EXPRESSION OF INTEREST

BHEL is setting up a 4 x 125 MW Thermal Power Plant in Kosti, Sudan. After construction, settlement has been noticed in the ground floor/ Cable Trenches/ Minor foundations etc., rested on compacted filled up soil in the following areas:

Area	Observed settlement (approx.)
River Water Intake Pump House – MCC Room	300 – 800 mm
CW Pump House – MCC Room	50 -- 200 mm
Switch Yard	50 -- 100 mm

Rectification/ restoration of settled structures including stabilization of filled up soil underneath are required to be carried out for the above areas so as to ensure that no further sinking / settlement takes place. BHEL is looking forward for suitable parties who can carry out the above mentioned works. The work has to be carried out during running Power Station without dismantling/breaking of existing structures including equipment.

Eligible and interested parties who are confident to carry out the above works having experience of similar work may submit their EOI in a sealed cover super scribed “Expression of Interest for carrying out Rectification/ restoration of settled structures at 4 x 125 MW TPP, Kosti-Sudan”. The EOI should include **“‘Proposed Methodology for carrying out work, credentials of the party and similar work experience details”.**

The documents attached with this EOI are as follows:

1. SYNOPSIS OF SUDAN PROJECT
2. GEO-TECHNICAL INVESTIGATION REPORT- 5 FILES.
3. PLOT PLAN- HIGHLIGHTED FOR SWITCHYARD & MCC-CWPH AREA
4. DRAWING OF MCC ROOM CW PUMP HOUSE
5. DRAWING OF MCC ROOM RIVER INTAKE PUMP HOUSE
6. DRAWING OF RIVER INTAKE PUMP HOUSE AREA
7. SITE PHOTOGRAPHS
8. DRAWING OF SWITCH_YARD_AREA

KOSTI 4 X 125 MW THERMAL POWER PLANT
UNIT-I COMPLETION : 29 months from Project Start Date
UNIT-II/III/IV COMPLETION :33/37/41 months from Project Start Date
PROJECT START DATE: 01-09-2006

PROJECT INFORMATION DATA

1.	**Owner**	NATIONAL ELECTRICITY CORPORATION, SUDAN
2.	**Project**	4 X 250 MW RATING, CRUDE OIL FIRED THERMAL POWER PLANT
3.	**Owner's consultant**	Fichtner Gmbh & Co. KG
4.	**Location**	The Power Station site is located near Kosti (White Nile State), 310 km south of Khartoum at latitude 13.10 North and longitude 32.6 East at an elevation of 380 meters above sea level. The northern boundary of the plot is adjacent to the Rabak-Sinnar highway
5.	**Nearest Airport**	KHARTOUM
6.	**Nearest Port**	PORT-SUDAN
7.	**Access to site**	PORT-SUDAN 850 km → KHARTOUM 320 km → KOSTI

Meteorological data

A	**Altitude [Observatory]**	380 meters above sea level
B	**Ambient Conditions:**	
1.	Mean Maximum Ambient Air Temperature (in hottest month)	45 Deg.C
2.	Mean Minimum Ambient Air Temperature (in coldest month)	18 Deg.C
	Temperatures	
1.	Minimum [Annual Mean]	25 –30 deg C, 16 deg C lowest
2.	Maximum [Annual Mean]	40-45 deg C
C	**RELATIVE HUMIDITY**	Low to very low in most part of the year. Rising only during rainy season.
1.	Maximum Humidity	71% in Aug
2.	Minimum Humidity	26% in April
D	**RAINFALL**	
1.	Annual Mean	300 to 400 mm spread over 150 days. Approx.50 TO 60% rainfall in July & Aug.
2.	Maximum	Max recorded is 182 mm in Aug,04
E	**WIND DATA**	
1.	Max Wind Speed	170Kmph
2.	Prevailing Wind Direction	Wind direction is northern from May to September and it is southern in other months
3.	Any other features	Occasional dust storms in May and June

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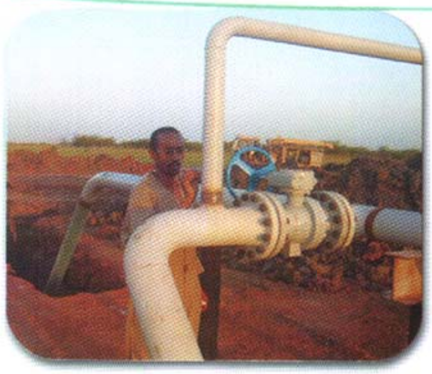


REPORT ON

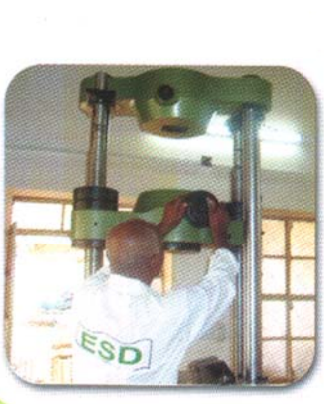
GEOTECHNICAL INVESTIGATION

FOR

ASSESSMENT ON SOIL SETTELMENT OF COMPACTED FILLS
AT 4X125 MW KOSTI THERMAL POWER STATION
RABAK, WHITE NILE STATE
SUDAN

SUBMITTED TO
BHARAT HEAVY ELECCTRICALS LIMITED
(BHEL)

FEBRUARY 17, 2014



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Contents

1.0 Introduction:

BHEL contracted with **E**ngineering **S**ervices & **D**esign (**ESD**), geotechnical consulting office, to carry out soil investigation to assess soil settlement of compacted fills at 4x125MW Kosti Thermal Power Station**,** in Rabak town, White Nile State.

The site investigation consisted of drilling thirteen (13) boreholes.Six borholes; BH.1, BH.2, BH.3, BH.4, BH.5 and BH.6 were drilled at power station area. Another six boreholes; BH.7, BH.8, BH.9, BH.10, BH.11and BH.12 were drilled at river water intake pump house location. Last borehole; BH.13 was drilled at intake water pipeline route;. Undisturbed and disturbed soil samples are taken as well as carried out appropriate field and laboratory testing. The field work was conducted during the period from 18th to the 26th of November 2013.

The following conditions were part of the agreement;

1. The client has determined the number of borehole to be drilled, their locations and depth, as well as frequencies of field tests. ESD followed the proposal with that specific program for testing and drilling.
2. Sampling in both disturbed and undisturbed tube had been difficult because some of layers at boreholes were very soft and almost saturated. At some of the depths, undisturbed tubes were recovered empty as shown in profile.
3. Two bulk soil samples marked SPILE & PCL collected from borrow areas were handed over by the client. Laboratory tests carried out for these samples are Atterberg limit, Sieve Analysis, Specific Gravity, Hydrometer, Compaction, Single and Double oedometre. Results of these tests are shown seperately in Appendix (F).

This report presents the results of the field investigations, laboratory tests, analysis of the results and recommendations for the remedial measures.

2.0 The Field Investigation:

2.1 Drilling of Boreholes

Thirteen boreholes were drilled in the specified locations. The location of these boreholes are shown in Fig (1). The boreholes were drilled using a rotary soil mechanics drilling rig. Disturbed soil samples and undisturbed samples were collected at one-meter depth intervals for visual inspection, identification of the soil type and laboratory testing. The Standard Penetration Test (SPT) was performed at a depth interval of 1.5m at some boreholes (shown the soil profile). A split spoon sampler, 50mm out side diameter was driven by the blows of a standard hammer weighing 64-kg and falling freely from a height of 760mm. The number of blows required to drive the tube a penetration of 300mm was taken as the SPT N-value of the soil tested at a specified borehole depth. The SPT results are shown in Appendix (A) at the corresponding borehole depths in terms of the measured N values.

It's to be mentioned that the boreholes at river intake pump house and power station were all in the compacted fill area.

2.2 Groundwater

The level of the ground water table was not observed at most of boreholes. In borehole No.7 ground water was observed at 8.0m depth. The moisture content in most of borehole were high and soil almost saturated below 2.0m depth, this may be due to ingress of water from rainfall or other sources in stations.

3.0 Soil Conditions:

The soil profile for the boreholes is shown in Fig. (2) and Appendix (A). The soil profile at most of boreholes are relatively similar. In power station the boreholes BH.1, BH.2, BH.3, BH.4, BH.5 and BH.6 indicate dark brown to light grey clayey sand (SC) layer and silty clay of low plasticity (CL) layer, followed by high plasticity (CH) layer. This three layers may happen in different sequences. The Boreholes arround the river water pump house BH.7, BH.8, BH.9, BH.10, BH.11 and BH.12 indicate dark brown and greyish brown, clayey sand (SC) layer and low plasticity silty clay (CL) layer. The SPT results for these boreholes indicate loose and soft soil. Except borehole No.10 where the SPT were high. BH.13 near pipe line, profile indicate to reddish brown poorly graded of silty sand (SP-SM) layer, followed by light brown clayey sand (SC) layer.

4.0 Laboratory Testing:

4.1 Objectives of the Testing Program

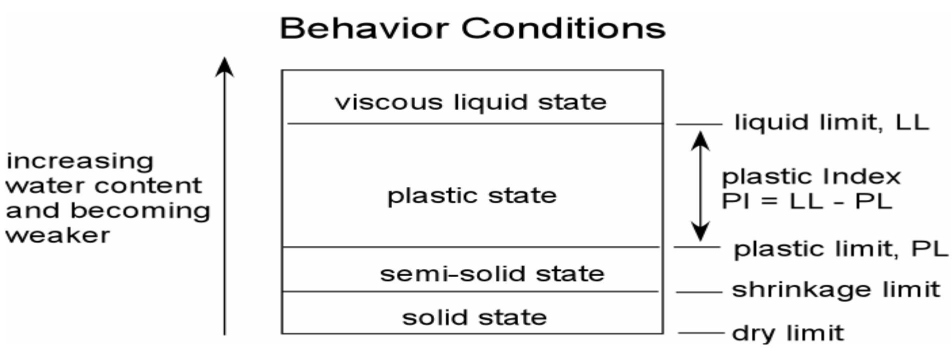
Laboratory testing program was conducted to evaluate the physical and chemical properties of the soils encountered during the boring. The tests included bulk density and moisture content, atterberg limits, grain size distribution, specific gravity, chemical tests, free swell index, consolidation, sensitivity, collapse potential using single and double oedometer, pinhole and permeability. The procedures followed were in general conformance with those recommended in the British Standard BS 1377 (1990) and American Society for Testing and Materials ASTM.

4.2 Classification Tests

The objective of these tests is to reveal soil types encountered at different depths of the boreholes. Tests carried out included atterberg limits, shrinkage limit and grain size analysis. All these classification tests confirmed the soil profiles shown in Appendix (A). Unified Soil Classification System (USCS) was followed for soil classification. See Fig. A-1 and Fig. B-1.

4.2.1 Consistency of Clays

The physical properties of clays are considerably influenced by the amount of water percent. Atterberg limits are the limits of water content used to define soil behavior. The consistency of soils according to Atterberg limits gives the following diagram.



4.2.1.1 Plastic Limit (PL) and Liquid Limit(LL)

The program of tests were carried out on clayey soil samples taken from different depths, based on standard test procedures at ASTM D 4313-03.

At boreholes in power station area, the results gave liquid limit values ranging between 75% to 34% and plastic index in the range of 45% to 16%, this range of Atterberg limits indicate possibility of occurence medium to high potential for swelling. At the boreholes in the river water intake pump house area, results gave liquid limit values ranging between 42% to 20% and plastic index range between 23% to 10%, the range indicate possibility of occurence medium to low swelling potential. Liquid limit values in the pipe line borehole between 23% to None and plastic index in range 8% to None, this range indicate to low swelling potential for swelling for the clayey samples.

4.2.1.2 Shrinkage Limit

The shrinkage is a measure of the average oven dry length of the sample after shrinkage to the original length which occurs at an initial water content at or above the Liquid Limit. According to the standared (ASTM D 427-98), results for samples from the boreholes are shown in soil profile. Range of the results at power station area between 7.71% to 20.0%, at river water intake pump house area between 5.34% to 10.79% and at pipe line nearly 2.07%. All of this results indicate to low shrink properties.

4.2.2 Grain Size Distribution

Grain size distribution or the percentage of the various size of soil grains percent in a given dry soil sample is carried out by mechanical sieve analysis for coarse grain and whereas fine-grained soils are analysed by the hydrometer method.

4.2.2.1 Sieve Analysis Test

The grain size distribution curve of the soil samples was determined in the laboratory. The results of the tests are shown in Appendix (B-1). Test was carried out according to ASTM D 1140-03.

4.2.2.2 Hydrometer Test

Distribution of soil particles having sizes less than 75 micron (Fine Grained soils) is determined by a sedimentation process using a hydrometer to obtain the necessary data such as the borderline between clay and silt. In appendix (B-2), results are shown for the hydrometer curves to different some samples.

4.2.3 Natural Moisture Content

The natural moisture content was determined from undisturbed soil samples. The test was performed according to ASTM D 2216-98. The test results are shown in the soil profile at Appendix (A) and figures(2). As mentioned previously, inspection by visual description reference a high moisture content at upper layers between 2.0m and 6.0m depth was observed.

4.3 Specific Gravity

Test is performed to determine the specific gravity of soil by using a pycnometer. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. standard reference for this test is ASTM D 854-02. Table (4.1) shows the results of specific gravity at different location.

BH. No.	Depth (m)	Specific Gravity
1	3.0	2.78
2	2.0	2.82
4	2.0	2.74
7	8.0	2.72
7	6.0	2.69
8	8.0	2.86
9	10.0	2.85
12	8.0	2.78

Table No.(4.1) Specific Gravity Test Results

4.4 Bulk Density Test

Table (4.2) shows the results of bulk density at different location in boreholes.

BH. No.	Depth (m)	Bulk Density (g/cm^3)
1	4.0	1.8187
2	2.0	2.1626
6	2.0	1.8468
6	4.0	2.0104
8	6.0	2.1349
12	8.0	1.8950

Table No.(4.2) Bulk Density Test Results

4.5 Permeability Test

This test is conducted in an apparatus using the procedure of falling head Test method. Performed in accordance with ASTM D 5856. Samples for this results were compacted at the laboratory, Results for this test are shown in table (4.3).

BH.No.	Depth	Cofficient of Permeability (K) (cm/s)
1	3.0	0.02282
4	2.0	0.02322
7	6.0	0.022699
8	8.0	0.02426
9	10.0	0.02378
12	8.0	0.022794

Table (4.3) Results of permeability test

4.6- Free Swelling

Free Swell Index is the increase in volume of a soil on submergence in water, without any external constraints. Test procedure carried out with standard (BS 1377-1990). Results are shown in Table(4.4),

BH.No.	*Depth (m)*	*Initial Volume of Specimen (I)*	*Final Volume of Specimen (F)*	*Free Swell (F.S %)*
1	3.0	156.3	250	60
4	2.0	120.4	170	41.17
6	1.0	149.3	235	57.45
7	6.0	104.2	125	20.0
7	8.0	58.6	81	38.27
8	8.0	124.6	180	44.45
10	10.0	126.8	185	45.94
12	8.0	114.4	155	35.48
13	2.0	58.2	80	37.50

Table (4.4) Free Swelling Test Results

4.7- Swelling Pressure Test

The swelling pressure tests were conducted on undisturbed soil samples. The volume of the soil was kept constant in an odometer cell, while the soil was saturated with water during the test.The results are shown in Table (4.5). Results reflected to very low of swelling pressures.

Borehole No.	**Depth (m)**	**Initial moisture content (%)**	**Final moisture content (%)**	**Swelling Pressure Kpa**	**Plasticity Index (%)**	**Classification of the Samples**
1	4.0m	25.94	28.40	20	41	CH
2	2.0m	14.50	15.54	0	17	SC
8	6.0m	9.21	14.14	10	20	SC
8	10.0m	10.23	15.12	0	16	SC
12	10.0m	10.42	15.97	10	18	SC

Table (4.5): Swelling Pressure Test Results

4.8 Consolidation Test

Consolidation tests provide information for use in evaluating the compressibility of the soils and estimating the settlement of foundations established on these soils. The consolidation tests were performed on clayey samples, according to the ASTM D 2435-03. Swelling pressure was conducted on the samples. Then the samples were loaded beyond the swelling pressure to allow consolidation to proceed. The results of these tests are shown in Appendix (C). Table (4.6) illustrate the summary results of consolidation parameters.

B.H. No.	Depth (m)	Initial moisture content	Final moisture content	Void ratio (e_o)	Degree of saturation (S_r)	Pre consolidation Pressure (P_C)	Over Consolidation Ratio (OCR)
1	4.0	25.937	28.398	0.8696	80.5336	52	0.728
2	2.0	14.498	15.538	0.4295	91.13961	78	1.83
6	2.0	28.116	31.301	0.873	87.2755	90	2.48
6	4.0	10.419	14.196	0.4829	58.25096	90	1.14
8	6.0	9.211	14.136	0.3812	65.243	58	0.45
12	10.0	10.918	15.966	0.5732	49.0731	370	1.99

Table (4.6) Consolidation Test Parameters

4.9 Collapse Potential Test

4.9.1 Single Oedometer Collapse Test

The undisturbed soil specimen at natural moisture content loaded in the conventional oedometer to a stress level ranging between 200 KPa and 400 KPa, and then inundation by distilled water is applied to induce collapse. Abelev (1948) used stress level of 300 KPa and defined the collapse potential (I_e) as: $I_e = \Delta e_c / 1 + e_1$

Δe_c: change in void ratio resulting from saturation

e_1: void ratio just before saturation recommended the using of stress level of 200 KPa, and calculate the collapse potential according to the following equation: Ie= $\Delta e_c/1+e_o$

Δe_c: change in void ratio resulting from saturation

e_o: natural void ratio

The stress level of 200 KPa adopted by (ASTM D 5333-96, 2000) to classify the severity of the collapse problem. Since the idea behind this test is to predict the amount of deformation that a foundation may experience upon subsurface wetting; a loading to the anticipated field loading conditions is recommended. A results obtained from this test in boreholes are shown in Appendix(C-1) and Table(4.7)

BH. No.	Depth	e_o	e_1	e_2	C_P
1	3.0	0.7122	0.6320	0.6206	0.6664
2	4.0	0.4537	0.4105	0.3950	1.0704
4	2.0	0.4780	0.4349	0.4317	0.2118
7	6.0	0.5371	0.4734	0.4635	0.6467
7	8.0	0.6382	0.5781	0.5703	0.4743
8	8.0	0.2690	0.1720	0.1610	0.8684
8	10.0	0.3756	0.3467	0.3158	2.2499
9	10.0	0.3559	0.3185	0.3026	1.1712
11	6.0	0.4740	0.4509	0.4204	2.0706

Table(4.7) Single oedometer and Collapse potential Results

4.9.2 Double Oedometer Collapse Test

Two identical samples are placed in oedometers; one tested at in-situ natural moisture content, and the other is fully saturated before the test begins, and then subjected to identical loading.

Two stress versus strain curves are generated. The difference between the compression curves is the amount of deformation that would occur at any stress level at which the soil get saturated. Critical stress (σcr) represents the stress level at which the dry sample loose structure breaks down and beyond it the two curves converge. This behavior could be explained also by that at high stress level, the limiting void ratio for the saturated sample is approached for particles packing It is common for natural soil that the initial void ratio of the two samples are not initiating from the same point; in this case adjustment of the two curves according to the procedure proposed by shall be adopted for the normally and overconsolidated clays. Results for double oedometer collapse test are shown in Appendix(C-2).

4.10 Pin Hole Test

In the pinhole test, a sample of soil at its natural water content is compacted into a plastic cylinder. A hole is formed in the specimen by inserting a needle through the center of the specimen. Distilled water under specified heads flows through the hole in the specimen. The water is carefully observed for turbidity, and the flow rate is closely monitored to determine if the hole in the sample is enlarging by erosion. Dispersive clays will rapidly erode as water flows through the 1 millimeter hole under a small water head pressure. Rapid enlargement of the hole is reflected in an increasing flow rate and the turbidity of the collected water.

Test was according the BS 1377- part 5, for compacted disturbed samples in the laboratory. Results for samples are shown in Table (4.8).

Pinhole tests results are recorded and interpreted using the following system:

A rating of D-1 or D-2 indicates the soils are dispersive enough to require special designs if the soils must be used in the project.

A rating of ND-1 indicates the soil is not dispersive.

A rating of ND-2, ND-3, or ND-4 indicates the soils are slightly to moderately dispersive. Only one sample gave the result of D2, which indicate dispersive, Other results are non dispersive.

Depth (m)	B.H NO.	Max Hydraulic Head Applied (mm)	Average of Last Head Rate of flow (ml/sec)	Classification
1	3	1020	3.13	ND2
2	4	1020	1.25	ND2
4	2	1020	2.56	ND1
6	1	1020	1.98	ND1
7	6	50	0.9	D2
8	8	50	0.9	ND4
9	10	50	0.8	ND4
11	6	50	0.8	ND4

Table (4.8) Pin hole Test Results

4.11 Sensitivity Tests

For many naturally deposited clayey soil, the unconfined compression strength (q_u) is greatly reduced when the soil is tested after remolding without any change in moisture content. This referred to as sensitivity and defined as

$$St = \frac{qu(undisturbed)}{qu(remolded)}$$

Results of samples for evaluation of sensitivity test are shown in Table(4.9).

BH. No.	Depth (m)	(q_u) unconfined compressive strength (undisturbed) (kpa)	(q_u) unconfined compressive strength (remolded) (kpa)	Sensitivity (S_t)	Description
1	3.0	4048.42	2146.58	1.886	Slightly sensitive
2	4.0	5305.22	2439.74	2.175	Medium sensitivity
7	6.0	2415.77	679.51	3.555	Medium sensitivity
8	8.0	20406.69	825.12	24.732	Medium quick
9	10.0	6784.28	1027.41	6.603	Very sensitive
12	8.0	344.43	586.44	0.587	Slightly sensitive

Table (4.9) Sensitivity Test Results

4.12 Chemical Tests

The test are preformed to determine the PH, organic matter, chloride, sulphate, PH of 1:2.5 soil/water suspension, Na+ and Mg++).

Chemical tests were performed according to BS 1377, Part 3- 1990 on soil samples taken from different depths of borehole. The results are shown in tables at appendix(D).

5.0 Analysis of the Results:

5.1 General review

Problematic soils in Sudan include expansive soils, collapsible soils as well as dispersive soils. The increase in water content of the soil has caused some difficulties in problematic soils and this geotechnical problem may lead to reduction in shear strength or excessive deformations, and consequently increase or decrease in soil thickness or volume. Knowledge of collapsible soils is not widely covered in Sudan, i.e, Generally, the areas where most of development projects were constructed didn't include collapsible soils. This is why many engineers were not exposed to this type of soils. However, now collapsible soils are been encountered more and new studies have been published as ref. "An Experimental Study on the Identification and Classification of Collapse Potential of Some Soils in Sudan", (E.M.Ali and M.A. Osman) 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris 2013).

Collapsible soils have high porosity rates and they are subset of unsaturated soils. In general, collapsibility in soils occurs when fabric of soils with partial saturation and metastable cause the formation of metastable structure under constant stress, and together with increase in water content high inter-aggregate suction or cementing agent becomes weaker or disappears and consequently causes soil structure to be collapsed. And this will cause reduction in volume and sudden collapse of the soil, which is possible with or without applying additional load. Therefore, collapsibility is possible either in the form of increase in water content or simultaneously together with applying the load.

Internationally such soils have recently been studied. These are soils that are found in arid and semiarid zoned and are now studied as partially saturated media.

5.2 Origins of Collapsible Soils

Collapsible soils include Aeolian, alluvial, colluvial, residual deposits as well as volcanic tuff material. Loess is the most known collapsible sand deposit; however compacted fill materials have been reported in the literature. Indiana, USA is one location where compacted fill has been studied and documented. (Identification and Behavior of Collapsible Soils, Joint Transportation Research Program, Purdue University).

5.3 Collapsible Soil Behavior:

Collapse soil is distinguished by high voids with low degree of saturation. In situ strength of natural condition may be high. Collapsible soils experience significant volume change as the moisture content increase whether associated with changes in confining pressures or not. Such volume changes if not considered in the geotechnical studies of the project will lead to differential settlements and major risks to the project.

5.4 Identification of Collapsible Soil

To be able to identify such soils, many methods were introduced. Table(5.1) gives a summary of some of the identification methods.

No.	Investigator , year	Criteria
1	Abelev,1948	$\delta_s=(\Delta e/1+e_L)$ Collapse is probable when: $\delta_s > 2\%$
2	Denisov, 1951	$K=e_L/e_o$ If k = 0.5-0.75 ; highly Collapsible If k = 1.0 ; non Collapsible loam If k = 1.5-2.0 ; non Collapsible soil
3	Priklonski, 1952	$K_D=(N.M.C-P.L)/PI$ If $k_D < 0$; highly Collapsible soil If $k_D > 0.5$; non Collapsible loam If $k_D > 1.0$; Swelling soil
4	Clevenger, 1958	$\gamma_{dry} < 12.6$ kn/m^3; Significant Settlement $\gamma_{dry} < 14.1$ kn/m^3; transitional Settlement
5	Gibbs and Bara, 1962	Collapse is probable when $\gamma_{dry} < 162.3/(1+0.026*L.L)$ Ib/ft^3 *or when:* $e_o > 2.6*L.L/100$
6	Soviet Building Code,1962	Collapse is probable when :is S > 60% and $(e_o-e_L)/(1+e_o) > -0.10$
7	Feda 1964 , 1966	$K_L=(N.M.C/S)-(PL/PI)$ If $K_L > 0.85$; Collapseible Soil
8	Handy, 1973	Clay Content <16% ; high probability for collapse 24%> Clay Content > 16% ; probably collapsible 32%> Clay Content >25% ; probability of collapse of less than 50% Clay Content > 32%; non collapsible
9	Zur and wiseman 1973	$\gamma_{dry} / \gamma_{dry\ L.L} < 1.1$; Soil prone to collapse $\gamma_{dry} / \gamma_{dry\ L.L} < 1.3$; Soil prone to swell

Table (5.1) Summary of Identification methods for collapse soil

5.5 Evaluation of Collapse Potential

A simplification of the volume change in the consolidation e-log-p graph given in Fig(3) leads to

$C_P = (e_2 - e_1)/(1+e_o)$

Where

C_P : Collapse potential

e_o: initial void ratio

e_1: void ratio

e_2: void ratio

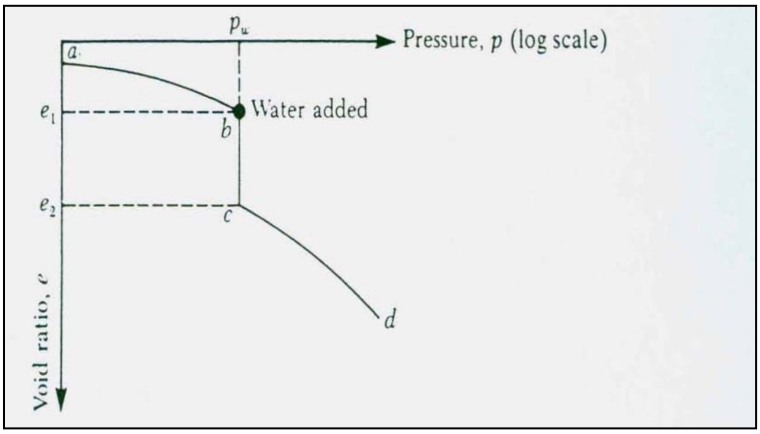


Fig.(3) Nature of variation of void ratio
with pressure for a collapsing soil

5.6 Classification of Collapsible soil

Classification of collapsible soils as non-collapsible, low, medium, high, very high collapsibility potential as given in Table (5.2).

Cp: Collapse Classification

Collapsibility degree	Percentage of soil collapsibility
0	**Non-collapsible**
0.1- 2	**Low collapsible**
2.1- 6	**medium collapsible**
6.1- 10	**Almost high collapsibe**
>10	**High collapsible**

Table (5.2) Collapse soil classification

5.7 Use of Collapsible Soils as A compaction Fill Material

Some compacted fill materials may have some collapse potential and the engineer may be compelled to use them. A detailed study was carried out for the Indiana loess (identification and Behavior of collapsible soils, Joint Transportation Research Program, Purdue University). The recommendations of this study were:

1- Compaction effort should be high as needed.
2- Compaction should be carried out wet of optimum.
3- Preloading of compacted fill may be considered
4- Sometime stabilization or grouting, maybe appropriate.

Estimates of collapse of a compacted fill due to increase in moisture content may be estimated from C_P values determined from results of single or double oedometer tests.

5.8 The Actual Situation in Kosti Thermal Power Station, Rabak is the Following:

1- For all foundation units in the power plant main elements and river water intake pump house, the existing expansive soils were excavated and main foundations are rested on the natural non expansive soil. But the backfilling was done using local fill materials from borrow areas, located outside power station area. However this fill, was not identified originally as possessing any collapse potential. The fill was placed and compacted by the client. The client has all the details about fill material, compaction testing, compaction operation and quality control.
2- The compacted backfill area was exposed for some periods of time and the rainy season may have caused wetting of those fills or other sources of moisture may also have contributed to wetting. The in situ moisture content and consequently the degree of saturation of subsoil as shown in soil profile is high.

3- After the installation, differential settlement were observed at few location in floors resting on compacted backfill. It is expected that collapse may have occurred.

4- The current soil investigation was carried out in the soil that has already experienced significant volume change due to soil collapse. The client has determined the number of borehole to be drilled and locations and depth. Laboratory test were carried out on collected soil samples. Few samples slipped during collection and at depths sample quantity is very less due to which some tests were carried out on the sample collected from other depths than those specified by the client.

5.9 Identification of Collapsible Soil

Due to the fact that compacted fill has already collapsed and experienced settlement it is expected that volumetric, density, moisture content characteristics cannot be used fully to identify the potential of the soil.

However published literature about collapse behavior of compacted fill in Indiana has indicated that plot fall between A-Line & U-Line as shown in figure (6).

The plot of LL against PL for Kosti power station, Rabak are shown in same fig. which shows very high level of consistency with the result from Indiana.

