Chapter V
5.1 OVERVIEW

The digital GIS database is created in order to derive the change detection map showing the variation of land use / land cover, impact on surface water quality/groundwater quality due to the incremental change of land use / land cover along the surface water bodies, impact on groundwater quality, the map showing the spatial distribution of water quality index and air quality index. The GIS database constitutes spatial and attribute data generated by using remote sensing satellite imageries, field data and other collateral information. The steps involved in the creation of these data products are discussed in the earlier chapters. The integrated study is then conducted using this GIS database with the help of GIS data analysis subsystem. In the present study the analysis subsystem of which, the following methods are applied on the database to derive the final maps for subsequent preparation of environmental management plans which are discussed in the next chapter.

EIA and GIS analysis methods used for the present project execution are Overly Analysis, Buffering Techniques, Land Surface Process Modeling, Developmental of Spatial Distribution Maps. In addition to these analysis techniques, the methods used for spatial arrangement of features and their topological modeling are Union, Intersect, Buffer, Aggregation, Sliver,
Transformation, Appending, and 3 D analysis of ARC/INFO GIS software. The spatial and non spatial attributes, and integration is shown in Fig 5.1

5.2 TOPOLOGICAL BUILDING

Topology is defined as the relationship between spatial and attribute data which includes information about how features are connected and interact in real terms. For instance, a road network might be classified functionally from the largest superhighway down to the most isolated rural road or suburban cul-de-sac based upon their role in the overall transportation system. Minor roads and
suburban streets "feed" major highways, but are not directly connected to them. As another example in assessing wildlife habitats, various environmental conditions function together to define the optimal living environments for certain species. Within cities, ownership is a functional classification of great importance as is land use and zoning classification. Logical relationships involve "if-then" and "and-or" conditions that must exist among features stored in the dataset. For example, no land may be permitted to be zoned for residential use if it lies within a river's five-year flood plain. Development may be disallowed in the habitat of some endangered species. Databases are designed and created to represent, model, and store information about these relationships as needed for this investigation.

Integration in a GIS context, is the synthesis of spatial and non-spatial / attribute information within framework of an application. All problems of GIS based integration involves a conjunctive analysis of multi-parameter data. The multi-parameter data include different spatial inputs like maps of land use, slopes, hydrogeomorphology, etc. and other non-spatial data sets. The GIS allows for the integration of these data sets so as to obtain a composite entropy.

5.3 OVERLAY ANALYSIS

Overlay analysis is an important technique in GIS by which new spatial features can be created by superimposing the features from two or more themes. Spatial geometry features like point, line and polygons and its corresponding attributes are also combined to describe the attributes of the derived theme. Based
on the configuration of features overlay operations generally are categorized into three types: (i) Polygon overlay, where the polygons of the two or more themes are merged or combined to create a new theme, (ii) Line-Polygon overlay, in which the line entities can be overlaid on an area feature and the third category is (iii) Point- Polygon overlay, in which the process of deriving the information on polygons of one theme with in which point features of another theme falls.

The overlay analysis is also carried out using two popular techniques of GIS in conjunction with attribute database. They are union and intersection. Union is a fundamental overlay operation which performs the spatial or geometric combination of two spatial data sets to generate a new integrated output. It also performs attribute combination and carries forward the attributes of the two input data sets into the output. All spatial features are combined into the new output theme. The intersect, is also an overlay operation where the geometry and/or spatial combination of two input themes is done on a selective basis based on the commonality of the spatial features. It also carries the attribute values into the output. Slivers are small polygons that are resulted when an overlay operation performed. These have to be removed before a proper analysis is done. Further, these small polygons would become “noise” in the spatial data and have to be merged with the neighboring polygons.
5.3.1 Database for Lu/Lc Change Detection Study

A detailed study is carried out to map the decadal changes of land use/land cover for a period of 30 years from 1970 to 2001 by using overlay analysis techniques. The data derived for this study from various sources like SOI toposheet, Land Sat of American Satellite and IRS LISS III of Indian Satellite data. The digital spatial database in the form of thematic maps for each one of the three years are presented in figures 3.8, 3.9 and 3.10. These databases are then converted to the form compatible to overlay analysis of ARC/INFO GIS software.

