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ESTIMATION OF HYDROLOGICAL PROPERTIES OF SOIL IN LOKAPAVANI AREA OF KR SAGAR COMMAND IN MANDY A DISTRICT, KARNATAKA

आपो हि ष्ठा मयोभुवः

NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAWAN
ROORKEE - 247 667 (UTTARANCHAL)

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PREFACE

The present report is the part of the Hydrology Project concern with the Estimation of irrigation return flow in Lokapavani area of KR Sagar command in Karnataka. In this project, Numerical model for subsurface flow in unsaturated zone has to be developed to estimate the irrigation return flow from the irrigated field. Hydrological soil properties are the important parameters that constitute the basic data for carrying out subsurface modelling for irrigation and drainage studies. The basic data must provide the knowledge of soil texture, saturated hydraulic conductivity, porosity and the soil moisture characteristic curves of the soil in the study area. Soil texture is a characteristic, which has a general relationship with hydraulic conductivity and water retention. It is difficult to measure the saturated hydraulic conductivity of the soil in the field where water table is at shallow depth. If the soil classification of the area is available than the saturated hydraulic conductivity can be determined indirectly by the Johnson's graph. The saturated moisture content of the soil can be taken as the porosity of the soil. The soil moisture relationship (Characteristic curve) is another important parameter. Wilting point, field capacity and available moisture can be found from the characteristic relationship.

In this study about 85 disturbed soil samples have been collected and analysed in the laboratory for the analysis of grain size distribution and determination of porosity, specific gravity and soil moisture characteristic curves with the help of Electromagnetic sieve shaker, Master Sizer, GeoPyc and Pressure plate apparatus respectively. 20 undisturbed soil samples have been collected for the determination of the saturated hydraulic conductivity in the laboratory using ICW Permeameter.

This study is part of the work program of the Drainage Division. Dr. Vivekanand Singh, Scientist "B", Sh S. Mittal, "R. A", Sh. S. L. Srivastava and Sh. N. K. Lakhera, Technician, Soil and Ground Water Laboratory prepare this report.

KS Ramasastri

(K. S. Ramasastri)
Director

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ABSTRACT

This study deals with the estimation of hydrological soil properties of the area of Lokapavani River in KR Sagar Command, District of Mandya, Karnataka. The soil properties determined are soil texture, porosity, saturated hydraulic conductivity using ICW Permeameter (for Laboratory measurement), specific gravity and soil moisture characteristics.

Eighteen locations have been selected in the study area in such a manner that whole study area is covered. The disturbed and undisturbed soil samples from 18 locations along different depths were collected and analysed in the Soil & Groundwater Laboratory of the Institute. Disturbed soil samples were used to determine the grain size distribution, porosity, specific gravity and soil moisture characteristic curves. Undisturbed soil samples were used with ICW Permeameter to determine saturated hydraulic conductivity. The results of the grain size distribution, porosity, specific gravity and soil moisture characteristic curves are presented in graphical and tabular forms. The textural analysis of the soil shows that there are two types of soil on the surface.

For sandy loam soil values of hydrological properties are as follows: saturated hydraulic conductivity, 0.251 (cm/hr); porosity, 0.506; Field capacity, 17.17 %; and wilting point, 10.15 % where as for loamy sand these are saturated hydraulic conductivity, 0.748 (cm/hr); porosity, 0.466; Field capacity, 11 %; and wilting point, 5.8 %

1 INTRODUCTION

1.1 General

A prime requirement for successful irrigated agriculture is the development and maintenance of soil root zone in which the water-air-salt balance is favorable for plant growth. When a water table rises or water gets stagnated in the fields and remains in the root-zone for longer period, the yield of the crop gets seriously affected due to the air deficiency in the root zone. This air deficiency requires drainage facilities in the cropped area. A simple but comprehensible definition of drainage is the removal of excess water from root zone which permit some air for normal plant growth. If the prime objective is to lower the ground water table below a certain level below root zone of the crops, then subsurface drainage system is necessary.

Selection of the optimum drainage plan and the design and construction of adequate and successful drainage facilities depend upon the reliability and adequacy of the basic drainage data. The basic data must provide the knowledge of soil texture, Porosity, saturated hydraulic conductivity of the soil and topography of the area under consideration.

The present study area is the Lokapavani river area near Mandya district of Karnataka State. Lokapavani River originates near Bhoosandra in Honakere Hobli and Nagamangala Taluk. It flows for about 40 kms before joining Cauvery River near Karighatta in Srirangapatna Taluk. The total catchment area of Lokapavani River is 420 sq. km. The flow in the Lokapavani River at upstream is very lean where as the flow at the confluence with Cauvery river (near Karighatta) is high. This is due to return flow from two major canals (namely Vishveshwaraiah Canal, VC and Chikkadevaraya Sagar Canal, CDS), that runs in the part of catchment area. It is proposed to carry out the return flow studies in this area under Hydrology Project. In this study, hydrological soil properties are required to estimate the return flow study. The hydrological soil parameters to be determined are soil texture, Porosity, Saturated hydraulic conductivity, soil moisture characteristics relationship.

1.2 Salient Features of the Study Area

1.2.1 Location:

1.	State	Karnataka
2.	District	Mandya, near Mysore
3.	Latitude	12° 28'N to 12° 32'N
4.	Longitude	76° 40'E to 76° 45'E.
5.	River	Lokapavani

1.2.2 Hydrology:

1.	Catchment area	VC Command	47.3 sq.km
		CDS Command	20.7 sq.km.
2.	Length of the canals	VC	42.2 km
		CDS	31 km
3.	Maximum annual rainfall	:949.0 mm (based on 1987 to 1996 data at KRSagar)	
4.	Minimum annual rainfall	:449.0 mm (based on 1987 to 1996 data at KRSagar)	
5.	Average annual rainfall	750.53 mm (based on 1987 to 1996 data at KRSagar)	

1.3 General Description of the Study Area

1.3.1 Location and extent:

The study area is in the Taluk of Pandavapura in the district of Mandya in Karnataka State as shown in Figure 1. This area lies between the Latitudes 12° 28'N to 12° 32'N and Longitudes 76° 40'E to 76° 45'E. The study area falls in KrishnaRaja Sagar Command, which consists of two contour canals, Vishveshwaraiah Canal (V.C.) and Chikkadeveraya Sagar Canal (C.D.S.). Total command area in this study area, is 68 sq. kms, in which 20.7 sq.km. comes under CDS canal command and 47.3 sq.km. under VC canal command. The lengths of the CDS and VC canals are 31 km and 42.2 km respectively. The discharge of the CDS canal at Darassaguppe village is 747.06 cusecs and that of VC is 2253 cusecs near Harohalli village. In the west and north, VC Canal limits the boundary of the study area and in the east, the extent of study area ends with the 24-VC distributary. In the south, Bangalore – Mysore highway covering the study area limits the boundary of the study area.

The study area is mostly agricultural area having no forest. Forest lies beyond the 24 distributary in the east of the study area. The main crops grown in the area are Sugar cane and paddy. Crops are sown in rotation basis.

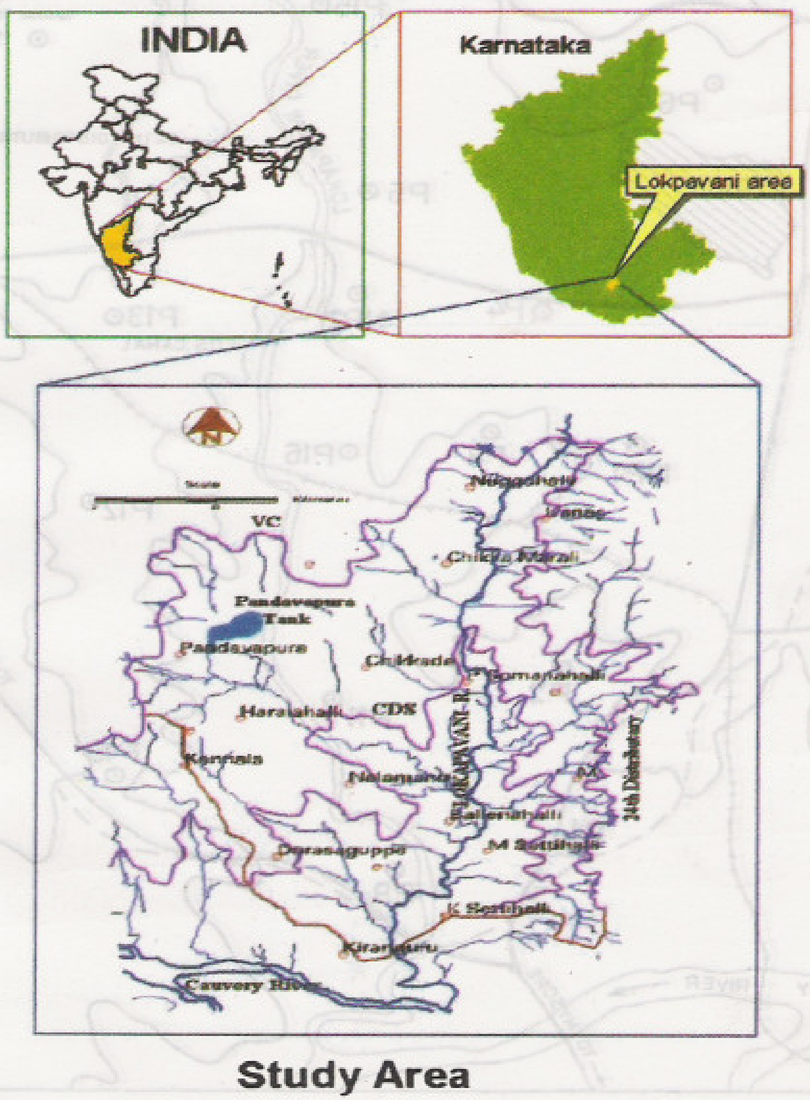

Fig. 1: Map of the study area showing Villages, Canal networks, and River

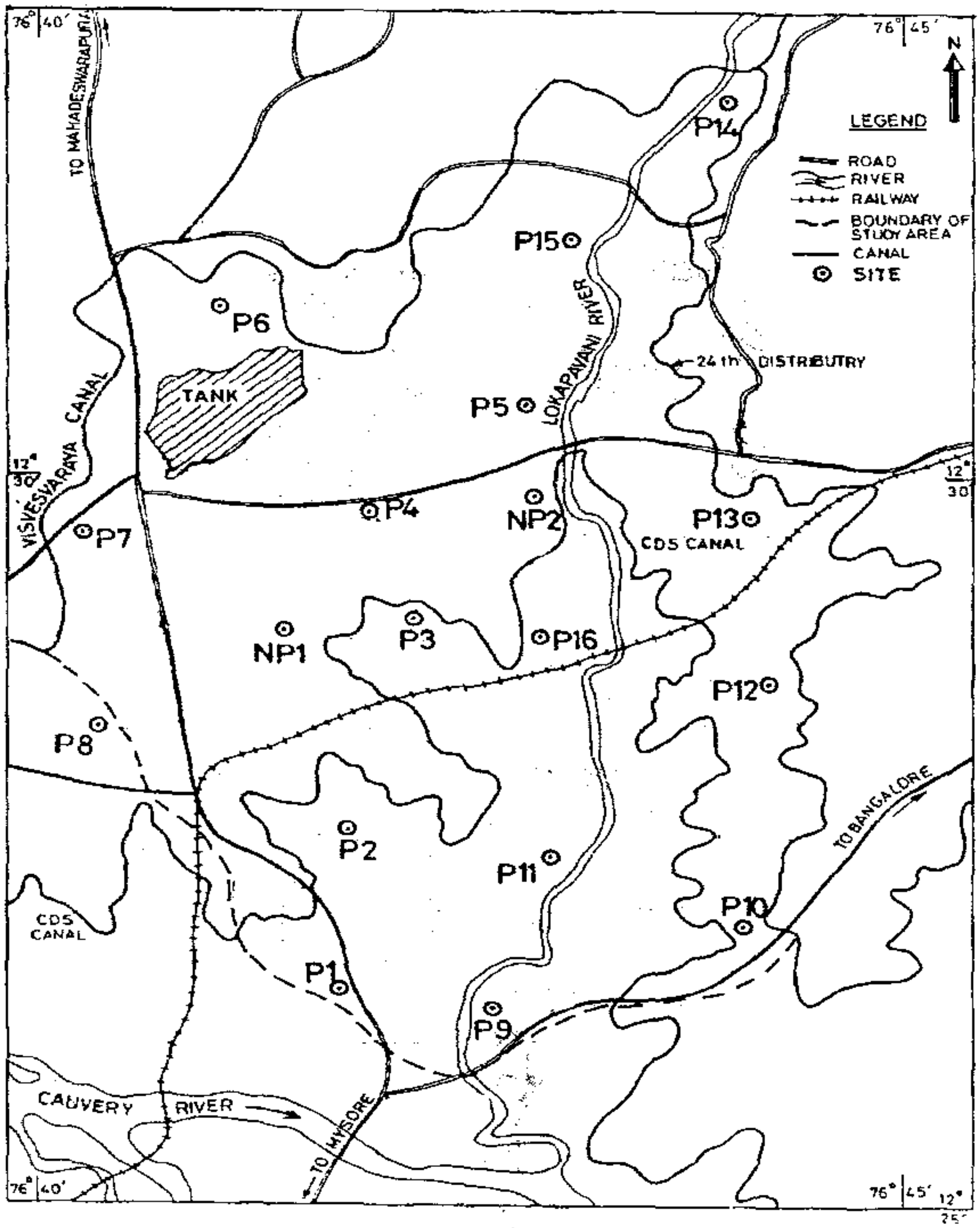

Fig. 2 Map showing soil samples collection sites in the study area

2 METHODOLOGY

2.1 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. The relative proportion of sand, silt and clay determines the soil texture. The diameter of the particles present in the soil sample makes the soil to be coarse, medium and fine. Table 1 gives the textural class names of soils as per particle diameter. The soil texture is determined by separating sand, silt and clay fractions and measuring their proportion, which is called the mechanical analysis. The soil texture triangle is then used to convert quantitative data from detailed gradation analysis of separates less than 2mm in diameter to textural class names of soils.

