CHAPTER-X

SUMMARY AND CONCLUSION

The region selected in the present study encompasses a part of Darjiling district with an area of about 832.11 km^2 lies in the northern part of the State of West Bengal, India. It is bordered on the north by Sikkim State, on the east by Jalpaiguri district of W. B. state and Bangladesh, on the south by Uttar Dinajpur district of W. B. and Bihar state and on the west it is bordered by Nepal having latitude 26°26' to 26°50' N and longitude 88°05' to 88°27' E. The study area has a special strategic importance so far as geographical location is concerned. The reported work on there hydrogeological aspects as also the published information is scanty. No systematic appraisal of the terrain is available interms of aquifers potentiality, groundwater quality and their proper utility. Information is also scarce on classification of groundwater for irrigation purpose, groundwater storage in relation to demand of water supply, as also on the delineation of fresh and saline water aquifer zone within the Terai region. Hence, the present study thus was undertaken to arrive at a integrated hydrogeological picture. Moreover, the development of the agro-economic conditions of the district is desirable as the majore part of the population are earning their livelihood through agricultural activities.

The study area is a monoclinal structure, more or less parallel to the foothill of the Lesser Himalayas in the north. It extends for about 35 kms in length and 24 kms in width. The general slope of the area is north-east to south-west direction having ranges from 0°54' to 22°58'. The average surface elevations along the N-S direction are respectively 350m and 30m above mean sea level. Geomorphologically, the area may be divided into three major units and a number of microunits. The major units are : a) the hilly structures, b) the piedmont plains and c) the Terai plains. The hilly structures are observed in the northern part of the study area where Siwalik formations are forming hogbacks and cuestas having high relief of rugged profile with some structurally controlled drainage. Long slopy lands from the hills to the rivers known as piedmont plains which are originated from the materials of the Siwalik as well as the Lesser Himalayas. The Terai plain occurs south of the piedmont plains with a gentle southernly slope. The junction of the terai plain and the piedmont plain is well marked by the presence of a spring line from where a number of springs originate and also separating the alluvial fans from the hills.

The area is drained by a number of perennial rivers and rivulets. Among these Mahananda, Panchanai, Balasan, Buri Balasan and Mechi are well known which originate from the Himalayas as well as piedmont plain through seepage. Most of the rivers are shallow in depth but are highly torrential in rainy season. Because of the steep slopes there rivers built up alluvial fans after debauching on the plains. There is a general tendency of eastward migration of the drainage channels due to tectonic activities. In plains, the rivers have often shifted as much as 5 km. during the last 50 years.

The climate of the study area is pronounced the continantal characters i.e., extreme summer heat alternate with extreme winter. In the north, snow clad mountain ranges and peaks of the Great Himalayas stand as a natural barrier and influences the pricipitation and other weather conditions in the investigated area. The average annual rainfall of 22 years is 3,339 mm. with 133 rainy days. Heavy rainfall causing landslide in hilly region accompanying hail strom and all the rivers carry a huge amount of eroded meterials with water due to high velocity towards down streams. Summer is hot in the plains while it is reasonably cool in the hills. May-June is the hottest months and December-January is the coldest months when the maximum temperature rises upto 39°C and the minimum temperature touches below 7°C. The atmosphere is highly humid with relative humidity ranging from 80 to 83 percent in rainy season while it is less humid in winter season ranging from 68 to 70 percent. The rate of evaporation is maximum in April-June and minimum in the month of January.

The soils of the study area vary from podzol to Terai soils. The podzol or forest soils in the hills are brown while those in the Terai are deep black, and grey black. Due to severe leaching by rain and presence of good amounts of organic matter, the soils in the plain is very porous and acidic in nature with pH value ranging from 5.0 to 6.2. The water retaining capacity of this soil is very poor. The fertility status of the soil in respect of nitrogen, phosphate and potash are medium to low. The podzol soil which is also acidic in nature with pH ranging from 4.5 to 5.5 is found in the hilly structures. This soil is suitable for cultivation of tea.

