

**WATER CONSERVATION AND MANAGEMENT  
IN IBRAHIMPUR MASAHI VILLAGE OF HARIDWAR DISTRICT  
(UTTARAKHAND)**



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## PREFACE

Water conservation encompasses the policies, strategies and activities to manage fresh water as a sustainable resource, to protect the water environment, and to meet current and future human demand. Population, household size and growth and affluence all affect how much water is used. Factors such as climate change will increase pressures on natural water resources especially in manufacturing and water availability for irrigation in agricultural sector. To ensure availability of fresh water for future generations, the withdrawal of fresh water from an ecosystem should not exceed its natural replacement rate. However, nowadays the demand of water is increasing day by day not only for agriculture, but also for household and industrial purposes. The rivers are becoming dry and ground water table is also depleting in most of the areas. On other hands, the country is facing floods and drought in the same year in many states, which reminds to take immediate appropriate action to conserve, harvest and manage the rain water efficiently. Rain water harvesting is a popular technique of developing surface & ground water resources that can be used to provide water for livestock, domestic use and irrigation purposes. The water conservation and rain harvesting may be helpful for improving the livelihood of the people by reducing the uncertainty of human life. In our country, most of the traditional water harvesting structures (viz. ponds) are disappearing/shrinking due to encroachment, siltation, dumping of solid and liquid waste (sewage) entry from the villages into the adjacent ponds. Consequently, pond water is no longer useful to the society due to poor water quality and higher levels of eutrophication, which ultimately affects the livelihood of the peoples. The ponds located in the Haridwar district are also suffering from various hydrological problems and need appropriate intervention for rejuvenating on priority basis. Therefore, water conservation and rejuvenation/retrofitting of village ponds is essential for proper utilizing the water for beneficial use in the society. The present study was taken for the Ibrahimpur Masahi Revenue village of the Haridwar district (Uttarakhand). A severely degraded village pond has been rejuvenated in this study followed by establishment of a phyto-remediation based natural treatment system for wastewater treatment.

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# Table of Contents

<b>PREFACE</b> .....	<b>i</b>
<b>Table of Contents</b> .....	<b>ii</b>
<b>List of Figures</b> .....	<b>v</b>
<b>List of Tables</b> .....	<b>xi</b>
<b>ABSTRACT</b> .....	<b>xv</b>
<b>1. INTRODUCTION</b> .....	<b>1</b>
1.1. Scope of the study.....	2
1.2. Objectives .....	2
<b>2. REVIEW OF LITERATURE</b> .....	<b>3</b>
2.1. Need for rain water harvesting .....	3
2.2. Methods of water harvesting in rural and urban areas .....	4
<b>3. STUDY AREA</b> .....	<b>6</b>
<b>4. METHODOLOGY</b> .....	<b>14</b>
4.1. Estimation of water demand.....	14
4.2. Norms for providing potable drinking water in rural areas .....	16
4.3. Livestock water requirement .....	17
4.4. Crop water requirement.....	18
4.5. Estimation of water availability .....	19
4.5.1. Probability analysis of rainfall data .....	19
4.5.2. Estimation of surface runoff .....	20
4.6. Planning of rainwater harvesting in the village .....	22
4.7. Planning for wastewater management .....	23

4.8.	Eutrophication estimation of ponds .....	24
<b>5.</b>	<b>RESULTS AND DISCUSSION .....</b>	<b>25</b>
5.1.	Estimation of water demand for various uses.....	25
5.1.1.	Domestic water demand for human.....	25
5.1.2.	Livestock water demand.....	30
5.1.3.	Crop water requirement.....	33
5.2.	Surface water availability analysis.....	35
5.2.1.	Frequency analysis of rainfall data .....	35
5.2.2.	Estimation of surface runoff .....	42
5.3.	Assessment of rainwater harvesting potential in Ibrahimpur Masahi Revenue Village .....	59
5.3.1.	Sub-village- Ibrahimpur Masahi: Rainwater harvesting potential and demand-deficit analyses.....	60
5.3.2.	Sub-village- Masahi Kala: Rainwater harvesting potential and demand-deficit analyses .....	63
5.3.3.	Sub-village- Belki Masahi: Rainwater harvesting potential and demand-deficit analyses .....	66
5.3.4.	Sub-village- Inayatpur: Rainwater harvesting potential and demand-deficit analyses .....	70
5.3.5.	Sub-village- Halzora: Rainwater harvesting potential and demand-deficit analyses .....	73
5.4.	Water quality status of the study area .....	77
5.4.1.	Water quality investigations during March, 2014 .....	77
5.4.2.	Water quality investigations during January, 2015 .....	88
5.5.	Assessment of available ponds in the study area .....	94
5.6.	Rainwater harvesting potential of ponds .....	99
<b>6.</b>	<b>DEVELOPMENT OF IWRM PLAN FOR THE VILLAGE .....</b>	<b>101</b>
6.1.	Steps for Water Management/IWRM Plan .....	102
<b>7.</b>	<b>REJUVENATION OF VILLAGE POND BY ESTABLISHING CW-BASED NTS .....</b>	<b>111</b>

<b>8. MASS AWARENESS CAMPAIGN ON WATER CONSERVATION.....</b>	<b>115</b>
<b>9. CONCLUSIONS.....</b>	<b>116</b>
<b>REFERENCES.....</b>	<b>119</b>
<b>Annexure I: Demographic and social data of the Revenue villages .....</b>	<b>121</b>
<b>[A] Sub-Village: Ibrahimpur Masahi.....</b>	<b>121</b>
<b>[B] Sub-Village: Masahi Kala .....</b>	<b>127</b>
<b>[C] Sub-Village: Belki Masahi.....</b>	<b>132</b>
<b>[D] Sub-Village: Inayatpur .....</b>	<b>136</b>
<b>[E] Sub-Village: Halzora.....</b>	<b>140</b>
<b>STUDY GROUP .....</b>	<b>143</b>

## List of Figures

Figure 3.1: Location map of the study area .....	6
Figure 3.2: Digitised map of the study area .....	7
Figure 3.3: Drainage map of Shipla-Halzora watershed upto Imlikhera .....	10
Figure 3.4: Landuse/landcover map of Shipla-Halzora W/S (Landsat-8, 16.5.2014).....	10
Figure 3.5: Landuse/landcover map of Revenue Village of Ibrahimpur Masahi .....	11
Figure 3.6: Contour map of Shipla-Halzora W/S (Landsat-8, 16.5.2014) .....	12
Figure 3.7: Percentage distribution of different land uses in the watershed .....	13
Figure 4.1: Relationship between rainfall and runoff (US-SCS, 1972) .....	22
Figure 5.1: Comparison of domestic water demand per month based on various scenarios .....	29
Figure 5.2: Rainfall frequency curve (January) for rainfall data of Roorkee (1987-2013) ..	36
Figure 5.3: Rainfall frequency curve (February) for rainfall data of Roorkee (1987-2013).	36
Figure 5.4: Rainfall frequency curve (March) for rainfall data of Roorkee (1987-2013).....	37
Figure 5.5: Rainfall frequency curve (April) for rainfall data of Roorkee (1987-2013).....	37
Figure 5.6: Rainfall frequency curve (May) for rainfall data of Roorkee (1987-2013).....	38
Figure 5.7: Rainfall frequency curve (June) for rainfall data of Roorkee (1987-2013).....	38
Figure 5.8: Rainfall frequency curve (July) for rainfall data of Roorkee (1987-2013) .....	39
Figure 5.9: Rainfall frequency curve (August) for rainfall data of Roorkee (1987-2013)....	39

Figure 5.10: Rainfall frequency curve (September) for rainfall data of Roorkee (1987-2013)	40
Figure 5.11: Rainfall frequency curve (October) for rainfall data of Roorkee (1987-2013)	40
Figure 5.12: Rainfall frequency curve (November) for rainfall data of Roorkee (1987-2013)	41
Figure 5.13: Rainfall frequency curve (December) for rainfall data of Roorkee (1987-2013)	41
Figure 5.14: Performing infiltration tests in the study area under different land-uses	43
Figure 5.15: Infiltration rate under agriculture	44
Figure 5.16: Infiltration rate under pond bed	44
Figure 5.17: Infiltration rate under forest land	45
Figure 5.18: Infiltration rate under grass land	45
Figure 5.19: Infiltration rate under fallow land	46
Figure 5.20: Particle size distribution curve of soil sample for agriculture land (Ibrahimpur)	48
Figure 5.21: Particle size distribution curve of soil sample for forest land (Masahi)	48
Figure 5.22: Particle size distribution curve of soil sample for pond bed (Ibrahimpur)	49
Figure 5.23: Particle size distribution curve of soil sample for forest land (Belki)	49
Figure 5.24: Particle size distribution curve of soil sample for grass land (Inayatpur)	50
Figure 5.25: Particle size distribution curve of soil sample for fallow land (Belki)	50
Figure 5.26: Cross section of the Shipla-Halzora River near bridge at Imlikhera	57

Figure 5.27: Cross section of the Shipla-Halzora river near bridge at Imlikhera.....	57
Figure 5.28: View of measuring stream velocity in the river using current meter .....	58
Figure 5.29: Variation of discharge in Shipla-Halzora River at Imlikhera, Dist. Haridwar ..	58
Figure 5.30: Average roof-top area available per household in Ibrahimpur Revenue Villages.....	59
Figure 5.31: Monthly rainwater harvested at average rainfall and other frequencies levels (50% & 75%) for Ibrahimpur Masahi .....	61
Figure 5.32: Monthly water balance for supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) for each family in Ibrahimpur Masahi.....	62
Figure 5.33: Monthly water balance for supply of water @ 12LPCD (washing clothes) for each family in Ibrahimpur Masahi.....	62
Figure 5.34: Monthly rainwater harvested at average rainfall and other frequencies (50% & 75%) for Masahi Kala .....	64
Figure 5.35: Monthly water balance for supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) for each family in Masahi Kala.....	65
Figure 5.36: Monthly water balance for supply of water @ 12LPCD (washing clothes) for each family in Masahi Kala.....	66
Figure 5.37: Monthly rainwater harvested at average rainfall and other frequencies (50% & 75%) for Belki Masahi .....	68
Figure 5.38: Monthly water balance for supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) for each family in Belki Masahi .....	69
Figure 5.39: Monthly water balance for supply of water @ 12LPCD (washing clothes) for each family in Belki Masahi .....	69

Figure 5.40: Monthly rainwater harvested at average rainfall and other frequencies (50% & 75%) for Inayatpur.....	71
Figure 5.41: Monthly water balance for supply of water @ 22LPCD (Toilet Flushing, Washing clothes and other uses only) for each family in Inayatpur.....	72
Figure 5.42: Monthly water balance for supply of water @ 12LPCD (washing clothes) for each family in Inayatpur .....	73
Figure 5.43: Monthly rainwater harvested at average rainfall and other frequencies (50% & 75%) for Halzora .....	75
Figure 5.44: Monthly water balance for supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) for each family in Halzora .....	75
Figure 5.45: Monthly water balance for supply of water @ 12LPCD (washing clothes) for each family in Halzora .....	76
Figure 5.46: Water quality monitoring in the study area (a) water quality monitoring from tubewell in the study area, (b) water quality monitoring from Halzora river in the study area, (c) water quality monitoring from pond in the study area, (d) water quality monitoring from hand pump in the study area.....	78
Figure 5.47: Variation of BOD in the water samples in the study area (March, 2014).....	87
Figure 5.48: Variation of total coliform & faecal coliform in the water samples in the study area (March, 2014).....	87
Figure 5.49: US Salinity diagram showing irrigation water quality in the study area (January, 2015) .....	93
Figure 5.50: Piper tri-linear diagram showing hydrochemical facies in ground water of the study area (January, 2015) .....	94
Figure 5.51: Bathymetric and water quality assessment of various ponds available in the study area .....	95

Figure 5.52: Results of bathymetric survey of pond at Masahi Kala sub-village in the study area.....	96
Figure 5.53: Variation in TDS in the pond waters in study area .....	96
Figure 5.54: Variation in turbidity in the pond waters in study area .....	97
Figure 5.55: Variation in dissolved oxygen (DO) in the pond waters in study area .....	97
Figure 5.56: Variation in electrical conductivity (EC) in the pond waters in study area.....	97
Figure 5.57: Variation of chlorophyll in the pond waters in study area .....	98
Figure 5.58: Variation in Blue Green Algae (BGA) in the pond waters in study area .....	98
Figure 5.59: Eutrophication status of ponds of various ponds in the study area .....	99
Figure 5.60: Existing ponds in the study area (a) pond at Ibrahimpur village, (b) pond at Masahi village, (c) extracting pond water for irrigation at Ibrahimpur village, (d) extracting pond water for irrigation at Ibrahimpur village .....	100
Figure 6.1: IWRM plan for a village community.....	102
Figure 6.2: Seasonal water demand of the area .....	104
Figure 6.3: Water budget of the Revenue Village.....	105
Figure 6.4: Water budget of the Revenue Village according to the current practices.....	106
Figure 6.5: Water demand for irrigation using different irrigation method.....	107
Figure 6.6: Water budget of the Revenue Village according to the suggested practices	109
Figure 6.7: Water budget of the Revenue Village according to suggested practices .....	110
Figure 7.1: Flow diagram of a CW- based NTS at village Ibrahimpur Masahi .....	112
Figure 7.2: Plan of a CW- based NTS at village Ibrahimpur Masahi .....	112

Figure 7.3: Pond stages before and after rejuvenation works ..... 114

Figure 8.1: View of Mass Awareness Campaign on Water Conservation Conducted on 16th Dec, 2016 in Ibrahimpur Masahi Village (Dist. Haridwar) ..... 115

## List of Tables

Table 3.1: Area under different Landuses in Shipla-Halzora watershed upto Imlikhera ....	13
Table 4.1: Recommended Per Capita Water Supply Levels for Designing Schemes (CPHEEO, 1990).....	15
Table 4.2: Per capita domestic water requirement for cities provided with piped water supply where system exists/ contemplated .....	15
Table 4.3: Break ups of per capita domestic water requirement (interim) .....	16
Table 4.4: Per capita livestock water requirement.....	17
Table 4.5: Standard values of crop deltas ( $S\Delta$ , m).....	18
Table 5.1: Domestic water demand (human) for Ibrahimpur Masahi Revenue village .....	26
Table 5.2: Total Domestic water demand per month of Ibrahimpur Revenue Villages in fulfilling various needs.....	27
Table 5.3: Domestic water demand per month for each family in Ibrahimpur Revenue Villages in fulfilling various needs.....	28
Table 5.4: Livestock water demand for in Ibrahimpur Masahi Revenue village.....	30
Table 5.5: Livestock population dynamics of the Ibrahimpur Revenue Villages .....	31
Table 5.6: Livestock Water demand ( $m^3$ / month) for various types of livestock population in Ibrahimpur Revenue Villages .....	32
Table 5.7: Crop water requirement of the Ibrahimpur Masahi Village for Rabi Season .....	33
Table 5.8: Crop water requirement of Ibrahimpur Masahi village for Kharif season .....	34
Table 5.9: Crop water requirement of the Ibrahimpur Masahi Village for Zaid season .....	34

Table 5.10: Estimated total water requirement for Ibrahimpur Masahi Revenue village....	35
Table 5.11: Monthly rainfall statistics and dependable rainfall, mm (F= 50% ; F=75%) of Roorkee (1987-2013) .....	42
Table 5.12: Hydrologic soil groups in the Ibrahimpur Masahi Revenue village .....	43
Table 5.13: Particle size analysis results of soil samples .....	47
Table 5.14: Soil texture of different soil samples in the study area (USDA Classification)	47
Table 5.15: Variation of soil moisture in the study area.....	51
Table 5.16: Monthly rain water availability (MCM) at Ibrahimpur Masahi Revenue village level and watershed level on the basis of 50% dependable rainfall .....	52
Table 5.17: Data of discharge measurement for Shipla-Halzora River.....	53
Table 5.18: Monthly rainwater harvesting potential per household (average roof-top area of 62 m <sup>2</sup> ) for Sub-village- Ibrahimpur Masahi .....	60
Table 5.19: Monthly rainwater harvesting potential per household (average roof-top area of 49m <sup>2</sup> ) for Sub-village- Masahi Kala .....	63
Table 5.20: Monthly rainwater harvesting potential per household (average roof-top area of 52m <sup>2</sup> ) for Sub-village- Belki Masahi .....	67
Table 5.21: Monthly rainwater harvesting potential per household (average roof-top area of 25 m <sup>2</sup> ) for Sub-village- Inayatpur.....	70
Table 5.22: Monthly rainwater harvesting potential per household (average roof-top area of 33 m <sup>2</sup> ) for Sub-village- Halzora .....	74
Table 5.23: Location details of water quality sampling during March, 2014 .....	79
Table 5.24: Water quality characteristics of river (March, 2014) .....	80

Table 5.25: Water quality characteristics of ponds (March, 2014).....	81
Table 5.26: Water quality characteristics of drains (March, 2014).....	82
Table 5.27: Groundwater quality characteristics in the Ibrahimpur Masahi revenue village (March, 2014).....	83
Table 5.28: Irrigation water quality parameters of Ibrahimpur Masahi village (March, 2014) .....	84
Table 5.29: Water quality rating (IS: 11624-1986) based on total salt concentration in Ibrahimpur Masahi village (March, 2014) .....	85
Table 5.30: Water quality rating (IS: 11624-1986) based on sodium adsorption ratio (SAR) in Ibrahimpur Masahi village (March, 2014) .....	85
Table 5.31: Water quality rating (IS:11624-1986) based on residual sodium carbonate (RSC) in Ibrahimpur Masahi village (March, 2014) .....	86
Table 5.32: Groundwater quality assessment for drinking purposes (IS-10500:2012) in Ibrahimpur Masahi revenue village (March 2014) .....	86
Table 5.33: Details of water samples collected in Ibrahimpur village (January, 2015) .....	89
Table 5.34: Water quality characteristics of Ibrahimpur and Masahi village Water samples (January, 2015) .....	90
Table 5.35: Water quality rating (IS: 11624-1986) based on total salt concentration in Ibrahimpur & Masahi villages (January, 2015) .....	91
Table 5.36: Water quality rating (IS: 11624-1986) based on sodium adsorption ratio (SAR) in Ibrahimpur & Masahi villages (January, 2015) .....	91
Table 5.37: Water quality rating (IS:11624-1986) based on residual sodium carbonate (RSC) in Ibrahimpur & Masahi villages (January, 2015).....	92

Table 5.38: Groundwater quality assessment for drinking purposes (IS-10500:2012) in Ibrahimpur & Masahi villages (Jan. 2015) .....	92
Table 5.39: Estimation of Carlson's Trophic Index (eutrophication status of ponds) .....	98
Table 5.40: Eutrophication status of ponds in the study area .....	99
Table 5.41: Major RWH structures (ponds) .....	100
Table 7.1: Status of Pond at village Ibrahimpur Masahi (before and after rejuvenation) .	114

## ABSTRACT

Present study was undertaken in Ibrahimpur Masahi Village, District-Haridwar (Uttarakhand) under Shipla-Halzora river watershed (Solani river sub-catchment), which lies between  $29^{\circ} 56'$  to  $30^{\circ} 05'$  N Latitude and  $77^{\circ} 48'$  to  $77^{\circ} 55'$  E Longitude. The study area of Ibrahimpur Masahi village is about  $14.26 \text{ km}^2$ , which mainly consists of five sub-villages, viz. Ibrahimpur Masahi, Masahi Kala, Belki Masahi, Inayatpur and Halzora. The main objectives of the study are: (i) Assessment of water demand for domestic, livestock and agricultural uses in the villages, (ii) Assessment of water availability, (iii) Assessment of water quality/eutrophication status of ponds, (iv) Development of WM Plan for the village, (v) Rejuvenation of village pond/s by establishing a CW-based Natural Treatment System (NTS), and (vi) Mass Awareness Activities.

Extensive field investigations (including door to door survey) were carried out in this study to collect relevant hydrological and socio-economic data. In this study, rainfall data (1987 to 2013) of the NIH Hydromet observatory was analysed using Weibull's method. The mean annual rainfall was obtained 1053 mm (27 year data). The annual probable maximum rainfall of Roorkee was obtained 866 mm and 537 mm at 50% and 75% frequency levels, respectively. The Monthly Rain Water Availability (MCM) at Village Level and Watershed Level was estimated on the basis of 50% dependable Rainfall. The annual rainwater availability at village level was obtained 12.35 MCM and at watershed level in the order of 48 MCM, respectively.

The water quality investigations were carried out from different sources pertaining to surface water (viz., ponds, drains to ponds, river) and ground water (viz., hand pumps, tube well) in the study area. The groundwater quality was evaluated for drinking purpose based on BIS norms (IS: 10500-2012), which indicates exceeding acceptable limit of total hardness (100% samples), total dissolved solids (15% samples), turbidity (77%), calcium (62% samples), magnesium (23% samples) and alkalinity (100% samples) in the study area. The suitability of water for irrigation was evaluated as per BIS norms (IS: 11624-1986), which shows a concern of higher RSC for ponds and drain water samples. The U.S. salinity diagram shows irrigation water quality varying from medium salinity-low SAR to high salinity-low SAR. The eutrophication status of ponds was estimated based on Carlson's Trophic State Indices (Carlson, 1977) using average values of secchi depth,

phosphate and chlorophyll content. The overall eutrophication status of the ponds indicates hyper-eutrophic condition (CTSI>70) of the village ponds.

As per soil testing results, the soil types are: sandy loam, loamy sand, loam and silt loam in the study area. The soil health cards were also prepared for prospective farmers and distributed to them for optimizing the doses of supplemental fertilizers and increasing crop productivity.

Monthly rainwater harvesting potential and balance of harvested rainwater after meeting few designated uses was also estimated for 5 sub-villages using Eqn. given by Ghisi et al., 2006. The analysis includes: (a) household monthly harvested rainwater & balance after ablution/toilet flushing, washing of clothes & other uses (combined), (b) assessment of household monthly harvested rainwater & balance after ablution/toilet needs, (c) rainwater harvesting potential of existing village ponds (d) monthly roof top water harvesting potential of schools/govt. buildings, etc. The household level average roof-top area ( $m^2$ ) in 5 sub-villages, viz., Ibrahimpur Masahi, Masahi Kala, Belki Masahi, Inayatpur and Halzora was obtained in the order of 62, 49, 52, 25, 33 respectively. Based on average roof-top area available in 5 sub-villages, the monthly rainwater harvesting potential ( $m^3$ ) was estimated for three scenarios of rainfall conditions, viz., (i) at monthly average rainfalls of Roorkee (27 rainfall years data), (ii) at 50% dependable monthly rainfalls, (iii) at 75% dependable monthly rainfalls, respectively. Household monthly harvested rainwater & balance after ablution / toilet flushing, washing clothes & other uses (combined) based on average rainfall. The size of a suitable tank for rain water harvesting in each sub village was also recommended in the study.

A WM Plan has been developed for Ibrahimpur-Masahi village. The plan demonstrates conversion from a water-deficit status to a water-surplus status through appropriate water conservation practices. Mass awareness activities were also conducted in the study area to sensitize the public including school children regarding water conservation.

Finally, a severely degraded village pond was rejuvenated alongwith establishment of a phyto-remediation based Natural Treatment System-NTS) at village Ibrahimpur Masahi. The water quality of the pond was also assessed before and after rejuvenation works. The results indicate improvement in the water quality of this pond. However, the performance of the developed NTS will be assessed in subsequent years by growing suitable plants in the constructed wetland.

# 1. INTRODUCTION

Water is one of the nature's precious gifts to mankind. It is essential for life on the planet and play decisive role for growth and development of human civilization. Water is known as the elixir of life. India is a developing country with a vast territory, complex topography, varied climate and a large population. The precipitation and runoff in the country is not only unevenly distributed, but also uneven with regard to time of distribution of water during the year. Frequent Water Resource Management floods, drought and unstable agricultural production have always been a serious problem. According to Indian Meteorological Department (IMD), there are only 40 rainy days in India, and hence a long dry period. The availability of adequate and safe water is pre-requisite for any sustainable developmental activity and agricultural activities. The effects of climate change on hydrological cycle viz., erratic rainfall and reduced number of rainy days may adversely affect water availability and subsequently developmental activities in every sector.

India, being an agricultural country, its economic development is linked with agriculture. The major limiting factor for agriculture is water. A growing population and consequent need for increase in food production requiring increasing area of agricultural fields and irrigation are resulting in over use of water. Due to overexploitation of water resources, it has become scarce in many parts of our country. The most of the precipitation is lost by way of surface runoff through rivers to sea and causes gully formation and stream bank erosion. Needless to say, water conservation is of great importance to the economic, social and cultural development in India. The Ministry of Water Resources (Government of India) has declared year 2013 as “Water Conservation Year” in order to create mass awareness among general public to conserve the water for judicial uses.

Rainwater harvesting (RWH) refers to collection of rain falling on earth surfaces for beneficial uses before it drains away as run-off. The concept of RWH has a long history. Evidences indicate domestic RWH having been used in the Middle East for about 3000 years and in other parts of Asia for at least 2000 years. Collection and storages of rainwater in earthen tanks for domestic and agricultural uses is very common in India since

historical times. The traditional knowledge and practice of RWH has largely been abandoned in many parts of India after the implementation of dam and irrigation projects.

### **1.1. Scope of the study**

In our country, most of the traditional sources of water in villages are on the verge of disappearing/shrinking due to encroachment, siltation and water quality deterioration and witnessing severe eutrophication. The ponds located in the Haridwar District are also suffering from various hydrological problems and are at the verge of extinction, which require immediate intervention to restore for various uses. Rain water harvesting is a popular technique of developing surface water resources that can be used to provide water for livestock, domestic use and irrigation purposes. The purpose of rain water harvesting is to either augment existing water supplies or to provide water where other sources are not available. It also aims to provide water in sufficient quantity and of suitable quality for the intended use. Therefore, water conservation and its management of village ponds is essential for proper utilizing the water for beneficial use in the society. The water conservation and rain harvesting may be helpful for improving the livelihood of the people by reducing the uncertainty of human life. The present study was taken for the Ibrahimpur Masahi Revenue village of the Haridwar District.

### **1.2. Objectives**

The specific objectives of the study and their corresponding tasks are given as below:

- Assessment of water demand for domestic, livestock and agricultural uses in the villages,
- Assessment of water availability,
- Assessment of water quality/eutrophication status of ponds,
- Development of IWRM Plan for the village.
- Rejuvenation of village pond/s by establishing a CW-based Natural Treatment System (NTS)
- Mass Awareness Activities.

## **2. REVIEW OF LITERATURE**

However, since the early 90s, there has been a renewed interest in RWH projects in India and elsewhere. Rainwater harvesting can be done at individual household level and at community level in both urban as well as rural areas. At household level, harvesting can be done through roof catchments, and at community level through ground catchments. Depending on the quantity, location and the intended use, harvested rainwater, it can be utilized immediately or after storage. Other than as a water supply, RWH can be practiced with the objectives of flood control and soil erosion control.

### **2.1. Need for rain water harvesting**

Water is becoming a scarce commodity. The demand of water is also increasing day by day not only for agriculture, but also for household and industrial purposes. Water demand for various uses is continuously increasing. The perennial rivers are becoming dry and ground water table is depleting in most of the areas. Country is facing floods and drought in the same year in many states. This is because, no concrete action was taken to conserve, harvest and manage the rain water efficiently. The rainfall is abundant in the world and also in India. But it is not evenly distributed in all places. In India the rain falls only for 3 to 4 months in a year with high intensity, which results more runoff and soil erosion primarily during monsoon periods. Total rain occurs only in about 100 hours out of 8760 hours in a year. It also erratic and fails once in 3 or 4 years. This is very common in many parts of the country. Water scarcity / stress is not limited to the arid regions only but also occurring in high rainfall areas also. Cherapunji gets more than 11,000mm of average annual rainfall but face drinking water problem. In Ralegaon Siddhi (M.S.) water scarcity problem are adequately mitigated though various rainwater harvesting measures even though the annual average rainfall of this area is only about 450mm. Hence to mitigate water problem / drought etc, there is an urgent need to follow our ancestral way of water harvesting and the latest technologies adopted in Soil and water conservation measures on watershed basis including roof water harvesting.

The Theme paper on Water vision 2050 of India, prepared by Indian Water Resources Society (IWRS) has indicated that a storage of 60 MHm is necessary to meet the demand of water for irrigation, drinking and other purposes. But the present live storage of all reservoirs put together is equivalent of about 17.5 MHm which is less than 10% of the annual flow in the rivers in the country. The projects under construction (7.5 MHm) and those contemplated (13 MHm) are added, it comes only 37.50 MHm and hence we have to go a long way in water harvesting to build up storage structures in order to store about 60 MHm.

## **2.2. Methods of water harvesting in rural and urban areas**

There are different / various system of water harvesting depending upon the source of water supply and places as classified below:

### **a) In situ Rainwater harvesting**

- Bunding and terracing.
- Vegetative / stone contour barriers.
- Contour trenching.
- Contour stone walls.
- Contour farming.
- Micro catchments.
- Tie ridging methods
- Farm ponds.

### **b) Direct surface runoff harvesting**

- Roof water collection
- Dug out ponds / storage tanks
- Tankas
- Kundis
- Ooranis
- Temple tanks
- Diversion bunds
- Water spreading

### **c) Stream flow / runoff harvesting**

- Nalla bunding
- Gully control structures
- Check dams – Temporary, Permanent

- Silt detention tanks
- Percolation ponds

**d) Sub surface flow harvesting**

- Sub surface dams
- Diaphragm dams

**e) Micro-catchment's/ watershed**

- Inter terrace / inter plot water harvesting
- Conservation bench terrace

**f) Runoff inducement by surface treatment**

- Roded catchments
- Use of cover materials – Aluminum foils,
- Plastic sheet, bentonite, Rubber, etc
- Using chemicals for water proofing, water repellent etc. to get more runoff water.

### 3. STUDY AREA

The study area (i.e. Ibrahimpur Masahi revenue village) is falling under Shipla Nadi-Halzora Nadi watershed, District Haridwar (Uttarakhand). The location map of the study area is given in Figure 3.1 and Digitised map of the study area is given in Figure 3.2. The Shipla Nadi-Halzora Nadi watershed lies from 29° 56' to 30° 05' North latitude and 77° 48' to 77° 55' East longitude under SOI Toposheet Nos. 53 F/16 and 53 G/13 (1:50,000). The geographical area of the Shipla Nadi-Halzora Nadi watershed is 101.5 km<sup>2</sup> upto river bridge at village Imlikhera. The area of Ibrahimpur Masahi revenue village is 14.26 km<sup>2</sup> which represents about 1/7<sup>th</sup> of the watershed area upto Imlikhera bridge. The Ibrahimpur Masahi revenue village consists of the following five sub-villages under its jurisdiction:

- Ibrahimpur
- Masahi
- Belki
- Inayatpur
- Halzora

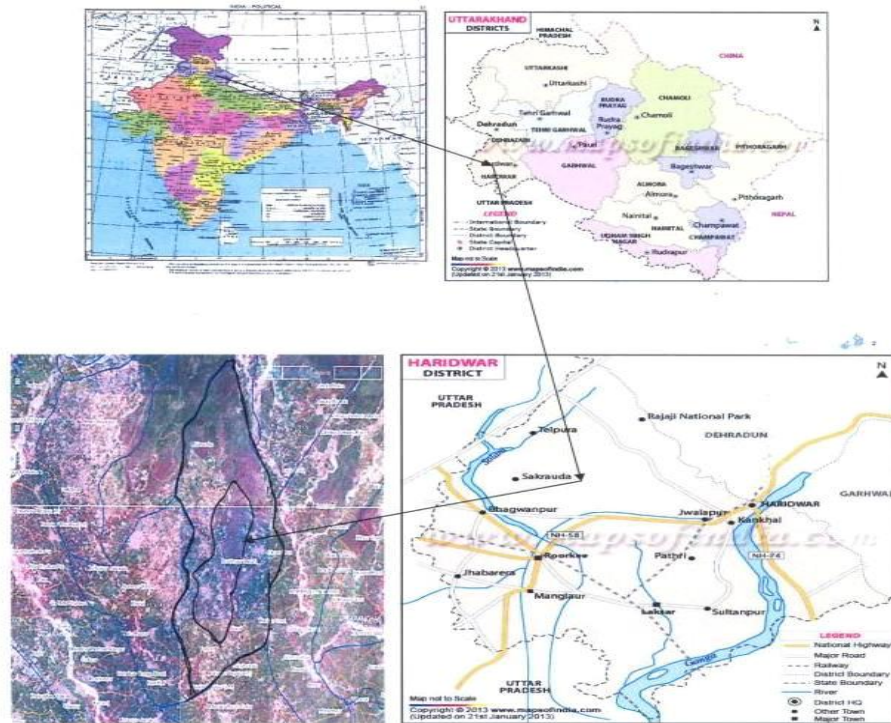


Figure 3.1: Location map of the study area

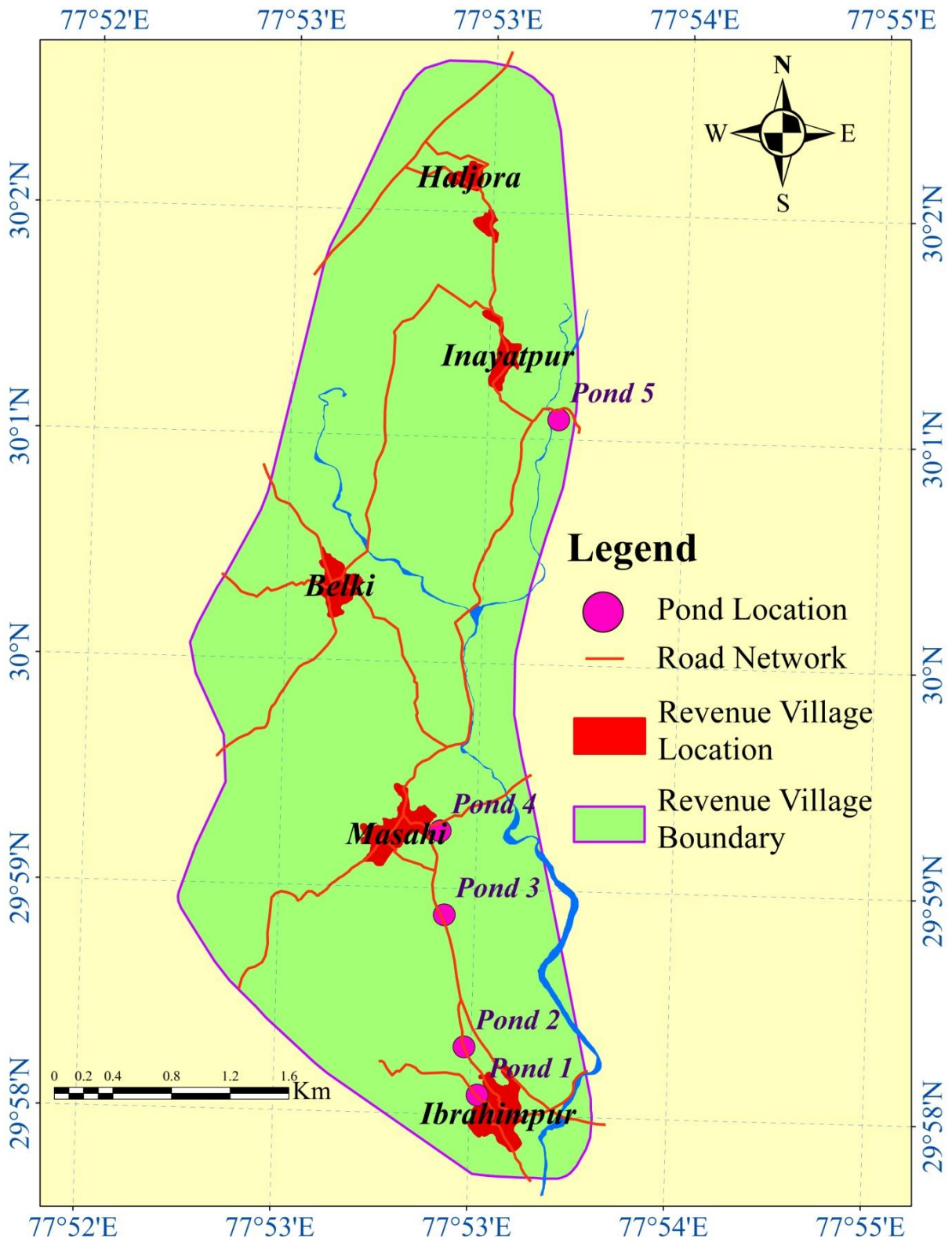


Figure 3.2: Digitised map of the study area

The drainage map (**Figure 3.3**) of the watershed was deciphered using DEM. The landuse/ land cover map of watershed (**Figure 3.4**) and Revenue Village of Ibrahimpur Masahi (**Figure 3.5**) were prepared using LANDAST 8 image and contour map (**Figure 3.6**) was prepared using DEM. Area obtained under different landuses in the Shipla-Halzora watershed (upto Imlikhera) is given in **Table 3.1** and **Figure 3.7**, respectively.

The climate of Hardwar District is moderate subtropical to humid climate with three distinct seasons viz. summer followed by rainy and winter seasons. Temperature begins to rise from March ( $29.1^{\circ}\text{C}$ ) and reaches to its maximum in May ( $39.2^{\circ}\text{C}$ ), with the commencement of monsoon season by mid-June, the temperature begins to fall. During the winter season in the month of November to February the temperature ranges between  $10.5^{\circ}\text{C}$  and  $6.1^{\circ}\text{C}$ . The relative humidity is highest in monsoon season (85% in the morning and 79% in the evening). The lowest humidity is observed during the month of April and May i.e. 24% (in evening) and 40% in May (in morning). The mean monthly wind speed is highest in the summer season when it goes up to 7.4 and 7.2 km/hour in the month of May and June and the minimum wind speed is observed during winter when it is 2.6 km/hour in the month of October. The potential evapotranspiration is maximum in the month of May 198.9 mm and minimum 38.5 mm in the month of December (CGWB, 2009). The average normal annual rainfall in Hardwar district is 1174.3 mm, out of which 84% is received during monsoon season and only 16% occurs during non-monsoon period.

Geo-morphologically, Haridwar district can be divided into four geomorphic units. These are flood plain, lower piedmont plain, upper piedmont plain and structural hills. The study area is part of Solani river watershed. The flood plain area is relatively flat, low lying and adjacent to Solani River. It comprises unconsolidated, coarse to fine sand with silt and clay. The area is repeatedly inundated during the floods. The lower piedmont plain is flat to undulating with gradient towards southwest having micro relief. Soils play an important role in ground water recharge and the agriculture production of the area. The land of Bhagwanpur block is highly fertile. Geologically, Haridwar District may be divided into three zones viz. Siwaliks, Bhabar and Gangetic Alluvial Plains from North to South, as given below (CGWB, 2009):

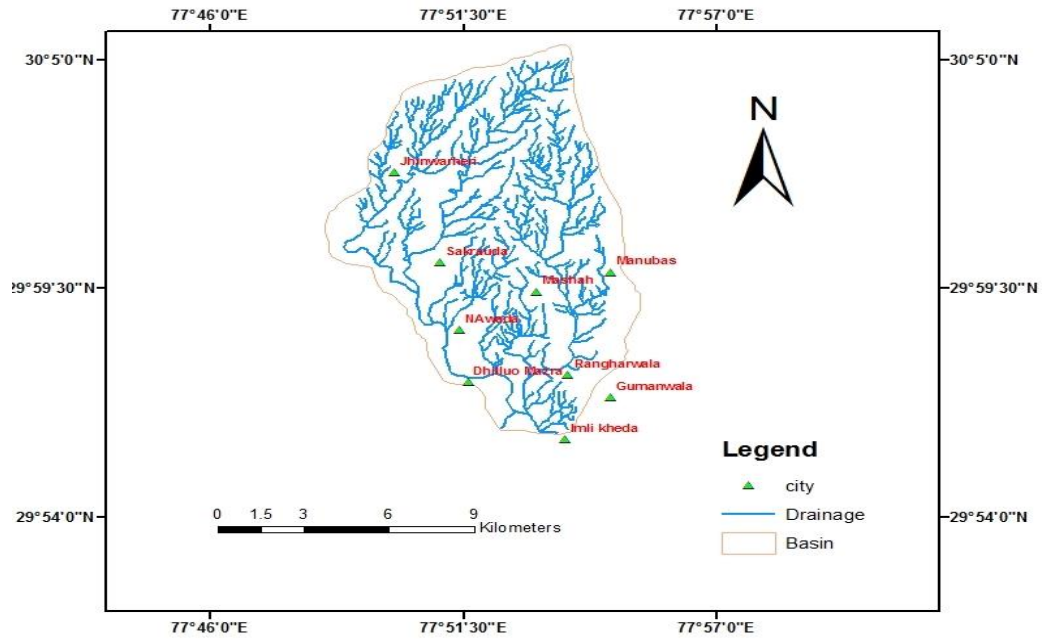
**Siwalik Range:** This forms the outermost part of Himalaya and comprise Tertiary Group of rocks. In Bhagwanpur block only Upper and Middle Siwaliks are exposed. The Upper Siwaliks is constituted of boulders, pebbles, sand and clay. The boulders and pebbles are mostly of quartzites. Middle Siwaliks comprises mainly grey micaceous sandstone and siltstone.

**Older Alluvium (Piedmont Plains or Bhabar):** The Piedmont Plains are formed along the foothills of Siwaliks. It is formed by flooding hill torrents and nallahs (locally termed as 'Rao'). Alluvial fans in the piedmont zones are wider and longer when formed along mature streams. The Older Alluvium consist of polycyclic sequence of brown to grey silt, clay with boulders and pebbles.

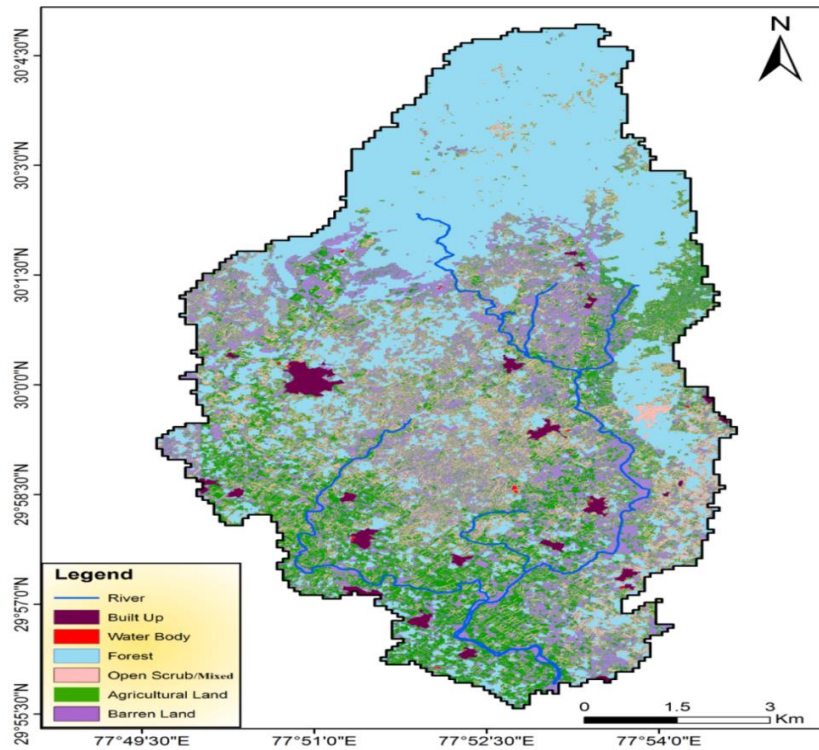
**Gangetic Alluvial Plains:** The region south of the piedmont plains occupied by Gangetic Alluvial Plains, forms major part of the Bhagwanpur block. Lithologically, the alluvium is formed of unconsolidated to semi-consolidated deposits of sand, silt, clay and kankar.

