CHAPTER XI
SUMMARY AND CONCLUSION

Situated at the southern part of the west coast of India, the delicate eco system prevailing in the Kerala coastal belt is affected by stress due to the rapidly growing population and unscientific exploitation of fresh water resources. This has resulted in the depletion of ground water aquifers of the coastal tracts especially that of Central Kerala, major portion of which is extracted from the unconfined aquifers, thickness of which varies from 3-27 Kms. The non judicious withdrawal of fresh water has also leads to detrimental impact on the water quality of the region mainly due to the migration of salt water in to the fresh water coastal aquifers due to a decrease in the seaward ground water flow which is necessary to maintain the balance between fresh water – sea water interface at safer depth. This exerts a disastrous and almost irreversible impact on fresh water coastal aquifers, if it is not managed timely and judiciously. It is under these circumstances that a detailed investigation, evaluation and monitoring (during different seasons) of water quality of the aquifer conditions of Central Coastal Tract of Kerala, extending from Azhikkode of Thrissur district to Ponnani of Malappuram district have undertaken for the present study. The main objective of the investigation is to establish the hydrological scenario and current status of this segment of the Kerala coastal aquifer belt. The outcome of the study can be applicable to other similar areas.

The study area is located between North latitudes $10^\circ 10' 49''$ and $10^\circ 46' 53''$ and East longitudes $75^\circ 54' 06''$ and $76^\circ 09' 12''$. It forms an integral part of the Arabian sea coast and stretches to 64 Km in length and 2.5 Km in average width, covering 160 sq Km. Out of this, 58 Km long stretches from Azhikkode to Andathode covering an area of 145 sq Km comes under Thrissur district and the remaining 6 Km, covering an area of 15 sq Km falls under the Malappuram district of Kerala. The entire study area is divided in to six zones viz. Azhikkode, Perinjanam, Nattika, Chavakkad (Thrissur district), Palappetty and Ponnani (Malappuram district)

Systematic monitoring of water level data from the sample stations of the study area indicate that the fluctuations of water table is from 1.21 m to 1.85 m during pre monsoon, from 0.56 m to 0.81 m during monsoon and from 0.88 m to 1.22 m during post monsoon. Critical evaluation and analysis of collected data shows that the recharge to ground water is greatly influenced by South-West monsoon and to a lesser extent by the North-East monsoon.
and that there is a direct relationship between rain fall and recharge through out the entire study area. Detailed analysis of rainfall data and water table fluctuation reveals that the rate of recharge reflecting the permeability of the area is more towards the southern zones of Azhikkode, Perinjanam and Nattika, compared with the northern zones of Chavakkad, Palappetty and Ponnani. This variation in recharge capacity observed between the southern and northern region may be due to the presence of clay matter or other impermeable matter present towards the northern region and the predominant sandy nature prevailing at the southern region of the study area.

Studies on water quality parameters of the study area reveal that during monsoon season there is no significant variations in temperature between zones. However temperature of the Ponnani zone is the lowest and is homogenous with Chavakkad and Palappetty zones. In the case of pH there is considerable variation between the different seasons. These changes in pH can also be directly correlated with the depth of variation in water table at different zones. Electrical conductivity values of northern zones, especially Palappetty and Ponnani are higher than southern zones. Least values of EC were observed at Perinjanam zone of the southern part of the study area. During monsoon season and post monsoon season most of the sample stations are represented with standard values of EC.

In the case of Total Dissolved Solid (TDS) values considerable variations were observed between the seasons. During pre monsoon, higher values of TDS were observed towards northern zones. Critical evaluation of the variation of TDS values shows that direct relationship exists between TDS and water table depth at different zones. Variations of turbidity values observed in the study area were associated with the seasonal changes and also related to the variations in the depth of water table. Zonal variation of acidity observed with in the study area during different seasons closely follows the changes in pH of the study area. Similarly alkalinity values also vary zone wise and also season wise. These variations in alkalinity values are also closely associated with the lowering of water table depth of the entire study area.

