CHAPTER 6

SUMMARY AND CONCLUSIONS

This chapter comprises of the observations and conclusions derived from the field and laboratory investigations carried out in Rupnagar district of Punjab State. The present work is an attempt to provide a comprehensive description of land use/land cover study with special reference to geo-environmental problems. The study has revealed a range of features, which would help in better understanding of geo-environmental problems of the studied area and for proper planning and management of land and water resources of the area. The significant findings pertaining of the study area are described in sequel.

The general features of the area are presented in chapter 1. Rupnagar district is the smallest district of Punjab State with diverse nature and it is located both on the west and east of river Sutlej. According to 2001 Census, the total population of Rupnagar District was 6,28,846. Of this number, 1,31,051 reside in urban areas and 4,97,795 reside in rural areas spread over an area of 1382 sq km. The climate of Rupnagar district is of continental type which is characterized by the extreme climatic conditions. The average rainfall of the area is about 708.99mm/year. The area under investigation suffers from geo-environmental problems such as: deterioration of chemical quality of surface and groundwater around industrial units, deterioration of surface and groundwater quality by agricultural activities, decrease in forest cover leading to changes in biodiversity, erosion of Siwalik hills leading to increase inflow of silt into the rainwater harvesting structures and in the Ropar wetland leading to decrease in ponded areas as well as shortening the life of rainwater harvesting structures.

The geology of the area is simple. The rocks of Siwalik system are exposed in the north-east parts of the district. Rest of the area is occupied by Indo-Gangetic alluvium of Quaternary age. The detailed geology of the study area is discussed in the chapter 1.

Situated in the eastern and east-central peripheral parts of the Punjab State, Rupnagar district is one of the smallest districts in the state. Despite its small size, the
district displays the large physiographic diversity. Consistent with its transitional location between the outer Himalayas and the Punjab plains, the district has a whole range of physiographic features, which has made its impact on the characteristics of the human landscape of this region. On the basis of relief, slope, drainage and overlain material, the district may be divided into following seven physiographic units: the Anandpur Doon, Structural hills, Denudational hills, Alluvial plain, the Flood plain of the Sutlej, Piedmont plain and Seasonal streams and River channel. The detailed geomorphology of the study area is also discussed in the chapter 1.

One major perennial river Sutlej drains the area under investigation. There are several other ephemerals flowing in the area, which are of lesser significance, and these ephemerals are locally known as Nadi, Naallah or Choe. The river Sutlej is one of the major rivers of Punjab, the other being Beas and Ravi. The river Sutlej, originating from the Himalayas (Mansarovar lake in Tibet), traverses through many gorges in the state of Himachal Pradesh and enters Punjab state just above Nangal town of Ropar District. Nangal is situated at the downstream of Bakhra Dam (H.P). The river Sutlej meanders about 277km in the state of Punjab before entering into Pakistan.

The depth to groundwater varies from area to area in the district. In the hills, depth to groundwater is more than 15m deep. In the foothill plain and in the doon, its depth ranges between 10 and 15m below ground level and in the upland plains between 5 and 10mts below ground level.

In the second chapter, study of land use has been described which was carried out in the laboratory of Punjab Remote Sensing Centre, Ludhiana. In the present work LULC study from year 1960 to 2005 was carried out in district Rupnagar, Punjab following standard methodology and approach. Remote sensing technology and GIS used in the present study, constitutes the important theme of the research. The methodology adopted for remote sensing and GIS studies is described in detail in chapter one. The digital database was created from data sources of primary and secondary origin, which are satellite imageries and Survey of India toposheets respectively. All the data acquired from primary and secondary data sources were digitized with the help of digitizer and
different types of thematic maps were prepared with the help of Arc info GIS software. The different thematic maps were checked and validated in the field and after verification, the final maps were prepared. GIS analysis was done by overlaying and crossing different thematic maps.