### **Ground water scenario**

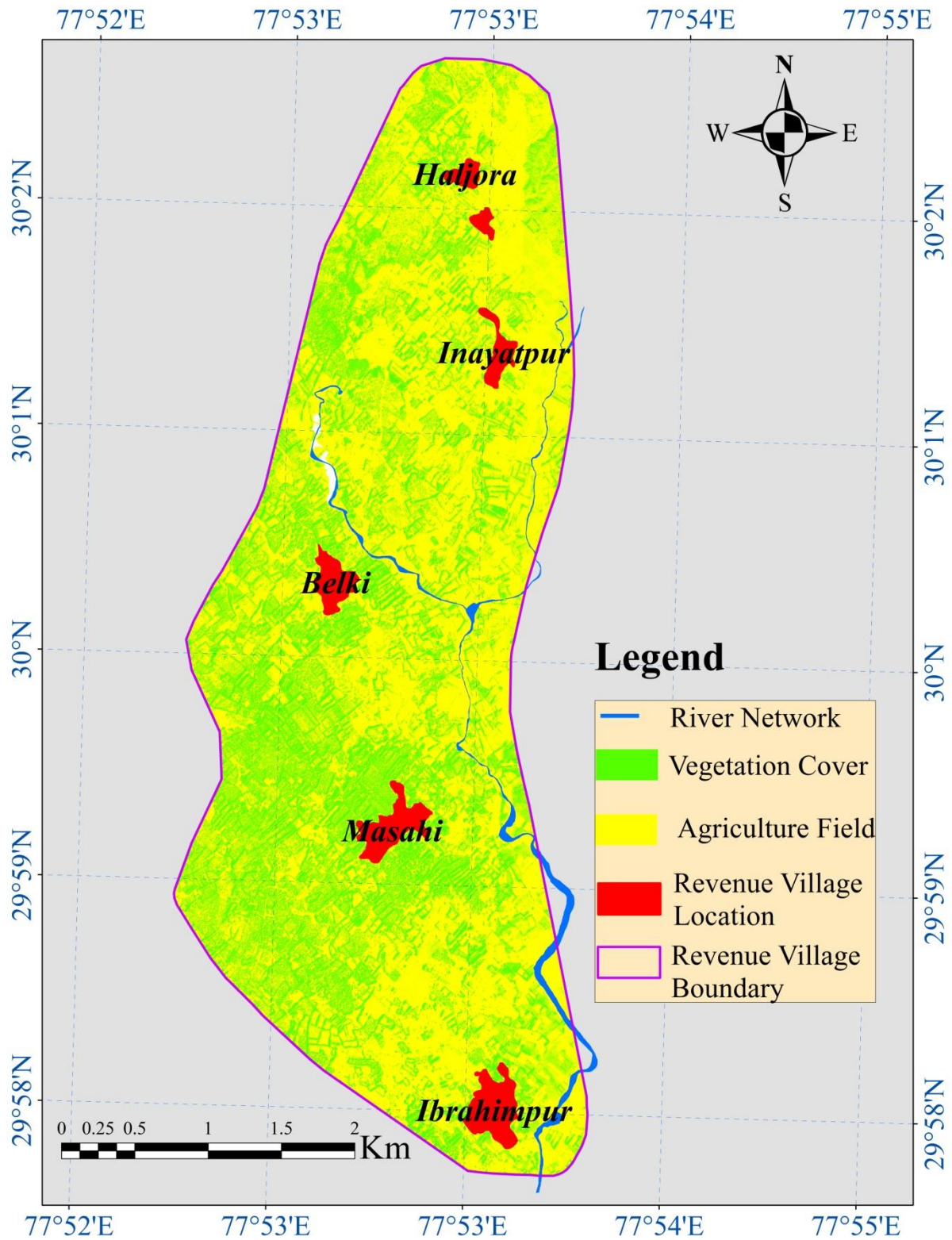
Haridwar district comes under Ganga river system. The main tributaries of Ganges like Solani, Ratmau Rao and Banganga and their feeding nallahs drain the area. These tributaries are ephemeral in nature. As far as canal irrigation is concerned, western part of the district is well covered with 300 km length canal network. Bhagwanpur block comes under non-command area. Hence, there is an immense pressure on ground water due to which water levels are declining at faster pace. There are 225 State Government tubewells and 32930 private tubewells. The ground water abstraction for drinking, domestic and agriculture purposes is higher in Bhagwanpur block as compared to other blocks. Ground water resource of Hardwar district are estimated using Rainfall Infiltration Factor Method (RIF). Based on resource estimation, the total ground water availability in Hardwar district is arrived (as on March 2004) as 87719.6 ham and the gross ground water draft from all uses is estimated as 84563.89 ham. The stage of ground water development is 96.40% and the district is categorized as critical (CGWB, 2009). In study area of Ibrahimpur Masahi village, there are 52 (50 private & 2 Govt.) operated tubewells withdrawing groundwater for agriculture.



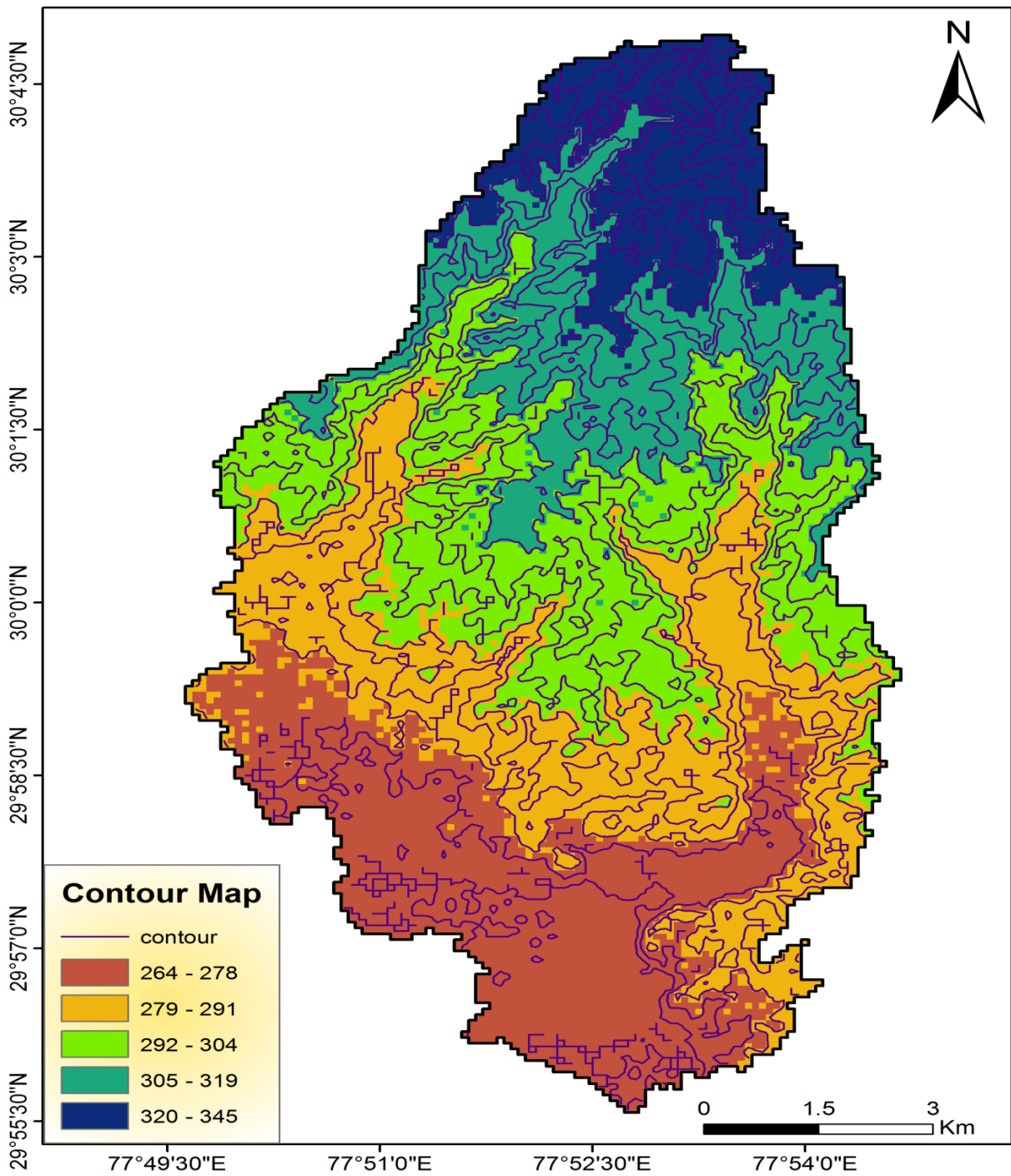
**Figure 3.3:** Drainage map of Shipla-Halzora watershed up to Imlikhera



**Figure 3.4:** Landuse/landcover map of Shipla-Halzora W/S (Landsat-8, 16.5.2014)



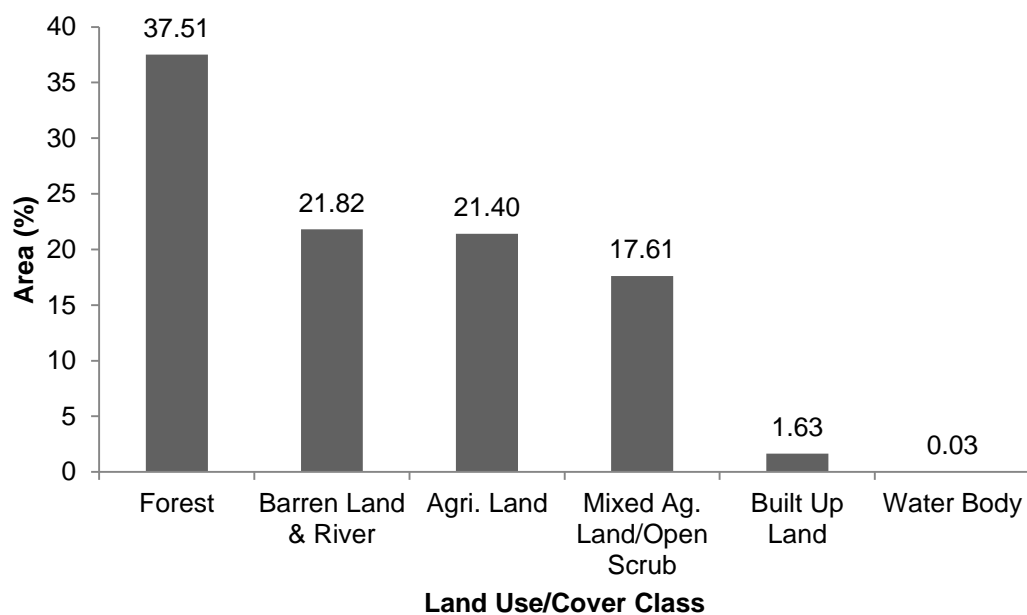
**Figure 3.5:** Landuse/landcover map of Revenue Village of Ibrahimpur Masahi



**Figure 3.6:** Contour map of Shipla-Halzora W/S (Landsat-8, 16.5.2014)

**Table 3.1:** Area under different Landuses in Shipla-Halzora watershed upto Imlikhhera

Landuse/Land cover	Area (Ha)	Area in %
Forest	3805.67	37.5
Barren Land & River	2214.14	21.8
Agri. Land	2171.11	21.4
Mixed Ag. Land/Open Scrub	1787.01	17.6
Built Up Land	165.65	1.63
Water Body	3.01	0.03
	10146.59	100



**Figure 3.7:** Percentage distribution of different land uses in the watershed

## 4. METHODOLOGY

In this study, aim is to assess water demand for domestic, cattle and irrigation in the identified village of Ibrahimpur Masahi and estimate water availability for various uses. The necessary data from different sources was obtained for human population, cattle and crop acreage and types in the area. Field investigation being carried out to study soil characteristics (Infiltration, Soil texture and soil moisture, etc.) under different land uses. The surface and ground water quality monitoring and analysis was carried out as per standard procedures (APHA 1992; Jain and Bhatia, 1988). Eutrophication of ponds will be assessed using Carlson's Trophic State Index (Carlson, 1977) and to suggest rejuvenation of the ponds. The long term rainfall data (1987 to 2013) was obtained from NIH observatory for the study. Accordingly, a water conservation plan for the identified village (s) will be prepared. The mass awareness activities will also be carried out for creating awareness among the local people/school students for water conservation and management of local water sources.

### 4.1. Estimation of water demand

**Domestic:** Daily Domestic Water Requirement ( $DWR_d$ ) is for drinking, cooking and personal hygiene of population living in urban ( $P_{urban}$ ) or rural ( $P_{rural}$ ). The basic human water requirements are taken about 5 L/person/day for drinking, 20 L/person/day for basic sanitation; 15 L/person/day for bathing, and 10 L/person/day for food preparation (Gleick 1996). As per Drinking Water Supply Agency (Govt. of M.S.), the recommended water per person in urban areas is 135 litres per day and in rural areas (population less than 10000) 45 litres/day. The Central Public Health and Environmental Engineering Organization (M/o Urban Development, GOI, 1999) has recommended maximum water supply levels (litre per capita per day, LPCD) as below (**Table 4.1**):

**Table 4.1:** Recommended Per Capita Water Supply Levels for Designing Schemes  
(CPHEEO, 1990)

S.No.	Classification of towns/cities	Recommended maximum water supply levels (LPCD)
1.	Towns provided with piped water supply but without sewerage system	70.00
2.	Cities provided with piped water supply where sewerage system is existing/contemplated	135.00
3.	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing/contemplated	150.00
4.	In urban area, where water is provided through public standpoints	40.00

The details of water requirement per capita per day is given in **Table 4.2** for category of cities provided with piped water supply where sewerage system is existing/contemplated:

**Table 4.2:** Per capita domestic water requirement for cities provided with piped water supply where system exists/ contemplated

S.No.	Purpose	Litres/person/day
1.	Drinking	03
2.	Cooking	04
3.	Bathing	20
4.	Flushing	40
5.	Washing Clothes	25
6.	Washing Utensils	20
7.	Gardening	23
<b>Total</b>		<b>135</b>

## 4.2. Norms for providing potable drinking water in rural areas

Under the ARWSP guideline the norms that have been adopted since the inception of the programme (1972) for providing potable drinking water to the rural population based on basic minimum need was 40 LPCD. From the 12<sup>th</sup> Five year Plan the focus has shifted to provision of piped water supply. The vision for rural domestic water supply in the Strategic Plan of the Ministry is to cover all rural households with safe piped drinking water supply @ 70 LPCD. Considering the fact that the norm of 40 LPCD has been continuing for the last 4 decades and there is a large population that has to be provided with higher service levels, as an interim measure the norm is 55 litres per capita per day (LPCD) for humans to meet the following requirements (MDWS, 2013) (**Table 4.3**):

**Table 4.3:** Break ups of per capita domestic water requirement (interim)

S.No.	Purpose	Litres/ person/ day
1.	Drinking	03
2.	Cooking	05
3.	Bathing	15
4.	Washing utensils and house	10
5.	Ablution/ Toilets	10
	Washing clothes and other uses	12
<b>Total</b>		<b>55</b>

The quantity of domestic water ( $m^3$ ) per capita per day ( $DWR_d$ ), per month ( $DWR_m$ ), and per annum ( $DWR_a$ ) was estimated as follows:

$$DWR_d (m^3/day) = (P_{rural} \times 70 + P_{urban} \times 135) \times 10^{-3}$$

$$DWR_m (m^3/month) = (P_{rural} \times 70 + P_{urban} \times 135) \times 10^{-3} \times 30$$

$$DWR_a (m^3/annum) = (P_{rural} \times 70 + P_{urban} \times 135) \times 10^{-3} \times 365$$

### 4.3. Livestock water requirement

Livestock Water requirement (LWR) refers to the quantity of water required for drinking and animal hygiene conditions (animal and place washing). The water required for livestock rearing depends on the number of animals and consumptive use per head (Amarasinghe *et al.*, 2004). The total livestock water requirement daily (LWR<sub>d</sub>, m<sup>3</sup>/day), monthly (LWR<sub>m</sub>, m<sup>3</sup>/month) and annually (LWR<sub>a</sub>, m<sup>3</sup>/annum) were estimated by adding water required for all domestic animals such as- cattle (cow family), buffaloes, bovines (cow family)/yak, sheep, goat, swine, and poultry as per below given **Table 4.4** (Frasier and Myers, 1983):

**Table 4.4:** Per capita livestock water requirement

S.No.	Type of livestock	Litres/ capita/ day
1.	Cattle/Cow family (C)	85
2.	Buffalo (B)	85
3.	Bovines (cow family)/yak (B <sub>o</sub> )	85
4.	Sheep (S)	10
5.	Goat (G)	10
6.	Swines (S <sub>w</sub> )	15
7.	Poultry (P)	0.4

Accordingly,

$$LWR_d \text{ (m}^3\text{/day)} = \{C \times 85 + B \times 85 + B_o \times 85 + S \times 10 + G \times 10 + S_w \times 15 + P \times 0.40\} \times 10^{-3}$$

$$LWR_m \text{ (m}^3\text{/month)} = \{C \times 85 + B \times 85 + B_o \times 85 + S \times 10 + G \times 10 + S_w \times 15 + P \times 0.40\} \times 10^{-3} \times 30$$

$$LWR_a \text{ (m}^3\text{/yr)} = \{C \times 85 + B \times 85 + B_o \times 85 + S \times 10 + G \times 10 + S_w \times 15 + P \times 0.40\} \times 10^{-3} \times 365$$

Where, C is number of Cattles, B is number Buffaloes, B<sub>o</sub> is number of Bovines/yalk, S is number of Sheep, G is number of Goats, Sw is number of Swines, P is number birds (poultry).

#### 4.4. Crop water requirement

Crop water requirement was estimated broadly using Inductive method based on standard crop deltas (Varshney, *et. al*, 1983; Garg, 2005). Accordingly, the quantity of water requirements (IWR, m<sup>3</sup>) is the product of cropped area (CA, m<sup>2</sup>) and standard delta ( $\Delta$ , m) of respective crops during different seasons as given below:

$$\text{CWR (m}^3\text{)} = \text{CA (m}^2\text{)} \times \Delta(\text{m})$$

Typical values of standard deltas ( $S_{\Delta}$ ) are given in **Table 4.5** (Varshney, *et. al.*, 1983):

**Table 4.5:** Standard values of crop deltas ( $S_{\Delta}$ , m)

S.No.	Crop	Standard crop deltas ( $S_{\Delta}$ , m)
1.	Wheat	0.25
2.	Sugarcane	1.52
3.	Rice	1.52
4.	Cotton	0.76
5.	Jowar	0.25
6.	Maize	0.30
7.	Bajra	0.20
8.	Vegetables	0.64
9.	Gardens	0.76
10.	Mustard	0.25
11.	Fodder*	0.225
12.	Pulses*	0.15

(Source: Garg, 2005)

## 4.5. Estimation of water availability

### 4.5.1. Probability analysis of rainfall data

Rainfall forms the main input in all hydrological studies for a catchment area for which the distribution of rainfall assumes considerable importance. Among the several meteorological factors, rainfall is considered as of utmost importance especially for agricultural activity and water balance components. Besides providing water to the growing crops, rain brings out a favourable change in the climate surrounding the plants thereby promoting active vegetative growth. Apart from the quantum of rainfall, its time distribution also plays a decisive role in the cropping pattern of a particular region and also for the planning and management of watersheds.

The analysis of rainfall trend for the study area was carried out using 27 years monthly rainfall data pertaining to Hydro-meteorological Observatory of NIH Roorkee. The monthly data was arranged in descending order of their magnitude. The recurrence interval  $T$  (return period) of a particular magnitude was determined using Kimball's method (Weibull, 1939; cited from: Raghunath, 1990) as below:

$$T = (n + 1)/m$$

Where,  $T$  = recurrence interval (return period)

$n$  = total number of items data series

$m$  = order number or rank of any particular storm value after arranging in descending order of their magnitude.

The frequency  $F$  (expressed as percent of time) of that storm magnitude (having recurrence interval,  $T$ ) is given by:

$$F (\%) = (1/T)100$$

In the present study, frequency curve (Precipitation  $P$  or  $I$  v/s  $F\%$ ) were developed for monthly rainfall data of the Roorkee using 27 years rainfall data.

#### 4.5.2. Estimation of surface runoff

Estimation of surface runoff is essential for the assessment of water yield potential of a watershed, planning of soil and water conservation measures, reducing the sedimentation and flooding hazards downstream. The Soil Conservation Service Curve Number (SCS-N) method, developed by the USDA-Soil Conservation Service (USDA-SCS, 1972), is widely used for the estimation of direct runoff for a given rainfall event from small agricultural watersheds. The method is simple to use and requires basic descriptive inputs that are converted to numeric values for estimation of watershed direct runoff volume (Bonta, 1997). A curve number (N) that is descriptive of major runoff producing characteristics of watershed such as soil type, land use/treatment classes, hydrologic soil group, hydrologic condition, most importantly the antecedent moisture condition (AMC) is required in the method. The mathematical form of SCS-N method is given below:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

Where, Q= direct surface runoff in depth (mm)

P= Storm rainfall (mm)

S= maximum potential difference between rainfall and runoff (mm)

For convenience in evaluating antecedent moisture, soil condition, land use, and conservation practices, the U.S. Soil Conservation Service (USDA-SCS, 1972) defines

$$S = \frac{25400}{N} - 254$$

Where, N= an arbitrary curve number varying from 0 to 100. The curve number (N) can be obtained for various hydrologic soil group (A, B, C, D) on the basis of landuse/land cover, treatment/practice and hydrologic condition (good/poor/fair) as depicted under USDA-Soil Conservation Service (USDA-SCS, 1972).

The USDA Natural Resources Conservation Service (NRCS) curve number is related to soil type, soil infiltration capability, land use, and the depth of the seasonal high water table. To account for different soils' ability to infiltrate, NRCS has divided soils into four hydrologic soil groups (HSGs). They are defined as follows:

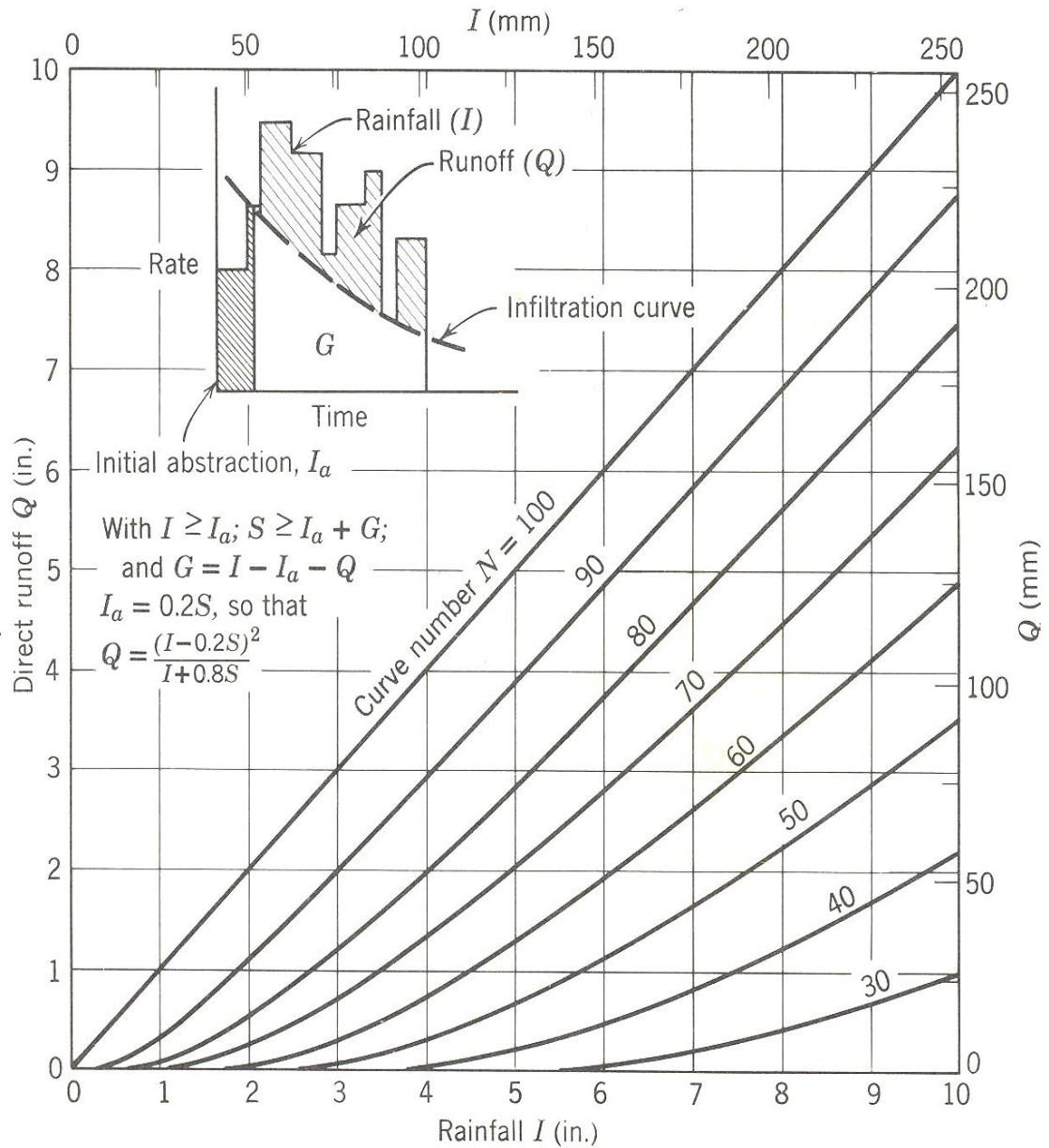
**HSG Group A** (low runoff potential): Soils with high infiltration rates even when thoroughly wetted. These consist chiefly of deep, well-drained sands and gravels. These soils have a high rate of water transmission (final infiltration rate greater than 0.3 in./h).

**HSG Group B** Soils with moderate infiltration rates when thoroughly wetted. These consist chiefly of soils that are moderately deep to deep, moderately well drained to well drained with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (final infiltration rate of 0.15 to 0.30 in./h).

**HSG Group C:** Soils with slow infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine textures. These soils have a slow rate of water transmission (final infiltration rate 0.05 to 0.15 in./h).

**HSG Group D** (high runoff potential): Soils with very slow infiltration rates when thoroughly wetted. These consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission (final infiltration rate less than 0.05 in./h).

Selection of a hydrologic soil group should be done based on measured infiltration rates and soil survey. The relationship between rainfall and runoff (USDA-SCS, 1972) with curve numbers is given in **Figure 4.1**.



**Figure 4.1:** Relationship between rainfall and runoff (US-SCS, 1972)

#### 4.6. Planning of rainwater harvesting in the village

The rainwater harvesting potential in the study area would be carried out as below:

- Household monthly harvested rainwater & balance after ablution/toilet needs

- Household monthly harvested rainwater & balance after ablution/toilet, washing clothes & other uses (combined)
- Estimation of household monthly harvested rainwater & balance after livestock (cattle, buffaloes & yak) need fulfilment.
- Rainwater harvesting potential of village ponds
- Monthly roof top water harvesting potential of schools/govt. buildings

#### **4.7. Planning for wastewater management**

The ponds are generally used as sink for all wastewater as well as for solid waste generated in the villages. Accordingly, village ponds are going to vanish due to the entry of sewage causing eutrophication. In this study, overall development of pond including in-situ wastewater treatment enabling ponds for rainwater harvesting for the benefit of local people has been carried out. The steps are given below:

- Bathymetry survey and monitoring of wastewater volume in the pond.
- Selection of experimental site & design of constructed wetland (Natural Treatment System, NTS) for treatment of wastewater.
- Evaluation of water quality parameters in raw (inflow) sewage and treated sewage water (outflow).

The wastewater treatment through natural low cost treatments systems has been extensively studied (Kumar and Asolekar 2016; Kumar, D. et. al. 2016), which is basis of the present wastewater treatment system at Village Ibrahimpur Masahi.

#### 4.8. Eutrophication estimation of ponds

Eutrophication of ponds will be assessed using Carlson's Trophic State Index (Carlson, 1977) based on Secchi disk transparency, phosphate concentration and chlorophyll content. The equations are given below:

$$\text{TSI (TP)} = 14.42 \ln (\text{TP}) + 4.15 \quad \text{.....(Eq. 1)}$$

$$\text{TSI (SD)} = 60 - 14.41 \ln (\text{SD}) \quad \text{.....(Eq.2)}$$

$$\text{TSI (CHL)} = 9.81 \ln (\text{CHL}) + 30.6 \quad \text{.....(Eq. 3)}$$

## **5. RESULTS AND DISCUSSION**

In the present study, the Ibrahimpur Masahi revenue village was selected to study ground conditions about water demand, availability, gaps, surface and ground water quality status of various sources in the area to suggest improvement of water conservation structures. During past years, field investigations were carried out to study some important soil characteristics (*viz.* infiltration, soil moisture, soil texture) and surface and ground water quality (stream, ponds, hand pumps) of the study area. The rainfall data of the nearest location (NIH Hydromet observatory, Roorkee) was collected for the period of 27 years (1987 to 2013) for the study. The results are discussed below:

### **5.1. Estimation of water demand for various uses**

The water demand has been estimated for domestic, livestock and agricultural purposes for the entire Ibrahimpur Masahi revenue village on the basis of relevant data collected from the various sources.

#### **5.1.1. Domestic water demand for human**

The human population in Ibrahimpur Masahi Revenue village (comprising of Ibrahimpur, Masahi, Belki, Inayatpur and Halzora) was obtained from District Administration. Accordingly, this village had a total human population of 5535 and 7135 during 2001 and 2011 as per Census of India data, respectively.

The Projected Population of the Ibrahimpur Masahi was estimated using average populated growth rate of Haridwar District and subsequently rectification for Ibrahimpur Village using the Census 2001 data. In Haridwar District, there was a change of 30.63 percent in the population compared to population as per 2001. In the previous census of India 2001, Haridwar District recorded increase of 28.70 percent to its population compared to 1991 (<http://www.census2011.co.in/census/district/586-haridwar.html>). In this study, the projected population increase of the Ibrahimpur Masahi village was estimated @

28.9 % per decade. The estimated domestic water demand of the Ibrahimpur Masahi village @ 70 Litre/person/day has been estimated for the years 2001, 2011 and projected population of the village (2021, 2031). The results are given in **Table 5.1**.

**Table 5.1:** Domestic water demand (human) for Ibrahimpur Masahi Revenue village

Year	Population	Water Demand			
		m <sup>3</sup> /day	m <sup>3</sup> /month	m <sup>3</sup> /year	MCM/Yr
2001	5535	387	11624	141419	0.141
2011	7135	499	14984	182299	0.182
2021*	9197	644	19314	234983	0.235
2031*	11855	830	24896	302895	0.303

(Projected Population)

During the field survey and assessment, demographic and social data were collected for all the Ibrahimpur Revenue Villages (Ibrahimpur Masahi, Masahi Kala, Belki Masahi, Inayatpur, Halzora). Data were comprises as follows:

- I. Total number of household in each village,
- II. Number of individuals in each family,
- III. Total number of rooms per family and their dimensions,
- IV. Drinking water hand pumps possessed per family
- V. Tube wells used on farmland for irrigation and
- VI. Tube wells operating days in year

Details of these data for all the Ibrahimpur Revenue Villages have been presented in **Annexure I**. Further, data were processed aimed to get the domestic water demand per month for various activities for all the Ibrahimpur Revenue Villages (depicted in **Table 5.2**).

Similarly, Domestic water demand for various activities per month for each family were estimated for all the Ibrahimpur Revenue Villages (depicted in **Table 5.3**).

**Table 5.2:** Total Domestic water demand per month of Ibrahimpur Revenue Villages in fulfilling various needs

S.No.	Name of Village	No. of Houses	Population	Average No. of individuals/ household	Domestic water demand (m <sup>3</sup> /month) @ of 55 LPCD	Domestic water demand (m <sup>3</sup> /month) for toilet flushing (10), washing clothes and other uses (12LPCD) (total 22LPCD)	Domestic water demand (m <sup>3</sup> /month) for washing clothes and other uses @ of 12 LPCD
1	Ibrahimpur Masahi	223	2170	10	3581	1432	781
2	Masahi Kala	165	1528	9	2521	1008	550
3	Belki Masahi	112	898	8	1482	593	323
4	Inayatpur	138	767	6	1266	506	276
5	Halzora	101	939	9	1549	620	338
<b>6</b>	<b>Ibrahimpur Masahi Revenue (Total)</b>	<b>739</b>	<b>6302</b>	<b>9</b>	<b>10398</b>	<b>4159</b>	<b>2269</b>

**Table 5.3:** Domestic water demand per month for each family in Ibrahimpur Revenue Villages in fulfilling various needs

S.No.	Name of Village	No. of Houses	Population	Average No. of individuals/ household	Domestic water demand (m <sup>3</sup> /month) @ of 55 LPCD	Domestic water demand (m <sup>3</sup> /month) for toilet flushing (10), washing clothes and other uses (12LPCD) (Total @22LPCD*)	Domestic water demand (m <sup>3</sup> /month) for washing clothes and other uses @ of 12 LPCD
1	Ibrahimpur Masahi	223	2170	10	16	6.42	3.50
2	Masahi Kala	165	1528	9	15	6.11	3.33
3	Belki Masahi	112	898	8	13	5.29	2.89
4	Inayatpur	138	767	6	9	3.67	2.00
5	Halzora	101	939	9	15	6.14	3.35
<b>6</b>	<b>Ibrahimpur Masahi Revenue (Total)</b>	<b>739</b>	<b>6302</b>	<b>9</b>	<b>69</b>	<b>27.63</b>	<b>15.07</b>

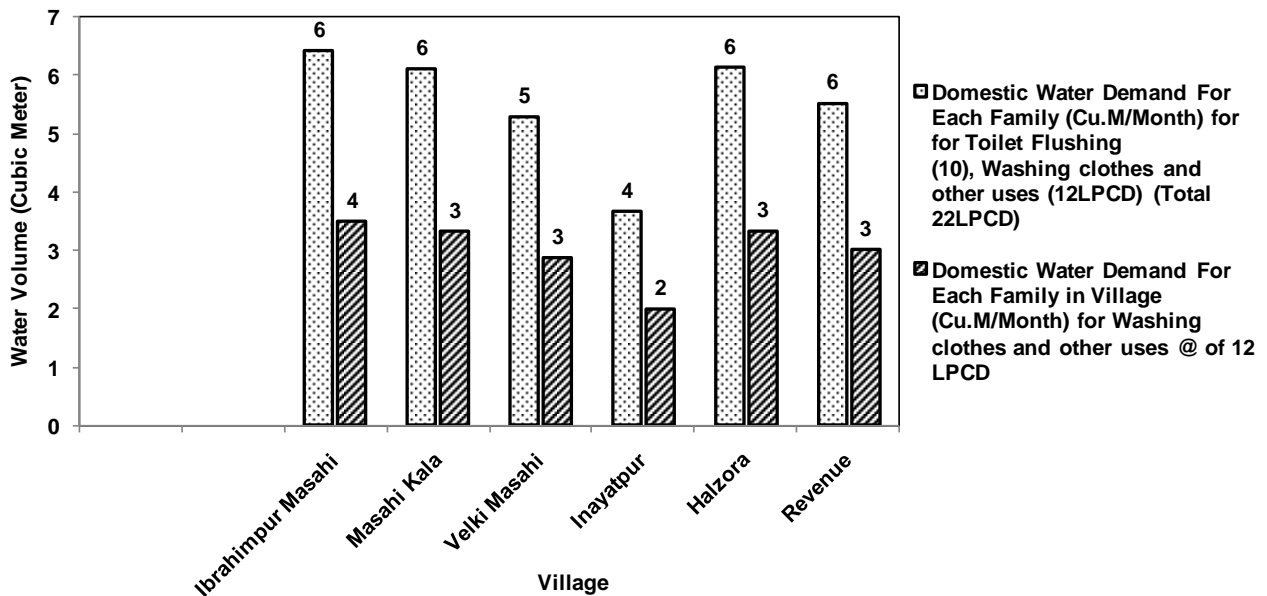
\*LPCD = Litre Per Capita/Day

It has been evident for the Table 5.2 and Table 5.3, the domestic water demand based on various scenarios were varies. This was due varying average number of individuals per family in Ibrahimpur Revenue Villages.

Further, comparison was made for domestic water demand for each family per month based on the following two scenarios (as mentioned in **Figure 5.1**):

- I. Domestic water demand for each family ( $m^3$ /Month) for fulfilling the needs of toilet flushing (10LPCD) and washing clothes and other uses (12LPCD) which gives the sum of 22 LPCD
- II. Domestic water demand for each family in village ( $m^3$ /Month) for washing clothes and other uses @ of 12 LPCD

The comparative results are depicted in the Figure 5.1.



**Figure 5.1:** Comparison of domestic water demand per month based on various scenarios

### 5.1.2. Livestock water demand

The total livestock water requirement daily ( $LWR_d$ ,  $m^3/day$ ), monthly ( $LWR_m$ ,  $m^3/month$ ) and annually ( $LWR_a$ ,  $m^3/annum$ ) were estimated by adding water required for all domestic animals such as- cattle (cow family), buffaloes, bovines (cow family)/yak, sheep, goat, swine, and Fowls (poultry birds) and results are is given **Table 5.4**.

**Table 5.4:** Livestock water demand for in Ibrahimpur Masahi Revenue village

Livestock	Population	Water demand			
		$m^3/day$	$m^3/month$	$m^3/year$	MCM/yr
Cattle (i/c Indigenous, Exotic and Cross breed)	4138	351.7	10551.9	128381.5	0.128381
Buffaloes	799	67.9	2037.5	24789.0	0.024789
Bovines (cow family)/Yak	2996	254.7	7639.8	92950.9	0.092951
Sheep	0	0.0	0.0	0.0	0
Goat	189	1.9	56.7	689.9	0.00069
Swines (Pig)	14	0.2	6.3	76.7	7.67E-05
Fowls (birds)	455	0.2	5.5	66.4	6.64E-05
<b>Total</b>		676.6	20297.6	246954.3	0.246954

Further, population of the Ibrahimpur Revenue Villages has been depicted in **Table 5.5** and the water demand depicted in **Table 5.6**.

**Table 5.5:** Livestock population dynamics of the Ibrahimpur Revenue Villages

<b>S.No.</b>	<b>Type Livestock</b>	<b>Total No.</b>	<b>Ibrahimpur Masahi</b>	<b>Masahi Kala</b>	<b>Belki Masahi</b>	<b>Inayatpur</b>	<b>Halzora</b>
1	Cattle (i/c Indigenous, Exotic and Cross breed)	4138	1249	924	627	773	566
2	Buffaloes	799	241	178	121	149	109
3	Bovines (cow family)/Yak	2996	904	669	454	559	409
4	Sheep	0	0	0	0	0	0
5	Goat	189	57	42	29	35	26
6	Swines (Pig)	14	4	3	2	3	2
7	Fowls (birds)	455	137	102	69	85	62
<b>8</b>	<b>Number of Livestock in Ibrahimpur Masahi Revenue (Total)</b>	<b>8591</b>	<b>2592</b>	<b>1918</b>	<b>1302</b>	<b>1604</b>	<b>1174</b>

**Table 5.6:** Livestock Water demand (m<sup>3</sup>/ month) for various types of livestock population in Ibrahimpur Revenue Villages

S.No.	Name of Vallage	No. of Household	Cattle (m <sup>3</sup> / month)	Buffaloes (m <sup>3</sup> / month)	Bovines (m <sup>3</sup> / month)	Sheep (m <sup>3</sup> / month)	Goat (m <sup>3</sup> / month)	Swines (m <sup>3</sup> / month)	Fowls (m <sup>3</sup> / month)	Livestock water demand (m <sup>3</sup> / month)	Livestock water demand/ family(m <sup>3</sup> / month)
1	Ibrahimpur Masahi	223	3184	615	2305	0.0	17.1	1.8	1.6	<b>6125</b>	<b>27.4659</b>
2	Masahi Kala	165	2356	455	1706	0.0	12.7	1.4	1.2	<b>4532</b>	<b>27.4660</b>
3	Belki Masahi	112	1599	309	1158	0.0	8.6	0.9	0.8	<b>3076</b>	<b>27.4658</b>
4	Inayatpur	138	1970	380	1427	0.0	10.6	1.4	1.0	<b>3791</b>	<b>27.4676</b>
5	Halzora	101	1442	278	1044	0.0	7.7	0.9	0.7	<b>2774</b>	<b>27.4667</b>
6	Ibrahimpur Masahi Revenue (Total)	739	<b>10552</b>	<b>2037</b>	<b>7640</b>	<b>0</b>	<b>57</b>	<b>6</b>	<b>5</b>	<b>20298</b>	<b>27.4663</b>

### 5.1.3. Crop water requirement

Crop water requirement was estimated broadly using Inductive method based on standard crop deltas of different crops (Varshney, *et. al*, 1983; Garg, 2005). Accordingly, the crop water requirements (CWR, m<sup>3</sup> or MCM) is the product of cropped area (CA, m<sup>2</sup>) and standard delta ( $\Delta$ , m) of respective crops during different seasons (Rabi, Kharif and Zaid) as given below (Tables 5.7 to Table 5.9):

**Table 5.7:** Crop water requirement of the Ibrahimpur Masahi Village for Rabi Season

S.No.	Crops	Cropped Area(ha)	Cropped Area(m <sup>2</sup> )	Standard Crop Deltas (S $\Delta$ , m)	CWR (m <sup>3</sup> )	CWR (MCM)
1.	Wheat	250	250x10 <sup>4</sup>	0.25	625000	0.625
2.	Vegetables	57	57 x10 <sup>4</sup>	0.64	364800	0.3648
3.	Fodder* (i/c Berseem/Jayee)	60	60 x10 <sup>4</sup>	0.225	135000	0.135
4.	Pulses*(Massor)	60	60 x10 <sup>4</sup>	0.15	90000	0.09
<b>Sub-total (Rabi season)</b>					<b>1214800</b>	<b>1.2148</b>

**Table 5.8:** Crop water requirement of Ibrahimipur Masahi village for Kharif season

S.No.	Crops	Cropped area(ha)	Cropped area(m <sup>2</sup> )	Standard crop deltas (S <sub>Δ</sub> , m)	CWR (m <sup>3</sup> )	CWR (MCM)
1.	Sugarcane	285	285 x10 <sup>4</sup>	1.52	4332000	4.332
2.	Paddy (Rice)	52	52 x10 <sup>4</sup>	1.52	790400	0.7904
3.	Maize	12	12 x10 <sup>4</sup>	0.30	36000	0.036
4.	Vegetables (i/c chillies)	54	54 x10 <sup>4</sup>	0.64	345600	0.3456
5.	Gardens (Floriculture)	133	133 x10 <sup>4</sup>	0.76	1010800	1.0108
6.	Fodder* (i/c Jowar/Til)	133	133 x10 <sup>4</sup>	0.225	299250	0.29925
<b>Sub-total (Kharif season)</b>					<b>6814050</b>	<b>6.81405</b>

**Table 5.9:** Crop water requirement of the Ibrahimipur Masahi Village for Zaid season

S.No.	Crops	Cropped area(ha)	Cropped area(m <sup>2</sup> )	Standard crop deltas (S <sub>Δ</sub> , m)	CWR (m <sup>3</sup> )	CWR (MCM)
1.	Gardens (Mango)	66	66 x10 <sup>4</sup>	0.76	501600	0.5016
2.	Fodder* (i/c maize & bajra)	17	17 x10 <sup>4</sup>	0.225	38250	0.03825
3.	Pulses* (Urad)	1.5	1.5 x10 <sup>4</sup>	0.15	0.225	2.25E-07
<b>Sub-total (Zaid season)</b>					<b>539850.2</b>	<b>0.53985</b>

The total annual crop water requirement for Ibrahimpur Masahi village is given below:

$$\text{CWR (MCM/yr)} = 1.2148 + 6.81405 + 0.53985 = 8.569$$

Thus, the total water requirement (i/c drinking, livestock and agriculture) has been broadly estimated as below (**Table 5.10**):

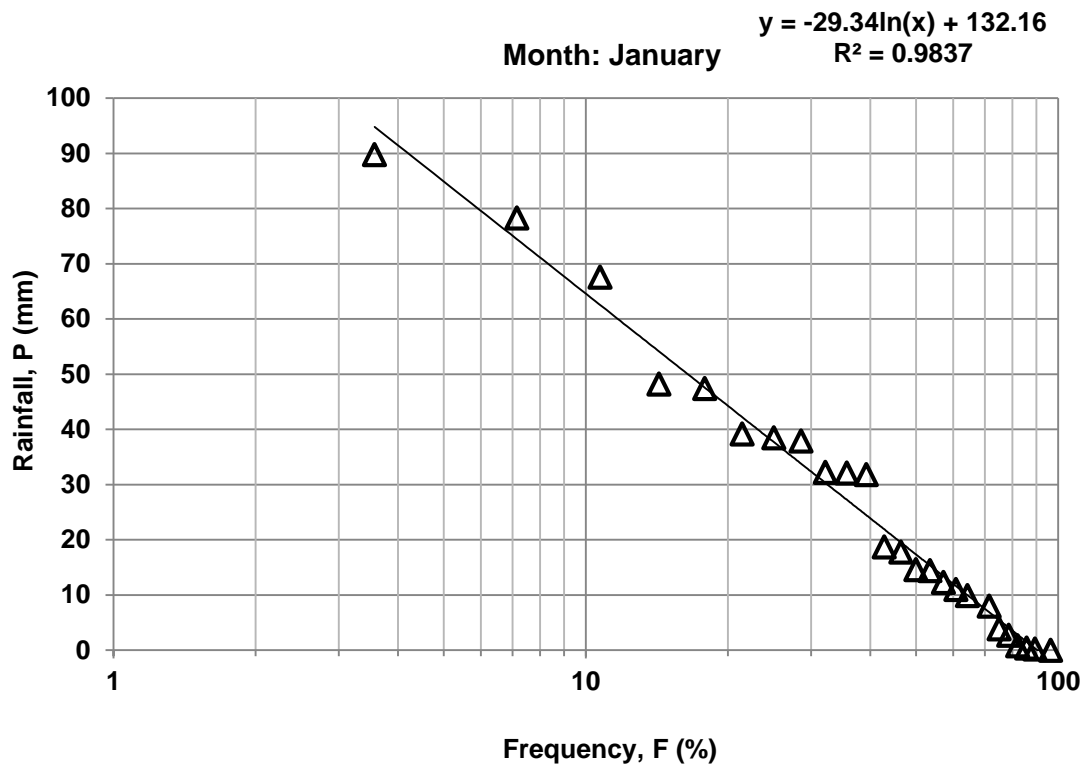
**Table 5.10:** Estimated total water requirement for Ibrahimpur Masahi Revenue village

S.No.	Sector	Water requirement (MCM/Year)
1.	Domestic (As per Human Population of the village, 2011)	0.182
2.	Domestic (Livestock)	0.247
3.	Agriculture	8.569
<b>Total</b>		<b>8.998</b>

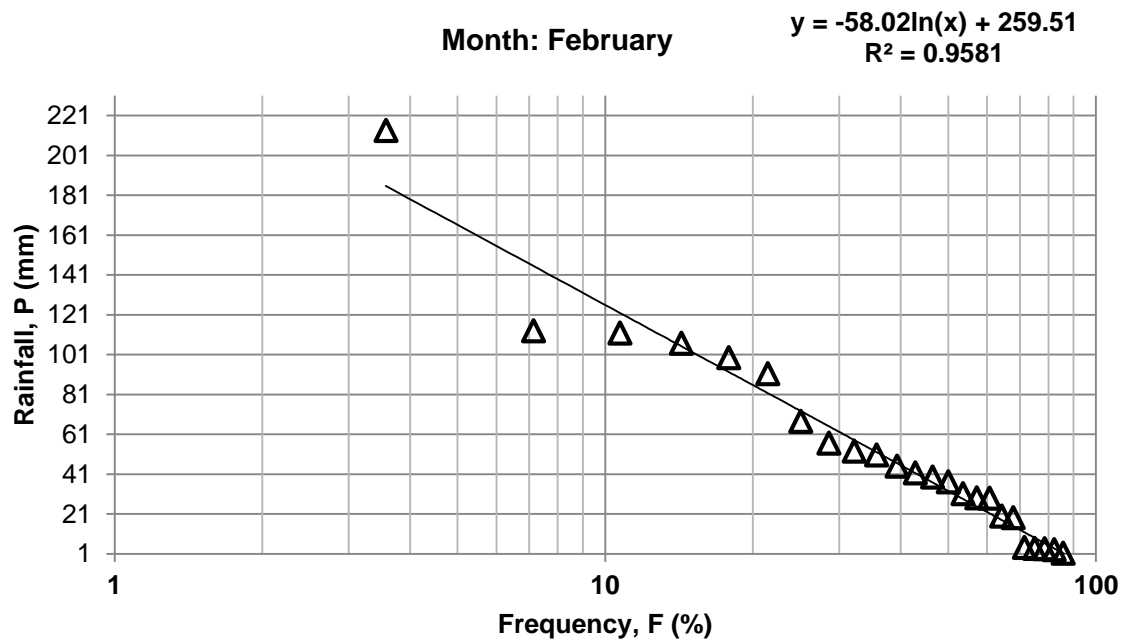
## 5.2. Surface water availability analysis

### 5.2.1. Frequency analysis of rainfall data

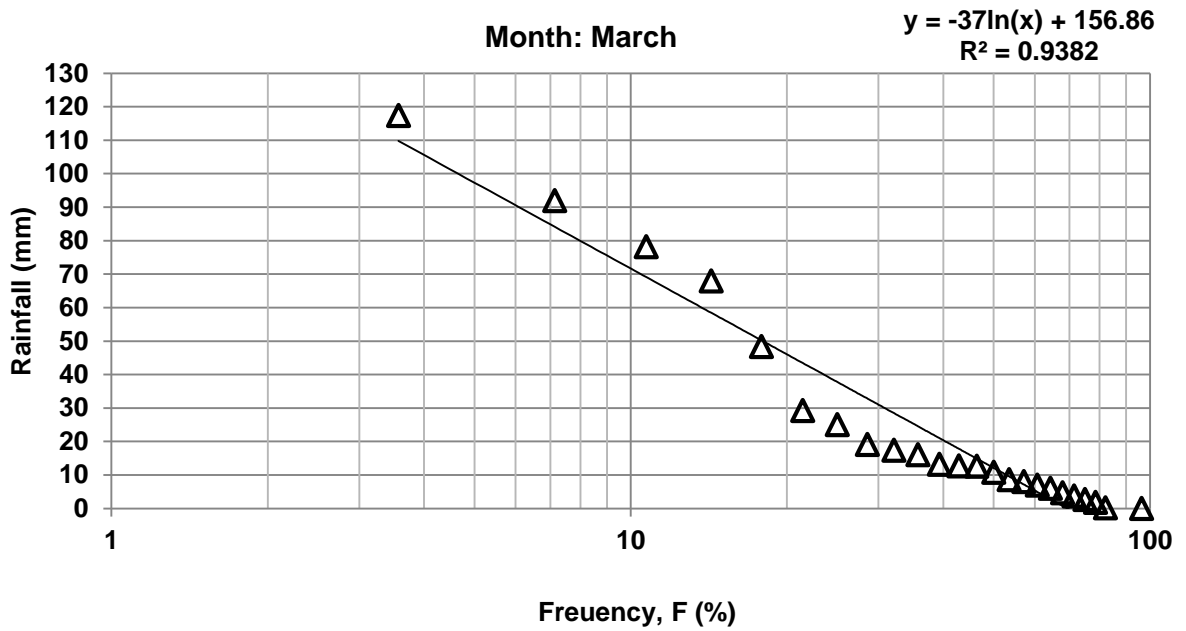
The 27 year (1987 to 2013) rainfall data of the NIH Hydromet observatory, Roorkee was analysed for common statistical measures (minimum, maximum, mean) along with frequency analysis of the rainfall data on monthly basis. The rainfall frequency curves for all months are given in **Figure 5.2** to **Figure 5.13**. The mean annual rainfall was obtained 1053 mm (27 year data). The annual probable maximum rainfall of Roorkee was obtained 866 mm and 537 mm at 50% and 75% frequency levels, respectively (**Table 5.11**).



