CHAPTER VI

INTEGRATED ANALYSIS FOR GEOENVIRONMENTAL MANAGEMENT
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INTEGRATED ANALYSIS FOR ENVIRONMENTAL MANAGEMENT

6.1 Introduction

Environmental Management has become a priority throughout the world because of the serious consequences that have either been experienced by mankind or likely to happen in future. There is a growing urgency of the management of land, water, minerals, soil, grasslands, forests, animal life, atmosphere, etc. in other wards, the whole environment. In recent years environmental management has been accepted as a tool for sustainable development and a number of countries have already developed a system of environment management at all levels i.e., national, provincial and local as well as domestic. It has been widely recognized that conservation of resources and maintenance of the quality of environment is possible only through proper management. This is more true and essential for developing countries, where degradation of environment is going on at a faster rate due to unscientific and overexploitation of natural resources. Geoenvironmental management involves the utilization of the knowledge about the terrain characteristics, which necessitates inputs from various fields of earth sciences towards the betterment of the environment.

6.2 Methodology

For environmental management planning a number of approaches such as adhoc approach, problem solving approach, system approach, specialised discipline approach, human ecology approach etc., have been used. However it has been recognized that an integrated approach which involves inputs from various disciplines and their analysis as the best approach towards environmental management (Saxena, 2000) and the same has been adopted for the present study. In the earlier chapters, a detailed account on the important terrain characteristics, natural processes, natural resources and anthropogenic environment of the study area has been given. By the integration of this information, it is possible to get a comprehensive picture of each land parcel including the environmental problems. Once the area is thoroughly understood, it becomes possible to prescribe suitable
environmental management plan for each and every part of the study area. For the present study analysis has done made using the GIS softwares such as Arc view, Arc info and the analysis has been carried out on watershed basis.

6.3 Groundwater resources development

- **Identification of Artificial recharge zones**

  Groundwater, unlike surface water, is available in some quantity almost everywhere. Although, it is replenishable, it is not inexhaustible. The continuous failure of monsoons and indiscriminate withdrawal of groundwater – out of balance with input into groundwater aquifer systems – have also added to the depletion of groundwater resources in general and in the hilly terrains in particular. The practice of artificial recharging is increasingly emerging as a powerful tool in water resource management.

  Surface and sub-surface hydrological features such as lithology, geological structure, landforms, drainage density, water bodies and weathered thickness of the overburden material play an important role in groundwater replenishment. But through conventional methods alone it is not an easy task to study the surficial parameters of a large area to identify suitable sites for artificial recharge, since many controlling parameters must be independently derived and integrated, which involves additional cost, time and man power.

  The remote sensing methods for demarcation of suitable areas for groundwater replenishment are able to take into account the diversity of factors that control groundwater recharge. Hence an attempt has been made to demarcate the suitable sites for artificial recharge in the study area.

**Methodology**

In the first phase of work a number of thematic maps that reflect factors that directly influence the recharge of groundwater were prepared from remote sensed data and from data collected by conventional field methods. Thematic maps prepared from remote sensing sources included: landforms, lineament, landuse, and water bodies from Indian Remote Sensing (IRS) satellite – IRS 1C LISS-III Geocoded photographic products. Additional
thematic maps that were development from the data collected by conventional field method included: base details, drainage density. Details collected during field checks were incorporated during final preparation of thematic maps.

In the second phase of the study, GIS techniques were used to integrate various thematic maps.

- **A GIS – based model for Artificial Recharge Zones demarcation**

  To demarcate areas suitable for artificial recharge of groundwater, a GIS-based model was developed for integrating and analyzing different thematic maps.

  **Categorisation and weight assignment**

  The thematic layers pertaining to lithology, landforms, soils, land use, drainage density and lineament were digitized and all the polygons were labeled. Each polygon on each thematic layer was categorized according to its recharge characters as **Excellent, Very good, good, moderate and poor**. It imperative to note here that the relative ranking of polygons is based on the positive and negative consequences of their characters.

  After understanding their behavior with respect to recharge, different classes were weighted relative to their importance in comparison to other classes in the same thematic layer. Also, due care was taken while assigning a weight to each class by considering its local conditions and not merely judging its importance on recharge characteristics alone.

  **Integration of thematic layers**

  After categorisation, all the thematic layers were integrated with one another by a GIS technique. In the first step, lithology (A1) and Landforms (A2) layers were integrated with one another and U1 (the resultant output) was obtained. The U1 layer was then integrated with the Landuse layer (A3) and the resultant layer, U2, was obtained. This process was repeated until U6 was integrated with the well yield (A8). The resultant layer, U7, was multiplied with the polygons of surface water body / settlement – which had been assigned 0 value to prevent them being considered as artificial zones – to give U8. Finally, polygons made around lineaments
were integrated with the U8 layer to produce the final integrated layer (U9). The polygons of the final integrated layer were classed as excellent, high, moderate and poor based on the weight ranges obtained from logical conditions that had been established. The way in which the upper and lower limits of the weights were derived for demarcation of artificial recharges zones. By integrating the different thematic layers using a GIS-based model developed specifically for this purpose, an artificial recharge zones map of the study area was prepared (fig. 6.1). From the figure, it is evident that the excellent zones are restricted to the foothills and plains of the study area. Albeit, in the study area, the following areas are considered as high artificial recharge zones that in and around Maniyarpallam, Pegadupattu and Vellimalai villages of western part of the study area.

The drainage map of the study area was superimposed over the artificial recharge zones map and taking into consideration terrain conditions, suitable sites for construction of check dam (Fig.6.3), percolation pond (Fig.6.4) and various artificial recharge structures were identified. Though there are more sites are considered as favourable zones for the construction of check dams, the specific location that have proposed in the map are more suitable sites based on precise overlay analysis of artificial recharge zone map with drainage.

