CHAPTER – II

OBJECTIVES AND RESEARCH METHODOLOGY

2.1 INTRODUCTION

This chapter deals with objectives and methodologies of the present research. On the basis of conceptual framework and emerging issues from literature review in the present study the following objectives have been set.

1. Determining geological and hydro-geological parameters and status of natural resources of selected watersheds.
2. Evaluation of watershed with respect to land use/land cover change, slope analysis, drainage analysis, geo-morphological analysis by application of remote sensing & GIS techniques.
3. Assessment of ecological, economic, and socio-cultural sustainability of watershed programmes on the basis of field survey and through collection of primary & secondary data.

To fulfill the mentioned objectives following methodology are used in the present study to carry out systematic assessment of watersheds in the study area.

2.2 STUDY OF HYDROLOGICAL AND GEO-CHEMICAL PARAMETERS

2.2.1 SAMPLING

Water samples (Surface or Ground water) and soil samples were collected from various watershed villages of the study area in the month of May – July 2008. Water samples were collected mainly from the tap water, spring water (used for drinking and irrigation purposes) tank water (mainly used for irrigation purposes) and hand pumps. Soil samples were collected from the agricultural fields. The survey of India topographic...
sheet nos. 52H/2, 52H/3, 52L/3, 52L/4, 52H/4, 53E/1, 53F/1 and 53B/13 (scale 1: 50,000) and a hand held Global Positioning System (GPS make-Garmin, E-Tx vista) were used for marking water and soil sampling locations. Further sampling points noted by GPS were marked on the final map with the help of ARC GIS 9.1 & ERDAS imagine 8.4 software. Moreover other relevant information’s pertaining to study area was obtained from concerned departments like DRDA & DoA etc.

2.2.2 WATER SAMPLING

In total 52 water samples have been collected randomly from selected watersheds in study area during the months of May to July 2008 (pre – monsoon period). Out of 52 water samples, 36 samples were collected from spring & tap water mainly used for drinking purpose. During scarcity of water these water sources are used for irrigation purposes by storing (rainwater, spring water, and tap water) in water harvesting tanks built during the project period. Fourteen samples were collected from streams & tank water, mainly used for irrigation purposes and two samples of hand pump water from two watersheds were collected from Spiti valley of Lahaul & Spiti district. In case of hand pump water, prior to sampling, water was pumped out for about 5 to 10 minutes. The initial pumping serves to remove water in contact with the metal well casting.

All samples were collected from the study area in 2 litres hard plastic bottles. Before sampling, these bottles were washed with distilled water to ensure compositional originality of water samples. Water bottles were rinsed 3 to 4 times with the water to be sampled during sampling. After the bottles were filled to their capacity, they were sealed with wax to minimize escape of gases and labeled properly. All the particulars regarding the sample were written in the field itself, immediately after sampling, and tagged to the sample bottles.

2.2.3 CHEMICAL PARAMETERS

The collected water samples were immediately subjected to measure chemical parameters such as pH, EC, and TDS with the help of Soil and Water Analysis Kit and thermometer to ensure accurate determination of temperature. 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.

2.3 LABORATORY TECHNIQUES FOR GEO-CHEMICAL PARAMETERS FOR WATER SAMPLES ANALYSIS

The collected samples were brought to the laboratory for determination of various parameters (Table 2.1) like bicarbonate, carbonate, chloride, calcium, magnesium, fluoride, nitrate, phosphate, sulphate, sodium, & potassium ions by geochemical methods at Geochemical Laboratory in the Centre of Advanced Study (CAS), Geology, Panjab University, Chandigarh. For this purpose the samples were filtered through filter paper, Whatman No. 42, until a pure and clean solution was obtained. Some of the chemical attributes of water samples were also used to evaluate the quality of these materials for use in irrigation.

2.3.1 pH

pH is a unit used 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. It is represented by