The results indicate that the area is largely dominated by agricultural crops. Data for the period 1960, 1992 and 2005 were studied to know the land use land cover changes in the area. The data revealed that agricultural land in 1960 covered an area of 43.16% of the total geographical area. This category increased to 49.39% by the year 1992 and this increase was propelled by conversion of other land use categories like conversion of wastelands into arable land, utilizing dry water bodies to cropland and also deforestation activities which brought forest land into cropland. From 1992 to 2005, this category was further increased by 4.16% i.e. by the year 2005 total area occupied by agricultural land alone was 53.55% of the total geographical area.

Built-up area in 1960 occupies the least class with only 2.25% of the total geographical area of the district. This category increased by 4.11% during 1960 to 1992 and 2.38% during 1992 to 2005 due to the conversion of wasteland into urban areas. The study revealed that urban expansion in the study period did not occur evenly in all directions; new developments were observed along the periphery of urban areas as well as in the areas that had already been urbanized. By the year 2005 this category covered 8.74% of the total geographical area.

Water bodies in the district hold total area of 17.59% in the year 1960. This category got decreased to 5.68% during 1960 to 1992 and 2.62% during 1992 to 2005. By the year 2005 this category decreased to only 9.28%. This decrease occurred due to the diversion and drying up of water bodies and this area was utilized for built-up and agriculture purposes. It was noticed in the area that choe area is encroached upon for urbanization and agricultural activities which causes problem of natural drainage and flooding in the study area during monsoon periods.

Forest area in the year 1960, accounts for 21.33% of the total geographical area and got decreased to 18.38% by 1992 (decrease of 2.15%). However, slight increase of
0.74% was observed during 1992 to 2005. This increase in forest area occurred due to the action of State government by bringing more land under forest area.

Wastelands which occupied large area in the district got decreased by 1.75% during 1960 to 1992 and 4.62% during 1992 to 2005 respectively due to the conversion of this category to agriculture and built-up categories. (Chapter 2)

Third chapter deals with the hydro-chemical studies of groundwater and surface water. Fifty three samples in total were collected from the study area in the month of June, 2007 (pre monsoon) and Nov-Dec, 2007 (post monsoon) for groundwater. The samples for groundwater were collected from hand pumps and tube wells at varying depths ranging from 2.5 m to 110 m below the ground level. Twenty five samples were collected for surface water from river, drains and canal during June, 2007 and Dec, 2007. Samples were chemically analyzed following standard techniques and methodology given by APHA (1976), Trivedy (1986) etc. Moreover, out of 53 groundwater samples, 10 groundwater samples were collected around the industrial units and agricultural fields for chemical analysis for heavy metals viz mercury, lead, iron, cadmium and arsenic to evaluate the contamination of groundwater. Chemical parameters of water samples for the pre monsoon period does not show significant variation from the chemical parameters of samples collected during post monsoon period. The observations and analysis of samples has revealed a gamut of data from various parameters.

pH of the area ranges from 6.5 to 7.5 indicating its suitability for irrigation and domestic purpose. The EC of water samples varies from 513 mmhos/cm to 1173 mmhos/cm which indicates that water is good for irrigation and domestic purposes. TDS of the water samples in the studied area varies from 195 mg/l to 759 mg/l which shows that water is fresh and non-saline in nature and is suitable for drinking and domestic purposes.

The concentration of calcium varies from 31.26 mg/l to 145 mg/l. Magnesium concentration ranged from 7.3 mg/l to 76.99 mg/l. The results revealed that concentration of Mg is low and the area is free from magnesium hazard.
Sodium concentration in the study area varies from 3 mg/l to 470 mg/l. As no prescribed limit is given for sodium for drinking purpose; it is difficult to evaluate the use for domestic water supply. However, Hart (1974) proposed that water with less than 270 mg/l sodium is good for drinking purposes. This limit if taken into consideration, in the study area reveals that as sodium content is below 270 mg/l and therefore water is good for drinking purposes.

