CHAPTER- III

METHODOLOGY

This chapter contains a brief description of various field and laboratory techniques adopted during the course of research to generate primary data. These include measurements, calculations, analyses and preparation of maps and figures. Three types of analyses viz. Drainage Analysis, Hydrological Analyses and Geochemical Analyses are an integral part of methodology for the research in hand.

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,

\[ L_u = \frac{\sum L}{N_u} \]

where \( L_u \) = mean stream length
\( L \) = 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 \( R_b \) 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:

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

24
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.

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:

\[ DF = \sum N / A \]

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:

\[ Dd = \sum L / A \]

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):

\[ 25 \]
Rt = Nu/P
where 'Rt' = Drainage texture
'Nu' = Total number of streams of all orders
'P' = Perimeter (in Km)

**HYDROLOGICAL ANALYSIS**

It includes the measurement of the water levels, calculations, analysis and preparation of maps and figures.

The water table or phreatic surface is the surface where the water pressure is equal to the atmospheric pressure. The water table is also often erroneously defined as the surface that separates the phreatic from the vadose zone, below which all the rocks are saturated with water. The depth to water table is the distance from the land surface to the water table. The depth to water level is measured using a steel tape that is incremented to the hundredth of a foot. The bottom of the tape is covered with blue chalk. When the tape is lowered in the well, it crosses the water table and makes a very clear and distinct mark on the chalk covered tape which is called the 'cut'. The depth to water table can be calculated based on the distance from the top of the well to the cut.

**Water Table Contour Maps**

Contour maps of water tables or piezometric surfaces are prepared from the observation of water levels in boreholes. The depths to water level so measured in the field are plotted on the base map and by using the triangulation method i.e. triangles are made by joining the nearest water level points, and then by measuring the distance between the two points and the difference between the water levels at the two points, the point of the contour to be constructed is plotted. The contour lines on water table or piezometric surface map are drawn joining all the points having the same head. The movement of ground water is perpendicular to these lines.
Depth to water levels measured, are subtracted from the reduced levels at the point of measurement and then water table elevation contour maps are made by using GIS Techniques.

**Water Quality Plots**

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 is good 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.

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.

Interionic relationships are shown by plotting Ca\(^{2+}\) vs. Mg\(^{2+}\), Cl\(^{-}\) vs. HCO\(_{3}^{-}\) and Na\(^{+}\) vs. Cl\(^{-}\).

**CHEMICAL ANALYSIS**

The usability of ground water for drinking purpose is determined by its physical and chemical properties. For irrigation, the chemical quality of ground water is very important and plays a significant role in maintaining crop - soil - water relationship.

The ground water quality of the study area has been determined on the basis of the chemical analysis of water samples collected from different locations. In order to broadly assess the ground water scenario, maps depicting important chemical characteristics have been prepared.
FIELD TECHNIQUES

In order to understand the quality of ground water of the study area, water samples from Tubewells (56%) and Handpumps (44%) were collected from 54 locations (Plate 2 - 4) spread over the different geomorphic units of the research area (Map.3). Properly cleaned high quality plastic (polyethylene) bottles of 1 litre capacity were used to collect water samples. Before taking handpump or well water sample, it was pumped out for 5 to 10 minutes so that the sample will represent the ground water from which the well is fed. All the bottles were rinsed with water to be sampled before collecting the sample for analysis. All the particulars regarding the sample were written in the field itself, immediately after sampling, and tagged to the sample bottle. pH, Electrical Conductivity (EC) of the water samples were recorded at the time of sampling with the help of portable soil and water analysis kit.

The survey of India Topographic sheet nos. 44M/8, 11, 12,14,15,16 and 53 A/2,3,4,7,8 (scale 1: 50,000) and a hand held GPS (make-Garmiss, E-Tx vista) were used for marking location besides the informations about tubewells, handpumps etc. obtained from the legal agencies / inhabitants.