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

The pH scale usually ranges 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 & dissolution of acid (c) relative concentration of acid and its conjugate base. A brief description of the method of chemical analysis of water samples is given in Table – 2.1
Table 2.1: 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>Electro-metric method, pH meter (Electronic India, Model 161E)</td>
</tr>
<tr>
<td>3.</td>
<td>Electrical Conductivity (EC)</td>
<td>Electrical conductivity method, EC meter (Electronic India, Model 161E)</td>
</tr>
<tr>
<td>4.</td>
<td>Total Dissolve Solids (TDS)</td>
<td>-- do--</td>
</tr>
<tr>
<td>5.</td>
<td>Bicarbonate (HCO₃)</td>
<td>Titrimetric method using standard sulphuric acid with phenolphthalein and methyl orange as indicators.</td>
</tr>
<tr>
<td>6.</td>
<td>Carbonate (CO₃)</td>
<td>--do--</td>
</tr>
<tr>
<td>7.</td>
<td>Chloride (Cl)</td>
<td>Argenometric method with potassium chromate as indicator.</td>
</tr>
<tr>
<td>8.</td>
<td>Calcium (Ca)</td>
<td>EDTA-Titrmetric method</td>
</tr>
<tr>
<td>9.</td>
<td>Magnesium (Mg)</td>
<td>EDTA-Titrmetric method</td>
</tr>
<tr>
<td>10.</td>
<td>Fluoride (F)</td>
<td>SPADNS method</td>
</tr>
<tr>
<td>11.</td>
<td>Nitrate (NO₃)</td>
<td>Colorometric method</td>
</tr>
<tr>
<td>12.</td>
<td>Phosphate (PO₄)</td>
<td>Colorometric method</td>
</tr>
<tr>
<td>13.</td>
<td>Sulphate (SO₄)</td>
<td>Colorometric method</td>
</tr>
<tr>
<td>14.</td>
<td>Sodium (Na)</td>
<td>Flame photometric method</td>
</tr>
<tr>
<td>15.</td>
<td>Potassium (K)</td>
<td>Flame photometric method</td>
</tr>
</tbody>
</table>

2.3.2 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 micro mhos/cm at 25°C with necessary corrections for variation in temperature of water sample using the standard curve by soil and water analysis kit. The
qualities of groundwater for irrigational use, based on the electrical conductivity values, are rated according to following three classes as given in Table – 2.2.

Table 2.2: Water classes based on EC values

<table>
<thead>
<tr>
<th>EC in micro mhos/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>

2.3.3 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 cation and anion 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.

2.3.4 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 reacts with hydrogen ion. The total alkalinity can be found if acid is added to water.
2.3.5 Carbonate and Bicarbonate

The main sources 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 phenolphthalein disappears, it shows the conversion of carbonate into bicarbonate. Now methyl red is added which gives yellow color. The change in color from yellow to rose red gives an indication of neutralization of bicarbonates. According to ISI: 10500 (1991) drinking water quality standards as given in Table-2.3, the desirable limit for Alkalinity is 200mg/l and permissible limit is 600mg/l.

2.3.6 Chloride

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 Institutions (ISI 1983, 1991), for drinking water, the desirable and the maximum permissible limits of chloride for drinking water are 250 mg/l and 1000 mg/l, respectively.

As per World Health Organisation (WHO, 1984) drinking water standards, the highest desirable limit and maximum permissible limits are 250 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 2.3: DRINKING WATER QUALITY STANDARDS (ISI 1983, 1991 & WHO 1983)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Highest desirable limit</td>
<td>Maximum permissible limit</td>
<td>Requirement (desirable limit)</td>
<td>Permissible limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Highest (desirable 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>
<td>6.5 - 8.5</td>
</tr>
<tr>
<td>2</td>
<td>TDS</td>
<td>500</td>
<td>1000</td>
<td>&lt;500</td>
</tr>
<tr>
<td>3</td>
<td>Chloride (as Cl) mg/l</td>
<td>250</td>
<td>1000</td>
<td>250</td>
</tr>
<tr>
<td>4</td>
<td>Calcium (as Ca) mg/l, max.</td>
<td>75</td>
<td>200</td>
<td>75</td>
</tr>
<tr>
<td>5</td>
<td>Magnesium (as Mg) mg/l, max.</td>
<td>30</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>Fluoride (as F) mg/l, max.</td>
<td>0.6 - 1.2</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>7</td>
<td>Nitrate (as NO₃) mg/l, max.</td>
<td>45</td>
<td>100</td>
<td>45</td>
</tr>
<tr>
<td>8</td>
<td>Sulphate (as SO₄) mg/l, max.</td>
<td>150</td>
<td>400</td>
<td>200</td>
</tr>
<tr>
<td>9</td>
<td>Sodium as Na</td>
<td>No Guideline</td>
<td>No Guideline</td>
<td>No Guideline</td>
</tr>
<tr>
<td>10</td>
<td>Potassium as K</td>
<td>No Guideline</td>
<td>No Guideline</td>
<td>No Guideline</td>
</tr>
<tr>
<td>11</td>
<td>Alkalinity mg/l, max.</td>
<td>200</td>
<td>600</td>
<td></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.

59
2.3.7 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 calcium bicarbonate, 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.

