CHAPTER 4

REMOTE SENSING ANALYSIS OF ONGUR MINOR RIVER BASIN

4.1 GENERAL

Generally, the movement of groundwater tends to conform to topography so that its general lateral movement takes place from a topographically high to a lower region (Sophocleus, 1992). Consequently, throughout the basin, the movement is influenced by drainage characteristics which, in turn, are controlled by geological structure and geomorphic features of the region (Adyalkar, 1976). In this context, the usefulness of remote sensing data to analyse geologic and geomorphic controls on a basin is vital since it provides information on the regional setting due to the synoptic view and repetitive coverage (Jensen, 1986).

Fracture related groundwater resource evaluation using Landsat TM and SPOT by Knapp *et al.* (1994) and the study on geohydrological features from satellite imagery by Alessandro *et al.* (1994) emphasize the importance of satellite data analysis in groundwater investigation. Bobba *et al.*, (1992) analysed temporal satellite data to understand the seasonal variations in groundwater level inferred from vegetation cover and land use practice of the region. The use of IRS-1A remotely sensed data to delineate geomorphological units to identify potential groundwater resources of a terrain is amply discussed by Ravi Prakash and Mishra (1993).

In the present study, remote sensing satellite data has been used to generate various thematic maps like geology, hydrogeomorphology, soil and land use to study the groundwater condition of the terrain. These pieces of spatial information are further used in GIS analysis (Krishnamurthy *et al.*, 1996) in conjunction with spatially generated water level and water quality parameters of the study area. These thematic maps are prepared by using both remote sensing data and field data. The details of data used and the methods of preparing thematic maps are discussed in the following sections.

4.2 SATELLITE DATA

In the present study, Indian Remote sensing Satellite (IRS – 1A) data was used to generate thematic maps like geology, hydrogeomorphology, soil, and land use. IRS-1A LISS II (Linear Imaging Self-scanning Sensor II) FCC (False Colour Composite) satellite data was studied to understand the regional setting of the Ongur minor river basin. The spatial resolution of LISS II is 36.25 m and its spectral band width extends from visible to near-infra red region of the electromagnetic spectrum. The details of sensor characters of LISS II and comparison of the same with Landsat TM, MSS and SPOT- MLA were discussed in the previous chapter (refer 3.3.1). The satellite data, used in this study, was rectified by National Remote Sensing Agency (NRSA) and brought to a standard scale of 1:50,000. The spectral characteristics of IRS-1A and their principal application are listed in the following table.

Table 4.1 Spectral characteristics of IRS – 1 A and their applications

S. No	Wavelength (in microns)	Applications
1	0.45 – 0.52	Coastal Environment Studies (coastal morphology and sedimentation studies) Soil/vegetation differentiation; coniferous/deciduous flora discrimination
2	0.52 – 0.59	Vegetation vigor assessment rock/soil boundary discrimination ; turbidity and bathymetry in shallow water
3	0.62 – 0.68	Strong chlorophyll absorption leading to discrimination of vegetation types and sub-types, mapping of cultural features
4	0.77 – 0.86	Delineation of surface water features, landform/geology, mapping of settlement and transport network.

For the analysis, the image characteristics like tone, texture, shape, size and association pattern are used to interpret various features and discrimination among them to generate the required thematic maps (Lilliesand and Kiefer, 1987). The basis for such analysis and classification systems for geomorphology, soil and land use are discussed in the following sections.

4.3 DATA ANALYSIS

Satellite data analysis is carried out to prepare various thematic maps like geology, hydrogeomorphology, soil and land use. An interpretation key to infer image characteristics and delineate thematic units was prepared for each map. The discussion involves significance of various thematic maps prepared for the study area using satellite data.

Two principal techniques are employed for analyzing satellite data *viz.*, digital image processing and visual Interpretation. Digital processing employs digital numbers (DN) of a pixel to enhance and classify features. Enhancement techniques and classification procedures are adopted for this purpose to generate meaningful information.

The present study is based upon the thematic maps derived from visual interpretation employing key elements like color, tone, texture, shape, size and the associated pattern. Based on this principle, thematic maps like hydrogeomorphology, geology, soil and land use of the study area were prepared. Using interpretation key elements and local field knowledge, a pre-field interpretation map was prepared. A field check was carried out to verify the thematic units and a final map was prepared after introducing proper corrections. The flow chart showing steps for data selection, preparation of pre-field thematic maps, field investigation and compilation of post-field final maps is illustrated in Fig. 4.1

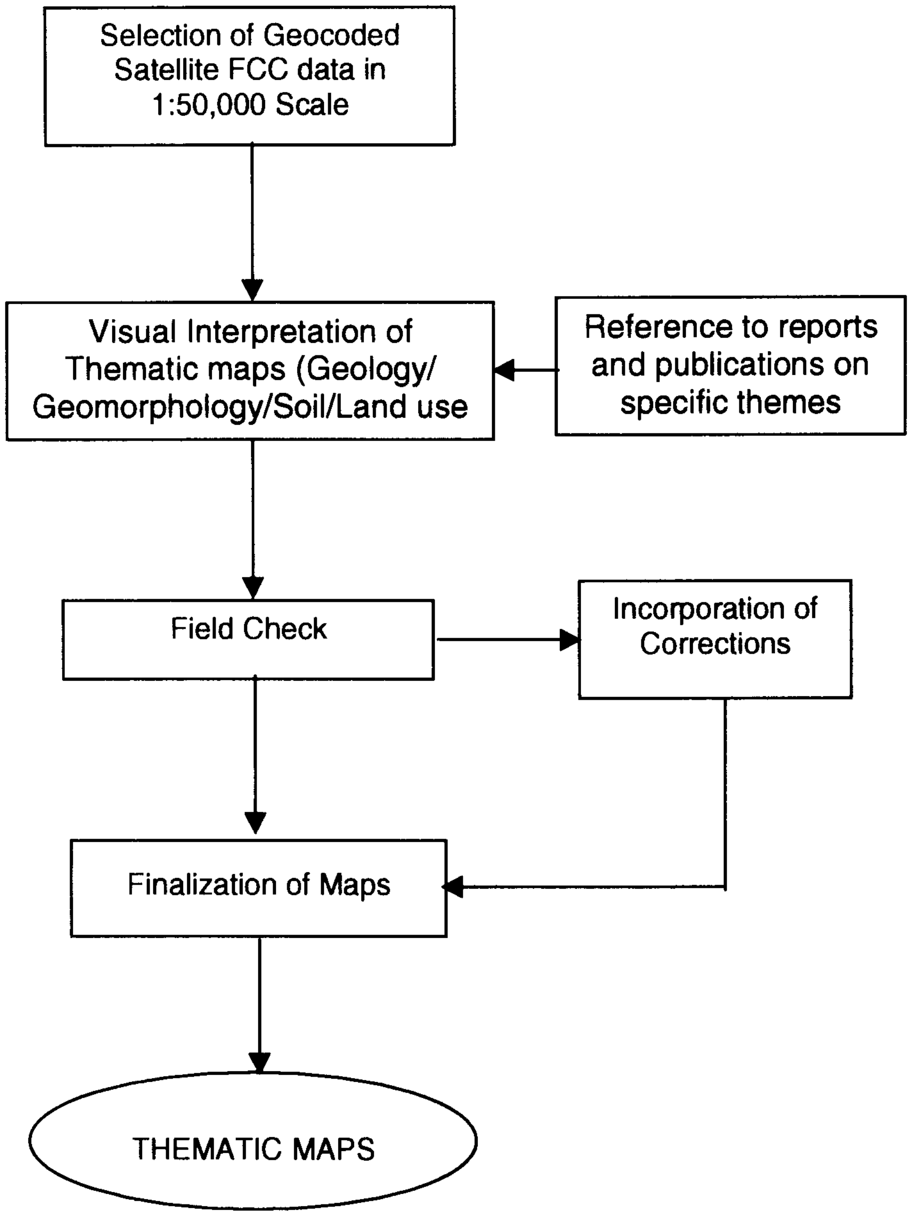

Fig.4.1 Flow chart showing procedures to prepare thematic maps

4.4 GENERATION OF THEMATIC MAPS

Based on the above procedures, various thematic maps such as geology, geomorphology, soil and land use for the study area were prepared and the details are discussed in the following section.

