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Determination of Soil Parameters and Groundwater Salinity in Yamuna-Hindon Inter-basin

A

DISSERTATION

Submitted In Partial Fulfillment for the Award of the Degree Of Master of Technology in Applied Geology

By

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CANDIDATE'S DECLARATION

I, hereby, certify that the Dissertation entitled **"Determination of Soil Parameters and Groundwater Salinity in Yamuna-Hindon Inter-basin"** being submitted in partial fulfillment of the requirement for award of the degree of **M.Tech (Applied Geology)**, from Kurukshetra University, Kurukshetra, India. This work, during the period of **1st February 2016** to **29th July 2016**, is a record of my own work under the supervision of **Dr. Anupama Sharma**, Scientist 'D', Groundwater Hydrology Division, National Institute of Hydrology (NIH), Roorkee (Uttarakhand). The matter embodied in this dissertation has not been submitted for the award of anyother degree or diploma.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

The study of soil parameters and the salinity of groundwater is an important aspect in understanding the behavior of soil and water and what can they be used for. The two essential properties of soil are soil texture and soil structure. Apart from being a natural filter, it enables plants and wildlife to grow. In this work soil's physical and hydraulic properties and salinity of groundwater of Yamuna Hindon inter basin falling in Muzaffarnagar and Shamli districts of Uttar Pradesh have been studied. This study gives us a valuable information on the general properties of soil such as soil texture, soil moisture retention, water holding capacity, bulk density and groundwater quality parameters like pH, electrical conductivity and the total dissolved solids of the study area. Four locations were decided for soil sampling namely Peenna, Dholra, Salhakheri, and near Yamuna River. For the groundwater analysis twenty four site location were decided. At the sites of soil sampling, disturbed and undisturbed soil samples were taken from different depths. The soil samples were analyzed in the Soil and Water laboratory of National institute of hydrology, Roorkee for soil texture, particle size distribution, moisture content, bulk density, pore space percentage and soil moisture retention.. The result of the particle size distribution along different depth at particular location shows that there were not much variation in the grain size. Sandy loam and Silt loam are the major soil texture of the study area. The value of bulk density varied from 1.32 to 1.68 (gm/cm^3) in upper layer (0-15 cm). 1.65 to 1.73 (gm/cm^3) in the intermediate layer (30-50 cm) and 1.38 to 1.75 (gm/cm3) in the lowest layer (60-100 cm), respectively. And the moisture content was found to vary from 4.01 to 10.00 % in upper layer (0-15cm). 5.98 to 18.65% in the intermediate layer (30-50 cm) and 4.30 to 21.39 % in lowest layer (60-100 cm), respectively. The value of the field capacity varied from 8.98 % to 28.91 % and wilting point varied from 1.22% to 12.30%. The water samples were analyzed at the field for pH, electrical conductivity and total dissolved solids. The pH of groundwater of the study area lies between 6.4 and 7.87, the range of electrical conductivity falls from 415 μS/cm to 3170 μS/cm and the value of total dissolved solids vary from 300.16 mg/l to 2123 mg/l. It was concluded that the type of soil in the study area supports crop cultivation and facilitates groundwater recharge. Groundwater of the study area is suitable for drinking purpose, except for few locations and it is also suitable for the irrigation. The study can be helpful in improving the management of land use cover and method of irrigation. The results from this study can be further used in modeling studies such as estimation of ground water recharge.

CHAPTER – 1

INTRODUCTION

1.1 GENERAL

1.1.1 Soil and Its Importance

Soil is a natural body engaged in dynamic interactions with the atmosphere above and the strata below, that influences the planet's climate and hydrological cycle and that serves as a growth medium for a versatile community of living organisms. In addition, the soil plays a major environmental role as a bio-physico-chemical reactor that decomposes waste products and recycles them into nutrients for the continual regeneration of life on earth (Hillel, 1999).

Soil is composed of inorganic solid particles of various sizes and irregular shapes. The origins of these particles are weathered rocks, erupted materials, and sediment in ocean, lakes, marshes, and rivers. The pore space in between soil particles are termed as soil pores. When soil pores are filled with liquid-phase material, the soil is termed saturated; when gas-phase material is contained in the pore spaces, the soil is termed unsaturated. In natural fields, however, it is not likely that soil pores will be filled completely with liquid-phase material, so the terms saturated and unsaturated are accepted in common usage.

Soil properties are important for any hydrological study. One such property is soil texture which is an essential for understanding the behavior of soil. Soil texture refers to the proportion of the soil "separates" that make up the mineral component of soil. These separates are called sand, silt, and clay. According to United States Department of Agriculture these soil separates have the following size ranges. (Miyazaki, 2006).

- Gravel — larger than 2.0 mm
- Coarse sand — between 2.0 and 0.2 mm
- Fine sand — between 0.2 and 0.02 mm
- Silt — between 0.02 and 0.002 mm
- Clay — smaller than 0.002 mm

Soil has wide use in different fields such as agriculture, microbial growth and groundwater etc. Followings are the uses of soil.

- **Agriculture**: Top soil is used for agricultural production of crops necessary for human and animal food and clothing needs. Soil has fertility like essential minerals and organic matter needed for cultivation.

- **Microbial growth**: Soil texture is suitable for cultivation of bacteria, fungus etc. These bacteria are suitable for fixing nitrogen and fertility in soil. Further these microbes produce medicine like antibiotic.

- **Water harvesting**: When there is rain, soil absorbs water. This water goes into deeper layer of soil and is available for plants and forest to grow. Further this water is also available as ground water for drinking and irrigation purposes.

- **Soil supports germination:** Without soil, the earth would have lacked plants, trees and forests. When a seed from tree falls on to soil, it gives safe protection and environment for seed growth. Hence it is useful for germination of seeds to grow into plants. Without soil there would have been no trees and plants on the earth.

- **Waste Decay**: Soil layers promote decay of waste and pollutants by microbes. The decay of organic matter converts to petroleum and other essential resources. Without soil there would have been no waste decay and world would have been a place full of corpses (dead bodies) and other waste.

- **Groundwater:** Generally, soil refer to as the top few feet of the land surface. The soil act as a natural filter to the screen out many substance that mix with the water. But water will transport some contaminates into the groundwater. The amount of groundwater recharge, storage, discharge, as well as the extent of groundwater contamination, all depend on the soil properties such as;

  - Soil texture
  - Porosity
  - Permeability
  - Specific yield
  - Attenuation capacity (soil's filtering ability)

1.1.2 Importance of Groundwater Availability and Quality

Water from beneath the ground has been exploited for domestic use, livestock and irrigation since the earliest times. Although the precise nature of its occurrence was not necessarily understood, successful methods of bringing the water to the surface have been developed and groundwater use has grown consistently ever since. It is, however, common for the dominant role of groundwater in the freshwater part of the hydrological cycle to be overlooked.

Groundwater is easily the most important component and constitutes about two thirds of the freshwater resources of the world and, if the polar ice caps and glaciers are not considered, groundwater accounts for nearly 90% all usable freshwater. Even if

consideration is further limited to only the most active and accessible groundwater bodies then they constitute 95 per cent of total freshwater. Lakes, swamps, reservoirs and rivers account for 3.5 per cent and soil moisture accounts for only 1.5 per cent. The dominant role of groundwater resources is clear and their use and protection is, therefore, of fundamental importance to human life and economic activity. Fresh water is second to oxygen, for survival of life. Groundwater, unlike surface water, is available in some quantity everywhere and has following advantages over surface water (Davis and De Wiest, 1966).

- Groundwater is commonly free of pathogenic organisms and needs no purification for domestic or industrial uses.
- The temperature is nearly constant which a great advantage is if the water is used for heat exchange.
- Turbidity and color are generally absent.
- Chemical composition is by and large constant.
- Groundwater storage is generally greater than surface water storage, so groundwater supplies are not seriously affected by short droughts.
- Radio chemical and biological contamination of most groundwater is difficult.
- Groundwater which has been stored by nature through recharge of many years, is available in many areas which do not have dependable Surface water supplies.
- Groundwater can be usually developed for lesser costs in comparison to Surface water schemes

Even in areas where normally there are abundant surface water supplies, available through major, medium, and minor irrigation projects, groundwater plays an increasingly vital role in supplementing surface water. The important of the role of groundwater to meet water supply requirements for domestic, rural, urban, and industrial and agriculture use needs little emphasis. Today, recognition of groundwater as an important water resource has galloped to the forefront.

1.2 Objectives of Study

The present study has been taken up with the following objectives

1. To determine the soil properties such as soil texture, soil moisture retention characteristics, bulk density and pore spaces percentage in the region of Yamuna-Hindon inter basin falling in Shamli and Muzaffarnagar districts

2. To determine groundwater salinity in the region Yamuna-Hindon Inter-basin falling in Shamli and Muzaffarnagar districts.

1.3 Organization of Dissertation

- Chapter one discusses the importance and general properties of soil and groundwater availability

- Chapter two reviews the literature on properties of soil and ground water quality.

- Chapter three provide the description of study area and illustrates the locations of soil and water sampling carried out during the present study

- Chapter four highlights the materials and methodology adopted for the present study. This includes description of instruments and equipmental work done at site and at National Institute of Hydrology (NIH) laboratory.

- Chapter five provides the results and details of the analysis of soil properties and groundwater analysis of the study area.

- Chapter six presents the conclusion of this study.

CHAPTER- 2

LITERATURE REVIEW

2.1 GENERAL

Studies on soil properties and groundwater quality are important for management of water resources. In the past, number of researchers have studied soil properties and groundwater. Some of the studies conducted in and around Muzaffarnagar and Shamli districts are described here in subsequent sections. These studies help us to understand the behavior and condition of soil and water of the study area.

2.2 REVIEW OF LITERATURE

2.2.1 Soil Properties

Kumar *et al.* (2008) studied soil moisture retention characteristics and hydraulic conductivity for different areas in India. Field and laboratory investigations have been carried out to determine the soil moisture characteristics (saturated hydraulic conductivity and soil moisture retention curve) in different areas of the country and empirical relationships have been derived for each study area to obtain the soil moisture retention characteristic from saturated hydraulic conductivity. Retention were studied through pressure plate apparatus. Results indicated that the retention and movement of water and chemicals in the unsaturated zone is necessary to know the relationships between soil water pressure, water content and hydraulic conductivity. The hydraulic conductivity relation can be evaluated if the saturated hydraulic conductivity is known through a retention function based on observed set of data(s).

Choubey *et al.* (2009) studied the salt affected soils in the plains of Haryana state. The three distinct kinds of soils met with are alkali, saline and saline-alkali. Rainfall, surface topography, surface configuration (relief, aspect, micro-relief and microclimate) have influenced mineral weathering, ionic mobility and macro-chromatographic separation leading to formation of these soils in three distinct zones. The color code and color of the soils in the study area were determined from Munsell Classification. The results of textural analysis indicated that silt loam is a major textural group in the study area. The soil pH varied from 8.12 to 9.01 which show an alkaline reaction of the soil of the study area. Total dissolved solids (TDS) in the soil extract were found to vary from 700 mg/l to 11000.00 mg/l showing higher concentration of salts in the root zone causing low food, fodder and fiber production. The obtained results indicated that the study site around Gohana affected by water logging and salinity.

Kumar *et al.* (2013) explained soil fertility status in some soils of Muzaffarnagar District of Uttar Pradesh, India, along with Ganga canal command area. Surface and subsurface soil samples of Muzaffarnagar district were collected to characterize their chemical

properties and accordingly to develop optimum land use plan to realize maximum agricultural productivity. The pH value of study area varied from 6.02 to 8.39 and 6.35 to 8.50 for surface and sub-surface, respectively, electrical conductivity from 0.069 to 0.390 and 0.073 to 1.10 dSm-1, organic matter content 7.241 to 15.221 and 3.695 to 10.179 g kg-1, available nitrogen (N) 131.53 to 348.97 and 99.32 to 217.44 kg ha-1, Phosphorus (P) 15.67 to 52.61 and 11.17 to 45.40 P2O5 kg ha-1, potassium (K) 79.16 to 436.8 and 47.04 to 399.84 K2O kg ha-1 for surface (0-15 cm) and subsurface soil (15-30 cm). Cationic Micronutrients Zn, Cu, Fe and Mn varied from 1.636 to 6.164, 1.024 to 4.282, 0.672 to 5.802 and 0.332 to 2.652, and 113.13 to 11.232, 10.33 to 79.326, 10.272 to 38.572 and 29.578 to 77.882 mg kg-1 in surface (0 - 15 cm) and subsurface soil (15-30 cm) respectively. The authors concluded that the soil chemical composition of the study area did not followed a particular pattern with increasing distance from Ganga Canal which may be due to variation in management practices, cropping sequence and their yield potential. Study area was dominated by sugarcane, wheat, rice and fodder crops. About sixty seven percent area is under sugar cane. Physico chemical characteristics and nutrient status of soil in Muzaffarnagar district of Uttar Pradesh as discussed previously indicates that soil of study area were neutral to strongly alkaline in reaction and non-saline in nature.

2.2.2 Ground Water Quality

Jain *et al.* (2003) carried out a Hydrochemical study of the Hindon river system in western Uttar Pradesh India with the objective to examine variation in water quality characteristics within the river system, and to establish water quality-quantity relationships to provide a proper basis for establishing water quality objectives for the basin. The main sources of pollution in the Hindon River include the municipal waste of the Saharanpur, Muzaffarnagar and Ghaziabad districts and industrial effluents of sugar, pulp and paper, distilleries and other miscellaneous industries through tributaries as well as direct outfalls. The authors concluded that Hindon River is subjected to domestic and industrial pollution because of absence of, or poor enforcement, of water pollution control laws and regulations. The seasonal variations in the intensity of rainfall cause both the quality and quantity of flow of the rivers to vary widely.

Tyagi *et al.* (2008) investigated the Hydrochemical appraisal of groundwater and its suitability in the intensive agricultural area of Muzaffarnagar district, the study has been carried out to understand the hydrochemistry of the groundwater and its suitability for irrigation uses. Groundwater in the study area is neutral to moderately alkaline in nature. Chemistry of groundwater suggests that alkaline earths (Ca + Mg) significantly exceed the alkalis (Na + K) and weak acids exceed the strong acids (Cl + SO4), suggesting the dominance of carbonate weathering followed by silicate weathering. The groundwater sources in the Muzaffarnagar district of Uttar Pradesh were evaluated for their chemical composition and suitability for irrigation uses. Majority of the groundwater samples exhibited the alkaline earths (Ca + Mg) significantly exceeding the alkalis (Na + K) and weak acids exceed the strong acids (Cl + SO4). Majority of groundwater samples (62%)

possess Ca–Mg–HCO3 type of Hydrochemical species followed by Ca–Na–Mg–HCO3, Na–Ca–Mg–HCO3, Ca–Mg–Na–HCO3–Cl and Na–Ca– HCO3–SO4 types. Ca2+ and Mg2+ exhibit good positive correlation between each other and both independently show good positive correlation with Cl- and bicarbonate. Wilcox and US Laboratory Salinity Staff diagrams reveal that barring a few locations, most of the groundwater samples are suitable for irrigation purposes.. Groundwater chemistry in the area is mainly dominated by carbonate weathering followed by silicate weathering. (Ca + Mg) and (HCO3 + SO4) relationship suggests that high values of Sulphate are balanced by (Ca + Mg) and drawing contribution from chemical fertilizers, small/big sugar factories and anthropogenic activities.

Kumar and Singh (2010) estimated the water quality status of Kali Nadi in district of Muzaffarnagar, Uttar Pradesh, for irrigation purpose. For understanding the status of kali Nadi water's chemical properties like total salt (electrical conductivity), pH, Anions (Cl, HCO3, SO4, NO3, F, B), Cations (Ca2+ + Mg2+, Na+, K+) were analyzed. The EC of kali Nadi shows good positive correlation with chloride, Sulphate, Ca + Mg, Nitrate, bicarbonate, potassium, sodium and negative correlation with pH. 0.45 to 2.81 mg L-1 and Boron 0.54 to 4.10 mg L-1. It can be concluded that the Kali Nadi water of twenty five different locations (villages) of three Tehsil of Muzaffarnagar district is safe for irrigation purposes on the basis of most parameter, however its suitability is questionable on the basis of few parameters for irrigation.

Krishna *et al.* (2016) have done the work on the water quality index report of Muzaffarnagar and Shamli district. Water quality index numerically gives the information from multiple water quality parameters into a single value that is understandable and usable by the public. This information can be used to assess spatial and temporal variations in overall water quality. A total of 104 groundwater samples covering the whole districts were collected. The Water Quality Index was computed using five parameters viz., pH, Total Dissolved Solids, Total Hardness, Chloride and Sulphate. The WQI results showed that the overall water quality class is 'good' and water is acceptable for domestic use. To add, most of the groundwater samples are suitable as per drinking standard and remaining In addition, It may also be noted that two parameters, particularly chloride and hardness are found to be higher in most of the samples compared to permissible levels resulting in higher TDS value owing to anthropogenic contribution which might take place in the vicinity of industrial and agricultural areas in the districts Muzaffarnagar and Shamli.

2.2.3 Summary

From the above reviews, it is concluded the soil and water conditions of area(s) around Muzaffarnagar and Shamli district need to be investigated to analyze the soil characteristics that will help in understanding the groundwater recharge In the region, further, in the view of the polluted rivers like Kali and Hindon flowing through the region, it is also essential to analyze the groundwater salinity in the region. The present study,

therefore is taken up to improve understanding of soil and water conditions in the region by studying soil properties such as texture, bulk density etc. and groundwater conditions.

CHAPTER-3

STUDY AREA

3.1 GENERAL

The study area chosen for the present study is Yamuna-Hindon inter-basin region falling in the Shamli district and partly in the Muzaffarnagar district (fig.3.1). Salient features of the study area are described in subsequent sections.

3.1.1 Location

The study area comprises of Shamli district and part of Muzaffarnagar district. It is bounded by the Saharanpur district in the north, Haridwar in the northeast, remaining part of Muzaffarnagar district in the east, Meerut district in the south and river Yamuna separates it from the adjoining state of Haryana in the west.

Muzaffarnagar district lies in the northwest of Uttar Pradesh, covering an area of 4008 sq. km in between latitudes 29°34' N and 30°24' N and longitude 77°7' E and 78°12' E. Shamli district lies in the fertile Doab region between the Ganga and Yamuna rivers. Area of Shamli district is 1043.94 sq. km. It was declared as a district in September 2011 by then Utter Pradesh government. Shamli is around 99 km from Delhi, 38 km from Panipat, 70 km from Meerut, 40 km from Karnal and 65 km from Saharanpur. It lies to the east of the Yamuna River which marks the borders of two Indian states, Haryana and Uttar Pradesh.