6.4 A GIS—based model for Soil erosion prone areas identification

Soil erosion prone areas were demarcated with the help of Arc-GIS software. The parameters considered for demarcating the soil erosion hazard zones are average annual rainfall, slope, soil type and land use/land cover. Suitable weightage factors were assigned for the various categories of these parameters. For the rainfall parameters, higher weightage values were assigned to the areas of very high rainfall and the values were progressively reduced for the lower rainfall categories. As far as slope is concerned, the highest weightage value was assigned to the very steep slopes followed steep categories and the weightage values were progressively reduced. For the lower steep slope categories for the soil
KALRAYAN HILLS AND ITS ENVIRONS
ARTIFICIAL RECHARGE ZONES

LEGEND
- Excellent
- Good
- Moderate
- Poor

FIG. 6.1
parameters the gradually loamy soil, which have greater potential for erosion are given higher weightage factors. For the other soil categories lower values were assigned to clay soil followed by loamy soil. The gravel clay soil was assigned the last values. As for as the land use / land cover is concerned, higher values were assigned to agriculture and human habitation category. Lower values were assigned for scrubs and forest for least values were assigned.

After assigning the weightage factors for each of the parameters they were overlayed and integrated it one another and various soil erosion prone areas were demarcated and shown in figure 6.2. Form the figure, it is evident that very high soil erosion hazard zones are found at the inner slopes of the plateau portion and these areas represent the steep slopes in the human habitation where agricultural activities is practiced. Also, such high very soil erosion prone areas are found the higher outer slopes of Tumbal extension reserved forest. The high soil erosion hazard zones found mainly used for agricultural purposes. Also the higher slopes of Pattimedu, Jadayagaundan slopes ,Kanai and Puttai reserved forest. The area with moderate soil erosions hazard are formed confined to the lower outer slopes of the reserved forest and more confined to the plateau portions of study area. Areas with low soil erosion hazards are found confined to the foothills and plain regions of the study area.

GEOENVIRONMENTAL MANAGEMENT

In the following section, a comprehensive picture of the various characteristics of the watersheds of the study area is given in detail. The environmental problems in these watersheds have also been analyzed and lastly by considering the characteristics of the watersheds suitable management plans have been suggested.
KALRAYAN HILLS AND ITS ENVIRONS

SOIL EROSION PRONE AREAS MODEL

FIG. 6.2
SUITABLE SITES FOR PERCOLATION POND

LEGEND
- Percolation Pond Sites
- Third order Stream
- Fourth order Stream

FIG. 6.3
Watershed 1

This watershed lies in the northern most part of the study area and has an areal extent of 77.02 Sq.km. Almost entire watershed lies in the Sankarapuram block of Villupuram district. Except a small patch on the western parts of the watershed which falls in the Thandrampet block of Thiruvannamalai District. The altitude ranges from 180 to 912 m above Mean Sea Level (MSL). The altitude is generally higher on the western part of the study area and it gradually decreases towards the east.

The Slopes are found to be moderately steep on the western side and it is very steep on the central part and gently on the eastern part. Buried Pediments which lies in the plain areas on the eastern side of the watershed occupies greater areal extent than other landforms. The other landforms of the watershed include debris slope, valley fill, hill top plains, scarp face and cliffs.

Gravelly Loamy soil occupies the hilly portion, especially the northern part of the watershed. Gravelly clay soil is found restricted to the eastern part of the watershed especially the plains. Except a small portion of the western part, where the annual rainfall is 1000 – 1400 mm, in all other parts of the watershed, the rainfall is relatively less (<1000 mm). The Mean annual run off, Denudation rate, Sediment yield and peak discharge rates are relatively moderate.

In the eastern plain regions, a number of clustered human isolated habitations are found and on the other hand, smaller, isolated hamlets are found in the other parts of the watershed.

Major portion of the northeastern, central and western sides of the watershed are suitable for artificial recharge. The soil erosion condition is comparatively less in major portion of the watershed. Forests cover was moderate (>15 sq.km) in 1931 and it was reduced as 6.03 sq.km. As far as groundwater potential zone is concerned the watershed fall in the category of high potential in general, the northeastern part the watershed is possess very high groundwater potential and the western side it possess good groundwater potential.

Watershed 2

It lies in the northern part of the study area. The area of the watershed is 8.86 Sq.km. The whole watershed belongs to Sankarapuram administrative block
of Villupuram District. The altitude ranges from 195 to 522 m above MSL. The altitude is generally higher on the western part of the study area and it gradually decreases towards the east.

The slopes are found to be very steep on the western side and it gradually decreases towards east and most of the portion is covered by gentle slope. Debris slope which lies in the western side of the watershed and Bajada zone occupies greater areal extent than other landforms. The other landforms of the watershed include buried pediments medium and shallow. Gravelly clay soil occupies greater areal extent than the calcareous clay soil of the watershed.

Major portion of the northern part, where the annual rainfall is confined to < 1000 mm. except a small portion where rainfall ranges from 1000 – 1200 mm. Mean annual run off, Denudation rate, Sediment yield and peak discharge rates are low.

Major portion in and around the Rangappanur reserved forests is more suitable for artificial recharge. The watershed also has moderate to good groundwater potential. Soil erosion is also less in the watershed.

In addition to that, it is obvious that most part of the watershed is covered by Rangappanur reserved forests and therefore there is no habitation in the watershed.

Watershed No.3

This watershed lies in the eastern part of the study area and has an areal extent of 15.05 Sq.km. The western part of the watershed lies in the Kalrayan hills block and the eastern part fall in the Sankarapuram block of Villupuram district. The elevation varies from 190 – 845 m above MSL. In the watershed, the relief gradually decreases from the western part towards east. Based on the slope, the watershed has very steep slope on the western side and it does gradually decreases towards east.

Geomorphic features such as hill top plains, Debris slope, pediments, buried pediments (shallow and medium) are characteristically present in the study area. Gravelly clay occupies the major portion of the study area and the rest of the portion is covered by calcareous clay. Rainfall in the watershed varies 1000 – 1200 mm. Based on the morphometric characteristics, the mean annual run off is
low; Denudation rate is high and peak discharge is moderate. Human environment: Smaller isolated habitations are found in the watershed and population is 91 per Sq.Km; from 1981 – 2001, there is 26.33 per cent of population growth has taken in the watershed area.