4.4.1 Geology

As already stated in section 4.1, the geological condition of a terrain plays a major role in groundwater occurrence and movement. In the present study, the lithological units of the study area were delineated from the remotely sensed data (False Colour Composite of IRS – 1A, LISS II) and the methodology adopted for preparation of geology map is as follows.

A base map was prepared from the Survey of India (SOI) topographical map on 1:50,000 scale. This was used as the base reference to fix control points common to both the base map and satellite data. The ground control points, mostly linear features like transport network *viz.*, roads, railway lines, drainage networks, tanks etc., were identified from the SOI topographical map. This enabled to exactly transfer the geological details of the terrain from the satellite imagery. The prepared geological map was compared with the geological map from the Department of Geology and Mines (DGM), field checked and necessary corrections were incorporated.

The geology of the terrain could be broadly demarcated into two categories, *viz.*, hard rock terrain and coastal sedimentary terrain (Fig. 4.2). The major part of the study area comes under hard rock terrain. The coastal sedimentary units are observed along the coast evolving with numerous micro-relief landforms.

The study area is comprised of Recent formations along the coastal tract. Cuddalore sandstone of Tertiary formation, shale and clayey sandstone are overlain by Archaean crystallines, hornblende-mica schist and charnockitic complex as basement in the western part of the catchment area.

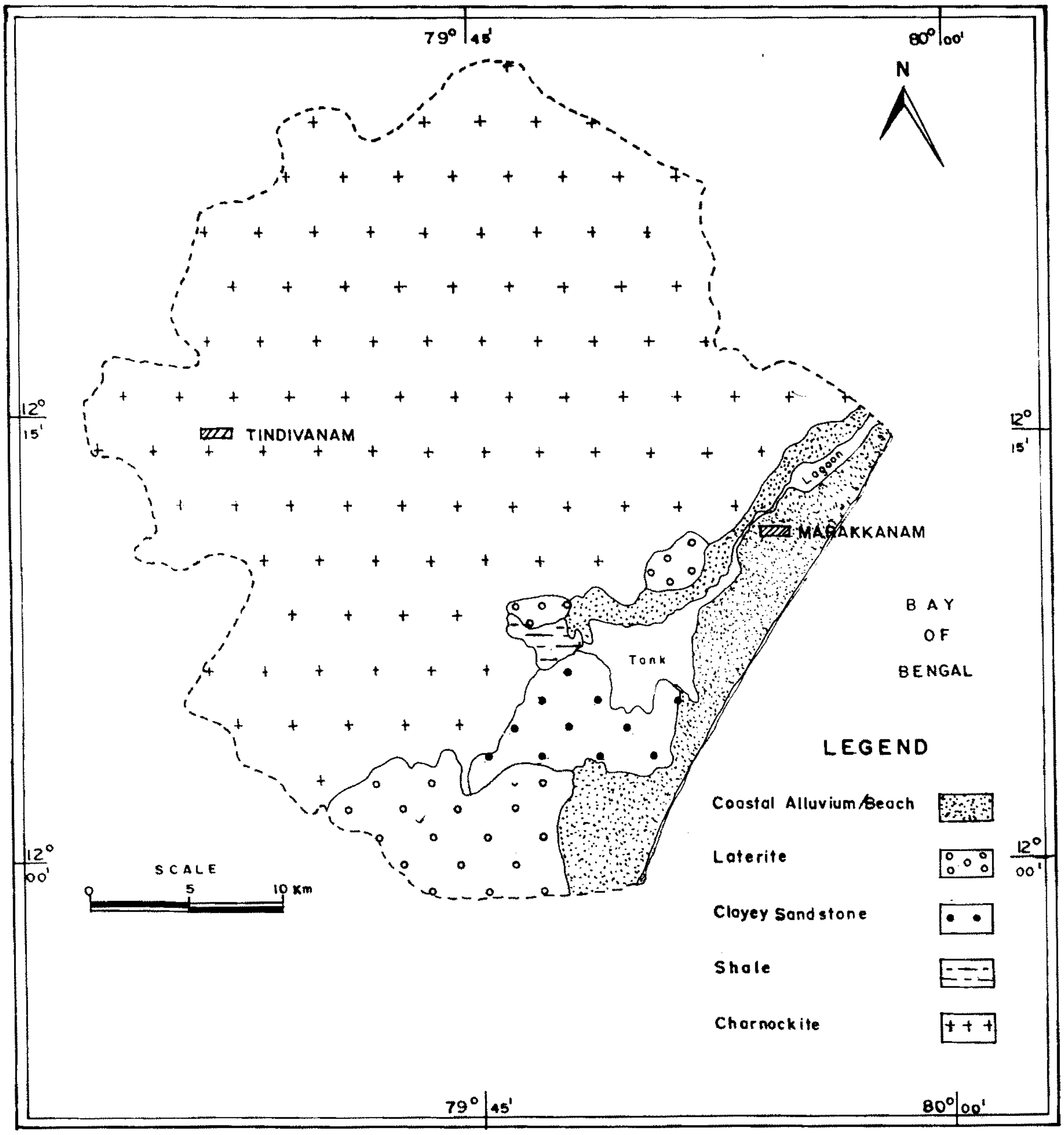

Fig. 4.2 Map showing lithological units of the study area

The geological succession of the study area may be given as

Quaternary	Recent alluvium, sandy areas
Tertiary	Cuddalore sandstone, clayey sands, shale
Archaean	Hornblende gneissic complex, mica schist charnockite

The tonal and textural variations inferred from the satellite imagery were used to demarcate all the lithological features of the study area. The succession was clearly inferred and demarcated from the satellite imagery with the aid of already existing surveyed field maps. The recent alluvium was identified along the coastal tract as stabilized dunes and sandy formations with typical plantation, *casuarina spp.* The Tertiary formation, (Cuddalore sandstone) was identified from its isolated patches, with typical yellow color and coarse texture in the satellite imagery. The lateritic capping of the sandstone was seen with sparse vegetation. Shale formation was identified by its typical grey tone in the imagery along the Kalveli tank. Clayey sandstone is seen as a mixture of shale and sandstone formation. The crystalline hard rocks of the Archaean group were observed in the major part of the area with the presence of hornblende schistose-gneissic complex and charnockite as basement. The geological map showing various lithological units was later used in GIS raster analysis for delineation of groundwater potential zones and groundwater environment studies (see chapter 5).

