CHAPTER 11
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary of the work carried out along with the conclusions drawn is presented in this Chapter. On the basis of the observations made in the different Chapters recommendations for the management of the groundwater resources and further studies are given.

11.1 Summary and Conclusions

The Kozhikode coast is 72.5 km long and it extends from Kadalundikadavu in south and Aliyur in the north near Mahi river covering an area of 91 sq.km. The coastal area is thickly populated and also have a humid tropical climate with an average rain fall of 3000 mm. Kuttiyadi, Kallayi, Chaliyar and Kadalundi are the major rivers draining the coastal belt. The coast has a large backwater body and is formed by the confluence of Agalapuzha with Panurpuza and it meets the sea at Elathur.

The coastal alluvial soil is distributed all along the coast. The riverine alluvium composed of moderately well-drained soil is distributed mainly on the banks of rivers and their tributaries. The various geomorphic units identified from the
coastal area of Kozhikode include beach, sandbars, shore platforms, lateritic hills and valleys. Two major types of shorelines are identified in Kozhikode coast, namely cliffed and neutral.

The Kozhikode coast is mainly underlain by hardrocks of Archaean age forming part of peninsular shield. Archean rocks include charnockites and gneisses. Laterite is also found in Kozhikode region. Based on the lithological units present the coast can be grouped into coastal sandy formation, coastal alluvial formation, coastal alluvial-laterite formation and laterite formation underlain by crystalline rocks.

The sub-surface geology of the coast has been studied using bore hole data. The coastal stretches of Kozhikode comprises of four types of aquifer zones namely sandy, lateritic, weathered rock, and fractured rock. The bed rock depth of the coast varies from 20 to 35 m. The bed rock encountered in all the bore holes are quartz-feldspathic and granitic gneisses. The thickness of various aquifers tapped from the bore holes are given in Ch. 3. Analysis of bore holes show that there are three types of fractured aquifers along and across the coast. They are (a) weathered rock aquifer above the basement rock (b) weathered and
fractured aquifer and (c) fractured rock aquifer below the basement. They are low to moderately permeable, sub-horizontal to horizontal fractures between the massive gneissic rocks.

Hydrogeological observations are made from 150 wells along the coast. Based on this information 36 permanent observation wells are identified for regular monitoring of water levels and water quality parameters for four years. Study shows that small diameter wells of 0.70 to 0.80 m are found in abundance in sandy formation. More than 1.00 m. diameter wells are found distributed towards coastal alluvium and laterite formation. The coastal open wells along Kozhikode coast can be grouped based on depth of penetration, cross-sectional area and formation are given in Ch. 4.

A close look at the depth-to-waterlevel data through the observation network all along the coastal belt of Kozhikode coast indicate that there are 6 main groundwater fluctuation zones with mean annual fluctuation of 0.50, 0.75, 1.00, 1.50, 2.00 and 3.00m. Near the shore the groundwater is found shallow. Depth to water along the coast and across the coast vary from 0.21 to 4.5m below the groundlevel. Wells near the backwater bodies also show high water level. Coastal wells near the shore, but situated at
high grounds of sand bar, show low ground water level. Naduvattom beach is one of the examples of such phenomena. Temporal variations of depth-to-water level is minimum along the shore, whereas they are maximum away from the shore. Perched water table conditions are noted in the coastal areas of east Kallayi, part of west Kallayi and KSRTC bus stand near Mavur road. The above mentioned places are marshy during rainy season and water logging is also common. In this area near the surface clay-bed separates the underlying sandy zone giving rise to perched water table conditions.

The analysis of the pumping test data of open wells show that the discharge of the wells vary from 15 lpm to 292 lpm. The rate of inflow of the well depends on the type of geological formation and the diameter of well. The recuperation rate is found to vary from 15 lpm to 20 lpm in coastal sandy formation, but it is found 3.5 lpm in alluvial formations. The inflow of laterite wells show 2 to 3 lpm indicating low recuperation rate. Hence laterite wells can be pumped once in a day. These wells take one full day for recovery. Other wells show that they can be pumped twice in a day. These wells take 2 to 7 hours to obtain full recovery. Depth of water columns in different wells in different seasons are mentioned. The estimated availability of

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water from wells of 1.5 diameter are given in Ch. 4.

The piezometric surface of the crystalline rock aquifer varies from 2.67m to 19.00m The discharge of the bore wells vary from 129m to 731 m$^3$/per day. For evaluating aquifer parameters five pumping tests are carried out. The test results indicate that there are two types of hydraulic conditions. Test data analysed is fitting with Boulton curve as these aquifers are unconfined. The transmissivity of these aquifers range from 1.60 to 19.69 m$^3$/day. The permeability of the aquifer varies from 0.16 m/day to more than a 1.00 m/day. The fractured zones tapping the borewell at Namenkulan is of confined nature, as the field data is fitting the Theis type curve. The transmissivity of the well is found to be 6.70 m$^3$/day.

