CHAPTER XII

FINDINGS AND CONCLUSIONS

The study area of Erumaipatti watershed is located in Cauvery basin at Longitude 78° 13' 56" to 78° 21' 55" and Latitude 11° 06' 05" to 11°13' 22" in Survey of India topographic sheets 58 I/ 4 & 8. It covers an area of 121.5 Km². The watershed falls in part of Erumaipatti block of Namakkal Taluk, Namakkal District.

Physiographically the area comprises of upland hills, isolated hillocks and undulated plain. The maximum and minimum elevation is 1336 m and 130 m above MSL respectively. As per the p-e index of 30.9, the area enjoys semi-arid climate.

Annual average rainfall is 804 mm and average annual rainy days are 50. The area experiences 45% of rainfall from Southwest monsoon (July – September), 37.5% from Northeast monsoon (October-December) and 17.5% from transitional period of January to May.

There are 1062 irrigation wells and 99 borewells (1999 status) functioning to cater the needs of irrigation and drinking water requirements of 39061 rural population (1991 census) in the watershed area.

Agriculture is the mainstay of rural populace and small scale poultry forms and brick work are the other occupation.
Remote sensing data products such as aerial photographs and satellite imageries on 1:50,000 scale are used for preparation of various thematic maps like geology, geomorphology, structure, drainage, landuse, land cover, soil etc by visual interpretation. The bazada zone is prevalent in the foot of the upland hills with moderate slope. Geomorphic units like deep, shallow buried pediment and pediment spread over the watershed area are delineated based on the land use, tonal variations and other photo recognition and geotechnical elements.

67 lineaments of 0.5 to 5.5 km length and two major sets of lineaments are derived from frequency azimuth diagram. The lineament density concentration derived from lineament density map is regarded as major trends. The major axis is in the NE-SW and NW-SE direction.

The watershed is having 5 orders of drainage and the main river forms the Vth order. Total length of the stream is 191.55 km and number of streams is 205. The major land use unit is dry crop area (34.5%) wet crop area 30% and degraded forest 21.2% water body covers 2.7%. The remaining are barren land, settlement and rock outcrop.

Percentage of coverage of C group of soil (36.9%) and D group soil (32.62%) are more prevalent in the central and eastern part of the watershed. A & B groups covers only 5.5% and 1.3% mostly in the NW and southern part. The remaining is the runoff zone of upland hills.
The pediplain area show <5% slope and the bazada zone is 5-10% slope. Steep and very steep slope of >10% is in the upland hills. <1% of nearly bed level occupies about 40% of the total watershed area.

The area forms part of Archaean complex of south Indian Peninsula and comprise of Hornblende biotite gneiss, pyroxene-granulites, charnockite, magnetite-quartzite, pyroxenites and dolerite dykes. The southern part of the area is characterized by hornblende gneiss and biotite gneiss and the northern part including the upland hills is composed of charnockite. Since the streams are ephemeral in nature recent alluvium deposition along the course of the stream is not significant.

Morphometric analysis show the higher bifurcation ratio of 3.64, the stream take up natural surface irregularities for their Path. Horton's law of stream length is confirmed by the falling of points in a plot of log of stream length as a function of stream order in a straight line.

Drainage density of the watershed area is 1.58/km, which shows moderate permeability of the soil. The stream frequency of 1.70 is indicative of low run-off due to moderate permeability and infiltration condition of the soil. The circularity ratio of 0.73 indicates the near homogenous character of the sub surface geology of the water shed.

Moderate values of Ruggedness 1.9 show the moderate slope of the watershed. Hypsometric analysis of the watershed area indicates that the water shed is in the old stage and the hypsometric
integer is 29% i.e. remaining value of material type removed to the subdued surface.

Hydrogeologically the area is divided into three zone viz. (a) weathered zone comprises of soil zone, decomposed zone and disintegrated zone, (b) jointed, fissured and fractured zone and (c) hard massive rock zone.

