CHAPTER – VII

OBSERVATIONS AND CONCLUSIONS

This chapter comprises the observations and conclusions derived from the field and laboratory investigations carried out for the assessment of geoenvironment of Dharamshala area of District Kangra, Himachal Pradesh. An attempt has been made towards establishing relationship between the varying trends in geoenvironmental parameters and their distribution in space and time. The chapter also includes the suggestions and recommendations to protect geoenvironment of the area prone to many natural and man-made disasters and necessary measures that has to be taken to check further degradation of geoenvironment. The significant findings of the research work are concluded at the end.

7.1 OBSERVATIONS

Dharamshala is one of the famous hill towns situated in the foothills of the Himalayas. The area has a very good climate and comes under wet sub-temperate zone. May is the hottest month of the year with maximum and minimum temperature of 30.5°C and 18.2°C respectively. January is the coldest month of the year with maximum and minimum mean temperature of 16.4°C and 5.2°C respectively and the month of August receives the heaviest rainfall with 522.7 mm on an average. The floral and faunal diversity of the area is very rich. The soils of the study area represent the combination of shallow black, brown and alluvial soils. The significant mineral deposits of the research area are slates and limestones found in Bhagsu Nag, Thatri and Khaniara. The area is prone to many natural and man-made disasters. Dharamshala is a seismically active area and has experienced several destructive earthquakes in the 20th century namely in 1905, 1968, 1978 and 1986 with magnitudes of 7.0, 4.5, 5.0 and 5.5 respectively on the Richter scale. With the increase in population pressure, requirement for higher standards of living, unsystematic urbanization, growing tourist promotions, commercial movements, unscientific quarrying, indiscriminate deforestation, conversion of agricultural land into concrete
jungles, destruction of grazing land for human habitation, the basic elements of life i.e. air, water and land are being polluted continuously. Another factor which is contributing towards the degradation of the geoenvironment is the open disposal of waste. These activities have created the unpredictable changes in the area which ultimately hampers the planning and management of georesources. The hot spots (problematic areas) of the research area were spotted and discussed in detail that needs urgent attention. It is only the proper management of geoenvironment and its resources that can make us to live in harmony with nature and is must for sustainable development.

The calculated values of all the physico-chemical parameters (pH, electrical conductivity, total dissolved solids, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate, phosphate, nitrate, and fluoride) of surface water samples collected from lake and four different streams during pre-monsoon and post-monsoon period were within the desirable limits recommended by the Bureau of Indian standards (BIS), Indian Council for Medical Research (ICMR) and World Health Organization (WHO) for drinking purpose. Results of dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) were also within the prescribed limits but bacteriological contamination was observed in few samples during both pre-monsoon and post-monsoon periods. After analyzing the surface water samples (Dal lake and different streams) for different physico-chemical parameters in pre-monsoon and post-monsoon periods, the results were subjected to statistical analysis.

In case of Dal lake, negative and significant correlation with temperature \( r = -0.891^* \) at 0.05 level of significance during pre-monsoon period was observed whereas no such correlation was observed during post-monsoon period. In case of TDS, negative and significant correlation was observed with temperature \( r = -0.896^* \) at 0.05 level of significance whereas no such correlation was observed in post-monsoon period. Also, TDS exhibited strong positive and significant correlation with EC during both pre-monsoon \( r = 1.000^{**} \) and post-monsoon period \( r = 1.000^{**} \) at 0.01 level of significance. During post-monsoon period, pH showed negative and significant correlation with EC \( r = -0.882^* \) and with TDS \( r = -0.888^* \) at 0.05 level of significance whereas during pre-monsoon period pH exhibited no significant correlation with any of the parameter. During pre-monsoon period, calcium exhibited

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positive and significant correlation with EC ($r = .900^*$) and with TDS ($r = .896^*$) at 0.05 level of significance whereas during post-monsoon period calcium exhibited no significant correlation with any of the parameter. During pre-monsoon period, negative and significant correlation was observed between magnesium and temperature ($r = -.927^*$) at 0.05 level of significance. Magnesium also showed positive and significant correlation with EC ($r = .936^*$) and with TDS ($r = .940^*$) at 0.05 level of significance whereas no significant correlation was noticed between calcium and any of the parameter during post-monsoon period. Potassium showed positive and significant correlation with temperature ($r = .954^*$) at 0.05 level of significance during pre-monsoon season whereas during post-monsoon period, positive and significant correlation was noticed between potassium and sodium ($r = .940^*$) at 0.05 level of significance. During pre-monsoon period, negative and significant correlation was observed between carbonate and temperature ($r = -.932^*$) at 0.05 level of significance, positive and significant correlation was observed between carbonate and EC ($r = .891^*$) and between carbonate and TDS ($r = .896^*$) at 0.05 level of significance. Carbonate also showed strong positive and significant correlation with magnesium ($r = .991^{**}$) 0.01 level of significance whereas carbonate exhibited no correlation with any of the parameter during post-monsoon period as it was not detected in any of the sample. Bicarbonate showed positive and significant correlation with calcium during both pre-monsoon ($r = .879^*$) and post-monsoon period ($r = .915^*$) at 0.05 level of significance. Chloride showed positive and significant correlation with EC ($r = .888^*$) and with TDS ($r = .884^*$) at 0.05 level of significance during post-monsoon period whereas no such correlation was noticed during pre-monsoon period. A negative and significant correlation was observed between sulphate and magnesium ($r = -.879^*$) at 0.05 level of significance during post-monsoon period whereas no significant correlation was observed between sulphate and any of the parameter during pre-monsoon season. A positive and significant correlation was observed between phosphate and chloride ($r = .955^*$) at 0.05 level of significance during pre-monsoon period whereas no significant correlation was observed between phosphate and any of the parameter during post-monsoon season. A negative and significant correlation between nitrate and bicarbonate ($r = -.952^*$) at 0.05 level of significance was observed during pre-monsoon season whereas during post-monsoon period strong positive and significant
correlation was noticed between nitrate and sulphate \( (r = 0.969^{**}) \) at 0.01 level of significance. A significant seasonal change was observed in temperature, pH and sodium at 0.05 level of significance. Comparison of mean values showed higher values of temperature, pH and sodium during pre-monsoon and lower values during post-monsoon period. EC and TDS also showed impact of monsoon and were found significant at 0.01 level of significance and lower mean values were observed during post-monsoon period. The high temperature recorded in pre-monsoon period could be due to high air temperature in summer season (pre-monsoon period). The variation in water temperature may be due to different timing of collection and the influence of season (Jayaraman et al., 2003). The pH and TDS recorded highest in pre-monsoon period in comparison to post-monsoon which could be due to acidification of water by elevated microbial degradation of organic remains and concentrated dissolved solids in summer season (Venkatesharaju et al., 2010). From the correlation analysis it has been observed that TDS exhibited strong positive and significant correlation with EC during both pre-monsoon \( (r = 1.000^{**}) \) and post-monsoon period \( (r = 1.000^{**}) \) at 0.01 level of significance. From here it can be concluded that with the increase in TDS, there would be increase in EC also. A significant change was also observed in magnesium concentration in between two seasons, at 0.01 level of significance. The mean value of magnesium showed high concentration during post-monsoon period and this may be due to composition of rocks (dolomite, sandstone and clays) in the study area.

