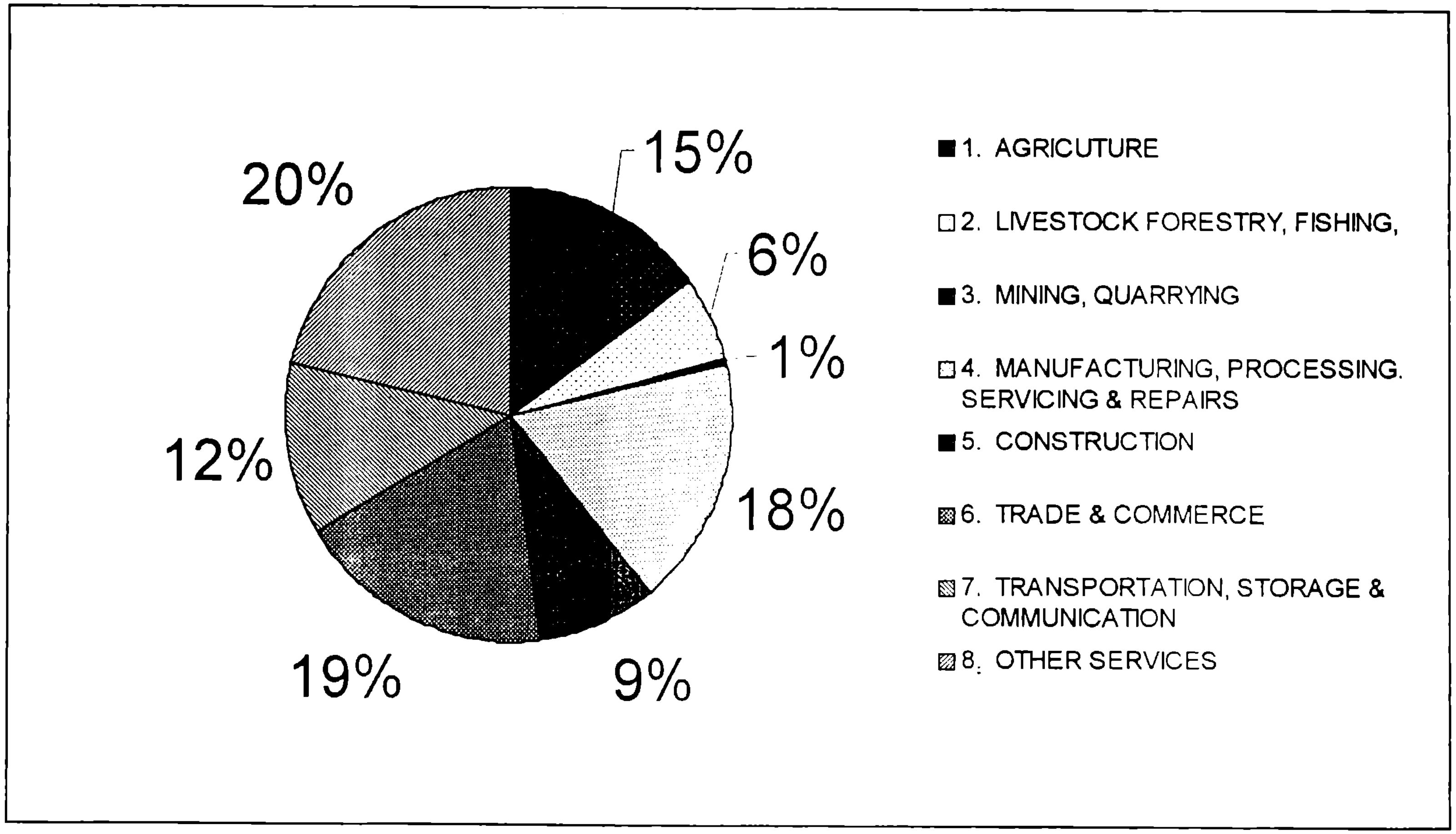


Fig: 7.6. CATEGORY WISE DISTRIBUTION OF WORKERS IN THE STUDY AREA.

They together form 5.66% of the total working force. Because of the existence of vast lagoons and water bodies, there is very high potential for the growth in the fishing sector.

b) Mining and quarrying

Since there are only a few minerals of commercial importance in the study area, mining & quarrying contribute only very little to the employment opportunities and hence the percentage of workers in mining and quarrying is very low and comes up to only 0.76 % of the total working force.

c) Manufacturing, Processing, Servicing and Repairs.

This sector, which forms the economic base of central city, engages 17.79% of the total workers of the study area. Household industries form 1.03% of the total work force and those of other than household industries 16.76 %. An increase in this sector is necessary to provide a strong economic base to the population of the area.

d) Construction

In 1981, 4.47% of the city population was engaged in this sector, as against 2.71 in 1971. By 1991, in spite of including several slow-growing rural areas, this proportion has risen to 8.58%. Such a fast growth in this sector, despite mechanisation of construction activities, is a clear indicator of urbanisation boom.

e) Trade and Commerce

The population engaged in trade and commerce in Cochin central city was 16.6% in 1981 which grew to 18.59 % for the entire study area by 1991 indicating an increase in trade and commercial activities as in the case of construction sector.

f) Transportation/storage and communication – 12.19 %

g) Other services

The other services include professional service, jobs in offices, institutions and administration, sales and marketing etc. The labourers engaged in this service sector in the central city area was 37.40% in 1961, 27.77% in 1971 and 28.94 % in 1981, which decreased to 21.37% by 1991. This decreasing trend indicates that ratio of employment in this services, is actually decreasing while in all other sectors and especially in manufacturing, trade and commerce are increasing. This is a strong indicator of the transformation of the city from an administrative town to an industrial/commercial metropolis.

7.3.2. Housing

In 1991, there were 2,66,038 households in the study area while the number of houses was merely 2,60,597 leaving a backlog of 5,441 units. This was an improvement from the 1981 situation, when the deficit in the central city area alone was 9,000 units. Such a reduction in the housing shortage during the last decade is indicative of a spurt in economic growth as well as construction activities which is reflected in the increase in the construction labour force as mentioned earlier. However, the increase in the number of houses failed to meet the demand, brought about by the rapid population growth and a consequent increase in households due to financial, technological and administrative constraints.

By GCDA estimates, about 30 per cent of all the houses in 1981 were in the category of Kutcha Construction with inadequate facilities and poor environmental quality which required alteration, modification or repairs to keep them habitable. Also, it was estimated that only 1.24 lakh units of 1981 stock would continue to serve the function during 1991 and only 1.12 lakhs will remain in habitable condition in 2001 (GCDA Structure Plan - 2001).

The average family size in the Cochin central city area during 1981 was 5.9 persons per household, which was reduced to 5.08 (for the whole study area), within a span of 10 years (Fig 7.4). This decrease in family size is likely to accelerate in future which implies that the future requirement will be a larger number of smaller houses.

The 1991 census report reveals that in the old parts of the Corporation (which includes Mattancherry and Fort Kochi) where there are a large number of slums, 8.75% of the families share their houses with other families, whereas, in the new area of Cochin Corporation (part of Kanayannoor taluk) only 1.66% share their house with other families (Table.7.1).

TABLE - 7 . 1 HOUSING SHORTAGE*

LOCAL BODY	AREA (km^2)	No. of Houses	No. of Households	Housing Shortage
COCHIN CORPORATION (PART KOCHI TALUK	39.58	43,296	47,448	4,152
COCHIN CORPORATION (PART KANAYANNOR TALUK)	55.3	60,455	41,476	1,021
KALAMASSERY	27	11,430	11,436	6
TRIPOONITHURA	18.69	10,415	10,434	19
VENGOLA	35.65	7,049	7,079	30
VAZHAKKULAM	19.64	5,351	5,389	38
KIZHAKKAMBALAM	31.57	5,340	5,348	8
CHOORNIKKARA	11.01	5,010	5,017	7
EDATHALA	15.98	5,655	5,655	0
CERANALLOOR	10.59	4,104	4,106	2
THRIKKAKARA	27.46	10,448	10,468	20
MULAVUKAD	19.27	4,247	4,248	1
NJARACKAL	8.6	4,348	4,350	2
ELAMKUNNAPUZHA	11.66	8,970	8,971	1
CHELLANAM	17.6	5,955	5,955	0
MARADU	12.35	6,769	6,769	0
KUMBALAM	20.79	4,669	4,688	19
UDAYAMPEROOR	24.8	5,557	5,582	25
MULAMTHURUTHY	21.47	4,535	4,545	10
THIRUVANKULAM	10.49	3,966	3,966	0
CHOTTANIKKARA	12.68	3,356	3,386	30
EDAKKATTUVAYAL	26.28	3,465	3,467	2
AMBALLOOR	22.6	4,244	4,248	4
POOTHRIKA	25.53	3,810	3,815	5
THIRUVANIYUR	21.91	4,371	4,376	5
VADAVUKODU-PUTHENCRUZ	36.89	5,595	5,612	17
MAZHUVANNOOR	49.11	6,059	6,062	3
AIKKARANADU	25.65	3,873	3,875	2
KUNNATHUNADU	26.86	5,014	5,022	8
MANEED	26.2	3,241	3,245	4
TOTAL	713.27	260597	266038	5441

CALCULATED FROM 1991 CENSUS REPORT

THE CALCULATION IS FOR ADMINISTRATIVE UNITS WHICH FORM PART OF THE STUDY AREA EITHER FULLY OR PARTIALLY.

There were about 34 major slums (harbouring about 25,000 people) in the in Cochin city itself in 1988, i.e., 5% of the city population as given in Table 7.2 (Report of the Center-State team for integrated development of Cochin and adjoining islands - March, 1988). By 1996, the total number of slums and squatter settlements have grown to 272 (with a population of 1,20,102 living in 21334 households), the locations of which are shown in figure 7.7, comprising 21.27% of the total population of Cochin corporation. Gravity of the problem is less alarming compared to the situation in other Indian cities (Fig 7.8 & Table 7.3), but effective planning can prevent the situation from deteriorating further.

Cochin is having two kinds of slums - slums resulting from rapid deterioration of economic activities as in the Mattancherry area and the slums formed by migration of labourers due to rapid industrialization and increased commercial activities as in Ernakulam area.

The development of Cochin port and consequent rapid progress in Ernakulam area as well as the traffic congestion on the two bridges connecting Mattancherry to the mainland prompted the shifting of business activities from Mattancherry to Ernakulam. This shift in the economic activities created sudden unemployment problem in Mattancherry making the people economically weak, which made the members of a family unable to segregate from the parental house due to financial constraints. This has resulted in a peculiar situation where several families are forced to stay in a single house creating over-congestion and consequent degradation in the

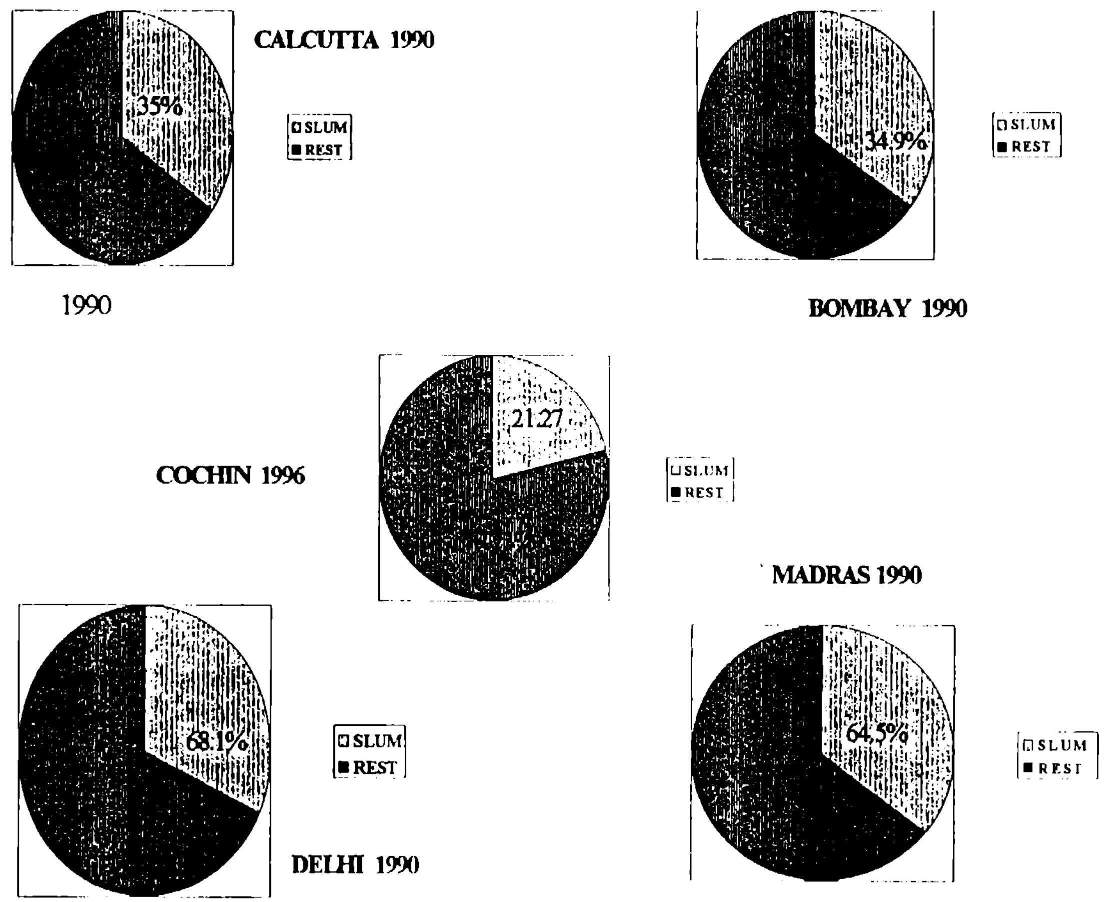


Fig 7.8 SLUM POPULATION AS PERCENTAGE OF TOTAL POPULATION IN MAJOR CITIES AND COCHIN

TABLE - 7.2 . MAJOR SLUMS IN COCHIN

SL.NO	Name of Slums	Populatio	No. of houses	No. of house hold	Persons per house
1	Soudy Colony	110	15	15	7.33
2	Cheliparambu	564	70	76	8.06
3	Manthara Pulaya Colony	220	16	49	13.75
4	Puthiyaveettil Parambu	144	10	17	14.40
5	Pulimoottil Parambu	617	121	1222	5.10
6	Adhikarivalappu	935	106	138	8.82
7	Thundi Parambu	200	29	52	6.90
8	Thuruthi colony	1943	221	287	8.70
9	Kochuparambu Valiaparambu	2346	148	327	15.89
10	Eraveli	1983	262	285	7.57
11	North of Varma&Co.	399	63	65	6.33
12	Cerlaikadavu	1267	109	184	11.62
13	Kalvathy Canal	182	590	850	8.27
14	Near Metal Box Co. Edappa	140	30	32	4.67
15	Near Perumanoor Junction	183	45	45	4.07
16	Kochukadavanthra	348	59	59	5.9
17	Near Railway line,Ponekka	77	12	18	6.42
18	North of Ekm. Stadium Bus	182	38	48	4.88
19	Chilavannur	202	45	45	4.06
20	Old Railway Station	108	25	25	4.32
21	Near E.S.I. Hospital	86	19	20	4.3
22	Near P&T Compound, Elamku	335	93	98	4.14
23	Koithara area	190	18	19	10.55
24	Vathuruthy area	9175	367	497	25.0
25	Panikkassery Parambu	268	30	46	8.93
26	Military Parambu	223	40	40	5.58
27	Kavilampilly Padam	319	54	60	5.90
28	Ponoth	135	29	29	4.65
29	Velloparambu	130	26	26	5
30	Kavappilly Colony	460	71	71	6.47
31	East of St.Agnes Church	21	5	5	4.2
32	Vadayar Parambu	45	7	8	6.42

Table. 7.3.

Slums & Squatter Settlements in the Study Area

No.	Name of Slum	Household	Popln	Area
1	Vypeen Colony	27	156	0.44
2	Kurikkuzhi Parambu	168	1020	0.98
3	Kalvathy Colony	69	369	0.53
4	Thuruthy/Panan Colony	404	2168	3.46
5	S.R. Colony, Mollukkadavu	78	912	1.4
6	Eraveli Colony	290	1850	1.89
7	Chaliparambu Colony Dn.3	314	1751	1.78
8	Rahmania Colony	187	1020	0.43
9	Hassan Colony	12	113	0.4
10	Galesett Colony	401	2700	2.17
11	Kochu/Valia/Banglow Parambu colony	353	2010	2.6
12	Chaliparambu Colony Dn.4	97	588	1.28
13	Pandaraparambu Colony	37	207	0.68
14	Bazar Road Colony	27	178	0.25
15	Cherlaikadavu Colony/ P.Parambu	51	397	0.42
16	Bigben Colony	9	109	0.1
17	Adhikaryvalappu Colony	158	894	0.75
18	Kalathiparambu Colony	28	177	0
19	MKS Parambu Colony	230	1560	[illegible]
20	Mangalathuparambu Colony	153	901	0.99
21	Maliekalparambu Colony	201	1276	1.82
22	Valiamalothuparambu Cololny	137	870	0.97
23	Krishnan nair edavazhi Colony	12	67	0.12
24	JDStreet Colony	135	735	0.87
25	Kudumbi Colony	37	192	0.35
26	Mahajanavadi Colony	68	379	0.85
27	Bazar South Colony	12	60	0.2
28	Chundiparambu Colony	59	553	0.8
29	Kocheriparambu Colony	233	1117	2.1
30	Thengakood Colony	31	168	0.28
31	Ajantha Cinema Colony	32	181	0.42
32	Juthan parambu Colny	170	1010	1.2
33	Pulaya Colony	22	132	0.4
34	Manthara Colony	68	390	0.71
35	Chakkamadom colony	212	1198	2.28
36	Kembri Colony	37	190	0.68
37	Meparambu Colony	50	297	0.9
38	Anakket parambu Colony	91	532	1.31
39	Veli Colony	102	502	2
40	Murukkuthara Colony	33	161	0.14
41	Marakkadavu Colony	20	117	0.28
42	Mini Colony	77	416	1.81
43	Kochangadi Colony	31	170	0.5
44	St.John Pattom Colony	186	1112	3.6
45	Nazareth Colony	31	208	0.72
46	Ammaimukku Colony	47	235	0.69
47	Fishermen Colony-Fort Cochin	108	1822	2.5
48	Panayappilly Colony	124	639	1
49	Srambikkalparambu Colony	47	252	0.49
50	Rameshwaram Colony	310	1716	3.68
51	Kiliyampadam Colony	142	786	4.6
52	Loreth Colony	37	198	0.92

53	Chirakkapadam Colony	41	199	0.87
54	Choolezhathu Colony	67	340	1.7
55	Moolamkuzhy Colony	45	226	1.3
56	A D Puram Colony	30	168	0.8
57	PT Jacob Road Colony	24	132	0.25
58	Vattamakkal Colony	82	330	1.9
59	Saudi North Colony	196	1053	3.48
60	Aryad Colony	158	920	2.5
61	Odampilly Colony	26	135	0.85
62	Patel Market Colony	18	108	0.27
63	Mundamveli West Colony	128	658	5.9
64	Manachorry Colony	220	1198	8
65	Mass Colony	10	95	0.12
66	Moonamcherryparambu Colony	31	171	0.28
67	Babakkutty Colony	12	113	0.16
68	Harijan Colony-Dn15	62	303	1.01
69	Chemmeen Fisheries Colony	132	612	0.95
70	Moolamkuzhy Beach Road Colony	55	318	1.2
71	Palliparambu Colony	27	168	0.82
72	Kannammaly Bus Stop Colony	76	430	0.71
73	Chullikkal Muslim Colony	78	402	0.95
74	Chullikkal West Colony	46	316	0.53
75	Karuppatti parambu Colony	29	175	0.8
76	VolluVoliparambu Colony	50	286	1
77	Aramcherry CM Parambu Colony	37	250	0.61
78	Chakkaraidukku Colony	60	258	0.58
79	Puduvasserry parambu Colony	27	160	0.2
80	Marthandanparambu Colony	55	[illegible]	0.45
81	Madappallymodu Colony	74	261	0.81
82	Palliparambu Mosque Colony	106	577	0.7
83	Alathukutty Colony	105	304	0.32
84	Ambadi Valappu Colony	31	209	0.8
85	Kunnupuram Colony	54	294	0.5
86	Chirattappalam East&West Cololny	127	740	1.28
87	Karingathuruthy Prambu Colony	82	480	0.75
88	Bandakka parambu Colony	150	799	1.3
89	Devaswom parambu Colony	67	367	0.81
90	Pandikudy	27	129	0.38
91	Palamarathil parambu	127	760	1.8
92	Tommassery colony	137	690	3.21
93	Kochupally road colony	9	54	0.1
94	DLB colony	36	216	0.72
95	Bell fisheries colony	16	87	0.35
96	Jayalekshmy theatre road	45	230	0.8
97	Valummel colony	75	450	1.18
98	Poklavparampu colony	39	220	0.85
99	Pallichal colony	49	285	1.9
100	Indiranagar colony	32	175	1.08
101	Marampilly colony	54	288	1.5
102	Nadakav colony	36	180	0.86
103	Kadebhagam colony	82	410	3.78
104	KMP oil mill colony	130	657	7.74
105	Pandarachira colony	56	290	2.2
106	Omasanam road	216	1188	7.64
107	Moopan colony	34	180	0.89
108	Federal bank colony	25	140	0.61
109	SP Puram north colony	87	460	2.1
110	SP Puram south colony	130	780	4.2
111	Pullardesom colony	22	130	0.8
112	S D P Y west colony	130	645	13.1
113	S D P Y West puramboke colony	58	348	0.45
114	Pipe line north colony	100	576	2.92
115	Pipe line south colony	146	784	3.2
116	K E K colony	15	72	0.28
117	Talappiparamb colony	150	850	6.1
118	Kacheryppady colony	71	401	2.77
119	Kaduthanath colony	120	700	2.08
120	Kammathi madom colony	100	607	2.08