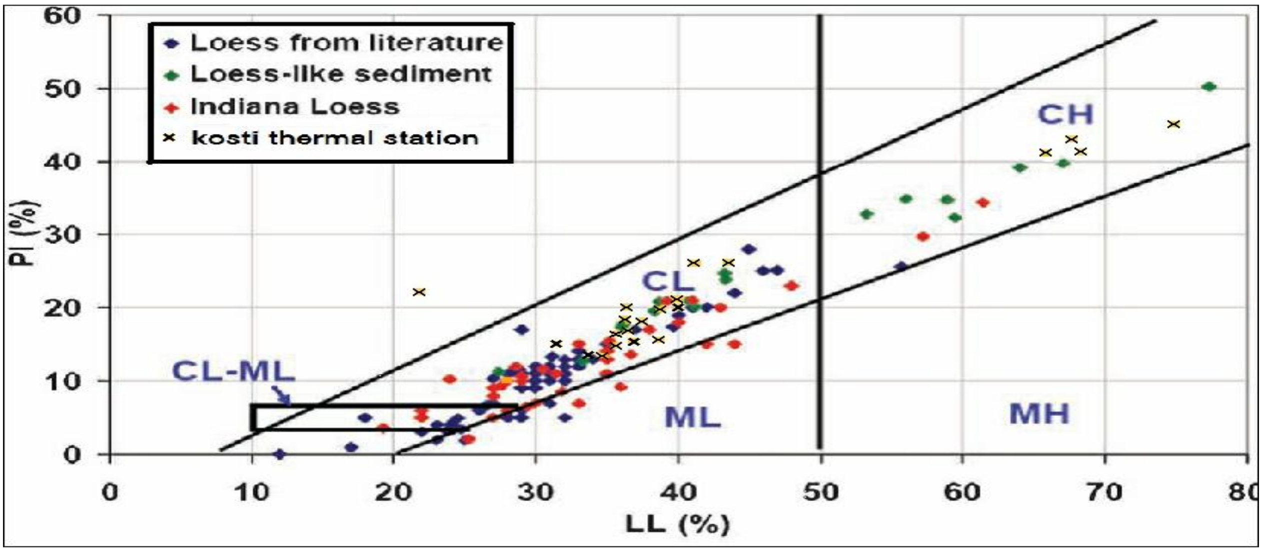
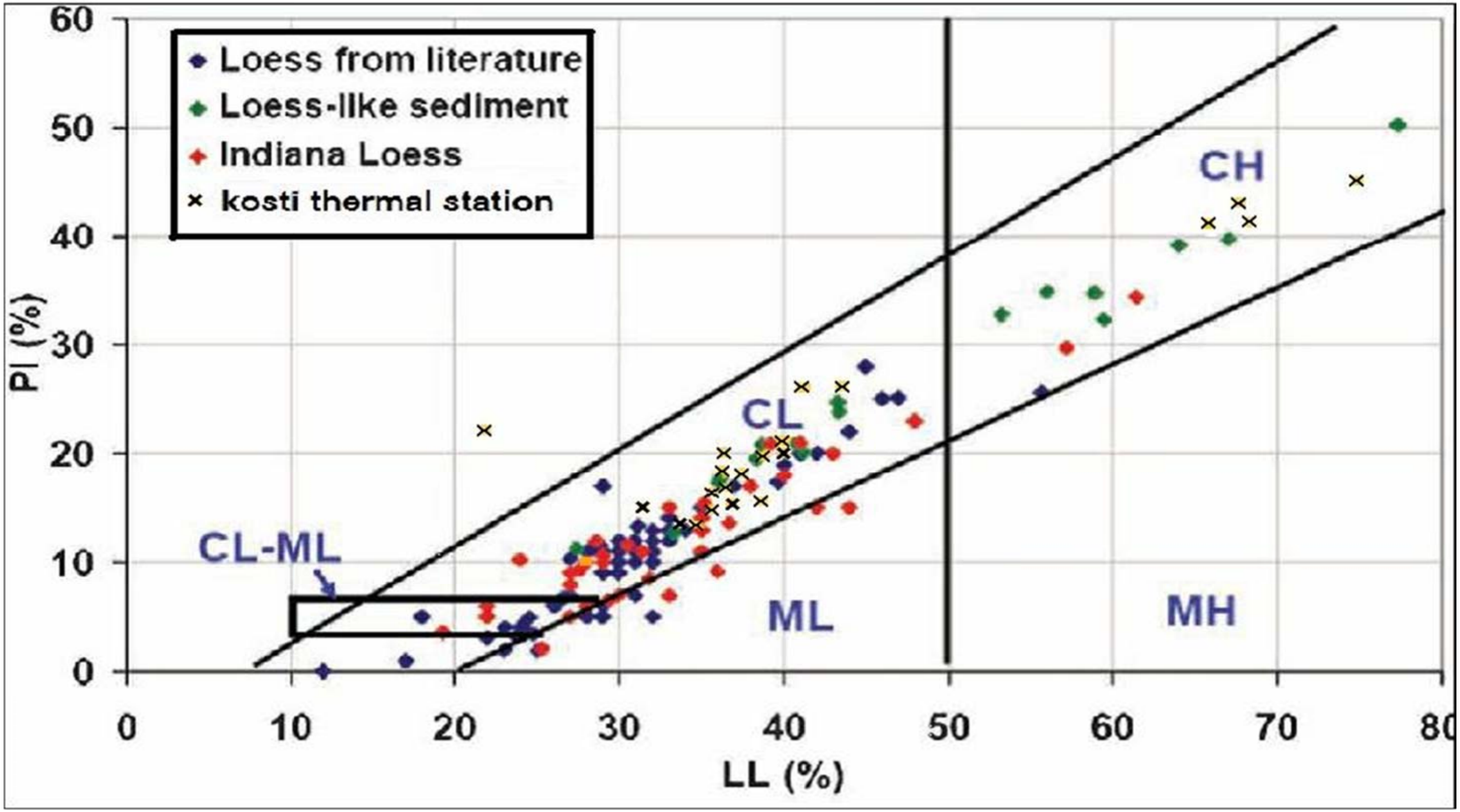


Fig.(6) Behavior of compacted fill in Indiana, A- Line & U- Line



Loess from literature
Loess-like sediment
Indiana Loess
kosti thermal station
CH
CL
CL-ML
ML
MH
PI (%)
LL (%)
0
10
20
30
40
50
60
70
80

The grain size in Indiana and other location indicate that for (CL) compacted fill, clay content between (10 – 30 %) is critical for collapse potential. When silt is mixed with clay at about equal value the potential of collapse is greater. For sandy clay the same condition exist.

5.10 Evaluation

We carried out oedemeter test to determine the collapse potential. The oedemeter test carried out by single and double oedemeter type.

Because of the reason mentioned about the collapse in field, the result of the oedemeter test gave values that are small compared with the actual value if collapse did not happen earlier.

Results from the single oedometer are given in table (4.7) and show that the collapse potential vary between (1.0 – 2.0) with indicate low to medium collapse potential.

For the double oedemeter test two tests were carried out for undisturbed samples one sample was conduct without adding any more water in the test. In second sample water was added from the beginning. Five tests were carried out with double oedemeter method, it is noted that the initial moister content for both test were not equal although the samples were physically near to each other. This may be due to heterogeneity in the soil or due to stress release or other sample disturbance. This condition was reported also in Indiana soil for samples that where treatment from compacted fill materials. (Identification and Behavior of Collapsible Soils, Joint Transportation Research Program, Purdue University).

In order to asses the collapse potential of the original fill material from borrow areas, the two samples given by he client were tested and the report is furnished in appendix (F).

5.11 Collapse Classification

According to table (5.2) and based on the assumption and results mentioned previously, the collapse potential of the backfill soil at site is expected to be in the range C_P value from (1 to 2). These low values may be due to the reason that existing backfill has already experienced significant volume change due to soil collapse.

But the C_p values of the original soil from borrow area ranges between 1 to 7 (Ref. Appendix (F) Table.3). However, the C_p Values of this soil compacted at 8% moisture content (which is less by about 2% – 3% from O.M.C) is ranging between 3 to 7 which shows medium to high collapsible nature of the soil.

5.12 Data About the Fill Material

The client has supplied ESD with some data about the fill materials. This included proctor compaction test and quality control records for fill in river water intake pump house area. Presentation of the results of the compaction controll is given in figure (7). This shows the moisture content values of different layers with the average moisture content (amc) ± standard deviation value.

The optimum moisture content from the compaction test is also shown. The final moisture content determined by ESD also, plotted for all boreholes in the project, it's clear that;

1. Compaction was carried out at dry than optimum moisture content.
2. Moisture content has increased directly after wards.

6.0 Discussion of the Results:

After review of all the results of this study, the consultant believes that the major cause of the settlement is due to the soil collapse induced by increase of moisture content in compacted fill materials.

6.1 Proposal of Remedial Measure

For the existing condition of the installed equipment/ground floor slab already constructed in power plant, one of the remedial option is to use soil stabilization with grouting to stabilize the fill material. This is a specialized procedure calling for experienced sub contractor in this field.

Second option is to remove the equipments and floors, then recompact the exsiting fill at high moisture content, so that the collapse potential of the fill soil is minimuzed.

Third option is to excavate the fill and make a new fill with non collapsible, non expansive and non dispersive fill materials.The fill should be compacted at the wet than optimum moisture content and high compacted effort. This should be based on detailed study of compaction process of the fill materials.

Drainage of the site should be a high priority, so that rain or other site sources of water should not cause problems to the fills.

7.0 Conclusion

A geotechnical of investigation was carried out at Kosti power plant, Rabak to study the settlement after construction. It's found that the backfill soil below ground floor level was soaked and moisture content increased considerably. It's believed that the major cause of the settlement is collapse of the fill material. This material has not been identified to have collapse potential prior to construction. The compaction operation did not address this issue. The fact, that the compaction was carried dry of optimum moisture content values and surface with poor drainage led to collapse induced by change in moisture content.

Three remedial options are given in the report:

1. Stablization by cement grouting carried out by highly experienced specialized subcontractor.
2. Remove the equipments and floors, then compact the exsiting fill at high moisture content.
3. Excavate the fill and make a new fill with non collapsible, non expansive and non dispersive fill materials.

This report is based on laboratory and field tests made on boreholes that were drilled in the present site and two soil samples from borrow areas. ESD is not responsible for soil conditions at site different from those exposed at the boreholes drilled in this investigation.

8. References:

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5- Materials Testing, Field Manual 5-472*, NAVFAC M0 330, AFJMAN 32-1221(I), Headquarters Department of the Army Department of the Navy Department of the Air Force Washington, DC, 27 October 1999.
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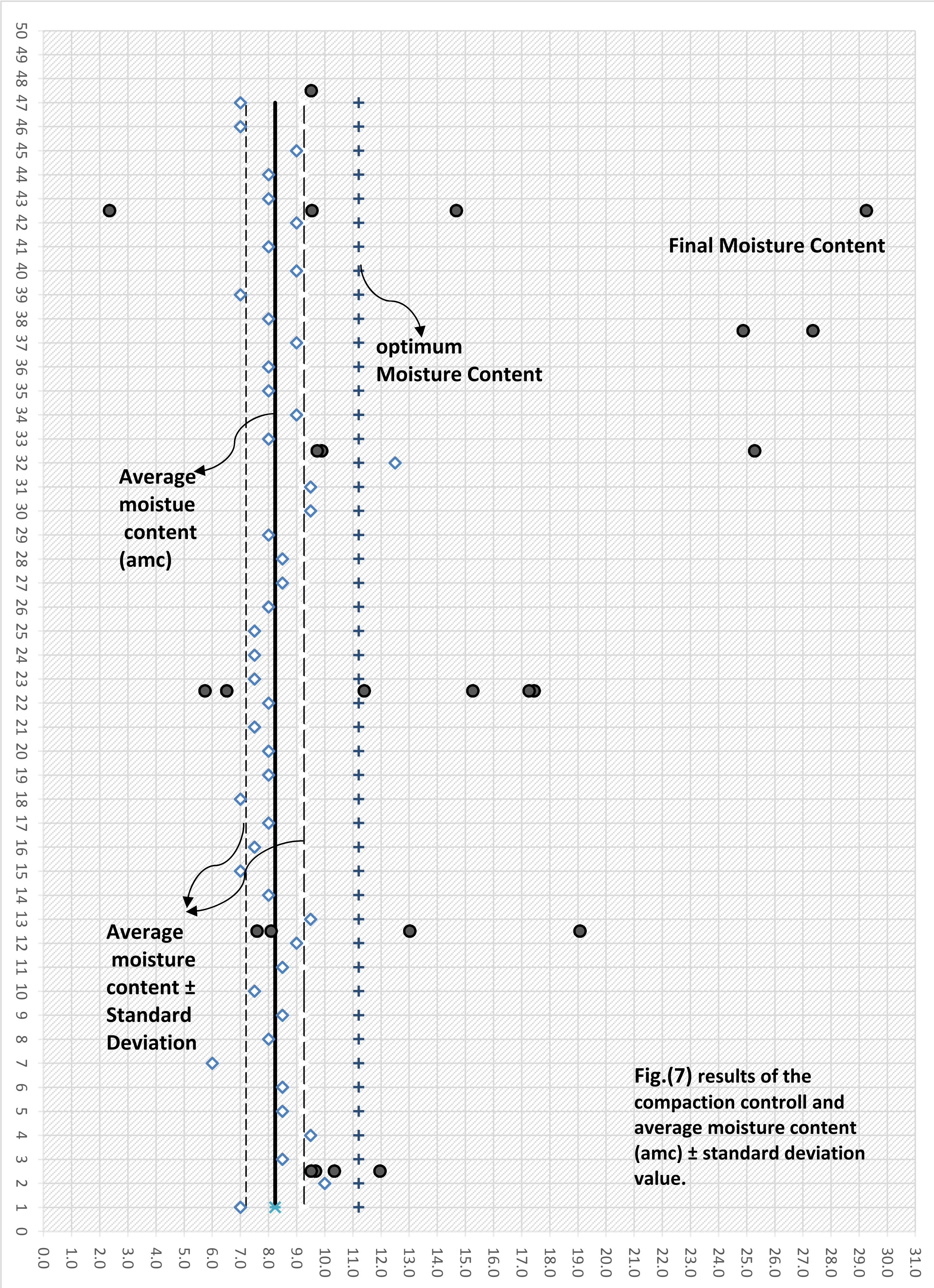


Fig.(7) results of the compaction controll and average moisture content (amc) ± standard deviation value.

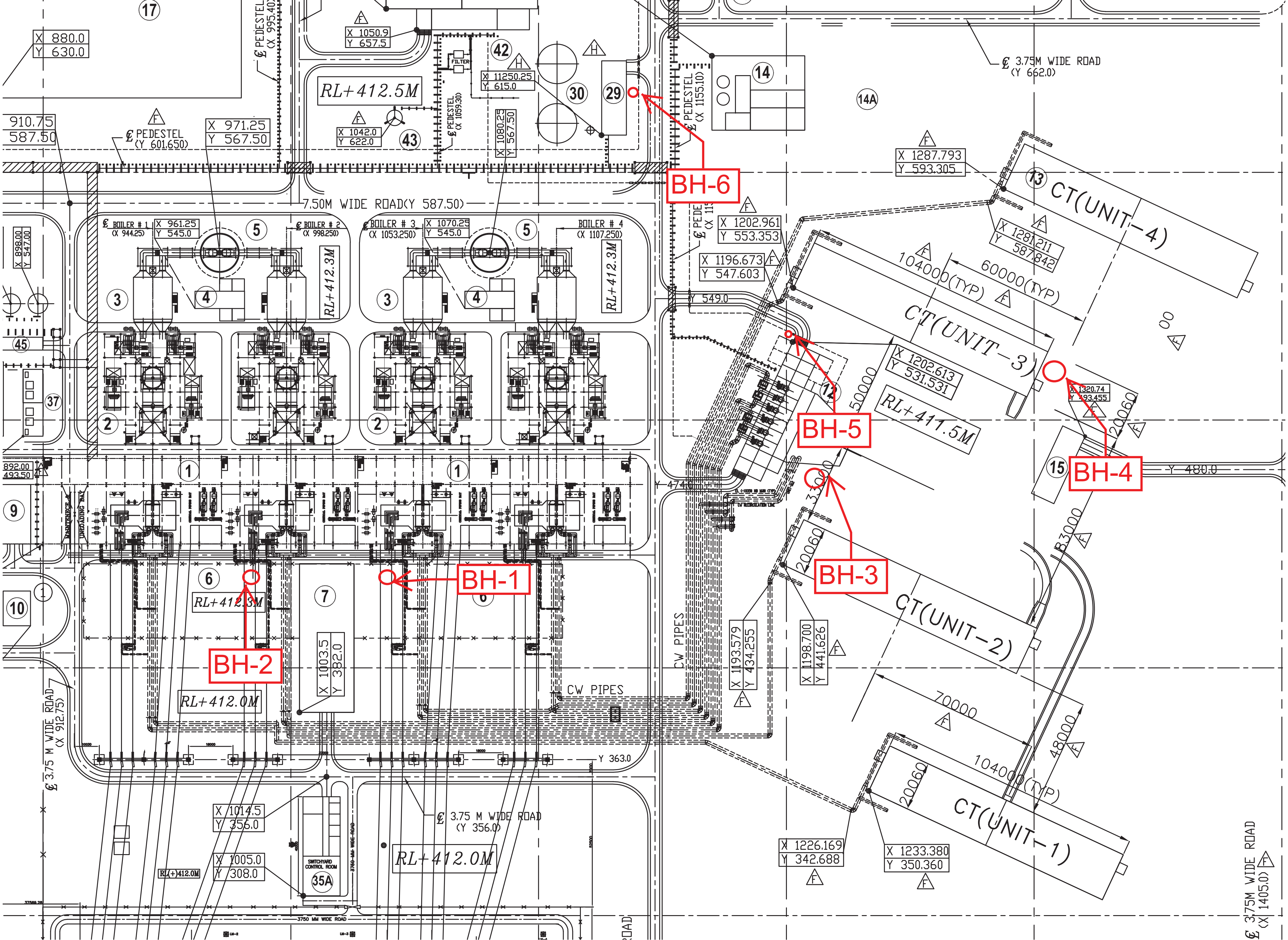
APPENDIX (A)
LOCATION OF BOREHOLES
AND
SUMMARY OF
LABORATORY TEST RESULTS

FIGURES (1)
LOCATION OF BOREHOLES

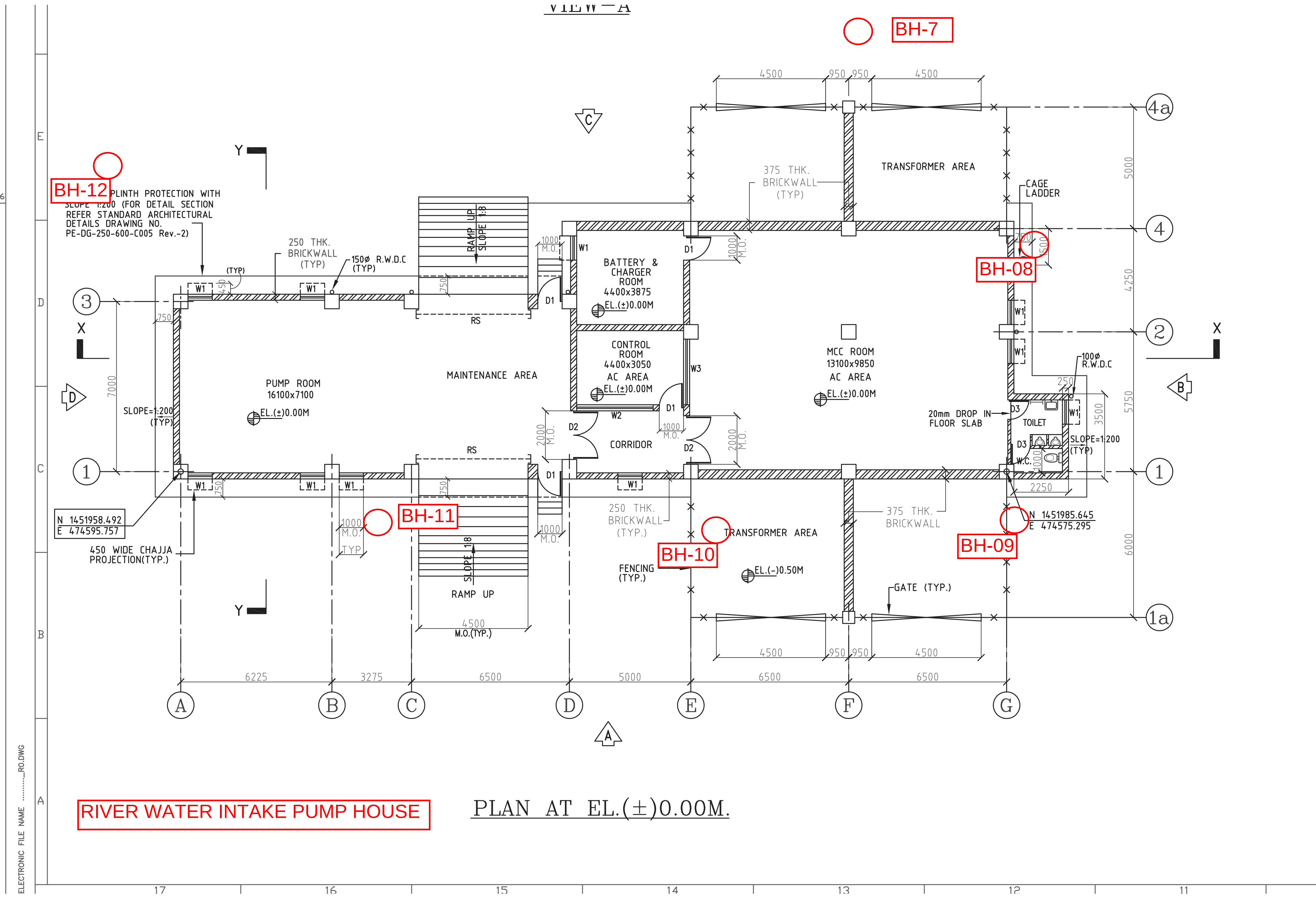

Kosti Thermal Power Station
Power Station Area
Location of Boreholes
BH -2
BH -6
BH -1
BH -5
BH -3
BH -4
© 2013 Google
Image © 2013 DigitalGlobe
Google earth


Kosti Thermal Power Station
Pump Station Area
Location of Boreholes
BH -9
BH -8
BH -10
BH -7
BH -11
BH -12
23 متر
© 2013 Google
Image © 2013 DigitalGlobe
Google earth

Kosti Thermal Power Station
Pipe Line Area
Location of Boreholes



BH-1
BH-2
BH-3
BH-4
BH-5
BH-6
CT(UNIT-1)
CT(UNIT-2)
CT(UNIT-3)
CT(UNIT-4)
RL+412.5M
RL+412.3M
RL+412.0M
RL+411.5M
7.50M WIDE ROAD(Y 587.50)
3.75M WIDE ROAD (Y 662.0)
3.75 M WIDE ROAD (Y 356.0)
3.75 M WIDE ROAD (X 912.75)
3.75M WIDE ROAD (X 1405.0)
PEDESTEL (Y 601.650)
BOILER # 1 (X 944.25)
BOILER # 2 (X 998.250)
BOILER # 3 (X 1053.250)
BOILER # 4 (X 1107.250)
CW PIPES
X 880.0 Y 630.0
X 971.25 Y 567.50
X 1050.9 Y 657.5
X 1042.0 Y 622.0
X 11250.25 Y 615.0
X 1080.25 Y 567.50
X 961.25 Y 545.0
X 1070.25 Y 545.0
X 1287.793 Y 593.305
X 1202.961 Y 553.353
X 1196.673 Y 547.603
X 1281.211 Y 587.842
X 1202.613 Y 531.531
X 1193.579 Y 434.255
X 1198.700 Y 441.626
X 1003.5 Y 382.0
X 1014.5 Y 356.0
X 1005.0 Y 308.0
X 1226.169 Y 342.688
X 1233.380 Y 350.360
Y 549.0
Y 480.0
Y 363.0
104000(TYP)
60000(TYP)
70000
48000
50000
20060
SWITCHYARD CONTROL ROOM



RIVER WATER INTAKE PUMP HOUSE

PLAN AT EL.(±)0.00M.

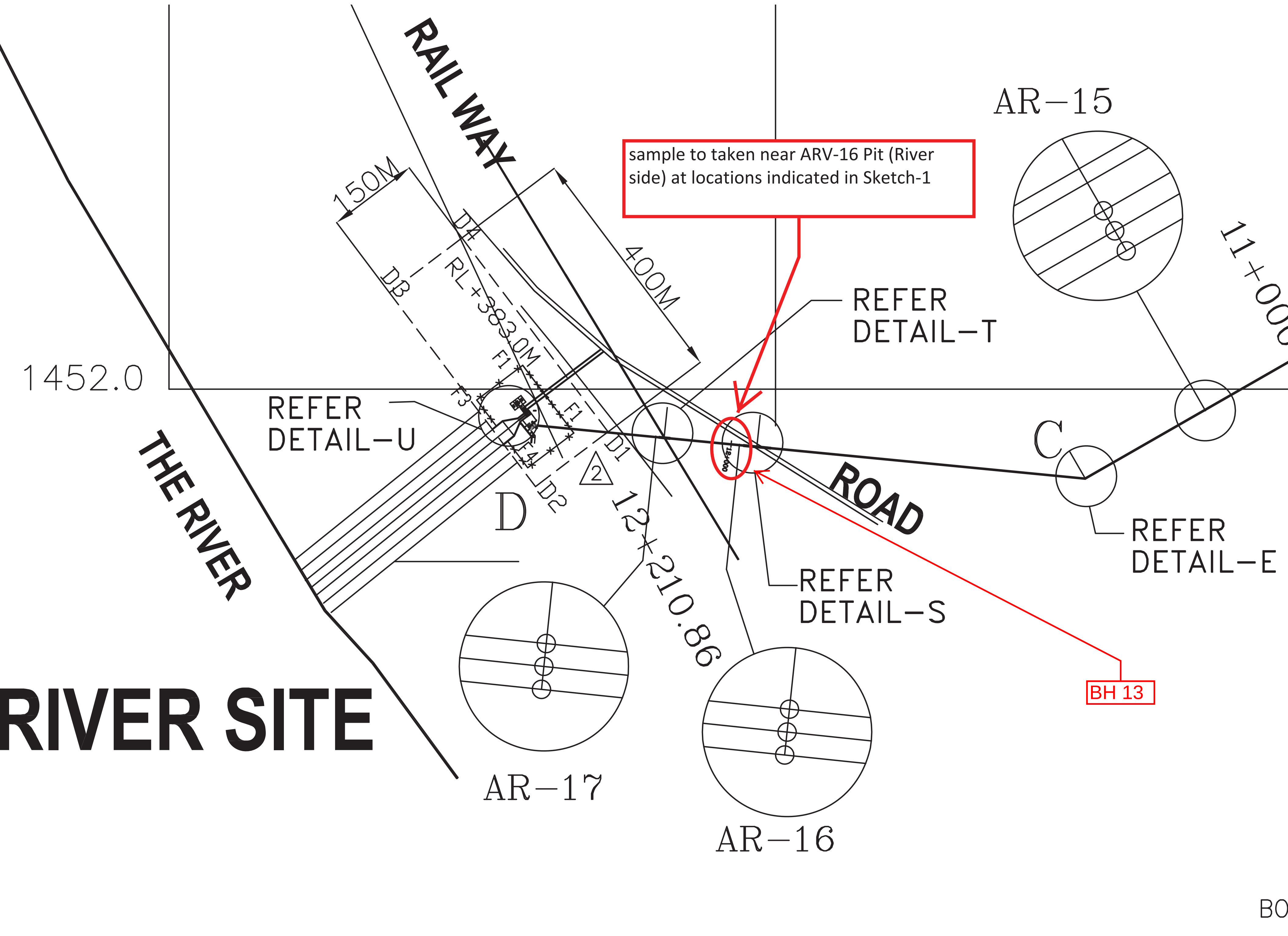

RAIL WAY
150M
400M
D4
D3
RL+383.0M
F1
F3
F4
D1
D2
2
1452.0
REFER
DETAIL–U
REFER
DETAIL–T
REFER
DETAIL–S
REFER
DETAIL–E
sample to taken near ARV-16 Pit (River side) at locations indicated in Sketch-1
AR–15
11+000
ROAD
C
D
12+210.86
THE RIVER
RIVER SITE
AR–17
AR–16
BH 13
BO

FIGURE (2)

BOREHOLE LOGS AND SUMMARY OF LABORATORY TEST RESULTS

Soil Profile
Kosti Thermal Power Station
Power Station Area

B.H # 1 Coordinates: E: 480719 N: 1460153 Starting date: 24/11/2013

Elevation : From the existing ground surface level Ground Water Level : Not observed Finishing date: 24/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0	Dark brown silty clay of low plasticity	CL	37	21	16		9.51	54.14								UDS
2.0	Light grey moist poorly graded silty sand	SP-SM		N.P	N.P		2.34	5.64								UDS
3.0	Dark gery silty clay of high plasticity	CH	68	25	43	19.07	24.87	84.72								UDS
4.0			67	26	41	19.00	25.28	74.42								UDS
Bottom of borehole @ 4.0m																

Soil Profile
Kosti Thermal Power Station
Power Station Area

B.H # 2 Coordinates: E: 480705 N:1460207 Starting date: 24/11/2013
Elevation : From the existing ground surface level Ground Water Level : Not observed Finishing date: 24/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0	Dark brown dry silty clay of low plasticity	CL	45	19	26			58.13								
2.0	Light grey moist clayey sand	SC	39	22	17	11.14	14.67	41.61								UDS
3.0	Geryish brown moist silty clay of high plasticity	CH	68	27	41	15.0	27.35	80.53								UDS
4.0	Geryish brown moist clayey sand	SC	44	18	26		9.89	29.21								UDS
Bottom of borehole @ 4.0m																

Soil Profile
Kosti Thermal Power Station
Power Station Area

B.H # 3 Coordinates: E: 480877 N:1460040 Starting date: 25/11/2013
Elevation : From the existing ground surface level Ground Water Level: Not observed Finishing date: 25/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0	Soft dark brown moist silty clay of low plasticity	CL	45	18	27	12.29		63.13								
									1	1	1	1		3		
2.0																
3.0	Very loose dark brown moist clayey sand	SC	37	19	20	9.71		45.72	1	1	1	1	1	4		
4.0			40	18	22	10.00		29.69								
									2	1	1	1	1	4		
5.0			45	23	22	9.21		33.54								
6.0	Soft dark brown silty clay of low plasticity .	CL	43	21	22	9.86		59.77	2	1	1	1		3		UDS (Empty)
7.0	Dark brown clayey sand .	SC	48	26	22	7.71		36.66								
8.0	Soft dark brown silty clay of low plasticity .	CL	43	23	20	9.14		53.23	2	1	1	1		3		UDS (Empty)
9.0																
10.0																UDS (Empty)

Bottom of borehole @ 10.0m

Soil Profile
Kosti Thermal Power Station
Power Station Area

B.H # 4 Coordinates: E: 480944 N:1469983 Starting date: 26/11/2013

Elevation : From the existing ground surface level Ground Water Level : Not observed Finishing date:26/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0	Dark brown moist clayey sand															
2.0	Light grey moist poorly graded silty sand	SC	41	19	22	11.71	9.54	21.44								UDS
3.0																UDS (Empty)
4.0																

Bottom of borehole @ 4.0m

Soil Profile
Kosti Thermal Power Station
Power Station Area

B.H # 5 Coordinates: E: 480920 N:1460080 Starting date: 25/11/2013

Elevation : From the existing ground surface level Ground Water Level :Not observed Finishing date: 25/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0	Loose dark brown moist clayey sand															
									2	1	1	1	1	4		
2.0																
3.0									4	3	1	2	1	7		
4.0			48	20	28	10.79		35.93								
									3	2	1	1	2	6		
5.0																
6.0	Dark brown moist clayey sand	SC	40	19	21		17.44	13.81								UDS
7.0																
8.0	Same but poorly and dense	SP-SC	34	18	16			10.11	5	11	9	8	7	35		UDS (Empty)
9.0																
10.0	Same but very dense		20	6	14			39.07	51					51		UDS (Empty)
Bottom of borehole @ 10.0m																

Soil Profile
Kosti Thermal Power Station
Power Station Area

B.H # 6 Coordinates: E: 480988 N:1460171 Starting date: 26/11/2013
Elevation : From the existing ground surface level Ground Water Level : Not observed Finishing date: 26/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0	Dark brown moist clayey sand															UDS (Empty)
2.0	Light grey moist silty clay of high plasticity	CH	75	30	45	20.00	29.25	89.89								UDS
3.0	Medium dense greyish brown moist clayey sand	SC	43	20	23	11.38		24.80	6	5	4	4	3	16		UDS (Empty)
4.0			36	16	20	10.57	9.73	48.70								UDS
Bottom of borehole @ 4.0m																

Soil Profile
Kosti Thermal Power Station
Pump Station Area

B.H # 7 Coordinates: E: 474637 N:1452189 Starting date: 18/11/2013
Elevation : From the existing ground surface level Ground Water Level : 8.0m Finishing date: 18/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0	Medium dense dark brown moist clayey sand	SC	42	24	18	7.50		40.55								
									7	5	5	5	5	20		
2.0																
3.0	Dark brown moist silty clay of low plasticity	CL	20	9	11			53.37	7	3	2	3	4	12		
4.0			38	15	23			72.61								
	same but medium stiff.								2	2	2	1	2	7		
5.0																
6.0			34	19	15	7.29	17.26	75.63								UDS
7.0																
8.0	same but greyish brown .		35	20	15	6.79	19.07	73.91								UDS
9.0																
10.0																