Potassium concentration varies from 0.3 mg/l to 85 mg/l. Concentration of potassium in the study area is very low.

Carbonate concentration varies from nil to 60 mg/l. Bicarbonates are the highest in concentration within the groundwater of the study area. Its concentration varies from 165 mg/l to 760 mg/l. High bicarbonate also results in increase in pH of the soil rendering it to a condition known as black alkali soil. Bicarbonate concentration above the permissible limit of 600 mg/l (BIS, 1991) was recorded at village Singh (660 mg/l), Baldev Nagar (735 mg/l), Sarhana (630 mg/l), Garh Dollian (680 mg/l) and Chotti Mandauli (620 mg/l).

The chloride concentration in the groundwater of Rupnagar district varies from 35.5 mg/l to 301.26 mg/l. The concentration of chloride above the permissible limit of 250 mg/l (BIS, 1991) was observed only in three samples.

Sulphate concentration in the groundwater ranged from 1.28 mg/l to 9.97 mg/l and is well within the desirable range.

Fluoride concentration varies from 0.09 mg/l to 0.65 mg/l. It is well within the prescribed limit of 1.5 mg/l (WHO, 2006) for drinking water, thus indicating absence of fluoride hazard in the area.

The concentration of nitrate in the area ranged from 6.87 mg/l to 90.58 mg/l. The desirable limit given by BIS (1991) is 45 mg/l and WHO (2006) has set a limit of 50 mg/l. However, nitrate concentration above desirable limits of BIS (1991) and WHO (2006) are observed at Singh (76.82 mg/l), Vaspara (90.58 mg/l), Majran (53.14 mg/l), Naya Malakpur (84.73 mg/l) and Manglur (55.25 mg/l).
Hydro-chemical facies for groundwater were studied based on Piper Trilinear diagram which revealed that groundwater belongs to Ca- Mg- HCO₃ type and the plot of chemical data illustrate that majority of the groundwater falls in the fields of 1, 3, 5 suggesting that alkaline earths exceed alkalies and weak acids exceed strong acids.

In order to evaluate the chemical quality of groundwater for irrigation purposes percent sodium, sodium adsorption ratio and residual sodium carbonate were calculated. Results indicated that % Na in the study area varies from 2.64% to 87.59% and SAR ranges from 0.09 to 17.03. Based on % Na, groundwater of the study area falls under excellent to good category for irrigation purposes. SAR values of all the samples are found to be less than 26 which show that water is fit for agricultural purposes. RSC values ranges from -5.74 meq/l to 10.41 meq/l. Results revealed that at some places in the study area is having high RSC concentration. Thus water quality in the study area has been classified as medium to high based on RSC.

The results of the heavy metal analysis of groundwater samples indicate that the groundwater around the industrial belt is contaminated with iron. The concentration of iron in the groundwater of Rupnagar district ranges from nil to 3.272 ppm (Mauzewala). Iron concentration above 0.3ppm (BIS, 1991) indicates that such localized pollution plumes exist around industrial places like Mauzewala, Pipal Majra (0.614 ppm), Kalara (0.487 ppm), Khairpur (3.01 ppm). Out of 11 samples, 7 samples crossed the desirable limit of 0.3 ppm and 3 samples crossed the maximum permissible limit of 1ppm.

The concentration of mercury in groundwater of the study area ranges from nil to 0.002 ppm. Samples collected from Pipal Majra (0.002 ppm), Ghanauli (0.002 ppm), Chakki (0.002 ppm), Mauzewala (0.002 ppm) crossed the maximum permissible limit of 0.001 ppm set by BIS (1991). However, none of the sample crossed the maximum permissible limit of 0.006 ppm of WHO (2006).