3.1.2 Climate

The average annual rainfall of the study area is 753.2 mm. The climate is sub humid and it is characterized by general dryness except in the brief monsoon season, a hot summer and pleasant cold season. About 80% of rainfall takes places from June to September. During monsoon surplus water is available for deep percolation to ground water. There is a meteorological observatory at Meerut, which may be taken as representative of meteorological condition. May is the hottest month. The mean daily maximum temperature is about 40°C, mean daily minimum temperature is about 24°C and maximum temperature some time rises to 44°C. With the onset of southern monsoon by the end of June, there is appreciable drop in temperature. January is the coldest month with mean daily temperature at about 20°C and mean daily minimum at 7°C. The air is dry during the year. In south-west monsoon season, the air is very humid and April and May are usually driest months. The mean monthly relative humidity is 67%. The mean wind velocity is 6.70 Km. /h. The potential evapotranspiration is 1545.90 mm (Bhargava, 2008)

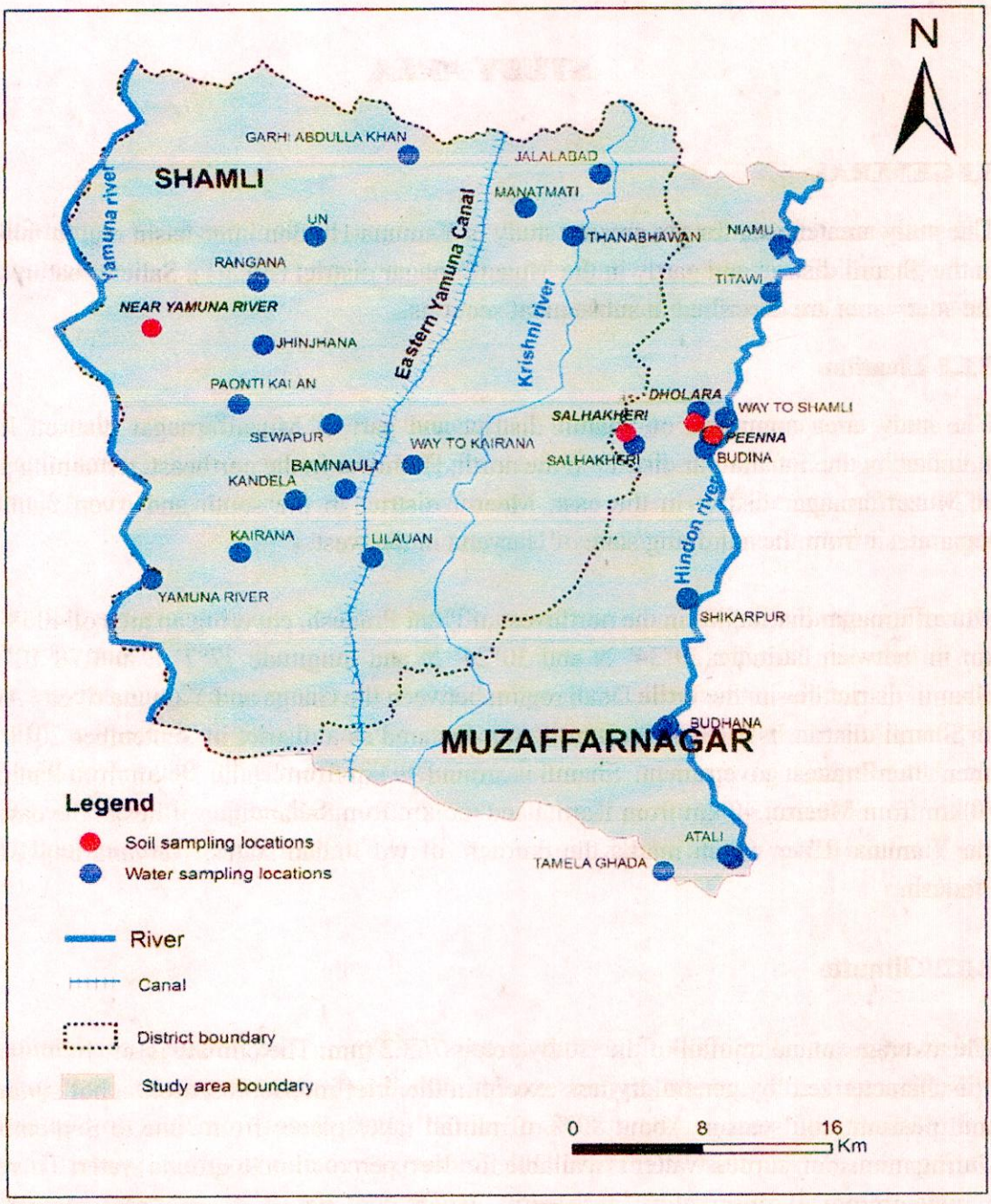

Figure 3.1 Location Map of Study Area (Total of twelve samples were collected depth wise from four locations)

3.1.3 Drainage

The study area is demarcated by river Ganga in the east and by river Yamuna in the west. In fact, the drainage pattern of the district is strictly governed by these two major rivers. Both the rivers in their respective course flow more or less north to south. Major tributary of Ganga is Solani River. Yamuna has the tributaries named Hindon, Krisni and the Katna nala

3.1.4 Major Crops

Average productivity of major crops like wheat, paddy, oilseeds and sugarcane in district is higher as compare to the state's average productivity, excepting average productivity of potato, which is 150.23 quintal per hectare in the district, and 232.00 quintal per hectare in the state. Despite higher productivity of cereals, oilseeds and sugarcane, majority of farmers in the district are facing acute problems due to small land holdings and irregular payment by sugarcane factory owners (see table 3.1).

Table 3.1: Productivity of Major Crops (2004 - 05)
(Production in quintal per hectare)

Crop	Muzaffarnagar	Uttar Pradesh
Wheat	32.98	25.90
Paddy	25.93	18.40
Potato	150.23	232.00
Oilseeds	9.92	8.70
Sugarcane	707.28	562.80

Source: District Sankhyaki Patrika, Muzaffarnagar, 2006

3.1.5 Geomorphology and Soil Type

The study area is a flat terrain falling in Muzaffarnagar and Shamli districts. The highest point in the study area is 201.0 m above mean sea level (amsl) in the north and lowest in the south is 222.0 m amsl giving rise an average slope of about 0.40 m/km. north to south. The districts can be sub divided into followings geographic units.

- Sand Bars: Along the courses of Ganga and Yamuna rivers, the sand bars are characteristic which dynamically change during floods.

- Flood Plain: The flat, low lying poorly drained area adjacent to Ganga and Yamuna rivers forms the flood plains frequented by floods during monsoons

- Ravines: In the western part of the district, this unit is characterized by the gullies along the rivers Kari, Hindon and Krishni. This is probably due to the erosion of unconsolidated material by localized surface run off forming channels and ultimately giving rise to undulating topography and hence the formation of ravines.

3.2. HYDROGEOLOGY

The entire Muzaffarnagar district underlains by the quaternary alluvium deposited by Ganga and Yamuna river system. Lithologically the alluvial sediments comprise of sand, silt, clay and kankars in varying proportions.

The perusal of all available lithological logs of the tube wells in the area reveal the complex configuration of alluvial sediments showing quick alteration from finer to coarser lithology. By and large the four distinct groups of permeable layers occurs in the area down to 450.00 mbgl. The top sandy clay bed 3-75 m in thickness covers the entire district. After top clayey layer first aquifer starts and with varying thickness at different places continues down to 185 mbgl. Lithologically the aquifer comprises mostly medium to coarse sand but gravels and kankars are also encountered sometimes. This aquifer at places, can be sub divided into two sub groups due to the presence of either clay lenses or sub regional clay layers. The second aquifer occurring at varying depths between 115 and 235 mbgl is separated by 10-15 m thick clay layer from the first upper aquifer. The second group of aquifer consists of less coarse sediments than that of first one and at places kankar and clay lenses also occur. The third aquifer is separated by second aquifer by thick clay layer. The fine textural third aquifer ranges in thickness between the depths 255 to 329 mbgl. The third aquifer is followed by a clay layer. The thickness of the fourth aquifer varies between the depths 355-488 mbgl (Bhargava, 2008).

The aquifer material becomes coarser from west to east. The top clay layer is thickest at Lakkheri, Rajpur and Budhana in the south western part of the district but is almost absent at Sukratal in the eastern most part of the district. In general it can be observed that the river Ganga has deposited coarser material compared to those deposited by river Yamuna.

3.2.1 Ground Water Condition

Ground water occurs in pore spaces and interstices of unconsolidated alluvial sediments under phreatic to semi confined to confined conditions. The near surface aquifer is under unconfined / water table condition. The shallow phreatic aquifer is tapped by dug wells. The depth to water ranges from 3.20 to 9.95 mbgl in pre monsoon period whereas it ranges from 2.50 to 7.95 mbgl in post monsoon period. According to CGWB, the water level fluctuation varies from 0.70 to 2.00 m. (Bhargava, 2008)

3.3 SAMPLING LOCATIONS

3.3.1 Soil sampling

Soil and groundwater conditions of the study area were studied by carrying out soil and water sampling. Locations for soil sampling are shown in Fig. 3.1. Four sites were selected for soil sampling and are listed in Table 3.2. These sites were Peenna, Dholra, Salhakheri and near Yamuna river. At each site, undisturbed and disturbed soil samples were collected from different depth upto a total depth of 100 cm below the ground surface.

- Undisturbed soil samples: Soil samples collected from field without disturbing the natural conditions such as its structure, texture, density, and natural water contents, are called undisturbed soil samples. These soil samples were collected in steel rings of diameter 5 cm and height 5.1 cm Figure 3.2 shows an undisturbed soil sample with auger (instrument for collecting soil sample).

- Disturbed soil sample: Soil samples collected with disturbing the natural conditions of a sample such as its structure, texture, density, natural water contents are called disturbed soil samples. These soil samples were collected in polythene bags. Figure 3.3 2 shows a disturbed soil sample with auger (instrument for collecting soil sample).

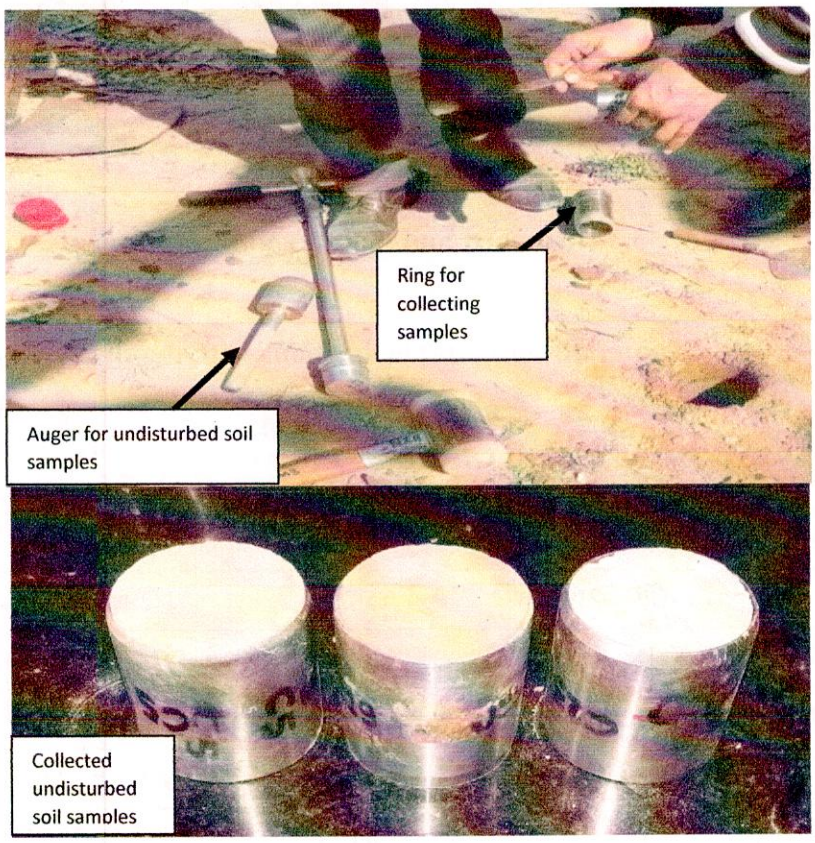

Figure 3.2 Undisturbed Soil Sampling and sample In Rings.

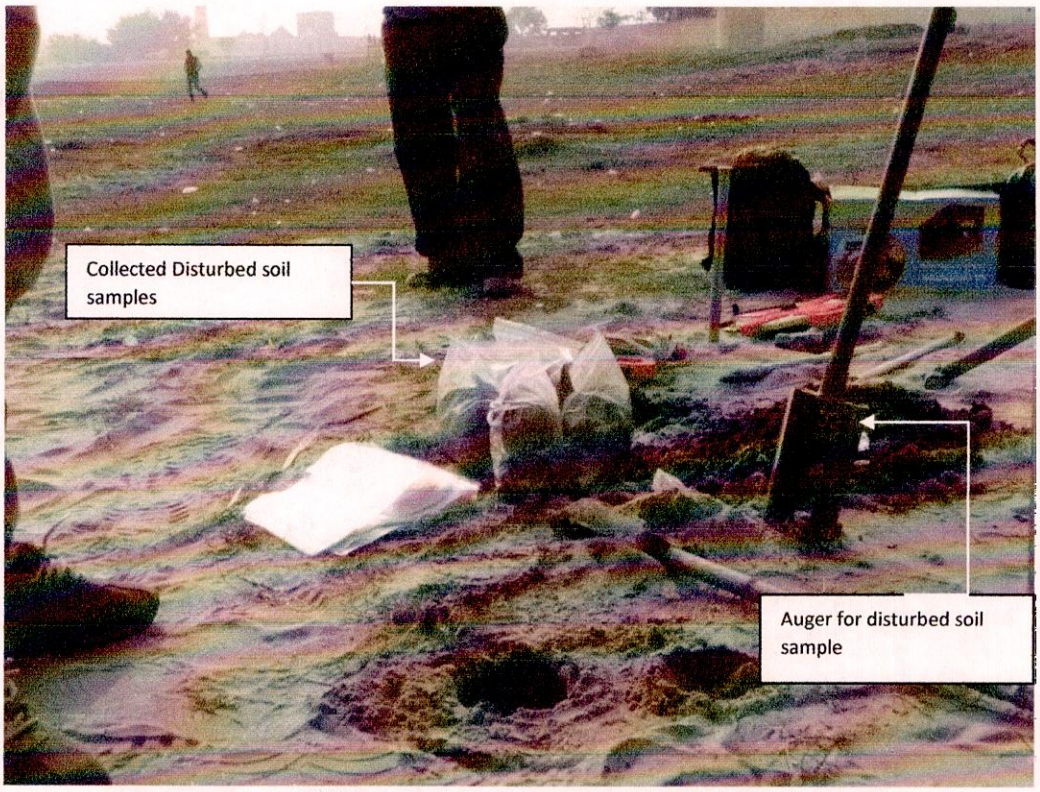

Figure 3.3 Disturbed Soil Samples and Instruments

Table 3.2: Soil sample locations with depth

S.NO.	LOCATION WITH CODE	DEPTH FROM GROUND SURFACE (cm)	LATITUDE	LONGITUDE
1	Peenna (YHPIN-1S)	0-15	N29°28'6.6"	E77°30'34.8"
2	Peenna (YHPIN-2)	15-35	N29°28'6.6"	E77°30'34.8"
3	Peenna (YHPIN-1-S)	50-100	N29°28'6.6"	E77°30'34.8"
4	Dholra (YHDHO-1S)	0-15	N29°28'33.9	E77°29'55.2"
5	Dholra (YHDHO-2)	30-50	N29°28'33.9"	E77°29'55.2"
6	Dholra (YHDHO-3)	70-100	N29°28'33.9"	E77°29'55.2"
7	Salhakheri (YHSAL-1S)	0-15	N29°28'11.4"	E77°27'17.2"
8	Salhakheri (YHSAL-2)	40-60	N29°28'11.4"	E77°27'17.2"
9	Salhakheri (YHSAL-3)	80-100	N29°28'11.4"	E77°27'17.2"
10	Near Yamuna river (YHYB-1S)	0-15	N29°22'55.4"	E77°09'9.5"
11	Near Yamuna river (YHYB-2)	40-50	N29°22'55.4"	E77°09'9.5"
12	Near Yamuna river (YHYB-3)	90-100	N29°22'55.4"	E77°09'9.5"

3.3.2 Groundwater sampling

Groundwater sampling locations are shown in Fig. 3.1. A total of 31 sites were selected for water sampling (Table 3.3). Water samples were collected from hand pumps and tube-well

Table 3.3: Water Sample Locations

S.NO.	LOCATION	LATITUDE	LONGITUDE	SOURCE OF WATER
1	Anandpuri	N29°28'57.4"	E77°41'50.6"	Hand pump
2	Muzaffarnagar Shamli road	N29°28'42.8"	E77°31'4.9"	Hand pump
3	Dholra	N29°28'58.2"	E77°30'4.6"	Hand pump
4	Dholri 1	N29°27'59.4"	E77°30'31.7"	Hand pump
5	Dholri 2	N29°28'3.2"	E77°30'30.3"	Hand pump
6	Salhakheri	N29°27'45.1"	E77°27'35.9"	Hand pump
7	Shamli Kairana road	N29°27'3.5"	E77°19'8.9"	Hand pump
8	Lilauan	N29°23'41.71"	E77°17'34.83"	Hand pump
9	Bamnauli 1	N29°26'10.5"	E77°16'33.4"	Hand pump
10	Bamnauli 2	N29°26'8.8"	E77°16'35.4"	Tube- well
11	Kandela	N29°25'47.1"	E77°14'37.7"	Hand pump
12	Kairana	N29°23'51.8"	E77°12'31.9"	Hand pump
13	Jalalabad	N29°37'34.34"	E77°26'20.23"	Hand pump
14	Thanabhawan	N29°35'20.74"	E77°25'16.24"	Hand pump
15	Manatmanti	N29°36'21.65"	E77°23'27.42"	Hand pump
16	Garhi Abdulla Khan	N29°38'18.11"	E77°18'58.15"	Hand pump
17	Un	N29°35'21.6"	E77°15'23.82"	Hand pump
18	Rangana	N29°33'43.28"	E77°13'12.64"	Hand pump
19	Jhinjhana	N29°31'24.83"	E77°13'25.15"	Hand pump
20	Paonti kalan	N29°29'16.21"	E77°12'29.23	Hand pump
21	Sewapur	N29°28'32.42"	E77°16'2.49"	Hand pump
22	Niamu	N29°35"0.3'	E77°33"12'	Hand pump
23	Budiana kalan	N29°27"35'	E77°30"17'	Hand pump
24	Shikarpur	N29°22"0.9'	E77°29"37.2'	Hand pump
25	Budhana 1	N29°17"34'	E77°28"51.6'	Hand pump

S.NO.	LOCATION	LATITUDE	LONGITUDE	SOURCE OF WATER
26	Budhana 2	N29°16"58'	E77°28"38'	Hand pump
27	Atali 1	N29°12"43'	E77°31"16'	Hand pump
28	Atali 2	N29°12"46'	E77°31"16'	Hand pump
29	Atali 3	N29°12"51.3'	E77°31"8'	Hand pump
30	Atali 4	N29°12"51'	E77°31"7.2'	Hand pump
31	Tamela Ghada	N29°12"17'	E77°31"17'	Tube-well

CHAPTER – 4

METHODOLOGY

4.1 SOIL ANALYSIS

4.1.1 Particle Size Distribution

Particle size distribution means different grain sizes on the soil that makes a given soil mass. Soil has three main parts such as sand, silt and clay. These parts determines the soil texture.

(i) Sand is the largest of the mineral particles. Sand particles create large pore spaces that improve aeration. Water flows through the large pore spaces quickly. Soils with a high percentage of sand are generally well drained. Sandy soils lack the ability to hold nutrients and are not fertile. Sandy soils also feel gritty to the touch

(ii) Silt is the mid-size soil particle. Silt has good water-holding ability and good fertility characteristics. It feels like flour when dry and smooth like velvet when moist.