5.3.2 Development of Lu/Lc Change Detection Map.

Land use/land cover changes from 1970-1980-2001 are studied by overlay analysis in ARC/INFO GIS platform, using land use/land cover maps of 1970, 1980 and 2001. The flow chart showing the methodology adopted for the change detection map is shown in Fig. 5.2. The change detection maps and the corresponding legends for the years 1970-80, 1980-01 and 1970-01 are presented in Fig. 5.3 a, 5.3 b, and 5.3 c respectively. The areas statistics are given in Table 5.1. Percent changes in land use/land cover to the unit class is given in Table 5.2. The land use/land cover area statistics are shown in figure 5.4 (a,b,c) for the years 1970, 1980, and 2001.
Fig 5.2 Methodology adopted for preparation of change detection map
## Legend for Lu/Lc Change Detection Map - 1970-80

<table>
<thead>
<tr>
<th></th>
<th>Forest</th>
<th>Streams</th>
<th>Barren</th>
<th>Tanks</th>
<th>Crop Land</th>
<th>Fallow Land</th>
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<tr>
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<tr>
<td>Builtup</td>
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</tr>
</tbody>
</table>

- **Forest**
- **Streams**
- **Barren**
- **Tanks**
- **Crop Land**
- **Fallow Land**
- **Builtup**

Legend:
- **Forest**
- **Streams**
- **Barren**
- **Tanks**
- **Crop Land**
- **Fallow Land**
- **Builtup**

**Legend Values:**
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</tr>
<tr>
<td>Fallow land</td>
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<tr>
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<td>199.56</td>
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Legend for Ln/Le Change Detection Map-1970-01
### Table 5.1  Land use / land cover change detection

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<tr>
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<td>50.0625</td>
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<td>Stream</td>
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<tr>
<td>Waste land</td>
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<td>0</td>
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<td>Built-up land</td>
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<td>0.875</td>
</tr>
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<td>Total</td>
<td>3204.38</td>
<td>323.25</td>
</tr>
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</table>

**Land Use Land Cover Change Detection - 1970-01.**
Fig 5.4a Pie chart showing Lu/Lc - 1970

- Forest
- Stream
- Waste land
- Tanks
- Crop land
- Built-up land

Fig 5.4b Pie chart showing Lu/Lc - 1980

- Forest
- Stream
- Waste land
- Tanks
- Crop land
- Fallow
- Built-up land

Fig 5.4c Pie chart showing Lu/Lc - 2001

- Forest
- Stream
- Waste land
- Tanks
- Crop land
- Fallow
- Built-up land
5.3.3 Discussion on Lu / Lc Change Detection Map

During 1970-80 there is a decrease of forest area by 3.05 % while between 1980-01 there is a slight change in the forest area accounting to 0.03 %. It is observed that the forest cover change between 1970 and 01 is 3.09 % decrease. This indicative of the realization of deforestation is to be curbed and laws are being enforced seriously. Infact protective forestation principles are coming in to focus during this period. But the area under streams decreased between 1970-80 is 3.33 %, and between 1980-01 stream area is decreased by 11.40%. And over a period of 30 years i.e., 1970-2001 stream area is decreased by 14.35%. This decrease in stream area is the symptoms of urbanization and industrialization due to increase in population (Table 1.1). Wastelands also decreased by 5.50% in the watershed area during 1970-80, between 1980-01 the change in waste lands is 37.05% and during 1970-01 the change observed is 40.52%. The wastelands have been converted into built up land between 1980-01.

In Nakkavagu watershed area, a good watershed management practices were implemented during 1980-01. Wastelands have been converted into cropland because of well / borewell irrigation practices. Consequently, however, because of the extensive exploitation of groundwater resources, groundwater contamination also increased drastically. In the Nakakvangu watershed area, during 1970 tanks were occupying 5.6 % of the total geographical area. This area is decreased to 5.0 % by 01. There is no change in tank area between 1980-01. When tank area is considered as a whole there is a decrease of 11.44 % of the area between 1970-
5.3.3 Discussion on Lu / Lc Change Detection Map

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01, and it is 11.02% between 1980-01 and a very negligible change of 0.46% is seen between 1970-80. The overall observations reveal that tank area over the years has been converted into cropland, fallow land, and built up lands. Because of the surface water, groundwater pollution and soil contamination and solid waste dumping and loss of soil fertility etc. There is a decrease of 42.20% of the cropland between 1970-01, with a change of 36.17% between 1980-01 and 9.45% between 1970-80.