The cadmium content in groundwater of the study area varies from nil to 0.047 ppm (Mauzewala). BIS (1991) has prescribed a maximum limit of 0.01 ppm and WHO (2006) has set a maximum limit of 0.003 ppm. Water samples collected from the bank of
river Sutlej passing through the villages, Pipal Majra (0.02 ppm), Chakki (0.02 ppm), Ghanauli (0.02 ppm), Mauzewala (0.047 ppm) crossed the limit prescribed by BIS (1991). Whereas, majority of the sample crossed the limit of 0.003 ppm set by WHO (2006).

Arsenic was not detected in the groundwater samples of the area. This is in contrast to the observations of Hundal et al., 2007 who reported higher concentration (42 μg/l) in the area. No case of arsenic skin lesions was observed in the field indicating that the area is free from arsenic hazard.

Lead concentration in the groundwater of the study area was not detected in any of the samples which indicates that water is free from lead contamination.

In order to control the groundwater contamination due to industrial effluents in the area, it is suggested that industries should be asked to treat the waste water before disposal on land (Chapter 3).

Results of chemical analysis of surface water do not show much variation from the parameters determine from pre and post monsoon periods. pH of the surface water varies from 5.5 (Mauzewala) to 10.5 (Pipal Majra) with an average of 7.5.

EC varies from 104 mnhos/cm to 1037 mnhos/cm with an average of 349.61 mnhos/cm. Low EC values of surface water show that water is good for domestic and irrigation purposes.

TDS concentration ranges from 122 mg/l to 1024 mg/l. Concentration of TDS in surface water sample shows that water is fresh and non-saline and therefore can be safely used for agricultural and industrial purposes.

Sodium concentration in the surface water varies from 3 to 330 mg/l with an average of 55.77 mg/l.

Potassium concentration varies from 1.9 mg/l to 247 mg/l in the pre monsoon period with an average of 38.53 mg/l. Post monsoon data does not show much variation.
Calcium content varies from 24.84 mg/l to 165 mg/l. Its concentration in all the samples is well below the permissible limit of 200 mg/l given by BIS (1991) and WHO (2006).

Magnesium concentration varies from 4.38 mg/l to 65.38 mg/l. Concentration of magnesium is low in the area which shows that water is free from magnesium hazard.

The concentration of carbonate in the surface water ranges from nil to 60 mg/l with ar. average of 10.55 mg/l. The presence of bicarbonate in surface water in the area varies from 110 mg/l to 1045 mg/l with an average of 300.5 mg/l. Highest concentration (1045 mg/l) is exhibited by the sample collected from river Sutlej passing through village Kalara.

Sulphate concentration varies from 1.3 mg/l to 7.8 mg/l with an average of 3.49 mg/l.

Phosphate concentration in the study area varies from 0.008 to 0.79 mg/l with an average of 0.14 mg/l. Concentration of sulphate and phosphate is quite low in the surface water samples.

Fluoride concentration in surface water ranges from nil to 0.65 mg/l which is well within the desirable limits of BIS (1991) and WHO (2006) for drinking water. As such water is good for domestic use.

Nitrate concentration in the surface water of the study area varies from 8.4 mg/l to 76.38 mg/l. Nitrate concentration above permissible limit of 45 mg/l (BIS, 1991) and 50 mg/l (V/HO, 2006) is exhibited by the samples collected from the banks of river Sutlej passing from village Bheura (72.38 mg/l), Kalara (56.38 mg/l) and Agampur (76.38 mg/l). High nitrate concentration at these places is due to the runoff from nearby agricultural fields.

Hydro-chemical facies reveal that surface water belongs to Ca-Mg-HCO₃ type of facies. Calcium and magnesium are the major cations in the surface water of the study area for about 75 to 80% of the cations. Bicarbonate is the major anion for about 80-85%
of the anions. The plotting of the chemical quality data in the present study for surface water shows the dominance of calcium-bicarbonate. The Ca, Mg and HCO$_3^-$ indicate the temporary hardness, alkalinity and the total hydrochemistry is dominated by alkaline earths and weak acids.

