CHAPTER – II

METHODOLOGY

This chapter reveals the systematic approach to the research problem, which starts with a preliminary survey of research area, field investigation and laboratory methods employed to determine their Geochemical, Hydrological, Drainage and Land use properties. This further includes measurements, calculations, analysis and preparation of maps and figures. Five types of analysis viz. Hydrological analysis, Geochemical analysis, Drainage, soil, rock and Land use analysis are an integral part of methodology for the research in hand.

PRELIMINARY SURVEY

Preliminary survey of the research area was carried out by investigating the land use, geology, demography of the research area. The information so collected was transferred to a pre-modulated Questionaire (Text Table – II).

Text Table – II : Questionaire for preliminary survey.

<table>
<thead>
<tr>
<th>1. Name of the Village</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Location</td>
<td></td>
</tr>
<tr>
<td>3. Topography of the area</td>
<td></td>
</tr>
<tr>
<td>4. Vegetation</td>
<td></td>
</tr>
<tr>
<td>5. Land – Use</td>
<td></td>
</tr>
<tr>
<td>6. Major Occupation</td>
<td></td>
</tr>
<tr>
<td>7. Drainage</td>
<td></td>
</tr>
<tr>
<td>8. Industries</td>
<td></td>
</tr>
</tbody>
</table>
FIELD INVESTIGATION

WATER TABLE

The depth of the water-table in the study area was measured in the field from available sites, which includes open wells and hand-pumps. The water level in the hand-pump was confirmed by opening the top cover and recording depth with the help of a metric measuring-tape. In addition to this definite data of the water depth, some approximate information about the depth of water table was also obtained from the owner of hand-pumps and open wells at some of the sites.

SAMPLING

Surface water, Ground water, Soil and Rock samples were collected from various sites in the study area in the month of June. The survey of India Topographic sheet nos. 53B/9, 53B/10 and 53B/13 (scale 1: 50,000) and a hand held GPS (make-Garmiss, E-Tx vista) were used for marking location besides the information about tubewells, hand pumps etc. obtained from the legal agencies / inhabitants.

Water Sampling

The total number of water samples collected was 35 including 16 samples of surface water and 25 of ground water, which were collected randomly from the study area. The samples were collected in polythene bottles. Hard bottles, washed with distilled water, were used so as to ensure compositional originality of water samples. The water samples were collected in 2 liter bottles as per requirement from the selected sites (Plate – 1c). Water bottles were rinsed 3-4 times with the water to be sampled. After the bottle was filled to their capacity, they were sealed and labeled properly. All the particulars regarding the sample were written in the field itself, immediately after sampling, and tagged to the sample bottle.

The surface water samples were collected from the streams and nalas which are flowing in the research area (Siswan Nadi, Jainta Devi Ki Rao, Patiali Rao and Kansal nala) (Plate – 1d). These streams start from Siwalik hills to the
Northwest of Chandigarh and run several kilometers before joining the main river. Siswan Nadi is an important seasonal stream. Initially, it flows north-east to south-west, but gradually turns north-west to finally merge with the Satluj near Khizarpur village after traversing a distance of about 40 kilometers over the plain. Jainta Devi Ki Rao and Patiali Rao are the two southern streams which flow in Northeast to Southwest direction and ultimately to merge with the Ghaggar River.

Ground water samples were collected from the open wells (Plate – 2a) and hand pumps (Plate – 2b) of the research area. In case of hand pumps and open wells, prior to sampling, water was pumped out for about 5 - 10 minutes. The initial pumping serves to remove water in contact with the metal well casting from the well borne and adjacent aquifer and allows for the collection of representative samples of water present in the aquifer. To minimize the change in chemical quality due to the lack of time between the collection and analysis, special precautions were taken to make the samples true representative of the water body. One sample from each sampling station for major and minor analysis was collected in polythene bottle and sealed with wax to minimize escape of gases.

**Soil Sampling**

Field study of soils generally begins with working out a general soil pattern of an area and for this, soil samples were collected from 16 different location of the research area with the help of a sharp edge weapon after removal of excess pebbles and grass (Plate – 2c). The samples were collected in polythene transparent bags and after the bag was filled to their capacity, they were sealed and labeled properly. The samples are to represent the whole of the research area so the area was divided into certain blocks and the samples were collected from each block so as to include specimen of both plane and hilly areas.

**Rock Sampling**

Rocks specimen had been collected (Plate – 2d), total 5 in number and were packed, labeled and taken to geological Lab to analyze the required parameters.
The location of various samples sites for surface water, ground water, soil and rocks is shown in (Map – 3).

CHEMICAL PARAMETERS

The surface water, ground water, soil and rocks samples collected from the field were immediately subjected to measurement of chemical parameters such as pH, EC, TDS and Temperature with the help of *Soil and Water Analysis Kit* and Thermometer to ensure accurate determination. The values were recorded, once these got stabilized in the instrument. Replicate determination was done and the mean value elemental composition was worked out in the laboratory.

LABORATORY INVESTIGATION

Water Sample Analysis

The collected samples were brought to the laboratory for determination of various parameters (Plate – 3a and 3b) like carbonate, bicarbonate, calcium, magnesium, sodium potassium ions by Geochemical methods at Geochemical Laboratory in the Department of Geology, Panjab University, Chandigarh. For this purpose the samples were filtered through filter paper, Whatman No.42, until the pure and clean solution was obtained. Some of the chemical attributes of water samples were used to evaluate the quality of these materials for use in irrigation.