4.4.2 Hydrogeomorphology

Geomorphological analysis from the satellite data indicates two major landforms *viz.*, erosional and depositional. The erosional landforms are observed in the western part in the crystalline formations of the study area. The depositional landforms are observed along the coastal tract of the basin. Various landforms inferred and demarcated from the observed satellite imagery (Fig. 4.3) are as follows:

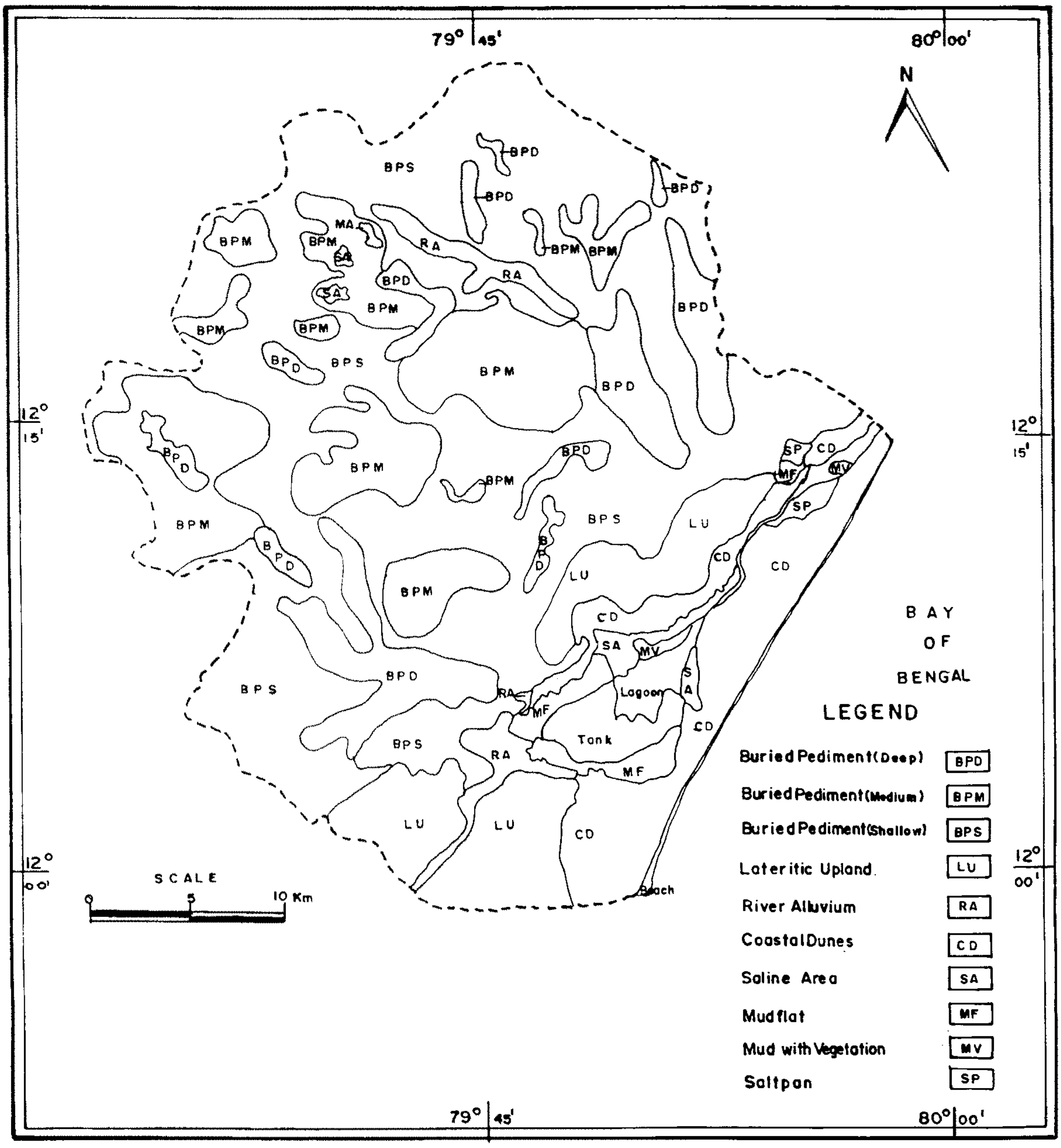

Fig. 4.3 Map showing landform units of the study area

In the coastal part, the beach is interpreted along the coastline by its narrow and linear shape. Along the beach, Quaternary sand dune deposits are inferred. They are clearly delineated by their linear, narrow and elongate nature along the shoreline. Mostly, dune landforms of this region are associated with the typical plantation varieties, *casuarina spp.* Two narrow stretches of such dune landforms are observed in this area. The successive formation of dune deposits may be inferred from the presence of a lagoonal water body (Yedayanthittu) and a paleo-lagoon that has been cut off from direct contact with the sea, Kalveli tank. Interestingly, a contact is observed even now between Kalveli tank and Yedayanthittu, by the presence of the Buckingham Canal. Moreover, on the southern part of Kalveli tank, a narrow, low lying area is observed, which might have been a part of swale system, forming the shoreline configuration (Radhakrishnan *et al.*, 1994). The tank itself is occupied by marshy vegetation, mudflats and salt affected areas along their fringes, indicating a tidal influence during the monsoon period (Radhakrishnan and Elango, 1996). This is connected to a lagoon in the north, corroborating marine transgression activities during the late Cretaceous (Krishnan, 1980). The lateritic uplands to the west and south of Kalveli tank are of Cretaceous period, observed by the presence of *casuarina spp.* plantations. They were inferred from the satellite imagery by their medium to coarse texture and yellowish tone. Moreover, presence of scrubs and sparse plantations indicate the lateritic upland. A large patch of river alluvium, observed in the north and northwestern part of the basin, may be a relict alluvial deposit.

The crystalline rocks of Archaean group indicate an erosional behavior with a vast stretch of buried pediments, which may again be classified as deep, medium and shallow, depending upon the thickness of weathered materials (see also chapter 3). Few inselbergs are also seen in this area, strongly pointing to subaerial erosion. The buried pediments (deep) may be defined as erosional landforms with loose weathered material up to 20 m thickness; those with 5-10 m thickness as medium. Buried pediments (shallow), seen in this area, may be defined as erosional surfaces with a veneer of 2-5 m of weathered material. Few patches of salt affected areas, seen in the upper part of the basin, may be erosional surfaces due to wash-off or excessive pumping leading to higher concentration of kankar.

The geomorphic nomenclature, which is widely used throughout the country, is adopted from the National Remote Sensing Agency's (NRSA) classification system. These landform units, demarcated from satellite imagery, are used to understand their significance in identifying groundwater potential zones using GIS techniques. Moreover, they are also studied to comprehend their role in controlling the groundwater environment of the study area by adopting GIS raster techniques. The landform units, their definition and image characters are listed in Table 4.2.

Table 4.2 Landform units, their definition and image characters

S. No	Landform Unit	Character	Image Interpretation
1.	Beach	Comprises wind blown sand	White color with smooth tone showing linear feature
2.	Coastal Dunes (CD)	Comprise wind blown sand and silt	Elongated linear to curvi-linear feature with smooth to coarse texture and white to red color depending on the presence or absence of vegetation.
3.	Buried Pediment (Deep) (BPD)	With very thick overburden of weathered material of varying lithology (more than 20 m)	Dark red in tone and smooth texture with excellent vegetation cover.
4.	Buried Pediment (Medium) (BPM)	With moderately thick overburden of weathered material of varying lithology (5 - 20 m)	Dark red in tone and medium texture with vegetation cover.

Table 4.2 (Continued)

S. No.	Landform Unit	Character	Image Interpretation
5.	Buried Pediment (Shallow) (BPS)	With thin overburden of weathered material of varying lithology (0 - 5 m)	Dark red in tone and coarse texture with sparse vegetation cover.
6.	Lateritic Upland (LU)	Moderately elevated land with lateritic capping with extensive dissections marked by gullies.	Yellowish red tone and medium to coarse texture with or without vegetation cover.
7.	River Alluvium (RA)	Predominantly of gravel, sand, silt and clay of varying lithology.	White tone and fine texture with excellent vegetation cover.
8.	Marsh Vegetation (MV)	Muddy area of silt and clay along the shore covered with salt tolerant vegetation.	Brownish red tone and medium to coarse texture with sparse vegetation.
9.	Mudflat (MF)	Muddy flat area of silt and clay along the shore inundated by tide and devoid of vegetation.	Brown tone with smooth texture around lagoon without vegetation.
10.	Lagoon	Narrow and elongated backwaters having connection to sea.	Blue tone, elongated and connected to sea.
11.	Salt Affected Area (SA)	Area around lagoon and mudflat	White to light blue tone with fine texture near the lagoon and marshy area.
12.	Inselberg (I)	Isolated low relief formed due to differential erosion so that more resistant formation stands as residue like small hills.	Dark tone with medium fine texture. Circular shape in isolated patches.