(iii) Clay is the smallest size soil particle. Clay has the ability to hold both nutrients and water that can be used by plants. It creates very small pore spaces, resulting in poor aeration and poor water drainage. Clay forms hard clumps when dry and is sticky when wet. All three soil's types have their own characteristics, which shown in below Table 4.1

Table 4.1: Characteristics of Sand, Silt and Clay

CHARACTERISTICS	SAND	SILT	CLAY
Looseness	Good	Fair	Poor
Air space	Good	Fair to Good	Poor
Drainage	Good	Fair to Good	Poor
Ease of working	Good	Fair to Good	Poor
Moisture-holding ability	Poor	Fair to Good	Good
Fertility	Poor	Fair to Good	Fair to Good

Soil texture describes the proportion of three sizes of soil particles and the fineness or coarseness of a soil. Soil texture may be determined in one of two ways. The percentages of sand, silt, and clay may be tested in the lab. Once tested, the textural classes of the soil can be determined by referring to the textural triangle by United State Department of Agriculture (Shukla *et al.* 1995)

Soils with different amounts of sand, silt, and clay are given different names. For instance, a soil containing 40 percent sand, 40 percent silt, and 20 percent clay is called loam soil. The other classes of soil describe by textural triangle described in Table 4.2 by USDA (Shukla *et al.* 1995).

Table 4.2. Soil Textural Classes

CLASS OF SOIL	SAND	SILT	CLAY
Sand	85-100%	0-15%	0-10%
Loamy Sand	70-90%	0-30%	0-15%
Sandy Loam	43-85%	0-50%	0-20%
Loam	23-52%	28-50%	7-27%
Silt loam	0-50%	50-88%	0-27%
Clay loam	20-45%	15-53%	27-40%
Silt clay loam	0-20%	40-73 %	27-40 %
Sandy clay loam	45-80%	0-28%	20-35%
Clay	0-45%	0-40%.	40-100%

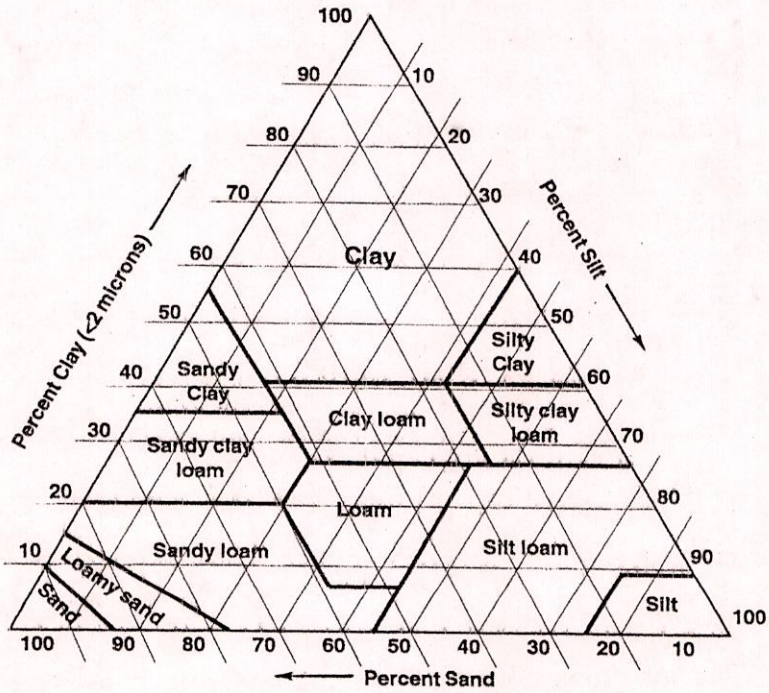

Figure 4.1. Soil texture triangle by USDA (Shukla *et al.* 1995)

The particle's diameter present in the soil makes the soil to be coarse, medium and fine. Table 4.3 shows the textural class names of soil as per particle diameter by international society of soil science, soils are classified by a particle size into five classes.

Table 4.3. Textural Classification as Per Particle Diameter by ISSS

MATERIAL	DIAMETER(mm)
Gravel	Larger than 2.0
Coarse sand	Between 2.0 – 0.2
Fine sand	Between 0.2 – 0.02
Silt	Between 0.02 – 0.002
Clay	Less than 0.002

In the Indian standard (IS: 460-1662), the sieves are designated by the size of aperture in mm, whereas in BS (410-1962) and ASTM (E11-1961) standards, the sieve sizes are given in the terms of the number of openings per inch.(Seth., 1990)

The sieving process does not provide information on the shape of the soil grains. It only give the information of grains that can pass through rectangular sieve opening of a certain size.

The result are presented in the graph of percent passing versus the sieve size. On the graph the sieve size scale is logarithmic.

4.1.1.1 Adopted Methodology for Particle Size Distribution

Procedure

1. Oven dried soil sample weighing 500 gm was taken and soaked in water for 24 hours.
2. Soil samples were then washed through sieve no.200 (75μ). For washing distilled Water was used
3. After washing, the above 75μm soil sample (coarse particles) were collected in beaker and below 75μm soil sample (fine particles) were collected in tray. These were then kept in oven for 24 hours.

   Sieve analysis for particle of size above 75 μm

4. Above 75μm soil sample were processed through the process of sieve analysis. The soil samples were passed through different sieve number such as 4 (4.750 mm), 10 (2 mm), 14 (1.400 mm), 20(0.850 mm), 40 (0.425), 60 (0.250 mm), 70 (0.212 mm), and 200 (0.075 mm). The sieving was performed for 30 minutes with mechanical sieve shaker (Fig. 4.2).

5. The stack of sieves was removed from sieve shaker. Than weight of the particles were weighed, one by one from different sieve number. The percentage of total soil sample retained on each sieve was also calculated.

6. The calculation was started with 100% and subtracting the percentage retained on each sieve as cumulative procedure as given by

% passing = % arriving - % retained

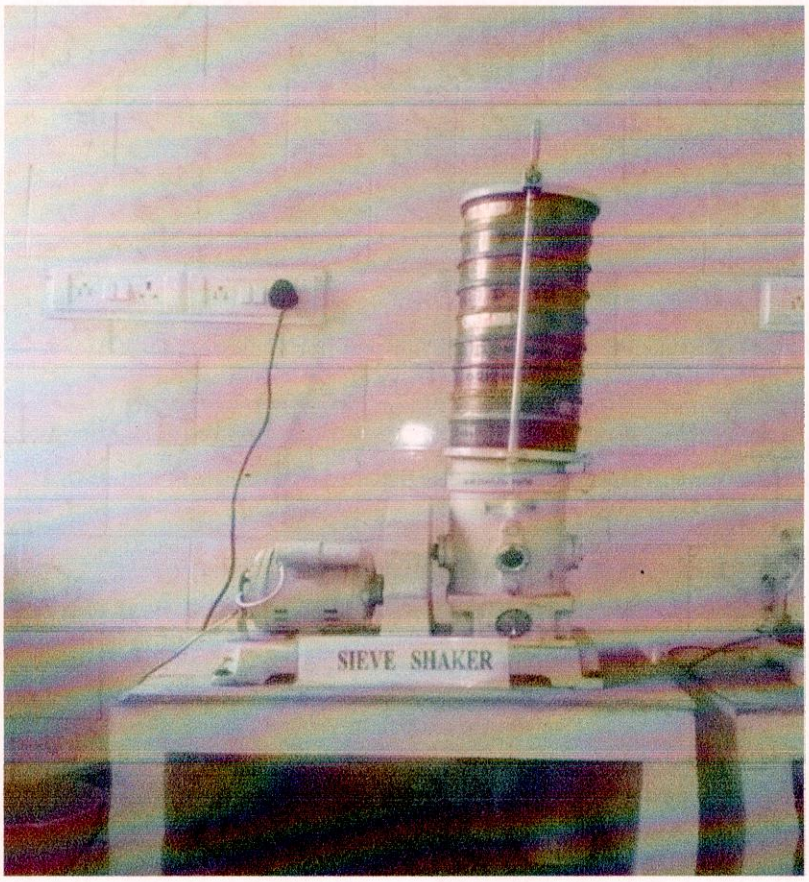

Figure 4.2 Sieve Shaker

Mastersizer analysis for particle of size below 75 μm

Mastersizer instrument (model MAE build version 12) was used for analyses of soil particles of size below 75 μm (Fig. 4.3). The Mastersizer uses the technique of laser diffraction to measure the size of particle by measuring the intensity of light scattered as a laser beam passing through a dispersed particulate sample. This data is then analyzed to calculate the size of the particles that created the scattering pattern. In this procedure following steps were used.

7. 25gm of the soil sample (below 75 μm) was taken in a beaker for Mastersizer analysis.

8. Added Sodium Hexametaphosphate (33gm) and sodium carbonate (7 gm) in the beaker. This soil solution was then diluted by adding one liter of distilled water. This

step was done to properly disperse the soil particles. The soil solution was then stirred for a minute

9. The soil solution was then kept at room temperature for 24 hours.
10. After 24 hours, the solution was run in Mastersizer E system instrument and results were obtained.

The combined result of sieve analysis and Mastersizer gives soil texture. A plot of grain size versus percent passing was plotted on semi logarithm scale.

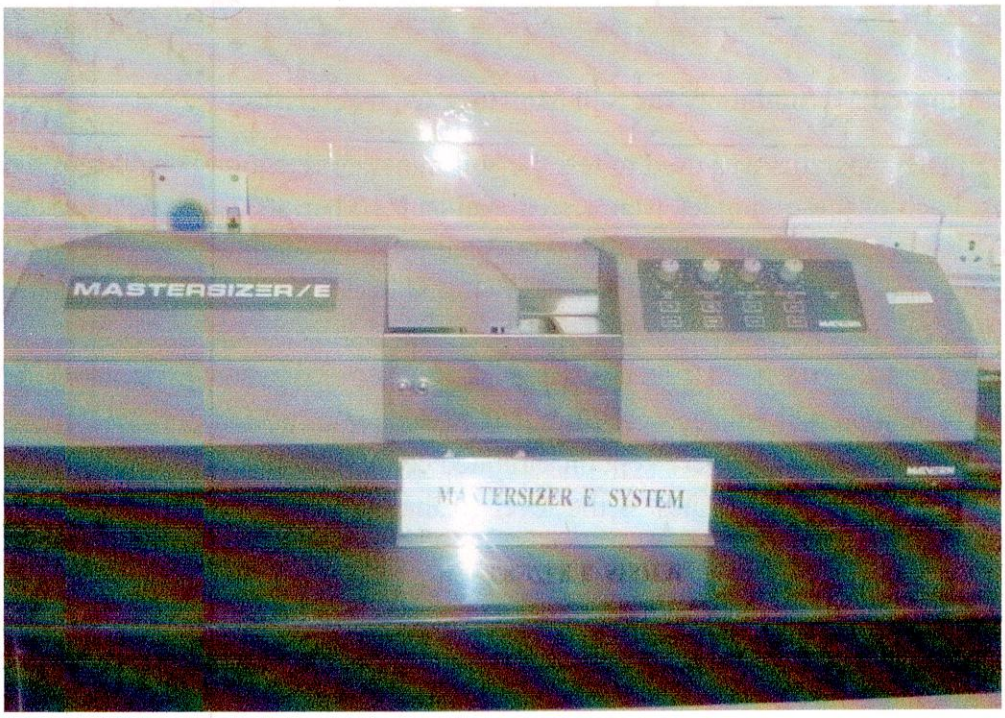

Figure 4.3 Mastersizer

4.1.2 Soil Moisture Characteristics

Soil moisture retention curves, also called moisture characteristics curves, are the plots of moisture content versus suction head. It shows the amount of moisture a soil can hold under different pressures (suction).

The moisture characteristics curve of a soil sample can generally be determined by equilibrating a soil sample at a succession of known tension value and each time determine the amount of moisture. The graph is plotted between the tension and corresponding moisture value to obtain the soil moisture characteristics curve. Different soils type gives different characteristics curves.

Pressure plate apparatus is a standard method for obtaining the soil moisture characteristics (fig 4.3). It consists of a pressure chamber in which a saturated soil sample is placed on a porous ceramic plate through which the soil solution passes but no soil

particle or air can pass easily. The soil solution, which passes through the membrane is in contact with atmospheric pressure.

In this method, soil sample are crushed and pass through 2mm sieve. Soil particles of size below 2mm are used for this method because soil particles of size above 2mm cannot retain moisture.

Soil moisture characteristics curves are useful to understand the amount of water that is available to plants, the water that can be taken up by the soil before percolation starts, and the amount of water that must be used for irrigation (Micheal, 1986).

4.1.2.1 Adopted Methodology for Soil Moisture Characteristics

Pressure plate apparatus was used to test the soil moisture retention behavior of the soil samples. Each of these samples were tested against 0.10 bar, 0.33 bar, 0.50 bar and 1.0 bar, by 1 bar pressure ceramic plate, 3 bar by 3 bar pressure ceramic plate, 5 bar by 5 bar pressure ceramic plate. 10 bar and 15 bar were tested by 15 bar pressure ceramic plate.

Procedure

1. The ceramic pressure plates were saturated. Soil samples passed through 2 mm sieve were taken in rings and were kept on saturated ceramic plates. Water was then added slowly to the pressure plates to the level so that water may fully saturate the soil samples.
2. Saturated plate containing soil samples were placed in pressure chambers of pressure plate apparatus. Desired pressure were then applied, and were left till an equilibrium stage is obtained.
3. Samples were taken out from the pressure chambers and were weighed to record the moist weight of the samples. This weight is called wet weight of the sample.
4. Weighed samples were then placed in oven at 105^0C -110^0C for 24 hours. The dried samples were weighed. This weight is called dry weight of the sample
5. Soil moisture content was calculated by the difference in the recorded dry weight and wet weight of the soil samples

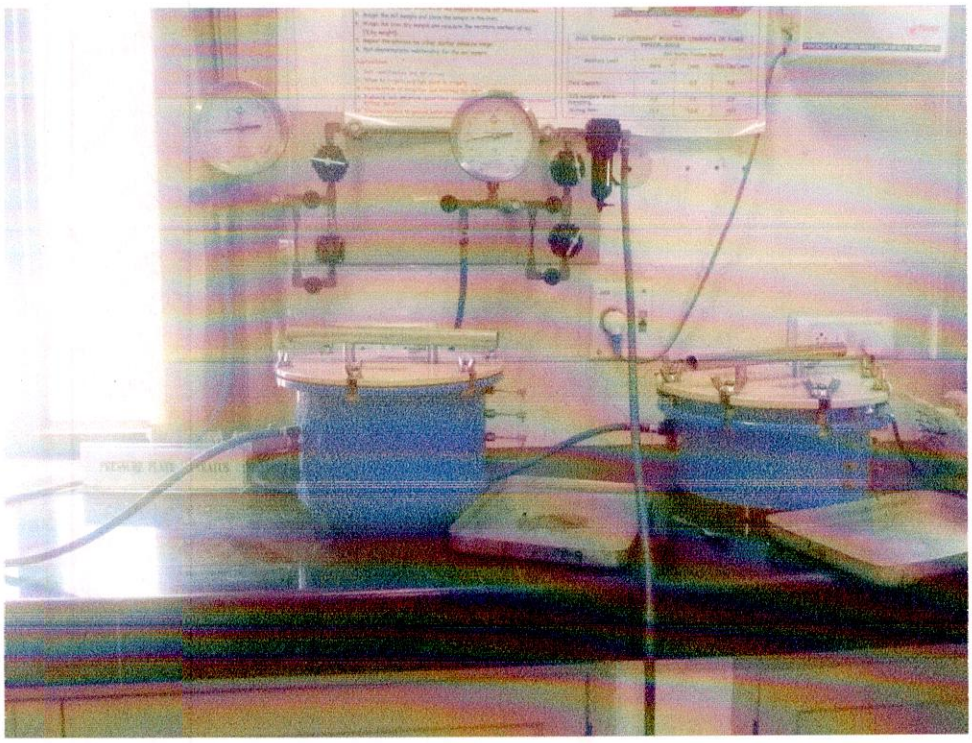

Figure 4.4 Pressure Plate Apparatus

4.2 METHODOLOGY FOR GROUND WATER QUALITY

For groundwater quality, three parameters were recorded from the field. These parameter are described in subsequent sections.

4.2.1 pH

pH is mean potential of hydrogen ion in water. It can be represented as,

$$\mathbf{pH = -log(H^{+})}$$

Where, log is a base 10 logarithm and (H^{+}) is the concentration of hydrogen ions in moles per liter of a solution. pH is reported in logarithmic unit. If more free hydrogen ion in water than it is acid. If more free hydroxyl ion in water than it is basic. A pH meter is used to measure the hydrogen ion H^{+} concentration in a solution and indicate it is acidic or alkaline (Fig. 4.5).

Most natural water range from pH 4 to 9 and are often slightly basic due to the presence of carbonates and bicarbonates. A major deviation from the normal pH for given water indicates the industrial wastes. Practically every phase of water supply and wastewater treatment, e.g., acid- base neutralization, water softening, precipitation, coagulation, disinfection, and corrosion control, is pH dependent

Figure 4.5 Monitoring of pH value in field

Procedure for measuring pH

The pH was measured by a pH meter and a combination electrode (a set of glass electrode and a reference electrode).

- Firstly, the electrode was rinsed with distilled water and cleaned with tissue paper.
- Then the electrode was first calibrated against a pH value of 4, 7 and 10 at a temperature of 25 °C.
- After calibration the electrode or probe was rinsed with the distilled water and cleaned with tissue paper
- The electrode or probe was then immersed in the sample and stirred gently and. After that take observations were taken.

4.2.2. Electrical Conductivity (EC) and Total Dissolved Solids (TDS)

The electrical conductivity of water estimates the total amount of solids dissolved in water -TDS, which stands for Total Dissolved Solids. TDS is measured in ppm (parts per million) or in mg/l.

The unit of electrical conductivity is μS/cm. The conductivity of water is an expression of its ability to conduct an electric current. As this property is related to the ionic content of the sample which is in turn a function of the dissolved solids concentration, the relevance of easily performed conductivity measurements is apparent. In itself conductivity is a property of little interest to a water analyst but it is an invaluable indicator of the range into which hardness and alkalinity values are likely to fall, and also of the order of the dissolved solids content of the water. While a certain proportion of the dissolved solids (for example, those which are of vegetable origin) will not be ionized (and hence will not be reflected in the conductivity figures) for many surface waters the following approximation will apply.

Procedure for analysis TDS and EC

The conductivity was determined by means of a conductivity meter, as follows

- The conductivity probe was rinsed with distilled water, cleaned with tissue paper and calibrated against NaCl solution. For 1413 μS/cm.
- After calibration the probe was rinsed with distilled water and cleaned with tissue paper.
- Then the probe is immersed in the sample and readings are noted.
- For determining the value of TDS, multiply the value of Electrical conductivity with 0.67.

CHAPTER- 5

RESULTS AND DISCUSSION

5.1 SOIL ANALYSIS

Soil samples were analyzed for different soil properties in the Soil and Water laboratory, NIH, Roorkee. Analyses are described in subsequent sections.

5.1.1 Particle Size Distribution

Particle size distribution is an attempt to determine the relative proportions of the different grain sizes that makes a given soil mass. Twelve soil samples were collected at four locations in the study area to find out grain size distribution. The grain size analysis was carried out in the soil water laboratory of the NIH institute.