Table 1: Textural classification as per Particle Diameter

Material	Diameter
Stones	> 250 mm
Cobbles	250 – 75 mm
Coarse gravel	75 – 12.7 mm
Fine gravel	12.7 - 2 mm
Very coarse sand	2 – 1 mm
Coarse sand	1 – 0.5 mm
Medium sand	0.5 - 0.25 mm
Fine sand	0.25 - 0.1 mm
Very fine sand	0.1 - 0.05 mm
Silt	0.05 - 0.002 mm
Clay	<0.002 mm

To carry out the particle size distribution, first of all the oven dried soil sample weighing 500 gm is washed through the sieve of number 200. The portion of the soil particles retained on sieve is subjected to sieve analysis and the particles passing through the sieve is subjected to Master Sizer analysis.

In sieve analysis, the portion retained on each sieve is collected and weighted. The percentage of soil sample retained on each sieve on the basis of total weight of soil sample and the percentage of weight passing through each sieve is calculated (Bowles, 1986).

In the Indian Standard (IS: 460-1962), 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 terms of the number of openings per inch. These are described in Report TR-82 by Dr. Seth, 1990.

The fraction of the soil, which is finer than 75-micron (-75 micron) size, is used for Master Sizer E System analysis. The Master Sizer works on the principle of laser ensemble light scattering. They fall into the category of non imaging optical systems due to the fact that sizing is accomplished without forming an image of the particle onto a detector.

The sieving process does not provide information on the shape of the soil grains. It only yields information on grains that can pass through rectangular sieve opening of a certain size. Information obtained from the grain size analysis is presented in the form of a curve. In such a curve, the y-axis or the ordinate in the graph indicates the percentage of soil particles having diameter finer than indicated on X-axis.

The capacity of soil to hold water is related to surface area as well as pore space volume. Hence, Water holding capacity is related to both structure and texture of the soil. In general, fine textured soils have the maximum total water holding capacity, but maximum available water is held in medium-textured soils. Soil texture is especially important in subsurface drainage as it has a direct relationship with hydraulic conductivity and water retention (David 1982).

2.2 Porosity

To calculate the porosity of soils, the particle density and the bulk density have to be known. Particle density (specific gravity) is the mass per unit volume of the soil particle. Particle density is some times referred to as true density. The bulk density (apparent density) is the dry weight per unit volume of soil (volume of solids and pores) in its field condition. The porosity is the volume percentage of the unit bulk volume not occupied by the solid particles.

$$n = \left(1 - \frac{bulk\ density}{particle\ density}\right)100$$

where, n = porosity in percent.

Particle density has been calculated using Multi volume Pycnometer. Multi volume Pycnometer work on the principle of measurement of skeletal volumes by observing the reduction of gas capacity in the sample chamber caused by the presence of the sample. Since helium or most other suitable gases penetrate even the smallest pores and surface irregularities, the volume obtained permits computation of the ultimate theoretical density of the solid comprising the sample if there are no closed pores.

Bulk density has been calculated using GeoPyc 1360. It measures the bulk volume and calculates the bulk density of granular and powdered samples under a wide range of compaction conditions.

2.3 Specific Gravity

The specific gravity of any substance is defined as the ratio of unit weight of the material and the unit weight of the distilled water at 4°C. The specific gravity of a material can be computed using any ratio of weight of substance to the weight of water as long as equal volumes are involved.

$$G_s = \frac{W_s}{W_w}$$

Where, W_s is the weight of the soil of known volume; W_w is the weight of equal volume of distilled water at 4°C. The volume of a known weight of soil grains can be obtained by using a container of known volume and the Archimedes principle that a body submerged in a volume of water will displace a volume of water equal to the volume of the submerged body.

2.4 Permeability

The permeability is defined as the property of a material, which permits the passage or seepage of water through its interconnected voids. Gravels are high permeable while stiff clay is the least permeable. The various factors affecting permeability includes grain size, properties of the pore fluid, void ratio of the soil, structural arrangement of the soil particles, entrapped air and foreign matter, and adsorbed water in clayey soils.

Two general laboratory methods are available for the determination of coefficient of permeability, these methods are constant head and falling head Permeameter. Both methods use basic Darcy's law. These are explained in all the standard classical textbook. ICW Permeameter has been used for the purpose with constant head and falling head methods.

2.5 Soil Moisture Characteristics

2.5.1 Soil Moisture Tension and pF values

The moisture contained in the pore spaces of a soil mass is subjected to the capillary forces This capillary force causes a negative soil moisture tension, which is also called suction. The suction is expressed as the height of water column (h) that will rise from the water table against the force of gravity. This height is inversely proportional to the diameter of the pores. Therefore, $h=0.3/d$, where d is equivalent pore diameter of a cylindrical pore with the same capillary. The negative logarithm of soil moisture tension in centimeters of water is used to indicate the soil moisture tension. This negative log of soil moisture is referred to as pF.

2.5.2 Field Capacity

The moisture or water present in a saturated soil is allowed to drain out, the water quickly leaves the soil via largest pores and air is pulled into the soil. This movement of water is mainly due to the gravitational potential difference. When the rapidly moving water in the unsaturated soil ceases to move then the soil is said to be at field capacity. Field capacity occurs when soil retains the maximum amount of water with little or no further loss of water by drainage or loss of gravitational water. A soil water matrix potential of about –1/3 bars has been found to correspond to the field capacity. A bar is equal to 1020 cm of water column or 1020 gm/cm^2.

2.5.3 Wilting Point

As soil becomes drier, the conductivity rapidly decreases and movement and uptake of water becomes slower. Therefore, if no additional water is added to the soil, the plant will absorb water slower than water is lost by transpiration. Thus a water deficit develops in the plant. This point is called wilting point. A soil water matrix potential of about –15 bars has been found to correspond to wilting point (Zaradny, 1993).

2.5.4 Available Water

The water present in the soil between field capacity and wilting point is known as available water. It is generally considered to be matrix potential in the range of –0.33 to –15.0 bars.

2.5.5 Effect of Texture on Available Water

The capacity of soil to hold water is related to surface area as well as pore space volume Hence, water-holding capacity is related to both structure and texture of the soil. In general fine textured soils have the maximum total water holding capacity. Several researchers have indicated that available water in many soils is closely correlated with content of silt and very fine sand. It is well known that sandy soils are droughtier than clayey soils, because fine-textured soils are able to retain more available water. Also, there is a difference in the soil of soil-moisture characteristic curves of sand and clay. The flatness of the curve for fine sandy loam at water matrix potential is less than –4.0 bars which means that most of the available water in the sandy soils have a high potential. Therefore, plants can readily use this water in sandy soils. Since in clay or clay loam soils the water is available at lower potential therefore it can be rapidly used by the plants.

Soil Moisture Characteristics, also called soil moisture retention curves, are the plots of moisture content versus suction head. It shows the amount of moisture in a given soil holds at various tensions. The moisture characteristic curve of a soil sample can generally be determined by equilibrating a soil sample at a succession of known tension value and each time determining the amount of moisture. The graph is plotted between the tension and corresponding soil moisture value to obtain the soil moisture characteristic curve. Different soil type gives different characteristic curves.

Pressure plate apparatus is a standard method for obtaining the soil moisture characteristic curves. It consists of a pressure chamber in which a saturated soil sample (either disturbed or undisturbed) 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. As soon as the air pressure inside the chambers are raised above the atmospheric it takes excess water from the soil and flow out of the chamber through the membrane outlet. Soil water will flow out from the soil sample until the metric potential of the unsaturated flow is same as the applied air pressure. The air pressure is then, released and the moisture content of the soil is gravimetrically determined for that particular tension. When air pressure in the chamber is increased flow of water from the samples starts again and continue until a new equilibrium is reached. The same procedure is repeated at various pressures. The pair of pressure and moisture content data so obtained is used to construct the soil moisture characteristic curves. Soil moisture characteristic 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).

A soil water matrix potential of about -1/3 bars has been found to correspond to the field capacity, where as a soil water matrix potential of about -15 bars has been found to correspond to wilt point (Henry, 1984). The water present in the soil between field capacity and wilting point is known as available water. It is generally considered to be matrix potential in the range of -0.3 to -15.0 bars.

3 PROCEDURE

3.1 Soil Sampling

The study area, Fig.1, was selected for the estimation of hydrological soil properties of the study area. This figure shows the road network, villages and canals network of the area. Figure 2 presents the locations of the soil sampling sites. These sites were tentatively chosen in such a way that different types of soils found in the area are covered and the sites are easily approachable and are well distributed all over the study area. Total eighteen sites selected are P1, P2, P3, P4, P5, P6 P7, P8, P9, P10, P11, P12, P13, P14, P15, P16, NP1 and NP2 as located on the map and it can be seen in Fig. 2. Disturbed and undisturbed soil samples were collected from these sites and along different depths. Disturbed soil samples were collected for grain size analysis, porosity, specific gravity and soil moisture characteristics. The undisturbed soil samples were collected to measure the saturated hydraulic conductivity in the laboratory through ICW Permeameter. Figure 3 and Fig 4 presents the photographs at the time of collecting disturbed and undisturbed soil samples respectively from the study area.

3.2 Grain Size Analysis

1. Oven dried soil sample weighing 500 gm was taken and soaked with water for 24 hours.
2. This soil sample was washed through sieve No. 200 (75-micron sieve). Washing was carried out carefully.
3. Two groups of soil, one passing through the sieve No. 200 i,e –75 microns (called as fine particles) and another retained on the sieve No. 200 i,e +75 microns (called coarse particles) were collected separately.
4. Both the fractions of soil were than oven dried. The group retained on sieve i,e +75 microns were subjected to sieve analysis and the group passing through the sieve i,e -75 microns was subjected to Master Sizer analysis.

3.2.1 Mechanical Sieve Analysis

1 Oven dried soil sample retained on Sieve No. 200 were taken for the sieve analysis.

2 The soil sample was sieved through a set of sieves i.e. 4, 10, 14, 20, 40, 60, 70, 200 Sieves No. The sieving was performed with mechanical sieve shaker for 10 to 15 minutes.

3. The stack of sieves was removed from sieve shaker and weight of material retained on each sieve was calculated. The percentage of total soil sample retained on each sieve was also calculated.
4. The percentage of weight passing through each sieve was calculated. The calculation was started with 100 percent and subtracting the percentage retained on each sieve as a

cumulative procedure as given by

Percentage passing = Percentage arriving-percentage retained

5. A plot of grain size versus percent passing was plotted on semi logarithmic scale.

Fig. 3: Photograph at the time of disturbed soil samples collection

Fig. 4: Photograph at the time of undisturbed soil samples collection

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7. The percentage of weight passing through each sieve was calculated. The calculation was started with 100 percent and subtracting the percentage retained on each sieve as a cumulative procedure as given by

   Percentage passing = Percentage arriving-percentage retained

8. A plot of grain size versus percent passing was plotted on semi logarithmic scale.

3.3.2 Master Sizer E System Analysis

The essential steps in measuring a sample are as follows

1. The soil group passing through the Sieve No. 200 was oven dried and 20 gm of the sample was taken for this analysis.
2. The soil sample (20 gm, representative of the bulk of the soil) was soaked with sufficient quantity of dispersing agent (33 gm sodium hexametaphosphate+ 7 gm Sodium bicarbonate + 1 liter distilled water) solution along with distilled water for 24 hours.
3. Check the instrument is setup correctly (Laser alignment)
4. Enter sample documentation (Samples details)

5. Measure the background (in distilled water).
6. Add the sample to the system at a suitable concentration (corresponding obscuration 10 30 %)
7. Measure the sample (Volumetric percent of particles size in sample)
8. View and save the results
9. Print the results.

3.3.3 Blending of the Results of Sieve and Master Sizer Analysis:

Results of coarse grain analysis and fine grain analysis are blended. The results obtained from Master Sizer E System are volumetric and converted in to the gravimetric results by multiplying the results with density of the soil. The results of the fine grain analysis are converted into the percentage of the total soil samples. The type of soil is determined from the textural classification curve based on the sand, silt, and clay percentage.

% finer of any size = {wt of fine grain soil, (-75 micron)/wt. of total soil samples}*
% finer of corresponding size in Master Sizer/Bulk density of the soil.

Finally both the results are blended and plotted on the same curve. The grain size was plotted against percentage finer on semi log paper. The textural analysis has been carried out based on the percentage sand, silt and clay (Fig. 5).

3.4 Specific Gravity

The specific gravity of soil sample can be calculated by obtaining the volume of the known weight of soil grains and dividing this by the weight of the same volume of distilled water. The volume of a known weight of soil grains can be obtained by using a container of known volume. Procedure is as follows:

1. Weight of oven dry soil sample has been taken;
2. Oven dry soil of known weight has been kept in a known volume of container;
3. Known volume of distilled water has been added in the container, such that soil is completely saturated and water level should reach up to level marked for the known volume;
4. Volume of soil grain has been calculated by subtracting the volume of added distilled water from the volume of the container;
5. Weight of same volume of distilled water has been taken;
6. The specific gravity has been calculated by dividing weight of the soil grains by the weight of the same volume of distilled water at 4°C.

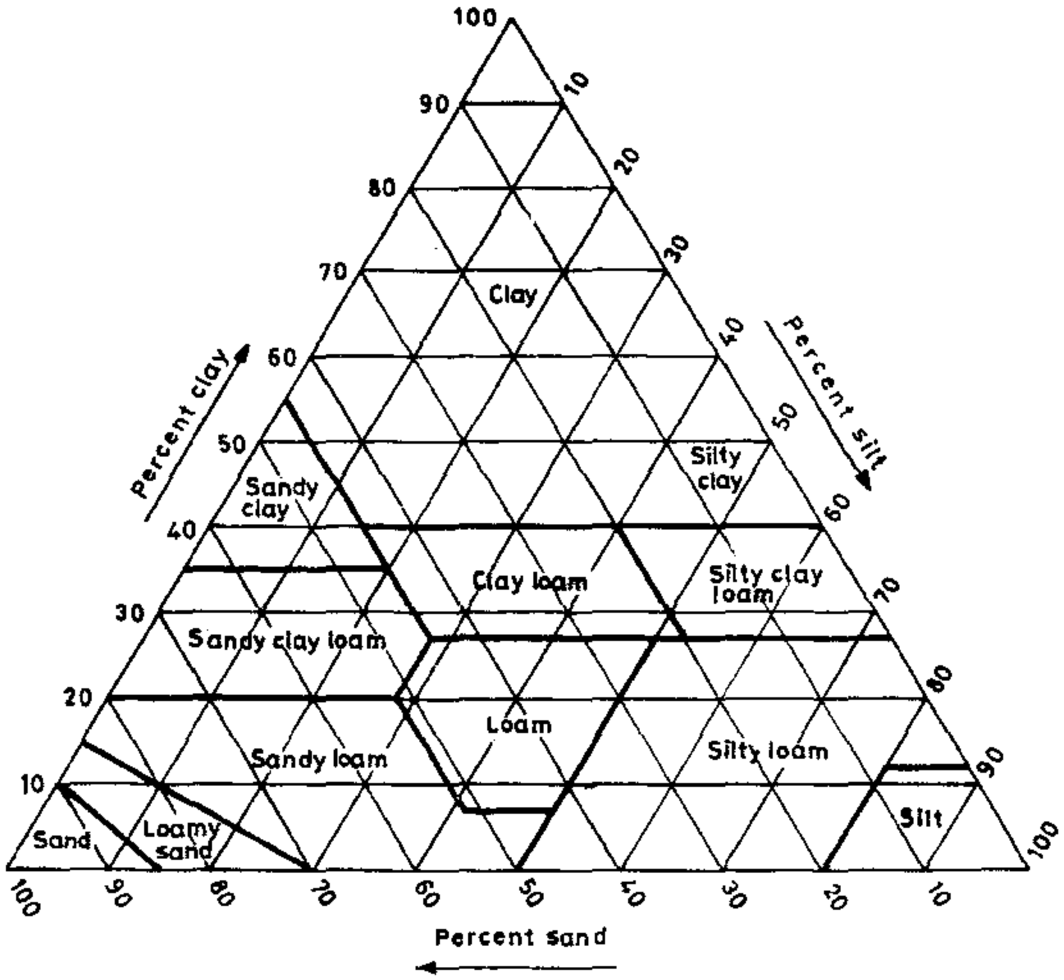

Fig. 5 Textural Classification of Soil based on Percentage of Sand, Silt and Clay

3.5 Porosity

Porosity has been calculated using the Multi Volume Pycnometer and GeoPyc 1360. This is advanced equipment, which calculate the particle density and bulk density respectively and finally percent porosity.