The accuracy of interpreting landforms from the satellite data using the above key was checked by undertaking field trips. The final map was prepared after field verification of landform units and comparison with existing maps and literature. These landforms in the later stage were given weightage and analysed for groundwater prospective zones and environment using GIS techniques. This is discussed in chapter 5.

Having prepared the geomorphological map, a similar method was adopted for preparation of soil map. The next section discusses the soil types of the study area, and their physical characters in general. In this study, the soils are classified up to family level taking few of the parameters to determine their importance in studying groundwater environment while carrying out GIS analysis.

4.4.3 Soils

Soils have a significant role in analysing the groundwater potential of a region. Realizing this significance, soils of Ongur minor river basin have been given due consideration and included for analysis in this study.

The soil units were demarcated (Fig. 4.4) mainly based upon the existing reference maps and literature. The nomenclature of various soil types was adopted from USDA soil classification system (Reeves, 1985). The coastal plains of the study area were seen comprised of loamy sands, *typic Ustipsamments*, highly drained in nature. The water holding capacity of the soil is very low and the soil is not suitable for sustained irrigation. Plantation of *casuarina spp.* is practiced in this soil. *Vertic Ustropepts* were seen near Yedayanthittu lagoon and along the fringes of Kalveli tank. Another type of soil, *typic chromusters,* of montmorollinite clay soil, moderately suitable for irrigation after prolonged conservation measures, was observed in the northwestern part of the Kalveli tank. Calcareous soil was seen in the northwestern part of the catchment but a major part of the basin has well drained sandy loam with a higher gravel percentage. Generally, the soils show an erosional behavior with calcareousness, except along the coastal part,

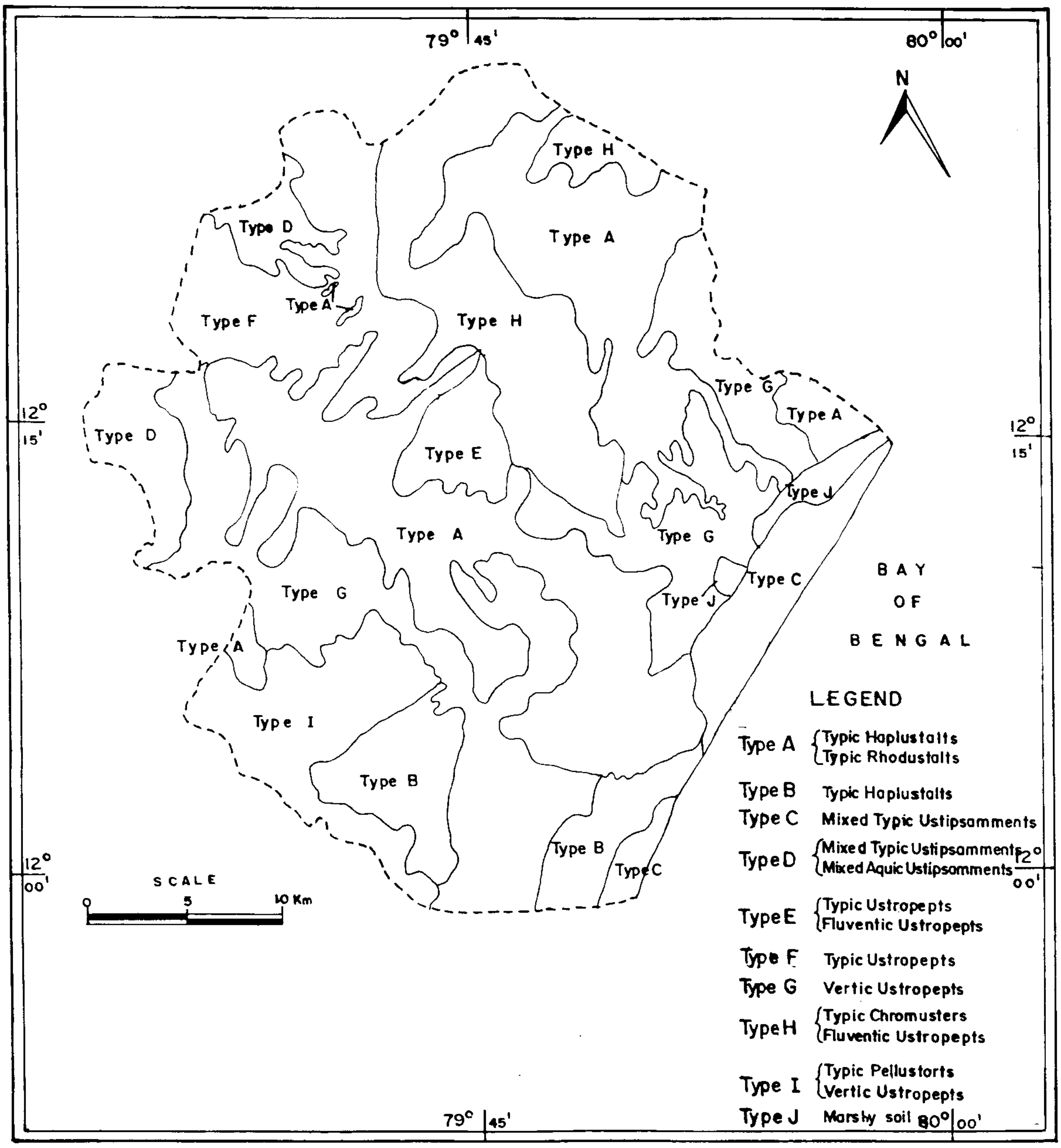

Fig. 4.4 Map showing soil units of the study area

where the soil is loamy sand with limited landuse capability. The major soil groups of the study area and descriptions of their characters are shown in Table 4.3.

Table 4.3 Soil types and their characters

Type No.	Description of Major Soils	Classification	Soil Characters
Type A	Deep, well drained, gravely clay soils on gently sloping lands; moderately eroded; associated with deep, well drained, gravely clay soils on undulating lands with severe erosion.	1 Clayey skeletal mixed Typic Haplustalfs 2. Clayey skeletal mixed Typic Rhodustalfs	Fine loamy, mixed Typic Haplustalfs
Type B	Moderately shallow, well drained, loamy soils on gently sloping lands. Moderately eroded ; associated with deep, well drained, clayey soils	1. Fine loamy mixed Typic Haplustalfs 2 Fine mixed Typic Haplustalfs	
Type C	Very deep, somewhat excessively drained, sandy soils on very gently sloping plains; slightly eroded	1 Mixed Typic Ustipsamments	
Type D	Very deep, imperfectly drained, sandy soils on nearly level lands. Moderately eroded; associated with very deep, excessively drained sandy soils.	1.Mixed,Aquic Ustipsamments 2.Mixed Typic ustipsamments	
Type E	Very deep, well drained loamy soils of nearly level valleys, slightly eroded; Associated with deep, moderately well drained, loamy soils with moderate erosion.	1. Fine , loamy mixed Typic Ustropepts 2. Fine loamy mixed Fluventic Ustropepts	Sandy over loamy mixed Typic Ustifluents.

Table 4.3 (Continued)

Type No.	Description of Major Soils	Classification	Soil Characters
Type F	Deep, imperfectly drained, calcareous, clayey soils on nearly level low lands and slightly eroded.	1. Fine mixed, Typic Ustropepts	Fine loamy, mixed, Typic Ustropepts
Type G	Very deep, moderately well drained, calcareous, cracking clay soils on nearly level low lands, slightly eroded; Associated with very deep, moderately well drained, calcareous clay soils.	1.Fine, montmorillonitic, Vertic Ustropepts 2.Fine,mixed Typic Ustropepts	Fine montmorollinitic Typic Chromusters
Type H	Very deep, imperfectly drained, cracking clay soils of nearly level valleys, moderately eroded; Associated with very deep, moderately well drained, calcareous loamy soils.	1. Fine, montmorillonitic Typic Chromusters 2. Fine loamy, mixed Fluventic Ustropepts	
Type I	Moderately deep, moderately well drained, calcareous cracking clay soils on gently sloping low lands, slightly eroded; Associated with moderately shallow, moderately well drained, calcareous clay soils	1. Very Fine, montmorillonitic Typic Pellusterts 2. Fine montmorillonitic Vertic Ustropepts	
Type J	Miscellaneous lands	Marshy lands	

The soil types mentioned above are characterised by their specific physical parameters such as land capability, land irrigability, depth, texture, erosion, water holding capacity, graveliness and calcareousness. The parameters have been considered while giving weightage in GIS analysis (Chapter 5). Table 4.4 lists the characteristics of the soil types found in the study area - Ongur minor river basin.