The result of sieve analysis (particle size > 0.75mm) and laser particle size analyzer were blended to determine the percentages of sand, silt, clay and gravel in each soil sample. Table 5.1 lists the results of sand, silt and clay percentages of different locations in the study area. Making use of U.S. Department of Agriculture (Shukla *et al.* 1995) method for naming soils, the textural classification of soil samples was done. Results show that the presence of gravel content in the soil samples is very less 0 to 0.95 percent. The variation of sand content in soil samples ranges from 9.92 to 83.91 percent. The percentage of silt contents in soil sample lies from 14.62 to 78.86 percent. The presence of clay contents was seen less and is found varying from 1.39 to 11.84 percent. Based on textural classification of soil samples, the soil of the study area could be classified into two major groups: sandy loam and silt loam, except for lower depth (90-100 cm) of sample near Yamuna River which contains more sand content. Hence, mainly three types of soil types were found in the study area i.e. sandy loam, silt loam and sand.

The plots for each of the twelve samples are depicted in Figure 5.1 to 5.12. The results of particle size distribution along depth at particular location shows that there are not much variations in the grain size except for few locations. This implies that the soil in vertical direction is nearly homogenous up to one meter depth. The particle size distribution table for every sample are given in appendices (appendix A to L)

Table 5.1 Soil Type and Gravel, Silt and Clay Percentage of the Soil

S.NO.	LOCATION	SITE CODE WITH DEPTH	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	TYPE OF SOIL
1	Peenna	YHPIN_1S (0-15cm)	0.01	53.249	41.919	4.822	Sandy Loam
2	Peenna	YHPIN_2 (15-35cm)	0.00	52.370	41.006	6.625	Sandy Loam
3	Peenna	YHPIN_3 (50-100cm)	0.00	52.163	41.378	6.459	Sandy Loam
4	Dholara	YHDHO_1S (0-15cm)	0.95	16.491	73.861	8.698	Silt Loam
5	Dholara	YHDHO_2 (30-50cm)	0.01	9.981	78.167	11.842	Silt Loam
6	Dholara	YHDHO_3 (70-100cm)	0.03	9.216	78.820	11.934	Silt Loam
7	Salhakheri	YHSAL_1S (0-15cm)	0.67	24.887	69.036	5.407	Silt Loam
8	Salhakheri	YHSAL_2 (40-60cm)	0.25	18.640	72.900	8.210	Silt Loam
9	Salhakheri	YHSAL_3 (80-100cm)	0.01	19.168	72.340	8.482	Silt Loam
10	Near Yamuna river	YHYB_1S (0-15cm)	0.05	68.674	29.376	1.900	Sandy Loam
11	Near Yamuna river	YHYB_2 (40-50cm)	0.03	80.249	18.328	1.393	Sandy Loam
12	Near Yamuna river	YHYB_3 (90-100cm)	0.00	83.908	14.620	1.472	Sand

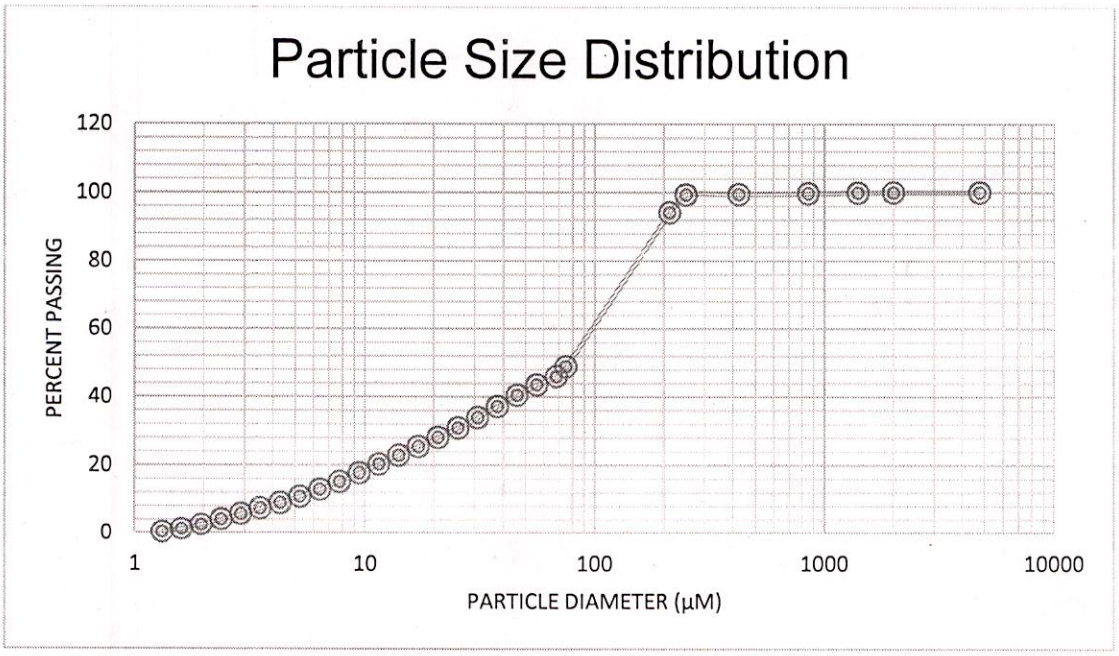

Figure 5.1 Particle size distribution at Peenna (0-15 cm)

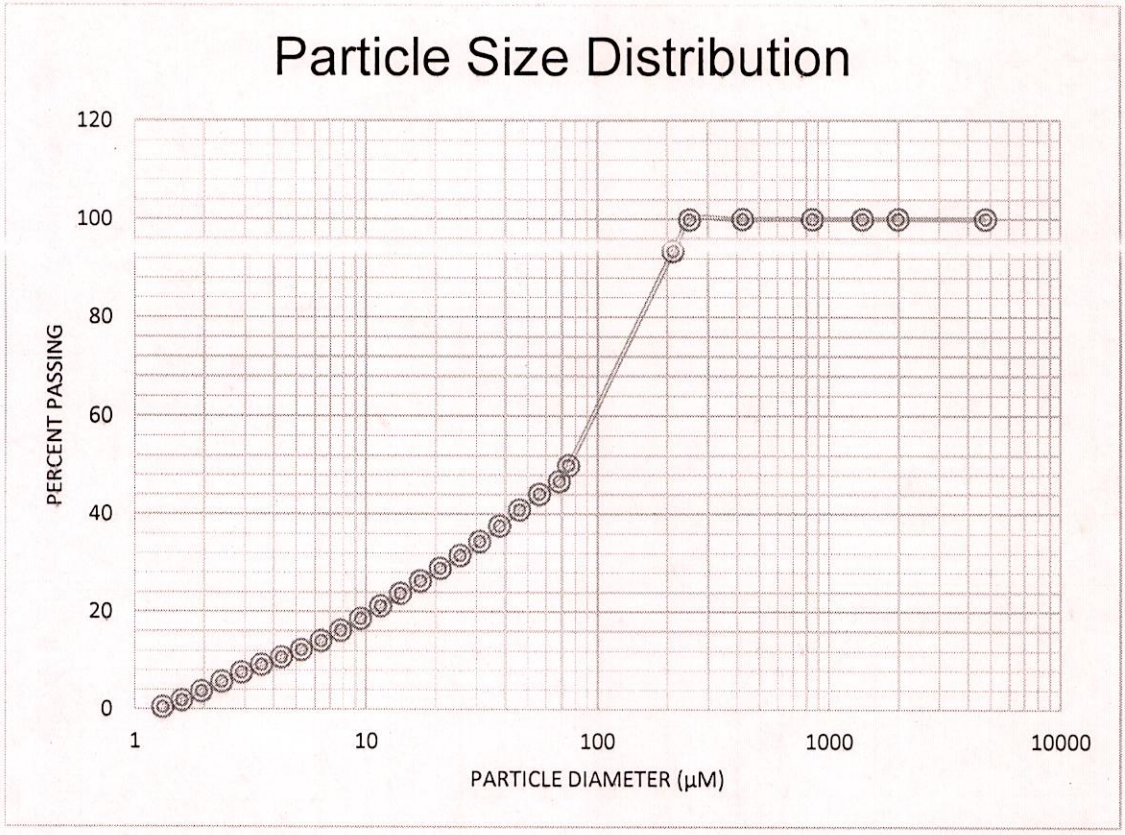

Figure 5.2 Particle Size Distribution at Peenna (15-35 cm)

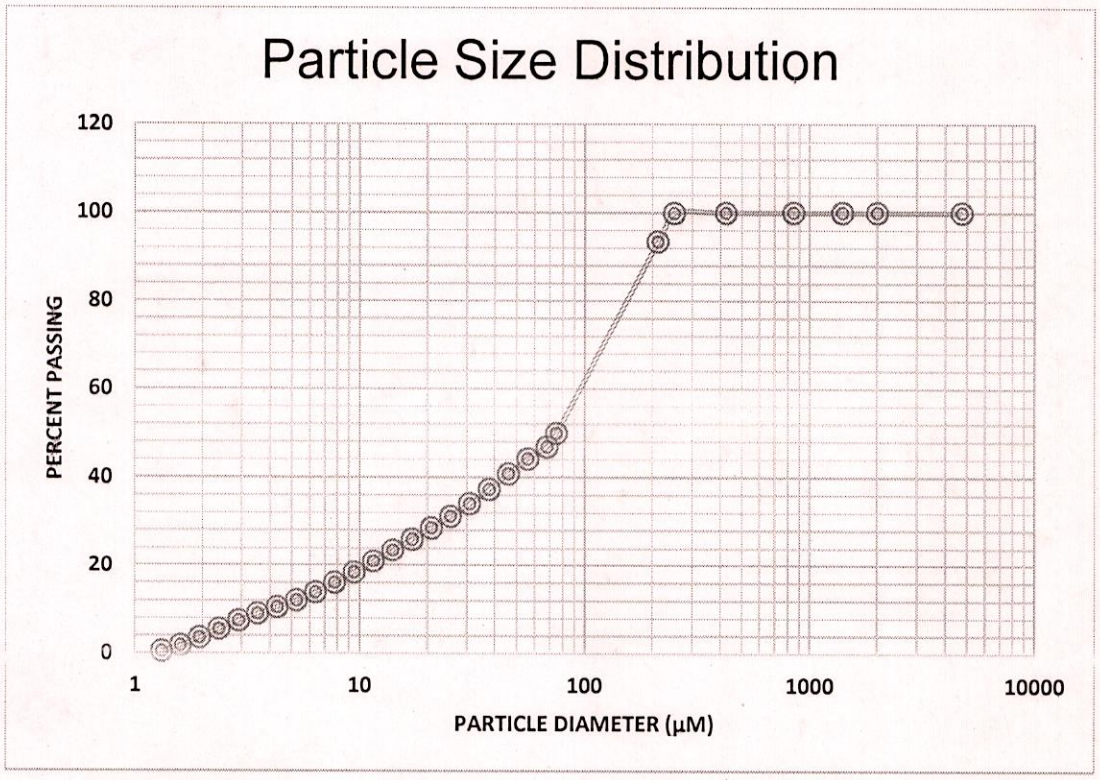

Figure 5.3 Particle Size Distribution at Peenna (50-100 cm)

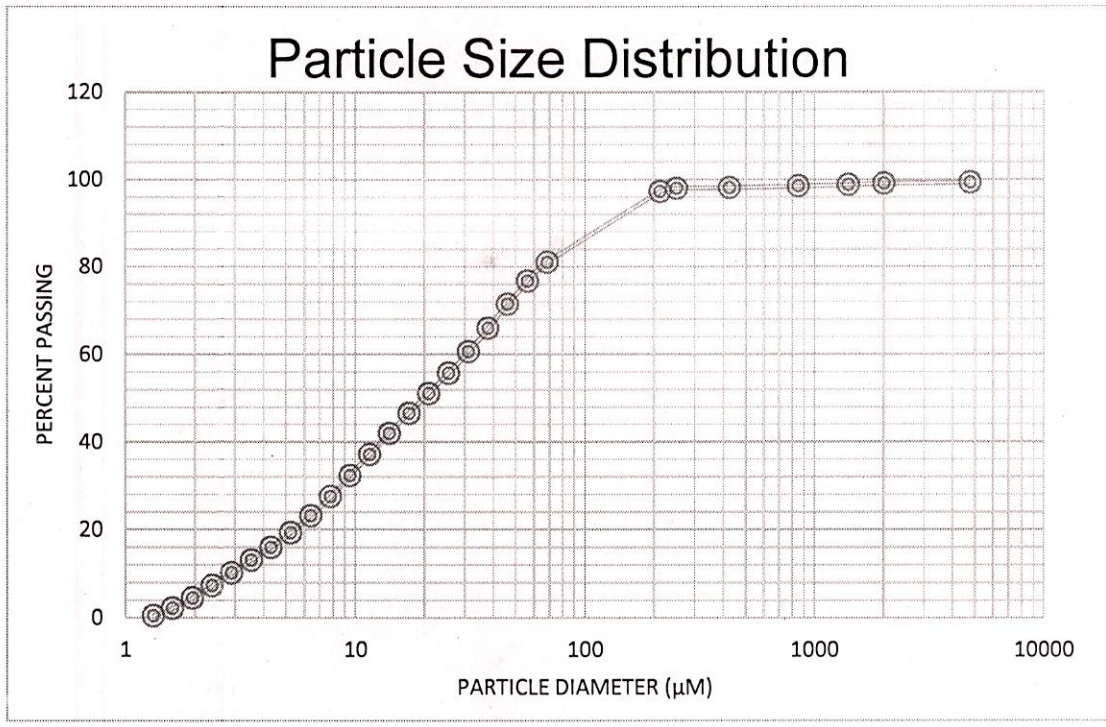

Figure 5.4 Particle Size Distribution at Dholara (0-15 cm)

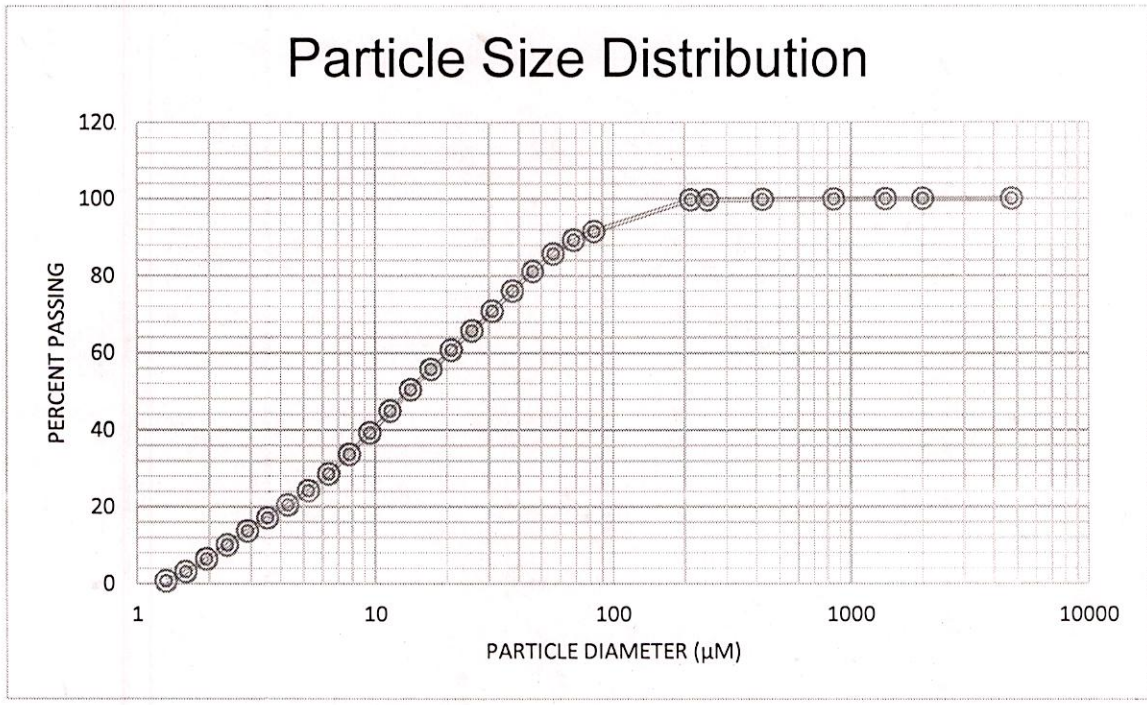

Figure 5.5 Particle Size Distribution at Dholara (30-50 cm)

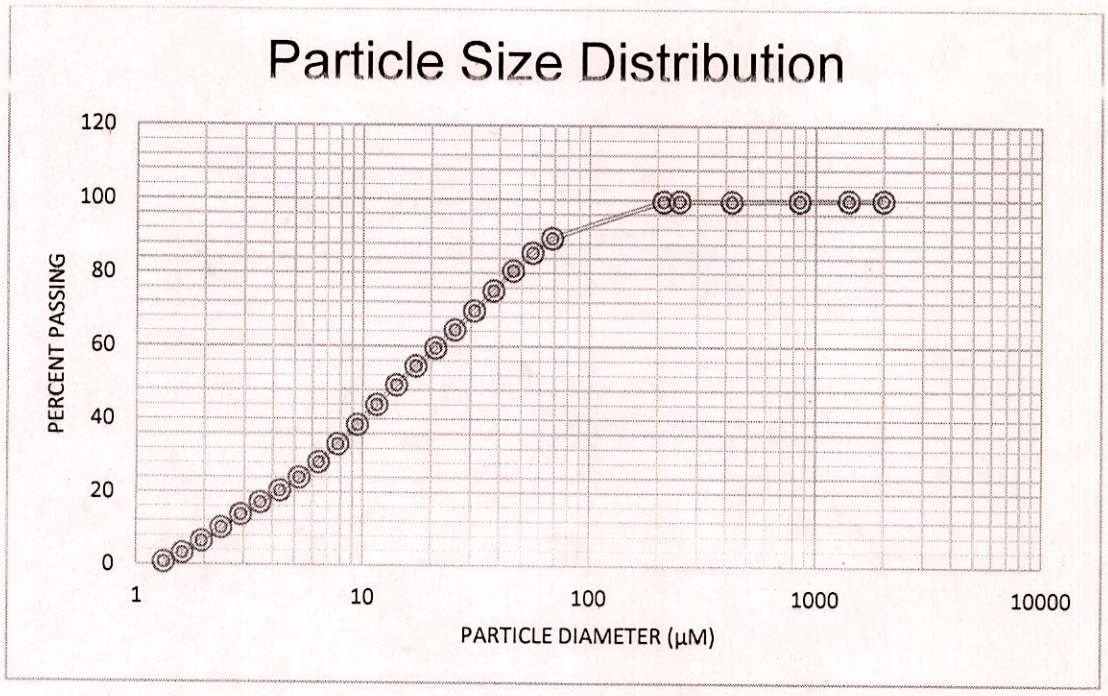

Figure 5.6 Particle Size Distribution at Dholara (70-100 cm)