The major part of the area is coverd by cultivable land and the land use pattern of the study area shows that there has been reduction of total land utilization in forest, net sown and gross cropped area during the last 50 years. However, the trend towards deforestation in the study area for growing urbanization and upcoming small scale industries has considerable impacts on ecological balance, and exposes large area to serious soil erosion. The availability of cultivable land in the study area is maximum and is of the order of 432.02 km^2 where paddy, jute, maize, wheat, lentiles, mustered and vegetables are grown. Now a day, a huge amount of pineapple orchards are cultivated. The forests and tea gardens cover an area of about 217.46 km^2 and 185.76km^2 respectively.

Due to hilly nature, the irrigation practices in the Terai area involve both from surface and groundwater sources. An area of about 46,395 hectares fall under irrigation of which surface water mainly rainfall, rivers and canals cover 37,822 hectares and the rest 8,573 hectares by groundwater through different types of tubewells and dugwells as recorded during 1997-98. With the completion of first phase of Mahananda Barrage Project, the irrigation is likely to get big boost as an area of over 12,000 hectares is espected to be brought under irrigation. Because of rapid increase of population and continuous decreases of cultivable land and problems of different natural calamities, the farmers are trying to produce more crops for the fulfilment of the rising demands for the present requirements of the study area through a number of popular chemical fertilizers as well as pesticides and insecticides.

Geology plays a vital role for groundwater determination and its potentiality. The groundwater movement is inter-related with the lithology, structures and their control. In the present area, the geological formations consist of unconsolidated alluvial sediments of Quaternary age confined to high level terraces and piedmont plains, unaltered semi-consolidated sediments of the Permian and the Tertiary era in the foothills. The sub-surface lithological disposition in the unconsolidated sediment of the piedmont plains has been deciphered from the borehole data of a few deep tubewells constructed in the area. The maximum depth for which sub-surface information is available is down to 219m. below ground level. On the basis of the lithological logs it can be concluded the sediments consisting of alternations of clay, sand, gravel, pebble, boulder etc. have been deposited cyclothemically. Each cyclothem is represented by gravel to coarse sand at the bottom and clay at the top. Two to three such cyclothems have been recognised in the area. The thickness of the sediments decreases towards the north where gravels, cobbles, pebbles and boulders are predominant. Landsat interpretation of the study area was carried out with the objectives to locate all possible geomorphostructural features. All these features have very important bearing on the groundwater conditions. The present study has provided an unique opportunity to understand broad hydrogeological characters of the study area.

The groundwater hydrology in the Terai region is profoundly influenced by the rainfall. The statistical analysis of 22 years of rainfall data has revealed that rainfall of the study area is of monsoon type, the major part of which is due to south-west monsoons. The concentration of rainfall in any year in the four-month period of June to September, which accounts for about 80 percent of the total annual. The long-term average annual rainfall is recorded about 3,968 mm which is adequate and the second highest rainfall in the Indian Subcontinent. The variation in rainfall, both with respect to time and space, is rather low. The frequency of occurrence if heavy falls of rain too is quite low. The study area is essentially an undulating plain, sloping almost imperceptibly southwards and ranges from 0° to 23°. The maximum and minimum surface elevations vary between 200 m and 60 m above mean sea level in a distance of 37 kms in the north to south direction of maximum surface gradients 1 in 23. The area does get somewhat broken up by the slightly elevated tracts or interfluves separating the drainage basins, or by the slightly lower ground along the stream courses. A uniform distribution of land area, with respect to its elevation above mean sea-level is revealed from the area-height and hypsometric curves. The stream order and drainage density values are extremely variables i.e. from 1 to 4 km./ km^2.

The three perennial rivers–Mahananda, Balason and Mechi, their tributaries, and a large number of ponds, tanks and jhoras are the main sources of surface water supply, tapped through a network of canals. On the other hand, the chief source of groundwater is the rainfall. The recharge to groundwater body is mainly through rain water by the return seepage of irrigation water and downward percolation of stream run-off are also the sources of groundwater supply, tapped through a number of different types of well.