A brief description of the method of chemical analysis of water samples are given in Text Table - III
### TEXT TABLE – III: Summary of Analytical Methods used for Chemical Analysis of water samples.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>PARAMETERS</th>
<th>ANALYTICAL METHODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Temperature (T°C)</td>
<td>Thermometer</td>
</tr>
<tr>
<td>2</td>
<td>pH</td>
<td>Electrometric, pH meter (Electronics India, Model 161E)</td>
</tr>
<tr>
<td>3</td>
<td>EC (micromhos/cm at 25°C)</td>
<td>Water and Soil Analysis Kit (Electronics India, Model 161E)</td>
</tr>
<tr>
<td>4</td>
<td>TDS (mg/l)</td>
<td>--do--</td>
</tr>
<tr>
<td>5</td>
<td>CO$_3^{2-}$ and HCO$_3^-$ (mg/l)</td>
<td>Titrimetric Method using standard sulphuric acid with phenolphthalein and methyl orange as indicators.</td>
</tr>
<tr>
<td>6</td>
<td>Na (mg/l)</td>
<td>Flame Photometer</td>
</tr>
<tr>
<td>7</td>
<td>K (mg/l)</td>
<td>Flame Photometer</td>
</tr>
<tr>
<td>8</td>
<td>Ca (mg/l)</td>
<td>Titration with EDTA</td>
</tr>
<tr>
<td>9</td>
<td>Mg (mg/l)</td>
<td>Titration with EDTA</td>
</tr>
<tr>
<td>10</td>
<td>Chloride (mg/l)</td>
<td>Titration method with potassium chromate as indicator.</td>
</tr>
</tbody>
</table>

### Soil and rock samples analysis

Elemental composition of soils is the most important indicator of their genesis as it reflects transformation and transportation of matter. So for the determination of total element composition of the soils and rocks the specimen were analyzed for various oxides as SiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$, MgO, CaO, Na$_2$O, K$_2$O, TiO$_2$ and P$_2$O$_5$. First of all the samples were crushed with the help of a steel mortar and pestle to bring it upto <80 mesh size. Finally each samples was powered in electric agate mortar till the size is reduced to <200 mesh. The powder samples were dried at 110°C in oven for about 3 hours and then stored in dessicator. Following the rapid methods of Shapiro and Brannock (1962) the major elemental oxides were determined by preparing the solution ‘A’ and ‘B’ from soil samples. The solution ‘A’ was used for the determination of SiO$_2$ and Al$_2$O$_3$ where as solution ‘B’ was employed for analysis of Fe$_2$O$_3$ (total Iron), MgO, CaO, Na$_2$O, K$_2$O, TiO$_2$ and P$_2$O$_5$. 
A brief description of the method of chemical analysis of soil and rock samples are given in Text Table - IV

TEXT TABLE – IV: Summary of Analytical Methods used for Chemical Analysis of Soil and Rock samples.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>PARAMETERS</th>
<th>ANALYTICAL METHODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Temperature (T°C)</td>
<td>Thermometer</td>
</tr>
<tr>
<td>2</td>
<td>pH</td>
<td>Electrometric, pH meter (Electronics India, Model 161E)</td>
</tr>
<tr>
<td>3</td>
<td>EC (micromhos/cm at 25°C)</td>
<td>Water and Soil Analysis Kit (Electronics India, Model 161E)</td>
</tr>
<tr>
<td>4</td>
<td>TDS (mg/l)</td>
<td>--do--</td>
</tr>
<tr>
<td>5</td>
<td>Weight % of SiO₂</td>
<td>UV Spectrophotometer (Hilger and Watt), λ = 640nm</td>
</tr>
<tr>
<td>6</td>
<td>Weight % of Al₂O₃</td>
<td>UV Spectrophotometer (Hilger and Watt), λ = 475nm</td>
</tr>
<tr>
<td>7</td>
<td>Weight % of Fe₂O₃ (total Iron)</td>
<td>UV Spectrophotometer (Hilger and Watt), λ = 555nm</td>
</tr>
<tr>
<td>8</td>
<td>Weight % of TiO₂</td>
<td>UV Spectrophotometer (Hilger and Watt), λ = 430nm</td>
</tr>
<tr>
<td>9</td>
<td>Weight % of P₂O₅</td>
<td>UV Spectrophotometer (Hilger and Watt), λ = 420nm</td>
</tr>
<tr>
<td>10</td>
<td>Na₂O</td>
<td>Flame - photometer</td>
</tr>
<tr>
<td>11</td>
<td>K₂O</td>
<td>Flame - photometer</td>
</tr>
<tr>
<td>12</td>
<td>CaO</td>
<td>Titration with EDTA</td>
</tr>
<tr>
<td>13</td>
<td>MgO</td>
<td>Titration with EDTA</td>
</tr>
</tbody>
</table>

Morphological Characteristics

The morphological characteristics have been considered the most important for distinguishing one type of soil from the other. The morphological properties of a soil are partially the result of inheritance from the parent material and partially soil forming processes. The description of such properties therefore serves as a fundamental basis for identification, classification and interpretation.
of different soils. The important morphological characteristics described in field include color, mottling, texture, structure. These parameters are briefly explained herein.

**Soil color** - color is the most obvious and easily determined soil characteristic. It is an important soil property and used in identification of soil especially when it is interpreted jointly with soil structure. Although it does not interfere of many soil properties. The color of a soil depends upon many factors, the important amongst are organic matter, mineralogy, colloidal clay, and amount and state of iron and manganese. The soil color are described by using Munsell Soil Color Chart (Munsell, 1971) from which soil color is easily identified by comparing it with color charts arranged in a systematic manner in the booklet. Soil color is reported in two complimentary parts, viz. color name and Munsell notation. Each color in munsell color chart has been given a definite color name. For writing Munsell notation the three variables of Hue, value, chroma are represented in numerical form by a set pattern of hue value/chroma.

**Mottling** - Mottling in soil is predicted by local accumulation of some specific materials, such as organic matter, lime, clays or iron compounds etc. the mottles which are of special importance in soil studies are those having grey and brown color. These mottles are often used to decide the drainage class of a soil. Mottling in soil is described by writing color of the principal mottles and giving the pattern of the mottling (Soil Survey Staff, 1951). The color of the mottle may be described by using Munsell Soil Color Chart (Munsell, 1971) as is done for description of soil color. The pattern of mottles is described by noticing three variables, viz. contrast, abundance and size of mottle.

**Soil texture** - texture is an important property of soils. It is nearly a permanent property and influences almost all the soil characteristics or processes, be it physical, chemical or biological. Soil texture is determined by the relative proportion of sand, silt and clay in a soil. Textural analysis of soil is important in many ways as it helps to assess the inherent fertility of soil, its exchange and water holding capacities and to some extent the weathering stage of the soil. An accurate determination of soil texture is possible only in the
laboratory. In the field however only an approximation is possible. During the field study of the soils of research area, the feel method was adopted for an approximate assessment of soil texture as described in Soil Survey Manual (Soil Survey Staff 1951).

