CHAPTER 9

SUMMARY AND CONCLUSIONS

9.1 SUMMARY

Securing water for sustainable developments is a major challenge facing the global community. Provision of safe adequate water to meet demands of domestic sector remains a focal objective to be attained for developing countries. In today's world developing countries face fundamental environmental pressures induced by high population growth, rapid urbanisation, and deficient water sector services reflecting on improper water resources management. As such, communities seeking to cope with these challenges resort to an overexploitation of groundwater aquifers. Water samples were collected in different season and analysed as per standard procedure and to evaluate the quality of coastal groundwater system. Geophysical studies were conducted along the study area to identify the freshwater saltwater interface.

A numerical model of variable-density groundwater flow and contaminant transport is developed to investigate the extent of saltwater intrusion into the coastal aquifers of south Kerala. The SEAWAT code is used to solve the density-dependent groundwater flow and solute transport governing equations. Using the calibrated model and assuming all the hydrogeologic conditions remain the same as those in 1996, a predictive 40-year simulation run indicates that further saltwater intrusion into the coastal aquifers can occur in the study area. Moreover, the predicted intrusion may be more significant in the deeper aquifer than the shallower ones. As the population continues to grow and the demand for groundwater pumping intensifies, it can be expected that the actual extent of saltwater intrusion in the future would be more severe than the model prediction. Better strategies for groundwater management are developed by optimisation model.

9.2 CONCLUSIONS

Following are the conclusions drawn from the study

1. Water quality analysis showed that higher concentration of salinity is noticed at all places except Pulluvia during pre monsoon season, whereas, during post monsoon season, high concentration of salinity is found at Valiyathura, Pachalloor, Vizhinjam, Poovar and Pozhiyur.

2. Analysis using Piper trilinear diagram for the water samples collected from open wells established the fact of advancement of saltwater intrusion into the study area.

3. R-mode and Q-mode factor analysis was performed on hydrochemical data of water samples collected from open wells in the study area revealed that among three factors, factor 1 was highly dominant. The variables included in this factor showed that they were contributing to salinisation. Based on this scores of factor 1 areas were classified into areas having intense influence of salinisation, moderate influence and areas unaffected. This analysis also proved that Poovar – Pozhiyur stretch is intensely affected which is in line with the finding of water quality analysis.

4. The area prone to saltwater intrusion was identified by GALDIT model and indicators of saltwater intrusion such as $Cl/(HCO_3+CO_3)$ and (Na/Cl)ratio. GALDIT model shows that moderate to injurious contamination is found at almost all parts of the study area during post monsoon. The GALDIT model gives an idea of area vulnerable to contamination. Indicators of saltwater intrusion also gave results on the intensity and extent of saltwater intrusion in the study area which was almost identical to that derived through GALDIT model. The areas identified as strongly vulnerable to saltwater intrusion through these indicators conform to the earlier findings derived from multivariate and physical analysis of water samples.

5. Lateral extent of saltwater intrusion and trend line of saltwater freshwater interface are developed from the analysis of indicators. The saltwater freshwater interface

developed is considered as a guiding parameter for the selection of safe zone in which open wells can be developed in the study area.

6. Limiting depth of open wells at different stretches of the study area was estimated based on the information of the lateral extent of saltwater intrusion and vertical extent of freshwater. Series of curves are developed for different location which would serve as the design curves for fixing the depth of open wells at a specified distance from the sea. This has practical significance and will help in the design of depth and location of open wells in the coastal stretches of the study area

7. The results of simulation of groundwater flow model and contaminant transport model reflected clearly the effect of boundaries like rivers, rocky strata, confluence of streams, low elevation of water table etc.

8. Lateral extent of saltwater intrusion was estimated based on the advancement of concentration contour of value 2.8 (SWII contour). Under normal pumping, no wells are affected by saltwater intrusion even in 2020 and the maximum lateral extent was found to reach a value of 1.297km at Karikkakom pumping well location.

9. To predict the effect of urbanisation on saltwater intrusion into the study area, three scenarios are considered namely increase in pumping, reduction in recharge and average sea level rise. The definition and idealisation of these scenarios is carried out scientifically from the information obtained by analysing the landuse maps collected for a period of 40 years.

10. Under the effect of different scenarios of urbanisation such as increase in pumping, reduction in recharge and average sea level rise, it is seen that there is reduction in ground water head in all selected wells while considering the scenarios namely reduction in recharge and sea level rise. It is also inferred that out of the different factors of urbanisation considered in the present study, the reduction in recharge has the greatest impact and hence this factor has to be given due consideration when any developmental activity is taken up in the study area.

11. The effect of urbanisation on the advancement of saltwater intrusion into the wells was studied. It is seen that Pulinkudi and Valavunada pumping wells are strongly affected by saltwater intrusion wherein the lateral extent is 2.19km in 2011 and 2.35km in 2020, which is well ahead of 1.5km (well location). The well at Karikkakom is on the verge of saltwater intrusion by 2020 wherein the lateral extent becomes almost equal (1.52km) to the well location which is 1.5km.

12. The feasibility of existing pumping ratios in the wells in the study area were analysed through an optimisation – simulation model. The optimum values of pumping rate generated by the model were compared with the existing rates for the different wells. The wells which had higher pumping rate than the optimum rate were considered as infeasible. To make these wells feasible injection wells were proposed. The location and rate of injection were decided using trial and error approach. In the present study, it is seen that Valavunada is the feasible location and the feasible rate of injection is 150 m^3/day.

9.3 CONTRIBUTIONS FROM THE PRESENT RESEARCH WORK

Following are the contributions from the present research work.

1. Saltwater intrusion in a selected stretch of coastal tract is studied employing hydrochemical analysis, geophysical analysis, use of different indices/indicators and numerical modelling of groundwater flow and contaminant transport. In all the analyses, it was seen that the affected stretches were same.

2. Design curves specifying safe location and limiting depth of open wells in the selected study area were developed.

3. The key factors which will induce additional stresses due to urbanisation were identified by analyzing landuse landcover maps for a period of 40 years and the identified factors were increased pumping, reduction in recharge and average sea level rise. When the study area was subjected to these stresses and the

model was run for a future period of 10 years, it was seen that the greatest impact was created by the factor namely reduction in recharge and hence this urbanisation factor requires maximum concern in the study area.

4. The simulation optimisation model applied to the study area yielded feasible rates of pumping from the pumping wells in the area to prevent saltwater intrusion. Wherever the existing rates exceeded the feasible rate, attempts to improve the situations were tried using injection wells.

9.4 SCOPE FOR FURTHER STUDIES

The coastal groundwater system may be monitored on a micro level scale and preferably on spatial platform leading to the development of an information system about the coastal groundwater system of the study area. Similarly the land use /land cover changes and the landscape alteration have to be evaluated with respect to the predicted climatic change. Later these two studies can be integrated to find out the impacts of the climatic change predicted for the study area.