IMPACTS OF A POSSIBLE SEA LEVEL RISE ON PARADEEP AND ITS ADJOINING AREAS, ORISSA.

Dissertation submitted to Jawaharlal Nehru University
in partial fulfilment of the requirements
for the award of the degree of

MASTER OF PHILOSOPHY

by
ANJAN KUMAR MOHANTY

SCHOOL OF ENVIRONMENTAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI
1989

जवाहरलाल नेहरू विश्वविद्यालय
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI - 110067

CERTIFICATE

21st July 1989

Certified that the work embodied in this dissertation titled "IMPACTS OF A POSSIBLE SEA LEVEL RISE ON PARADEEP AND ITS ADJOINING AREAS, ORISSA" has been carried out in the School of Environmental Sciences, Jawaharlal Nerhu University, New Delhi. This work is original and has not been submitted in part or in full for any other degree or diploma in this or any other university.

24.7.89

PROF. V. ASTHANA
(SUPERVISOR)

ANJAN KUMAR MOHANTY
(CANDIDATE)

PROF. L.K. PANDE
(DEAN)

SCHOOL OF ENVIRONMENTAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI

Prof. L. K. PANDE
Dean
School of Environmental Sciences
Jawaharlal Nehru University
New Delhi-110067.

GRAM : JAYENU TEL. : 667676, 667557 TELEX : 031-73167 JNU IN

ACKNOWLEDGEMENT

Throughout this work, I have been helped by the excellent supervision and guidance of Prof. Virendra Asthana. I am highly indebted to him.

I am also grateful to Mr M. Akhlaque, Chief Engineer Paradeep Port Trust; Prof. N.K. Mahalik, Deptt. of Geology, Utkal University; Deptt. of Geography, Utkal University and Orissa Remote Sensing Application Centre (ORSAC) for providing me valuable informations and materials regarding my work.

I am also thankful to all my friends who have extended their sincere help whenever and wherever I needed.

Anjan Kumar Mohanty

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER - I

INTRODUCTION

For over a century Scientists have known that the carbor dioxide and water vapour in the atmpsphere warm our planet by absorbing outgoing infrared radiation. This feature of the climate is commonly known as the 'Green house effect'. Gases that absorb infrared radiation are known as green house gases. Without this effect earth would be much colder than it is today.

Among the immediate concerns regarding the environmental effects that may result from this change in climate, is a rise in sea level. Impact of sea level rise will be more severe than a corresponding global warming of atmosphere, as due to a CO2 induced climate change we are not going to be fried rather we will be drowned.

Since the realisation of irreversible effects of sea level rise, research in this field has gained cosiderable momentum in the last decade particularly in the western countries. At the same time the research trend seem to be shifting from causes towards the impacts direction.

Area of focus

In this work also only the impacts of a possible sea level rise have been studied. The area chosen for this is Paradeep and its adjoining areas located in Cuttack district, orissa (Fig 2.3). The area forms a part of the low coastal plain along the east coast of India situated in the Mahanadi delta sorrounding the mouth of the river.

Objective

Attempt has been made in this work to study the geomorphic impacts and effects on population and land use of the area due to future rise in sea level. In the geomorphic studies the influence of local factors & processes which may be operating actively have not been taken into account, those are magnitude of sediment discharge from rivers to the sea, local tectonic activities, subsidence of nearshore bottom due to increased water load, atmospheric parameters etc. Also for the population and land use studies the curent data only has been examined. It does not take into account the future measures, adaptive responses or future changes in the distribution of population and land use. Hence the result is a rough approximation of the future stakes. The area is a low coastal plain made up of alluvialsediments. In the geomorphic study the total area to be submerged due to sea level rise and the resulting effects have been discussed. Then the erosion potential of the beaches has been determined. Following this, the impacts on population and land use have been discussed. Throughout this study all the figures and discussions given are for the future impacts only.

Importance of Present study

The present topic has been choosen keeping in view the disastrous consequences of future rise in sea level. Because of its immediate impacts on many aspects of human life, it necessiates the involvement of scientists and scholars in this study. And also this type of work helps in one or other way in taking apropriate measures in this connection by the planning and decission making process of the government.

Considering the following aspects the present area was chosen. Slope is the chief controling factor with regard to horizontal shoreline displacement. Along the east coast of India slopes are gentler and areal extention of deltas are more compared to those of west coast. So the severity of the effects due to sea level rise will be more in the east west. Particulary Paradeep area was chosen because studies related to this work has been started in other states along the east coast. And also the easy accessibtility to the existing material helped a lot.

CHAPTER - II

AREA OF STUDY

2.1 Location and accessibility

For the present work studies were undertaken for Paradip town and its adjoining areas. The area lying between 20° I'N & 20° 31'N and 86 15'E & 86 46'E contstitutes most of the coastal tract of cuttack district (Fig - 2.2). It also forms a significant part of the Mahanadi - Kathojori delta system located along the Bay of Bengal, the area consists of four P.S. areas. Paradip is located at the mouth of the Mahanadi river and out of the four P.S. areas Ersama and Tirtol lie south of Mahanadi river and Patk·ura & Mahakal para to the north. (Fig 2.3) All these five areas (Mahakalpara, Ersama, Tirtol and paradeep) taken here as the sub-areas of the whole study area. Paradip is 120 km away from Bhubaneswar, the state capital. It is also approachable by rail from cuttack which is 70 km away.

The location of the area in the country map has been shown in Fig 2.1.

2.2 Climate

The climate of the area is humid and tropical in nature. There are three distinct seasons in the area, the winter season from November to February is followed by summer from march to mid-June and the third from mid-June to october is the monsoon period. During the last mentioned period the area experiences heavy rainfall by

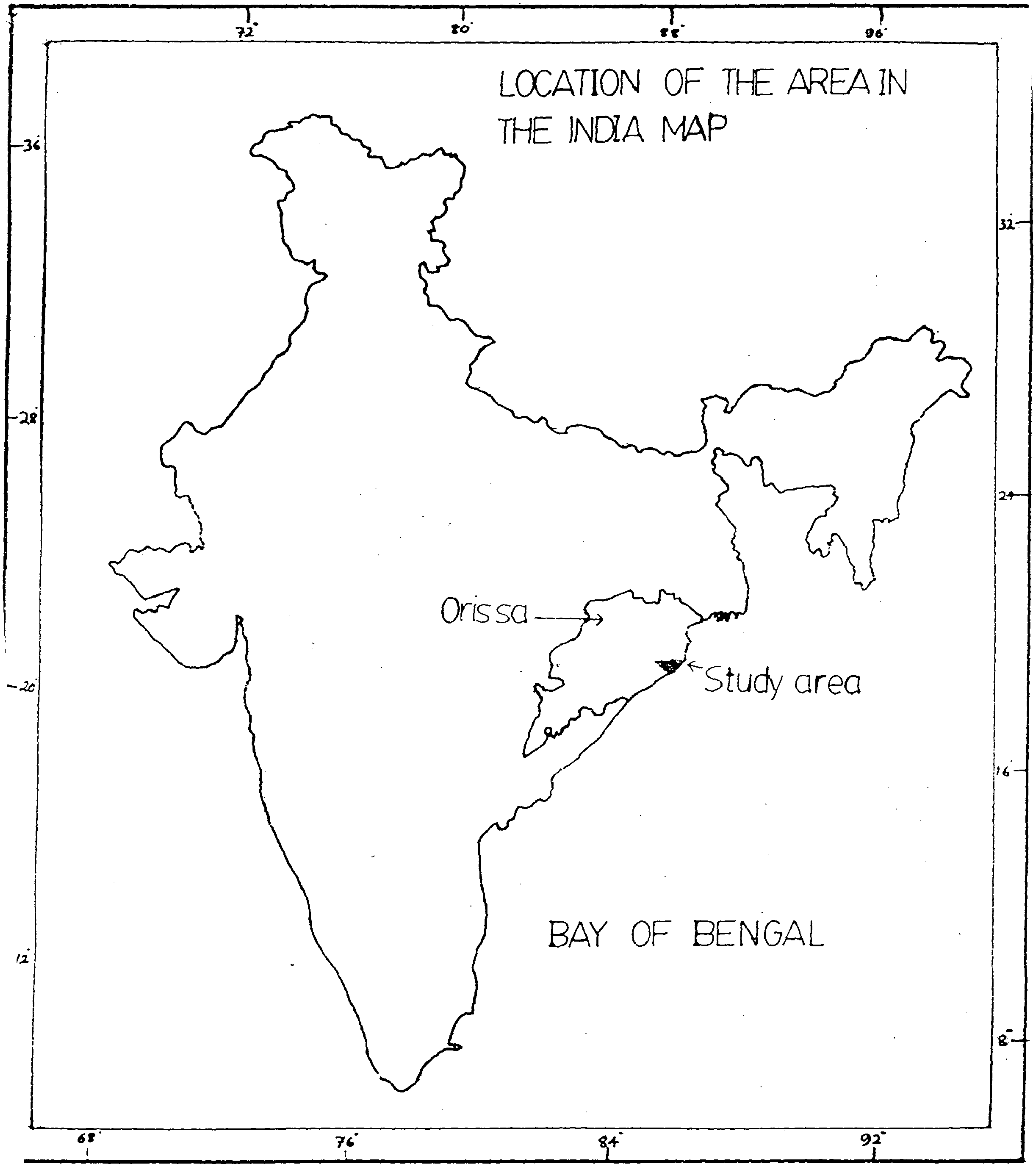


FIG. 2.1 : LOCATION OF THE STUDY AREA (DARKENED) IN THE INDIA MAP

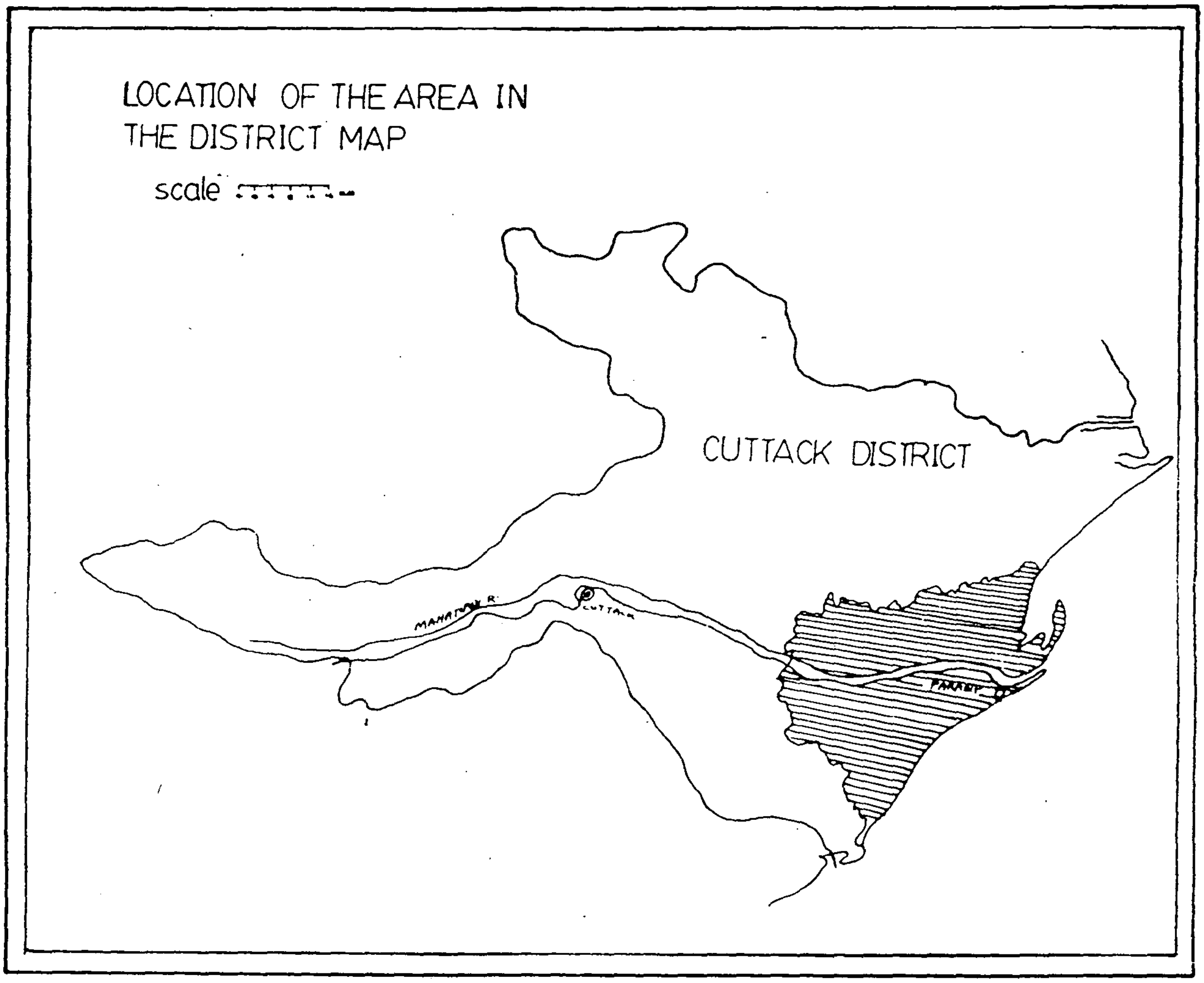


FIG. 2.2 : LOCATION OF THE STUDY AREA (SHADED) IN THE DISTRICT MAP.

SOURCE : DISTRICT CENSUS HANDBOOK, CUTTACK DISTRICT.

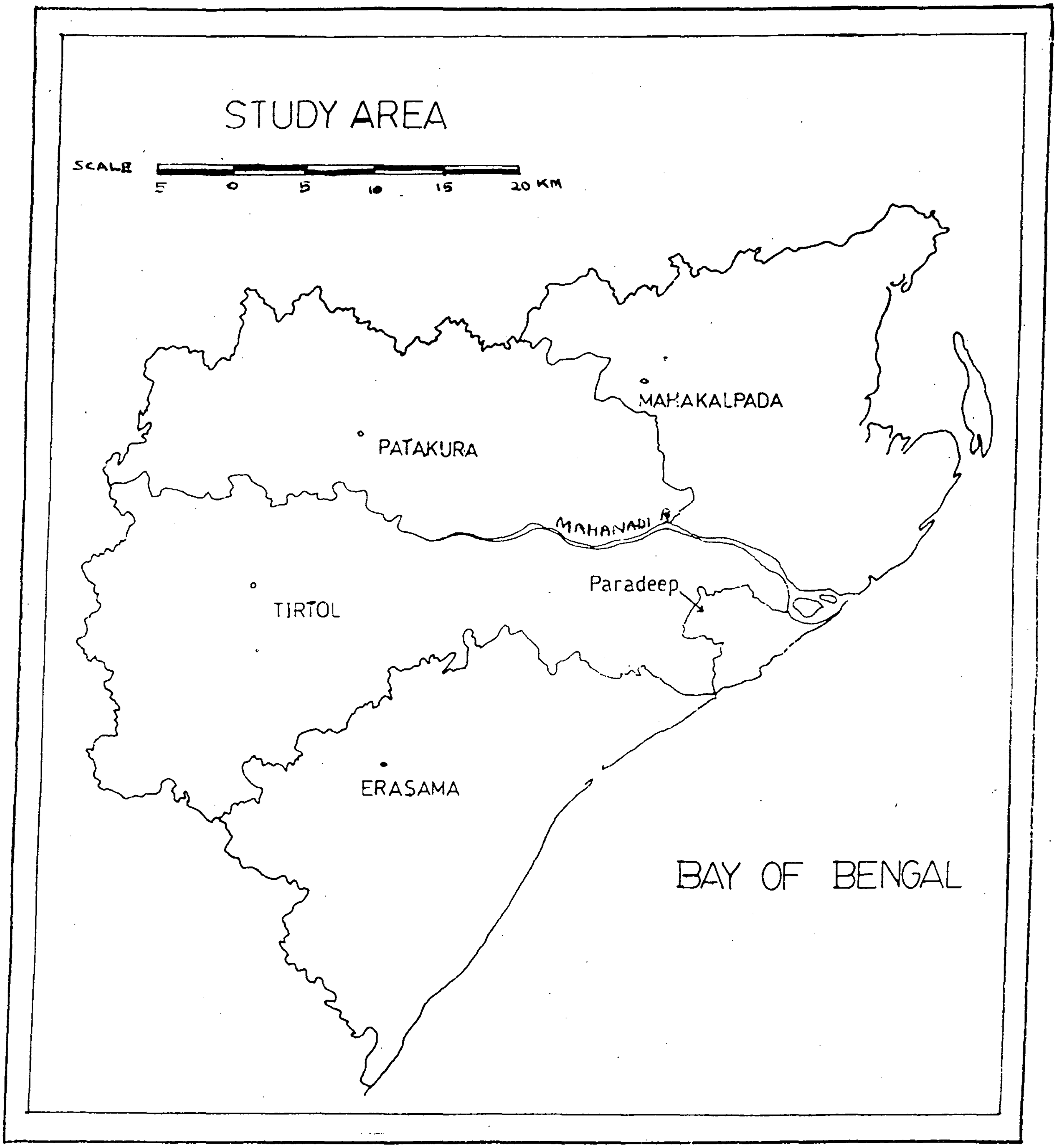


FIG. 2.3 : MAP OF THE STUDY AREA.