2.3.8 Calcium and Magnesium

Calcium and magnesium are similar in many crystallo-chemical properties and both are dissolved freely from many rocks and soils into water. Some important source of calcium and magnesium in water are: (a) rain water (b) dissolution of evaporized deposits (c) weathering of calcium and magnesium 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.

\[
\begin{align*}
\text{H}_2\text{O} + \text{CO}_2 & \rightarrow \text{H}_2\text{CO}_3 \\
\text{H}_2\text{CO}_3 & \rightarrow \text{H}^+ + \text{HCO}_3^- \\
\text{CaCO}_3 + \text{H}^+ & \rightarrow \text{Ca}^{++} + \text{HCO}_3^- 
\end{align*}
\]

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.
The presence of calcium in water supplies results from passage through or over deposits of limestone, dolomite, gypsum and gypsiferous scale. Total hardness and calcium content were measured with EDTA method. Then 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. After that 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. After that 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:

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

Where \(Y\) = EDTA used in hardness determination
\(X\) = EDTA used in calcium determination for the same volume of the sample.

As per ISI (1983, 1991) and WHO (1984) drinking standards, the desirable limit of calcium is 75 mg/l and permissible limit is 200mg/l (Table – 2.3).

Magnesium and 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 100 mg/l, respectively, and as per World Health Organization (WHO, 1984) drinking water quality standards, maximum permissible limit for Mg (as mg) is 100 mg/l.

2.3.9 Fluoride

Fluorine is the most electronegative of all the elements of the periodic table so it has unique chemical characteristics. Fluorine is the fairly common element that does not occur in elemental state in nature because of its high reactivity. In solutions, it forms fluoride (F) ions. Fluoride ions have the same charge and nearly the same radius as hydroxide ion; thus the ion may replace each other on mineral structure. The principle source of fluoride available to living world is drinking water. The elemental fluorine is used by higher life forms in the structure of bones and teeth. The importance of fluoride, its anion, in forming human teeth and role of fluoride intake from drinking water in controlling the characteristics of tooth structure was recognized during 1930s (Hem, 1989). Fluoride is commonly associated with volcanic or fumarolic gases, and in some areas these may be important source of fluoride in ground water (Hem, 1989). According to Indian Standards for drinking water (1983 & 1991), the desirable and the maximum permissible limits of fluoride for drinking water are 0.6 – 1.2 mg/l and 1.5 mg/l & 1.0 mg/l and 1.5 mg/l, respectively and as per World Health Organisation (WHO, 1984) drinking water standards, the highest desirable limit and maximum permissible limits are <1 -5 mg/l and 10 mg/l. Fluoride in the water samples was determined by SPADNS method.

2.3.10 Nitrate

The nitrogen in the form of dissolved nitrate is important nutrient for vegetative cover and an essential for all forms of life. Of all the fertilizers applied to the soil for increasing crop production, nitrogenous ones are the most important. These are rapidly converted in arable soils to nitrate form, which are readily available to plants, but are highly soluble and hence easily leachable. When quantity of nitrogen added to the soil exceeds the amount that the plant can use, excess nitrate does not get much adsorbed by
soil particles leaches out from the root zone by water percolation through the soil profile and ultimately accumulates in to the groundwater (Hem, 1985). According to Indian Standards for drinking water (1991), the desirable and the maximum permissible limits of nitrate for drinking water are 45 mg/l and 100 mg/l, respectively. As per World Health Organisation (WHO, 1984) drinking water standards, the highest desirable limit and maximum permissible limits are 10 mg/l and 50 mg/l. Nitrate in the water samples was determined by colorometric method.

2.3.11 Phosphate

Phosphate is made available to water bodies as a byproduct of several kinds of cultural applications of the elements that occur through activities of man (Hem, 1970). Phosphate consequently occur in surface and ground water as a result of leaching from minerals or ores in natural process, degradation of cleaning products, industrial wastes, and as a major element of municipal sewage (Mckee and Wolf, 1963). Its concentration in natural potable groundwater is usually less than a few tenths or hundreds of a milligram per litres, as a result of low solubility of most inorganic phosphorous compounds. Phosphorous is used as biota as an essential nutrient as it is important to plant and animal metabolism and occur in their waste products. Which is another reason for its low content and mobility in natural ground water and at the same time explains its extensive use as a fertilizer. But the phosphorous added to the subsurface through disposal of waste or leaching of fertilized fields may not remain available for longer periods. Various forms of phosphate fertilizers, detergents, liquids and solid waste, and soil erosion from agricultural fields provide a major source of phosphate in surface water, causing negative effect such as eutrophication. There are no guidelines for the phosphate concentration in both the ISI and WHO guidelines. Phosphate in the water samples was determined by colorometric method.