Surface water analysis for irrigation purposes reveal that surface water has low percent sodium (6.82% to 54.34%) and low sodium adsorption ratio (0.161 to 7.94) and is therefore fit for irrigation. RSC in surface water is below 1.25 meq/l which shows that water can be used safely and is suitable for all conditions.

Fourth chapter deals with the geo-environmental problems of Ropar wetland which came into existence after the construction of Ropar barrage over river Sultej in the year 1952. The wetland has unique ecological, hydrological and socio-economic values because of which it has been designated as Ramsar site in the year 2002. Over the last 2 decades, population in Rupnagar district has almost tripled. Industrialisation around the Ropar wetland has increased very much which ultimately has exploited land, water bodies and forest area. This led to the pronounced problem in the wetland. The most important threat to Ropar wetland is from anthropogenic pressure i.e. indiscriminate use of wetlands for cultivation, habitation, prolific growth of aquatic weeds like water hyacinth and degradation of chemical quality.

In order to evaluate the chemical quality of Ropar wetland for domestic and agricultural use, 12 water samples were collected during pre and post monsoon period of the year 2007. These samples were also subjected for trace element analysis for Hg, Pb, Cd, Fe and As. Chemical analysis of the water samples does not show much variation from pre to post monsoon period results.

pH of the wetland waters varies from 5.5 to 10.5 with an average of 7.8 indicating alkaline nature.

Electrical Conductivity varies from 196 μmhos/cm to 756 μmhos/cm with an average of 438 μmhos/cm. Electrical conductivity values are low indicating its suitability of wetland water for irrigation purpose.
Total dissolved solids vary from 128 mg/l to 484 mg/l with an average of 316 mg/l. Concentration of TDS in wetland water shows that water is fresh and non-saline and can be used safely for agricultural purposes.

Calcium concentration varies from 24.8 mg/l to 87.4 mg/l with an average of 56.1 mg/l and lies well within the permissible limits of BIS (1991) and WHO (2006). Magnesium concentration varies from 4.38 mg/l to 39.7 mg/l.

Sodium concentration varies from 4.0 mg/l to 115.0 with an average of 59.5 mg/l and potassium concentration ranges from 2.1 mg/l to 185 mg/l with an average of 93.5 mg/l.

Carbonate concentration during both pre and post monsoon is very low and varies from 0 to 60 mg/l with an average of 30 mg/l. Bicarbonate concentration during pre monsoon varies from 110 mg/l to 480 mg/l with an average of 295 mg/l. Nowhere in the wetland, the concentration crossed the permissible limits of bicarbonate given by BIS (1991) and WHO (2006).

The concentration of total hardness of wetland varies from 90 mg/l to 381 mg/l with an average of 177 mg/l.

Chloride concentration in the water samples collected from Ropar wetland varies from 35.5 mg/l to 230.7 mg/l with an average of 133.1 mg/l.

Concentration of sulphate varies from 1.86 mg/l to 7.8 mg/l. Phosphate ranges from 0.03 mg/l to 0.5 mg/l with an average of 0.26 mg/l.

Fluoride concentration ranges from 0.3 mg/l to 0.5 mg/l with an average of 0.4 mg/l. Concentration of fluoride is well within the desirable limits of BIS (1991) and WHO (2006) for drinking water use.

Nitrate concentration varies from 9.54 mg/l to 76.38 mg/l with an average of 47.92 mg/l. High nitrate content in Ropar wetland water is due to the runoff from agricultural fields.
The chemical quality data of the Ropar wetland are plotted in the Piper Trilinear diagram for graphical analysis (Chapter 4). Results indicated that the water samples show Ca-Mg-HCO₃ dominance.

For irrigation and agricultural purposes, water quality of Ropar wetland can be classified as excellent to good quality as it has low SAR, % Na and RSC.

The concentration of Fe in Ropar wetland ranges from nil to 7.90 ppm. Out of 12 samples 3 samples crossed the maximum desirable limit of 0.3 ppm and 7 samples crossed the maximum permissible limit of 1.0 ppm prescribed by BIS (1991).