SOURCE: DISTRICT CENSUS HANDBOOK, CUTTACK DISTRICT.

the S-W monsoon. The spring autumn and dewy seasons are actually of very short duration and also are least felt.

2.2.1 Rainfall

The average annual rainfall is about 1572 mm falling mostly during SW monsoon from June to Sept (73.%) and during NE monsoon from october to December (17.%). Uncertainty in the distribution of rainfall prevails even in the monsoon months.

Inundations due to occassional high floods keep many areas water-logged and swampy besides bringing damage to life and property.

2.2.2 Temperature & humidity

Temperature and humidity are high through out the year the mean maximum monthly temp ranges from 29° C to 43.4 °C and mean minimum temp from 12° C to 24° C.

The mean monthly humidity ranges from 41% to 86%.

2.2.3 Wind speed & Cyclones

The mean monthly wind speed varies from 2.6 kmph to 26.2 kmph.

However the area is sometimes subjected to severe cyclonic storms which arise out of depressions formed in the bay of Bengal. Here the wind speed may rise upto 200 kmph. particularly in the coastal

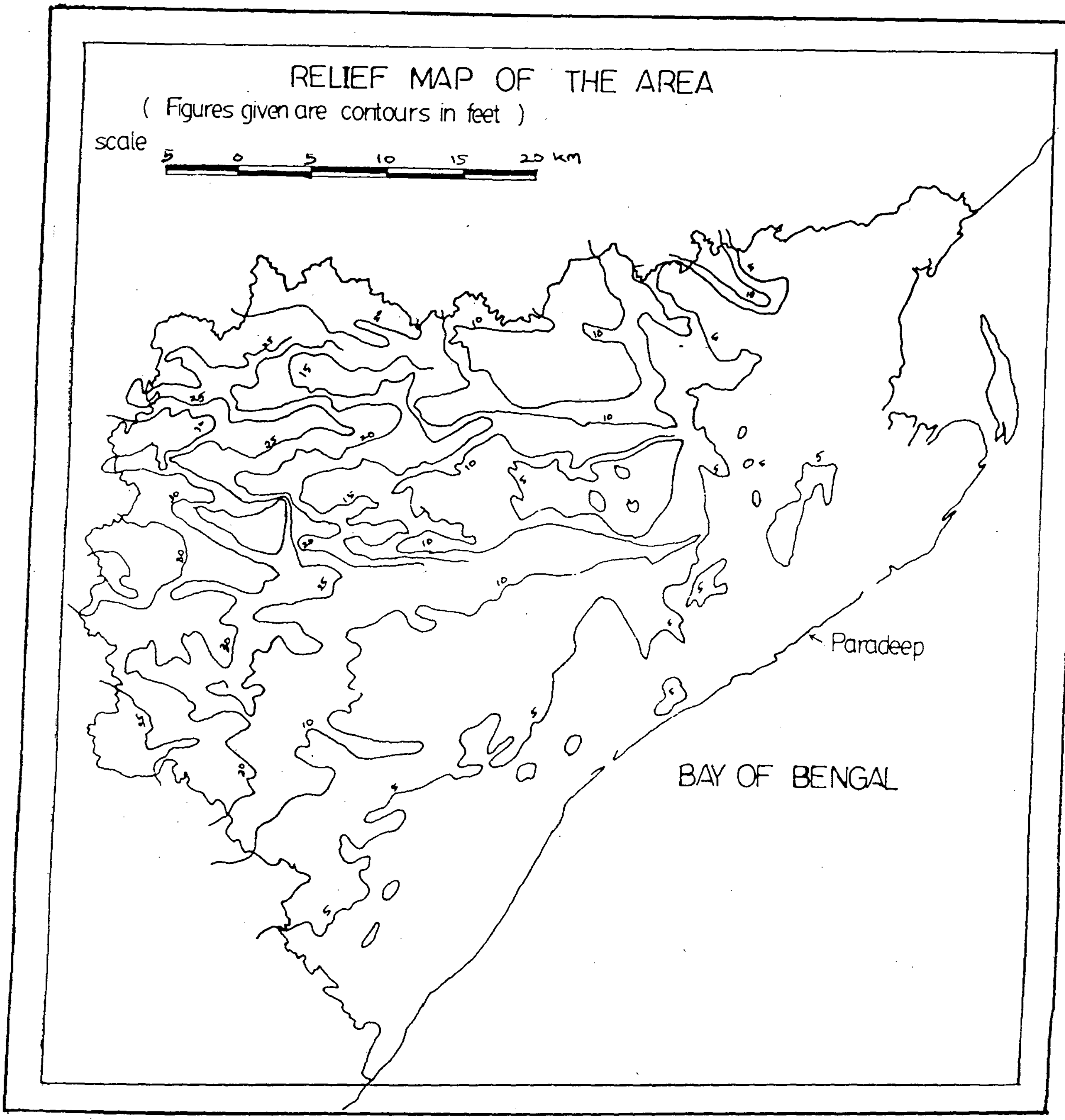


FIG. 2.4 : RELIEF MAP OF THE AREA CONTOUR HEIGHTS ARE GIVEN IN FEET.

SOURCE: DEPARTMENT OF GEOGRAPHY, UTKAL UNIVERSITY.

belt. This is sometimes accompanied by tidal bores of 6 m to 7 m high and very heavy rainfall in the affected areas.

2.2.4 Special weather phenomena like hail storm, dust storm, fog, thunder storm etc occur at times and are sporadic in nature. But the area is not prone to any of such weather vagaris.

2.3. Topography

The flatness of the area is due to its deltaic nature. The highest lands are located generally along the river branches which dissect the delta, forming doabs (area between two rivers). The doabs tend to slope down from the top of the delta apex to the bottom at the coast.The slopes in the doabs are generally in the range of 1:500. The land form is quite flat but broken by numerous small & large natural drainage lines, minor depressions and slightly elevated areas. Small streams and creek in the doab interior flow into the larger streams and provide the primary natural drainage for the doab. General ground slope of the area has been shown in fig 2.4.

2.4 Geomorphology

The geomorphology of the area comprises of varied regional & local land forms and belongs to different ages & modes of origin. The western part of the area which more or less belongs to the Mahanadi delta head is

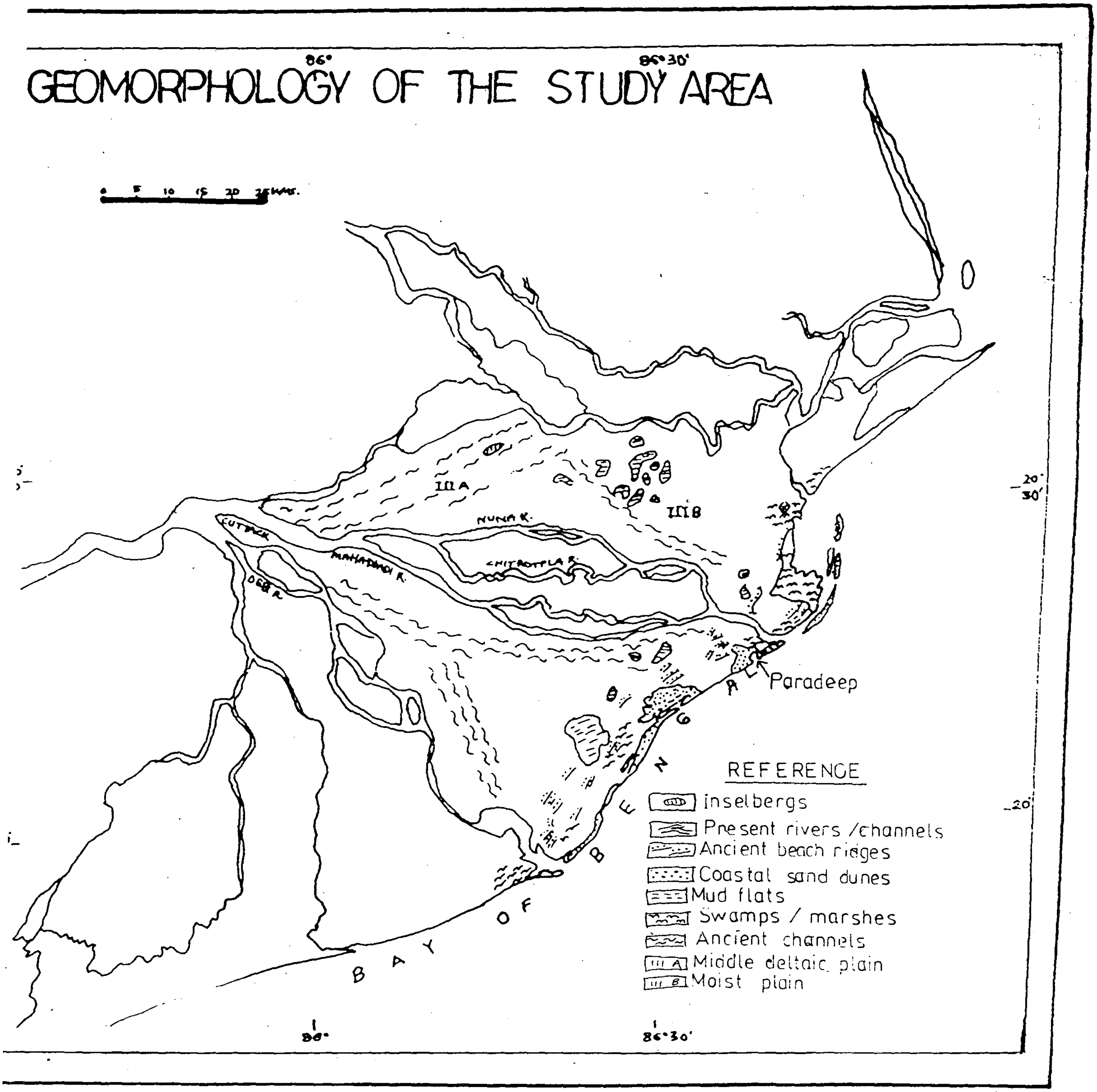


FIG. 2.5 : MAP SHOWING GEOMORPHOLOGY OF THE STUDY AREA.

SOURCE : N.K. MAHALIK, UTKAL UNIVERSITY

controlled by weathering, erosion and mass-wasting processes. In the fluvial plains sediments are deposited in fluvial environments by rivers, and along the west both fluvial and marine processes operate together. Wind has been an important co-agent working with both fluvial and marine agents to give rise to many geomorphic features like river channels dunes, beach dunes, beach sand dunes etc.

The distributary system has formed at lower reaches of the delta and ultimately meets the sea at several discharge points. Both fluvial and marine forces operate to distribute the river-borne sediments, the result has been the growth of a vast deltaic plain partly fluvial, partly marine and partly mixed.

The geomorphology of the area has been shown in fig 2.5.

It may be said that many rivers which were active in the past are now burried beneath the flood plain with the sediments leaving behind the traces of what are known as ancient channels.
The ill-drained areas (Swamps) lie in the centre of all doabs and constitute important geomorphic features in the aluvial flood plains they are the lowest areas in between the present day active distributaries and there is difficulty in natural drainage of these areas.

2.5 Reported Geology-The geology of the delta shown in Fig

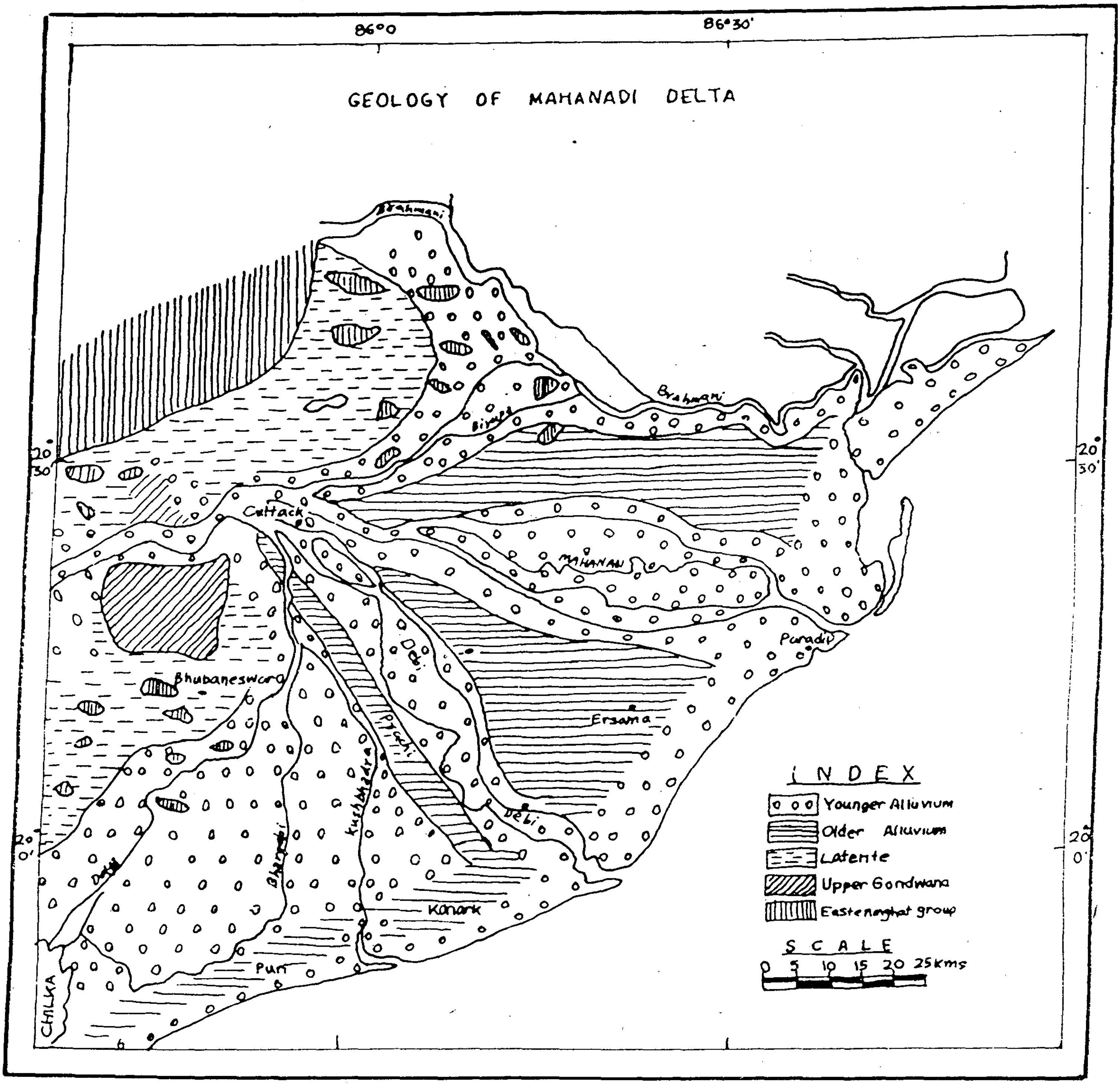


FIG. 2.6 : MAP SHOWING GEOLOGY OF THE MAHANADI DELTA.

SOURCE:N.K. MAHALIK, UTKAL UNIVERSITY

TABLE - 2.1

STRATIGRAPHY OF MAHANADI DELTA

Lithostratigraphy	Lithology	Age
Devi Formation (Fluvial) & Paradip Formation (Marine)	Younger alluvium sand, silt, clay	Late Holocene
Prachi Formation (Fluvial) & Ersama Formation (Marine)	Older Alluvium sand, silt, clay	Upp. Pleistocene to Late Holocene
Khurda Formation	Laterites	Middle to Upp. Pleistocene
Baripada Beds	Marine and estuarine sediments	Mio-pliocene
Naraj Dolerite	Dolerite dykes	Late Cretaceous
Athgarh Formation	Sandstone, shale and fireclay	Upp. Jurassic
Easternghat Group	Khondalites, charnockite, Gniesse, Amphibolites	Archean

(SOURCE : MAHALIK - N.K)

2.6 Drainage

Different from early mentioned channels, another class of channels are also observed in the area, which carry water that accummulate in the flood plain either due to rain or excess spill from the active distributaries during floods they occupy the lowest contours of the doabs and carry very little sediment. They are termed as drainage channels.

Some important channels are :-

i - The drainage channel Gobri is observed along the Birupa - Brahmani - Nuna doab

ii - Hansala - Badnala - saulia drainage channel, draining at Jatadharmuhan to the sea.