The principal hydrologic properties of a rock formation i.e., porosity, specific yeild and permeability, control its capacity to hold, deliver and transmit groundwater. From the mechanical analysis of the tubewell samples, a general uniformity is revealed all over the study area, both horizontally and vertically i.e. the hydrologic properties of soils and water-bearing material of the area have been determined. It is found that porosities of soils and water-bearing materials are repectively 41 percent and 40.5 percent. The specific yeild , specific retention and coefficient of permeability of good water-bearing formations in the area are respectively 31 percent, 9.5 percent and 0.005m^3 per minute. On the other hand, the soil have an average specific yeild of 18 percent, specific retention of 23.5 percent, wilting coefficient of 12 percent by weight, hygroscopic coefficient of 10 percent by weight and 46 percent by weight of water available for growth which confirm that soils in the alluvial tract of the study area are of very rich description and agricultural development of the area thus can successfully be achieved. The good water-bearing formation in the piedmont as well as the alluvial tract of the study area is expected to meet at an economic depth that is between 79.20 m and 124.53 m below the ground surface and is having an average thickness of 105 metres. The storage capacity of groundwater reservoir, which can freely yeild water, in the study area is 1,10,70,000 m^3/ km^2 and is, therefore, the groundwater reservoir is having an enormous capacity.

The groundwater, being unconfined, occurs under water table conditions, at least upto the depths reached by the deepeast well i.e. 219m. in the area of investigation. The water table is an indicator of the hydraulic conditions prevailing in the zone of saturation. The from of water table is largely controlled by topography: the depth increasing from higher ground or interfluves towards the adjoining streams. The water table stage fluctuations are being significantly influenced by seasonal variations in recharge from rainfall and tubewell pumping with respect to time. Generally, the water table in the piedmont plain is deeper than that of alluvial plains and average level ranges between 4m. and 6m. bgl. during the postmonsoon period and it varies during the premonsoon period from 8 m to 10 m bgl. Seasonal fluctuation of water table is also higher in this plain ranging from 4m. to over 6m. In the alluvial plain the water table generally varies from 2 m to 6 m b.g.l during premonsoon period and 0.75 m to 4.5m b.g.l during the postmonsoon period. The seasonal fluctuation of water table in this plain is restricted within 2.5 m only. In marginal areas between 'Bhabar' and 'Terai', behaviour of water levels show general low fluctuation in pre and post-monsoon seasons. The long term trend of water levels indicate that the declining and rising trend is restricted with in 1m. only during the last 10 years (1989-1998) and hence it can be sum up that no deliterious effects have developed in the area.

The movement of groundwater of the study area confirms to the north to south direction of surface gradients. The quantity of groundwater flow is moderately high to high owing to the fact that the hydraulic gradient in the area varies widely. In Trihana-Ambari tract the steepest hydraulic gradient of 10 m per km is recorded . A steeper hydraulic gradient of 4 m per km is observed in Naxalbari-Kharibari section whereas, it is about 1 m/ km^2 in Siliguri-Sukna section. But, interfluve area of the Mahananda – Chenga has a more flat hydraulic gradient of less than a metre per km where groundwater flow is towards SSW. Based on the available lithological log data of exploratory and other boreholes drilled in the area, it is observed that aquifer zones considerable thickness are present within the depth span of 105 m with yeild prospects above 150 m^3/ hr with a drawdown of 3.66 m to 12.20 m. The transmissivity values range between 85.25 and 425.16m^2/ day.