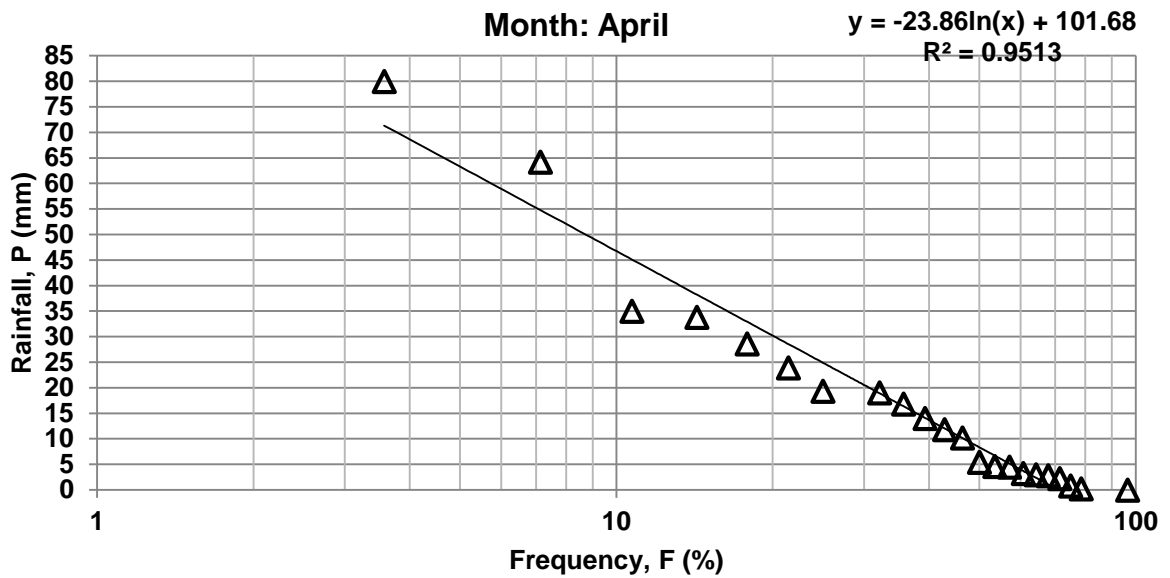
**Figure 5.2:** Rainfall frequency curve (January) for rainfall data of Roorkee (1987-2013)



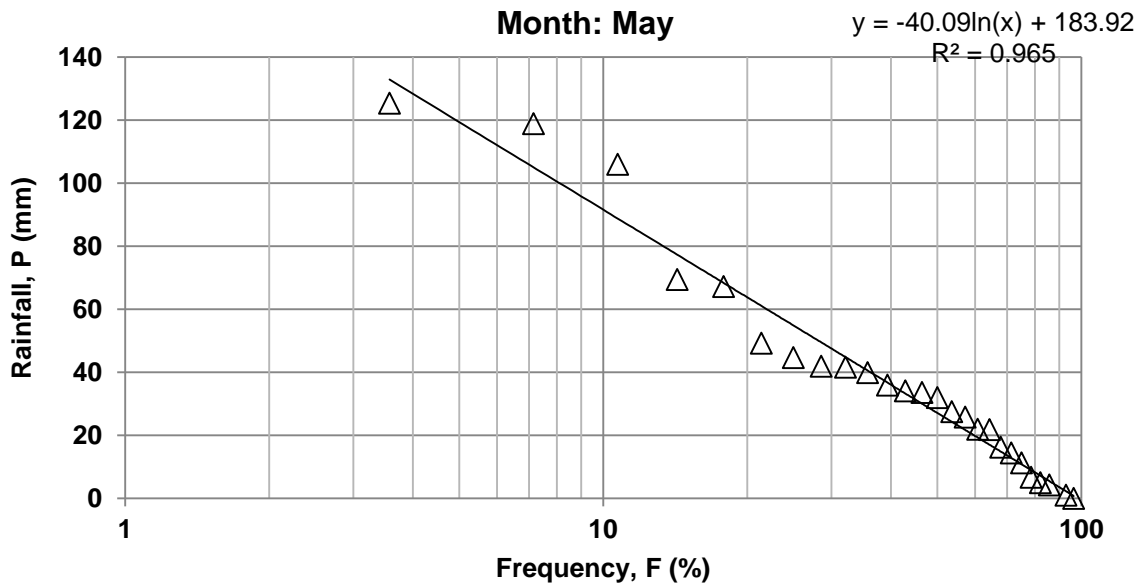
**Figure 5.3:** Rainfall frequency curve (February) for rainfall data of Roorkee (1987-2013)



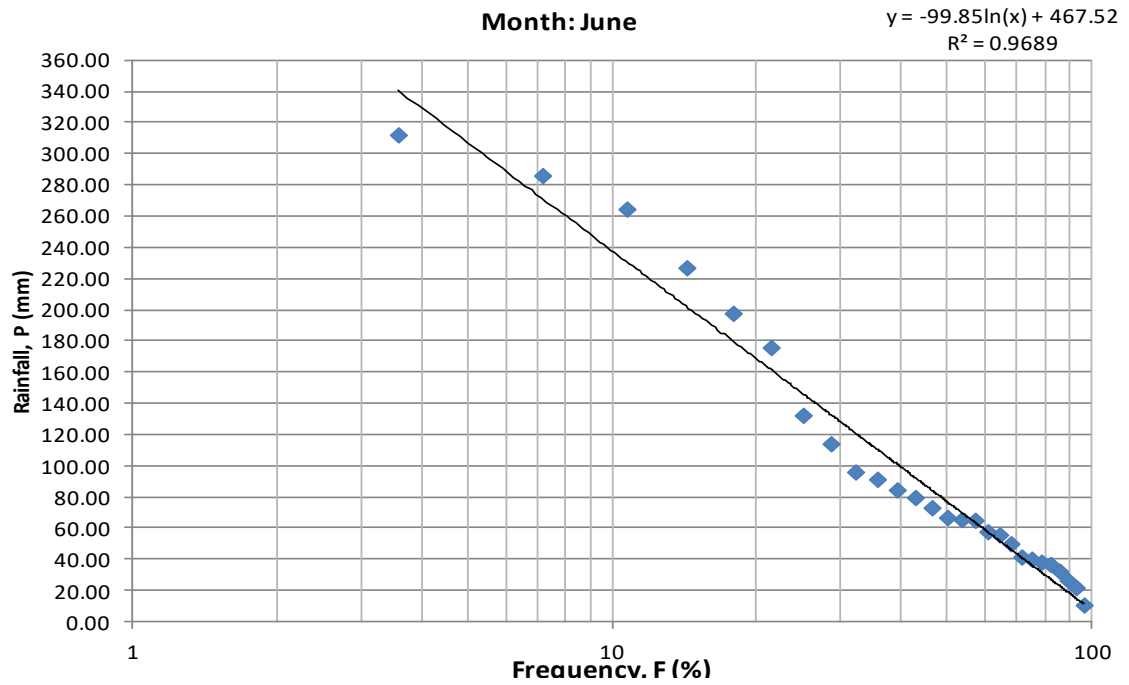
**Figure 5.4:** Rainfall frequency curve (March) for rainfall data of Roorkee (1987-2013)



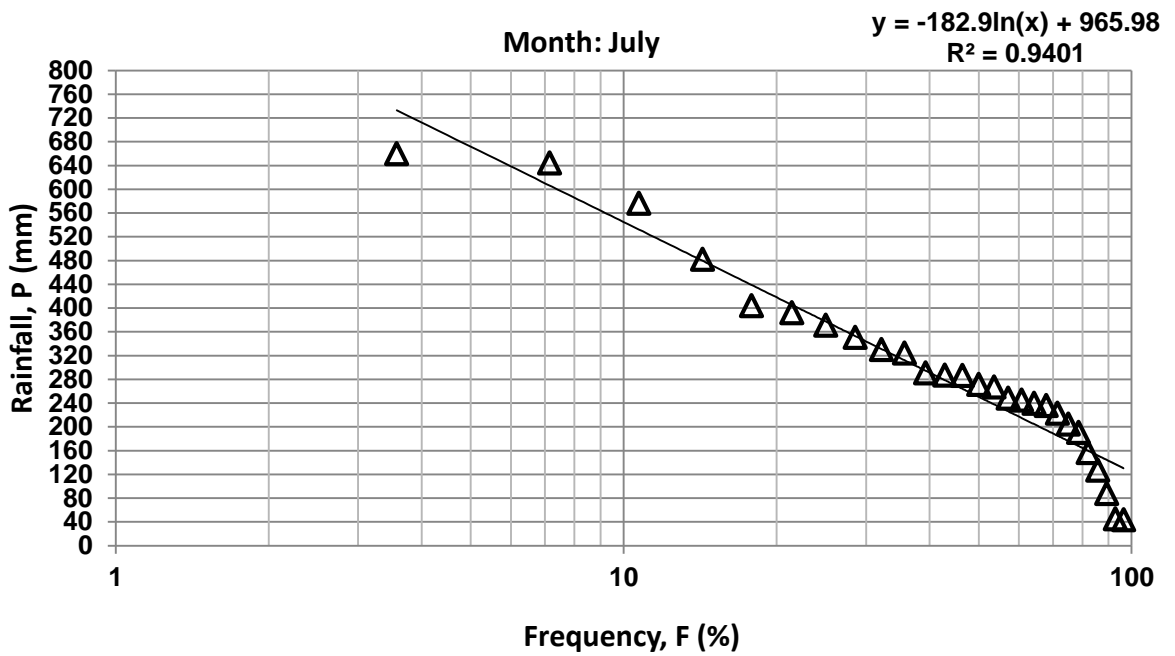
**Figure 5.5:** Rainfall frequency curve (April) for rainfall data of Roorkee (1987-2013)



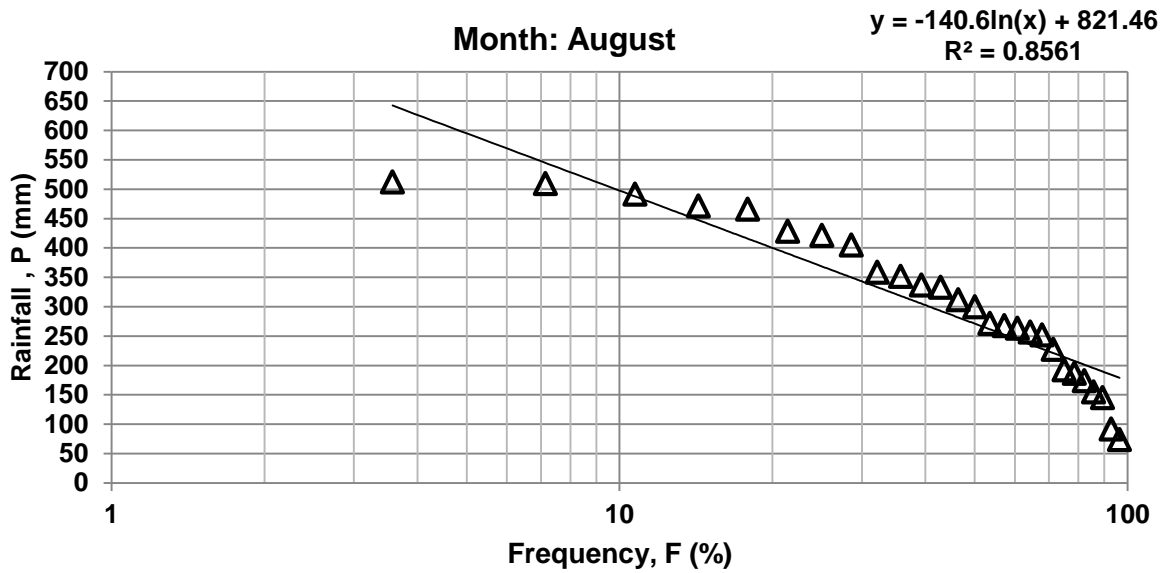
**Figure 5.6:** Rainfall frequency curve (May) for rainfall data of Roorkee (1987-2013)



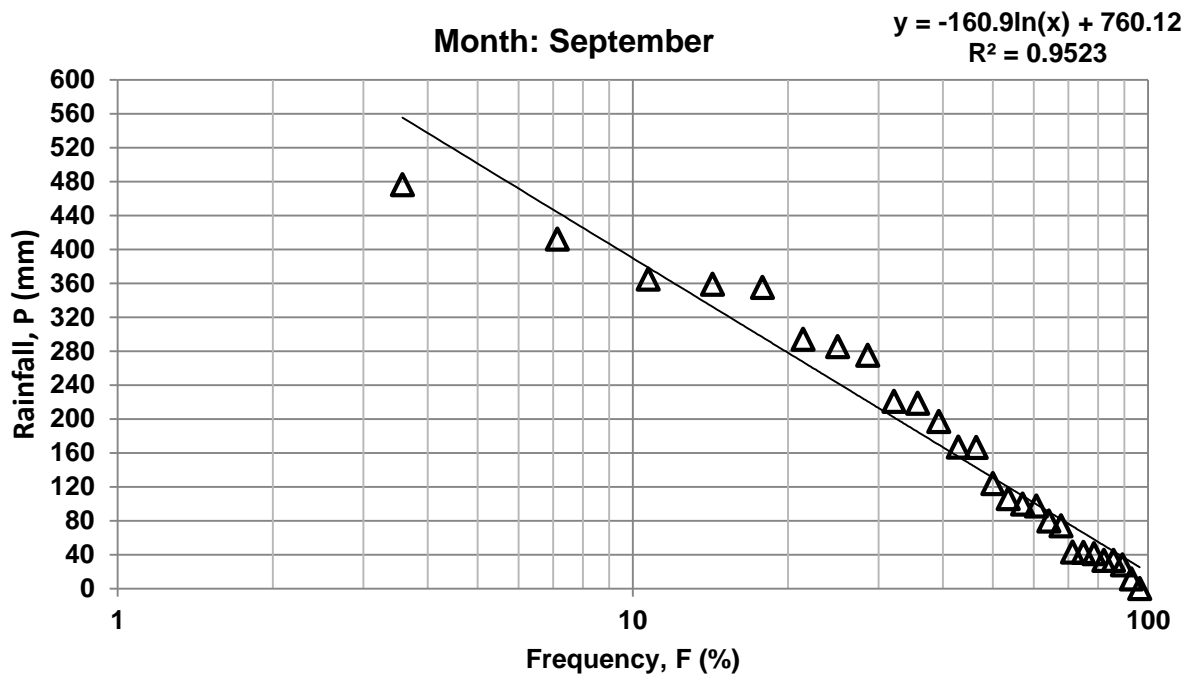
**Figure 5.7:** Rainfall frequency curve (June) for rainfall data of Roorkee (1987-2013)



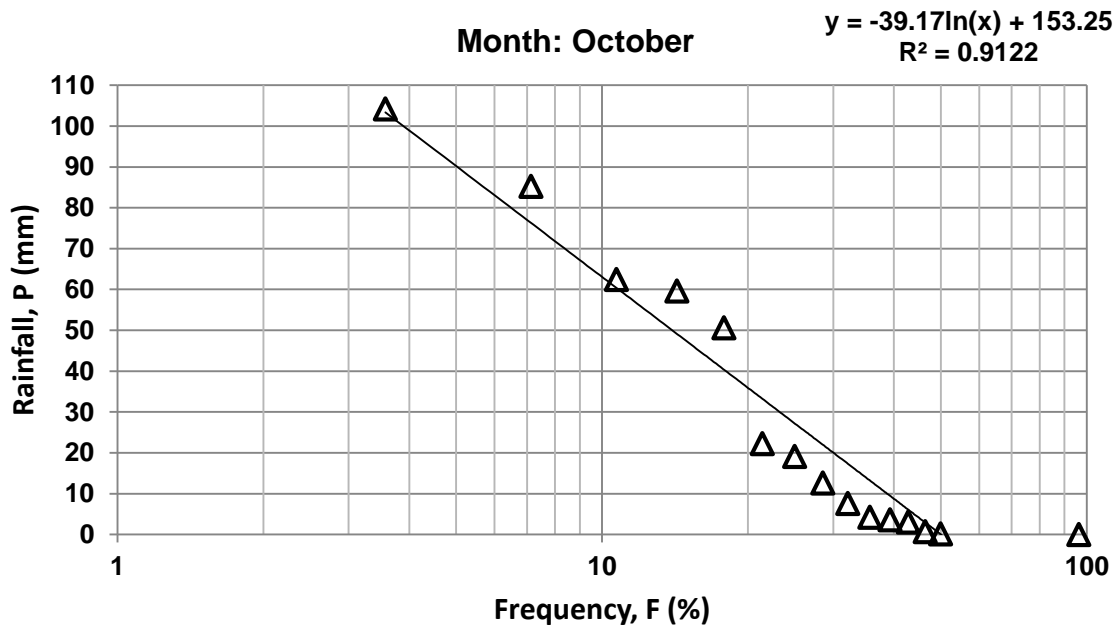
**Figure 5.8:** Rainfall frequency curve (July) for rainfall data of Roorkee (1987-2013)



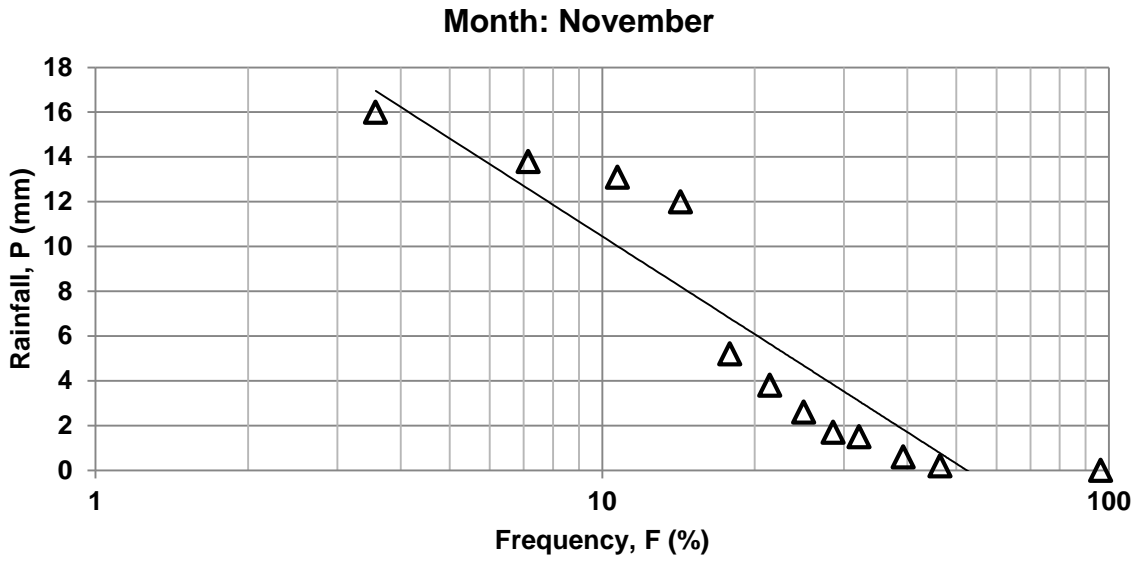
**Figure 5.9:** Rainfall frequency curve (August) for rainfall data of Roorkee (1987-2013)



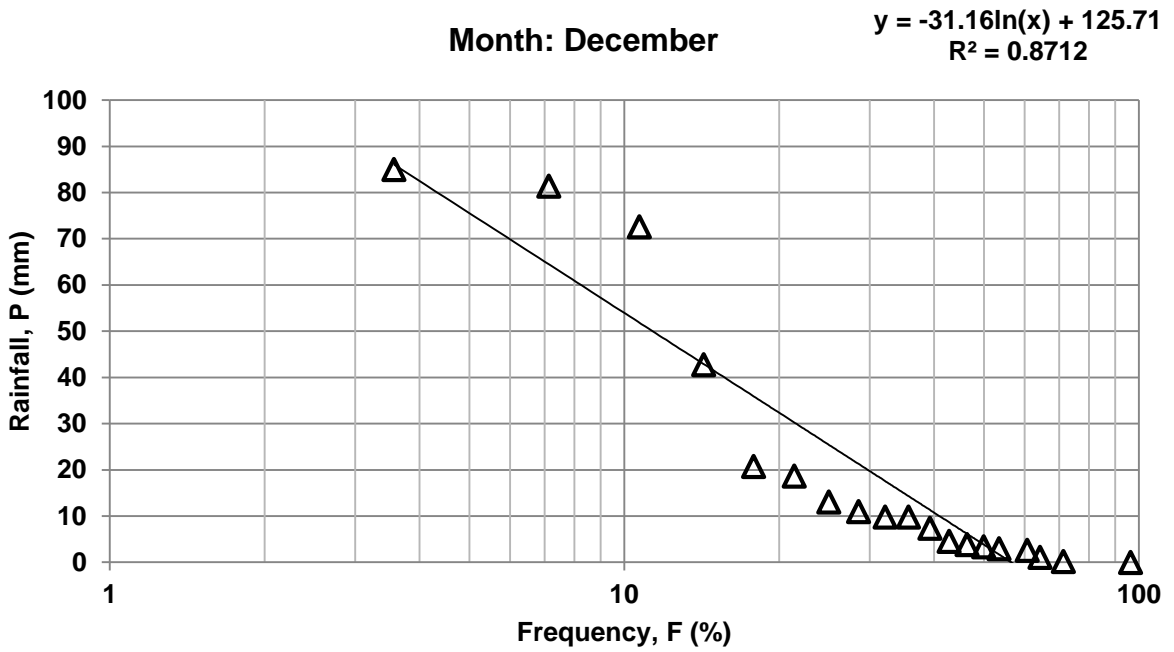
**Figure 5.10:** Rainfall frequency curve (September) for rainfall data of Roorkee (1987-2013)



**Figure 5.11:** Rainfall frequency curve (October) for rainfall data of Roorkee (1987-2013)



**Figure 5.12:** Rainfall frequency curve (November) for rainfall data of Roorkee (1987-2013)



**Figure 5.13:** Rainfall frequency curve (December) for rainfall data of Roorkee (1987-2013)

**Table 5.11:** Monthly rainfall statistics and dependable rainfall, mm (F= 50% ; F=75%) of Roorkee (1987-2013)

Month	Statistics					
	n	min	max	mean	F= 50%	F=75%
January	27	0	89.8	24.7	14.6	3.9
February	27	0	213.6	47	37.2	37
March	27	0	117.4	22.3	10.8	2.7
April	27	0	80	14.9	5.4	0.8
May	27	0	125.4	36.9	32.0	11.3
June	27	10.8	312.2	101.7	66.9	40.2
July	27	43.4	660	295.8	271.7	204.6
August	27	74.3	512.8	306	300.1	193.2
September	27	0	476.3	170.5	123.9	42.8
October	27	0	104.2	16.1	0.10	0
November	27	0	16	2.6	0.16	0
December	27	0	85	14.6	3.40	0.16
<b>Total</b>				<b>1053.1</b>	<b>866.3</b>	<b>536.7</b>

### 5.2.2. Estimation of surface runoff

The surface runoff of the Shipla Nadi-Halzora Nadi sub-watershed (tributary of Solani River) was estimated used SCS curve number techniques as below:

### 5.2.2.1. Determination of infiltration rates and hydrologic soil group

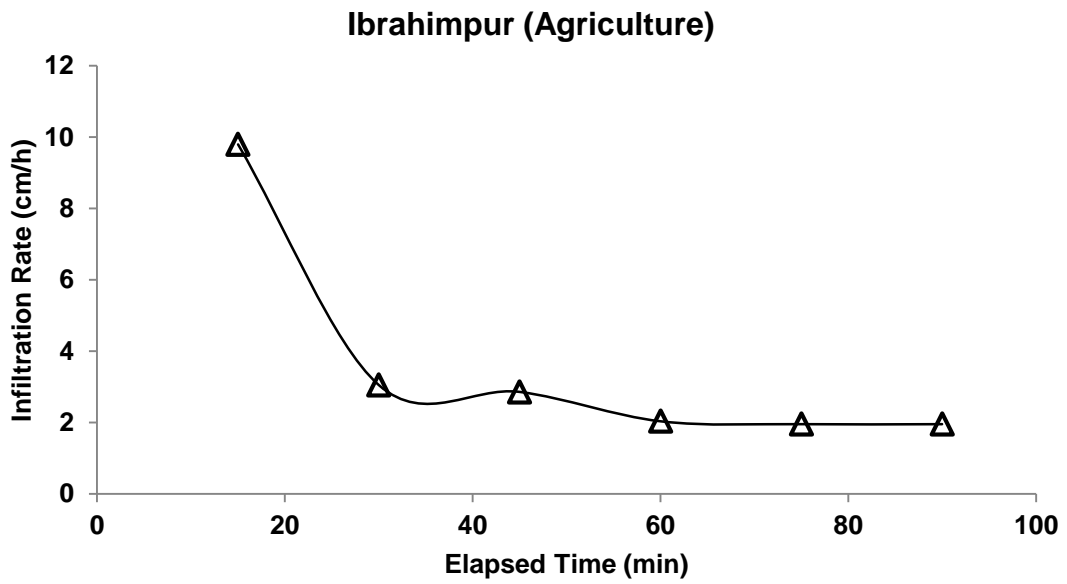
SCS curve number method of estimating surface runoff utilizes infiltration characteristics of the soils in the study area. Infiltration tests were conducted under different land uses (Agriculture, Pond bed, Forest Land, Grass Land and Fallow Land) in the study area (**Figure 5.14**). The results are shown in **Figure 5.15** to **Figure 5.19**. The initial infiltration rates were obtained in the order of 9.8 cm/hr, 3.82 cm/hr, 57.3 cm/hr, 3.12 cm/hr and 4.58 cm/hr under Agriculture, Pond bed, Forest Land, Grass Land and Fallow Land, respectively. The final infiltration rates were obtained in the order of 1.96 cm/hr, 0.72 cm/hr, 2.4 cm/hr, 1.1 cm/hr and 0.96 cm/hr under Agriculture, Pond bed, Forest Land, Grass Land and Fallow Land, respectively. Accordingly, the study area lies under Hydrologic Soil Group-A (Final Infiltration Rate: >0.3 in/hr) and Hydrologic Soil Group-B (Final Infiltration Rate: 0.15 to 0.30 in./h), respectively, **Table 5.12**.



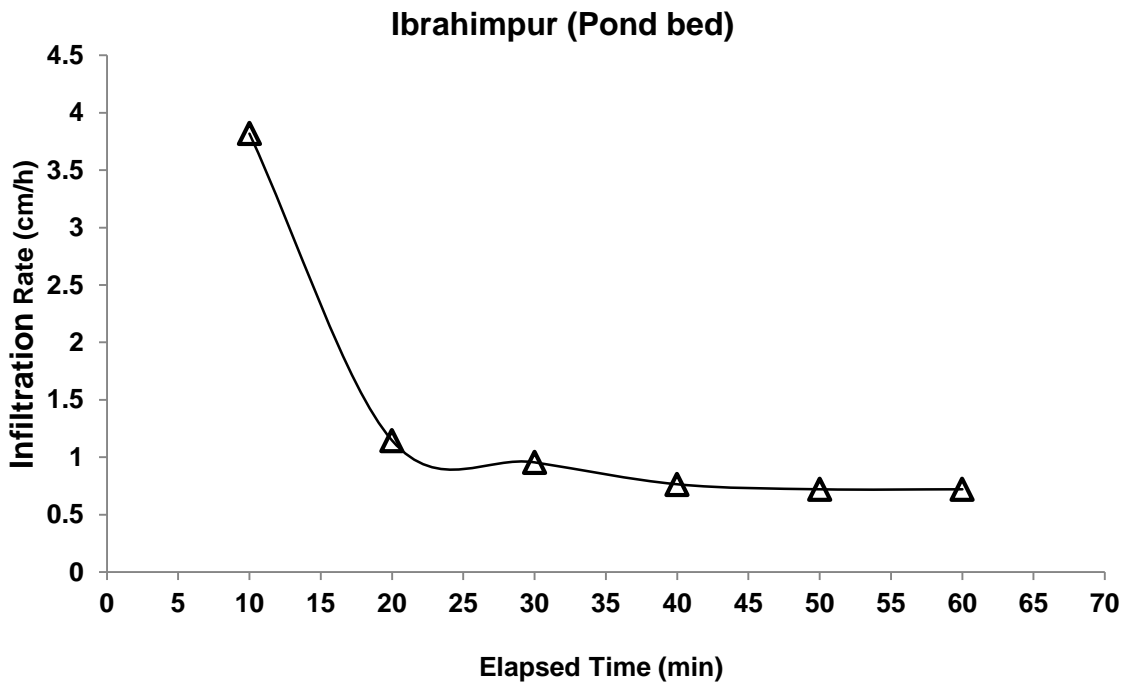
**Figure 5.14:** Performing infiltration tests in the study area under different land-uses

**Table 5.12:** Hydrologic soil groups in the Ibrahimpur Masahi Revenue village

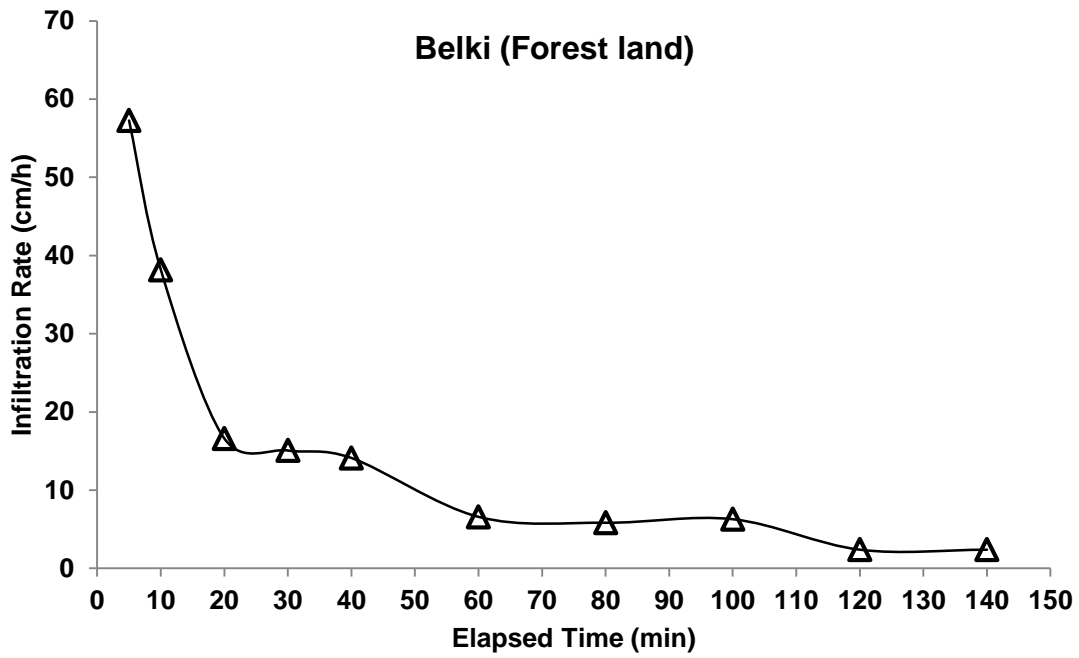
S.No.	Site	Landuse	Initial infiltration rate (cm/h)	Final infiltration rate (cm/h)	Hydrologic soil group
1	Ibrahimpur	Agriculture	9.8	1.96	A
2	Ibrahimpur	Pond	3.82	0.72	B
3	Belki	Forest Land	57.3	2.4	A
4	Inayatpur	Grass Land	3.12	1.1	A
5	Belki	Fallow Land	4.58	0.96	A



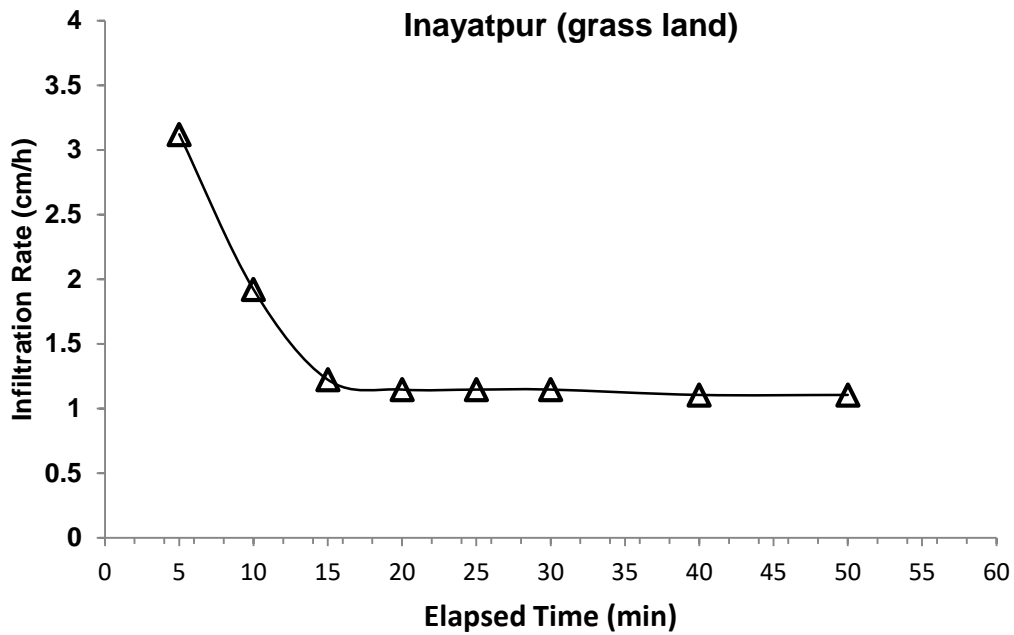
**Figure 5.15:** Infiltration rate under agriculture



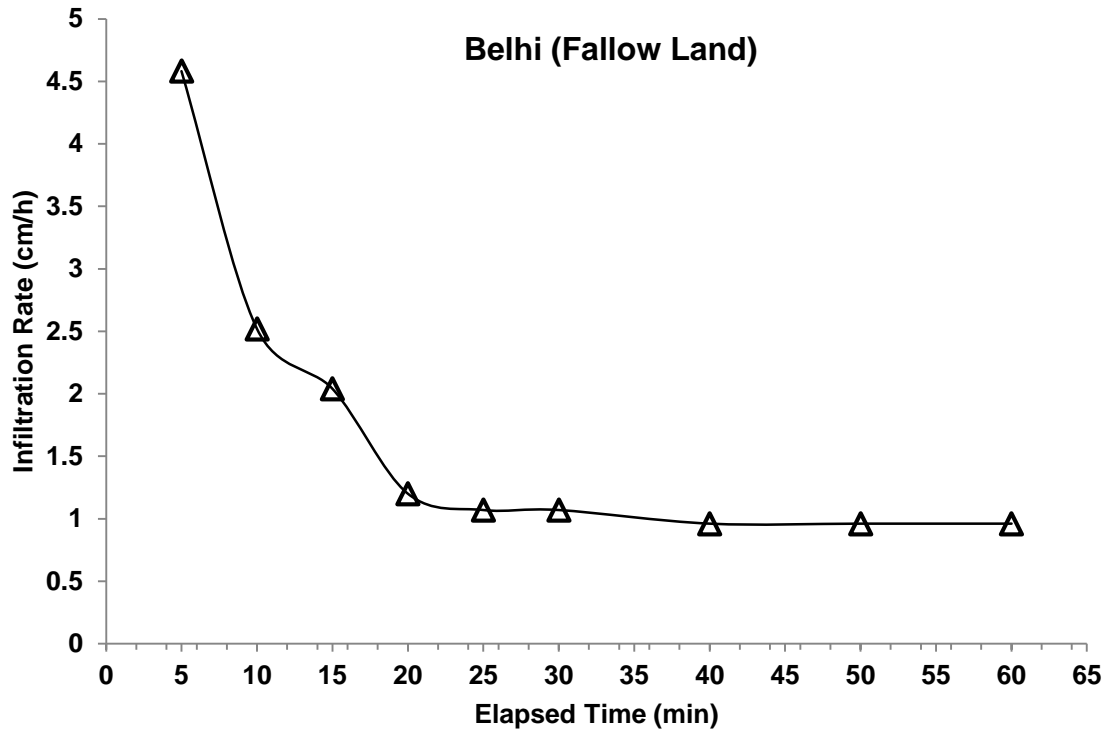
**Figure 5.16:** Infiltration rate under pond bed



**Figure 5.17:** Infiltration rate under forest land



**Figure 5.18:** Infiltration rate under grass land



**Figure 5.19:** Infiltration rate under fallow land

#### 5.2.2.2. Soil textural and soil moisture analysis

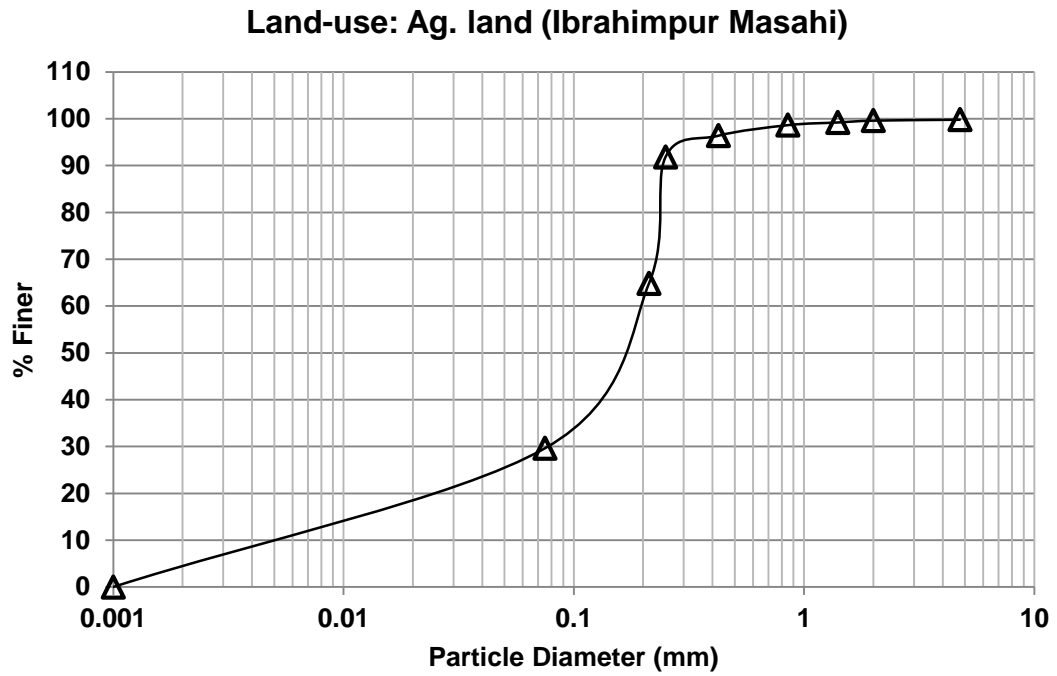
The soil samples were collected from different landuses in the study area. The particle size analysis of collected soil samples was carried out in the Soil & Water Lab of the Institute using mechanical sieve analysis (sieve sizes: 4.75 mm, 2.00 mm, 1.4 mm, 0.85 mm, 0.425 mm, 0.25 mm, 0.212 mm, 0.075 mm) and sedimentation analysis of soil collected at pan passing through 0.075 mm sieve using Master Sizer (Make: Malvern, Ver. 1.2b). The results of particle size analysis are given in **Table 5.13**. Based on the particle size analysis, the soil textures were obtained using USDA classification, as given **Table 5.14**. The particle size distribution curves of different landuses of the study area are given in **Figure 5.20** to **Figure 5.25**.

