CHAPTER VI

DISCUSSION & CONCLUSIONS
The research area considered is a place close to the west coast of India, in Karnataka State, Uttar Kannada District. The Bhatkal and Shirali are two townships in southern part of the said district. The study area is bounded by the Arabian Sea on the western side and Western Ghats on the eastern side. The laterites are the litho units in the study area. These laterites are derived from the weathering of granitic gneisses of Precambrian age. The laterites possess primary openings in the form of cavities and secondary openings in the form of fractures and fissures. These openings help in infiltration of rain water and storage and movement of groundwater in aquifer system. The study area is close to Western Ghat and receives on an average of 5000 mm rainfall from southwest monsoon. A part of water flows into the Arabian Sea and a part of it infiltrates into the ground to form groundwater. The groundwater occurs in unconfined conditions within the laterite and highly weathered and fractured granitic gneisses.

The groundwater is popularly extracted from the dug wells and rarely from the bore wells. During monsoon season (August month) the water table is close to the groundwater level and overflowing of the dug wells is a common feature in the study area. The hard laterite exposed on the surface is not uncommon. Wherever lateritic
reddish soil is found the agriculture is practiced. Groundnut, paddy and others are the major crops. Cashew and coconut plantations are very common in the study area.

The laterite occurs upto a depth of 20 meters and it grades into granitic gneisses. There are two rivers in the study area viz., Venkatapur and Sabri. Both these rivers originates in the Western Ghat hills and flow towards Arabian Sea. The groundwater also flows towards west. The water table fluctuation is less close to the coast and more away from the coast. The vulnerability study using DRASTIC and GALDIT models show susceptibility of laterites for sea water intrusion and other pollutants.

The chemical characters of groundwater show that it is suitable for drinking and agricultural uses, except from some localities. The groundwater quality during post monsoon season is low in soluble constituents when compared to the pre monsoon season samples. This may be due is the addition of fresh monsoon rains into the aquifers. The groundwater close to the coast is more saline when compared with groundwater away from the coast. There is significant increase in the EC values from March 2001 to March 2002. This may be due to low rainfall in the monsoon season of 2001 year. There are some localities in the study area where the sewage water is mixes with groundwater. The biological oxygen demand values are more than the prescribed limits in such localities. The groundwater quality of the study area is comparable with other coastal tracks of India, and is distinctly different from the inland groundwater samples from the lateritic terrains.

The closeness of Arabian Sea and porous nature of the litho units in the study area have vulnerability for the intrusion of area water and water pollution. The influx of sea water into the two rivers has caused salinity into the wells close to the rivers. Large quantity of surface water flows into sea through base flow. The heavy pumping of groundwater has caused upconing of sea water into to the wells. The ionic ratios of some contaminations show that there are sea water contaminations into the fresh water aquifer system. There is wide variation in the ionic ratios of the groundwater samples from study area and inland groundwater samples from the lateritic terrains.

A physical model is proposed for management of surface water and prevention of sea water intrusion. A lined canal is proposed to transport stored water during dry season and is forced into ground to withhold sea water intrusion.
CONCLUSIONS

The detailed study of hydrogeological characters around Shirali and Bhatkal area has revealed following points;

1) The topography is undulating with variation of ‘0’ meters MSL to ‘60’ meters MSL elevations.
2) There are two perennial rivers viz., Venkatapur and Sarbi.
3) The general drainage pattern is dendritic and all rivers flow from east to west and join the Arabian Sea.
4) There is good amount of natural vegetation with coconut and cashew plantations.
5) The plain areas are used for the agriculture purposes.
6) The south west monsoon is the main source of rainfall.
7) The average annual rainfall is around 5000 mm.
8) The study area is accessible in seasons by motorable roads.
9) The laterites are the litho units and they are derived from alteration of Precambrian granitic gneisses.
10) The low lying plain areas are covered with red coloured lateritic soils.
11) The laterites are found upto a depth of 20 meters approximately.
12) The laterites possesses primary openings by virtue of cavities and secondary openings by the presence of fractures and fissures.
13) These openings help in easy infiltration of rain water, storage and movement of water as groundwater.
14) The study area is divided into 50 grids. Each grid is with 1 sq.km dimension for further study.
15) At each grid static water levels and the characters of dug wells are recorded and studied.
16) The water table fluctuates from 0.08 meters to 3.5 meters.
17) The water table fluctuation is little close to the coast, and more away from the coast.
18) The water table contour maps show that sub-surface groundwater flows towards west that is towards Arabian Sea.