The recharge to coastal groundwater is evaluated by analysis of water level fluctuation in observation wells and by rainfall-recharge method. Thus the groundwater availability in the top unconfined aquifer along the entire Kozhikode coast comes out to be 27 MCM and an average utilisation is of the order of 31% through an estimated 23,478 open dug wells along the coast. The distribution of groundwater availability and utilisation in the above mentioned coastal stretches are presented in table 6.1.
Utilization is found to vary from 50% to 75% towards the coast from inland in that order.

For arriving at the groundwater utilisation and use pattern field surveys are conducted at two representative areas, i.e. Tiruvangur-Pookad and Meladi-Payyoli areas. In the estimated 23,478 wells, 97 to 98% are operated manually and only 2 to 3% of wells are fitted with pumps. The result also shows that the wells are lined either by concrete ring or by laterite bricks. Most of the wells are found open and have no platform around. The average draft from domestic wells along Kozhikode is found to be 800 litres/day. Assuming a conservative draft of 800 litres/day per well estimation for the total draft for domestic needs comes to 18.8 X 10^6 litres per day. The irrigation wells in the coastal zone seem to be negligible in number and hence draft from these wells can be neglected. The results of the investigation indicate that out of an estimated annual recharge of 27 billion litres, the annual groundwater draft is found to be only 6.4 billion litres which points towards a great untapped potential underneath. These figures agree with the results obtained with the groundwater fluctuation method.

Water quality problems due to coconut husk retting,
industrial waste, to fishing and agriculture are discussed. The general groundwater quality of open well in Kozhikode coast are studied from a network of 36 open wells. The chemical parameters like pH, T.D.S., chloride, magnesium, calcium, iron, total hardness and conductivity of water samples from open wells are determined.

Generally water quality of open wells along coast are found neutral in character during pre-monsoon season. The well water becomes alkaline in character in other seasons. Perched water table conditions of the wells located in coastal alluvial zone and adjacent coir retting zones may be the cause of low pH in well water. Results reveal that certain pockets in Kozhikode coastal stretches are found to contain hard water and are due to concentration of lime industries. Groundwater is found to contain excessive iron (greater than 1 ppm) at Beypore port, Edakulam Beach and in Kozhikode city near KSRTC bus stand.

The field investigation and chemical data on water samples from wells at Aliyur, Payyoli and Chaliyam indicate that groundwater remain unpotable throughout the year. This unpotability is due to the high pH, iron and TDS. Barring the pockets mentioned above groundwater along the coast of Kozhikode is found to remain potable throughout the year.
Sea water intrusion studies along the coastal belt of Kozhikode region show the qualitative response of change of depth-to-water table to the change of water quality parameters (TDS and Chloride) in the coastal unconfined aquifer. Pattern of variation of quality parameters with depth-to-water table is similar to other coastal aquifers.

An exponential decrease of QDI (Quality Depth Index) with well distance (from the shoreline) is observed. The coastal aquifers of Kozhikode can be divided into sensitive and insensitive.

The QDI variation is in between 2000 and 60 ppm/m for TDS and in between 800 and 15 ppm/m for chloride. Nearer the well to the coast, higher is the value of QDI. At higher distances from the shore, it is found that QDI is insensitive to the change in depth.

The estimated width of sensitive zone in Kozhikode coast extends up to 400 m from the shore. This zone should be avoided while drilling any deep tube wells or bore wells along the coast.

Identification of sensitive zone is extremely important, because much care has to be taken to maintain minimum possible
depth for groundwater table. This can be achieved by a combination of restricted groundwater withdrawal and appropriate recharging in this zone.

Groundwater must be managed efficiently and within the management there should be a programme of periodic monitoring of wells to determine whether groundwater resources are shrinking or becoming more saline.

Preservation of natural vegetation, preservation of beach ridge gradation, regulation of growth of wells and construction of barriers are the major suggestions put forth for reducing the seawater intrusion problems along the coast.

The exact depth of fractured zones giving saline zones are given in Section 9.3.4. Similar saline problems are also found at Vadakara, Thiruvangur, Beypore and Kozhikode beach. Saline groundwater can be sealed off putting concrete blocks inside the bore and gradually the hole can be plugged with cement thus arresting the salinity intrusion permanently. The salinity in these fractures may be due to interconnections of fractures towards the sea. The saline water trapped in the clay and soil layers may also be percolating down and causing the salinity in
these fractures.

The salinity levels show the following variations in different stretches of the entire coast.