This Lu/Lc change pattern clearly indicates the impacts of one land use activity on the other. Because of this there is an increase of 6.2% of fallow land between 1980-01. Increase is mainly due to the conversion of 60% of the cropland to fallow land. The change in built up land between 1970-80 is 58.21%, 1980-01 it is 67.5% and between 1970-01 it is 165.08%. Major land uses contributing to the increase in built up land between 1970-01 is wastelands 26.48%, 1.30% tanks, 40% of the crop land, and 3.80% of the fallow land. This critical examination of land use/land cover change detection analysis infers that conversion of one land use to another land use without proper perspective leads to overall environmental deterioration and is a serious factor in sustainable development.
5.3.4 Generation of Groundwater Prospect Map by Overlay Analysis

The groundwater prospects map has been prepared for the Nakkavagu watershed as per the methodology adopted by Rajiv Gandhi Drinking Water Mission, National Remote Sensing Agency. The inference used for preparation of groundwater prospects map is given in Table 5.2. Thematic layers like hydrogeomorphology, geology, structural and lithology and soil maps generated during spatial database creation are used in preparation of groundwater prospects map. The groundwater potential yield ranges are between good, moderate, low and poor and are given a color code which is shown in Fig 5.5.

From the groundwater prospects map, most of the Nakkavagu watershed area is having moderate to low yield ranges. This is mainly due to the decrease in ground water table, as the hydrology of watershed is affected by the anthropogenic activity. Areas having moderate to good ground water yield ranges are found along the Nakkavagu stream and its tributaries.

Table 5.2 Inference used for preparation of groundwater potential zone map.

<table>
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<tr>
<th>S.No</th>
<th>Data from different thematic maps</th>
<th>Inference on groundwater potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Very less to no drainage net work</td>
<td>Land use / land cover map</td>
</tr>
<tr>
<td></td>
<td>Alluvial fan / flood plain zone</td>
<td>Hydrogeological map</td>
</tr>
<tr>
<td></td>
<td>Intersection of lineaments, buried pediment shallow or deep</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High to very high</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Less drainage net work</td>
<td>Agricultural area / settlements / plain land</td>
</tr>
<tr>
<td></td>
<td>More lineaments / pediment zone.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate to high</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Moderate drainage net work</td>
<td>No agricultural land or settlements</td>
</tr>
<tr>
<td></td>
<td>Slightly hilly and presence of residual hills</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low to moderate.</td>
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</tr>
<tr>
<td>4.</td>
<td>Moderate drainage net work</td>
<td>Uplands with pediments, sloping lands</td>
</tr>
<tr>
<td></td>
<td>Very few lineaments or no intersection of lineaments</td>
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</tr>
<tr>
<td></td>
<td>Unfavorable</td>
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</tr>
<tr>
<td>5.</td>
<td>More drainage net work</td>
<td>Hilly area / residual hills and uplands etc.</td>
</tr>
<tr>
<td></td>
<td>No lineament</td>
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<tr>
<td></td>
<td>Poor.</td>
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</tbody>
</table>
Fig 5.5

LEGEND

- Settlement
- Bore Well
- Inferred Fracture (Minor)
- Inferred Fracture (Major)
- Dyke
- Bunds
- Drainage
- Major Roads
- Metalled Roads
- Unmetalled Roads
- Railway line
- Map Boundary

Ground Water Yield Ranges

- Water Bodies
- Dry Water Bodies
- Good
- Moderate
- Low
- Poor

Source: SOI Toposheets 56k/2, 3, 6, 7
IRS ID - LISS III FCC
DOP: Aug. 2000

Prepared by:
T Vijaya Lakshmi
Centre for Environment
JNTU, HYD (A.P.) INDIA.
5.4 BUFFERING TECHNIQUES

