INTRODUCTION

The Balason river, one of the most important right bank tributary of the river Mahananda arises near Lepchajagat, (Latitude 27°3'55" N and Longitude 88°14'12" E), at an elevation of 2416 meter a.s.l., on the Ghum - Simana ridge. It flows through the southern part of the district of Darjeeling almost parallel to the 88°13"E meridian, till it reaches the plain at an altitude of 305 metre from where it turns towards the southeast and meets the river Mahananda near Siliguri town.

The important right bank tributaries include the Pulungdung Khola, Rangbang Khola, Marma Khola, Dudhia Jhora, Chenga and Manjha Khola. The Bhim Khola, Rangnu Khola, Jor Khola, Pachhim Khola, Rinchington khola, Rungsung Khola, Rakti Khola and the Rohini Khola are the major left bank tributaries. The tributaries have carved out deep gorges in the hilly section even though they have very small catchments.

A. Problems

Environmental degradation and associated phenomena are the most pervasive of natural problems that undermine the economic and cultural development of the Balason catchment in the Darjeeling district of Sub-Himalayan West Bengal. Deforestation along with high intensity rainstorm induced accelerated soil erosion, mass movements in the upper catchment and massive flood and aggradation in the lower part of the catchment area.

Implementation of various development schemes, construction of human settlement and road to cater the ever-increasing population, exploitation of forest produce to generate work potential, boosting of agricultural growth, tourism, tea plantation, quarrying, on the Himalayan immature geology trigger the disaster, huge and complex, never encountered before.

The situation was different even 150 years before. The hills were densely covered by natural vegetation with very thin population and the harmonious relation

between the upper and lower catchment was well preserved. Extensive heedless deforestation, haphazard construction of roads and settlements, unscientific and illegal quarrying, over grazing, inadequate drainage, in other words – unscientific and unplanned usage of land has led to the establishment of vicious cycle of degradation. During heavy and concentrated rainfall, catastrophic soil erosion and innumerable landslides are caused to transport huge amount of sediments (400,000 m^3 of suspended load and over 600,000 m^3 of bed load) from the upper part of the catchment to the river Balason.

Incapable of transporting the load efficiently under the existing hydrological condition, especially along its lower reaches, the riverbed is rising at many places at an alarming rate along its lower reaches. The channel pattern is thus, characterized by braiding even along the lower hilly section. The reduced cross section being incapable of arresting the unusual monsoon discharge (940.3 cumecs in 1998) caused heavy devastating flood.

In the non-monsoon period, however, the paucity of water is so acute that the local people are unable to reap any benefit from the river itself. It therefore, becomes imperative to suggest remedial measures and actively implement these suggestions. Only then can the geo-political and ecological stability of this extremely vulnerable region of the Darjeeling Himalaya be protected.

B. The Study Area

The area under study includes the south western part of the Darjeeling hills and a section of the North Bengal *terai* falling within 26°41' N to 27° 01' N latitudes and 88°7' E to 88°24' E longitudes covering an area of 367.42 sq. km (figure 0.1).

The Balason basin is still without major artificial control, and thus affords an ideal situation for making a direct observation of the various geo-environmental processes. The study area was confined upto the confluence with the river

LOCATION OF THE STUDY AREA

Figure 0.1

Mahananda, a little below Siliguri (latitude 26°48'37" N and longitude 88°18'30" E), as it is considered as one of the environmental hot spot of the country.

C. Methodology

In order to study the above-mentioned problem, a rationalistic methodology comprising of quantitative integration of geological, geomorphological, meteorological, pedological and hydrological parameters of the study area has been undertaken. the detail of which is outlined below:

The basic aerial data has been obtained from the Survey of India topographical sheets no.78B/1, B/5 and B/6 and 78A/4 and A/8 (1:50,000) and aerial photographs (Run nos, 78 4-A/ 19-5 to 10, 78 4-A/ 21-5 to 10, 78 4 –A/ 22-3 to 8, 78 4-A/ 23-5 to 10, 78 4/24-5 to 10). Maps published by the Geological Survey of India and Forest Departments have also been used for preparing the detailed programme of the present research work, specially the surveying plan, the layout of cross sections and test pits. Comparison of the old and new documents has been made to follow chronological depletion of the natural resources.

Basic data on geology, topography, climate, vegetation, land-use pattern have been collected from secondary sources like topographical maps, G.S.I. records, Revenue maps, Satellite Imagery and maps and reports published by individuals and Institutions.

Meteorological data i.e. rainfall, temperature, humidity etc. in and around the study area has been collected from Regional, Meteorological Office, Alipur, Planters Club Darjeeling, Agricultural Department, Forest Department and individual tea gardens.