SEDIMENTOLOGY INVESTIGATION

**Size analysis** - Size of soil and rocks samples collected from the research area has been determined. Size analysis refers to the quantitative determination of frequency distribution of various size fractions. Several techniques are available for determination of size frequency distribution of detrital grains. These techniques are primarily based on one of the three principles i.e., sieving, settling velocity of particle and thin section measurement. Each of these techniques has its own limitations. The choice of techniques to be adopted depends primarily on factors such as nature of the material to be analyzed, viz. its grain size, degree of induration and type of cement, and purpose of the analysis.

**Sieving Technique** - for the purpose of size analysis by sieving technique each air dried sample was weighed to 50 g and placed in 500 ml beaker. The sample was soaked in 100 ml of distilled water for at least 24 hours. After the preliminary soaking the lumps, if any, were disaggregated with a rubber pestle using small volume of distilled water in order to destroy the organic matter and calcium carbonate the sample was treated with varying volumes of hydrogen per oxide (30 %) and hydrochloric acid (2N). After these treatments the sample was washed with distilled water to remove the dissolved salt by the decantation and centrifuge method. The sample was stirred on an electric stirrer for about 20 minutes after adding 200 ml of N/100 sodium carbonate solution which was used here as a peptizing agent to make the particle dispersed completely and behave rather individually in the suspension. The content was then transformed to a 325 mesh sieve placed into the funnel which was held over the top of one litre cylinder. The residual was washed thoroughly by using N/100 sodium carbonate solution on to the sieve, keeping the volume of suspension in the cylinder less
than one litre. The sieve was dried in an oven for a few minutes and then tapped to pass the remaining silt particle of less than 44 μm lodged in the sieve openings. The material retained on the sieve was collected in a separate beaker, dried and subjected to dried sieving at half Φ interval ranging from -1.0 Φ to + 4.5 Φ. A compound sieve was made by placing various sieve one above another with the mesh size increasing from bottom to top with a pan at the lower end and lid at the upper end. Sieve shaking was carried out for about 15 minutes with a Ro-tap sieve shaker (Plate – 3c). The fraction retain on each sieve was weighed and weight percentage frequency and cumulative weight percentage frequency was calculated. The suspension collected in the cylinder was made to 1 litre only and used for determination of content of clay fraction (< 2 μm) following the international pipette method (Day, 1965).

GEOCHEMICAL PARAMETERS

For Water Samples

pH- pH is a term used rather universally to express the intensity of the acid or alkaline condition of a solution. It is a way to express the hydrogen – ion concentration, or more precisely, the hydrogen-ion activity. The term may be represented by

\[
\text{pH} = - \log (\text{H}^+) \quad \text{or} \quad \text{pH} = \log 1/(\text{H}^+)
\]

, the pH scale is usually represented as ranging from 0 to 14, with Ph 7 at 25°C representing absolute neutrality. pH measurement was done by first calibrating the instrument (soil and water analysis kit) with standards of pH 4.0 and 9.2 buffer solutions. According to ISI (1991), the desirable pH limits are 6.5 – 8.5 for potable water. Mostly the pH level of water depends upon a) temperature and nature of water b) degree of association of base of dissolution of acid c) relative concentration of acid and its conjugate base.

Electrical Conductivity (EC) – It determines the total concentration of soluble salts or ionized constituents in water. It denotes the characteristics of a
medium to passage of electricity (a reciprocal of resistance) and is a function of temperature, type of ions present and concentration of various ions (Walton, 1970). The Electrical conductivity (EC) of water samples was measured in microhm/cm at 25 degree Celsius with necessary corrections for variation in temperature of water sample using the standard curve by soil and water analysis kit. The quality of groundwater for irrigation use, based on the electrical conductivity values, can be rated according to following three classes (Text Table – V)

**TEXT TABLE – V: Water classes based on EC values**

<table>
<thead>
<tr>
<th>EC in micromhos/cm at 25°C</th>
<th>Water Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2000</td>
<td>Fresh</td>
</tr>
<tr>
<td>2000-6000</td>
<td>Marginal Fit</td>
</tr>
<tr>
<td>&gt;6000</td>
<td>Saline and Unfit</td>
</tr>
</tbody>
</table>

**Total Dissolved Solid (TDS)** – A large number of solids are found dissolved in natural waters, the common ones are carbonates, bicarbonates, chlorides, phosphates, and nitrates of calcium, magnesium, sodium, potassium, iron and magnesium etc. in other words, TDS is simply the sum of the cations and anions concentration expressed in mg/l. TDS generally refers to the weight of the residue left over after the water in the sample is evaporated.

The value of TDS is significant since it gives an indication of the past and present environment of the water. Total dissolved solids are a measure of total concentration of all constituents present in water and have a bearing on its taste. It does not include suspended sediments, colloids or dissolved gasses (Walton, 1970). A high content of dissolved solids elevates the density of water, influences osmoregulation of freshwater organisms, reduce solubility of gases (like oxygen) and reduce utility of water for drinking, irrigation and industrial purposes.

**Alkalinity** - The amount of carbonate and bicarbonate ions quantifies the alkalinity of water and is defined as the capacity of a solution to neutralize acid which react with hydrogen ion. The total alkalinity can be found if acid is added to water.
Carbonate and Bicarbonate - The main source of carbonate and bicarbonate are carbon in atmosphere, dissolution of carbonate rocks, carbon dioxide in soil and CO₂ released due to bacterial oxidation of organic matter. It was estimated by titrimetric method using phenolphthalein and methyl orange as indicators and N/10 standard sulphuric acid as a titrant. When the color of the phenolphathalein disappears, it shows the conversion of carbonate into bicarbonate. Now methyl red is added which gives yellow color. The change in colour from yellow to rose red gives an indication of the neutralization of bicarbonates. According to ISI: 10500(1991) drinking water quality standards (Text Table-VI), the desirable limit for Alkalinity is 200mg/l and permissible limit as 600mg/l.