Bottom of borehole @ 10.0m

Soil Profile
Kosti Thermal Power Station
Pump Station Area

B.H # 8 Coordinates: E: 475637 N:1452202 Starting date: 19/11/2013

Elevation : From the existing ground surface level Ground Water Level : Not observed Finishing date: 19/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits L.L %	Atterberg Limits P.L %	Atterberg Limits P.I %	Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result Blows for inch 6	3	3	3	3	N Value	pen. inch	Remarks
1.0	Dark brown moist clayey sand															
2.0	Light grey moist poorly graded silty sand					10										
3.0																
4.0																
5.0																
6.0		SC	39	19	20	10.79	6.51	29.58								UDS
7.0																
8.0	Dark brown silty clay of low plasticity.	CL	32	16	16	9.14	7.59	56.61								UDS
9.0																
10.0	Dark brown clayey sand	SC	36	20	16	8.64	9.67	39.08								UDS

Bottom of borehole @ 10.0m

Soil Profile
Kosti Thermal Power Station
Pump Station Area

B.H # 9 Coordinates: E: 475649 N:1452204 Starting date: 22/11/2013

Elevation : From the existing ground surface level Ground Water Level : Not observed Finishing date: 23/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits L.L %	Atterberg Limits P.L %	Atterberg Limits P.I %	Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result Blows for inch 6	SPT Result Blows for inch 3	SPT Result Blows for inch 3	SPT Result Blows for inch 3	SPT Result Blows for inch 3	SPT Result N Value	SPT Result pen. inch	Remarks
1.0																
	Loose dark brown moist clayey sand								2	1	2	1		4		
2.0																
3.0	same but medium dense								6	4	5	4	6	19		
4.0																
	same but dense								9	9	10	9	11	39		
5.0																
6.0		SC														UDS (Empty)
7.0																
8.0	same but very dense		39	20	19	8.00		41.79	24	13	14	17	7	51		UDS (Empty)
9.0																
10.0	same but greyish brown		41	22	19		9.51	29.06								UDS
Bottom of borehole @ 10.0m																

Soil Profile
Kosti Thermal Power Station
Pump Station Area

B.H # 10 Coordinates: E: 474670 N:1452189 Starting date: 21/11/2013

Elevation : From the existing ground surface level Ground Water Level : Not observed Finishing date: 22/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0																
	Very dense dark brown moist clayey sand								20	12	13	16	10	51		
2.0																
3.0									17	14	15	16	6	51		
4.0																
									21	13	15	15	8	51		
5.0																
6.0		SC	37	18	19	9.86	5.74	42.76								UDS
7.0																
8.0	Greyish brown moist silty clay of low plasticity .	CL	38	20	18	7.29		74.88	51					51		UDS (Empty)
9.0																
10.0			35	20	15	7.86	11.96	73.77								UDS

Bottom of borehole @ 10.0m

Soil Profile
Kosti Thermal Power Station
Pump Station Area

B.H # 11 Coordinates: E: 474667 N:1452182 Starting date: 23/11/2013

Elevation : From the existing ground surface level Ground Water Level : 3.0m Finishing date: 23/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0																
	Loose dark brown moist clayey sand	SC							1	1	2	2	1	6		
2.0																
3.0									2	1	2	1	2	6		
4.0																
									2	1	2	2	2	7		
5.0																
6.0	Dark brown moist silty clay of low plasticity	CL	38	19	19	9.14	15.26	51.41								UDS
7.0																
8.0	Dark brown moist clayey sand	SC	28	18	10	8.00	8.09	45.91								UDS
9.0																
10.0	same but greyish brown		36	19	17	7.86	10.34	35.05								UDS
Bottom of borehole @ 10.0m																

Soil Profile
Kosti Thermal Power Station
Pump Station Area

B.H # 12 Coordinates: E: 474635 N:1452175 Starting date: 20/11/2013

Elevation : From the existing ground surface level Ground Water Level : Not observed Finishing date: 20/11/2013

Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0																
	Dark brown moist clayey sandy gravel															
2.0																
3.0																
4.0																
5.0																
6.0	Light brown clayey sand	SC	40	18	22	8.79	11.40	32.55								UDS
7.0																
8.0	same but greyish brown		37	19	18	5.34	13.02	43.25								UDS
9.0																
10.0																UDS (Empty)

Bottom of borehole @ 10.0m

Soil Profile
Kosti Thermal Power Station
Pipe Line Area

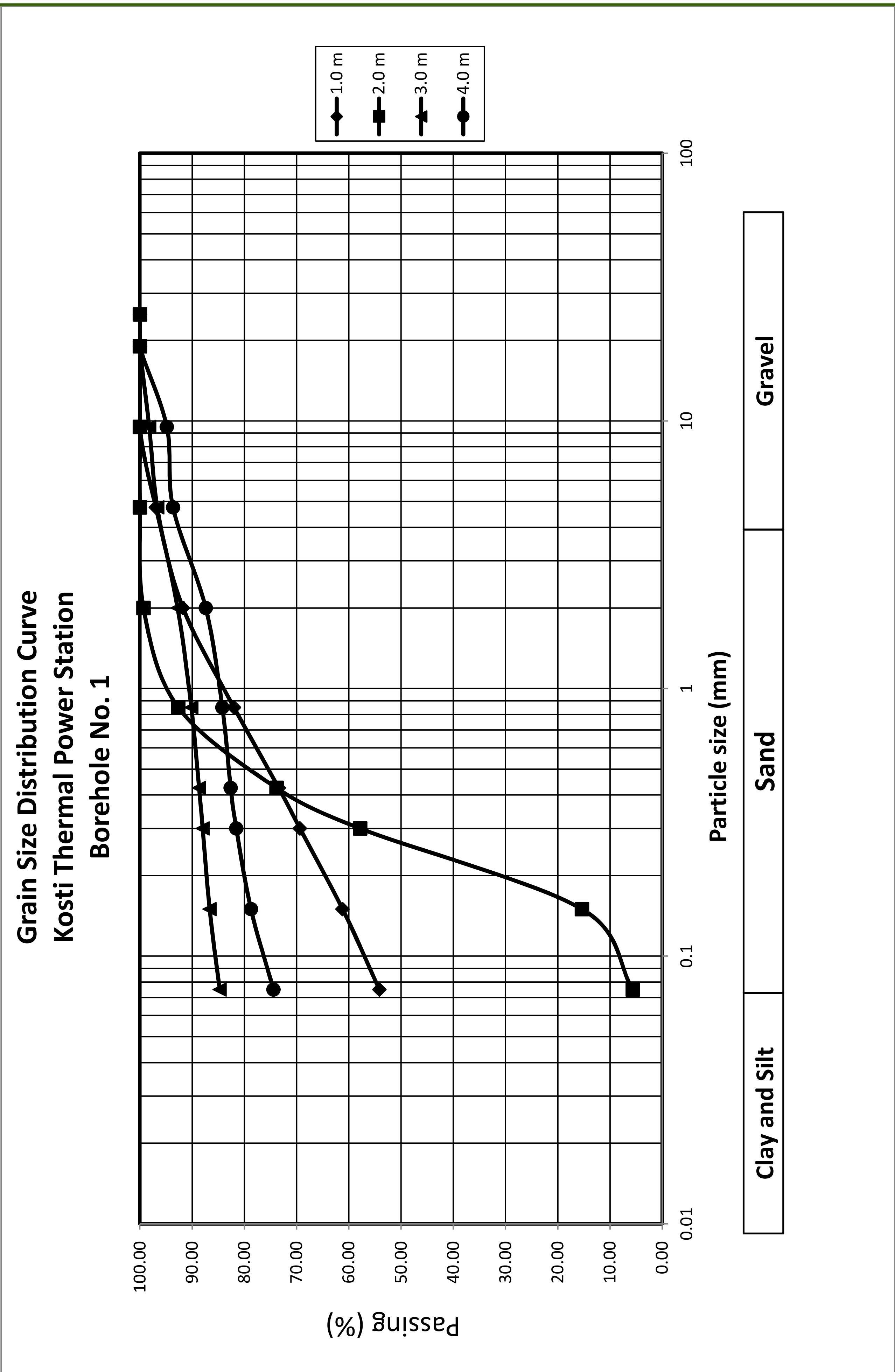
B.H # 13 Coordinates: E: 480988 N:1460171 Starting date: 24/11/2013

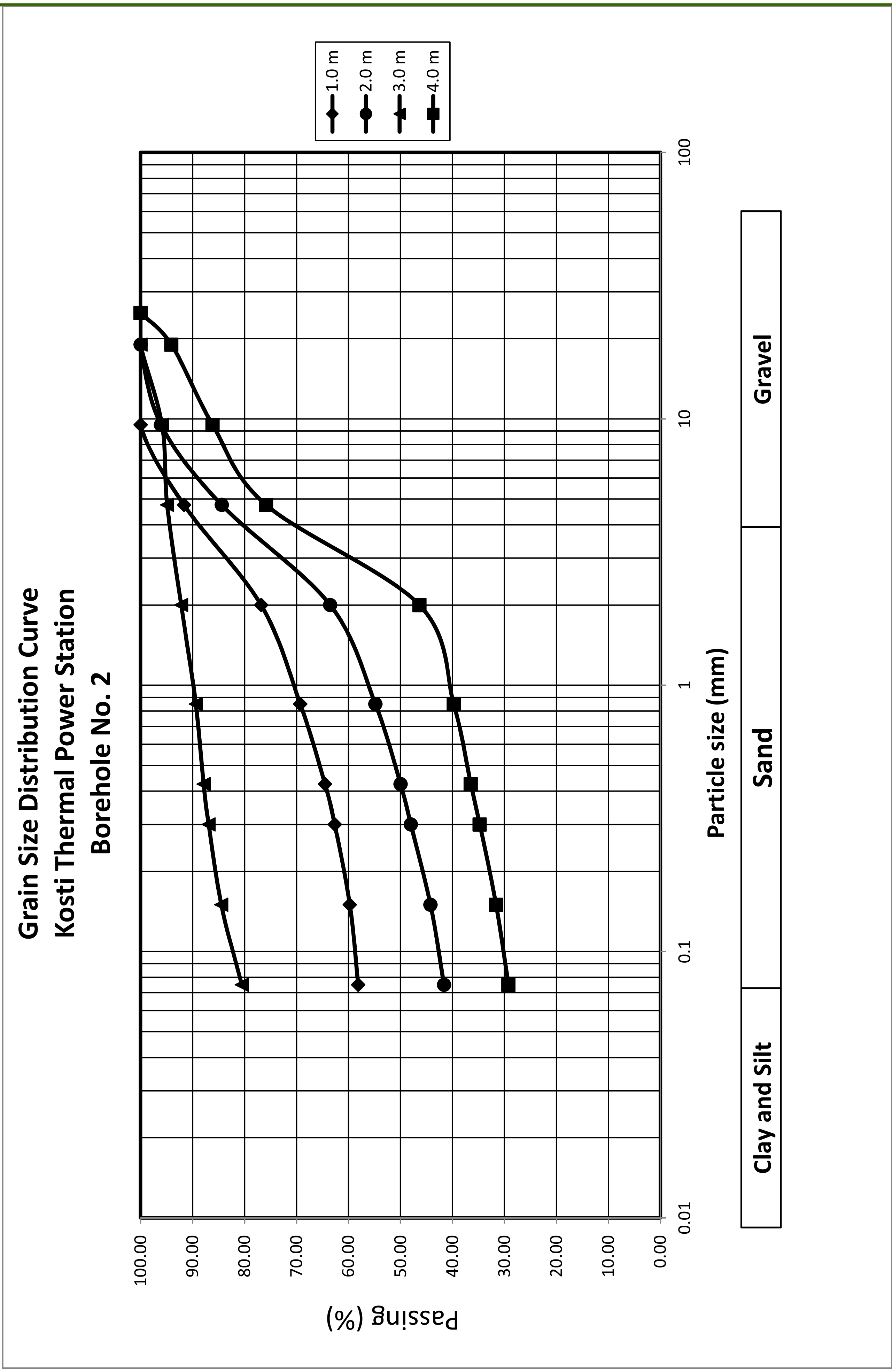
Elevation : From the existing ground surface level Ground Water Level : Not observed Finishing date: 24/11/2013

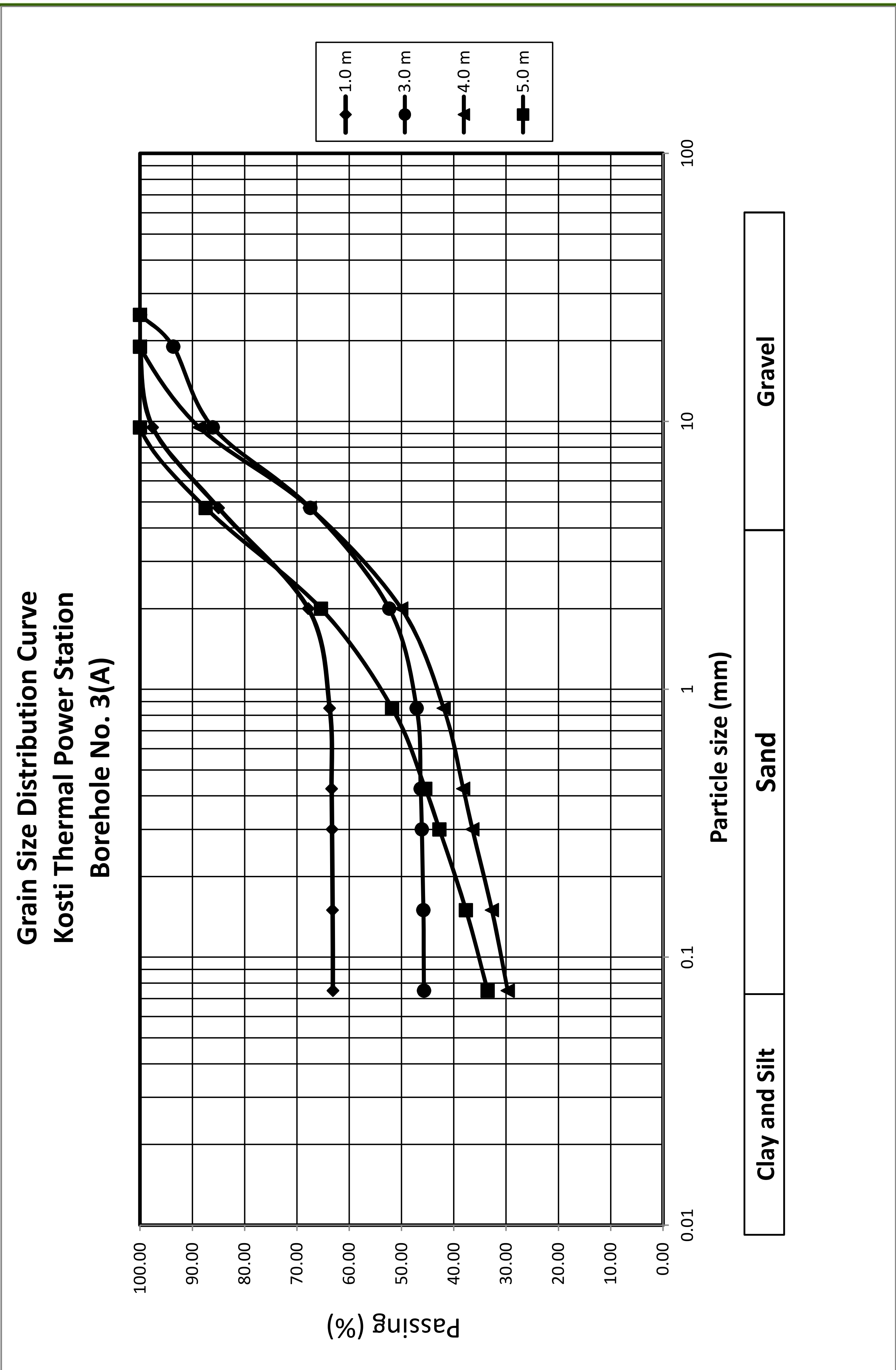
Depth (m)	Description	Group Symbol	Atterberg Limits			Shrinkage Limit (%)	N.M.C %	%pass sieve #200	SPT Result							Remarks
			L.L %	P.L %	P.I %				Blows for inch					N Value	pen. inch	
									6	3	3	3	3			
1.0	Reddish brown poorly graded silty sand	SP-SM		NP	NP			9.12								
2.0	Same but loose.	SM		NP	NP			14.78	1	1	2	1		4		UDS (Empty)
3.0				NP	NP			17.90	1	1	1	1		3		UDS (Empty)
4.0	Medium dense light brown clayey sand	SC	23	15	8	2.07		29.25	5	3	5	5	6	19		UDS (Empty)

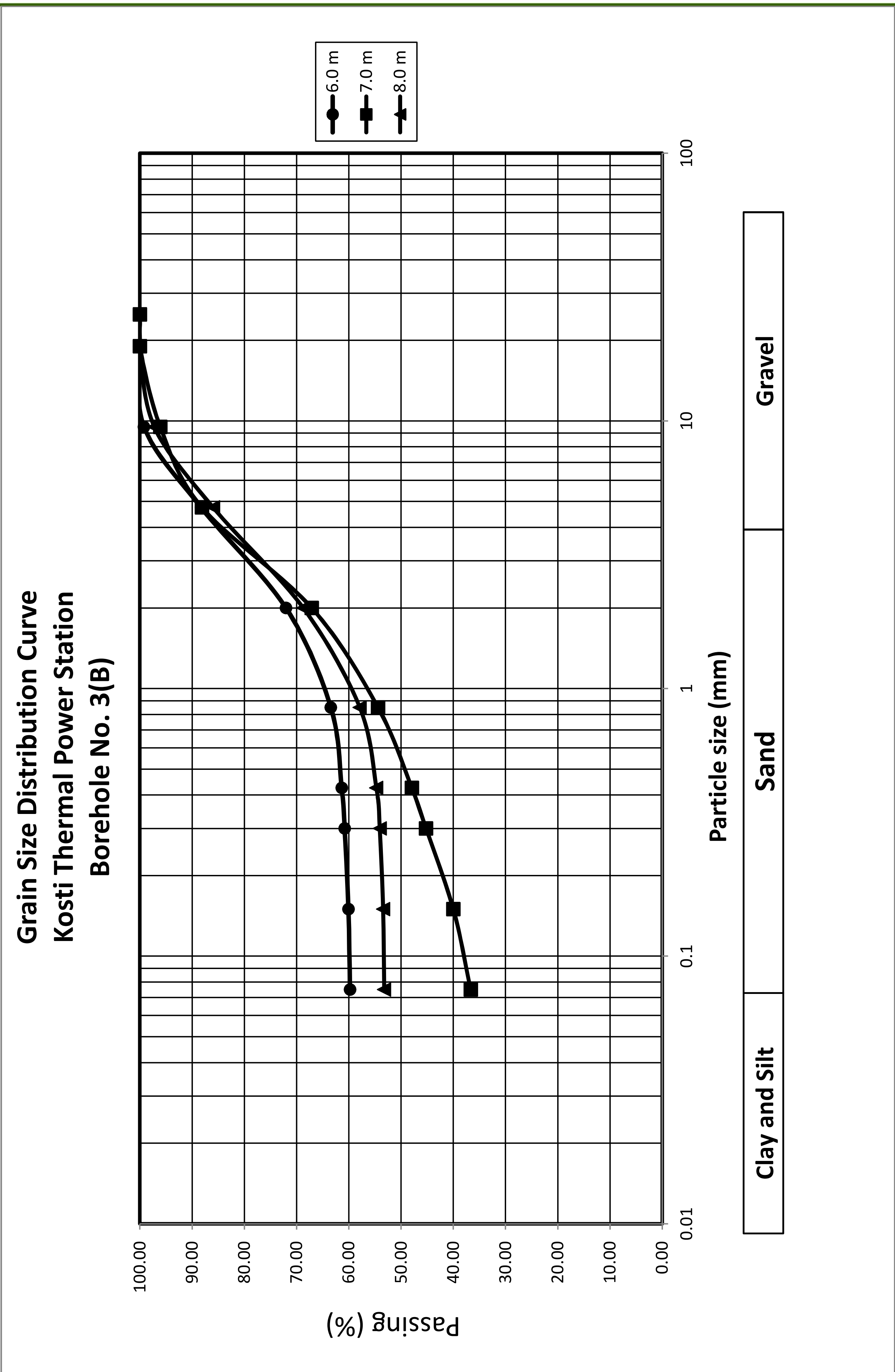
Bottom of borehole @ 4.0m

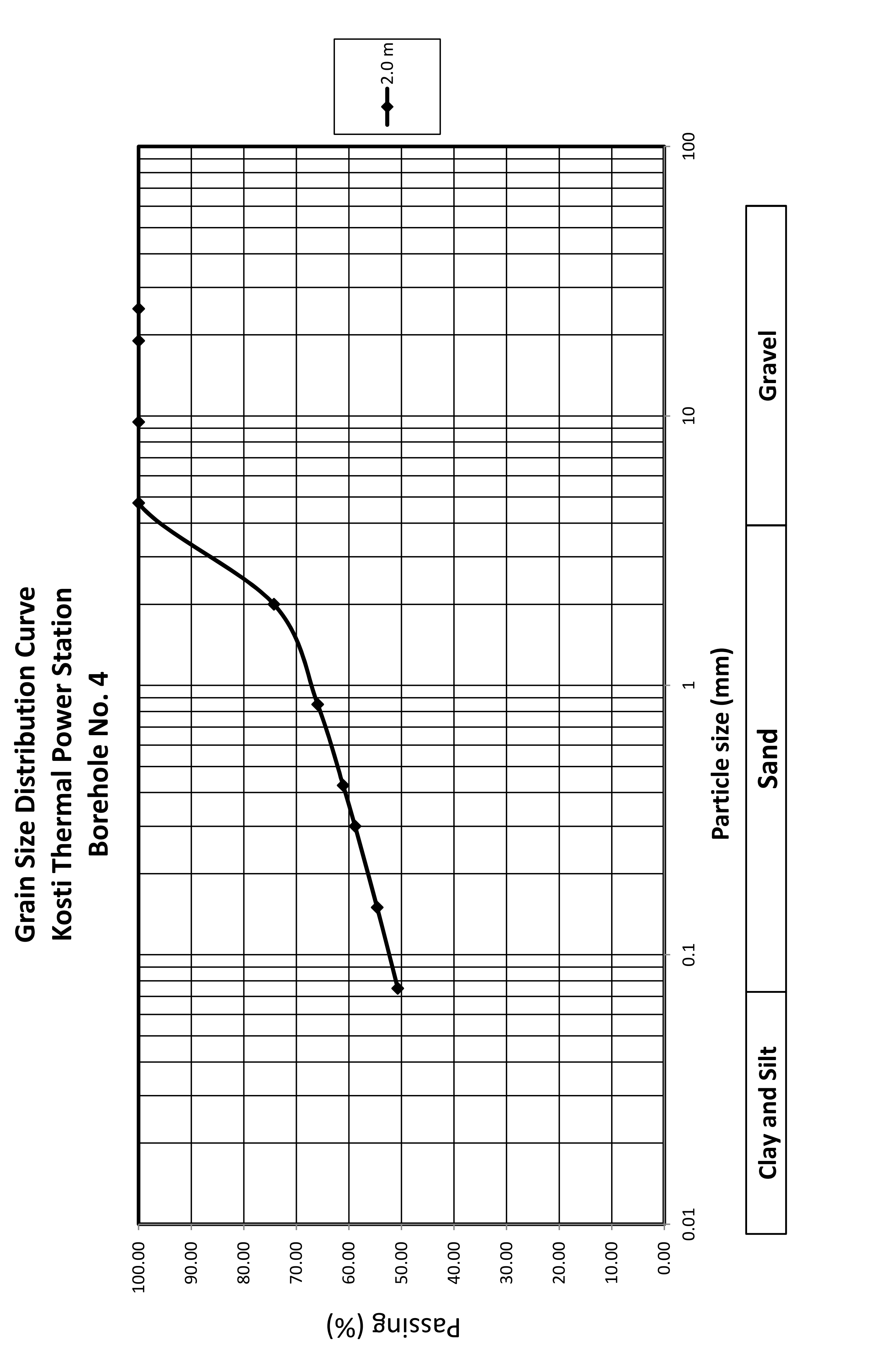
APPENDIX (B-1)
GRAIN SIZE DISTRIBUTION RESULTS
SIEVE ANALYSIS TESTT

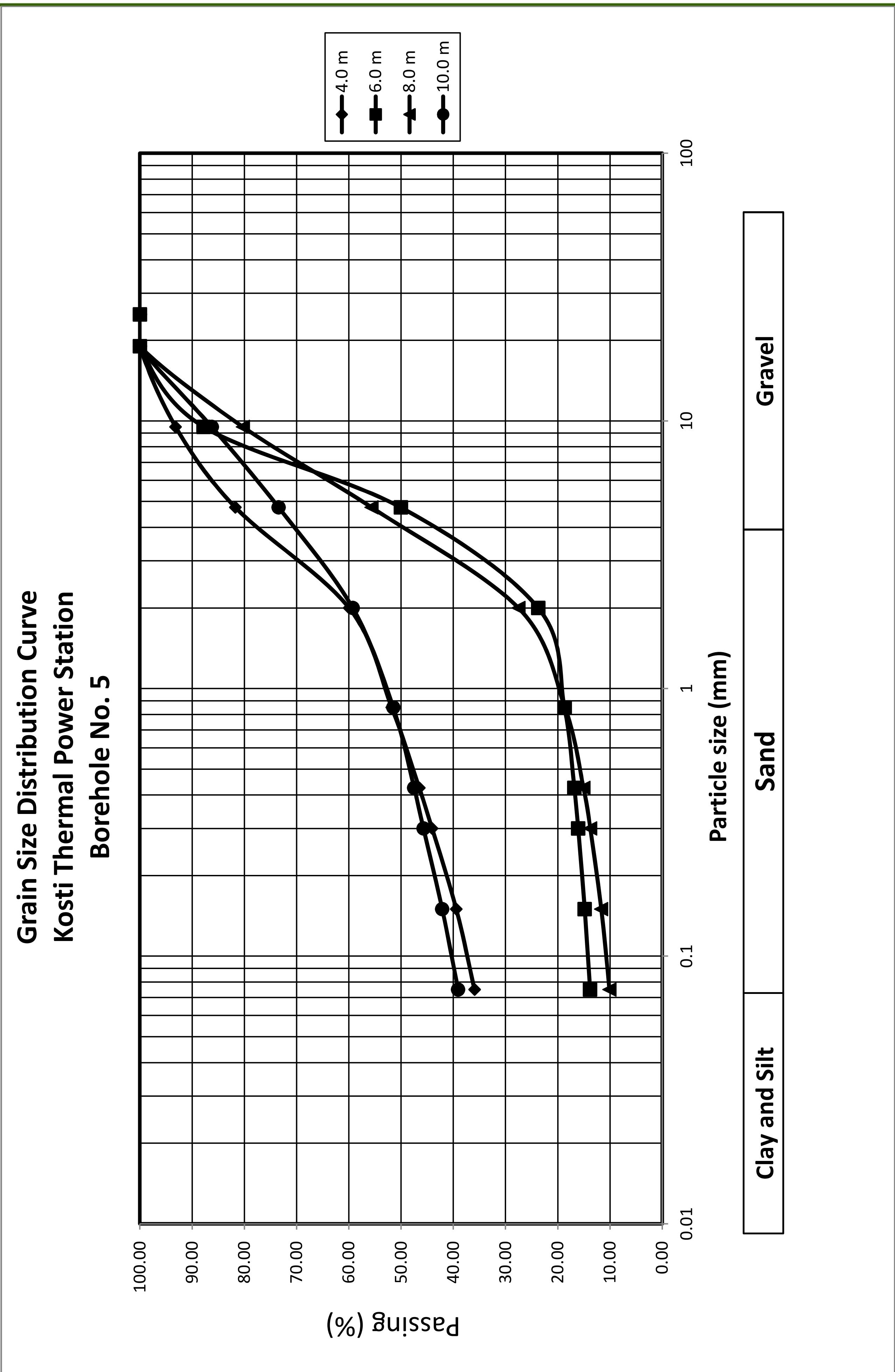

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 1
1.0 m
2.0 m
3.0 m
4.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

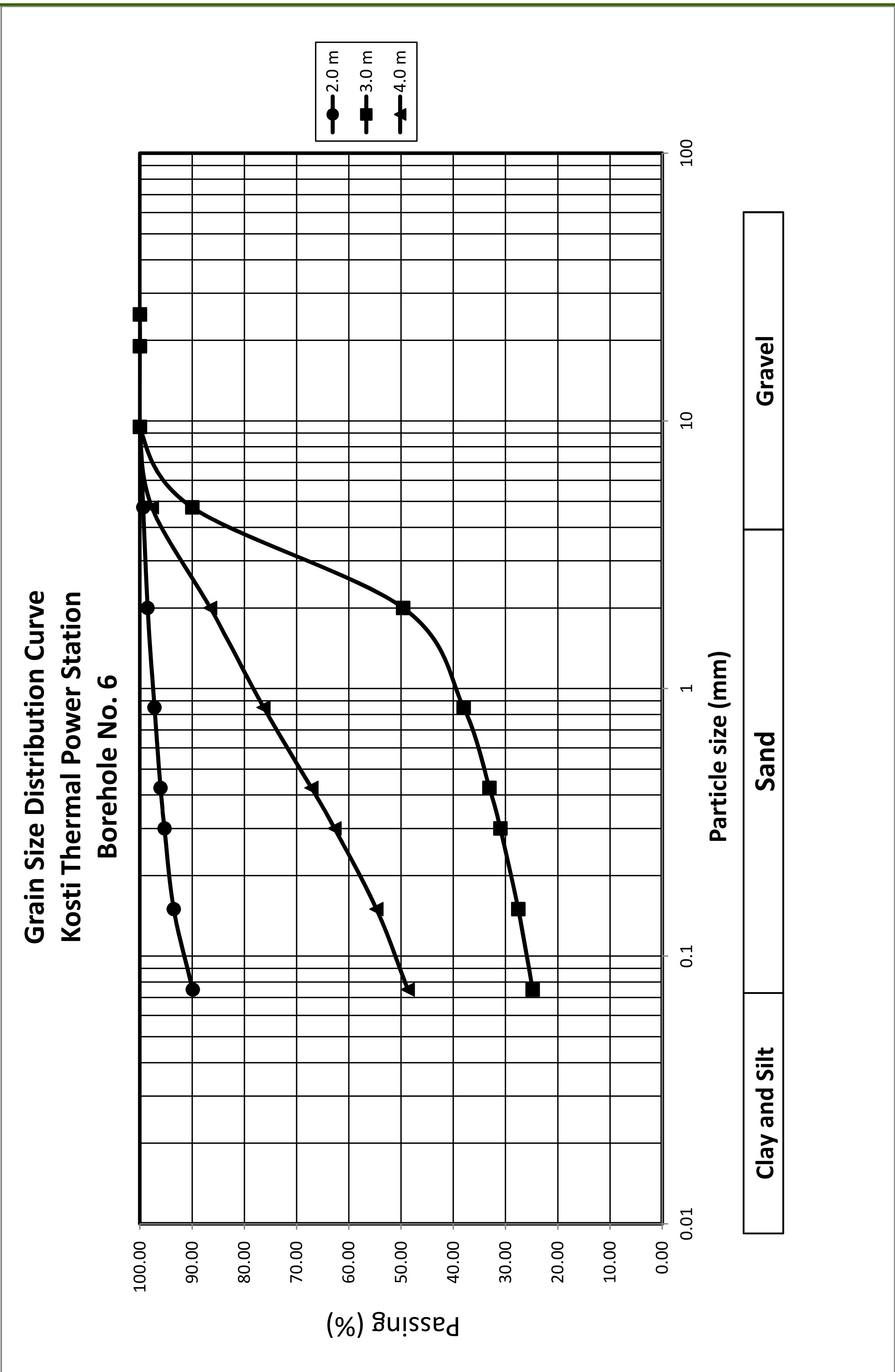

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 2
1.0 m
2.0 m
3.0 m
4.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