3.6 Permeability

The permeability is determined in the laboratory using ICW Permeameter with both the methods constant head and falling head. Procedures are as follows:

1. Undisturbed soil samples have been collected from the field using core cutter (sampling set).
2. Collected soil samples of Permeameter mould have been saturated completely for 24 hours.
3. Permeameter mould have been kept in the bottom tank and filled the bottom tank with water up to its outlet.
4. Water inlet nozzle of the mould has been connected to the stand pipe filled with water. Water has been permitted to flow for some time till steady state of the flow is reached.
5. The required time interval for the water level in the stand pipe to fall from some convenient initial value to some final value has been noted with the help of the stop watch.
6. Steps 1 to 5 have been repeated and the time for the water level in the stand pipe to drop from the same initial head to the same final value has been determined.
7. By using the formula given in all classical text book, the coefficient of permeability have been calculated.

3.7 Soil Moisture Characteristic

Soil samples were prepared after drying, light hammering and passing through 2.0 mm sieve. The passing soils from 2.0 mm sieve were used for determining soil moisture characteristic by applying 0.10, 0.33, 0.50, 0.70, 1.00, 3.00, 5.00, 10.00, 15.00 bars pressure respectively.

Pressure plate apparatus (Soil Moisture Corporation Co. USA) was used to test the soil moisture retention behavior of the soil samples. Each of these samples, were tested against 0.10, 0.33, 0.50 and 1.0 bar, by one bar pressure plate. Where as 3 bar, by 3 bar plate and 5 bar, by 5 bar plate as well as 10 bar and 15 bar with 15 bar pressure plate and following procedures were followed in the experiment.

1. First of all saturate the pressure plates and then prepared soil sample placed on plate in three separate rings and soaked with water for complete saturation.
2. Saturated plate containing soil samples were placed in pressure chambers and applied desired pressure till it reached equilibrium.
3. Samples were taken out from the pressure chambers and weighed on the high precision microbalance to record the moist weight of the samples.
4. These weighed samples placed in the oven at 105 C-110 C till weight became constant on drying. The dry weight was recorded by weighing and soil moisture by weight was determined from the moist and dry weight of the sample.

Soil moisture measurement for all soil samples of 18 sites at different depth were carried out and results are given in the Table 5. Soil moisture retention curves are also plotted and are shown in Fig. 26 to 29 respectively.

4 RESULTS AND DISCUSSION

The disturbed and undisturbed soil samples collected from 18 different locations along different depth in the study area were analyzed in the Soil and Groundwater Laboratory of the Institute to determine the grain size distribution, porosity, saturated hydraulic conductivity and soil characteristic curve. Using the analyzed data, the particle size distribution curves were plotted putting grain size (mm) on log scale and the percentage passing of the soil through sieves on normal scale for all the soil samples. Figure 6 to Fig 23 show variation of the particle size distribution along depth at particular site. It is clearly evident from these figures that there are no much variations in the grain size along the depth except few locations, which implies that soils in vertical direction are nearly homogeneous. The spatial variation of grain size distribution for all locations are shown in Fig. 24 through Fig. 26. It could be seen from Figs 24 to 26 that the grain size distributions vary spatially.

Making use of these particle size distributions curves (Figs. 6 through 26), the grain size distribution of the soils were assessed to determine the textural classifications of the soils using textural classification graph of soils, Fig. 5. The textural formations of soil including effective and mean size are presented in Table 2. The grain size distribution of soil samples show the presence of gravel contents, which varies from 0 % to 20 % except few samples, it goes up to 30 percent also. The variation of sand content in the soil sample ranges from 40 % to 70 %, except few samples. The silt content varies, by and large, from 20 to 45 %. The variation of clay content is found varying from 1 to 8 %. Based on the textural classification of soil samples, the soil of the study area could be classified into two major groups: sandy loam and loamy sand, except few locations, which are sand and loam. Table 3 presents the soil type along the vertical direction at surface, 30, 60, and 100 cm below the ground surface. Table 3 also depicts that there are mainly two types of soil on the surface i.e. sandy loam and loamy sand, which extended up to 30 cm below the ground surface except P16 (Chandgirikoppalu), where it is loam. Figure 27 presents the extent of soil types present in the study area based on textural analysis.