Total Hardness - It refers to overall effect of several dissolved constituents. It prevents the lather formation with soap and increases the boiling point of water. It does not have geochemical significance but it gives an idea about the behavior of water when used for domestic purpose. Certain other cations like iron, manganese and aluminium may also impart hardness to water, but these are usually present in very small amount. The anions responsible for hardness are mainly bicarbonate, carbonate, sulphate, chloride, nitrate etc. Hardness in water resulting from the presence of bicarbonate, calcium, Ca(HCO₃), which can be removed by boiling is referred to as temporary hardness. The permanent hardness is caused mainly by sulphate and chloride of the metals and it cannot be removed by boiling.

Calcium and Magnesium – calcium and magnesium are similar in many crystallo-chemical properties and both are dissolved freely from many rocks and soils. Some important source of Ca and Mg in water are: a) rain water b) dissolution of evaporized deposits c) weathering of Ca and Mg silicate minerals d) leaching from fertilized and soil amendments and e) use of surface water for irrigation. Minerals from sedimentary rocks like anorthite, diopside etc. are also chief source of calcium. Both air and soil cause enrichment of carbon dioxide in rainwater, which makes it more effective as weathering agent. The reaction of carbon dioxide and calcite can be expressed by the chemical equations:

$$\text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{Ca(HCO}_3\text{)}_2$$
If pressure of carbon dioxide is very low and water is saturated with respect to calcium carbonate, calcium has a tendency to get precipitated as calcium carbonate in the form of concretions known as **kankar**. Part of calcium may be deleted during its contact with clays due to ion exchange reaction which can be expressed:

\[
2\text{Na} - \text{Clay} + \text{Ca}^{++} (aq) = \text{Ca}^{++} (\text{Clay}) + 2\text{Na}^+ (aq)
\]

The presence of calcium in water supplies results from passage through or over deposits of limestone, dolomite, gypsum and gyspiferous scale. Total hardness and calcium content were measured with EDTA method. 50 ml of sample was taken in a conical flask and 1 ml of buffer solution prepared by dissolving standard amounts of ammonium hydroxide, di-sodium EDTA and magnesium sulphate in distilled water was added to it. 100 mg of Erichrome Black T indicator was added to turn the solution wine red. The contents were titrated against EDTA solution to turn the color blue. Total hardness in mg/l CaCO_3 was calculated by dividing the amount of EDTA used with the amount of sample and multiplied by 1000. For calcium contents another 50 ml of sample was taken in a conical flask and 2 ml of NaOH solution was added to it. 100 mg of murexide indicator was added to obtain pink color. The contents were titrated against EDTA solution until the pink color changes to purple. Calcium content was obtained in mg/l by multiplying the volume of EDTA with 400.8 and dividing the product by the amount of water sample. Magnesium contents were calculated in mg/l by using the formula:

\[
\text{Mg}^{++}, \text{mg/l} = \frac{Y - X \times 400.8}{\text{Volume of sample} \times 1.645}
\]

Where, \(Y = \text{EDTA used in hardness determination}\)

\(X = \text{EDTA used in calcium determination for the same volume of the sample}\).
Sodium and potassium in water samples were determined by Flame Photometric method. Satisfactory results for alkalis were obtained by comparing each sample solution with two standard solutions, one in which the concentration of alkali being determined was higher than the sample solution and the other in which it was lower.

Standard solution of sodium and potassium were prepared by dissolving sodium chloride and potassium chloride equivalent to 0.5, 1, 2, 4, 6, 8 and 10%. The burner of Flame Photometer was lighted and the flame adjusted. The standard solution of sodium (10 % equivalent) was taken in a beaker and the beaker was placed such that the atomizer inlet tube was fully immersed in the solution. As the solution was atomized into the flame, the element selector was set to the position of maximum response for sodium (to zero with distilled water). Reading with other standards sodium solutions were taken. After this standardization of the instrument, solutions were atomized and the readings were recorded and calculated for sodium. Similar procedure was followed for potassium estimation.

As per ISI (1991) and WHO (1971) drinking standards, the desirable limit of calcium is 75 mg/l and permissible limit is 200mg/l (Text Table – VI).

Magnesium, as calcium is also a common constituent of the natural water. It is one of the important contributors of the hardness of water. Magnesium concentration in water may vary from zero to several hundreds mg/l depending upon the source of water. Concentrations greater than 125 mg/l can exert a cathartic and diuretic action.

According to Indian standards (1991) for drinking water, the desirable and maximum permissible limit of magnesium for drinking water is 30 mg/l and 100mg/l, respectively and as per World Health organization (WHO, 1971) drinking water quality standards maximum permissible limit for Mg (as mg) is 100 mg/l.

Chloride is one of the major inorganic anions in water and it occurs in all the natural waters in widely varying concentration. It is present in water supplies exclusively as the chloride ion. Although hydrolysis products of chloride can exit temporarily where chlorine has been added as a disinfectant. The chloride
content normally increases as the mineral content increases. Rainwater, evaporate deposit, industrial effluents and surface water used for irrigation containing chloride are major source of chloride and it is not affected by ion exchange, absorption and biological processes.

Chloride in the water samples was determined by titrimetric method using potassium chromate as an indicator and standard silver nitrate as a titrant. According to Indian Standards for drinking water (1991) the desirable and the maximum permissible limits of chloride for drinking water are 250 mg/l and 1000 mg/l, respectively and as per World Health Organisation (WHO, 1971) drinking water standards, the highest desirable limit and maximum permissible limits are 200 mg/l and 1000 mg/l. At concentrations above 250 mg/l it gives a salty taste to water. Chloride is not strictly a pollutant but concentration above 1000 mg/l may harm agricultural crops and corrode the metallic pipes.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S.N No.</td>
<td>Substance or Characteristic</td>
<td>Highest permissible limit</td>
<td>Maximum permissible limit</td>
</tr>
<tr>
<td>1</td>
<td>pH</td>
<td>6.5-8.5</td>
<td>6.5-9.2</td>
</tr>
<tr>
<td>2</td>
<td>Calcium (as Ca ) mg/l, max.</td>
<td>75</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>Magnesium (as Mg ) mg/l, max.</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>Chloride mg/l</td>
<td>250</td>
<td>1000</td>
</tr>
<tr>
<td>5</td>
<td>Alkalinity mg/l, max</td>
<td>200</td>
<td>600</td>
</tr>
</tbody>
</table>

XXX Not more than 50mg/l, if there are 200mg/l sulphate, if there is less sulphate, magnesium may be extended up to 100mg/l at the rate of 1mg/l Mg for every 4 mg/l, decrease in sulphate.
Sodium—Sodium is present in all natural water as a free ion and its salt impart softness to water. However, several complexes and ion pair may occur including sodium carbonate, sodium bicarbonate, sodium sulphate and sodium chloride. Most of sodium containing rocks/deposits is relatively susceptible to weathering reactions. The principle source of sodium in water is the evaporate deposits, although industrial water, rain water and sewage may contribute sodium to water supply.