121 Pathinettukandom colony	175	990	4.45
122 Tangal nagar colony	180	1073	7.2
123 Pokkanamuri colony	151	789	5.02
124 Toppithara colony	270	1710	7.2
125 Kannangatt Ithithara colony	71	397	1.8
126 Vilakkanezhath colony	36	182	1
127 Pattalath colony	64	370	7
128 Konam-porumpadappu colony	100	560	2.2
129 Companypparamb colony	103	535	4
130 Aquinas colony	130	620	5.3
131 Pambaimoola colony	207	998	7.3
132 Paruthithara colony	30	152	3.4
133 Ayyankali colony	82	453	6
134 V A T colony	118	674	3.8
135 Vathuruthi colony	1100	5600	5.2
136 Metal box colony	27	164	0.36
137 Peeliyad colony	60	340	3.1
138 Meenchira colony	37	187	1.1
139 Mahatma colony	58	315	0.85
140 Nikathil colony	36	154	2.06
141 Kotheri road colony	38	200	1.2
142 Perandoor north colony	52	260	1.35
143 Perandoor Rly bridge colony	35	175	0.9
144 Elamakkara colony	12	49	0.37
145 Kurumba colony	124	637	1.88
146 Pottaiyl colony	50	290	1.1
147 Changadampokku colony	10	52	0.13
148 Chullikad fishermen colony	65	294	1.09
149 Kuruppambadam colony	47	267	1
150 Kaippilly colony	52	260	1.1
151 Chatholy colony	8	42	0.12
152 Chomalipparamb colony	9	45	0.21
153 Methara colony - Padivattom	86	432	0.55
154 Ettukattu colony	14	62	0.25
155 Karuvolippadam colny	31	175	1
156 Karukapally colony	7	27	0.08
157 Pottakkuzhi colony	8	48	0.09
158 Ulladan colony	8	42	0.32
159 Perandoor south colony	48	281	1.15
160 Deshabhimani road colony	35	245	0.65
161 Sastha temple colony	8	42	0.06
162 Karathatt colony	27	150	0.4
163 Panakkapparamb colony	37	172	0.85
164 Puzhakkarappadam colony	27	168	0.56
165 Chettiyat colony	64	367	1.36
166 Talipparamb colony	145	856	2.25
167 Ulakampara colony	18	72	0.49
168 Tannuthara colony	25	150	1.35
169 Nedumtottumkal colony	15	69	0.28
170 Kamsan colony	24	111	0.58
171 Kodalipparamb colony	50	250	1.2
172 Kothappadypparamb colony	96	513	5.71
173 Uzhinjath colony	27	152	0.82
174 Kannoth colony	56	290	1.2
175 Choruviruppu colony	42	160	0.78
176 Nedupallichal colony	20	101	0.59
177 Tadipparamb colony	47	250	0.71
178 Kadappath colony	38	210	0.76
179 Kanniyambuzha colony	25	132	0.48
180 Chullikkad colony	19	95	0.41
181 Nechoor kadavu colony	21	142	0.27
182 Madavanathazhe colony	36	181	0.7
183 Vennalapara colony	28	122	0.17
184 Vennala colony	52	222	1.66
185 Michabhoomi colony	35	185	0.75
186 Alinchuvadu colony	22	112	0.3
187 Vattamthitta	28	167	0.62
188 Thuruthyil - Vennala	18	120	0.52

189 Chaveli veli	18	98	0.31
190 Thalamittam	12	62	0.28
191 Mannarkara	32	175	0.57
192 Vadakkathara	47	260	0.75
193 Vattathipadam	27	165	1.81
194 Kuruppampadam	26	140	0.91
195 Anottiparambu	10	52	0.2
196 Makkaparambu	68	342	1.95
197 River landing colony	45	240	1.32
198 Vaduthala colony	82	521	2
199 St. Joseph's colony	48	260	0.8
200 Boat jetty road colony	47	230	0.95
201 Companyparambu colony	27	118	0.93
202 Tantonnithuruthu colony	62	191	1.36
203 Pushpaka colony	38	168	1.05
204 Shanmughapuram colony	111	570	2.38
205 Erattukkulangaracolony	14	84	0.6
206 Pullethundil colony	17	100	0.8
207 Kuruppuchira colony	21	120	0.4
208 Chooreparambu colony	15	86	0.3
209 Pozhakkara colony		571	1.08
210 Talapuram colony	28	140	0.4
211 Manappattipparambu	100	595	1.5
212 S F M road colony	36	164	0.37
213 E R G colony	43	200	0.6
214 Kanakathu parambu	12	67	0.3
215 Jagajeevan Ram colony	24	128	0.8
216 Ponoth colony	31	158	0.4
217 Kadapparambu colony	24	142	1.1
218 Mannullipadam colony	32	132	0.37
219 Town hall colony	18	143	0.25
220 Kottakkanal colony	30	178	0.52
221 Chamathumkad colony	102	588	0.9
222 Near Kavitha theatre	28	156	0.25
223 Stadium colony	55	245	0.42
224 Padiyathukulam west colony	28	116	0.12
225 Mooppan colony	22	188	0.38
226 Vellayiparambu colony	46	213	0.78
227 Kallungal colony	10	80	0.2
228 Kissan colony	197	979	1.22
229 Mothirapadam	29	118	0.4
230 Chammani colony	18	101	0.18
231 Karanakkodam	18	97	0.41
232 Labour colony	55	326	1.24
233 Kathrukadav colony	24	168	0.32
234 E W S colony	1101	6566	9.2
235 Marshalling yard colony	171	923	1.73
236 Vettuva colony	39	237	0.85
237 Kuthappady colony	61	317	0.6
238 P & T colony	106	576	0.42
239 Koothappally colony	45	281	0.6
240 Kudumbi colony	73	452	1.38
241 Old Kudumbi colony	226	1220	1.49
242 Udaya colony	205	1182	2.81
243 Manikandanthuruthu colony	27	148	0.65
244 Fathima church colony	12	62	0.38
245 Ambalamchery colony	17	82	0.42
246 Shipyard colony	89	512	1.4
247 Pottanamkery colony	18	102	0.12
248 Parambithara colony	14	178	0.18
249 Atlantis colony	21	124	0.2
250 Ambedkar colony	42	179	1.27
251 A I school colony	27	148	0.38
252 Koiyatharathodu colony	177	1060	7.8
253 Chilavannor colony	56	248	1.23
254 Militariparambu colony	27	163	0.51
255 Chilavannoor bund	60	335	1.5
256 Koiythara puramboke colony	38	188	0.3

257	Cheriya Kadavanthara colony	28	160	0.25
258	Pulaya colony	31	167	2.8
259	Konthuruthy colony	40	191	0.55
260	Chaithannyapuram colony	28	160	0.3
261	Fishermen colony	76	385	3.24
262	Paduva lane	45	202	0.28
263	Njarakedavu	60	248	0.92
264	Mini Gandhinagar colony	20	122	0.4
265	Petta colony	32	180	0.55
266	Jubilee road south colony	61	340	1.1
267	Kadavanthara gas plant colony	40	202	0.8
268	Valappikadavu	25	138	0.48
269	Kadavilcheri	21	120	0.71
270	Thaippilodathu puramboke colony	12	96	0.38
271	Ambadithazham	18	97	0.2
272	Thykoodam bund colony	17	102	0.8
273	Thykoodam church colony	62	323	1.35

FIG - 7 .7 .LOCATION OF SLUMS

SOURCE :- CORPORATION OF COCHIN

immediate environment. Thus, the whole area degenerated into an urban blight in planning terms. Hence, any future development proposals for an area should take into consideration the possibilities for degradation in another area because of that.

The recent rapid growth of Cochin brought a large number of migrant labourers from other parts of Kerala as well as from Tamilnadu. Several slums are in the formative stages particularly in Thrikkakara area where job opportunities underwent a sudden boom by large-scale construction activities as well as various industrial activities mainly related to the Central Export Processing Zone (CEPZ). With the absence of adequate accommodation facilities, the labourers, most of whom unskilled and underpaid, are forced to live in hutments without proper basic amenities. Such areas will degenerate to major slums if appropriate housing projects are not envisaged and implemented soon.

Unless immediate steps are taken by the authorities to rehabilitate these urban poor, the children of the slums are likely to create serious social problems by becoming anti-social elements as in the other major cities. Also, the unhygienic conditions in the slums can provide breeding grounds for pestilence.

7.3.3. Water Supply.

Cochin did not have potable water even at olden times and drinking water used to be brought by boat from Alwaye, 20 miles from Cochin

(Logan, 1901). Filtered water from Chowara was first brought through pipeline for distribution in Ernakulam during the time of Diwan A.R.Banerji (1907-1914). This systematized scheme had 2.3-million litre/day plant to serve a total target of about 20,000-population i.e., 115 lpcd (Ernakulam District Gazetteer,'65.)

The Kerala Water Authority, an autonomous body under the Government of Kerala, is responsible for the public water supply system in Cochin. Since, the groundwater in the highly populated western flatland area is mostly saline and/or with dissolved gases, the public water supply system has to be depended upon, even for washing and construction purposes.

The two fresh water sources on which the regional water supply scheme depends on are (1) the **Periyar River** which lies to the north of the study area and (2) the **Muvattupuzha River** which lies towards the east as well as south of the study area. This system derives most of its requirements from Periyar River at Alwaye. The Alwaye water works is the major water supply installation on the Periyar River, which has got 5 intake points from which water is supplied after treatment to the major portion of the study area. There is one intake point in the Muvattupuzha River, which serves the remaining parts in the southeast including Ambalmugal - Karimugal industrial zone. The quality of water in the Periyar and Muvattupuzha River is generally satisfactory after the adoption of normal methods of drinking water treatment. In the hilly areas, treated water is pumped to overhead tanks, which serve as storage tanks and thendistributed. In lowlands, water is directly pumped into the distribution system with overhead tanks to serve as hydrostatic pressure balancing tanks.

The summer flow of rivers estimated to be 133m ^{3}/ sec (Joy 1992) and that of Muvattupuzha river is estimated to be 33 m^3 / sec which would be sufficient to meet the water requirement of the region if properly tapped along with efficient supply system. There is already a severe gap between the demand and supply.

The Central Public Health Engineering Organisation's manual on water, water supply and treatment stipulate the following standards of per capita water supply.

Community population		Per capita requirement of drinking water. (Litre per capita per day)
Less than 10,000 population	--	70 to 100 lpcd.
Between 10,000 to 50,000	--	100 to 120 lpcd
Above 50,000	--	120 to 200 lpcd

In 1914, when the public water supply scheme was introduced in the area covered by the present Cochincorporation, the supply was 115 lpcd, whereas at present, it is only 35 lpcd, while it should be 120 to 200 pcd asper standards. In the adjoining municipalities and panchayats, water supply is worse

TABLE - 7 . 4. WATER SUPPLY SCHEMES IN THE STUDY AREA

	Name of Scheme	Area	Present Per Capita Supply of drinking Water	Proposed Per Capita Supply of drinking Water
	(1)	(2)	(3)	(4)
1.	Water Supply Scheme for Tripunithura	Tripunithura Municipality	30 lpcd	125 lpcd
2.	- do - Cheranalloor	Cheranalloor Panchayat	30 lpcd	140 lpcd
3.	World Bank aided Scheme for South West and Central GCDA	Chellanam Sub zone. Kumbalam sub zone. Thrikkakara sub zone. Kalamassery sub zone. Choornikkara Keezhmadu	20 lpcd in rural area, 40 lpcd in urban and industrial area.	80 lpcd in rural area. 150 lpcd in urban and industrial area.
4.	Puthencruz Water supply Scheme	Puthenxruz Poothrikka Aikkaranadu Vadvucode Thiruvaniyoor	15 lpcd	80 lpcd for house connections 40 lpcd for street pipes.
5.	Water supply Scheme for Thiruvankulam	Thiruvankulam	5 lpcd	40 lpcd
6.	- do - for Mulanthuruthy	Mulanthuruthy Villages.	5 lpcd	40 lpcd
7.	Augmentation of Water supply Supply to Cochin Corporation	Cochin City	35 lpcd	150 lpcd
8.	Water Supply Scheme to Njarakkal and adjoining panchayats	Njarakkal Edavanakkadu Elamkunnapuzha Kuzhuppally Nayarambalam Pallippuram Mulavukadu etc. Chennamangalam Chitrattukara	20 lpcd	70 lpcd

The distribution system suffers many drawbacks. Many of the pipelines, which were laid during the initial installation (in 1914 for the Ernakulam area), are still in service. These pipelines often cross the drains and are partially damaged due to aging. Especially, in the thickly populated western parts of Cochin, the pipes are heavily corroded resulting in heavy loss of water due to leakage. Also, at times of low water pressure drain water get into the water supply system, thus contaminating it. This is the cause of the periodic outbreak of gastroenteritis and other water-borne diseases in these areas.

As early as in 1984, from a field study conducted by National Environmental Engineering Research Institute, Nagpur (NEERI, 1984), the following observations were made.

a) The water waste assessment test was conducted and the rates of leakage in the mains and in the service connections (including public hydrants) were found to be very high.

b) Rectification of leakage of the very old pipe is practically impossible. Hence, these pipes are to be replaced urgently with new ones with higher diameter size considering the likely increase in population.

c) Loose deposits and waste matter are present in the distribution mains. As this is highly hazardous to health, revamping of the existing distribution system seems imperative.

Since 1984, no major repair/rectification work in the water supply system has been reported to have undertaken. In the light of the NEERI observations, the problems associated with the water supply system now might have worsened further and are likely to aggravate in future.

Apart from the above problems associated with the water supply system, the following aspects at the intake points deserve immediate attention without which serious problems can crop up in future.

a) The drainage outfalls from the riverbank municipalities of Alwaye and Perumbavoor are discharged directly to the Periyar River upstream at points fairly close to the intake wells.

b) The summer flow in the Periyar River, the major source of the water supply scheme, is found to be low particularly during drought years. Since the headworks are situated not very far from the river mouth, the hazard of saltwater intrusion from the backwater system, particularly during high tides, has to be given due consideration. For example, in 1983, salt water reached the intake wells at Alwaye and the water supplied was saline. But in the Muvattupuzha River the intake well is situated far upstream at Piravom, where the ingress of salt water is unlikely.

c) Also, some of the major chemical and metallurgical industries of the state located in Udyogamandal, Eloor belts discharge their effluents into the Periyar river at points only a few kms downstream the intake area. The discharge of water containing mercury from the Travancore Cochin Chemicals Ltd. (TCC) and acid & insecticide wastes from the Hindustan Insecticides Ltd. (HIL), has to be viewed with concern. No systematic study is known to have assessed the chances of transportation of these pollutants along with the saline water from the backwater system eastwards to reach the well-intake area during summer months, particularly in high tide situations.

The Edamalayar dam regulates the water flow in the Periyar river. Hence the reservoir discharge has to be regulated, particularly during summer months, to keep a desired minimal level of water flow that can ensure freedom from contamination of water near the intake wells with due allowance for irrigation needs.

The ground water in most parts of Coastal belt of Cochin is saline and hence not potable. However, even though close to the backwater/sea, in some locations potable fresh water is available at a depth of about 75 to 80 meters in archaic riverine sediments or as perched aquifers in the upper layer of sediments. In such areas water exists in a condition of hydrostatic equilibrium with the saline water of backwaters/sea. An indiscriminate withdrawal can upset the hydrostatic equilibrium resulting in salt-water intrusion into these aquifers.

However, the eastern upland portion of the study area is endowed with abundant quantities of potable ground water, which is generally protected from contamination by the relatively impervious overlying laterite layer. This water is being presently used by individual households in the rural areas, but can be exploited on a larger scale after due assessment of the potential.

7.3.4. Solid waste (garbage) disposal

Garbage collection and disposal is a routine function of any local body and one of its most serious duties in the urban area. The Cochin Municipal Corporation has conducted a sample survey and the quantity of generation per day of garbage is assessed as 377 tonnes (Gopalakrishnan, '97). Out of these 377 tonnes, 270 tonnes are from domestic waste and the remaining 107 tonnes is the combined generation of commercial, institutional, road sweeping, drain cleaning, clinical wastes and construction & demolition sources i.e. domestic generation is 0.48 kg/head/day, combined generation 0.67 kg/head/day. Density of waste is assessed to be 414 kg/m^3. The calorific value of the waste is less than 1500 K Cal /kg and 40% of the waste is compostable. 10 to 12 % of the waste is recyclable paper, plastics, metal, coir, coconut husk, coconut shells, glass etc at the source of generation. But by the time it gets into the dust bin or collection vehicle, many recyclable fractions may be removed by the rag pickers. The hotel waste generation in a day is about 12 tonnes containing a very high percentage of leftover food, which could be used to feed animals. Vegetable, fish and meat markets generate 36 tonnes of compostable waste per day. An annual increase of 5-10% in waste generation can be anticipated due to increase in population and change in the life style. It is calculated that by 2001, the waste generation may be to the tune of 450 tonnes per day but with a lesser density than the present garbage, resulting in a higher volume to be handled.

By the study done by the Corporation of Cochin (Gopalakrishnan, 1997) about 40 to 45% of waste gets accumulated in roadside margins, drains, and open spaces. The percentage of wastes disposed by various ways is detailed below:

Domestic.	Communal storage	- 33.0%
	individual bins(door to door collection)	- 0.4%
	open throwing	- 46.6%
	on plot disposal	- 17.0%
	recovery	- 3.0%
Commercial	communal storage	- 37.0%
	direct collection	- 8.0%
	open throwing	- 46.0%
	recovery	- 9.0%
Hospital	at source in plastic bags	- 64.0%
(Clinical wastes)	communal storage	- 27.0%
	incineration	- 3.0%
	open throwing	- 6.0%

In the Cochin Corporation area, solid waste is collected from roadside communal bins and also directly from shops, hotels and houses manually by the use of handcarts, wheelbarrows, tillers, tractor-trailers and a few automatic loading trucks as primary collection vehicles. This waste is then transferred to open sub depots from where secondary collection vehicles like ordinary tractors and tractor trailers carry the waste to land fill sites where the dumped waste is covered with a layer of earth daily. This kind of waste disposal in low-lying regions of the thickly populated western flatland area can contaminate the groundwater with chemicals, organic matter as well as disease germs. Also, it provides excellent breeding grounds for mosquitoes, houseflies etc. Moreover, at present the City Corporation owns not many landfilling sites and now filling is done in small private lands, most of which are unsuitable for the purpose.

A series of health and environmental issues emerged from the poor service and management of solid waste disposal. 50% of the waste accumulates in the city - about 150 tonnes a day. Two major health hazards of the city are directly linked to the inadequacy of solid waste disposal - the large-scale mosquito breeding and flooding during monsoon. Cochin Corporation is spending about Rs.300 lakhs per annum to reduce mosquito breeding by applying chemical larvicides and to reduce drain blockage by annual cleaning prior to monsoon, which is caused mainly by dumping of wastes into drains.

Ground and surface water contamination due to leachate percolation is another environmental problem. The most obvious environmental damage is bad aesthetic condition due to uncontrolled dumps. Multiple handling of wastes causes health risks to workers. Handling of clinical wastes is more hazardous.

In the eastern upland, the garbage disposal is not yet a serious problem because of the availability of plenty of land. But in the western flatland area with the high density of population, it is rather a difficult problem since the quantity of garbage generated is nearly 9,44,637 x 0.48 kg day = 4,53,426 kg per day. Here, the disposal is a serious problem due to a very high water table and lack of enough space for local waste disposal. Hence, the accumulated wastes have to be transported and disposed.

Garbage collection and disposal is a routine function of any local authority and is one of the most serious problems in any urban area. Hence, it implies that at present day Cochin Corporation area alone, comprising of 87 km^2, with a population of about 0.56 millions, about 270 tonne of garbage is generated per day. Out of this, Corporation (by its own statistics) is able to collect and dispose only 120 tonnes /day (about 60 truckloads) due to inadequacy of necessary infrastructure. That is, about half of the waste generated is not collected, but get dumped into streets, open spaces and drains creating serious environmental problems.

Out of the three major options of disposal, incineration is to be ruled out (except for clinical wastes) as the waste has low calorific value and high moisture content. Hence, sanitary land filling with due consideration to the groundwater, supported by composting plants, would be the ideal disposal solution with minimum pollution. Cochin Corporation has recently installed biotechnologically managed compost plants in a few places on an experimental basis. Installation of such small-scale plants in each neighbour-hood seems to be the ultimate solution to the garbage disposal problem, which will reduce the transportation cost also.

Added to the above urban garbage load is the contribution from the other local bodies of the study area which is estimated to be about 380 tonnes / day. Hence, in the study area a total quantity of 650 tonnes of garbage is generated daily (at the rate of 0.48 kg per head per day) by a population of .13,53,040.

At present, in the eastern parts of the study area, there exists no institutional system of waste collection and disposal. Thinly populated areas in this region can resort to compost pits and in thickly populated pockets covered type of land filling can be depended upon, because in this region, contamination of the deep-lying ground water is less likely, being protected by the relatively impervious overlying laterite layer. However, this can only be a temporary solution till the urbanisation spreads to these areas with ensuing increase in population density and resultant increase in garbage.

7.3.5.. Liquid waste disposal.

The liquid waste in the city can be classified into sewage, sullage & storm water and industrial effluents.

7.3.5.1. Sewage Disposal

A well planned sewerage system is absent in Cochin though efforts were taken long back during the period 1967-70 by the then Public Health Engineering Department (Water Authority) in which Cochin Corporation and its surroundings were brought under a sewerage scheme after dividing the area into four zones (Mathew, 1995). They are

a. Ernakulam North Scheme

Northern part of Ernakulam town, Edapally and a portion of Vennala

b. Ernakulam South Scheme

Southern part of Ernakulam town, remaining portion of Vennala area and a major portion of Vytila area.