Buffering is one of the essential GIS data analysis tool for the creation of polygons that surround other points, lines, or polygons. A buffer is a polygon created as a zone of influence around an entity or around individual objects or multiple objects. The creation of buffer is based on the location, shape, characteristics influential parameters and the nature of application. Buffering techniques can be used to determine spatial proximate or nearness of various feature by defining the distance zone around map features. A buffer may be termed as point buffer, line buffer and polygon buffer. Buffers are useful methods for analysis land use / land cover evaluation, environmental problem solving, water quality studies, road highways and alignment studies. In the present study the mandatory line buffers are used to study the impact of land use / land cover on water quality which is discussed in the following sections.

5.4.1 Generation of Buffers

Earlier investigations revealed that the Nakkavagu catchment is facing severe environmental problems due to water pollution. The Nakkavagu and its tributaries namely, Pamulavagu, and Iskavagu are suffering from the contamination caused by domestic sewage, industrial effluents, and agricultural non point source pollution. Supreme court directed NEERI (1994) and CPCB (1998) to carry out a study for pollution evaluation and status of these streams.
with respect to environmental quality parameters and problems. Keeping this in view, a number of studies were conducted and reports are submitted to the Government for remediation of this catchment. But there is no clear cut mandatory for restoration of this situation. Hence an attempt is made to create a mandatory buffer of these suffered streams with the help of line buffer techniques. The line buffers along Nakkavagu and other streams are created by providing 5 km on either side of the stream as an area of influence. 5 km buffer is considered because of the following reasons.

i) The human habitats / the major industries are located within the radius of 5 km and beyond as per the land use / land cover map.

ii) The terrain slope towards the channels is steep, the flow conditions are favorable to carry the effluents from uplands to the stream course (refer slope map).

iii) The groundwater quality is below the permissible limits for potable water up to 5 km in most of the areas and beyond at few places. This is evident by the information derived from hydro geomorphology map.

5.4.2 Significance of Buffers

The setting of specific buffer zones or separation distances has the obvious advantage of providing a clear indication to a developer of sitting preferences and limitations which should minimize the potential for disagreements and provide considerable assistance to decision makers in determining applications. However, when adopted on a state or region wide
basis, no allowance can be made for local environmental, geological, social, or technical conditions. This could lead to blighting of land unable to be developed in the vicinity of a facility. If the objective of a buffer zone is to protect health then that zone must be defined on the basis of public health risk assessment of specific types of facility, storage and handling capacity and technology with consideration of other social and economic factors of potential importance.

5.5. LAND SURFACE PROCESS MODELING

Generic knowledge-based modelling techniques, that are transportable across environments are rapidly becoming the basis of analytical methods used to examine and resolve complex resource and environmental issues. Models can incorporate descriptions of the key processes that modulate environmental information system performance and behavior with varying degrees of sophistication. Knowledge-based system allows a variety of hypotheses to be explored and permit the evaluation of environmental system parameters from observations so as to prepare EMP. A generic framework is needed for the development of such EMP that can be applied to a variety of institutional arrangements, human settlement patterns, landscapes and weather and climate input patterns.

Information systems and databases for addressing resource and environmental issues must be capable of integrating spatial as well as attribute information. They also must be capable of integration's with models and other analytical tools used for analysis. Geographic information systems that incorporate and spatially relate water, air, soil and biophysical and
principles that should guide model development in Environmental studies using GIS technology.

Parsimony: “A model should not be any more complex than it needs to be and should include only the smallest number of parameters whose values must be obtained from data”,

Modesty: “A model should not pretend to do too much”, “there is no such thing as the model”,

Accuracy: “We need not have our model depict a phenomenon much more accurately than our ability to measure it”, and

Testability: “A model must be testable” and we need to know “if it is valid or not, and what are the limits of its validity.

Considering all these guiding principles digital elevation model for the study area is developed using ARC/INFO GIS Software.