Potassium—potassium occurs only in ionic or molecular form and is a constituent of many silicates making up the soil. It has similar chemistry like sodium and remains mostly in solution without undergoing any precipitation. However, the behavior of potassium in chemical weathering processes is different from sodium. Potassium is easily recombined with other products of weathering, particularly with clay minerals whereas sodium remains in solution when it is leached out from complex silicates. The core of potassium in water is very quite small due to removal of potassium through base exchange or formation of mica or mica minerals except when it is contributed by activities of man like extensive use of potash fertilizers etc.

The sodium and potassium ions in the water samples were determined by Flame photometric method. Standard calibration graph was prepared for determination of sodium and potassium of the unknown sample (water). The guidelines for drinking water as per World Health Organization (W.H.O, 1993) give the limiting value of 200 mg/l for sodium and for potassium in potable waters, a desirable limit of 10 mg/l is recommended but only very high concentration of potassium above 2000 mg/l may be harmful to human nervous and digestive systems.

Percent Sodium

Sodium concentration is important in classifying irrigation water (Text Table-VII) and is expressed in terms of sodium percentage. The percent sodium (%Na) values are plotted against Electrical Conductivity (EC) values of water samples after Wilcox (1955). The water is classified in to five categories for irrigation purposes i.e. Excellent to good, Good to permissible, Permissible to
Doubtful, Doubtful to Unsuitable and Unsuitable, on the basis of Electrical Conductivity and Sodium percentage.

\[ \text{Na (\%)} = \left( \frac{\text{Na}^+ + \text{K}^+}{\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+} \right) \times 100 \]

Where all the ionic concentrations are expressed in meq./l.

**Text Table VII: Water classes based on % Na (Wilcox, 1955)**

<table>
<thead>
<tr>
<th>PERCENT SODIUM</th>
<th>WATER CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 20</td>
<td>Excellent</td>
</tr>
<tr>
<td>20-40</td>
<td>Good</td>
</tr>
<tr>
<td>40-60</td>
<td>Permissible</td>
</tr>
<tr>
<td>60-80</td>
<td>Doubtful</td>
</tr>
<tr>
<td>&gt; 80</td>
<td>Unsuitable</td>
</tr>
</tbody>
</table>

**Sodium Adsorption Ratio (SAR)**

The sodium adsorption ratio (SAR) has been recommended by the U.S. Salinity Laboratory Staff (1954) for assessing the suitability of water for irrigational purposes (Text Table VIII). Sodium adsorption ratio (SAR) values are plotted against Electrical Conductivity (EC) values in the diagram constructed by the U.S. Regional Salinity Laboratory for classification of irrigation waters describing 16 classes with reference to SAR as an index for Sodium hazard S and EC as an index of Salinity hazard C. In general water if its position in the U.S. Salinity diagram is within the zone of good or moderate waters. Waters other than these are generally but not invariably either unfit for irrigation or have restricted use depending upon the soil type, nature of crops and drainage conditions etc.

Sodium adsorption ratio (SAR) is determined by:

\[ \text{SAR} = \frac{\text{Na}^+}{\sqrt{\text{Ca}^{2+} + \text{Mg}^{2+}}} \times 2 \]

Where the ionic concentrations are expressed in meq./l.
TEXT TABLE VIII: Water classes based on SAR (after U.S. Salinity Laboratory Staff, 1954)

<table>
<thead>
<tr>
<th>S.A.R</th>
<th>WATER CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
<td>Excellent</td>
</tr>
<tr>
<td>10-18</td>
<td>Good</td>
</tr>
<tr>
<td>18-26</td>
<td>Fair</td>
</tr>
<tr>
<td>&gt;26</td>
<td>Poor</td>
</tr>
</tbody>
</table>

**Kelly’s Index**

The ratio of sodium to calcium and magnesium ions (all cations expressed as meq./l) is Kelly’s Index and is a reflection of the alkali hazard of the waters. Kelly’s Index is 1 or <1 for good quality of natural ground water.

**Residual Sodium Carbonate (R.S.C.)**

The irrigation water in which bicarbonate ions exceeds the alkaline earth (calculated on the basis of equivalents) are said to contain “Residual Sodium Carbonate”. For computing “Bicarbonate Hazard”, Eaton’s method has been used, which is caused by R.S.C. or residual alkalinity (Raghunath, H.M, 1987, p.353) in water, and is expressed as:

\[
R.S.C. = (\text{CO}_3^{2-} + \text{HCO}_3^-) - (\text{Ca}^{2+} + \text{Mg}^{2+})
\]

where all the concentrations are expressed in milli equivalent per litre.

The irrigation waters are divided into three categories on the basis of Residual Sodium Carbonate as per the norms fixed by Department of Soils, PAU Ludhiana, which are as per under:

- if R.S.C. is < +2.5 meq./l (fit for irrigation)
- if R.S.C. is between + 2.5 - 5.0 meq./l (marginal for irrigation)
- if R.S.C. is > 5.0 meq./l (unsuitable for irrigation)
For Soil and Rock Samples

**pH** of the soil is the measure of the $H^+$ ion activity of the soil water system. It indicates whether the soil is acidic, neutral or alkaline in nature. The pH is defined as the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration and can be expressed as follows:

$$pH = - \log (H^+) \; \text{or} \; \log \frac{1}{[H^+]^1}$$

The pH scale extends from 0 to 14 mid point of 7 indicating a neutral reaction. With increase in hydrogen ion activity the pH value decreases whereas with decrease it increases. The pH value is thus a measure of hydrogen ion activity. As the scale is logarithmic, so a change in pH of one unit represents a ten-fold change in hydrogen concentration. Since the growth suffers much both under very low (strongly acidic) as well as high (alkaline) pH, correction of pH becomes necessary for commencement of bioreclamation work.