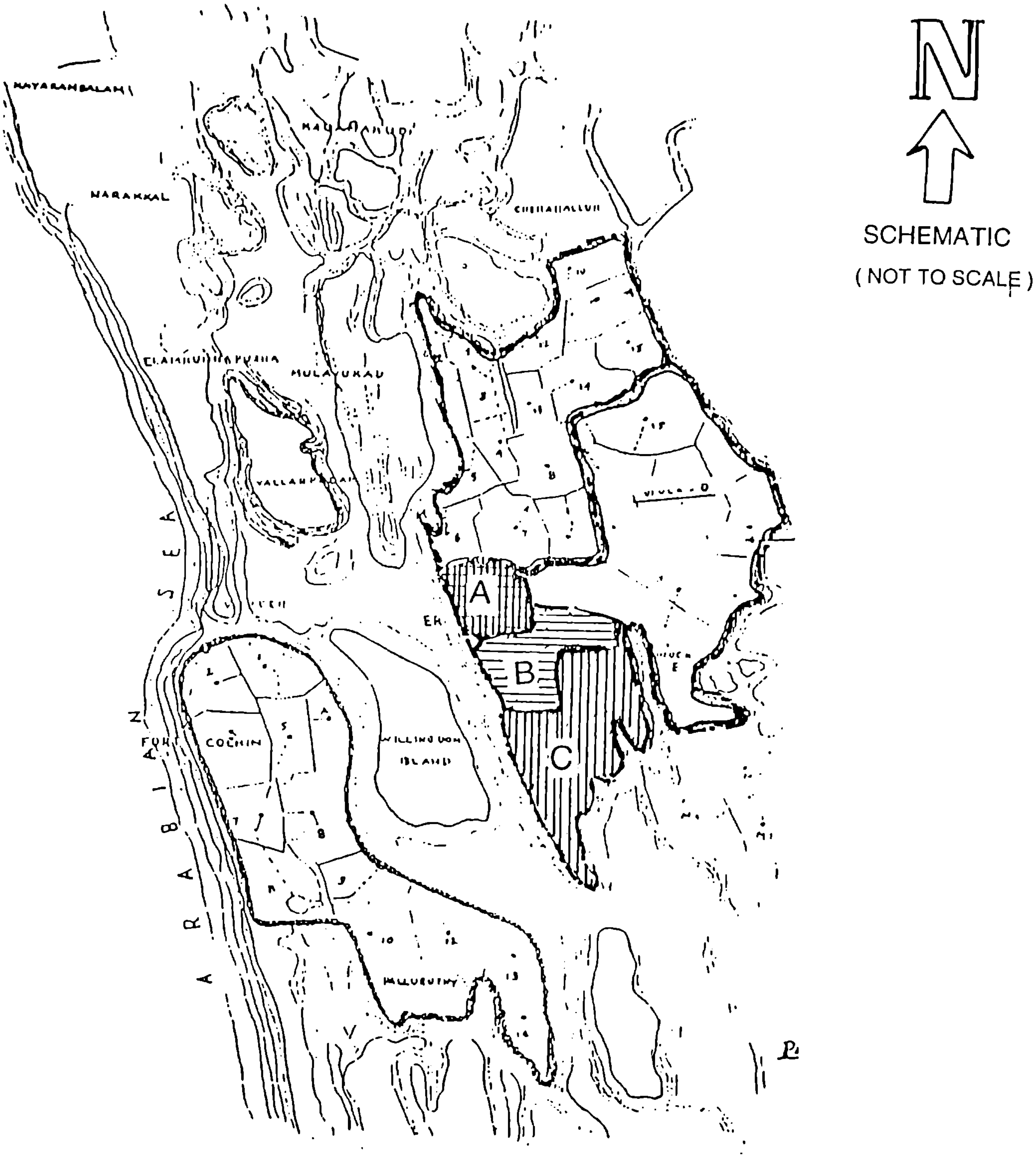
c. Marad-Tripunithura Scheme

Remaining portion of Vytila, Marad and Tripunithura municipality.

d The Mattancherry, Fort-Cochin, Palluruthy Zone

Fort-Cochin. Mattancherry, Palluruthy

Even though schemes were prepared. very little was executed except for a small portion of Ernakulam south scheme in which at present, the sewerage system is functioning only in about 3 Sq.kms out of the total 535 Sq.kms (Fig.7.9). Also, in many of the thickly populated housing colonies in the central city area itself, anticipating the planned large-scale sewerage system, cystern type of sewage disposal was resorted to as an interim arrangement. Due to the delay in implementation of the sewerage scheme, these cystern pits often overflow, particularly in rainy season with the ensuing health hazards. In other areas, conservancy system (pits in the ground) or septic tank system is followed which was essentially evolved to suit the rural houses. Their effectiveness is reduced in the urban areas due to the small size of the plots and consequent shortage of space for dispersion of the effluent. In the case of the highly populated low-lying



A SEWER LAYING COMPLETED (COMMISSIONED)

B MAJOR PORTION COMPLETED (NOT COMMISSIONED)

C MAJOR PORTION INCOMPLETE (NOT COMMISSIONED)

FIG - 7.9 . SEWERAGE IN COCHIN

western parts of the study area, an elevated water table adds to the problem. Hence, these methods can be best adopted only in the eastern upland areas of the study area with a low population density. In all other areas a well-organized sewerage is highly essential.

Considering the flat nature of the city terrain, it may be necessary to design the sewerage system by dividing the city into several zones depending on the elevation of the area from sea level. The sewage treatment plants may be suitably located for treating the load of each of these zones. The treated effluent can be either disposed in the backwaters or for farming purposes.

7.3.5.2. Storm water & Sullage Disposal.

The disposal of storm water and sullage is a serious problem in Cochin. In the western flatland portion of the study area, the storm water and sullage flows through the roadside drains into the canal system and finally to the backwaters. But in many places, the drains are absent or do not function properly due to the flat nature of the terrain. Besides, Cochin city is mostly a low-lying area with clayey soil and hence relatively impervious to surface waters. These factors cause severe waterlogging in Cochin during the monsoon season. During high tides, the problems are further aggravated, since road-side drains are at or below sea level in several places. So the floodwater cannot be discharged into the backwaters by the existing system of gravitational drains. The storm water drainage is dealt in the chapter on surface hydrology.

Water-logging in the western flatland, particularly in the Cochin city, is due to the following reasons: -

a. The difference in level between the highest and lowest area in the western part of the study area is roughly 1.5 meters (Fig.7.10). The difference between high tide and low tide is about 1.2 meter. Since, the tide water level is the deciding factor in the drain flow depth, flood water level will not recede during torrential rains if the drains do not have adequate width, even if the drains are deep enough. Also, the drains are often blocked by dumping of building debris, garbage and other wastes, leading to the blocking of the drains. Most of the drains are of inadequate size and frequently, the drains are traversed by water supply pipes, electric cables, telephone conduits etc.. The floating matters get entrapped between the conduits and the flow is blocked.

b. Filling up of many of the 'thodus' or natural drains in the last few decades has diminished the drainage capacity of many of the areas in the central city. M.G.Road, Mullassery Canal Road and many other roads in Cochin city were 'Thodus' a few decades earlier, which were converted to roads by filling up. Now these roads retain only small roadside drains. The flood water from large areas, which were earlier relieved by such wide natural drains, now find the road side drains grossly inadequate, thus causing water-logging in the city even during times of relatively weak rainstorms. Also, many drainage channels are being encroached upon by individuals as well

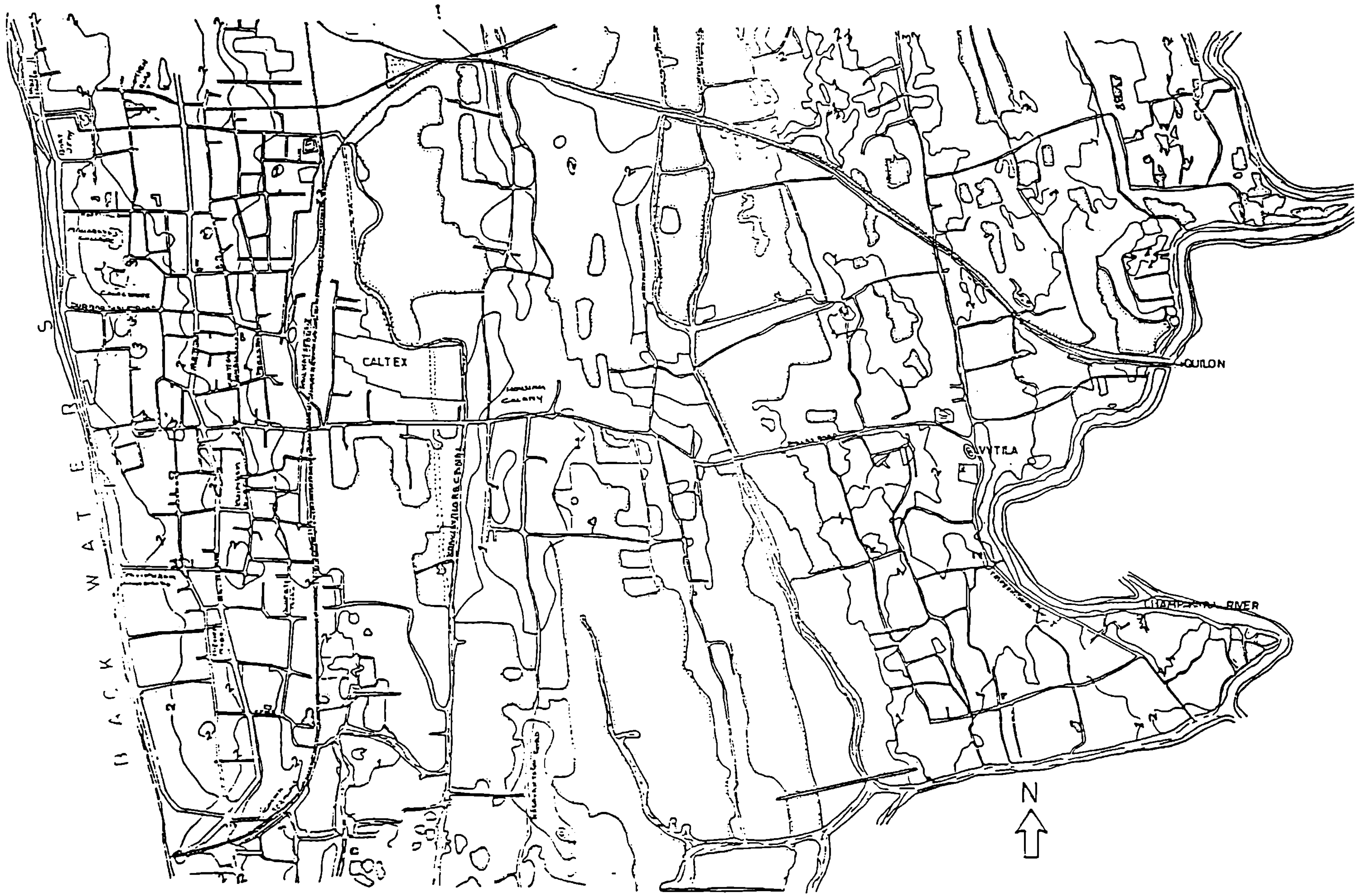


FiG - 7 . 10 . OLD CONTOUR MAP OF ERNAKULAM TOWN
(WESTERN FLAT LAND)

as institutions resulting in the formation of bottlenecks that reduces the flow considerably.

c. Formerly during heavy rains, the storm water drained into the natural pools of marshes and paddy fields, which slowly emptied into the backwaters and sea. So, in the old days, even when during torrential rains coinciding with high tides, there was no flooding in these residential areas. But now, for building purposes, many of these natural catch basins have been filled up higher than the formerly high adjoining residential plots. Since there is no outlet for the storm water and also because of water inflow from the newly filled up areas, the old residential areas are now subject to frequent floods.

d. Reduction in seepage of rain water into the soil by the land being filled up with laterite (the easily available one) which consolidates into an impervious strata or cement concreting of courtyards results in the increased run off.

e. Large natural drains and tidal canals are often blocked by a profuse growth of Eichhornia (Water hyacinth) due to eutrophication caused by domestic waste water and sullage inflow. Also, putting up of bunds in canals to prevent the entry of saline water by various agencies blocks the flow of water and results in floods during monsoons.

The flooding of storm water along with sullage in low-lying areas affects transportation, telecommunication, electric supply, water supply and other public utility services besides causing innumerable human discomforts. It also poses health hazards particularly by contaminating drinking water, when taken from street taps in the low-lying areas.

Many of the water-logging problems in the highly urbanised western flatland can be ameliorated by the following steps: -

1. Linking the drains of all residential, commercial and industrial areas to the main tidal canals, by a grid of drains along the roads which is possible since all the areas in the western flatland are within 1 to 2 km of the north-south running tidal canals. Also their proper maintenance has to be ensured.
2. Deepening of the main canals may not be of much use since their bottoms are already below the low tide level. Only widening can increase the capacity of the canals considerably.
3. Encroachers into the canals are to be evicted and the 'Thodu's are widened to their original size, wherever possible.

In the eastern upland regions, comprising of 21 stream catchments, at present there are no serious flood problems. This is because, there are sufficient low-lying paddy fields in the flood zone of these streams, which act as buffer containers to store the flood water. However, the recent trend in filling up of those paddy fields, particularly those lying close to the outlets of the streams, will reduce the discharge capacity of the streams, thus causing frequent floods in the upstream areas. Moreover, during torrential rains, the surging water, particularly from the vast Kadambrayar and Puthencruz catchments (81 and 58 square kms respectively), may demolish the 'earthen dam' of land filling in the flood zone along with the buildings constructed there. Hence, filling up of paddy fields in such crucial areas must be discouraged.

7.3.6. Traffic and Transport

The operational efficiency of any urban system depends on the adequacy of linkages between various activity areas by a system of traffic network and goods transportation. Cochin is uniquely served with the concentration of different modes of transportation on air water and land. Goods traffic in any region, in general, is contributed by the factors like population, which directly influence the consumption requirement of commodities, agricultural and industrial production and distributional or commercial importance of the region.

However, the road transportation in Cochin is seriously affected by the suburban spread of the city, which leads to excess pressure on the arterial roads during peak hours, which were not adequately planned and designed to meet the demand. When the roads do not have adequate width to contain traffic and parking vehicles, the roadside trees are often cut down to provide for carriageway. Also, in very narrow roads, traffic signals and hoardings become visually very unsightly.

Traffic congestion results in burning of more fuel, particularly at peak hours causing serious air pollution which will be more acute when the roads are narrow with tall buildings on either side forming a canyon preventing air circulation. When there is atmospheric inversion or isothermal condition the atmosphere will be more stagnant resulting in the production of phototoxicants during daytime.

The land under transportation and communication (in the central city area) constitutes 6.14% of the net dry land area (GCDA Structure Plan - 2001). This includes area under railway installations, road transport, dock yards, jetties etc. and airport. However, the roads are narrow and streets are usually irregular lanes. The railway line divides the city into two in north-south direction. The landing facilities for ferry services and for inland navigation are grossly inadequate.

Though the number of vehicles on the road has increased several times, the road surface within the region in the past fifteen years has not increased proportionately. The road congestion in the central business district area of Ernakulam is the primary reason for the area being unable to bear further commercialization. Another reason for over-congestion in the region is that the potential of water transport has not been adequately utilised.

The road transport in the study area is served by National Highways, State highways and City level road network (Fig.7.11).

Three National Highways touch the city which facilitate fast movement of people and commodities from its hinterland to Cochin and add to the improvement of the economic environment of Cochin.

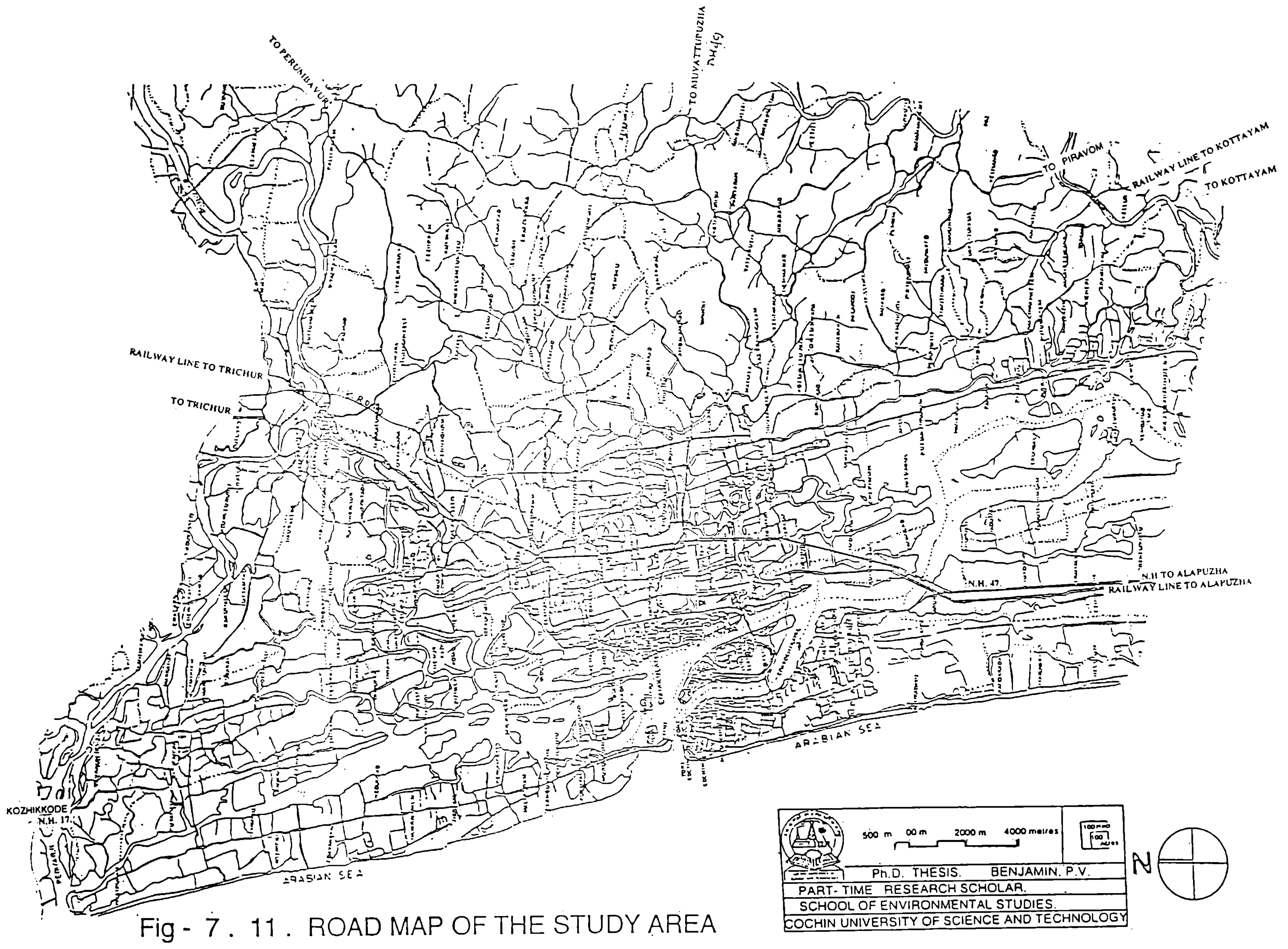


Fig - 7 . 11 . ROAD MAP OF THE STUDY AREA

(1). NH-47 running between Kanyakumari and Salem passes through Cochin. Formerly this highway passed through very congested areas of Ernakulam, Thoppumpady and Palluruthy. Now a Bypass has been constructed from Edappally passing through Vytila, Marad and Kumbalam to join the highway at Aroor. It is laid as a 4-lane roadway with service roads on either side.

(2). A coastal highway NH-17 links Cochin directly to Parur and beyond, to Mangalore.

(3). Another National Highway (NH-49) links Cochin to Madurai via Muvattupuzha, Kothamangalam, Adimali and Munnar.

The city is directly connected to other urban centres of the region through state highways and district roads. These roads radiate from the city. The most important roads in this group are: -

1. Ernakulam - Muvattupuzha road
2. Ernakulam - Piravom road
3. Ernakulam - Perumbavoor road
4. Ernakulam - Parur road.
5. Fort Cochin - Chellanam road
6. Vypeen - Parur road

The operational efficiency of transportation along these radial roads is very much hampered by poor alignment and road geometrics, uncontrolled ribbon development along the road sides, bottlenecks created by narrow bridges; railway crossings etc and insufficiency of roads connecting radial roads with each other. These roads are linked to each other at several points by ring roads, which are the major link roads in the region and are the following.

1) The inner ring road, of which the Elamkulam - Kaloor - Perandoor road forms a major part, facilitate quick access to the central business district comprising the trading centres around Ernakulam, Cochin Port and Mattancherry.

2) The middle ring road is constituted by the existing Cochin Bypass and the NH-17.

3) The outer ring road is the Irimpanam - Kalamassery industrial road which links the industrial centres of Eloor, Ambalamugal as well as civil station (office complex), the Cochin Export Processing Zone, the Naval Physical and Oceanographic Laboratory at Thrikkakara and other prospective work centres of the region.

The bulk of the hinterland of Cochin lies on its east and the rest on its south and north. The regional roads from the hinterland have easy access to the middle ring road of NH-47 Bypass on the periphery of the present highly urbanised areas. From the middle ring road, at present there are only three main roads to reach the inner ring road and the Central Business District (CBD), which is the nerve centre of Cochin - Road via Thoppumpady - Wellington Island, Vytila - Pallimukku Sahodaran Ayyappan Road via Kadavanthara junction and Banergi Road from Palarivattom - Madhava Pharmacy via Kaloor. Besides, there is another road, Thammanam - Pulleppady Road via Kathrukadavu which is very narrow. Now a new road parallel to the Sahodaran Ayyappan road is nearing completion. All these roads are at present very congested which make the entry of vehicles from the hinterland to the CBD area very difficult. The widening of the Sahodaran Ayyappan road, which has now begun and the completion of its parallel road (Ponnurunny – Gandhinagar) along with widening of Thammanam - Pulleppady road may solve this problem to a great extent.

The road network in the city is a broken grid-iron pattern. The main emphasis is on the north-south axis with minor roads giving the east-west connection. Vast portions of peripheral areas remain isolated from bus services. This is due to the fact that most of the peripheral roads are of poor quality with narrow sections of the roadway, crossing of railway lines and lack of continuity created by unbridged canals and streams.

The City has two bus terminals - the State-owned KSRTC bus station lying in the CBD which is about 4 kms away from the second one, the Private Bus Stand at Kaloor. No co-ordination exists between the operation of buses from these two terminals. There is also overlapping of suburban and city services within the city. The interchange from the suburban bus system to city bus system and vice versa is not defined. If there are separate but close by terminal facilities for inter-state, inter-city and city service buses irrespective of whether they are operated in the private sector or the government sector, can reduce considerably the number of buses plying in the CBD area unnecessarily. Further, if inter-state and inter city buses are allowed to bypass the city through the NH-47, a considerable amount of fuel, time as well as money can be saved in addition to reducing traffic congestion in the city.