Table 4.4 Soil characteristics of the study area

Symbol	Land Capability	Land Irrigability	Depth	Texture	Drainage	Erosion	Water holding	Graveliness	Calcareousness
181	III s	3s	4 – 5	SL	4	1	2 - 3	2 - 0	0
184	III e	3s	3 – 5	SL	5	2	3	0	0
193	Iv es	4s	6	LS	6	1	1	0	0
199	IV es	6s	6	LS	3 - 5	2	1	0	0
213	II sw	2s	6.5	SL – SCl	5 - 4	1 - 2	4	0	0
220	II w	2d	5	CL – C	3 - 4	1	4	0	3
259	II s	2s	6	C – CL	4	1	4	0	2
267	III e	3d	6	CL	3 - 4	2	5	0	0 - 2
275	II es	3d	4 – 3	C	4	1	5	0	1
277	VII sw	6s	M	M	M	M	M	M	M
281	VII sw	6s	M	M	M	M	M	M	M

The descriptions of each class units in the above table are given hereunder.

Calcareousness:

0 Non-calcareous
1 Slightly calcareous
2 Moderately calcareous
3 Strongly calcareous
M Miscellaneous land

Graveliness:

0 Less than 15%
2 range from 30 to 85%
M Miscellaneous land

Drainage class

3 Imperfectly drained
4 Moderately well drained
5 Well drained
6 Somewhat excessively drained

Soil depth

3 50 to 75 cm
4 75 to 100 cm
5 100 to 150 cm
6 > 150 cm

M Miscellaneous land

Erosion class

1 None to slight
2 Moderate
3 Excessive

Soil texture

SL Sandy loam
LS Loamy sand
SCL Sandy clayey loam
CL Clayey loam
C Clay

Water holding capacity

1 Very low < 50 mm
2 Low 50 – 100 mm
3 Medium 100 – 150 mm
4 High 150 – 200 mm
5 Very high >200 mm
M Miscellaneous land

Note: Millimetres of water for every 100 cm of soil or the entire column if shallower

Land irrigability class

2s Lands that have moderate limitation of soil for sustained use under cultivation

2d Lands that have moderate limitation of drainage for sustained use under cultivation

3s Lands that have severe limitation of soil for sustained use under cultivation

3d Lands that have severe limitation of drainage for sustained use under cultivation

4s Lands that have very severe limitation of soil for sustained use under cultivation

6s Lands not suitable for sustained use under cultivation

Land capability class

II s	Good cultivable land having soil problem
II w	Good cultivable land having drainage problem
II sw	Good cultivable land having soil and drainage problem
II es	Good cultivable land having erosion and soil problem
III s	Moderately good cultivable land having soil problem
III e	Moderately good cultivable land having erosion problem
IV es	Fairly good cultivable land having erosion and soil problem
VII sw	Lands fairly suited only for grazing and having soil and drainage problem

The table showing soil types and description of their physical parameters in relation to land use helps to understand the role of landforms and soil on the land use practice of the study area.

4.4.4 Land use

The land use of the study area primarily depends upon the groundwater resources, apart from soil condition. So, it is important to understand the land use pattern of the study area, Ongur minor river basin, (Fig. 4.5) to establish such a relation between land use units and groundwater condition.

The major land use pattern of the area is identified under agriculture with crop land and fallow land as subclasses. The agricultural activities of the area depend upon the tank irrigation system and dugwells. The socio economic condition of the basin thrives upon the surface water storage like ponds and tanks for irrigation, which is available during monsoon. The post-monsoon period witnesses a spell of drought and the cultivation depends upon borewell irrigation. The land supported by tube wells shows sustained irrigation activity throughout the season. The coastal area is observed to have *casuarina spp.* plantation and scrubs. The Yedayanthittu lagoon, a fishing ground, supports the socio-economic condition of the surrounding area. The Kalveli tank, which is often inundated by seawater during monsoon, supports

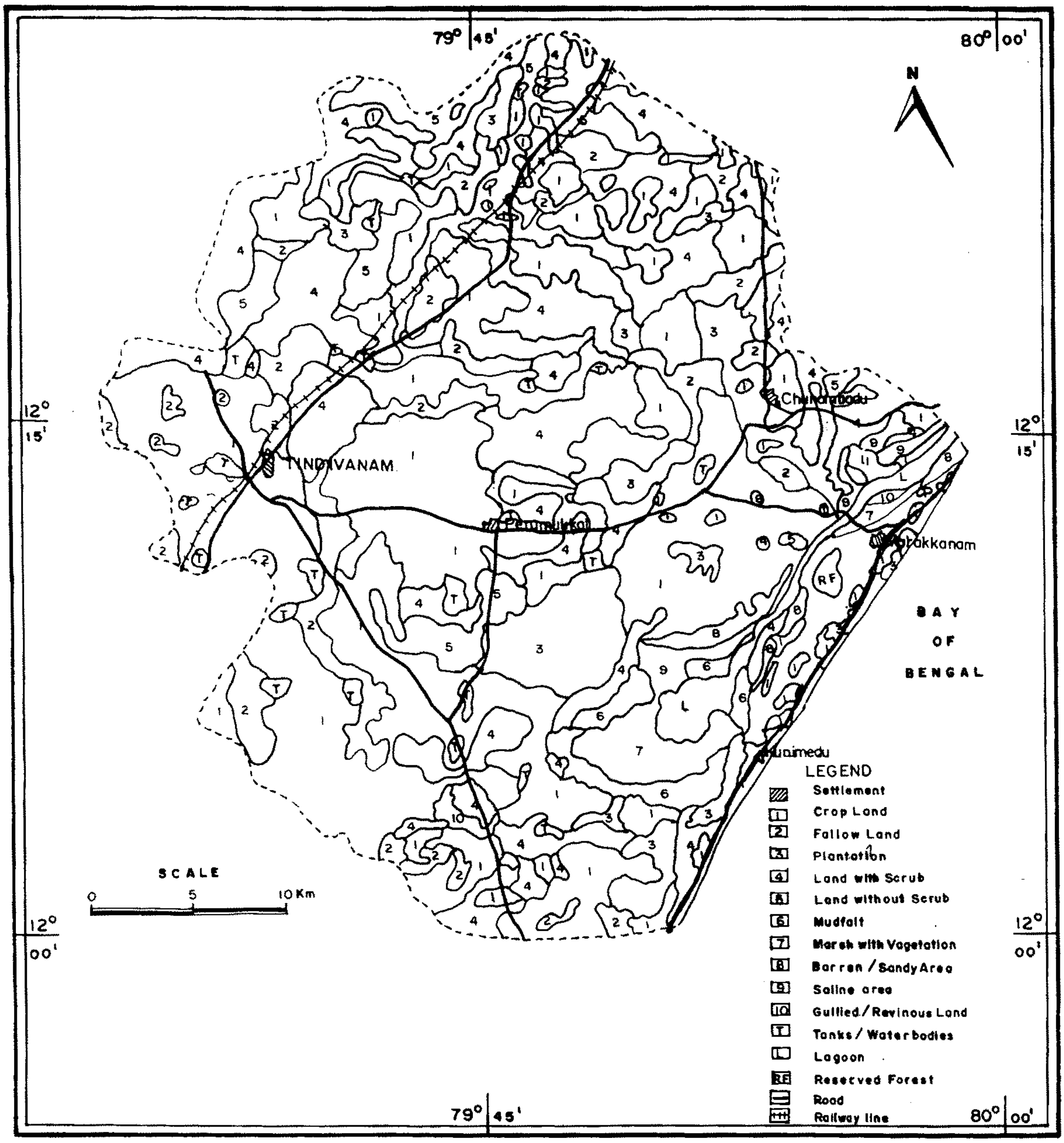

Fig. 4.5 Map showing land use units of the study area

the local agricultural practices during post-monsoon period after adopting conservation measures.