Determination of soil pH is of great significance in the study of soil genesis. The degree of soil weathering, extent of leaching of basic cations and drainage condition of soils are to some extent indicated by the soil pH. The pH tends to be related to rainfall. As rainfall increases the pH value falls as a result of the depletion of basic cations from soils.

pH measurement was done by first calibrating the instrument (soil and water analysis kit) with standards of pH 4.0 and 9.2 buffer solutions.

**Electrical Conductivity (EC)** - Since ions are the carrier of electricity, the electrical conductivity (EC) of the soil water system rises according to the content of soluble salts. So, Electrical Conductivity is commonly used as a measure of amount of water soluble salts or in other words salinity in soil. Inadequate drainage, high water table and excess of evaporation cause the higher salt content. The higher salt content is harmful for the crop growth. Electrical Conductivity is thus an important property of soils which not only tell about their salt status but also points to their drainage and leaching capacities. It is closely related to the sum of cations or anions that are determined chemically. Electrical Conductivity is defined as the reciprocal of the conductance and is expressed in
micromhos/cm at 25 degree Celsius with necessary corrections for variation in
temperature of water sample using the standard curve by soil and water analysis
kit.

**Sodium and Potassium** - The elements like Na and K belong to group 1
A of the periodic table known as alkali metals. They are characterized by a single
electron in their outermost shell. This electron is easily lost, and thereby readily
form stable monovalent. It is the most abundant of all alkali elements. It is
present in a number of minerals, the principle one being rock salt (sodium
Chloride). Sodium is mainly present as silicate minerals, such as micas,
amphiboles, feldspars and pyroxenes.

Exchangeable K is the major source of K to the plants. It is presents in
relatively large quantity in moist soil. A relatively small proportion of K in soil is
exchangeable. K is more abundant in sedimentary rocks and commonly present
in feldspar, mica and other clay minerals. Potassium is added to soil in the form
of soluble salt because there is depletion of potassium due to continuous
cropping. The amount of potassium in soil is controlled by nature of clays,
organic matter and moisture content (Buckman and Brady, 1960).

Most soil analyst interested in Na, are concerned with diagnosis of sodic
and sodic - saline problems. There are wide spread problems in arid areas of the
world and especially in arid and semiarid regions in world where irrigation is
practiced.

Sodium and potassium sodium and potassium ions in the soil and rock
samples were determined by Flame photometric method.

**Calcium and Magnesium** – They are essential nutrients to the plants and
is widely distributed and generally abundant in elements in soil. The Ca and Mg
share common chemical properties, like their natural occurrence as carbonate,
phosphate, sulphate and they precipitate in similar fashion.

Calcium is abundant in the earth’s crust as major constituents of most
igneous, metamorphic and sedimentary rocks. Silicates minerals of these rocks
containing calcium are not soluble in water. The carbonates and sulphates of
calcium present in metamorphic and sedimentary rocks, however, are soluble.
Calcium is absorbed by plants as $\text{Ca}^{2+}$ from soil solution. Ca deficiency is uncommon but can occur in highly leached and unlimited soil. Even though $\text{Ca}^{2+}$ concentration of the soil is about 10 times greater than $\text{k}^+$, its uptake is usually lower than that of $\text{K}^+$. Calcium is supplied by both dolomite and calcite limestone as well as gypsum.

Magnesium is an important component of basic igneous rocks such as dunite, pyroxenites and amphiboles; volcanic rocks such as basalts, metamorphic rocks such as talc and tremolite-schists; and sedimentary rocks such as dolomite. Some limestones also contain some magnesium carbonate.

**Iron** - Iron is widely distributed in the earth's crust. It is a common component of rocks and soils. It may be derived from weathering of ferruginous minerals of igneous, sedimentary and metamorphic rocks. It is a constituent of oxides, carbonates, sulphides or iron clay minerals. Apart from natural sources, the fertilizers also add to the iron content of soils. Iron is present in almost all soils as insoluble ferric oxide. The iron content of soils is both inherited from parent rocks and the result of soil processes. Iron compounds are greatly involved in the behavior of some macronutrients and many heavy metals. The degree to which soil iron is responsible for trace metal solubility and availability is strongly governed by several soil factors. Soil iron exhibits a great affinity to form mobile organic complexes and chelates. These compounds are largely responsible for the iron migration between soil horizons and iron leaching from soil profiles and also important of iron to plant roots. Soil standards of major elements are given in Text Table – IX.

**TEXT TABLE – IX: Soil standards of major elements (Turekian and Wedepohl, 1961).**

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>STANDARD VALUE FOR SHALE</th>
<th>STANDARD VALUE FOR SANDSTONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>273000</td>
<td>368000</td>
</tr>
<tr>
<td>Al</td>
<td>80000</td>
<td>25000</td>
</tr>
<tr>
<td>Element</td>
<td>Solution A</td>
<td>Solution B</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>Ti</td>
<td>4600</td>
<td>1500</td>
</tr>
<tr>
<td>P</td>
<td>700</td>
<td>170</td>
</tr>
<tr>
<td>Ca</td>
<td>22100</td>
<td>39100</td>
</tr>
<tr>
<td>Mg</td>
<td>15000</td>
<td>7000</td>
</tr>
<tr>
<td>Na</td>
<td>9600</td>
<td>3300</td>
</tr>
<tr>
<td>K</td>
<td>26600</td>
<td>10700</td>
</tr>
<tr>
<td>Fe</td>
<td>47200</td>
<td>9800</td>
</tr>
</tbody>
</table>

**Major Elements of soil and rocks**

The samples were analyzed for SiO₂, Al₂O₃ by preparing solution A. Other Oxides (Fe₂O₃ (total Iron), MgO, CaO, Na₂O, K₂O, TiO₂ and P₂O₅) were determined by preparing solution B following the procedure of Shapiro and Brannock (1962).