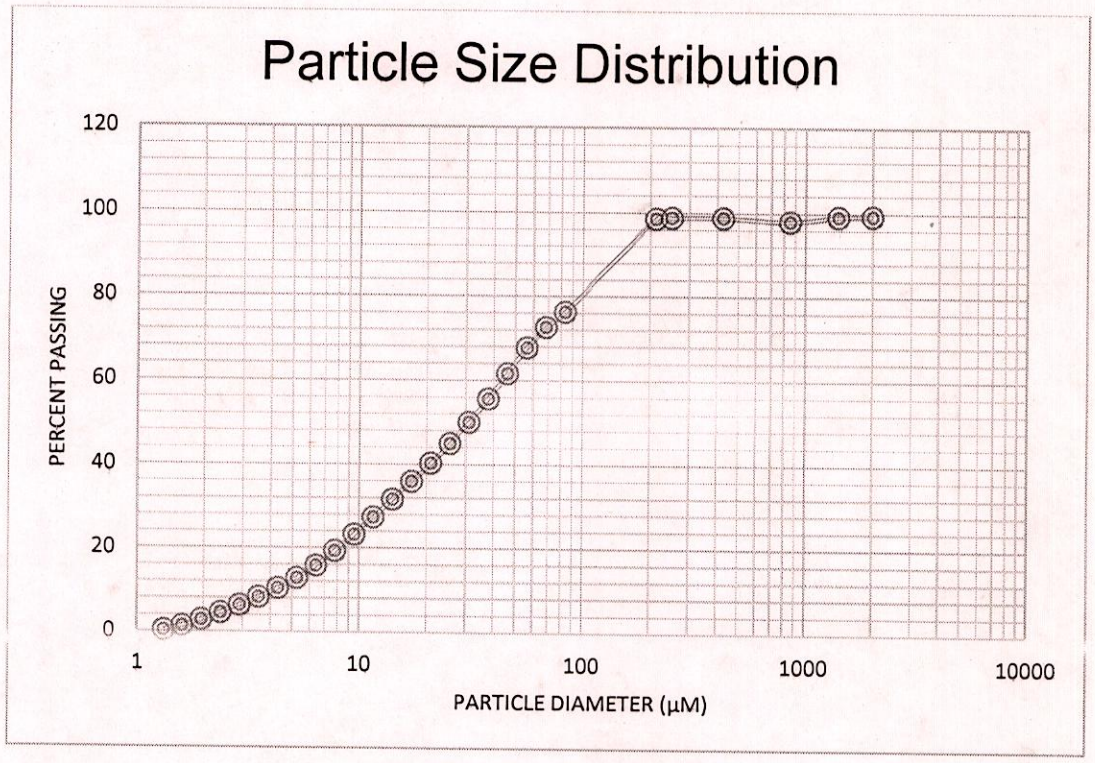

Figure. 5.7 Particle size distribution at salhakheri (0-15 cm)

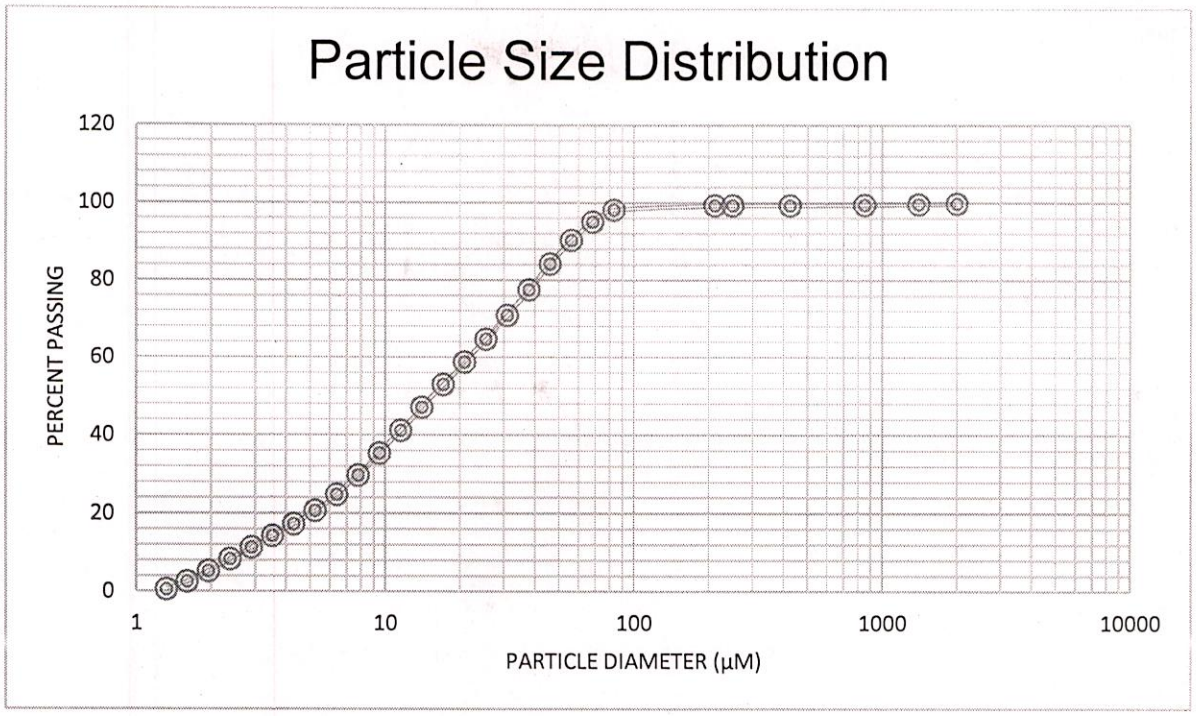

Fig 5.8 Particle size distribution at salhakheri (40-60 cm)

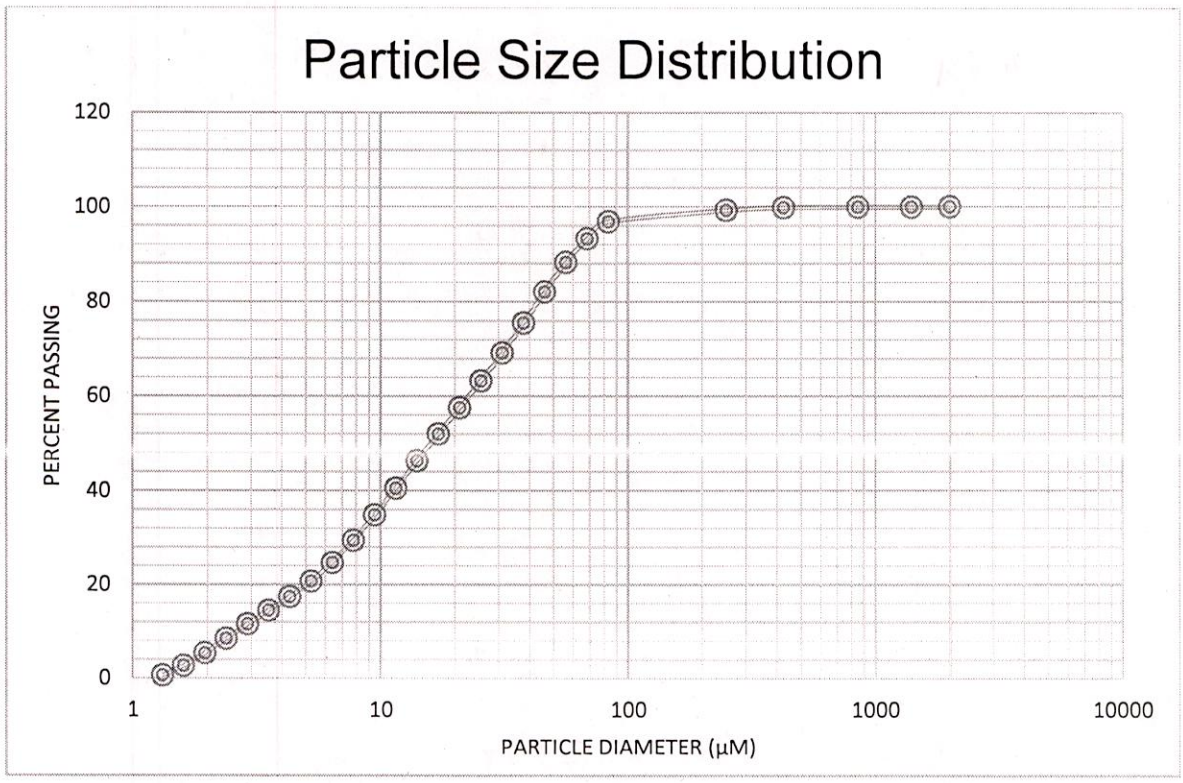

Figure 5.9 Particle Size Distribution at Salhakheri (80-100 cm)

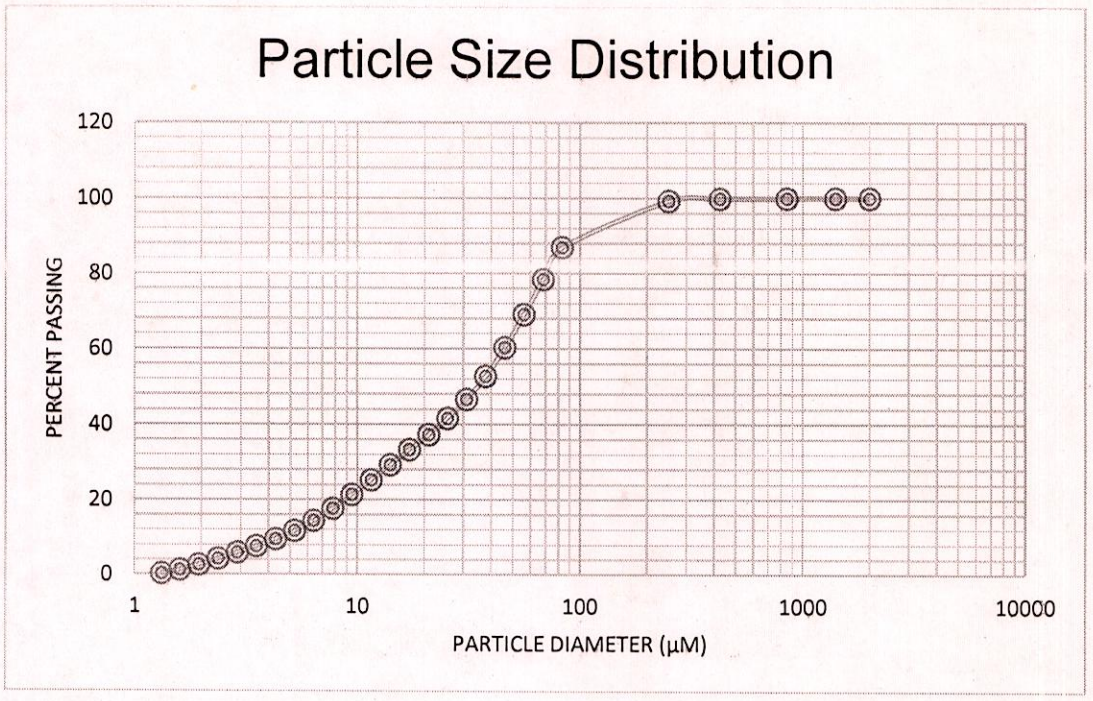

Figure 5.10 Particle Size Distribution at Yamuna River Bank (0-15 cm)

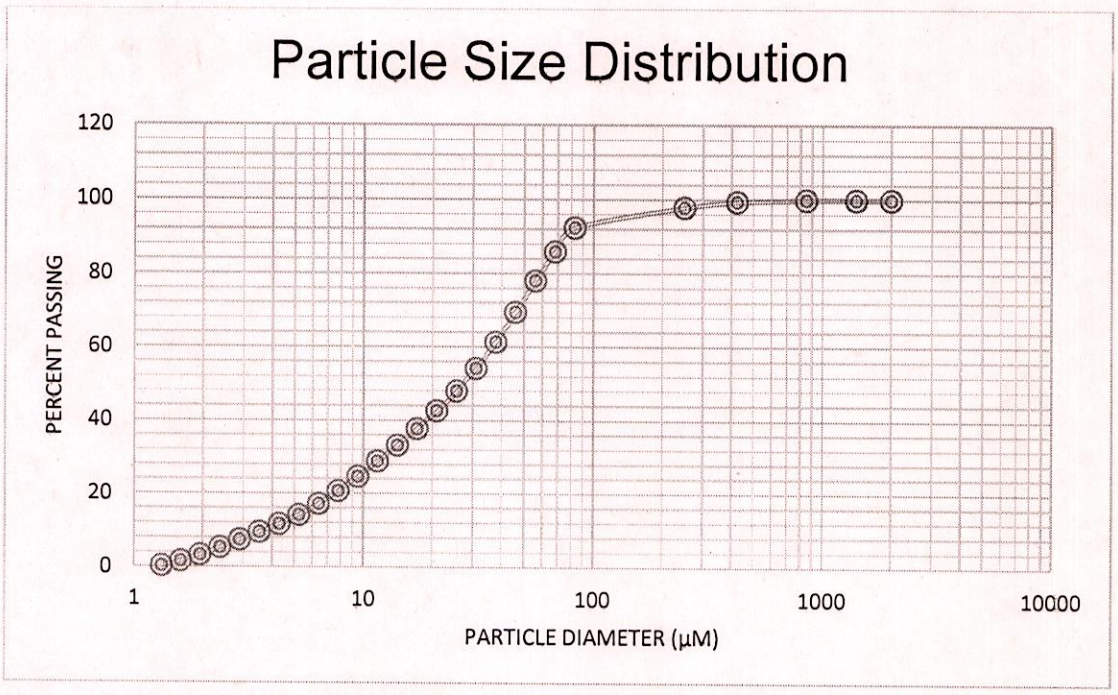

Figure 5.11 Particle Size Distribution at Yamuna River Bank (40-50 cm)

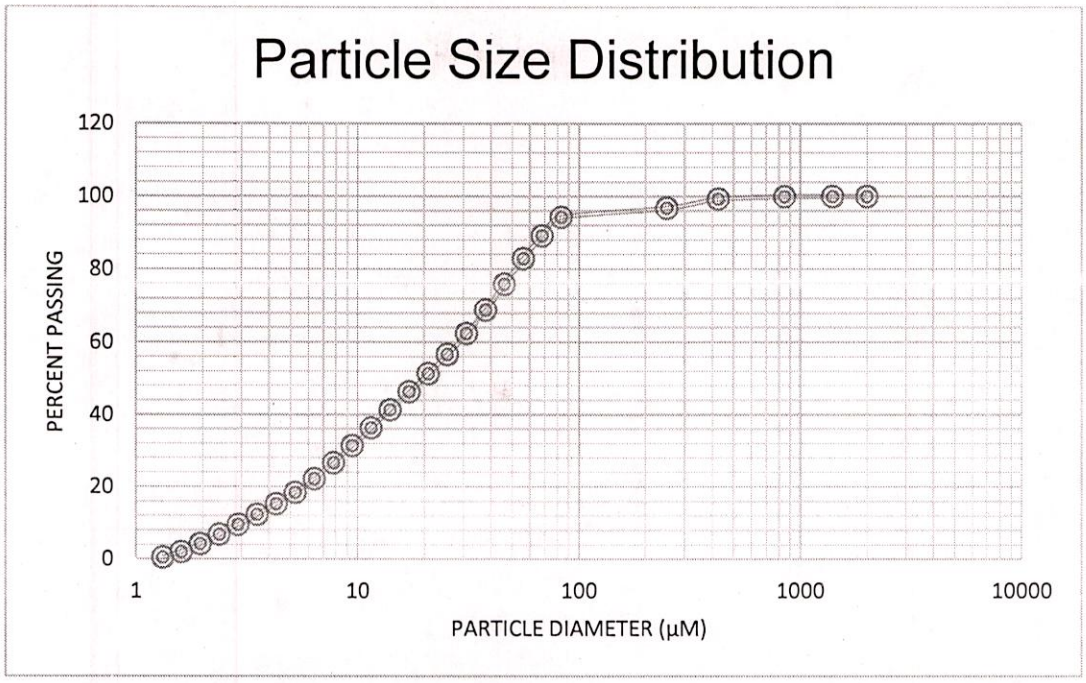

Figure 5.12 Particle Size Distribution at Yamuna River Bank (90-100 cm

5.1.2 Moisture Content and Bulk Density of Soil

Results of moisture content and bulk density analyses of soil samples are shown in table 5.2. The moisture content was found to vary from 4.01 to 10.00 % in upper layer (0-15cm). 5.98 to 18.65% in the intermediate layer (30-50 cm) and 4.30 to 21.39 % in lowest layer (60-100 cm), respectively. In general, the moisture content was found to be increasing with the depth in the field.

The value of bulk density varied from 1.32 to 1.68 (gm/cm^3) in upper layer (0-15 cm). 1.65 to 1.73 (gm/cm^3) in the intermediate layer (30-50 cm) and 1.38 to 1.75 (gm/cm3) in the lowest layer (60-100 cm), respectively (Table 5.2). The bulk density of the soil samples was found ideal for plant growth and supports cultivation. The result of bulk density of this study is shown in the Table 5.3.

Table 5.2 General Relationship of Soil Bulk Density to Root Growth Based on Soil Texture

S.NO.	SOIL TEXTURE	IDEAL BULK DENSITY FOR PLANT GROWTH (gm/cm^3)	BULK DENSITY THAT AFFECT ROOT GROWTH (gm/cm^3)	BULK DENSITY THAT RESTRICT ROOT GROWTH (gm/cm^3)
1	Sands, Loamy Sand	< 1.60	1.69	> 1.80
2	Sandy Loams, Loams	< 1.40	1.63	> 1.80
3	Sandy Clay Loams, Clay Loams	< 1.40	1.60	> 1.75
4	Silts, Silt Loams	< 1.40	1.60	> 1.75
5	Silt Loams, Silty Clay Loams	< 1.40	1.55	> 1.65
6	Sandy Clays, Silty Clays, clay loams	< 1.10	4.49	> 1.58
7	Clays (>45% clay)	< 1.10	1.39	> 1.47

5.2 Soil Moisture Retention Curve

Twelve disturbed soil samples were tested in the NIH. Roorkee laboratory. Continuous testing was performed for about one month. Volumetric moisture contents were obtained at ten different pressures (0.10, 0.33, 0.50, 0.70, 1.0, 3.0, 5.0, 7.0, 10.0, 15.0 bars). Soil moisture retention curve gives the variation of moisture with pressure and provides the moisture holding capacity of soil. Using the data of soil moisture obtained from pressure plate apparatus, the soil moisture characteristic curves were prepared and are presented in figures 5.13 to 5.24 based on soil types.