2.3.12 Sulphate

Sulphate is common in natural water and its major sources in ground water and surface water include rain water, solution of sulphate minerals in sedimentary rocks, surface irrigation water, burning of coal and oil, oxidation of sulphate from primary
rocks, addition of pyrite, gypsum, anhydride, sulphate rich fertilizers and smelting process. The sulphate content of atmospheric precipitation is only about 2 mg/l but a wide range in sulphate content in ground water is made possible through oxidation, precipitation, solution and concentration, as the water traverses through rocks. Sulphate ion in association with higher concentration of magnesium and sodium ions act as a laxative and may cause gastric disorders. It has been proposed that presence of moderately high concentration of sulphate ions (200-300 mg/l) in drinking water may result in cathartic effects to human beings (Mcneely et al., 1979). Water with more than 500 mg/l sulphate imparts bitter taste and may cause gastro-intestinal irritation and catharsis. ISI 1983 & 1991 have fixed the highest desirable limit of 150 mg/l & 200 mg/l and maximum permissible limit of 400 mg/l. WHO 1984 have proposed the highest desirable limit of <1-5 mg/l and maximum permissible limit of 500 mg/l for sulphate in drinking water. Sulphate in the water samples was determined by colorometric method.

2.3.13 Sodium

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.

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. As estimated, 25 to 50% of salt used on road for snow and ice control enters the groundwater and can elevate levels of sodium in public water supplies. Sodium concentrations vary considerably depending on regional and local hydrological and geological conditions, the time of year, and salt utilization patterns. In groundwater, sodium concentrations normally range between 6 and 130 mg/l (Bond et al., 1973) much higher level may be associated with saline salts.

For health considerations sodium is the most abundant cation in the extra cellular fluid. It is largely associated with chloride and bicarbonate in regulation of acid base equilibrium. The minimum sodium chloride requirement is about 120 mg/day. Sodium is required for normal functioning of human body but high level of sodium for people suffering from cardiac, renal and circulatory disease is harmful. Persons on restricted sodium diets are advised not to drink water with sodium levels exceeding 20 mg/l (McNeely et al., 1979).

Drinking water having high sodium content is rendered unpalatable or saltish in taste. Plants use sodium in limited amount of growth, but the presence of large amounts of sodium often proves injurious, especially to fruit crops. The guidelines for drinking water as per World Health Organization (W.H.O, 1984) give the limiting value of 200 mg/l for sodium and no guidelines as per ISI 1983 & 1991.

2.3.14 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 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. Similar procedure was followed for potassium estimation as explained in case of sodium.

The guidelines for drinking water as per W.H.O, 1984 give for potassium in potable waters, a desirable limit of 50 mg/l is recommended but only very high concentration of potassium above 2000 mg/l may be harmful to human nervous and digestive systems and no guidelines as per ISI 1983 & 1991. Potassium in the water samples was determined by flame photometric method.

2.3.15 Percent Sodium

Sodium concentration is important in classifying irrigation water is given in Table-2.4 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). Water is classified into 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.

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

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

Table 2.4: 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>
2.3.16 Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR) has been recommended by the U. S. Salinity Laboratory Staff (USSL) (1954) for assessing the suitability of water for irrigational purposes as given in (Table- 2.5). 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 as S and EC as an index of salinity hazard as C. In general water, if its position in the U. S. Salinity diagram is within the zone of good or moderate 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:

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

Where the ionic concentrations are expressed in meq./l

<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>

2.3.17 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.
2.3.18 Residual Sodium Carbonate (RSC)

The irrigation water in which bicarbonate ions exceed 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, 1992) in water, and is expressed as:

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

Where all the concentrations are expressed in meq./l. The irrigation water is divided into three categories on the basis of Residual Sodium Carbonate.

- 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)

2.4 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 35 different locations of different watersheds of the research area with the help of a small spade or trowel after removal of excess pebbles and grass. The samples were collected in polythene transparent bags and after the bag was filled to their capacity, they were sealed and labeled properly for further laboratory investigation.

2.5 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, and structure. These parameters are briefly explained herein.
2.5.1 Soil color

Color is the most obvious and easily determined soil characteristics. It is an important soil property and is used in identification of soil especially when it is interpreted jointly with soil structure. Although it does not interfere with 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 is 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, three variables of Hue, value, chroma are represented in numerical form by a set pattern of hue, value, and chroma.

2.5.2 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.

2.5.3 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 hand feel method was adopted for an approximate assessment of soil texture as described in Soil Survey Manual (Soil Survey Staff 1951).