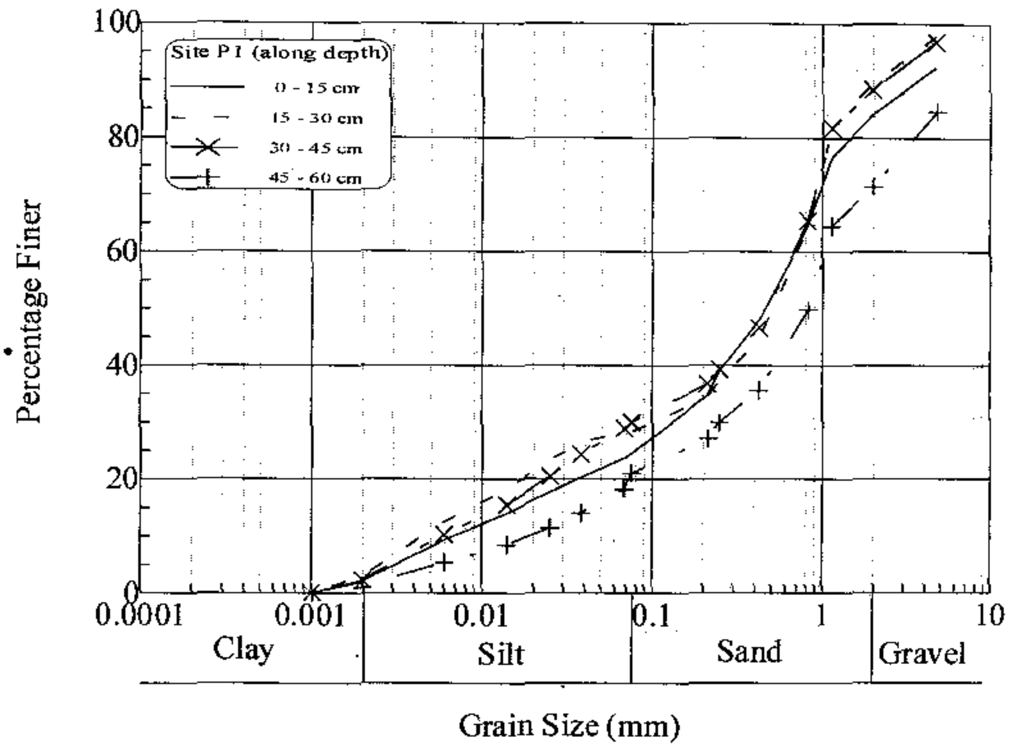

Fig.6 Grain Size Distribution along Depths at Site P1

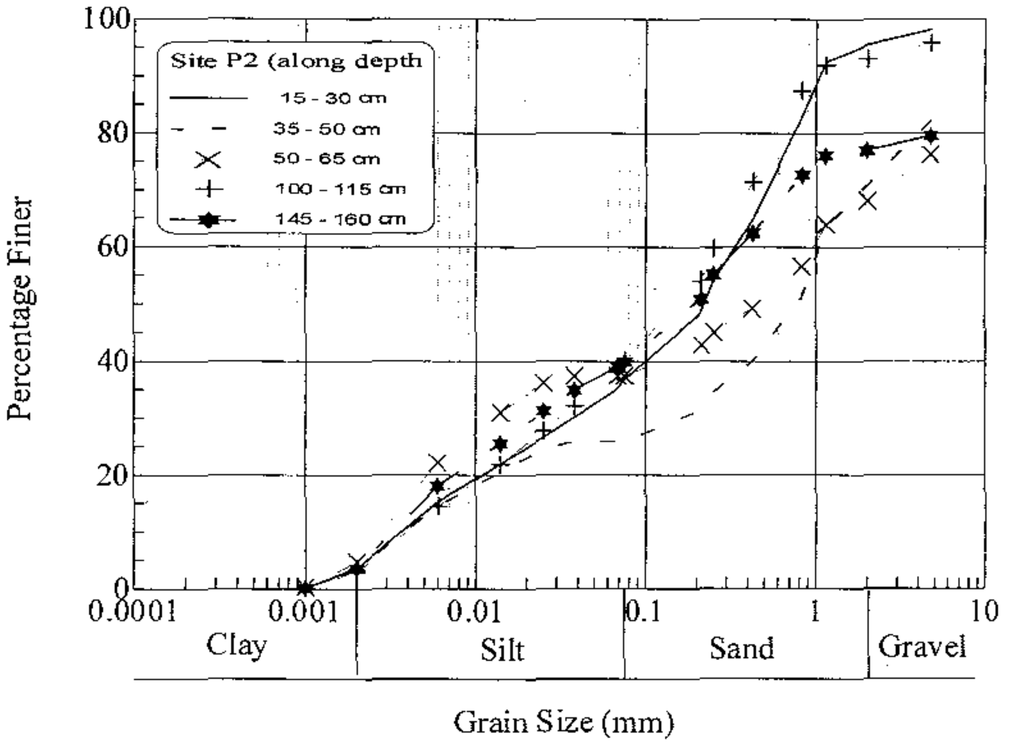

Fig.7 Grain Size Distribution along Depths at Site P2

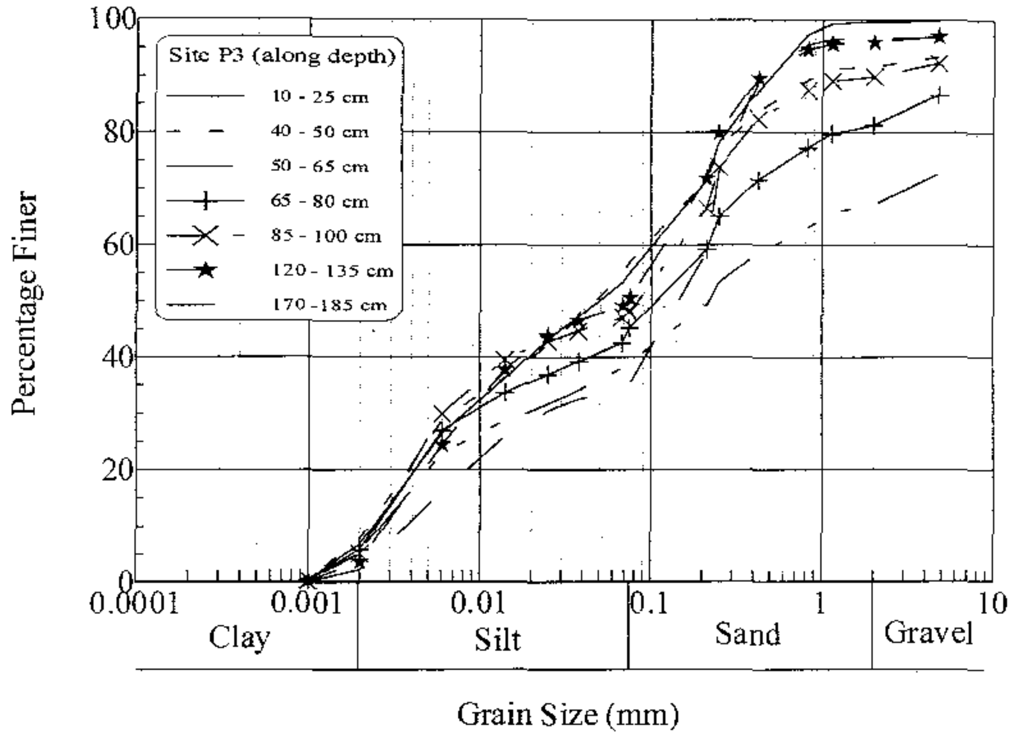

Fig. 8 Grain Size Distribution along Depths at Site P3

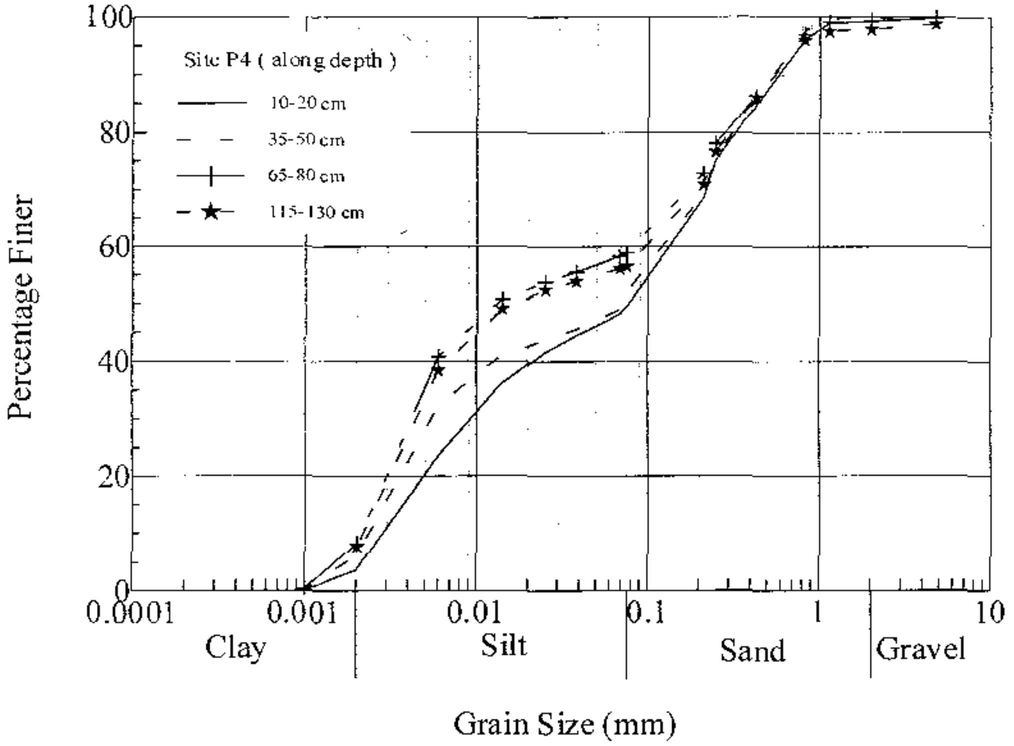

Fig.9 Grain Size Distribution along Depths at Site P4

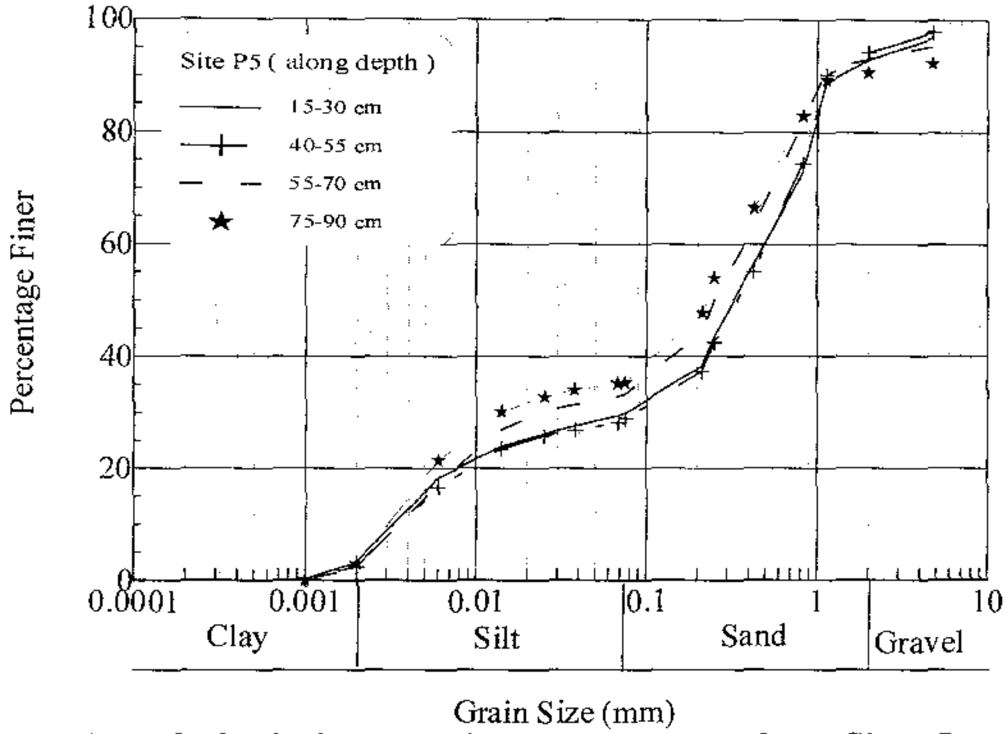

Fig.10. Grain Size Distribution along Depths at Site P5

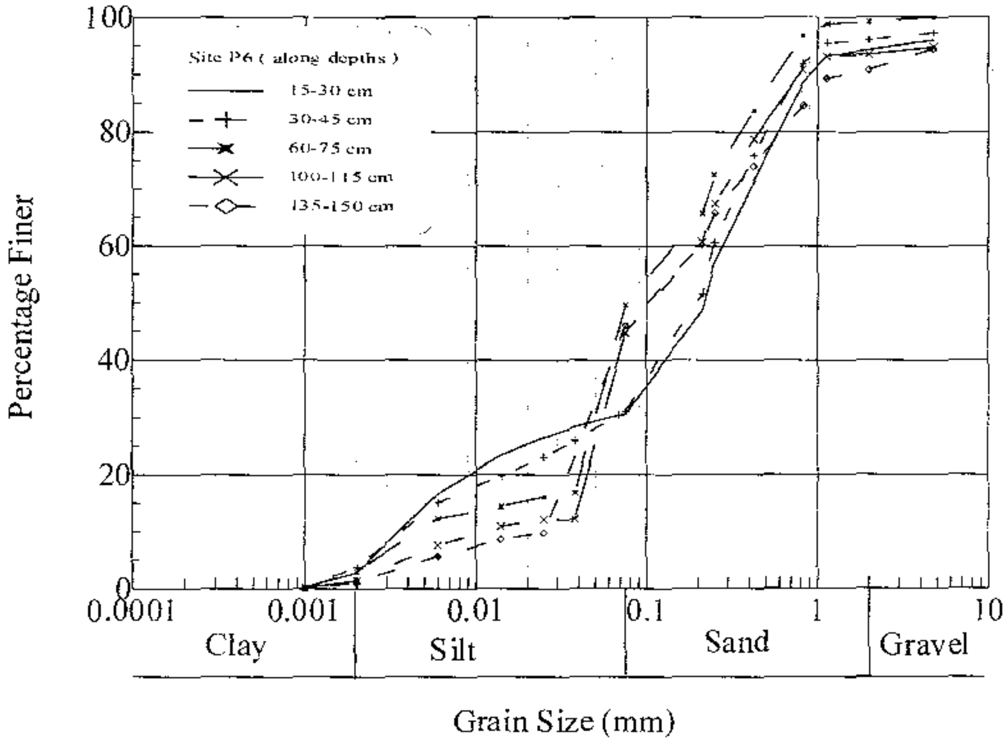

Fig.11. Grain Size Distribution along Depths at Site P6

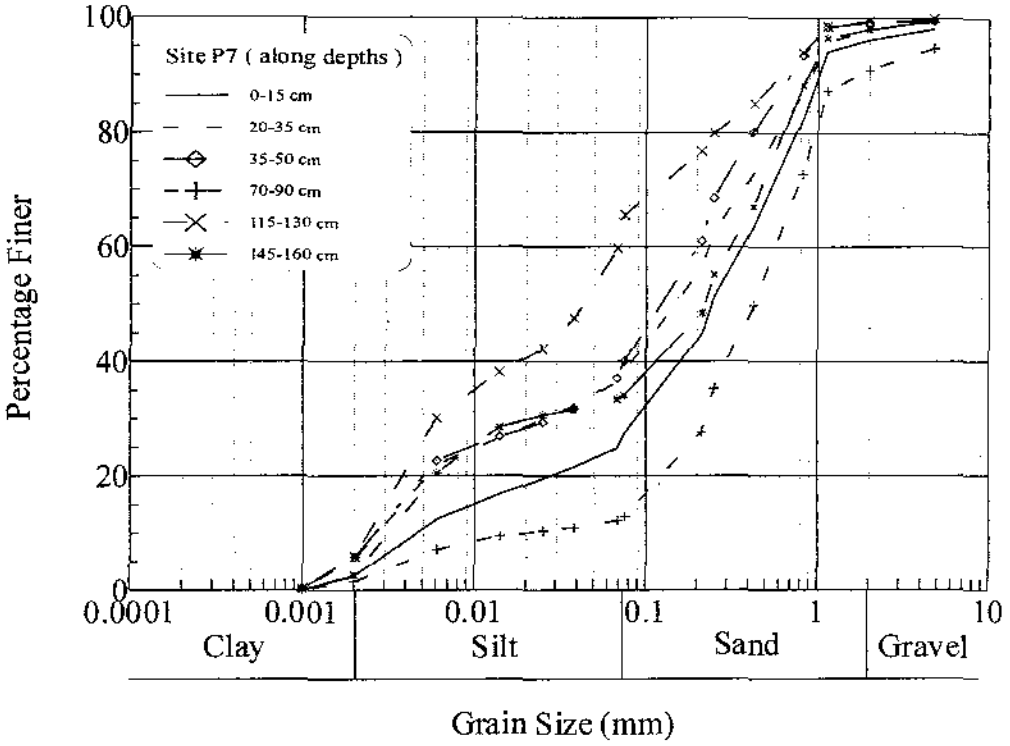

Fig.12. Grain Size Distribution along Depths at Site P7

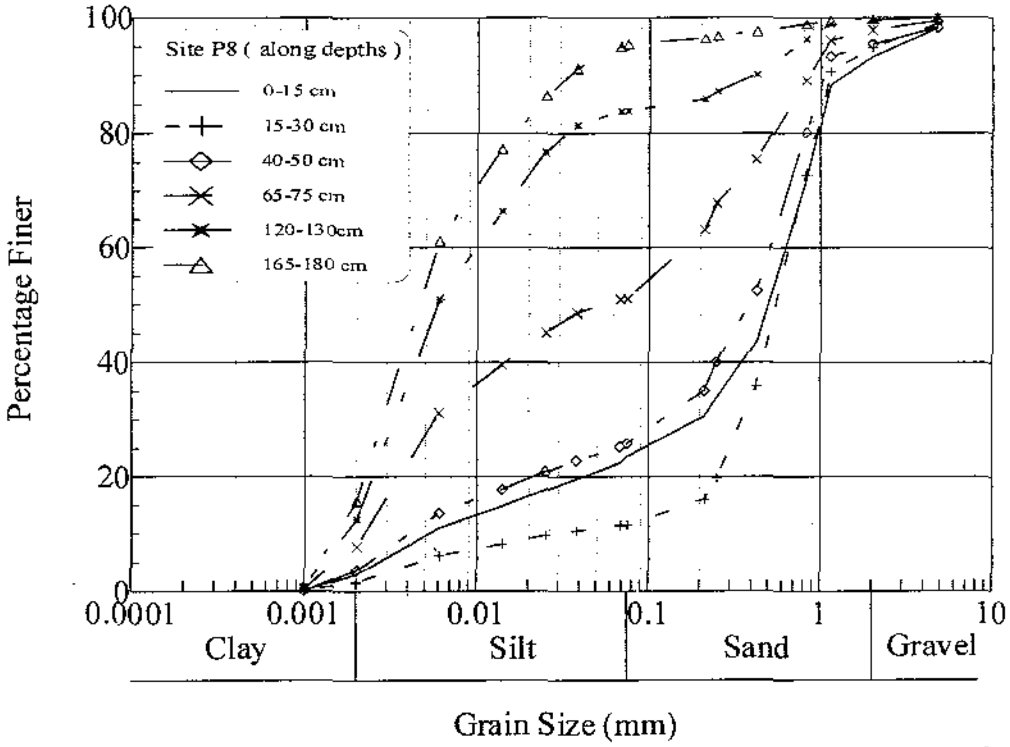

Fig.13. Grain Size Distribution along Depths at Site P8

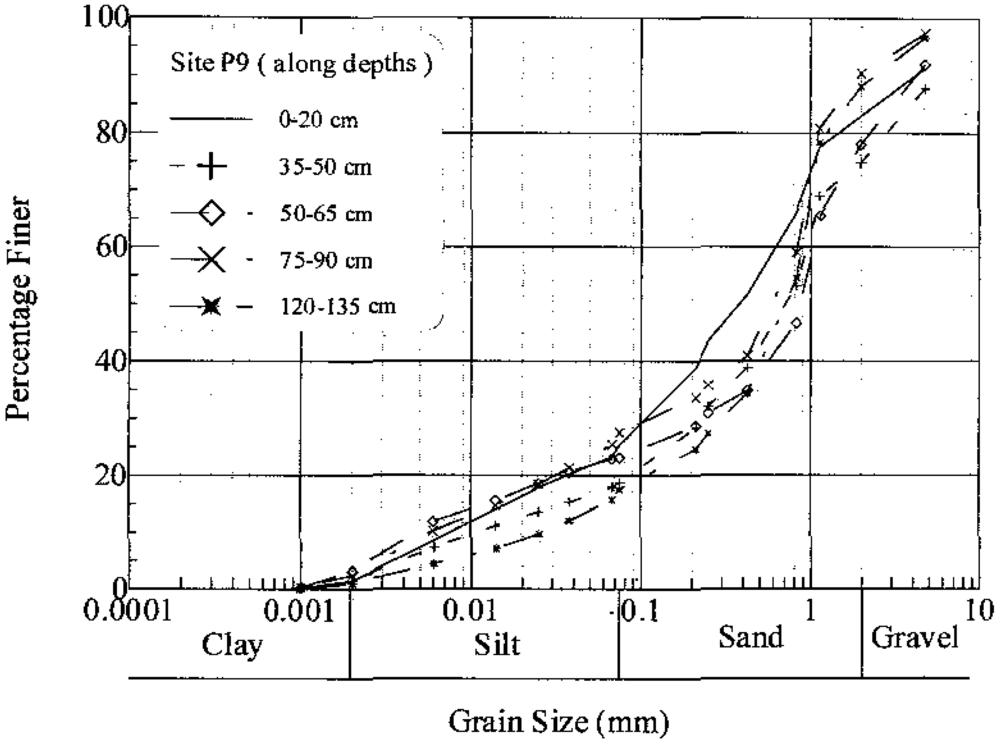

Fig.14. Grain Size Distribution along Depths at Site P9

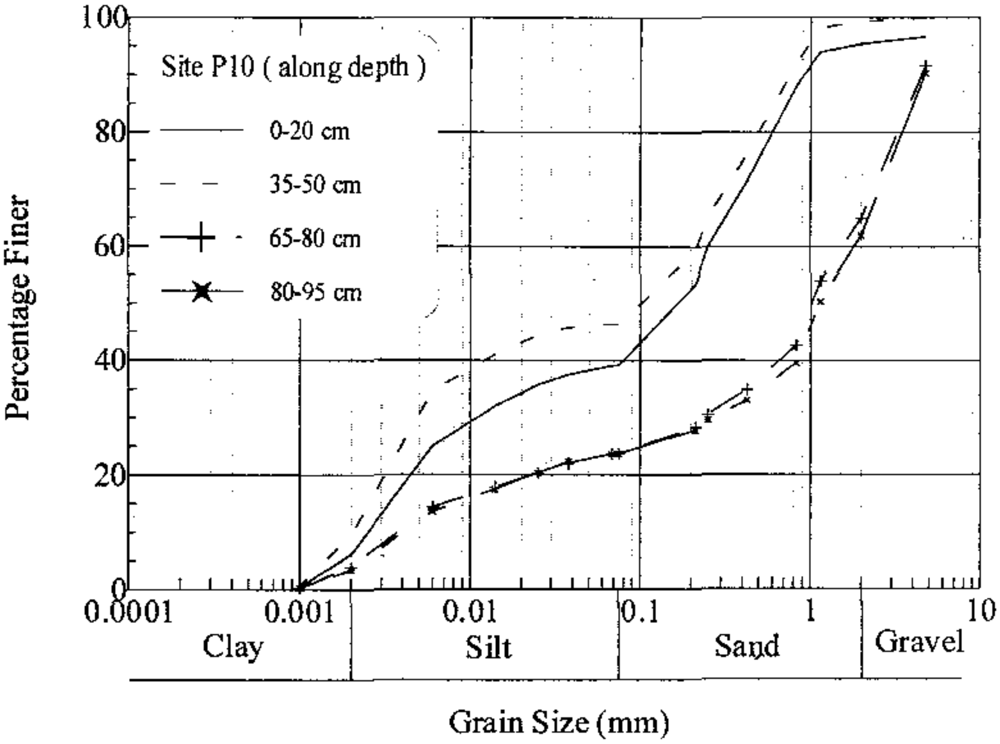

Fig.15. Grain Size Distribution along Depths at Site P10

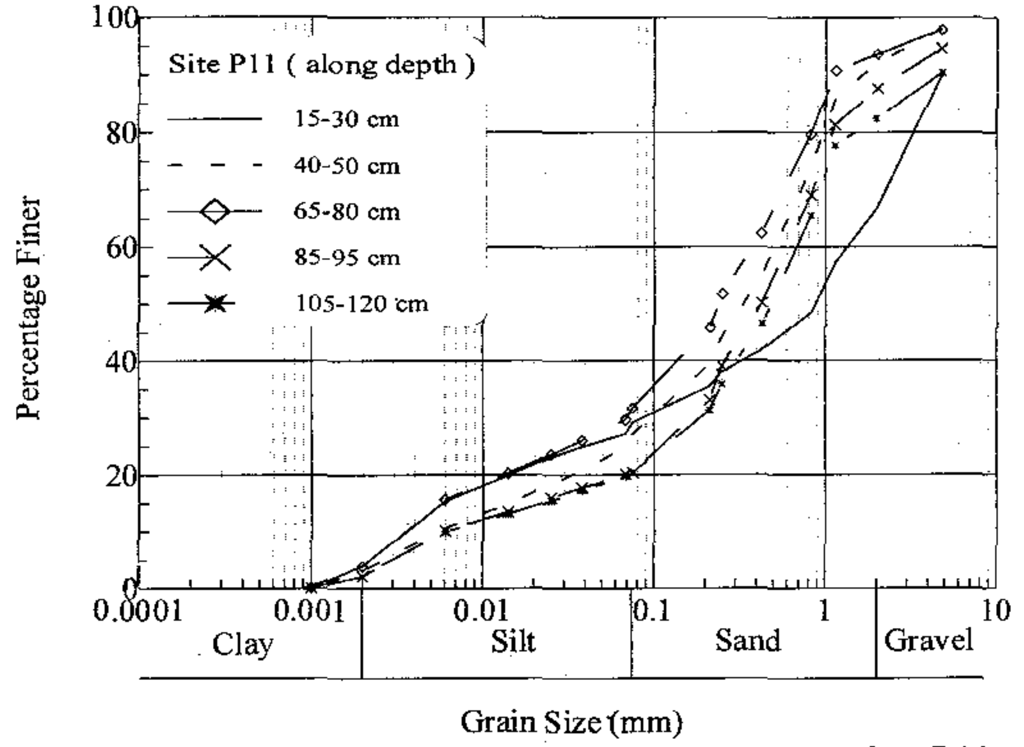

Fig.16. Grain Size Distribution along Depths at Site P11