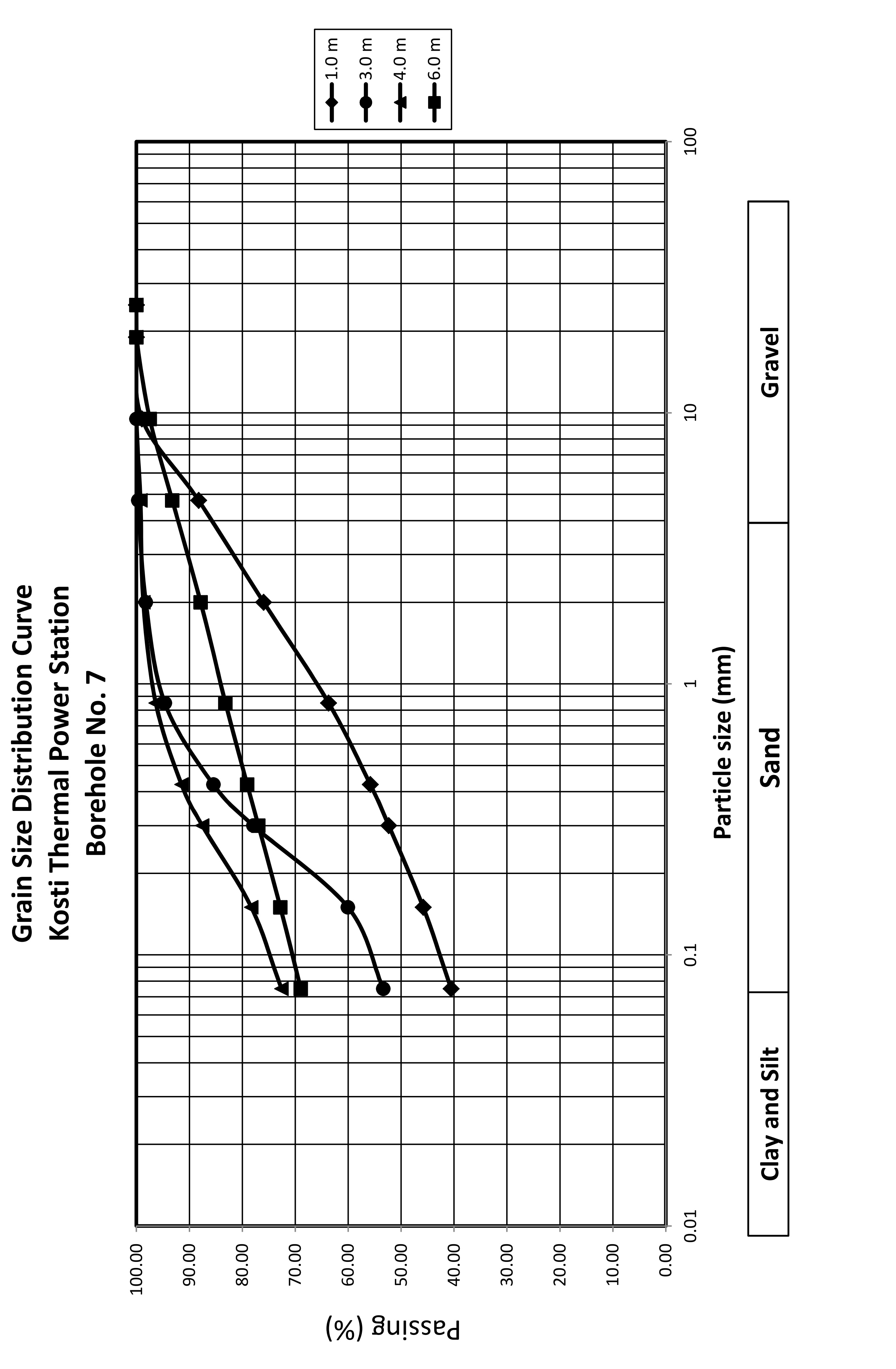

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 3(A)
1.0 m
3.0 m
4.0 m
5.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

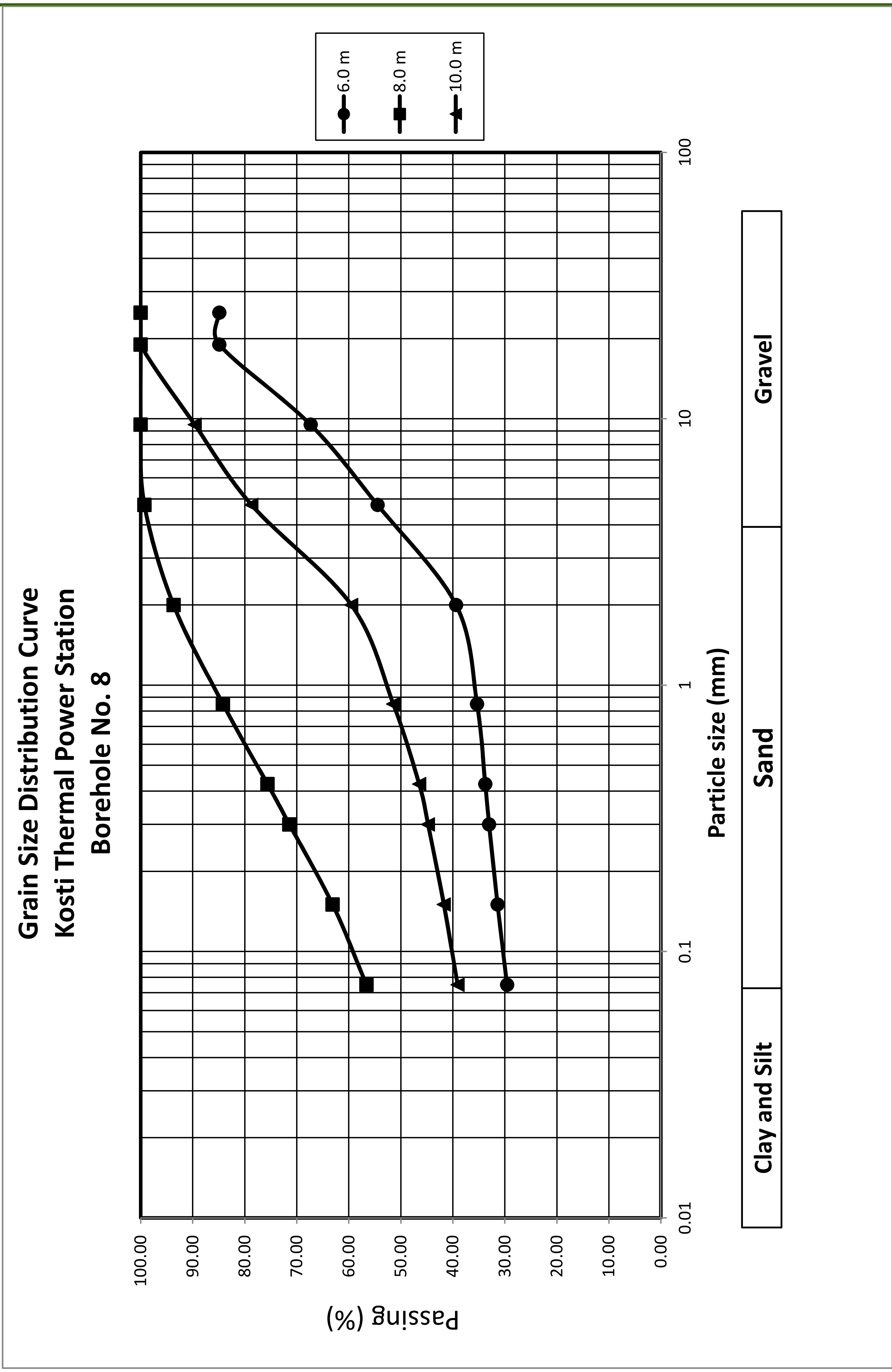

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 3(B)
6.0 m
7.0 m
8.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

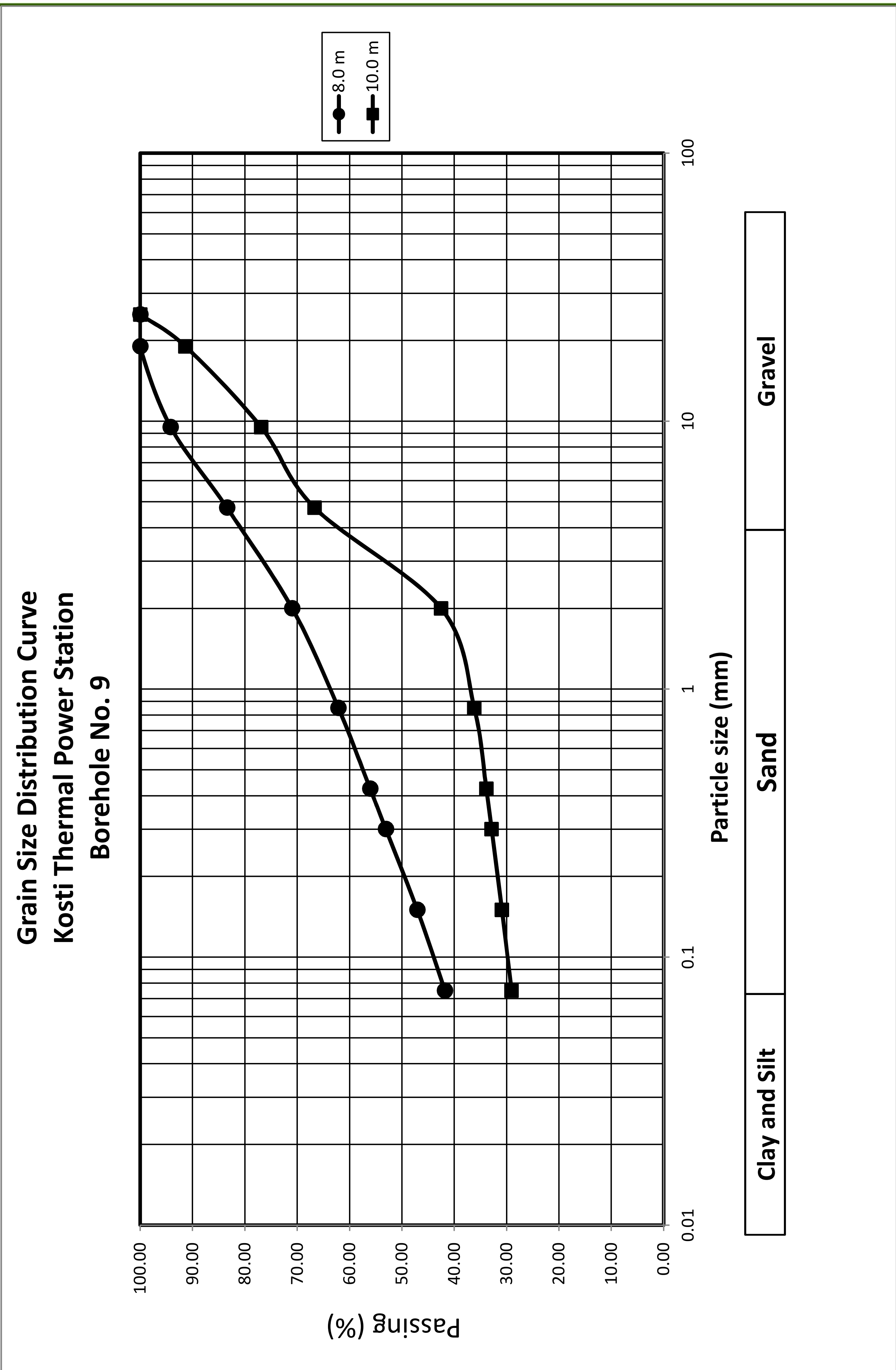

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 4
2.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

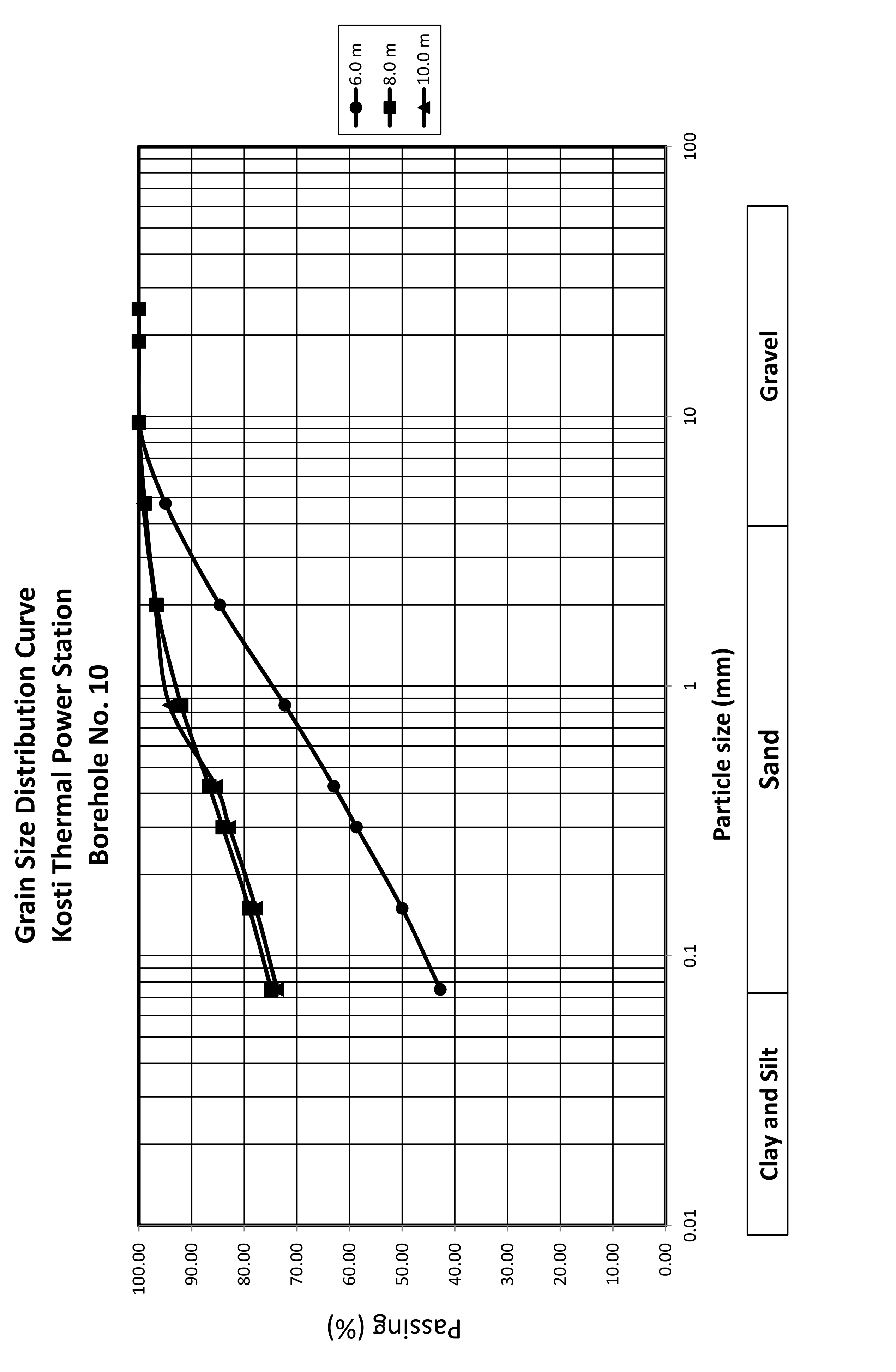

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 5
4.0 m
6.0 m
8.0 m
10.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

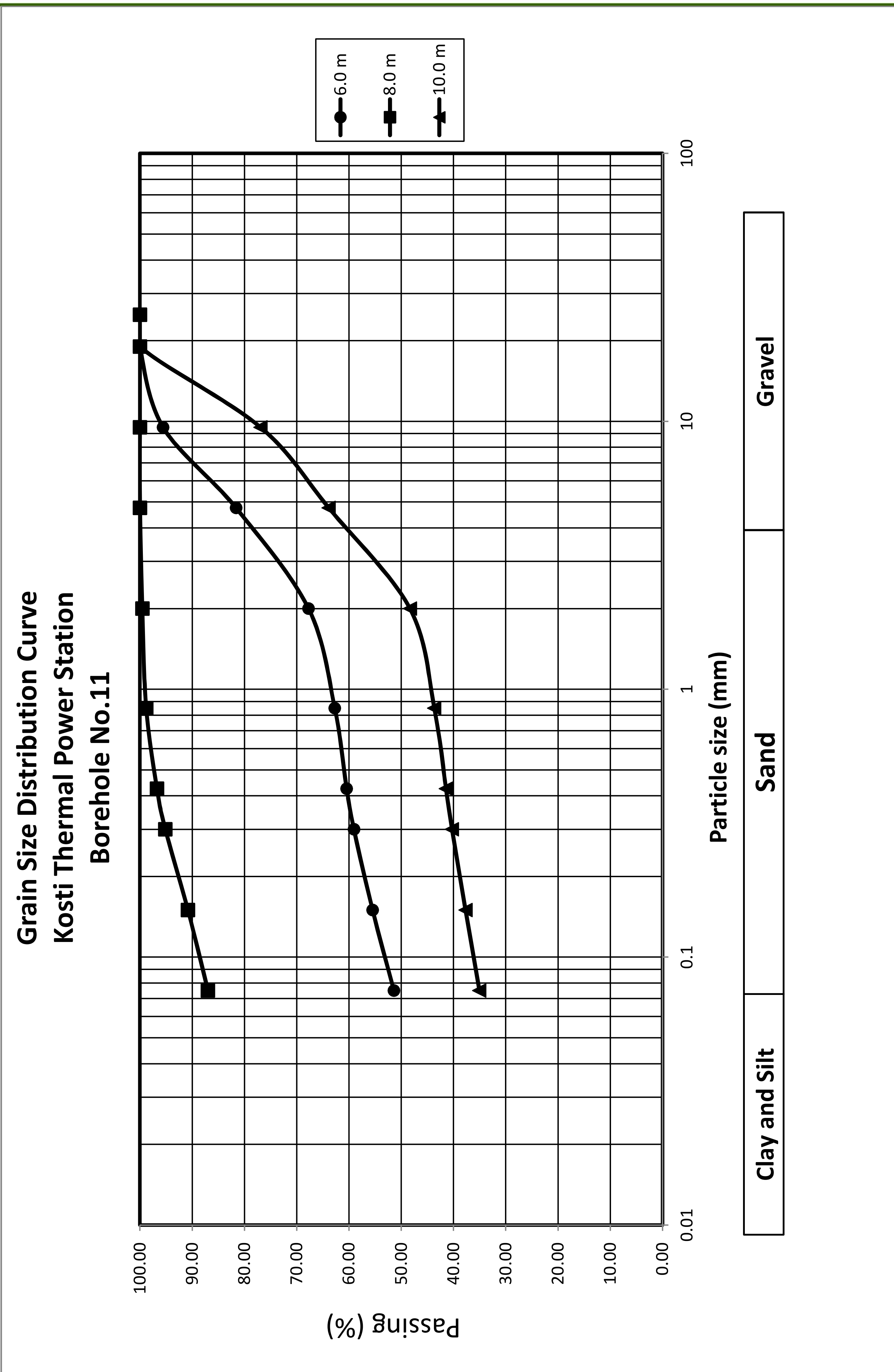

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 6
2.0 m
3.0 m
4.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

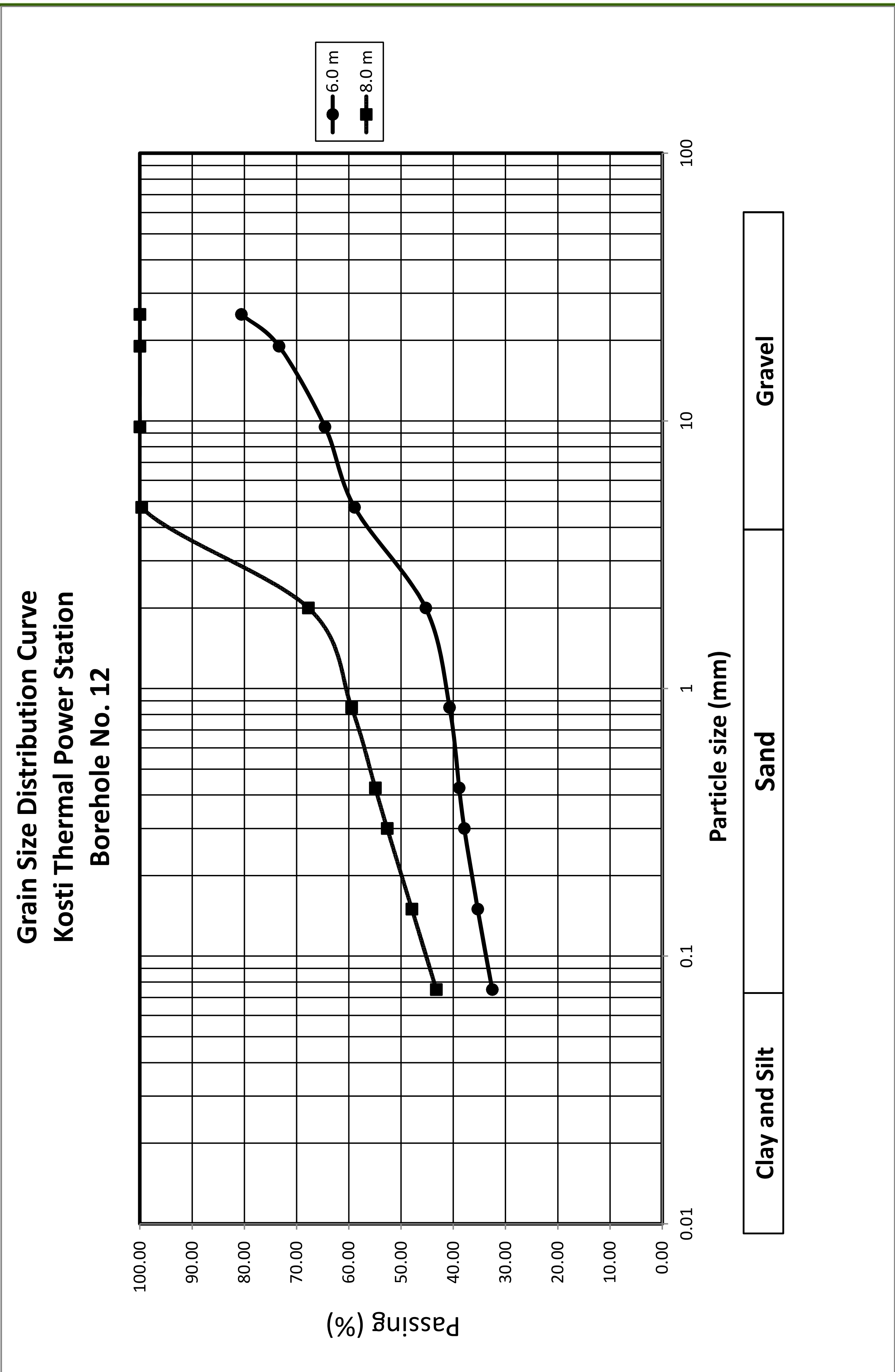

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 7
1.0 m
3.0 m
4.0 m
6.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

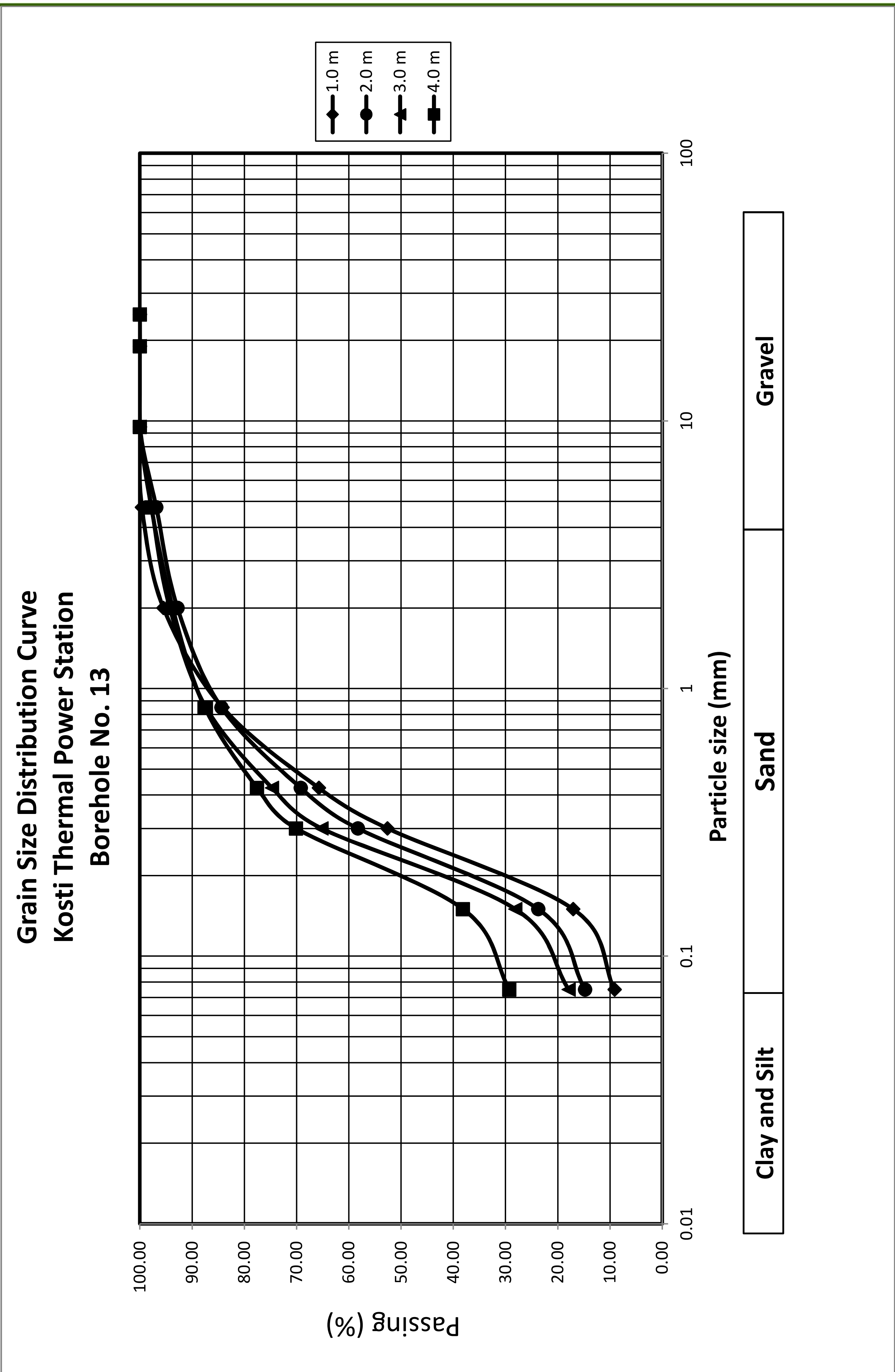

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 8
6.0 m
8.0 m
10.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel


Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 9
8.0 m
10.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel


Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 10
6.0 m
8.0 m
10.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel


Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No.11
6.0 m
8.0 m
10.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

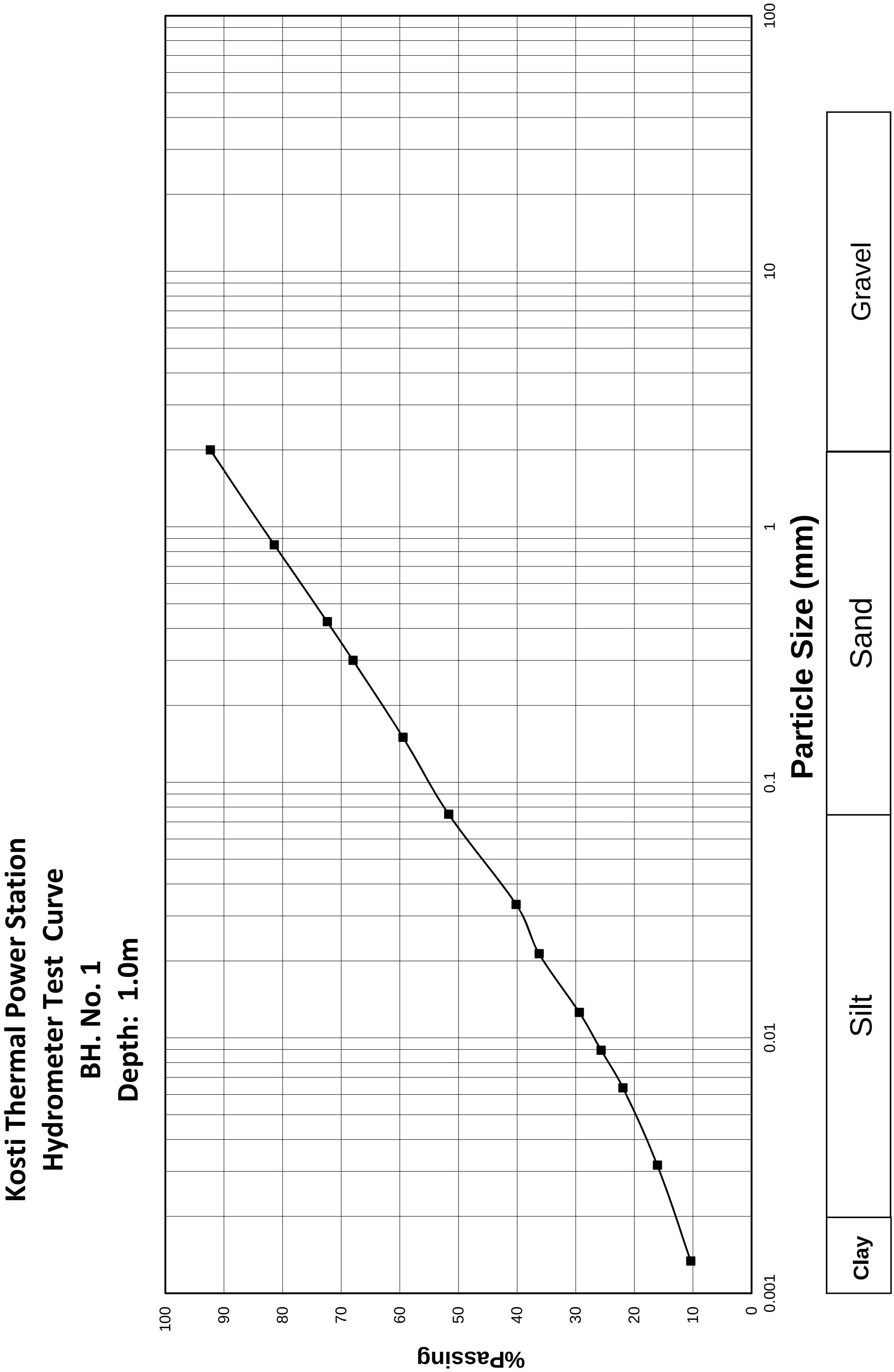

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 12
6.0 m
8.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