The eastern part of the watershed is more suitable for artificial recharge. Most of the area has moderate groundwater potential and as for as soil erosion the southwestern part of the is found to be very high prone for soil erosion. In the watershed, drastic decrease in forests cover, from 5.84 sq.km (in 1931) to 0.55 sq.km (in 2001) was observed.

Watershed 4

This watershed lies in the eastern part of the study area and has an areal extent of 8.75 Sq.km. Almost entire eastern portion of the watershed lies in the Sankarapuram block and except a small patch on the western part of the watershed, which falls in the Kalayan hills block of Villupuram district. The altitude ranges from 165 to 847 m above MSL. The altitude is generally higher on the western part of the study area and it gradually decreases towards the east more area is occupied by gentle foothills plains.

The slopes are found to be very steep on the western side and it is moderate on the central part and gentle on the eastern part. A buried pediment, which lies in the plain areas on the eastern side of the watershed, occupies greater areal extent than other landforms. The other landforms of the watershed include debris slope and scarp face. Gravelly clay soil occupies the major portion of the watershed. Calcareous clay soil is found restricted to the eastern part of the watershed especially on the plains.

Based on the average annual rainfall analysis, the watershed receives 1000 – 1200 mm rainfall. The mean annual run off is low, Denudation rate is higher, Sediment yield and peak discharge rates are relatively moderate in this watershed. In this watershed only very meager human isolated habitations are found.

The major portion of the watershed is more suitable for artificial recharge; high groundwater potential zones are found in the eastern part. In the watershed, the central portion is high soil erosion prone zone. In the watershed, the eastern part is under agriculture and human activities and there is no much variations in
the forests cover in the watershed. More areas were fall in the unchanged category. Forests cover has reduced from 4.12 sq.km (1931) to 1.76 sq.km (2001)

Watershed 5

It is one of the large watersheds in the study area. It lies in the central part of the study area. The areal extent of the watershed is 107.98 Sq.km. Almost the entire watershed belongs to Kalarayn hills block of and only meager portion falls in the Sankarapuram block of Villupuram District. The altitude ranges from 170 to 987 m above MSL. In the watershed, on the western part the relief is high in some isolated patches and it gradually decreases towards the east. Major portion is occupied by moderately high relief (800-1000 m) terrain and besides this the other portion is low relief (200-400) terrain. The slopes, in the watershed, are found to be moderately steep on the western side and it is very steep in the central part and most of the portion of east part is covered by gentle slope.

Geomorphologically, the watershed is characterized by denudational, erosional and depositional landforms. Among these, the scarp face and debris slope occupies greater areal extent than other landforms. The hilltop plains are discriminately present in the other landforms of the watershed included buried pediments medium and shallow. Based on groundwater potential, the most of the area in the watershed fall in the poor and moderate potential category and excellent groundwater potential zones are sporadically present. Major portion of the watershed fall in the zone of low Soil erosion prone. Gravelly loamy in the western part and clay soil in the central part occupy greater areal extent. The minor distribution of calcareous clay and Gravelly clay are noted in the foot hills, on the eastern side of the watershed. Major portion of the watershed receives moderate rainfall (ranges from 1000-1200mm). Except a small portion in the northwestern part of the watershed, where rainfall is less than 1000 mm. Mean annual run off is relatively high; Mean denudation rate is moderate; Sub surface flow and infiltration rates are high; Sediment yield and peak discharge rates are low. It is obvious that most part of the watershed is intensively under agriculture activities. Besides these, forests, scrub forests are present in the watershed.
In the watershed, the nearby areas of Vanjkuzhi and Pacheri are more suitable for artificial recharge. Groundwater potential is high in and around the following villages of the watershed Serappattu, Innadu, Vengodu and Pudupalapattu, Arasampattu and Pottai of Villupuram district. The suitable sites for artificial recharge are found in the following villages of the watershed viz., Innadu, Kilakkadu, Vengodu, Palappattu (high) and Pacheri (excellent). Soil erosion is more confined to the upper portion of Vengodu and Kilakkadu, Pachcheri, Pudupalapattu and Arasampattu villages that have located in the eastern part of the watershed.

Changes in the forests cover have taken place in the nearby areas of Pacheri, and the upper portion of Palapattu and the southern portion of Vanjkuzhi villages and the forests have turned into scrub forests. The area under forests was 53.23 sq.km (in 1931) and reduced to 28.16 sq.km (in 2001) and consequently the area under scrub forests and agriculture and human habitation were substantially increased.

Watershed 6

This watershed lies in the eastern part of the study area and has an areal extent of 18.19 Sq.km. The western part of the watershed belongs to Kalrayan block and eastern part belongs to Sankarapuram block of Villupuram district. The altitude ranges from 175 to 850 m above MSL. The altitude is generally high (600-800 m) in the western part and it gradually decreases (<200 m) towards the east of the study area.

The Slopes are found to be very steep (>32°) on the western side and it is moderate (16-24°) on the central part and gentle (<8°) on the eastern part. Buried Pediments (shallow and deep), which lie in the plain areas on the eastern side of the watershed, occupy greater areal extent than other landforms. The other landforms of the watershed include scarp face and a hilltop plain is characteristically present. Gravelly Loamy soil occupies the hilly portion, especially the western part of the watershed. Calcareous clay soil occupies the major portion of the study area and Gravelly clay is restricted to the northern part of the watershed. The rainfall ranges from 1000 – 1200 mm in the watershed. The Mean annual run off is low; Denudation rate is high; Sediment yield and peak
discharge rates are relatively less. In the watershed smaller, isolated hamlets are found. The most of the villages in the watershed fall in the category of moderate population distribution and has high population density. In the watershed, the suitable zones artificial recharge are confined to nearby areas of Pudupalapattu (excellent) and Kosapady and Arasampattu (good).