2.6 SOIL 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 samples were analyzed for various oxides as SiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, Na₂O, K₂O, TiO₂ and P₂O₅. A brief description of the method of chemical analysis of soil samples is given in Table – 2.6

Table 2.6: Summary of Analytical Methods used for Chemical Analysis of Soil samples

<table>
<thead>
<tr>
<th>S. No.</th>
<th>PARAMETERS</th>
<th>ANALYTICAL METHODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pH</td>
<td>Electrometric, pH meter (Electronics India, Model 161E)</td>
</tr>
<tr>
<td>2</td>
<td>EC (micromhos/cm at 25°C)</td>
<td>Water and Soil Analysis Kit (Electronics India, Model 161E)</td>
</tr>
<tr>
<td>3</td>
<td>TDS (mg/l)</td>
<td>--do--</td>
</tr>
<tr>
<td>4</td>
<td>Weight % of SiO₂</td>
<td>UV Spectrophotometer (Hilger and Watt), λ= 640nm</td>
</tr>
<tr>
<td>5</td>
<td>Weight % of Al₂O₃</td>
<td>UV Spectrophotometer (Hilger and Watt), λ= 475nm</td>
</tr>
<tr>
<td>6</td>
<td>Weight % of Fe₂O₃ (total Iron)</td>
<td>UV Spectrophotometer (Hilger and Watt), λ= 555nm</td>
</tr>
<tr>
<td>7</td>
<td>Weight % of TiO₂</td>
<td>UV Spectrophotometer (Hilger and Watt), λ= 430nm</td>
</tr>
<tr>
<td>8</td>
<td>Weight % of P₂O₅</td>
<td>UV Spectrophotometer (Hilger and Watt), λ= 420nm</td>
</tr>
<tr>
<td>9</td>
<td>Na₂O</td>
<td>EEL Flame - photometer</td>
</tr>
<tr>
<td>10</td>
<td>K₂O</td>
<td>EEL Flame - photometer</td>
</tr>
<tr>
<td>11</td>
<td>CaO</td>
<td>Titration with EDTA</td>
</tr>
<tr>
<td>12</td>
<td>MgO</td>
<td>Titration with EDTA</td>
</tr>
</tbody>
</table>
First of all, samples were crushed with the help of a steel mortar and pestle to bring it up to <80 mesh size. Finally each sample was powdered in electric agate mortar till the size is reduced to <200 mesh. The powdered 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 SiO₂ and Al₂O₃ whereas solution ‘B’ was employed for analysis of Fe₂O₃ (total Iron), MgO, CaO, Na₂O, K₂O, TiO₂ and P₂O₅.

2.7 GEO-CHEMICAL PARAMETERS FOR SOIL SAMPLES

2.7.1 pH

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:

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

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.

2.7.2 Electrical Conductivity (EC)

Since ions are the carrier of electricity, the electrical conductivity 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°C with necessary corrections for variation in temperature of water sample using the standard curve by soil and water analysis kit.

2.7.3 Sodium and Potassium

The elements like sodium and potassium 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 forms stable monovalent bonds. 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 potassium is the major source of potassium to the plants. It is present in relatively large quantity in moist soil. A relatively small proportion of potassium in soil is exchangeable. Potassium 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 analysts interested in sodium, are concerned with diagnosis of sodic and sodic - saline problems. There are wide spread problems (sodic and sodic – saline) 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.

2.7.4 Calcium and Magnesium

They are essential nutrients to the plants and are widely distributed and generally abundant elements in soil. The calcium and magnesium share common chemical properties, like their natural occurrence as carbonate, phosphate, and 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. Silicate minerals of these rocks containing calcium are not soluble in water. The carbonates and sulphate of calcium present in metamorphic and sedimentary rocks, however, are soluble. Calcium is absorbed by plants as Ca$^{2+}$ from soil solution. Calcium deficiency is uncommon but can occur in highly leached and unlimited soil. Even though Ca$^{2+}$ concentration of the soil is about 10 times greater than K$^+$, its uptake is usually lower than that of K$^+$. Calcium is supplied by 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.

2.7.5 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 ion 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 iron in soils 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 to plant roots. Soil standards of major elements are given in Table – 2.7.

2.8 LABORATORY TECHNIQUE FOR GEO-CHEMICAL PARAMETERS OF SOIL SAMPLES

The samples were analyzed for SiO₂, Al₂O₃ by preparing solution A. Other Oxides (Fe₂O₃, 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:** Take 0.5 g of soil sample each dried and passed through 200 sieve number and heated up to 100° C in an oven and then taken in a 50 ml nickel crucible and 10 to 15 pellets of NaOH were added. The crucible was gently heated for five 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 determination of MgO, CaO, TiO₂, P₂O₅, Na₂O and K₂O. Took 0.5 gm of soil sample, each dried and passed through 200 sieve number and heated up to 100° C in an oven and than taken in a 50 ml nickel
crucible of samples was transferred to the Teflon digestion bombs and 5 ml H$_2$SO$_4$ 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 three 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 HNO$_3$ 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.