The value of the field capacity varied from 8.98 % to 28.91 % and wilting point varied from 1.22% to 12.30% respectively. The result of moisture content of disturbed soil sample shown in table 5.4

Table 5.3 Soil moisture content of undisturbed soil sample's bulk density

SAMPLE CODE (DEPTH)	WEIGHT OF MOIST SOIL & RING WITH RING	WEIGHT OF DRY SOIL WITH RING &CONTAINER IN GRAMS	MOISTURE CONTENT IN GRAMS	WEIGHT OF DRY SOIL IN GRAMS	% MOISTURE CONTENT AT THE TIME OF	BULK DENSITY (G/CM^3)	PORE SPACE %
YHPIN-1S (0-15 CM)	265.10	257.69	7.14	147.09	4.85	1.46	44.59
YHPIN-2 (15-30 CM)	301.98	281.29	20.69	166.88	12.40	1.66	37.13
YHPIN-3 (50-100 CM)	298.59	283.29	15.30	162.62	9.41	1.62	38.74
YHDHO_1S (0-15cm)	301.22	280.91	20.31	168.49	12.05	1.68	36.53
YHDHO_2 (30-50cm)	303.67	283.02	20.65	166.16	12.43	1.65	37.40
YHDHO_3 (70-100cm)	318.73	288.34	30.39	175.42	17.32	1.75	33.92
YHSAL_1S (0-15cm)	253.49	246.73	6.76	133.13	5.08	1.32	49.85
YHSAL_2 (40-60cm)	298.65	283.12	15.53	173.75	8.94	1.73	34.54
YHSAL_3 (80-100cm)	267.83	254.01	13.82	138.84	9.95	1.38	47.70
YHYB_1S (0-15cm)	267.88	258.98	8.90	144.71	6.15	1.44	45.48
YHYB_2 (40-50cm)	287.62	274.77	12.85	162.25	7.92	1.61	38.88
YHYB_3 (90-100cm)	268.84	260.54	8.30	148.62	5.58	1.48	44.01

Table 5.4. Soil Moisture Content Percentage Obtained In 10 Pressure in Pressure Plate Analysis

S.NO.	LOCATION (DEPTH)	PRESSURE HEAD										
		(bar)	0.1	0.33	0.5	0.7	1	3	5	7	10	15
		(cm of H_2O)	101.98	336.53	509.9	713.86	1019.8	3059.4	5099	7138.6	10198	15297
		SOIL MOISTURE CONTENT (%)										
1	YHPIN_1S (0-15 cm)		20.06	18.13	12.04	11.22	10.28	7.3	6.17	5.64	5.58	4.72
2	YHPIN_2 (15-35cm)		19.5	19.21	12.82	12.03	11.08	9.21	8.27	7.9	7.47	7.26
3	YHPIN_3 (50-100cm)		19.72	19.18	13.15	12	11.56	9.4	8.43	8.03	7.67	7.49
4	YHDHO_1S (0-15cm)		32.77	28.91	21.33	19.71	18.17	13.46	11.15	10.21	9.09	8.33
5	YHDHO_2 (30-50cm)		32.94	27.91	22.61	20.7	20.58	14.99	13.12	12.28	11.86	11
6	YHDHO_3 (70-100cm)		34.33	26.95	23.54	21.73	21.56	16.77	14.53	13.66	13.31	12.3
7	YHSAL_1S (0-15cm)		31.65	27.27	18.25	15.7	15.24	9.82	7.29	6.73	5.84	5.33
8	YHSAL_2 (40-60cm)		29.11	27.94	17.03	15.44	14.02	10.52	7.95	7.4	7.07	6.66
9	YHSAL_3 (80-100cm)		30.68	26.09	17.76	16.92	14.16	10.5	9.15	8.36	7.98	7.46
10	YHYB_1S (0-15cm)		20.29	19.49	7.96	7.71	5.81	4.06	3.6	2.75	2.32	2.01
11	YHYB_2 (40-50cm)		13.8	12.67	5.21	4.83	4.43	2.85	2.74	2.02	1.59	1.56
12	YHYB_3 (90-100cm)		10.57	8.98	3.65	3.64	3.4	2.09	2.06	1.67	1.36	1.22

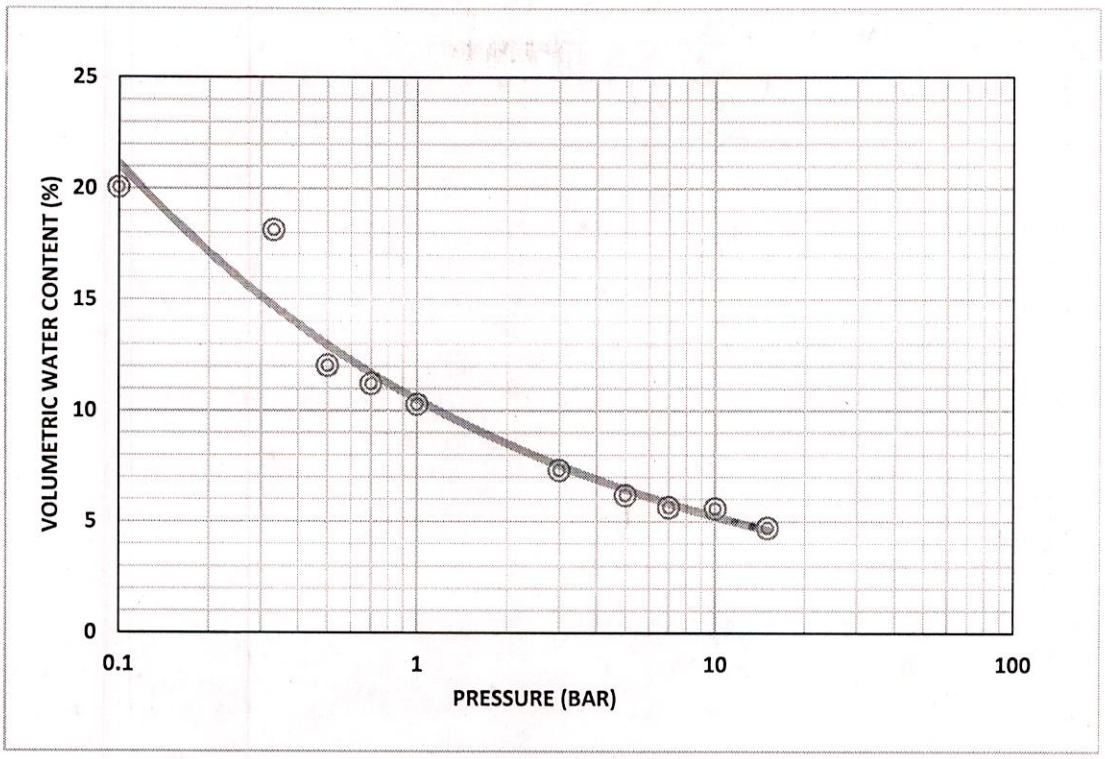

Figure 5.13 Soil Moisture Characteristic Curve for Peenna (0-15 Cm)

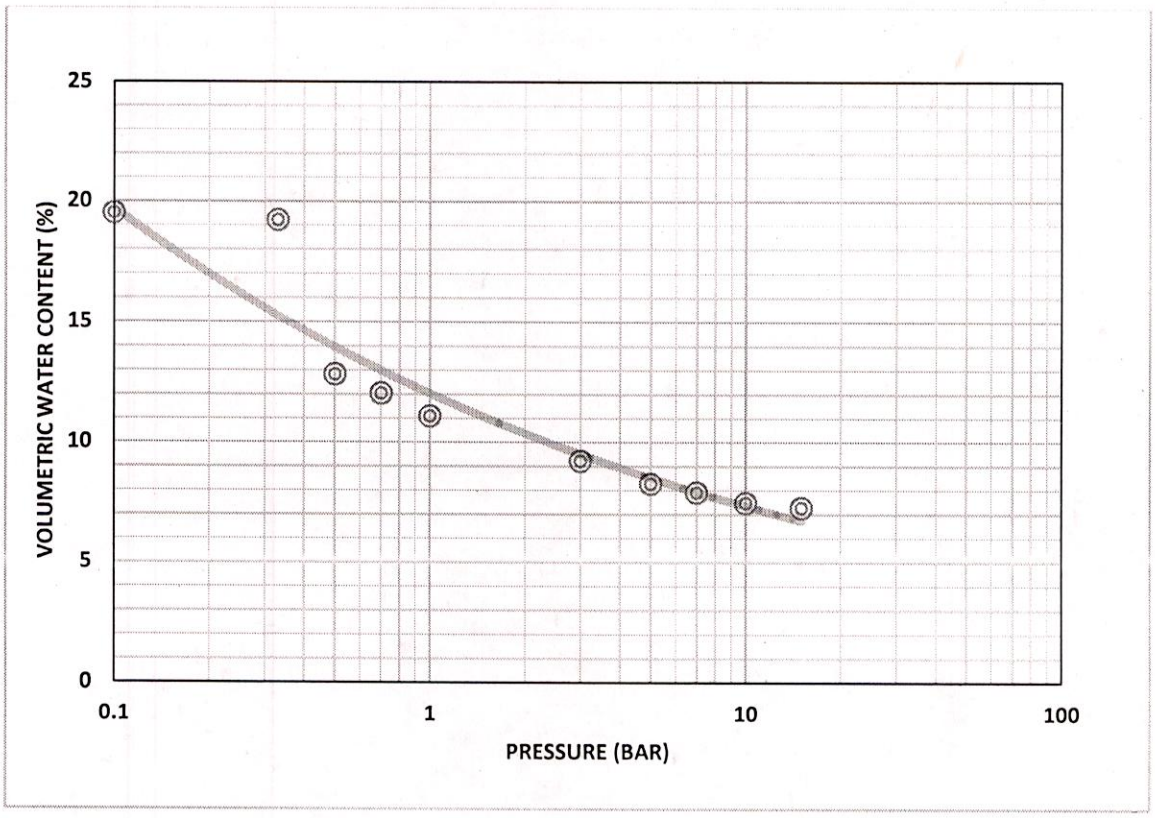

Figure 5.14 Soil Moisture Characteristic Curve for Peenna (15-35 Cm)

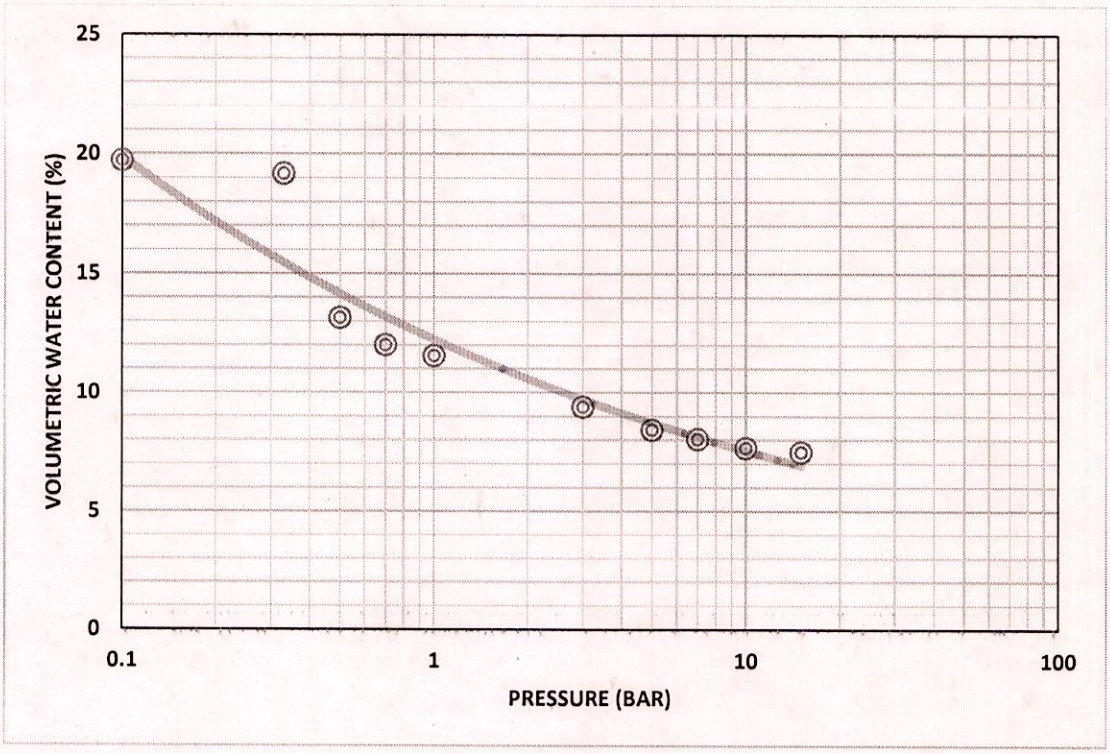

Figure 5.15 Soil Moisture Characteristic Curve for Peenna (50-100 cm)

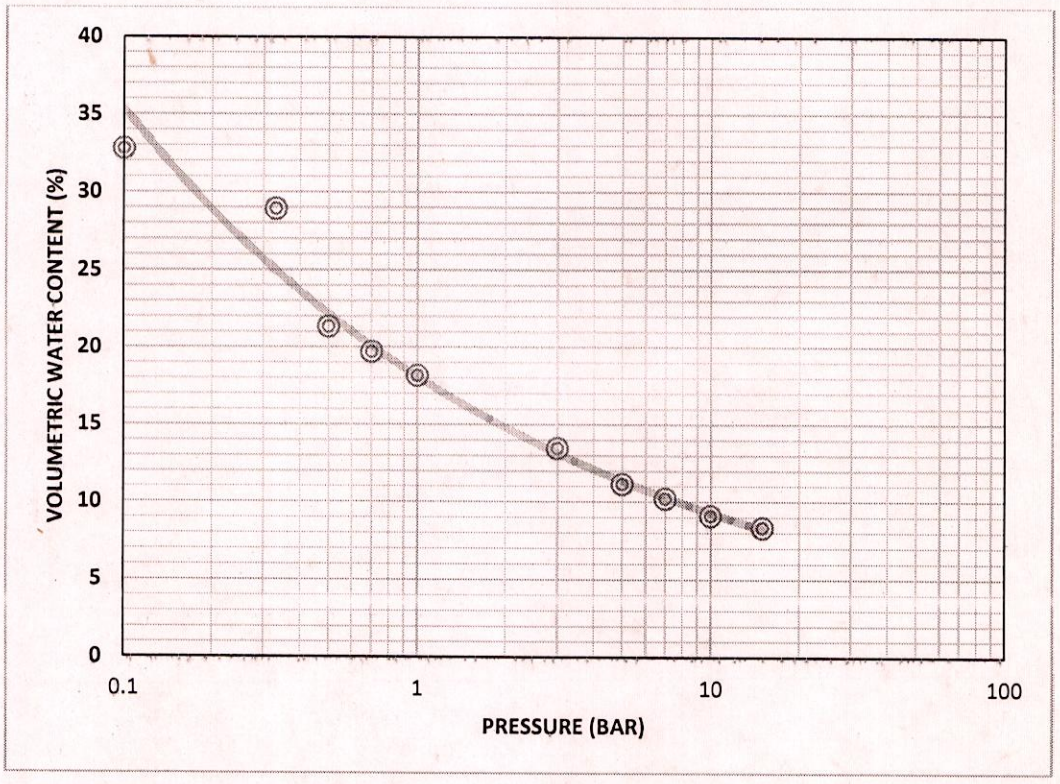

Figure 5.16 Soil Moisture Characteristic Curve for Dholara (0-15cm)

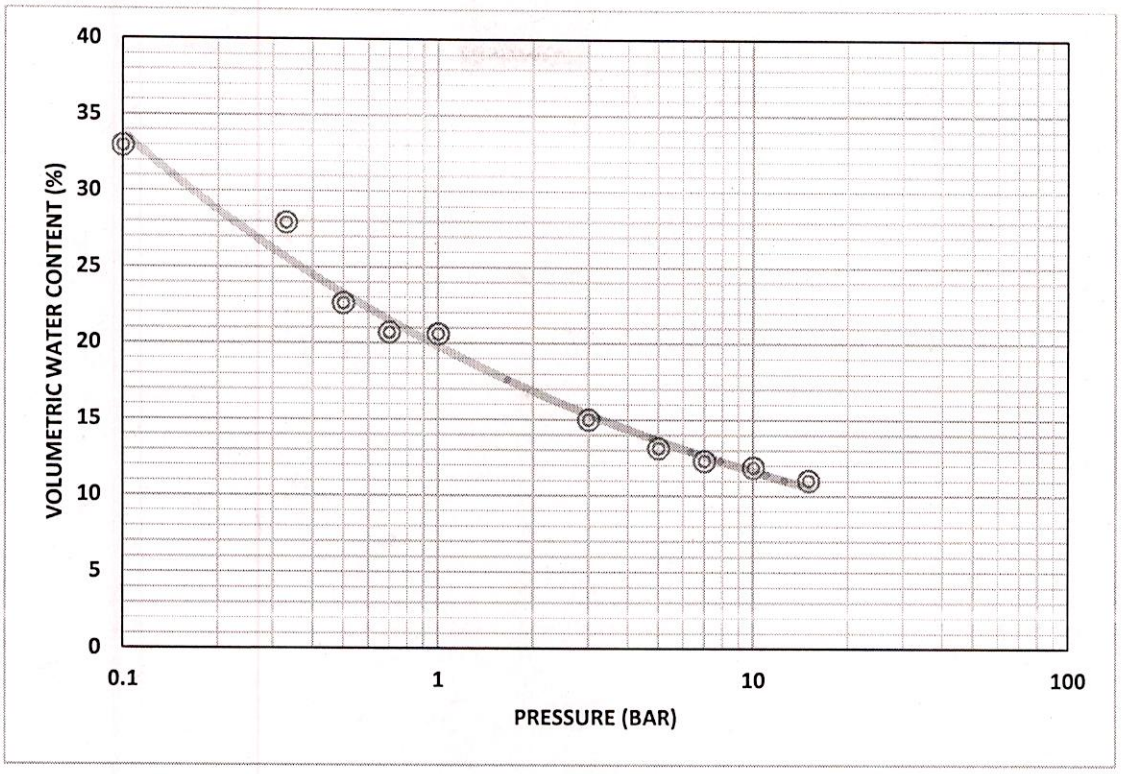

Figure 5.17 Soil Moisture Characteristic Curve for Dholara (30-50 cm)

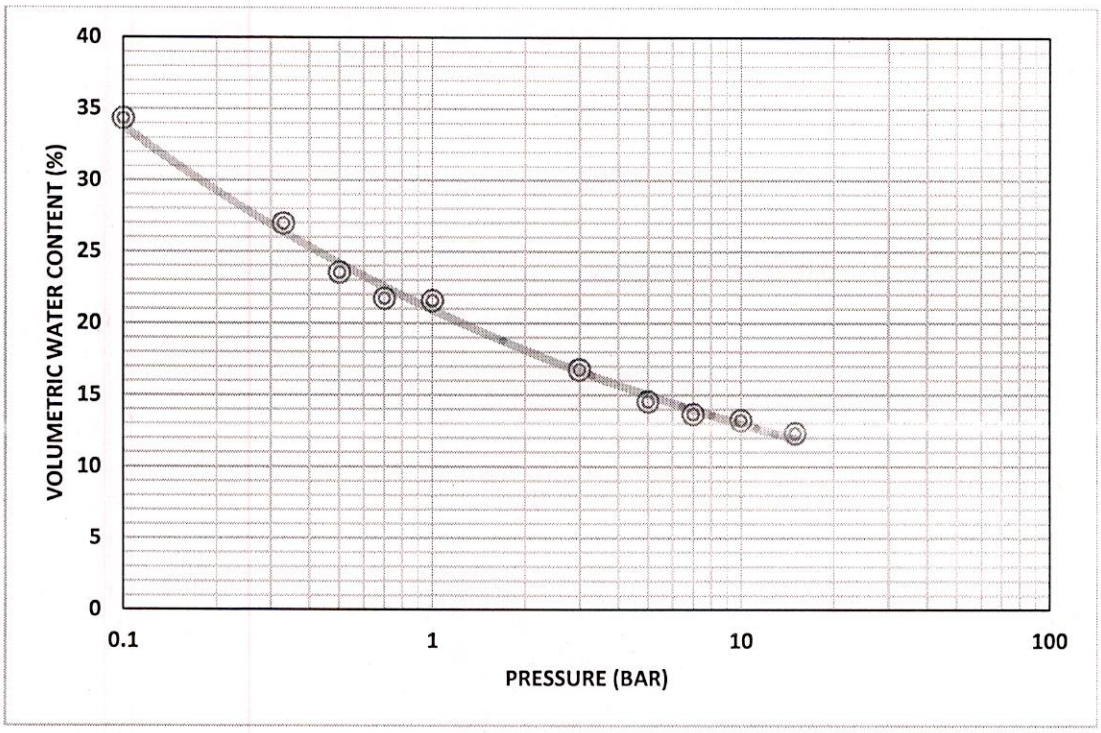

Figure 5.18 Soil Moisture Characteristic Curve for Dholara (70-100 cm)

