Chapter 6. Future Scope

This study has enabled identification of important geohydrological processes and the controls that topographic, climatic, tectonic and geothermal factors exert on the quantity and quality of groundwater in the NGC region. While some of the conclusions may appear not fully substantiated at present, an effort is made to suggest future studies that will either confirm or reject the conclusions in favour of more viable models/ hypotheses leading to further improvement in understanding of the operating hydrologic processes.

6.1 Injection of Hydrothermal Fluids

The geographical coincidence of very high concentrations of dissolved ^4He in groundwater and high groundwater temperatures in certain pockets overlying the basement faults in the NGC region, has been ascribed to injection of deeper fluids (having high temperatures and high dissolved helium) in groundwater overlying the deep seated faults and fractures. This opens up the possibility that some of these fluids may be coming up from deep crustal/ upper mantle region. In the present study, it has not been possible to check if these hydrothermal fluids originated from the deep crustal region or else from the upper mantle. This can, however, be checked using $^3He/^4He$ isotopic ratio measurements in ground waters.

In addition to the atmospheric noble gases (He, Ne, Ar, Kr, Xe, Rn) dissolved in solubility equilibrium, groundwater can also have two other terrigenic components (Kipfer et al, 2002). These can be of: (i) crustal origin; and/ or (ii) mantle origin; each with characteristic $^3He/^4He$ ratios. The continental crust is dominated by the heavier isotope of helium (^4He) that is produced radiogenically in the crustal rocks and minerals. Therefore, crustal rocks and minerals have $^3He/^4He$ ratio ($<10^{-7}$; Mamyrin and Tolstikhin, 1984; Ballentine and Burnard, 2002). The earth's mantle, on the other hand, contains besides radiogenic ^4He relatively higher proportion of isotopically lighter helium (^3He) inherited during formation of the earth and has a distinct $^3He/^4He$ ratio ($>10^{-5}$; Mamyrin and Tolstikhin, 1984; Porcelli and Ballentine, 2002; Graham, 2002). This provides a means for identifying the deep crustal/ mantle fluids and has also been used to infer the possible signatures of mantle fluids in groundwaters and deep lake waters from different parts of the world (Imbach, 1997; Hoke et al, 2000; Kipfer et al 2002).

In India, helium isotopic investigations of several thermal springs in the Narmada-Son-Tapti rift zone do not indicate the presence of any appreciable amount of primordial ^{3}He (Minissale et al, 2000). However, such an investigation has not been carried out in the NGC region and may, therefore, be useful to check if there is an influx of fluids originating from the upper mantle. The present study can be advantageously used to identify suitable sites for collecting groundwater samples having high dissolved helium and high temperatures, in which $^{3}He/^{4}He$ ratio can be measured to identify the source region of the hydrothermal fluids and to ascertain if there is any significant contribution of mantle derived fluids in relatively shallower groundwater.

6.2 Estimation of Palaeo-recharge Temperature

This study has identified imprints of past aridity around the Last Glacial Maxima (LGM) in the NGC region in the form of higher values of fluoride concentration and EC, higher values of $\delta^{18}O$ and δD, and lower values of *d*-excess in groundwater recharged around 20 ± 5 ka BP (Section 4.2.2 and 4.2.3). This inference from chemical and isotopic proxies relates the observed signatures in groundwater to the possible effect of (i) increased evaporation, (ii) increased dry deposition and (iii) decreased rainfall, on groundwater recharged during relatively more arid climate that possibly prevailed in this region in the past (Prasad and Gupta, 1999; Pandarinath et al, 1999b; Wasson et al, 1983; Juyal et al, 2003). However, palaeo-recharge temperatures could not be investigated in this study. Estimation of which can provide a definite signature of past climatic fluctuations as recorded in groundwater.

Noble gases dissolved in groundwater provide a useful tool to estimate the palaeo-recharge temperature. The role that noble gases can play in climate studies was recognised way back in early seventies by Mazor (1972), who noted that the noble gas abundance patterns in ground waters reflect the air temperatures in the recharge area. He suggested that groundwater could be used as an archive of the past climate, because it appears to retain the dissolved gases over many thousands of years. It has been shown that progressively older groundwater down gradient in aquifers preserve record of past temperature variations (Porcelli et al, 2002).

6.3 Identifying the Modern Recharge

To overcome the general scarcity of water, a community and the State driven movement for groundwater recharge has been underway in the NGC region since past several years. Numerous groundwater recharge structures have been constructed but their usefulness and efficiency for artificial recharge has not been tested. The data on lowering of water levels in surface reservoirs and rise of water levels in nearby dug wells is interpreted as due to the groundwater recharge caused by the constructed structure. However, reduction in water levels in reservoirs may also be due to evaporation and consumptive use by human and cattle population. Rise in water levels in adjoining dug wells may partly arise from reduction in groundwater withdrawal due to surface availability of water in the vicinity. Therefore, variation in water levels in reservoirs and dug wells may not necessarily be related to the efficacy of the construction of recharge structures. Measuring dissolved CFCs in the groundwater in vicinity of the recharge structures may provide a more conclusive method to identify as well as quantify the modern recharge for assessing the efficacy of such structures.

Unrelated to any recharge structure, the CFC concentration in groundwater of unconfined aquifer can also be used to estimate the time since the water became isolated from the unsaturated zone during the past few decades. Presence of detectable CFC concentration in confined aquifer indicates mixing of modern water with groundwater recharged prior to 1945 after they were introduced into the atmosphere. Therefore, investigation of dissolved CFCs in groundwater can identify regions where modern waters have infiltrated into deeper layers.

The analytical capabilities for measuring CFC concentration, build during the present study can be readily employed for this purpose.