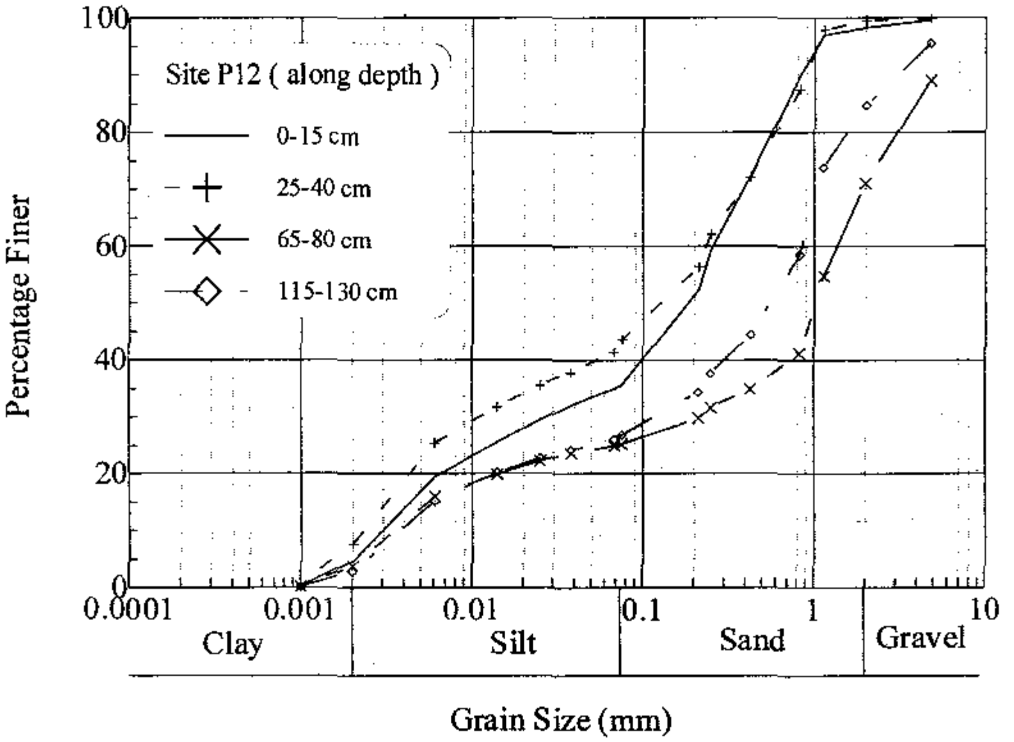

Fig.17. Grain Size Distribution along Depths at Site P12

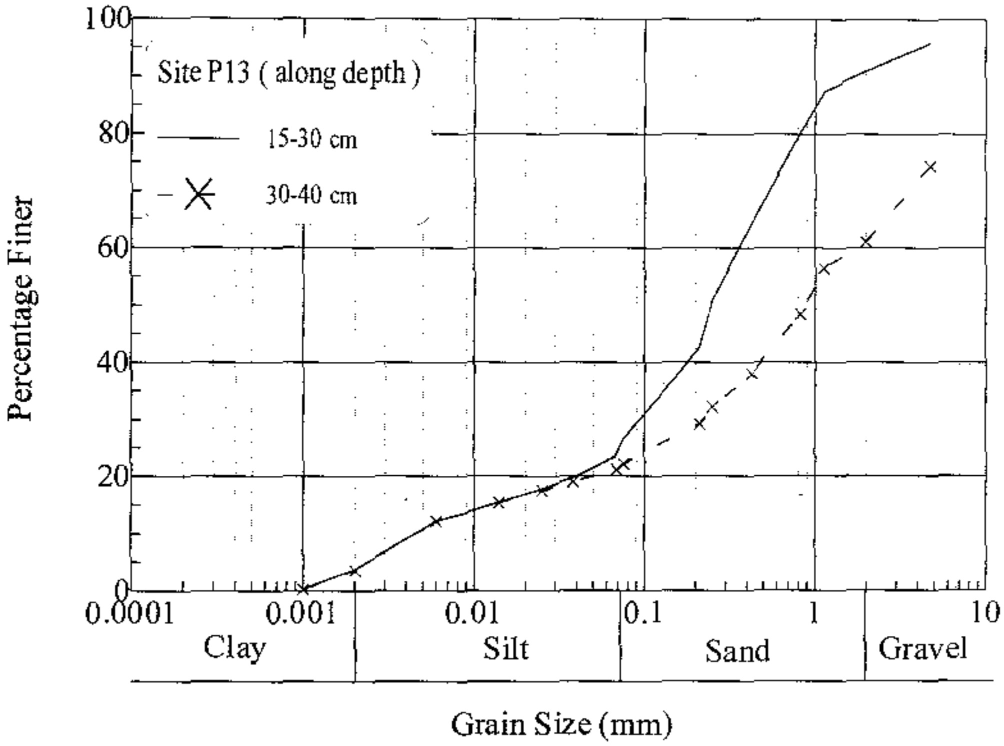

Fig.18. Grain Size Distribution along Depths at Site P13

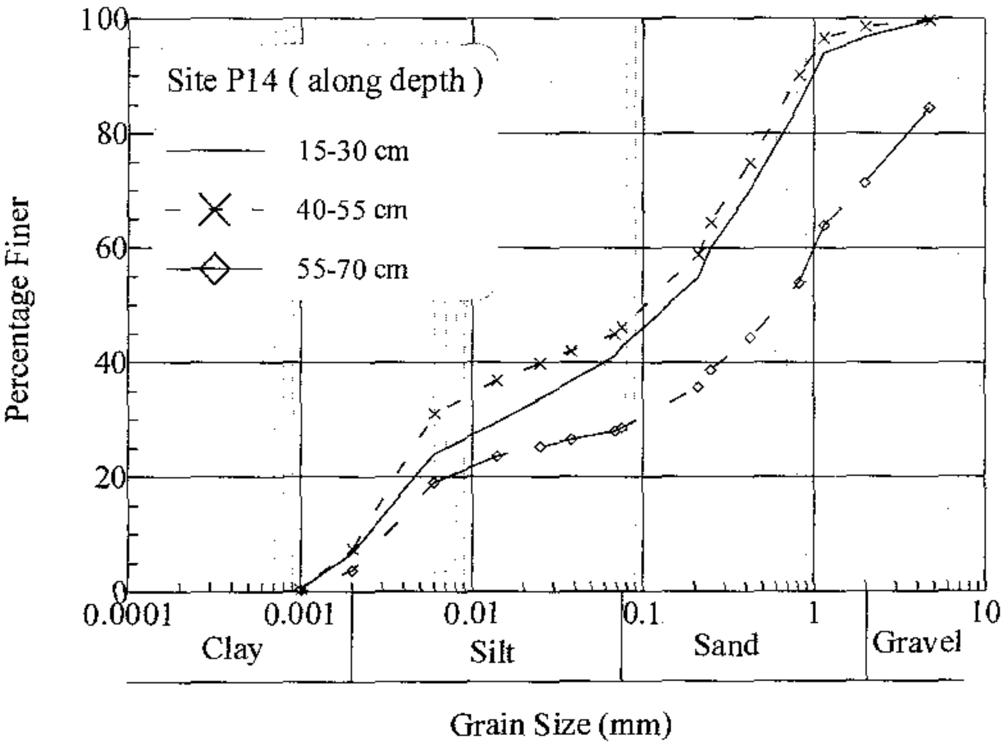

Fig.19. Grain Size Distribution along Depths at Site P14

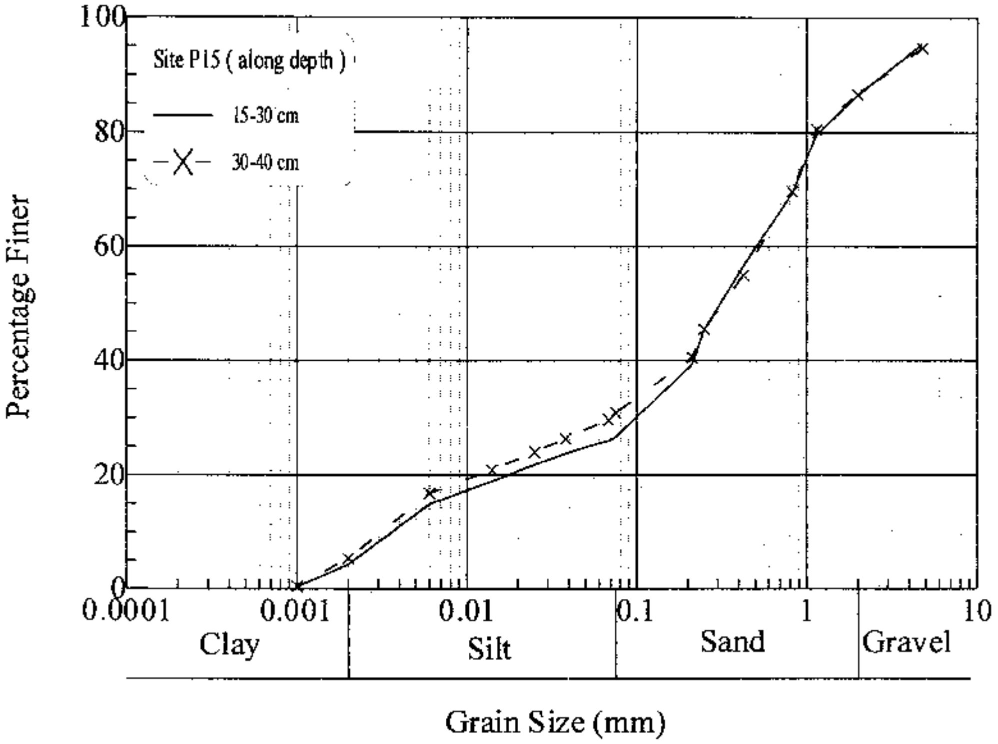

Fig.20. Grain Size Distribution along Depths at Site P15

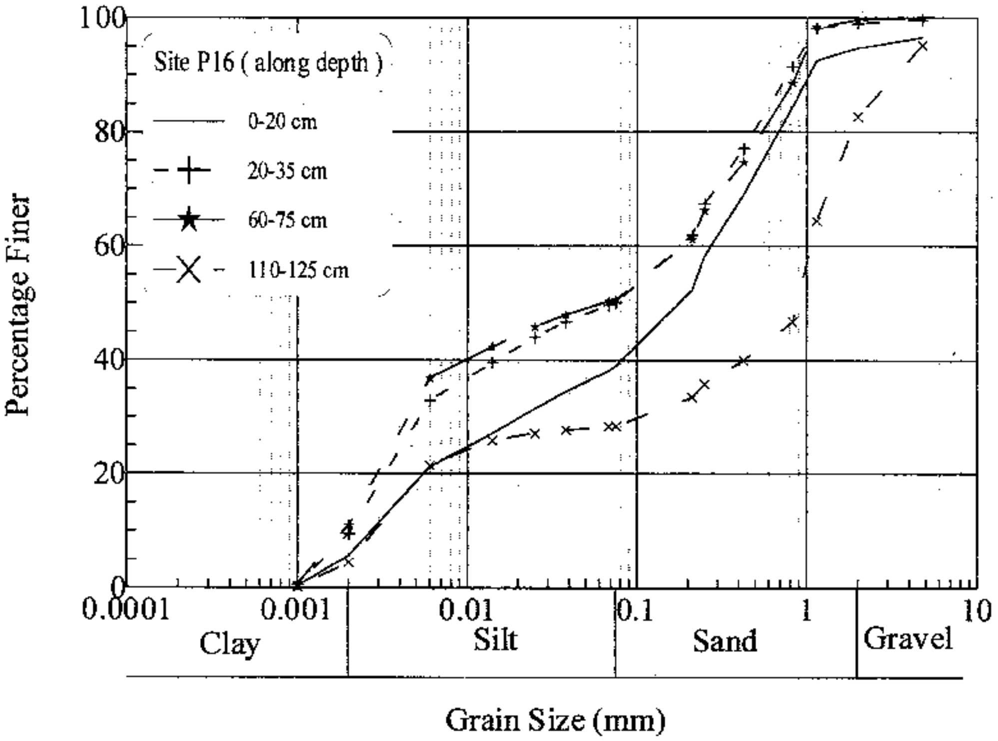

Fig.21. Grain Size Distribution along Depths at Site P16

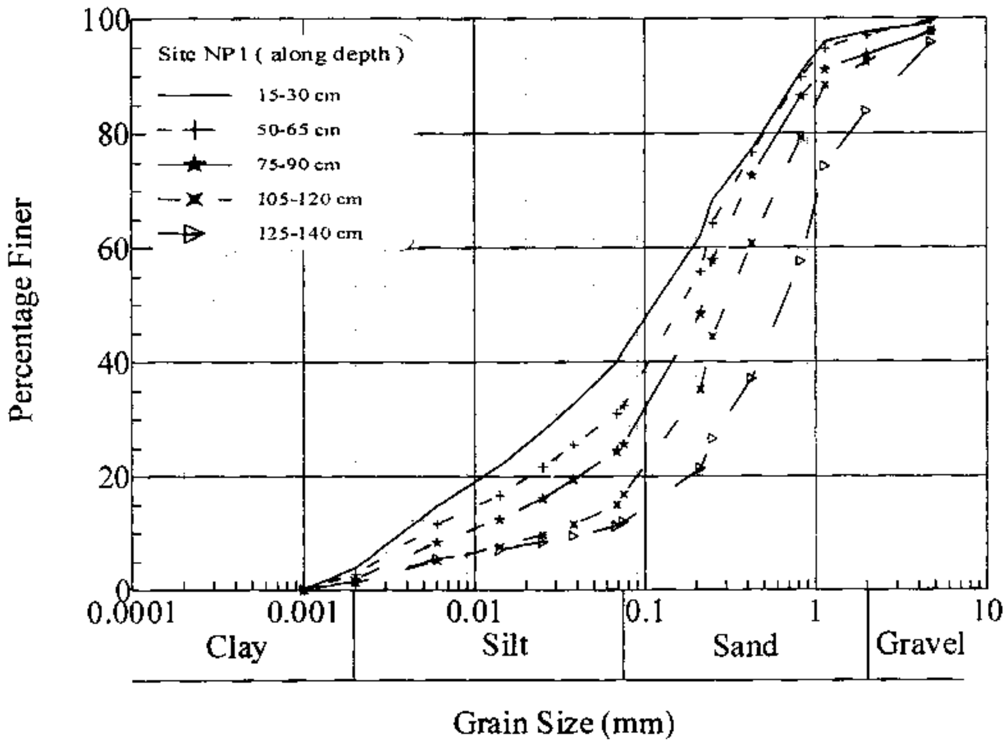

Fig.22. Grain Size Distribution along Depths at Site NP1

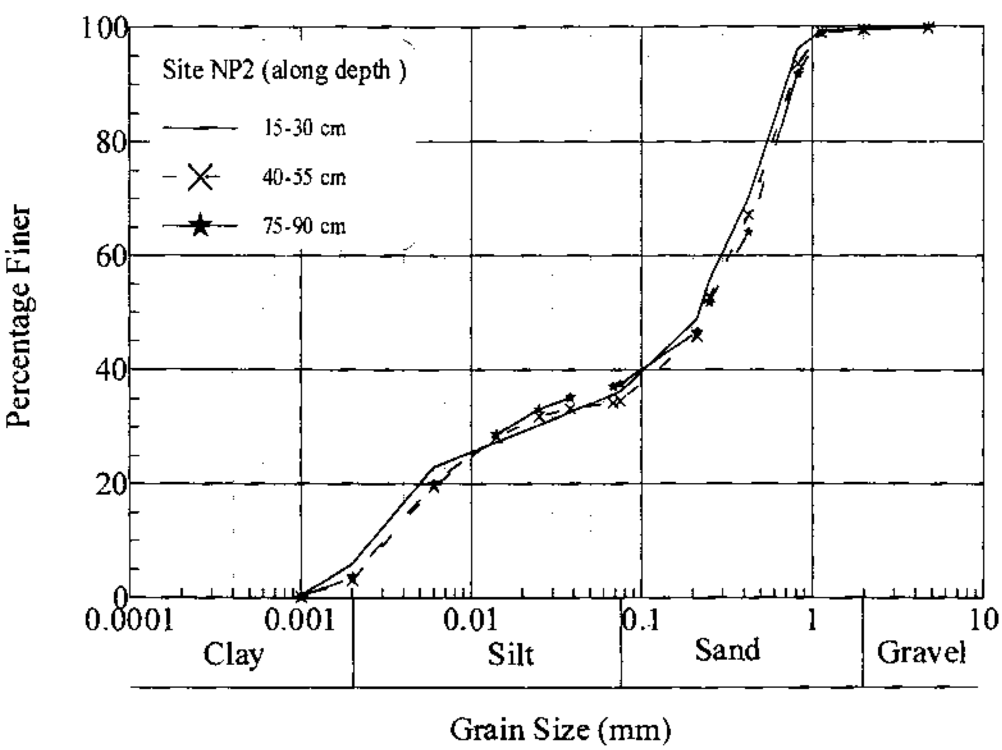

Fig.23. Grain Size Distribution along Depths at Site NP2

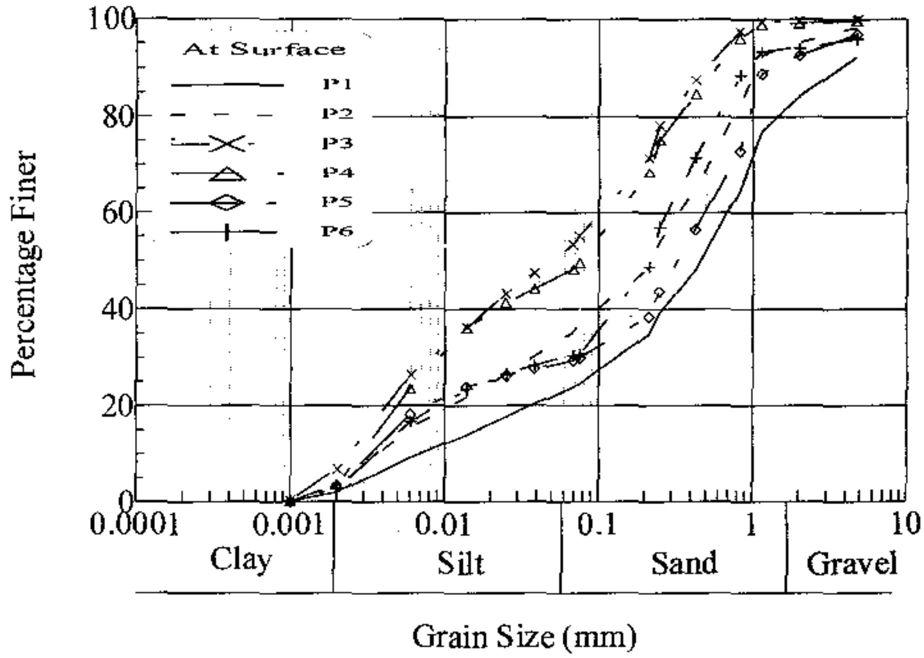

Fig. 24 Grain Size Distribution at Sites P1, P2, P3, P4, P5 & P6

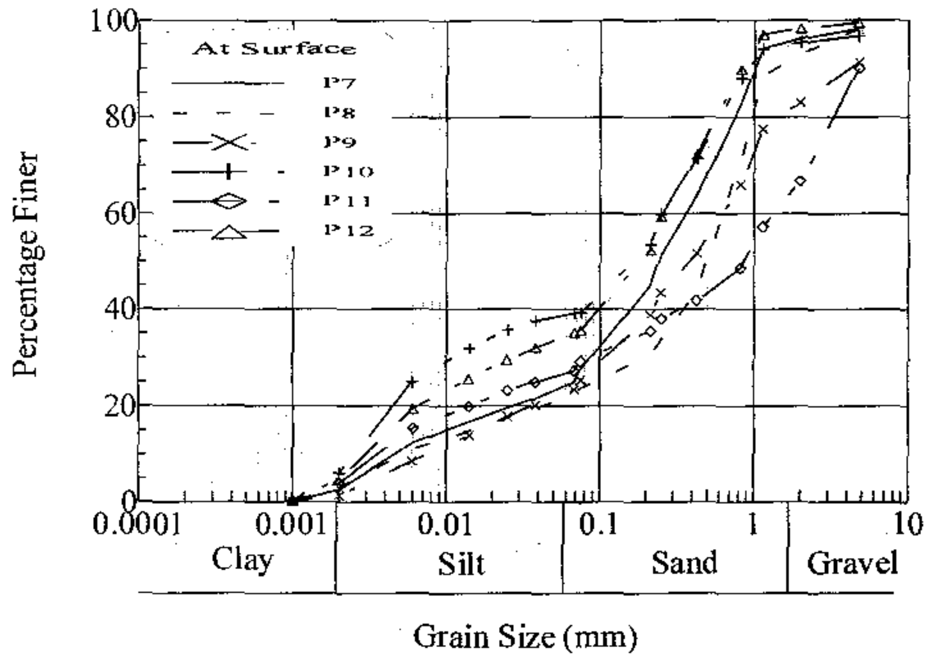

Fig. 25 Grain Size Distribution at Sites P7, P8, P9, P10, P11 & P12

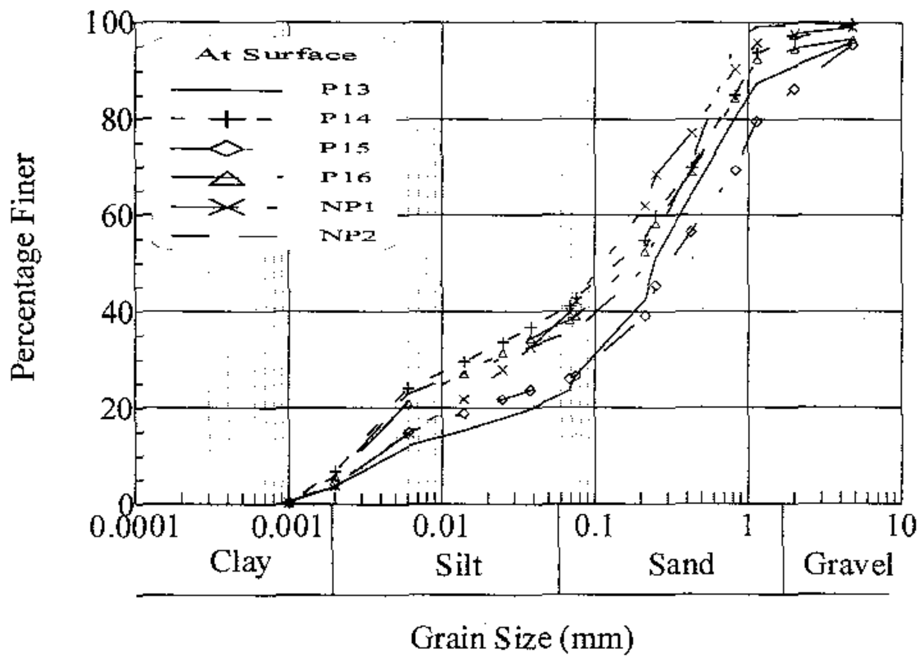

Fig. 26 Grain Size Distribution at Sites P13, P14, P15, P16, NP1 & NP2

Table 2: Textural Classification of Soil