The drainage pattern in the Mahanadi delta is radial and parallel. Most of the rivers take significant turns close to the sea. The main rivers Mahanadi and Devi turn at right angles in a anticlockwise direction and run parallel to the west before meeting the sea. All the drainages in the Mahanadi Devi doab run parallel to the west in a SW-NE direction. The Jatadharamuhan is an example of such drainage parallel to the coast.The bends in Mahanadi and Devi might be due to effects of longshore currents and presence of ancient beach ridges. Drainage map of the area has been shown in Fig 2.7

2.6) is very varried in lithology as well as age of rocks. Here one finds rocks which are geologically most ancient to very loose recent sediments. The ancient crystalline rocks particularly the Khondalites coccur as isolated hills at some points. Most of the basement is also made up of the archean crystallines as seen in many bore holes.

Next in age are the upper Gondwana sedimentary rocks found extensively particularly at the western portion of the study area. They are represented by sandstones and shales. The Baripada Beds consisting of estuarine and marine sediments are hidden beneath and are seen only in bore holes underlying the recent deltaic sediments.

Overlying all of these,the deltaic sediments have been deposited spanning the holocene period. They are further classified into older alluviums and younger alluviums. The stratigraphy of the lithologic formation observed in the delta region is presented in table 2.1

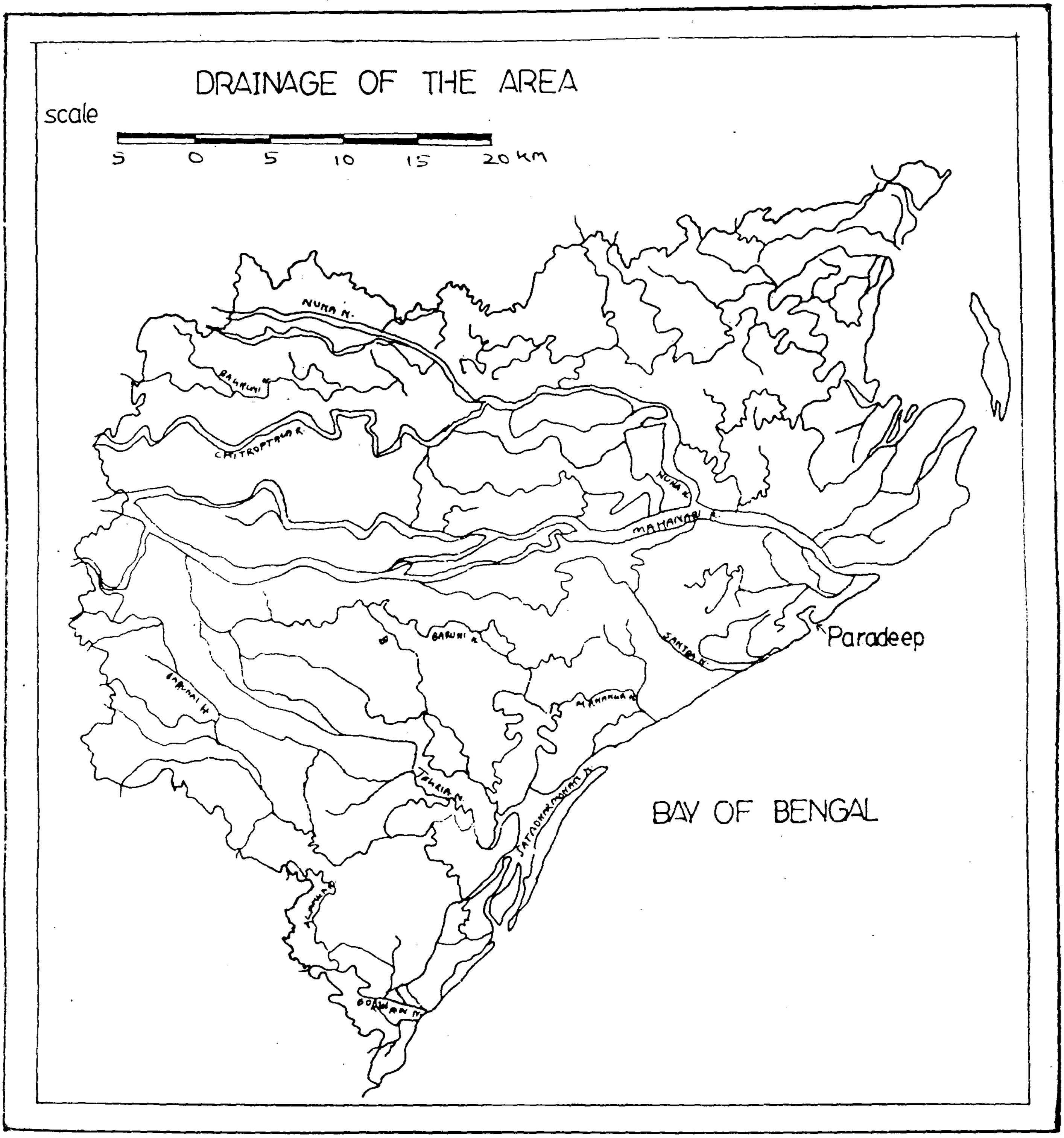


FIG. 2.7 : DRAINAGE MAP OF THE STUDY AREA.

SOURCE : DEPARTMENT OF GEOGRAPHY, UTKAL UNIVERSITY.

2.7 Soil

The soils in the area are mostly river transported alluvial soils which are moderately sandy along the rivers to sandy clay loam in the low lying areas. In general the soil becomes heavier and deeper from river edges to the doab interiors and delta apices to the lower areas closer to the sea. In the lower areas the soils are moist and pale yellow in colour. They are moderately fertile and slightly acidic.

2.8 Vegetation

A very small percentage of this area is under forest. Most of the flat low lying areas are devoted to agriculture. Natural vegetation is in the form of littoral forests, marshes & swamps, scrub woodland etc. Tropical wet decidous forests in a haphazard manner are found here. Littoral forests occur in a narrow strip along the sea coast.

2.9 Agricultue

Paddy is the primary crop of this area covering nearly all the irrigated area in the Kharif season and some 28% area in the rabi season.

Allthough the soil is ideal for paddy cultivation, potential for high productivity depends primarily on elevation (which have less flooding and water logging damage) and intensity & duration of inundation during each season. There are also considerable areas of relatively light soils, well-suited for diversified cultivation,but productivity here also tends to be limited by poor-drainage condition.

The paddy yield in the delta is very low, which for irrigated rice is among the lowest in India.

Prior to the construction of Hirakud dam at the upper reaches of the Mahanadi during the early 1960s (i.e. before the extension of irrigation network facilities) the yield was still lower.

CHAPTER III
STATE OF KNOWLEDGE

Literatures on sea level change has grown exponentially in the last twenty-five years.

Effects of Climatic Change

As a result of increasing rate of modernisation atmospheric concentrations of CO_2 etc are increasing at an alarming rate while due to wide-scale deforestation mostly in the developing countries absorption of rate of CO_2 has come down substantially.

The combined effect is an increasing rate of concentration of CO_2, CH_4, CFC, N_2O etc; the impact of which is many faceted. The areas which need immediate attention as the impact is going to be severe are greenhouse effect, ecological impact, effects in agriculture and forestry and sea level rise.

Recent measurements show that the concentration of CO_2, CH_4, CFC,N_2O and other gases released by human activities are increasing at an alarming rate. Because these gases can trap infrared (heat) part of the insolation, scientists expect the earth to warm substantially. Although some scientists have indicated some under-defined factors which may help reduce warming rate, the National Academy of Science, USA has ruled out all such possibilities The trapping of solar heat by the atmosphere in a manner somewhat analogous to the glass panels of a green house, is known as Green house effect Without the Green house effect the earth would be approximately 33°C colder than it is currently (Hansen, 1984).

Although people may adapt to climatic changes upto a considerable period, other species which are going to be affectd may not be as able to control their habitats.The changes in climate would place multiple stresses on some species which would become extinct resulting in a significant decline in biodiversity, in turn bringing disastrous consequences to the ecology.

The warming could also affect agriculture & forestry by altering water availability, length of growing season and the number of extreme days.

The most disastrous consequence of a global warming would be a rise in sea level. A few degree warming could be expected to raise the sea level in the future, as it has in the past (Mercener 1970, Gornitz et al 1982).

Causes of sea level change

Global warming results in sea level rise in two ways by thermal expansion of ocean water and deglaciation of the ice masses.

Apart from global warming which is most important in resulting sea leval rise, other less significant factors also need to be mentioned. These factors influence the sea level mostly in local and regional scale.

One of such factors is terrain subsidence due to crustal downthrust and/or sediment compaction. The work of Newman et al (1980) suggests that the value of sea level increase can simply be correlated with a typical subsidence rate.

Palumbo and Mazzarrella (1985) have classified some other factors as external and internal sources of sea level rise. These factors mostly effect short term variations (Fairbridge, 1962) in sea level. Those sources include atmospheric pressure, rainfall, evaporation rate, surface water density etc.

Records of past rises

Sea level has risen & fallen by over 300m throughout the geologic history. It has been established that during the last age (15,000 years ago) mean sea level was approximately 100m lower than the present level (Don, Farrand, Ewing 1962) when the global temperature was 50 °C colder than the present temperature. Sea level rise was most rapid upto 6000 years ago after which the rate became quite slow.

Sea level rise in the last century

The last century has witnessed that mean sea level has maintained a steady rise on a global scale, much in consonant with the steady rise in the concentration of atmospheric green-house gases. Combined studies have concluded that the average worldwide sea level has risen 10-15 cm in the last century (Barnett 1983, Gornitz et al 1982). This has been attributed to ocean water expansion (Gornitz et al 1982) and meltwater from mountain glaciers (Meier 1984).

Fig 3.1 shows the trends of global temperature and sea level in the last century.

Future Estimates

Groups of workers have attempted to project the future rises in sea level which have some direct relationship with the global warming.

Bruun (1962) has given an early estimation that the complete deglaciation of the existing ice mass (of approximately 37.5 x 106 cu cm) would cause a sea level rise of 95 m. But due to oceanic crustal lowering and to the fact that the rising sea would spill over enoromous costal lowlands, the final level of the ocean might be perhaps only approximately 50 m. above the present level.

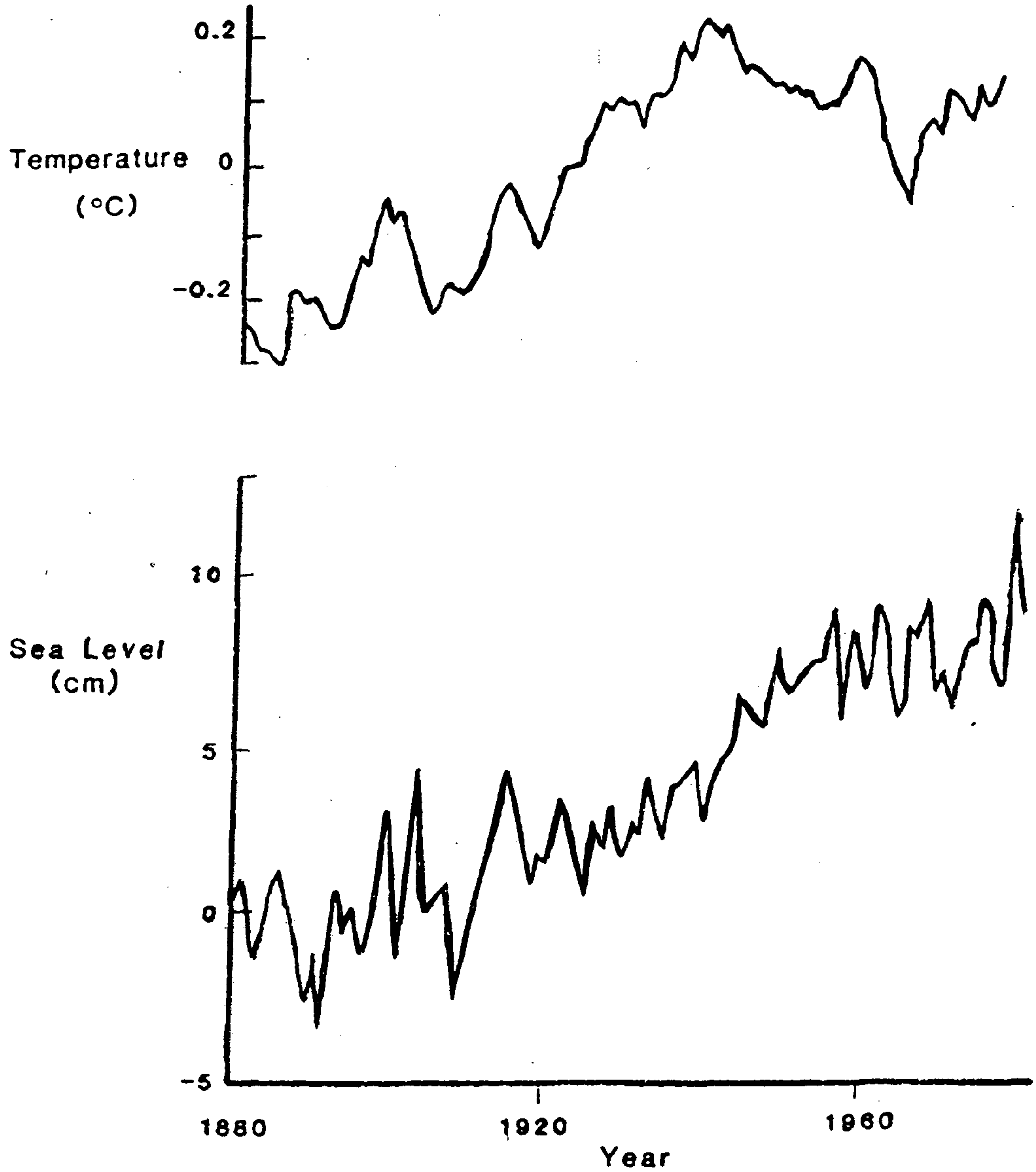


Fig. 3.1 Global Temperatures and Sea level rise in the last century.

SOURCES : Temperature curve from Hansen et al 1981, Sea level curve adapted from Gorniz et al 1982.

According to Revelle (1983) on the basis of a global warming of 3-4°C in the next century thermal expansion of ocean water would result a 30-50 cm rise in sea level and deglaciation of Greenland and mountain glaciers would contribute 10-30 cm each (assumed that no Antarctica deglaciation will take place in this period). Meier (1984) also supported that contribution of alpine glaciers would be 10-30 cm in the next century.

Hoffman et al (1983) estimated that sea level was likely to rise between 26 and 39 cm by the year 2025 and between 91 and 137 cm by 2075. Later in 1986 they revised their projection and estimated the rise by 2025 to be between 10 & 21 cm and by 2075 to be between 36 & 91 cm (Table 3.1 and Table 3.2). According to Thomas (1986)the total sea level rise by 2100 is estimated to be 0.9 to 1.7 m with a preferred value close to 110 cm (Fig 3.2).

Although the impact of Antarctica is unknown it is generally agree that a complete deglaciation of west Antarctica ice sheet would result a 5-7 cm rise in sea level which would take 3 to 5 centuries (Bantley 1983, Hughes 1983). Thomas (1985) estimated that the Antarctica contribution resulting from a 4 °C warming would most likely be 28 cm, but could be as high as 2.2m

TABLE - 3.1

Contributions to Future Sea Level Rise in the Year 2100 [in centimeters]

Study	Thermal Expansion	Alpine Glaciers	Greenland	Antar-ctica	Total
Hoffman et al. (1986)	28-83	12-37	6-27	12-220	57-368
Thomas (1985)	--	--	--	0-229	--
Meier (1984)	--	10-30	--	--	--
Hoffman et al. (1983)	28-115	b	b	b	56-345
Revelle (1983)[a]	30	12	12	c	70

[a] Contribution in the year 2085.

[b] Hoffman et al. assumed that the glacial contribution would be one to two times the contribution of thermal expansion.

[c] Revelle attributes 16 cm to other factors.

TABLE - 3.2

Temporal Estimates of Future Sea Level Rise [in centimeters]

Study	Year				
	2000	2025	2050	2075	2085
Hoffman et al. (1986)					
Low	3.5	10	20	36	44
High	5.5	21	55	191	258
Hoffman et al.(1983)					
Low	4.8	13	23	38	--
Mid-range low	8.8	26	53	91	--
Mid-range high	13.2	39	79	137	--
Revelle (1983)[a]	--	--	--	--	70

[a]Other studies only provided an estimate for a specific year.