Groundwater recharge in the study area occurs from local rainfall seepage from surface water bodies, recycled water from applied irrigation and groundwater inflow. Whereas, the groundwater discharge is mainly due to withdrawl of groundwater for irrigation purpose by means of tubewells and dugwells, losses due to natural seepage, evapotranspiration and groundwater outflow. The inflow is almost equal to the outflow. The 'water table' and the 'general inventory' methods have been used in the present study for a quantitative determination of recharge. But the volume of groundwater withdrawn by tubewell pumping per unit area has been calculated both from a consideration of the water table decline due to pumping and the portion of groundwater inflow intercepted by pumping and from the average discharge and number of running hours per tubwell. A study of the water balance, involving water surplus and deficiency estimations, becomes highly significant in the present investigation. The average annual rainfall which is the chief source of groundwater recharge of the study area is almost same and from the well-hydrograph it is observed that the recharge of groundwater is also same and during last few years it is somewhat increased. But in comparison to increasing of discharge since 1992, the rate of recharge is not significantly increasing, and the area suffers locally from some of the water table releted hazards only because of large scale abstraction of groundwater due to irrigation – mainly tea plantation and very recently industrial purposes. Based on ARDC norms groundwater balance has been calculated block-wise and based on these compilations developed and undeveloped blocks have been identified. The gross total groundwater resources of the four blocks including the SMC of siliguri subdivision is 48,817.94 ha m per year, and the net annual druft is 18,951.46 ha m per year and balance groundwater resource potential is 30,866.48 ha m per year. Level of groundwater development in the area is 38.82 percent which is not so insignificant. Thus, overall study in the area of 832.11 km² indicates that, till now there is no deficite, found in the projected area, but one thing is observing i.e.the rapid increase of the progressive annual discharges through different uses. Hence, there is a very good scope for large scale groundwater development in these four blocks including SMC for different uses.

To study the chemistry of the groundwater occuring in different litho-Units of the area and to define and decipher the chemestry of surface water and groundwater and its variation with depth. Detailed groundwater sampling has been carried out for complete and partial analysis. Attempts have been made to identify the study area having salinity, pollution and suitiability of groundwater for different uses—agricultural, drinking and industrial purposes. Chemically, groundwater in the study area is fresh and potable having low chloride concentration except three dugwell samples which varies from 05 ppm to 380 ppm and average value is 57 ppm. The pH variation in this area is 6.80 to 7.85 indicating the alkaline nature of water. The specific conductance of groundwater ranges from 103 to 2100 micromhos/ cm at 25°C of which 48 percent of the total samples are safe water under all conditions.

Normally, carbonate ions are not available in groundwater of the study area. But the range of bi-carbonate in groundwater is from 21 ppm to 545 ppm, whereas 70 percent of the total samples belong to low concentration group. The hardness of water in the area ranges from 35 ppm to 220 ppm belongs to moderately hard to hard water class. On account of their hardness, the water of the study area is not generally good for use in boilers and water heaters. The invistigated area is seriously affected by the iron component which ranges from 0.02 ppm to 9.24 ppm and from 0.12 ppm to 0.5 ppm in groundwater and surfacewater respectively. Except the filtered and Iron Elemination plant (IEP) deep tubewell water samples and surface water samples, all other samples have the much higher concentrations of iron of the standard permissible limit. Most of the dugwell water have the iron concentration upto 2.35 ppm. The maximum iron concentration is occurred at the upper side of the study area and is located at some places in the shallow aquifers (ranges from 2.05 ppm to 9.24 ppm) and in the deeper aquifers of 'Terai' plain. For the safety of human life as well as other animals, this higher concentration of iron can be removed by simple aeration and elimination or carbon-di-oxide followed by sedimentation and filtration. Excess of iron can be treated with lime. Contact oxidation and zeolites can also aid in eliminating iron. Depending upon the permissible limit of other chemical components of groundwater – TDS, Ca, Mg, Na, K, As, B, SO_4, NO_3, F, SSP, RSC, SAR and PI, more than 60 percent of the water samples have been classified as excellent to good quality of water and the rest are classified as good to permissible quality for agriculture, domestic, livestock and industrial uses.