SN	Site	Depth (cm)	Gravel %	Sand %	Silt %	Clay %	Soil Texture	Mean Size (mm)	Effective Size (mm)
1	P1-A	000	15.7	59.7	22.6	2.0	Loamy Sand	0.473	0.007
2	P1-B	015	10.4	61.2	25.5	2.9	Sandy Loam	0.534	0.005
3	P1-C	030	11.5	58.4	27.8	2.3	Sandy Loam	0.495	0.006
4	P1-D	045	28.5	50.4	20.0	1.1	Loamy Sand	0.827	0.020
5	P2-A	015	4.5	58.6	33.4	3.5	Sandy Loam	0.222	0.004
6	P2-B	035	29.1	45.0	22.6	3.3	Loamy Sand	0.785	0.004
7	P2-C	050	31.9	30.6	32.8	4.7	Sandy Loam	0.463	0.003
8	P2-D	100	7.0	52.8	37.3	2.9	Sandy Loam	0.171	0.004
9	P2-E	145	23.0	37.0	36.4	3.6	Sandy Loam	0.200	0.004
10	P3-A	010	0.3	44.6	48.3	6.8	Loam	0.052	0.003
11	P3-B	040	8.3	34.7	49.3	7.7	Sandy Loam	0.049	0.002
12	P3-C	050	32.8	28.3	33.4	5.5	Sandy Loam	0.218	0.003
13	P3-D	065	18.7	36.1	39.4	5.8	Sandy Loam	0.122	0.003
14	P3-E	085	10.1	41.8	43.0	5.1	Sandy Loam	0.089	0.003
15	P3-F	120	3.9	45.5	47.0	3.6	Sandy Loam	0.072	0.003
16	P3-G	170	3.3	61.7	32.8	2.2	Sandy Loam	0.161	0.004
17	P4-A	010	0.8	49.7	45.9	3.6	Sandy Loam	0.079	0.003
18	P4-B	035	0.2	47.7	46.0	6.1	Sandy Loam	0.070	0.003
19	P4-C	065	0.7	40.4	50.8	8.1	Silty Loam	0.013	0.002