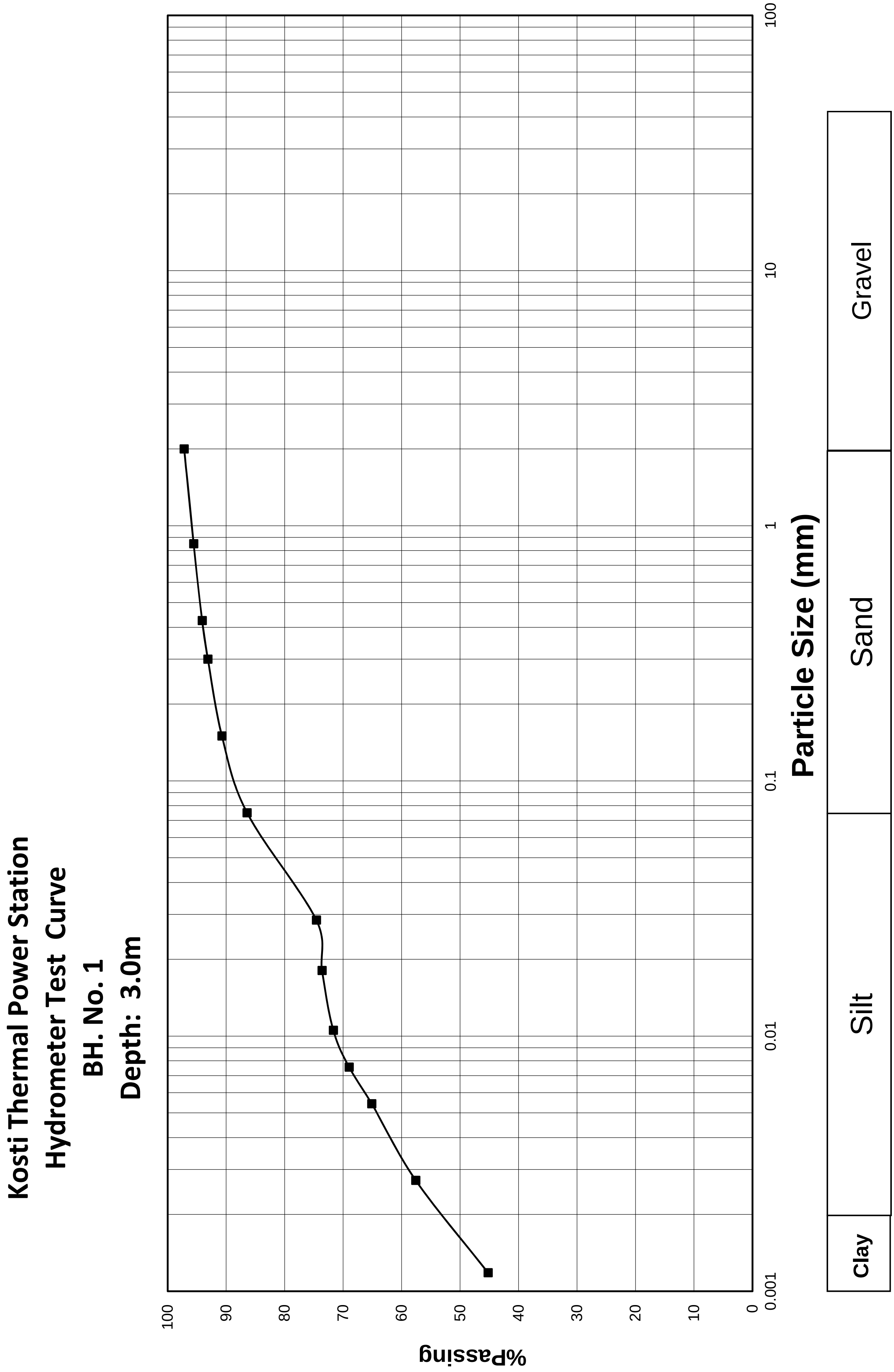

Grain Size Distribution Curve
Kosti Thermal Power Station
Borehole No. 13
1.0 m
2.0 m
3.0 m
4.0 m
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

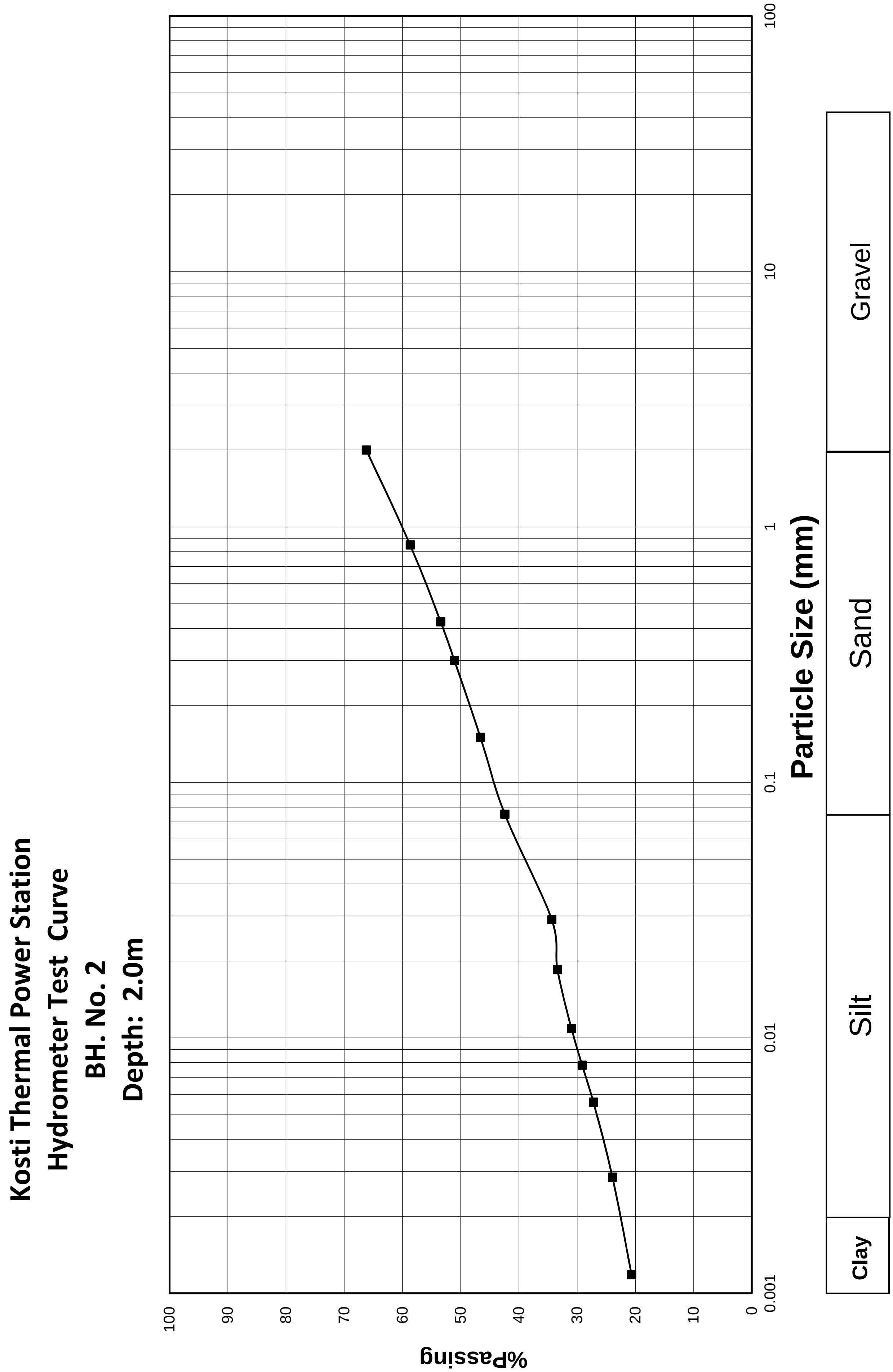
APPENDIX (B-2)

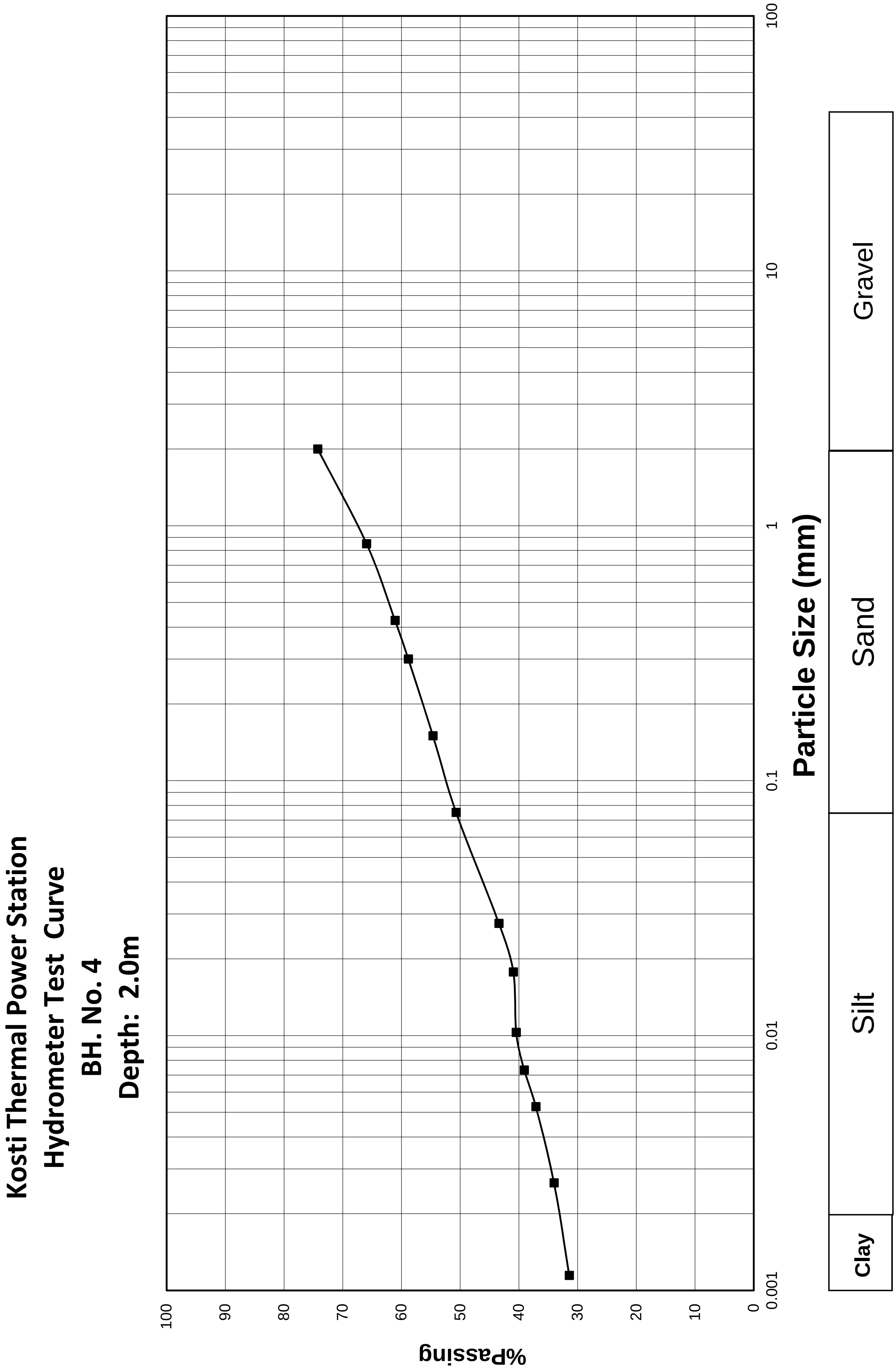
GRAIN SIZE DISTRIBUTION RESULTS

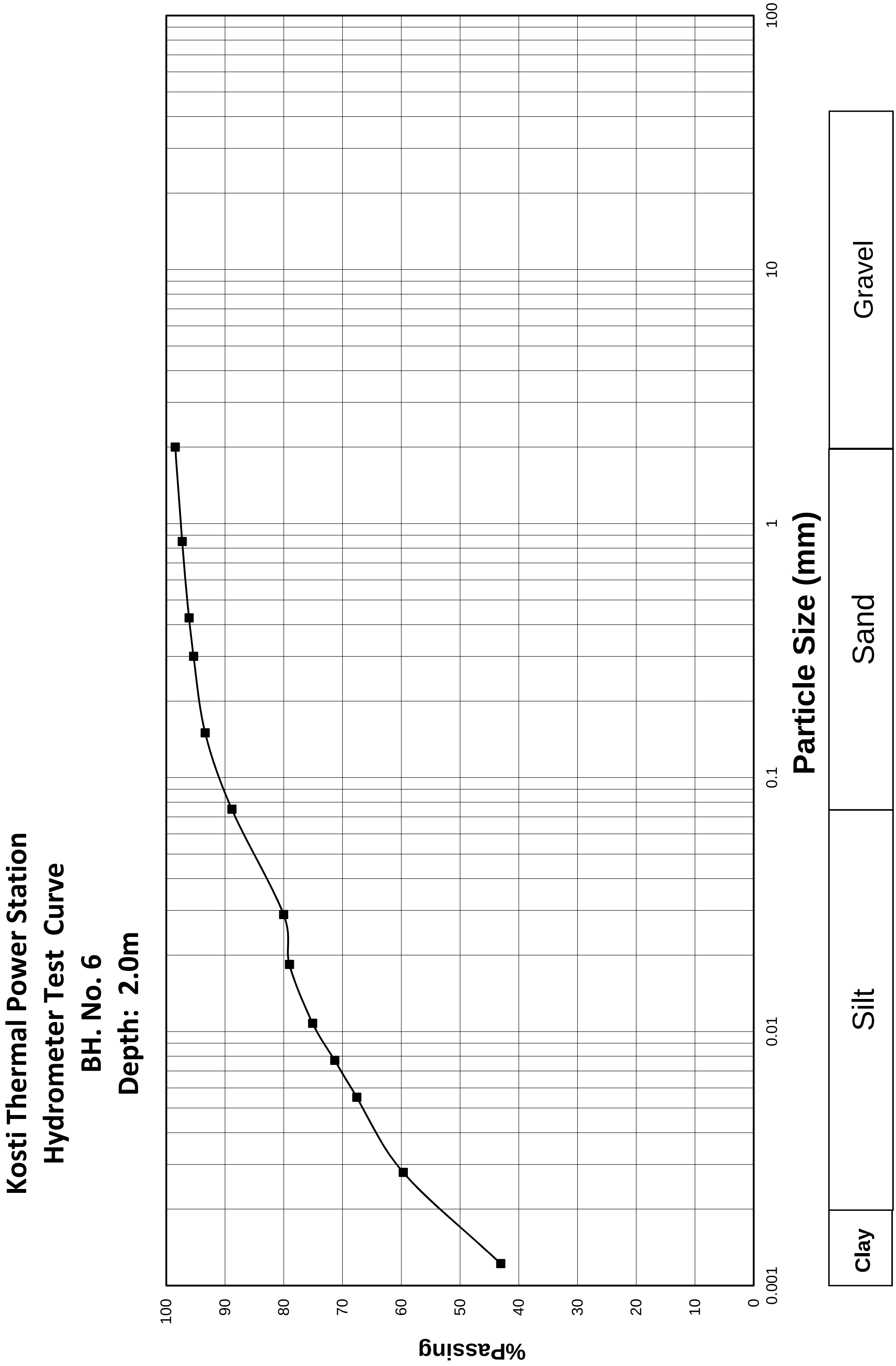
HYDROMETER TESTT

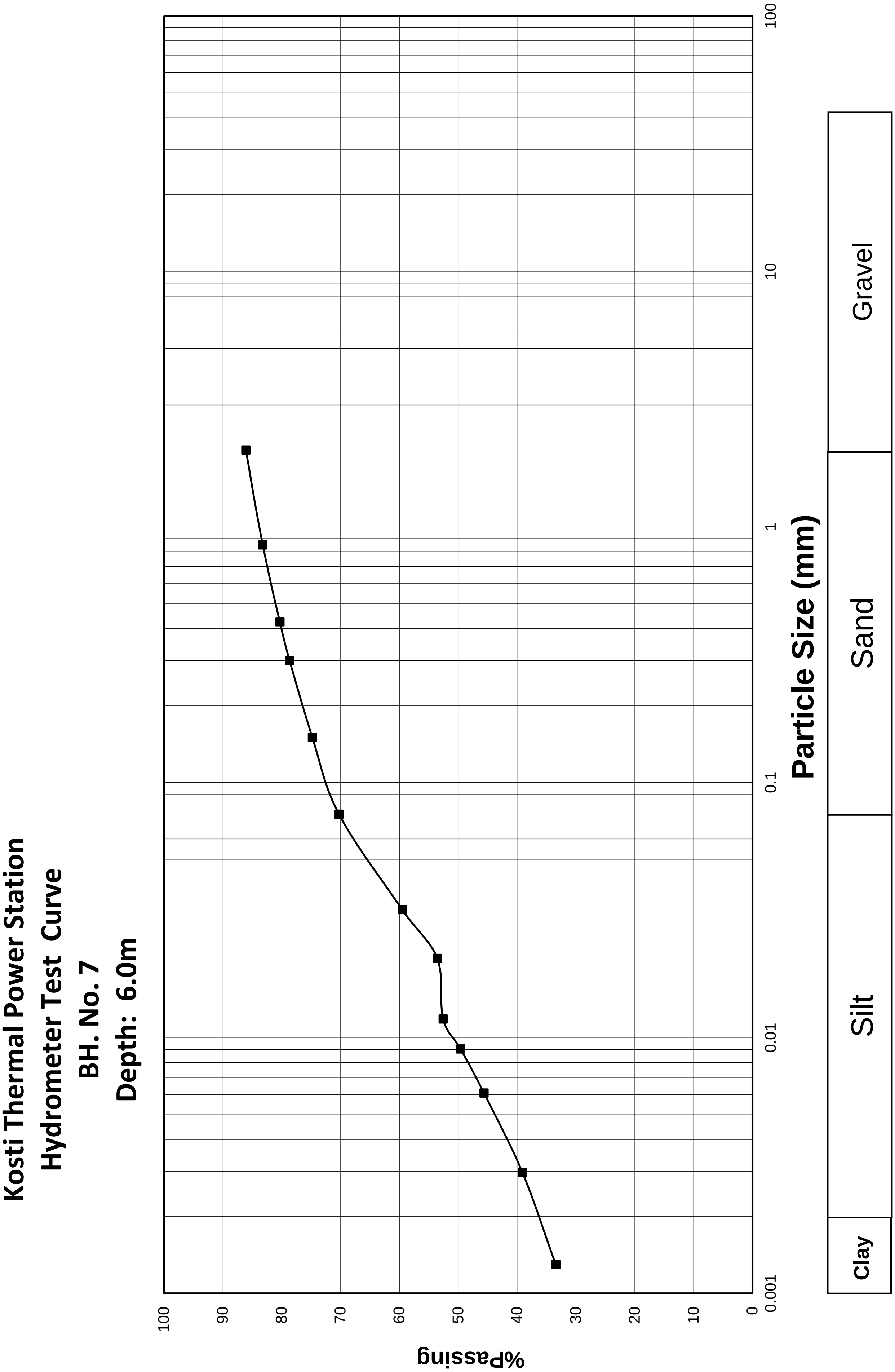

Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 1
Depth: 1.0m
%Passing
0
10
20
30
40
50
60
70
80
90
100
0.001
0.01
0.1
1
10
100
Particle Size (mm)
Clay
Silt
Sand
Gravel


Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 1
Depth: 3.0m
%Passing
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
100
Particle Size (mm)
Clay
Silt
Sand
Gravel

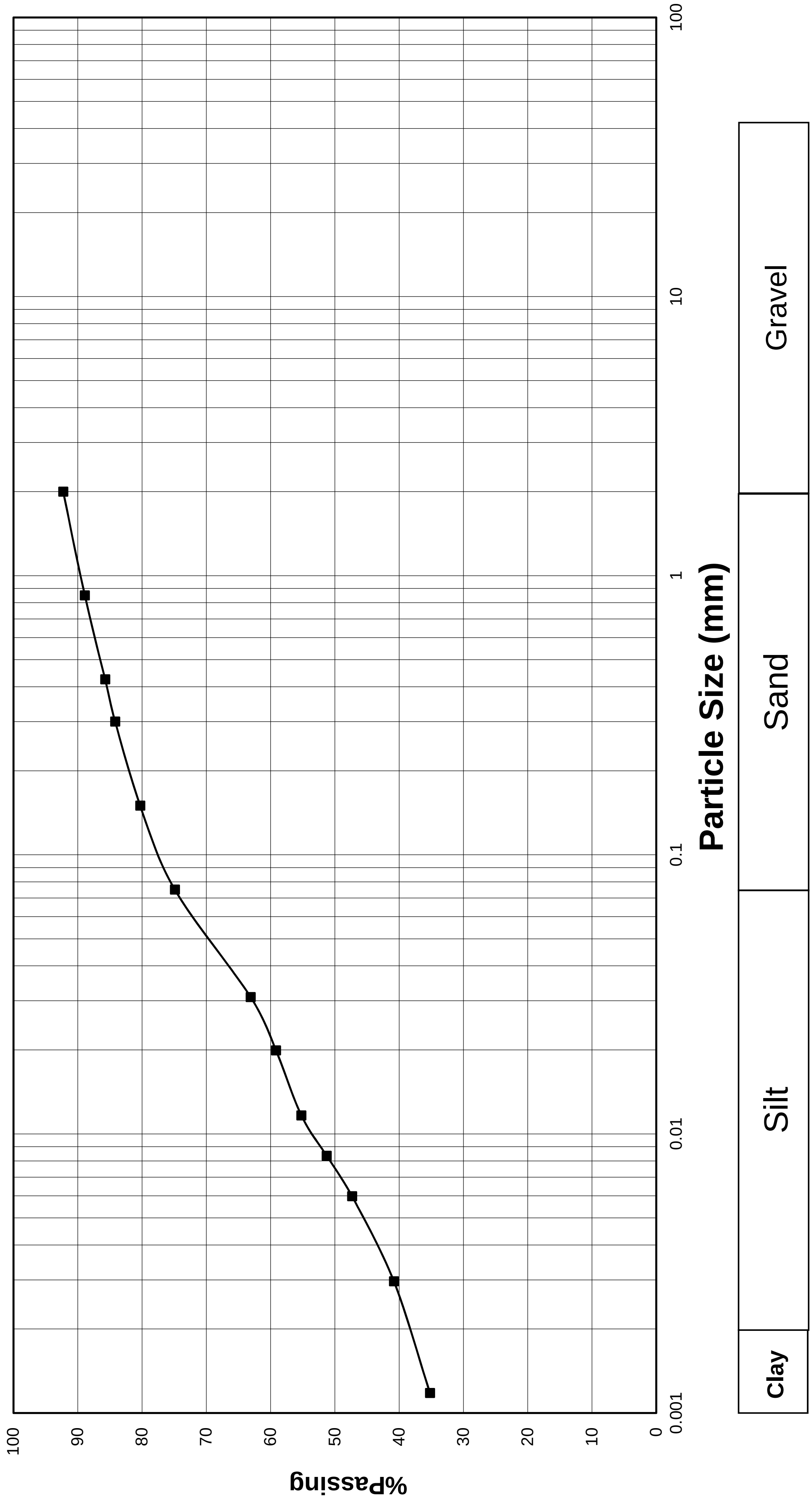

Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 2
Depth: 2.0m
%Passing
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
100
Particle Size (mm)
Clay
Silt
Sand
Gravel

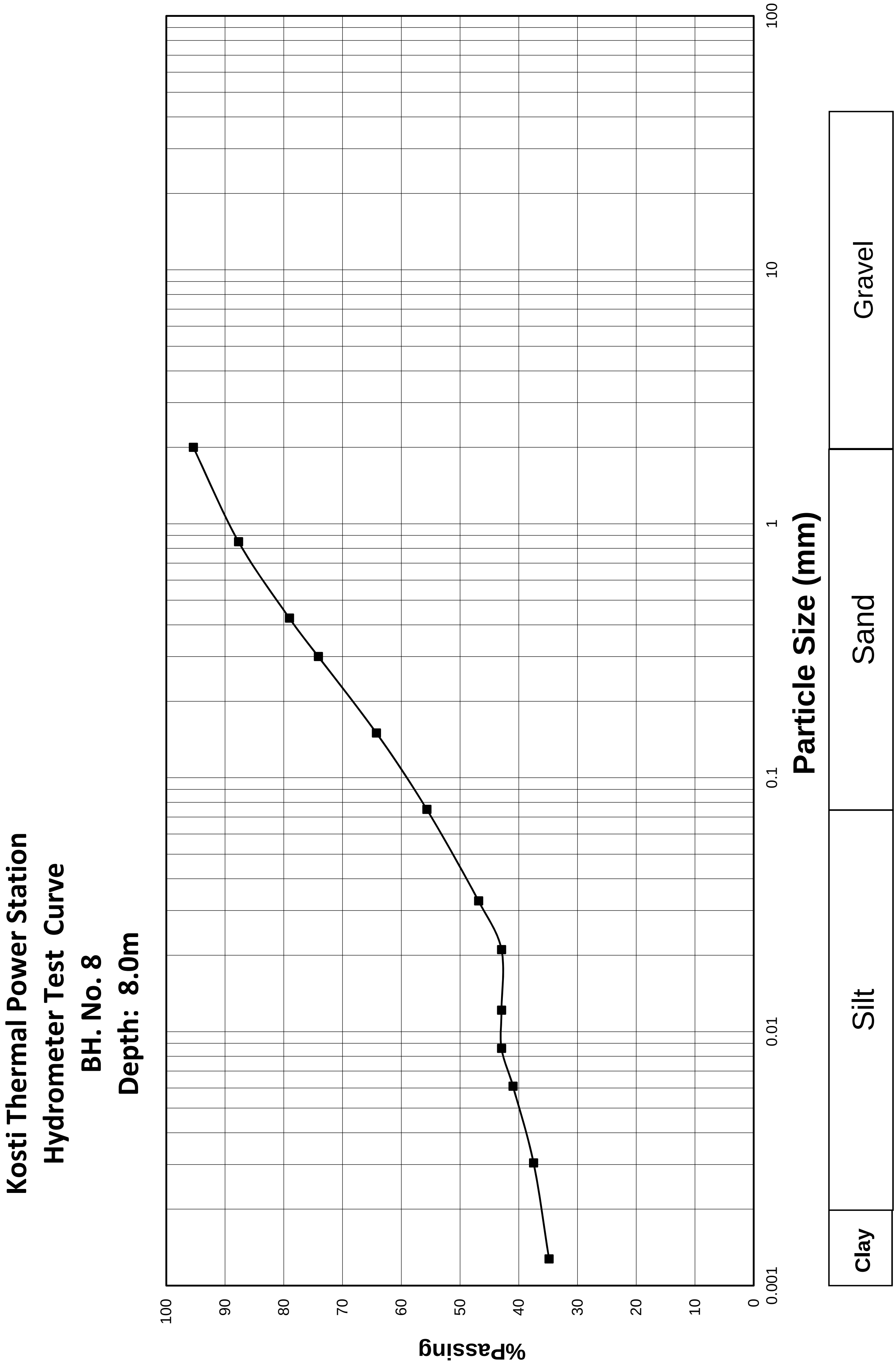

Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 4
Depth: 2.0m
%Passing
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
100
Particle Size (mm)
Clay
Silt
Sand
Gravel

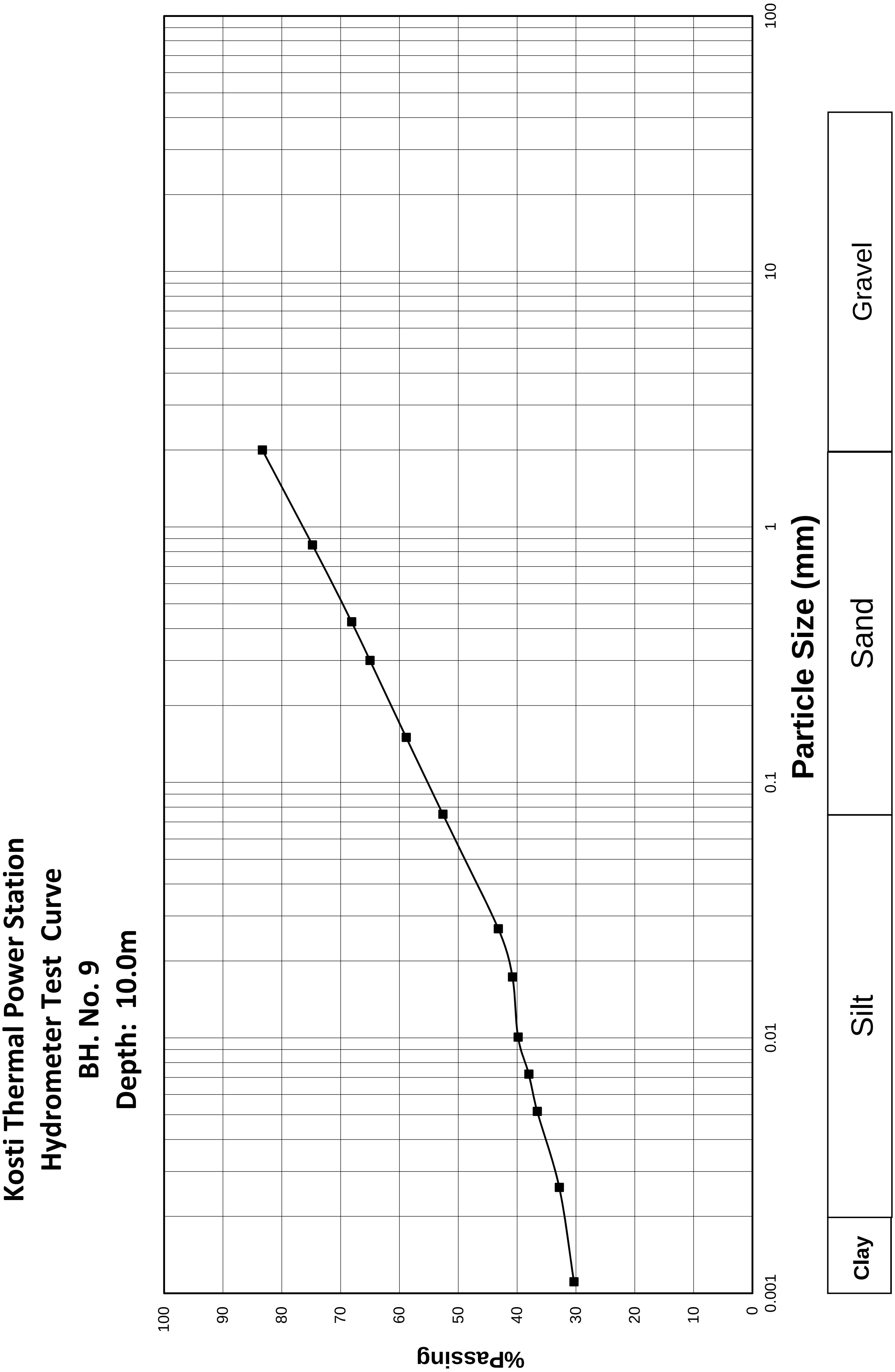

Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 6
Depth: 2.0m
%Passing
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
100
Particle Size (mm)
Clay
Silt
Sand
Gravel

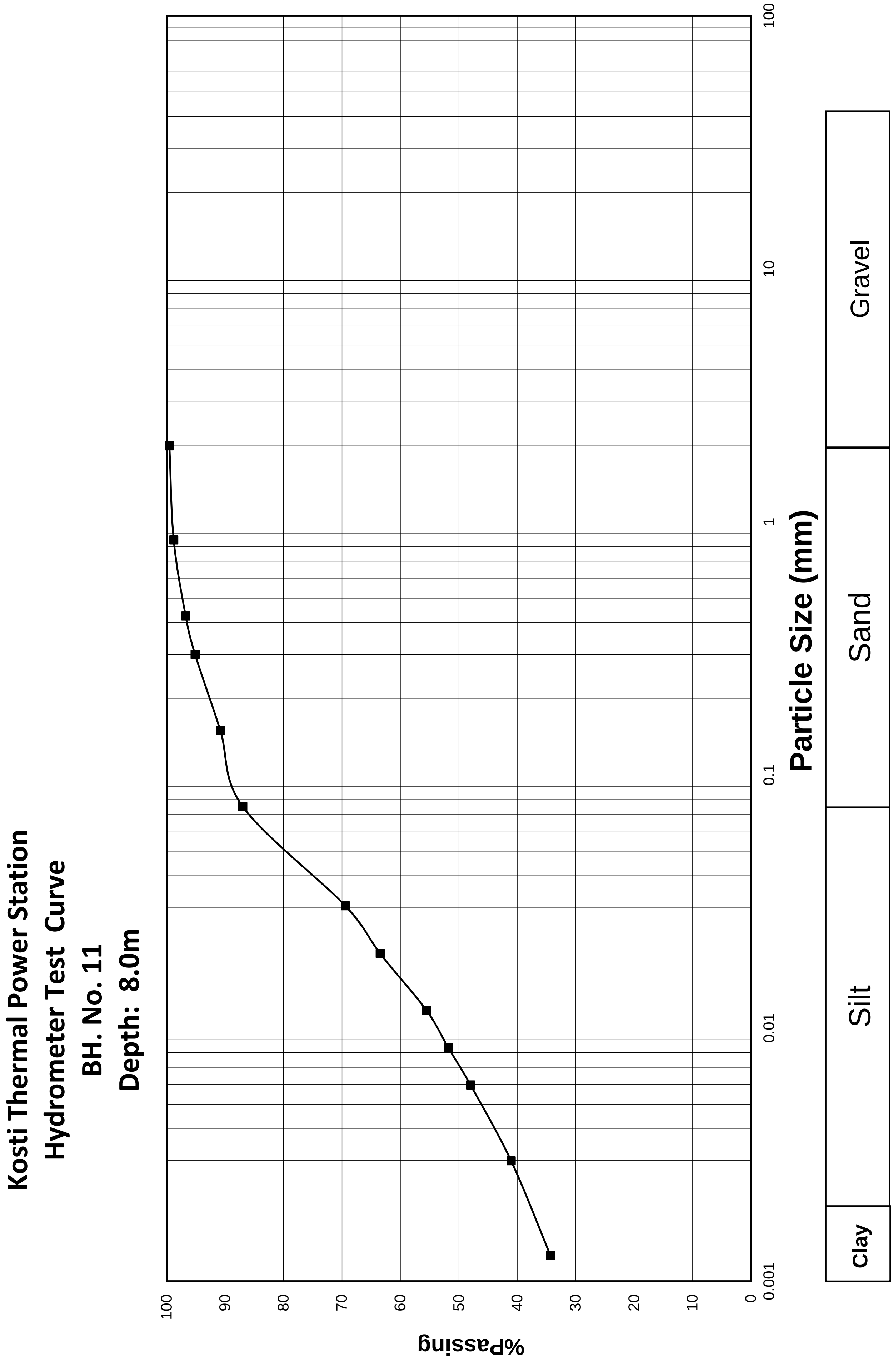

Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 7
Depth: 6.0m
%Passing
0
10
20
30
40
50
60
70
80
90
100
0.001
0.01
0.1
1
10
100
Particle Size (mm)
Clay
Silt
Sand
Gravel