19) Hydraulic gradient values varies from 2 to 17 meters / km. Close to the coast it is slow and moderately fast away from the coast.

20) The groundwater is popularly recovered by dug wells and rarely by bore wells.

21) The vertical electrical sounding study show general low resistivity values close to the coast and slight higher resistivity values away from the coast.

22) The low resistivity values indicate possible subsurface saline water intrusion close to the coast.

23) The aquifer characters like transmissivity (T), storativity (S) and hydraulic conductivity (K) are estimated by conducting pumping tests at 10 locations distributed throughout the study area.

24) The transmissivity values varies from 76 to 4117 m²/day The storativity values varies from $1.10 \times 10^{-4}$ to $7.2 \times 10^{-3}$ and hydraulic conductivity values varies from 1.90 to 205 meters /day.

25) The groundwater recharge is estimated by utilizing rainfall data and it is $37.14 \times 10^6$ m³.

26) At each grid groundwater samples are collected from regularly used dug wells.

27) Each groundwater sample is estimated for major cat and an ions viz. Ca, Mg, Na, K, HCO₃, CO₃, Cl and SO₄. In addition to these major ions the groundwater samples are estimated for pH, EC, TDS and TH.

28) The high values of Na and Cl in pre monsoon groundwater samples close to sea indicate possible intrusion of sea water into the aquifer during dry seasons.

29) In the pre monsoon samples Ca varies from 4 to 115 mg/l with an average of 20 mg/l. 19 samples are above average and 31 samples below average.

30) In the pre monsoon samples Mg varies from 1 to 42 mg/l with an average of 8 mg/l. 19 samples are above average and 31 samples below average.

31) In the pre monsoon samples Na+K varies from 23 to 397 mg/l with an average of 69 mg/l. 14 samples are above average and 36 samples below average.

32) In the pre monsoon samples HCO₃+CO₃ varies from 60 to 450 mg/l with an average of 139 mg/l. 19 samples are above average and 31 samples below average.

33) In the pre monsoon samples Cl varies from 17 to 710 mg/l with an average of 70 mg/l. 8 samples are above average and 42 samples below average.
34) In the pre monsoon samples SO$_4$ varies from 12 to 86 mg/l with an average of 24 mg/l. 21 samples are above average and 29 samples below average.

35) In the pre monsoon samples pH varies from 4.9 to 8.1 with an average of 7.14. 26 samples are above average and 24 samples below average.

36) In the pre monsoon samples EC varies from 140 to 3400 micro mohs/cm with an average of 722 micro mohs/cm. 18 samples are above average and 32 samples below average.

37) In the pre monsoon samples TDS varies from 88 to 2142 mg/l with an average of 459 mg/l. 18 samples are above average and 32 samples below average.

38) In the pre monsoon samples TH varies from 22 to 460 mg/l with an average of 83 mg/l. 15 samples are above average and 35 samples below average.

39) In the post monsoon samples Ca varies from 3 to 90 mg/l with an average of 17 mg/l. 20 samples are above average and 30 samples below average.

40) In the post monsoon samples Mg varies from 1 to 41 mg/l with an average of 8 mg/l. 20 samples are above average and 30 samples below average.

41) In the post monsoon samples Na+K varies from 6 to 335 mg/l with an average of 60 mg/l. 13 samples are above average and 37 samples below average.

42) In the post monsoon samples HCO$_3$+CO$_3$ varies from 50 to 360 mg/l with an average of 126 mg/l. 18 samples are above average and 32 samples below average.

43) In the post monsoon samples Cl varies from 16 to 605 mg/l with an average of 62 mg/l. 8 samples are above average and 42 samples below average.

44) In the post monsoon samples SO$_4$ varies from 8 to 66 mg/l with an average of 22 mg/l. 20 samples are above average and 30 samples below average.

45) In the post monsoon samples pH varies from 5.5 to 8.9 mg/l with an average of 7.64 mg/l. 20 samples are above average and 30 samples below average.

46) In the post monsoon samples EC varies from 158 to 1997 micro mohs/cm with an average of 706 micro mohs/cm. 18 samples are above average and 32 samples below average.

47) In the post monsoon samples TDS varies from 100 to 1258 mg/l with an average of 443 mg/l. 17 samples are above average and 33 samples below average.