In case of stream water, positive and significant correlation was noticed between sodium and EC \( (r = 0.708^{*}) \) at 0.05 level of significance during pre-monsoon period whereas no such correlation was observed during post-monsoon period. During pre-monsoon period positive and significant correlation was observed between potassium and sodium \( (r = 0.746^{*}) \) at 0.05 level of significance whereas during post-monsoon period potassium exhibited positive and significant correlation with EC \( (r = 0.844^{**}), \) TDS \( (r = 0.842^{**}) \) and sodium \( (r = 0.938^{**}) \) at 0.01 level of significance and with calcium \( (r = 0.816^{*}) \) at 0.05 level of significance. During post-monsoon period carbonate exhibited positive and significant correlation with EC \( (r = 0.793^{*}) \) and TDS \( (r = 0.785^{*}) \) at 0.05 level of significance. Carbonate also showed positive and significant correlation with pH \( (r = 0.972^{**}) \) and calcium \( (r = 0.895^{**}) \) at 0.01 level of significance whereas no such correlation was noticed during pre-monsoon period.
During pre-monsoon period bicarbonate exhibited strong positive and significant correlation with EC ($r = .992^{**}$), TDS ($r = .992^{**}$) and calcium ($r = .996^{**}$) at 0.01 level of significance. Bicarbonate also showed positive and significant correlation with magnesium ($r = .745^{*}$) at 0.05 level of significance. During post-monsoon period bicarbonate showed strong positive and significant correlation with EC ($r = .947^{**}$), TDS ($r = .951^{**}$) and magnesium ($r = .856^{**}$). It also showed positive and significant correlation with pH ($r = .749^{*}$), calcium ($r = .825^{*}$) and potassium ($r = .744^{*}$) at 0.05 level of significance. Chloride showed positive and significant correlation with sodium ($r = .802^{*}$) and potassium ($r = .926^{*}$) at 0.05 and 0.01 level of significance respectively during pre-monsoon period whereas positive and significant correlation was observed between chloride and pH ($r = .750^{*}$) and between chloride and carbonate ($r = .707^{*}$) at 0.05 level of significance during post-monsoon period. During post-monsoon period, phosphate showed positive and significant correlation with sodium ($r = .882^{**}$) and potassium ($r = .869^{**}$) at 0.01 level of significance whereas no significant correlation was observed between phosphate and any of the parameter during pre-monsoon period. Nitrate exhibited positive and significant correlation with sodium ($r = .883^{**}$), potassium ($r = .852^{**}$) and phosphate ($r = .988^{**}$) at 0.01 level of significance during post-monsoon period whereas no such correlation was observed during pre-monsoon period. Fluoride showed positive and significant correlation with chloride ($r = .717^{*}$) at 0.05 level of significance during pre-monsoon period whereas negative and significant correlation was observed between fluoride and calcium ($r = -.743^{*}$) and fluoride and potassium ($r = -.772^{*}$) at 0.05 level of significance. A significant seasonal change at 0.01 level of significance was observed in temperature, EC, TDS, pH, magnesium, sodium and sulphate. Comparison of mean values showed higher values of temperature, EC, TDS, pH, sodium and sulphate during pre-monsoon and lower values during post-monsoon period whereas magnesium showed higher mean value during post-monsoon period. Calcium and potassium also showed impact of monsoon and were found significant at 0.05 level of significance and higher mean values were observed during post-monsoon period.

The results of irrigational parameters were compared with the standards based on U.S. Salinity laboratory Staff (1954), Wilcox (1955), Eaton (1950), Richards (1954), and Carroll (1962) and found that the lake water is fit for irrigational purposes
during both pre-monsoon and post-monsoon periods except few sites during post-monsoon season where kelley’s limit has crossed. The plot of chemical data on Trilinear diagram reveals that all the samples of Dal lake fall in the field of 1, 3 and 5 suggesting that alkaline earth (Ca + Mg) exceeds alkalis (Na + K) and weak acids (CO$_3$ + HCO$_3$) exceeds strong acids (SO$_4$ + Cl) respectively (Table 2.11). The ions representing carbonate hardness (secondary alkalinity) exceeds 50%. From the above it can be concluded that total hydrochemistry of lake is dominated by alkaline earths and weak acids. The results indicate that Ca-Mg-HCO$_3$ is the dominant water type during both pre-monsoon and post-monsoon period.

The results of irrigational parameters showed that stream water in the study area is fit for irrigational purposes during both pre-monsoon and post-monsoon periods except few sites where the calculated values has crossed the limit of kelley’s ratio and magnesium hazard during post-monsoon period. Also few sites fall under class – III (unsuitable category) according to permeability index during both pre-monsoon and post-monsoon periods. The plot of chemical data on Trilinear diagram reveals that all the samples (except sample no. 12) fall in the field of 1, 3 and 5 during both pre-monsoon and post-monsoon periods suggesting that alkaline earth (Ca + Mg) exceeds alkalis (Na + K) and weak acids (CO$_3$ + HCO$_3$) exceeds strong acids (SO$_4$ + Cl) respectively (Table 2.11). The ions representing carbonate hardness (secondary alkalinity) exceeds 50%. From the above it can be concluded that total hydrochemistry of streams is dominated by alkaline earths and weak acids. The results indicate that Ca-Mg-HCO$_3$ is the dominant water type during both pre-monsoon and post-monsoon period.

Heavy metal analysis of Dal lake sample 2 (DW2) showed that the iron (Fe) content of the sample exceeded the standard limits. The concentration of lead (Pb) was not detected in pre-monsoon sample but it was calculated as 0.11 ppm in the post-monsoon sample. The observed value exceeded the maximum permissible limit of 0.05 ppm prescribed by ICMR (1975) and 0.01 ppm set by WHO (1984). The value also crossed the highest desirable limit of 0.05 ppm prescribed by BIS (1991). The amount of zinc (Zn) in the sample of lake during pre-monsoon and post-monsoon period were within the standard limits suggested by ICMR (1975), WHO (1984) and BIS (1991). The concentration of cadmium (Cd), copper (Cu), chromium (Cr) and
nickel (Ni) was not detected in the sample during both pre-monsoon and post-monsoon period.

The calculated values of all the physico-chemical parameters (pH, electrical conductivity, total dissolved solids, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate, phosphate, nitrate, and fluoride) of groundwater samples during pre-monsoon and post-monsoon period were within the desirable limits (except sample no. 7 for nitrate during post-monsoon period) recommended by the Bureau of Indian standards (BIS), Indian Council for Medical Research (ICMR) and World Health Organization (WHO) for drinking purpose. But bacteriological contamination was observed in few samples during both pre-monsoon and post-monsoon periods. After analyzing the groundwater samples for different physico-chemical parameters in pre-monsoon and post-monsoon periods, the results were subjected to statistical analysis.