5.5.2 DEM Development

Digital Elevation Model (DEM) is developed using the topographic attributes like spot heights and contour data and stored. The data as a stored as a digital terrain model (DTM) as part of a GIS. Terrain Analysis Techniques are then applied on the DEM and computed terrain attributes from DEM within GIS.

Methods that used to fit a surface sequentially to local regions of the DEM are the local interpolation methods. Moore et al. (1991) present equations for calculating slope and aspect from surfaces fitted using local interpolation methods to a range of DEM structures. The equations are simple and easy to implement
within a GIS and produce identical results to finite differencing methods, depending on the form of the finite differencing scheme an ideal DEM structure is created.

5.5.3 DEM Structure

The ideal structure for a DEM depends on the intended use of the data and how it might relate to the structure of a model. Grid-based methods may use a regularly spaced triangular, square, or rectangular mesh or a regular angular grid, such as the 3 arc second spacing used by the U.S. Defence Mapping Agency. The choice of grid-based method relates primarily to the scale of the area to be examined. The data can be stored in a variety of ways, but the most efficient is as z coordinates corresponding to sequential points along a profile with the starting point and grid spacing also specified.

Triangulated irregular networks (TINs) usually sample surface-specific points, such as peak, ridges and breaks in slope and form an irregular network of points stored as a set of x,y and z coordinates together with pointers to their neighbors in the net (Peucker et al., 1978; Mark, 1975). Vector or contour-based methods consist of digitized contour lines and are stored as digital line graphs (DLGs) in the form of x,y coordinate pairs along each contour line of specified elevation. These can be used to subdivide an area into irregular polygons bounded by adjacent contour lines and adjacent streamlines (Moore et al., 1988; Moore and Grayson, 1991). The method is based on the stream path analogy first proposed by Onstad and Brakensiek (1968). Subsurface characterization; Three-dimensional GIS; Statistical evaluation and sensitivity analysis; and Ground
water flow and contaminant transport modeling. The 3D GIS must, therefore, be used in combination with the remaining modules that use many developed analytical tools.

The process starts when the geologist investigator combines geological experience with limited field data to begin the subsurface characterization process. The subsurface characterization module contains a variety of analytical techniques, including geological process simulation models that may combine both stochastic and deterministic elements. The information generated by the subsurface characterization module is linked directly to the 3D GIS module.

5.6 SPATIAL DISTRIBUTION MAPS

Spatial distribution maps for both water quality and air quality parameters are prepared based on the index computed from the results of the laboratory analysis using ARC INFO software. The computations of quality indices for water and air are shown in Table 4.9 and 4.15. According to earlier investigations carried out by several authors, a five point scale namely excellent, good, poor, very poor, and unfit for drinking for water quality and clean air, light air pollution, moderate air pollution, heavy air pollution and severe air pollution for air quality.

The surface could be visualized as representing a third dimension to the 2-Dimensional x y data and the third axis can be represented by any attribute. The procedure for the generation of maps are detailed in the following sections.
5.6.1. Spatial Distribution of Water Quality

Spatial distribution of water quality index maps are generated for 6 years namely 1979, 1984, 1989, 1994, 1999 and 2001 based on the attribute data given in Tables 4.9. The ranges of water quality indices for 5 point scale is as below:

- 0-25 : excellent
- 26-50 : Good
- 51-75 : Poor
- 76-100 : Very Poor
- > 100 : unfit for drinking

The entire study area consisting of a number of polygons, and all these polygons are categorized into five groups for preparation for spatial distribution of water quality index and each group is colored with a different color which is shown in the maps. Water quality data is collected from earlier reports (A.P. Sata Ground water board, District ground water department, NGO organizations, CPCB reports, NGRI, IPM) for the years 1979, 1984, 1989, 1994, and monitored from 1999-2001 for the villages namely Mutangi, Ismailkhan pet, Arutla, Gaudacherla, Patancheru, Nakakvagu at near national highway 9, Palapnur. The villages are selected mainly because of their location in the watershed area. These villages lie near to the Nakkavagu stream and industrial pollution is more evident as the streams and tanks carry spillovers/treated/untreated industrial effluents and domestic waste. And more so, water quality data of these villages is available from 1979 onwards and for comparative study with the present monitoring locations. Estimated water quality index taken as z value for the
generation of spatial distribution maps of water quality, as a function of 3 dimensional surface modeling.