The weathered thickness observed in 73 locations indicates the range of 3-30m and the average weathered zone thickness is 14.4m. A linear zone of 10-15m thickness falls in the NW-SE direction and coincides with the set of lineaments falls in this direction. The existing bore well yielding zones reveals the existence of shallow and deep seated open fracture. There is no indication of high yield borewells along the shear zone, which may be due to the crushing nature with poor hydraulic conductivity. Sheet joints are encountered at deeper depth beyond 200 m depth. But the study indicates that these joints may not equally distributed in space.

Geomorphic/structural unit wise and stream order wise classification of 34 observation wells are made to assess their behavior. The long-term water level (1971-93) indicates the average lowest water level of 14.8m during 1978 and deepest level of 31.0m during 1989. The monthly average water level indicates the rising trend during SW monsoon and NE monsoon and falling during transitional period.

The water table contours of the observed seasons of November 97. May '98 and July '99 shows no vast variation and the
general gradient is from NE to SW which follows the major lineament direction and foliation trend.

The gradient is steeper in the charnockite terrain and gentle in the gneiss terrain. The flow from the piedmont (Bazada) is towards south and in the other sides of the watershed i.e. in the SE, East and West is towards NW, West and SE respectively.

There is a relative convergence of flow near the well located at NW of Varagur (well no. 16), near Erumaipatti (well no. 21) and at Ponneri west (well no. 32). The relative convergence flow indicates of higher transmissivity from water table aquifer. A linear flow direction is noticed along Pottireddipatti, Ponneri west and Valayapatti indicative of major hydraulic conductive zone (losing).

Water level fluctuation taking November '97 as a base the water level difference between November '97 – May '98 and November '97 - July '99 indicates that all the wells show negative deviation except in three wells and the fluctuation varies from 0.5 to 20m. During November '97 – May '98, fall in water level in all the wells in the range of 0.5 to 20 m is noticed. 5-10m fall in water level is more prominent in the northern part, which is mostly occupied by charnockite.

Rainfall and water level correlation indicates that there is a mixed response by the saturated zone due to the variation in infiltration capacity of different soil groups and degree of weathering of the country rock.
The response of water level over geomorphic unit is assessed. The pediment associated with lineament shows deepest water level whereas in other units it is near normal. Piedmont zone shows fall in water level due to the fact that it acts as recharge zone.

The behavior of water level in proximity to the II, III and IV order is near normal. The fall of water level for the I\textsuperscript{st} order stream is comparatively high. The water level in the V order stream area is shallow compared to IV\textsuperscript{th} order, may be either due to the over exploitation in the IV\textsuperscript{th} order area or existence of sub surface barrier which arrests the outflow of ground water from the water shed. While correlating the average weathered thickness with water level in the stream orders, water level in the I\textsuperscript{st} to IV\textsuperscript{th} order is below weathered zone and in the V order water level is within the weathered zone thickness. The average water level shows a linear relationship from November '97 to July '99 and the water level is below average weathered zone thickness of 14.4m after November '98.

Pumping test conducted in phreatic aquifer in 11 nos. existing open wells and aquifer and yield character of the well is assessed. The permeability value show vide range of 0.35 to 8.48 m/hour with mean value of 3.81 m/hour due to the heterogeneous nature of the phreatic aquifer system. The average specific yield value is 0.058. (Chapter VII – Table VII.5).
The yield characteristics of the phreatic aquifer by Romani\textsuperscript{164} method indicate the optimum yield of the well in the range of 10 to 246 cubic metre/day. The yield and aquifer characters while correlating. Moderate degree of positive correlation is obtained between permeability with the optimum yield. The saturated zone thickness is directly related to the specific yield of the aquifer. Fast recovery for higher permeability and slow recovery for low permeability is observed. (Chapter VII – Figure VII.25).

While correlating the geomorphic unit with aquifer and well characters, high permeability and optimum yield is observed in bazada zone, deep buried pediment and lineament and low permeability and optimum yield is in the pediment area.

Deep fracture aquifer test in 13 bore wells shows the T value in the discharge test ranges from 9.7 to 315 m\textsuperscript{2}/day and in recovery test from 23.6 to 270.5 m\textsuperscript{2}/day. The high T values at Varagur tank, Pottireddipatti, Varadarajapuram, Konangipatti and Muttanchetti are due to the yield from both deep and shallow fractures. The specific capacity of the bore wells varies from 8.4 to 107 lpm/metre draw down. A correlation of T value and specific capacity shows a positive correlation with slope of 0.314. (Chapter VII – Figure VII.26).