Variation of hardness observed was more towards northern zones of Ponnani Palappetty and Chavakkad. These zones record high values of hardness during the pre monsoon season compared with monsoon and post monsoon seasons. The chloride values show more variations during pre monsoon period in all sample stations of the study area. The rate of increase of chloride values are more pronounced towards the northern zones. This increase in chloride values is also associated with a corresponding decrease
in the pH value. The presence of high values of chloride in some sample stations is due the saline ingress into the aquifers especially during pre monsoon period. In to case of sulphate values there are considerable variations between the seasons. The value shows an increasing trend during the pre monsoon period. Northern zones of the study area are characterized by more sulphate values compared with southern zones. These changes in sulphate values are also reflected in the pH values.

According to the statistics from the local administrative bodies, population density of the study area is more towards the northern part. It is important to note that the population of Ponnani and Chavakkad municipal areas are high compared to Kodungallur municipal area (www.census india.net/results, www.prokerala.com/kerala/population.htm). Critical analysis of water quality data reveals that the quality of water decreases towards the northern part of the study area. Thus it is explicit that the influence of population density is an important factor in the deterioration of water quality. Another important factor which may adversely affect the quality of water towards the northern part of the study area is the presence of a major fishing harbour at Ponnani zone and minor fishing harbours at Palappetty and Chavakkad zones. Fish manure units and prawn peeling units associated with these harbours has a significant role in the deterioration of the quality of water of this area.

Water Quality Index (WQI) determined for the entire study area reveals that all sample stations of Perinjanam and Nattika zones are in the good category (class1/ slightly unclean) during monsoon and post monsoon periods. However towards the northern region of the study area i.e. Chavakkad, Palappetty and Ponnani zones, there is no sample stations belongs to the good category (class1/ slightly unclean) during the entire seasons of pre monsoon, monsoon and post monsoon. If we consider the average value of WQI most of the stations of the southern region viz. Azhikkode, Perinjanam and Nattika zones of the study area are in good category. But towards the northern part no sample stations come under good category (class1/ slightly unclean). All sample stations of the northern part of the study area fall under fair/marginal (class2- moderately/ excessively unclean) category. Thus from a critical analysis and assessment it is concluded that 42% of the study area belongs to good category (class1/ slightly unclean), 8% of the study area falls under fair category (class2/ moderately unclean), 47% of the study area are with in marginal category (class2/excessively unclean) and 3% are in poor category (class3/severly unclean). It is important to note that the results of the f water quality (physico-chemical parameters) analysis are also in agreement with the findings of the WQI studies.
Soil sample analysis of the study area reveals that the pH and EC variations of the samples from different zones are in accordance with the pH and EC values observed in water quality analysis. In general the pH of the soil samples are low towards the northern region whereas the EC values show an increasing trend compared to the southern zones which is in accordance with the water quality analysis data. Hence it is evident that the soil pH values and soil EC values have important role in determining the corresponding water quality of water of the study area.

Rainfall data analysis of the study area shows that the southern zones of Azhikkode, Perinjanam and Nattika altogether received 4031 mm of rainfall during the period of study. Out of this Chavakkad zone received 3909 mm, Palappetty and Ponnani zones 3102 mm rainfall during the study period. This shows a decrease in rainfall towards the northern region of the study area. This may also be one of the reasons for the deterioration of water quality towards the northern part of the study area.

The Quality-Depth Index (QDI) studies reveal that deterioration of water quality has a direct relation with increase in depth of water table. TDS and chloride values are increasing linearly with depth of water table and closeness to the salt water body is the main factor in determining the quality of water. The QDI value in a locality is extremely important because from this values the local inhabitants of the region can judge the quality of water prior to well digging in a particular area. Also the planners and executing hydro-geologists would be able to effectively propose a plan for the optimum extraction of ground water resources of coastal aquifers, if the parameter QDI and width of the sensitive zones are known a priori.

Many measures are possible for improving availability and quality of fresh water coastal aquifers. The first and foremost is the implementation of suitable recharging methods for coastal aquifer system such as recharge ponds/tanks, recharge wells, spreading channels (this method is particularly applicable to the present investigation area as it falls between the two major rivers of Kerala, namely Periyar and Bharathappuzha), extraction barriers etc. The following are the important remedial measures suggested against the problem of saline ingression.