During both pre-monsoon and post-monsoon period, TDS showed strong positive and significant correlation with EC \( r = 1.000^{**} \) at 0.01 level of significance. During pre-monsoon period, calcium showed negative and significant correlation with temperature \( r = -.487^{*} \) at 0.05 level of significance whereas no such correlation was observed during post-monsoon period. During pre-monsoon period, calcium also exhibited positive and significant correlation with EC \( r = .680^{**} \) and TDS \( r = .677^{**} \) at 0.01 level of significance whereas strong positive and significant correlation was observed between calcium and EC \( r = .861^{**} \) and calcium and TDS \( r = .861^{**} \) at 0.01 level of significance during post-monsoon period. Magnesium showed strong positive and significant correlation with EC \( r = .896^{**} \) and TDS \( r = .895^{**} \) at 0.01 level of significance. During post-monsoon period, magnesium showed positive and significant correlation with EC \( r = .743^{**} \), TDS \( r = .747^{**} \) and calcium \( r = .645^{**} \) at 0.01 level of significance. During pre-monsoon period, positive and significant correlation was observed between sodium and EC \( r = .487^{*} \) and sodium and TDS \( r = .488^{*} \) at 0.05 level of significance whereas no significant correlation was noticed between sodium and any of the parameter during post-monsoon period. Potassium showed negative and significant correlation with calcium \( r = -.578^{*} \) at 0.05 level of significance during pre-monsoon period whereas during post-monsoon period no such correlation was noticed. During pre-monsoon period,
positive and significant correlation was observed between carbonate and sodium (r = .629**) at 0.01 level of significance whereas carbonate exhibited negative and significant correlation with potassium (r = -.493*) during post-monsoon period. Bicarbonate showed strong positive and significant correlation with EC (r = .909**), TDS (r = .907**), calcium (r = .765**) and magnesium (r = .806**) at 0.01 level of significance during pre-monsoon period. Also, it showed strong and positive correlation with EC (r = .933**), TDS (r = .932**) and calcium (r = .895**) during post-monsoon period. Correlation between bicarbonate and magnesium during post-monsoon period (r = .641**) was not as strong as it was in pre-monsoon period (r = .806**) at 0.01 level of significance. Chloride showed positive and significant correlation with EC (r = .525*) and TDS (r = .524*) and carbonate (r = .545*) at 0.05 level of significance during pre-monsoon period. Also, chloride showed positive and significant correlation with sodium (r = .673**) during pre-monsoon period at 0.01 level of significance whereas during post-monsoon period strong positive and significant correlation was observed between chloride and EC (r = .766*) and chloride and TDS (r = .768**) at 0.01 level of significance. Chloride also exhibited positive and significant correlation with magnesium (r = .746**) at 0.01 level of significance and with bicarbonate (r = .529*) at 0.05 level of significance during post-monsoon period. Nitrate exhibited positive and significant correlation with EC (r = .535*) and TDS (r = .537*) at 0.05 level of significance and with chloride (r = .745**) at 0.01 level of significance whereas no significant correlation was observed between nitrate and any of the parameter during post-monsoon season. A positive and significant correlation between sulphate and chloride (r = .650**) at 0.01 level of significance was observed during post-monsoon season whereas during pre-monsoon period no such correlation was observed. Positive and significant correlation was noticed between fluoride and pH (r = .597*) at 0.05 level of significance during pre-monsoon period whereas fluoride exhibited positive and significant correlation with EC (r = .627**), TDS (r = .628**) and bicarbonate (r = .649**) at 0.01 level of significance and with calcium (r = .516*) at 0.05 level of significance during post-monsoon period. A significant variation between pre-monsoon and post-monsoon values of the parameters was tested by using paired t-test. Paired t-test was applied because the samples were taken from the same location during both pre-monsoon and post-monsoon period. A significant seasonal change was observed in temperature and pH
at 0.01 level of significance. Comparison of mean values showed higher values of
temperature and pH during pre-monsoon and lower values during post-monsoon
season (Table 4.6). EC, TDS, sodium and fluoride also showed impact of monsoon
and were found significant at 0.05 level of significance and lower mean values were
observed during post-monsoon period. A significant change was observed in
potassium and bicarbonate concentration in between two seasons, at 0.01 level of
significance whereas magnesium showed seasonal variation at 0.05 level of
significance. The mean value of magnesium showed high concentration during post-
monsoon period. Low mean value of fluoride in groundwater during post-
monsoon period may be due to the dilution. Bedrock containing fluoride is normally
responsible for elevated concentration of fluoride in groundwater (Handa, 1975;
Wenzel and Blum, 1992). These different relationships do indicate some impact of
seasonal variations on water quality of the study area. In terms of seasonal impact,
obtained result shows dilution and flushing of some parameters by the monsoon but
other parameters show high leaching of different chemical elements to the
groundwater leading to enrichment of different parameters. Consequently, some
contents were affected by seasonal variations.

The results of irrigational parameters showed that the groundwater of the
study area is fit for irrigational purposes during both pre-monsoon and post-monsoon
periods except few sites where the values of % sodium, kelley’s ratio, magnesium
hazard and permeability index has crossed the acceptable limit and falls under
unsuitable category.

Heavy metal analysis of sample number 4 (GWS4) showed that during pre-
monsoon and post-monsoon period the iron (Fe) content was 0.44 ppm and 0.77 ppm
(Table 4.7) respectively. ICMR (1975) and WHO (2004) have prescribed highest
desirable limit of 0.1 ppm and maximum permissible of 1.0 ppm. While BIS (1991)
has fixed the highest desirable limit of 0.3 ppm and maximum permissible limit of 1.0
ppm (Table 2.12) in drinking water supplies and the observed values exceeded the
highest desirable limit as prescribed by ICMR (1975), BIS (1991) and WHO (2004).
The concentration of lead (Pb) during pre-monsoon period was 0.07 ppm and it was
calculated as 0.12 ppm in the post-monsoon sample. The observed value exceeded the
maximum permissible limit of 0.05 ppm prescribed by ICMR (1975) and 0.01 ppm
set by WHO (1984). The value also crossed the highest desirable limit of 0.05 ppm
prescribed by BIS (1991). The amount of zinc (Zn) in the water sample was calculated 0.06 ppm during both pre-monsoon and post-monsoon period and the values were within the standard limits suggested by ICMR (1975), WHO (1984) and BIS (1991) (Table 2.13). Cadmium (Cd) content in the sample was calculated as 0.01 ppm during both the periods and is equivalent to the maximum permissible limit of 0.01 ppm as prescribed by ICMR (1975) and WHO (1984). Copper (Cu) was not detected during pre-monsoon period but it was calculated as 0.05 ppm during post-monsoon period and the value is equivalent to the highest desirable limit of 0.05 ppm as prescribed by ICMR (1975), WHO (1984) and BIS (1991). The concentration of chromium (Cr) and nickel (Ni) was not detected in the sample during both pre-monsoon and post-monsoon period.

In case of municipal water samples, the calculated values of all the physicochemical parameters (pH, electrical conductivity, total dissolved solids, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate, phosphate, nitrate, and fluoride) were within the desirable limits recommended by the Bureau of Indian standards (BIS), Indian Council for Medical Research (ICMR) and World Health Organization (WHO) for drinking purpose for both pre-monsoon and post-monsoon period. Results of dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) were also within the prescribed limits but bacteriological contamination was observed in few samples during both pre-monsoon and post-monsoon periods. After analyzing the samples for different physicochemical parameters in pre-monsoon and post-monsoon periods, the results were subjected to statistical analysis.