Table 2.7: Soil standards of major elements (Turekian and Wedepohl, 1961)

<table>
<thead>
<tr>
<th>ELEMENTS</th>
<th>STANDARD VALUE FOR SHALE (in µg/g)</th>
<th>STANDARD VALUE FOR SANDSTONE (in µg/g)</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>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>

2.8.1 Determination of SiO$_2$

Take 8 ml of the solution A, reagent blank solution, standard solution and the sample solution were transferred to 100 ml volumetric flasks. After that 50 ml of distilled water was added to all flasks. Then 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. Four ml of tartaric acid solution (prepared by dissolving 10 g of reagent in 250 ml of distilled water) was added by swirling the flask. One ml of reducing agent (prepared by dissolving 0.35 g of sodium

75
sulphite in 5 ml water and then 0.075 g of 1 amino-2 naptho-4 sulphonic acid was added and stirred well until dissolved. Four 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.

2.8.2 Determination of Al₂O₃

Fifteen ml of solution A, reagent blank solution, standard solution and the sample was transferred to 100 ml volumetric flasks. Two ml of calcium chloride solution (prepared by dissolving 0.7 g of CaCO₃ and adding 20 ml of water and 2 ml of concentrated HCL and diluted to 50 ml) was added. One ml of hydroxylamina-hydrochloride (prepared by dissolving 2.5 g hydroxylamine hydrochloride in 25 ml) was added by swirling the flask. After that 1 ml of potassium ferricyanide (0.75%) was added to each flask and mixed. Two ml of thioglycolic acid solution (4%) was added and kept for five minutes. Add 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. Then 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.

2.8.3 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 litres 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.

2.8.4 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. Then 5 ml of 1:1 HCL were added to each beaker. After that 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 litres of water) using Naphtha green B and ortho cresaphtholine complexone Napthol as indicators and the color change to from purple to green was recorded.

Calcium can be determined by titration with EDTA using calcine as indicator. Twenty ml of solution B was transferred in a 500 ml flask. After that 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. Then 150 ml of H₂O and a pinch of indicator were 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. Then 50 ml of stock solution was transferred to 1 litres flask and volume was made up to 1 litre. 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.

2.8.5 Determination of \( \text{P}_2\text{O}_5 \)

Transfer 25 ml of solution B to 100 ml beaker. After that 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.

2.8.6 Determination of TiO₂

With a pipette, transferred 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. Then 125 mg of tiron powder were added to each beaker. After that 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 litre) was added to each beaker. At the end 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.

2.9 SEDIMENTOLOGICAL INVESTIGATION

2.9.1 Grain Size analysis by Sieving Technique

Grain size analysis by sieving technique refers to the quantitative determination of frequency distribution of soil samples.
various grain 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. 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 peroxide (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 sieves 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. The fraction retained 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).
2.10 SOCIO-ECONOMIC EVALUATION OF STUDY AREA

Socio-economic evaluation of study area on the basis of ecological, economic, and socio-cultural sustainability of watershed programmes was carried out with help of primary & secondary data collection by field survey and different government agencies. Primary data was collected randomly as pre project and post project period from the selected watershed villages through well designed questionnaire by door to door interview, group discussion with villagers and participatory rural appraisal (PRA) exercises.

Participatory Rural Appraisal (PRA) is a family of approaches and methods to enable rural people to share enhances and analyse their traditional knowledge and condition to plan and to act (Chambers, 1994).

Secondary data was collected from various district rural development agencies (DRDA), agriculture department, forest department, horticulture department and rural development department etc as a number of evaluation reports, detail project report, old district gazetteers, and 2001 census reports etc.

Summary of cost and expenditure on development work of watershed villages was mainly based on the basis of secondary data. Village profile of all the watershed villages was prepared with the help of primary and secondary data collection. Interview schedule was divided into three sections as general household information followed by detail evaluation of watershed management programmes based on three aspects given as follows.

Ecological sustainability includes tangible and non tangible factors influencing the ecology of community such as increase in productive potential of resource base, management of common property resources like water potential, forest cover and reduction in soil erosion etc, and improvement in biodiversity of the region.

Economic sustainability indicators consist of factors required for livelihood and economic well being of the people in terms of increase in income levels, availability of food and fodder security, improvement in standard of living, off farm income to families, improvement in rural economy, improvement in credit and market support.

Social-cultural sustainability indicators deal with the social and cultural well being of the watershed dwellers. This includes factors like decision making power of the
community, empowerment of women, formation of farmer’s group and self help groups, change in ownership of land, improvement in quality of life, harmonious social life in terms of social equality with respect to caste, class and gender, and people’s participation.