The land use of the study area shows two distinct types governed by the landforms *viz.*, *inland* land use, in general, and *coastal* land use. The land use practice in the coastal part is mainly plantation, especially *casuarina* species in the coastal dune landform, and intense agriculture in the remaining part of the study area. This is clearly evident from the satellite data while preparing the land use map. In the inland hard rock terrain, landforms of buried pediment (deep) show intense agriculture activities because of the availability of groundwater and soil irrigability. The buried pediment (deep) has weathered overburden of 25 to 30 m thickness. The soil types are well drained and well sorted allowing maximum recharge in these zones. The buried pediment (medium) has less overburden thickness with less problem-soil having coarse and moderately sorted soil condition. They restrict the irrigability condition of the area. Buried pediment (shallow) shows mostly scrub land with limited land use because of the poor soil condition. It is not well drained or sorted and shows poor irrigability condition.

In contrast to inland, the coastal land use of the area is mainly characterised by plantation varieties. This may be because of well sorted soil condition with shallow depth in the coastal landforms. At the same time, few places near the Kalveli tank show poorly drained soil condition, and are not suitable for intense agriculture. These areas may be used for seasonal cropping only during the post-monsoon period when the water in the Kalveli tank recedes. For example, mud flat in the southern part of Kalveli tank is seen reclaimed with agricultural crops when the tidal influence on the tank recedes. Most of the areas around the Kalveli tank from Yedayanthittu lagoon and Buckingham Canal are marshy and were demarcated in the satellite imagery using their image characteristics (grey to brown tone with medium to coarse texture) as described in Table 4.2. But the presence of *casuarina* plantation inferred in the western part of these regions shows that stabilized coastal dunes are used for plantation type of vegetation. *Casuarina* plantations show a brownish red tone and smooth texture. They are mostly seen in the dune landform along the coast and on either side of the Buckingham Canal and on the banks of Kalveli tank. The marshy areas show scrubs and marsh vegetation (*sueda* spp). The above land use units seen in the study area were interpreted from the satellite imagery based on the classification system adopted by NRSA as listed in Table 4.5.

Table 4.5 Land use / Land cover classification system (NRSA)

Level I	Level II	Level III
1. Built – up land	Town/ City Village	---
2. Agricultural Land	Crop Land Fallow Land Plantations	Single Crop (Kharif / Rabi) & Double Crop
3.Forest	Evergreen/ Semi Evergreen Deciduous (Moist & Dry) Scrub Forest Forest Blanks Forest Plantations Mangrove	i. Dense & ii. Open i. Dense & ii. Open
4. Wastelands	Salt Affected Land Water Logged Land Marshy / Swampy Land Gullied / Ravinous Land Land with Scrub Land Without Scrub Sandy Area Mining / Industrial wasteland Barren Rocky/ Stony Waste	
5. Water Bodies	River/Stream Canals Lake / Reservoir / Tanks	
6. Others	Grass / Grazing Land Salt Pans	

The description of various land use units inferred from the satellite data using the above classification system is as follows.

Crop lands are inferred from the satellite data by their red tone and medium to coarse texture. They are mostly observed in the northwest, west and southern parts of the study area. They are distinct from other land use units (for example scrubs) showing similar tone due to their field pattern.

Fallow lands are inferred by the absence of vegetation in the first place. They show a greyish tone and fine to medium texture. They differ from similar wasteland units such as land without scrub, by their field pattern. Moreover they are mainly seen to be surrounded by agricultural lands.

Plantations are mostly inferred along the coast except for a few places inland. They show a distinct brownish red color and fine to medium texture. They are very easily identified in the coastal area by their association with coastal dune landforms and, in few places, near the lateritic uplands.

Land with scrub is a type of wasteland mostly observed in the north, northwest and southeastern parts of the study area. It is identified by its dark red color, medium to coarse texture and as isolated patches spread over a large area. It is also observed near lateritic uplands in the south and southeastern parts of the study area.

Land without scrub is another type of wasteland inferred by its distinct light grey to white color and medium to coarse texture. It is devoid of vegetation and is observed in isolated patches around the scrub land. The barren stony area is identified by its light brown colour with sparse or no vegetation. It is encountered mostly in the north and northwestern parts of the study area.

Marshy lands are observed along the Yedayanthittu lagoon, Buckingham Canal, and in and around Kalveli tank. They are easily inferred and delineated by dark brownish red color and smooth texture. They may or may not have vegetation. The halophytes (*prosophis spp.*) observed in some places of this unit show a bright red color and smooth texture.

Salt affected lands are mostly observed in the coastal part. Their bright white tone and medium texture identifies them easily. They are observed near the lagoon and along the Buckingham Canal. Areas around Kalveli tank are also seen with salt affected lands and, especially in the western part, a larger patch is observed.

Salt pans are observed in a small patch near the lagoon and are inferred by their geometric pattern and association with the lagoon. They show white to light blue colour depending upon their harvesting stage.

Three major **Water bodies** are identified in the coastal part namely Yedayanthittu lagoon, Buckingham Canal and Kalveli tank. Many small ponds and tanks are also identified in the study area by their shape and blue to dark blue color.

To verify the accuracy of the land use map prepared from IRS-1A LISS II FCC, an intense field visit was undertaken. The necessary corrections in the land use units were incorporated after carrying out field investigation and final map was prepared.

4.5 OTHER THEMATIC MAPS

Apart from the thematic maps prepared from satellite data, drainage map and contour maps are prepared from SOI topographical maps. A drainage density map was also prepared from the drainage map and the details are discussed below.

4.5.1 Drainage pattern and Contour of the study area

The drainage map (Fig. 4.6) of the study area, showing all the 1st and higher order streams, was prepared from the SOI topographic map on1: 50,000 scale to prepare a drainage density map (Fig. 4.7) to be used later for identifying groundwater potential zones using GIS techniques. The drainage density is calculated by using the ratio of length of streams and area of a micro watershed unit.

Also, a contour map (Fig. 4.8) was prepared from SOI topographical map on 1:50,000 scale. The contour map revealed that most of the area along the coastal tract is almost a flat terrain or with a low elevation. The lateritic upland has a height of 20 m to 40 m. A small patch of residual hill is observed in the southern part of the study area with a height of 60 m. All this information was later taken as input into GIS to generate slope map. Fig. 4.9 showing location of sample points (observation wells) were also prepared from SOI topographical maps on 1:50,000 scale.

4.6 SUMMARY

The study area, Ongur minor river basin, shows a complex terrain with Archaean formation in the western part and Tertiary and Recent alluvium along the coastal tract. This study, using remotely sensed satellite data, has brought out ample information on the hydrogeological and geomorphological setting of the terrain. The extent and influence of tidal effect in the coastal zone is clearly identified from the satellite image by the presence of marshy environment, tidal flats and saline areas and, in turn, by their impact on the land utilization. The remote sensing analysis of various thematic maps like geology, geomorphology soil and land use of the study area suggests an influence of coastal landforms on the land use practice of the area.

The thematic maps prepared from satellite data and other collateral references were further used to study the groundwater potential and groundwater environment of the study area using GIS techniques. Integration of remote sensing and GIS techniques is carried out to demonstrate their utility in understanding the groundwater condition of the study area and their relationship to the land use conditions. These aspects are discussed in the following chapters.