In case of municipal water samples, TDS showed strong positive and significant correlation with EC during both pre-monsoon (r = 1.000**) and post-monsoon periods (r = 1.000**) at 0.01 level of significance. Calcium exhibited strong positive and significant correlation with EC during both pre-monsoon (r = .972**) and post-monsoon periods (r = .916**) at 0.01 level of significance. Calcium also exhibited strong positive and significant correlation with TDS during both pre-monsoon (r = .973**) and post-monsoon periods (r = .914**) at 0.01 level of significance. During pre-monsoon period, magnesium exhibited strong positive and significant correlation with EC (r = .854**), TDS (r = .850**) and calcium (r = .831**) at 0.01 level of significance. Magnesium also showed strong positive and
significant correlation with EC ($r = .903^{**}$) and TDS ($r = .905^{**}$) at 0.01 level of significance during post-monsoon period. Also, positive and significant correlation was observed between magnesium and calcium ($r = .706^{**}$) at 0.01 level of significance during post-monsoon period. Sodium exhibited positive and significant correlation with EC ($r = .583^{*}$) and TDS ($r = .585^{*}$) at 0.05 level of significance during pre-monsoon period. Also, negative and significant correlation was observed between sodium and pH ($r = -.578^{*}$) at 0.05 level of significance. During post-monsoon period sodium exhibited strong positive and significant correlation with EC ($r = .829^{**}$), TDS ($r = .832^{**}$) and magnesium ($r = .829^{**}$) at 0.01 level of significance and with calcium ($r = .572^{*}$) at 0.01 level of significance. Potassium exhibited positive and significant correlation with sodium ($r = .593^{*}$) at 0.05 level of significance during pre-monsoon period and at 0.01 level of significance ($r = .703^{**}$) during post-monsoon period. Carbonate exhibited strong positive and significant correlation with EC ($r = .851^{**}$), TDS ($r = .848^{**}$), calcium ($r = .819^{**}$) and magnesium ($r = .792^{**}$) at 0.01 level of significance and with sodium ($r = .520^{*}$) at 0.05 level of significance during pre-monsoon period whereas during post-monsoon period, strong positive and significant correlation was observed only between carbonate and calcium ($r = .833^{**}$) at 0.01 level of significance. Carbonate also exhibited positive and significant correlation with EC ($r = .579^{*}$) and TDS ($r = .575^{*}$) at 0.05 level of significance during post-monsoon period. During both pre-monsoon and post-monsoon periods, bicarbonate exhibited strong positive and significant correlation with EC, TDS, calcium and magnesium at 0.01 level of significance. Bicarbonate also exhibited positive and significant correlation with carbonate ($r = .767^{**}$) at 0.01 level of significance during pre-monsoon period and at 0.05 level of significance during post-monsoon period ($r = .605^{*}$). Positive and significant correlation was also observed between bicarbonate and sodium ($r = .753^{**}$) at 0.01 level of significance during post-monsoon period but no such correlation was noticed during pre-monsoon period. During both pre-monsoon and post-monsoon periods, chloride showed positive and significant correlation with EC and TDS at 0.01 level of significance. Strong positive and significant correlation was also observed between chloride and sodium during both pre-monsoon and post-monsoon period at 0.01 level of significance. Chloride exhibited positive and significant correlation with calcium ($r = .527^{*}$) at 0.05 level of significance and with carbonate ($r = .679^{**}$) at 0.01 level of
significance whereas no such correlation was noticed during post-monsoon period. During post-monsoon period, chloride showed positive and significant correlation with magnesium ($r = .747^{**}$) and potassium ($r = .698^{**}$) at 0.01 level of significance and with bicarbonate ($r = .618^{*}$) at 0.05 level of significance whereas no such correlation was observed during pre-monsoon period. Sulphate showed positive and significant correlation with carbonate ($r = .520^{*}$) at 0.05 level of significance during pre-monsoon period whereas no significant correlation was observed between sulphate and any of the parameter during post-monsoon period. Phosphate showed negative and significant correlation with chloride ($r = -.622^{*}$) at 0.05 level of significance during post-monsoon period whereas no significant correlation was observed between phosphate and any of the parameter during pre-monsoon period. Nitrate exhibited positive and significant correlation with sodium ($r = .696^{**}$), potassium ($r = .747^{**}$) and chloride ($r = .788^{**}$) at 0.01 level of significance during pre-monsoon period whereas during post-monsoon period, correlation with sodium ($r = .524^{*}$), potassium ($r = .627^{*}$) and chloride ($r = .640^{*}$) was observed at 0.05 level of significance. During pre-monsoon period nitrate showed positive and significant correlation with temperature ($r = .557^{*}$) at 0.05 level of significance whereas no such correlation was observed during post-monsoon period. Negative and significant correlation was also noticed between nitrate and pH during post-monsoon period whereas no such correlation was observed during pre-monsoon period. Negative and significant correlation was observed between fluoride and bicarbonate ($r = -.516^{*}$) at 0.05 level of significance during pre-monsoon period whereas positive and significant correlation was noticed between fluoride and phosphate ($r = .527^{*}$) during post-monsoon period.

To assess the impact of seasonal variation, mean values of samples were taken into the consideration as characteristics values. The mean values of temperature, EC, TDS, pH, calcium, sodium, carbonate and sulphate were observed high during pre-monsoon period whereas magnesium, potassium, bicarbonate, phosphate, nitrate and fluoride were observed high during post-monsoon period. A significant variation between pre-monsoon and post-monsoon values of the parameters was tested by using paired t-test. A significant seasonal change at 0.01 level of significance was observed in temperature and pH. Comparison of mean values showed higher values of temperature and pH during pre-monsoon whereas potassium and nitrate showed
higher mean values during post-monsoon period at 0.01 level of significance (Table 4.20). Sulphate also showed impact of monsoon and were found significant at 0.05 level of significance and higher mean values were observed during pre-monsoon period.

From the geochemical analysis of Dal lake samples it has been observed that during pre-monsoon period the average value of silica for all the lake samples showed more closeness towards the standard value for shale (273000 µg/g) for silica whereas during post-monsoon period the average value was more close to standard value of sandstone (368000 µg/g) for silica. In case of alumina, the average value showed more closeness towards the standard value for sandstone (25000 µg/g) for alumina during both the seasons. The average concentration of calcium in lake was appreciably less as compared to the standard values of calcium in shale (22100 µg/g) and sandstone (39100 µg/g) during both pre-monsoon and post-monsoon period. During pre-monsoon period the average concentration of magnesium in Dal lake was 26602.36 µg/g which is closer to the standard value for shale (15000 µg/g) than to the standard value for sandstone (7000 µg/g) for magnesium whereas during post-monsoon period the average concentration increases to 30586.14 µg/g and the value exceeded the standard value for shale (15000 µg/g) and sandstone (7000 µg/g) for magnesium. The average value of titanium showed more closeness towards the standard value for shale (4600 µg/g) for titanium during both pre-monsoon and post-monsoon period. The average concentration of phosphorus during pre-monsoon period was 314 µg/g and is more closer to the standard value for sandstone (170 µg/g) than for the standard value for shale (700 µg/g) for phosphorus whereas during post-monsoon period the average content of phosphorus increases to 483.43 µg/g which is more closer to the standard value for shale (700 µg/g) than to the standard value for sandstone (170 µg/g) for phosphorus. During both the periods, the average value of iron showed more closeness towards the standard value for sandstone (9800 µg/g) than to the standard value for shale (47200 µg/g) for iron. The average value of sodium of lake soil showed more closeness towards the standard value for shale (9600 µg/g) than to the standard value for sandstone (3300 µg/g) for sodium during both the periods. The average concentration of potassium during pre-monsoon and post-monsoon period was 31736.17 µg/g and 38087.24 µg/g and is more closer to the
standard value for shale (26600 μg/g) for potassium than to the standard value for shale (10700 μg/g) for potassium.

In case of geochemical analysis of agricultural fields, the average value of silica showed more closeness towards the standard value for shale (273000 μg/g) for silica during pre-monsoon period whereas during post-monsoon period the average value was more close to standard value of sandstone (368000 μg/g) for silica. In case of alumina, the average value showed more closeness towards the standard value for sandstone (25000 μg/g) for alumina during both the periods. The average concentration of calcium was appreciably less as compared to the standard values of calcium in shale (22100 μg/g) and sandstone (39100 μg/g) during both pre-monsoon and post-monsoon period. The average content of magnesium was more closer to the standard value for shale (15000 μg/g) than to the standard value for sandstone (7000 μg/g) for magnesium. The average value of titanium showed more closeness towards the standard value for shale (4600 μg/g) for titanium during both pre-monsoon and post-monsoon period. During pre-monsoon period, the average content of phosphorus was closer to the standard value for sandstone (170 μg/g) for phosphorus whereas during post-monsoon period more closeness was towards the standard value for sandstone for phosphorus. During both the periods, the average value of iron showed more closeness towards the standard value for sandstone (9800 μg/g) for iron. The average value of sodium showed more closeness towards the standard value for shale for sodium exceeds the standard value for shale (9600 μg/g) and sandstone (3300 μg/g) for sodium during both pre-monsoon and post-monsoon period. Also in case of potassium, the average value exceeded the standard value for shale (26600 μg/g) and sandstone (10700 μg/g) for potassium (Figure 4.20) for both the periods.