The lions share of the total goods traffic is handled by fast vehicles consisting of trucks and tempo vans. The special requirements of these goods vehicles for parking, driver's rest, petty repairs, transit of goods, storage etc. are presently ill-organized and randomly distributed all over the city.

Cochin is connected to the north and south by broad gauge lines. The north line bifurcates at Shornur towards Mangalore and Madras. Towards the south there are two lines - one going to Kanyakumari via Kottayam and the other via Alapuzha The railway lines in the city serves mainly for transportation of bulk goods for trade and commerce and the long distance passengers. It also serves a section of the commuter traffic to the city within a zone of about 75 kms from the city centre. The commuter traffic has been steadily increasing. But, the restriction of the single line to the south Kerala creates delay in the travel and inadequacies of trips to cater to the increasing demand. Since railway is to be assessed on a regional scale, it is not dealt with in detail.

Railways play a prominent part in the goods movement to and from the city especially catering to the finished petroleum products from the Cochin Refinery and Fertilizers from FACT unit at Ambalamugal. It also carries a large bulk of the port traffic between the port and its hinterland, which extends to the whole of Kerala, and Coimbatore and Salem districts of

Tamilnadu. Considering the growth of goods traffic movement by railways in the future decades, it is necessary to make provision for the expansion of goods shed, marshaling yards and allied needs of the railway in Cochin.

Providing the entrance to the North and South railway stations from the eastern side also will reduce the traffic congestion in the C.B.D.area due to the reduction in criss cross traffic.

Water transport is the most energy efficient and economical transport system. It includes sea routes, and inland waterways.

Sea routes links other ports of India as well as ports of foreign nations. Cochin harbour, which is an all-weather protected harbour, lies in the main ship routes in the Laccadives Sea. The entrance to the harbour is 450 m wide with the approach channel extending to about 5 kms into the sea. The shipping channel on entering the harbour branches into Mattancherry channel and Ernakulam channel. There are mid-stream mooring facilities in these channels and wharfs on either side of Willingdon Island. facing these channels. The Cochin Shipyard and the oil tanker berth are located on the Ernakulam foreshore facing Ernakulam channel. The channel can accommodate only ships up to a maximum tonnage of 80,000 tonnes since the depth of the channel is only about 9 meters. This shows that the potentialities of this natural harbour are not fully exploited. .

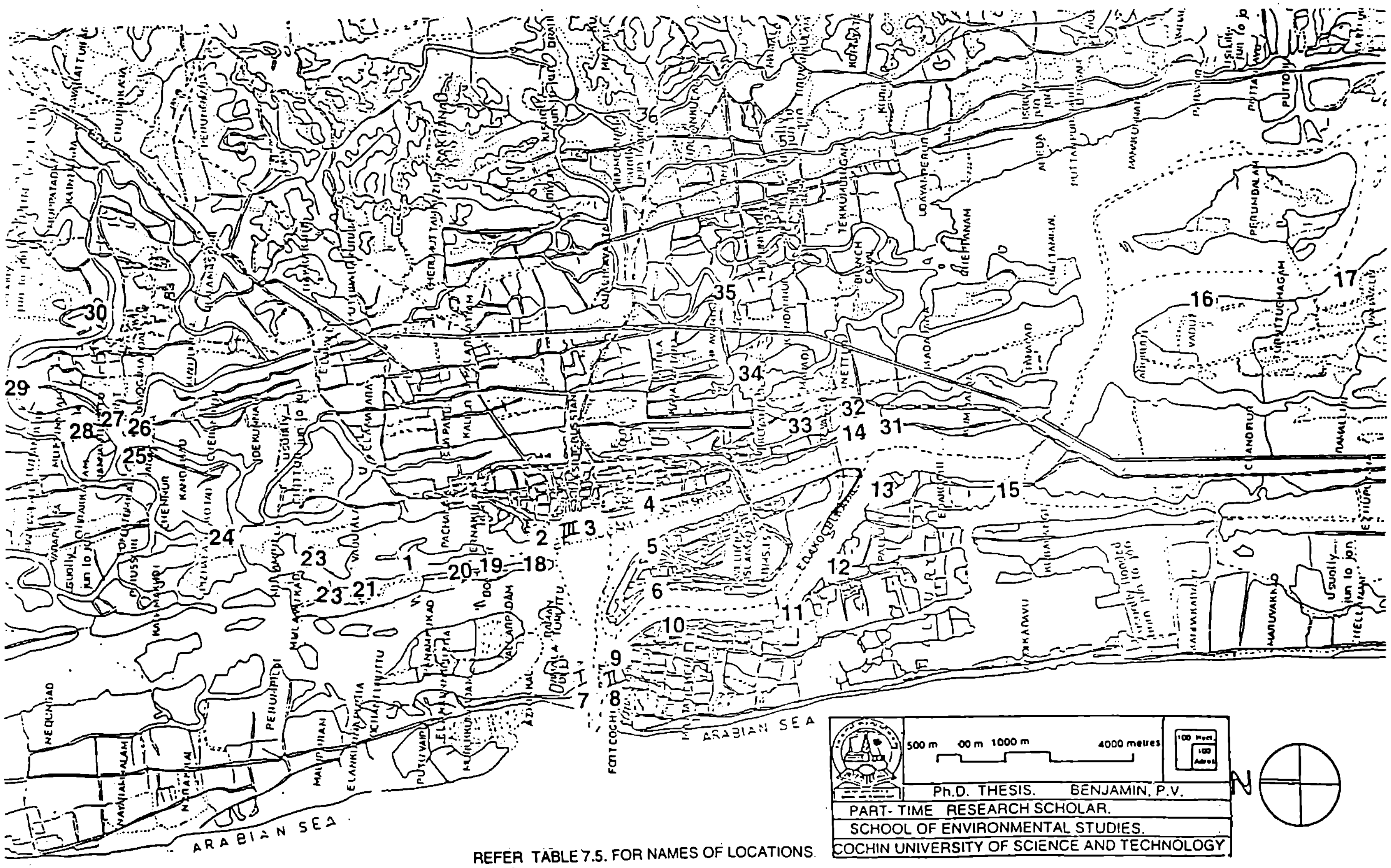
In Cochin region, inland waterways play an important role in the transportation of goods and people. The geographical set up of the region is such that an alternative to waterways would involve more cost and travel time. Hence, waterways help to reduce expenditure and also to conserve energy.

The inland waterways of Cochin region comprise of the feeder canals to Ambalamugal and Udyogamandal, the stretch of west coast canal and other water areas of Vembanad lake in the region thus linking major areas of the region with the city by water (Fig.7.12). Distance by waterways from Cochin to important places along the west coast canal are given below which indicates the possibility of having longer navigation services of regional and interregional character.

Alapuzha - 70 kms
Quilon - 145 kms
Trivandrum - 205 kms
Munambam - 22 kms
Ponnani - 75 kms
Kadalundi - 135 kms
Badagara - 210 kms
Azhikkal - 255 kms
Hosdurg - 310 kms

On an average 70,000 daily passenger trips are being effected by inland water transport services in the Cochin region excluding the passenger trips by private boat operators. In the Ernakulam-Vypeen route 20,000 passengers travel daily and this route serves as the main link for the Vypeen based population for interacting with Cochin City.

The main boat jetty at Shanmugham road is the busiest terminal in the region. The main jetty handles on an average 40,000 passengers per

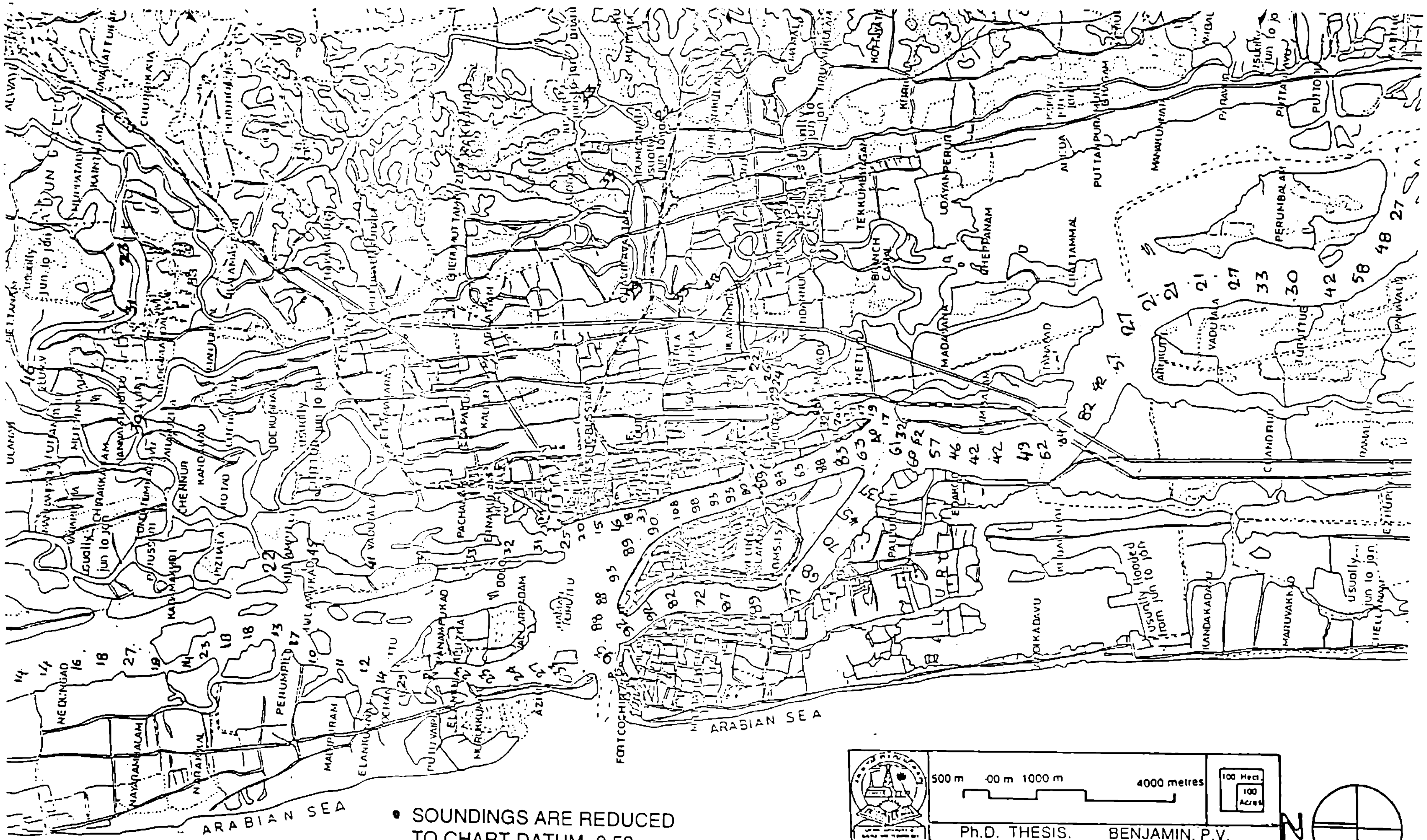


REFER TABLE 7.5. FOR NAMES OF LOCATIONS.

Fig - 7 . 12 . LOCATION OF IMPORTANT JETTIES ALONG THE WATERWAYS IN THE BACKWATERS OF THE STUDY AREA - COCHIN .

TABLE - 7.5. NAMES OF IMPORTANT JETTIES ALONG THE WATERWAYS OF COCHIN.

1) THANTHONNITHURUTHU
2) HIGH COURT
3) ERNAKULAM
4) PERUMANOOR
5) ISLAND EMBARKATION
6) ISLAND TERMINUS
7) VYPEEN
8) FORT-KOCHI TERMINAL
9) FORT-KOCHI CUSTOMS
10) MATTANCHERRY
11) THOPPUMPADY
12) NADAKADAV
13) KANNANGAD
14) THEVARA
15) EDAKOCHI
16) VADUTHALA(S)
17) PANAVALLI
18) BOLGATTY
9) PONJIKKARA
20) PONNARIMANGALAM
21) PONNARIMANGALAM HOSPITAL
22) MULAVUKAD PANCHAYAT
23) KORUNGOTA
24) KOTHADU
25) VARAPUZHA
26) CHERANALLOR
27) ELOOR
28) MUTTINAKAM
29) ELOOR (N)
30) EDAYAR
31) KUMBALANGI(N)
32) NETTOOR(S)
33) NETTOOR(N)
34) KUNDANNOOR
35) CHAMPAKKARA
36) AMBALAMUGAL



- SOUNDINGS ARE REDUCED TO CHART DATUM 0.58 m BELOW M.S.L. AT COCHIN
- DEPTH IN DECIMETRES
- DATA SOURCE ; INLAND WATERWAYS AUTHORITY OF INDIA

500 m -00 m 1000 m 4000 metres	100 Hect. 100 Acres
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Fig - 7 .13 . DEPTH OF BACKWATER SYSTEM ALONG THE MAIN WATERWAYS day and nearly 320 boat trips. Other major boat terminals are Embarkation jetty, Fort Cochin Jetty, Vypeen Jetty and High Court Jetty.

Movement of goods by waterways in the state is carried out generally by country crafts. In the public sector, KINCO is moving raw materials like sulphur and rock phosphate for FACT Cochin Division from port.

Lack of adequate boat services in the existing routes, absence of boat services to some islands, lack of proper terminal facilities, inadequate interchange facilities in most of the boat jetties and inadequate canal dredging are the main hindrances which affects the inland water navigation in the Cochin region.

Inland water transport generates more employment compared to other modes. There are also benefits like reduction in atmospheric pollution, more effective maintenance of environmental and ecological balances, reduction in congestion and accidents in the roads, savings due to reduction of consumption of non-renewable energy resources and development of tourism.

Cochin is having air traffic facility also. Cochin airport is located in the Willingdon Island within an enclave controlled by the Indian Navy. The airport has two runways of 1620 m and 1440 m in length and a width of 45 m each, suitable only for small aircraft. There is no scope for the expansion of the aerodrome at the present location because of the non-availability of space.

In order to provide facilities for big aircrafts, a new airport is being constructed at Nedumbassery near Angamaly, which is about 10 kms to the north of the study area. The construction of the aerodrome is expected to be complete by 1998.

7.3.7. Parks, Play grounds and open spaces

The percentage of land under parks, playgrounds and open spaces in the city comes to only 0.78% of the net dry land (GCDA Structure Plan-2001). Although water sheets and agricultural land provides the lung space of the city and supplement the open space requirements, their use for passive and active recreation is limited.

The minimum standard prescribed by TCPO (Town and Country Planning Organisation - Government of India) is 0.5-hectares/1000 population. In Cochin, this comes to only 0.145 hectares/1000 population, which is much below Indian standard. Even this 0.145 hectares/1000 population is inclusive of marshlands and watersheets. In the near future this land also is likely to be converted into built-up areas. (GCDA Structure Plan-2001)

The open space requirement for the passive and active recreation of the city population is to be met by adequate provision of spaces catering to various levels of demands are as suggested below: -

i. Provision for a major city park and development of a botanical garden as central city facility.

ii. Provision for the green strip systems with special function such as open-air theaters, rally maidan etc. in specified parcels extending to 10-12 hectares each.

iii. Parks, play grounds and the sports fields in different divisions of the city,

iv. Enough land should be assigned for social forestry to act as buffer zone around the industrial areas.

v. Development of tourist villages on small islands in the back waters.

Acquisition of land for public open space is a non-remunerative activity for the city development authorities. Hence, in order to make this proposal economically viable, it is necessary to integrate other remunerative schemes such as housing or commercial development with the development of public open space.

With all the modes of transportation, an amiable climate, a long tropical beach line, proximity to hill stations, relatively clean premises, availability of hotels, boating & yachting facilities and a rich cultural heritage etc, there is every potential for Cochin to become one of the important tourism centres of the world. This resource is not yet exploited properly for want of necessary awareness as well as exposure.

Meanwhile, even government lands such as coconut farm at Vytila, extending several hectares, lying on the shores of Kaniampuzha river and acting as a buffer zone between industrial area at Ambalamugal and Cochin Corporation has been converted into industrial use by the Government itself in spite of public outcry against such a conversion. Only a collective effort of various governmental agencies and local bodies with public participation can achieve the necessary open space standards in Cochin.

7.4. Summary and conclusion.

Comfort in urban life lies in the condition of basic amenities and services which in turn is linked to the socio-economic environment. Day by day the urban limit of Cochin is increasing with consequent overload in the available basic amenities and services. Proper assessment of the existing condition of them is necessary to plan for the future. Water supply, drainage, solid and liquid waste disposal, traffic and transport, park and recreational facilities and housing problems are assessed. The observations are summarized below: -

The western flat land portion of the study area where the economic and commercial activities are centred - Central Business District (CBD) in planning terms - has a considerably higher density of population than the eastern upland. The population density decreases fast towards the east with increasing distance from the CBD area. But there is no such remarkable variation in the population density along the north-south direction. Hence, eastern upland is having more potential for future urban expansion.

The rise in workers to population ratio also reflects a rapid economic growth-induced increase in job opportunities. The manufacturing, processing and servicing sector are found to be the major contributor, thus forming the economic base of the area. Despite widespread mechanisation during the last decade, the percentage composition of construction workers almost doubled indicating a healthy economic development and rapid construction boom, signs of fast urbanisation.

Even though, the housing shortage has decreased in the last decade, still there exists a shortfall of about 21 houses per 1000 households. When remedial measures for this deficit is envisaged for future planning, the trend in family size variation in the past has to be taken into consideration. Between 1971 and 1991, the average family size has decreased from 6.33 to 5.08 persons, a result of high literacy rate and high living standards - a trend which is likely to continue - implying that future housing policies should be oriented towards construction of small houses.

The slum dwellers account for about 21.27% of the city population; a not-too-alarming figure when compared to other cities in India, however, environmentally a very alarming one. Also, the number of slums is found to increase with time. The availability of low-priced lands, as islands without road connections, within the city or in close proximity, has so far been successful in limiting the growth of slums to the present rates. However, once these isolated land-strips are road-linked by construction of bridges, land value may shoot up to heights beyond the reach of the urban poor. This will accelerate the development of urban slums.

Hence, proper planning backed by a thorough comprehension of all contributory factors leading to the timely implementation of appropriate housing policies, alone can prevent a degeneration in the urban environment.

Potable fresh water is naturally available in most of the eastern upland portion of the study area, whereas, it is scarce in the western flatland areas. The requirement is met by the public water supply system drawing water mostly from Periyar River at Alwaye and Muvattupuzha river at Ramamangalam. In spite of recent augmentation, water supply in Cochin is insufficient even by Indian Standards, which itself is far below the standards of the developed countries. This is partly due to insufficient treatment & pumping capacity and partly due to insufficient distribution system as well as wastages in transit.

The river water, above the intake wells at Alwaye is contaminated with municipal effluents from Perumbavoor and Alwaye. Moreover, factory effluents from the Eloor industrial belt about 1 km downstream may reach the pumping station during high tides when the river flow is very weak. The contaminants from these factories, containing Mercury (TCC), Acids & insecticides (HIL) may reach the headwork area in large concentrations along with tidal saline water in summer, if Periyar river flow is reduced considerably due to insufficient water being released from Edamalayar Dam or because of an intense drought.

At present, a major part of the study area is dependent upon water supply from Periyar River alone. In case of a serious contamination (either due to above-mentioned natural causes or due to man-made causes), the whole water supply system will have to be shut down, with disastrous consequences. So, as a precaution as well as for augmenting the present insufficient water supply system, additional intake facility with suitable treatment system has to be added to the Ramamangalam headworks in the Muvattupuzha River, which at present meets mainly the industrial requirements alone. Such a system can be connected to the existing water supply grid so that the two systems together will meet the water demand in normal times and in times of emergency, one system can be completely closed while the other pumping system can provide water to the whole area at least partially.

The distribution system is affected by age-old pipelines, which are corroded at several places. In the western flatland area where the water table is high, has salty soil in several places, which accelerates corrosion of pipelines. Moreover, tidal action corrodes exposed pipelines by frequent wetting & drying. In many places, the pipelines which cross the drains develop holes by accelerated corrosion resulting in leaks during times of pressure and contamination of the water supply by sucking of sullage from the drains during low pressure. Timely replacement of the corroded and damaged pipelines made of corrosion-resistant and break-proof materials is the only solution to this problem.

Solid waste disposal is becoming an increasingly serious problem in Cochin particularly in the densely populated western flatland area where there is high water table and absence of proper disposal sites. In the less populated eastern uplands, the garbage disposal is not difficult due to availability of vacant lands. In the small townships of the eastern parts of the study area, covered type of land filling can be depended upon, but in the western flatland area, effective and environmentally sound garbage disposal can be done by compost plants in appropriate places or sanitary land filling outside the densely populated areas.

Sewage & sullage disposal also is a serious problem in the western low land due to the high water table. Present system of septic tank or pit for individual houses affects the environment adversely. Particularly during heavy rains, waste levels in the tank rises to the level of floodwater causing contamination by fecal matter. This intrusion may cause epidemic outbursts any time and hence has to be viewed with sufficient seriousness. The sewerage system, covering only a very small portion of the city at present, has to be extended to the whole flatland area. However, in the western flatland area, due to the absence of gradient, it is rather very difficult to convey the sewage from a vast area to a single or a few large-scale sewage treatment plants. Hence, it is more suitable to install mini treatment plants sector wise or one in a colony of appropriate size.

In the eastern upland areas, not only there is sufficient space for sewage and sullage disposal, but it is unlikely to contaminate the groundwater which lies deep below a relatively impermeable laterite layer. Hence, a sewerage system may not be essential at present because septic tank system is sufficient to meet the current requirements. Not only that, since the houses are wide apart a sewerage system will be very expensive also.

Storm water and sullage disposal is also a matter of serious concern in the western flatland area. Flooding of storm water with sullage leads to environmental contamination and other human sufferings. In the western flatland area the flood problem is local either due to the inadequacy of drains or due to local depressions. This can be solved by properly linking the roadside drains to the tidal canals, since, no place in the western flatland area is more than about two kms away from a tidal canal. Also, the encroachers into the canals and 'thodus' are to be evacuated along with widening. Deepening of the main canals may not be sufficient from drainage point of view, since the bottom of many of these canals are already below the low tide level. Hence, widening is necessary to increase the drain capacity effectively.