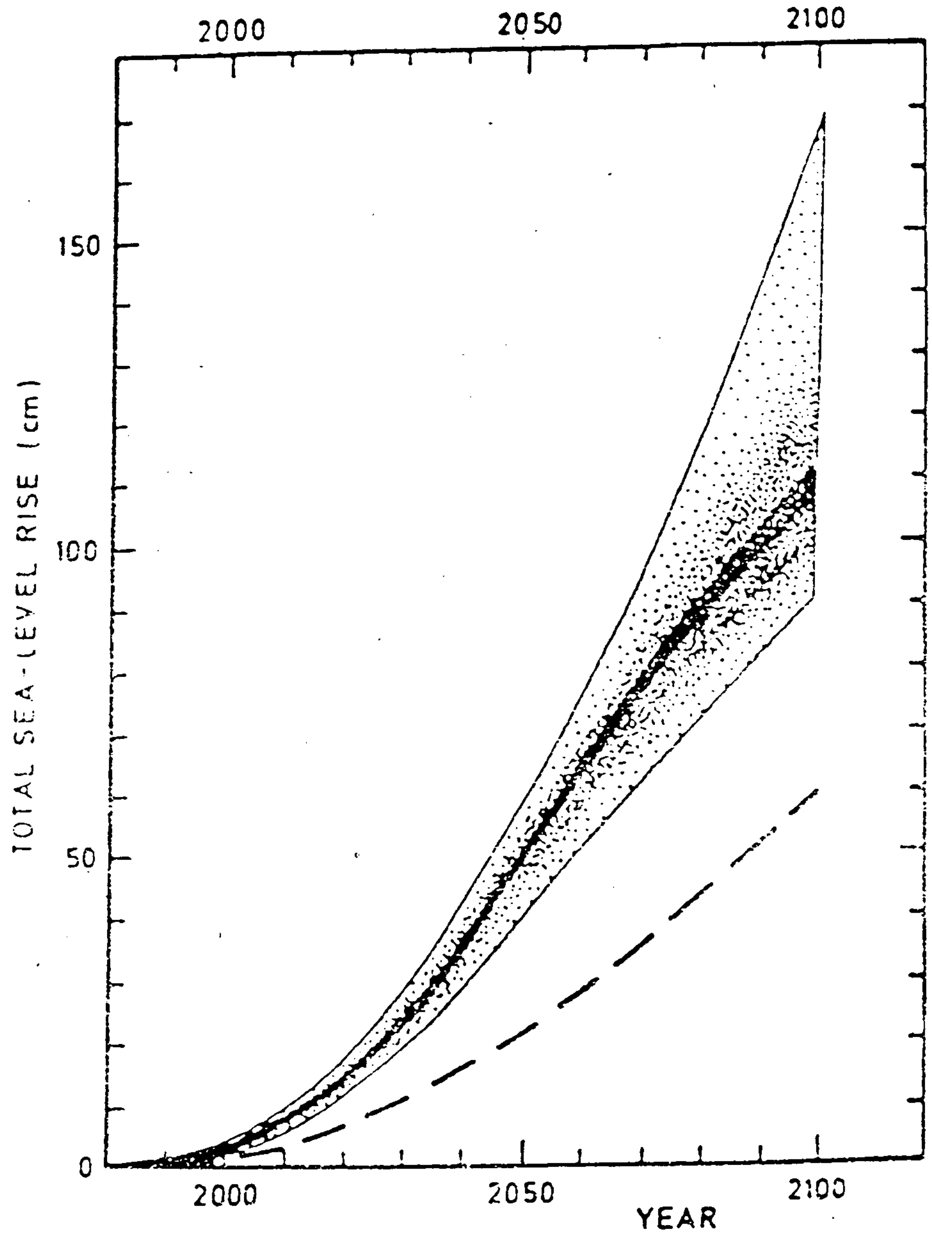


Fig. 3.2 Total Sea Level Rise During the Next Century

The dark shading indicates the most probable response to the climate scenario. The broken line depicts the response to a warming trend delayed 100 years by thermal inertia of the ocean. A global warming of 6°C by 2100, which represents an extreme upper limit, would result in a sea level rise of about 2.3 m, but errors on this estimate are very large.

SOURCE : Thomas 1986.

General Effects of sea-level rise

A sea level rise tends to cause a general recession of the shoreline due to inundation and/or erosion except where this trend is totally off–set by an adequate influx of sediment.

Inundation is the submergence of the unaltered shore, while erosion is the physical removal of the shore material.

By submergence uplands are slowly converted to marsh lands. For this Kana et al (1984) have given drowned valley concept (Fig 3.3). Here slope is the chief controlling variable. Steep slope areas will experience little horizontal shoreline displacement with each increment of water level rise, while gently sloping shores will undergo a much broader area of flooding for a given sea level rise.

The relationship between the rising sea level and beach was first formulated by Bruun (1962). This is known as °Bruun theory', °Bruun rule' or °Bruun effect', which holds that assuming a profile of equilibrum, as the sea level rises, material eroded from the upper beach is deposited on the nearshore bottom (Fig 4.1). Quantitative relationship in this exchange are as follows.

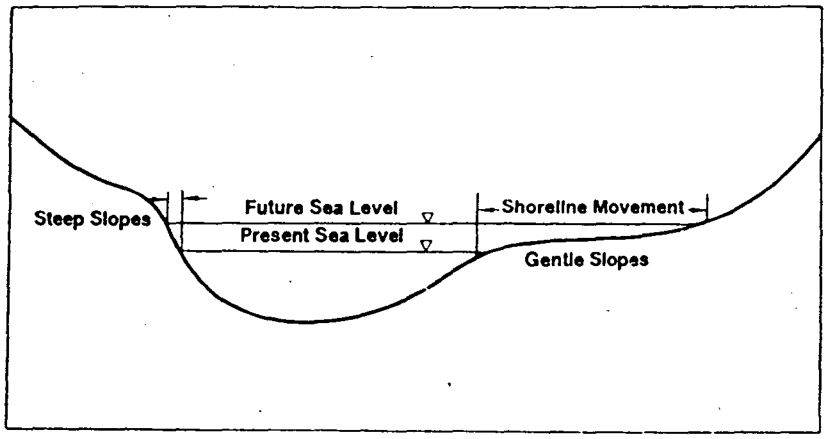


Fig. 3.3 - Drowned valley concept

SOURCE : Kana et al (1984)

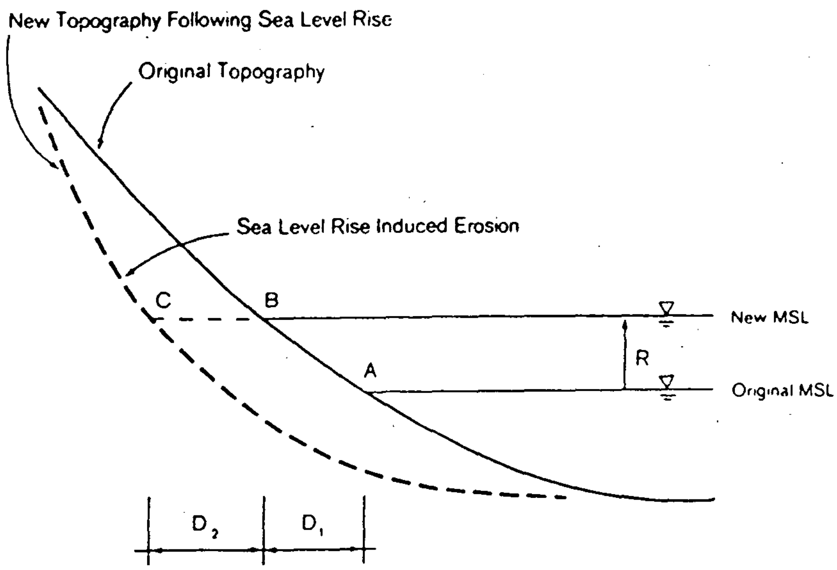


Fig. 3.4 - Combined effects of submergence and erosion

SOURCE : Leatherman (1984)

a - There is a shoreward displacement of the beach profile as the upper beach is eroded.

b - The material eroded from the upper beach is equal in volume to the material deposited on the nearshore bottom.

c - The rise of the nearshore bottom as a result of this deposition is equal to the rise in sea level, thus maintaining a constant water depth in that area.

Thus it is a two-dimensional quantitative relationship. Bruun (1962) applied his rule in Florida coast and Gulf Coast (Santa Rosa Island) to test the validity.

After the publication of this theory several workers have performed regional tests, most of which have been ended up with fair degree of accuracy. The regional tests which need mention are those of schwartz (1967) at two cape cod beaches (Massachussets), Dubois (1975) at Terry Andre state Park (wisconsin), Rosen (1978) at Virginia Chesapeake bay etc.

Also Schwartz (1965a) conducted two small-scale laboratory model studies with wave basin experiment to test the validity of the Bruun theory.

The underlying reason (Responding to changes in Sea level, 1987, NAP) that a rise in sea level would cause beach erosion is that natural beach profiles are concave upward, this geometry results in the wave energy being dissipated in smaller water volume than without sea level rise and thus the turbulence generated within the surf zone is greater. The profile responds by conforming to a more gentle nearshore slope, which needs additional sediment to be eroded from the beach.

With sea level rise both the processes erosion and submergence may act jointly (Leatherman 1984). The figure 3.4 illurates this combined effect. The term 'D,' represents the landward movement of the sea due to simple submergence of the land, for which the response time is instantaneous.

The second displacement term °D2' refers to costal erosion. Thus D1 + D2 represents the combined effect due to sea level rise.

Sea level rise would also result coastal flooding in many ways (Titus et al 1987). Natural drainage would be decreased because of higher ground water table, decreased hydraulic head on the surface etc. More areas will be flooded by spring tides.

The effects will be more pronounced in the coastal lowlands where the population, land use and economic set up will get severely affected. The possible consequences for many lowlands have been discussed, on which numerous literatures are available.

CHAPTER IV
STUDY APPROACH

In the present work two types of study have been undertaken geomorphic impacts and the effects on population and landuse. Two scales of future scenarios of sea level rise have been followed in this work. The first one is : to show the area of submergence and the effects on population and land use for which two scenarios were examined. The more optimistic scenario assumes a future 1m. rise in sea level. The more pessimistic high figure assumes a 3 m rise in sea level.

Then coming to show erosion potential another scale has been adopted, i.e. the worldwide rate of eustatic sea level rise (1.2 mm/year).

Preparation of flood Map

Paradeep and its adjoining areas have been taken as the area of focus. The final map of this area (Fig 2.3) was prepared with the help of maps given in the Census Handbook. The flood map (map showing area of submergence) was prepared from the "Ecosystem mapping of Mahanadi Delta" (which also shows relief) of the Deptt of Geography, Utkal University. In that map heights of the contours are given in feet. Those were converted to metres and the 1m & 3 m lines were drwn which are taken as the future shorelines as the sea level rise by 1m & 3m respectively. The new shorelines were drawn from the present high water line. Hence the 1m & 3m lines represent the limit of highwater rather than the mean sea level.

Estimation of the area of submergence

The areas that are going to be submerged when the new shorelines of 1m & 3m were projected on the study area, were estimated by planimeter.

Application of Bruun's theory

Bruun rule of shore erosion has been applied to estimate the erosion potential of this area due to sea level rise.

Accoding to Bruun rule as the sea level rises material eroded from the upper beach is deposited on the nearshore bottom. As the sea level rises by 'a' unit (Bruun 1962) the quantity of material needed to reestablish the same bottom depth over a width of shelf 'b' is 'b' times 'a' (i.e. ba). The quantity 'ba' is derived from the shore erosion. This will give rise to a shore recession of 'X'. If the elevation of the shore is 'e' the quantity eroded above the shore is 'xe' Meanwhile to re-establish the original bottom profile, the entire profile must be moved shoreward by the same distance 'x' upto a depth 'd' at dstance 'b' from the shoreline (Fig 4.1). The balance between eroded & deposited quantities is expressed by x(e+d) = ab

$$\text{or the magnitude of shore recession } x = \frac{ab}{e + d}$$

To apply this rule, the three variables, b, d & e (a is the rate of sea level rise) are to be obtained from the beach profile.

Beach profiles at four locations were prepared with the help of Paradeep Port Trust authorities. With these beach profiles future erosion potentials were claculated applying Bruun rule.

Effects on population and land use of the area

The effects on population and the land use of the area have been examined village-wise. The map showing distribution of villages in the study area was prepared with the help of census Handbook. Then the earlier prepared flood map (showing 1m & 3m shorelines) was superimposed on the village map.

The population and land use of the villages were estimated that are to be submerged due to 1m & 3m rises in sea level. The villagewise population and land use data & infomation were obtained from the same Census Handbook.

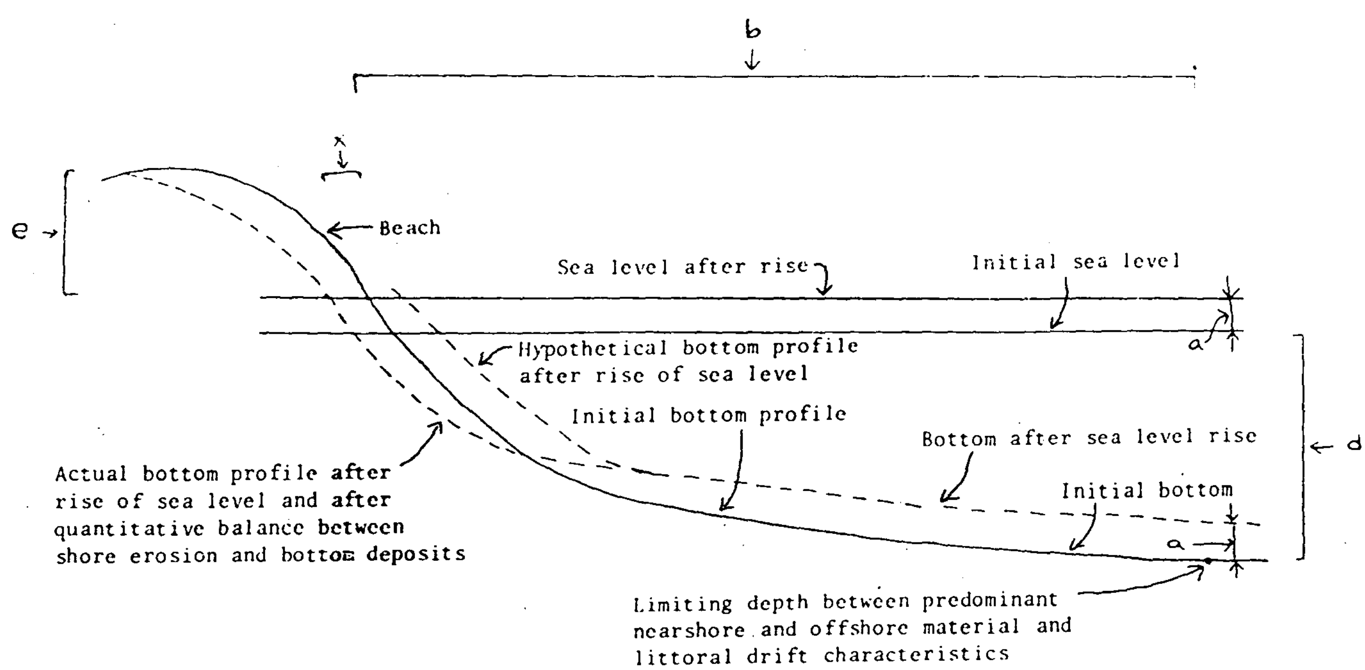


Fig. 4.1 - Influence of sea-level rise on the development of beach and offshore profile.

SOURCE : Bruun (1962)

CHAPTER V
RESULTS AND DISCUSSION

5.1 Submergence & its effects

The area forms a part of the coastal plain which slopes gently seaward. Therefore a slight rise in the sea level would cause a significant horizontal displacement of the shoreline.

With an 1m rise of sea level (Fig 5.1) the area of submergence will be 335.67 sq.km which is 19.9%. of the study area and with 3m the figures are 905.52 sq. km. & 53.7% repectively (Table 5.1)

Effects on wetlands :-

The 1m shoreline will submerge all the wetlands lying around the mouth of Mahanadi river and more than three-fourth of the wet lands present around the Jatadharmohan river. These lands normally store floodwater and provide potection from storm surges and high tides (allowing excess water to spill over there). With the loss of these lands new lands of relatively lower elevation than the sorrounding areas may be converted to wetlands. In the other words wetland loss would remove an important barrier to storm surges etc. The 3m shoreline will submerge all the remaining wetlands in the area.