SN	Site	Depth (cm)	Gravel %	Sand %	Silt %	Clay %	Soil Texture	Mean Size (mm)	Effective Size (mm)
20	P4-D	115	2.2	41.3	48.9	7.6	Loam	0.017	0.002
21	P5-A	015	7.1	63.0	26.6	3.3	Sandy Loam	0.338	0.004
22	P5-B	040	5.8	65.3	26.4	2.5	Sandy Loam	0.354	0.004
23	P5-C	055	6.9	59.9	31.1	2.1	Sandy Loam	0.248	0.004
24	P5-D	075	9.3	55.4	32.2	3.1	Sandy Loam	0.225	0.004
25	P6-A	015	5.7	63.7	27.8	2.8	Sandy Loam	0.218	0.004
26	P6-B	030	4.0	64.9	27.4	3.7	Sandy Loam	0.201	0.004
27	P6-C	060	0.8	49.5	46.7	3.0	Sandy Loam	0.078	0.005
28	P6-D	100	6.5	48.7	43.4	1.4	Sandy Loam	0.120	0.012
29	P6-E	135	9.2	44.7	45.1	1.0	Sandy Loam	0.113	0.068
30	P7-A	000	3.8	68.7	25.0	2.5	Loamy Sand	0.242	0.005
31	P7-B	020	2.0	59.8	32.7	5.5	Sandy Loam	0.164	0.003
32	P7-C	035	0.8	59.1	34.3	5.8	Sandy Loam	0.140	0.003
33	P7-D	070	9.0	78.1	11.4	1.5	Sand	0.428	0.020
34	P7-E	115	0.5	33.9	59.7	5.9	Silty Loam	0.044	0.003
35	P7-F	145	1.9	64.0	31.4	2.7	Sandy Loam	0.221	0.004
36	P8-A	000	6.8	69.6	20.7	2.9	Loamy Sand	0.519	0.006
37	P8-B	015	5.2	83.3	9.9	1.6	Sand	0.578	0.031
38	P8-C	040	4.6	69.5	22.3	3.6	Loamy Sand	0.391	0.005
39	P8-D	065	2.2	46.7	43.3	7.8	Loam	0.056	0.002
40	P8-E	120	0.5	15.6	71.4	12.5	Silty Loam	0.006	0.002
41	P8-F	165	0.3	4.3	79.7	15.7	Silty Loam	0.005	0.002
42	P9-A	000	17.0	57.7	23.9	1.4	Loamy Sand	0.390	0.008
43	P9-B	035	25.2	56.1	17.3	1.4	Loamy Sand	0.738	0.012
44	P9-C	050	22.0	54.9	20.0	3.1	Loamy Sand	0.882	0.005
45	P9-D	075	9.5	63.0	25.1	2.4	Loamy Sand	0.627	0.006
46	P9-E	120	11.8	70.7	16.6	0.9	Loamy Sand	0.736	0.027
47	P10-A	000	4.6	56.2	33.1	6.1	Sandy Loam	0.178	0.003
48	P10-B	035	0.7	52.9	36.9	9.5	Sandy Loam	0.114	0.002
49	P10-C	065	35.0	41.3	19.8	3.9	Loamy Sand	1.027	0.004
50	P10-D	080	38.0	38.3	20.3	3.4	Loamy Sand	1.128	0.005
51	P11-A	015	33.3	37.5	25.2	4.0	Sandy Loam	0.879	0.004
52	P11-B	040	7.8	65.0	24.1	3.1	Sandy Loam	0.342	0.006
53	P11-C	065	6.3	62.0	27.8	3.9	Sandy Loam	0.239	0.004
54	P11-D	085	12.3	67.3	18.2	2.2	Loamy Sand	0.419	0.006
55	P11-E	105	17.5	62.0	18.3	2.2	Loamy Sand	0.498	0.006
56	P12-A	000	1.7	62.7	31.0	4.6	Sandy Loam	0.192	0.003
57	P12-B	025	0.5	55.8	36.1	7.6	Sandy Loam	0.143	0.003
58	P12-C	065	28.9	45.8	21.5	3.8	Loamy Sand	1.028	0.004
59	P12-D	115	15.3	57.8	24.1	2.8	Sandy Loam	0.582	0.004
60	P13-A	015	8.9	64.6	22.8	3.7	Loamy Sand	0.246	0.005
61	P13-B	030	38.9	38.9	18.7	3.5	Loamy Sand	0.884	0.005

SN	Site	Depth (cm)	Gravel %	Sand %	Silt %	Clay %	Soil Texture	Mean Size (mm)	Effective Size (mm)
62	P14-A	015	3.3	53.9	36.0	6.8	Sandy Loam	0.157	0.003
63	P14-B	040	1.5	52.3	38.7	7.5	Sandy Loam	0.116	0.002
64	P14-C	055	28.7	42.7	24.9	3.7	Sandy Loam	0.664	0.004
65	P15-A	015	13.5	59.9	22.4	4.2	Sandy Loam	0.323	0.004
66	P15-B	030	13.3	55.9	25.5	5.3	Sandy Loam	0.334	0.004
67	P16-A	000	5.3	55.7	33.3	5.7	Sandy Loam	0.187	0.003
68	P16-B	020	1.0	48.9	40.6	9.5	Loam	0.073	0.002
69	P16-C	060	0.4	48.9	39.7	11.0	Loam	0.063	0.002
70	P16-D	110	17.3	54.3	23.9	4.5	Sandy Loam	0.882	0.003
71	NP1-A	015	2.3	55.6	38.2	3.9	Sandy Loam	0.129	0.004
72	NP1-B	050	2.9	64.7	29.6	2.8	Sandy Loam	0.178	0.005
73	NP1-C	075	6.3	68.1	23.6	2.0	Loamy Sand	0.218	0.009
74	NP1-D	105	7.6	75.6	15.5	1.3	Loamy Sand	0.310	0.027
75	NP1-E	125	16.1	72.0	10.4	1.5	Sand	0.677	0.047
76	NP2-A	015	0.5	63.3	30.3	5.9	Sandy Loam	0.218	0.003
77	NP2-B	040	0.5	64.9	31.6	3.0	Sandy Loam	0.235	0.004
78	NP2-C	075	0.5	61.9	34.0	3.6	Sandy Loam	0.236	0.004

Table 3: Types of Soil along Depths at all locations

SN	Site	At Ground Surface	At 30 cm below Ground Surface	At 60 cm below Ground Surface	At 100 cm below Ground Surface
1	P1	Loamy Sand	Sandy Loam	Loamy Sand	-
2	P2	Sandy Loam	Loamy Sand	Sandy Loam	Sandy Loam
3	P3	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
4	P4	Sandy Loam	Sandy Loam	Silty Loam	Loam
5	P5	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
6	P6	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
7	P7	Loamy Sand	Sandy Loam	Sand	Silty Loam
8	P8	Loamy Sand	Loamy Sand	Loam	Silty Loam
9	P9	Loamy Sand	Loamy Sand	Loamy Sand	Loamy Sand
10	P10	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand
11	P11	Sandy Loam	Sandy Loam	Sandy Loam	Loamy Sand
12	P12	Sandy Loam	Sandy Loam	Loamy Sand	Sandy Loam
13	P13	Loamy Sand	Loamy Sand	-	-
14	P14	Sandy Loam	Sandy Loam	Sandy Loam	-
15	P15	Sandy Loam	Sandy Loam	-	-
16	P16	Sandy Loam	Loam	Loam	Sandy Loam
17	NP1	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand
18	NP2	Sandy Loam	Sandy Loam	Sandy Loam	-

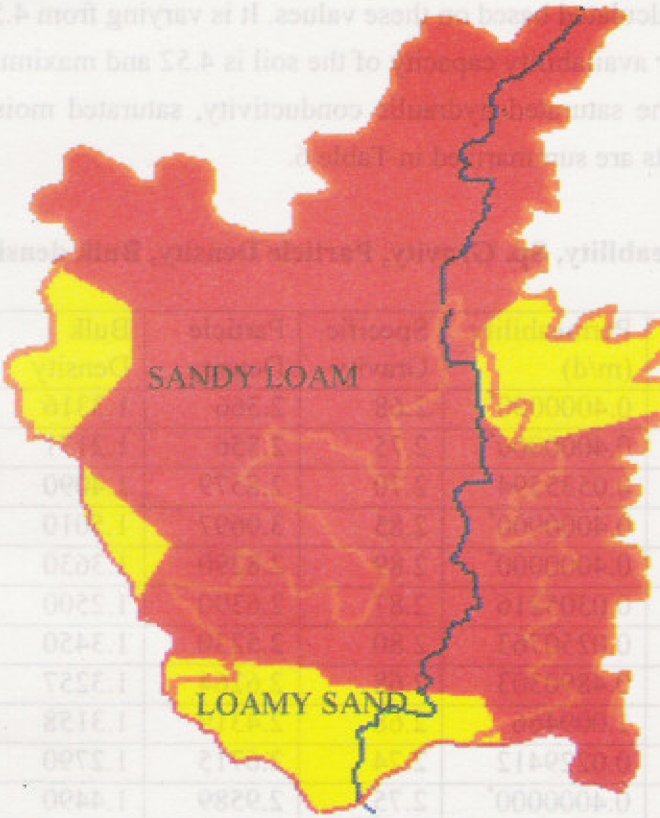

Fig. 27: Map Showing the distribution of Soil types in the Study Area.

The undisturbed soil samples have been collected for the determination of the permeability in the laboratory using ICW Permeameter. Table 4 presents the values of permeability, specific gravity, particle density, bulk density and porosity of the soil samples. The values of Permeability vary from 0.022 to 1.009 m/day except at site NP2, it has 15.3 m/day. The Specific gravity of the soil samples varies from 2.5 to 2.89.

The soil moisture measurement for different disturbed soil samples were determined using different pressures (0.1, 0.33, 1.0, 3.0, 5.0, 10.0, 15.0 bar). The results are presented in Table.5. Using the data of soil moisture obtained for different pressures the soil moisture characteristic curves are prepared and are presented in Fig 28 through Fig 31, for different locations. The moisture content at field capacity and wilting point were obtained. The ranges of field capacity and wilting points vary from 10.69 % to 21.10 % and 5.3 % to 14.75 % respectively. The available moisture that is useful to plant can be calculated based on these values. It is varying from 4.52 % to 10.02 %. It means the minimum water availability capacity of the soil is 4.52 and maximum is 10.02 %. The location wise values of the saturated hydraulic conductivity, saturated moisture content, field capacity, and wilting points are summarized in Table 6.

Table 4: Values of Permeability, Sp. Gravity, Particle Density, Bulk density and Porosity

S.N	Site	Depth (cm)	Permeability (m/d)	Specific Gravity	Particle Density	Bulk Density	Porosity
1	P1	0-20	0.4000000*	2.68	2.366	1.3316	0.437
2	P2	0-20	0.4000000*	2.75	2.556	1.2171	0.524
3	P3	35-45	0.0535594	2.70	2.8579	1.4090	0.507
4	P4	0-20	0.4000000*	2.85	3.0697	1.5010	0.511
5	P5	0-20	0.4000000*	2.89	2.8290	1.3630	0.518
6	P6	30-40	0.0305216	2.87	2.6390	1.2500	0.5260
7	P7	50-6-	0.0250763	2.80	2.5230	1.3450	0.4670
8	P8	15-25	0.4890303	2.68	2.6264	1.3257	0.495
9	P9	40-50	1.009466	2.68	2.4319	1.3158	0.4589
10	P10	35-45	0.0229412	2.74	2.6715	1.2790	0.5200
11	P11	0-20	0.4000000*	2.75	2.9589	1.4490	0.51
12	P12	10-20	0.0927767	2.69	2.3845	1.2200	0.488
13	P13	30-40	0.0246210	2.75	2.4922	1.3180	0.471
14	P14	0-20	0.4000000*	2.77	2.8600	1.3670	0.522
15	P15	0-20	0.4000000*	2.72	2.6750	1.3100	0.5103
16	P16	40-50	0.1067274	2.54	2.7506	1.3750	0.5
17	NP1	40-50	0.0542094	2.50	2.4287	1.2200	0.4977
18	NP2	65-75	15.348610	2.53	2.3870	1.3200	0.4470

- - values from Johnson curve

Table 5.: Soil Moisture Characteristic Data at the Ground Surface

S.N	Site	Pressure , Ist Row in Bar, 2nd Row in cm							Available moisture content %
		0.1	0.33	1.0	3.0	5.0	10.0	15.0	
		101.9	336.5	1019.8	3059.4	5099	10198	15297	
1	P1	14.99	10.69	8.29	7.10	6.61	6.00	5.50	5.19
2	P2	23.08	18.2	14.87	13.42	12.50	11.65	11.0	7.20
3	P3	27.67	21.1	18.32	16.55	15.34	14.90	14.75	6.35
4	P4	30.00	19.04	15.61	13.17	12.40.	11.77	11.00	8.04
5	P5	21.44	15.20	12.65	10.50	9.81	9.20	9.00	6.20
6	P6	22.47	12.89	10.18	9.10	8.20	7.85	7.70	5.19
7	P7	15.98	11.16	9.19	7.16	7.18	6.64	6.64	4.52
8	P8	13.81	11.05	9.39	7.80	6.20	5.79	5.60	5.45
9	P9	19.68	11.29	8.25	6.47	5.65	5.51	5.30	5.99
10	P10	22.20	15.37	13.60	11.28	9.81	9.24	9.10	6.27
11	P11	24.99	19.88	16.94	13.81	12.25	11.83	11.30	8.58
12	P12	21.21	14.06	12.35	9.64	9.30	8.54	8.03	6.03
13	P13	17.77	10.83	9.21	6.80	6.45	6.31	6.00	4.83
14	P14	26.87	20.02	18.63	14.93	13.89	13.27	12.8	7.22
15	P15	22.17	14.38	11.80	10.50	9.40	8.70	8.21	6.17
16	P16	24.53	17.03	14.41	11.29	10.75	10.45	9.90	7.13
17	NP1	29.30	19.93	15.46	12.07	11.15	10.08	9.85	10.08
18	NP2	25.58	17.43	14.51	11.93	10.78	9.80	9.30	8.13