After analyzing the soil samples (Dal lake and agricultural fields) for different parameters during pre-monsoon and post-monsoon periods, statistical analysis (correlation analysis, mean, standard deviation and standard error and paired t-test) was also carried out in order to assess the significant variation between pre-monsoon and post-monsoon values of different parameters.

In case of Dal lake, EC showed negative and significant correlation with pH ($r = -.966**$) at 0.01 level of significance during pre-monsoon period whereas no such correlation was observed during post-monsoon period. In case of TDS, negative and significant correlation was observed with pH ($r = -.963**$) at 0.01 level of
significance whereas no such correlation was observed in post-monsoon period. Also, TDS exhibited strong positive and significant correlation with EC during both pre-monsoon ($r = .998^{**}$) and post-monsoon period ($r = .999^{**}$) at 0.01 level of significance. During pre-monsoon period, silica showed positive and significant correlation with pH ($r = .987^{**}$) at 0.01 level of significance. Silica also exhibited negative and significant correlation with EC ($r = -.974^{**}$) and TDS ($r = -.975^{**}$) at 0.01 level of significance whereas during post-monsoon period silica exhibited no significant correlation with any of the parameter. During pre-monsoon period, alumina showed negative and significant correlation with pH ($r = -.902^{*}$) and silica ($r = -.956^{*}$) at 0.05 level of significance. Also, positive and significant correlation was noticed between alumina & EC ($r = .936^{*}$) and alumina & TDS ($r = .950^{*}$) at 0.05 level of significance during pre-monsoon period whereas no significant correlation was noticed between silica and any of the parameter during post-monsoon period. Magnesium showed positive and significant correlation with alumina ($r = .931^{*}$) and calcium ($r = .913^{*}$) at 0.05 level of significance during pre-monsoon period whereas during post-monsoon period, negative and significant correlation was noticed between magnesium and pH ($r = -.889^{*}$) at 0.05 level of significance. A negative and significant correlation was observed between phosphorus and pH during both pre-monsoon ($r = -.923^{*}$) and post-monsoon period ($r = -.904^{*}$). During post-monsoon period, phosphorus also showed positive and significant correlation with magnesium ($r = .933^{*}$) at 0.05 level of significance and with titanium ($r = .959^{**}$) at 0.01 level of significance whereas no such correlation was noticed during pre-monsoon period. Iron exhibited negative and significant correlation with pH ($r = -.932^{*}$) at 0.05 level of significance, positive and significant correlation with EC ($r = .887^{*}$) at 0.05 level and with phosphorus ($r = .975^{**}$) at 0.01 level of significance during pre-monsoon period whereas no significant correlation was observed between iron and any of the parameter during post-monsoon period. During pre-monsoon period, a strong negative and significant correlation was noticed between potassium & pH ($r = -.985^{**}$) and potassium & silica ($r = -.989^{**}$) at 0.01 level of significance. A strong positive and significant correlation was noticed between potassium and TDS ($r = .934^{**}$) at 0.01 level of significance. Also potassium showed positive and significant correlation with EC ($r = .935^{*}$), alumina ($r = .920^{*}$), phosphorus ($r = .886^{*}$) and iron ($r = .879^{*}$) at 0.05 level of significance during pre-monsoon season whereas no such significant
correlation was observed during post-monsoon period. A significant seasonal
variation was observed in silica at 0.01 level of significance. Comparison of mean
values showed higher silica during post-monsoon period. The calcium content was
also found significant at 0.05 level of significance and showed high concentration
during post-monsoon period. During post-monsoon period, the quantity of surface
water increases which results into the increase in velocity and dissolution of rocks in
the area. The increase in velocity increases the capacity of water to carry more of sand
sized grains (sandstone) and deposit these into the lake sediments or fields. The effect
of this increase in sand sized grains results into the significant increase in silica during
post-monsoon period. The values of silica also exhibit closer affinity to sandstone.
The increase in solubility of source rocks during post-monsoon dissolves more and
more of calcium oxide from lime rich rock. The dissolved constituents are carried
through surface streams and calcium compounds get precipitated in the stagnant water
of lake. This results into the significant increase in calcium oxide in the soil samples
of lake collected during post-monsoon period.

In case of agricultural fields, EC showed positive and significant correlation
with pH ($r = .735^*$) at 0.05 level of significance during post-monsoon period whereas
no such correlation was observed during pre-monsoon period. TDS exhibited strong
positive and significant correlation with EC during both pre-monsoon ($r = .999^{**}$)
and post-monsoon period ($r = .1.000^{**}$) at 0.01 level of significance. Also, it showed
positive and significant correlation with pH ($r = .731^*$) at 0.05 level of significance
during post-monsoon period whereas no such correlation was observed during pre­
monsoon period. Calcium exhibited positive and significant correlation with EC
during both pre-monsoon ($r = .750^*$) and post-monsoon ($r = .709^*$) periods at 0.05
level of significance. Also, calcium showed positive and significant correlation with
TDS during pre-monsoon ($r = .753^*$) and post-monsoon ($r = .722^*$) periods at 0.05
level of significance. Magnesium showed positive and significant correlation with
alumina ($r = .729^*$) at 0.05 level of significance during pre-monsoon season whereas
during post-monsoon period negative and significant correlation was noticed between
magnesium and silica ($r = -.753^*$) at 0.05 level of significance and positive and
significant correlation was observed between magnesium & calcium ($r = .808^*$) at
0.05 level of significance. A strong positive and significant correlation was observed
between phosphorus and EC during both pre-monsoon ($r = .845^{**}$) and post-monsoon
period ($r = .938^{**}$) and between phosphorus and TDS during both pre-monsoon ($r = .852^{**}$) and post-monsoon period ($r = .938^{**}$) at 0.01 level of significance. During pre-monsoon period, phosphorus also showed negative and significant correlation with silica ($r = -.774^{*}$) at 0.05 level of significance. Phosphorus also exhibited positive and significant correlation with pH ($r = .787^{*}$) at 0.05 level of significance whereas no such correlation was noticed during pre-monsoon period. A positive and significant correlation was observed between iron & alumina ($r = .811^{*}$) and iron & magnesium ($r = .772^{*}$) at 0.05 level of significance during pre-monsoon season whereas no significant correlation was observed between iron and any of the parameter during post-monsoon period. During pre-monsoon period, a strong positive and significant correlation was noticed between potassium & sodium ($r = .915^{**}$) at 0.01 level of significance whereas potassium exhibited no significant correlation with any of the parameter during post-monsoon period. The samples from agricultural fields showed significant seasonal variation in EC, TDS, silica and calcium at 0.01 level of significance and in sodium at 0.05 level of significance. Comparison of mean values showed higher EC, TDS, silica and calcium during post-monsoon period whereas the concentration of sodium decreases during post-monsoon period.