48) In the post monsoon samples TH varies from 15 to 393 mg/l with an average of 75 mg/l. 17 samples are above average and 33 samples below average.
49) Most of the constituents in collected groundwater samples are within the proposed ranges of WHO, ISI and ICMR standards for domestic uses with a few exceptions.

50) The groundwater samples show following hydrochemical types (Piper, 1944)
   a) Carbonate hardness exceeds 50%
   b) Non-Carbonate hardness exceeds 50%
   c) Non Carbonate alkali exceeds 50%
   d) Carbonate alkali exceeds 50%
   e) No one cat ion – an ion pair exceeds 50%

51) The groundwater samples show following hydrochemical facies (Back, 1966)
   a) Ca + Mg – Na + K
   b) Na + K – Ca + Mg
   c) Cl + SO₄ – HCO₃
   d) HCO₃ – Cl + SO₄

52) The Scholler’s classification classifies groundwater samples into
   a) Oligo chloride and normal chloride water
   b) Normal sulphate water
   c) Normal and under carbonate water
   d) Both positive and negative index of base exchange

53) Based on % of An and Cat ion concentrations,
   a) Cl > CO₃ > SO₄, CO₃ > Cl > SO₄ and CO₃ > SO₄ > Cl
   b) Na > Mg > Ca, Na > Ca > Mg, Ca > Na > Mg and Mg > Na > Ca

54) The Soutine’s classification classifies groundwater samples into
   a) Na-SO₄ water
   b) Na-HCO₃ water
   c) Mg-Cl water
   d) Ca-Cl water

55) The Alkin’s classifications classifies groundwater samples into
   a) HCO₃ > (Ca+Mg)
   b) HCO₃ < (Ca+Mg) < (HCO₃ + SO₄)
   c) (HCO₃ + SO₄) < (Ca + Mg) or Cl > Na

56) The Durov’s classification classifies groundwater samples into
   a) Pure water
   b) Uncontaminated water
c) Moderate quality water

57) The groundwater samples have acquired their chemistry by interacting with litho units (Gibbs, 1970).

58) Based on CR values most of the groundwater samples are non corrosive and only few are corrosive in nature.

59) There is a significant increase in the ionic values in the premonsoon groundwater samples when compared to the post monsoon groundwater samples.

60) The groundwater samples are studied for the suitability for agricultural uses by estimating popularly used ionic ratios, like % Na, SAR, TDS, RSC, KI, Salinity, NCH, PI and PS.

61) Based on % Na ratios, a few samples are safe and more number of samples are unsafe and doubtful to unsuitable for agricultural uses.

62) Based on SAR values, all samples are excellent to good for agricultural uses.

63) Based on EC / TDS values all samples are excellent to good for agricultural uses.

64) Based on RSC values only five samples are poor in character and others are good to medium for agricultural uses.

65) Based on KI values 42 samples show alkali hazardous character and only 8 samples are free from alkali hazards for agricultural uses.

66) Based on USSSL classification samples fall in moderate salinity – low sodium hazards group and medium salinity – medium sodium hazards group for agricultural uses.

67) Based on Wilcox classification, samples fall in excellent to permissible group and doubtful to unsuitable group for agricultural uses.

68) Based on salinity level more number of samples shows no problem for agricultural uses.

69) Based on chloride concentration maximum number of samples shows no problem for agricultural uses.

70) Based on bicarbonate concentration more number of samples falls in increasing problem group and few in the no problem group for agriculture uses.

71) Based on sulphate concentration all samples fall in excellent class for agricultural uses.
72) Based on adjusted SAR values maximum number of samples fall in no problem for toxicity and permeability group and a few samples cross this limit for agricultural uses.

73) Based on NCH values maximum numbers of samples are safe and a few samples are unsafe for agricultural uses.

74) The permeability index and potential soil salinity values fall in the unsafe and injurious to unsatisfactory classes.

75) The groundwater samples are free from soft and hard type incrustations but are of corrosive in nature.

76) The electrical conductivity (salinity) values are higher in the samples close the coast and lower in the samples away from the coast.

77) There is increase in the EC values from March 2001 to March 2002. This may be due to the lack of rainfall in 2001 (i.e., less amount of fresh water recharge).

78) The chemical characters of groundwater samples are compared with the groundwater samples from other areas where laterites are the litho units.

79) The chemical characters are comparable with coastal samples from other areas and are significantly different from the inland area samples.