**Table 5.13:** Particle size analysis results of soil samples

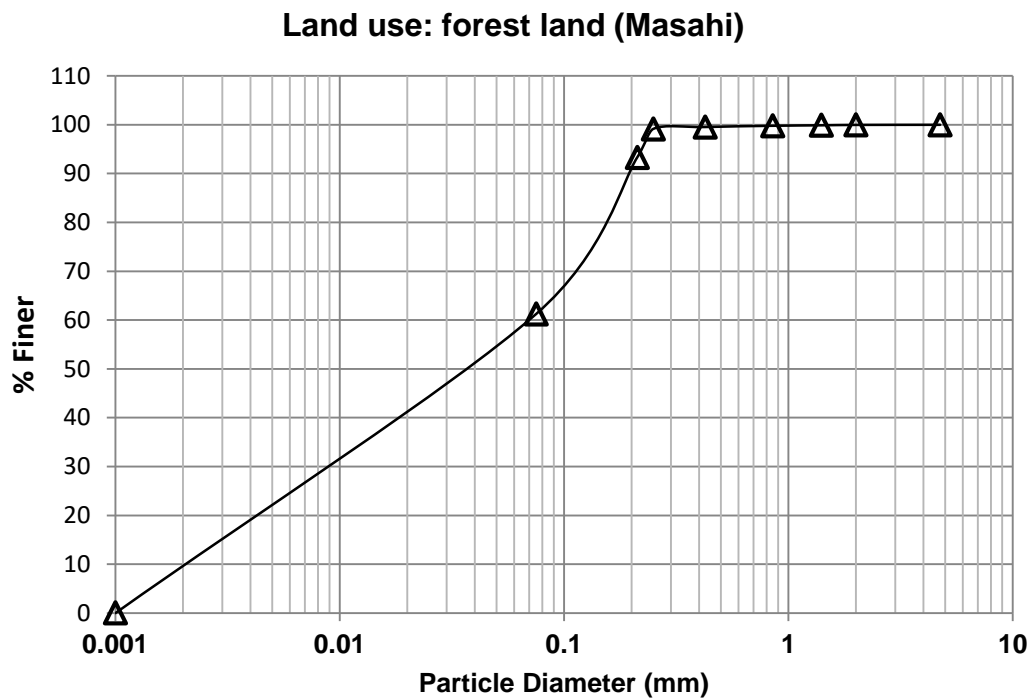
Particle Diameter (D), mm	% Finer					
	Agri. land (Ibrahimpur Masahi)	Forest land (Masahi)	Pond bed (Ibrahimpur Masahi)	Forest land (Belki)	Grass land (Inayatpur )	Fallow land (Belki)
4.75	99.82	99.96	100	100	100	100
2	99.62	99.94	100	100	100	100
1.4	99.23	99.86	99.88	99.98	100	99.99
0.85	98.65	99.76	99.61	99.92	99.99	99.96
0.425	96.4	99.51	99.36	99.73	99.94	99.48
0.25	91.81	99.12	99.14	99.03	99.76	97.24
0.212	64.82	93.28	98.14	87.04	93.67	78.59
0.075	29.64	61.21	90.35	27.58	43.43	47.52
0.001	0	0	0	0	0	0

**Table 5.14:** Soil texture of different soil samples in the study area (USDA Classification)

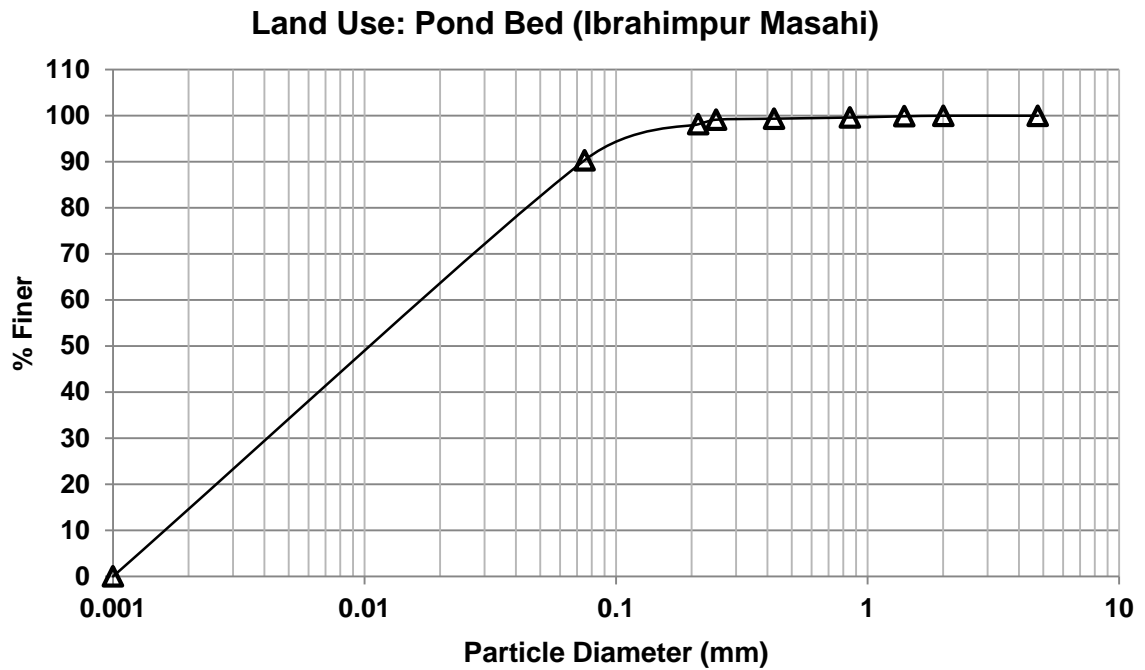
S.No.	Landuse	Soil Texture			Soil Type
		% Clay	% Silt	% Sand	
1.	Ag. Land (Ibrahimpur)	4	21	75	Loamy Sand
2.	Forest Land (Masahi)	9	46	45	Loam
3.	Pond Bed (Ibrahimpur)	15	68	17	Silt Loam
4.	Forest Land (Belki)	4	19	77	Loamy Sand
5.	Grass Land (Inayatpur)	7	31	62	Sandy Loam
6.	Fallow Land (Belki)	8	34	58	Sandy Loam



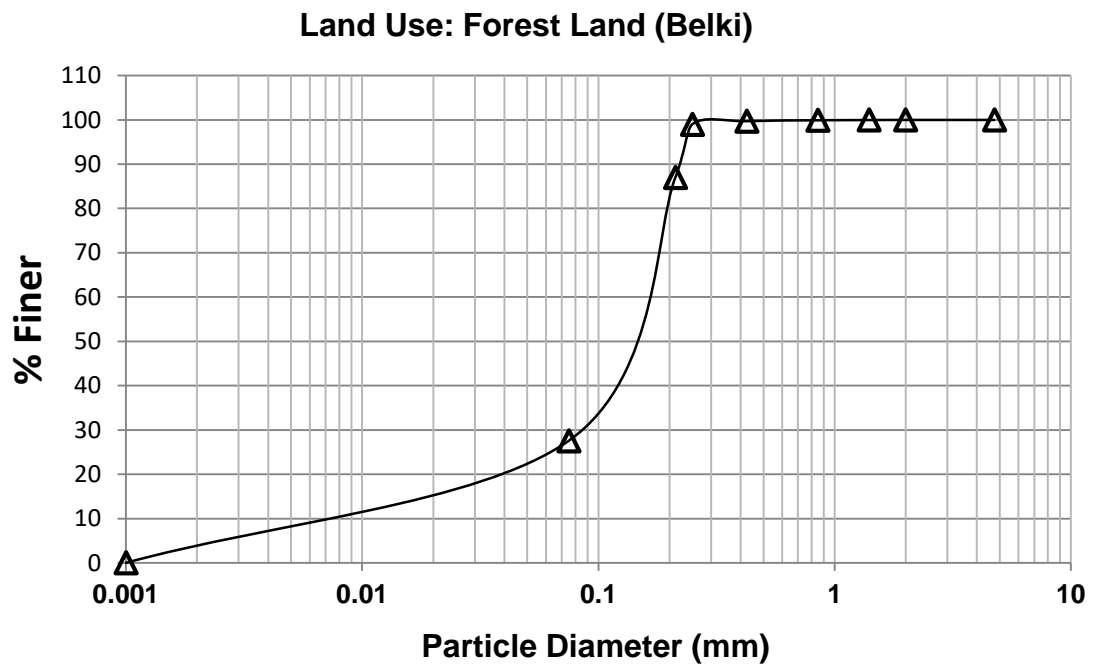
**Figure 5.20:** Particle size distribution curve of soil sample for agriculture land (Ibrahimpur)



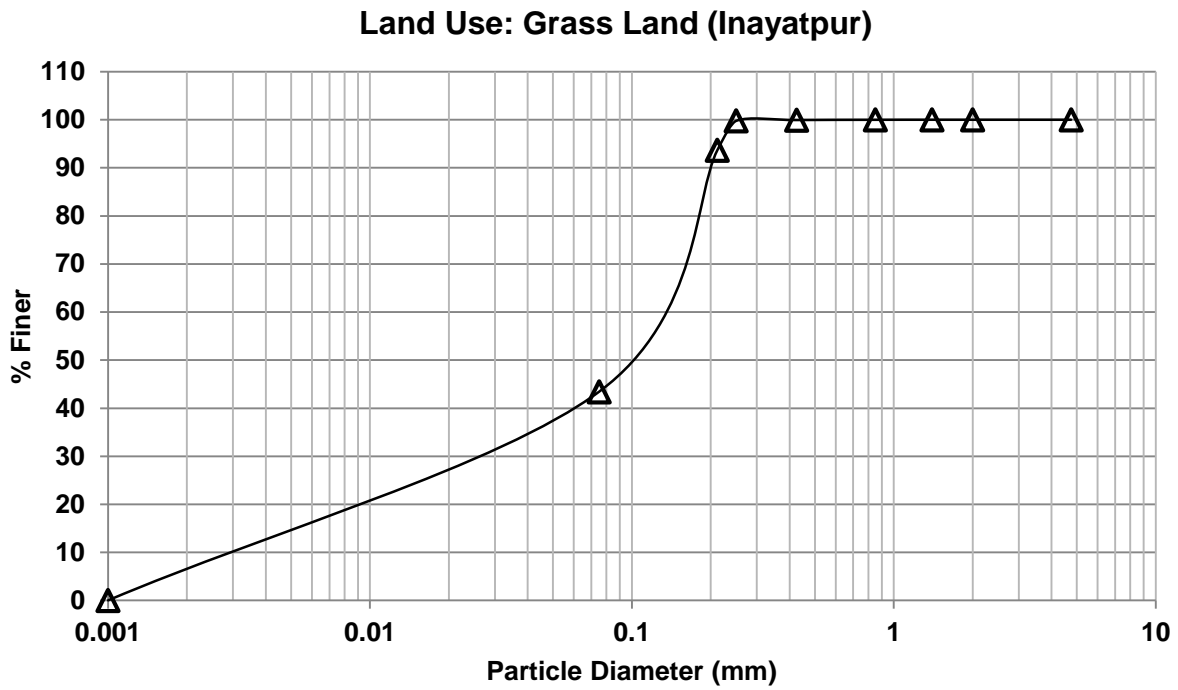
**Figure 5.21:** Particle size distribution curve of soil sample for forest land (Masahi)



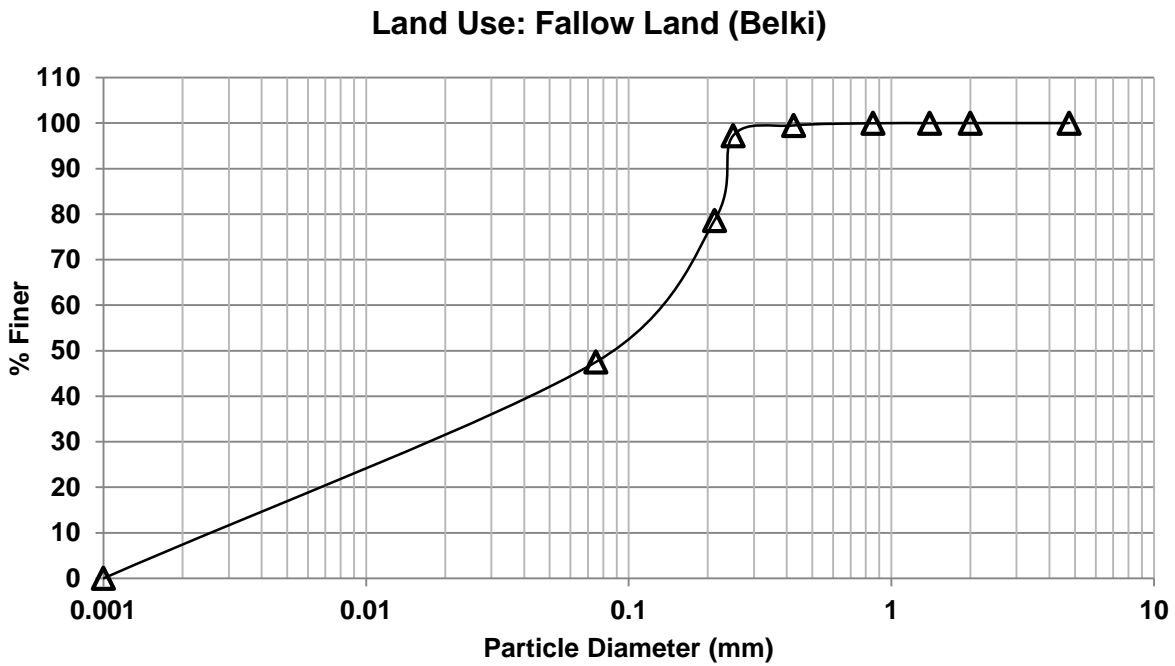
**Figure 5.22:** Particle size distribution curve of soil sample for pond bed (Ibrahimpur)



**Figure 5.23:** Particle size distribution curve of soil sample for forest land (Belki)



**Figure 5.24:** Particle size distribution curve of soil sample for grass land (Inayatpur)



**Figure 5.25:** Particle size distribution curve of soil sample for fallow land (Belki)

The soil samples were collected from surface (0-15cm) under different landuses during February, 2014. The moisture content of the soil samples was determined using gravimetric method. The results are given in **Table 5.15**. The soil moisture at 0-15 cm depth was obtained in the order of 12.00 % under agriculture, 13.62% to 16.32% under forest, 25.41% under pond bed, 17.62 % under grass land and 13.14 % under fallow land, respectively.

**Table 5.15:** Variation of soil moisture in the study area

S.No.	Landuse & location	Depth	Soil moisture (% dry basis)
1.	Agri. Land (Ibrahimpur)	0-15 cm	12.00
2.	Forest Land (Masahi)	0-15 cm	16.32
3.	Pond Bed (Ibrahimpur)	0-15 cm	25.41
4.	Forest Land (Belki)	0-15 cm	13.62
5.	Grass Land (Inayatpur)	0-15 cm	17.62
6.	Fallow Land (Belki)	0-15 cm	13.14

### 5.2.2.3. Determination of rainwater availability

The Monthly Rain Water Availability (MCM) at Ibrahimpur Masahi Revenue Village Level (area=14.26 Sq. km) and at watershed level upto Imlikhera bridge (area= 101.5 Sq. km) was estimated on the basis of 50% dependable Rainfall. The results are given in **Table 5.16**. Accordingly, the annual rainwater availability at village level was obtained 12.35 MCM and at watershed level (upto Imlikhera) in the order of 88 MCM, respectively.

### 5.2.2.4. Estimation of river discharge

In order to estimated daily discharge of the Shipla Halzora river at Imlikhera, velocity of water and water depth of the river was measured daily during 28.8.2014 to 30.9.2014 along the bridge (**Figure 5.26**). The discharge data is given in **Table 5.17**. The cross

section of the river was measuring once during the month and plotted in **Figure 5.27**. The velocity of the river was measured daily using current meter (**Figure 5.28**).

**Table 5.16:** Monthly rain water availability (MCM) at Ibrahimpur Masahi Revenue village level and watershed level on the basis of 50% dependable rainfall

Month	Rainfall (mm) at F= 50%	Rain Water Availability (MCM)	
		At Watershed Scale (upto Imlikhera bridge)	Ibrahimpur Masahi Revenue Village Scale
January	14.6	1.5	0.2
February	37.2	3.8	0.5
March	10.8	1.1	0.2
April	5.4	0.5	0.1
May	32.0	3.2	0.5
June	66.9	6.8	1
July	271.7	28	3.9
August	300.1	30	4.3
September	123.9	13	1.8
October	0.10	0	0
November	0.16	0	0
December	3.40	0.3	0
<b>Total</b>	<b>866.3</b>	<b>88</b>	<b>12</b>

The daily rivers discharge was estimated using the below given equation:

$$Q = A * V$$

Where, Q= river discharge ( $\text{m}^3/\text{s}$ ), A= cross section area of the river ( $\text{m}^2$ ), V= mean velocity of flowing water ( $\text{m}/\text{s}$ ). The river discharge varied from  $0.32 \text{ m}^3/\text{s}$  to  $14.7 \text{ m}^3/\text{s}$  (mean discharge:  $1.42 \text{ m}^3/\text{s}$ ) during 28.8.2014 to 30.9.2014. A plot of daily discharge along with rainfall is given in **Figure 5.29**.

**Table 5.17:** Data of discharge measurement for Shipla-Halzora River

Date	Time	Top of water level (from bridge) meter	Water level (meters)	Mean velocity (m/sec)	X- Area ( $\text{m}^2$ )	Q ( $\text{m}^3/\text{s}$ )
28-Aug-2014	10:30 AM	6.05	0.85	0.21	1.5	0.315
28-Aug-2014	6:18 PM	6.05	0.85	0.21	1.5	0.315
29-Aug-2014	10:10 AM	6	0.9	0.22	2.3	0.506
29-Aug-2014	5:45 PM	5	1.9	0.38	38.7	14.70 6
30-Aug-2014	9:55 AM	5.9	1	0.28	3.5	0.98
30-Aug-2014	5:00 PM	5.95	0.95	0.26	2.2	0.572
31-Aug-2014	9:40 AM	6	0.9	0.22	2.3	0.506
31-Aug-2014	4:00 PM	6	0.9	0.21	2.3	0.483
1-Sep-2014	10:25 AM	6	0.9	0.22	2.3	0.506
1-Sep-2014	5:45 PM	6	0.9	0.21	2.3	0.483
2-Sep-2014	10:00 AM	6.01	0.89	0.21	2.3	0.483
2-Sep-2014	5:45 PM	6.02	0.88	0.21	2.3	0.483
3-Sep-2014	10:30AM	6.02	0.88	0.21	2.2	0.462

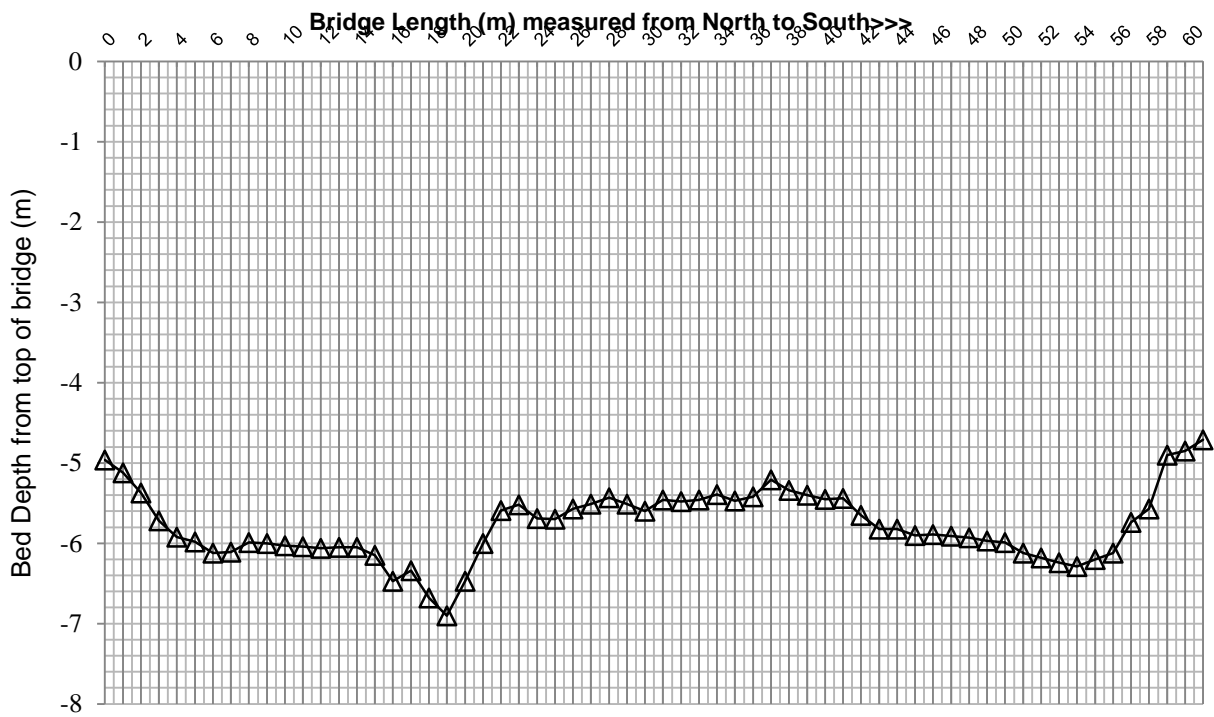
Date	Time	Top of water level (from bridge) meter	Water level (meters)	Mean velocity (m/sec)	X- Area (m <sup>2</sup> )	Q (m <sup>3</sup> /s)
3-Sep-2014	06:30PM	6.04	0.86	0.22	1.9	0.418
4-Sep-2014	10:50AM	6.02	0.88	0.22	2.1	0.462
4-Sep-2014	06:10PM	6.06	0.84	0.2	1.8	0.36
5-Sep-2014	10:30AM	6.02	0.88	0.22	2.2	0.484
5-Sep-2014	06:20PM	6	0.9	0.22	2.3	0.506
6-Sep-2014	10:00AM	5.35	1.55	0.35	22	7.7
6-Sep-2014	06:00PM	5.42	1.48	0.32	21.6	6.912
7-Sep-2014	08:00AM	5.85	1.05	0.24	3.4	0.816
7-Sep-2014	06:00PM	5.9	1	0.22	3.5	0.77
8-Sep-2014	10:00AM	5.84	1.06	0.24	3.4	0.816
8-Sep-2014	01:00PM	5.85	1.05	0.24	3.4	0.816
9-Sep-2014	10:15AM	5.9	1	0.23	3.5	0.805
9-Sep-2014	06:10PM	5.92	0.98	0.22	3.3	0.726
10-Sep-2014	06:00PM	5.97	0.93	0.22	2.9	0.638
11-Sep-2014	10:00AM	6	0.9	0.22	2.3	0.506
11-Sep-2014	06:00PM	5.98	0.92	0.22	2.3	0.506
12-Sep-2014	10:00AM	5.93	0.97	0.23	3.3	0.759
12-Sep-2014	06:00PM	5.62	1.28	0.28	11.2	3.136

Date	Time	Top of water level (from bridge) meter	Water level (meters)	Mean velocity (m/sec)	X- Area (m <sup>2</sup> )	Q (m <sup>3</sup> /s)
13-Sep-2014	10:00AM	5.47	1.43	0.32	14.7	4.704
13-Sep-2014	06:00PM	5.5	1.4	0.31	14.6	4.526
14-Sep-2014	10:00AM	5.53	1.37	0.31	14.5	4.495
14-Sep-2014	06:00PM	5.59	1.31	0.29	11.3	3.277
15-Sep-2014	10:30AM	5.7	1.2	0.27	8.1	2.187
15-Sep-2014	06:30PM	5.9	1	0.24	3.5	0.84
16-Sep-2014	10:00 AM	5.94	0.96	0.23	3.3	0.759
16-Sep-2014	6:00 PM	6	0.9	0.22	2.3	0.506
17-Sep-2014	10:00AM	6.01	0.89	0.22	2.3	0.506
17-Sep-2014	6:00 PM	6.03	0.87	0.21	2.1	0.441
18-Sep-2014	10:15 AM	6.02	0.88	0.22	2.1	0.462
18-Sep-2014	6:30 PM	6.01	0.89	0.22	2.2	0.484
19-Sep-2014	10:15 AM	6	0.9	0.22	2.3	0.506
19-Sep-2014	6:45 PM	6	0.9	0.22	2.3	0.506
20-Sep-2014	10:00 AM	6.01	0.89	0.22	2.3	0.506
20-Sep-2014	6:00 PM	6.02	0.88	0.22	2.3	0.506
21-Sep-2014	10:00 AM	6.01	0.89	0.22	2.3	0.506
21-Sep-2014	6:00 PM	6.01	0.89	0.22	2.3	0.506

<b>Date</b>	<b>Time</b>	<b>Top of water level (from bridge) meter</b>	<b>Water level (meters)</b>	<b>Mean velocity (m/sec)</b>	<b>X- Area (m<sup>2</sup>)</b>	<b>Q (m<sup>3</sup>/s)</b>
22-Sep-2014	10:00 AM	6.02	0.88	0.22	2.3	0.506
22-Sep-2014	6:00 PM	6.01	0.89	0.22	2.3	0.506
23-Sep-2014	9:45 AM	6.02	0.88	0.22	2.2	0.484
23-Sep-2014	6:00 PM	6.02	0.88	0.22	2.2	0.484
24-Sep-2014	10:00 AM	6.02	0.88	0.22	2.2	0.484
24-Sep-2014	6:00 PM	6.01	0.89	0.22	2.3	0.506
25-Sep-2014	9:45 AM	6.02	0.88	0.22	2.2	0.484
25-Sep-2014	6:00 PM	6.02	0.88	0.22	2.2	0.484
26-Sep-2014	10:00AM	6.03	0.87	0.22	2.1	0.462
26-Sep-2014	06:00PM	6.02	0.88	0.22	2.2	0.484
27-Sep-2014	10:00AM	6.02	0.88	0.22	2.2	0.484
27-Sep-2014	06:00PM	6.02	0.88	0.22	2.2	0.484
28-Sep-2014	10:00AM	6.01	0.89	0.23	2.3	0.529
28-Sep-2014	06:00PM	6.02	0.88	0.22	2.2	0.484
29-Sep-2014	10:00AM	6.03	0.87	0.22	2.1	0.462
29-Sep-2014	06:00PM	6.03	0.87	0.22	2.1	0.462
30-Sep-2014	10:00AM	6.04	0.86	0.22	2.1	0.462
30-Sep-2014	06:00PM	6.04	0.86	0.22	2.1	0.462



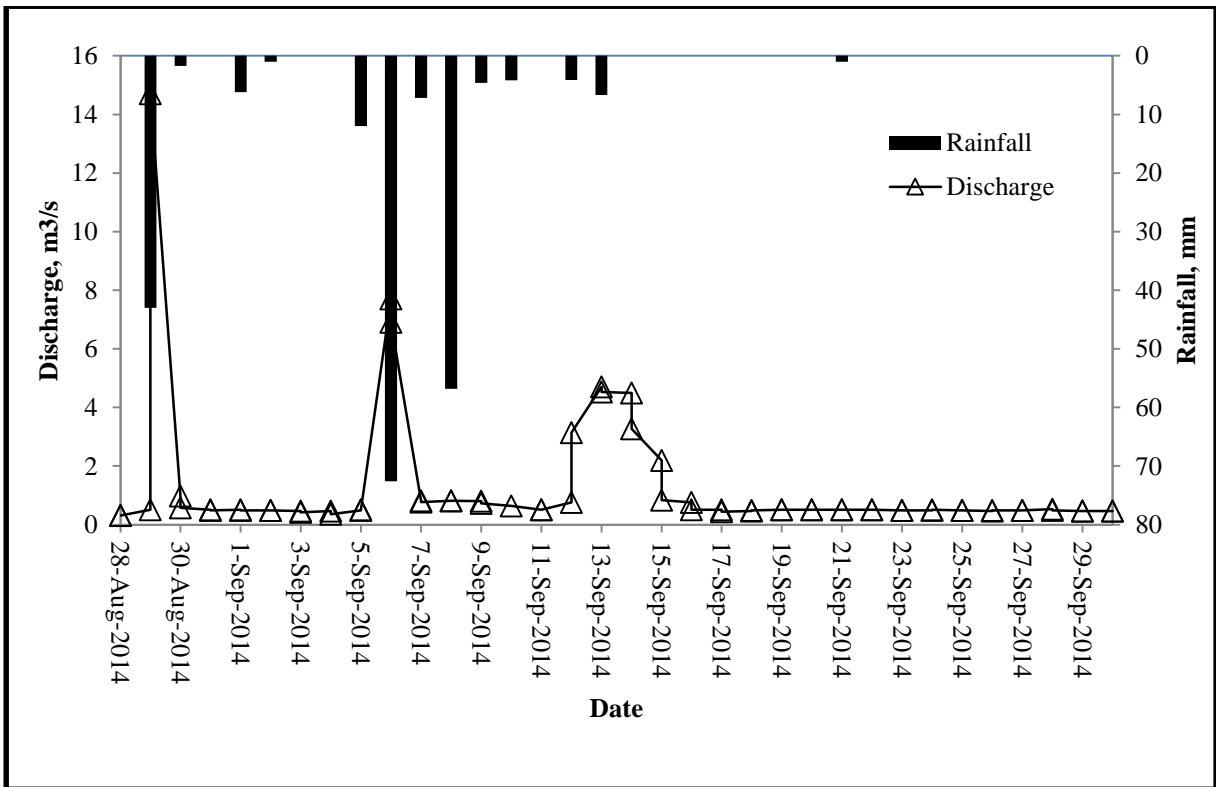
**Figure 5.26:** Cross section of the Shipla-Halzora River near bridge at Imlikhera



**Figure 5.27:** Cross section of the Shipla-Halzora river near bridge at Imlikhera



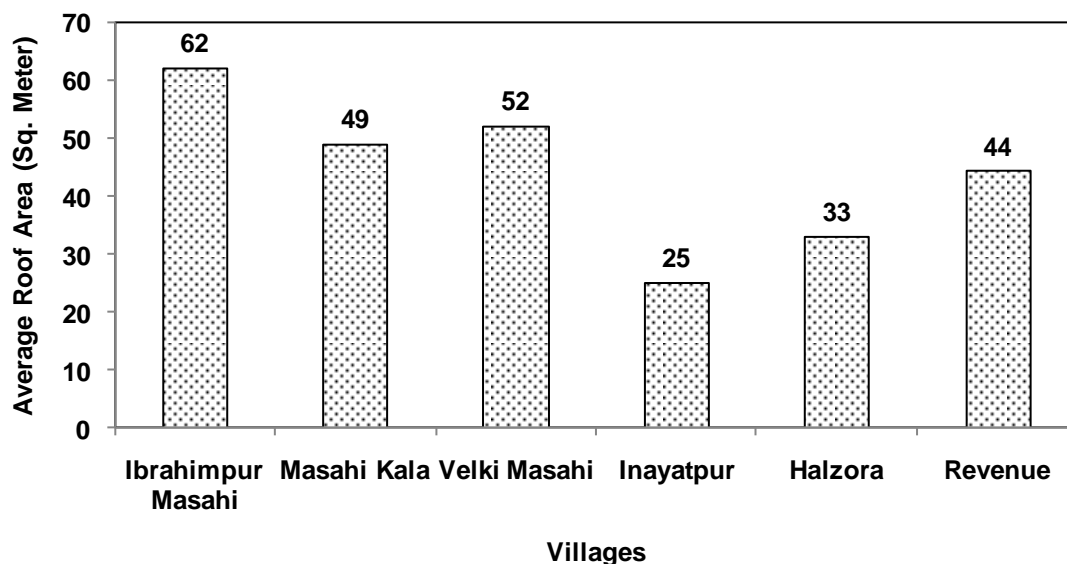
**Figure 5.28:** View of measuring stream velocity in the river using current meter



**Figure 5.29:** Variation of discharge in Shipla-Halzora River at Imlikhera, Dist. Haridwar

### 5.3. Assessment of rainwater harvesting potential in Ibrahimpur Masahi Revenue Village

During assessment of rainwater harvesting potential in Ibrahimpur Revenue Villages, roof-top method was adopted. The average available rooftop per household in Revenue Villages was calculated based on the actual dimensions of roofs taken during the survey and data collection (detailed data presented in Annexure I). Average available roof-top areas were calculated for all the villages (depicted in **Figure 5.30**).



**Figure 5.30:** Average roof-top area available per household in Ibrahimpur Revenue Villages

Further, average rainwater harvesting potential ( $m^3$ / month) of each household were estimated based on the available roof-top area. During estimation of rainwater harvesting potential, the runoff coefficient (RC) was taken as 0.85 (Rahman et al. 2010). Subsequently, monthly rainwater harvesting potential for all the Revenue Villages were estimated based on 30 years average rainfall data of Roorkee region as well as the frequency level of 50% and 75%, respectively.

Monthly, rainwater harvesting potential as well as demand and supply deficit for all the Revenue Villages are given in the subsequent sections.

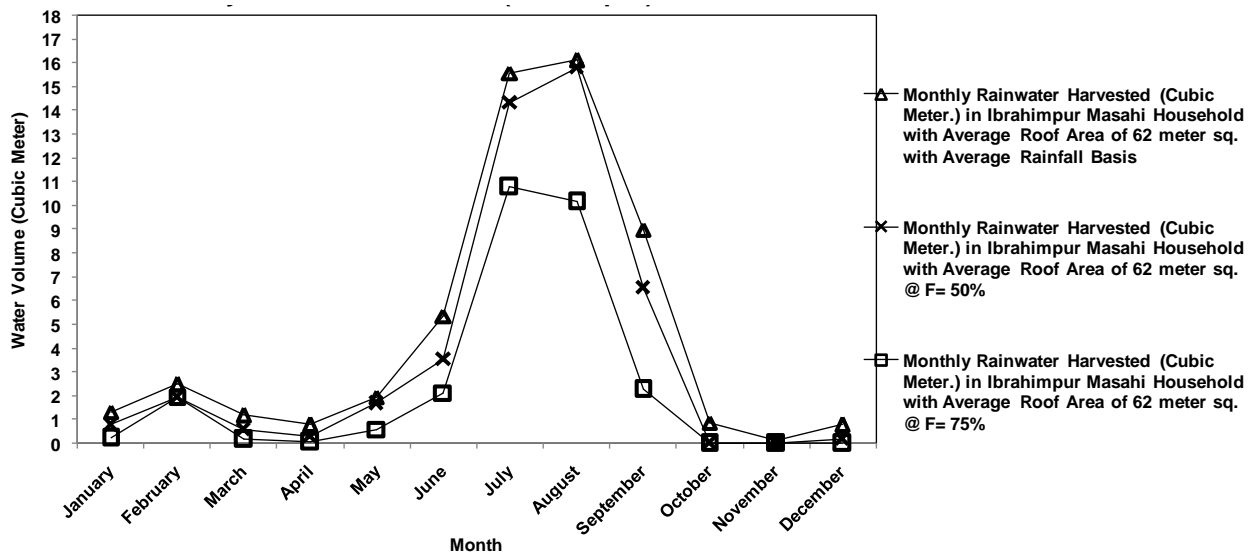
### 5.3.1. Sub-village- Ibrahimpur Masahi: Rainwater harvesting potential and demand-deficit analyses

Based on the roof-top area analyses, the average roof-top area of 62m<sup>2</sup> per household was found in sub-village- Ibrahimpur Masahi. This average roof-top area was used in estimation of rainwater harvesting potential per household on monthly bases. During estimation of rainwater harvesting potential, assessment were made based on three scenarios, first on the basis of average rainfall (calculated from 30 years rainfall data), second based on 50% frequency and third based on 75% rainfall frequency, respectively. The amount of potential rainwater harvested on monthly basis for all the three scenarios in Ibrahimpur Masahi is depicted in **Table 5.18** and **Figure 5.31**.

**Table 5.18:** Monthly rainwater harvesting potential per household (average roof-top area of 62 m<sup>2</sup>) for Sub-village- Ibrahimpur Masahi

Month	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall data of 27 years (1053 mm)	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall @ F= 50% (866 mm)	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall @ F= 75% (537mm)
January	1.30	0.77	0.21
February	2.48	1.96	1.95
March	1.18	0.57	0.14
April	0.79	0.28	0.04
May	1.94	1.69	0.60
June	5.36	3.53	2.12
July	15.59	14.32	10.78
August	16.13	15.82	10.18
September	8.99	6.53	2.26
October	0.85	0.01	0.00
November	0.14	0.01	0.00
December	0.77	0.18	0.01
<b>Total (m<sup>3</sup>)</b>	<b>55.50</b>	<b>45.65</b>	<b>28.28</b>

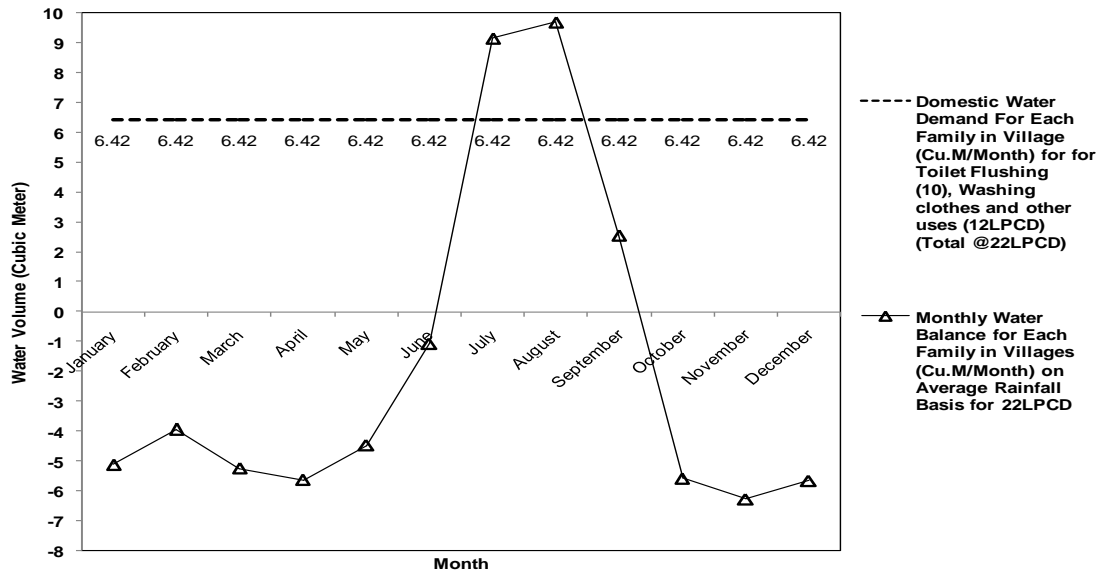
It was observed from the Table 5.18 and Figure 5.31 that during the four months (June to October) have the plenty of rainfall and rest of eight months have very little rainfall.



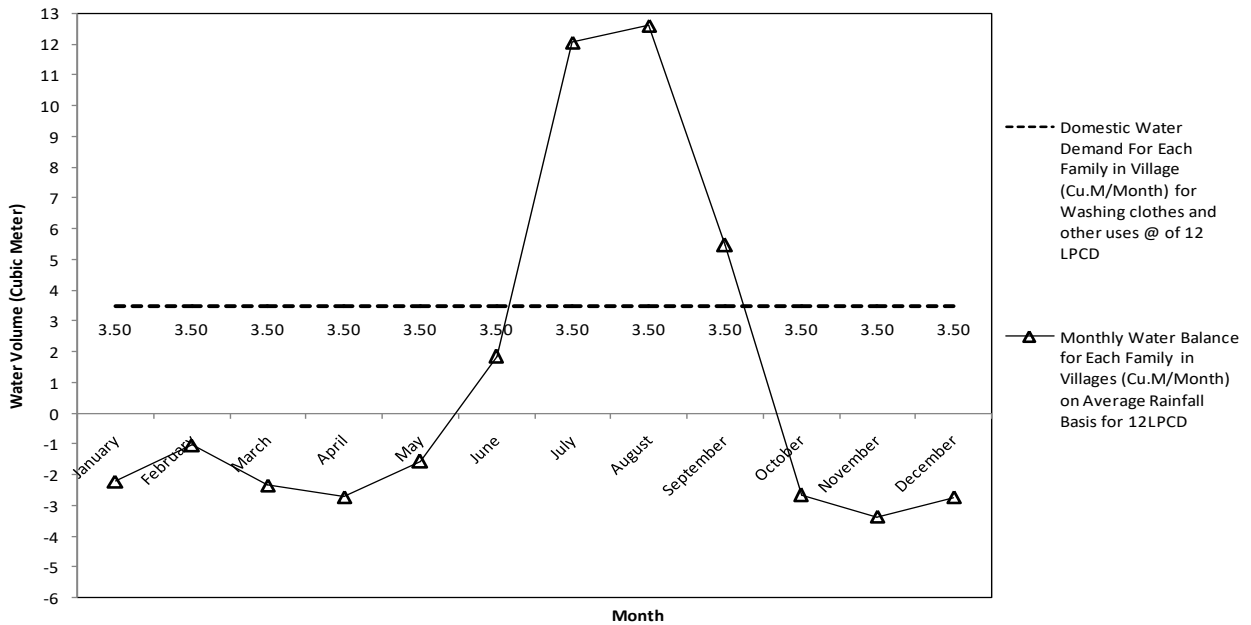
**Figure 5.31:** Monthly rainwater harvested at average rainfall and other frequencies levels (50% & 75%) for Ibrahimpur Masahi

Further, rainfall estimated based on the average yearly rainfall data were used in feasibility assessment of water harvesting potential in the study area of Ibrahimpur Masahi, which seems to highest when compared with the estimated rainfall based on the rainfall frequencies of 50% and 75%. To maximize the availability of water for the important daily sanitation activities, feasibility assessment based on monthly water balance were made for two scenario; first, supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) and second, supply of water @ 12LPCD (washing clothes). The results of these two scenarios have been depicted in **Figure 5.32** and **Figure 5.33**.

In case of water supply @ 22LPCD (toilet flushing, washing of clothes and other uses only), monthly water demand of 6.42m<sup>3</sup> was estimated in Ibrahimpur Masahi which should be available round the years for fulfilling these demands. It was observed from the Figure 5.32 that this water demand (@ 22LPCD) can be fulfilled from month of June (middle days) to about third week of September. However, at the same time (July to September) rainwater seems to be in surplus, therefore, appropriate rainwater harvesting tank need to be constructed in order to fulfil the water supply during the remaining months.



**Figure 5.32:** Monthly water balance for supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) for each family in Ibrahimpur Masahi



**Figure 5.33:** Monthly water balance for supply of water @ 12LPCD (washing clothes) for each family in Ibrahimpur Masahi

Further, In case of water supply @12LPCD (washing of clothes and other uses only), the average monthly water demand of 3.50m<sup>3</sup> per family in Ibrahimpur Masahi was estimated

which should be available round the years for fulfilling the demand. It was observed from the Figure 5.33 that this water demand (@12LPCD) can be fulfilled from month of June to about second week of October. However, disparity during months from June to September, rainwater seems to be in surplus, therefore, appropriate rainwater harvesting tank need to be established in order to fulfil the water supply in the remaining months.

Further, trends were observed in monthly water harvesting potential and monthly water balance for other Ibrahimpur Revenue Villages which are depicted in the following sections.