With respect to groundwater potential, the villages Pudupalapattu and Arasampattu are classified as very high potential zones. Soil erosion is more dominant in the near by areas of the western part of Pudupalapattu village and commonly less in all places. Deterioration in forests cover has taken place in the nearby areas of Pudupalapattu village and agriculture land and human settlement cover more area in the eastern part of the watershed. Area under forests 1931 was 5.31 sq.km and in 2001.

Watershed 7

The watershed spreads an area of 9.51 Sq.Km. It lies in the eastern part of the study area. The village Kosapady is notable settlement in the watershed. The elevation ranges from 167 to 632 m above MSL. The altitude is generally higher on the western part (ranges from 600 – 800 m above MSL) of the study area and it gradually decreases towards the east. The watershed covers three blocks of Villupuram District viz., Sankarapuram in the eastern part; Kalrayar hills in the central part and Kallakurichi in the western part. The Slopes are found to be very steep on the western side and it gradually decreases towards east and most of the eastern part of the study area is covered by gentle slope. Hilltop plains and scarp face lie in the western part of the watershed and Pediments occupies greater areal extent than other landforms. Besides these, the other landforms in the watershed include buried pediments medium and shallow. Calcareous clay Soil occupies entire area of the watershed. The entire area of the watershed receives 1000 – 1200 mm of average rainfall. Mean annual run off is low, Sediment yield and peak discharge rates are moderate. It is obvious that most part of the watershed is covered by intensive agriculture practices and in the western part is covered by scrub forests.

In the watershed, from the figures, it is understood that the areas in and the village Kosapady are the favourable zones for groundwater potential and highly suitable for artificial recharge. Soil erosion prone areas in general less and it is
confined to the nearby areas of Pudupalapattu village. In the watershed, forests cover changes in the Kanai reserved forests have taken place and the forests have turned into scrub forests and in some areas the scrub forests have deforested for agriculture purposes.

**Watershed No.8**

This watershed lies in the central part of the study area and has an areal extent of 64.09 Sq.km. The major western part of the watershed lies in the Kalrayan hills block and the eastern part fall in the Kallakurichi block of Villupuram district. The elevation varies from 179 – 904 m above MSL. In the watershed, the outer brim is characteristics of high relief (varies from 800 – 1000 m) and low relief category occupies major portion of the study area. Based on the slope, the watershed has very steep slope (>32°) on the western and eastern parts and it is also noted that in the western part the slope varies from moderate (8-16°) to moderately steep (16°-24°). Besides these, gentle slope (< 8°) is noted in the eastern part. The combinations of geomorphic features that pass to outer slope and plateau portion are characteristically present. The hierarchical arrangements of features such as plateau highland, moderately sloping land, hill top plains, scarp face, debris slope, pediments are characteristically present in the watershed. Among these features, scarp face occupies more area. Clay soil is present in the western part; gravelly loamy and gravelly clay occupy the central and eastern part respectively and rest of the portion in the eastern part is covered by calcareous clay soil. The watershed receives 1000 – 1200 mm of annual rainfall. Based on the morphometric characteristics, the mean annual run off is high; Denudation rate is relatively low; infiltration is more and peak discharge is moderate. Human environment: Vengodu, Erikkampattu and some other smaller isolated habitations are found in the watershed and population density is 127 people per Sq.Km.

In the watershed, zones for artificial recharge are confined to nearby areas of Eduthavainattam village. Favourable groundwater potential zones are found in the nearby areas of Vengodu and Kondiyannattam villages. **Soil erosion prone are noted in the upper part of Vengodu, Pudupalapattu, Eduthavainattam and Kondiyannattam villages.** Forests cover changes have taken place in the upper portion of Vengodu...
village and northern part of Kondiyantham village. In the reserved forests, the most area has been changed as scrub forests.

**Watershed 9**

The watershed is elongated in shape and located in the Middle Eastern part of the study area and has an areal extent of 6.00 Sq.km. Almost entire watershed lies in the Kallakurichi block of Villupuram district. The altitude ranges from 158 to 200 m. Almost it has a gentle relief as plain. The Slope is found to be gentle. Buried Pediments (shallow and deep) occupy the entire watershed. Gravelly clay soil occupies the major portion of the watershed. Clay soil is found restricted to the western part of the watershed. Based on the average annual rainfall analysis, the watershed receives 1000 – 1200 mm rainfall. The mean annual run off is low, sub surface flow and infiltration rate is high; Sediment yield / unit area is relatively high and peak discharge rate is relatively moderate in this watershed. In this watershed only very meager human isolated habitations are found and the population density is also moderate.

The area suitable for artificial recharge is moderate and it is confined to the eastern side of the watershed. The groundwater potential zones are restricted to foothills of the study area and the eastern portion of the watershed is having high potential. The western part of the watershed is more prone to soil erosion. Since, all the areas have been made use of for agricultural activities and human habitation.

**Watershed 10**

It is located in the eastern part of the study area. The areal extent of the watershed is 7.58 Sq.km. Almost the entire watershed belongs to Kallakurichi block of Villupuram District. The altitude ranges from 160 to 263 m above MSL. The entire watershed has gentle relief and almost plain terrain. In the watershed, slope is gentle. Geomorphologically, depositional landforms especially buried pediments shallow, medium and deep characterize the watershed. Gravelly Clay is noted in the northern part and clay soil occupies the entire watershed. Major portion of the
watershed receives moderate average annual rainfall (ranges from 1000-1200mm). Mean annual run off is relatively high; Sub surface flow and infiltration rates are high Sediment yield / unit area is relatively high and Mean denudation rate and peak discharge rates are relatively moderate. The areas that are found in and around the village Manmalai and Karadichittur are more suitable for artificial recharge and have high groundwater potential. Soil erosion is less. Entire watershed is mostly used for agriculture and human habitations.