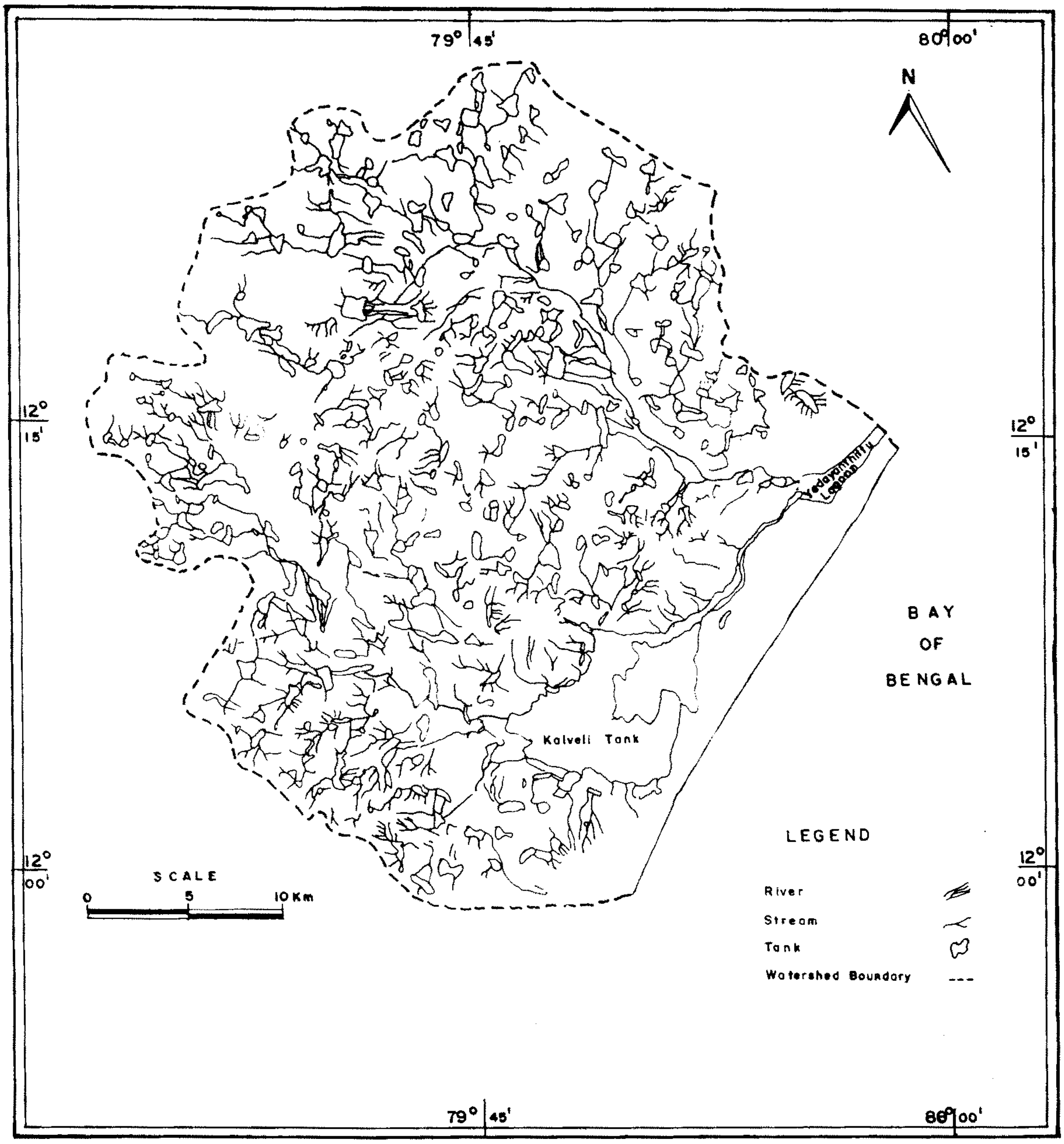

Fig. 4.6 Map showing drainage pattern of the study area

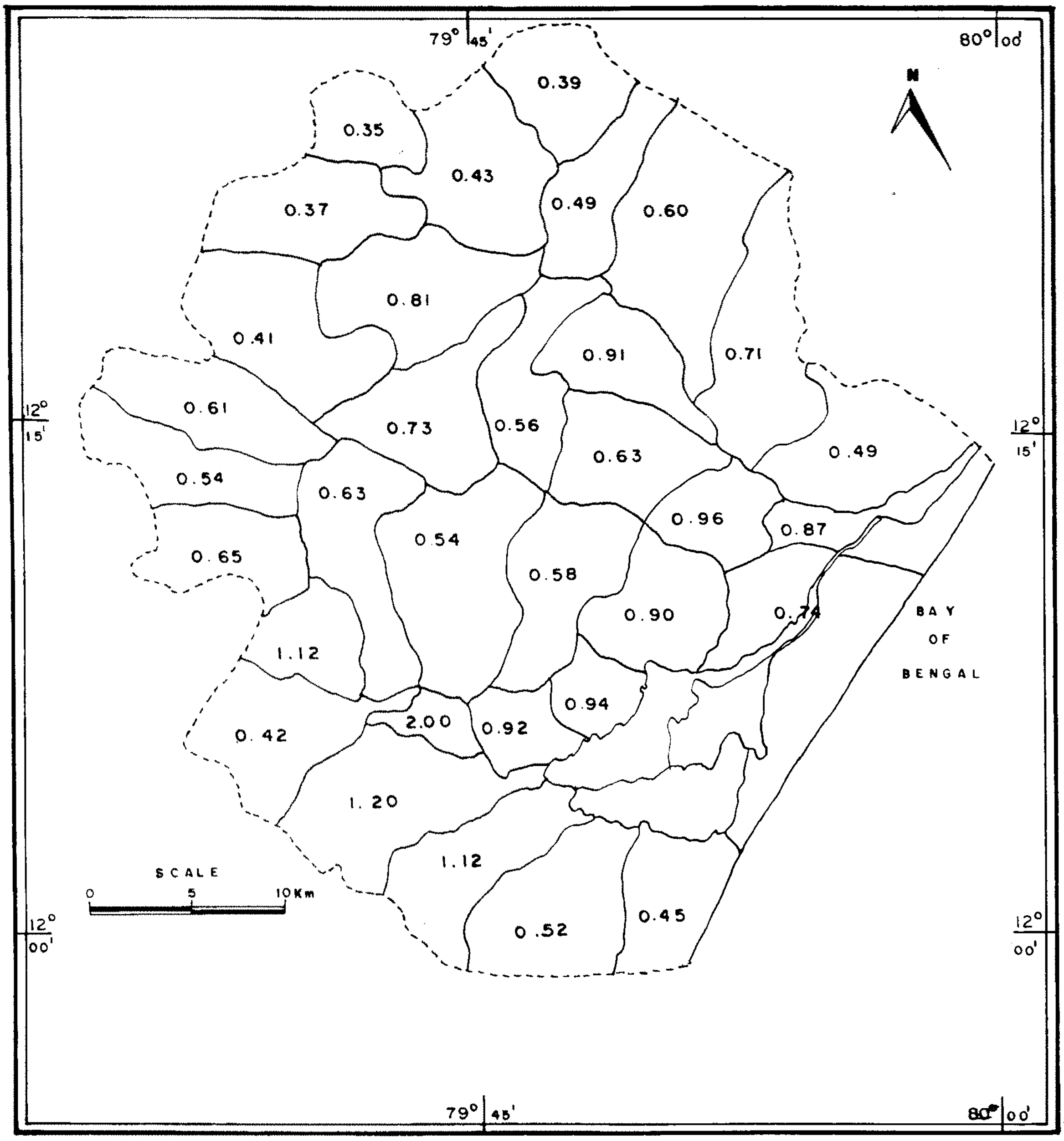

Fig. 4.7 Map showing drainage density of the study area