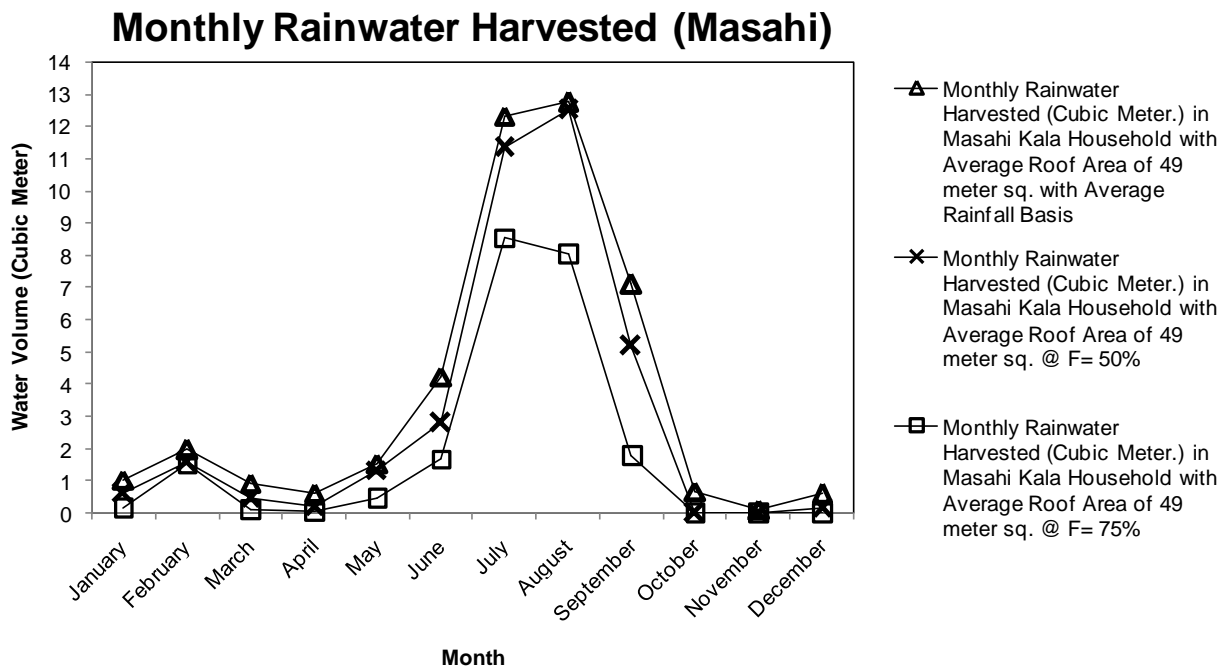
### 5.3.2. Sub-village- Masahi Kala: Rainwater harvesting potential and demand-deficit analyses

**Table 5.19:** Monthly rainwater harvesting potential per household (average roof-top area of 49m<sup>2</sup>) for Sub-village- Masahi Kala

Month	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall data of 27 years (1053 mm)	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall @ F= 50% (866 mm)	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall @ F= 75% (537mm)
January	1.03	0.61	0.16
February	1.96	1.55	1.54
March	0.93	0.45	0.11
April	0.62	0.22	0.03
May	1.54	1.33	0.47
June	4.24	2.79	1.67
July	12.32	11.32	8.52
August	12.74	12.50	8.05
September	7.10	5.16	1.78
October	0.67	0.00	0.00
November	0.11	0.01	0.00
December	0.61	0.14	0.01
<b>Total (m<sup>3</sup>)</b>	<b>43.86</b>	<b>36.08</b>	<b>22.35</b>

Based on the roof-top area analyses, the average roof-top area of 49m<sup>2</sup> per household was found in sub-village- Masahi Kala. This average roof-top area was used in estimation of rainwater harvesting potential per household on monthly bases in the village. As earlier discussed, during estimation of rainwater harvesting potential, assessment were made based on three scenarios, first on the basis of average rainfall (calculated from 30 years rainfall data), second based on 50% frequency and third based on 75% rainfall frequency, respectively. The amount of potential rainwater harvested on monthly basis for all the three scenarios in Masahi Kala is depicted in **Table 5.19** and **Figure 5.34**.

It was observed from the Table 5.19 and Figure 5.34 that during the four months (June to October) have the plenty of rainfall and rest of eight months have very little rainfall.

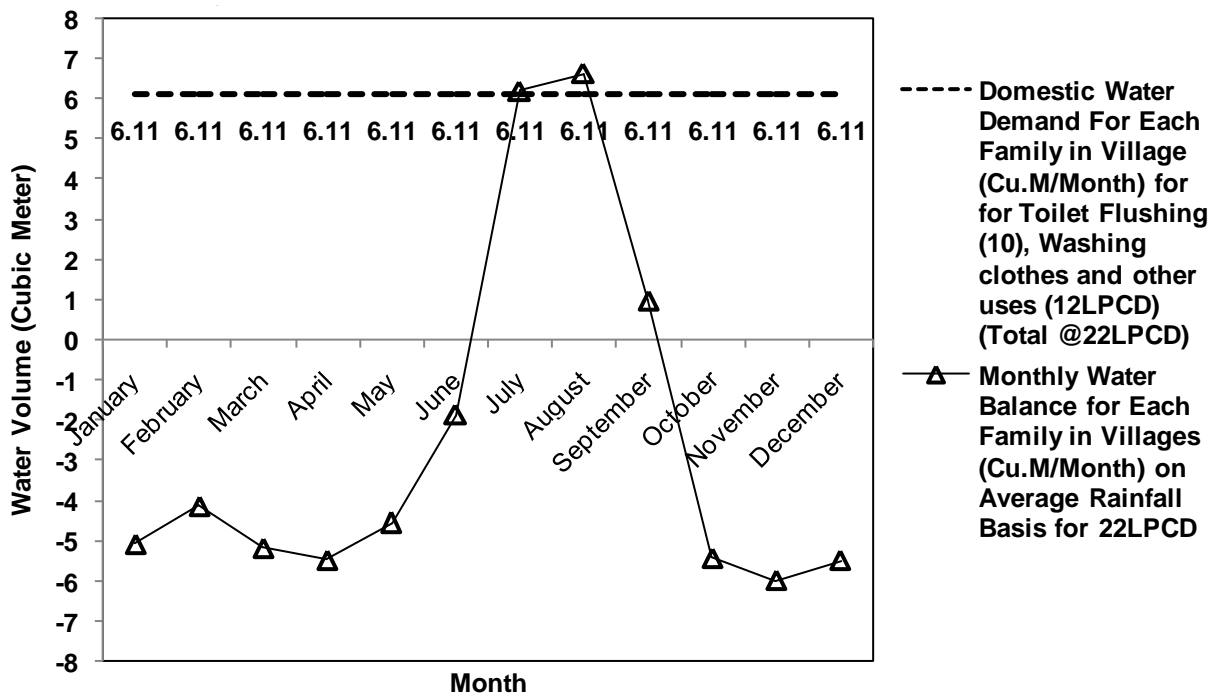


**Figure 5.34:** Monthly rainwater harvested at average rainfall and other frequencies (50% & 75%) for Masahi Kala

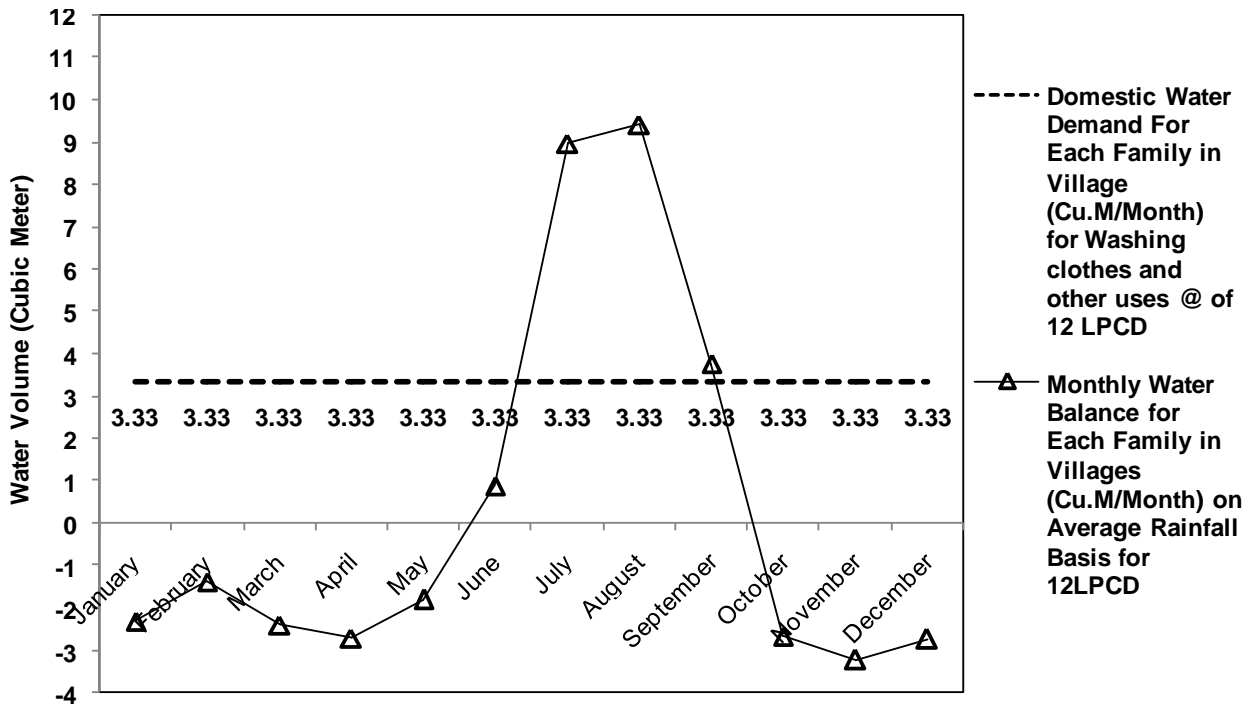
Further, rainfall estimated based on the average yearly rainfall data were used in feasibility assessment of water harvesting potential in the study area of Masahi Kala, which seems to highest when compared with the estimated rainfall based on the rainfall frequencies of 50% and 75%. To maximize the availability of water for the important daily sanitation

activities, feasibility assessment based on monthly water balance were made for two scenario; first, supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) and second, supply of water @ 12LPCD (washing clothes). The results of these possibilities have been depicted in **Figure 5.35** and **Figure 5.36**.

In case of water supply @ 22LPCD (toilet flushing, washing of clothes and other uses only), monthly water demand of  $6.11\text{m}^3$  was estimated in Masahi Kala which should be available round the years for fulfilling these demands. It was observed from the Figure 5.35 that this water demand (@ 22LPCD) can be fulfilled from month of June (middle days) to about third week of September. However, at the same time (July to September) rainwater seems to be in surplus, therefore, appropriate rainwater harvesting tank need to be constructed in order to fulfil the water supply during the remaining months.



**Figure 5.35:** Monthly water balance for supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) for each family in Masahi Kala



**Figure 5.36:** Monthly water balance for supply of water @ 12LPCD (washing clothes) for each family in Masahi Kala

Further, In case of water supply @12LPCD (washing of clothes and other uses only), the average monthly water demand of 3.33m<sup>3</sup> per family in Masahi Kala was estimated which should be available round the years for fulfilling the demand. It was observed from the Figure 5.36 that this water demand (@12 LPCD) can be fulfilled from month of June to October. However, disparity during months from June to September, rainwater seems to be in surplus, therefore, appropriate rainwater harvesting tank need to be established in order to fulfil the water supply in the remaining months.

**5.3.3. Sub-village- Belki Masahi: Rainwater harvesting potential and demand-deficit analyses**

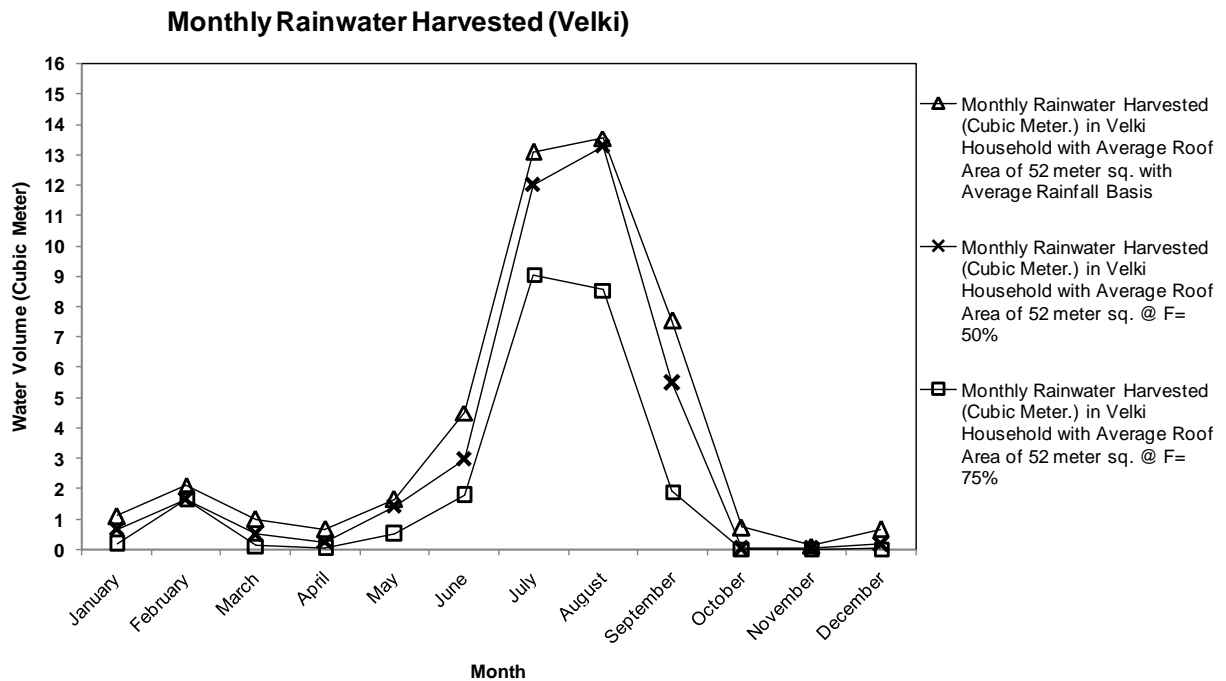
The average roof-top area of 52m<sup>2</sup> per household was found in sub-village- Belki Masahi. This average roof-top area was used in estimation of rainwater harvesting potential per household on monthly bases in the village. The amount of potential rainwater harvested on

monthly basis for all the three scenarios in **Belki Masahi** is depicted in **Table 5.20** and **Figure 5.37**.

**Table 5.20:** Monthly rainwater harvesting potential per household (average roof-top area of 52m<sup>2</sup>) for Sub-village- Belki Masahi

Month	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall data of 27 years (1053 mm)	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall @ F= 50% (866 mm)	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall @ F= 75% (537mm)
January	1.09	0.65	0.17
February	2.08	1.64	1.64
March	0.99	0.48	0.12
April	0.66	0.24	0.04
May	1.63	1.41	0.50
June	4.50	2.96	1.78
July	13.07	12.01	9.04
August	13.53	13.26	8.54
September	7.54	5.48	1.89
October	0.71	0.00	0.00
November	0.11	0.01	0.00
December	0.65	0.15	0.01
<b>Total (m<sup>3</sup>)</b>	<b>46.55</b>	<b>38.29</b>	<b>23.72</b>

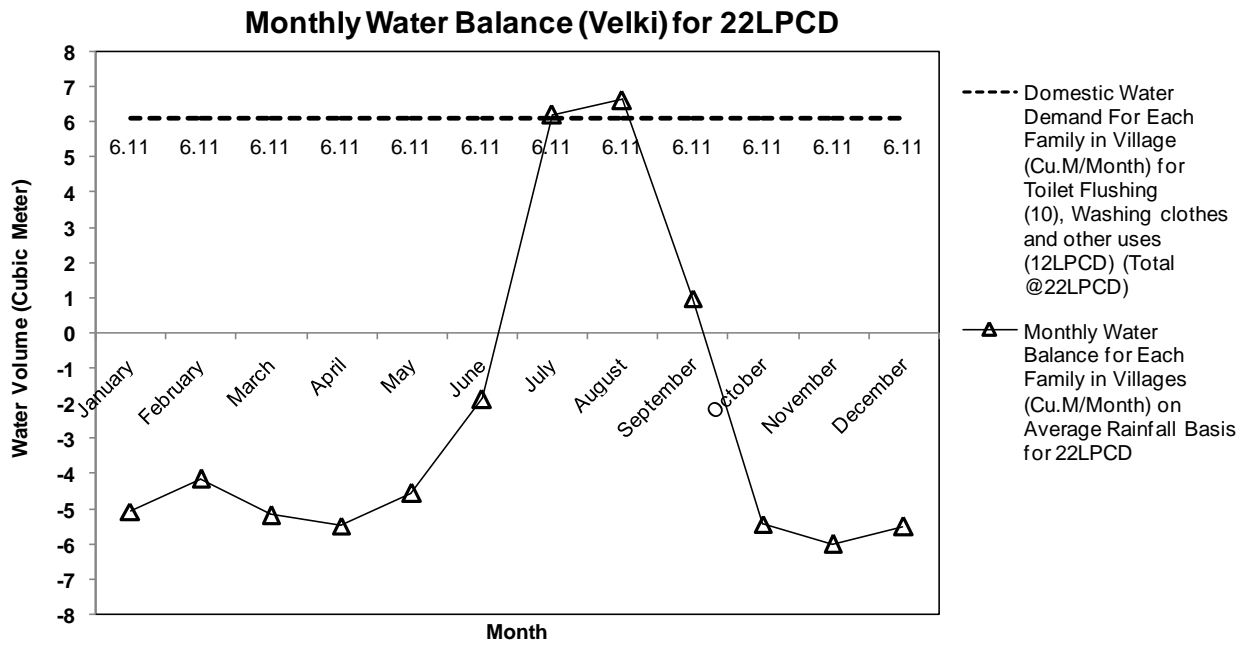
It was observed from the Table 5.20 and Figure 5.37 that during the four months (July to September) have the plenty of rainfall and rest of eight months have very little rainfall.



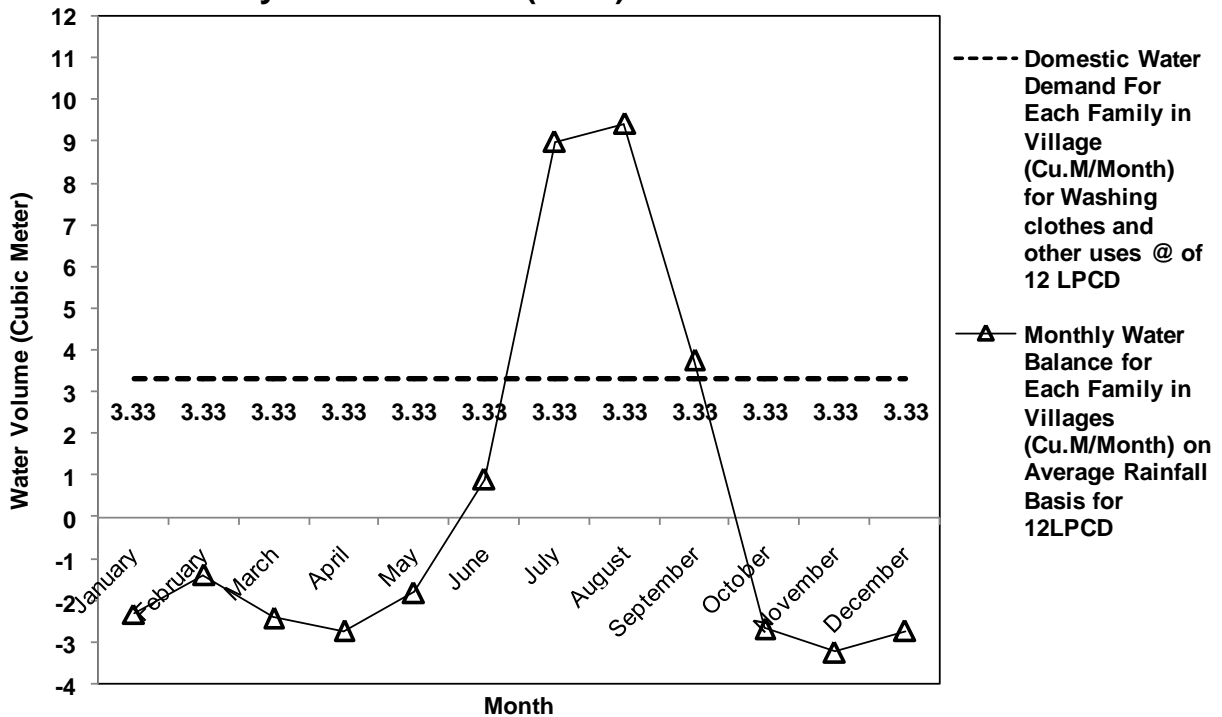
**Figure 5.37:** Monthly rainwater harvested at average rainfall and other frequencies (50% & 75%) for Belki Masahi

The availability of water for the important daily sanitation activities, feasibility assessment based on monthly water balance were made for two scenario; first, supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) and second, supply of water @ 12LPCD (washing clothes). The results of these possibilities have been depicted in **Figure 5.38** and **Figure 5.37**.

In case of water supply @ 22LPCD (toilet flushing, washing of clothes and other uses only), monthly water demand of  $6.11\text{m}^3$  was estimated in Belki Masahi which should be available round the years for fulfilling these demands. It was observed from the Figure 5.38 that this water demand (@ 22LPCD) can be fulfilled during July and August. However, at the same time rainwater seems to be in surplus, therefore, appropriate rainwater harvesting tank need to be constructed in order to fulfil the water supply during the remaining months.



**Figure 5.38:** Monthly water balance for supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) for each family in Belki Masahi



**Figure 5.39:** Monthly water balance for supply of water @ 12LPCD (washing clothes) for each family in Belki Masahi

Further, In case of water supply @12LPCD (washing of clothes and other uses only), the average monthly water demand of 3.33m<sup>3</sup> per family in Belki Masahi was estimated which should be available round the years for fulfilling the demand. It was observed from the **Figure 5.39** that this water demand (@12LPCD) can be fulfilled from month of May (about 3<sup>rd</sup> week) to September (about 3<sup>rd</sup> week). However, disparity during months from June to September, rainwater seems to be in surplus, therefore, appropriate rainwater harvesting tank need to be established in order to fulfil the water supply in the remaining months.

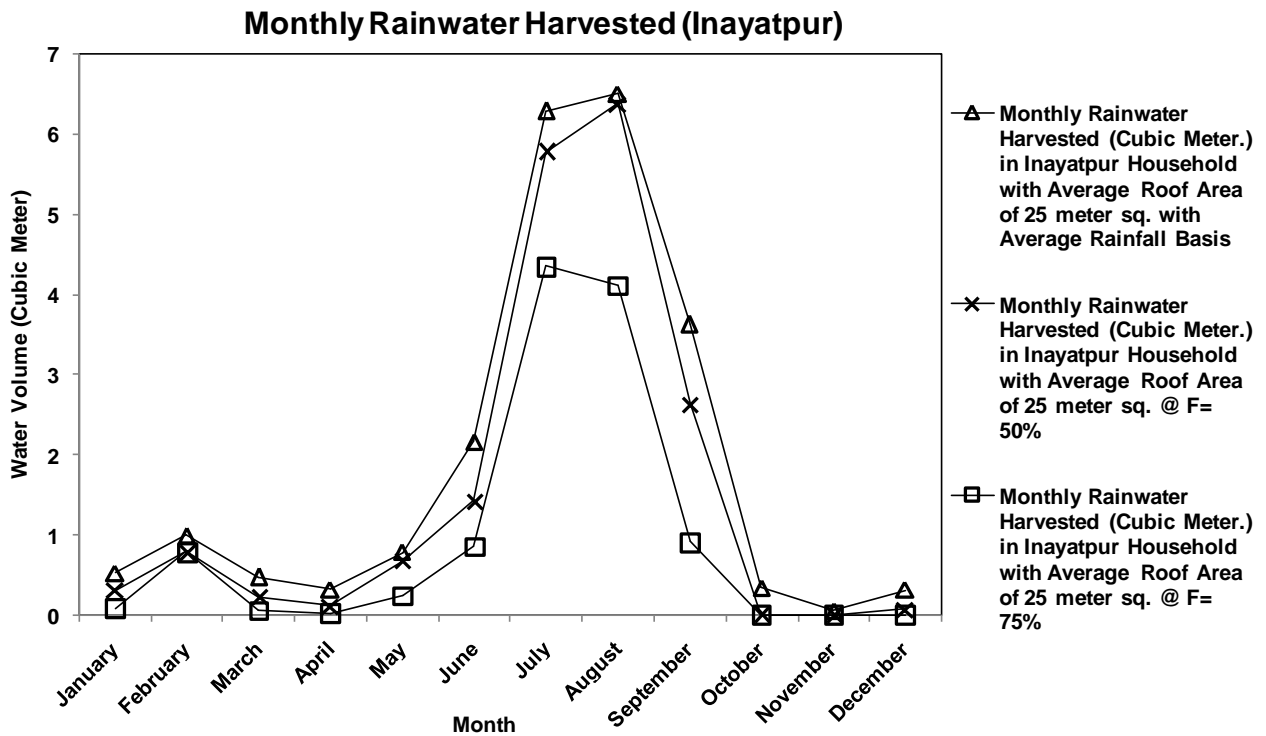
#### 5.3.4. Sub-village- Inayatpur: Rainwater harvesting potential and demand-deficit analyses

**Table 5.21:** Monthly rainwater harvesting potential per household (average roof-top area of 25 m<sup>2</sup>) for Sub-village- Inayatpur

Month	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall data of 27 years (1053 mm)	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall @ F= 50% (866 mm)	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall @ F= 75% (537mm)
January	0.52	0.31	0.08
February	1.00	0.79	0.79
March	0.47	0.23	0.06
April	0.32	0.11	0.02
May	0.78	0.68	0.24
June	2.16	1.42	0.85
July	6.29	5.77	4.35
August	6.50	6.38	4.11
September	3.62	2.63	0.91
October	0.34	0.00	0.00
November	0.06	0.00	0.00
December	0.31	0.07	0.00
<b>Total (m<sup>3</sup>)</b>	<b>22.38</b>	<b>18.41</b>	<b>11.40</b>

The average roof-top area of 25m<sup>2</sup> per household was found in sub-village- Inayatpur. This average roof-top area was used in estimation of rainwater harvesting potential per household on monthly bases in the village. The amount of potential rainwater harvested on monthly basis for all the three scenarios in Inayatpur is depicted in **Table 5.21** and **Figure 5.40**.

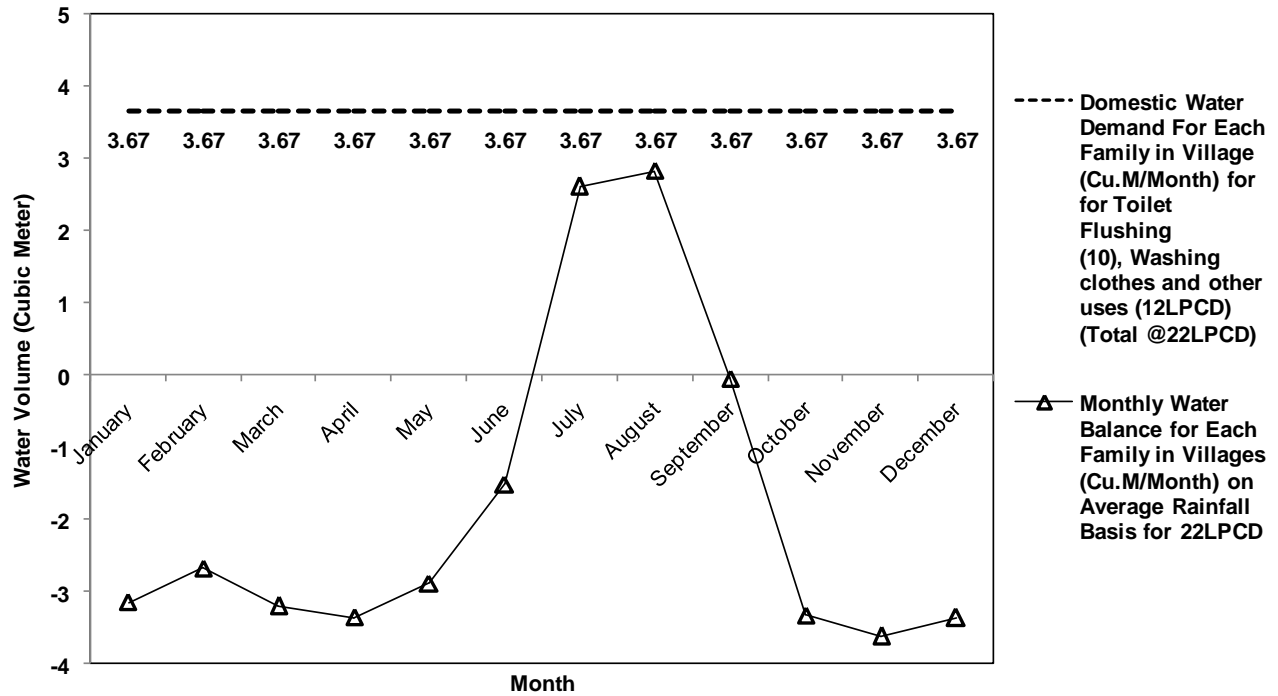
It was observed from the Table 5.21 and Figure 5.40 that during the four months (July to September) have the plenty of rainfall and rest of months have very little rainfall.



**Figure 5.40:** Monthly rainwater harvested at average rainfall and other frequencies (50% & 75%) for Inayatpur

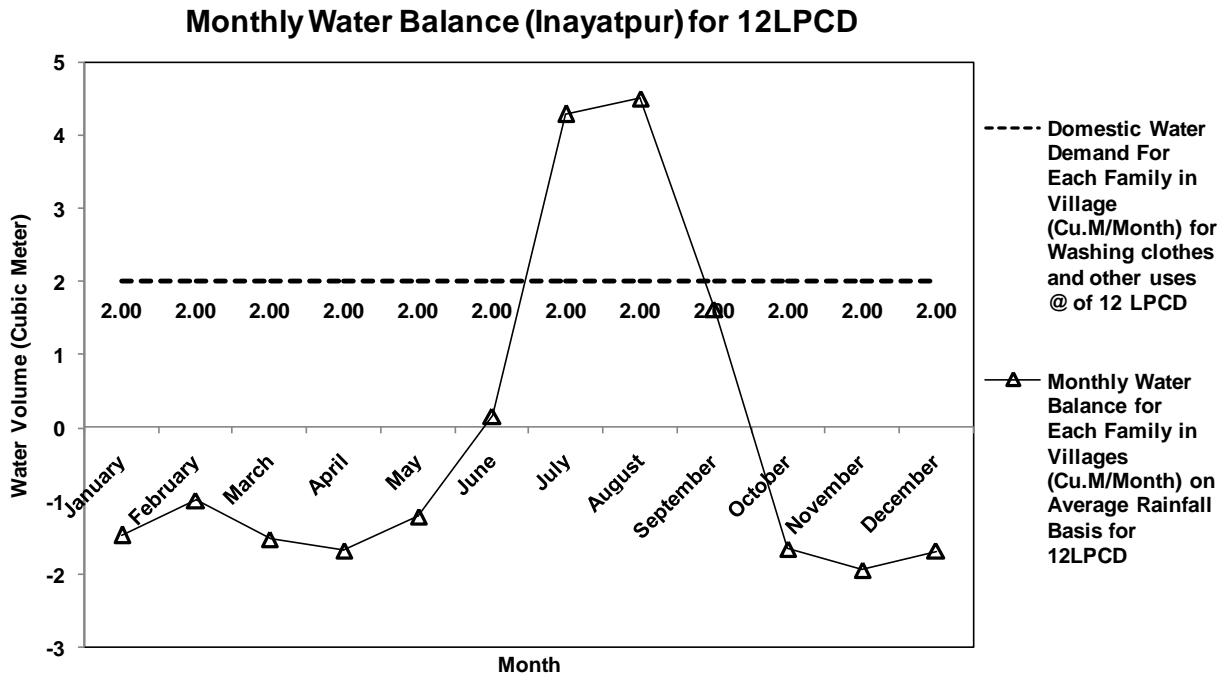
The availability of water for the important daily sanitation activities, feasibility assessment based on monthly water balance were made for two scenario; first, supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) and second, supply of water @ 12LPCD (washing clothes). The results of these possibilities have been depicted in **Figure 5.41** and **Figure 5.42**.

In case of water supply @ 22LPCD (toilet flushing, washing of clothes and other uses only), monthly water demand of 3.67m<sup>3</sup> was estimated in Inayatpur which should be available round the years for fulfilling these demands. It was observed from the Figure 5.41 that this water demand (@ 22LPCD) cannot be fulfilled in any month of the year. This was happened due to lower roof-top area available in the sub-village Inayatpur.



**Figure 5.41:** Monthly water balance for supply of water @ 22LPCD (Toilet Flushing, Washing clothes and other uses only) for each family in Inayatpur

Further, In case of water supply @12LPCD (washing of clothes and other uses only), the average monthly water demand of 2.00m<sup>3</sup> per family in Inayatpur was estimated which should be available round the years for fulfilling the demand. It was observed from the **Figure 5.42** that this water demand (@12LPCD) can be fulfilled from month of June (about 3<sup>rd</sup> week) to September. However, disparity during months from June to September, rainwater seems to be in surplus, therefore, appropriate rainwater harvesting tank need to be established in order to fulfil the water supply in the remaining months.



**Figure 5.42:** Monthly water balance for supply of water @ 12LPCD (washing clothes) for each family in Inayatpur

**5.3.5. Sub-village- Halzora: Rainwater harvesting potential and demand-deficit analyses**

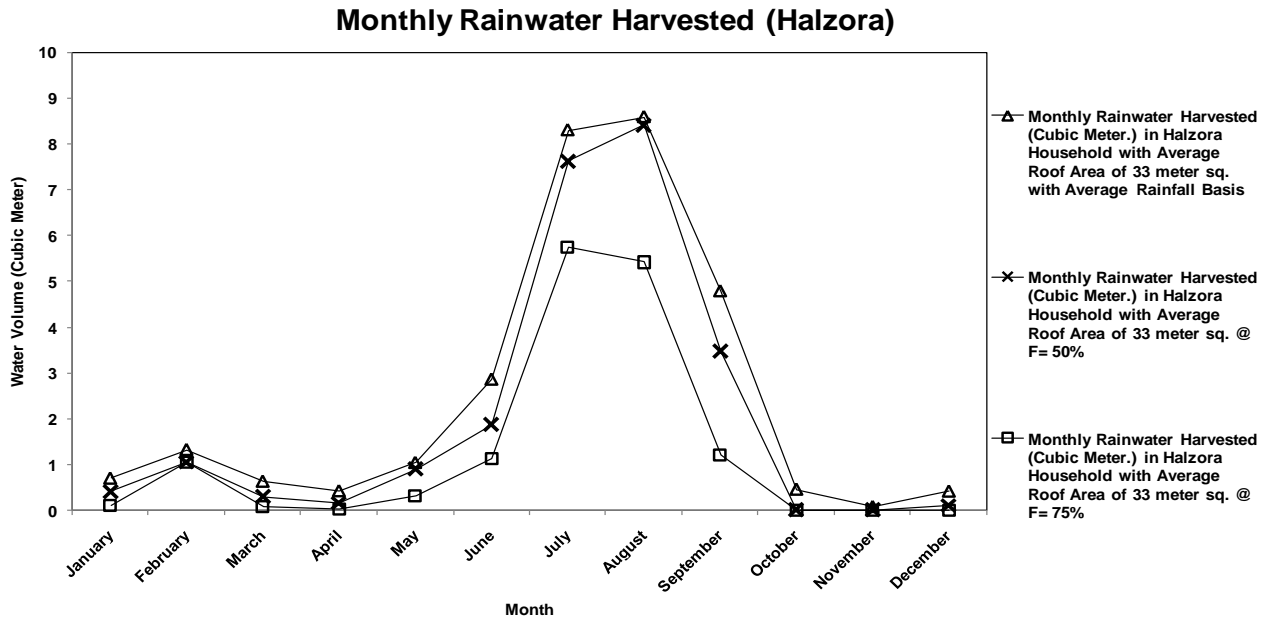
The average roof-top area of 33m<sup>2</sup> per household was found in sub-village- Halzora. This average roof-top area was used in estimation of rainwater harvesting potential per household on monthly bases in the village. The amount of potential rainwater harvested on monthly basis for all the three scenarios in Halzora is depicted in **Table 5.22** and **Figure 5.43**.

**Table 5.22:** Monthly rainwater harvesting potential per household (average roof-top area of 33 m<sup>2</sup>) for Sub-village- Halzora

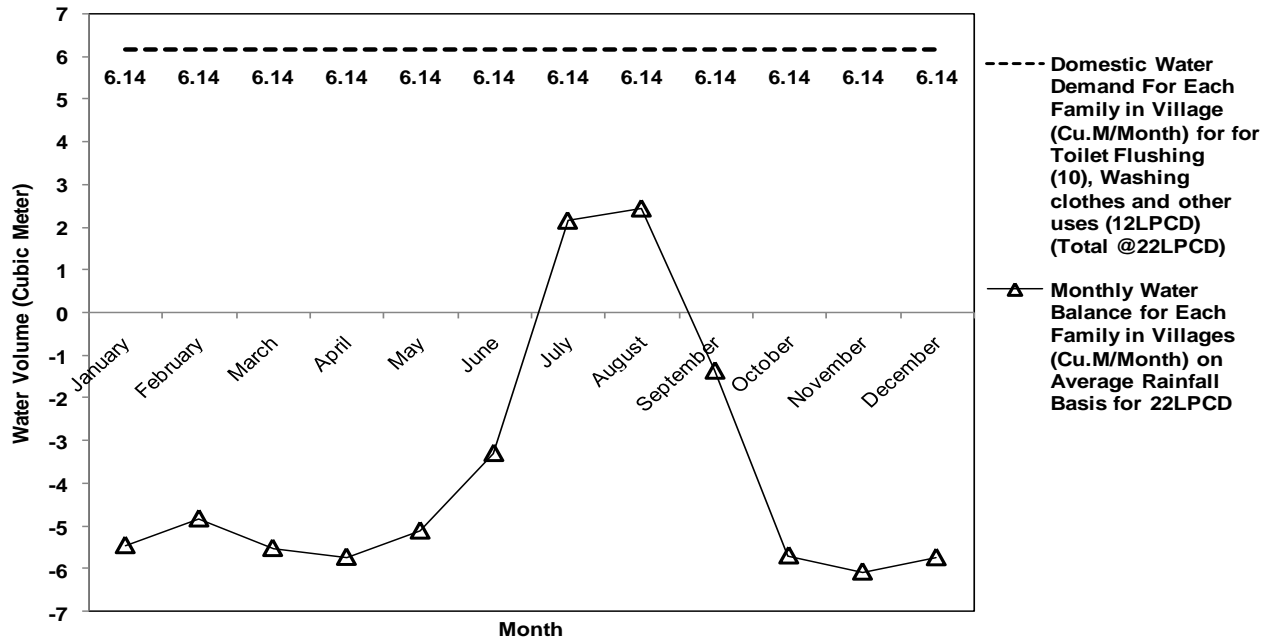
Month	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall data of 27 years (1053 mm)	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall @ F= 50% (866 mm)	Monthly rainwater harvested (m <sup>3</sup> ) based on average rainfall @ F= 75% (537mm)
January	0.52	0.31	0.08
February	1.00	0.79	0.79
March	0.47	0.23	0.06
April	0.32	0.11	0.02
May	0.78	0.68	0.24
June	2.16	1.42	0.85
July	6.29	5.77	4.35
August	6.50	6.38	4.11
September	3.62	2.63	0.91
October	0.34	0.00	0.00
November	0.06	0.00	0.00
December	0.31	0.07	0.00
<b>Total (m<sup>3</sup>)</b>	<b>22.38</b>	<b>18.41</b>	<b>11.40</b>

It was observed from the Table 5.22 and Figure 5.43 that during the four months (July to September) have the plenty of rainfall and rest of eight months have very little rainfall.

The availability of water for the important daily sanitation activities, feasibility assessment based on monthly water balance were made for two scenario; first, supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) and second, supply of water @ 12LPCD (washing clothes). The results of these possibilities have been depicted in **Figure 5.44** and **Figure 5.45**.

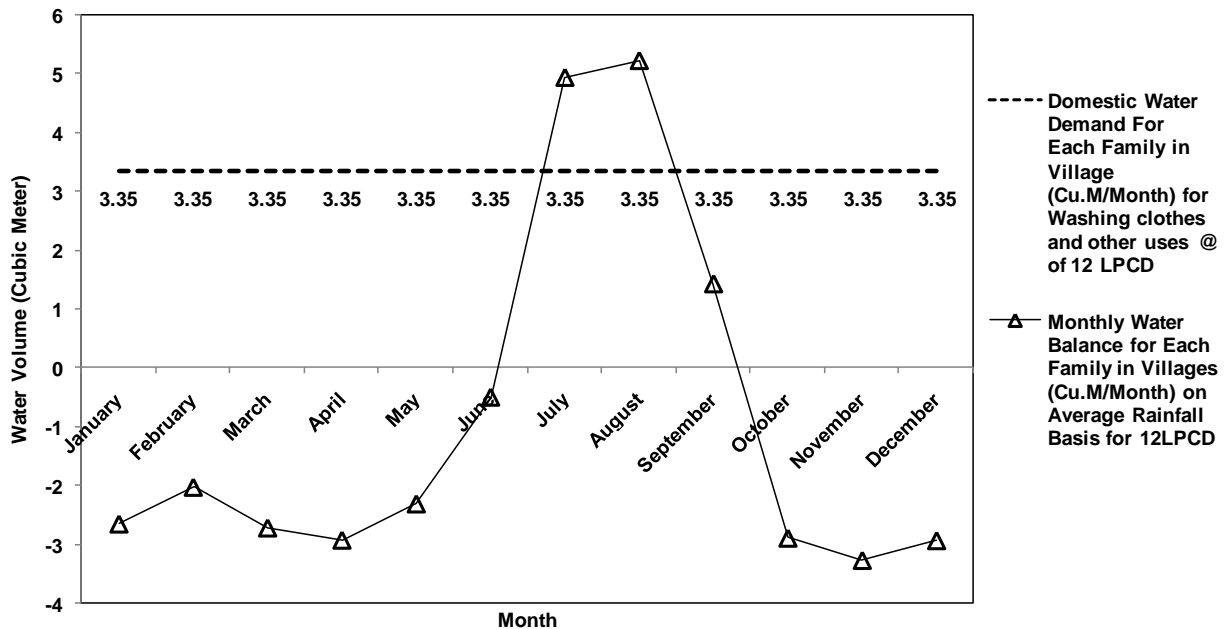


**Figure 5.43:** Monthly rainwater harvested at average rainfall and other frequencies (50% & 75%) for Halzora



**Figure 5.44:** Monthly water balance for supply of water @ 22LPCD (toilet flushing, washing clothes and other uses only) for each family in Halzora

In case of water supply @ 22LPCD (toilet flushing, washing of clothes and other uses only), monthly water demand of 6.14m<sup>3</sup> was estimated in Halzora which should be available round the years for fulfilling these demands. It was observed from the Figure 5.44 that this water demand (@ 22LPCD) cannot be fulfilled in any month of the year. This was happened due to lower roof-top area available in the sub-village Halzora.



**Figure 5.45:** Monthly water balance for supply of water @ 12LPCD (washing clothes) for each family in Halzora

Further, In case of water supply @12LPCD (washing of clothes and other uses only), the average monthly water demand of 3.35m<sup>3</sup> per family in Halzora was estimated which should be available round the years for fulfilling the demand. It was observed from the **Figure 5.45** that this water demand (@12LPCD) can be fulfilled from month of June to August. However, disparity during months from June to August, rainwater seems to be in surplus, therefore, appropriate rainwater harvesting tank need to be established in order to fulfil the water supply in the remaining months.

## 5.4. Water quality status of the study area

The water quality investigations were carried out in the study area during March, 2014 and January, 2015, respectively (**Figure 5.46**). Water samples were collected from different sources pertaining to surface water (viz., ponds, drains to ponds, and river) and ground water (viz., hand pumps, tube-well). The water quality was assessed for drinking (IS: 10500-2012) and irrigation (IS:11624-1986) purposes. The results are described as below:

### 5.4.1. Water quality investigations during March, 2014

The location details of water quality sampling program for the March, 2014 is given in **Table 5.23**. The water quality parameters include: pH, EC, TDS, hardness, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium, magnesium, BOD (**Figure 5.47**), total coliform and faecal coliform (**Figure 5.48**) for river, pond, drain and groundwater sources (**Table 5.24 to Table 5.27**).

The suitability of water for irrigation was evaluated as per BIS norms (IS:11624-1986) and relevant irrigation water quality parameters are given in **Table 5.28**. All the water samples pertaining to river, ponds and groundwater lie under low salinity class. However, drain water samples were found under medium and high salinity class. Therefore, drain water should be avoid for direct use in irrigation. The water quality rating based on SAR values lie under low class for all sources (river, ponds, drain, groundwater) under the study. Water quality rating based on residual sodium carbonate (RSC) indicates drain water representing high to very high class. Some samples from the ponds were also indicated high value of RSC in the study (**Table 5.29 to Table 5.31**).

The drinking water quality was evaluated based on limited water quality parameters using BIS norms (IS: 10500-2012). The results are given in Table 5.31, which indicate exceeding acceptable limit as per BIS norms for total hardness (92% samples), total dissolved solids (58% samples), calcium (8% samples), magnesium (75% samples) and alkalinity (100% samples) in the study area for ground water mostly extracted from hand-pumps. It may be recommended to remove the temporary hardness of water by either boiling the water or by using any appropriate water purifier before drinking.