Watershed 11

This watershed lies in the northern most part of the study area and has an areal extent of 19.48 Sq.km. Most part of the watershed lie in the Kallakurichi administrative block and only the western part of the watershed fall in the Kalravanahills block of Villupuram district. The altitude ranges from 160 to 810 m above Mean Sea Level (MSL). The altitude is generally higher on the western part outer slopes of the study area and it gradually decreases towards the east. Major area is covered by low relief (< 200 m). The Slopes are found to be moderately steep on the western side and it is very steep on the central part and gently on the eastern part. Buried Pediments which lies in the plain areas on the eastern side of the watershed occupies greater areal extent than other landforms. The other landforms of the watershed include debris slope, valley fill, hill top plains, scarp face and cliffs. Major portion in the watershed is most suitable for artificial recharge and as for as groundwater potential zone concern the watershed fall in the category of high potential and the soil erosion condition is comparatively less in major portion of the watershed. Gravelly Loamy soil occupies the hilly portion, especially the northern part of the watershed. Gravelly clay soil is found restricted to the eastern part of the watershed especially the plains. Except a small portion of the western part, where the annual rainfall is 1000 – 1400 mm, in all other parts of the watershed, the rainfall is relatively less (<1000 mm). The Mean annual run off, Denudation rate, Sediment yield and peak discharge rates are relatively moderate. In the eastern plain regions, a number of clustered human isolated habitations are found and on the other hand, smaller, isolated hamlets are found in the other parts of the watershed.
In the watershed the areas suitable for artificial recharge and groundwater potential zones are restricted to eastern part and found in and around the Eduthavainattam and Mathur villages. Soil erosion is generally low and it is found to be high in higher elevation areas of Kondiyannattam village. There was some notable variation in forests cover that the area under forests was 1.78 sq.km (in 1931) and was increased to 2.06 sq.km (in 2001) and they were converted into scrub forests.

**Watershed 12**

It is located in the northern side of the Gomukhi reservoir and in the eastern side of the study area. The area of the watershed is 9.36 Sq.km. The western part of the watershed lies in the Kalrayan block and rest of the portion fall in the Kallakurichy administrative block of Villupuram District. The altitude ranges from 162 to 680 m above MSL. The altitude is generally higher on the western part of the study area and it gradually decreases towards the east and most of area is gentle plain terrain. The slopes are found to be very steep on the western side and it gradually decreases towards east and major portion is covered by gentle slope in the foothills of the study area. Scarp face occupies the major portion in and around the village parigam in the western side of the watershed and Buried Pediments occupies greater areal extent than other landforms in and around Vadakkananthal. The other landforms of the watershed include Debris slope and flat valley. Clay Soil occupies the entire watershed. Major portion of the northern part, where the average annual rainfall ranges from 1000 - 1200 mm, except a small portion where average rainfall ranges from 1200 – 1400 mm. Mean annual run off is low, Denudation rate is high, overland flow is dominant; Sediment yield and peak discharge rate is moderate.

The eastern part, areas nearby the Vadakkananthal and Mathurof the watershed are the suitable sites for artificial recharge and the groundwater potential is moderate in the watershed. Soil erosion is high in the outer slopes of MelParigam village. Forests cover has reduced from 2.10 sq.km (in 1931) to 0.56
sq.km (in 2001) and the percentage of area under agriculture and human habitation has also been considerably increased.

Watershed No.13

The watershed is located in the central part and it is one of the large watersheds of the study area. It has an areal extent of 130.69 Sq.km. This watershed can be called as Gomukhi river watershed. The western part of the watershed lies in the Peddhanaicken block of Salem district and central part lies in the Kalrayan hills block and the eastern brim falls in the Kallakurichi block of Villupuram district. The elevation varies from 190 - 1072 m above MSL. In the watershed, the relief is high in western (near the village Maniyarpalayam) and southern parts (in the and around vellimalai village) of the watershed. Major portion is occupied by moderately high relief (800-1000 m above MSL). In the watershed, major portion of eastern side (in and around Kondiyanattam village) fall under very steep slope; western side (in and around Vellimalai village) fall under steep slope; western side (in and around Karumanthurai village) fall under gentle slope and rest of the portions are having moderate slope. In the watershed, there is diversity of geomorphic features distributed. Some of them are Flat valley (northwestern side and in and around Chinnakalrayan hills Vadakkunadu), hill top plains (western side), Scarp face (all along the western margin the watershed), Debris slope (western side and in and around villages of Kariyalur and the eastern tip of the watershed) and moderately sloping land (major portion of Vellimalai village). Clay soil occupies the major portion of western part of the watershed and the rest of the portion is covered by Gravelly clay. Rainfall in the watershed ranges from greater than 1600 mm in western part, where the Karumanthurai rain gauge is located and reduces to 1000 – 1200 mm towards the eastern side, where the Gomukhi reservoir rain gauge station is located. Based on the morphometric characteristics, the mean annual run off is relatively high; Denudation rate is moderate and subsurface flow and infiltration is dominant process and peak discharge is moderate. Human environment: Notable human habitations and important settlements are located in the watershed and population density is 130 person / Sq.Km. In the watershed, the suitable zones for artificial recharge are
confined to areas in and around Chinna Kalrayan Vadakkunadu, Kariyalur, Vellimalai (good) and Pottiyam (excellent). The groundwater potential zones are restricted to western part (Chinna Kalrayan vadakkunadu village), central part (Vellimalai village) and eastern part (Kondiyanattam village) of the watershed. In the watershed, the soil erosion prone areas are less in general and very high in the areas in and around northern part of Vellimalai and southern part of Kariyalur villages. In the watershed, area under forests, scrub forests and agriculture and human habitations have substantially increased from 7.58 sq.km (in 1931) to 22.59 sq.km (in 2001) and the area under agriculture and human habitations was 40.53 sq.km (in 1931) and has drastically increased up to 65.71 sq.km (in 2001). Thus, it is evident that the forests area is under severe pressure due to human interference. In the watershed, the some semi evergreen forests occupy some areal extent in Vellimalai and Alathi villages.