However, the storm water drainage is bound to become a serious threat in the near future in the valleys of the eastern upland. In these regions, the flood zones of the streams, which drain, into the valleys are being filled up for raising plantation crops and construction purposes, which reduces the discharge capacity of the streams. This aspect is dealt with in detail in the chapter on surface hydrology.

Cochin is served with all modes of transportation by air, water and land. However, due to improper location of the various transportation services, the potential remains grossly unutilised. The roads are narrow and the railway line bifurcates the city, thereby obstructing the road links between the two sides. The potential for inland navigation remains under-utilised. Cochin is having an all-weather protected harbour lying in the main ship route but due to inadequate depth of the shipping channel the port remains inaccessible to large vessels. The existing aerodrome at Willingdon Island has space restrictions, which preclude future expansions so as to accommodate international air traffic. However, the commissioning of Nedumbasserry airport on the outskirts of the study area will improve the situation to a large extent.

Among the three ring roads - inner, middle and outer - the inner ring road is too narrow to serve the existing passenger and goods traffic. (The GCDA has recently started widening). The radial road connections between the inner and middle (NH-47 Bypass) ring roads. originating from the CBD area, are grossly inadequate both in number as well as width. Widening of the existing roads, wherever possible along with construction of new roads and flyovers can alone solve the present imbroglio. The new roads should be constructed with enough strength to bear the heavy container traffic.

The important railway terminals in the city are Ernakulam Junction and Ernakulam Town. The entries to these stations are confined to the western side only. In view of the fast development of the town on the eastern side of the railway line. entries to the station from the east will be most desirable. This will also relieve the number of the criss-cross traffic in the central business district of the city. The proposal for a Ring Railway connecting the major nodes of the metropolis, if implemented, will be a boon to the city in not only reducing the traffic congestion but also in reducing the pollution substantially.

Inland waterways offer a cheap and efficient transportation of goods and people. In the western part of the study area bestowed with tidal canals, water transport if properly designed, would reduce road congestion considerably.

The interchanges between waterways and roadways are very important in the city owing to the complementing roles of these two modes in the transportation system. The facilities at these interchanges are noticeably poor considering the character and volume of traffic. These are to be specially designed for efficient and comfortable transfer of goods and passengers.

A properly planned water transport system utilising the tidal canals, rivers and sea as well as limiting the inter-city and inter-state road transit to the periphery of the highly urbanised area through NH-47 Bypass will greatly reduce the urban road congestion. Locating the terminals of the three traffic systems - road, water and railways - in close proximity will reduce unnecessary criss-cross traffic within the city. The Vytila area where the NH-47 Bypass, Kaniampuzha canal and railway line lie in close proximity may be an ideal site for such a development. Vacant land is also available in the locality at present. Since the area lies close to the middle ring road, city level traffic can also originate from there and enter the city through the road passage below the Vytila over bridge and enter the parallel road to Sahodaran Ayyappan Road.

The area allotted for parks and open spaces come to only 0.78% of the net dry land even in the Cochin Corporation area while in other areas it is almost absent although water sheets, paddy fields and plantation areas provide lung space at present. But 0.5 hectares/ 1000 population need to be earmarked and kept for the population projected to another 50 or hundred years from now. Otherwise, when full urbanization takes place, the area will suffer from acute shortage of open spaces and parks. Planned buffer zones between industrial and residential area are also lacking in Cochin, which need immediate attention.

Tourism may play a major role in the socio-economic improvement of any region if judiciously managed. Cochin has a vast potential of natural scenic areas and places of historic and architectural values. Such places should be identified, maintained and managed so that it can become a good resource.

Chapter- 8

Summary and Conclusions

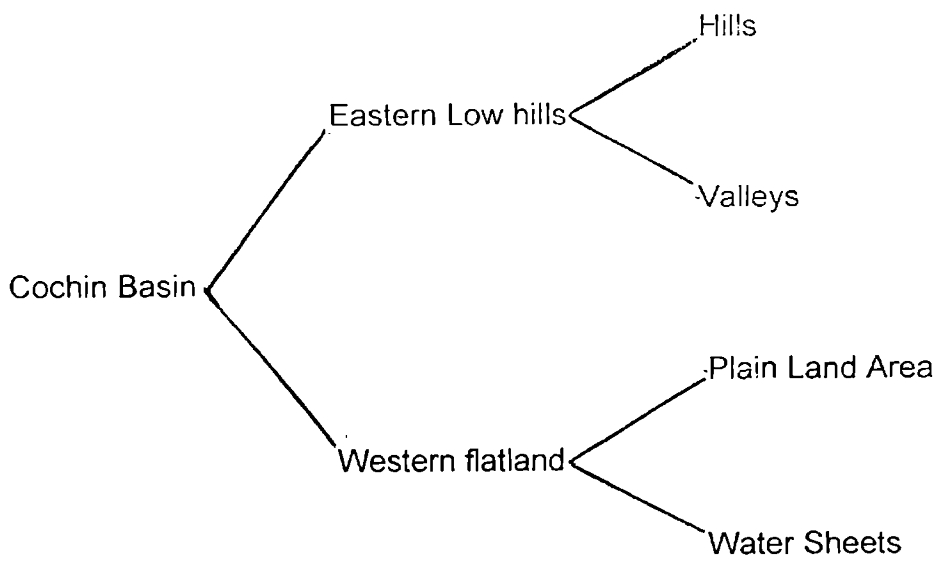
Population explosion and urbanization cause enormous stress on the environment resulting in its rapid deterioration. Maximum human comfort in the long run must be the objective of any human settlement planning. For short-term benefits, this aspect is often neglected or left without giving proper weightage resulting in irrecoverable damage to the environment, which leads to unforeseen human sufferings. Hence it is necessary to propose appropriate land uses which are complimentary and compatible with various resources in the long run. Environmental planning is to allocate appropriate land use pattern with optimisation of resource utilisation in such a way that the quality of the environment is sustained.

The present study is aimed at assessing the various environmental resources from a physical planning point of view so as to propose probable and compatible urban developments in the various locations within the study area. The Cochin basin - which is bounded by the ridgeline of Muvattu-puzha river basin on the east and part of the south; and Periyar river basin on part of the north side and Laccadives sea on the west. In the backwater zone, there are interbasin linkages and hence there is no well-defined boundary

Cochin is a coastal settlement interspersed with a large backwater system. The ridgeline of the eastern low laterite-capped hills provides a well-defined watershed delimiting Cochin basin, which help to confine the environmental parameters within a physical limit. This enables to arrive at comprehensive conclusions regarding each of these parameters. The study area - Cochin basin - covers an area of approximately 535 km^2 within 9° 45' N to 10° 14' N and 76° 10' E and 76° 31' east in the southwestern coast of India.

The basic environmental resources are assessed under the headings 1. Physiography, 2. Geology & Groundwater, 3. Surface hydrology & Backwater system, 4. Climate, 5. Vegetation and 6. Socio-economic environment & Basic amenities.

Physiography of the study area can be divided as follows:-



All these areas are physiographically distinct. The eastern low hills are laterite-capped with moderate slopes in most of the areas. Such a terrain provides a generally stable land for any kinds of construction activities, provided, care being taken while cutting and filling is done. The valley floors of the midstream areas and the lower reaches of the streams are vulnerable to flood. At present the floodwater is being drained through the flood zones of the valleys and, in the case of heavy floods, the water occupies the flood fringe zone also. But the current pace of urban sprawl with filling up of the flood zone and flood fringe zone is sure to cause serious damage to buildings and other constructions during floods leading to economic loss and human suffering. Hence a detailed level survey of the area is a pre-requisite for commencing developmental activities.

If physiography alone is considered, the western flatland is ideal for urban development, being a level land linked by roads and railways and also by commutable tidal canals and an extensive backwater system. However, at present there is large scale filling up of shallow mangrove-fringed water sheets (paddy fields and estuary) by various private individuals and government organisations, which may lead to serious environmental crises. The decline in the fish catch seen in recent years is indicative of such an environmental degradation since the shallow water is the breeding ground for many estuarine and brackish water fauna. Hence urban developments in such areas are to be regulated in the line of coastal zone regulation notification which assumes added importance in view of the predicted sea level rise resulting from global warming.

It is reported that there is a 2.2-mm annual rise in sea level in Cochin, which will amount to 22 cms in the next 100 years. When it happens, millions of people would be forced to relocate; human stress, anxiety and discomfort would be severe. International Panel for Climatic change (IPCC) in 1990 has predicted a 31-cm rise in sea level (lower scenario) induced by greenhouse warming, by the year 2100. Such a rise in ocean levels would cause the sea to move several meters farther inland thus permanently inundating a large area of the highly urbanised western flatland region of the study area.

The eastern low hills and western flatland are geologically also distinct. The eastern low hills are eroding areas while the western flatland is a deposition area formed by the sediments brought by various streams and rivers. The eastern low hills are geomorphically an etched plain formed due to differential erosion, the surface unprotected by laterite duricrust eroded rapidly and formed the valleys while the comparatively stable laterite-covered areas formed the hills. Lithostratigraphic study with the help of bore-logs and historical evidences of seismic activity clearly indicates that the western flatland is geologiclly unsuitable for urban development.

Also, in most of the areas of the western flatland potable groundwater is absent, or if at all present, it is found either as perched aquifers (which is easy to get contaminated by land pollutants like sewage, factory effluents etc.) or rarely as deep-seated (about 75 m below ground level) primeval non-rechargeable aquifers, which, if extracted on a large scale, may cause not only their extinction, but also the disastrous subsidence of overlying layers. Hence it is recommended that future urban development in the western part should be restricted or regulated taking into consideration the following aspects: -

1. Litho-stratigraphical evidence indicates periodic sinking and upheaval and/or transgression and regression of the sea.
2. The area has a history of seismic activity
3. Large scale filling up of low-lying areas can lead to crustal imbalance, which may induce tremors
4. The western flatland being very close to sea level, any sea level rise due to global warming can inundate the area in the foreseeable future.
5. This area being of sedimentary origin, with clay as the major component, which increases the building foundation costs
6. Large-scale reclamation and dredging of backwater system will induce not only geo-logical instability, but also increased wave action and intrusion of tidal waters further inland
7. In most of the areas, the groundwater in the upper strata is not potable and unsuitable for construction purposes either due to salinity or high organic content

8. Excessive groundwater mining from recently discovered deep-seated aquifers may lead to land subsidence.

9 Being a flat terrain drainage is difficult.

The eastern low hills are comparatively stable being formed of laterite or lateritic soil over a laterite layer forming a coping on the hills, which in turn lies over crystalline parent rock. Hence this area is suitable for construction activities and hence congenial for urbanisation due to the following reasons.

1. The substrata are geologically stable in most of the areas, and hence the foundation cost will be less.

2. Also locally quarried laterite blocks/ granite can be utilized thereby reducing construction costs

3 Potable groundwater is available

4 There is adequate slope for efficient drainage

However, developmental activities on steep slopes and flood zones of streams should be discouraged or legally regulated.

Individual microcatchments (sub-basins) in the eastern low hill region and drainage planning areas in the western flatland zone are identified with the help of contour as well as land use maps supplemented with field investigations. The study area (535 km^2) is divisible into 3 regions with distinct surface hydrological characteristics.

1. The eastern upland (291 km^2) with the highest point 115 m above M.S.L. comprises of 21 sub-basins which drains into the backwater system through streams
2. The western flat land (115 km^2) interspersed with tidal canals and the islands in the backwater system (56.4 km^2)
3. The backwater system (72.59 km^2).

The discharge efficiency of each stream and thereby the flood probability in various catchments are studied. Based on calculations, the flood-prone areas in the eastern hill valleys are identified. These areas (existing mostly as paddy fields at present) are unsuitable for urban development or for raising plantation crops, since such areas if reclaimed by filling up are liable to be washed away by surging flood waters. Such areas should be declared as filling-free zones where only regulated development can be permitted.

Many of the environmental problems of Cochin are hydrologic in origin because hydrologic cycle gets drastically modified during urbanisation. The drainage basins, on which some modifications are done, often form a portion of a larger drainage basin and hence these modifications may inadvertently affect other areas of the drainage basin also, unless they are carefully planned. Hence, drainage basin dynamics give a better understanding of hydrologic and geomorphic processes for analysing the spatial linkages between different areas that can affect both regional and site planning

In the land area of the western low-lying region, the main hydrologic problem is waterlogging due to absence of slope. Hence water gets logged in the depressions and the areas where there are no drains or where the drains are blocked by various reasons. Waterlogging also occurs due to inadequacy of drain size and/or due to unnecessary meandering of drains through low-lying areas. Another serious problem is that land originally above waterlogging levels becomes prone to frequent waterlogging due to filling up of surrounding low lying areas to comparatively higher levels for construction activities from where, during rains, water drains into the originally flood-free areas.

The waterlogging problem in the western flatland can be easily remedied by engineering solutions (linking the road-side drains to the nearby tidal canals), since no part of the area is more than 2 or 3 km away from a major tidal canal and the maximum extent of a catchment is only a few hectares. Proper drainage planning with engineering solutions in all the drainage planning areas will solve the problems if executed along with proper maintenance system.

The islands in the backwater system are mostly rural in nature and hence the abundant natural channels existing in these islands are sufficient at present to meet the drainage requirements. In future when urbanisation takes place, sufficient drains are to be laid with proper slopes and hierarchy. These drains are to be linked to the backwaters at the nearest point.

The Cochin backwater is a part of the Vembanad estuary, which has a perennial fresh-water influx mainly from various rivers originating in the Western Ghats. The width of the backwater extends from narrow channels of a few meters to about 9 kms with a maximum depth of 9.3 m at the bar mouth. The backwater system is mostly shallow, but along the main waterways the depth varies from 1m to 9.3m. The backwater system is open to sea at Cochin and at Azhikod (which lies towards north of the study area). Through these guts seawater intrusion occurs during high tides. The large fresh water inflow during the Southwest monsoon season (June-September) drives out the entire saline water along ebb flow. This salinity variation gives rise to a high primary productivity which nurtures an excellent fish population. Also, the backwater system provides an easy navigational system, which adds to the economy of the area. The current trend in reclamation of the estuary and adjoining marshlands is ecologically detrimental to the fish population and to biodiversity. Also, the increasing pollution load from various industrial sources, urban sewage & drainage and the residues of pesticide and fertilizers from agricultural sources has serious repercussions on the productivity and biodiversity of the backwater system.

Cochin is a fast-developing industrial metropolis lying in central Kerala, the southern state of India. Being a tropical coastal settlement, the annual and diurnal variation in temperature and humidity is not very significant. It can be said that the study area is free from winter season and has only rainy season and summer season.

The study area enjoys a vigorous Southwest monsoon season and a mild North-east monsoon with an yearly average rainfall of about 300 cm. Since the rainy season extends to about 6 months, drainage is very important particularly when urban settlements are developed. Not only that, since there is continuous rain during rainy season any modification of the land surface, without due consideration to the rainfall climatology, is likely to cause denudation in the eastern sloped terrain due to erosion and waterlogging in the flat areas.

Since Cochin lies at about 9^0 N, for about 8 months in a year, the sun will be towards the south and hence, the southern slopes of hills receive more concentrated solar rays for most part of the year and thereby becoming warmer than flat terrain. Hence, south slopes in a hilly terrain as in the eastern lowhills of the study area are less suitable for human occupation. Northwest, north, northeast and east facing slopes are the most ideal for residential development in this region from the solar radiation point of view.

The relative humidity also is very high making it necessary to have human settlements with appropriate orientation and ventilation. The buildings are to be oriented so as to obtain maximum ventilation in relation to wind direction during the most humid and hottest months. Also, buildings are to be designed with minimum incidence of sunrays on the south side walls or appropriate shade trees are to be planted on the southern side of buildings.

Cochin is the industrial capital of Kerala. The major industries are located in 2 clusters in the study area - one at Ambalamugal - Karimugal area and the other at the Udyogamandal - Kalamasserry - Edayar area. Some of these industries release large quantities of air pollutants and their dispersion is a function of meteorological and physiographical aspects. An important factor in the pollution climatology is the direction of the wind when the speed is minimum i.e., during night and early morning hours particularly during winter season. Rainfall also is a major determinant in the pollution levels due to the scrubbing effect of rains resulting in reduced atmospheric concentration of pollutants.

The winds are mostly from west (westerlies) during daytime and carry pollutants towards east or southeast during daytime. The nighttime winds are either absent or very weak north-easterlies and hence pollutants are not transported to long distances resulting in the accumulation of pollutants in the vicinity of source.

Pollution hazard will be maximum during inversions or isothermal conditions, since such a condition blocks the dispersion of pollutants and results in high ground level concentration. Inversion or isothermal conditions are found to be maximum during December, January and February in Cochin. Hence the areas in the direction of nightwind during these months in relation to the major industrial zones will have considerable increase in atmospheric pollution. Thus most of the thickly populated areas in the western flatland are high-risk areas both in the case of normal atmospheric pollution or during a disaster (as happened in Bhopal).

As far as the location of the existing industries is concerned, the ideal place would have been the extreme south west portion of the study area so that the interior of the city and all the thickly populated areas would have been relatively free from pollution. In such a case most of the spread of the pollutants would have been over the ocean.

This study reveals that the places most safe from pollution is the upper reaches of Kadambrayar, Puthencruz, Pallikkara, Kanjiramattom, Pulikkamaly, Churnikkara and Thrikakkara East basins. Also, during daytime, when strong winds blow towards east, these areas will have lesser pollution, which is due to physiographical peculiarities. Besides these, some areas far off from the pollution sources such as Udayamperoor, Kumbalam and Chellanam Panchayats and Cochin taluk areas of Cochin Corporation and the areas free from the night time wind direction such as Nayarambalam, Kadamakkudy and Elamkunnapuzha panchayats may also be free from air pollution from major industries within the study area.

Plants have an important role in the preservation as well as improvement of environmental quality besides its fundamental role as the only way of trapping solar energy to prepare food for all the biota. Vegetation plays a pivotal role in the soil conservation, amelioration of microclimate, reduction of urban noise, pollution reduction by active stomatal absorption of polluting gases as well as providing vast areas of leaves for the settling of suspended particulate matter. Vegetation during photosynthesis traps vast quantities of CO_2 and releases O_2 to the atmosphere and it is an important source of fuel. Urban forests can be planted in wastelands for timber and firewood.

The study of vegetation was carried out to identify the trees, shrubs and climbers of aesthetic and /or economic value to provide information on the germplasm. A detailed taxonomic survey was not attempted, instead an ecological/ environmental planning approach was adopted in which trees, perennial shrubs and perennial climbers, which have basic influence on the environment, are considered.

A comprehensive study of the species diversity of vegetation is an important pre-requisite for the assessment of environmental resource of any area. The vegetation of any place is determined by edaphic, climatic and biotic factors. Such a study will enable the authorities to propose appropriate planting materials from the trees, shrubs and climbers of economic, aesthetic and. medicinal value which have proven capacity to grow successfully in the various edaphic and microclimatic conditions of an area.

In the study area, due to its unique physiography, edaphic and climatic zonation is clearly distinguishable with their own characteristic vegetation types. However, this vegetation, originally tropical rain forest, is drastically modified by biotic influence of urbanization and increased agricultural activities. The vegetation in its original form exists only in a few sacred groves and mangrove forest bits.

Alien species, which were once introduced for aesthetic planting or for agricultural purposes, are found in large numbers among the vegetation cover of the western flatland area, whereas, alien plantation and agricultural crops have significantly replaced the native vegetation in the eastern upland area.

In Cochin altitude-based vegetation difference is negligible since the altitude variation in the study area is less than 108 meters.

The western flatland shows a distinct edaphic condition of clayey or sandy-clay or sandy soil with a very high water table. The land is less than 1 meter above MSL at Cochin. In this area, the predominant mesophytic vegetation is *Cocos nucifera*, *Areca catechu*, *Samadera indica*, *Dipterocarpus indicus*, *Hydnocarpus wightiana* and bamboo thickets. Most other native mesophytic trees, shrubs and climbers, though identified in the study area, occur very rarely and that too mostly limited to individual plants.

Natural regeneration seems to be very low for the native plants except for a few species like *Samadera indica, Dipterocarpus indicus, Thespesia populnea, Macranga indica, Alstonia scholaris* and a few species of *Eugenia* (all of which regenerate naturally only in isolated pockets), while alien species of *Pithecolobium saman, Peltophorum inermi, Delonix regia, Muntingia calabura* and *Lucaena lucocephala* show vigorous regeneration in the western flatland area.

If this trend continues, the alien species are likely to replace the native species from the scene as they now occur only as isolated patches or individually with very low regeneration capacity. This is environmentally very undesirable since birds and animals in the area are ecologically adapted to the native vegetation and this kind of transformation to alien vegetation is sure to upset the food chain and thereby the ecosystem, though the quantification of the damage is not possible. Also, the pollens of these species are likely to cause allergies. Hence, it is suggested that, as far as possible, the planting of native species must be recommended in urban aesthetic planting schemes instead of going for the ephemeral beautiful flowers of the alien species with due consideration to aesthetic appeal.

The shore line vegetation shows pronounced zoning - the species composition changes within a few meters from the shore line - both near the sea as well as backwaters. In the case of backwater shores, the waterward edge of intertidal zone is predominantly occupied by mangrove species of *Bruguiera roxburghiana, Rhizophora mucronata* and *Accanthus ilicifolius.* Behind this, about 12 mangrove species occupy the landward edge of intertidal zone. The land just above the intertidal zone has about 36 species of trees and shrubs, which are the combination of mangrove and mesophytic vegetation.

This zoning is disturbed in many places either due to human intervention or due to acute steepness of the shoreline. If the land suddenly rises from the backwaters, only the second and/or the third zone will be present. In the study area fifteen major locations of mangrove vegetation are present besides the occasional existence of a few isolated mangrove species here and there along the backwater shorelines.

For the prevention of backwater shore erosion and fisheries protection, mangrove replanting should be done along with the conservation of existing patches.