**Figure 5.46:** Water quality monitoring in the study area **(a)** water quality monitoring from tubewell in the study area, **(b)** water quality monitoring from Halzora river in the study area, **(c)** water quality monitoring from pond in the study area, **(d)** water quality monitoring from hand pump in the study area.

**Table 5.23:** Location details of water quality sampling during March, 2014

<b>S.No.</b>	<b>Location</b>	<b>Source</b>	<b>Latitude</b>	<b>Longitude</b>
1.	Halzora Nadi	River	29°58'21"	77°53'43.08"
2.	Shilpa Nadi	River	29°57'15.94"	77°51'44.89"
3.	Ibrahimpur	Pond	29°58'24.35"	77°53'22.29"
4.	Ibrahimpur-Masai Road	Pond	29°59'4.94"	77°53'12.35"
5.	Masai	Pond	29°59'22.97"	77°53'10.86"
6.	Inayatpur	pond	30°0'54.4"	77°53'38.35"
7.	Drain to Pond, Masai	Drain	29°59'23.19"	77°53'10.71"
8.	Drain to Pond, Ibrahimpur	Drain	29°58'23.24"	77°53'24.2"
9.	Ibrahimpur	HP	29°58'23.24"	77°53'23.52"
10.	Primary School Ibrahimpur	HP	29°58'22.81"	77°53'40.91"
11.	Lal Singh Public School, Masahi	HP	29°59'17.37"	77°53'12.11"
12.	H/o Mr. Satya Pal Saini, Masahi	HP	29°59'23.41"	77°53'7.63"
13.	Primary School, Belki	HP	30°0'11.87"	77°52'43.73"
14.	H/O Dhanpal, Belki	HP	30°8'21.49"	77°52'39.74"
15.	Primary School, Halzora	HP	30°01'49.99"	77°53'7.61"
16.	H/o Mehraban, Halzora	HP	30°01'50.39"	77°53'17.24"
17.	H/o Rashan Lal, Inayatpur	HP	30°01'18.27"	77°53'20.03"
18.	Primary School, Inayatpur	HP	30°01'14.39"	77°53'23.39"
19.	H/o Mr. Ilam Chand (Pradhan), Inayatpur	HP	30°01'5.44"	77°53'22.10"
20.	Dheer Majra	TW	29°57'16.11"	77°51'36.29"

**Table 5.24:** Water quality characteristics of river (March, 2014)

Location	Source	pH	EC	TDS	Hardness	HCO <sub>3</sub>	Cl	SO <sub>4</sub>	NO <sub>3</sub>	Na	K	Ca	Mg	BOD
		-	mS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Haljora Nadi	River	8.45	709	454	218	329	5.2	2	6.6	40	5.1	28	36	0.1
Shilpa Nadi	River	8.53	576	369	155	264	0.4	3.0	4.0	41	3.9	34	17	2.3
	Avg.	8.49	642.5	411.2	186.5	296.5	2.8	2.5	5.3	40.38	4.5	31	26.5	1.2
	Min.	8.45	576	368.64	155	263.5	0.4	2	4	40	3.9	28	17	0.1
	Max.	8.53	709	453.76	218	329.4	5.2	3	6.6	40.75	5.1	34	36	2.3

**Table 5.25:** Water quality characteristics of ponds (March, 2014)

Location	Source	pH	EC	TDS	Hardness	HCO <sub>3</sub>	Cl	SO <sub>4</sub>	NO <sub>3</sub>	Na	K	Ca	Mg	BOD
			mS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Ibrahimpur	Pond	7.35	1048	671	355	381	85	13	2.6	55	16	78	39	6.8
Ibra. Masahi Road	Pond	7.68	251	161	71	85	0.1	10	20	12	4.9	22	4	16.8
Masahi	Pond	8.15	1102	705	155	390	52	5.0	43	100	56	44	11	20
Inayatpur	pond	7.68	183	117	51	56	0.1	15	13	10	4.2	9.0	7.0	11
	Avg.	7.72	646	413.44	158	228.1	34.3	10.8	20	44.17	20.3	38	15.3	13.6
	min	7.35	183	117.12	51	56.12	0.1	5	2.6	10	4.2	9	4	6.8
	max	8.15	1102	705.28	355	390.4	85.2	15	43	99.68	56	78	39	20.3

**Table 5.26:** Water quality characteristics of drains (March, 2014)

Location	Source	pH	EC	TDS	Hardness	HCO3	Cl	SO4	NO3	Na	K	Ca	Mg	BOD
Drain to Pond Masahi	Drain	8.16	1867	1195	364	659	88	85	1.8	182	48	98	29	88
Drain to Pond Ibrahimpur	Drain	8.48	3057	1956	509	1074	236	30	19	352	75	110	57	79
	Avg.	8.32	2462	1575.7	436.5	866.2	162	57.5	11	267	61.5	104	43	83.5
	min	8.16	1867	1194.9	364	658.8	88	30	1.8	182	48	98	29	79.4
	max	8.48	3057	1956.5	509	1074	236	85	19	352	75	110	57	87.6

**Table 5.27:** Groundwater quality characteristics in the Ibrahimpur Masahi revenue village (March, 2014)

Location	Source	Depth	pH	EC	TDS	Hardness	HCO <sub>3</sub>	Cl	SO <sub>4</sub>	NO <sub>3</sub>	Na	K	Ca	Mg
		m		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Ibrahimpur	HP	22.86	6.96	1165	746	347	508	30	12	5.7	75	0.5	70	42
Primary School Ibrahimpur	HP	21.34	7.64	839	537	243	383	10	1.0	3.5	58	3.3	43	33
Lal Singh Public School, Masahi	HP	-	7.51	747	478	222	349	3.2	1.0	4.4	45	0.7	43	28
H/o Mr. Satya Pal Saini, Masahi	HP	-	7.5	850	544	268	390	11	3.0	4.4	46	0.6	53	33
Primary School, Belki	HP	21.34	7.38	1269	812	412	464	68	35	28	78	0.2	96	42
H/O Dhanpal, Belki	HP	36.58	7.38	802	513	258	381	4.8	1.0	4.4	38	1.3	44	36
Primary School, Halzora	HP	39.62	7.36	795	509	291	386	5.4	1.0	3.1	24	1.7	39	47
H/o Mehraban, Halzora	HP	9.14	7.68	546	349	198	264	1.6	8.0	3.5	15	0.1	15	39
H/o Rshan Lal, Inayatpur	HP	24.38	7.56	710	454	236	332	2.8	5.0	4.0	26	0.8	60	21
Primary School, Inayatpur	HP	27.43	7.68	601	385	213	281	2.4	5.0	5.3	15	0.4	49	22
H/o Mr. Ilam Chand (Pradhan), Inayatpur	HP	39.62	7.5	799	511	245	364	3.6	20	4.4	40	2.6	39	36
Dheer Majra	TW	18.29	7.69	735	470	231	332	2.8	9.0	11	38	2.2	40	32
		Avg.	7.49	821.5	525.76	263.7	369.3	12.2	8.42	6.8	41.5	1.2	49	34.3
		min	6.96	546	349.44	198	263.5	1.6	1	3.1	14.99	0.06	15	21
		max	7.69	1269	812.16	412	507.5	67.6	35	28	78	3.26	96	47

**Table 5.28:** Irrigation water quality parameters of Ibrahimpur Masahi village (March, 2014)

S.No.	Location	Source	EC ( $\mu\text{S/cm}$ )	SAR	RSC
1.	Halzora Nadi	River	709	1.2	1.0
2.	Shilpa Nadi	River	576	1.4	1.2
3.	Ibrahimpur	Pond	1048	1.3	-0.9
4.	Ibrahimpur-Masahi Road	Pond	251	0.6	0
5.	Masahi	Pond	1102	3.5	3.3
6.	Inayatpur	pond	183	0.6	-0.1
7.	Drain to Pond, Masahi	Drain	1867	4.2	3.5
8.	Drain to Pond, Ibrahimpur	Drain	3050	6.8	7.4
9.	Ibrahimpur	HP	1165	1.8	1.4
10.	Primary School Ibrahimpur	HP	839	1.6	1.4
11.	Lal Singh Public School, Masahi	HP	747	1.3	1.3
12.	H/o Mr. Satya Pal Saini, Masahi	HP	850	1.2	1.0
13.	Primary School, Belki	HP	1269	1.7	-0.6
14.	H/O Dhanpal, Belki	HP	802	1.0	1.1
15.	Primary School, Halzora	HP	795	0.6	0.5
16.	H/o Mehraban, Halzora	HP	546	0.5	0.4
17.	H/o Rashan Lal, Inayatpur	HP	710	0.7	0.7
18.	Primary School, Inayatpur	HP	601	0.5	0.3
19.	H/o Mr. Ilam Chand (Pradhan), Inayatpur	HP	799	1.1	1.1
20.	Dheer Majra	TW	735	1.1	0.8

**Table 5.29:** Water quality rating (IS: 11624-1986) based on total salt concentration in Ibrahimpur Masahi village (March, 2014)

S.No.	Class	EC (µS/cm)	River water samples	Pond water samples	Groundwater samples	Drain samples
1.	Low	<1500	100%	100%	100%	-
2.	Medium	1500-3000	-	-	-	50%
3.	High	3000-6000	-	-	-	50%
4.	Very High	>6000	-	-	-	-

**Table 5.30:** Water quality rating (IS: 11624-1986) based on sodium adsorption ratio (SAR) in Ibrahimpur Masahi village (March, 2014)

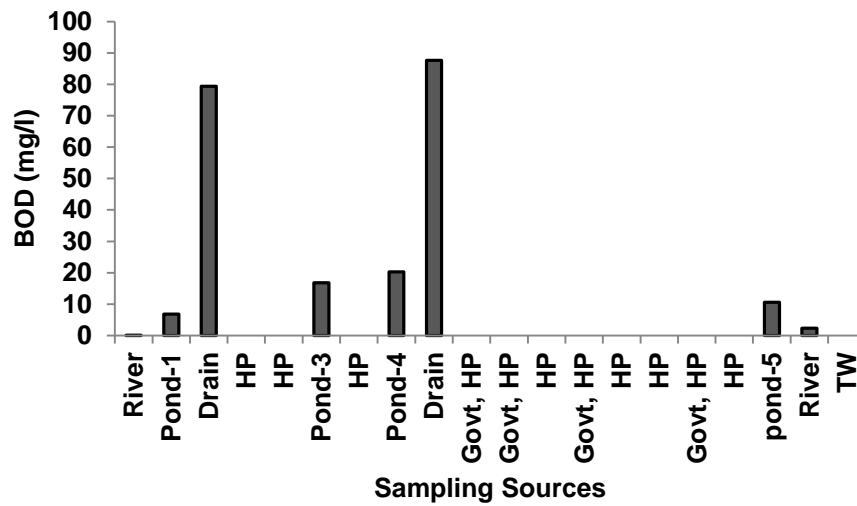
S.No.	Class	SAR	River water samples	Pond water samples	Groundwater samples	Drain samples
1.	Low	<10	100%	100%	100%	100%
2.	Medium	10-18	-	-	-	-
3.	High	18-26	-	-	-	-
4.	Very High	>26	-	-	-	-

**Table 5.31:** Water quality rating (IS:11624-1986) based on residual sodium carbonate (RSC) in Ibrahimpur Masahi village (March, 2014)

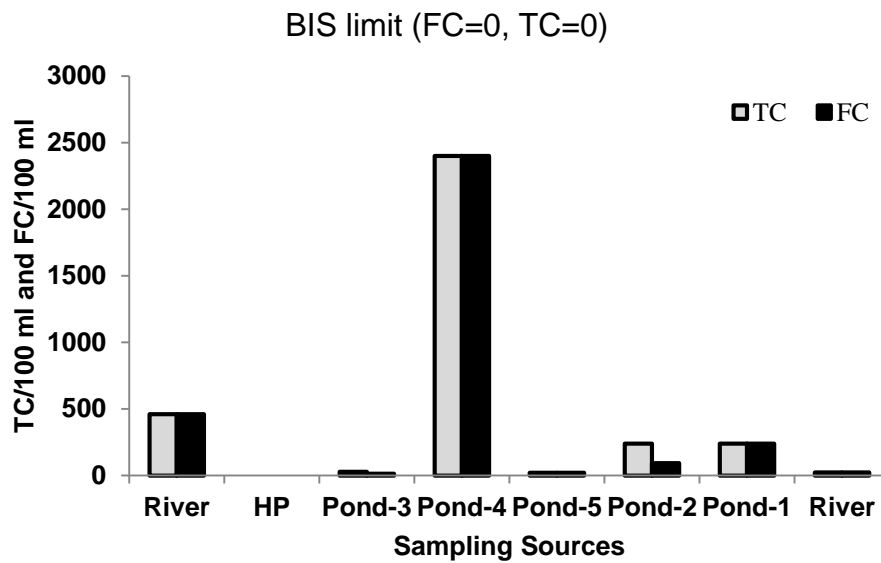
S.No.	Class	SAR	River water samples	Pond water samples	Groundwater samples	Drain samples
1.	Low	<1.5	100%	75%	100%	-
2.	Medium	1.5-3.0	-	-	-	-
3.	High	3.0-6.0	-	25%	-	50%
4.	Very High	>6.0	-	-	-	50%

**Table 5.32:** Groundwater quality assessment for drinking purposes (IS-10500:2012) in Ibrahimpur Masahi revenue village (March 2014)

Sl. No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the absence of any alternate source	Water Quality (Range)	% of samples exceeding acceptable limit
1.	pH Value	6.5 to 8.5	No Relaxation	6.96-7.69	-
2.	Total Hardness (as CaCO <sub>3</sub> ) mg/l, Max	200	600	198-412	92%
3.	Chlorides (as Cl) mg/l, Max.	250	1000	1.6-68	-
4.	Total Dissolved solids mg/l, Max	500	2000	349-812	58%
5.	Calcium (as Ca) mg/l, Max	75	200	15-96	8%
6.	Magnesium mg/l, Max	30	100	21-47	75%
7.	Sulphate (as SO <sub>4</sub> ) mg/l, Max	200	400	1-35	-
8.	Nitrate (as NO <sub>3</sub> ) mg/l, Max	45	No Relaxation	3-28	-
9.	Alkalinity mg/l, Max	200	600	264-508	100%



**Figure 5.47:** Variation of BOD in the water samples in the study area (March, 2014)



**Figure 5.48:** Variation of total coliform & faecal coliform in the water samples in the study area (March, 2014)

#### 5.4.2. Water quality investigations during January, 2015

The location details of water quality sampling program for the month of January, 2015 is given in **Table 5.33**. The water quality parameters include: pH, EC, turbidity, hardness, alkalinity, bicarbonate, chloride, sulphate, nitrate, phosphate, sodium, potassium, calcium, magnesium and BOD for pond, drain and groundwater sources in Ibrahimpur and Masahi villages (**Table 5.34**).

The suitability of water for irrigation was evaluated as per BIS norms (IS: 11624-1986) and relevant irrigation water quality parameters are given in **Table 5.35 to Table 5.37**. Majority of groundwater samples (92%) and pond water samples (75%) lie under low salinity class. The drain water samples were found equally under low salinity to medium salinity class. The water quality rating based on SAR values lie under low class for all sources (groundwater, ponds, drain) during January, 2015. Residual sodium carbonate (RSC) for groundwater samples varied from low to medium, for pond water samples varied from low to high, and for drain water samples varied from medium to high RSC class. Hence, irrigation using pond water and drain water should be restricted to avoid the effect of high RSC values for the agriculture. The data was plotted using U.S. Salinity diagram (**Figure 5.49**), which show irrigation water quality varying from medium salinity-low SAR to high salinity-low SAR during January, 2015. The piper diagram (**Figure 5.50** for ground water samples indicated all water samples under Ca-Mg-HCO<sub>3</sub> hydrochemical facies.

The drinking water quality was evaluated based on limited water quality parameters using BIS norms (IS: 10500-2012). The results are given in **Table 5.38**, which indicate exceeding acceptable limit as per BIS norms for total hardness (100% samples), total dissolved solids (15% samples), turbidity (77%) calcium (62% samples), magnesium (23% samples) and alkalinity (100% samples) in the study area for ground water mostly extracted from hand-pumps.

**Table 5.33:** Details of water samples collected in Ibrahimpur village (January, 2015)

<b>Sample ID</b>	<b>Source</b>	<b>Place of water collection site</b>	<b>Latitude</b>	<b>Longitude</b>
IBH – 1	Hand pump	House of Mr. Adesh Saini	29° 58.431'	77° 53.524'
IBH – 2	Hand pump	Agricultural field	29° 58.647'	77° 53.610'
IBH – 3	Hand pump	Govt. Primary School, Ibrahimpur	29° 58.379'	77° 53.680'
IBH – 4	Hand pump	House of Mr. Tillo Ram-1	29° 58.313'	77° 53.521'
IBH – 5	Hand pump	House of Mr. Tillo Ram-2	29° 58.313'	77° 53.517'
IBH – 6	Hand pump	Hand Pump near pond	29° 58.389'	77° 53.393'
IBB – 1	Tube well	House of Mr. Adesh Saini	29° 58.423'	77° 53.517'
IBB – 2	Tube well	Agri field opp. Mr. Aadesh Saini's house	29° 58.447'	77° 53.562'
IBP – 1	Pond	Pond at Ibrahimpur	29° 58.408'	77° 53.371'
IBD – 1	Drain	Drain to Pond Ibrahimpur	29° 58.392'	77° 53.394'
MP – 1	Pond	Pond at Masahi	77° 53.233'	29° 59.390'
MP – 2	Pond	Pond at Masahi	77° 53.209'	29° 59.369'
MP - 3	Pond	Pond at Masahi	77° 53.216'	29° 59.358'
MD	Drain	Drain to Pond at Masahi	77° 53.182'	29° 59.381'
MH - 1	Hand pump	Hand pump ( near temple at Masahi)	77° 53.204'	29° 59.283'
MH - 2	Hand pump	Hand pump (Mr. Satpal's house)	77° 53.126'	29° 59.383'
MH - 3	Hand pump	Hand pump (Govt. School, Masahi)	77° 53.009'	29° 59.315'
MH - 4	Hand pump	Hand pump (Mr. Rampal's House)	77° 53.006'	29° 59.324'
MH - 5	Hand pump	Hand pump (Mr. Sita Ram Saini's House)	77° 53.002'	29° 59.348'

**Table 5.34:** Water quality characteristics of Ibrahimpur and Masahi village Water samples (January, 2015)

Sample ID	pH	EC μS/cm	Turb. NTU	TDS mg/L	Alk. mg/L	T.H. mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO <sub>3</sub> mg/L	Cl mg/L	SO <sub>4</sub> <sup>2-</sup> mg/L	NO <sub>3</sub> <sup>-</sup> mg/L	PO <sub>4</sub> <sup>3-</sup> mg/L	BOD mg/L	SAR	RSC
IBH-1	6.95	1148	408	638	517	549	65	1	171	30	631	76	39	11	-	0	1.2	-0.7
IBH-2	7.52	559	149	272	311	231	36	1	67	15	379	18	1	8.36	-	1.8	1.0	1.6
IBH-3	7.59	582	3.78	322	354	269	32	2	42	40	432	12	1	5.72	-	0	0.9	1.7
IBH-4	6.97	2058	19.2	1560	576	915	111	2	289	47	703	221	45	11	-	0	1.6	-6.8
IBH-5	7.66	587	2.5	356	315	274	39	1	70	24	384	21	6	4.4	-	1.1	1.0	0.8
IBH-6	6.9	1084	2.1	498	528	536	46	1	160	33	644	58	18	11.8	-	0.7	0.9	-0.1
MH-1	7.25	554	5.8	250	326	281	20	0	80	19	398	12	1	2.2	-	0	0.5	1.0
MH-2	7.3	623	3.2	190	332	311	28	1	87	22	405	22	3	3.9	-	1.5	0.7	0.5
MH-3	7.26	703	2	278	336	353	29	1	101	24	410	35	7	14.5	-	0	0.7	-0.3
MH-4	7.2	703	4.5	374	325	363	30	1	105	24	396	42	8	12.8	-	0	0.7	-0.7
MH-5	7.3	627	1	272	323	331	26	1	92	24	394	20	12	11.9	-	0	0.6	-0.1
IBB-1	7.53	543	0.7	347	316	254	34	1	70	19	386	10	3	3.52	-	-	0.9	1.3
IBB-2	7.78	571	1	365	331	243	39	2	54	26	404	9	2	2.64	-	-	1.1	1.8
IBP-1	7.37	1619	48	652	578	452	112	73	98	50	705	162	26	10.2	8.46	7.9	2.3	2.6
MP-1	6.99	1005	49	480	461	396	72	61	65	56	562	71	7	43.6	13.23	-	1.6	1.4
MP-2	7.82	1009	85	562	485	336	75	62	62	43	592	82	7	6.2	12.33	2.8	1.8	3.1
MP-3	7.98	1027	32	582	453	280	73	60	63	29	553	64	8	2.2	10.44	8.7	1.9	3.5
IBD-1	8.23	1987	273	1076	811	690	106	28	115	98	989	222	49	11.4	13.5	3.1	1.8	2.4
MD	7.98	1130	325	572	519	354	103	36	69	44	633	85	21	31.2	11.79	2.5	2.4	3.3

**Table 5.35:** Water quality rating (IS: 11624-1986) based on total salt concentration in Ibrahimpur & Masahi villages (January, 2015)

S. No.	Class	EC ( $\mu\text{S}/\text{cm}$ )	Groundwater samples	Pond water samples	Drain samples
1.	Low	<1500	92%	75%	50%
2.	Medium	1500-3000	8%	25%	50%
3.	High	3000-6000	-	-	-
4.	Very High	>6000	-	-	-

**Table 5.36:** Water quality rating (IS: 11624-1986) based on sodium adsorption ratio (SAR) in Ibrahimpur & Masahi villages (January, 2015)

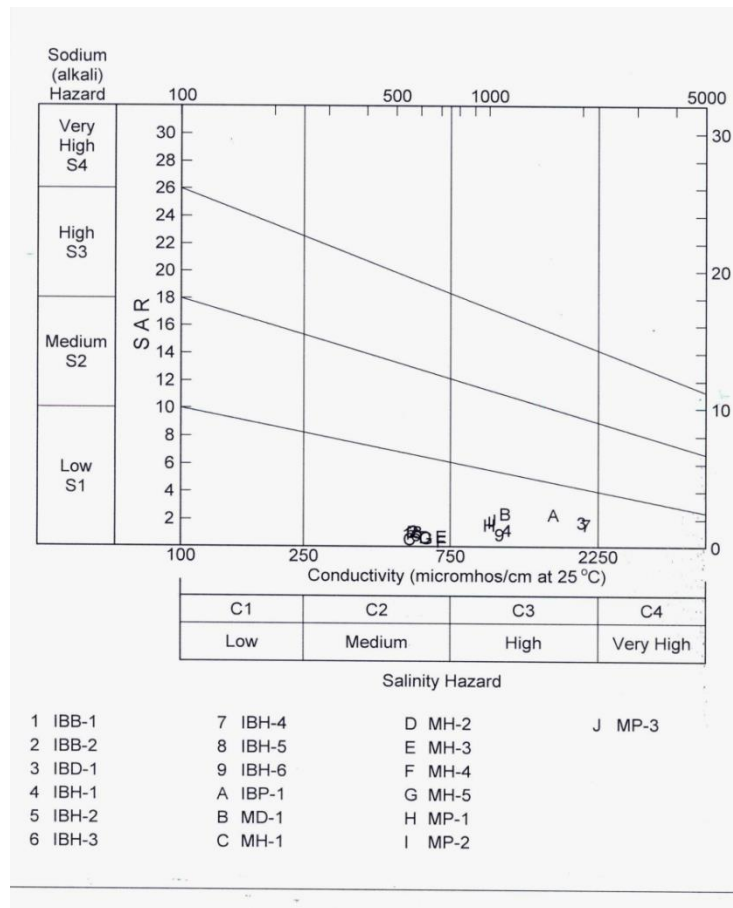
S. No.	Class	SAR	Groundwater samples	Pond water samples	Drain samples
1.	Low	<10	100%	100%	100%
2.	Medium	10-18	-	-	-
3.	High	18-26	-	-	-
4.	Very High	>26	-	-	-

**Table 5.37:** Water quality rating (IS:11624-1986) based on residual sodium carbonate (RSC) in Ibrahimpur & Masahi villages (January, 2015)

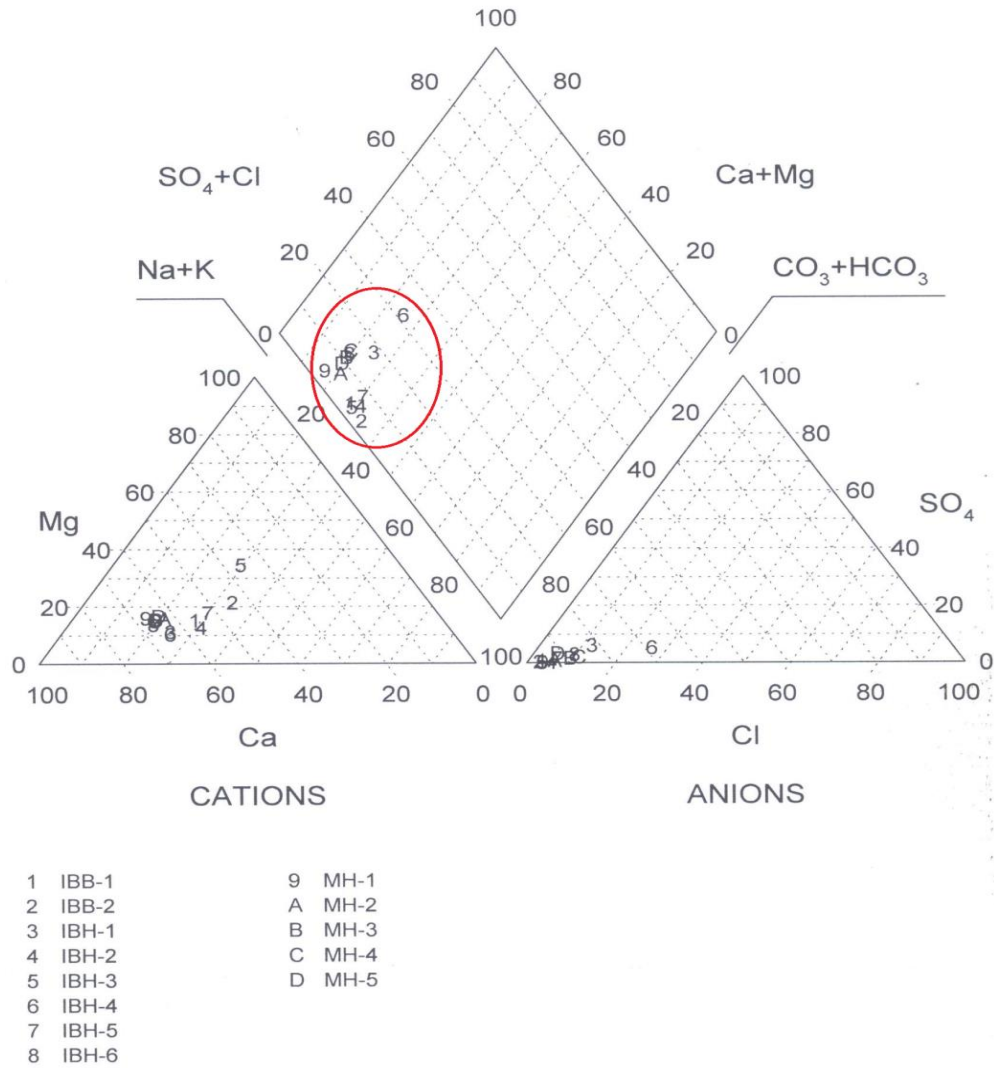
S. No.	Class	SAR	Groundwater samples	Pond water samples	Drain samples
1.	Low	<1.5	77%	25%	-
2.	Medium	1.5-3.0	23%	25%	50%
3.	High	3.0-6.0	-	50%	50%
4.	Very High	>6.0	-	-	-

**Table 5.38:** Groundwater quality assessment for drinking purposes (IS-10500:2012) in Ibrahimpur & Masahi villages (Jan. 2015)

S. No.	Characteristic	Requirement (acceptable limit)	Permissible limit in the absence of any alternate source	Water quality (range)	% of samples exceeding acceptable limit
1.	pH Value	6.5 to 8.5	No Relaxation	6.9-7.8	-
2.	Total Hardness (as CaCO <sub>3</sub> ) mg/l, Max	200	600	231-915	100%
3.	Chlorides (as Cl) mg/l, Max.	250	1000	9-221	-
4.	Total Dissolved solids mg/l, Max	500	2000	190-1560	15%
5.	Turbidity, NTU, Max.	1	5	0.7-408	77%
6.	Calcium (as Ca) mg/l, Max	75	200	42-289	62%
7.	Magnesium mg/l, Max	30	100	15-47	23%
8.	Sulphate (as SO <sub>4</sub> ) mg/l, Max	200	400	1-45	-
9.	Nitrate (as NO <sub>3</sub> ) mg/l, Max	45	No Relaxation	2.6-5.7	-
10.	Alkalinity mg/l, Max	200	600	311-576	100%



**Figure 5.49:** US Salinity diagram showing irrigation water quality in the study area (January, 2015)



**Figure 5.50:** Piper tri-linear diagram showing hydrochemical facies in ground water of the study area (January, 2015)

### 5.5. Assessment of available ponds in the study area

The available ponds in the study area were selected for the evaluation of hydrological status (**Figure 5.51**). Important parameters were selected know the current status of the ponds available in various sub-villages of Ibrahimpur Revenue Villages.

During management practices of the ponds, it should always start with an assessment and inspection of the current conditions in the pond. Some of the critical parameters were identified and inspected before tackling pond management issues of Ibrahimpur Revenue Villages.



**[A]** Bathymetric survey in village pond at sub-village Masahi Kala



**[B]** Water quality assessment in village pond at sub-village Masahi Kala



**[C]** Bathymetric survey in village pond at sub-village Masahi Kala

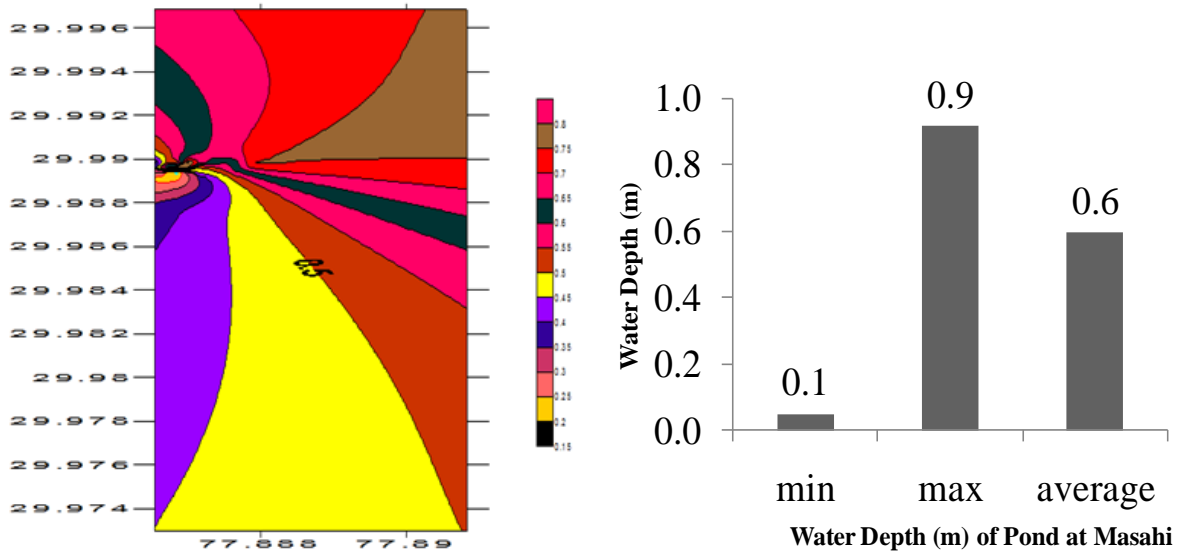


**[D]** Bathymetric survey in village pond at sub-village Inayatpur

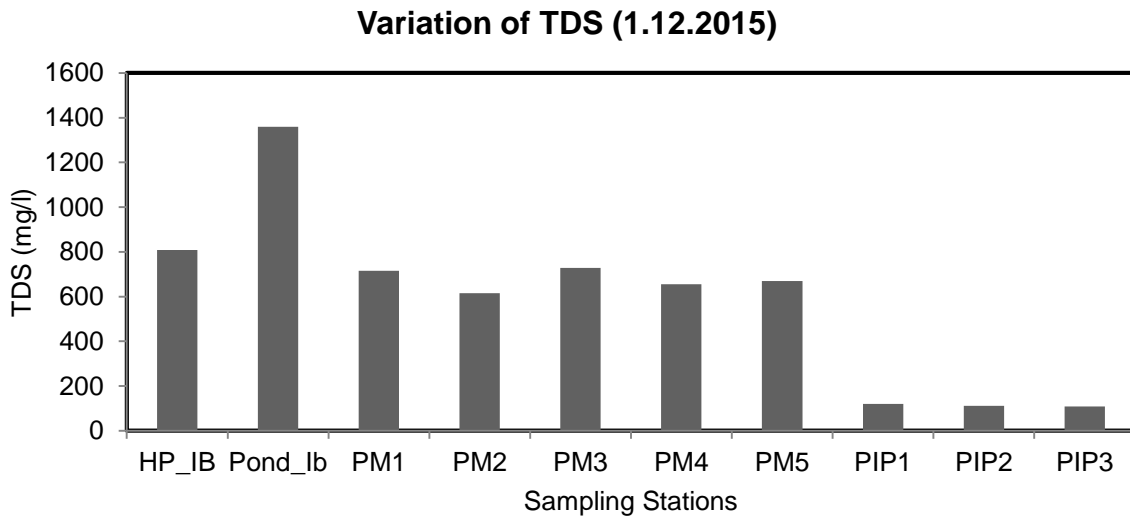
**Figure 5.51:** Bathymetric and water quality assessment of various ponds available in the study area

The key parameters taken during the assessment of ponds were as follows:

- a) Bathymetric survey
- b) Water quality status (TDS, Turbidity, DO, EC)
- c) Eutrophication status

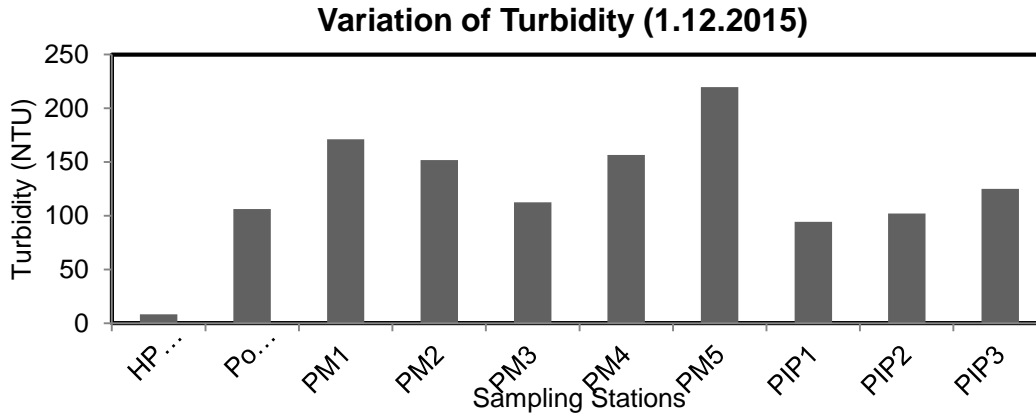


**Figure 5.52:** Results of bathymetric survey of pond at Masahi Kala sub-village in the study area

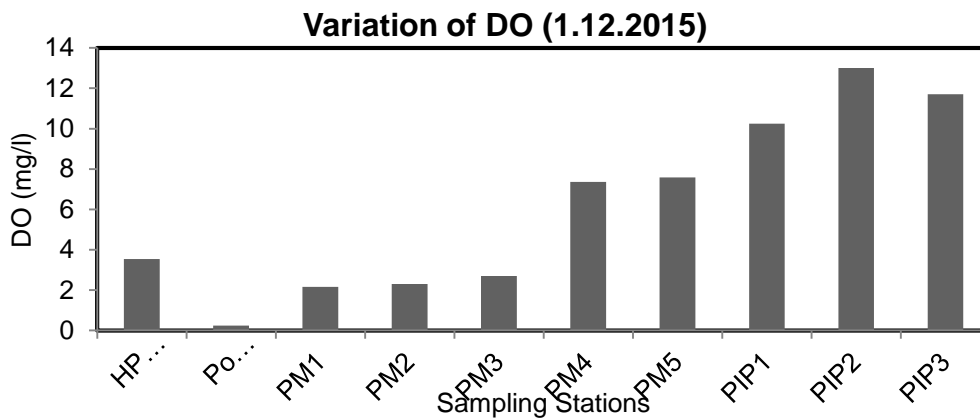


**Figure 5.53:** Variation in TDS in the pond waters in study area

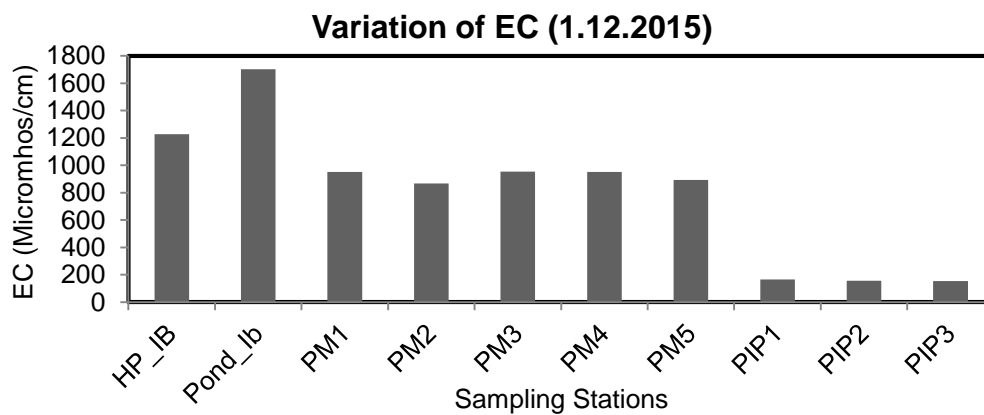
The results of the above key parameters (a to c) are given in **Figure 5.52 to Figure 5.59**. Further, Eutrophication status of ponds of various ponds in the study area are depicted in **Table 5.39** and **Table 5.40**.



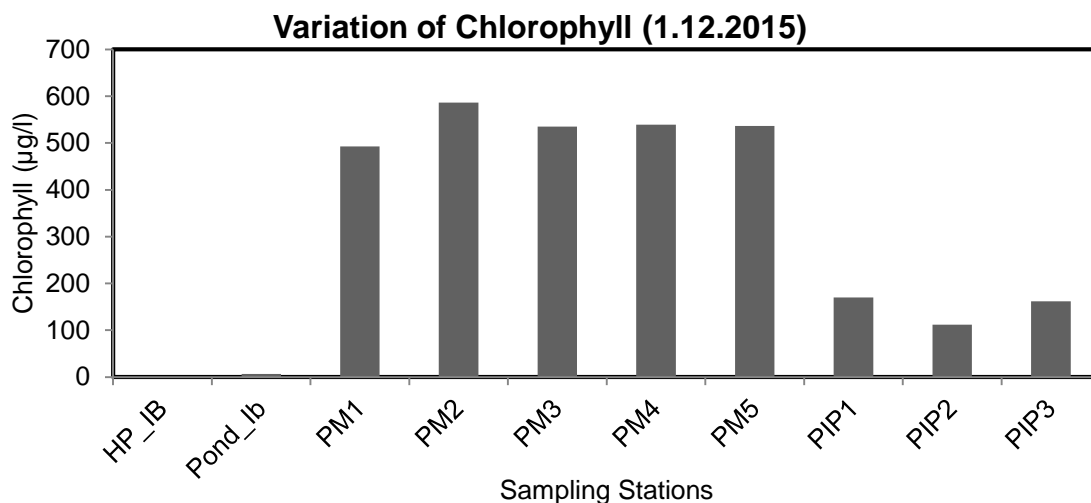
**Figure 5.54:** Variation in turbidity in the pond waters in study area



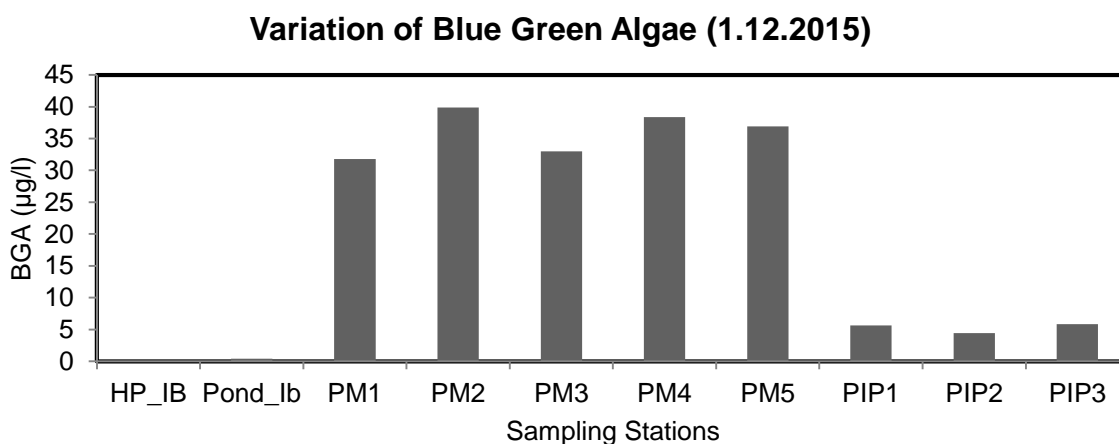
**Figure 5.55:** Variation in dissolved oxygen (DO) in the pond waters in study area



**Figure 5.56:** Variation in electrical conductivity (EC) in the pond waters in study area



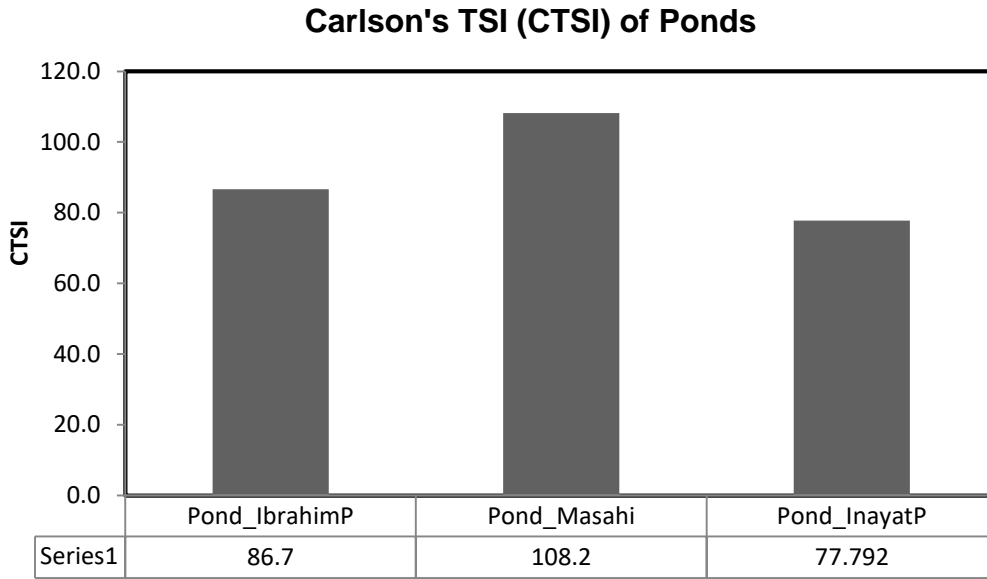
**Figure 5.57:** Variation of chlorophyll in the pond waters in study area



**Figure 5.58:** Variation in Blue Green Algae (BGA) in the pond waters in study area

**Table 5.39:** Estimation of Carlson's Trophic Index (eutrophication status of ponds)

Village Ponds	Chl (µg/l)	SD (m)	PO4 ( µg/l)	TSI (Chl)	TSI (SD)	TSI (PO4)	CTSI
Ibrahimpur	6.77	0.22	5680	49	81	129	87
Masahi	537.73	0.09	10400	92	95	138	108
Inayatpur	148.03	0.28	140	80	78	75	78



**Figure 5.59:** Eutrophication status of ponds of various ponds in the study area

**Table 5.40:** Eutrophication status of ponds in the study area

TSI	Chl (ug/L)	SD (m)	TP (ug/L)	Attributes	Fisheries & Recreation
70-80	56-155	0.25 - 0.5	96-192	Hypereutrophy:	
>80	>155	<0.25	192-384	Algal scums, few macrophytes	Rough fish dominate; fish kills possible

## 5.6. Rainwater harvesting potential of ponds

The study area comprises of some traditional ponds of varying size and capacity. At present all these ponds are severely degraded due to siltation, wastewater input from villages, emergence of macrophytes and other vegetation (**Figure 5.51a** and **Figure 5.51b**). The preliminary investigations were carried out to estimate the capacity of ponds and the details are given in **Table 5.39**. These pond are used to supplement the irrigation needs in the area (**Figure 5.51c** and **Figure 5.51d**).