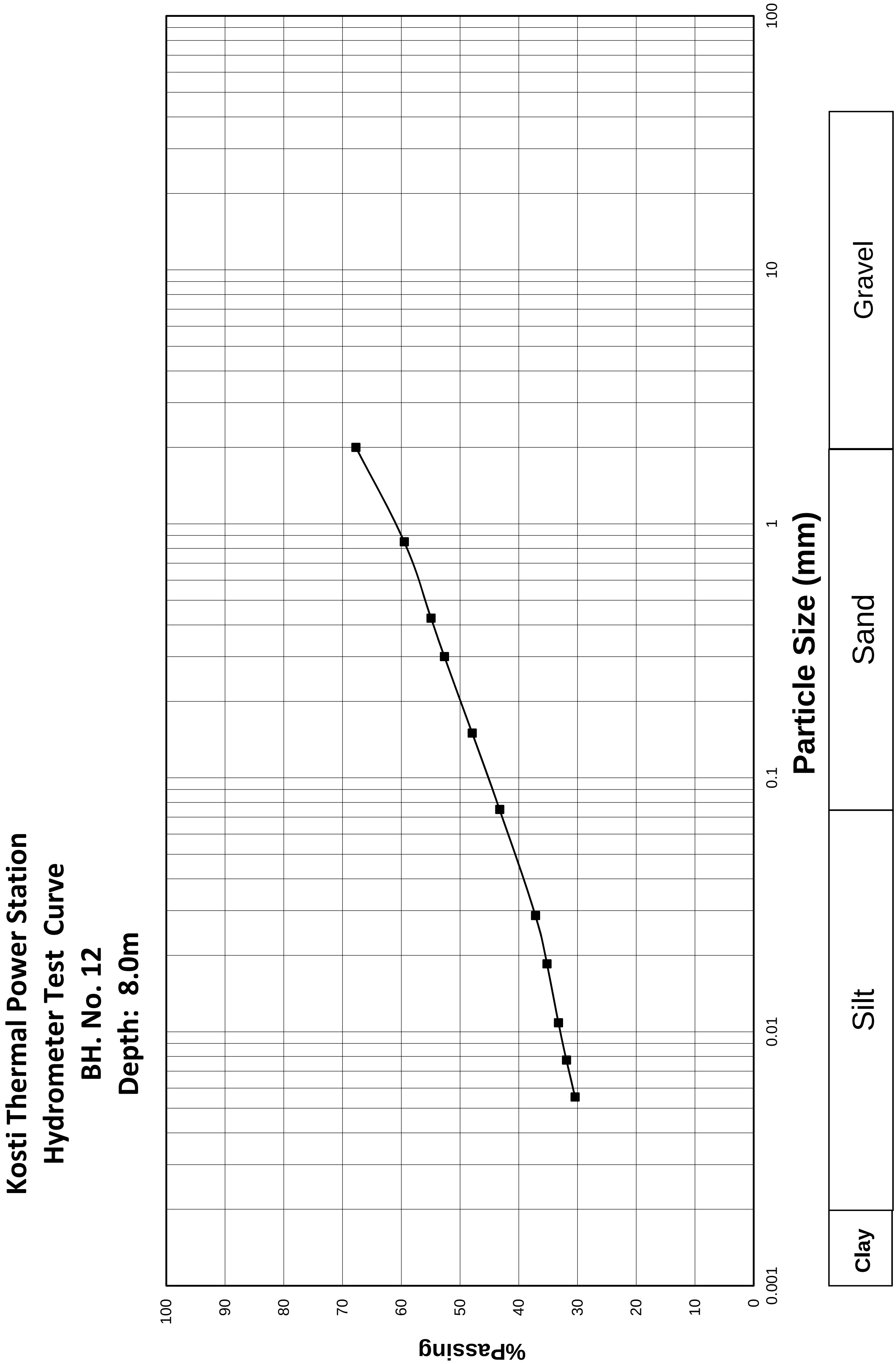
Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 7
Depth: 8.0m



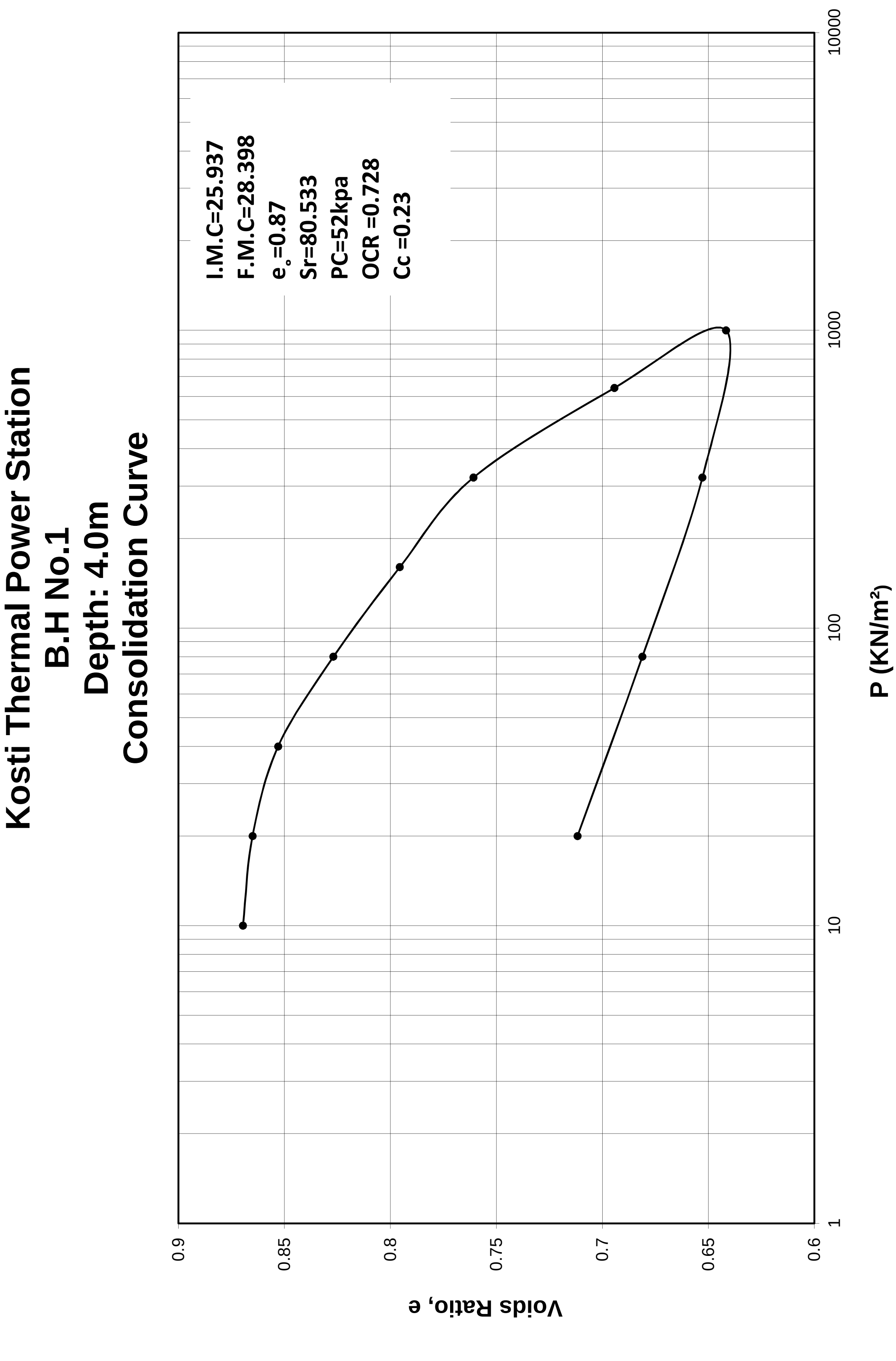

Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 8
Depth: 8.0m
%Passing
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
100
Particle Size (mm)
Clay
Silt
Sand
Gravel

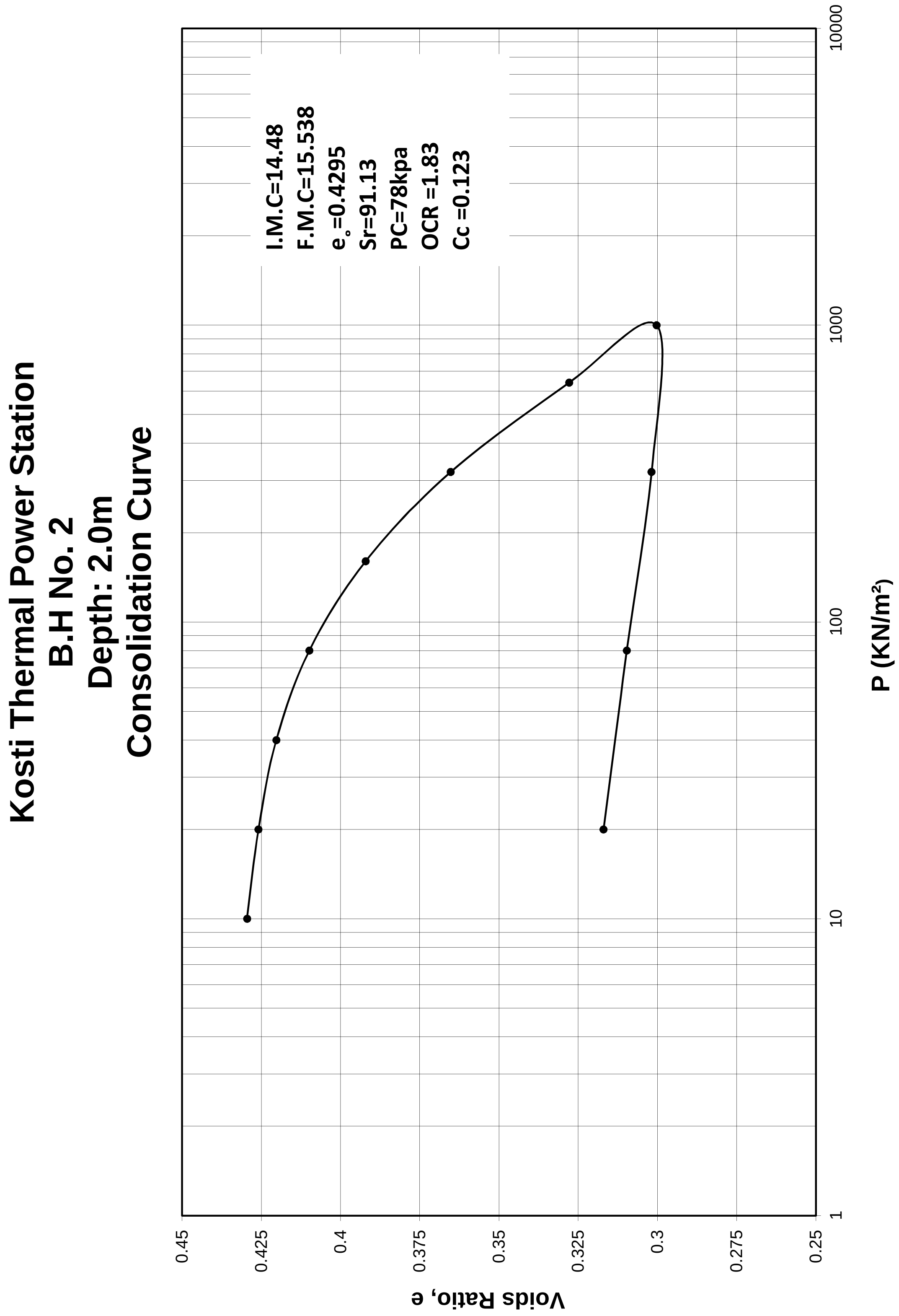

Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 9
Depth: 10.0m
%Passing
0
10
20
30
40
50
60
70
80
90
100
0.001
0.01
0.1
1
10
100
Particle Size (mm)
Clay
Silt
Sand
Gravel

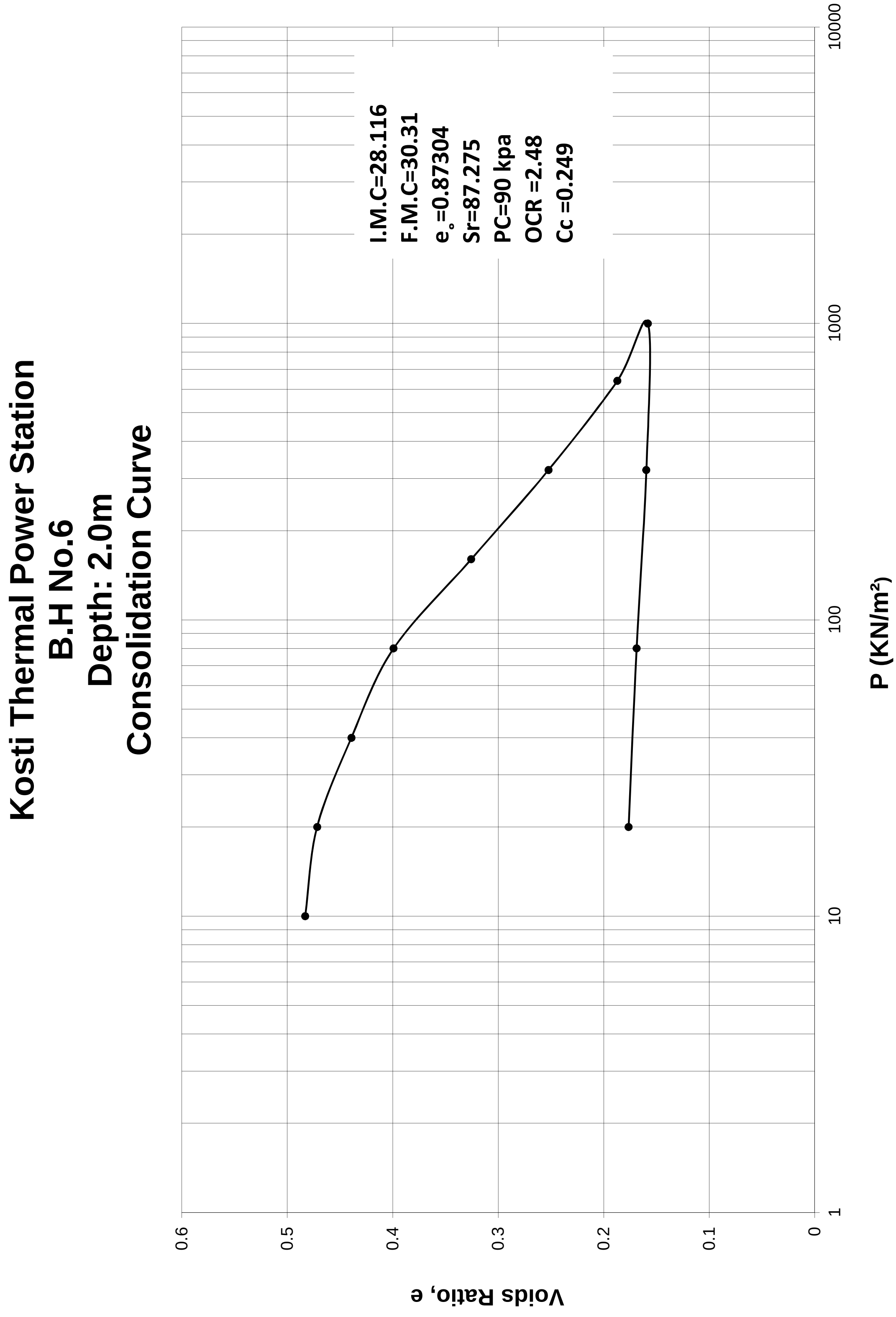

Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 11
Depth: 8.0m
%Passing
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
100
Particle Size (mm)
Clay
Silt
Sand
Gravel

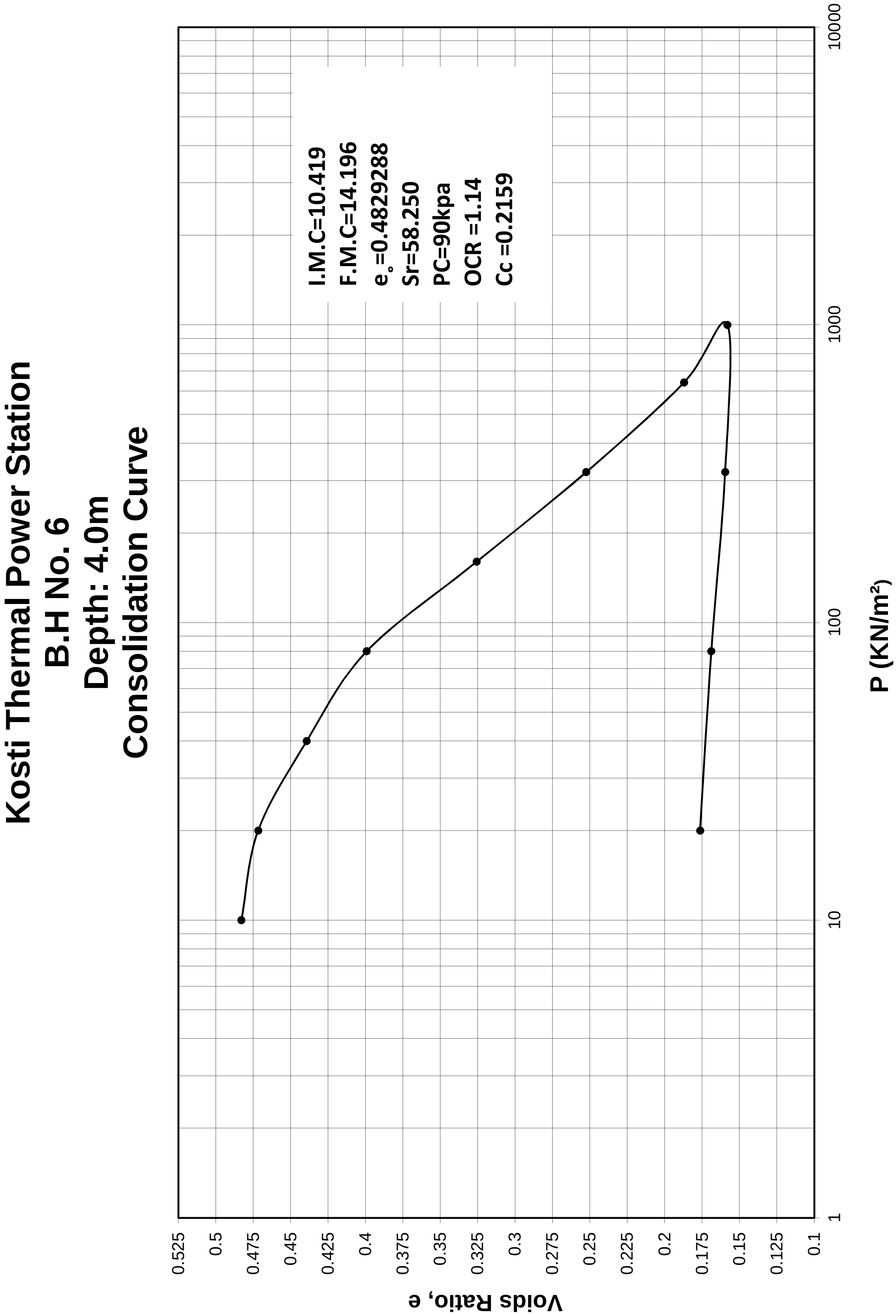

Kosti Thermal Power Station
Hydrometer Test Curve
BH. No. 12
Depth: 8.0m
%Passing
100
90
80
70
60
50
40
30
20
10
0
0.001
0.01
0.1
1
10
100
Particle Size (mm)
Clay
Silt
Sand
Gravel

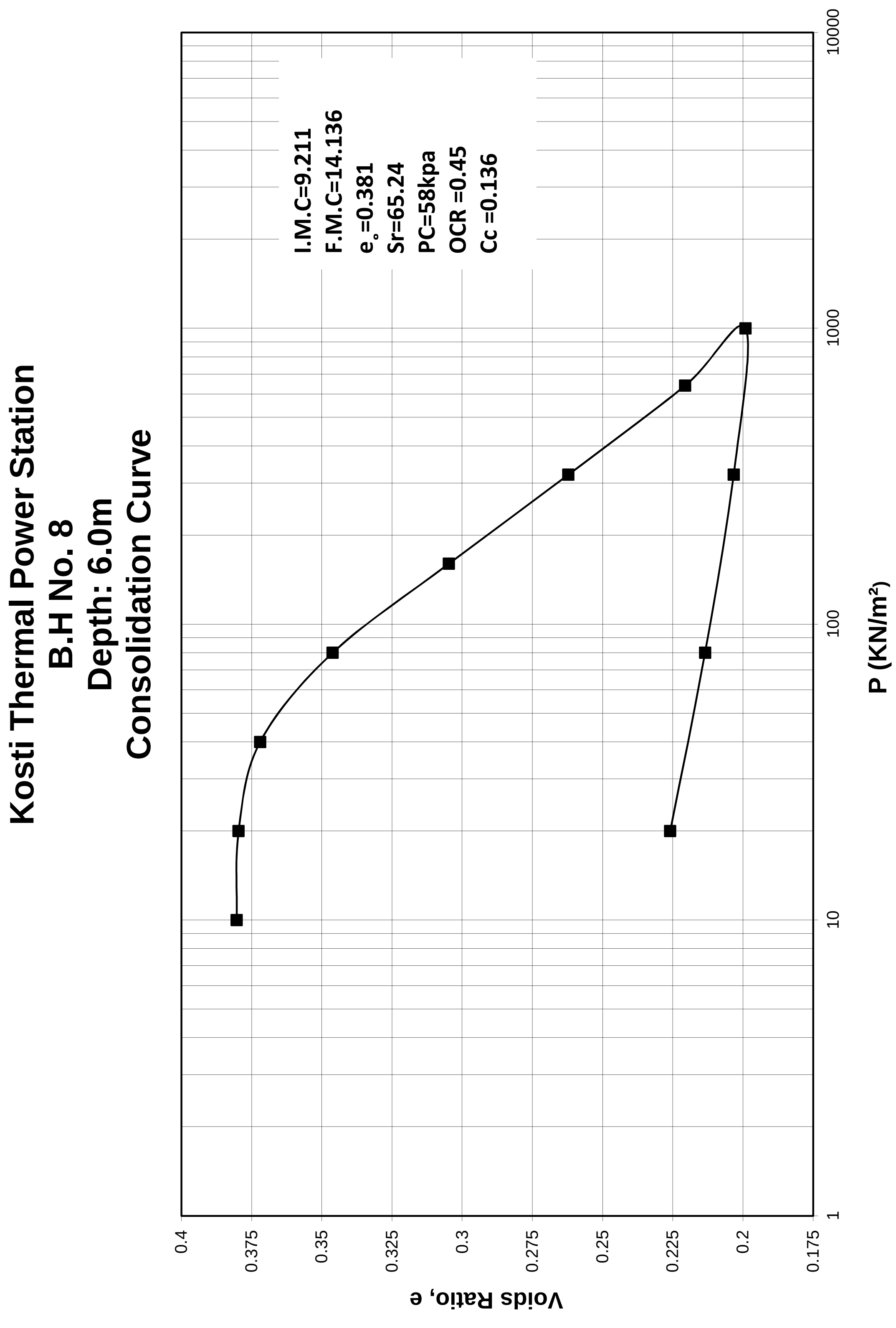
APPENDIX (C)
CONSOLIDATION TEST RESULTS

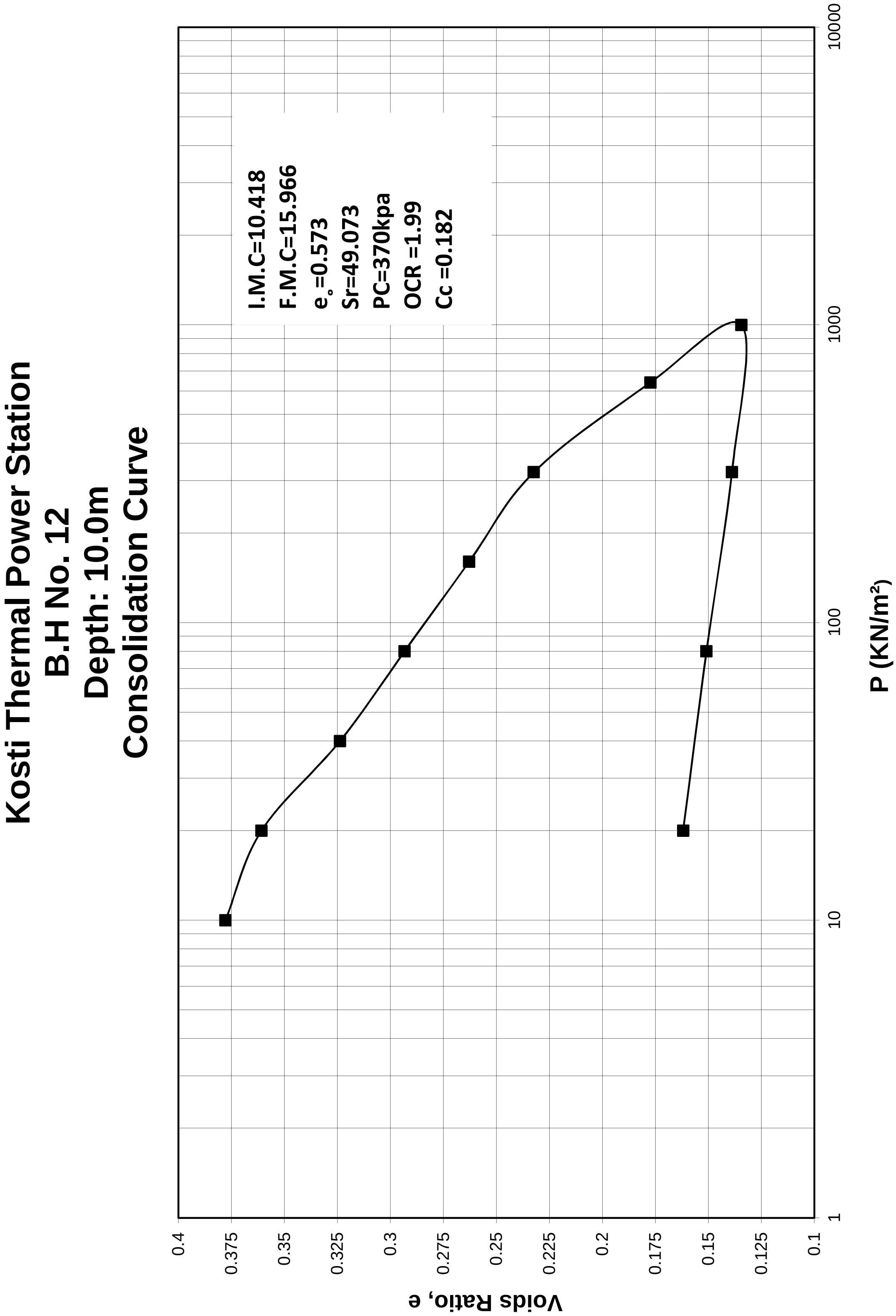

Kosti Thermal Power Station
B.H No.1
Depth: 4.0m
Consolidation Curve
I.M.C=25.937
F.M.C=28.398
e$_o$=0.87
Sr=80.533
PC=52kpa
OCR =0.728
Cc =0.23
Voids Ratio, e
0.9
0.85
0.8
0.75
0.7
0.65
0.6
P (KN/m²)
1
10
100
1000
10000


Kosti Thermal Power Station
B.H No. 2
Depth: 2.0m
Consolidation Curve
I.M.C=14.48
F.M.C=15.538
e_o=0.4295
Sr=91.13
PC=78kpa
OCR =1.83
Cc =0.123
Voids Ratio, e
P (KN/m²)
0.45
0.425
0.4
0.375
0.35
0.325
0.3
0.275
0.25
1
10
100
1000
10000


Kosti Thermal Power Station
B.H No.6
Depth: 2.0m
Consolidation Curve
I.M.C=28.116
F.M.C=30.31
e。=0.87304
Sr=87.275
PC=90 kpa
OCR =2.48
Cc =0.249
Voids Ratio, e
P (KN/m²)
0
0.1
0.2
0.3
0.4
0.5
0.6
1
10
100
1000
10000


Kosti Thermal Power Station
B.H No. 6
Depth: 4.0m
Consolidation Curve
I.M.C=10.419
F.M.C=14.196
e∘=0.4829288
Sr=58.250
PC=90kpa
OCR =1.14
Cc =0.2159
Voids Ratio, e
P (KN/m²)
0.525
0.5
0.475
0.45
0.425
0.4
0.375
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
0.125
0.1
1
10
100
1000
10000

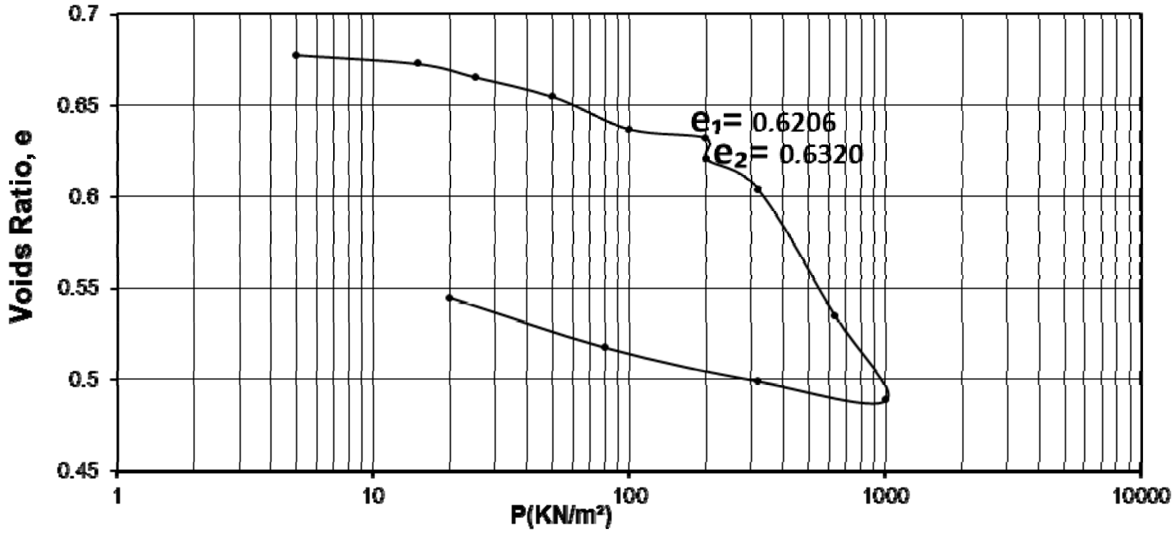

Kosti Thermal Power Station
B.H No. 8
Depth: 6.0m
Consolidation Curve
I.M.C=9.211
F.M.C=14.136
e∘=0.381
Sr=65.24
PC=58kpa
OCR =0.45
Cc =0.136
P (KN/m²)
Voids Ratio, e
0.4
0.375
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
1
10
100
1000
10000