Watershed 14

This watershed lies in the central part of the study area and has an areal extent of 34.94 Sq.km. The watershed fall in the following villages of the study area such as Vellimalai and Parigam of Kalrayan hills block of Villupuram district. The altitude ranges from 195 to 994 m above MSL. The altitude is generally higher on the western part of the watershed and it gradually decreases towards the east more area is occupied by moderate relief. The slopes are found to be very steep on the western part (i.e. in and around Vellimalai and Pottiyam villages) and it is moderate on the central part and gentle on the eastern part. A buried pediment which lies in the plain areas on the eastern side of the watershed occupies greater areal extent than other landforms. The other landforms of the watershed include debris slope and scarp face. Gravelly clay soil occupies the major portion of the watershed. Calcareous clay soil is found restricted to the eastern part of the watershed especially on the plains. Based on the average annual rainfall analysis, the watershed receives 1000 – 1200 mm rainfall. The mean annual run off is low, Denudation rate is higher, Sediment yield and peak discharge rates are relatively moderate in this watershed. In this watershed only very meager human isolated habitations are found. The suitable sites for artificial
recharge are found in the eastern part of the Vellimalai village and northern part of Pottiyyam village.

The ground water potential is high in the southern and eastern part of the Vellimalai village. Soil erosion is moderate in general and it is high in the eastern part of the village. Drastic change in the forests cover has taken place in the watershed and consequently 30.77 sq.km was under scrub forests during 1931 and it has been reduced to 10.04 sq.km in 2001.

**Watershed 15**

It is one of the large watersheds in the study area and located in the central part of the study area. It is imperative note here that in the watershed, structurally contained Gomukhi River flows and drains in the reservoir. The areal extent of the watershed is 120.09 Sq.km. Almost the entire watershed belongs to Kalarayan hills block of Villupuram district and only meager portion in the western part falls in the Peddhanaickenpalayam block of Salem District. Major area of Arampoondi, Mel Thoradipattu and Melpacheri villages. In the watershed, the distribution of settlement and hamlets are high. The altitude ranges from 190 to 1298 m above MSL. In the watershed, on the western part, the relief is high; moderate in the central part and gradually decreases towards the east. The highest point (summit) of the study area is found in the southern part of the watershed. Major portion is occupied by moderately high relief (600-800 m) terrain and besides this the other portion is high relief (800-1000) terrain. The slope, in the watershed, varies from very steep (in and around Arampoondi and Mel pacheri and Mel Thoradipattu villages) in the western and central part of the watershed. Gentle slope is sporadically distributed especially in the western part of the watershed. Geomorphologically, the watershed is characterized by denudational, erosional and depositional landforms. Among these, the Plateau high lands and moderately sloping land occupy greater areal extent than other landforms and they are characteristically present in central part of the Arampoondi village and western part of the MelThoradipattu Village. The hilltop plains are sporadically distributed in the watershed and more confined to eastern part. The other landforms of the
watershed include flat valley in the nearby areas of Melthoradipattu village; debris slope is found in and around the Melpacheri and Pottiym villages buried pediments deep is confined to eastern part of the watershed and nearer to Pottiym village. Gravelly loamy in the western part and clay soil in the central part occupy greater areal extent. The minor distribution of calcareous clay and Gravelly clay are noted in the foothills, on the eastern side of the watershed. Major portion of the watershed receives moderate rainfall (ranges from 1000-1200mm). Except a small portion in the northwestern part of the watershed, where rainfall is less than 1000 mm. Mean annual run off is relatively high; Mean denudation rate is moderate; Sub surface flow and infiltration rates are high; Sediment yield and peak discharge rates are low.

In the watershed, groundwater potential is very low and in some areas of eastern part in and around Melpacheri and Pottiym villages are having high ground water potentials. The areas suitable for artificial recharge are confined to Melpacheri and Pottiym villages. **Major portion of the watershed is found to be very less in Soil erosion status.**

It is obvious that most part of the watershed is occupied by scrub forests about an area of 109.61 sq.km (91.28 %) during the year 2001 and in the northern and southern portion of the watershed comparatively large areas (4.70 sq.km in the year 2001) are under agriculture practices.

**Watershed 16**

This watershed lies in the eastern part of the study area and has an areal extent of 12.22 Sq.km. The northern part of the watershed belongs to Parigam village of Kallakurichi block and eastern part belongs to Vadakkanandal village of Chinnasalem block of Villupuram district. The altitude ranges from 162 to 703 m above MSL. The altitude is generally in the outer slope of the study area and high (600-800 m) in the western part and it gradually decreases (<200 m) towards the east of the study area. The Slopes are found to be very steep (>32°) on the western side and it is moderate (16-24°) on the central part and gentle (<8°) on the eastern part. Pediments, which lie in the plain areas on the eastern side of the watershed, occupies greater areal extent. The other landforms of the watershed include Debris slope and buried pediments
deep. Gravelly clay soil occupies the hilly portion, especially the western part of the watershed. Clay soil occupies the major portion of eastern part of the watershed. The rainfall ranges from 1000 to 1200 mm in the watershed. The Mean annual run off, Denudation rate are low; Sediment yield and peak discharge rates are relatively are moderate. In the watershed smaller, isolated hamlets are found. The watershed falls in the category of high population growth and also has high (293.94 persons per sq.km) population density.

Groundwater potential is moderate in the watershed. Areas for artificial recharge are confined to eastern part of the watershed and rests of the areas are comparatively not suitable. Soil erosion is high in the southern part of the watershed. Forests cover has been decreased from 87.65% (in 1931) to 42.22% (in 2001). In the watershed, other plantations have also occupied some considerable areal extent.