**Table 5.41:** Major RWH structures (ponds)

	Pond-1	Pond-2	Pond-3	Pond-4	Pond-5
Latitude	29°58'24.4	29°58'34.99	29°59'4.12"	29°59'22.7"	30°00'54.40"
Longitude	77°53'22.3	77°53'18.65	77°53'12.7"	77°53'11.11"	77°53'38.4"
Altitude	250.59	238.75	238.59	241.64	248.76
Area (m2)	2251.96	872.93	1662.62	2954.3	1653.48
Perimeter	209.63	132.37	172.77	251.08	167.56
Depth (m)	2.36	0.91	2.29	1.75	2.13
Volume (m3)	5315	794	3807	5170	3522



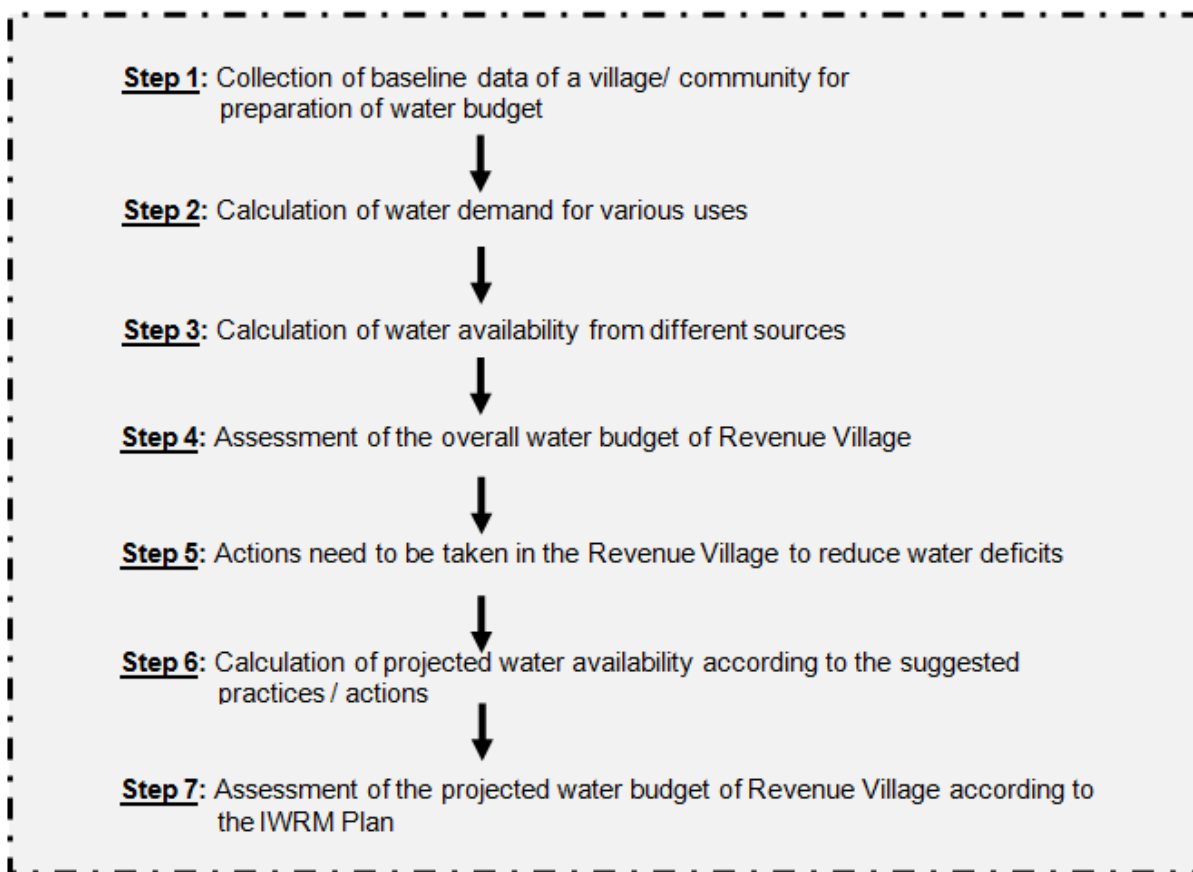
**Figure 5.60:** Existing ponds in the study area (a) pond at Ibrahimpur village, (b) pond at Masahi village, (c) extracting pond water for irrigation at Ibrahimpur village, (d) extracting pond water for irrigation at Ibrahimpur village

## 6. DEVELOPMENT OF IWRM PLAN FOR THE VILLAGE

Water security is widely recognised as one of the major challenges to India's economic and social development. India's average annual rainfall is enormously plentiful as compared to other nations, but much of this rain falls takes place in relatively short duration during the monsoon season which results in great disparity across various regions. Further, the impact of climate change has also created pressures on every community in India, including farmers, households, and industry to maintain the current need – which results in increasingly exploration of groundwater rather than surface waters. Moreover, the reliability of surface-water in various daily application has also decreased due to much of them are loaded with contaminants originated from domestic, agricultural and industrial activities.

Further, governmental policies such as providing free water or lack of accountability on amount of usage have resulted in indiscriminate use of water adding to the exhaustion and lowering of water table. Most of the time, almost every community / sector / municipalities found the easiest way to manage the shortfall in water demands through exploration of groundwater. On one hand, demands of water is going to be increased in almost every sector which has accelerated the ground water exploration, and on other hand the sectors like real estate boom in urban areas has blocked the passage of rain water and thus impacting their absorption. All these activities have resulted in rapidly decrease in groundwater, or in other words we may call this situation that every community progressing in “*water deficit state*”. In this endeavour, it is the urgent need to adopt the principles integrated water resource management (IWRM) for developing a village water conservation plan to make the system self sustainable or “at least zero water deficit communities”.

In the present efforts, IWRM plan has been prepared for the Ibrahimpur Revenue Village, in Dist. Haridwar by taking the holistic approach, including public health and sanitation, environmental sustainability, fulfilment of societal aspirations and implementation of certain out-of-box ideas on institutional arrangements. Accordingly, an IWRM plan for Ibrahimpur Revenue Village (depicted in **Fig. 6.1**) has been proposed based on the baseline data collected from the field.



**Figure 6.1:** IWRM plan for a village community

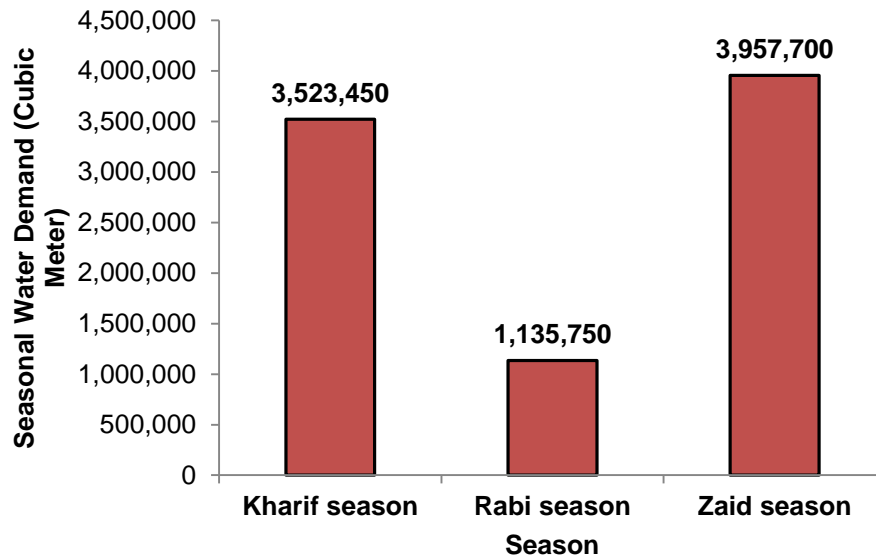
## 6.1. Steps for Water Management/IWRM Plan

Step 1: Collection of baseline data of a village/ community for preparation of water budget

S.No.	Activity	Value
<b>1. Non-agricultural area of revenue village = 103 Hectare</b>		
1.1	Residential	34 Hectare
1.2	Roads	47 Hectare
1.3	Village Ponds	22 Hectare
<b>2. Agricultural area of revenue village = 1324 Hectare</b>		

## Step 2: Calculation of water demand

S.No.	Activity	Value
<b>1. Non-agricultural water demand (Domestic + Livestock) of Revenue Village = 4,03,778 m<sup>3</sup> per year</b>		
1.1	<b>Domestic water demand</b> [(Population x @70 LPCD x 365 days)/1000] = [(6302 x 70 x 365)/1000]	1,61,016 m <sup>3</sup>
1.2	<b>Livestock water demand</b> (No. of Family x @900 LPCD x 365 days)/1000 = (739 x 900 x 365)/1000	2,42,762 m <sup>3</sup>
<b>2. Agricultural water demand (Kharif + Rabi + Zaid) of Revenue Village = 86,16,900 m<sup>3</sup> per year</b>		
<b>2.1</b>	<b>Kharif season</b>	<b>35,23,450 m<sup>3</sup></b>
2.1.1	<b>For Rice Fields</b> = [(Crop Area in Hectare x 10,000) x (SΔ, m)] = (55 x 10,000) x (1.52)	8,36,000 m <sup>3</sup>
2.1.2	<b>For Maize Fields</b> = [(Crop Area in Hectare x 10,000) x (SΔ, m)] = (6 x 10000) x (0.3)	18,000 m <sup>3</sup>
2.1.3	<b>For Sugarcane Fields</b> = [(Crop Area in Hectare x 10,000) x (SΔ, m)] = (144 x 10,000) x (1.52)	21,88,800 m <sup>3</sup>
2.1.4	<b>For Vegetables Fields</b> = [(Crop Area in Hectare x 10,000) x (SΔ, m)] = (41 x 10,000) x (0.64)	2,62,400 m <sup>3</sup>
2.1.5	<b>For Fodder Fields</b> = [(Crop Area in Hectare x 10,000) x (SΔ, m)] = (97 x 10,000) x (0.225)	2,18,250 m <sup>3</sup>
<b>2.2</b>	<b>Rabi season</b>	<b>11,35,750 m<sup>3</sup></b>
2.2.1	<b>For Wheat Fields</b> = [(Crop Area in Hectare x 10,000) x (SΔ, m)] = (249 x 10,000) x (0.25)	6,22,500 m <sup>3</sup>
2.2.2	<b>For Vegetables Fields</b> = [(Crop Area in Hectare x 10,000) x (SΔ, m)] = (10 x 10000) x (0.64)	64,000 m <sup>3</sup>
2.2.3	<b>For Pulses Fields</b> = [(Crop Area in Hectare x 10000) x (SΔ, m)] = (7 x 10,000) x (0.15)	10,500 m <sup>3</sup>
2.2.4	<b>For Fodder Fields</b> = [(Crop Area in Hectare x 10,000) x (SΔ, m)] = (195 x 10,000) x (0.225)	4,38,750 m <sup>3</sup>
<b>2.3</b>	<b>Zaid season</b>	<b>39,57,700 m<sup>3</sup></b>
2.3.1	<b>For Mango Fields</b> = [(Crop Area in Hectare x 10,000) x (SΔ, m)] = (460 x 10,000) x (0.76)	34,96,000 m <sup>3</sup>
2.3.2	<b>For Vegetables Fields</b> = [(Crop Area in Hectare x 10000) x (SΔ, m)] = (63 x 10,000) x (0.64)	4,03,200 m <sup>3</sup>
2.3.3	<b>For Fodder Fields</b> = [(Crop Area in Hectare x 10,000) x (SΔ, m)] = (26 x 10,000) x (0.225)	58,500 m <sup>3</sup>
<b>Total water demand of the Revenue Village = sum of 1 &amp; 2 = 4,03,778 + 86,16,900</b>		<b>90,20,678 m<sup>3</sup></b>



**Figure 6.2:** Seasonal water demand of the area

**Step 3: Calculation of water availability from different sources**

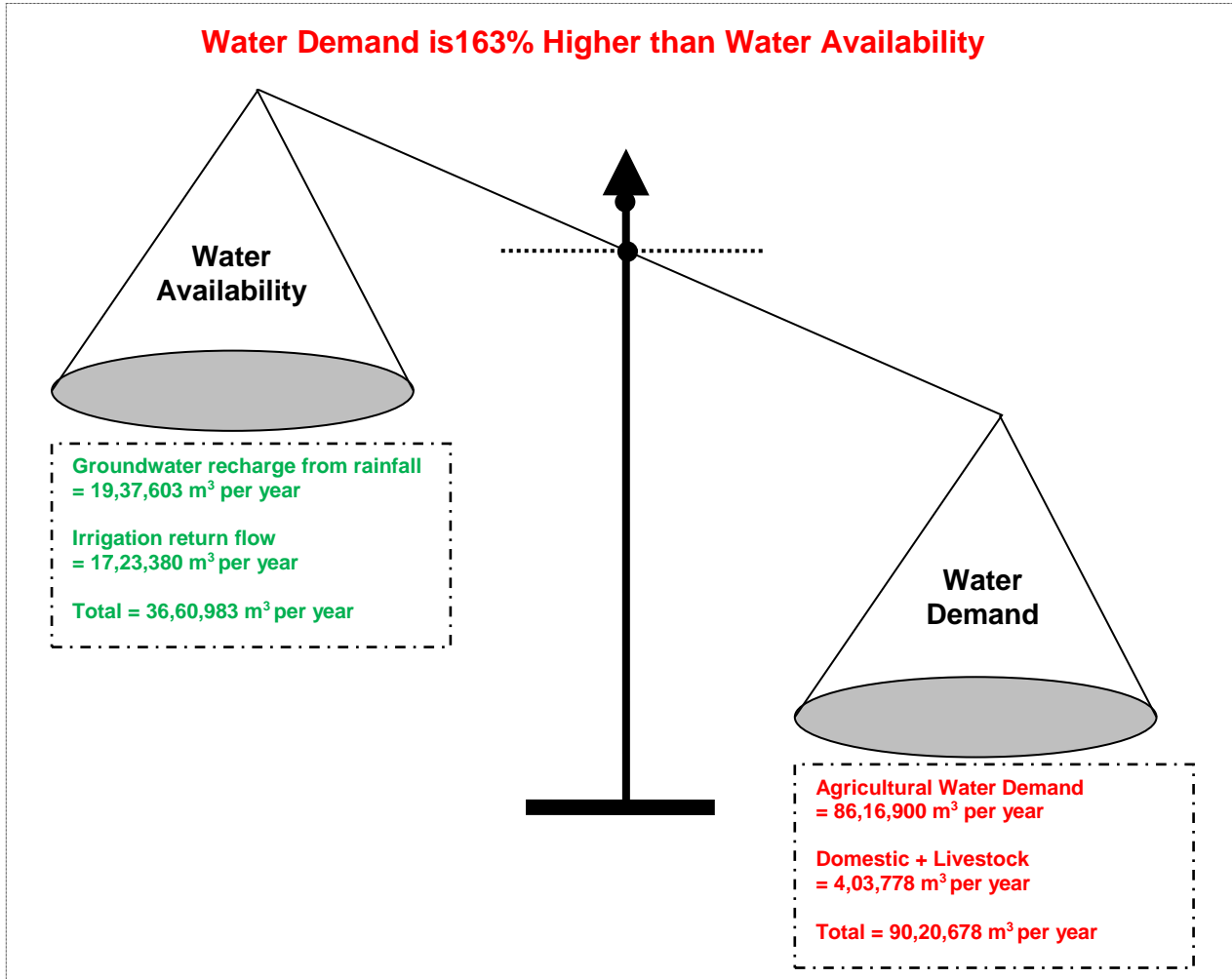
- Groundwater recharge from rainfall: It will be sum of a) recharge from non-agricultural areas and, b) recharge from agricultural areas
- Groundwater recharge from canal
- Direct canal irrigation
- Irrigation return flow

S.No.	Activity	Value
<b>Water availability = Sum of i to iv = 19,37,603+ 0.0+ 0.0 + 17,23,380 = 36,60,983 m<sup>3</sup></b>		
<b>i. Groundwater recharge from rainfall = 2,20,000 + 14,90,559 = 19,37,603 m<sup>3</sup></b>		
<b>a) Recharge from non-agricultural areas = 2,20,000 m<sup>3</sup></b>		
1.1	Groundwater recharge from residential = [(effective rainfall in m <sup>3</sup> ) x (percentage of groundwater recharge)] = [(0.866 m x 0.65 x 34 x 10,000) x (0)]	0.0 m <sup>3</sup>
1.2	Groundwater recharge from roads = [(effective rainfall) x (percentage of groundwater recharge)] = [(0.866 m x 0.65 x 47 x 10,000) x (0)]	0.0 m <sup>3</sup>
1.3	Groundwater recharge from village ponds = may be consider as the storage capacity having one meter of water column depth = (area of ponds in hectare x 10,000 x depth) = (22 x 10,000 x 1)	2,20,000 m <sup>3</sup>
<b>b) Recharge from agricultural areas (m<sup>3</sup>) = [(effective rainfall in m<sup>3</sup>) x (percentage of rainwater recharges to groundwater)] = [(0.866 m x 0.65 x 1324 x 10,000) x (0.20)] = 14,90,559 m<sup>3</sup></b>		
<b>ii) Groundwater recharge from canal = (length of canal within the village periphery x water available/meter of canal) x ground water recharge rate (@ 10%) = 0 x 0 x 0.10 = 0.0 m<sup>3</sup></b>		
<b>iii) Direct canal irrigation = volume (m<sup>3</sup>) = 0.0 (m<sup>3</sup>)</b>		
<b>iv) Irrigation return flow (m<sup>3</sup>) = water used for irrigation x rate of percolation (@ 20%) = 86,16,900 x 0.20 = 17,23,380 m<sup>3</sup></b>		

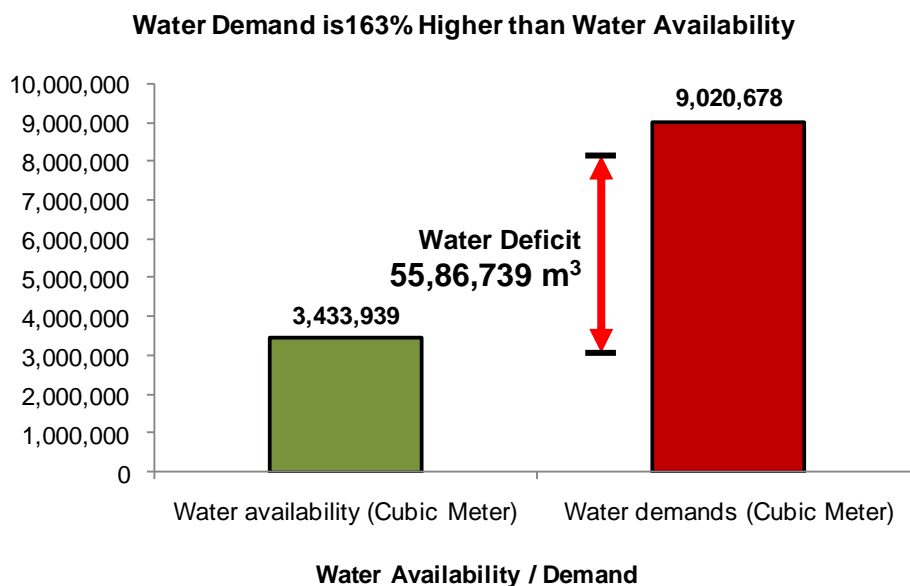
\*Effective Rainfall (m<sup>3</sup>) = [(Actual rain fall (m) x 0.65) x (area in Hectare x 10,000)]

**Step 4: Assessment of the overall water budget**

Water budget = Total water availability – Total water demands  
= 34,33,939 m<sup>3</sup> - 90,20,678 m<sup>3</sup> = -55,86,739 m<sup>3</sup>  
% Deficit = (Total deficit / Total availability) x 100 = (55,86,739 / 34,33,939) x 100  
= 163%



**Figure 6.3:** Water budget of the Revenue Village



**Figure 6.4:** Water budget of the Revenue Village according to the current practices

**Step 5: Actions need to be taken in the Revenue Village to reduce water deficits**

- I. Change of flood irrigation system to drip irrigation to reduced the crop water requirement (% 50).
- II. Collection of water runoff from Villages and creation of ponds in the vicinity aimed to enhance groundwater recharge.
- III. Implementation of roof-top rainwater harvesting system to conserve rain water.
- IV. Implementation of natural wastewater treatment system for gainful recycling and reuse.

**i. Water demand of the Village using drip irrigation system**

S.No.	Activity	Value
<b>1. Non-agricultural water demand (Domestic + Livestock) = 4,03,778 m<sup>3</sup> per year</b>		
1.1	<b>Domestic water demand</b> [(Population x @70 LPCD x 365 days)/1,000] = [(6,302 x 70 x 365)/1,000]	1,61,016 m <sup>3</sup>
1.2	<b>Livestock water demand</b> (No. of Family x @900 LPCD x 365 days)/1,000 = (739 x 900 x 365)/1,000	2,42,762 m <sup>3</sup>
<b>2. Agricultural water demand (Kharif + Rabi + Zaid) of Revenue Village = 43,08,450 m<sup>3</sup> per year</b>		
2.1	Kharif season = Demand According to Flood Irrigation System x 0.5 = 35,23,450 x 0.5	17,61,725 m <sup>3</sup>
2.2	Rabi season = Demand According to Flood Irrigation System = 11,35,750 x 0.5	5,67,875 m <sup>3</sup>
2.2	Zaid season = Demand According to Flood Irrigation System = 39,57,700 x 0.5	19,78,850 m <sup>3</sup>
<b>Total water demand of the Village = sum of 1 &amp; 2 = 4,03,778 + 43,08,450</b>		<b>47,12,228 m<sup>3</sup></b>

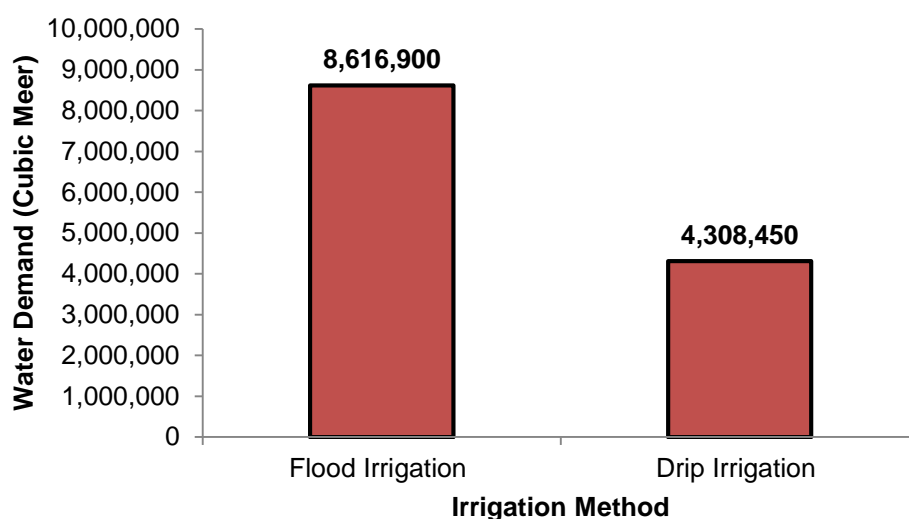


Figure 6.5: Water demand for irrigation using different irrigation method

### ii. Water runoff from agricultural fields and creation of farm ponds

S.No.	Activity	Value
1.1	Runoff from non-agricultural areas excluding ponds = [(Area in Hectare x 10,000) x (Effective Rainfall in Meter) x (Runoff Coefficient) ] = [(80 x 10,000) x (0.566) x (0.7)]	3,16,960 m <sup>3</sup>
1.2	Runoff from agricultural areas = [(Area In hectare X 10,000) X (Effective rainfall In meter) X (Runoff coefficient) ] = [(1,324 X 10,000) X (0.566) X (0.7)]	52,45,688 m <sup>3</sup>
<b>Total runoff generated from the Revenue Village = 3,16,960 + 52,45,688</b>		<b>55,62,648 m<sup>3</sup></b>

### iii. Implementation of roof-top rainwater harvesting system to conserve rain water

S.No.	Activity	Value
1.1	Water that can be harvested from rooftop = [(Average area of rooftop) x (Effective rainfall) x (Number of houses) x (Runoff Coefficient)] = [(44) x (0.566) x (739) x (0.85)]	15,643 m <sup>3</sup> per year

**iv. Implementation of natural wastewater treatment system aimed it for gainful recycling**

S.No.	Activity	Value
1.1	Wastewater generated from the Village: = Domestic water demand x Wastewater generation factor = 1,61,016 x 0.80	1,28,813 m <sup>3</sup>
1.2	Amount of treated wastewater = Domestic wastewater collected x Treatment Factor = 1,28,813 x 0.70	90,169 m <sup>3</sup>
<b>Amount of additional water for possible reuse in irrigation</b>		<b>90,169 m<sup>3</sup></b>

**Step 6: Calculation of water availability according to the suggested actions**

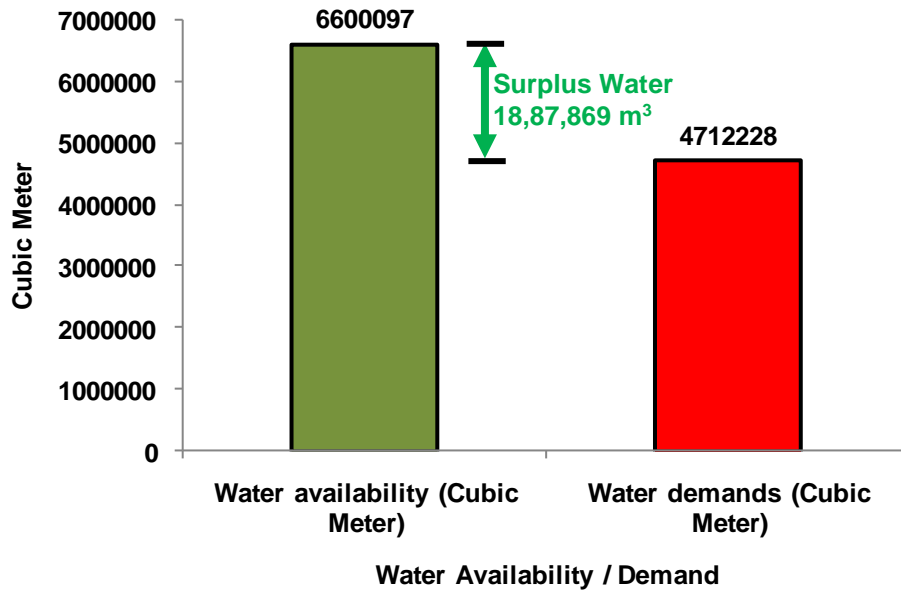
- I. Groundwater recharge from rainfall: It will be sum of a) recharge from non-agricultural areas and, b) recharge from agricultural areas
- II. Groundwater recharge from canal
- III. Direct canal irrigation
- IV. Irrigation return flow
- V. Recharge through ponds
- VI. Availability of treated wastewater

S.No.	Activity	Value
<b>Water availability = Sum of i to iv = 56,48,238 + 0.0 + 0.0 + 8,61,690 + 90169 = 66,00,097 m<sup>3</sup></b>		
<b>i. Groundwater recharge from rainfall = 4,85,697 + 14,90,559 + 36,71,982 = 56,48,238 m<sup>3</sup></b>		
<b>a) Recharge from non-agricultural areas = 4,85,697 m<sup>3</sup></b>		
1.1	Groundwater recharge from residential areas = [(effective rainfall in m <sup>3</sup> ) x (percentage of groundwater recharge)] = [(0.866 m x 0.65 x 34 x 10,000) x (0.70)]	1,33,970 m <sup>3</sup>
1.2	Groundwater recharge from roads = [(effective rainfall) x (percentage of groundwater recharge)] = [(0.866 m x 0.65 x 47 x 10,000) x (0.70)]	2,64,563 m <sup>3</sup>
1.3	Groundwater recharge from village ponds = (area of ponds in hectare x 10,000 x effective rainfall x 0.70) = (22 x 10,000 x 0.566 x 0.70)	87,164 m <sup>3</sup>
<b>b) Recharge from agricultural areas (m<sup>3</sup>) = [(effective rainfall in m<sup>3</sup>) x (percentage of rainwater recharges to groundwater)] = [(0.866 m x 0.65 x 1324 x 10,000) x (0.20)] = 14,90,559 m<sup>3</sup></b>		
<b>c) Recharge through proposed ponds = Amount of runoff from agricultural areas x recharge factor = 52,45,688 x 0.70 = 36,71,982 m<sup>3</sup></b>		
<b>ii) Groundwater recharge from canal = (length of canal within the village periphery x water available/meter of canal) x ground water recharge rate (@ 10%) = 0 x 0 x 0.10 = 0.0 m<sup>3</sup></b>		
<b>iii) Direct canal irrigation = volume (m<sup>3</sup>) = 0.0 (m<sup>3</sup>)</b>		
<b>iv) Irrigation return flow (m<sup>3</sup>) = water used for irrigation x rate of percolation (@ 20%) = 43,08,450 x 0.20 = 8,61,690 m<sup>3</sup></b>		
<b>v) Amount of treated wastewater the Village = Domestic wastewater collected x Treatment Factor = 1,28,813 x 0.70 = 90,169</b>		

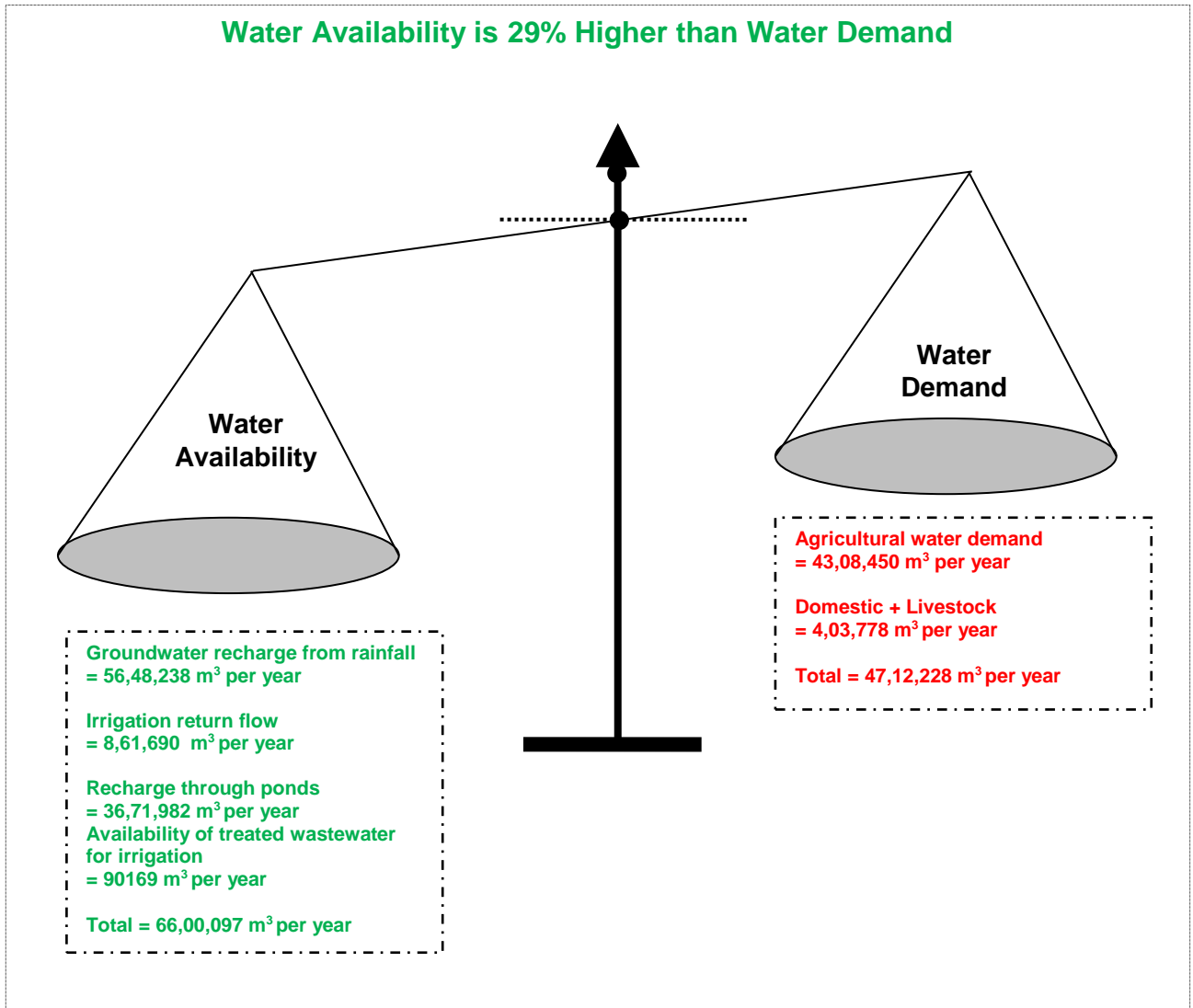
**Step 7: Assessment of the projected water budget of Revenue Village according to IWRM Plan**

Water Budget = Total water availability – Total water demands  
= 66,00,097 m<sup>3</sup> - 47,12,228 m<sup>3</sup> = +18,87,869 m<sup>3</sup>  
% Profit = (Total profit / Total availability) x 100 = (2172329 / 6884557) x 100  
= 29%

**Water Availability is 29% Higher than its Demand**



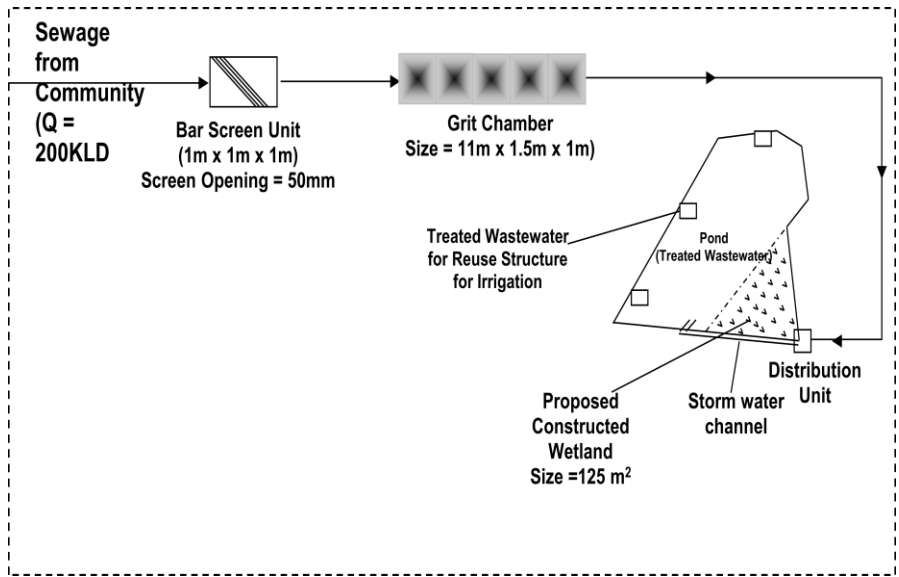
**Figure 6.6:** Water budget of the Revenue Village according to the suggested practices



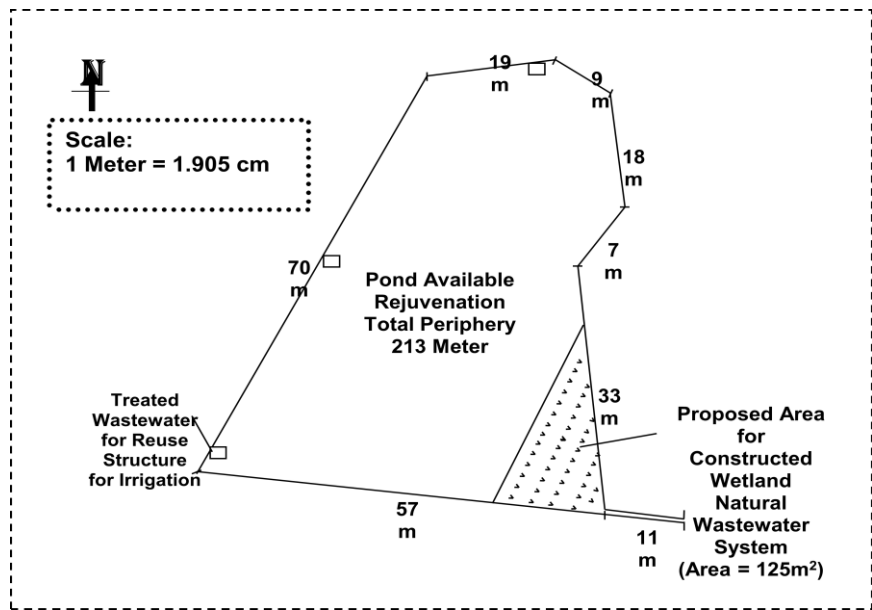
**Figure 6.7:** Water budget of the Revenue Village according to suggested practices

## **7. REJUVENATION OF VILLAGE POND BY ESTABLISHING CW-BASED NTS**

Constructed Wetland (CW) is an artificially constructed natural treatment system, using aquatic plants and microbes, for treatment of wastewater laden with organics and nutrients. It is constructed with the locally available material like gravel, brick ballast, and Reed grass & Canna plants etc. It is an eco-friendly, low cost, and chemical free technology. The system helps in maintaining the healthy aquatic ecosystem by reducing the oxygen need of the wastewater after treatment. Moreover, it also reduces the fecal coliforms present in the domestic wastewater harmful for human health. CW is highly suitable for treating the effluents generated from villages, especially septic tanks constructed under “Swachh Bharat Mission”, to avoid the eutrophication of the ponds which are a source of sustainable water supply for the livelihood of the villagers. A flow diagram and plan of CW-based NTS at village pond at Ibrahimpur Masahi are given in Figs. 7.1 & 7.2. The pond rejuvenation stages, establishment of NTS and status of pond during pre/post rejuvenation works are shown in Figs. 7.3 a, b, c and d respectively. The water quality of the pond was also assessed before and after rejuvenation works. The key results are given below (Table- 7.1), which indicate improvement in the water quality of this pond. However, the detailed performance of this NTS will be assessed in subsequent year/s during fully operational stage of the NTS by growing suitable plants in the constructed wetland.



**Figure 7.1:** Flow diagram of a CW- based NTS at village Ibrahimpur Masahi



**Figure 7.2:** Plan of a CW- based NTS at village Ibrahimpur Masahi



**a: Rejuvenation works of village pond at Ibrahimpur Masahi**



**b: Establishment of CW in pond with connecting sedimentation chamber**



**c: Plantation works in CW in a village pond at Ibrahimpur Masahi**



**d: A comparative view of pond before and after rejuvenation works**

**Figure 7.3:** Pond stages before and after rejuvenation works

**Table 7.1:** Status of Pond at village Ibrahimpur Masahi (before and after rejuvenation)

Parameters	Before Rejuvenation (Mar.2014*/Dec. 2015**/Jan.2015)	After Rejuvenation (Jan 2018)
Volume (m <sup>3</sup> )	5315	8390
Av. Depth (m)	2.36	3.29
pH	7.37	7.71
Turbidity (NTU)	48	43.1
Alkalinity (mg/l)	578	276
NO <sub>3</sub> (mg/l)	10.2	0.98
PO <sub>4</sub> (mg/l)	8.46	0
DO (mg/l)	0.25**	5.5
FC (MPN/100 ml)x10 <sup>3</sup>	240*	150

## 8. MASS AWARENESS CAMPAIGN ON WATER CONSERVATION

The following activities were carried out in this study:

- Rally and oath (sankalp) in Schools of 5 Sub Villages of village Ibrahimpur Masahi Revenue village for awareness in children and villagers (through NIH staff and School Teachers)
- Plantation in different schools by ATHAK Foundation, Roorkee
- Program by Rashtriya Jagriti Dal, Dist. Haridwar
- Screening of water related films/activities through Bioscope for school children (through Delhi based Agency)
- Theater Program by School children coordinated by Dr. Archana Sarkar, Sc. D (through Delhi based Agency)
- Visit at Pond site (Village: Ibrahimpur Masahi) and program site (Junior High School, Belki Masahi) & address/talk of Er. R D Singh, Director (NIH); Dr. Bhishm Kumar (Former Scientist F, NIH) ; Dr. N.C. Ghosh, Sc. G & Head (GWHD); Dr. V.C. Goyal, Sc. G & Head (RMOD); Shri Ghildyal ji (Tehsildar, Bhagwanpur); Scientists from KVK, Dhanauri; Er. Omkar Singh, Sc. F; Dr. Dinesh Kumar, Sr. Resource Person, and Gram Panchayat Pradhan, etc.



**Figure 8.1:** View of Mass Awareness Campaign on Water Conservation Conducted on 16th Dec, 2016 in Ibrahimpur Masahi Village (Dist. Haridwar)

## 9. CONCLUSIONS

Present study was undertaken in Ibrahimpur Masahi Village, District-Haridwar (Uttarakhand) under Shipla-Halzora river watershed (Solani river sub-catchment). In this study, extensive field investigations (including door to door survey) were carried out to collect relevant hydrological and socio-economic data. Rainfall data (1987 to 2013) of the NIH Hydromet observatory was analysed using Weibull's method for calculating dependable rainfall at various probabilities. Mean annual rainfall was 1053 mm (27 year data). The annual probable maximum rainfall was obtained 866 mm and 537 mm at 50% and 75% frequency levels, respectively. The Monthly Rain Water Availability (MCM) at Village Level and Watershed Level was estimated on the basis of 50% dependable Rainfall. The annual rainwater availability at village level was obtained 12.35 MCM and at watershed level in the order of 48 MCM, respectively.

The water quality investigations were carried out from different sources pertaining to surface water (viz., ponds, drains to ponds, river) and ground water (viz., hand pumps, tube well) in the study area. The groundwater quality was evaluated for drinking purpose based on BIS norms (IS: 10500-2012), which indicates exceeding acceptable limit of total hardness (100% samples), total dissolved solids (15% samples), turbidity (77%), calcium (62% samples), magnesium (23% samples) and alkalinity (100% samples) in the study area. The suitability of water for irrigation was evaluated as per BIS norms (IS: 11624-1986), which shows a concern of higher RSC for ponds and drain water samples. The U.S. salinity diagram shows irrigation water quality varying from medium salinity-low SAR to high salinity-low SAR. The eutrophication status of ponds was estimated based on Carlson's Trophic State Indices (Carlson, 1977) using average values of secchi depth, phosphate and chlorophyll content. The overall eutrophication status of the ponds indicates hyper-eutrophic condition (CTSI>70) of the village ponds.

As per soil testing results, the soil types are: sandy loam, loamy sand, loam and silt loam in the study area. The soil health cards of were also prepared for prospective

farmers and distributed to them for optimizing the doses of supplemental fertilizers and increasing crop productivity.

Monthly rainwater harvesting potential and balance of harvested rainwater after meeting few designated uses was also estimated for 5 sub-villages using Eqn. given by Ghisi et al., 2006. The analysis include: (a) household monthly harvested rainwater & balance after ablution/toilet flushing, washing of clothes & other uses (combined), (b) assessment of household monthly harvested rainwater & balance after ablution/toilet needs, (c) rainwater harvesting potential of existing village ponds (d) monthly roof top water harvesting potential of schools/govt. buildings, etc. The household level average roof-top area ( $m^2$ ) in 5 sub-villages, viz., Ibrahimpur Masahi, Masahi Kala, Belki Masahi, Inayatpur and Halzora was obtained in the order of 62, 49, 52, 25, 33 respectively. Based on average roof-top area available in 5 sub-villages, the monthly rainwater harvesting potential ( $m^3$ ) was estimated for three scenarios of rainfall conditions, viz., (i) at monthly average rainfalls of Roorkee (27 rainfall years data), (ii) at 50% dependable monthly rainfalls, (iii) at 75% dependable monthly rainfalls, respectively. Household monthly harvested rainwater & balance after ablution / toilet flushing, washing clothes & other uses (combined) based on average rainfall. The size of a suitable tank for rain water harvesting in each sub villages was also recommended in the study.

An IWRM Plan has been developed for water management in Ibrahimpur-Masahi village. The IWRM Plan demonstrates conversion from a water-deficit status to a water-surplus status through appropriate water conservation practices. Mass awareness activities were also conducted in the study area to sensitize the public including school children regarding water conservation.

Finally, a severely degraded village pond was rejuvenated alongwith establishment of a phyto-remediation based Natural Treatment System-NTS) at village Ibrahimpur Masahi. The water quality of the pond was also assessed before and after rejuvenation works. The results indicate improvement in the water quality of this

pond. However, the performance of the developed NTS will be assessed in subsequent years by growing suitable plants in the constructed wetland.