Kosti Thermal Power Station
B.H No. 12
Depth: 10.0m
Consolidation Curve
I.M.C=10.418
F.M.C=15.966
e$_o$=0.573
Sr=49.073
PC=370kpa
OCR =1.99
Cc =0.182
Voids Ratio, e
0.4
0.375
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
0.125
0.1
1
10
100
1000
10000
P (KN/m²)

APPENDIX (C-1)
SINGLE OEDOMETER TEST RESULTS

Sample of Single Oedometrer Test
Sample of Calculations:

1. BH.No.1 Depth 1.5m



Calculation:

For e_o=0.7122

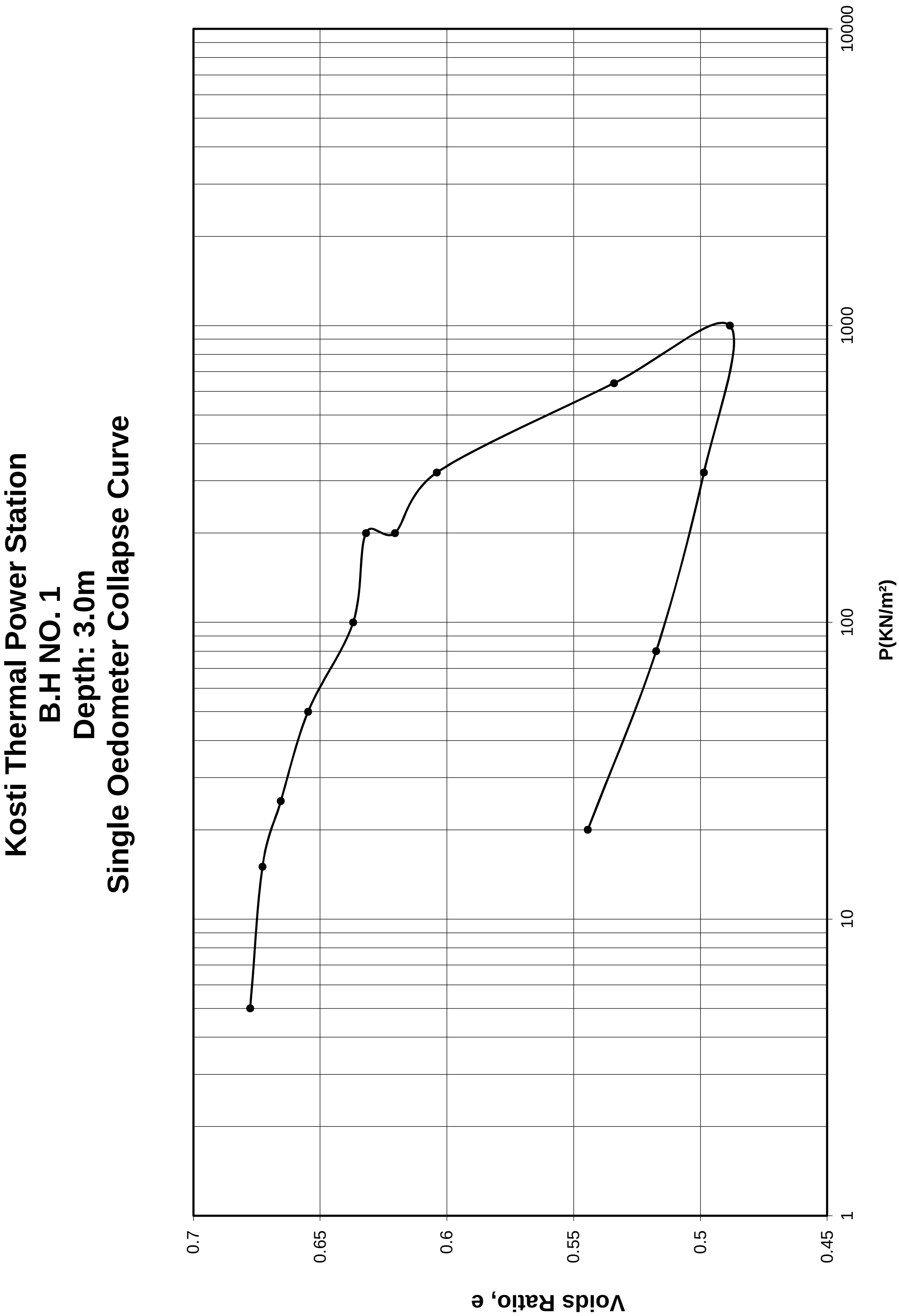
$$Cp(\%) = \frac{(e_2 - e_1)}{1 + e_o} = \frac{(0.6320 - 0.6206)}{1 + 0.7122} x100 = 0.67$$

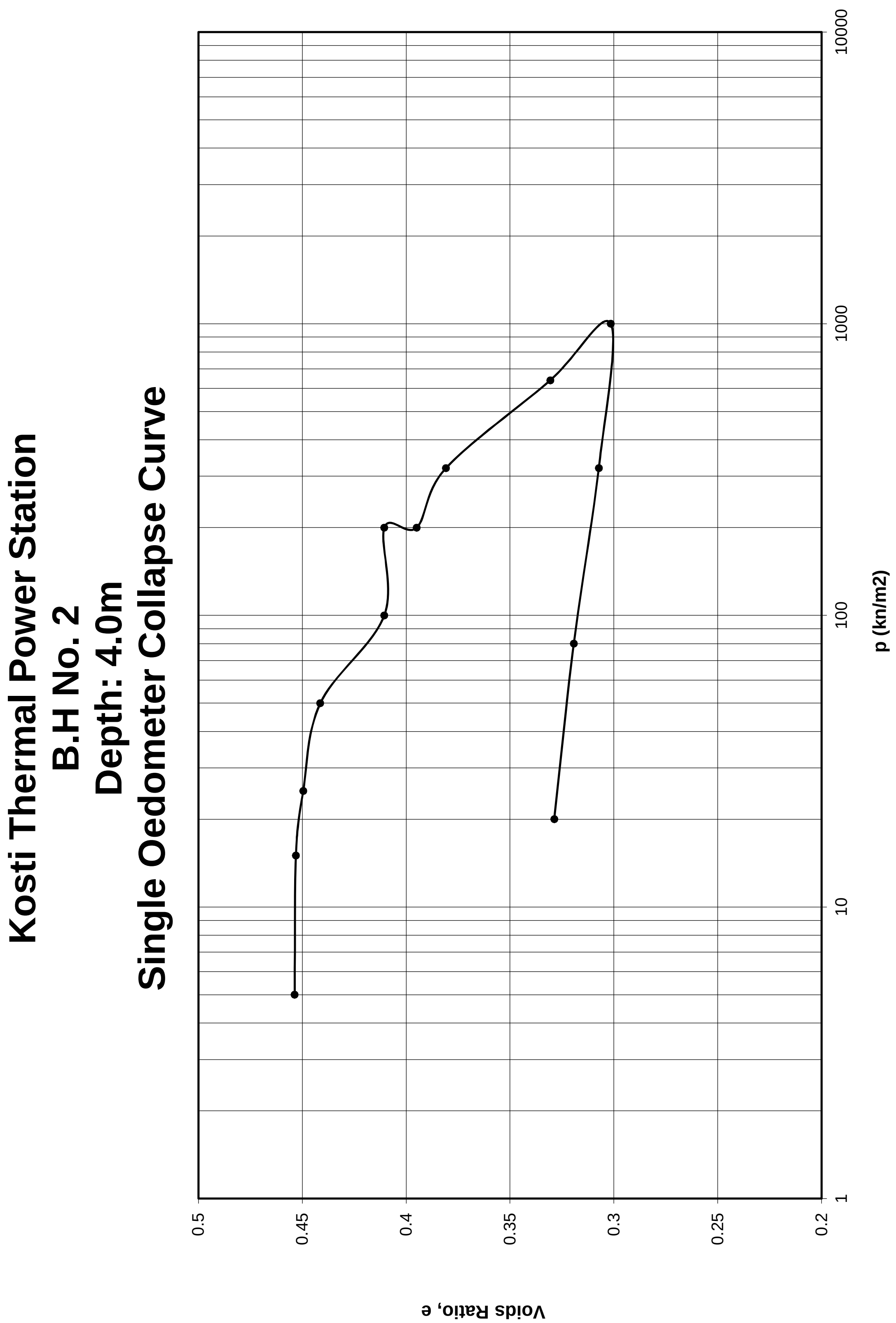
where e_o *: natural void ratio and*

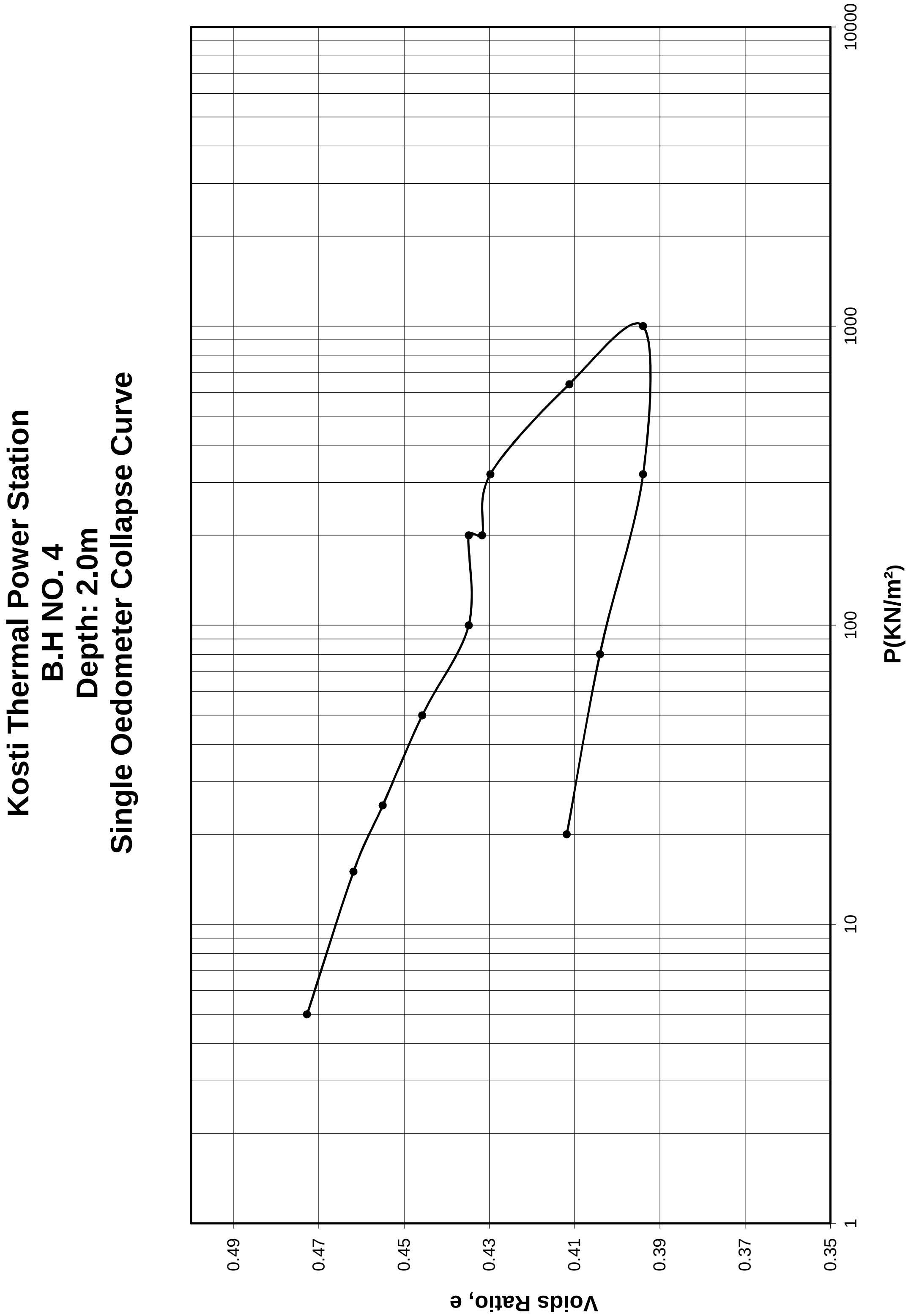
$(e_2 - e_1)$: *vertical strain*

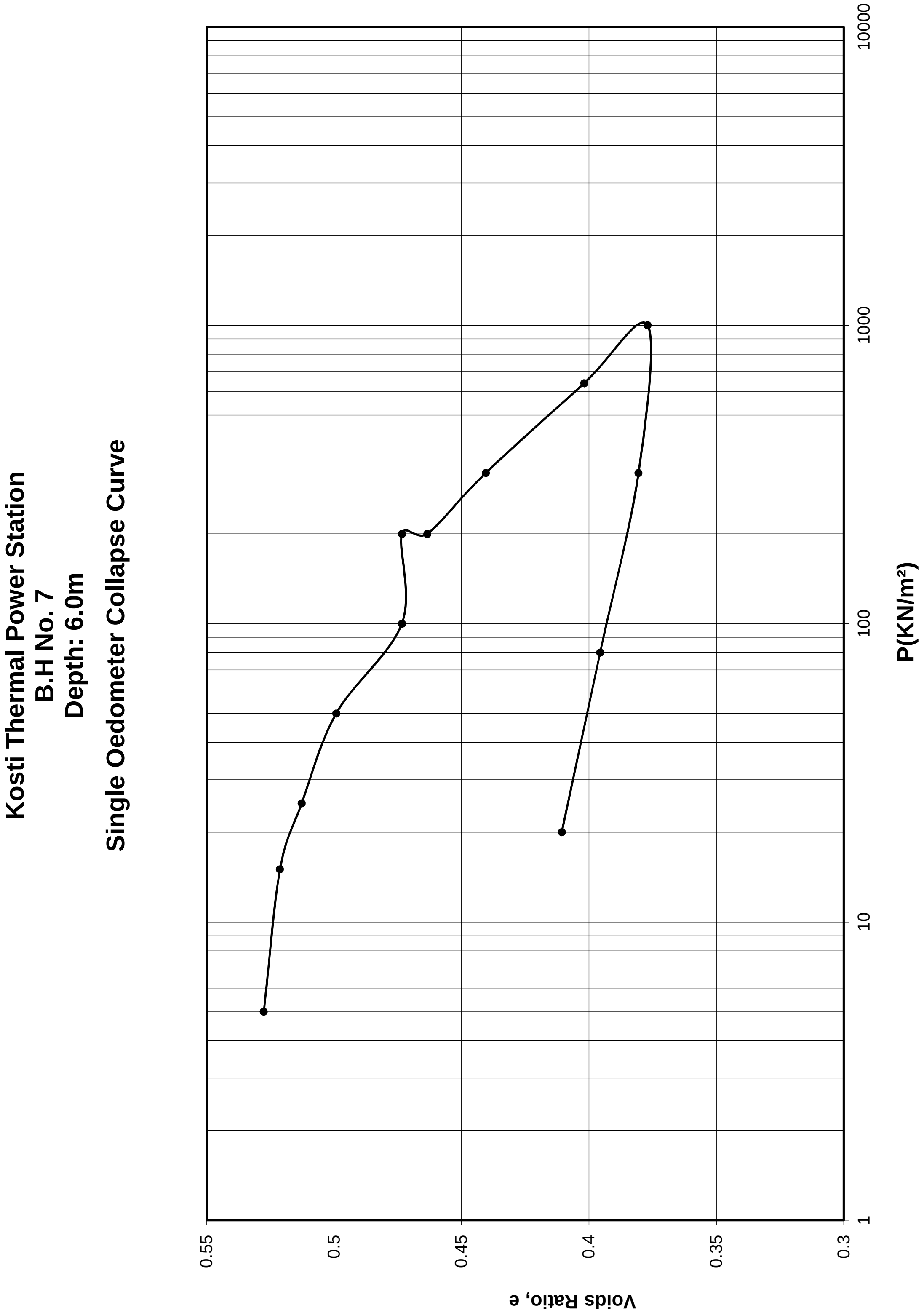
2. Table Below shows the results of C_P in single Oedometer Test

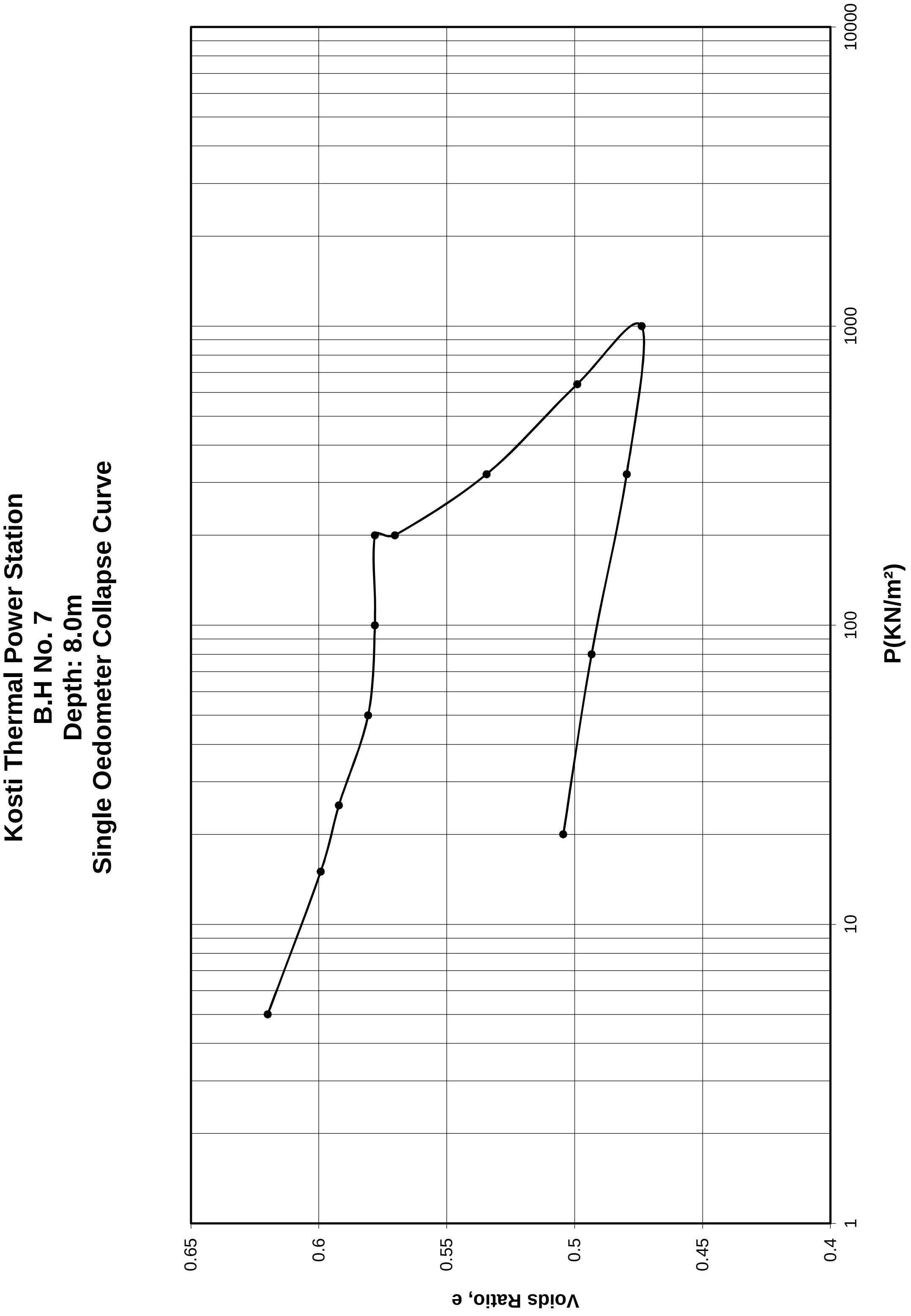
BH. No.	Depth	e_o	e_1	e_2	C_P(%)
2	4	0.4537	0.4105	0.395	1.07
4	2	0.478	0.4349	0.4317	0.22
7	6	0.5371	0.4734	0.4635	0.64
7	8	0.6382	0.5781	0.5703	0.48
8	8	0.269	0.172	0.161	0.87
8	10	0.3756	0.3467	0.3158	2.25
9	10	0.3559	0.3185	0.3026	1.17
11	6	0.474	0.4509	0.4204	2.07

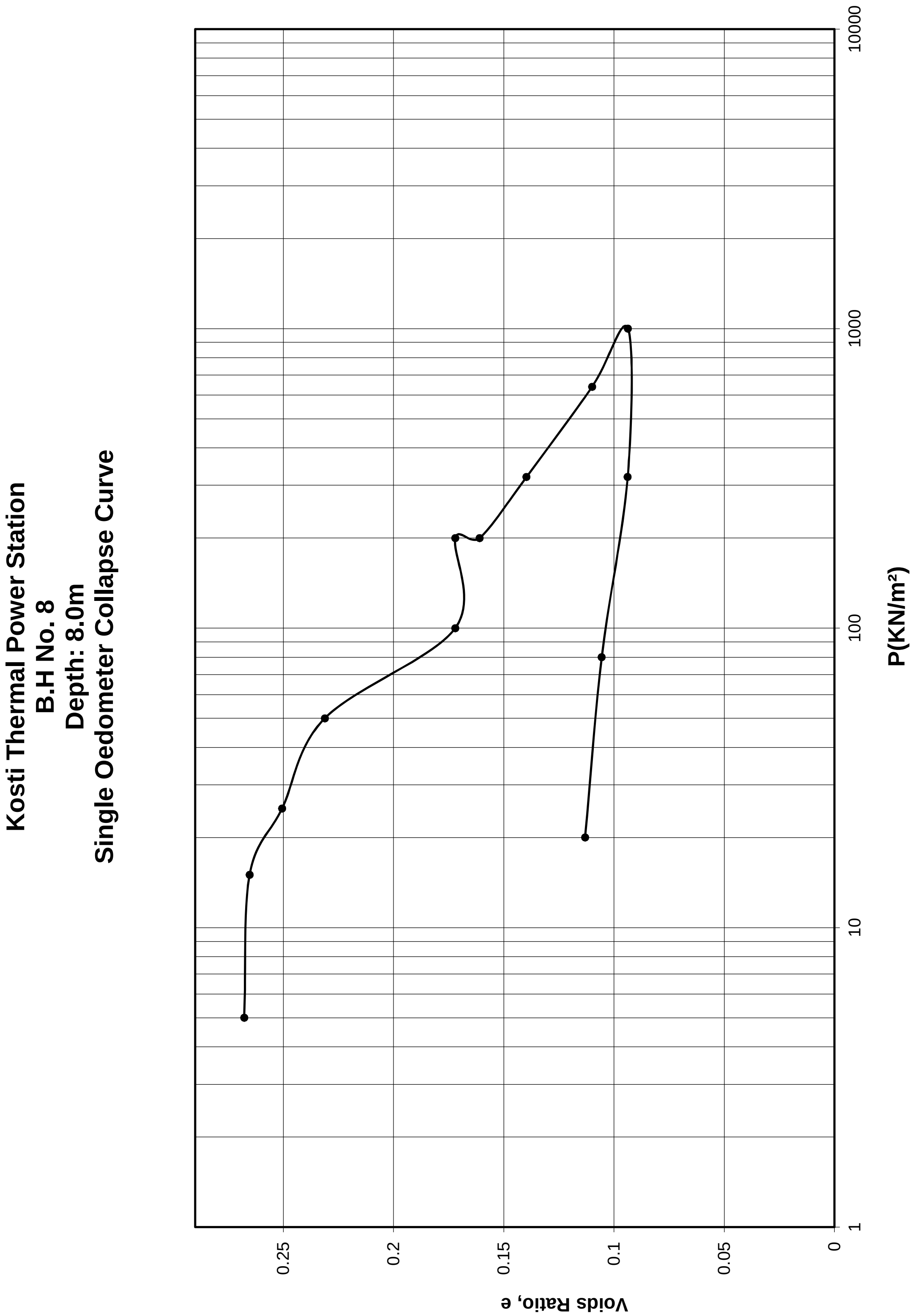

Kosti Thermal Power Station
B.H NO. 1
Depth: 3.0m
Single Oedometer Collapse Curve
Voids Ratio, e
P(KN/m²)
0.7
0.65
0.6
0.55
0.5
0.45
1
10
100
1000
10000

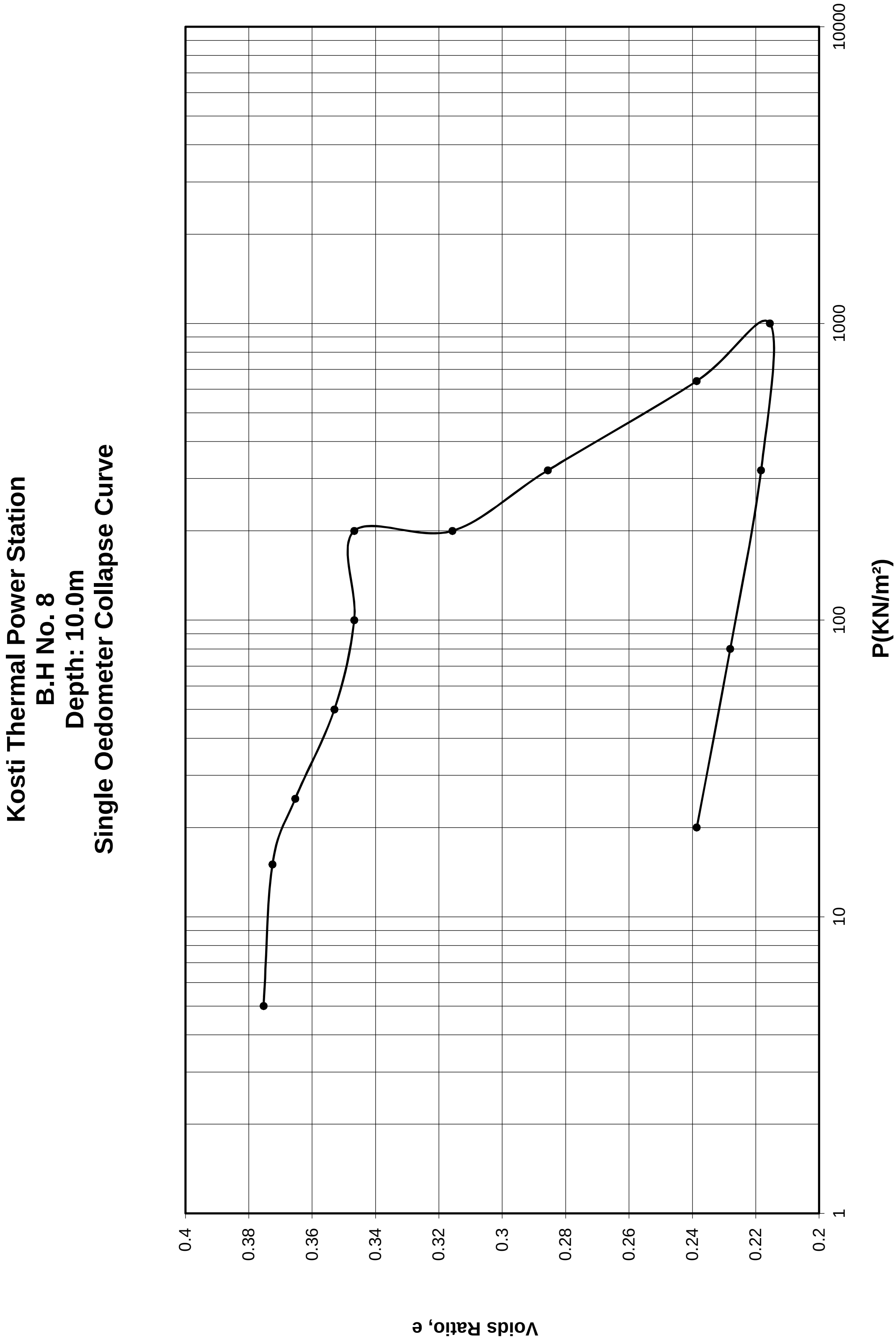

Kosti Thermal Power Station
B.H No. 2
Depth: 4.0m
Single Oedometer Collapse Curve
0.5
0.45
0.4
0.35
0.3
0.25
0.2
Voids Ratio, e
1
10
100
1000
10000
p (kn/m2)

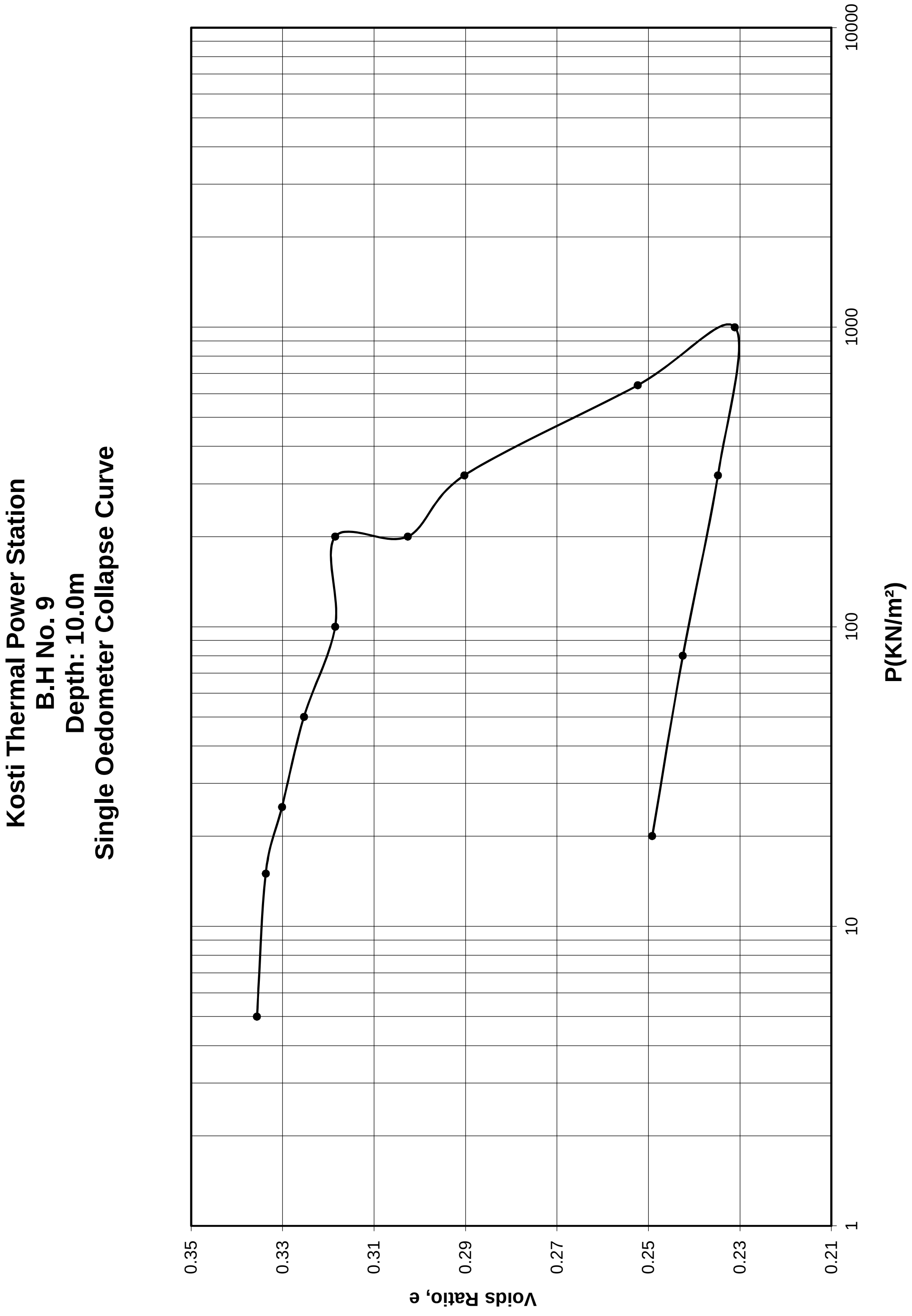

Kosti Thermal Power Station
B.H NO. 4
Depth: 2.0m
Single Oedometer Collapse Curve
Voids Ratio, e
0.49
0.47
0.45
0.43
0.41
0.39
0.37
0.35
P(KN/m²)
1
10
100
1000
10000