Data on soil, vegetation, geology, geomorphology and hydrology have been collected from primary sources by intensive traverse and field studies.

Various hydrological data regarding cross-sectional area, velocity, discharge, data

were collected directly from field survey and wherever possible these have been verified with the official data and records of Central Water Commission.

The geomorphological information along with the morphometric data of the basin and sub-basins (55 third order basins), have been collected from the topographical maps at a scale of 1:50,000. Both bivariate and multivariate statistical analysis of morphometric data have been carried out using:

i. Correlation analysis
ii. Regression and
iii. Multiple regression

Quantitative analysis of various geomorphic forms and processes have been attempted to find out the nature and form of micro-topographical units in addition to slope, relative relief, drainage density, dissection index etc. traditional methods.

Pedological information have been gathered from the 50 sample sites selected randomly and analyzed in the Pedological laboratory of the Department of Geography and Applied Geography, North Bengal University. The following soil properties have been assessed:

a. Soil colour (Munsell colour chart);
b. Soil texture (International pipette method);
c. Hygroscopic moisture (Ignition method);
d. Soil porosity, permeability, specific gravity, water holding capacity etc. (Keen Box method);
e. pH (pH Meter);
f. Soil organic carbon (Walkey and Black's Rapid Titration method);
g. Base exchange Capacity (Saturation method);
h. NPK (Kit Box)
i. Soil Plasticity Index (Liquid Limit device method);
j. Compressive strength of soil (Vane Shear Meter);
k. Penetration limit by cone penetrometre;

The rate of infiltration was measured with the help of a galvanized steel tube with a diameter of about 20 cm. This was inserted into the soil and a head of water of 6 mm was maintained to record the rate of infiltration.

Primary data related to various other geo-environmental parameters was collected through direct field observation and either by questionnaire or checklist.

Assessment of soil loss by water erosion has been carried out based on the existing standard methods (Wischmier and Smith, 1965, 1978; Fournier 1972; FAO/UNEP, 1978; Arnoldus, 1980, Requier, 1980 and Sarkar, 1987 and 1991), Universal Soil Loss Equation (USLE) with the necessary modifications have been applied based on the diagnostic criteria of rain erosivity (R); topographic erosivity (L.S); soil erodibility (K) and biotic erosivity (C.P). Based on these the potential and the predicted soil loss have been assessed. A comprehensive soil conservation plan for the study area was laid out keeping in mind all possible interactions among the variables.

The study of landslide and related problems were entirely field based through intense traverse method and field observation with the help of check lists. Each landslide has been examined carefully under the heading of bedrock, climate, soil, forest cover, and human interference to find out the trigger mechanism. After apprehending the processes, mechanism and causes of the movement, the investigator has tried to offer the corrective measures for them.

Various information related to the hydrological regime have been collected from the field stations at NH 31 bridge, near Matigara. In order to have an idea about the changing nature of the channel and specially the impact of huge flood water on the channel form, a detailed study at the following three different sites were made: the central station gauge (C/G) located 100 metre north of NH 31 Bridge across the river Balason, near Matigara, the up-stream gauge (U/G) 500 m north of the central station gauge and the down-stream gauge (D/G) 700 m south of the central station gauge. Hydrological records of the Central Water Commission station at Matigara have also been consulted wherever necessary. An attempt has also been made to assess the bed load of the river indirectly from the information

of gravel extraction from the river at four different sites between Dudhia to Matigara.

The water resource of the basin has been determined by Khosla's method through the study of rainfall, runoff and rate of evaporation. Water resource has also been assessed based on discharge and run off of the river. An attempt has also been made to have a comparative study of the water resource estimates based on empirical method and discharge-runoff method.

Modified Leopold matrix (1971) has been employed to assess the environmental impact of development projects in the Balason basin. It involves 39 development activities under 9 broad headings and 58 environmental components under 4 broad and 12 sub-headings. Environmental impacts have been identified under the headings of impact magnitude and impact significance. The matrix has been applied on checklist in 45 different sites. Two case study have also been performed one on the monoculture of Dhupi plantation and the other on cutting of hill tops and dumping of materials on slope.

To compile the bibliography as well as the reference work, the libraries of North Bengal University, Calcutta University, National Library, Kolkata, Geological Survey of India, Kolkata, Natural History Museum, Darjeeling, River Research Institute, Haringhata have been thoroughly consulted.

In order to understand the problems under study, all the data collected from the field and various institutional and other sources have been processed, analysed and computed in the Department of Geography and Applied Geography, North Bengal University to predict the exact sequence of events and to provide a workable formula for their control and finally to offer corrective measures for the over all environmental stability of this extremely vulnerable part of the country.