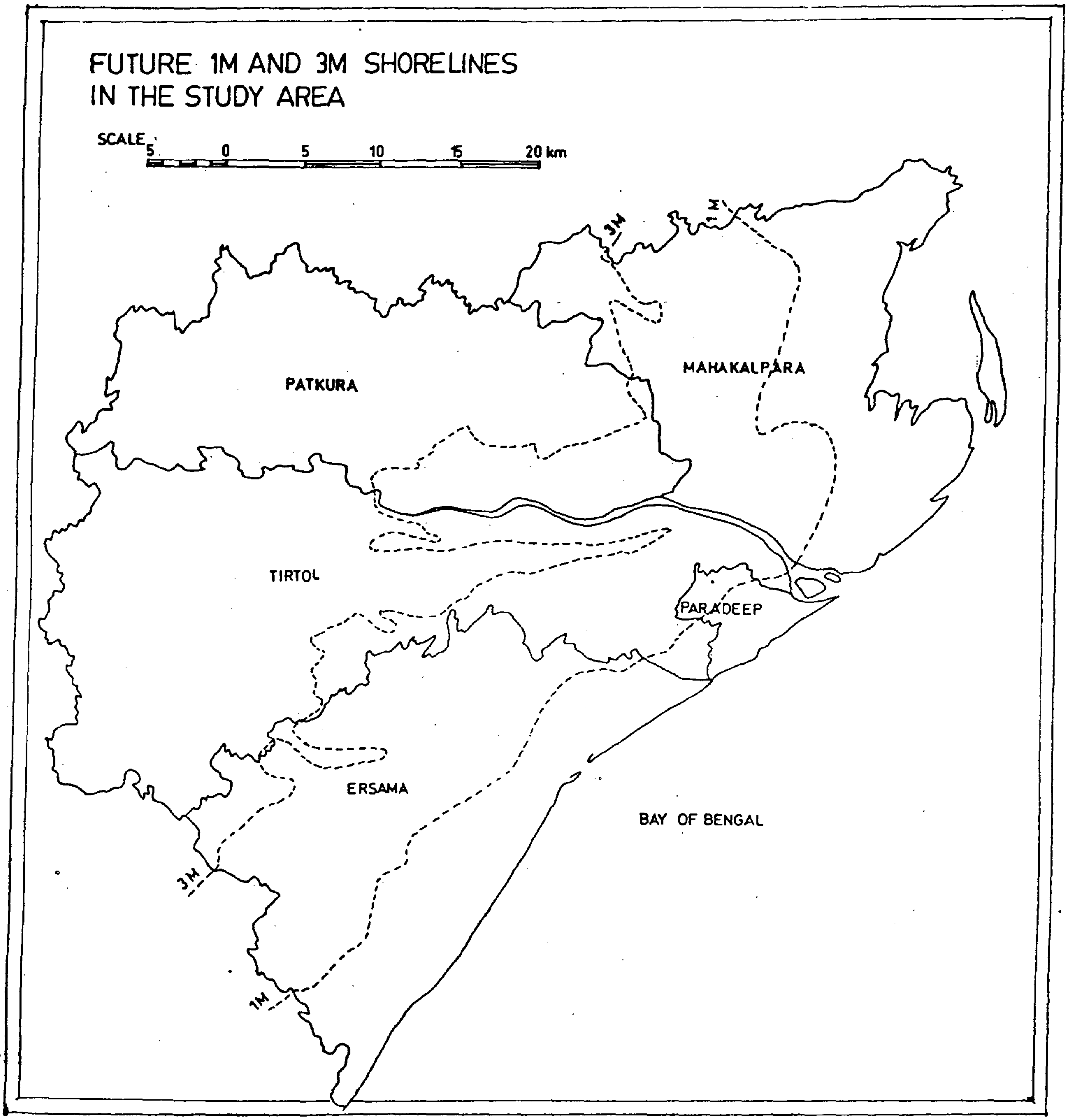


Figure 5.1 Area of submergence in 1m and 3m rise in the sea level in the study area.

TABLE 5.1. AREA OF SUBMERGENCE (IN SQ.KM.)

Sub areas	Total Area	for 1m	for 3 m	Unaffected area
MAHAKALPADA	376.77	151.71	340.1	36.68
PATKURA	380.26	0	69.14	311.12
ERSAMA	382.5	145.59	357.35	25.09
TIRTOL	523.49	19.27	115.62	407.87
PARADEEP	23.31	19.1	23.31	0
TOTAL	1686.33	335.67	905.52	780.76
PERCENTAGE	100	19.9	53.7	46.3

Coastal flooding & river damming :-

Sea level rise causes coastal flooding in two ways: storm surge & backwater effect.

The effective area to be affected will be more than what is estimated, when storm surge (which takes place in the viscinity of the coast) will cross the future shoreline, (1m. or 3m)

The floodwater from upstream backs up along the river because of a rise in sea level at the basin outlet. This is known as backwater effect. This will be hard-felt particularly along the major rivers like Mahanadi, Santra etc in this area. Again the flatness of the area will enhance this problem. The result will be flooding of river water across the levees. This effect will diminish gradually towards uprtream direction. The flatness which exists along the upper reaches of the major rivers would bring fear that the future rises of sea level would threaten more areas than protrayed in the present scenarios. These flat areas now frequently experience severe flooding (mostly during the monsoon seasons). If the scenarios, discussed here unfolds, flooding might intensify in these regions.

The sea level rise will also effect damming of the river courses resulting in the reduction in sediment discharge to the sea. Thus deposition of excess sediments enroute would add to local subsidence due to overloading and sediment compaction.

Effects on drainage :-

The area is marked by high drainage density. This surface drainage will again be increased when the rise in sea level would result rise in ground-water table which in turn would reduce underground drainage.

Increase in the water levels in the rivers and high tides would cause substantial lowering of hydraulic head (the difference in elevation between source to sink) along the slopes which will further slow down the drainage process.

Decreased flow rates along the channels would allow more siltation & deposition. Thus the effective capacity of the rivers would decrease.

All these would ultimately result a higher drainage density (which will include new channels), slow & poor drainage in the area.

5.2 Shore retreat due to Erosion

Erosion potential of the study area due to sea level rise has been determined applying Bruun rule, at four beach locations.

The locations are:

Beach profile No.1-2.25 km south of Paradeep port along the shore.

Beach profile No.2 - 1 km North of Paradeep port.
Beach Profile No.3 - 3.75 km North of Paradeep port.
Beach profile No.4 - 8 km north of Paredeep Port.

According to Bruun rule the rate of shore erosion

$$x = \frac{ab}{e + d}$$

where a = rate of sea level rise
b = width of the shelf
c = shore elevation
d = depth at distance 'b'

In all the following calcualtions the rate of sea level rise (the quantity 'a') has been taken as 1.2 mm/yr. which is the worldwide tatic sea level rise rate. For the quantity 'd', it is the 18 m depth; the limiting depth between the near hore and offshore material.

so 'a' = 1.2 mm/yr
d = 18 m

For sandy, open sea shores Bruun assumed the value of 'd' as 18m, the depth contour which forms some kind of limit between nearshore and deepsea littoral drift phenomena. Again the slope of the shelf is of prime importance here. The transverse migration of eroded sediments is retarded by the gentle slope which exists at around 18 m depth in most of the shores of open & sandy character. With a close look at the beach profiles (Fig 5.2 & Fig 5.3) drawn for the study area, it can be marked that the slope between 12m & 18 m depths (approximately) is gentle enough to retard the transverse movement of the sediments. Hence the depth contour 18m has been taken here as the outer limit of nearshore sediment migration. This figure (for quantity 'd') is also approximately same for most other shores world-wide.

Shore retreat at location-1:

$b = 9$ km

$e = 2$ km

$$\text{thus } x = \frac{ab}{e + d} = \frac{0.12 \times 900{,}000}{200 + 1800}$$

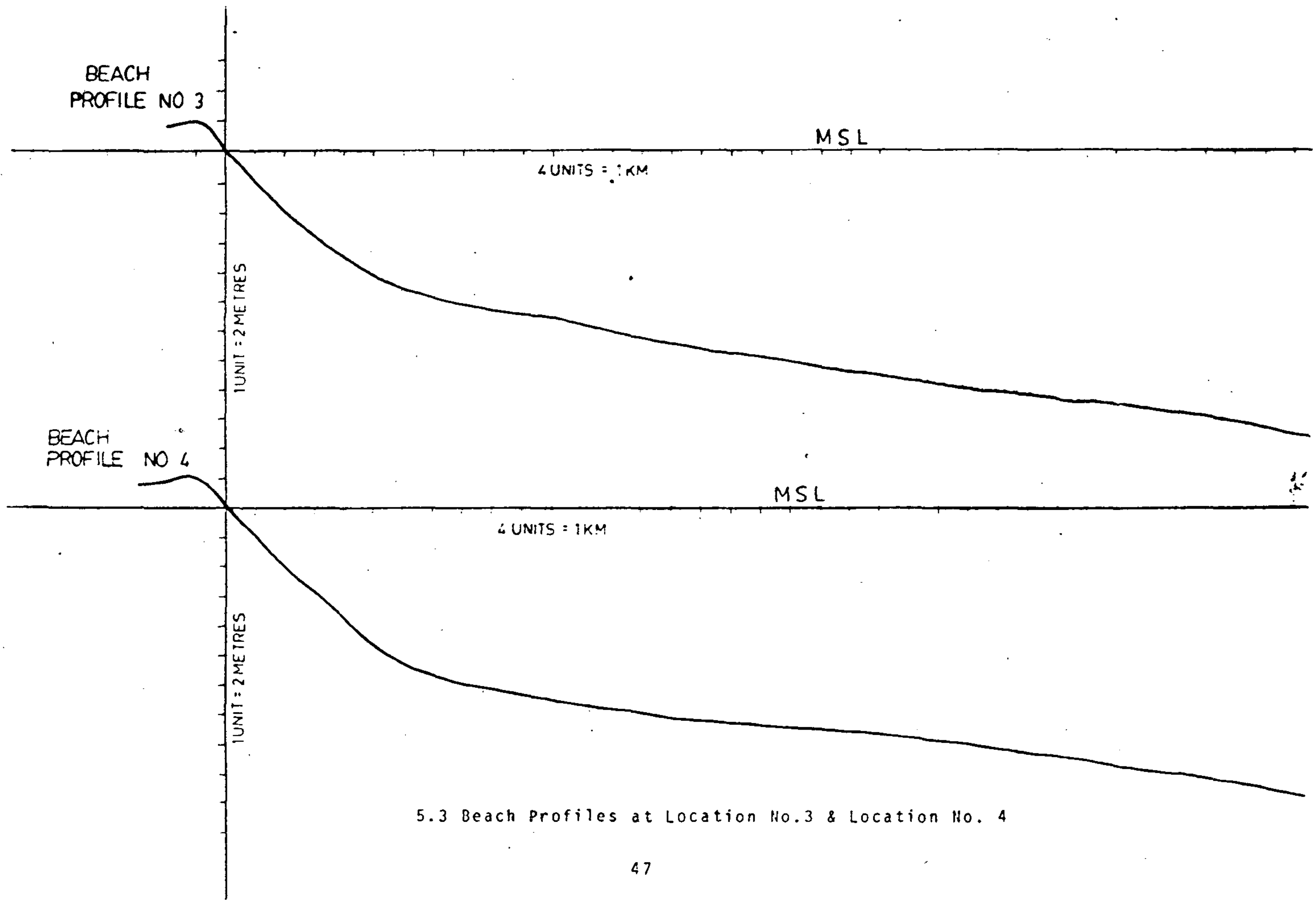
$= 54$ cm/yr

at location - 2:

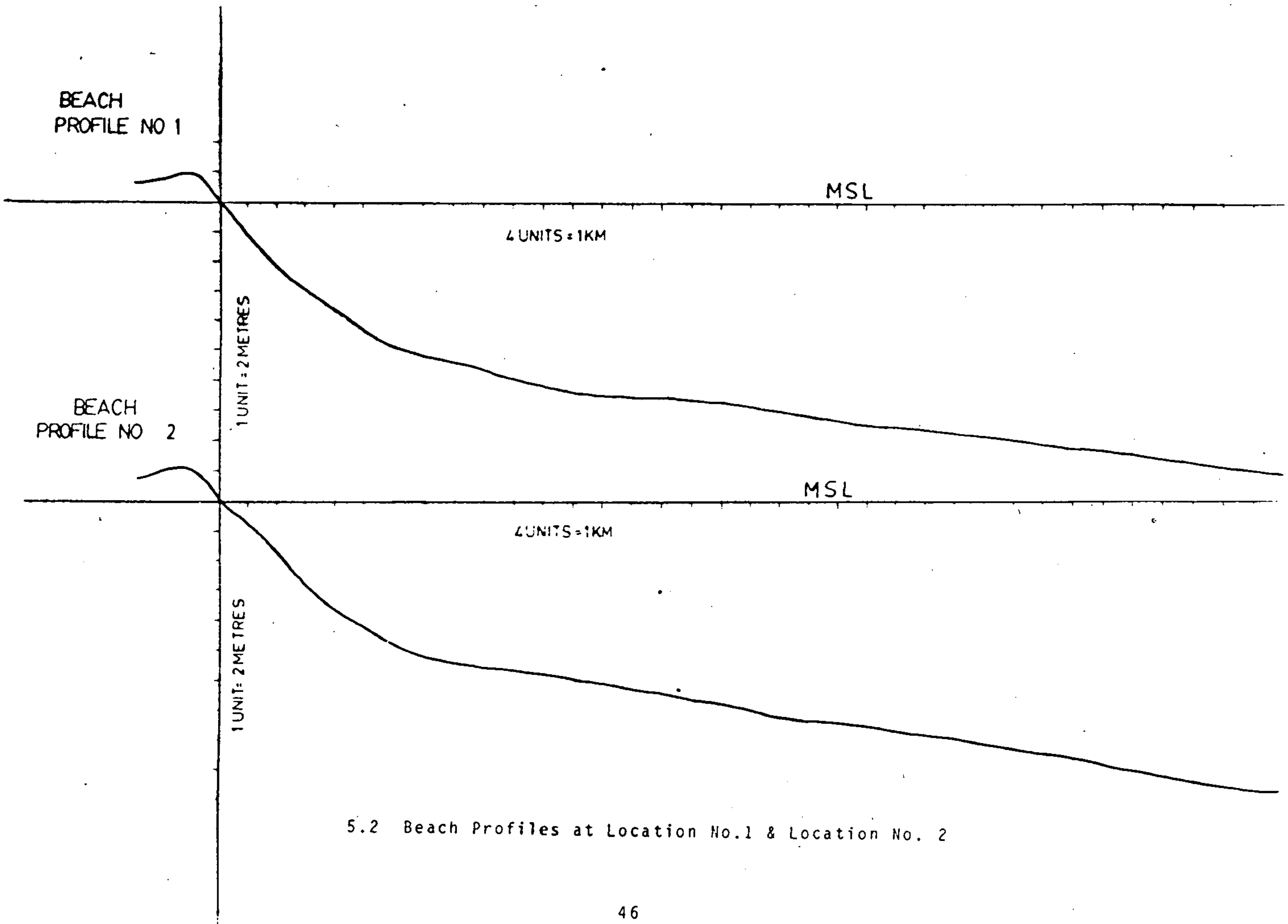
$b = 8.025$ km

$e = 2.25$ m

$$\text{thus } x = \frac{0.12 \times 802500}{225 + 1800} = 47.6 \text{ cm/yr}$$



5.3 Beach Profiles at Location No.3 & Location No. 4



5.2 Beach Profiles at Location No.1 & Location No. 2

at location 3 :

b = 8.35 km

e = 1.9 m

$$\text{thus } x = \frac{0.12 \times 8350,00}{190 + 1800} = 50.35 \text{ cm/yr}$$

at location 4 :

b = 8.05 km

e = 2.2 m.

$$x = \frac{0.12 \times 8050,00}{220 + 1800} = 47.82 \text{ cm/yr.}$$

In a test study carried out by Bruun along the southern coast of Florida, where the shelf width upto the depth contour 18m is 2000m ('d'). The beach elevation 'e' is 3 m. Thus the shore retreat is 11 cm/yr. Again for the areas north of Cape canaveral to Daytona beach and from the Cape South to about St. Lucia in-let where b = 8,000m and e = 4.5m. The whole reteat is estimated to be 43 cm/yr. For the upper Gulf coast (Santa Rosa island) he predicted the shore retreat to be 16cm/year (where b = 3,000 m and e = cm). In all these calculations he took 18m for 'd' and 1.2 mm/yr for the quanity 'a'.

Again Rosen (1978) obtained the average shore retreat figure as 98 cm/yr for his study area at the beaches of Virginia chesa peake bay. Local rate of sea level rise in that area was taken to be varies from -0.46 mm/yr to 5.43 mm/yr at differnet beaches.

The magnitude of average shore retreat calculated for the present study area (aprox. 50 cm/yr) seems too high for this region. The factors which may be compansating for such a retreat are; high sediment influx from rivers, local tectonic movements, increased water load (resulting the subsidence of nearshore bottom) etc. The contributions of these factors have not been taken into consideration, which may set a sea level change rate for this locality far away from the rate adopted for the present study (1.2 mm/yr).

The rate of reaction (erosion) in response to action (sea level rise) will probably depend to a large extent on the slope of the offshore bottom (Bruun, 1962). Steep pofiles are sensitive to short term rises in sea level than the long term rises, whereas the gentle profiles respond to long-term changes and demonstrate a prounced phase lag (the time gap between action and reaction). In case of Paradeep, the profiles have nearhore steep part as well as an offshore flat part. The steep part will respond to short-term flactuations whereas the profile as a whole including the flat portion will respond to the long term rises in sea level.