The Cd content in the water samples of Ropar wetland varies from nil to 0.01 ppm. Cadmium concentration in the wetland was found to be within the prescribed limits of BIS (1991) and WHO (2006) which shows that water is free from cadmium contamination.

The concentration of mercury in the wetland ranges from nil to 0.002 ppm. The Bureau of Indian Standards has prescribed 0.001 ppm as the desirable limits for drinking water beyond which the water becomes toxic. Concentration above the permissible limit was observed in 9 samples. Highest concentration with 0.1 ppm was found in the sample no. 6 collected near the Ropar Thermal Plant.

Concentration of arsenic was not detected in any of the samples which show that wetland water is not contaminated with arsenic.

PPCB (2005) reported that there is no contamination of Ropar wetland waters due to industrial and agricultural activities. However, results of the analysis of water samples in the present study indicate that there is contamination of nitrate, lead, mercury, iron and cadmium. The industries directly responsible for these high concentrations are Thermal Power Plant located upstream of the wetland, M/s National Fertilizers Limited, M/s Punjab Alkalis and Chemicals Limited and M/s Punjab National Fertilizers and Chemicals. Improper handling of chemicals/wastes and emissions from these industries is the major cause of wetland water contamination. There is a need to control the contamination of wetland water so the same is being supplied through canals for drinking.
purposes in the downstream areas. The detailed chemical analysis is discussed in chapter 4.

The field observations, geological and study of land use data of Ropar wetland indicates that the catchment area shows high degree of erosion due to the soft and fragile nature of rocks of upper Siwalik Formation. The inflow of silt from these Siwalik hills around the Ropar wetland has resulted in heavy sedimentation resulting in large littoral deposits colonized by dense heavy macrophytic growth and shrinkage of lake. Data and field observations revealed that Ropar wetland has been a major source of fisheries. However, illegal fishing throughout the year has caused considerable disturbance to the aquatic life. In Ropar wetland, due to the increase in level of nutrients and heavy sedimentation has led to the prolific growth of aquatic plants. The infestation of aquatic plants has resulted in the reduction of open water area and the potential of wetlands for water supply, navigation, fishing and recreational values. In order to conserve and manage the Ropar wetland, an action plan has also been evolved (Chapter 4).

In fifth chapter, impact of rainwater harvesting structures on socio-economic condition of people living in the Siwalik belt and adjoining areas of the district has been studied. Besides these, impact on the hydro-geological environment has also been discussed. Rainwater harvesting structures have been constructed in the area in order to tap the rainfall which is high (1000/1100mm). Socio-economic aspects of such structures were studied by undertaking field surveys which include interviews/discussion with the farmers. 37 earthen dams have been constructed in Siwaliks of Rupnagar district. The catchment area of such dams varies from a low of 6.50 ha in Parch I to 19.00 ha in Bardar. The height of the dams varies from 8.20 m to 15.00 m and storage capacity from 2.13 ha (Parch II) to 62.26 ha in Bardar. The cost of dams including pipelines vary from Rs 0.25 lakhs in Kakot majri to Rs 35.49 lakh in Parol.

In order to study the overall impact of rainwater harvesting structures, two representative villages, Chotti Bari Naggal and Parol Naggal where 6 rainwater harvesting structures have been constructed were investigated in detail. The observations made during the study are applicable to all rainwater harvesting structures of the area because
of the similar nature. The pre and post construction approaches were adopted for the collection and analysis of data. The year 1986 for village Chotti Bari Naggal and the year 1991 for Parol Naggal are taken as pre (before) and the year 2007 being the study year represented the post (after) situation. The pre construction data was also collected from the farmers through interviews. For carrying out field interviews and observations 30 sample households from village Chotti Bari Naggal and 20 sample households from village Parol Naggal were selected.