While grouping the tested bore wells according to the set of lineaments, NW-SE set of lineament shows high T value of 203 m\textsuperscript{2}/day and NE-SW set of lineament show 73 m\textsuperscript{2}/day.
Electrical resistivity survey in 20 locations of the watershed area is analyzed and layer resistivity and corresponding thickness are derived. Layer mean resistivity ranges from 69 ohm-m to 4734 ohm-m and minimum three layers and maximum 8 layers are interpreted. Mean thickness of layer ranges from 3 to 20m. The mean resistivity value indicate the steady increase in the resistivity of the layers where as in the sixth layer there is a fall in resistivity due to the deep seated fractures/fissures sandwiched between highly resistive strata. Lithological correlation is also made with reference to the resistivity range and weathered zone shows 100-300 ohm range, fracture zone 300-.600 ohm-m range and >2000 ohm-m shows massive rock.

Geo electric sections along SW - NE direction has the slope towards SW direction and in the cross section W-E, the slope is from east to west. The fracture zone follows soil and weathered zone. A 10 m thick fracture zone with resistivity of 377 ohm-m & 78 ohm is sandwiched between the highly resistivity layer at Varagur and K.Pudur. (Chapter VIII - Figure VIII.11&12).

The layer resistivity contour at 5, 20, 40 & 80 m depth indicates that low resistivity in the top layer in the eastern side is due to D group soil and high resistivity in B & C group soil. Poor conductive layer at the depth of 20 m and 40 m depth in the eastern side of watershed is indicated. At 80 m depth low resistivity is encountered in the eastern side of the water shed due to the existence of fracture zone.
below high resistive material. Piedmont zone shows low resistivity of <500 ohm-m. (Chapter VIII - Figure VIII.13-16).

Based on the geophysical survey results 'T' value of the aquifer is also calculated and correlated with the observed 'T' value. A positive correlation with regression equation of

\[ T'_{\text{observed}} = 0.7861 \cdot T'_{\text{cal}} - 34.75 \]

Longitudinal conductance (S) is correlated with T value observed and calculated and -ve correlation is obtained with the following regression line equation

\[ T_{\text{calculated}} = -1456 \cdot S + 536.05 \]
\[ T_{\text{observed}} = -1028 \cdot S + 358.05 \]

Magnetic survey conducted by using vertical magnetometer and intensity is correlated with soil and weathering thickness. Negative anomaly correlates with B & C group of soil and deep weathering and positive anomaly correlates with D group of soil and shallow weathering. A linear zone of negative anomaly in NW-SE direction and elongated shape of the intensity contours indicative of major sets of lineaments. The magnetic profile correlates with the SW – NE resistivity cross season.

Out of 17 water samples tested 11 and 13 samples are not potable as per drinking water standard during November '97 and May '98 respectively. During August '99 out of 27 samples tested 16 are not potable. The major constituent, which exceeds for not potability is TDS, Total hardness No₃, and SO₄. Schoeller diagram for all the three
seasons observed are made, which represent the cumulative percentage of composition of water. (Chapter IX - Figure IX.1-3).

Iso-conductivity maps are plotted and permissible, excessive and not potable zones are delineated. (Chapter IX-Figure IX.4-6). The ratio of ionic of chloride is calculated and the ratios K/Cl, Na/Cl, Mg/Cl and HCO₃/Cl sink on the salt content increased. The relationship between conductivity and concentration of major ions of HCO₃, TH, Cl, Na, Ca, and Mg are correlated. The regression coefficient of correlation is high for TH, Cl and Na showing high degree of correlation. Low degree correlation is observed for Mg. Ca & HCO₃ shows mixed correlation during the seasons observed.

Chloro-alkaline indices are used to evaluate the extent of Base Exchange and based on the +ve / -ve value number of samples fall in recharge/discharge area is delineated.

Piper trilinear diagrams are plotted for all the observed seasons and geo-chemical type of ground water is classified. Most of the samples fall in CaHCO₃ type during November '97 and May '98 and CaCl type during August '99. While correlating the average water level conditions the water type changes from HCO₃ type to Chloride type due to fall in water level. (Chapter IX - Figure IX.19-21).