The erosion rates at the beaches north of Mahanadi river may exceed the estimated rate. The explanation for this is; the longshore drift direction here is form south to north. The main river in this localty (Mahanadi) is also the major source of sediment supply. With the submergence of river mouth, the rate of sediment discharge will also come down (as already mentioned in 5.1). This gap in supply to the up-drift beaches will be filled up by increased erosion of thse beaches.

Other factors and procceses which may become operative to facilitate increased erosion are: increased wave attack resulting from the deepening of the nearshore bottom due to sea level rise, increased wave attack due to climatic change yielding a high frequency, duration & severity of storms in costal waters. Sea level rise will also cause increased erosion resulting from the rise in water table, increase in rainfall or local drainage modifications rendering the beach sand wet and more readily erodible.

5.3 Effect on Population and land use

The future Shorelines of 1m. & 3m were projected on map prepared with the help of Census Handbook. The village wise population and landuse were estimted separately for 1m & 3m rise, which are going to be affected (Table 5.2 & Table 5.3). The affected villages have been listed in the appendix.

Although this study employs a detailed scale of data available to arrive at a meaningful characterization of the present level of pupulation and land use pattern in potentially effected areas, it does not take into

TABLE 5.2. 1m SCENARIO IN THE SUB AREAS (AREA IN ACRES)

The Sub-areas		No.of villages	Pop^n	Total Area	Forest Area	Irrigated Area	Non-irri-gated Area	Culti-vable Waste	Notav ilabl For cult.
MAHAKALPADA	A	163	71861	92596	15068	3020	40094	25579	8835
	B	56	25502	49798	15068	809	11291	19708	2922
	C	-	35.48	53.8	100	26.8	28.2	77.0	33.1
PATKURA	A	278	173938	93217	0	3545	69322	9250	11100
	B	0	0	0	0	0	0	0	0
	C	-	0	0	-	0	0	0	0
ERSAMA	A	209	83577	95096	2702	440	63688	11687	1657[illegible]
	B	33	23883	37942	2429	0	21845	4519	9149
	C	-	28.6	39.9	89.9	0	34.3	38.7	55.2
TIRTOL	A	487	215549	129399	1860	24877	69567	7924	2517[illegible]
	B	7	142	4865	1025	1065	1326	187	1262
	C	-	0.1	3.8	55.1	4.3	1.9	2.4	5.0
PARADEEP	A	-	6705	5758	0	0	0	0	5758
	B	-	6705	5758	0	0	0	0	5758
	C	-	100	100	-	-	-	-	100

A - Total No. of villages, population and total area

B - Affected villages, population and area

C - Percentage

TABLE 5.3. 3 M SCENARIO IN THE SUB AREAS (AREA IN ACRES)

Sub Areas		No.of Villages	pop^n	Total Area	Forest Area	Irrigated Area	Non-irrigated area	Cultivable area	Area not available for cultivation
MAHAKALPADA	A	163	71861	92596	15068	3020	40094	25579	8835
	B	143	61728	84410	15068	2516	34938	25288	6600
	C		85.9	91.2	100	83.3	87.1	98.9	74.7
PATKURA	A	278	173938	93217	0	3545	69322	9250	11100
	B	57	26999	21521	0	0	16813	3568	1140
	C		15.5	23.1	-	0	24.2	38.6	10.3
ERSAMA	A	209	83577	95096	2702	440	63688	11687	16579
	B	188	76246	90129	2702	440	59647	11275	16065
	C		91.2	94.8	100	100	93.6	96.5	96.9
TIRTOL	A	487	215549	129399	1860	24877	69567	7924	25171
	B	100	56228	39980	1123	5371	24214	2761	6511
	C		26.1	30.9	60.4	21.6	34.8	34.8	25.9
PARADEEP	A	-	6705	5758	0	0	0	0	5758
	B	-	6705	5758	0	0	0	0	5758
	C	-	100	100	-	-	-	-	100

A - Total No. of villages, population and total area

B - Affected villages, population and area

C - Percentage

account the future measures, adaptive responses or the future changes in the distribution of pupulation & land use pattern.

Here the whole village is taken as affected area even if it is intercepted partially by the new shorelines (1m. cr 3m). That is why for the same shoreline the total area affected, calcuated village wise is more than the area going to be submerged, as described in the earlier section 5.1 (Table 5.1).

The area that might be inundated in the low scenario (1m.) represents approximately 23-24% land of the study area, which contain 10.2 % of the estimated population of the area inhabitd in 96 villages (Table 5.4). The area that could be lost by flooding in the 3m scenario represents about 58-59% area inhabited by 41.37% of the total population in 488 vilages.

Nearly 66% land of the study area is presently being cultivated (amounting 274553 acres) out of whch 13.27% will be submerged with the low scenario & 52.47 % cultivable land for a 3m scanario (these figures do not include cultivable waste lands). In this area rice accounts bulk of the total grain output of the net cropped area. It accounts more than 90% land in the kharif season and 28% in the rabi season. It will be difficult to imagine and replace the loss of croplands due to sea level rise because the area is already

TABLE 5.4 1m and 3m Scenarios for the whole study area

(Area in acres)

		No.of Villages	Pop ^{n}	Total Area	Forest Area	Irrigated Area	Non-irri gated Area	Culti-vable Waste	Area not available for culti-vation
For 1m	A	1137	551630	416066	19630	31882	242671	54440	67443
	B	96	56232	98363	18522	1874	34462	24414	19091
	C	-	10.2	23.6	94.4	5.9	14.2	44.8	28.3
For 3m	A	1137	551630	416066	19630	31882	242671	54440	67443
	B	488	227906	241798	18893	8327	135612	42892	36074
	C	-	41.3	58.1	96.2	26.1	55.9	78.9	53.5

A - Total No. of villages, population and total area

B - Affected villages, population and area

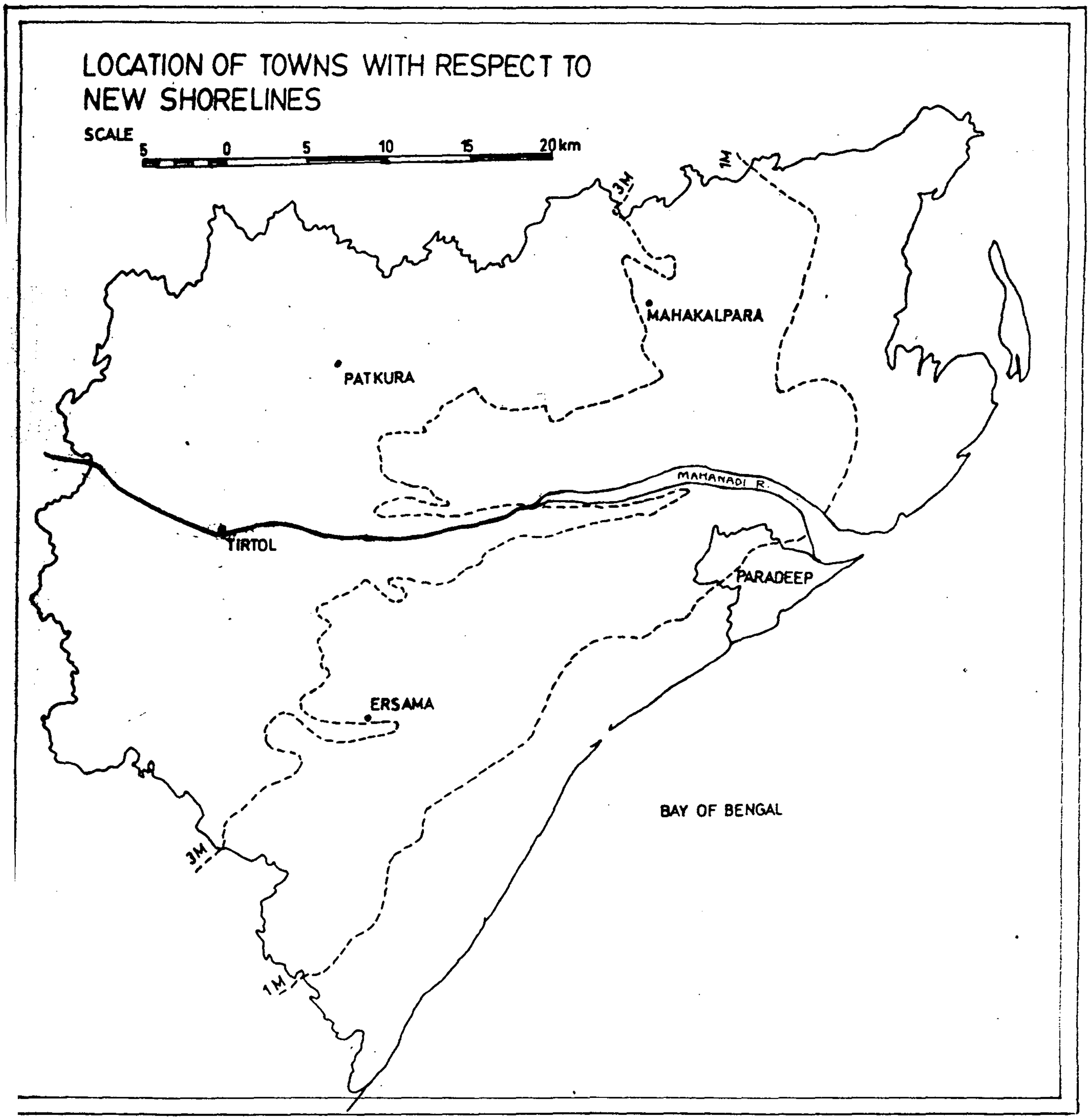
C - Percentage

extensively cultivated. The cultivable waste areas which will remain unaffected even after a 3m i e is a negligible area (11548 acres) to compansate for the loss of total croplands which amounts 134939 acres. Adoption of strategies of intensive cropping and land utilisation may bring some promise as a compansation for the loss of agricultural lands.

Again an additional amount of agricultural land may become unsuitable for cultivation as the saltwater would trangress further landward with the encroachment of sea water over the land.

The major towns in this area are Ersama, Mahakalpara, Tirtol, Patkura and Paradeep which also form the nuclei of relatively densely pupulated areas. Out of these, with the 1m level rise, Paradeep would be the only & most effected town area (Fig 5.4). More than 80% of the area will be directly afected with the 1m. rise and the rest would be submerged under the 3 m rise. But for population and land use study, whole paradeep is considered to be affected with the 1m. rise. (Table 5.2)

With the 3m rise, two more towns i.e. Mahakalpada & Erasma will be submerged. However, Tirtol & Patkura will remain unaffected in these scenarios.



5.4 Location of major towns with respect to future shorelines of 1 m & 3m.

The amenities like storage, transport, communication, trade & services, power, water, sanitation etc are assumed to be distributed as population in this area. These activities will also get affected due to sea level rise in a scale more or less same as population. The 1m rise would submerge 2km of the Kendrapara canal which runs E-W in the north of the study area and an additional 8km with the 3m rise. The other major canal which is to be affected is Taladanda canal running E-W at the centre of the study area will loose .5km with a 1m rise and additional 5km for 3m rise. The NH-5A which joins Daitari & Parardeep is also known as Express Highway. Of this highway 6km & additional 21 km will be affected with the 1m. & 3m rise respectively. Paradeep is also connected with Cuttack by SE Railway's Cuttack-Paradeep branch. It would also be affected with 8km & 14km with the rises of 1m & 3m respectively.

CHAPTER VI
SUMMARY AND CONCLUSION

In this area the 1m rise in the sea level would result in the submergence of 335.67 sq.km which is 19.9% of the total area and for the 3m rise the figures are 905.52 & 53.7 respectively. The wetlands along the coast would be lost to these rises. There will be an increase in the backwater effect in the rivers and severity in the storm surges. Due to the rise in sea level, groundwater table will also rise. This will allow the saltwater wedge to intrude further landward. Ground water table rise would also affect the drainage condition of the area. Underground drainage will be decreased effecting the opening of new chanels on the land.

Beach profiles taken across the shore of the area have been examined to estimate the erosion potential. Applying Bruun's theory it was found out that on an average beaches would be eroded at a rate, of 50 cm/yr approximately for a sea level rise rate of 1.2mm/yr (assuming neutrality of local modifying factors).

The nearshore portion the profile would respond to short term rises in sea level due to their steepness but the profile as a whole (which include a much gentler off shore bottom) would respond to the long-term rises. Sea level rise would result in many other factors to play which will accelerate the beach erosion rate.

Most of the area here is occupied with cultivation (especially of rice). So agriculture is going to be the worst effected field in the land use map. 10.2% of the estimated poplation in 96 villages are to be affected with the 1m rise. This also include 13.2% of the cultiable land. With the 3m, scenario 41.3% population inhabited in 488 villages will be affected. The cultivable land to be affected is 52.2%.

Little progradation has been documented in this area in the last decade although in detail the shore line has shown alternating advance & retreat, while just towards north of this area the coastline has just started to erode (Bird, 1986). The sediment currently delivered to the delta mouth seems to be maintaining a near equilibrium, a balanced state with the forces of tectonic and deltaic subsidence, to maintain a nearly static situation with little deltaic progradation. Any substantial reduction in the sediments delivery to the delta would disrupt this balance & expose it to wide scale erosion. Hence careful attention to this possibility is very important in the planning and design of upstream water management projects such as dams & barrages and soil conservation measures involving afforestation (which is presently going on in the costal tracts of orissa on a massive scale). All of which would reduce sediment discharge to a large extent to induce beach erosion.

There is a need for refined estimates of current and future rates of sediment discharge, land subsidence, sediment compaction, nearshore bottom subsidence, population growth, change in land-use distribution which can be incorporated to the present study to make the future impacts estimates, of sea level rise more meaningful.

Considering the magnitude of human and economic stakes feared for the two sea level rise scenarios discussed, it is suggested that the private and public agencies involved in the development or other processes in this area should begin to include consideration of the possible effects of sea level rise in the coming future in their long-range planning & project development. The types of activities to be threatened soonest and maximum are agriculture, storm effect & erosion are to be given prior attention.

Maintaining natural deltaic processes to combat shore retreat nor slowing the rise of sea level due to greenhouse effect would be easy to think & handle. However if the sediment washing would be let continue to reach the delta the future possible processes (impacts) can be delayed to some extent.

REFERNCES REVIEWED

AKWLICHEV-VA, IN-AK, 1984. Mesurement of Tidal Sea-Level Fluctuations by a Hydrostatic method. OCEANOL. ACAD. SCI. USSR : VOL.24 : NO 6 : pp 760-62.

BIRD-ECF AND ML-SCHWARTZ (eds), 1985. The World's Coastline. NEW YORK : VAN-NOSTRAND, REINHOLD.

BIRD-ECF, 1985. Coastline Changes : A Global Review. CHICHESTER : WILLEY INTERSCIENCE.

BARNETT-TP, 1983a. Global Sea Level : Estimating and Explaining Apparent Changes. IN COASTAL ZONE 83, O.T.MAGOON (ed), pp 2777-95 : NEW YORK : ASCE.

BARNETT-TP, 1983b. Recent Changes in Sea Level and their Possible Causes. CLIM. CHANGE : VOL.5 : NO 1 : pp 15-38.

BARTH-MC AND JG-TITUS (eds), 1984. Greenhouse Effect and Sea Level Rise. NEW YORK : VAN NOSTRAND REINHOLD.

BENTLEY-L, 1983. The West Antarctic Ice Sheet : Diagnosis and Prognosis. PROCEEDINGS : CARBON DIOXIDE, SCIENCE AND CONSENSUS : DOE CONFERENCE 820970 : WASHINGTON D.C. : DEPTT. OF ENRGY.

BRUUN-P, 1962. Sea Level Rise as a Cause of Shore Erosion. J.WATERWAYS AND HARBOUR DIV : PROC. OF AMER. SOC. CIVIL. ENGRS : VOL.88 : pp 117-30.

DELAUNE-RD, RH BAUMANN AND JG-GOSSELINK, 1983. Relationship Among Vertical Acretion, Coastal Submergence and Erosion in a Louisiana Gulf Coast : MARCH J.OF SED. PETR. : VOL.53 : pp 147-57.

DISTRICT CENSUS HANDBOOK, 1971. CUTTACK DISTRICT, ORISSA.

DONN-WL, WR-FARRAND AND M-EWING, 1962. Pleistocene Ice Volumes and Sea Level Lowering. JOURNAL OF ECOLOGY : VOL.70 : pp 206-14.

DUBOIS-RN, 1975. Support and Refinèment of Bruun Rule on Beach Erosion. JOURNAL OF GEOL. : VOL.83 : pp 651-7.

DUBOIS-RN, 1976. Nearshore Evidence in Support of the Bruun Rule on Shore Erosion. JOURN. GEOL : VOL.84 : pp 485-91.

ETKINS-R AND E.S.-EPSTEIN, 1982. The rise of Global Mean Sea Level as an Indication of Climatic Change: SCIENCE: VOL. 215: pp 287-89.