2.11 EVALUATION OF WATERSHEDS USING REMOTE SENSING & GIS TECHNIQUE

Evaluation of watershed w.r.t base map, drainage, land use/land cover, slope and geo-morphology was carried out with the help of Remote Sensing & GIS technology at Himachal Pradesh Remote Sensing Centre (HPRSC), State Council for Science & Technology Complex, Kusumpti Shimla, Himachal Pradesh. All data like Survey of India maps and satellite imageries (Hard copy & Digital data) was acquired from remote sensing lab of HPRSC and maps were prepared during the time span of four months from November 2008 to February 2009.

2.11.1 MATERIAL FOR THE STUDY

Survey of India (SOI) topographical sheets of the selected watershed 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 features on the satellite image.


2. The Indian remote sensing satellite data (IRS – 1B, IRS -1C) in the form of geocoded paper print hardcopy False Color Composite (FCC) of sensor LISS – II & LISS - III with band combination of 2, 3 and 4 on 1:50,000 scale, were used. These imageries depicting lat/long reference to SOI toposheet no 52H/2, 52H/3, 52L/3, 52L/4, 52H/4, 53E/1, 53F/1 and 53B/13.
3. The hardcopy FCC imageries were used for the preparation of LULC map for the pre project period i.e. before 2000 & geo-morphology map was also prepared from these satellite imageries.

4. For post project period to study LULC digital mosaic remote sensing satellite imagery data (IRS – 1C LISS - III) of 1:50,000 scale acquired on October 2005 was used.

Details of satellite data with satellite ID, their acquired date along with image extent and path and row of all the watersheds from three regions are given in detail in the below Table 2.8.

Table – 2.8: Detail of Satellite data used for all watersheds

<table>
<thead>
<tr>
<th>S. No.</th>
<th>District: Lahaul &amp; Spiti</th>
<th>Watersheds</th>
<th>Satellite - ID</th>
<th>Acquired</th>
<th>Image Extent</th>
<th>Path</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td>a. Khinang</td>
<td>IRS – 1C LISS - III</td>
<td>5 - 9 - 98</td>
<td>77D00' 77D15'E 32D30' 32D45'N</td>
<td>95</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Jagla</td>
<td>IRS – 1C LISS - III</td>
<td>5 - 9 - 98</td>
<td>77D00' 77D15'E 32D30' 32D45'N</td>
<td>95</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. Kaza</td>
<td>IRS – 1B LISS – II A 2</td>
<td>28 - 8 - 93</td>
<td>78D00' 78D15'E 32D00' 32D15'N</td>
<td>28</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d. Yargo Margo Rangrik</td>
<td>IRS – 1B LISS – II A 2</td>
<td>28 - 8 - 93</td>
<td>78D00' 78D15'E 32D15' 32D30'N</td>
<td>29</td>
<td>45</td>
</tr>
<tr>
<td>2.</td>
<td>District: Kullu</td>
<td>a. Phallan</td>
<td>IRS -1C LISS - III</td>
<td>28 - 5 - 98</td>
<td>77D00' 77D15'E 31D45' 32D00'N</td>
<td>96</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Mashna</td>
<td>IRS – 1C LISS - III</td>
<td>28 - 5 - 98</td>
<td>77D00' 77D15'E 32D00' 32D15'N</td>
<td>96</td>
<td>48</td>
</tr>
<tr>
<td>3.</td>
<td>District: Solan</td>
<td>a. Giri River North iii-iv</td>
<td>IRS – 1C LISS - III</td>
<td>6 - 2 - 97</td>
<td>77D00' 77D15'E 30D45' 31D00'N</td>
<td>95</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Gulhari Dagroh Khad</td>
<td>IRS – 1C LISS - III</td>
<td>6 - 2 - 97</td>
<td>76D45' 77D00'E 30D45' 31D00'N</td>
<td>95</td>
<td>49</td>
</tr>
</tbody>
</table>

(D = Degree, E = East, N = North)
2.11.2 PROCEDURE FOR PREPARATION OF DIFFERENT THEMATIC MAPS

Procedure for preparation of different thematic maps is explained in Figure 2.1 by Thapa, R., et al 2008. Survey of India topographical map in the scale of 1:50,000 were visually analyzed/ interpreted followed by ground truth survey.

Base map of the study area were also consulted for ground truthing, on screen visual interpretation and digital classification of digital satellite data and geo-coded paper print satellite imagery at 1:50,000.

The computer system with windows 2000 and GIS Software ARC GIS 9.1 and ERDAS 8.4 was used for preparation of different thematic maps like, base map, drainage map, slope map, geomorphology map and land use land cover map. Then digitization of all maps of the study area and bring them to same projection system.