As per irrigation quality of ground water most of the samples fall in medium high to high salinity category, which is suitable for irrigation purposes. The sodium absorption ratio for all the seasons is <10 and suitable for irrigation purpose. The Wilcox diagram indicates
high to very high salinity hazard since all the samples fall in C3S1, C3S2 and C4S2 category. (Chapter IX - Figure IX.22-24).

Corrosivity ratio for all the samples are determined and season wise maps are plotted delineating the area prone for corrosive (CR<1) and non-corrosive area (CR >1).

Gibb's plot indicates that when the water level is deep, the concentration is on the rock dominance area and when water level is shallow it is in the central portion indicating the interaction between the weathered rock and percolating water. The interaction of percolating water with weathered zone is more when water level is shallow and when the water level depleted below weathered zone, the movement of water is through fractures and interaction of water is with the rock.

Surface water potential is estimated as 8.2 MCM. Ground water potential zonation is made by trend surface analysis. The residuals of the actual and predicted values show the potential status of the watershed. Over exploited and under exploited zone are determined for all the seasons of water level observation. The under exploited area occupies mainly the central part of the study area.

Recharge and discharge area is delineated based on grid average water table and the positive deviation prominent in the piedmont zone and along the eastern side indicating the ground water recharge condition caused by rain fall run off. The negative value
concentration is mainly in the center and SW part of the study area indicating the discharge area.

The ground water recharge based on water level fluctuation method is 232 mm. Run off estimation based on Soil Conservation Service (SCS) method is calculated for monthly rainfall and average annual run off is 310 mm and infiltration is 466 mm. (Chapter X - Table X.2). Correlation of rainfall and run off is made and a polynomial correlation is perfectly fit in with the equation of runoff \( R \) (mm) = 0.0007 \( P^2 \)-0.6239\( P+181.4 \) (P is rainfall in mm). (Chapter X - Figure X.10).

Peak rate of run off from the watershed for recurrence interval of 5 years is 60.75 cubic meter/sec.

Total annual discharges from the phreatic and fractured aquifer through open wells and bore well used for irrigation and a domestic use is 39.88 Million Cubic Metre (MCM). Return flow from the irrigated field is 10.85 MCM. Year wise recharge and discharge of the watershed for the five year period by water level fluctuation method is calculated and correlated with the average rainfall. The recharge ranges from 12.90 MCM to 51.56 MCM and discharge ranges from 22.05 to 46.77 MCM.

Safe yield of the watershed is calculated based on Harding method of annual average recharge and corresponding change in water level. The safe yield of the watershed is 36.0 MCM per annum. (Chapter X - Figure X.13).
Annual ground water balance for 10 years 1989-98 is worked out based on SCS method and over extraction of the aquifer during the year 1992, 1993, 1995 is observed due to below normal rainfall. A linear correlation between the ground water balance and annual rainfall is obtained with the equation of ground water balance = 0.036 R - 23.661. In order to meet out the requirement by various sectors, a minimum annual rainfall of 640 mm is required to maintain the hydrological equilibrium. (Chapter X - Figure X.14).

From the ground water fluctuation method average recharge is 32.57 MCM and discharge is 33.87 MCM respectively indicating an average over extraction of 1.3 MCM from the static ground water potential of the aquifer.

The thematic and derived maps are converted into digital format and integrated by using ARC/INFO and ARCVIEW GIS software. Assigning suitable ranking for each layer favorable for categorization of ground water potential zones and area suitability for artificial recharge are made.

Ground water potential zones, which are in the 'Excellent' and 'Good' category, fall in the north and north west of Varagur, around Erumaipatti, Konangipatti and in isolated pockets near Muttanchetti, Pottireddipatti, north of Pudukottai.

The 'Excellent' and 'Good' area favorable for artificial recharge falls as an elongated zone in the NE-SW direction covering Varagur, Devarayapuram, Erumaipatti, Konangipatti village and in
isolated pockets of other Muttanchetti in the south and Gajakombai in the northwest of the watershed area.