A similar zonation parallel to shorelines is observed in the vegetation near the sea. The first layer of plants is that which can withstand the contact with waves of the sea with its salt. Nineteen species of trees, shrubs and other ground covers are found to grow in this zone. Protected either by the above-mentioned vegetation or by the sea wall is the second zone, where, 46 species of trees, shrubs or climbers are found to thrive. These plants can be ideally planted in this zone in future planting programmes. Behind the second zone of beach vegetation, there exists a region, which is not exposed to the direct impact of the sea, but with traces of salt in the soil. 66 species of trees, shrubs and climbers are identified in this zone which can be used for future planting schemes in the sand bars from Njarakal to Chellanam where these plants occur in natural condition or cultivated condition and found to survive.

Except the mangroves and beach vegetation in zones 1 and 2, almost all the species survive in the eastern upland where they can be best utilized for planting schemes depending upon the local edaphic and microclimatic conditions.

Comfort in urban life lies in the condition of basic amenities and services which in turn is linked to the socio-economic environment. Day by day the urban limit of Cochin is increasing with consequent overload in the available basic amenities and services. Proper assessment of the existing condition of them is necessary to plan for the future.

Water supply, drainage, solid and liquid waste disposal, traffic and transport, park and recreational facilities and housing problems are assessed in this chapter. The observations are summarized below: -

The western flat land portion of the study area where the economic and commercial activities are centred - Central Business District (CBD) in planning terms - has a considerably higher density of population than the eastern upland. The population density decreases fast towards the east with increasing distance from the CBD area. But there is no such remarkable variation in the population density along the north-south direction. Hence, eastern upland is having more potential for future urban expansion.

The rise in workers to population ratio also reflects a rapid economic growth-induced increase in job opportunities. The manufacturing, processing and servicing sector are found to be the major contributor, thus forming the economic base of the area. Despite widespread mechanisation during the last decade, the percentage composition of construction workers almost doubled indicating a healthy economic development and rapid construction boom - signs of fast urbanisation.

Even though, the housing shortage has decreased in the last decade, still there exists a shortfall of about 21 houses per 1000 households. When remedial measures for this deficit is envisaged for future planning, the trend in family size variation in the past has to be taken into consideration. During the eighties, the average family size has decreased from 5.81 to 5.08 persons, a result of high literacy rate and high living standards - a trend which is likely to continue - implying that future housing policies should be oriented towards construction of small houses.

The slum dwellers account for about 21.27% of the city population; a not-too-alarming figure when compared to other cities in India, however, environmentally a very significant one. Also, the number of slums is found to increase with time. The availability of low-priced lands, as islands without road connections, within the city or in close proximity, has so far been successful in limiting the growth of slums to the present rates. However, once these isolated land-strips are road-linked by the construction of bridges, land value may shoot up to heights beyond the reach of the urban poor. This will accelerate the development of urban slums.

Hence, proper planning backed by a thorough comprehension of all contributory factors leading to the timely implementation of appropriate housing policies, alone can prevent a degeneration of the urban environment.

Potable fresh water is naturally available in most of the eastern upland portion of the study area whereas, it is scarce in the western flatland areas. The requirement is met by the public water supply system drawing water mostly from Periyar River at Alwaye and Muvattupuzha River at Ramamangalam. In spite of recent augmentation, water supply in Cochin is insufficient even by Indian Standards, which itself is far below the standards of the developed countries. This is partly due to insufficient treatment & pumping capacity and partly due to insufficient distribution system as well as wastages in transit.

The river water, above the intake wells at Alwaye is contaminated with municipal effluents from Perumbavoor and Alwaye. Moreover, factory effluents from the Eloor industrial belt about 1 km downstream may reach the pumping station during high tides when the river flow is weak. The contaminants from these factories, containing Mercury (TCC), Acids & insecticides (HIL) may reach the headwork area in large concentrations along with tidal saline water during summer, if Periyar river flow is reduced considerably due to insufficient water being released from Edamalayar Dam or because of an intense drought. Already, the Idukki project has substantially humbled the Periyar as water is diverted to the Muvattupuzha River.

At present, a major part of the study area is dependent upon water supply from Periyar River. In case of a serious contamination (either due to above-mentioned natural causes or due to man-made causes), the whole water supply system will have to be shut down, with disastrous consequences. So, as a precaution as well as for augmenting the present insufficient water supply system, additional intake facility with suitable treatment system has to be added to the Ramamangalam headworks in the Muvattupuzha

River, which at present meets mostly industrial requirements. Such a system can be connected to the existing water supply grid of the Cochin City so that the two systems together can meet the water demand in normal times as well as during emergencies when one system can be completely closed while the other pumping system can provide water to the whole area at least partially.

The distribution system is affected by age-old pipelines, which are corroded at several places. In the western flatland area where the water-table is high, has salty soil in several places, which accelerates corrosion of pipelines. Moreover, tidal action corrodes exposed pipelines by frequent wetting & drying. In many places, the pipelines which cross the drains eventually develop holes by accelerated corrosion resulting in leaks during times of pressure and contamination of the water supply by sucking of sullage from the drains during low pressure. Timely replacement of the corroded and damaged pipelines made of corrosion-resistant and break-proof materials is the only solution to this problem.

Solid waste disposal is becoming an increasingly serious problem in Cochin particularly in the thickly populated western flatland area where there is high water table and absence of proper disposal sites. In the less populated eastern uplands, the garbage disposal is not difficult due to availability of vacant lands. In the small townships of the eastern parts of the study area, covered type of land filling can be depended upon, but in the western flatland area, effective and environmentally sound garbage disposal can be done by compost plants in appropriate places or sanitary land filling outside the thickly populated areas.

Sewage & sullage disposal also is a serious problem in the western low land due to the high water table. Present system of septic tank or pit for individual houses affects the environment adversely. Particularly during heavy rains, waste levels in the tank rises to the level of floodwater causing contamination by fecal matter. This intrusion may cause epidemic outbursts any time and hence has to be viewed with seriousness. The sewerage system, covering only a very small portion of the city at present, has to be extended to the whole flatland area. However, in the western flatland area, due to the absence of gradient. it is rather very difficult to convey the sewage from a vast area to a single or a few large-scale sewage treatment plants. Hence, it is more suitable to install mini treatment plants sector wise or one in a neighbourhood of appropriate size.

In the eastern upland areas, not only there is sufficient space for sewage and sullage disposal but also it is unlikely to contaminate the groundwater, which lies deep below a relatively impermeable laterite layer. Hence, a sewerage system may not be essential at present because septic tank system is sufficient to meet the current requirements.

Storm water and sullage disposal is also a matter of serious concern in the western flatland area. Flooding of storm water with sullage leads to environmental contamination and other human sufferings. In the western flatland area the flood problem is local either due to the inadequacy of drains or due to local depressions. This can be solved by properly linking the roadside drains to the tidal canals, since, no place in the western flatland area is more than about two kms away from a tidal canal. Also, the encroachers into the canals and 'thodus' are to be evacuated along with widening. Deepening of the main canals may not be sufficient from drainage point of view, since the bottom of these canals are mostly below the low tide level. Hence, widening is necessary to increase the drain capacity.

However, the storm water drainage is bound to become a serious threat in the near future in the valleys of the eastern upland. In these regions, the flood zones of the streams, which drain, into the valleys are being filled up for raising plantation crops and construction purposes, which reduces the discharge capacity of the streams. This aspect is dealt with in detail in the chapter on surface hydrology.

Cochin is served with all modes of transportation by air, water and land. However, due to improper location of the various transportation services, the potential remains grossly unutilised. The roads are narrow, the railway line bifurcates the city, thereby obstructing the road linkage between the two sides. The potential for inland navigation remains under-utilised. Cochin is having an all-weather protected harbour lying in the main ship route but due to inadequate depth of the shipping channel the port remains inaccessible to large vessels. The existing aerodrome at Willingdon Island has space restrictions, which preclude future expansions so as to accommodate international air traffic. However, the commissioning of Nedumbasserry airport on the outskirts of the study area will improve the situation to a large extent.

Among the three ring roads - inner, middle and outer - the inner ring road is too narrow to serve the existing passenger and goods traffic. The radial road connections between the inner and middle (NH-47 Bypass) ring roads, originating from the CBD area, are grossly inadequate both in number and width. Widening of the existing roads, wherever possible along with construction of new roads and flyovers can alone solve the present imbroglio. The new roads should be constructed with enough strength to bear the container traffic.

The important railway stations in the city are Ernakulam Junction and Ernakulam Town. The entries to these stations are confined to the western side only. In view of the fast development of the town on the eastern side of the railway line, entries to the station from the east will be most desirable. This will also relieve the number of the criss-cross traffic in the central business district of the city. The proposed Ring Railway connecting the important nodes within the City will substantially reduce the traffic congestion.

Inland waterways offer a cheap and efficient transportation of goods and people. In the western part of the study area bestowed with tidal canals, water transport if properly designed, would reduce road congestion considerably.

The interchanges between waterways and roadways are very important in the city owing to the complementing roles of these two modes in the transportation system. The facilities at these interchanges are noticeably poor considering the character and volume of traffic. These are to be specially designed for efficient and comfortable transfer of goods and passengers.

A properly planned water transport system utilising the tidal canals, rivers and sea as well as limiting the inter-city and inter-state road transit to the periphery of the highly urbanised area through NH-47 Bypass will greatly reduce the urban road congestion. Locating the terminals of the three traffic systems - road, water and railways - in close proximity will reduce unnecessary criss-cross traffic within the city. The Vytila area where the NH-47 Bypass, Kaniampuzha canal and railway line lie in close proximity may be an ideal site for such a development. Vacant land is also available in the locality at present. Since the area lies close to the middle ring road, city level traffic can also originate from there.

The area allotted for parks and open spaces come to only 0.78% of the net dry land even in the Cochin Corporation area while in other areas it is almost absent although water sheets, paddy fields and plantation areas provide lung space at present. But 0.5 hectares/ 1000 population need to be earmarked and kept for the population projected to another 50 or hundred years from now. Otherwise, when full urbanization takes place, the area will suffer from acute shortage of open spaces and parks. Planned buffer zones between industrial and residential area are also lacking in Cochin which need immediate attention.

Tourism may play a major role in the socio-economic improvement of any region if judiciously managed. Cochin has a vast potential of natural scenic areas and places of historic and architectural values. Such places should be identified maintained and managed so that it can become a good resource.

Suggestions and Recommendations

This study has revealed the above-mentioned aspects regarding the limitations and possibilities of the environmental resources of the study area. In view of the fast pace of urbanisation and hence alteration of the environment, the following basic recommendations are made which if taken into consideration by the planners and decision-making authorities, will reduce the adverse impact on the environment to a considerable extent.

In view of the physiographical peculiarities of the study area, land modification will have serious impact on the environment, if cutting and removal of hills in the eastern high lands for reclaiming the marshlands in the western flat land and valleys of the eastern hills proceed unchecked at the current rate. This has to be regulated after assessing the impact of such a removal and / or filling up on (1) the opening of valleys to the pollution sources of factories which are at present protected by the hills (ridgelines). (2) changes in ground water regime where steep cuttings are done, (3) increased erosion and siltation, (4) modification of the floodways of streams of the sub basins in the eastern lowhills, (5) impairment of hill-slope stability due to cutting of hills, (6) changes in geological stability of the western lowlands(which are not immune to seismic activity)due to large-scale filling and construction activities, (7) productivity changes of the backwater system due to large scale reclamation and increased sedimentation etc.

Within the limitations of the present study, the following suggestions are made: -

1. Considering the sub-surface geological stability, availability of vacant lands air and groundwater quality, construction costs. drainage and sewerage facilities, flood and waterlogging possibilities and commutation facilities, the eastern lowhill region is more suitable for future urban development. However, steep slopes. flood zones of streams (valley floors) and areas close to industrial areas are to be avoided for residential purposes. Strict regulations are required to preserve the flood zones of stream basins from reclamation and human occupation which at present remains as paddy fields. Based on the drainage efficiency and flood possibility assessments extensive field level surveys are to be undertaken and flood zones and levels are to be permanently marked in the fields itself along with legal enactments and empowering of suitable authorities so as to discourage land development and human occupation.

2. Considering different aspects of the environment, the highly urbanised western flatland is environmentally less suitable for urbanisation. However

this region has already attained a high degree of urbanisation. The future developments and expansions have to be strictly regulated considering the following aspects.(1) Lack of drainage facility due to soil condition as well as flatness of the terrain which is close to the sea level, (2) Deficiency of potable ground water (3) seismic history (4) land shortage, (5) predicted sea level rise due to global warming and (6) high construction costs. However, the present situation can be salvaged to a certain extent by (a) planning and execution of an efficient water supply, drainage and sewerage system, (b) reducing traffic congestions within the city by shifting inter-state and inter-city bus terminal, railway station and boat terminal in close proximity near national highway at Vytila, a city level ring railway and promoting water transport system to avoid road congestion(c) maintenance of existing vacant lands and marshes as lung space by suitable regulations (d) promoting tree planting for pollution reduction and aesthetic appeal along road sides & other vacant spaces and enforcing the establishment of greenbelts around industrial areas.

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Annex - 1.1

Regulatory Bodies of Various Environmental Resources

Natural Resources	Land	Soil	Minerals	Forest	Surface water	Groundwater	Fish & Marine	Air quality
State Bodies:-								
KSPCB					*	*		*
Keral State Land Use Board	*	*				*		
Kerala Land Dev.Corp.	*							
Command Area Dev. Authority	*							
Soil Survey Org.		*						
Centre for Water Res. Dev. & Man.					*	*		
Ground Water Dept.						*		
Dept. Of Forest	*	*		*				
Central Bodies :-								
Central Water Comm.					*			
Central Ground Water Board						*		
Dept. Of Ocean Dev.							*	
NEERI		*			*	*		
Geo. Survey of India	*	*	*			*		
Central Inst. of Fish.. Nautiacal & Engg. Trg							*	
Central Inst. Of Fish. Tech.							*	
Central Marine Fish. Res. Inst.					*		*	
Fisheries Survey of India							*	

ANNEXURE-2.1

.Sub-basins in the eastern lowhills

1. Kadambrayar Basin:

   This is the area drained by Kadambrayar river and it includes Kizhakambalam, Kumarapuram area covering an area of 81.072 km^2 . The highest peak in the study area is, in this basin, and is near Arakkappady with a height of 115 m above sea level. This basin drains westwards into a tidal canal east of Kakkanad. This basin is the largest drainage basin of Cochin major basin and it lies in the northeast corner.

2. Pallikkara basin:

   This basin, covering an area of 21.325 km^2 lies to the south of Kadambrayar basin drains westwards into a tidal canal near the east of Kadambrayar basin. The highest peak in the basin is 70 meters above MSL near Vembilli.

3. Brahmapuram basin:

   This is a very narrow drainage basin covering a total area of 3.880 km^2 lying on the south west of Pallikkara basin. This basin drains westward into a tidal canal near Brahmapuram. The highest peak in the basin is about 40 meter above MSL.

4. Muttam Basin:

   This basin, covering a total area of 6.037 km^2 , lies on the south of Brahmapuram basin. The highest peak in the area is only 40 m above MSL. The basin drains westwards into a tidal canal, which extends to several kilometers on its western edge.

5. Varikkoli basin:

This basin covers an area of 14.496 km^2 and slopes down to the west. It is separated by ridgelines from Muttam, Brahmapuram and Pallikkara basins on the northern side and from the Puthencruz basin on its east and south side. The highest peak in the basin is only 60 meter above MSL.

6. Puthencruz Basin:

This, the second largest basin in the Cochin major basin, covering an area of 57.773 km^2 , originates in the eastern side of Kadambrayar and Varikkoli basins and is separated from them by a ridge line. It slopes towards south for about half its way to backwater system and then slopes towards west on the southern side of Varikkoli basin and Mamala basin and drains into the backwater system on the south of Varikkoli basin. The highest peak in its ridgeline is 80m above MSL.

7. Pulikkamali - Amballur basin:

This basin covers an area of 22.4905 km^2 and is bounded on the north by the ridge line of Puthencruz and Kandanad basins, on the south by Kanjiramattom basin and on the east by the ridge of Muvattupuzha valley and reaches the backwater system at the north of Parur. The highest peak in its ridgeline is 67 m above MSL near Pembara.

8. Kanjiramattom basin:

This is the northernmost sub-basin of Cochin basin and it covers an area of 6.9889 km^2. It slopes towards west and joins the backwater system at Puthenkavu. It is bounded on the south by the delta of Muvattupuzha River, on the east by

Muvattupuzha valley and on the north by Pulikkmali - Amballur basin. Its highest point is only 20 m above MSL.

9. Kandanad basin:

It lies in close proximity to the backwater system with a maximum height of only 20m above MSL and covers an area of 5.9524 km^2 and is surrounded on its south by Pulikkmali - Amballur basin, on its east by Puthencruz basin and on its north by Udayamperoor basin. It slopes towards the west and drains into the tidal canal which bounds its western side.

10. Udayamperoor basin:

It covers an area of 4.617 km^2 and is bounded by canal and Kandanad.basin on the south. Puthencruz basin on the east and Thiruvankulam basin on the north. It slopes westwards and joins the tidal canal which form its western boundary. Its highest peak is only 20 m above MSL.

11. Thiruvankulam basin:

It covers an area of 3.861 km^2 with its highest peak only 20 m above MSL. It is bounded on its north and east by Puthencruz basin and on its south by Udayamperoor basin. It slopes towards west and joins the tidal canal, which forms its western boundary.

12. Mamala Basin:

It covers a total area of 0.9658 km^2 only and is bounded on the east and south by Puthencruz basin and on the north by Varikkoli basin. It slopes towards west and drains into a tidal canal, Chitrapuzha, which forms its western boundary. The highest level in it is only 20m above MSL.

13 Kakkanad South Basin:

The basin covers an area of 3.8532 km^2 and slopes down in the south-east direction and drains into a tidal canal which forms its south-east boundary. The highest level in the basin is only 20 m above MSL. It is bounded on its west and north by Thudiyur basin and on its east by Kakkanad East basin.

14 Kakkanad East Basin:

This basin covers an area of 5.9474 km^2 and slopes towards east. Four small streams flow from this basin eastward and join the tidal canal, which forms the eastern and south boundary of the basin. Its ridgeline is only about 20 m above MSL. It is bounded on the west by Kakkanad South basin, Thudiyur basin and Cherumuttapuzha basin and on its north by Cherumuttapuzha basin and Trikkakara East basin.

15. Thrikkakara East Basin.

This basin covers an area of 10,4581 km^2 and drains southwards into Kandrakathu thodu, which is a tidal canal. Its ridgeline is only about 20m above MSL. This basin is bounded on its east by Churnikara basin and Kadambrayar basin, and on its north by Churnikara basin and on its west by Cherumuttapuzha basin, Edappilly East basin and Kakkanad East basin

16. Churnikara basin:

It covers an area of 20.701 km^2 and it drains westwards into Edappally Thodu, which is a tidal canal. It is bounded on its west by Edappally thodu, north by Periyar valley, East by Kadambrayar basin and south by Thrikkakara east and Kalamassery basins. Its highest ridge is only about 40 m above MSL.

17. Kalamassery basin.

This basin covers an area of 2.4813 km^2 and drains westwards into Edappally thodu, which forms its western boundary. It is bounded on the south by Edappally East and Edappally South basins, east by Thrikkakara East basin and north by Churnikara basin. The highest point on its ridges is only about 20 m above MSL.

18. Edappally North Basin.

It drains northwards and westwards into Edappally thodu, which forms its northern and western boundaries. It covers an area of 2.1631 km^2 and is bounded on its east by Kalamassery basin and on its south by Edappally East basin. Its highest ridge is only about 20 m above MSL.

19. Edappally East basin:

This has an area of 4.175 km^2 and drains westward into the southern arm of Edappally thodu. It is bounded on its west by Edappally thodu, on its east by Thrikkakara East basin, south by Edappally North and north by Cherumuttapuzha basin. Its highest level is only 20 m above MSL.

20. Cherumuttapuzha basin:

It has a total area of 5.475 km^2 and drains westward into southern area of Edappally thodu. It is bounded on the west by the southern arm of Edappally thodu, south by Thudiyur basin, east by Kakkanad East basin and north by Edappally East basin. The highest point in this basin is only about 20 m above MSL.

21 Thudiyoor Basin

It has a total area of 6.327 km^2. 3 small streams flowing in a southwestern direction drains this basin into a tidal canal. It is bounded on the north by Cherumuttapuzha basin, east by Kakkanad-East basin and souh by Kakkanad-South basin and west by tidal canal. The highest point in this basin is about 20 m above MSL.

ANNEXURE- 2.2

Drainage units in the western flatland

1). Thiruvankulam East

This unit covers an area of 4.165 km^2 and is bounded by Chitrapuzha in the east, Karingachira-Irumpanam road in the west, Thudiyur puzha in the north and Tripunithura-Muvattupuzha road in the south. This has a small lateritic upland at Hill Palace

2) Irumpanam west:

This unit covers an area of 2.860 km^2 and is bounded by Thidyur-Thiruvamkulam road in the east, Eroor puzha in the west, Tripunithura-Muvattupuzha road in the south and Thudiyur puzha in the north.

3) Eroor-Puthotta road East

This is a long stretch of land lying in a north-south direction. This strip covers an area of 12.206 km^2 and is bounded by Eroor-Puthotta thodu on the east, Eroor-Puthotta road in the west, Puthotta in the south and Eroor bridge in the north. The general slope is towards east.

4) Eroor-Puthotta road west.

This is also a long stretch of land more or less parallel to Eroor-Puthotta road and covers an area of 17.855 km^2. This is bounded on the east by Eroor-Puthotta road, west by Kandakadavu puzha and Kayal, Puthotta in the south and Eroor bridge in the north. This has a general slope towards west.

5) Chathamma East.

This is a small strip of land covering an area of 0.571 km^2. Its boundaries are Vembanad Kayal on the south, east and north, and a local road on the west. It lies on the east of Panangad. The general slope is towards east.

6) Chathamma West

This lies on the west of Chathamma East with a road in between which forms its eastern boundary. On its south side is Vembanad Lake and west and north are tidal canals. The general slope is towards west. This has an area of 0.326 km^2 It is bounded on its west, south and north by tidal canals and on its east by a road. The general slope is towards west.

7). Cheppanam East.

This covers an area of 0.616 km^2 and is bounded on the east by Vembanad lake, south and north by tidal canals and west by a road. The general slope is towards east.