GORNITZ-V., S-LEBEDEFF AND J-HANSEN, 1982. Golobal Sea Level Tend in the Post Century. SCIENCE (WASH.), VOL.215: NO 4540, pp 1611-14.

HANSEN-JE, D-JOHNSON, A-LACIS, S-LEBEDEFF, D-RIND AND G-RUSSELL, 1981. Climatic Impact of Increasing Atmosphere Carbon Dioxide. SCIENCE: VOL. 213: pp 957-66.

HAYES-MO, 1967. Hurricanes as Geological Agents, South Texas Coasts: AM. ASSOC. PETRON. GEOL. BULL: VOL. 51: pp 937-42.

HUGHES-T, 1983. The Stability of West Antarctic Ice Sheet: What has Happened and What will Happen. PROG. CARBON DIOXIDE RESEARCH CONF: CARBON DIOXIDE, SCIENCE AND CONSENSUS: DOE CONFERENCE 820970: WASHINGTON D.C.: DEPTT. OF ENERGY.

INMAN-DL AND CE-NORDSTROM, 1971. On the Tectonic and Morphological Classification of Coasts. JOURNAL OF GEOLOGY: VOL. 79: pp 1-21.

KESAVA DAS-V, 1979. Seasonal Variation in Mean Sea Level at Mormugao, West Coast of India. MAHASAGAR: VOL. 12(2): pp 59-67.

MAHALIK-NK, 1984. Sattellite Imageries in Geological Mapping of Orissa and Geomorphological Study of Mahanadi-Brahmani-Baitarini Compound Delta. RESEARCH BULL. NO. 22: DEC. 1984: EASTERN GEOGRAPHICAL SOCIETY: P.G. DEPTT. OF GEOGRAPHY: UTKAL UNIV.: BHUBANESWAR.

MEIER-MF, 1984. Contribution of Small Glaciers to Global Sea Level: SCIENCE: VOL. 226: 4681: pp 1418-21.

MERCENDER-JH, 1970. Antractic Ice and Interglacial High Sea Levels. SCIENCE: VOL. 168: pp 1605-06.

NEWMAN-WS AND RW-FAIRBRIDGE, 1986: The Management of Sea Level Rise: NATURE: VOL. 320: pp 319-21.

PALUMBO-A AND A MAZZARELLA, 1982. Mean Sea Level Variations and their Practical Applications. J. GEOPHYSICAL RES: VOL.87: pp 4249-56.

PALUMBO-A AND A-MAZZARELLA, 1985. Internal and External Sources of Mean Sea Level Variations. J. GEOPHYSICS. RES (C.OCEANS): VOL. 90: NO 4: pp 7075-86.

PRASAD-KVSR AND BSR-REDDY, 1983. Sea Level Variation Off Madras, East Coast of India. IND. JOURN. OF MAR. SCI: DEC: VOL. 14: pp 206-09.

REVELLE-R, 1983. Probable Future Changes in Sea Level Resulting from Increased Atmospheric Carbon Dioxide (Does not Inculde Antarctica). IN CHANGING CLIMATE: WASHINGTON, DC: NAP.

ROBINSON-IS, L-WAREN AND JF-LONGBOTTOM, 1983. Sea Level Fluctuation in the Fleet, An English Tidal Lagoon, ESTUAR. COAST SHELF. SCI: VOL. 16: NO.6: pp 651-68.

ROSEN-PS, 1978. A Regional Test of the Bruun Rule on Shoreline Erosion. MAR. GEOL: VOL. 26: M7-M16.

ROSEN-PS, 1977. Nearshore Evidence in Support of Bruun Rule on Shore Erosion. JOURN OF GEOL: VOL. 85: pp 491-2.

ROSSITER-JR, 1958. INST. HYDROGRAPHIC REVIEW: VOL. 35: pp 105.

SCHWARTZ-ML, 1965. Lab. Study of Sea Level Rise as a Cause of Shore Erosion. JOURN OF GEOL: VOL. 73(1): pp 528-34.

SCHWARTZ-ML, 1967. Bruun Rule of Sea Level Rise as a Cause of Shore Erosion. JOURN. OF GEOL: VOL. 75(1): pp 76-92.

SCHWARTZ-ML, 1968. Lab. The Scale of Shore Erosion. JOURN. OF GEOL: VOL. 76: pp 508-17.

SOBEY-EJC, 1982. What is Sea Level? SEA FRONT: VOL. 28: NO.3: pp 136-42.

THOMAS-RH, 1985. Responses of the Polar Ice Sheets to Climatic Warning. GLACIERS, ICE SHEETS AND SEA LEVEL: M.F. MEIER (ED.): WASHINGTON, D.C.:NAP.

TITUS-JG(ED.), 1986. See Level Rise. Effects of Changes in Stratospheric Ozone and Gl;obal Climate: VOL. 4: US ENVI. PROTECTION AGENCY AND UNITED NATIONS ENVI. PROGRAMME.

TITUS-JG, CY-KUO, MJ-GIBBS, TB-LAROCHE, MK-WEBB AND JO-WADDELL, 1987. Greenhouse effect, Sea Level Rise and Coastal Drainage System: J. OF WATER RESOURCES: AM.COC. CIVIL ENGGRS: MAR:VOL. 113(2).

WANLAS-HR, 1982. Editorial. Sea Level is Rising- So What? JOUR. SED. PETR: VOL. 52: NOV. 4: pp 1051-57.

WONG-KC, 1986. Sea Level Fluctuations in a Coastal Lagoon. ESTUAR. COAST. SHELF SCI: VOL. 22: NO.6: pp 739-52.

VARADARAJULU-R AND CH-BANGARUPPA, 1984. Seasonal Changes in Sea Level at Port-Blair: MAHASAGAR: VOL.17(2): pp 113-18.

VARADARAJULU-R, M-HARIKRISHNA AND K-HANUMANTHARAO, 1982. Sea Level Changes at Paradip, East Coast of India. IND. JOUR. OF MAR. SCI: MAR: VOL. 11: pp 32-34.

$

BIBLIOGRAPHY

ALLISON-H, 1980. Enigma of the Bruun Formula in Shore Erosion. PROC. OF BRUUN SYMPOSIUM, NEW PORT, INTERNATIONAL GEOGRAPHICAL UNION.

ARMENTANO-TV, RA-PARK AND CL-CLOONAN. Impacts on Wetlands Throughout the United States. IMPACTS OF SEA LEVEL RISE ON COASTAL WETLANDS IN THE UNITED STATES: pp 157-271: WASHINGTON, DC: US ENVIRONMENTAL PROTECTION AGENCY (IN PRESS).

BADYUKOV-DD, 1986. Ancient Shorelines as Indicators of Sea Level. JOURNAL OF COASTAL RESEARCH: VOL.2: NO.2: pp 147-57.

BIRD-ECF, 1976. Shoreline Changes During the Last Century. PROC. OF THE 23RD INTERNATIONAL GEOGRAPHICAL CONGRESS, MOSCOW: ELMSFORD, NEW YORK: pp 54.

BIRD-ECF, 1986. Man's Response to Changes in the Australian Coastal Zone. MAN AND COASTLINE CHANGES: ED. K. RUDDLE.

BIRD-ECF AND OSR-ONGKOSONGO, 1980. Environmental Changes on the Coasts of Indonesia. TOKYO, UNITED NATIONS UNIVERSITY.

BRUUN-P, 1954a. Coast Stability. DANISH TECHNICAL PRESS: COPENHAGEN, DENMARK.

BRUUN-P, 1954b. Coast Erosion and Development of Beach Profile. TECH. MEMO. NO. 44: CERC, ASCE.

BRUUN-P, 1973. The History and Philosophy of Coastal Protection. IN PROC. OF 13TH CONF. OF COASTAL ENGG: pp 33-74: VANCOUVER, ASCE.

BRUUN-P, 1980. The Bruun Rule: Discussion on Boundary Conditions. PROC. OF BRUUN SYMPOSIUM: NEW PORT: R.1: NOV. 1979: INTERNATIONAL GEOGRAPHIC UNION.

BRUUN-P, 1981. Port Engineering. 3RD ED.: GULF PUBLISHING, HOUSTON.

BRUUN-P, 1983. Review of Conditions for Uses of the Bruun Rule of Erosion. COASTAL ENGINEERING: VOL. 7: pp 77-89.

BRUUN-P, 1985. Cost Effective Coastal Protection. JOURN. OF COASTAL RESEARCH: VOL.1(1): pp 47-55.

BRUUN-P, 1986. Discussion of Paper by C.H. Everts, Titled "Sea Level Rise Effects on Shordine Position". PROC. OF AMER. SOC. CIVIL ENG.: JOURNAL OF WATERWAYS, PORTS AND COASTAL ENGINEERING DIVISION: VOL. 112(3).

BRUUN-P AND M-SCHWARTZ, 1985. Analytical Prediction of Beach Profile Change in Response to a Sea Level Rise. STUTTGART, W. GERMANY: ZEITSCHRIFT FOR GEOMORPHOLOGIE: BD. 36.

DAVIES-JL, 1973. Geographical Variation in Coastal Development. HATNER PUBLISHING CO.: NEW YORK.

DAVIES-JL, 1985. Coastal Sedimentary Environments. SPRINGVERLAG: NEW YORK.

DEAN-RG AND EM-MAURMEYER, 1983. Models for Beach Profile Response. CRC HANDBOOK OF COASTAL PROCESSES AND EROSION CONTROL: BOCARATON, FLA: CRC PRESS: pp 151-65.

EVERTS-CH, 1985. Sea Level Rise Effects on Shoreline Position. PROC. OF AM. SOC. CIVIL ENGS.: JOURNAL OF WATERWAYS, PORTS AND COASTAL ENGINEERING DIVISION: VOL.111: pp 995-1000.

FAUGERES-JC, R-CUIGNON, H-FENIES AND J-GAYET, 1986. Features of a Coastal Evolution: From an Estuary to a Lagoon (Arcachon Basin, France). BULL. INST. GEOL. BASS. AQUITAINE: NO. 39: pp 135-47.

FENNEMAN-MN, 1982. Development of the Profile of Equilibrium of the Subaquateous Shore Terrace. JOURN. OF GEOLOGY.

FIELD-MA AND DB-DANNE, 1976. Post-Pleistocence History of the United States Inner Continental Shelf: Significance to Origin of Barrier Islands. GEOL. SOC.OF. AM. BULL: VOL. 87: pp 691-701.

FISHER-JJ, 1980. Shoreline Erosion, Rhode Island and North Carolina Coasts: Test of Bruun Rule. PROC. OF BRUUN SYMPOSIUM, NEW PORT: R.1: NOV. 1979: INTERNATIONAL GEOGRAPHIAL UNION.

GODSHAL-FA AND RG-WILLIUMS (EDS.), 1981. Water Elevation Components and Comparative Risks. A CLIMATOLOGY AND OCEANOGRAPHIC ANALYSIS OF THE CALIFORNIA PACIFIC OUTER CONTINENTAL SHELF REGION: pp 7.1-7.21.

GRANT-DR, 1970. CANADIAN JOURNAL OF EARTH SCIENCES: VOL.7: pp 676-89.

HANDS-EB, 1983. The Great Lakes as a Test Model for Profile Response to Sea Level Changes. CRC HANDBOOK OF COASTAL PROCESSES AND EROSION CONTROL, BOCA RATION, FLA: CRC PRESS: pp 167-89.

HARRISON-CGA, GC-BRASS, E-SALTZMAN, J-SLOAN, J-SOUTHAM AND JM-WHITMAN, 1981. Sea Level Variations, Global Sedimentation Rates and the Hydrographic Curves. EARTH PLANET. SCI. LETT.: VOL. 54: NO.1: pp 1-16.

HEYWORTH-A AND C-KIDSON, 1982. Sea Level Changes in Southwest England and Wales. PROC. GEOL. ASSOC.,LONDON: VOL. 93: NO.1: pp 91-111.

HOFFMAN-IS, D-KEYES AND JG-TITUS, 1983. Projecting Future Sea Level Rise: Methodology, Estimates to the Year 2100 and Research Needs: WASHINGTON, DC: GOVT. PRINTING OFFICE.

HOWARD-JD, OH-PILKEY AND W-KAUFMAN, 1985. Strategy for Beach Preservation Proposed. GEOTIMES: VOL. 30(12): pp 15-19.

KAZANSKIY-AB, 1985. A Hypothesis for the Saw-like Pattern of World Sea-Level Fluctuations. QUART. RESEARCH: VOL.24: pp 2885-95.

KRAFT-JC, 1971. Sedimentary Facies Patterns and Geological History of a Holocene Marine Transgression. GEOL. SOC. AM. BULL.: VOL. 82: pp 2131-58.

KRUMBEIN, 1952. Principles of Facies Map Interpretation. JOURN. OF SEDIMENTARY PETROLOGY: VOL. 22: pp 200-11.

KUO-CY, 1986. Sea Level Rise and Coastal Stormwater Drainage. PROC. OF THE WATER FORUM: NEW YORK: AM. SOC. CIVIL ENGRS.

LEATHERMAN-SP, 1981. Barrier Beach Development: A Perspective on the Problem. SHORE AND BEACH: VOL. 49: pp 2-9.

LEATHERMAN-SP, 1982. Barrier Island Evolution in Response to Sea Level Rise: A Discussion. JOURN. OF SEDIMENTARY PETROLOGY: V

$
LETHERMAN-SP, 1983b. Shoreline Mapping. SHORE AND BEACH: VOL. 53: pp 28-33.

LETHERMAN-SP, 1986. Shoreline Response to Sea Level Rise: Ocean City, Maryland. PROC. OF ICELANDIC CONF. ON COASTS AND RIVERS: REYKJAVIK, ICELAND: (IN PRESS).

LESSERRE-P AND H-POSTMA (EDS.), 1982. Changes on Barriers and Spits Enclosing Coastal Lagoons. COASTAL LAGOONS, OCEANOL. ACTA.: VOL. 5: NO.4: pp 43-53.

LETZSCH-SW AND RW-FREY, 1980. Deposition and Erosion in a Holocene Tidal Saltmarch; Sapelo Island, Georgia. JOURN. SEDI. PETR.: VOL. 50: pp 529-42.

MACKIEWICZ-MC, 1984. Sea Level Rise. UNDERWAT. NAT.: VOL. 15: NO. 1: pp 20-22.

MARMER-HA, 1948. Is the Atlantic Coast Sinking? The Evidence from the Tides. GEOLOGICAL REVIEW: VOL. 38: pp 352.

McGILL-JT, 1958. Map of Coastal Landforms of the World. GEOGRAPHICAL REVIEW: VOL. 48: pp 402-05.

MEIER-MF, 1984. The Contribution of Small Glaciers to Global Sea-Level. SCIENCE: VOL. 226: pp 1418-21.

MILLIMAN-JD AND KO-EERY, 1968. Sea Level During the Past 35,000 years. SCIENCE: VOL. 168 (3558): pp 1121-23.

MOERNER-NA, 1982. Sea Level as an Illusive "Geological Index". EOS TRANS. AM. GEOPHYS. UNION.: VOL. 63: NO. 51: pp 1282.

MOHINDA SALIVA-AT, 1986. Environmental Changes, Ecological Conditions and Sociological Aspects of Two Lagoon Ecosystems in Southern Sri Lanka. MAN IN THE MANGROOVES: EDS-BIRD, KUNSTADTER, SABHASRI: TOKYO: UNITED NATIONS UNIV.

MOORE-RC, 1949. Meaning of Facies. GEOL. SOC. AM. MEMOIR: VOL. 39: pp 1-34.

NUMMEDAL-D, 1983. Future Sea Level Changes along the Louisiana Coast. SHORE AND BEACH.

PARK-RA, TV-ARMETANO AND CL-CLOONAN, 1986. Predicting the Impact of Sea Level Rise On Coastal Systems. SUPPLEMENTARY PROC. FOR THE 1986 EASTERN SIMULATION CONF., NORFOLK, VA: pp 149-53.

PIRAZOLLI-PA, 1986. Secular Trnds of Relative Sea Level (RSL) Changes Indicated by Tide-Gange Records. JOURN. OF COASTAL RESEARCH: SPECIAL ISSUE: NO.1: pp 1-26.

POPE-RM AND JG-GOSSELINK, 1973. A Tool for Use in Making Land Management Decisions Involving Tidal Marshlands. COASTAL ZONE MANAGEMENT JOURNAL: VOL. 1: pp 65-71.

POTTER-PE, 1959. Facies Model Conference. SCIENCE: VOL. 129: pp 1292-94.

PUTTALLO, MUNK, REVELLE AND STRONG, 1955. The Seasonal Oscillations in Sea Level. JOURN. OF MARINE RESEARCH: VOL.: 14: pp 88-156.

RAMPINO-MR AND JE-SANDENS, 1982. Barrier Island Evolution in Response to Sea Level Rise: Reply. JOURN. OF SEDY. PETROLOGY: VOL. 53: NO.3: pp 1031-33.