**Watershed 17**

The watershed spreads an area of 15.12 Sq.Km. It lies in the southeastern brim of the study area. The altitude ranges from 126 to 240 m above MSL and almost it is plain terrain and the Slope is gentle (< 8°). The watershed forms parts of Kadathur, Eliyathur and Thottiyam villages of Chinnasalem block of Villupuram District. Geomorphic features, Bajada zone is found in the upper portion of the watershed and rest of the portions of the watershed have occupied by buried pediments deep, medium and shallow. The soil type of the watershed is Gravelly clay. The entire area of the watershed receives 1000 – 1200 mm of average annual rainfall. Mean annual run off is high; Sediment yield is high and peak discharge rate is low. Population density is comparatively very high (514.81 person per sq.km). In the watershed, the sites for artificial recharges are high in and around Kadathur village; Groundwater potential is also high in and around Kadathur and Thottiyam villages; Soil erosion is comparatively low in the watershed. Moreover, the forests cover has substantially reduced from 4.55 sq.km (in 1931) to 0.09 sq.km (in 2001).
Watershed No.18

This watershed lies in the southeastern part of the study area and it has an areal extent of 28.79 Sq.km. It covers part of Thengianattam, Paithanthurai and Thenchettiyandal villages of Chinnasalem block of Villupuram district. The watershed receives 1000 – 1200 mm of average annual rainfall. The elevation varies from 126 – 804 m above MSL. In the watershed, the outer slopes of the study area of moderate relief (varies from 600 – 800 m above MSL) and low relief (< 200 m) comparatively occupies major portion of the study area. Based on the slope, the watershed has very steep slope (>32°) on the northern part and gradually decreases to gentle slope (< 8°) towards southern part of the watershed. The geomorphic features are Bajada zone and buried pediments occupy present in the watershed. Gravelly loamy soil found in the western part; loamy soil occupies the central part and rest of the southern portion is covered by Gravelly clay soil. Based on the morphometric characteristics, the mean annual run off is high; Denudation rate is relatively high; infiltration is more and peak discharge is moderate. Human environment: Thengianattam, Paithanthurai and Thenchettiyandal and some other smaller isolated habitations are found in the watershed and population density is 189.02 persons per Sq.Km.

The areas suitable for artificial recharge are confined to areas in and around Thengianattam village. The areas that prone to soil erosion are found in the nearby areas of western part of Kadathur village and central part of Thengianattam village and in general areas for soil erosion are considerably high in the watershed. There are more groundwater potential zones found in the southern part of the watershed.

Watershed 19

This watershed lies in the southern part of the study area and has an areal extent of 6.97 Sq.km. Almost entire watershed lies in the Chinnasalem block and covers part of areas of Thenchettiyandal and Maravanattam villages of Villupuram district. The altitude ranges from 137 to 180 m. The topography is generally gentle. The slope is also found to be gentle. In the watershed, geomorphic features such as buried pediments, which occupy comparatively more area than other landforms, and Bajada zone is located in the northern brim of the watershed. Gravelly clay soil
occupies the major portion of the watershed. Loamy soil is found restricted to the western part of the watershed especially in and around the plains of Maravanattam village. Based on the average annual rainfall analysis, the watershed receives 1000 – 1200 mm rainfall. The mean annual run off is high, infiltration rate is high; Denudation rate is higher, Sediment yield is relatively high and peak discharge rates are low in this watershed. It is evident that the areas in the watershed are highly suitable for artificial recharge and they have high groundwater potential. In addition to that, soil erosion in the watershed is very less. Reduction in scrub forests cover is comparatively more and about an area of 6.00 sq.km and thus the area under agriculture and human settlement has substantially increased up to 6.30 sq.km.

Watershed 20

The watershed is located in the southern part of the study area and it covers some portions of Takarai, Thenchettiyandal and Maravanattam villages. The areal extent of the watershed is 21.55 Sq.km. Almost the entire watershed belongs to Chinnasalem block of Villupuram District. The altitude ranges from 138 to 804 m. In the watershed, on the northern part in and around the Takarai, the relief is and it gradually decreases towards the south. Major portion is occupied by low relief (200-400) and i.e. in the foot hills. In the watershed, the steep slopes are found in northern part and it does gradually decreases towards southern part and it is covered by gentle slope. Geomorphologically, the watershed is characterized by Scarp face, debris slope, hill top plains, buried pediments (deep and shallow) and Bajada zone. Among these, the buried pediments (deep) and debris slope occupy greater areal extent than other landforms. Gravelly loamy in the northern part and loamy soil in the southern part occupy mutually equal areal extent in the watershed. The watershed receives moderate average annual rainfall (ranges from 1000-1200mm). Mean annual run off is relatively high; Mean denudation rate is high; Sub surface flow and infiltration rates are high; Sediment yield and peak discharge rates are moderate. According to site selection for artificial recharge zones, the area in and Takarai village is more suitable; Groundwater potential in the watershed is high and confined to southern part of the watershed. Soil erosion is comparatively more in northern part of the watershed. Forests cover was 12.55 sq.km (in 1931) and it has drastically reduced as
2.56 sq.km and most of the forests cover have converted into scrub forests (8.36 sq.km) and as well as agriculture and human habitations area.

Watershed 21

This watershed lies in the southern part of the study area and has an areal extent of 5.09 Sq.km. Almost entire watershed lies in the Chinnasalem block of Villupuram district. Some portion of Timmapuram village is found in the watershed. The altitude ranges from 138 to 565 m above Mean Sea Level (MSL). The altitude is generally higher on the northern part of the study area and it gradually decreases towards the south. The Slope is found to be very steep in the outer slope and it is gentle in the southern part. Buried Pediments medium and shallow that lie in the plain areas on the southern part of the watershed, occupy greater areal extent than other landforms. The other landforms of the watershed that are found in the upper portion of the watershed are scarp face and debris slope. Gravelly Loamy and loamy soils occupy the watershed. The watershed receives the moderate average annual rainfall (1000 - 1200 mm). The Mean annual run off is high and peak discharge rates are relatively low. Population growth was found to be low albeit the density of the population is moderate (142.44 persons per sq.km).

The areas that belong to Takarai are highly favourable for artificial recharge. Groundwater potential is moderate. And the soil erosion condition is comparatively less in major portion of the watershed. In the watershed, 67.57% of area under forests cover was made use of for agriculture and human habitations.