IRS – 1B LISS – II geo-coded paper print data & IRS - 1C LISS – III digital data procured for land use-land cover mapping, was geo-referenced with SOI, topographical sheets for pre and post project evaluation. This phase consists of delineation of land use/land cover type based on tonal and textural variation on the map which will later on help in identification of land use features in geo-coded paper print satellite imagery. These major details have facilitated to match the features on the satellite images while classifying or interpreting them visually and digitally.

The base map showing irrigation channels, drainage, road, vegetation, agriculture land and forest land etc. Drainage map showing major drainage, irrigation channels, nallah and river for characterization of area according to their drainage parameters.

Slope map was prepared using contour interval of 20 to 40 meter from Survey of India toposheet at 1:50,000 scale. Geo-morphology map was prepared to study the various geo-morphological features present in watershed area using the GIS software with relation to major slope categories.
Figure 2.1: Procedure for preparation of different thematic maps

Geo-coded Paper print satellite Imagery at 1:50,000 scale → Digital Satellite Imagery → S.O.I Topographic sheet

**Visual**
- Land use/Land cover map, Geomorphology map

**Interpretation**
- Base map Showing Villages, Drainage map, Slope map

**Ground**
- Preparation of pre-field maps
- Land use/cover by on screen Digitization of post watershed project area

**Truth**
- Preparation of post-field maps
- Map updation by onscreen Digitization

**Survey**
- Scanning and Digitization of final map
- Editing & Building topology in GIS environment

**Integrated**
- Polygon maps from digital and geo-coded satellite data showing Land use/cover map showing change in Land use/cover and Geomorphology map showing Structure valley, ridge line, terraces flood plane etc.

**Thematic**
- Polygon maps from S.O.I. maps showing Slope percentage, Slope aspect Drainage map showing drainage pattern Base map showing watershed villages & watershed boundary

**Maps**
- Base map, Drainage map, Slope map, Land use/Land cover map & Geo-morphology map
2.11.2.1 Preliminary Interpretation

A base map was prepared by extracting its boundary from the Survey of India, topographic map at 1:50,000 scale, showing important features like irrigation channels, drainage, road, agriculture land forest vegetation etc. The drainage map showing major drainage, irrigation channels, *nallah* and river of watershed area were prepared. Slope map showing slope percentage at 20 and 40 meter contour intervals by slope scale were prepared from the Survey of India topographic map.

The land use/land cover maps were prepared from geo-coded paper print satellite imagery at 1:50,000 scale before-the project implementation i.e. 2000, and from digital satellite imagery for after-the project implementation i.e. 2005. Geomorphology map showing structure valleys and ridge lines and also showing slope aspect of watershed area were prepared from geo-coded paper print satellite imagery at 1:50,000 scale. All these maps of the study area were traced to prepare different themes. Visual interpretation technique was used to study existing topographic map on the basis of image characteristics. This technique was chosen to avoid problem of misclassification of different land use/land cover categories.

2.11.2.2 Field Work

Reconnaissance visit in the different watershed area has been made to acquaint, with the landscape. Relationship between ground features and their respective image/map elements were identified in satellite imagery.

2.11.2.3 Post Field

The interpretation key was developed on the basis of tone, texture, pattern, association, location, shape, size, and contours. The visual interpretation of Survey of India topographical map was carried out. The area of each, drainage parameters, land use category, slope category and geomorphology was measured using ARC GIS 9.1 software. The thematic maps generated from both SOI topographic maps and IRS – 1B LISS – II geo-coded paper print data & IRS - 1C LISS – III satellite data were imported, geo-referenced, and digitized in GIS environment. Then the spatial and temporal analysis were done in the GIS environment for mapping, recognizing and evaluating the
environmental changes in land use/land cover area through statistical analysis and other thematic maps were also prepared.

2.11.3 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.

2.11.3.1 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.

2.11.3.2 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.

2.11.3.3 Stream Length

The total stream lengths of various orders have been measured with the help of ARC GIS 9.1, from drainage maps for all the selected watersheds.

2.11.3.4 Mean Stream Length

The mean stream length is a dimensional property revealing the characteristic size of the components of a drainage network and its contribution to 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
‘L’ = the total stream length
‘Nu’ = number of stream segments (N) of stream order (u)

2.11.3.5 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
‘Nu’ is the number of segments of given order
And ‘Nu+1’ is the number of segments of the next higher order.

2.11.3.6 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 ‘Rbw’ is the weighted mean bifurcation ratio,
‘Rb1’ is the bifurcation ratio between first and second order streams,
‘n1’ stands for the total number of stream segments involved in ‘Rb1’ calculation,
and ‘Rb2’ is the bifurcation ratio between second and third order streams and ‘n2’ is the total number of stream segments involved in ‘Rb2’ and so on so forth.

2.11.3.7 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.

2.11.3.8 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). 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).

2.11.3.9 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 and ‘P’ = Perimeter (in Km)