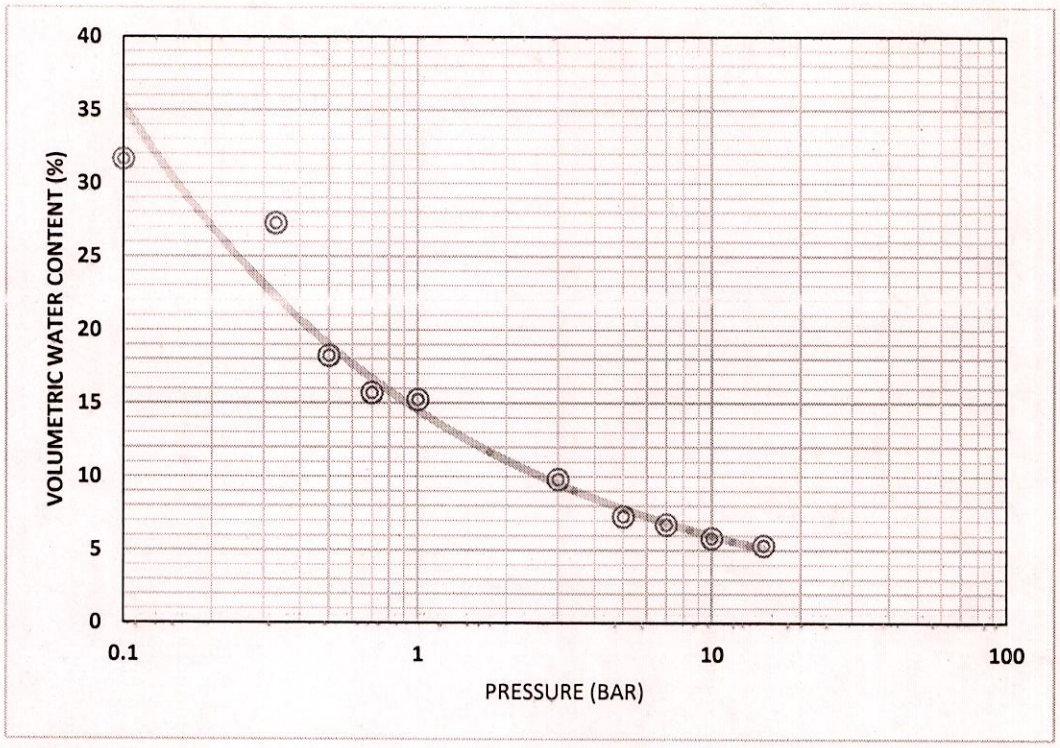

Figure 5.19 Soil Moisture Characteristic Curve for Salhakheri (0-15 cm)

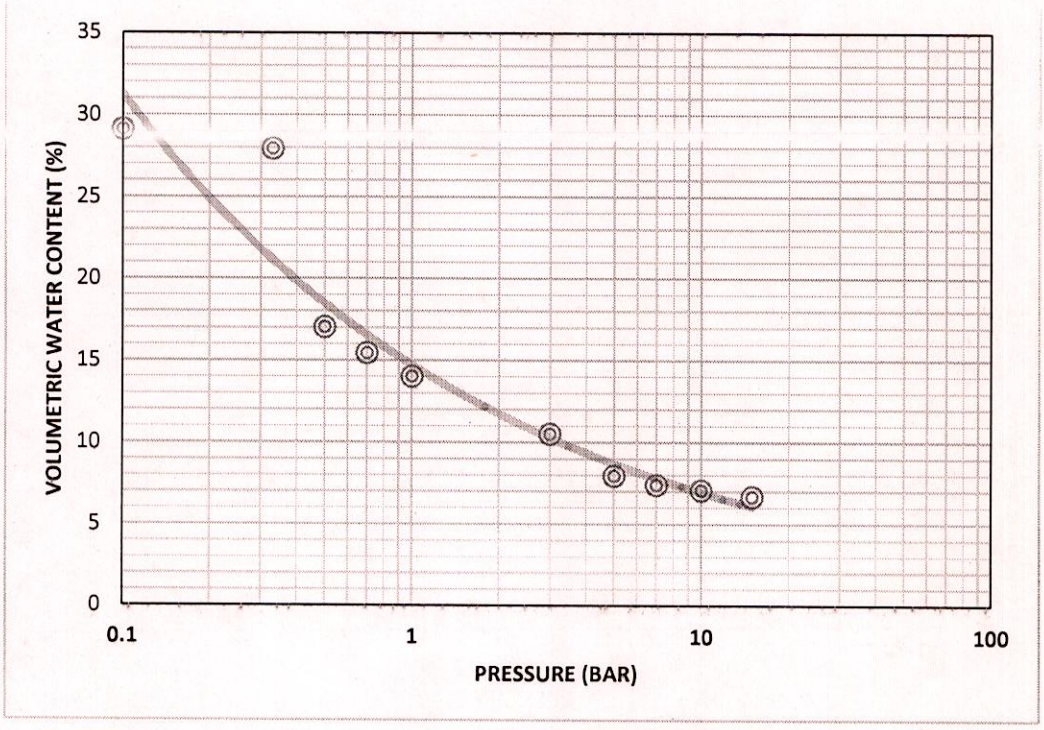

Figure 5.20 Soil Moisture Characteristic Curve for Salhakheri (40-60 cm)

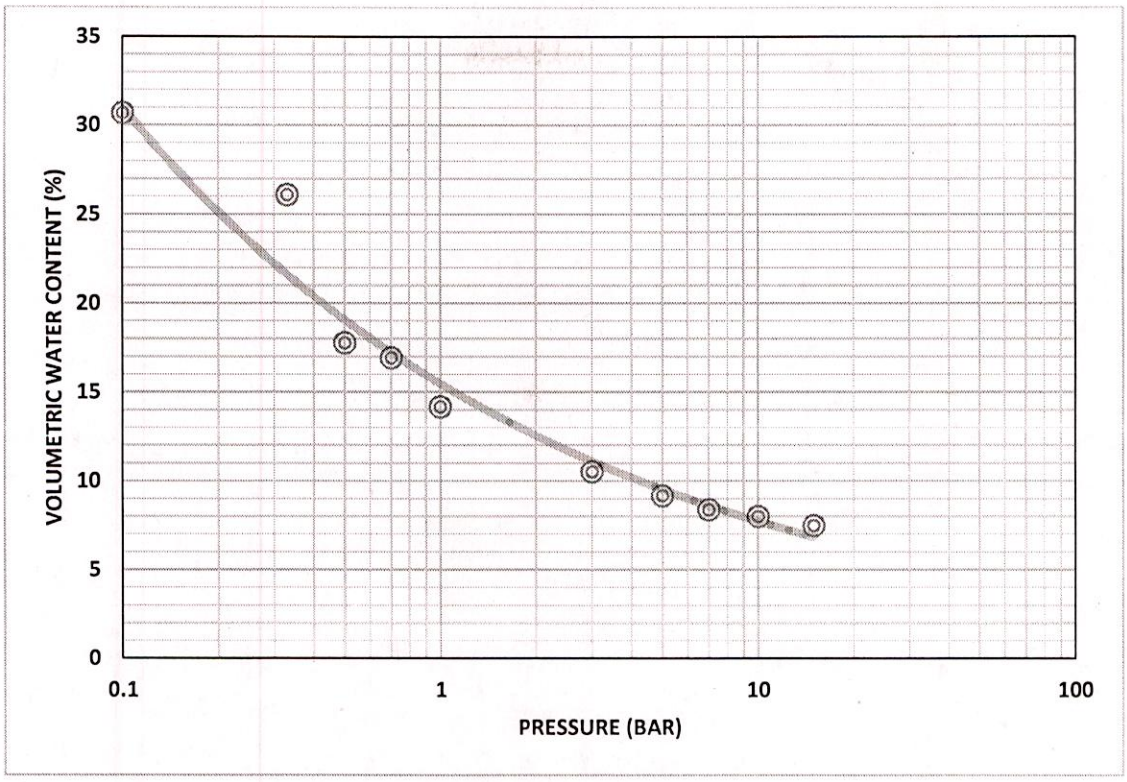

Figure 5.21 Soil Moisture Characteristic Curve for Salhakheri (80-100 cm)

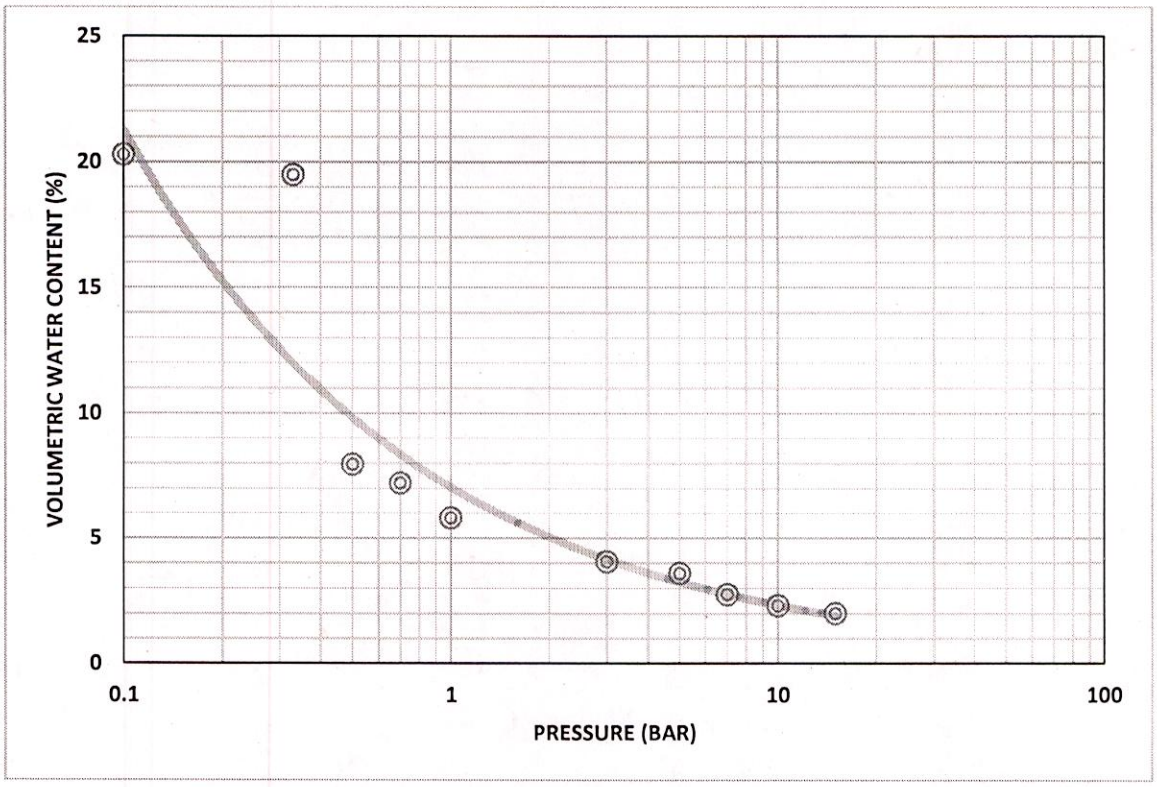

Figure 5.22 Soil Moisture Characteristic Curve for Yamuna River Bank (0-15 cm)

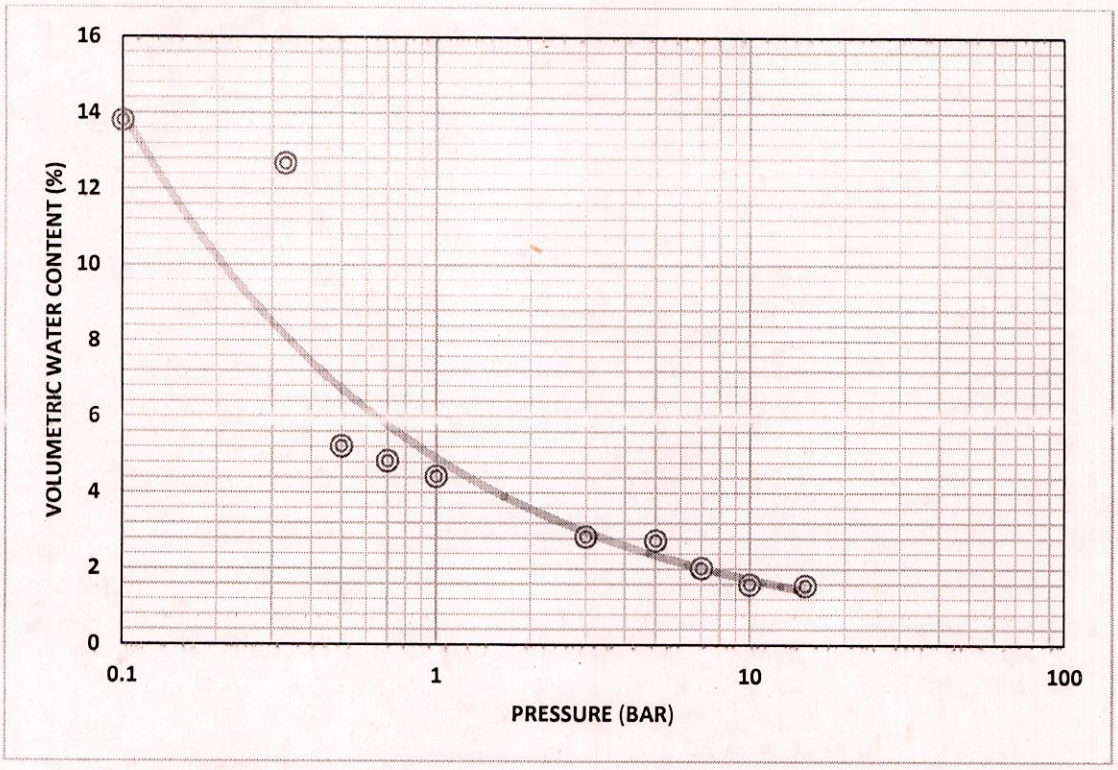

Figure 5.23 Soil Moisture Characteristic Curve for Yamuna River Bank (40-50 cm)

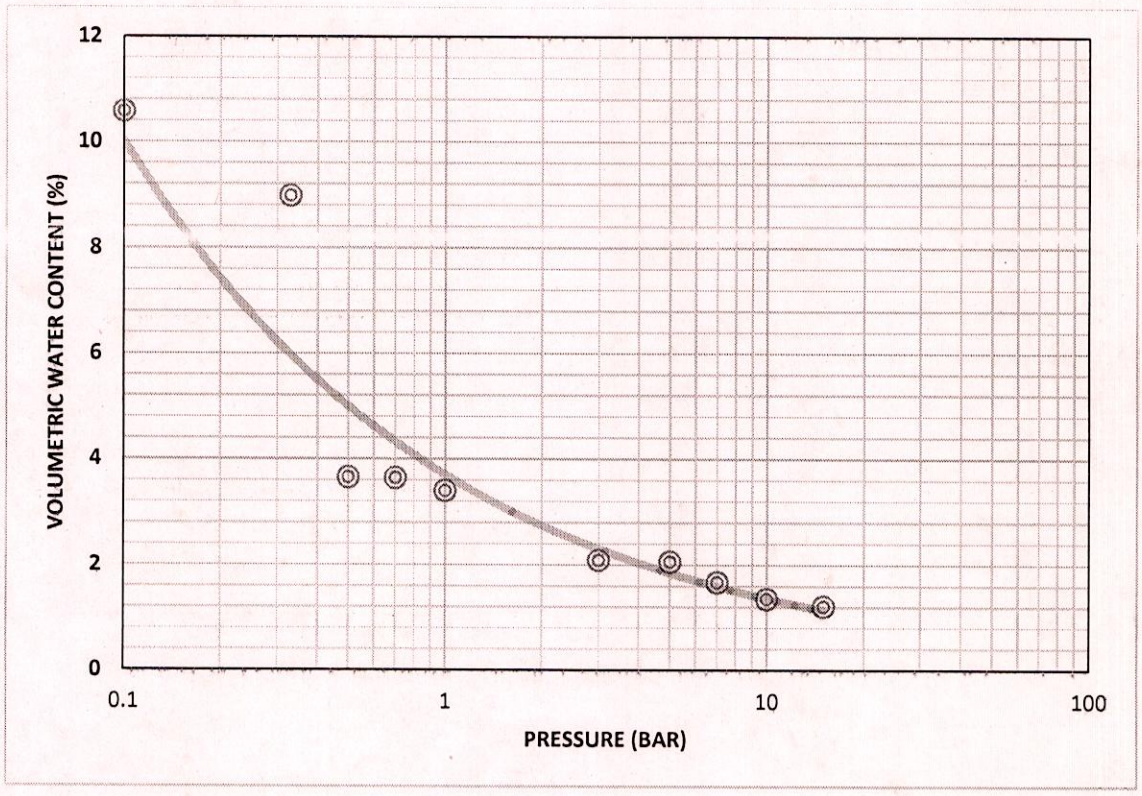

Figure 5.24 Soil Moisture Characteristic Curve for Yamuna River Bank (90-100 cm)

Table 5.5 Soil Moisture Content of Disturbed Soil

S. No.	LOCATION (Depth)	WEIGHT OF MOIST SOIL (gms)	WEIGHT OF DRY SOIL (gms)	MOISTURE CONTENT (%)
1	YHPIN-1S (0-15 CM)	120.36	110.36	9.06
2	YHPIN-2 (15-356 CM)	116.3	106.77	8.93
3	YHPIN-3 (50-100 CM)	109.43	97.63	12.09
4	YHDHO_1S (0-15cm)	128.19	115.08	11.39
5	YHDHO_2 (30-50cm)	154.13	132.74	16.11
6	YHDHO_3 (70-100cm)	127.11	108.61	17.03
7	YHSAL_1S (0-15cm)	83.03	79.02	5.07
8	YHSAL_2 (40-60cm)	71.11	65.38	8.76
9	YHSAL_3 (80-100cm)	68.39	62.4	9.60
10	YHYB_1S (0-15cm)	74.38	70.2	5.95
11	YHYB_2 (40-50cm)	67.34	62.4	7.92
12	YHYB_3 (90-100cm)	70.15	65.85	6.53

5.3 pH, Electrical conductivity & Total dissolved solids

The electrical conductivity, pH and TDS were measured at field as well as in NIH laboratory. The value of EC lies from 415 to 3170 (µS/cm) and the value of TDS varies from 300.16 to 2123.9 (mg/l) in the study area. According to Bureau of Indian Drinking Water Standards, (BIS: 10500, 2012), the value of 500 mg/l of TDS is suitable for drinking purpose , above 500 TDS mg/l is not suitable for drinking purpose but it's suitable for irrigation purpose. The result of pH show that the water quality of study is good and the water is suitable for drinking water. The water quality result of study area is shown in Table 5.6

Value of the TDS of the water sampling location shown in Figure 5.25. The maximum area has 200 mg/l-500 mg/l of TDS in water.it is suitable for the drinking purpose. Some locations have above 500 mg/l TDS value. It is not suitable for drinking purpose but it is suitable for irrigation.