With the construction of rainwater harvesting structures water was made available throughout the year which showed direct impact on agriculture sector. Moreover, farmers were encouraged to level their fields and soil conservation measures like sowing across the slope, timely hoeing and weeding were advocated to all the farmers. The adoption of these measures along with water availability led to the increase of crop production both during Kharif (summer) and Rabi (winter) season. Results indicated that wheat production increased from 29.5% to 54.5% in Chotti Bari Naggal and from 45.1% to 64.5% in Parol Naggal. After the rainwater harvesting project, farmer’s started growing Barseem (Trifolium alexandrium) which was not practiced earlier. Barseem cultivation increased from nil to 4.5% in Chotti Bari Naggal and from nil to 4.8% in Parol Naggal. After the construction of rainwater harvesting structures cultivation of gram, arhar showed a declining trend in both the sampled villages as framers preferred barseem cultivation over the crops. Similarly in Kharif season maize production increased from 27.2% to 38.6% in Chotti Bari Naggal and from 29.1% to 41.9% in Parol Naggal, production of jowar increased from 11.3% to 13.6% in Chotti Bari Naggal and from 11.2% to 14.3% in Parol Naggal. Similarly cultivation of Mung/Urd increased from 4.5% to 9.09% in Chotti Bari Naggal and from 8.06% to 6.4% in Parol Naggal. However, growing of Bajra decreased from 22.7% to 12.5% in Chotti Bari Naggal and from 16.1% to 11.2% in Parol Naggal.

During Kharif season, growing of paddy was not a practice with these framers due to non-availability of assured irrigation water. After the construction of rainwater harvesting structures, increased water availability prompted the farmers to raise paddy
which was nil earlier. Moreover, yields of all the crops increased by more than 55% where the average yield of wheat increased from 286 kg/ha to 528 Kg/ha in village Chotti Bari Naggal and from 280 kg/ha to 440 kg/ha in Parol Naggal.

Increase in agricultural productivity showed positive impact on the animal husbandry, as availability of fodder increased from agricultural fields as well as grass from the forest. Simultaneously, number of buffaloes and cows also increased. Data revealed that after the construction of rainwater harvesting structures, there is an increase of 196% in buffalo’s population in Chotti Bari Naggal and an increase of 247% in Parol Naggal. Similarly, cow population also increased by 123% in Chotti Bari Naggal and 59% in Parol Naggal whereas the goat population decreased by 30% and 42% in Chotti Bari Naggal and Parol Naggal respectively.

With the increase in livestock population in the sampled villages, increase of milk production by 118% in Chotti Bari Naggal and 140% in Parol Naggal was noticed which resulted in the upliftment of economic condition of the people. Improvement of economic conditions showed direct impact on the social status like better housing and living conditions, type of dwelling and increasing number of assets, etc. Field interviews with the females revealed that the status of women has also become better with the increase in economic conditions in terms of their education status and in their dependency. After the construction of rainwater harvesting structures, farmers have started sending their girl children to schools to acquire education which was not possible earlier due to the lack of school facility in the villages and also due to poor economic conditions. In terms of dependency, women are now less dependent as they spend more time in agricultural and dairy sector whereas earlier, they were only involved in household activities.

Data illustrates that construction of rainwater harvesting structures have also improved hydro geological environment. There has been a rise of 2 to 4 m regionally in the groundwater levels from the period 1975 to 2003 as revealed by the data of Central Ground Water Board (CGWB). This rise in water levels has facilitated the construction of more shallow handpumps and tubewells in the area which are now being used for the domestic water supply (Chapter 5).
It is hoped that the results of the present study would help in understanding the
geo-environmental problems of the area. Study carried out on land use land cover should
help in the management and future land use planning. The data acquired in chemical
quality of surface and groundwater should help in alleviating groundwater problems
especially around industrial units. The work done on geo-environmental problems of the
Ropar wetland would definitely enthuse new ideas for its conservation and management.
Work done on the socio-economic impacts of rainwater harvesting should help in
expansion of the project to uplift the socio-economic conditions of the people.