From the sedimentological analysis of Dal lake samples, it can be concluded that the log probability plots for the Dal lake soil samples are in general, three segmented showing involvement of traction, saltation and suspension processes in deposition of the sediments. A few samples, however, showed only two segments i.e. saltation and suspension in distribution curves. The lake mainly composed of materials that are finer in texture. These particles of the fine-textured soils exclusively fall in the size fractions of $> 4.00 \phi$ which represent the suspension load of the log probability curve. Thus, it seems possible that the parent material of most of the fine textured soils has been deposited mainly by suspension process. The log probability plot for most of the soil samples from the agricultural field showed two segments i.e. saltation and suspension. Two samples i.e. sample 8 and sample 10, however, showed the involvement of only single segment i.e. saltation whereas only one sample (sample 13) was three segmented i.e. showed involvement of traction, saltation and suspension processes in deposition of the sediments. Out of eight samples, seven samples showed finer texture of the particles and the particles of fine-textured soils exclusively fall in the size fractions of $> 4.00 \phi$ which represent the suspension load of
the log probability curve. Thus, it seems possible that the parent material of most of the fine textured soils has been deposited mainly by suspension process. The sample from municipal waste dumping site showed two segments i.e. saltation and suspension processes in deposition of the sediments. The sample is relatively coarser in texture as maximum distribution was observed at 2φ and the process of saltation was dominant during deposition of sediments.

The research area forms a part of highly tectonically active zone as the three major tectonic features i.e. Chail Thrust (equivalent to MCT: Main Central Thrust), MBT (Main Boundary Thrust), and Drini Thrust pass through this area resulting in severe seismological activity evident from the destructive earthquakes of 1905, 1965, 1978 and 1986. This is a strong reason that geoenvironmental study assumes an added importance. The area from north to south comprises of Dhauladhar granite, Chail formation, Dharamkot limestone, Subathu formation, Dharamsala traps, Dharamsala group, Siwalik group, and alluvium.

Based on the satellite data, the area of study has been divided into five major geomorphic zones i.e. permafrost zone (snow cover), zone of denudational hills, zone of structural hills, zone of siwalik dissected hills, and valley fill zone. Denudational hills cover maximum area with 67.03 sq. km. that comes out to be 55.12% of the total study area whereas minimum area is covered by structural hills i.e. 1.34 sq. km. (1.10%) of the total study area.

Various morphometric parameters such as linear aspect of the drainage network: stream order, stream number, stream length, bifurcation ratio and aerial aspects: stream frequency, drainage density, texture ratio have been computed using remote sensing and GIS technology in order to analyze the drainage of different streams in the study area. The study area has 4th order drainage, where 581 streams were identified of which 422 are 1st order streams, 127 are 2nd order, 28 are in 3rd order and 4 are indicating 4th order streams. Drainage pattern of stream network have been observed as mainly dendritic type which indicates the homogeneity in texture and lack of structural control. This pattern is characterized by a tree like or fernlike pattern with branches that intersect primarily at acute angles. While in some parts tributaries flow nearly parallel to one another and all the tributaries join the main channel at approximately the same angle which corresponds to parallel drainage pattern. Parallel drainage suggest that the area has a gentle, uniform slopes and with
less resistant bed rock. The plotting of logarithm of number of streams against stream order showed a linear relationship, with small deviation from a straight line. This means that the number of streams usually decreases in geometric progression as the stream order increases.

The stream length of 1st, 2nd, 3rd and 4th order is 255.68 km, 88.79 km, 28.55 km, and 49.37 km respectively. Plot of the logarithm of stream length versus stream order showed the linear pattern which indicates the homogenous rock material subjected to weathering-erosion characteristics of the area. The mean stream length increases as the drain order increases. Streams of relatively smaller lengths are characteristics of areas with larger slopes and fine textures. Longer lengths of streams are generally indicative of flatter gradients. Bifurcation ratios characteristically range between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern.

The drainage density of the area is 3.47 km/sq. km and categorized as moderate in nature. The drainage frequency of the study area is 4.78 and categorized as moderate in nature. The value of drainage frequency exhibit positive correlation with the drainage density value, indicating the increase in stream population with respect to increase in drainage density. Texture ratio value depends on the underlying geology, infiltration capacity of bedrock and relief aspect of the terrain. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. In the present study the texture ratio of the area is 8.79 and drainage density is moderate hence texture ratio has been categorized as moderate in nature.

The slope zone map of the study area has been prepared by applying Wentworth average slope method. Slope analysis in the study area has revealed ranges from < 15° to > 45°. The slope zone map has been categorized into five groups i.e. very gentle slope (< 15°), gentle slope (> 15° to 25°), moderately steep slope (> 25° to 35°), steep slope (> 35° to 45°), and very steep slope (> 45°). The major part i.e. 53.1 % (64.6 sq. km.) of the study area is under the category of very steep slope and mainly dominated by dense and open forests and inhabited the famous tourist destinations i.e. McLeod Ganj, Bhagsu Nag, Dharmkot, Triund and Naddi whereas minimum area (8.6 % i.e. 10.5 sq. km.) falls under moderately steep slope and mainly supported the habitation of the main township of Dharamshala, Mant and Dari.
Land use/land cover change information has an important role to play at local and regional as well as at macro level planning. In the present study land-use/land-cover (LU/LC) categorization is based on the classification scheme developed by National Remote Sensing Agency (NRSA, 1995). The land-use/land-cover was studied for 2 years i.e. 1969 and 2005. In 1969, the analysis was based on Survey of India topographical maps and in 2005, it was based on satellite imagery. In 1969, five classes and in 2005 six classes have been delineated in level I. In level II, nine classes have been delineated in 1969 and sixteen classes in 2005.

The study reveals that the settlement or the built up land occupied 10.42 sq. km. i.e. 8.57% of the total study area in 1969 which has grown to 14.45 sq. km. i.e. 11.88% in 2005. The area falling under agricultural land was 25.26 sq. km. i.e. 20.77% in 1969 and decreased to 24.14 sq. km. i.e. 19.85% in 2005. In 1969, 2.01 sq. km. i.e. 1.65% and in 2005, 2.46 sq. km. i.e. 2.02% was under agricultural plantation. A slight increase of 0.01% has been observed. In 1969 area under dense forest was 54.07 sq. km. i.e. 44.46% whereas in 2005 it has been decreased to 42.84 sq. km. i.e. 35.23%. A decrease of 9.23% has been observed. Area falling under open forest was 0 sq. km. i.e. 0% in 1969 but it has been covered the area of 8.37 sq. km. i.e. 6.88% in 2005. There was no scrub forest observed in the study area in 1969 but 3.48 sq. km. i.e. 2.86% of the total study area can be seen under scrub forest in 2005. No forest blank was observed in 1969 in whole of the study area but in 2005, 9.43 sq. km. i.e. 7.75% falls under the category of forest blank. Area falling under land with scrub was nil in 1969 whereas in 2005 it covers an area of 2.82 sq. km. i.e. 2.32% of the total study area. There was no area under the category of land without scrub in 1969 but 2.83 sq. km. i.e. 2.33% of the total study area can be seen under this category in 2005. In 1969 the area under mining was only 0.04 sq. km. i.e. 0.03% of the total study area but in 2005 it has been increased many folds i.e. 3.0 sq. km. (2.47%) of the total study area. In 1969 out of the total study area 27.53 sq. km i.e. 22.64% was under the category of barren/ rocky/ stony waste land whereas only 0.92 sq. km. i.e. 0.76% area was observed under this category in 2005. In the study area streams covers an area of 2.26 sq. km. i.e. 1.86% in 1969 whereas in 2005 it has been increased to 4.46 sq. km. i.e. 3.67%. In the topographical sheet of 1969 area under Dal lake was 0.02 sq. km but it has been reduced to half (0.01 sq. km.) as observed in the satellite imagery of 2005. No grassland or grazing land was observed in the study area in 1969 whereas 0.06 sq.
km. i.e. 0.05% area was under this category as per the satellite imagery of 2005. No area was observed under this category in the topographical sheet of 1969 however 2.34 sq. km i.e. 1.9% of the total area can be seen under this category in the satellite imagery of 2005.