Different types of wells are the most significant means of irrigation, accounting 34.23 percent of NAI in 1997-98 of which the maximum utility is by means of state shallow tubewell (13.60 percent) and the minimum uses by means of dugwells with pump (0.66 percent); Govt. canal accounted for 32.61 percent; private canal accounted for 10.99 percent, RLI is by means of 9.84 percent and the rest 12.33 percent came under ponds, tanks, rivers and jhoras. There is a significant change during the last five years period in the relative signeficance of irrigation by canals, wells and others, but the area under irrigation by STW and canals has registered a very significant mainly at the low cost of construction of a STW, is quite within the means of an average farmer, increase in infrastructural facilities like rural electrification and institutional credit, introduction of HYV seeds and implimentation of land reform measures are the contributary factors and the same reasons and factors are applicable in case of canal irrigation by different means. The GAI has increased from 54.69 percent in 1992-93 to 55.64 percent in 1997-98 due to development of irrigation facilities. The total water use in the study area in 1997-98 was to 22,405.15 ha m which was 9,293.68 ha m in 1992-93, registering an increase of 141.08 percent. In 1997-98, as much as 90.72 percent was used in irrigation, followed by domestic, livestock and industries to complete the rest of the percentage. The total water requirements in the study area in 1997-98 had been estimated at 48,150.10 ha m, which was 23,601.44 ha m in 1992-93, registering an increase of 104.01 percent, whereas, the maximum water requirments involved for irrigation purposes (92.07%) and is followed by domestic, livestock and industries. Thus, the intensity of water utilization (total) has increased from 11.17 ha m/ km^2 in 1992-93 to 26.93 ha m/ km^2 in 1997-98. Whereas, the water requirement intensity has been changed 28.36 ha m/ km^2 in 1992-93 to 57.87 ha m/ km^2 in 1997-98.

Waterlogging, drought, soil salinity and alkalinity, water table depletion over exploitation, land subsidence, legislative dimension are the main problems related to or arising out of water use in the area. Being situated in the lowermost part of Darjiling Himalayan foothill i.e. with in the Terai region, the study area is more or less prone to waterlogging causing extensive damage to property. During the 22 years period of 1978-99, the study area has experienced only moderate to low droughts. Soil salinity and alkalinity are not of much significance in the area. Due to overextraction of groundwater, water table depletion and land subsidence are of continuous local problems in the area of investigation. As the area is covered by a number of tea plantations and tea industries and the owners are busy to fulfill their business demand through the over extraction of groundwater without any consideration of the surrounding inhabitants, hence for the protection of the villagers, water pollution and water extraction rules and regulations should be execute properly and strictly.

The development of water resources for their optimum use involves proper planning and conservation of the resources. There is a need for conjunctive use of surface and groundwater resources. The irrigation water losses are due to application losses on the fields, following adoption of faulty irrigation practices like over irrigation and seepage from canal system. Water losses from over irrigation can be checked by volumetric charging for water, educating the farmers about its adverse consequences and providing them assured or rotational supply of water whereas those from canal seepage can be checked by lining the canals. There is also need for adoption of better methods of irrigation like drip and sprinkler irrigation which is now using widely only in the tea plantations. The greatest step towards the conservation vis-a-vis development would be to prevent large scale wastage of water by allowing the artesian wells to flow all the time. Putting a check valve on these and regulating its use would not only stop wastage of water but could help to eleminate the marshy conditions of the land around the wells. Losses from domestic, livestock and industrial uses can be checked by creation of general awareness within the inhabitants of the study area. There is enough scope for the development of the groundwater resources in the study area either by bringing new areas under the tubewell pumping scheme or by additional development in the existing tubewell areas by, firstly, increasing the tubewell running hours and secondly, by installing more than 335 DTWs.

A model for water resource management plan has been designed for the study area. It takes into account, amongst others, the constraints in developments the various modes of uses, the several problems and their remedies through consumptive and integrated use of water resources. The projected total requirements by 2011 AD has been computed to about 270,000 ha m of which 96.91 percent for irrigation; 2.51 percent for domestic; 0.48 percent for livestock and 0.10 percent for industrial uses, depending upon the trend of water utilisation, expected population as well as livestock growth rates and in different sectors of economy. These requirements would be normally fulfilled from the available water potential in the study area. The total water expected to be consumed in 2011 AD has been computed at about 215,000 ha m that is, 79.63 percent of total water requirements.