**Preparation of Solution A:** 0.05 g of soil/rock was taken in a 50 ml nickel crucible and 10 to 15 pellets of NaOH were added. The crucible was gently heated for 5 minutes shaking it gently so that the powder mixed with molten NaOH and then it was heated to dull redness for 30 minutes. Then the crucible was allowed to cool down to room temperature and 500 ml of water was added and kept overnight. The solution was transferred to a 50 ml beaker with the help of policeman 20 ml of 1:1 HCL and 100 ml of water was added. The solution was boiled till it was clear and the total volume was made to 500 ml by adding distilled water.

**Preparation of Solution B:** Solution B is used in the determination of MgO, CaO, TiO₂, P₂O₅, Na₂O and K₂O. 0.5 gm of samples was transferred to the Teflon digestion bombs and 5 ml H₂SO₄ and 7 ml HF was added to it. Then these digestion bombs were tightly closed and were placed in an oven at 150°C for 3 hours. These were then transferred to platinum crucibles and were put on the hot plate. After fuming of the liquid the crucibles were transferred to a 500 ml beaker. Then few drops of HNO₃ and perchloric acid were added to it. Then the solution
was heated with distilled water till the solution becomes clear. Then it was transferred to 250 ml flask and volume was made.

**Determination of SiO$_2$:** 8 ml of the solution A, reagent blank solution, standard solution and the sample solution were transferred to 100 ml volumetric flasks. 50 ml of distilled water was added to all flasks. 2 ml of ammonium molybdate solution (prepared by dissolving 3.75 g of ammonium molybdate in 37 ml of distilled water and adding 13 ml of 1:4 H$_2$SO$_4$ acid) was added and kept for 10 minutes. 4 ml of tartaric acid solution (prepared by dissolving 10 g of reagent in 250 ml distilled water) was added by swirling the flask. 1 ml of reducing agent (prepared by dissolving 0.35 g of sodium sulphite in 5 ml water and then 0.075 g of 1 amino-2 naphtho-4 sulphonylic acid was added and stirred well until dissolved. 4 g of sodium bisulphate was dissolved in 45 ml of water and this was mixed with the first solution) the mixture was added to the solution and the volume was made up to 100 ml by adding distilled water. The samples was stirred properly and kept for 30 minutes. The concentration was measured for standard as well as samples in Spectrophotometer after adjusting it with blank.

**Determination of Al$_2$O$_3$:** 15 ml of solution A, reagent blank solution, standard solution and the sample was transferred to 100 ml volumetric flasks. 2 ml of calcium chloride solution (prepared by dissolving 0.7 g of CaCO$_3$ and adding 20 ml of water and 2 ml of concentrated HCL and diluted to 50 ml) was added. 1 ml of hydroxylamine-hydrochloride (prepared by dissolving 2.5 g hydroxylamine hydrochloride in 25 ml) was added by swirling the flask. 1 ml of potassium ferricyanide (0.75%) was added to each flask and mixed. 2 ml of thioglycolic acid solution (4%) was added and kept for five minutes. 10 ml of buffer solution (prepared by dissolving 50 g of sodium acetate in water and adding 15 ml of glacial acetic acid and diluted to 250 ml) was added and kept for 10 minutes. 10 ml of Alizarian red-s solution (0.05%) was added to each flask and volume was diluted to 100 ml by adding distilled water. The samples were stirred properly and kept for 50 minutes. The concentration was measured for standard and samples using Spectrophotometer.
Determination of Na₂O and K₂O: Sodium and potassium were determined by Flame Photometric method. Satisfactory results for alkalies were obtained by comparing each sample solution with two standard solutions, one in which the concentration of alkalies being determined was higher than the sample solution and the other in which it was lower. Standard solution of sodium and potassium were prepared by dissolving sodium chloride and potassium chloride equivalent to 0.5, 1, 2, 4, 6, 8 and 10 %. Using transfer pipettes 25 ml of solution B was transferred to a pyrex beaker. Then 25 ml of distilled water and 50 ml of the internal standards solution (prepared by dissolving 1.844 g lithium sulphate in 1 liter of water) was added to the beaker.

Sodium and potassium were determined by using different filters on the Flame Photometer. The standard solution of Sodium (10% equivalent) was taken in a beaker and the beaker was placed such that the atomizer inlet tube was fully immersed in the solution. As the solution was atomized into the flame, the element selector was set to the position of maximum response for Sodium (to zero with distilled water). Reading with other standards sodium solution were taken. After this standardization of the instrument, readings were recorded and calculated for sodium. Similar procedure was followed for potassium estimation also.

Determination of CaO and MgO: The total amount of calcium and magnesium was determined by titration with EDTA. First the total calcium and magnesium and then calcium alone was determined by simple titration. For the determination of total calcium and magnesium 20 ml of solution B was taken in 500 ml beaker. 5 ml of 1:1 HCL were added to each beaker. 20 ml triethynolamine and 500 ml ammonia solution was added to each beaker. These were then titrated against EDTA (prepared by dissolving 2 g of disodium ethylenediamine tetra acetate in 2 liters of water) using Naptho green B and ortho cresalphtoline complexone Napthol as indicators and the color change from puple to green was recorded.

Calcium can be determined by titration with EDTA using calcine as indicator. 20 ml of solution B was transferred in a 500 ml flask. 2 ml of 1:1 HCL
(prepared by adding 25 ml HCL to 25 ml water) was added to each flask. Then 5 ml of 1:1 triethynolamine were added to all sample solutions. 150 ml of H₂O and a pinch of indicator was added to each flask. After this 5 ml of 30% KOH was added to each flask. The sample solution was titrated with EDTA. The end point showing a change in color from green to pink was recorded. 50 ml of stock solution was transferred to 1 liter flask and volume was made up to 1 liter. In two separate beakers, 20 ml of stock solutions, 2 ml HCL, 5 ml triethynolamine, 150 ml of water was taken and after that 5 ml KOH and indicator were added and both of them were titrated with EDTA and the standard reading was noted. After calculation of calcium, the values were subtracted from Ca + Mg values in each case and MgO percentage was determined.

**Determination of \( P_2O_5 \):** 25 ml of solution B was transferred to 100 ml beaker. 25 ml of the buffer solution (prepared by dissolving 0.3 g of sodium metavanadate in 100 ml, 1:1 HNO₃ and then preparing another solution by dissolving 18.75 sodium molybdate in 100 ml of water and then mixing the two solutions and making volume 500 ml) was added to each beaker. Then the solutions were allowed to stand for 5 minutes and percent transmission for standard solutions and sample solutions using reagent blank solution were determined with the help of Spectrophotometer.