<table>
<thead>
<tr>
<th></th>
<th>Pre-Monsoon chloride in ppm</th>
<th>Monsoon chloride in ppm</th>
<th>Post monsoon chloride in ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Aliyur-Kottakkal stretch</td>
<td>100-5000</td>
<td>20-100</td>
<td>20-30</td>
</tr>
<tr>
<td>b) Kottakkal-Kollam stretch</td>
<td>50-150</td>
<td>20-150</td>
<td>10-30</td>
</tr>
<tr>
<td>c) Kollam-Korapuzha</td>
<td>50-100</td>
<td>10-30</td>
<td>10-30</td>
</tr>
<tr>
<td>d) Korapuzha-Kallayi</td>
<td>150-300</td>
<td>50-200</td>
<td>50-150</td>
</tr>
<tr>
<td>e) Kallayi-Kadalundikadavu</td>
<td>50-200</td>
<td>30-50</td>
<td>20-50</td>
</tr>
</tbody>
</table>

The sea level is estimated to be rising 3 mm per year due to the normal eustatic processes accelerated by Greenhouse effect. If we assume a rise in sea level at the above mentioned rate the parts of coastal stretches that will be affected along the Kozhikode coast are parts of Aliyur-Kottakkal stretch, Elathur and low lying areas adjacent to Korapuzha, low lying parts of Moratupuzha, Chaliyam and Kadalundikadavu.

The management of groundwater systems are studied on the basis of natural and man-made problems in Kozhikode coast. The
problems due to natural phenomena include, coastal erosion, sea level rise and the damages due to tidal influx. The latter problems of groundwater management in Kozhikode are due to man-made factors such as (i) mining and development (ii) coir retting (iii) lime and other industries (iv) fishing industries (v) agriculture (vi) seawater intrusion (vii) indiscriminate drilling and associated problems and (viii) overpumping of bore wells. Suggestions for better management of coastal groundwater system are made. Further studies to be taken up in the protection, management and rational use of groundwater along the coast of Kozhikode are given.

At the present rate of groundwater exploitation and well development a scarcity for groundwater resources is likely to be experienced along Kozhikode Coast by the year 2058. Based on the hydrogeological studies, type of extraction structures and the availability of water future development plan of groundwater resources for Kozhikode coast is drawn. Specific recommendations for managing the groundwater resources are brought out taking into account the conservation, quality and salinity aspects.
11.2 Recommendations for Further Research

Based on the above study the following recommendations are made on the scientific management of groundwater resources of coastal belt of Kozhikode.

The coastal belt needs an oriented development on the basis of aquifer types. Regulation of groundwater withdrawal as per sustained yield capacity to retain the chemical quality of formation water tapped by the structure is also required.

A detailed study is recommended in the sand-laterite boundary for assessing the feasibility of making subsurface dams to arrest the subsurface flow of water in small valleys and between the laterite hills.

Groundwater development and conservation practices like harvesting rain water, deepening tanks and ponds and constructing sumps for collecting water are to be planned in the sand-laterite border area.

Periodic monitoring of groundwater levels and chemical quality to safeguard the precious groundwater reservoir from salinity and other quality problems is required.
Investigate and study the dominant characteristics of physico-chemical properties of groundwater under the action of natural and artificial factors and their relationship with physiological reaction in human body and various diseases. For example the harmful substances such as phenol, ethane, mercury, chromium, arsenic, etc, having detected in water, the organic substances such as nitrate, pesticide and fertiliser, the radioactive pollutants, and even the hardness of water which have brought serious harm to people’s health in a number of industrial cities.

For managing the groundwater along coast an investigation on groundwater contamination caused by man’s activity and it’s prevention is an important component. For managing the groundwater system along the coast, there is a need to study the conditions of groundwater contamination, the source of pollution, access of pollution, the intensity, distribution of pollution and also develop new techniques for relevant protection and treatments.

The groundwater quality is bound to affect the service life of machinery and concrete structures placed below the ground surface as part of foundation of bridges, buildings and the like.
It also would accelerate the corrosion of metallic pipes and tanks leading to leakage of fluids that are either transported or stored in these coastal areas. Contamination of aquifers of low lying coastal areas is a serious threat warranting research to identify suitable remedial measures.

Coastal aquifers face a very high probability of recharge by waters of high salinity by the entry of large volumes of sea water into the lagoons and wetlands, by way of washover of sea water to the backshore during storms, and by landward translation of sea water/ freshwater interface due to its deformations all resulting from the problem of sea level rise. Any new drinking water supply scheme proposed close to the seashore should be shifted to inland locations.

The new investments in the coastal zones for new buildings, bridges etc. should be planned taking into account the possible deterioration due to low groundwater quality resulting also due to sea level rise. Other appropriate measures are also to be adopted to face the challenges of sea level rise in the coastal areas.

Groundwater desalination plants are to be designed in the coastal areas for supply of drinking water to those areas under
threat of saline intrusion. Other suggestions made in the Govt. of India notification (Department of Environment, 1991) may also be implemented for preservation of groundwater system in the coastal stretches of Kozhikode.