READING-HG, 1985. Sedimentary Environment and Facies. 2ND ED.: NEW YORK, ELSEVIOR, OXFORD, BLACKWELL.

REDFIELD-AC, 1972. Development of a New England Salt-Marsh. ECOL. MONOGRAPH: VOL. 42: pp 201-37.

ROSEN-PS, 1980. An Application of the Bruun Rule in the Chesapeake Bay. PROC. OF BRUUN SYMP.: NEW PORT: R.I.: NOV. 1979: INTERNATIONAL GEOGRAPHICAL UNION.

ROSSITER-JR, 1962. Longterm Variation in Sea Level. THE SEA: VOL.1: pp 590-610: JOHN WILLEY AND SONS, INC.

SCHWARTZ-ML, 1980. The Bruun Rule: A Historic Perspective. PROC.OF BRUUN SYMP.: NEW PORT: R.1.: NOV. 1979: INTERNATIONAL GEOGRAPHICAL UNION.

SELLEY-RC, 1978. Ancient Sedimentary Environment. 2ND ED.: ITHACA, NEW YORK: CORNELL UNIV.PRESS.

SWIFT-DJP, 1968. Coastal Erosion and Transgressive Stratigraphy. JOUEN. OD GEOLOGY: VOL. 76: pp 445-56.

TEICHERT-C, 1958. Concept of Facies. BULL. OF AM. ASSOC. PETROL. GEOL.: VOL. 42: pp 2718-44.

TITUS-JG. GREENHOUSE Effect, Sea Level Rise and Wetland Loss. IMPACT OF SEA LEVEL RISE ON COASTAL WETLANDS IN US: WASHINGTON, DC: ENVIRONMENTAL PROTECTION AGENCY (IN PRESS).

TOOLEY-MJ, 1982. Sea Level Changes in Northern England. PROC. GEOL. ASSOCN., LONDON: VOL. 93: NO.1: pp 43-51.

VELLINGA-P, 1982. Beach and Dune Erosion During Stormsurge. COASTAL ENGINEERING: VOL. 6: pp 361-87.

VELLINGA-P AND P-BRUUN, 1984. Discussion on "Beach and Dune Erosion During Stormsurges" by P. Vellinga (In Coastal Engineering Vol. 6). COASTAL ENGINEERING: VOL. 8: pp 171-88.

WADDELL-JO AND RA-BAYLOCK. Impact of Sea Level Rise on Gap Greek Watershed in the Fort Walton Beach, Florida Area. SEA LEVEL RISE AND COASTAL DRAINAGE SYSTEMS: WASHINGTON, DC: US ENVIRONMENTA PROTECTION AGENCY (IN PRESS).

WALKER-RG, 1979. Facies and Facies Models. GEOL. ASSOCN. OF CANADA, TORONTO.

WATTS-G, 1954. Lab. Study of Effects of Tidal Action on Wave-Formed Beach Profiles. TECH. MEMORANDUM NO.52: CORPS OF ENGRS: BEACH EROSION BOARD.

WYRTKI-K, 1971. Ocxeanographic Atlas of the International Indian Ocean Expedition. NATIONAL SCIENCE FOUNDATION: WASHINGTON, DC.

YAMAMOTO-H AND T-ABE, 1983. The Behaviour of Water Table in the Seashore. UMI/MER: VOL. 21: NO.1: pp 29-33.

ZEIGLER-JG AND V-CHASE (EDS.), 1985. Sea Level Change, a Fundamental Process When Interpreting Coastal Geology and Geography. THE CHESAPEAKE: PROLOGUE TO THE FUTURE: PROC. FROM THE CHESAPEAKE SYMP.: NAT. MAR. ED. CONF.: JUL 30 - AUG 3, 1985: WILLIUMSBURG, VIRUINIA: pp 9-10.

$

APPENDIX-1

IA-VILLAGES UNDER 1M SCENARIO

MAHAKALAPARA

Serial No.	Loc-ation code No	Name of the village	Serial No.	Loc-ation code No.	Name of the village
1	29	Sanarahama	29	60	Kansarabadandua
2	30	Babara	30	61	Panchagachhia
3	34	Guludia	31	62	Kantilo
4	35	Kalatunga	32	63	Badapala
5	36	Gogua	33	64	Sugal
6	37	Baliganda	34	68	Kansara
7	38	Doligan	35	69	Pankapala
8	39	Nanjara	36	118	Baulakani
9	40	Garjung	37	122	Badatotachhapaii
10	41	Panikhia	38	123	Cansapal
11	42	Bhuinpada	39	124	Bagagahana
12	43	Sankhachit	40	125	Bhateni
13	44	Maladiha	41	126	Jamboo
14	45	Bhopal	42	127	Hukitola
15	46	Tantiapala	43	128	Kansaradia
16	47	Singhapura	44	129	Baligad
17	48	Sasan	45	130	Bhitarakharanasi
18	49	Tamulia	46	131	Kharinasi
19	50	Chakulidiha	47	132	Hariabanka
20	51	Baro	48	135	Petachhela
21	52	Paunsiapala	49	156	Badatubi
22	53	Oliasal	50	157	Sanatubi
23	54	Mundatalasaharakani	51	158	Nipania
24	55	Ratpanga	52	159	Jogidhanakud
25	56	Narsingpur	53	160	Saralikuda
26	57	Banapara	54	161	Hetamundia
27	58	Kandharapatia	55	162	Barakolikhala
28	59	Suniti	56	163	Lighthouse

ERASAMA

57	35	Kokakhanda	66	45	Gobindpur
58	36	Kankardia	67	46	Panigadiakandha
59	38	Badakantakandha	68	47	Nuagan
60	39	Trilochanpur	69	48	Baianalakandha
61	40	Badakandha	70	124	Polanga
62	41	Abhaychandrapur	71	125	Noliasahi
63	42	Kansaripatia	72	126	Bhuyanpal
64	43	Dhinkia	73	127	Jatadhartanda
65	44	Phirikichintakandha	74	128	Kankan

75	129	Dhobaijungle	83	183	Padanpur
76	130	Pinpudia	84	185	Asia
77	175	Gadabishnupur	85	205	Salio
78	178	Khatikholada	86	206	Goda
79	179	Ambiki	87	207	Garia
80	180	Pibarkani	88	208	Harispurgada
81	181	Jatadhar	89	209	Saharabedi
82	182	Barakuda			

TIRTOL

90	130	Musadiajungle	94	136	Chauliapalanda
91	131	Boitirakuda	95	137	Keruadiakandha
92	132	Kaudia	96	138	Kaduapalikandha
93	133	Udaychandrapur			

IB-VILLAGES UNDER 3M SCENARIO

MAHAKALAPARA

Serial No.	Location code No.	Name of the village	Serial No.	Location code No.	Name of the village
1	13	Basaghara	45	100	Mahakalapara
2	14	Andhuli	46	101	Gamhan
3	15	Kalapara	47	102	Jaganathpur
4	16	Ghantiapali	48	103	Mangalapur
5	17	Balipala	49	104	Baulapara
6	18	Srichandanpur	50	105	Dadhipur
7	19	Jasuapali	51	106	Kumbharpara
8	20	Balia	52	107	Gajabandha
9	21	Mulabasanta	53	108	Bandhapada
10	22	Sahoopara	54	109	Marichakani
11	23	Ramachandrapur	55	110	Mahulakandha
12	24	Potia	56	111	Batakudi
13	25	Chatar	57	112	Tithi
14	26	Itakandia	58	113	Jemadeipur
15	27	Baradiha	59	114	Nantara
16	28	Badarahama	60	115	Pareswarpur
17	31	Kakatapur	61	116	Adoi
18	32	Kholanai	62	117	Kiabaria
19	33	Bandhapada	63	119	Malladihi
20	65	Kharianta	64	120	Tankibelari
21	66	Kusiapalla	65	121	Bhitarasubala
22	67	Tarapada	66	133	Ramnagar
23	70	Badamatha	67	134	Brajabahakud
24	71	Balabhadrapura	68	136	Kentia
25	72	Radia	69	137	Sarumuhi
26	73	Badabaincha	70	138	Kochila
27	74	Akalapur	71	139	Bachhuria
28	75	Ranki	72	140	Potakani
29	76	Arada	73	141	Chhadakani
30	77	Kanpur	74	142	Sathiabati
31	78	Maliancha	75	143	Gokhakhati
32	79	Baharsubala	76	144	Lunamatia
33	80	Bardang	77	145	Tentulikandha
34	81	Jagati	78	146	Barakandha
35	82	Paiguda	79	147	Guptagiri
36	83	Janra	80	148	Rajendranagara
37	84	Kiarbanka	81	149	Bahargadabadadan
38	85	Bijayanagar	82	150	Nalitajoripala
39	86	Sankhapada	83	151	Dasarajpur
40	87	Sahobajpur	84	152	Akhalsali
41	89	Chandiapalli	85	153	Palligar
42	90	Amirabad	86	154	Bahakud
43	91	Deulapara	87	155	Banabiharipur
44	99	Reputa			

PATAKURA

88	76	Samantsinghpur	117	251	Mahangal
89	77	Belar	118	252	Raipur
90	78	Nuagan	119	253	Khurusia
91	92	Kalagar	120	254	Bandhakuda
92	103	Bhaganpur	121	255	Thantapalanda
93	226	Ramachandrapur	122	256	Naladiasasan
94	227	Balighai	123	257	Narayanpur
95	228	Baripala	124	258	Gatanai
96	229	Batia	125	259	Koratapanga
97	230	Potari	126	260	Dekani
98	231	Madhusudanpur	127	261	Khurusiapat
99	232	Mangarajpur	128	262	Patelipanka
100	233	Nachhipara	129	263	Nalidia
101	234	Potari	130	264	Kodakana
102	236	Alifa	131	265	Raghunathapur
103	237	Beruhan	132	266	Tekarpanga
104	238	Dhaniapada	133	267	Tiradeipur
105	239	Ratanpur	134	268	Anantpur
106	240	Nuagan	135	269	Ramachandrapur
107	241	Tikhiri	136	270	Paunsiapal
108	242	Balisuan	137	271	Chhanda
109	243	Gopalpur	138	272	Purusottampur
110	244	Bauda	139	273	Nandanpur
111	245	Sireinpur	140	274	Raula
112	246	Ameipal	141	275	Subala
113	247	Madhuragandakhamar	142	276	Madhusudanpur
114	248	Samjori	143	277	Gararomita
115	249	Nalidiapalanda	144	278	Srirampur
116	250	Badaghai			

ERASAMA

145	1	Bareikana	163	19	Chatua
146	2	Rupakhandi	164	20	Pokhariapada
147	3	Nuadihi	165	21	Jaganathapur
148	4	Dasipur	166	22	Chakulia
149	5	Kiadingiri	167	23	Aligarh
150	6	Dhalipang	168	24	Sanagabpur
151	7	Digitari	169	25	Badagabpur
152	8	Barabatia	170	26	Manapur
153	9	Bilapokhariapada	171	27	Parapada
154	10	Nalakani	172	28	Mulakani
155	11	Banipat	173	29	Bamadeipur
156	12	Baleipur	174	30	Chharakandha
157	13	Guruguria	175	31	Jalapadakandha
158	14	Nachhipura	176	32	Kuatarakandha
159	15	Janardanpur	177	33	Banpatkandha
160	16	Narindrapur	178	34	Balitutha
161	17	Arjunkul	179	37	Sunadiakandha
162	18	Balipari	180	49	Kandubelari

181	50	Gadakujanga	233	114	Kimilo
182	51	Badabuda	234	115	Ekagharia
183	52	Bhitarsrichandanpur	235	116	Bartol
184	53	Potaka	236	117	Sunadiakandha
185	54	Jamukana	237	118	Dhobei
186	55	Barabelari	238	119	Deika
187	56	Painchiamania	239	120	Botigan
188	57	Guamunda	240	121	Kunjakothi
189	58	Chadhaigahangharatakati	241	122	Khurantatutha
190	59	Uchanuagan	242	123	Kanaguli
191	60	Bhegibaripachera	243	131	Kiada
192	61	Kadakan	244	132	Kochilabedi
193	62	Rasakadapur	245	133	Sahadabedi
194	63	Bhitarandhari	246	134	Badabelari
195	64	Dasipurpaikasahi	247	135	Saraba
196	65	Malipur	248	136	Kuladanda
197	66	Bhainch	249	137	Nuapada
198	67	Dhuansahi	250	138	Oradilo
199	68	Mahimdeipur	251	139	Srichandanpur
200	69	Iribana	252	140	Bhajana
201	70	Achutdaspur	253	141	Kopalamandal
202	71	Japabhuyan	254	142	Asarana
203	72	Katijanga	255	143	Rurupada
204	73	Sundarkani	256	144	Madhupur
205	74	Kendurisala	257	145	Pokharipada
206	75	Mirjapur	258	146	Alanavas
207	76	Saintol	259	156	Sampur
208	77	Bharisola	260	157	Santol
209	78	Sumuda	261	158	Ghodadia
210	79	Mandira	262	159	Kanjiakan
211	80	Palikanta	263	160	Garadmal
212	81	Kanipada	264	161	Kanpada
213	82	Oriesal	265	162	Lachhamakan
214	83	Asarana	266	163	Balikani
215	84	Arada	267	164	Naradia
216	85	Oranal	268	165	Tikarapada
217	86	Talakusuma	269	166	Narasinghapur
218	89	Kothi	270	167	Paniendula
219	90	Krushnachandrapur	271	168	Gobindpur
220	91	Gangadharpur	272	169	Sribantapur
221	93	Atimati	273	170	Narayanaprasad
222	102	Rabhalochaka	274	171	Gambharikan
223	103	Bhiranga	275	172	Ganeswarpur
224	104	Gandhapur	276	173	Talang
225	105	Sihar	277	174	Dharijana
226	106	Jaipot	278	176	Biswanathpur
227	107	Jireilo	279	177	Gopalpur
228	108	Manikundal	280	184	Durgapur
229	110	Erasama	281	186	Aunri
230	111	Chaudhurikuda	282	187	Birakiswarpur
231	112	Pandiakan	283	188	Kadalibadi
232	113	Kaliakana	284	189	Jasapur

285	190	Machhapada
286	191	Rajapur
287	192	Basudeipur
288	193	Balaramapur
289	194	Lachhmakan
290	195	Balabhadrapur
291	196	Janakdeipur
292	197	Sahada
293	198	Padanpur
294	199	Gateswarpure
295	200	Biswanathpur
296	201	Paikabati
297	202	Kuanrbedi
298	203	Ghosaghar
299	204	Souapat

TIRTOL

300	67	Chaudhurikuda
301	70	Parikudapalanda
302	72	Badapala
303	73	Kaladip
304	79	Paramanandapur
305	81	Madhapurdiapalanda
306	82	Sanabalikani
307	83	Zilladiapalanda
308	84	Jayasankhapur
309	85	Jillanasi
310	89	Tentulikhamara
311	90	Saharadia
312	91	Naladiapalanda
313	92	Bhandua
314	95	Balarampur
315	99	Daudia
316	100	Hasina
317	104	Nalidiapalanda
318	105	Bahartari
319	106	Bahartaridia
320	107	Bhutamundi
321	108	Jagati
322	111	Nunakua
323	112	Kothi
324	113	Narendrapur
325	114	Pitambarpur
326	115	Katakula
327	116	Kathada
328	117	Koldia
329	118	Pipala
330	119	Telengadia
331	120	Thanaharadia
332	121	Singitali
333	122	Chakradharapur
334	123	Balidia
335	124	Paradipgada
336	125	Nuagada
337	126	Aganasi
338	127	Udayabata
339	128	Bijaychandrapur
340	129	Musadia
341	139	Kuabadi
342	140	Chaukimatha
343	141	Rangiagada
344	142	Niharuni
345	143	Nimidhi
346	144	Niharunikandha
347	145	Siju
348	146	Bagadia
349	147	Khasulidia
350	148	Pratapapur
351	149	Fatepur
352	150	Jhimani
353	151	Mangarajapur
354	152	Pangara
355	153	Gandakipur
356	154	Kharigotha
357	155	Mirigidiakandha
358	156	Barunakandha
359	157	Gopiakuda
360	158	Ghodamara
361	159	Panapali
362	160	Malipura
363	161	Jamukana
364	162	Mahakaladia
365	163	Baulanga
366	164	Badabandha
367	165	Sahada
368	166	Patapur
369	167	Balia
370	169	Bagoi
371	170	Brakhia
372	171	Karatutha
373	172	Tentulia
374	178	Potanai
375	180	Bhainarkula
376	181	Okala
377	188	Kothamul
378	190	Bharala
379	201	Banita
380	347	Katikena
381	348	Pandua

382	349	Dhusala
383	350	Adhankur
384	351	Sirola
385	352	Lathang
386	353	Chandapat
387	354	Bailo
388	355	Patila
389	356	Napang
390	357	Mithila
391	358	Parudi
392	359	Naiguan