From the land-use/land-cover analysis it has been observed that encouraging emphasis on infrastructure development projects due to increase in tourist activities has resulted in the rapid growth of construction sector. There is a significant difference in the scenic beauty and the overall ambience of Dal lake. The lake has been reduced to half of its original size. Mining in the study area is haphazard and is being carried out by traditional manual methods. The unscientific mining poses a serious threat to the environment, resulting in the reduction of forest cover, erosion of soil in a greater scale, pollution of air, water, and land and reduction in biodiversity. Depletion of natural water body (Dal lake), decrease in the cover of dense forests and increase in mining activities in the study area is mainly due to the mismanagement of natural resources and lack of sustainable approach.

In Dharamshala, Bhagsu Nag and Khaniara are the two sites where slate quarrying is presently going on. Bhagsu Nag lies in the north west part whereas Khaniara lies in the north east part of the study area. The unplanned and unscientific opencast mining of the slates throughout the entire stretch ranging from Bhagsu Nag to Khaniara along Churan, Manjhi and Manuni stream has resulted in number of unending environmental problems. Most of the area under mining is being exploited illegally and unauthorisedly. Mining in these areas is haphazard and the procedure adopted for mining are totally unscientific without using any standard mine plan maps or contour map or any standard method of national or international agencies. The slates are extracted either manually by using crowbars, chisels or by using local explosive for blasting. Unscientific excavation and use of high power explosives have resulted in cracking and loosening of the overlying rock formation. The villages below the mining sites often experiences flying rocks and rock fall result in number of causalities. Further, most of the area is under the protected forest demarcated by the Department of Forest, Himachal Pradesh which has been exploited in an unauthorized and illegal manner. No reclamation measures such as construction of check dams or retaining wall to check the erosional activity or other safety measures related to blasting are being taken up. Slate mining has blotted the serene beauty of the forests.
of the area. Mining activities in these areas have caused the degradation of vegetation and soil cover, destruction of agricultural land and encroachment of forest land, further leading to the deterioration of water resources, increase in erosional activities, silting of streams, and massive landslides. Comparison between Survey of India toposheet (1969) and satellite imagery (2005) shows the increase of 2.44% area under mining. As it can be inferred from the slope analysis of the study area that most of the mining sites fall under the category of steep slope and is considered to be highly prone to landslides. The mining activities in these areas have further led to the instability of the entire hills by increasing the slope angles of the rock formations.

The study area is seismically active and lies in Zone V of the Seismic Zoning Map of India (IS 1893:2002). The area has experienced several destructive earthquakes in the past. Few of them are the great Kangra earthquake of April 4, 1905 of magnitude 7.0, November 1968 of magnitude 4.5, June 1978 of magnitude 5 on Richter scale, and the area was again rocked by an earthquake on 26th April, 1986 with a loud sound which lasted for 5 to 6 seconds. It measured 5.5 on Richter scale. The area suffered heavy damage to property in the form of ground cracks and landslips. The strongest seismicity in the study area is attributed to movements along the MBT (Main Boundary Thrust) and MCT (Main Central Thrust).

The study area also experiences massive landslides especially during rainy seasons. Urbanization and mining activities in the northern part of the study area leads to deforestation which has contributed to landslides but these activities cannot be solely held responsible because the region is sandwiched between the two important longitudinal thrust systems i.e. Main Boundary Thrust (MBT) and the Main Central Thrust (MCT) and their activity have resulted in the formation of crushed and tectonically weak zone and has resulted in landsliding. So, the anthropogenic and natural factors both are responsible for the destabilization of the area. On the basis of lineaments, geological set up, slope, drainage, land cover, unscientific mining activities, unplanned urbanization and past records, the study area has been divided into five hazard zones i.e. the hazard zones were marked on the basis of vulnerability of different parts to the number of factors for hazard. Earthquakes have been identified on the basis of lineaments, epicentres and past records. Landslides have been identified on the basis of degree of slope and mining activities in the area. Drainage and stream length of the area have been taken as the base for identifying
floods. Land cover was taken into the consideration for identifying the forest fire (presence of forests) and avalanche (snow cover). Anthropogenic activities have been identified on the basis of mining and consequent urbanization.

Zone I (Very high Risk Zone) is characterized by four types of hazards and covers an area of 15.02 sq. km. i.e. 12.35% of the total research area. This zone needs proper investigation and monitoring prior to any developmental activity as tourist places like Forsytheganj, McLeod Ganj, Dharamkot and Naddi comes under this zone. Zone II (High Risk Zone) is marked by presence of three types of hazards responsible for the sensitivity of the zone. Forest dominates this zone and covers maximum area i.e. 40.31 sq. km. (33.15%) of the total study area. Zone III (Moderate Risk Zone) is prone to two types of hazards and out of the total study area it covers an area of 11.59 sq. km. i.e. 9.53%. Maximum part of this zone is under forest cover. Zone IV (Low Risk Zone) covers an area of 15.12 sq. km i.e. 12.43% of the total study area and is susceptible to one type of hazard. Zone V (Risk Free Zone) is not affected by any of the factors identified for natural hazards. After zone II this zone covers the maximum area with 39.57 sq. km i.e. 32.54% of the total study area. This zone covers most of the valley fill region and is highly inhabited and supports the habitation of main township i.e. Dharamshala and also includes the highly populated villages like Mant, Barol, Dari, Gharoh, Fatehpur and Sidhpur.

Anyone, who closely observes the unplanned activities in the study area cannot help but be alarmed about its safety in the near future. Also from the land-use/land-cover (LU/LC), it can be seen that new constructions are coming up in highly active zone present in the southern and the north western part of the study area. The growing number of multi-storied buildings and that too without following any building codes on this high zone shows that people have been intoxicated so much in keeping pace with the growing demand for housing and commercial complex that they have not given any consideration to seismology and are increasing their vulnerability every day, every hour and every second. If the issues like unplanned urbanization, haphazard mining operations, slope instability are not taken into the consideration or handled properly, could lead to mass movement of devastating nature and it could in turn prove to be very disastrous.
7.2 SUGGESTIONS

Following are the suggestions and recommendations in order to protect the geoenvironment of area prone to many natural and man-made disasters and necessary measures that has to be taken to check further degradation of geoenvironment.

7.2.1 SUGGESTIONS FOR MAINTAINING DAL LAKE

Keeping all the problems (siltation, deforestation etc.) in mind some concrete steps has been suggested in maintaining the only wetland in the study area:

- Proper channelization of run-off water should be there
- Construction of retaining walls that prevents the silt from coming into the lake.
- Check on deforestation and open grazing in upper catchment areas.
- The most important step is to hedge against erosion along the slope and for this vetiver grass can be grown.

The restoration goals suggested require profound planning, legislation, funding and active involvement from all levels of organization. The negligence has already resulted in the loss of this precious Divine gift. There is a dire need to restore, conserve and manage this neglected lot of nature and preserve this paradise from vanishing.