LABORATORY INVESTIGATIONS

Water samples, so collected in the field, were brought to the laboratory and were analysed for chemical parameters such as carbonate, bicarbonate, chloride, calcium, magnesium, total hardness, sodium and potassium ions at Geochemical Laboratory in the Department of Geology, Panjab University, Chandigarh and in the Laboratory of Ground Water Cell, Agriculture Department, Punjab, Chandigarh. A summary of analytical methods used for chemical analysis of water is given in Text Table-IV.
Map 3 Location of the water samples collected from the study area.
TEXT TABLE IV - Summary of analytical methods used for chemical analysis of water samples.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>ANALYTICAL METHODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. pH</td>
<td>Water and Soil Analysis Kit</td>
</tr>
<tr>
<td></td>
<td>(Electronics India, Model 161E)</td>
</tr>
<tr>
<td>2. Electrical Conductance (EC)</td>
<td>Water and Soil Analysis Kit</td>
</tr>
<tr>
<td>micromhos/cm at 25°C</td>
<td>(Electronics India, Model 161E)</td>
</tr>
<tr>
<td>3. Carbonates and Bicarbonates (mg/l)</td>
<td>Titrimetric method using standard sulphuric acid with phenolphthalein and methyl orange as indicators.</td>
</tr>
<tr>
<td>4. Chloride (ppm)</td>
<td>Argentiometric method with pottassium chromate as indicator.</td>
</tr>
<tr>
<td>5. Calcium (mg/l)</td>
<td>Titration with EDTA</td>
</tr>
<tr>
<td>6. Total Hardness (mg/l)</td>
<td>Titration with EDTA</td>
</tr>
<tr>
<td>7. Sodium (mg/l)</td>
<td>Flame Photometer</td>
</tr>
<tr>
<td>8. Pottassium (mg/l)</td>
<td>Flame Photometer</td>
</tr>
</tbody>
</table>

GEOCHEMICAL PARAMETERS

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

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

and 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.

Electrical Conductivity (EC) 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 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 Class</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>

Carbonate and Bicarbonate were estimated by titrimetric method using phenolphthalein and methyl orange as indicators and N/10 standard sulphuric acid as a titrant. When the colour of the phenolphathalein disappears, it shows the conversion of carbonate into bicarbonate. Now methyl red is added which gives yellow colour. 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.

Chloride is one of the major inorganic anions in water and it occurs in all the natural waters in widely varying concentration. The chloride content normally increases as the mineral content increases. Chloride in the ground 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.

The presence of calcium in water supplies results from passage through or over deposits of limestone, dolomite, gypsum and gypsiferous scale. Calcium was determined by titrimetric method using murexide as an indicator. The sample solution was titrated against Ethylene diammine tetra acetic acid (EDTA) solution until the colour changed from pink to purple. The EDTA solution (.01M) was prepared by dissolving 3.723 g of disodium salt of EDTA in triple distilled water and diluted to 1litre. 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).

Hard waters are generally considered to be those waters that require considerable amounts of soap to produce foam or lather and that also produce scale in hot - water pipes, heaters, boilers and other units in which the temperature of water is increased materially. The hardness of water reflects the nature of the geological formations with which it has been in contact. Hardness is normally expressed in terms of calcium carbonate. Calcium and Magnesium cause by far the greatest portion of the hardness occurring in natural waters. Total hardness was estimated by titrimetric method using eriochrome black -T as an indicator and using EDTA (Ethylene diammine tetra acetic acid) solution as a titrant. Change of colour from wine red to blue gives an end - point. The highest desirable and maximum permissible limit of total hardness are 300mg/l and 600 mg/l (as CaCO₃) as prescribed by I.S.I (1983, 1991) and WHO (1971) (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
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. Chemical softening or ion exchange reduces the magnesium and associated hardness to acceptable levels.

\[
\text{Mg hardness (mg/l)} = \text{Total hardness} - \text{Calcium hardness}
\]

In expression as \(\text{Mg}^{2+} = \text{Magnesium hardness} \times 0.243 \text{ mg/l}\)

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 organisation (WHO,1971) drinking water quality standards maximum permissible limit for Mg (as mg) is 100 mg/l (Text Table-VI).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pH</td>
<td>6.5 - 8.5</td>
<td>6.5 - 9.2</td>
<td>No relaxation</td>
</tr>
<tr>
<td>2</td>
<td>Total Hardness as CaCO₃(mg/l)</td>
<td>300</td>
<td>600</td>
<td>300</td>
</tr>
<tr>
<td>3</td>
<td>Calcium (as Ca) mg/l, Max.</td>
<td>75</td>
<td>200</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>Magnesium (as Mg) mg/l, max.</td>
<td>30</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Chloride mg/l</td>
<td>250</td>
<td>1000</td>
<td>250</td>
</tr>
<tr>
<td>6</td>
<td>Alkalinity mg/l, max.</td>
<td></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.

33
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 Organisation (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.

$$\text{Na} \, (\%) = \frac{(\text{Na}^+ + \text{K}^+) \times 100}{\text{Ca}^{2+} + \text{Mg}^{2+} + \text{Na}^+ + \text{K}^+}$$

where all the ionic concentrations are expressed in meq./l (TABLE-6)

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

<table>
<thead>
<tr>
<th>PERCENT SODIUM (% Na)</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) is determined by:

$$\text{SAR} = \frac{\text{Na}^+}{\sqrt{\text{Ca}^{2+} + \text{Mg}^{2+}}}$$

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. = (CO₃²⁻ + HCO₃⁻) – (Ca²⁺ + Mg²⁺)

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)