The categorization of the area suitability for artificial recharge is compared with the satisfactory performance of the percolation tank and check dams constructed during the period of study at Muttanchetti, Vaidyanathapuram and north of Devarayapuram, which falls in the 'Excellent' category area.

From the study carried out in the watershed area the following conclusions are made:

1. In the watershed area there is scarcity of water for irrigation as well as domestic uses due to the over exploitation of the aquifer system.

2. In the study area when the rainfall is below 640 mm which is the required calculated amount, the static ground water potential is tapped.

3. In the study area quality of water is also a major concern. The water quality is not suitable for drinking purpose in most part of the area of the watershed (Refer Chapter IX - Figure IX.4-6).

4. Periodic scientific assessment of ground water potential is the need of the hour taking in to consideration of the water quality and economic viability.

5. Exploration of ground water potential resource should be so regulated so as not to exceed the recharging possibilities.
6. Over exploitation due to intensive development of ground water has resulted in problems like progressive lowering of ground water level. Consequent by leading to decline in yield and productivity of wells and increased cost of lifting of water.

7. The pre monsoon rate of recession of water level is fast in the months of April, May and June. The available resource may not be fully utilized due to the sparse demand during that period. Deep fracture zones are good aquifer, which yield water to borewells used by various sectors. But their aerial and potential extent is limited due to poor recharge condition. Caution should be exercised while developing such aquifer zones for irrigation and other purposes.

8. Modern techniques including remote sensing, ground geophysical study and lineament mapping can be adopted for successful locating of wells.

9. Further locating of borewells/wells in the 'Poor' and 'Moderate' category (Example: Around Pudukottai, Ponneri, Valayapatti, Kavakaranpatti, Varadarajapuram, Muttanchetti and Kalichettipatti) should be avoided and care should be taken in locating sites in the 'Excellent' and 'Good' zones which falls in the area. (Example: Around Varagur, Erumaipatti, Konangipatti, Devarayapuram etc). Integrated
interdisciplinary approach is needed to resolve issues on accurate location of subsurface saturated fractures.

10. Ground water recharge project should be taken up in the feasible zones after complete investigation.

11. The bazada zone spread over in Gajakombai, Singiliankombai and Thoddamudayanpatti with the slope range of 5 to 10% and falls in the 'Moderate' and 'Good' category may be taken up for construction of contour bunding, check dams, subsurface dykes etc, to arrest the surface and sub-surface flow for recharge. Percolation tanks and check dams are also suitable in the areas marked as 'Good' and 'Excellent'. (Figure XII.1). (Example: Areas around Konangipatti, Ponneri, Kalichettipatti, Pottireddipatti, between Erumaipatti and Singiliankombai, Vaidyanathapuram, Varadarajapuram Sellipalayam and north of Varagur).

12. Desilting of the existing tanks located at Thipramadevi, Vaidyanathapuram, Varadarajapuram, Singiliankombai, Sellipalayam and north of Varagur should be undertaken to increase the surface storage for recharging the ground water.

13. Conservation of ground water can be achieved by restricted use especially in the 'Over exploited' zones through (i) legislation or (ii) administrative and technical measures, such as limiting institutional finance for construction of additional wells or installation of pumpsets, adoption of
ERUMAIPATTI WATERSHED
AREA SUITABILITY FOR ARTIFICIAL RECHARGE
( CONSIDERING WATER QUALITY )

Proposed recharge structures
- Check dam
- Percolation pond

Figure XII.1

Constituting water quality

0.9 0 0.9 Kilometers
cropping pattern that requires less water like groundnut, millets etc, for irrigation. (Refer Chapter XI- Figure XI.1). Modern irrigation techniques can be adopted in the wet crop area for conserving the available water resource where sugarcane, paddy etc is cultivated.

14. The energy pricing mechanism should be such that it makes excessive withdrawal unattractive but also encourage water conservation. Aquifer related to deep fractured zones are tapped excessively for irrigation through borewells and dug cum borewells in the area between Singiliankombai – Varagur and in the bazada zone, which may desaturate the phreatic aquifer considerably. Attention is required to save such aquifer from destruction. Fracture simulation modeling study shall throw a lot of light and immediate action is needed.