IWRM plan at the village level can give multi-fold benefits in the long term. It not only promotes water conservation practices but also facilitates enhancing water productivity. Additional water availability through water conservation measures facilitates livelihood opportunities. Water-related risks are mitigated leading to resiliency against climate change impacts. The Plan demonstrates conversion from a water-deficit status to a water-surplus status through appropriate water conservation practices. Some salient recommendations to improve the water conservation practices in Ibrahimpur-Masahi village are as follows:

- Increasing awareness for efficient use of water through demonstration of water conservation practices (e.g. rainwater harvesting, wastewater treatment and reuse).
- Regular audit for the current water use (both agricultural and non-agricultural).
- Maintenance of water sources (e.g. handpumps) and water supply systems to minimize losses and wastage of water.
- Use of efficient irrigation systems (e.g. drip) in place of flood irrigation- saving of 10 – 20% of water.
- Improved agricultural practices (improved seeds; appropriate dose of fertilizers, based on the soil health status; crop diversification to improve soil health and income).
- Switch over to “Crop Intensification Practices” (e.g. SWI, SRI) that use less water and give better yield.
- Promote cultivation of oilseed and pulses crops.
- Promote cultivation of aromatic and horticultural crops for better net returns.
- Promote organic farming (less water hungry).
- Promote conversion of solid waste to manure/compost.
- Treat wastewater through Natural Treatment Systems, and use treated water for livelihood activities (e.g. pisciculture) and agricultural activities.
- Develop Rainwater Harvesting Systems at community places (e.g. schools).
- Develop farm ponds at appropriate locations to capture runoff water. Stored water will help additional irrigation in farmers’ fields (e.g. for vegetable cultivation), and improve the groundwater table, finally will result in savings in terms of reduced expenditure on electricity tariffs.

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**Annexure I: Demographic and social data of the Revenue  
villages**

**[A] Sub-Village: Ibrahimpur Masahi**

Sr. #	Name of family head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions L x B (ft)	
1	Imrat Singh	21	3	0	0	13	15	13
2	Bhanwati	10	3	0	0	12	14	12
3	Roshan Lal	13	1	0	0	4	12	13
4	Samay Singh	26	6	0	0	16	14	13
5	Hukam Singh	16	1	0	0	7	11	13
6	Maan Singh	13	2	0	0	4	15	10
7	Simtra	9	1	0	0	7	15	10
8	Baburam	7	1	0	0	6	12	11
9	Malkhan Singh	7	1	0	0	3	14	13
10	Ratan Singh	9	2	0	0	3	12	12
11	Ram Singh	5	1	0	0	3	14	13
12	Malkhan Singh	14	1	0	0	7	16	10
13	Foolwati	17	2	0	0	7	10	9
14	Kartar Singh	9	2	0	0	5	12	8
15	Ram Pal	5	2	0	0	4	14	14
16	Prakash	4	0	0	0	2	16	12
17	Ram Prashad	9	1	0	0	5	12	10
18	Noorti	8	1	0	0	5	12	12
19	Bablu	5	1	0	0	2	14	14
20	Charan Singh	7	1	0	0	2	14	10
21	Sushma	5	1	0	0	2	14	10
22	Baburam	6	1	0	0	2	10	8
23	Ramesh	7	1	0	0	2	12	12
24	Ramchandra	20	1	0	0	11	16	10
25	Mohkum	13	1	0	0	4	13	10
26	Hukam Singh	4	0	0	0	4	13	10
27	Fool Singh	25	1	0	0	6	12	10

Sr. #	Name of family head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions L x B (ft)
28	Kanwar Singh	11	1	0	0	5	15 10
29	Chuhad Singh	21	1	0	0	4	14 12
30	Jagpal	13	1	0	0	4	14 12
31	Subhash	8	1	0	0	2	13 10
32	Raaj Singh	6	1	0	0	2	15 14
33	Ajab Singh	10	0	1	90	7	14 12
34	Rajendra	15	0	1	240	7	14 12
35	Prem Singh	15	1	0	0	5	13 12
36	Sevaram Pal	9	1	0	0	2	13 10
37	Kabul Singh	6	0	0	0	2	14 13
38	Vimla Pal	7	0	0	0	2	15 10
39	Subhash Pal	4	0	0	0	1	15 13
40	Sharma Pal	6	1	0	0	3	10 12
41	Ashok Pal	5	1	0	0	3	12 12
42	Sammi Pal	4	0	0	0	1	14 13
43	Nand Pal	5	1	0	0	1	15 10
44	Brijesh Pal	8	1	0	0	4	20 11
45	Vimod Pal	6	1	1	0	3	18 10
46	Basand Pal	5	1	0	0	2	16 15
47	Vedpal	4	0	0	0	2	16 15
48	Madan Pal	8	1	1	0	3	14 13
49	Lala Pal	7	1	0	0	1	16 12
50	Medhraj Pal	7	1	0	0	2	12 10
51	Gopal Pal	6	1	0	0	2	16 10
52	Nyader Pal	7	1	0	0	3	13 12
53	Shyamsunder Pal	14	1	0	0	8	14 10
54	Kiloram Pal	10	1	0	0	3	18 10
55	Shivechand	19	1	0	0	7	16 12
56	Dharam Singh Pal	19	1	1	0	5	12 12
57	Shive Kumar Saini	9	0	0	0	2	12 12
58	Ompal Saini	10	1	1	120	5	14 13
59	Janeshwar Prashad	26	2	2	150	10	12 10

Sr. #	Name of family head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions L x B (ft)	
60	Yashpal	13	1	0	0	7	15	10
61	Budhu	10	1	1	0	6	16	13
62	Vijaypal	6	1	1	0	5	15	10
63	Mahendar	6	0	1	0	4	13	12
64	Chatar Singh	5	1	1	0	4	13	12
65	Nathiram	5	1	1	0	6	14	12
66	Shevaram	7	1	0	0	5	14	14
67	Pawan	10	1	0	0	7	13	12
68	Kukan	15	1	0	0	7	13	12
69	Sukhveer	11	1	1	0	13	13	12
70	Ratan Singh Saini	9	1	1	0	4	12	12
71	Naresh Saini	7	1	1	240	4	12	12
72	Medhraj Saini	20	2	1	240	4	12	12
73	Teluram Saini	6	2	0	0	4	14	14
74	Subhash	4	1	0	0	4	13	10
75	Urjesh	10	1	0	0	4	13	10
76	Sahendar Saini	6	1	1	180	12	18	10
77	Mangeram Saini	8	2	0	0	6	12	10
78	Jaykumar	9	1	0	0	6	10	10
79	Kaliram	13	3	0	0	13	12	12
80	Jaychand	10	2	0	0	5	15	13
81	Vedpal Saini	10	3	2	210	14	16	14
82	Satyapal	11	2	1	150	8	14	13
83	Sethraj Saini	7	7	0	0	5	13	12
84	Sulekhchand	9	2	1	240	10	12	12
85	Nathiram	7	1	1	0	4	14	13
86	Neeraj Saini	5	1	0	0	4	14	13
87	Boby	4	1	1	0	4	12	12
88	Baburam	6	1	0	0	4	12	12
89	Jitram	12	1	1	150	10	13	12
90	Sadhuram	9	2	1	180	10	12	12
91	Satyapal	10	1	0	0	5	15	10
92	Ramsingh	9	1	1	260	3	15	10
93	Rishipal Saini	5	1	1	180	5	14	13
94	Nathiram	10	1	1	150	7	12	11

Sr. #	Name of family head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions L x B (ft)	
95	Ashok	15	3	1	210	10	10	10
96	Deepchand	5	1	0	0	3	10	8
97	Bablu	8	1	0	0	5	12	12
98	Jagdeesh	6	1	0	0	5	14	13
99	Bhushan	8	1	1	0	6	16	10
100	Shobharam	16	3	0	0	7	14	13
101	Ranjeet Saini	10	2	0	0	5	12	12
102	Baldev	11	1	0	0	5	12	12
103	Bijendar	9	1	0	0	5	15	10
104	Aatmaram	2	1	0	0	3	13	10
105	Ramprashad	22	1	0	0	4	12	12
106	Sheeshram	10	1	0	0	6	12	11
107	Fool Singh	10	1	0	0	3	12	10
108	Leela Devi	13	3	0	0	6	12	13
109	Prakshi Devi	32	3	0	0	10	14	10
110	Shobharam	18	1	0	0	8	15	10
111	Ruhala	21	3	0	0	5	18	10
112	Sommi	9	1	0	0	4	12	13
113	Shoam	21	2	0	0	8	14	12
114	Inderpal	16	2	0	0	3	14	10
115	chameli	27	3	0	0	12	12	12
116	Vedpal	8	1	0	0	3	12	12
117	Birampal	20	0	0	0	7	13	12
118	Baburam	9	0	0	0	4	12	10
119	Chamendei	8	0	0	0	2	15	10
120	Lalla	6	0	0	0	3	10	10
121	Motiram	5	0	0	0	2	12	8
122	Bhartu	11	1	0	0	5	10	14
123	Rajpal	9	0	0	0	4	12	10
124	Chanderpal	11	0	0	0	4	14	12
125	Jaisingh	15	0	0	0	3	13	12
126	Shevaram	6	1	0	0	4	12	12
127	Rishipal Saini	12	1	0	0	4	14	12
128	Ramesh	10	1	0	0	2	12	10
129	Mangeram Saini	6	0	0	0	1	13	12

Sr. #	Name of family head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions L x B (ft)
130	Ruhda	13	2	0	0	4	12 12
131	Mangatram	18	2	0	0	6	14 12
132	Puran Singh	15	1	0	0	8	14 14
133	Lal Singh	7	1	0	0	5	15 12
134	Barambari	8	1	0	0	5	13 12
135	Pal Singh	9	1	1	0	3	14 13
136	Atar Singh	21	1	0	0	3	15 14
137	Simtra	11	1	0	0	3	15 12
138	Satish	5	1	0	0	2	12 12
139	Gommi	7	1	2	0	4	13 13
140	Jagdeesh	10	0	0	0	2	12 12
141	Medh Singh	7	1	0	0	3	13 12
142	Sanjay	6	0	0	0	2	16 12
143	Sukkad	15	1	1	60	4	13 12
144	Jagdeesh	6	1	0	0	3	13 12
145	Shivekumar	5	0	0	0	5	13 12
146	Mahak Singh	8	1	0	0	2	10 10
147	Ismsingh	5	1	0	0	1	12 10
148	Amarnath	5	0	0	0	1	15 10
149	Munesh	5	1	0	0	2	13 10
150	Lal Singh	18	2	1	210	8	13 12
151	Surender Saini	5	1	0	0	4	12 10
152	Mahendra	4	1	0	0	2	12 10
153	Dharam Singh	9	1	2	240	5	13 12
154	Panto	17	3	0	0	9	15 10
155	Karm Singh	8	1	0	0	2	13 12
156	Shevawati	13	1	0	0	6	15 10
157	Pramod	12	2	0	0	10	12 12
158	Satyadev Arya	11	2	1	150	9	14 12
159	Rohitash	4	1	0	0	4	12 12
160	Bala Devi	6	1	0	0	3	12 10
161	Rajkali	8	0	0	0	4	12 10
162	Mulkiraj	5	0	0	0	2	12 10
163	Prakash Chand	14	3	0	0	6	13 12
164	Somprakash	12	2	1	150	5	13 12
165	Satyakumar	6	2	0	0	3	12 12

Sr. #	Name of family head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions L x B (ft)
166	Ramkumar	6	1	0	0	4	14 12
167	Vedpal	11	1	0	0	3	12 10
168	Satish	6	1	1	0	4	12 12
169	Prakash	5	1	1	0	3	12 12
170	Mahendar Saini	8	1	1	0	2	12 10
171	Nathiram	12	1	0	0	3	12 12
172	Santri	4	1	0	0	3	15 10
173	Dharampal	11	1	1	0	3	12 10
174	Dataram	5	1	0	0	4	12 12
175	Hazari	7	1	0	0	4	13 13
176	Dharampal	13	1	0	0	5	15 10
177	Harpal	5	1	0	0	3	15 12
178	Gajesingh	9	1	1	150	6	12 12
179	Surender Saini	5	1	1	150	6	12 12
180	Rajvir	5	1	1	150	4	12 12
181	Vinod	6	1	0	0	6	12 12
182	Bhura	10	1	0	0	3	12 10
183	Janki	12	1	0	0	3	12 10
184	Krishan	14	1	0	0	8	13 12
185	Sunder	8	1	0	0	2	15 10
186	Rakesh	4	1	0	0	3	12 12
187	Rajesh	5	1	0	0	1	11 10
188	Dharam Singh	10	1	1	240	7	12 10
189	Amarpal	6	1	1	240	5	12 10
190	Mahender Master	7	1	0	0	7	12 12
191	Goverdham	4	1	0	0	2	14 12
192	Biramchand	13	2	2	240	6	12 10
193	Yashpal	7	2	1	180	6	13 12
194	Kamarpal	6	1	0	0	1	14 12
195	Naresh Saini	7	1	0	0	2	12 12
196	Mahipal	8	1	0	0	4	12 10
197	Anil Kumar	5	1	0	0	1	12 12
198	Suresh Kumar	4	0	0	0	1	15 10
199	Ramkumar	6	0	0	0	1	15 10
200	Sanjay	5	0	0	0	1	15 10

Sr. #	Name of family head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions L x B (ft)	
201	Rajpal	8	1	1	180	8	15	10
202	Ramnath	1	1	2	240	6	15	10
203	Jaypal	8	1	0	0	5	15	10
204	Rajkumar	6	1	0	0	4	12	10
205	Deshraj	4	1	1	180	2	12	10
206	Manga	2	1	1	180	3	12	12
207	Kartar Singh	31	4	1	240	8	12	12
208	Sethraj	18	1	0	0	3	14	12
209	Babu	19	1	1	180	6	14	13
210	Jyoti	37	1	1	240	6	13	12
211	Rampal	9	1	1	180	2	13	12
212	Ramchandra	14	1	1	240	3	13	12
213	Pala	14	1	0	0	2	14	12
214	Shyamlal	10	1	0	0	2	14	12
215	Sweraj	6	1	1	240	1	13	12
216	Pitamber	6	1	0	0	1	13	12
217	Dhanni	1	0	0	0	0	0	0
218	Madan Singh	6	0	0	0	1	13	12
219	Rishipal	4	1	0	0	1	13	12
220	Sheetal	11	1	0	0	2	12	12
221	Ilam Singh	18	1	0	0	3	14	13
222	Rajesh	6	1	0	0	1	14	13
223	Tarachand	1	1	0	0	2	12	12
<b>Total</b>		<b>2170</b>	<b>255</b>	<b>63</b>	<b>7250</b>	<b>1004</b>		

## [B] Sub-Village: Masahi Kala

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions Lx B (ft)	
1	Ilam Chand Saini	12	1	0	0	4	15	12
2	Vijay Pal Saini	10	1	0	0	4	15	12
3	Prem Kali	15	1	0	0	4	15	12
4	Ramkala	21	3	0	0	7	13	12

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions Lx B (ft)
5	Chandharbhan	12	1	0	0	5	12 12
6	Rampal	7	1	0	0	3	12 10
7	Bablu	5	0	0	0	2	12 10
8	Kabol	2	1	0	0	2	12 12
9	Lahana	16	3	0	0	10	13 12
10	Sunder	5	1	0	0	4	12 12
11	Ramnath	9	1	0	0	4	12 12
12	Dheer Singh	5	1	0	0	2	12 10
13	Randheer	1	0	0	0	1	12 10
14	Rajkumar	8	1	0	0	3	12 12
15	Suresh	7	1	0	0	3	13 12
16	Tejpal	4	1	0	0	2	12 12
17	Sudesh	5	0	0	0	2	12 12
18	Shive Kumar	6	1	0	0	2	12 11
19	Dharam Singh	11	1	0	0	1	13 12
20	Sulekh Chand	9	1	0	0	2	12 12
21	Lata	8	1	0	0	2	13 12
22	Keshoram	26	1	0	0	9	12 12
23	Kadam Singh Saini	13	0	0	0	4	12 12
24	Ishwar Dayal	13	0	0	0	3	10 8
25	Ashok	4	1	0	0	4	12 10
26	Goverdhan	13	1	0	0	10	12 12
27	Khadak Singh	9	1	0	0	3	12 12
28	Jeele Singh	4	0	0	0	4	13 12
29	Mange Ram	5	1	0	0	5	13 12
30	Ram Kumar	5	1	0	0	2	13 12
31	Punita	3	0	0	0	2	13 12
32	Rakesh	5	1	0	0	3	12 12
33	Baleshar	1	1	0	0	2	12 12
34	Sukhdev	6	1	0	0	7	12 11
35	Rishipal	6	0	0	0	4	12 11
36	Vikash	4	1	0	0	4	12 13
37	Subhash	4	1	0	0	1	12 10
38	Dinesh	4	1	0	0	1	12 10
39	Chandan	4	1	0	0	9	12 12

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions Lx B (ft)
40	Kushal Pal	6	1	0	0	2	12 12
41	Devi Singh	4	1	0	0	2	12 12
42	Munna	4	1	0	0	2	12 12
43	Bishamber	33	5	0	0	10	12 12
44	Savita	4	1	0	0	2	12 12
45	Vinod	2	0	0	0	0	12 11
46	Rajpal	11	1	1	240	10	12 12
47	Basant	5	1	0	0	4	12 12
48	Promod	7	1	0	0	3	12 10
49	Ramesh	12	1	0	0	7	12 12
50	Malkhan	9	1	0	0	6	12 10
51	Jogindir	7	0	0	0	1	12 10
52	Pappu	7	1	0	0	2	12 8
53	Anand	7	0	0	0	1	12 12
54	Kashi	9	1	0	0	2	12 11
55	Vikram	5	1	0	0	2	12 10
56	Deshraj	11	1	0	0	6	12 10
57	Sushil	4	1	0	0	2	12 13
58	Ishwar Chand	3	0	0	0	2	12 10
59	Khajan	9	1	0	0	3	12 10
60	Nathiram	4	0	0	0	2	12 10
61	Prem	9	1	0	0	3	12 10
62	Suresh	9	1	0	0	4	12 11
63	Rakam Singh	9	1	0	0	4	12 10
64	Kela Devi	4	0	0	0	3	12 11
65	Vimla	5	1	0	0	2	12 11
66	Malkhan Singh	6	1	0	0	4	12 12
67	Tejpal	1	2	1	150	6	12 10
68	Sanjeev	16	1	1	150	5	12 13
69	Sunder Devi	8	1	0	0	2	12 13
70	Vishambri	8	1	0	0	2	12 13
71	Rameshwar	7	1	0	0	2	12 13
72	Mukesh	5	0	0	0	1	12 11
73	Ridka	5	1	1	210	2	12 14
74	Rajkumar	31	3	1	0	10	12 11
75	Ikram	24	0	0	0	3	12 11

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions Lx B (ft)	
76	Hukam Singh	12	2	0	0	4	12	13
77	Kulveer	10	2	0	0	4	12	14
78	Lakhmi Chand	8	1	1	180	6	12	13
79	Pawan Singh	9	2	1	180	8	12	14
80	Sulekh Chand	5	1	1	180	4	12	10
81	Ishwar Chand	5	1	1	180	2	12	13
82	Bhupendir	4	1	0	0	2	12	12
83	Ompraksh	6	1	1	180	4	12	12
84	Sheri	7	2	0	0	4	12	13
85	Baleshar	4	1	1	180	5	12	13
86	Jaysingh	7	1	1	150	7	12	12
87	Rohitash	7	1	0	0	3	12	12
88	Kartar Saini	9	2	1	180	6	12	13
89	Naresh	8	2	2	180	7	12	13
90	Satyapal	9	1	0	0	3	12	10
91	Lakshman	9	2	1	180	4	12	12
92	Rithha	10	2	1	210	5	12	10
93	Ishwar Chand	6	1	1	180	2	12	11
94	Geeta Ram	13	2	1	180	4	12	11
95	Sithu	10	2	1	240	6	12	12
96	Mulki Raj	7	2	1	180	3	12	13
97	Charan Singh	9	1	1	150	4	12	11
98	Pappu	7	1	1	180	4	12	13
99	Subodh	9	2	1	180	6	12	10
100	Ridka	15	2	1	180	6	12	11
101	Pravesh	12	2	1	180	7	12	11
102	Meela	10	1	1	180	4	12	10
103	Hinnu	7	1	1	180	4	12	10
104	Memchand	5	1	1	180	5	12	13
105	Shive datt	5	1	1	150	3	12	11
106	Champa Devi	21	1	0	0	3	12	10
107	Jalend	12	1	0	0	15	12	10
108	Manni	30	1	1	240	11	12	13
109	Ramo Devi	9	1	0	0	4	12	13
110	Rishipal	9	1	1	180	6	12	12
111	Ishaq Lal	13	0	0	0	2	15	10

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions Lx B (ft)
112	Soshin	8	0	0	0	1	10 12
113	Yashpal	9	0	0	0	1	10 12
114	Ishmpal	1	0	0	0	1	10 12
115	Sonu	3	0	0	0	1	10 12
116	Mukesh	7	0	0	0	1	10 12
117	Ram Singh	23	1	0	0	5	12 11
118	Ram Saroop	9	0	0	0	4	12 11
119	Lal Bahdur	15	1	0	0	7	10 12
120	Rajaram	8	1	0	0	3	10 12
121	Narender	27	1	0	0	15	12 12
122	Rakesh	6	1	0	0	4	12 12
123	Satyapal	13	1	0	0	5	12 12
124	Yashpal	13	0	0	0	3	10 12
125	Fool Kumar	30	2	0	0	16	12 12
126	Sitaram	15	1	0	0	4	12 12
127	Ompal	7	1	0	0	4	12 12
128	Mahender	8	1	0	0	8	12 12
129	Rahtu Singh	14	1	0	0	5	10 12
130	Rishipal	14	0	0	0	4	10 12
131	Geeta	4	1	0	0	2	10 12
132	Muninder Devi	10	1	0	0	4	13 12
133	Bala Devi	5	1	0	0	3	13 12
134	Sohan	23	3	0	0	9	13 12
135	Sanoop	4	1	0	0	2	10 12
136	Satish	6	1	0	0	2	12 12
137	Raju	4	1	0	0	2	10 12
138	Kanihya	7	1	0	0	2	13 12
139	Dheer Singh	19	1	0	0	5	12 12
140	Jagdeesh	16	1	0	0	5	10 12
141	Sadhuram	6	2	0	0	2	10 12
142	Prem Singh	20	1	0	0	8	12 12
143	Nain Singh	11	1	0	0	6	13 12
144	Vilendir	13	1	0	0	3	9 12
145	Amar Singh	11	0	0	0	2	10 12
146	Singhraj	15	1	0	0	4	10 12
147	Mange Ram	9	1	0	0	2	13 12

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions Lx B (ft)	
148	Jagpal	12	0	0	0	2	12	12
149	Bisan	9	0	0	0	3	10	12
150	Jatiram	9	0	0	0	2	13	12
151	Peela	6	1	0	0	2	10	12
152	Birampal	7	0	0	0	3	10	12
153	Sharavan	5	0	0	0	2	12	12
154	Balram	9	1	0	0	3	12	12
155	Nekiram	10	1	0	0	2	12	12
156	Suresh Pal	8	1	0	0	3	10	12
157	Sheeshpal	3	0	0	0	1	13	12
158	Pradeep	5	0	0	0	2	12	12
159	Rakesh	7	0	0	0	1	12	12
160	Deshraj	7	1	0	0	2	13	12
161	Pappu	9	1	0	0	2	12	12
162	Maan Singh	18	1	0	0	6	10	12
163	Pradeep	6	0	0	0	1	18	12
164	Iraklal	4	1	0	0	2	12	12
165	Kartari	26	1	3	150	10	12	11
<b>Total</b>		<b>1528</b>	<b>159</b>	<b>35</b>	<b>5640</b>	<b>651</b>	<b>1967</b>	<b>1922</b>

### [C] Sub-Village: Belki Masahi

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions Lx B (ft)	
1	Ilam	4	1	0	0	2	12	12
2	Murari	5	1	0	0	2	12	12
3	Raguveer	4	1	1	180	4	12	12
4	Mainpal	4	1	0	0	2	15	10
5	Rohitash	2	0	0	0	2	15	10
6	Aadesh	5	0	0	0	2	12	12
7	Raju	5	0	0	0	1	12	12
8	Balendra	5	0	0	0	0	14	14
9	Kadam	4	1	1	240	3	13	12

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions Lx B (ft)
10	Bhura	1	0	0	0	1	13 12
11	Sattu	4	1	0	0	2	13 11
12	Raju	1	0	0	0	1	13 12
13	Indar	2	1	1	240	1	13 10
14	Arjun	4	1	0	0	5	13 12
15	channu	10	1	0	0	7	13 14
16	Nathiram	17	1	0	0	14	13 14
17	Hushanpal	4	1	0	0	3	14 15
18	Shiveraj	5	1	0	0	5	12 14
19	Talluram	9	1	0	0	6	14 13
20	Jitendra	6	0	0	0	7	12 13
21	Subhash Chandra	10	1	0	0	3	12 12
22	Vhandmal	13	1	0	0	8	14 13
23	Ratan	10	1	0	0	4	14 14
24	Satish	24	1	0	0	6	14 14
25	Chambhelal	14	2	0	0	10	14 14
26	Dharampal	12	1	0	0	4	14 14
27	Sitaram	12	1	0	0	8	14 14
28	Pyrelal	11	2	0	0	9	14 14
29	Shymo	2	0	0	0	1	14 14
30	Jitendra	4	1	0	0	1	14 14
31	Ramesh	7	1	0	0	2	14 13
32	Tilka	6	1	0	0	6	12 13
33	Bhaghirath	12	2	0	0	8	12 14
34	Ratiram	6	0	0	0	3	14 14
35	Palla	19	2	0	0	10	14 14
36	Rajendra	9	1	0	0	4	12 13
37	Sudesh	10	1	0	0	5	14 13
38	Ramesh	4	1	0	0	4	14 13
39	Mahendra	13	1	0	0	9	14 13
40	Rajja	5	1	0	0	3	14 13
41	Rajkumar	6	1	0	0	3	14 13
42	Bhopal	25	1	0	0	6	15 10
43	Jaypal	21	1	0	0	3	15 10
44	Dhannu	23	1	0	0	5	13 14

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions Lx B (ft)
45	Paltu	18	1	0	0	4	13 14
46	Amarpal	10	1	0	0	3	13 12
47	Rajpal	4	0	1	240	3	12 12
48	Biram	17	0	0	0	2	15 12
49	Kala	8	0	0	0	3	12 12
50	Buchha	21	0	0	0	5	14 12
51	Palla	21	1	1	180	9	14 12
52	palla	9	1	0	0	3	15 12
53	Gyasu	8	0	0	0	1	13 10
54	Sheela	5	0	0	0	2	13 11
55	Manga	4	1	0	0	4	12 13
56	Tirath	7	1	0	0	2	12 13
57	Brijesh	7	1	0	0	1	12 13
58	Radha	7	1	0	0	3	12 13
59	Madan	6	1	0	0	3	12 13
60	Bedi	6	1	0	0	1	12 13
61	Mainpal	5	1	0	0	3	14 13
62	Chandarpal	8	1	0	0	2	14 12
63	Sheela	4	0	0	0	2	12 12
64	Soam	3	1	0	0	4	12 13
65	Hukum	6	1	0	0	7	12 14
66	Sheeshram	4	1	0	0	2	12 13
67	Kiranpal	6	1	0	0	3	12 14
68	Sunil	10	1	0	0	2	16 16
69	Rakesh	7	1	0	0	3	12 13
70	Vikram Singh	6	1	0	0	3	12 13
71	Sandeep	6	0	0	0	2	12 13
72	Bijendra	6	0	0	0	2	12 13
73	Prushottam	5	0	0	0	3	12 13
74	Naresh	10	1	0	0	3	12 13
75	Narendra	6	0	0	0	1	12 13
76	Soampal	4	0	0	0	3	12 14
77	Shevaram	9	1	1	210	3	12 12
78	Jagram	4	0	0	0	2	12 13
79	Harpal	6	0	0	0	1	12 14
80	Arvind	3	0	0	0	2	12 13

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions Lx B (ft)	
81	Baldev Singh	13	1	0	0	3	11	14
82	Ratan Singh Saini	8	1	0	0	3	12	13
83	Dheeer Singh	5	1	0	0	3	12	14
84	Bhamool Singh	5	1	0	0	2	12	13
85	Harpal	7	1	0	0	1	8	15
86	Roop Chand	5	1	0	0	1	12	10
87	Dharam Pal	5	0	0	0	1	12	14
88	Bhopal	9	1	0	0	2	14	14
89	Achupal	5	0	0	0	0	0	0
90	Rohitash	4	0	0	0	1	12	13
91	Jaypal Singh	8	0	1	120	3	14	13
92	Deshraj Singh	4	0	0	0	1	14	14
93	Savroop Kumar	4	0	0	0	1	12	13
94	Kushum Pal	4	0	0	0	1	10	10
95	Rampal	5	0	0	0	1	12	11
96	Ajaypal	5	0	0	0	3	12	13
97	Shyam Lal	14	2	0	0	8	12	13
98	Balchand	21	2	0	0	10	13	14
99	Ranjeet Singh	17	0	0	0	5	12	13
100	Rishipal	10	1	0	0	8	12	13
101	Omprakash	12	1	0	0	5	14	13
102	Naresh Kumar	6	1	0	0	7	12	13
103	Raghuveer	8	1	0	0	2	13	14
104	Rajesh	7	1	0	0	3	14	12
105	Promod	13	0	0	0	4	12	12
106	Vinod Kumar	5	0	0	0	2	12	13
107	Sukhveer	1	0	0	0	1	12	14
108	Balveer Singh	6	1	0	0	3	12	13
109	Mangeram	5	1	0	0	3	12	14
110	Chandmal	8	2	0	0	8	13	14
111	Mainpal	0	0	0	0	0	0	0
112	Banarshi Das	14	1	0	0	3	14	12
<b>Total</b>		<b>898</b>	<b>81</b>	<b>7</b>	<b>1410</b>	<b>396</b>	<b>1411</b>	<b>1415</b>

## [D] Sub-Village: Inayatpur

Sr#	Name of Family Head	Total nos. of Family Member	Nos. of Drinking Water Hand Pumps	Nos. of Tube Wells Farmland	Tube Wells Operating Days in Year	No. of Rooms	Room Dimensions L x B (ft)	
1	Yashpal	1	0	0	0	2	14	14
2	Hukum Dai	10	1	0	0	3	14	14
3	Mukesh	3	1	0	0	2	12	10
4	Pradeep	5	0	0	0	1	12	13
5	Kallu Singh	6	0	0	0	1	12	13
6	Sadhu Ram	6	0	0	0	2	12	13
7	Shive Kumar	4	0	0	0	1	12	10
8	Hari Chand	9	1	0	0	2	12	12
9	Nitu	5	0	0	0	1	12	12
10	Premvati	3	0	0	0	1	12	12
11	Ramesh Chand	7	1	0	0	2	14	13
12	Dilip Kumar	2	1	0	0	2	14	12
13	Jagram	5	0	0	0	2	14	14
14	Paltu Das	7	1	0	0	1	14	14
15	Soam Pal Singh	6	1	0	0	2	12	10
16	Soam Pal	1	0	0	0	1	12	10
17	Vinod Kumar	7	1	0	0	2	12	10
18	Satya Pal	4	1	0	0	1	13	10
19	Medhram	3	1	0	0	3	13	10
20	Karan Pal	6	0	0	0	2	13	12
21	Karam Singh	6	1	0	0	1	12	12
22	Fullo Devi	4	1	0	0	2	12	10
23	Rasla Singh	23	1	0	0	4	12	10
24	Rajendra Kumar	6	0	0	0	2	12	10
25	Mahndra Singh	6	1	0	0	2	14	14
26	Mainpal	5	0	0	0	2	14	14
27	Fullo Devi	4	1	0	0	2	14	10
28	Sakuntla Devi	6	1	0	0	1	14	13
29	Sarjeet Singh	4	0	0	0	1	12	12
30	Raghuveer Singh	2	1	0	0	1	12	12
31	Vijay Pal	3	1	0	0	1	12	12
32	Sharavan	4	0	0	0	1	13	12
33	Raja Ram	5	0	0	0	1	13	12
34	Lakhan	7	0	0	0	1	12	10

Sr#	Name of Family Head	Total nos. of Family Member	Nos. of Drinking Water Hand Pumps	Nos. of Tube Wells Farmland	Tube Wells Operating Days in Year	No. of Rooms	Room Dimensions L x B (ft)
35	Darbara	3	0	0	0	1	12 10
36	Mahaveer	4	1	0	0	1	12 14
37	Kabul Singh	10	1	0	0	1	12 13
38	Jay Pal	4	0	0	0	1	12 13
39	Tarachand	5	1	0	0	2	12 14
40	Bala	11	1	0	0	3	12 12
41	Karam Singh	4	1	0	0	2	12 10
42	Kamla	8	1	0	0	1	13 12
43	Balveer Singh	9	1	0	0	4	12 13
44	Indir Singh	13	1	0	0	4	12 10
45	Shanti	5	2	0	0	4	12 13
46	Subhash	4	0	0	0	2	12 10
47	Praksh Singh	7	0	0	0	1	12 11
48	Rajpal	7	0	0	0	3	12 13
49	Sadhuram	7	0	0	0	6	12 10
50	Shersingh	7	1	0	0	3	12 13
51	Mohan	6	1	0	0	3	12 14
52	Munnu	7	1	0	0	3	12 10
53	Champa	1	0	0	0	1	10 10
54	Mainna	4	1	0	0	3	12 13
55	Jaychand	5	1	0	0	3	14 13
56	Satveer	1	1	0	0	1	12 13
57	Ramphal	8	1	0	0	3	12 13
58	Chaman	6	1	0	0	1	12 13
59	Manoj Kumar	5	1	0	0	2	14 13
60	Ram Kishan	7	1	0	0	1	14 12
61	Dheer Singh	7	1	0	0	2	14 14
62	Bheeta Singh	4	0	0	0	1	12 13
63	Raj Kumar	2	0	0	0	2	12 13
64	Biram Pal Singh	4	0	0	0	1	12 12
65	Premchand	8	1	0	0	2	12 14
66	Mhaveer Singh	5	1	0	0	2	12 10
67	Chandar Bhaan	4	0	0	0	1	11 10
68	Chandkiran	5	0	0	0	1	12 13
69	Guddu Singh	4	0	0	0	1	12 14

Sr#	Name of Family Head	Total nos. of Family Member	Nos. of Drinking Water Hand Pumps	Nos. of Tube Wells Farmland	Tube Wells Operating Days in Year	No. of Rooms	Room Dimensions L x B (ft)
70	Rajkumar	6	0	0	0	1	12 13
71	Tilakram	6	1	0	0	1	12 13
72	Jaypal Singh	7	1	0	0	1	12 13
73	Banarsi	2	0	0	0	1	12 14
74	Ravindir Kumar	5	0	0	0	1	12 13
75	Sanjay Kumar	4	0	0	0	1	12 13
76	Rishi Pal	6	0	0	0	1	12 11
77	Harigyan Singh	4	1	0	0	2	12 11
78	Mangeram	4	0	0	0	1	12 13
79	Chandarpal	7	1	0	0	1	13 11
80	Pal Singh	5	1	0	0	2	13 10
81	Shanti Devi	7	0	0	0	1	12 13
82	Lakhmeri Devi	5	1	0	0	2	12 13
83	Dharam Singh	7	0	0	0	2	12 15
84	Mintar Pal	7	0	0	0	1	12 13
85	Praksh Singh	3	1	0	0	2	12 10
86	Yogendra	5	0	0	0	1	12 12
87	Sudeh Kumar	7	0	0	0	1	12 13
88	Aasho Devi	7	0	0	0	1	12 12
89	Sudeh Pal	9	1	0	0	1	12 10
90	Mohar Singh	3		0	0	1	12 10
91	Shyam Lal	5	1	0	0	2	12 13
92	Rajesh Kumar	4	0	0	0	1	12 13
93	Patram Singh	6	1	0	0	1	12 10
94	Narendra Kumar	6	0	0	0	1	12 13
95	Bhushan Kumar	8	0	0	0	1	12 15
96	Data Ram	5	1	0	0	4	12 15
97	Ilam Chand	7	1	0	0	6	12 13
98	Mahendra Singh	4	1	0	0	2	12 10
99	Arvind Kumar	8	1	0	0	2	12 10
100	Babu Ram	5	0	0	0	2	12 10
101	SatiSH Kumar	7	0	0	0	2	13 14
102	Itesh Kumar	8	0	0	0	2	13 14
103	Aasha Ram	7	1	0	0	1	13 15
104	Satkumar	6	0	0	0	1	12 10

Sr#	Name of Family Head	Total nos. of Family Member	Nos. of Drinking Water Hand Pumps	Nos. of Tube Wells Farmland	Tube Wells Operating Days in Year	No. of Rooms	Room Dimensions L x B (ft)	
105	Sulendra Kumar	8	1	0	0	2	12	12
106	Kali Ram	4	1	0	0	1	11	10
107	Amar Singh	2	0	0	0	1	12	10
108	Satya Pal Singh	5	0	0	0	1	12	11
109	Nekiram	5	0	0	0	1	12	11
110	Vijay Kumar	5	0	0	0	1	12	13
111	Mainpal	5	0	0	0	2	12	12
112	Rajendra Kumar	5	1	0	0	1	12	13
113	Atar Singh	9	1	0	0	3	12	13
114	Kabul Singh	4	1	0	0	2	12	12
115	Sunil Kumar	2	1	0	0	1	12	13
116	Arjun Kumar	4	0	0	0	1	12	13
117	Kabul Singh	3	0	0	0	1	12	13
118	Karam Singh	4	1	0	0	1	12	14
119	Kishan Kumar	4	1	0	0	2	12	14
120	Jay Pal Singh	7	1	0	0	2	12	13
121	Shukram	9	1	0	0	2	12	14
122	Vinod Kumar	7	1	0	0	2	13	14
123	Amarwati	7	1	0	0	2	13	14
124	Magan Singh	6	1	0	0	4	13	11
125	Kareshni	7	1	0	0	2	12	10
126	Ram Kumar	6	0	0	0	1	12	12
127	Babu Ram	3	0	0	0	2	12	13
128	Ram Prasad	6	1	0	0	2	12	14
129	Ram karan	5	1	0	0	4	12	13
130	Baljeet	2	1	0	0	2	10	10
131	Sansar	3	0	0	0	1	10	11
132	Charan Singh	6	1	0	0	3	10	11
133	Sita Ram	2	0	0	0	1	12	13
134	Rajesh Singh	5	0	0	0	1	12	13
135	Magan Singh	5	1	0	0	4	12	14
136	Mahendra Singh	6	1	0	0	3	12	14
137	Vikram Singh	7	0	0	0	1	12	10
138	Lachhiya	11	1	0	0	4	12	13
<b>Total</b>		<b>767</b>	<b>77</b>	<b>0</b>	<b>0</b>	<b>247</b>	<b>1688</b>	<b>1681</b>

## [E] Sub-Village: Halzora

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions L x B(ft)	
1	Chamanlal	6	1	0	0	2	10	12
2	Sambhulal	5	0	0	0	2	10	12
3	Rohitash	7	0	0	0	2	10	12
4	Munesh	7	0	0	0	2	12	11
5	Shobha Ram	7	1	0	0	7	12	11
6	Rajkumar	5	1	0	0	5	12	11
7	Malkhan	29	1	0	0	4	14	13
8	Dheer Singh	6	0	0	0	3	14	13
9	Gaje Singh	9	0	0	0	4	10	13
10	Pappu	7	1	0	0	4	12	10
11	Surender	8	1	0	0	4	12	15
12	Sanjay	5	1	0	0	1	12	13
13	Data Ram	5	1	0	0	4	12	13
14	Girvar Singh	6	1	0	0	1	12	15
15	Babu Ram	6	1	0	0	2	12	15
16	Sita Ram	1	1	0	0	5	12	15
17	Mahal Singh	8	1	0	0	5	12	12
18	Prem Singh	5	1	0	0	4	12	12
19	Mangeram	5	1	0	0	2	12	13
20	Subhash Singh	5	1	0	0	2	12	13
21	Vinod Singh	11	1	0	0	2	12	13
22	Rakesh Singh	5	1	0	0	2	12	10
23	Shersingh	5	1	0	0	5	12	14
24	Pitam Singh	6	1	0	0	3	12	14
25	Ratna	1	0	0	0	3	12	16
26	Roshan Singh	4	1	0	0	1	12	13
27	Mahender Singh	6	1	0	0	3	12	14
28	Vikram Singh	7	0	0	0	3	12	16
29	Rajveer	5	0	0	0	3	12	13
30	Mintar Pal	5	1	0	0	3	12	13
31	Maher Singh	4	0	0	0	1	12	13
32	Vishnu Singh	5	0	0	0	2	12	14
33	Krishan Singh	6	1	0	0	2	12	12
34	Malchand	5	1	0	0	3	12	10

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions L x B(ft)
35	Birma	7	1	0	0	3	10 12
36	Mohak Singh	5	1	0	0	3	12 10
37	Dyal Singh	10	1	0	0	8	12 13
38	Bhajan Singh	8	1	0	0	4	12 11
39	Banarsi	10	0	0	0	4	12 13
40	Norli	6	0	0	0	2	12 14
41	Sunil	11	1	0	0	3	12 15
42	Sheesh Pal	7	1	0	0	2	12 10
43	Ram Pal Singh	10	0	0	0	2	10 10
44	Mohllad	5	0	0	0	3	10 11
45	Pawan Singh	8	1	0	0	3	11 12
46	Rajpal Singh	6	1	0	0	3	12 13
47	Ishwar Singh	7	0	0	0	2	12 13
48	Gabbar Singh	4	1	0	0	4	12 14
49	Tilka Singh	14	1	0	0	3	12 15
50	Naresh Singh	15	1	0	0	1	12 13
51	Sabdar	8	0	0	0	1	12 13
52	Aabid	10	0	0	0	1	12 15
53	Kallu	8	0	0	0	1	13 15
54	Meer Hashan	10	0	0	0	2	10 11
55	Jushad	8	1	0	0	1	13 15
56	Ajeej	3	1	0	0	1	15 15
57	Chotta	5	0	0	0	2	15 12
58	Shameen	7	0	0	0	1	15 15
59	Noor Hashan	8	1	0	0	1	15 16
60	Shamim	6	0	0	0	1	15 15
61	Shokin	5	0	0	0	1	13 12
62	Tofik	5	1	0	0	2	14 13
63	Yamin	4	1	0	0	1	15 15
64	Nafish	5	0	0	0	1	13 13
65	Abdul	8	0	0	0	1	15 13
66	Maherbaan	10	1	0	0	2	12 14
67	Azad	8	1	0	0	1	15 14
68	Shamshad	20	1	0	0	1	15 13
69	Fhurkan	10	0	0	0	2	12 13

Sr#	Name of Family Head	Total nos. of family member	Nos. of drinking water hand pumps	Nos. of tube wells farmland	Tube wells operating days in year	No. of rooms	Room dimensions L x B(ft)	
70	Irfhan	2	0	0	0	1	15	13
71	Dilshad	6	0	0	0	1	12	14
72	Jamil	10	1	0	0	1	12	13
73	Anwar	17	0	0	0	1	12	13
74	Sajid	7	0	0	0	1	15	14
75	Chota	13	1	0	0	2	12	13
76	Hamid	9	1	0	0	1	12	13
77	Mazid	17	1	0	0	1	13	14
78	Nazir	10	1	0	0	1	15	16
79	Nasir	23	1	0	0	1	15	14
80	Sheed	19	1	0	0	2	15	12
81	Peeru	11	1	0	0	1	15	16
82	Yashin	16	1	0	0	1	15	15
83	Yamin	29	1	0	0	8	15	12
84	Yamin	4	1	0	0	1	15	12
85	Peeru	9	1	0	0	1	15	12
86	Mosam	13	0	0	0	2	15	12
87	Bholu	24	1	0	0	2	12	12
88	Islam	10	1	0	0	1	12	15
89	Islam	12	1	0	0	1	13	13
90	Toshin	16	1	0	0	1	13	14
91	Noor Hashan	12	1	0	0	1	13	15
92	Dilshad	7	1	0	0	1	13	14
93	Sheed	13	1	0	0	1	13	12
94	Sharif	10	1	0	0	2	12	13
95	Bhura	8	1	0	0	1	15	16
96	Peeru	8	0	0	0	1	13	14
97	Hasmuddin	11	0	0	0	1	13	12
98	Dilshad	14	1	0	0	2	16	12
99	Kallu	22	1	0	0	2	16	12
100	Chhajju	39	2	0	0	6	16	12
101	Yasin	20	1	0	0	2	12	12
<b>Total</b>		<b>767</b>	<b>77</b>	<b>0</b>	<b>0</b>	<b>247</b>	<b>1688</b>	<b>1681</b>

### STUDY GROUP

S.No.	Name	Designation
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	Dr. V. C. Goyal	Scientist "G" & Head, RMOD, NIH, Roorkee
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	Dr. V. C. Goyal	Scientist "G" & Head, RMOD, NIH, Roorkee
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	Shri Rakesh Goel	Tech-I