8.) Panangad East

This covers an area of 2.965 km^2 lying in a north-south direction. It is bounded on its south by Vembanad Lake, east and north by tidal canals and west by a local road and NH-47. The general slope is towards east.

9) Panangad West

It covers an area of 1.681 km^2 and is separated from Panangad East by a road and NH-47, which form its eastern boundary. It is bounded on its south by Vembanad lake and north and west by tidal canals. The general slope is towards west.

10) Kumbalam East

This covers an area of 0.857 km^2 and is bounded on the south by Vembanad Kayal, north and east by tidal canals and west by NH-47. The general slope is towards east.

11) Kumbalam Central:

This covers an area of 0.801 km^2 and lies between Alleppey railway line and NH-47 Bypass at Kumbalam. Its east is NH-47, west Alleppey railway line, south Vembanad Kayal and north a tidal canal.

12). Kumbalam West

It covers an area of 1.399 km^2 and is bounded on the east and south by railway lines and Vembanad Lake, north by a tidal canal and west by Vembanad Lake. The general slope is towards west.

13). Nettoor South

It covers an area of 1.271 km^2 and is bounded on all sides by tidal canals. A road and NH-47 run in north-south direction through it and on the western side of it. The slope is towards west and on the eastern side, the slope is towards east whereas in the space between NH-47 and old road, the slope is towards north in the northern part.

14) Nettoor North

This covers a total area of 1.900 km^2 and bounded on all sides by tidal canals. Two roads including NH-47 divide the area into 3 in north-south direction. In the western part, the slope is towards west and in the eastern part, the slope is towards east. In the central portion, slope is northwards on the northern part and southwards in the southern part.

15) Kundannoor West

This covers an area of 1.614 km^2. Its boundaries are tidal canals on the south and west, a local road on the north and NH-47 on the east. The general slope is towards west.

16) Kundannoor East

It covers an area of 2.904 km^2 and bounded by roads on the north, south and west and by tidal canal on the east. The general slope is towards east.

17). Maradu

It covers an area of 2.669 km^2. It is bounded by a road on the northern side and the other sides are bounded by tidal canals. The general slope is towards north.

18). Vytila East

It covers an area of 1.125 km^2 and is bounded by NH-47 on the west, a railway line on the north, and Champakkara canal on the east and south. The general slope is towards east.

19). Vytila West

It has an area of 1.777 km^2 and bounded on the north by Sahodaran Ayyappan Road,east by NH-47 Byepass, west and south by tidal canals. The general slope is towards west and south.

20). Chilavannoor

This has an area of 0.998 km^2 and bounded on the east and south by tidal canals, on the west by K.P.Vallon Road and on the north by Sahodaran Ayyappan Road. The slope on the eastern side is towards east. The central portion of the area is basically, paddy fields to which an arm of the backwater extends northwards and on either side of it the land slopes towards it.

21). Kadavanthara

This has an area of 0.773 km^2 and bounded on the west by Thevara-Perandore canal, east by K.P.Vallon Road, north by Sahodaran Ayyappan Road and south by a local road. The general slope is towards east.

22). Konthuruthy

It has an area of 0.750 km^2 and bounded by tidal canals all around except for a small port in the northern boundary. The general slope is towards south.

23). Panampilly Nagar

This has an area of 1.992 km^2 and bounded on the west by railway line, south and east by tidal canals and north by Sahodaran Ayyappan road. This land was originally low-lying paddy fields which was recently filled up for building construction. The slope of the land is not perceptible.

24). Thevara

It covers an area of 1.405 km^2. It is bounded on the east and south by tidal canals, west by Vembanad lake and north by M.G.Road and a railway line. The slope is towards east, west and south direction from the centre.

25) Ravipuram

This has an area of 1.439 km^2 and bounded on the west by Vembanad lake, south and east by M.G.Road and north by Church Landing Road. The general slope is towards west.

26) Ernakulam CBD Area

This has an area of 3.1 km^2 and bounded by Ernakulam backwaters in the west, a railway line in the east, Banerji Road in the north and Church Landing Road and Sahodaran Ayyappan Road in the south. The general slope is towards west. However, ridges that run in north-south direction can be identified at Chittoor Road and T.D. Road and have become insignificant when the area was completely built up.

27) Gandhinagar west

This has an area of 0.617 km^2 bounded in the west by a railway line, east by Thevara-Perandoor canal, Sahodaran Ayyappan Road in the south and a railway line in the north. This area is rather low-lying and hence the direction of the slope is not perceptible.

28) Gandhinagar East

This covers an area of 0.971 km^2. It is bounded on the west by Thevara-Perandoor canal, Kaloor-Kadavanthara road on the east Sahodaran Ayyappan road on the south and a railway line on the north. The area was originally low-lying marshlands except for localised elevated areas. Now, most of this area has been filled up and built up extensively. Hence, definite surface slope direction is not perceptible.

29). Pulleppady East:

This covers a total area of 0.066 km^2. This area was originally low-lying but now is mostly filled up. It is bounded on the north by Kathrukadavu-Pulleppady Road, west by a railway line, east by Thevara-Perandoor canal and south by a railway line. The general slope is towards east.

30). Kathrukadavu West

It covers an area of 0.162 km^2 bounded by Kaloor-Kadavanthara road on the east, Thevara-Perandoor canal on the west, a railway line on the south and Thammanam-Pulleppady road on the north. The general slope is towards west.

31). Kathrukadavu East

It has an area of 0.293 km^2 and bounded by Thammanam-Pullepady road on the north, a railway line on the south, a tidal canal on the east and Kaloor-Kadavanthara road on the west. The general slope is towards east but not perceptible since a lot of filling up has been done in it.

32). Asan Nagar - Jawahar Nagar Area

This covers an area of 1.161 km^2 and bounded on the west by Kaloor-Kadavanthara road, east by tidal canal, south by Sahodaran Ayyappan Road and north by a railway line. The general slope is towards east. However, it is not fully perceptible since the low-lying areas have been filled up to a great extent.

33) Ponnurunni

This covers an area of 1.666 km^2 and bounded on the west by tidal canal, east by NH-47, south by Sahodaran Ayyappan road, and north by a railway line. The general slope is towards west.

34) Thammanam:

This has an area of 1.286 km^2 and is bounded on the east by NH-47, west a by tidal canal, north by the Thammanam-Pullepady road and south by a railway line. The general slope is towards west.

35) Chalikkavattom

This has an area of 2.339 km^2 and is bounded on the north by the Thammanam-Arkakadavu road, south by a railway line and tidal canals, west by NH-47 Byepass, and east by a tidal canal. The general slope is towards east and south. However, in the northern part, the slope is towards west.

36). Arkakadavu

This covers an area of 1.190 km^2 and bounded on all sides by tidal canals. The general slope is towards the west in the western half and towards the east in the eastern half

37). Thrikkanarvatttom - Pachalam

This has an area of 2.897 km^2 and bounded by Ernakulam Kayal on the west, a railway line on the east, Banerji road on the south and a local road on the north. The general slope is towards west.

38) Kaloor - Indiranagar

This has an area of 0.319 km^2 and bounded on the east by the Thevara-Perandoor Canal, on the west by a railway line, south by the Thammanam-Pullepady road and north by the NH-47. This area was originally a marshland, which has been filled up and hence the definite slope direction is not perceptible.

39) Kathrukadavu - Kaloor west

This has an area of 0.5059 km^2 and is bounded by Kaloor Kathrukadavu road on the east, Thevara Perandoor canal on the west, the Pullepady-Thammanam road on the south and Nh 47 on the north. The general slope is towards west.

40). Kathrukadavu - Kaloor East

This covers an area of 1.436 km^2 and bounded on the east by a tidal canal, west by the Kaloor-Kathrukadavu road, NH-47 on the north and the Thammanam-Pullepady road on the south. The general slope is towards east through not clearly perceptible.

41). Palarivattom South

This has an area of 2.233 km^2 and bounded on the south by the Thammanam-Pullepady road, north by the Palarivatttom-Kaloor road west, by a tidal canal and the east by NH-47 Bypass. The general slope is towards west.

42). Vennala

This covers an area of 2.907 km^2 and bounded on the south by the Thammanam-Arkkakadavu road, west by the NH-47 Bypass, north by the Palarivattom-Kakkanad road and east by a tidal canal. The general slope is towards east in the eastern parts and west in the western parts with a ridge lying in the north-south direction.

43). Kaloor Sivaramamenon Road area

This has an area of 1.690 km^2 and bounded by the Thevara-Perandoor canal on the east, a railway line on the west, NH-47 on the south and a railway line on the north. This area is more or less flat with a gentle slope towards east.

44). Perandoor road West:

This covers an area of 0.788 km^2 and bounded by the Perandoor road on the east, the Thevara-Perandoor canal on the west, NH-47 on the south and a railway line on the north. The general slope is towards west.

45) Perandoor road East:

This has an area of 4.004 km^2 and bounded by a tidal canal and a railway line on the north, NH-47 in the south, the Perandoor road on the west and a tidal canal on the east. The general slope is towards the east and the north.

46). Vaduthala

This covers an area of 3.2 km^2 and bounded by tidal canals on the north and the east, backwaters on the west and a railway line in the south. This area slopes towards east and west from a central northwest ridge.

47). Chittoor

It covers an area of 2.504 km^2 and bounded on all sides by tidal canals. The land is flat.

48). Edappally South

This has an area of 2.685 km^2 and bounded on the west by tidal canal, south by the Palarivattom-Kaloor road, east by NH-47 Bypass and north by a local road. The general slope is towards west.

49). Edappally North

It covers an area of 2.393 km^2 and bounded on the west by tidal canal, east by a tidal canal and a road, south by road and north by a railway line. The central portion is slightly elevated and slopes towards east and west.

50). Cheranellur west

This has an area of 4.517 km^2 and bounded on the east by the Varapuzha ferry road, west and north by tidal canals and south by a railway line. The general slope is towards west.

51). Cheranellur east

It covers an area of 0.321 km^2 and bounded by a local road on the west, a tidal canal on the north and east and a railway line on the south. The general slope is towards east.

Annexure-6.1

List of common and naturally growing plants identified in the study area

Botanical name	Tree/Shrub/ Climber	Common name	Family	Uses
1. *Acacia auriculiformis*, A.cunn.ex.Benth.	T	Australian Wattle	Leguminosae	Timber
2. *Acacia mangium*,	T	Manjium	"	Timber
3. *Acacia intsia*, Willd.	C	Incha	"	Medicinal
4. *Acalypha hispida*, Burm.	S	Kuranguvalan	Euphorbiaceae	Ornamental
5. *Acalypha wilkesiana*, Muell.	S		,,	Ornamental
6. *Aclypha marginata*,	S		"	Ornamental
7. *Acalypha hamiltoniana*,	S		,,	Ornamental
8. *Acanthus ilicifolius*, L.	S	Muthala Chully	Acanthaceae	Soil Binder
9. *Achras sapota*, L.	T	Sapota	Sapotaceae	Fruit
10. *Adenanthera pavonia*, L.	T	Manjady	Leguminosae	Timber
11. *Adenocalymma alliaceum*	C	Veluthully Chedy	Bignoniaceae	Flowers
12. *Adhatoda vasica*, Nees.	C	Adalotakom	Acanthaceae	Medicinal
13. *Aegle marmelos*, L. Corr.	T	Koovalam	Rutaceae	Medicinal
14. *Agave americana*, L.	S	American aloe	Amaryllidaceae	Fibre
15. *Agave americana. 'marginata'*	S	,,	"	Ornamental
16. *Agave victoria reginae*	S	,,	"	Fibre
17. *Agave victoria reginae 'marginata'*	S	,,	"	Ornamental
18. *Ailanthus excelsa*, Roxb.	T	Perumaram	Simarubeae	Soft wood
19. *Ailanthus malaberica*, DC.	T	Pongaliam	,,	Soft wood
20. *Albizzia lebbeck*, L. Willd	T	Vaka	Leguminosae	Soft wood
21. *Albizzia procera*, Roxb. Benth.	T	Vella Vaka	,,	Soft wood
22. *Allamanda cathartica*, L.	C	Manja Kolambi	Apocynaceae	Ornamental
23. *Allamanda violacea*	C	Neela Kolambi	,,	Ornamental
24. *Alstonia scholaris*, L. R.Br.	T	Ezhilampala	,,	Soft wood
25. *Anacardium occidentale*, L.	T	Cashewnut tree	Anacardiaceae	Nut
26. *Ananas comosus*	S	Pine apple	Bromeliaceae	Fruit
27. *Anona squamosa*, L.	T	Seema Atha	Anonaceae	Fruit
28. *Anona reticulata*, L.	T	Seethapazham	,,	Fruit
29. *Anona muricata*, L.	T	Mullan Atha	,,	Fruit
30. *Antiaris toxicaria*, Pers. Lesch.	T	Arayanjily	Moraceae	Timber

31. *Aphelandra squarrosa*	S	Acanthaceae		Ornamental
32. *Aphelendra tetragona*	S	Acanthaceae		Ornamental
33. *Aporosa lindleyana*, Wt. Baill.	T	Vetty	Euphorbiaceae	Firewood
34. *Araucaria excelsa*, Br.	T	Christmas tree	Coniferae	Ornamental
35. *Araucaria cookii*, Br.	T	"	,,	Ornamental
36. *Areca catechu*, L	T	Kamuku	Palmae	Spice
37 *Areca lutescens*	T		,,	Ornamental
38. *Aristolochia indica*, L.	C	Garudakodi	Aristolochiaceae	Medicinal
40. *Artabotrys odoratisimuss*, Br.	S	Manoranjiny	Anonaceae	Ornamental
40. *Artocarpus incisa*, L.f..	T	Kataplavu	Moraceae	Fruit
41. *Artocarpus hirsutus*, Lamk.	T	Anjily	,,	Timber
42. *Artocarpus integrifolia*, L.f.	T	Plavu	,,	Tmber/Fruit
43. *Averrhoa carambola*, L.	T	Irimban Puly	Geraniaceae	Fruit
44. *Averrhoa bilimbii*, L.	T	Chemmeen puly	,,	Fruit
45. *Avicennia officinalis*, L.	T	Kandal	Verbenaceae	Firewood
46. *Azadirachta indica*, A.Juss.	T	Aryaveppu	Meliaceae	Medicinal
47. *Bambusa vulgaris*, Schrad.	T	Manja Illy	Gramineae	Industrial
48. *Bambusa arundinacea*, Willd.	T	Kallan Illy	,,	Industrial
49. *Barleria cristata*, L.	S	Kanakambaram	Acanthaceae	Ornamental
50. *Bauhinia variegata*, L.	T	Chuvanna mandaram	Leguminosae	Ornamental
51. *Bauhinia purpurea*, L.	T		,,	Ornamental
52. *Bauhinia tomentosa*	T	Manja Mandaram	,,	Ornamental
53. *Bauhinia galpinii*	S	Mandaram	,,	Ornamental
54. *Bixa orellana*, L.	T	Maramylanchi	Bixaceae	Ornamental
55. *Bombax malabaricum*, DC.	T	Ilavu	Malvaceae	Soft wood
56. *Borassus flabellifer*, L.	T	Karimpana	Palmae	Commercial
57. *Bougainvillaea glabra*, Chois	S/C	Bougain Villa	Nyctaginaceae	Ornamental
58. *Bougainvillaea spectabilis*,Willd.	S/C	..	,,	Ornamental
59. *Bruguiera gymnorhiza*, Lamk.	T	Kandal	Rhizophoraceae	Firewood
60. *Buchanania axillaris*, Derr.	T	Kulamavu	Anacardeaceae	Softwood
61. *Butea frondosa*, Koen. ex Roth.	T	Palash	Leguminosae	Firewood
62. *Caesalpinia pulcherrima*, Swatz.	S	Rajamally	,,	Ornamental
63. *Caesalpinia coriaria*, Willd.	T	Divi Divi	,,	Ornamental
64. *Calamus rotang*, L.	S/C	Chooral	Palmae	Commercial
65. *Calliandra brevipes*	S	Powder puff	Leguminosae	Ornamental
66. *Calliandra haematocephala*	S	Red Powder puff	,,	Ornamental
67. *Callistemon lanceolatus*, Sweet.	T	Bottle brush	Myrtaceae	Ornamental

68. *Calophyllum inophyllum*, L.	T	Punna	Guttiferae	Soft wood
69. *Calotropis gigantea*, Br..	S	Vella Erukku	Asclepiadaceae	Medicinal
70. *Calotropis procera*,Br..	S	Chuvanna Erukku	Asclepiadaceae	Medicinal
71. *Calycopteris floribunda*, Lamk.	S/C	Pullanthi	Combretaceae	Industrial
72. *Caralia integrrim*, D.C.	T	Varangu	Rhizophoraceae	Firewood
73. *Carica papaya*, L.	T	Papaya	Passifloraceae	Fruit
74. Carissa carandas, L.	S	Karavanda	Apocynaceae	Ornamental
75. *Caryota urens*,L.	T	Choonda pana	Palmae	Commercial
76. *Cassia fistula*, L.	T	Kanikonna	Leguminosae	Ornamental
77. *Cassia renigera*, Wall.	T		,,	Ornamental
78. *Cassia nodosa*, Han.ex.Roxb.	T		,,	Ornamental
79. *Cassia javanica*, L.	T		,,	Ornamental
80. *Cassia siamea*,Lamk.	T		,,	Ornamental
81. *Cassia alata*, L.	S	Puzhukkadi konna	,,	Medicinal
82. *Cassia laevigita*	S		,,	
83. *Cassia biflora*	S/T		,,	Ornamental
84. *Casuarina equisetifolia*, G.Forst.	T	Choola maram	Casuarineae	Firewood
85. *Ceiba pentandra*, L.Gaertn.	T	Panji	Malvaceae	Commercial
86. *Cerbera odollum*, Gaertn.	T	Othalam	Apocynaceae	Medicinal
87. *Cestrum nocturnum*	S	Nisha Gandhi	Solanaeceae	Ornamental
88. *Cestrum diurnum*	S		,,	Ornamental
89. *Cinnemomum camphora*, (L).Ness..	T	Karpooram	Lauraceae	Medicinal
90. *Cinnemomum zeylanicum*, Breyn.	T	Karuvappatta	,,	Spice
91. *Citrus acida*	S	Cherunarakam	Rutaceae	Fruit
92. *Citurs decumana*, L.	T	Bablimas	,,	Fruit
93. *Clerodendron fragrans*, Vent..(Br.)	S		Verbenaceae	Ornamental
94. *Clerodendron splendens*	S		,,	Ornamental
95. *Clerodendron thomsonoe*,Balf.	S	Kadala Poovu	,,	Ornamental
96. *Clerodendron trichotomum*	S		,,	Ornamental
97. *Clerodendron infortunatum*, Gaertn.	S	Paruvalam	,,	Ornamntal
98. *Clerodendron inerme*, Gaertn.	S	Visha madari	,,	Medicinal
99. *Cocos nucifera*, L.	T	Thengu	Palmae	Commercial
100 *Codiaeum variegatum*	S	Croton	Euphorbiaceae	Ornamental
101 *Coffea arabica*, L.	S	Coffee	Rubiaceae	Commercial
102 *Corypha umbraculifera*, L.	T	Kudappana	Palmae	Commercial
103.*Couroupita guianensis*, Aubl	T	Nagalingam	Myrtaceae	Ornamental
104. *Cycas circinalis*, L.	T	Eenth	Gymnosperm	Ornamental

105.*Cycas revoluta*, Thumb.Brandis	T		,,	Ornamental
106.*Dalbergia latifolia*, Roxb.	T	Eetti	Leguminosae	Timber
107.*Datura fastuosa*, L.	S	Neela Ummam	Solanaceae	Medicinal
108.*Datura stramonium*, L.	S	Vella Ummam	Solanaceae	Medicinal
109.*Delonix regia*, Boj.Rafin.	T	Gulmohur	Leguminosae	Ornamental
110.*Dendrocalamus strictus*, Nees.	T	Kallan illy	Gramineae	Commercial
111.*Dipterocarpus indicus*, Bedd.	T	Kalpain	Dipterocarpaceae	Soft wood
112.*Dracaena fragrans*	S		Liliaceae	Ornamental
113.*Duranta plumieri*,Jacq.	S	Golden dewdrop	Verbenaceae	Ornamental
114.*Elaeis guineensis*	T	Ennappana	Palmae	Commercial
115.*Ervatamia dicotoma*, Blatter.	S	Kuruttu Pala	Apocynaceae .	.
116.*Erythrina indica*, Lamk.	T	Murikku	Leguminosae	Soft wood
117.*Erythrina stricta*, Roxb.	T	Mullu Murikku	Leguminosae	Soft Wood
118.*Eucalyptus citriodora*, Hook.	T	Eucalyptus	Myrtaceae	Commercial
119.*Eucalyptus globulus*, Labill.	,T		,,	Commercial
120.*Eugenia jambolana*, Lamk.	T	Njaval	,,	Soft Wood
121.*Eupatorium odoratum*	S	Communist Patcha	Compositae ..	
122.*Euphorbia tirucallii*, L.	T	Thirikalli	Euphorbiacea	Ornamental
123.*Euphorbia nerifolia*, L.	S		,,	Ornamental
124.*Euphorbia antiqorum*, L.	S	Chathurakkalli	,,	Ornamental
125.*Euphorbia pulcherrima*,Willd	S		,,	Ornamental
126.*Euphorbia splendens*,Boj.	S	Christ's thorn	,,	Ornamental
127.*Excoecaria agallocha*, L.	S/T	Kammatti	"	Fire Wood
128.*Excoecaria bicolor* ,Hassk.	S/T		,,	Ornamental
129.*Ficus bengalensis*, L.	T	Peral	Moraceae	Religious
130.*Ficus benjamina*, L.	T	Vellal	,,	Ornamental
131.*Ficus elastica*, Roxb.	T	India rubber	,,	Ornamental
132.*Ficus asperina*, Roxb.	T	Therakom	,,	
133.*Ficus carica*	T	Fig	"	Fruit
134.*Ficus religiosa*, L.	T	Arayal	,,	
135.*Garcinia mangostana*, L.	T	Mangosteen	Guttiferae	Fruit
136.*Garcinia cambogia*, Gaertn.Desr.	T	Kudampuly		Spice
137.*Gardenia jasminoides*,Ellis.	S	Gandharajan	Rubiaceae	Ornamental
138.*Gloriosa superba*, L.	S	Menthonni	Liliaceae	Medicinal
139.*Glycosmis pentaphylla*, Correa	S	Panal	Rutaceae	Medicinal
140.*Glyricidia maculata*, H.B.K.	T	Seemakonna	Leguminosae	
141.*Gmelina arboria*, Roxb.	T	Kumbil	Verbenacea	Medicinal