**Determination of TiO₂:** with a pipette, transferred to 50 ml portions of standard TiO₂ solution and 5 ml of each solution B to 150 ml beaker, 5 ml of water were added to another beaker, to be used in preparation of reagent blank solution. 125 mg of tiron powder were added to each beaker. 50 ml of the buffer solution (prepared by mixing 40 g of ammonium acetate and 300 ml glacial acetic acid and then making the volume up to 1 liter) was added to each beaker. 10 to 20 mg of sodium dithionite was added to the solution to be used as reagent blank solution. The readings of the samples were noted on Spectrophotometer.
DRAINAGE ANALYSIS

Drainage analysis was carried out to calculate various drainage parameters such as stream order, stream number, stream length, mean stream length, bifurcation ratio, weighted mean bifurcation ratio, drainage frequency, drainage density and drainage texture.

STREAM ORDER
In this study, the channel segments of different drainage basins are ranked according to Strahler's (1964) stream ordering system. The streams which have no tributaries are ranked as of first order. The streams having tributaries of only first order channels are ranked as second order streams. A stream is ranked as of third order when two second order channels join whereas a stream formed by the joining of two third order channels is termed as of fourth order and so on. The trunk stream through which total discharge of water and sediments pass is the stream segment of the highest order.

STREAM NUMBER
The total number of order-wise stream segments is known as stream number. Horton's (1945) law of stream number states that the number of stream segments of each order form an inverse geometric sequence with an order number.

STREAM LENGTH
The total stream lengths of various orders have been measured with the help of rotameter, using topographical maps for all the five selected drainage basins.

MEAN STREAM LENGTH
The mean stream length is a dimensional property revealing the characteristic size of the components of a drainage network and its contributing of basin surfaces (Strahler, 1964). To obtain this value, the total length of streams is divided by the total number of segments of that order,
i.e. \( L_u = \frac{\Sigma L}{N_u} \)
where 'Lu' = mean stream length
'\Sigma L' = the total stream length
'N_u' = number of stream segments (N) of stream order (u)

**BIFURCATION RATIO**

The ratio between the total numbers of streams of one order to that of the next higher order in a drainage basin is known as 'bifurcation ratio'. It is computed by using the following formula:

\[ R_b = \frac{N_u}{N_{u+1}} \]

where 'Rb' is the bifurcation ratio
'N_u' is the number of segments of given order
And 'N_{u+1}' is the number of segments of the next higher order.

**WEIGHTED MEAN BIFURCATION RATIO**

Weighted mean bifurcation ratio is an index of more representative bifurcation ratio for each successive pair of orders. It is obtained by multiplying the bifurcation ratio for each successive pair of stream orders by the total number of streams included in the ratio and then dividing the sum of these values by the sum of total number of stream segments in each pair. It is calculated by using the following formula:

\[ R_{bw} = \frac{R_{b1} \times n_1 + R_{b2} \times n_2 + \ldots}{n_1 + n_2 + \ldots} \]

where 'R_{bw}' is the weighted mean bifurcation ratio,
'R_{b1}' is the bifurcation ratio between first and second order streams,
'n_1' stands for the total number of stream segments involved in 'R_{b1}' calculation, and
'R_{b2}' is the bifurcation ratio between second and third order streams and 'n_2' is the total number of stream segments involved in 'R_{b2}' and so on so forth.
DRAINAGE FREQUENCY
Drainage frequency (DF) is the number of stream segments per unit of area
(Horton, 1932 and 1945). It is an index of the different stages of landscape
evaluation.
Drainage frequency has been computed using the formula:
\[ DF = \frac{\Sigma N}{A} \]
where ‘DF’ stands for drainage frequency,
‘N’ is the number of stream segments,
and ‘A’ denotes the areal unit.

DRAINAGE DENSITY
Drainage Density is defined as the length of stream segments per unit area. A
systematic analysis of drainage analysis of drainage density was first introduced
by Horton (1932, P.357). It is calculated by using the following formula:
\[ Dd = \frac{\Sigma L}{A} \]
where ‘Dd’ is the drainage density,
‘L’ is the stream length and,
‘A’ is the areal unit.
Drainage density may also be thought of as an expression of the closeness of
spacing of channels. (Strahler, 1964, p.452).

DRAINAGE TEXTURE
Drainage Texture (Rt) is computed as below (By Horton, 1945):
\[ Rt = \frac{Nu}{P} \]
where ‘Rt’ = Drainage texture
‘Nu’ = Total number of streams of all orders
‘P’ = Perimeter (in Km)

LAND USE
Material for the study:
The Indian remote sensing satellite (IRS - 1D) digital data of sensor LISS -
III depicting the data for 53B/09, 53B/10 and 53B/13 was collected from National
Remote Sensing Agency (NRSA), Department of Space, Hyderabad. This spatial data was used to conclude the various land use pattern. The detail of satellite data used in the study is given below in text table – X.

**TEXT TABLE – X: Detail of Satellite data.**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Path / Row for IRS-1D, LISS – III Digital Satellite Data</th>
<th>Date of Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>95-49</td>
<td>28, Feb03</td>
</tr>
<tr>
<td>2.</td>
<td>95-49</td>
<td>28, Feb03</td>
</tr>
<tr>
<td>3.</td>
<td>95-49</td>
<td>28, Feb03</td>
</tr>
</tbody>
</table>

Survey of India topographical sheets of the said area on 1:50,000 scale were utilized for registration of satellite data, selection of ground control points and locating training sets as well as to identify and authenticate the various cultural feature on the satellite image. Administrative maps of the study area on 1:50,000 scale were also utilized to demarcate the study area on the satellite image.

**Methodology:**

1. Digitization of administrative base maps of the study area and bring them to a projection system.
2. IRS-1D digital data procured for land use-land cover mapping was georeferenced with survey of India topographical sheets. The three satellite scenes covering the said study area were mosaiced.
3. Digital Image Processing (DIP) was done using ERDAS software to prepare land use-land cover map.