On the critical examination of the spatial distribution maps of water quality indices, the following conclusions are drawn.

Spatial distribution map of water quality index for the year 1979 is given in Fig 5.6 a). During this year water quality index is ranging between excellent and good category. Most of the area is under crop land and agricultural practices are to the maximum. Because of this, agricultural non-point source pollution is mainly contributing to the quality. More so the domestic water pollution. Spatial distribution map is well correlating with the land use practices.

In 1984, the spatial distribution map of water quality index map shown in Fig 5.6 b) indicates excellent and good quality indices are found in this region. The areas namely Gaudacherla, Arutla, Chedrappa, Ismailkhan pet, Biathole, and Isnapur have water quality in excellent category in 1979 are converted to good water quality category in 1984. The change in water quality is mainly due to discharge of industrial effluents.

By the year 1989, Fig 5.6 c), pollution has increased and is clearly reflected in the water both surface and ground water quality, and soil contamination and is evident from the spatial distribution map of water quality index. Because of the increased usage of fertilizers, pesticides non point source pollution from agricultural activities also increased apart from the industrial pollution. Almost all the areas are under poor water quality category except Gaudacherla and Palapnur. Water quality during 1994, Fig 5.6 d) is almost in all
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the areas is under poor and very poor classes. Many of the researchers, scientists have submitted their evaluation reports to A.P. Pollution Control Board, High Court, and to Supreme Court. Areas namely Khazipally tank, Khazipally village, Kistareddy pet, Panancheru, Pocharam, Muttangi, Nakavagu, Ganapatiguda, Gandigudem have reached very poor water quality. And in villages Arutla, Bachugudem, Byathole, Chedruppa, Gaudacherla, Ismailkhanpet, Isnapur, Lakdaram, Peddakanjerla (Kanjerla Bhadruk) water quality index is poor by the year 1994. The results were tallied with the field observations like improper functioning of effluent treatment plants, the increase in number of registered industries in these industrial areas, and disposal of solid and hazardous waste etc.

By the year 1999, Fig 5.6 e), because of the increased exploitation of land like sand mining, quarrying, improper utilization of land etc., water quality in areas Panancheru, Nakavagu and Muttangi has become unfit for drinking. And in the areas Pocharam, Ganapatiguda, Isnapur, Bachuguda, Peddakanjerla (Kanjerla Bhadruk), Ismailkhan pet is very poor and in the areas Lakdaram, Biatul, Chedruppa, Arutla, Gaudacherla, and Palapnur water quality is rated as poor. The spatial distribution of water quality map for the year 2001, Fig 5.6 f) shows except Palapnur all the areas are classified under very poor and unfit for drinking. It is observed that from the spatial distribution maps after 1984 quality of water resources started deteriorating.
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- Poor
- Very Poor
- Unfit for Drinking
5.6.2 Spatial Distribution of Air Quality

Ambient air quality data for the year 2000 is used to calculate air quality indices on a 5-point scale for the total Nakkavagu watershed area (Fig 5.7). The ranges are Clean air, Light air pollution, Moderate air pollution, Heavy air pollution, Severe air pollution. Areas Palapnur is classified under clean air, Isnapur, Indrakaran show light air pollution, Patancheru, Khazipally, Lakdaram, Ramachandrapuram, Pashmylaram, Kistareddypet, Kardanoor, Pocharam, Bonthapally, are having moderate air pollution levels. and Bollarum and Patancheru industrial areas show severe air pollution. Spatial distribution air quality map is only based on the attribute data of the ambient air quality. And also air pollution monitoring stations are also limited and data is available only one year data. Wind direction, meteorological parameters are not taken in to account while preparing this map. Therefore, the spatial distribution map only can serve as a reference map showing the possible areas under threat, in case any major air pollution disaster occurs while preparing management plans for restoration of air quality.
LEGEND

- 26 - 50: Light air pollution
- 51 - 75: Moderate air pollution
- 76 - 100: Heavy air pollution
- > 100: Severe air pollution
5.7 REFERENCES