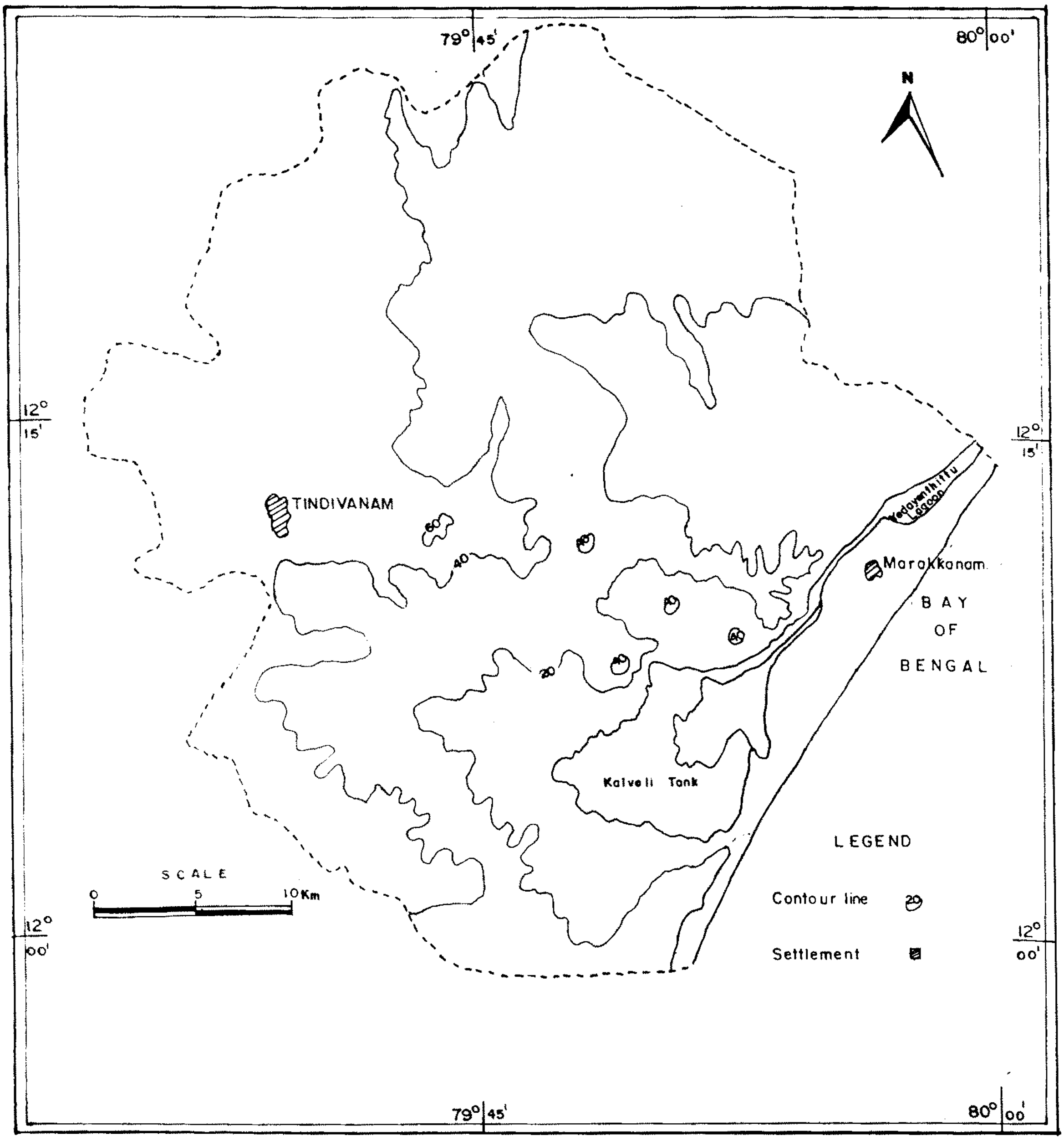

Fig. 4.8 Map showing contour details of the study area

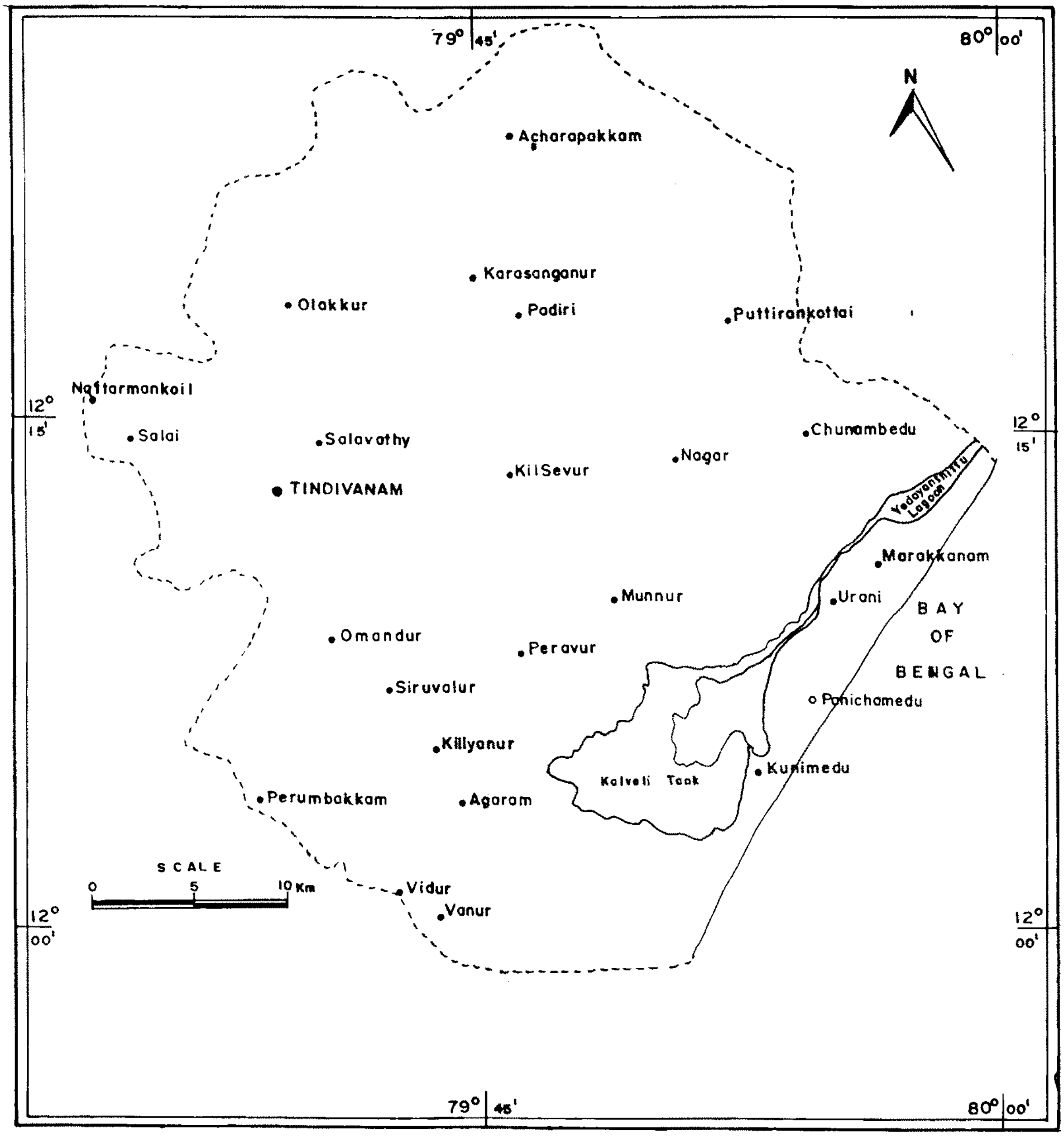

Fig.4.9 Map showing location of observation wells