Watershed 22

It lies in the southern part of the study area. The area of the watershed is 8.86 Sq.km. The whole watershed belongs to Thalaivasal administrative block of Villupuram District. The altitude ranges from 160 to 817 m above MSL. The altitude is generally higher on the northern part of the study area and it gradually decreases towards the south and most of the area is under gentle topography. The slope is found to be very steep (>32°) on the northern portion and it gradually decreases towards south and most of the portion is covered by gentle slope. The
geomorphic features that are found in the northern part of the study area are scarp face, debris slope. The other features are buried pediments (deep and shallow), which lie in the southern part of the watershed and occupy greater areal extent than other landforms. Gravelly loamy and loamy soils occupy the major area of the watershed. Major portion of the northern part of the watershed where the annual rainfall ranges from 1000 – 1200 mm and some area fall under the category of (<1000 mm). Mean annual run off, Denudation rate, Sediment yield and peak discharge rates are low. Major portion in and around the Rangappanur reserved forests is more suitable for artificial recharge. The watershed also has more groundwater potential zones ranges from moderate to good. Soil erosion is also less in the watershed.

Watershed No. 23

This watershed lies in the eastern part of the study area and has an areal extent of 15.05 Sq.km. The western part of the watershed lies in the Kalrayan hills block and the eastern part fall in the Sankarapuram block of Villupuram district. The elevation varies from 190 – 845 m above MSL. In the watershed, the relief gradually decreases from the western part towards east. Based on the slope, the watershed has very steep slope on the western side and it does gradually decreases towards east. Geomorphic features such as hill top plains, Debris slope, pediments, buried pediments (shallow and medium) are characteristically present in the study area. Gravelly clay occupies the major portion of the study area and the rest of the portion is covered by calcareous clay. Rainfall in the watershed varies 1000 – 1200 mm. Based on the morphometric characteristics, the mean annual run off is low; Denudation rate is high and peak discharge is moderate. Human environment: Smaller isolated habitations are found in the watershed and population is 91 per Sq.Km; from 1981 – 2001, there is 26.33 per cent of population growth has taken in the watershed area. The eastern part of the watershed is more suitable for artificial recharge. Most of the area has moderate groundwater potential and as for as soil erosion the southwestern part of the watershed has very high soil erosion prone areas. In the watershed, substantial changes in forests cover, from 5.84 sq.km (in 1931) to 0.55 sq.km(in 2001) and the scrub forests were converted
into agriculture land, have been taken place during the year 1931 – 2001 The rest of the watersheds (24 to 36) that are found in the outer slopes of the study are having relatively similar characteristics (High relief in the northern part; slope in the northern part are very high and decreases towards south; geomorphic features are scarp face, debris slope, and more area is occupied by pediments and buried pediments (deep, moderate and shallow); clay soil and loamy occupy more area; rainfall in the western part of the watersheds are high; human settlement are relatively high. They are having low ground water potential in general and high in the watersheds of western part of the study area; artificial recharge zones are moderate in general; soil erosion is also is high in watersheds of western part of the study area.

After complete analyses of the watersheds the following prioritization and ranking according to its suitability is given.

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<tr>
<th>Sl.No</th>
<th>Theme</th>
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<td>Reduction in forest cover</td>
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<td>3</td>
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<td>Ground Water potential</td>
<td>Artificial recharge Zones</td>
<td>Soil erosion prone areas</td>
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Table (6.1): Rank allocation is shown in the following table.

<table>
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<tr>
<th>S.No</th>
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<th>Watersheds No</th>
<th>Total Watersheds</th>
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<td>(13-15)</td>
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<td>2</td>
<td>Moderate</td>
<td>(10-12)</td>
<td>1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 17, 18, 19, 20, 21, 23, 27, 32, 35 and 36</td>
<td>21</td>
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<tr>
<td>3</td>
<td>Low</td>
<td>(7-9)</td>
<td>15, 16, 24, 25, 26, 28, 29, 30, 31, 33 and 34</td>
<td>11</td>
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</table>

Table (6.2): The above Table 6.1 clearly depicts the following

**Ranking**

- **Optimum watersheds**

The optimum watersheds having the priority ranks from 13 – 15, which indicates more than four parameters are in high ranking category. These are fall in the category. The sustainable development, management in these four watersheds (2, 9, 11, 22) needs less attention since they are having total potential than the other.

- Care should be taken to maintain the optimum level of extraction with respect to groundwater and other parameters for long term
sustainable development. The reason for this due to surplus amount of surface waters by means of Gomukhi and Muskunda rivers.

Moderate watersheds

The moderate watersheds include (1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 17, 18, 19, 20, 21, 23, 27, 32, 35 and 36) there are around 21 watersheds fall in this category. These watersheds require more attention with respect to the sustainable development and to bring them to optimum level.

- For these, conservation measures such as check dam, percolation ponds, recharge pits, contour bunding and contour terrace may be constructed in the appropriate places suggested in the chapter 6.
- Soil conservation measures should also be followed in the areas where there is high soil erosion within the watersheds. Extraction of groundwater in these watersheds should be in the optimum level and the extraction should be minimum.
- Measures coupled with artificial recharge in these watersheds may improve the groundwater quantity and quality and soil erosion.
- The afforestation programmes may be intensively taken up in these watersheds, public awareness may be taken up through government and NGO to improve afforestation programme. In these watersheds government and Nongovernmental organizations and institutions may work together to elevate the watersheds to optimum level. The programmes for improving these watersheds the phased manner according to the availability of the funds with the government and Nongovernmental organizations under different manner.
Deficit watersheds

There are around eleven watersheds (15, 16, 24, 25, 26, 28, 29, 30, 31, 33 and 34) fall in this category. These watersheds are sporadically distributed throughout the study area.

- The sources from the optimum watersheds may be diverted to these deficit watersheds to improve the scenario (surface and groundwater).
- As far as, the soil erosion practices in these watersheds are concerned, the intensified afforestation programmes may be implemented by Government and other organizations.

The sustainability may be brought in the study area by joint efforts and the government funds may be properly allocated to improve the moderate watershed to the surplus level in the study area.