80) In some parts of study area the underground drainage system is not available but popularly septic tanks and cesspools are used. At many places open garbage pits are found.

81) The leachets of garbage pits, effluents of septic tanks and leakages from underground drainage systems in thickly populated areas have caused pollution of groundwater.

82) The groundwater samples from polluted areas show high concentration of Biological Oxygen Demand (BOD).

83) The BOD values range from 4.4 to 13.6 indicating that the groundwater is highly polluted by organic matter.

84) The laterites being highly porous and are susceptible for movement for sea water into the aquifer during high tides and during dry season, when the aquifers are with little quantity of water.

85) The vulnerability study using DRASIC and GALDIT models show susceptibility of the laterites for sea water intrusion and other pollutants.

86) The depth to the saline water and fresh water interface is estimated by Ghyban-Herzberg equation and it varies from 60 to 440 meters.
87) The interface is closer to the ground level during post monsoon period than in pre monsoon period.

88) The steady flow of groundwater towards sea varies from $-1.2 \times 10^3$ to $-9.6 \times 10^5$ m/day.

89) The width of outflow varies from $-20.55$ to $-2182$ meters/day.

90) The height of water table at a known distance from the coast varies from 10.39 to 99.10 meters.

91) The fresh water flow rate from groundwater reservoir to the sea varies from 0.11 to 28.90 m$^2$/day/meter length.

92) There is significant upconing of sea water into the well where pumping is practiced.

93) The rate of pumping in wells per day is estimated and suggested at 10 locations.

94) The ionic ratios viz, TA / TH, Na / Cl, Cl / SO$_4$, Ca / Cl, Mg/Cl, Cl / CO$_3$+HCO$_3$, Na / Ca+Mg and [Cl$^-$ (Na+K) / Cl] are calculated to know the intensity of sea water intrusion into the aquifer system.

95) The above ratios show there is significant intrusion of sea water into the aquifers close to the sea and less significant away from the coast.

96) The sea water influx into the rivers is studied by collecting water samples from two rivers of the study area. These samples are collected along the rivers courses in upriver direction at an interval of one km in different seasons. The samples are subjected for estimation of EC values.

97) The EC values are high in the rivers in dry season indicating transgression of sea water along the river, because of low river flow rate.

98) The groundwater samples close to the estuaries / rivers show high concentration of dissolved solids in dry season samples.

99) The ionic ratios used to determine the sea water intrusions are used to compare with the inland groundwater samples from lateritic terrains of Belgaum and Bidar areas.

100) The ionic ratios values are distinctly different from the coastal and inland groundwater samples.

101) A physical model is proposed to combat with sea water transgression during dry seasons into the aquifer system.
102) The proposed model is quite different from the techniques proposed by the earlier researchers. A lined canal is proposed to transport stored water during dry season and forced into ground to withstand sea water intrusion.

103) Locations for sand and sand + cement barrages are proposed to restrict sea water movement into the rivers during slow movement of rivers (dry seasons).

104) There is a need to check the over pumping of groundwater in the study area i.e. the water resources should be used judiciously.

105) The transgression of sea water should be managed by forcing more surface water to infiltrate into the ground.

106) It is essential to check the pollution of groundwater by the septic tanks, cesspools and garbage pits as the litho units in the study area are highly vulnerable to pollution intrusion.

107) The irrigation return water into aquifer is significant in the study area.

108) The use of fertilizers, pesticides and insecticides should be minimized for agricultural practice. The leachates from the soil infiltrate into the aquifer system along with the undigested fertilizers, pesticides and insecticides.

109) The study has helped in demarcating polluted locations from unpolluted ones and the areas of sea water intrusion. The local people are advised not to use such polluted and contaminated groundwater.

110) It is advised to use poly vinyl chloride (PVC) pipes instead of iron or galvanized iron pipes in the areas where corrosivity ratio of groundwater is more than one.

111) The flow chart of surface and groundwater system in the study area is given in next page.
FLOW CHART OF SURFACE AND GROUNDWATER SYSTEM

1. Precipitation / Rainfall
   - Atmosphere
     - Evaporation
   - Land Surface
   - Sea Surface
     - Evaporation

2. Infiltration
   - Surface Runoff
     - Sea
       - Evaporation
   - Deep Aquifer
   - Shallow Aquifer
     - Dug Wells
     - Bore Wells
     - Domestic or Agricultural Uses
       - Evaporation
       - Atmosphere