- Recharging of existing wells/abandoned wells by making recharge pits with sand and pebbles, adjacent to the domestic well and by effectively directing the roof harvested water into the pit. This has to be made compulsory for all the inhabitants of the entire coastal area. For this necessary financial aid/scheme also has to be formulated by
the local/district/state administration. Local bodies/NGOs can also take up and implement existing schemes like ‘Mazhappolima’ in connection with this.

- Each well owners of the coastal area should make at least five to ten number of ‘rain pits’ around their well at a distance of approximately five meters apart from the well. This will ultimately lead to the enrichment of the aquifer and recharge to the well.

- Based on the results of the present investigation, the water quality status of each zone has to be published for the public awareness and necessary steps should be taken to maintain and improve the quality in those regions.

- Based on the aquifer status of each zone, the authorities should ensure judicious withdrawal of fresh water especially during pre monsoon season.

- Based on the WQI values of a particular zone, the quality of the water for drinking purpose has to be classified and published for public information.

- The local administers/authorities should publish the QDI values of each zone, so that the residents can judge the quality of water prior to digging of new wells. This will also help to identify and select suitable site for well digging.

- The study reveals that saline intrusion scenario is worse during the pre monsoon season. Therefore adequate measures has to be taken by the local governing bodies such as panchayats and municipalities for alternate water supply schemes to control the over exploitation of fresh water aquifers especially during pre monsoon season.

- Industries of the coastal zones that consume fresh water should be strictly controlled/prohibited by implementing suitable laws by the local administration/state government.

- Construction of small bunds/dams and spillways to prevent the salt water intrusion through the natural canals during the tides.

- In case of excessive ground water withdrawal, especially during the pre monsoon, artificial recharge is to be done by creating storage of fresh water by maintaining of head in aquifers to increase infiltration and also to increase detention – storage time of surface runoff through afforestation and other vegetative measures.
Installation of tidal regulators will help to prevent landward movement of sea water to a certain extent, while sub surface ingress can be effectively prevented by creating fresh water heads close to the saline body through ‘injection well barriers’. These injection tube wells are usually created parallel to the sea coast. This mechanism establishes a pressure ridge which will push the saline front seawards.

Remedial measures have to be done at war time basis whenever sea water intrusion has taken place.

The coastal areas have very fragile resource base that effect the economy, agriculture and other activities. The fresh water aquifers of this region are immensely precious and limited. Hence deterioration of the water quality and quantity of coastal aquifers due to saline ingestion have to be managed carefully and cautiously. The following are the key elements in coastal aquifer management.

Considering the rapidly growing population and the present unscientific exploration of fresh water resources and the fast depletion of ground water aquifers of the costal tract of Kerala, Government should take immediate steps to carry out a detailed and scientific investigation along the entire coastal tract of Kerala, using WQI and QDI techniques to establish the status of the entire coastal aquifers. The outcome of such a study will help a lot in tackling the health hazards of the coastal inhabitants related to the deterioration of water quality.

The state of Kerala has a fluvial control topography. Every inch of the land in Kerala is an integral part of one or other of the 44 river basins. Many of river mouths are facing the serious problem of saline ingestion. Hence an integrated river basin plan giving due consideration for the saline intrusion problem has to be formulated.

Making use of the QDI values of each zone of this coastal area the planners and hydro-geologists can plan and execute a proper implementable programme.

As a part of maintaining the fresh water aquifers in healthy condition, public awareness programmes should be conducted by NGOs with the help of local governing bodies.

Constant monitoring of the pumping and the movement of the fresh water-saline water interface are to be carried out.
Tidal influence in to the aquifer has to be studied in detail and to be monitored properly.

Safe yield of the aquifer has to be evaluated and accordingly the extraction has to be restricted.

Precaution is the best way to tackle the problems due to saline intrusion. If constant monitoring of the coastal aquifers is carried out, precautions can be taken at the right time to avoid future problems. Prevention starts where precaution ends. Certain regulations have to be implemented to discard the possibility of any untoward happenings in future.