7.2.2 SUGGESTIONS FOR MAINTAINING MUNICIPAL WASTE

- Household segregation should be promoted.
- People should be made aware of composting so that organic waste can be managed at source only.
- Inorganic waste can either be sell to small dealers directly for recycling or to nearby power plants for fuel (ACC Cement at Barmana or Ambuja Cement at Darlaghat) after drying and shredding.
- In order to ensure Zero garbage on road colored bins per 15 – 20 household should be provided for the collection of organic, inorganic and inert waste separately.
• Inert material such as mud, stone, sand, glass etc. can be used for filling purposes.

Figure 7.1 shows the proposed layout for managing the solid waste in the study area.

**Figure 7.1: Proposed layout for managing solid waste in the study area**
7.2.2.1 RESPONSIBILITY AT MUNICIPAL COMMITTEE LEVEL

- The segregated waste (Biodegradable and non-biodegradable) should be collected every day from the doorstep or from the containers by sweepers employed by the Municipal Committee.
- Regular emptying and maintenance of municipal containers
- Cleaning of container surrounding
- Open burning at dumpsite should be stopped
- Indiscriminate dumping and littering is prohibited by Indian law. Strict enforcement of this law can change the scenario.
- Organization of ‘mass clean-up’ drive and public awareness programmes.

7.2.2.2 RESPONSIBILITY AT INDIVIDUAL LEVEL

- Buy reusable and recyclable products.
- Less use of harmful products.
- Use products that last longer.
- Repair products.
- Management of biodegradable waste on one’s own level.
- Dumping of waste in waste containers rather than littering here and there.

7.2.3 SUGGESTIONS FOR MINING

- In order to restore the area that has been degraded by the mining, Government should take up the initiative by strictly imposing the complete ban on further quarrying in Bhagsu Nag and Khaniara.
- A complete survey of the area should be done to prepare an eco-restoration plan. There should be a regular check on unauthorized mine operators and if anyone found involved then strict action should be taken against him.
- NGO’s should also come up for the restoration project.
- First of all the mine debris or the slate waste over the slope should be removed in order to bring back the regolith cover. After that, the area should be seeded with quick growing grass and preference should be given to local species and
mixed culture. Although the best plant known and used worldwide to stop the erosion is *Vetiver*. It not only holds soil on mountain side but it creates its own terraces by collecting leaves, debris and eroded soil from above it. In addition to *vetiver*, a perennial grass known as Nash (*etiveria zizanioide*) can also be grown.

- The mining area can also be restored by hydroseeding. This technique involves spraying of soils, organic matter, grass seeds, adhesives and water in a fixed proportion which is kept in a slurry tank. The application of mixture is made at a pressure on slope. Such technique is successfully adopted in reclamation of limestone and rock phosphate mines in Dehradun and Mussorrie region (CMRI Report, 1997).

- After reclamation if mining has to be carried out then it should be purely on scientific basis.

- For planned and scientific mining, mining consultants should be appointed.

- Proper mine plans should be developed and only those areas should be identified for the mining that are compatible with the geology and the structural framework of the area.

- Mining should be avoided where there is a steep slope i.e. the slope angle is more than 45°. It should also be avoided in landslide prone areas.

- Check dams and gabion structure should be constructed to check the flow of soil, waste and debris along the hill slope.

- The problem of mine debris can be solved by utilizing it in making concrete blocks as it is eco-friendly and economically viable too and will also serve as a source of employment for the local population.

- According to Mackenzie (1981), another important use of slate waste lies in the manufacturing of pipe, sheets and roofing plus flooring products as substitutes for asbestos in asbestos industry. The advantage of slate as alternative to asbestos is that asbestos is a fibrous material and cause cancer. Hence, the use of slate can be accepted in asbestos industry.

- The scientific and planned underground mining if on one hand maintain the ecological balance, would also result in prosperity of the area as well as of the population. Thus, mining should be done with proper rehabilitation,
restoration and reclamation keeping in mind the environmental rules and regulations and not in a way to fill pockets of few and neglecting environment.

7.2.4 SUGGESTIONS TO REDUCE VULNERABILITY AND RISK

- Land should be used according to its capacity and capability i.e. there should be careful planning of land use to ensure that development and infrastructure are appropriately located. Urbanization in the steep to very steep slope should be very limited as such slope house major tectonic features in the area. All the developmental projects should be reserved to least active zones only. Also zoning can only be effective if it is properly enforced.

- Site should be investigated, monitored or surveyed conscientiously prior to any developmental activity keeping in mind the geology or the structural framework of the area.

- As whole of the study area lies in the Zone V of the Seismic Zoning Map of India, developing building and design codes that are appropriate to the circumstances should be taken into consideration but, again, these are only effective if properly enforced.

- Precautionary actions should be taken in case of most vulnerable areas (areas with highest risk) and monitoring systems should be set up to give early warning of problems that allows the evacuation or closure of traffic routes.

- Informative material (appropriate warnings and actions) should be prepared about the hazards, for public awareness and to educate the people.

- There is a need to introduce the concept of geological hazards along with environment sustainability into the school curricula.

In order to attain all the above said steps, proper understanding of the nature and extent of problem and the ways to respond to that is must and for that proper survey and research by experts is required. But survey and research will be of no use unless the results are easily accessible and understandable to everyone who needs to know. For instance the hazard zonation map of an area is important but often unintelligible to civil authorities and, even if, their importance is valued or appreciated, may not be used effectively unless they are directly linked into the regulatory administrative processes.
Therefore, it can be suggested that an integrated and participatory planning approach from the experts in geoscience, environment science, social and economic matters, the public administrations and the population at large is required for dealing with any type of hazard in an area. Anthropogenic activities multiplied with natural hazards have caused irreversible changes in the environment and has made the study area an environmentally sensitive zone. Investments should be made on hazard management measures and should be well adopted in the planning and regulatory systems. Relevant education and research are essential. It is also essential for the architects and engineers to work in harmony with nature (environment) i.e. construction should be in equilibrium or in balance with landscape, ground characteristics, climate and environmental change, rather than against these. The more it is easy to write, the more it is difficult to achieve. However, it is better to start now in a small way than to wait for any disaster to happen as it is rightly said that “Precautions are better than cure”.

7.3 CONCLUSION

After the detailed investigation of the study area, it can be concluded that the quality of existing natural resources of the area are free from any major degradation and is suitable for developing the area as an eco-town. The future sustainability of these resources depends upon the proper management of soil and water resources. In contrast, the natural hazards in the area pose a bigger challenge for the potentiality of Dharamshala as ecologically stable town as the area falls in the Zone V of the Seismic Zoning Map of India. The geological set up and geomorphological parameters indicate that some parts are very sensitive to natural hazards. In addition, the anthropogenic activities such as unscientific mining and unplanned urbanization contribute significantly to volume of susceptibility to hazards. The proper mitigation and disaster management structures are required for advocacy of development of Dharamshala as an eco-town.

If the platform for almost all the life support systems is to be protected for future generations, sustainable development is essential. So, there should be a proper management of Dal lake (the only wetland in the study area), municipal waste disposal site and area under mining activities. The present condition of degradation of geoenvironment in Dharamshala town is a result of unplanned and unscientific human
activities without taking into consideration the consequences or the harmful effects. Under these deteriorating situations, the thinking of human society towards environment needs a conscious, purposeful and sustainable approach. Through better understanding of the interrelationships between man’s activities and geoenvironmental factors, the present undesirable conditions can be improved and can further be avoided. We can get better environment only when each and every individual become aware of it.

We can think of a sustainable geoenvironment only when the measures that have been suggested would be applied properly - for without a sustainable geoenvironment, sustainable development will not be realized and without sustainable development one can’t think for an eco-town i.e. the town in harmony with environment.