142.*Golphimia glauca*	S			Ornamental
143.*Grevillea robusta*, A.Cunn.	T	Silver oak	Proteaceae	Soft Wood
144.*Hamelia patens*,Jacq.	S	Pavizha Mally	Rubiaccae	Ornamental
145.*Helecteres isora*, L.	S/T	Edambiri	Sterculiaceae	Medicinal
146.*Hevea brasiliensis*, Muell.	T	Para Rubber	Euphorbiaceae	Industrial
147.*Hibiscus mutabilis*,L.	S	Changeable rose	Malvaceae	Ornamental
148.*Hibiscus rosa-sinensis*, L.	S	Shoeflower	,,	Ornamental
149.*Hibiscus shizopetalous*	S	Kurunnila chemparathy	,,	Ornamental
150.*Hibiscus syriacus*, L.	S	Neela chemparathy	,,	Ornamental
151.*Hibiscus tiliaceus*	T	Attu Parathy	,,	Fire wood
152.*Holygarna arnottiana*, Hook.f.	T	Cheru	Anacardiaceae	Medicinal
153.*Hydnocarpus wightiana*, Bl.	T	Marotti	Bixaceae	Medicinal
154.*Ixora coccinea*, L.	S	Chetti	Rubeaceae	Medicinal
155.*Ixora parviflora* , Vahl.	S	Vella Chetti	,,	Ornamental
156.*Jacaranda mimosaefolia*, D.Don.	T	Neela gulmohur	Leguminosae	Ornamental
157.*Jacobinia coccinea*	S		Acanthaceae	Ornamental
158.*Jacqumontia pentantha*	C		Convolvulaceae	Ornamental
159.*Jasminium sambac*, Wight.	C	Mallika	Oleaceae	Ornamental
160.*Jasminium pubescens*, Willd.	C	Kurukuthi mulla	,,	Ornamental
161.*Jasminium rottarianum*, Wall.	C	Kattu mulla	,,	Ornamental
162.*Jatropha curcas*, L.	S	Kammatti	Euphorbiaceae	
163.*Lagerstroemea flos-reginae*, Retz.	T	Poomaruthu	Lythraceae	Ornamental
164.*Lagerstroemea indica* , L.	S	May flower	,,	Ornamental
165.*Lagerstroemea lancelata*, Wall.	T	Venthekku	,,	Soft Wood
166.*Lantana camara*, L.	S	Kongini	Verbenaceae	Ornamental
167.*Lantana sellowiana*	S	Neela kongini	,,	Ornamental
168.*Lantana depressa*	S	Manja kongini	,,	Ornamental
169.*Lawsonia alba*, Lamk.	S	Mylangi	Lythraceae	Medicinal
170.*Leucaena leucocephala*, Lamk.Benth.	T	Subabul	Leguminosae	Fire Wood
171.*Macranga indica*, Wt.	T	Vatta	Euphorbiaceae	Soft Wood
172.*Malpighia coccigera*	S		Malpighiaceae	Ornamental
173.*Malvaviscus arboreus*	S	Mulakuchemparathy	Malvaceae	Ornamental
174.*Malvaviscus mollis*	S	"	,,	,,
175.*Mangifera indica*, L.	T	Mavu	Anacardiaceae	Fruit
176. *Manihot utilissima*, Pohl.	S	Maracheeni	Eurphobiacea	Tuber
177.*Manihot glaziovii*, Muell.	S/T	Cera-rubber	,,	Ornamental
178.*Melia azadirachta*, L.	T	Arya Veppu	Meliaceae	Medicinal

179.*Michelia champaca*, L.	T	Chempakam	Anonaceae	Ornamental
180.*Millingtonia hortensis*, L.f.	T	UlinjiPadiri	Bignoniaceae	Ornamental
181.*Mimusops elenji*, L.	T	Elanji	Sapotaceae	Ornamental
182.*Morinda tinctoria*, Roxb.	T	Manjanatti	Rubeaceae	
183.*Moringa pterigosperma*, Gaertn.	T	Muringa	Moringaceae	Food
184.*Muntingia calabura*, L.	T	Wild Cherry	Elaeocarpaceae	Ornamental
185.*Murraya exotica*, L.	S		Rutaceae	Ornamental
186.*Murraya koenigli*, Spre..	S	Kariveppu	,,	Spice
187.*Mussaenda frondosa*, L.	S	Vellila Thali	Rubiaceae	..
188.*Mussaenda luteola*	S		,,	Ornamental
189.*Mussaenda erythrophylla*	S		,,	Ornamental
190.*Myristica fragrans*, Houtt.	T	Jathy	Myristicaceae	Spice
191.*Myristica malabarica*	T	Kattu Jathy	"	.....
192.*Nerium indicum*, Mill.	S	Araly	Apocynaceae	Ornamental
193.*Nyctanthes arbor-tristis*, L.	S	Parijatham	Oleaceae	Ornamental
194.*Ochlandra travancorica*, Benth.	T	Eetta	Gramineae	Commercial
195.*Ochroma pyramidale*, Cav.ex.La	T	Balsa	Bombaceae	Soft Wood
196.*Odina wodier*, Roxb.	T	Kalasam	Anacardiaceae	Soft Wood
197.*Oreodoxa regia*,H.B& K.	T	Royal palm	Palmae	Ornamental
198.*Oroxylum indicum*, Vent.	T	Palaka payyani	Bignoniaceae	...
199.*Patchystachys-coccinea*	S		Acanthaceae	Ornamental
200.*Pandanus odoratissimus*, Roxb	T	Kaitha	Pandanaceae	Commercial
201.*Pandanus veitchii*	S	,,	,,	Ornamental
202.*Peltophorum pterocarpum*, D.C.	T	Copper pod	Leguminosae	Ornamental
203.*Petraea volubilis*,Woodr.	C	Purple wreath	Verbenaceae	Ornamental
204.*Phyllanthus emblica*, L.	T	Nelli	Euphorbiaceae	Medicinal
205.*Piper betel*, L.	C	Vettila	Piperaceae	Medicinal
206.*Piper nigrum*, L.	C	Kurumulaku	,,	Spice
207.*Pithecoloblum dulce*, Roxb. Benth	T		Leguminosae	Firewood
208.*Plumeria acutifolia*, Poirst.	T	Eezhachempakam	Apocynaceae	Ornamental
209.*Plumeria rubra*, L.	T		,,	Ornamental
210.*Plumeria alba*, L.	T		,,	Ornamental
211.*Plumbago capensis*, L.	S	Neela koduveli	Plumbaginaceae	Medicinal
212.*Polyalthia longifolia*,Hk.f.	T	Aranamarom	Anonaceae	Soft Wood
213.*Polyalthia longifolia* 'pendula'	T	Drooping asoka	,,	Soft Wood
214.*Pongamia glabra*, Vent.	T	Minnari	Leguminosae	Medicinal
215.*Psidium guajava*, L.	T	Pera	Myrtaceae	Fruit

216.*Pterocarpus marsupium*, Roxb.	T	Venga	Leguminosae	Medicinal
217.*Pterocarpus santalinum*, L.	T	Raktha Chandanam	Leguminosae	Medicinal
218.*Pterospermum acerifolium*	T		Sterculiaceae	Ornamental
219.*Punica granatum*, L.	S	Mathalam	Lythraceae	Medicinal
220.*Quisqualis indica*, L.	C	Seema pullanthi	Combretaceae	Ornamental
221.*Ravenala madagascariensis*,Sonn	T	Traveller's palm	Musaceae	Ornamental
222.*Rhizophora mucronata*, Lamk.	T	Panicha kandal	Rhizophoreae	Fire Wood
223.*Rhizophora conjugata*, Lamk.	T	Kaya kandal	,,	Fire Wood
224.*Ricinus communis*, L.	S	Avanakku	Euphorbiaceae	Medicinal
225.*Samadera indica*, Gaertn.	T	K aringotta	Simarubiaceae	Medicinal
226.*Sapindus laurifolius*, Vahl.	T	Soap Maram		
227.*Saraca indica*, L.	T	Asokam	Leguminosae	Ornamental
228.*Schleichera trijuga*, Willd.	T	Poovam	Sapindaceae	Fire Wood
229.*Sida retusa*, L.	S	Kurumthotty	Malvaceae	Medicinal
230.*Sida cordifolia*, L.	S	Ooram	"..	
231.*Spathodea companulata*, Beauw.	T	Tulip tree	Bignoniaceae	Ornamental
232.*Spondias mangifera*, Willd.	T	Ambazham	Anacardiaceae	..
233.*Sterculia foetida*, L.	T	Pottakkavalam	Sterculiaceae	Ornamental
234.*Sterculia urens*, Roxb.	S	Thondippazham	..	..
235.*Strychnos nux-vomica*, L	T	Kanjiram	Loganiaceae	Medicinal
236.*Swietenia macrophylla*	T	Mahogany	Meliaceae	Timber
237.*Swietenia mahogany*	T		,,	,,
238.*Tabernaemontana dichotoma*, Roxb.	S	Koonan Pala	Apocynaceae	..
239.*Tabernaemontana coronaria*, Br.(Wild)	S	Nandyarvattom	,,	Medicinal
240.*Tabernaemontana devaricata*	S		,,	Ornamental
241.*Tamarindus indica*, L.	T	Valan Puly	Leguminosae	Spice
242.*Tecoma stans*, Juss.	S/T		Bignoniaceae	Ornamental
243.*Tecoma radicans*, Juss.	S		"	Ornamental
244.*Tectona grandis*, L.	T	Teak	Verbenaceae	Timber
245. *Terminalia catapa*, L.	T	Thalli Thenga	Combretaceae	....
246.*Terminalia bellerica*, Roxb.	T	Thanny	,,	Soft Wood
247.*Terminalia chebula*, Retz.	T	Kadukka	,,	Medicinal
248.*Theobroma cacao*	T	Coco	Sterculiaceae	Beverage
249.*Thespesia populnea*, Soland.ex..Correa	T	Poovarasu	Malvaceae	Timber
250.*Thevetia nerifolia*, Juss.	S/T	Manja Arali	Apocynaceae	Ornnamental
251.*Trema orientalis*, Blume.	T	Pottamy	Ulmaceae	Soft Wood
252.*Tinospora cordifolia*, Meers.	C	Amruthu	Menispermaceae	Medicinal

Annexure-6.2

Exotic trees identified in the study area

Botanical name	Common name	Family	Origin
Acacia auriculiformis, A.cunn.ex.Benth.	Australian Wattle	Leguminosae	Australia
Acacia mangium,	Manjium	"	Australia
Achras sapota, L.	Sapota	Sapotaceae	Mexico
Adenanthera pavonia, L.	Manjady	Leguminosae	Sri Lanka
Aegle marmelos, L. Corr.	Koovalam	Rutaceae	Eastern India
Anacardium occidentale, L.	Cashewnut tree	Anacardiaceae	Tropical America
Anona squamosa, L.	Seema Atha	Anonaceae	Tropical America
Anona reticulata, L.	Seethapazham	,,	Tropical America
Anona muricata, L.	Mullan Atha	,,	Tropical America
Araucaria excelsa, Br.	Christmas tree	Coniferae	Australia
Araucaria cookii, Br.	"	,,	Australia
Averrhoa carambola, L.	Irimban Puly	Geraniaceae	Indonesia
Averrhoa bilimbii, L.	Chemmeen puly	,,	Malaysia
Azadirachta indica, A.Juss.	Aryaveppu	Meliaceae	Eastern Ghats
Bauhinia variegata, L.	Chuvanna mandaram	Leguminosae	North west India
Bauhinia purpurea, L.		,,	North west India
Butea frondosa, Koen. ex Roth.	Palash	Leguminosae	Central India
Caesalpinia coriaria, Willd.	Divi Divi	,,	South America
Callistemonlanceolatus, Sweet.	Bottle brush	Myrtaceae	
Carica papaya, L.	Papaya	Passifloraceae	South America
Cassia renigera, Wall.		,,	
Cassia nodosa, Han.ex.Roxb.		,,	
Cassia javanica, L.		,,	Java
Cassia siamea.Lamk.		,,	Burma
Casuarina equisetifolia, G.Forst.	Choola maram	Casuarineae	Andamans-Polynesia
Ceiba pentandra, L.Gaertn.	Panji	Malvaceae	Tropical America
Couropita guianensis, Aubl	Nagalingam	Myrtaceae	South America
Delonix regia. Boj.Rafin.	Gulmohur	Leguminosae	Madagascar
Elaeis guineensis	Ennappana	Palmae	Africa
Eucalyptus citriodora, Hook.	Eucalyptus	Myrtaceae	Australia
Eucalyptus globulus, Labill.			Australia

Ficus benjamina, L.	Vellal	,,	South East Asia
Ficus religiosa, L.	Arayal	,,	South East Asia
Garcinia mangostana, L.	Mangosteen	Guttiferae	Malaysia
Glyricidia maculata, H.B.K.	Seemakonna	Leguminosae	Tropical America
Grevillea robusta, A.Cunn.	Silver oak	Proteaceae	Australia
Hevea brasiliensis, Muell.	Para Rubber	Euphorbiaceae	South America
Jacaranda mimosaefolia, D.Don.	Neela gulmohur	Leguminosae	South America
Leucaena leucocephala, Lamk.Benth.	Subabul	Leguminosae	Indonesia
Manihot glaziovii, Muell.	Cera-rubber	,,	South America
Millingtonia hortensis, L.f.	UlinjiPadiri	Bignoniaceae	Burma
Ochroma pyramidale, Cav.ex.La	Balsa	Bombaceae	South America
Peltophorum pterocarpum, D.C.	Copper pod	Leguminosae	South East Asia
Plumeria acutifolia, Poirst.	EezhaChempakam	Apocynaceae	Tropical America
Plumeria rubra, L.		,,	Tropical America
Plumeria alba, L.		,,	Tropical America
Polyalthia longifolia,Hk.f.	Aranamarom	Anonaceae	Tropical America
Polyalthia longifolia 'pendula'	Drooping Asoka	,,	Tropical America
Psidium guajava, L.	Pera	Myrtaceae	Tropical America
Pterocarpus santalinum, L.	Raktha Chandanam	Leguminosae	Deccan
Ravenala madagascariensis,Scnn	Traveller's palm	Musaceae	Madagascar
Spathodea companulata, Beauw.	Tulip tree	Bignoniaceae	Tropical America
Swietenia macrophylla	Mahogany	Meliaceae	Tropical America
Swietenia mahogany		,,	Tropical America
Tamarindus indica, L.	Valan Puly	Leguminosae	Tropical Africa
Tecoma stans, Juss.		Bignoniaceae	Central America
Terminalia catapa, L.	Thalli Thenga	Combretaceae	Andamans
Theobroma cacao	Coco	Sterculiaceae	Tropical America
Zyzygium aromaticum, L. Mer	Grampoo	Myrtaceae	Africa

ANNEXURE - 7

ABBREVIATIONS AND SYMBOLS

%	-	PERCENT
°C	-	DEGREE CENTIGRADE
A.D.	-	ANNO DOMINI
ARKDV	-	ARKKAKADAVU
Avg.	-	AVERAGE
BP	-	BEFORE PRESENT
BPCL	-	BHARAT PETROLEUM CORPORATION LIMITED
BZL	-	BINANI ZINC LIMITED
C.B.D.	-	CENTRAL BUSINESS DISTRICT
C.E.P.Z.	-	COCHIN EXPORT PROCESSING ZONE
C.L.Rd	-	CHURCH LANDING ROAD
C.P.T	-	COCHIN PORT TRUST
C.R.L.	-	COCHIN REFINERIES LIMITED
CGWB	-	CENTRAL GROUND WATER BOARD
cm		CENTIMETER
Co.		COMPANY
CO2	-	CARBON DI OXIDE
D.L.B.	-	DOCK LABOUR BOARD
dB		DECIBELL
DDD	-	DICHLORO DIPHENYL DICHLORO ETHANE
DDE	-	DICHLORO DIPHENYL DICHLORO ETHYLENE
DDT	-	DICHLORO DIPHENYL TRICHLOROETHANE
DIVN.	-	DIVISION
E	-	EAST
E.I.A.	-	ENVIRONMENTAL IMPACT ANALYSIS
E.S.I.	-	EMPLOYEE'S STATE INSURANCE
etc.	-	ET CETERA
eg.	-	EXAMPLE
EKM	-	ERNAKULAM
F.A.C.T.	-	FERTILIZERS AND CHEMICALS TRAVANCORE LIMITED
F.E.D.O.	-	FACT ENGINEERING AND DESIGN OEGANISATION
Fig.	-	FIGURE
g.	-	GRAM
G.C.D.A	-	GREATER COCHIN DEVELOPMENT AUTHORITY
G.House	-	GUEST HOUSE
H.I.L	-	HINDUSTAN INSECTICIDES LIMITED
ha.	-	HECTARE
HOC	-	HINDUSTAN ORGANIC CHEMICALS
HPCL	-	HINDUSTAN PETROLEUM CORPORATION LIMITED

hr.	-	HOUR
Ht	--	HEIGHT
I.e.	-	THAT IS
I.S.T.	-	INDIAN STANDARD TIME
IAC	-	INDIAN ALUMINIUM COMPANY
ID.B.I	-	INDUSTRIAL DEVELOPMENT BANK OF INDIA
INS	-	INDIAN NAVAL SHIP
IPCC	-	INTERNATIONAL PANEL FOR CLIMATIC CHANGE
IRPNM	-	IRIMPANAM
K.S.P.C.B-		KERALA STATE POLLUTION CONTROL BOARD
kcal.	-	KILO CALORIES
KDRA	-	KADAVANTHARA
kg	-	KILOGRAM
KGCRA	-	KARINGACHIRA
KINCO-		KERALA INLAND NAVIGATION CORPORATION
Km	-	KILOMETRE
KMPH	-	KILOMETER PER HOUR
KSIDC	-	KERALA STATE INDUSTRIAL DEVELOPMENT CORPORATION
KTKVD		KATHRIKADAVU
KUDP	-	KERALA URBAN DEVELOPMENT PROJECT
KWBSP	-	KUTTANAD WATER BALANCE STUDY PROJECT
LAT.	-	LATITUDE
LIC		LIFE INSURANCE CORPORATION
LON	.-	LONGITUDE
lpcd	-	LITRES PER CAPITA PER DAY
Ltd		LIMITED
m		METRE
M.E.S.	-	MILITARY ENGINEERING SERVICE
M.G.ROAD-		MAHATMA GANDHI ROAD
M.L.Arch. -		MASTER OF LANDSCAPE ARCHITECTURE
M.S.L	-	MEAN SEA LEVEL
m^3	-	CUBIC METRE
m^3/s	-	CUBIC METRE PER SECOND
mb	-	MILLI BARS
Mg	-	MICROGRAM
mg.	-	MILLIGRAM
min.		MINUTE
mm		MILLIMETRE
MVPA		MUVATTUPUZHA
MYBP		MILLION YEARS BEFORE PRESENT
N.	-	NORTH
N.E.E.R.I -		NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE
N.H	-	NATIONAL HIGHWAY
N.I.O.	-	NATIONAL INSTITUTE OF OCEANOGRAPHY

N.W.	-	NORTHWEST
NEPA	-	NATIONAL ENVIRONMENTAL POLICY ACT
NH3	-	AMMONIA
NO2	-	NITROUS OXIDE
No:	-	NUMBER
NPOL	-	NAVAL PHYSICAL AND OCEANOGRAPHIC LABORATORY
P&T	-	POST AND TELEGRAPH
P.M.	-	POST MERIDIAN
P.W.D.	-	PUBLIC WORKS DEPARTMENT
pH.	-	NEGATIVE LOGARITHM OF THE HYDROGEN ION CONCENTRATION
Ph.D.	-	DOCTOR OF PHILOSOPHY
PLPDY	-	PULLEPPADY
PLVTM	-	PALARIVATTOM
Qrts.	-	QUARTERS
R.C.C	-	REINFORCED CEMENT CONCRETE
Rd.	-	ROAD
Rlwy	-	RAILWAY
S	-	SOUTH
s	-	SECOND
S.A.Rd	-	SAHODARAN AYYAPPAN ROAD
S.B.I	-	STATE BANK OF INDIA
S.E.	-	SOUTHEAST
S.W.	-	SOUTHWEST
SAIL		STEEL AUTHORITY OF INDIA
SO2	-	SULPHUR DI OXIDE
Sp.		SPECIES
Sq. km	-	SQUARE KILOMETRES
Stn	-	STATION
Sy.		SURVEY
T.C.C	-	TRAVANCORE COCHIN CHEMICALS
T.C.P.O	-	TOWN AND COUNTRY PLANNING ORGANISATION
T.P. Canal-		THEVARA-PERANDOOR CANAL
TDYR	-	THUDIYUR
TE	-	TELEPHONE EXCHANGE
TMNM		THAMMANAM
TPRA	-	THRIPUNITHURA
TVKM	-	THIRUVAMKULAM
U.S.A	-	UNITED STATES OF AMERICA
Var.	-	VARIETY
Viz.	-	NAMELY
W	-	WEST
W.ISLAND-		WILLINGDON ISLAND

253. *Tylophora asthmatica*, Wight.	C	Vallippala	Asclepladaceae	Medicinal
254. *Uvaria narum*, Dunne.	S	Narumpanal	..	
255. *Viteria indica*, L.	T	Pine	Dipterocarpaceae	Soft Wood
256. *Vinca rosea*, L.	S	Ushamalari	Apocynaceae	Medicinal
257. *Vinca alba*, L.	S	,,	,,	Medicinal
258. *Vitex negundo*, L.	S	Karunechi	Verbenaceae	Medicinal
259. *Xylia xylocarpa*, Roxb.Taub.	T	Iru Mullu		Timber
260. *Zyziphus jujuba*, L.	T	Illanthapazham	Rhamnaceae	Fire Wood
261. *Zyzygium aromaticum*, L. Mer .	T	Grampoo	Myrtaceae	Spice