Table 6: Values of Permeability, Bulk density, Porosity, Wilting Point and Field Capacity

Site	Soil Type	Ks (m/d)	Ks (cm/h)	Bulk Density	Porosity	Wilting Point	Field Capacity	Avail. Moist.
P2	Sandy Loam	0.400	0.000	1.217	0.524	11.00	18.20	7.20
P3	Sandy Loam	0.054	0.223	1.409	0.507	14.75	21.10	6.35
P4	Sandy Loam	0.400	0.000	1.501	0.511	11.00	19.04	8.04
P5	Sandy Loam	0.400	0.000	1.363	0.518	9.00	15.20	6.20
P6	Sandy Loam	0.031	0.127	1.250	0.526	7.70	12.89	5.19
P10	Sandy Loam	0.023	0.096	1.279	0.520	9.10	15.37	6.27
P11	Sandy Loam	0.400	0.000	1.449	0.510	11.30	19.88	8.58
P12	Sandy Loam	0.093	0.387	1.220	0.488	8.03	14.06	6.03
P14	Sandy Loam	0.400	0.000	1.367	0.522	12.80	20.02	7.22
P15	Sandy Loam	0.400	0.000	1.310	0.510	8.21	14.38	6.17
P16	Sandy Loam	0.107	0.445	1.375	0.500	9.90	17.03	7.13
NP1	Sandy Loam	0.054	0.226	1.220	0.498	9.85	19.93	10.08
NP2	Sandy Loam	15.349	0.000	1.320	0.447	9.30	17.43	8.13
Average of Sandy Loam			**0.251**	**1.329**	**0.506**	**10.15**	**17.27**	**7.12**
P1	Loamy Sand	0.400	0.000	1.332	0.437	5.50	10.69	5.19
P7	Loamy Sand	0.025	0.104	1.345	0.467	6.64	11.16	4.52
P8	Loamy Sand	0.489	2.038	1.326	0.495	5.60	11.05	5.45
P9	Loamy Sand	1,009	0.000	1.316	0.459	5.30	11.29	5.99
P13	Loamy Sand	0.025	0.103	1.318	0.471	6.00	10.83	4.83
Average of Loamy Sand			**0.748**	**1.327**	**0.466**	**5.81**	**11.00**	**5.20**

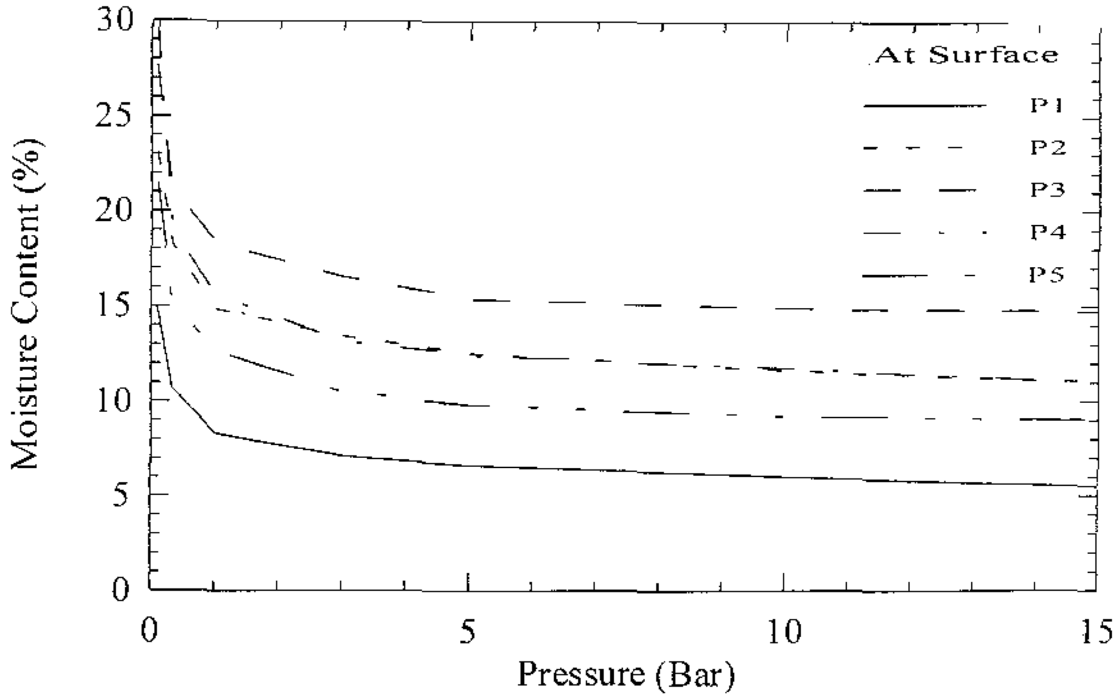

Fig. 28: Soil Moisture Characteristic Curve for Sites : P1,P2, P3 P4 and P5

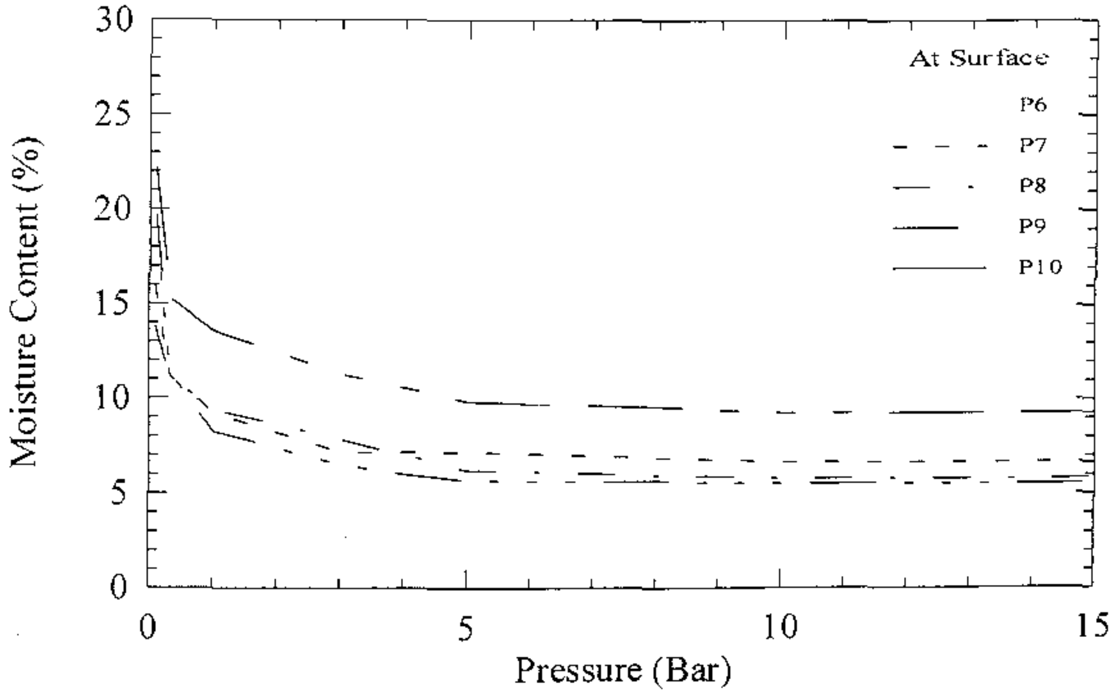

Fig.29: Soil Moisture Characteristic Curve for Sites: P6,P7, P8 P9 and P10

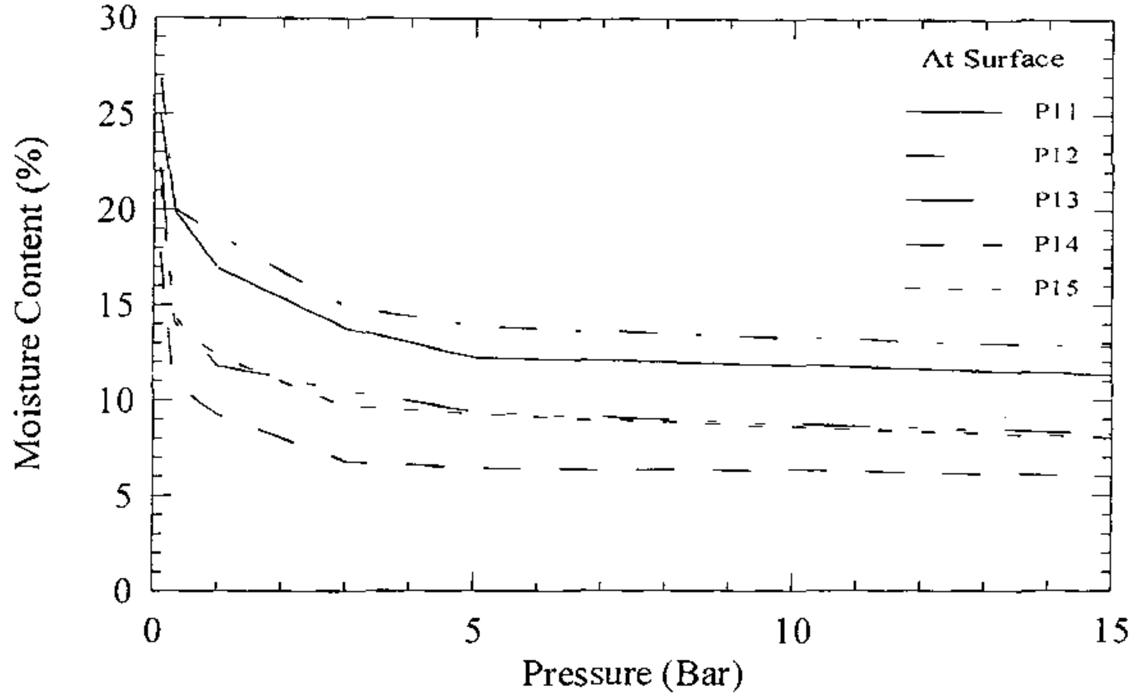

Fig. 30: Soil Moisture Characteristic Curve for Sites P11,P12, P13 P14 & P15

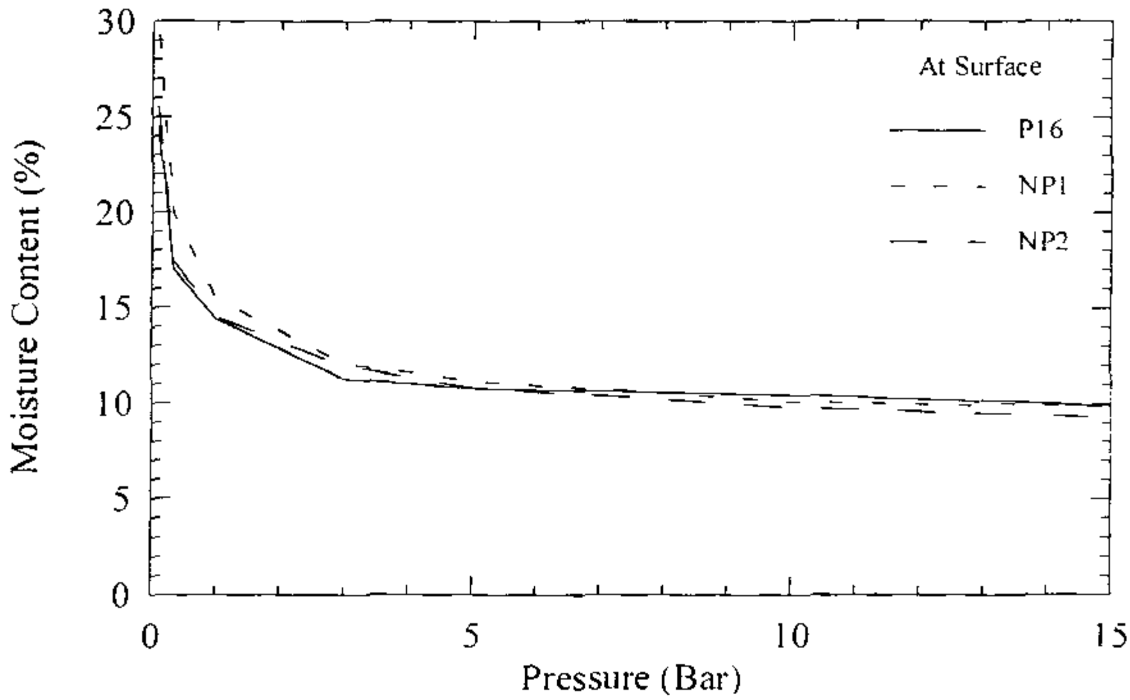

Fig. 31: Soil Moisture Characteristic Curve for Sites P16, NP1 & NP2

5 CONCLUSIONS

The disturbed and undisturbed soil samples from 18 locations along different depths were collected and analysed in the Soil & Groundwater Laboratory of the Institute. Disturbed soil samples were used to determine the grain size distribution, porosity, specific gravity and soil moisture characteristic curves. Undisturbed soil samples were used with ICW Permeameter to determine saturated hydraulic conductivity.

On the basis of the laboratory analysis carried out in the NIH Laboratory, the following conclusions can be made: There are mainly two types of soil on the surface i.e. sandy loam and loamy sand, which extended up to 30 cm below the ground surface. The values of saturated hydraulic conductivity in the study area varies from 0.02294 m/d to 1.0094 m/d. Field capacity varies from 10.69 to 21.1 %. Wilting points are lying between 5.5 to 14.75 %. Available soil moisture varies from 4.45 to 10.02 %. The specific gravity of the soils are from 2.5 to 2.89. The porosity values are from 0.4372 to 0.6381.

For sandy loam soil values of hydrological properties are as follows: saturated hydraulic conductivity, 0.251 (cm/hr); porosity, 0.506; Field capacity, 17.17 %; and wilting point, 10.15 % where as for loamy sand these are saturated hydraulic conductivity, 0.748 (cm/hr); porosity, 0.466; Field capacity, 11 %; and wilting point, 5.8 %

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Director	**:**	**Dr. K. S. Ramasastri**
Divisional Head	**:**	**Dr. V. K. Choubey**

STUDY GROUP

Scientist	**:**	**Dr. Vivekanand Singh**
Lab. Staff	**:**	**Mr. S. L. Srivastava**
	:	**Mr. S. Mittal**
	:	**Mr. N. K. Lakhera**