Table 5.6: Water quality status of different sites

S.NO.	LOCATION	EC(µS/cm)	pH	TDS (mg/l)
1	Anandpuri	515	7.16	345.05
2	Muzaffarnagar Shamli road	1110	7.87	743.7
3	Dholra	1049	7.28	702.83
4	Dholri	713	7.37	477.71
5	Dholri	1265	7.6	847.55
6	Salhakheri	818	7.23	548.06
7	Shamli Kairana road	893	7.14	598.31
8	Lilauan	837	7.04	560.79
9	Bamnauli1	718	7.14	481.06
10	Bamnauli 2	769	7.25	515.23
11	Kandela	1059	6.91	709.53
12	Kairana	515	7.51	345.05
13	Jalalabad	415	7.13	278.05
14	Thanabhawan	541	6.81	362.47
15	Manatmanti	749	6.79	501.83
16	Garhi abdulla khan	884	6.71	592.28
17	Un	642	6.98	430.14
18	Rangana	1209	6.88	810.3
19	Jhinjhana	1105	6.91	740.353
20	Paonti kalan	536	7.46	359.12
21	Sewapur	775	7.02	519.25
22	Niamu	448	7.93	300.16
23	Budiana kalan	1135	7.05	760.45
24	Shikarpur	1593	6.85	1067.31
25	Budhana	978	7.23	655.26
26	Budhana	826	7.30	553.42
27	Atali	1922	7.21	1334.64
28	Atali	1019	7.25	652.16
29	Atali	688	7.21	460.96
30	Atali	3170	6.92	2123.9
31	Tamela Ghada	737	6.45	493.79

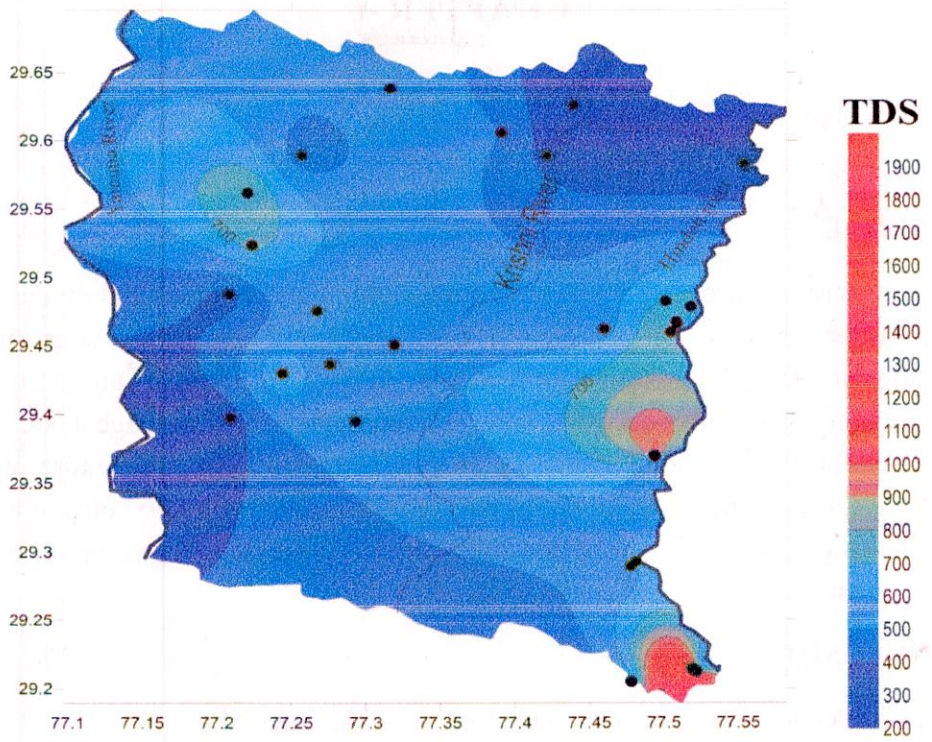

Figure 5.25 Map showing spatial variation of Total Dissolved Solids in the study area (black dots represent sampling locations)

Figure 5.26 shows pH of the groundwater in the study area. pH of groundwater of the study area lies between 6.5 and 8.5.According to BIS standard of drinking water 2012 the groundwater of the study area is suitable for drinking purpose.

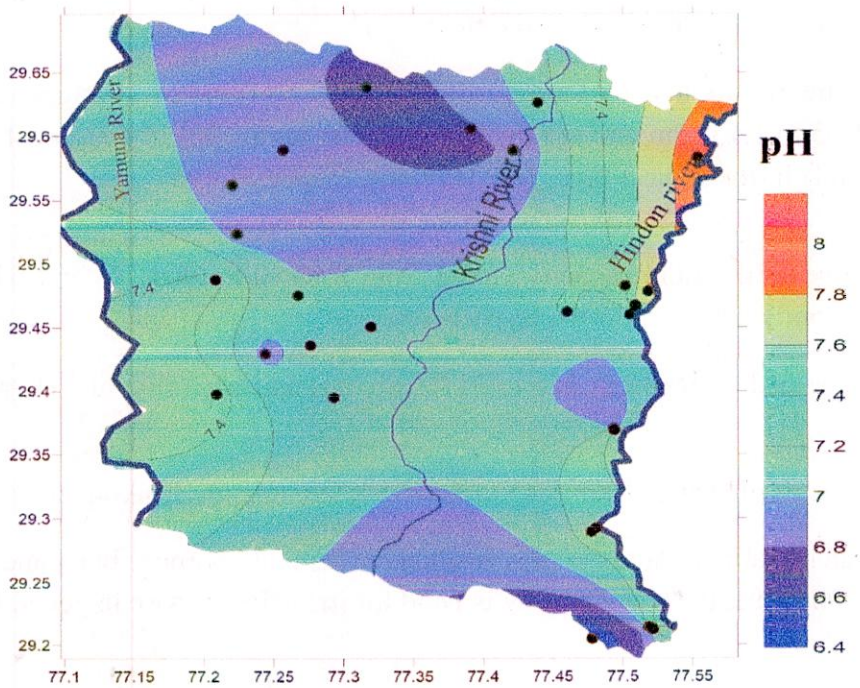

Figure 5.26 Map showing spatial variation of pH in the study area (black dots represent sampling locations)

CHAPTER -6

CONCLUSION

6.1 GENERAL

The properties of soil are very vital for understanding the allocation and management of soil and water resources in an area. Hydrological soil properties constitute basic information for carrying out studies related to groundwater, irrigation and drainage. The design and construction of successful and efficient subsurface drainage system depend upon the reliability and adequacy of the properties of soil like soil texture, grain size distribution, soil moisture characteristics curves of the area taken into consideration. The major conclusion from this study and the scope of future work are presented in the following section.

6.2 CONCLUSIONS

The following conclusions are made based on the experimental result:

- The soil of the study area could be classified into two major groups: sandy loam and silt loam, except for one location, which has sand (at the depth of 90-100 cm near Yamuna River).
- The moisture content was found to vary from 4.01 to 10.00 % in upper layer (0-15cm). 5.98 to 18.65% in the intermediate layer (30-50 cm) and 4.30 to 21.39 % in lowest layer (60-100 cm), respectively. In general, the moisture content was found to be increasing with the depth in the field.
- The value of bulk density varied from 1.32 to 1.68 (gm/cm^3) in upper layer (0-15 cm). 1.65 to 1.73 (gm/cm^3) in the intermediate layer (30-50 cm) and 1.38 to 1.75 (gm/cm3) in the lowest layer (60-100 cm), respectively.
- The value of the field capacity varied from 8.98 % to 28.91 % and wilting point varied from 1.22% to 12.30%. respectively.
- The value of EC lies from 415 to 3170 (μS/cm) and the value of TDS varies from 300.16 to 2123.9 (mg/l)
- The value of pH varies from 6.45 to 7.87. it is suitable for drinking purpose
- The water quality of study is mostly good for drinking purpose but some areas have high TDS value, the water quality is good for irrigation pupose in general.

6.3 Future Scope of Study

The physical and hydraulic properties of soil in the study area (region of Yamuna Hindon inter basin located of Shamli district and partly in Muzaffarnagar district) can be used to study the ground water recharge in the study area. The study can be helpful in improving the management of land use cover and method of irrigation. The data generated through present investigation may be useful for additional hydrological studies such as drainage management. The understanding of the groundwater salinity in study area can be used for developing the water quality index as well as management of ground water quality for irrigation purpose

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APPENDICES:

APPENDIX A: Particle size distribution at Peenna (0-15 cm)

Site: Peenna		
Depth: 0-15 cm		
Sample code: YHPIN-1S		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.20
1.32	1.6	1.14
1.6	1.95	2.44
1.95	2.38	4.00
2.38	2.9	5.63
2.9	3.53	7.26
3.53	4.3	8.93
4.3	5.24	10.75
5.24	6.39	12.82
6.39	7.78	15.13
7.78	9.48	17.63
9.48	77.55	20.21
11.55	14.08	22.82
14.08	17.5	25.42
17.15	20.9	28.07
20.9	25.46	30.85
25.46	31.01	33.86
31.01	37.79	37.13
37.79	46.03	40.46
46.03	56.09	43.53
56.09	68.33	45.94
0.075		48.78
0.212		94.08
0.25		99.30
0.425		99.43
0.85		99.67
1.4		99.89
2		99.99
4.75		100

APPENDIX B: Particle size distribution at Peenna (15-35 cm)

Site: Peenna		
Depth: 15-35 cm		
Sample code: YHPIN-12		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.45
1.32	1.6	1.81
1.6	1.95	3.67
1.95	2.38	5.68
2.38	2.9	7.56
2.9	3.53	9.18
3.53	4.3	10.66
4.3	5.24	12.20
5.24	6.39	14.02
6.39	7.78	18.60
7.78	9.48	21.15
9.48	77.55	23.74
11.55	14.08	26.31
14.08	17.5	28.87
17.15	20.9	28.87
20.9	25.46	31.51
25.46	31.01	34.36
31.01	37.79	37.51
37.79	46.03	40.85
46.03	56.09	44.06
56.09	68.33	46.71
0.075		49.94
0.212		93.45
0.25		99.89
0.425		99.98
0.85		100
1.4		100
2		100
4.75		100

APPENDIX C: Particle size distribution at Peenna (50-100 cm)

Site: Peenna		
Depth: 50-100 cm		
Sample code: YHPIN-3		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.43
1.32	1.6	1.75
1.6	1.95	3.55
1.95	2.38	5.53
2.38	2.9	7.38
2.9	3.53	9.00
3.53	4.3	10.49
4.3	5.24	12.04
5.24	6.39	13.87
6.39	7.78	16.02
7.78	9.48	18.41
9.48	77.55	20.92
11.55	14.08	23.47
14.08	17.5	26.00
17.15	20.9	28.53
20.9	25.46	31.15
25.46	31.01	34.02
31.01	37.79	37.27
37.79	46.03	40.79
46.03	56.09	44.145
56.09	68.33	46.87
0.075		49.94
0.212		93.45
0.25		99.89
0.425		99.98
0.85		100
1.4		100
2		100
4.75		100

APPENDIX D: Particle size distribution at Dholra (0-15 cm)

Site: Dholra		
Depth: 0-15 cm		
Sample code: YHDHO-1S		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.40
1.32	1.6	2.12
1.	1.95	4.48
1.95	2.38	7.26
2.38	2.9	10.12
2.9	3.53	12.97
3.53	4.3	15.93
4.3	5.24	19.22
5.24	6.39	23.08
6.39	7.78	27.47
7.78	9.48	32.23
9.48	77.55	37.10
11.55	14.08	41.89
14.08	17.5	46.53
17.15	20.9	51.07
20.9	25.46	55.67
25.46	31.01	60.57
31.01	37.79	60.57
37.79	46.03	65.89
46.03	56.09	71.42
56.09	68.33	76.65
0.212		81.00
0.25		97.19
0.425		97.94
0.85		98.13
1.4		98.46
2		98.77
4.75		99.05

APPENDIX E: Particle size distribution at Dholra (30-50 cm)

Site: Dholra		
Depth: 30-50cm		
Sample code: YHDHO-2		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.67
1.32	1.6	3.13
1.6	1.95	6.41
1.95	2.38	10.12
2.38	2.9	13.74
2.9	3.53	17.10
3.53	4.3	20.40
4.3	5.24	24.00
5.24	6.39	28.25
6.39	7.78	33.14
7.78	9.48	38.51
9.48	11.55	43.98
11.55	14.08	50.38
14.08	17.5	54.51
17.15	20.9	59.48
20.9	25.46	64.46
25.46	31.01	69.46
31.01	37.79	75.09
37.79	46.03	80.58
46.03	56.09	85.57
56.09	68.33	89.47
0.075		91.49
0.212		99.49
0.25		99.55
0.425		99.61
0.85		99.76
1.4		99.92
2		99.97
4.75		99.97

APENDIX F: Particle size distribution at Dholara (70-100 cm)

Site: Dholra		
Depth: 70-100cm		
Sample code: YHDHO-3		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.66
1.32	1.6	3.08
1.6	1.95	6.33
1.95	2.38	10.02
2.38	2.9	13.65
2.9	3.53	17.05
3.53	4.3	20.44
4.3	5.24	24.15
5.24	6.39	28.54
6.39	7.78	33.61
7.78	9.48	39.16
9.48	11.55	44.84
11.55	14.08	50.38
14.08	17.5	55.66
17.15	20.9	60.71
20.9	25.46	65.67
25.46	31.01	70.73
31.01	37.79	75.95
37.79	46.03	81.07
46.03	56.09	85.64
56.09	68.33	89.17
0.212		99.69
0.25		99.7
0.425		99.77
0.85		99.89
1.4		99.97
2		99.99
4.75		100

APPENDIX G: Particle size distribution at salhakheri (0-15 cm)

Site: Salhakheri		
Depth: 0-50 cm		
Sample code: YHSAL-1S		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.24
1.32	1.6	1.29
1.6	1.95	2.74
1.95	2.38	4.48
2.38	2.9	6.32
2.9	3.53	8.24
3.53	4.3	10.33
4.3	5.24	12.78
5.24	6.39	15.76
6.39	7.78	19.27
7.78	9.48	23.199
9.48	11.55	27.34
11.55	14.08	31.61
14.08	17.5	35.90
17.15	20.9	40.28
20.9	25.46	49.95
25.46	31.01	55.59
31.01	37.79	61.62
37.79	46.03	67.69
46.03	56.09	72.59
56.09	68.33	76.29
0.212		98.56
0.25		98.76
0.425		98.82
0.85		99.02
1.4		99.18
2		99.33
4.75		99.38

APPENDIX H: Particle size distribution at salhakheri (40-60 cm)

Site: Salhakheri		
Depth: 0-50 cm		
Sample code: YHSAL-1S		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.45
1.32	1.6	2.12
1.6	1.95	4.36
1.95	2.38	6.93
2.38	2.9	9.49
2.9	3.53	11.95
3.53	4.3	14.48
4.3	5.24	17.34
5.24	6.39	20.82
6.39	7.78	24.96
7.78	9.48	29.62
9.48	11.55	34.54
11.55	14.08	39.54
14.08	17.5	44.47
17.15	20.9	49.33
20.9	25.46	54.29
25.46	31.01	59.50
31.01	37.79	65.06
37.79	46.03	70.69
46.03	56.09	75.84
56.09	68.33	79.83
0.212		99.21
0.25		99.24
0.425		99.28
0.85		99.41
1.4		99.60
2		99.75
4.75		99.81

APPENDIX I: Particle size distribution at salhakheri (80-100 cm)

Site: Salhakheri		
Depth: 80-1000 cm		
Sample code: YHSAL-3		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.47
1.32	1.6	2.21
1.6	1.95	4.54
1.95	2.38	7.18
2.38	2.9	9.77
2.9	3.53	12.24
3.53	4.3	14.73
4.3	5.24	17.53
5.24	6.39	20.94
6.39	7.78	25.00
7.78	9.48	29.58
9.48	11.55	34.41
11.55	14.08	34.41
14.08	17.5	39.31
17.15	20.9	44.13
20.9	25.46	48.88
25.46	31.01	53.70
31.01	37.79	58.76
37.79	46.03	69.74
46.03	56.09	79.30
56.09	68.33	82.34
0.25		99.22
0.425		99.79
0.85		99.92
1.4		99.93
2		99.95
4.75		99.95

APPENDIX J: Particle size distribution at Yamuna river bank (0-15 cm)

Site: Yamuna river bank		
Depth: 0-15 cm		
Sample code: YHYB-1S		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.90
1.32	1.6	0.46
1.6	1.95	0.97
1.95	2.38	1.58
2.38	2.9	2.21
2.9	3.53	2.87
3.53	4.3	3.58
4.3	5.24	4.42
5.24	6.39	5.45
6.39	7.78	6.68
7.78	9.48	8.07
9.48	77.55	9.56
11.55	14.08	11.08
14.08	17.5	12.60
17.15	20.9	14.13
20.9	25.46	15.75
25.46	31.01	17.62
31.01	37.79	19.94
37.79	46.03	22.80
46.03	56.09	26.15
56.09	68.33	29.66
0.212		32.89
0.25		99.22
0.425		99.79
0.85		99.92
1.4		99.93
2		99.95
4.75		99.95

APPENDIX K: Particle size distribution at Yamuna river bank (40-50 cm)

Site: Yamuna river bank		
Depth: 40-50 cm		
Sample code: YHYB-2		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.06
1.32	1.6	0.34
1.6	1.95	0.71
1.95	2.38	1.16
2.38	2.9	1.62
2.9	3.53	2.08
3.53	4.3	2.57
4.3	5.24	3.12
5.24	6.39	3.79
6.39	7.78	4.57
7.78	9.48	5.44
9.48	77.55	6.37
11.55	14.08	7.34
14.08	17.5	8.35
17.15	20.9	9.42
20.9	25.46	10.60
25.46	31.01	11.96
31.01	37.79	13.55
37.79	46.03	15.36
46.03	56.09	17.25
56.09	68.33	19.00
0.25		99.82
0.425		99.4
0.85		99.92
1.4		99.95
2		99.97
4.75		100

APPENDIX L: Particle size distribution at Yamuna river bank (90-100 cm)

Site: Yamuna river bank		
Depth: 90-100 cm		
Sample code: YHYB-3		
Size Low (mm)	**Size high (mm)**	**Cumulative % passed**
0.5	1.32	0.068
1.32	1.6	0.35
1.6	1.95	0.75
1.95	2.38	1.22
2.38	2.9	1.71
2.9	3.53	2.21
3.53	4.3	2.74
4.3	5.24	3.31
5.24	6.39	3.98
6.39	7.78	4.78
7.78	9.48	5.64
9.48	77.55	6.54
11.55	14.08	7.45
14.08	17.5	8.35
17.15	20.9	9.26
20.9	25.46	10.22
25.46	31.01	11.26
31.01	37.79	12.42
37.79	46.03	13.68
46.03	56.09	14.94
56.09	68.33	16.09
0.25		99.77
0.425		99.21
0.85		99.92
1.4		99.97
2		100
4.75		100