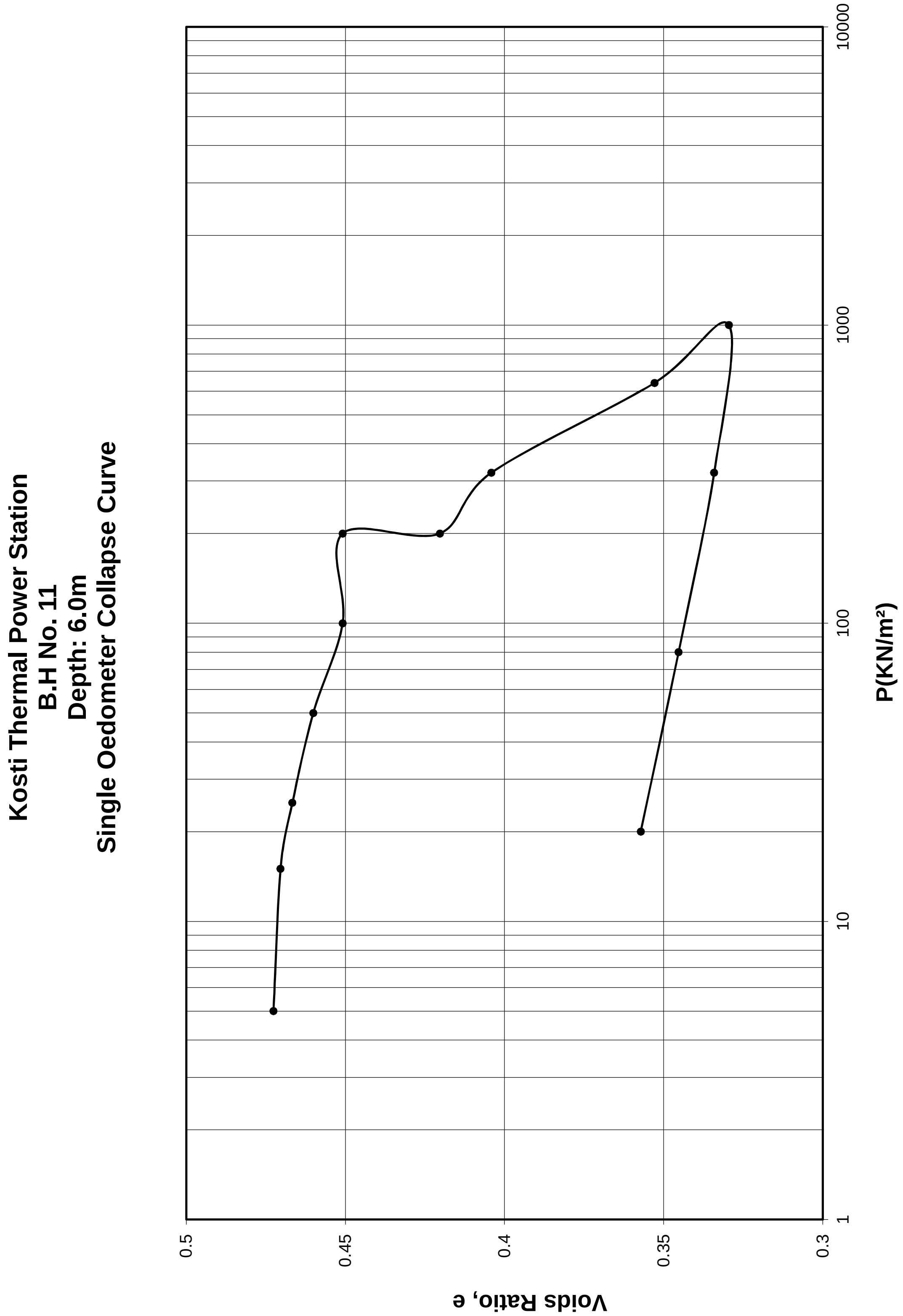

Kosti Thermal Power Station
B.H No. 7
Depth: 6.0m
Single Oedometer Collapse Curve
Voids Ratio, e
0.55
0.5
0.45
0.4
0.35
0.3
P(KN/m²)
1
10
100
1000
10000


Kosti Thermal Power Station
B.H No. 7
Depth: 8.0m
Single Oedometer Collapse Curve
Voids Ratio, e
P(KN/m²)
0.65
0.6
0.55
0.5
0.45
0.4
1
10
100
1000
10000


Kosti Thermal Power Station
B.H No. 8
Depth: 8.0m
Single Oedometer Collapse Curve
Voids Ratio, e
0
0.05
0.1
0.15
0.2
0.25
P(KN/m²)
1
10
100
1000
10000

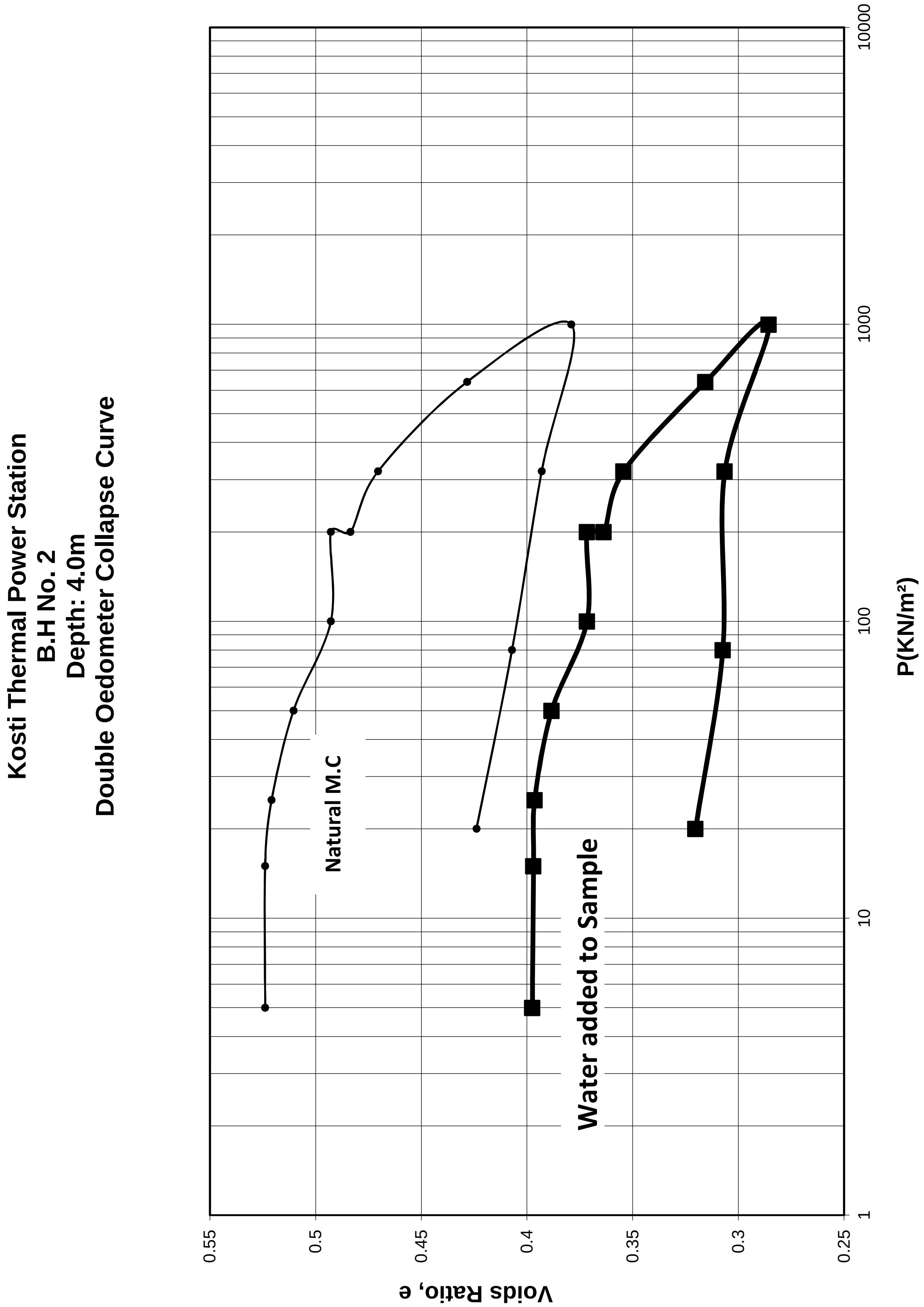

Kosti Thermal Power Station
B.H No. 8
Depth: 10.0m
Single Oedometer Collapse Curve
Voids Ratio, e
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
0.2
1
10
100
1000
10000
P(KN/m²)

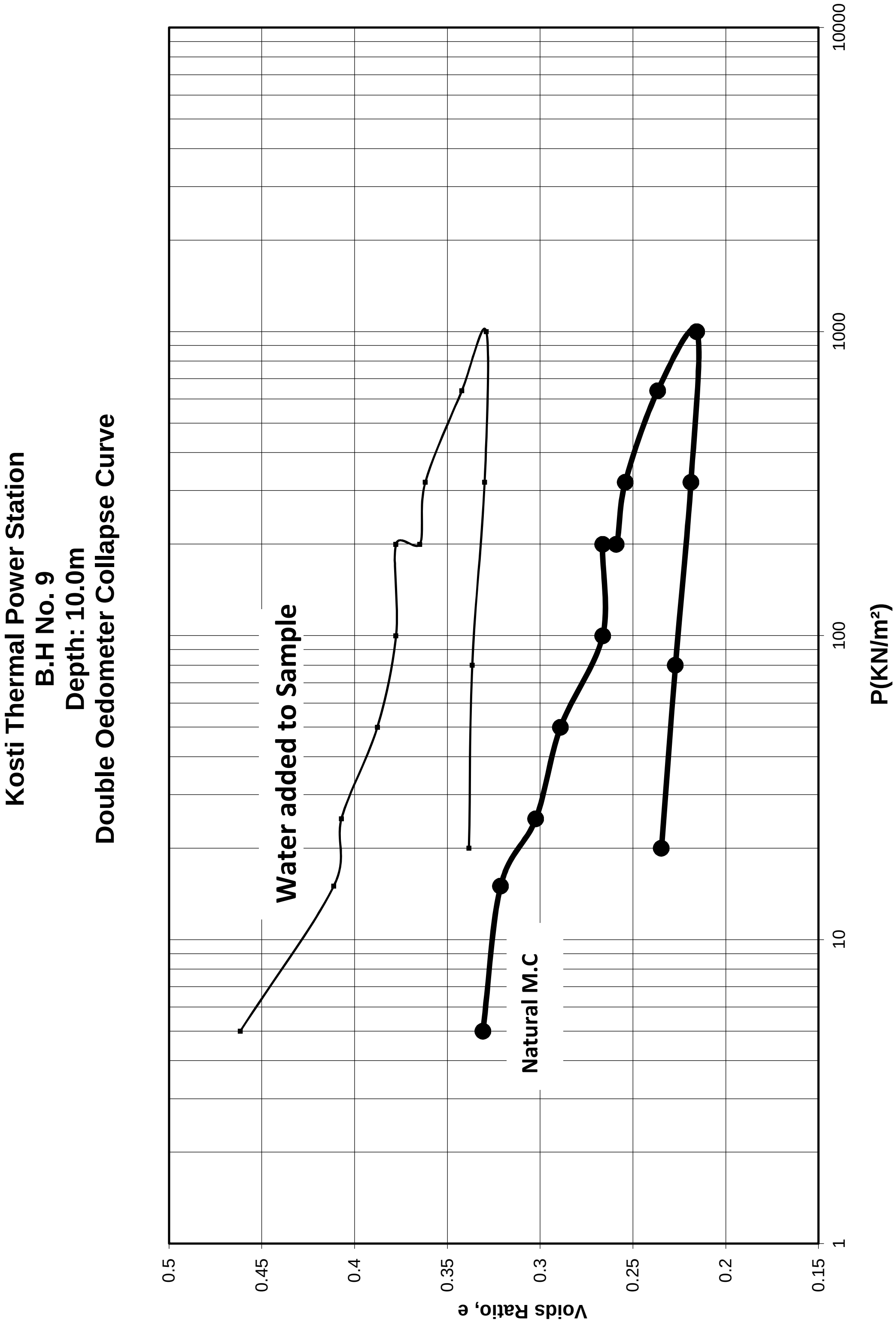

Kosti Thermal Power Station
B.H No. 9
Depth: 10.0m
Single Oedometer Collapse Curve
Voids Ratio, e
0.35
0.33
0.31
0.29
0.27
0.25
0.23
0.21
P(KN/m²)
1
10
100
1000
10000

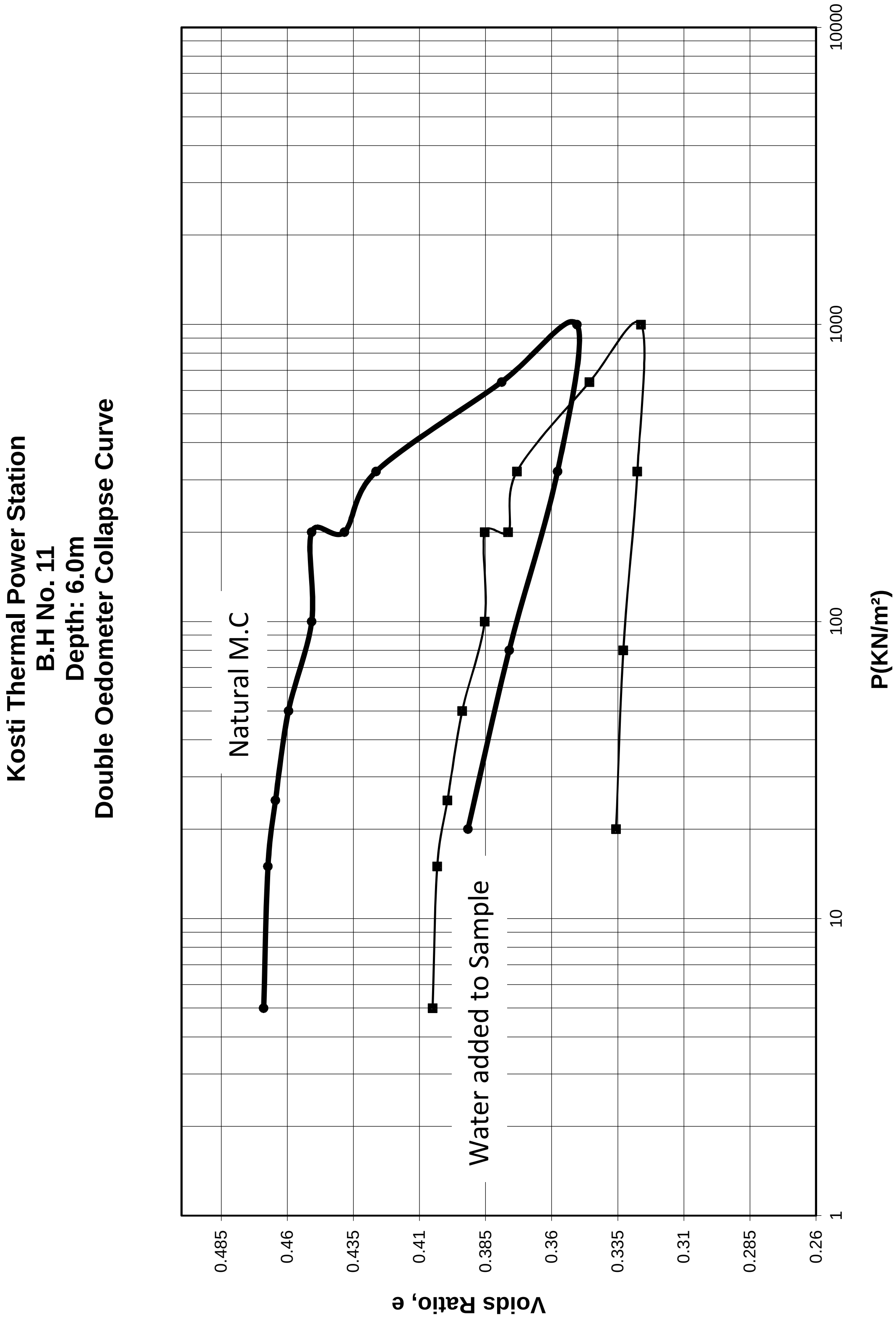

Kosti Thermal Power Station
B.H No. 11
Depth: 6.0m
Single Oedometer Collapse Curve
Voids Ratio, e
0.5
0.45
0.4
0.35
0.3
P(KN/m²)
1
10
100
1000
10000

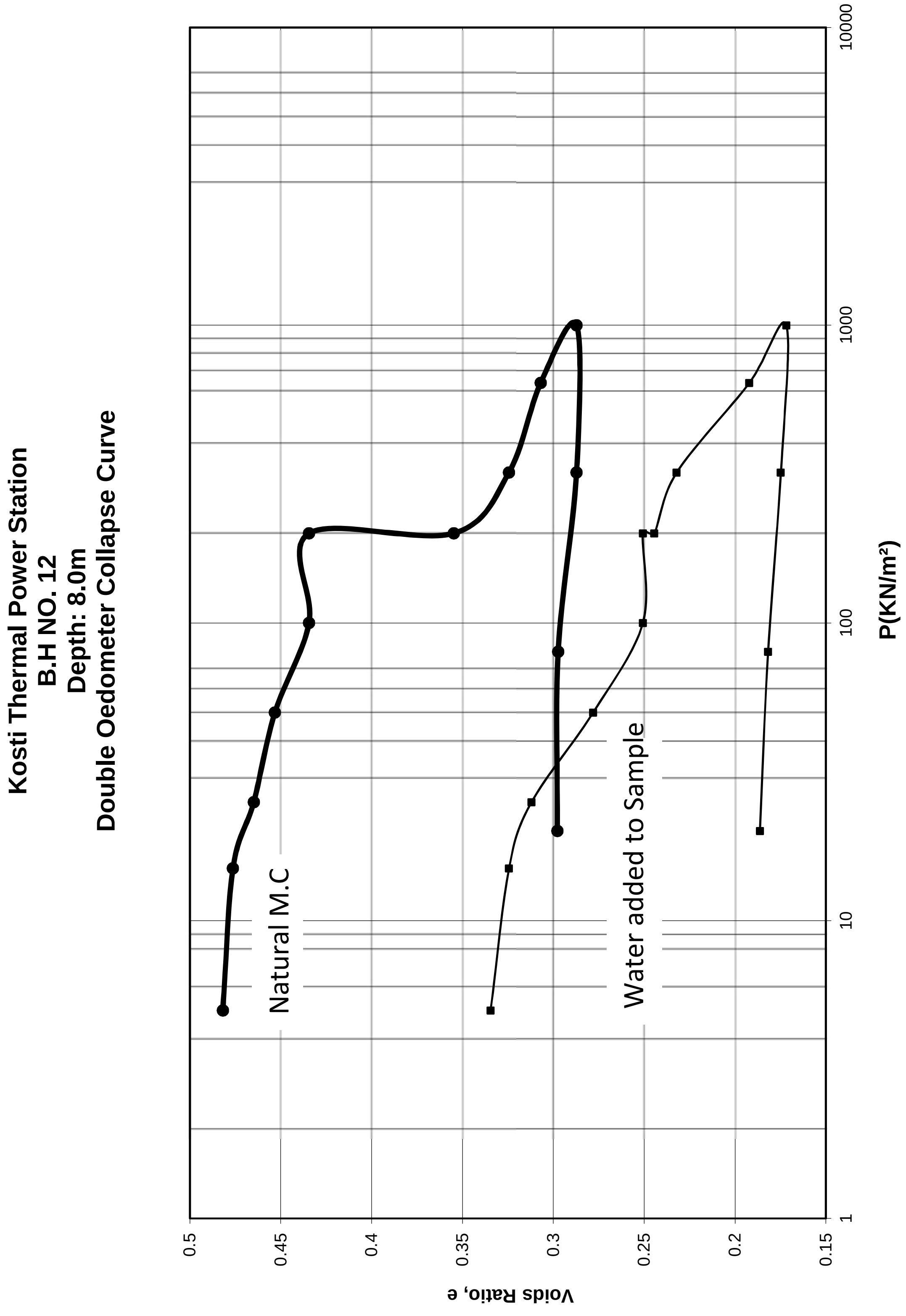
APPENDIX (C-2)

DOUBLE OEDOMETER TEST RESULTS


Kosti Thermal Power Station
B.H No. 2
Depth: 4.0m
Double Oedometer Collapse Curve
Natural M.C
Water added to Sample
Voids Ratio, e
P(KN/m²)
0.55
0.5
0.45
0.4
0.35
0.3
0.25
1
10
100
1000
10000


Kosti Thermal Power Station
B.H No. 9
Depth: 10.0m
Double Oedometer Collapse Curve
Water added to Sample
Natural M.C
Voids Ratio, e
P(KN/m²)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
1
10
100
1000
10000


Kosti Thermal Power Station
B.H No. 11
Depth: 6.0m
Double Oedometer Collapse Curve
Natural M.C
Water added to Sample
Voids Ratio, e
P(KN/m²)
0.485
0.46
0.435
0.41
0.385
0.36
0.335
0.31
0.285
0.26
1
10
100
1000
10000


Kosti Thermal Power Station
B.H NO. 12
Depth: 8.0m
Double Oedometer Collapse Curve
Natural M.C
Water added to Sample
Voids Ratio, e
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
P(KN/m²)
1
10
100
1000
10000

APPENDIX (D)
CHEMICAL ANALYSIS TEST RESULTS

Chemical Test Report **KostiThermal Power Station**

Chemical and Physical Analysis

Methods of Tests: BS 1377 - Part 3 -1990

B.H. No.	Depth	T.Hardness	Calcium	Magnesium	Sodium	Unit
1	3.0	680	204	40.8	28.13	Mg/l
1	4.0	650	260	NIL	24.65	Mg/l
2	2.0	110	NIL	26.4	14.43	Mg/l
3	2.0	80	NIL	19.2	14.99	Mg/l
3	9.0	80	NIL	19.8	14.03	Mg/l
4	2.0	150	12	28.8	21.76	Mg/l
4	4.0	190	16	36	13.7	Mg/l
5	6.0	60	NIL	14.4	13.07	Mg/l
6	1.0	280	100	7.2	22	Mg/l
6	4.0	110	24	12	20.8	Mg/l
7	6.0	100	NIL	24	15.71	Mg/l
7	8.0	100	NIL	24	14.75	Mg/l
7	10.0	90	NIL	21.6	14.67	Mg/l
8	6.0	140	NIL	30.6	17.15	Mg/l
8	8.0	80	NIL	19.2	15.79	Mg/l
8	10.0	90	NIL	21.6	15.07	Mg/l
9	10.0	100	NIL	24	15.39	Mg/l
10	6.0	70	NIL	16.8	16.83	Mg/l
10	10.0	240	12	50.4	16.91	Mg/l
11	10.0	170	NIL	40.8	14.11	Mg/l
11	6.0	100	NIL	24	14.92	Mg/l
12	6.0	90	NIL	21.6	14.43	Mg/l
12	8.0	100	12	16.8	14.91	Mg/l
12	10.0	90	NIL	21.6	16.27	Mg/l
13	2.0	100	NIL	24	14.92	Mg/l

Table (D - 1) Chemical Tests Results

Chemical Test Report **KostiThermal Power Station**

Chemical and Physical Analysis

Methods of Tests: BS 1377 - Part 3 -1990

B.H. No.	Depth	PH	PH 1:2.5 soil/Water	Sulphate	Chloride	Organic Matter
1	3.0	8.18	8.54	0.0856	0.0142	2.7894
1	4.0	8.29	8.56	0.0687	0.0689	2.9068
2	2.0	7.9	8.3	0.0514	0.0142	1.3284
3	2.0	7.92	7.15	0.0343	0.0142	1.3178
3	9.0	8.22	7.17	0.0341	0.0352	1.2164
4	2.0	8.63	7.25	0.0343	0.0312	2.6174
4	4.0	8.4	8.15	0.0685	0.0284	2.0146
5	6.0	7.98	6.55	0.0685	0.0173	3.835
6	1.0	7.25	6.88	0.1714	0.0312	4.8281
6	4.0	8.2	9.25	0.0513	0.0355	4.6853
7	6.0	7.68	8.69	0.0339	0.0173	1.1982
7	8.0	7.85	8.05	0.0342	0.0242	1.145
7	10.0	7.86	8.2	0.0857	0.0173	0.8446
8	6.0	7.68	7.76	0.0343	0.0379	2.13
8	8.0	7.6	7.7	0.0684	0.0312	2.3886
8	10.0	7.7	7.92	0.0685	0.0379	2.01
9	10.0	8.79	8.86	0.0343	0.0213	2.5838
10	6.0	8.7	8.69	0.0513	0.0379	4.7553
10	10.0	9.3	9.04	0.0685	0.0448	1.9028
11	10.0	8.82	7.65	0.0343	0.0379	3.2761
11	6.0	8.95	9.26	0.0342	0.0158	1.986
12	6.0	8.07	7.76	0.0514	0.0379	2.00887
12	8.0	7.9	7.75	0.0514	0.0448	3.8077
12	10.0	7.9	7.86	0.0857	0.0312	2.0296
13	2.0	9.14	8.8	0.0342	0.0071	0.5596

Table (D - 1) Chemical Tests Results

APPENDIX (E)

TABLES AND TESTS RESULTS

- **Specific Gravity**

BH. No.	Depth (m)	Specific Gravity
1	3.0	2.78
2	2.0	2.82
4	2.0	2.74
7	8.0	2.72
7	6.0	2.69
8	8.0	2.86
9	10.0	2.85
12	8.0	2.78

Table No.(4.1) Specific Gravity Test Results

- **Bulk Density Test**

BH. No.	Depth (m)	Bulk Density (g/cm^3)
1	4.0	1.8187
2	2.0	2.1626
6	2.0	1.8468
6	4.0	2.0104
8	6.0	2.1349
12	8.0	1.8950

Table No.(4.2) Bulk Density Test Results

- **Permeability Test**

BH.No.	Depth	Cofficient of Permeability (K) (cm/s)
1	3.0	0.02282
4	2.0	0.02322
7	6.0	0.022699
8	8.0	0.02426
9	10.0	0.02378
12	8.0	0.022794

Table (4.3) Results of permeability test

- **Free Swelling**

BH.No.	*Depth (m)*	*Initial Volume of Specimen (I)*	*Final Volume of Specimen (F)*	*Free Swell (F.S %)*
1	3.0	156.3	250	60
4	2.0	120.4	170	41.17
6	1.0	149.3	235	57.45
7	6.0	104.2	125	20.0
7	8.0	58.6	81	38.27
8	8.0	124.6	180	44.45
10	10.0	126.8	185	45.94
12	8.0	114.4	155	35.48
13	2.0	58.2	80	37.50

Table (4.4) Free Swelling Test Results

- **Swelling Pressure Test**

Borehole No.	**Depth (m)**	**Initial moisture content (%)**	**Final moisture content (%)**	**Swelling Pressure Kpa**	**Plasticity Index (%)**	**Classification of the Samples**
1	4.0m	25.94	28.40	20	41	CH
2	2.0m	14.50	15.54	0	17	SC
8	6.0m	9.21	14.14	10	20	SC
8	10.0m	10.23	15.12	0	16	SC
12	10.0m	10.42	15.97	10	18	SC

Table (4.5): Swelling Pressure Test Results

- **Pin hole Test**

Depth (m)	B.H NO.	Max Hydraulic Head Applied (mm)	Average of Last Head Rate of flow (ml/sec)	Classification
1	3	1020	3.13	ND2
2	4	1020	1.25	ND2
4	2	1020	2.56	ND1
6	1	1020	1.98	ND1
7	6	50	0.9	D2
8	8	50	0.9	ND4
9	10	50	0.8	ND4
11	6	50	0.8	ND4

Table (4.8) Pin hole Test Results

- **Sensitivity Tests**

BH. No.	Depth (m)	(q_u) unconfined compressive strength (undisturbed) (kpa)	(q_u) unconfined compressive strength (remolded) (kpa)	Sensitivity (S_t)	Description
1	3.0	4048.42	2146.58	1.886	Slightly sensitive
2	4.0	5305.22	2439.74	2.175	Medium sensitivity
7	6.0	2415.77	679.51	3.555	Medium sensitivity
8	8.0	20406.69	825.12	24.732	Medium quick
9	10.0	6784.28	1027.41	6.603	Very sensitive
12	8.0	344.43	586.44	0.587	Slightly sensitive

Table (4.9) Sensitivity Test Results

- **Summary of Identification Methods for Collapse Soil**

No.	Investigator , year	Criteria
1	Abelev,1948	$\delta_s=(\Delta e/1+e_L)$ Collapse is probable when: $\delta_s > 2\%$
2	Denisov, 1951	$K=e_L/e_o$ If k = 0.5-0.75 ; highly Collapsible If k = 1.0 ; non Collapsible loam If k = 1.5-2.0 ; non Collapsible soil
3	Priklonski, 1952	$K_D=(N.M.C-P.L)/PI$ If $k_D < 0$; highly Collapsible soil If $k_D > 0.5$; non Collapsible loam If $k_D > 1.0$; Swelling soil
4	Clevenger, 1958	$\gamma_{dry} < 12.6$ kn/m^3; Significant Settlement $\gamma_{dry} < 14.1$ kn/m^3; transitional Settlement
5	Gibbs and Bara, 1962	Collapse is probable when $\gamma_{dry} < 162.3/(1+0.026*L.L)$ Ib/ft^3 *or when:* $e_o > 2.6*L.L/100$
6	Soviet Building Code,1962	Collapse is probable when :is S > 60% *and* $(e_o-e_L)/(1+e_o) > -0.10$
7	Feda 1964 , 1966	$K_L=(N.M.C/S)-(PL/PI)$ If $K_L > 0.85$; Collapseible Soil
8	Handy, 1973	Clay Content <16% ; high probability for collapse 24%> Clay Content > 16% ; probably collapsible 32%> Clay Content >25% ; probability of collapse of less than 50% Clay Content > 32%; non collapsible
9	Zur and wiseman 1973	$\gamma_{dry} / \gamma_{dry\ L.L} < 1.1$; Soil prone to collapse $\gamma_{dry} / \gamma_{dry\ L.L} < 1.3$; Soil prone to swell

Table (5.1) Summary of Identification methods for collapse soil

APPENDIX (F)

SAMPLES CLASSIFICATION ON BORROW AREA SOIL SAMPLES GIVEN BY BHEL MARKED SPILE AND PCL

Introduction:

The client has selected two samples from borrow areas, PCL and SPILE. Tests are carried out on these two samples for Atterberg limit, Sieve analysis, Hydrometer, Specific Gravity, Compaction Test, Single and Double Oedometer Test.

Classification Results for these samples are shown in table (1) below.

Sample No.	Description	LL%	PL%	PI%	%Pass Sieve #200	Classification of sample	MDD g/cm³	OMC %
SPILE	Dark brown clayey gravel	40	23	17	24.04	GC	2.05	10.4
PCL	Dark brown to light clayey sand	38	22	16	40.50	SC	1.97	11.4

Table (1) Soil Samples Classificaion

The classificatoion results are shown in table (1) illustrated, soil is dark brown clayey gravel (GC) for SPILE sample and dark to light brown clayey sand (SC) for PCL sample. Optimum moisture content is 10.4% for SPILE sample and 11.4% for PCL sample in compaction test results which are shown in Appendix A. Also, maximum dry density equal 2.05g/cm^3 and 1.97g/cm^3 for SPILE sample and PCL sample respectively.

At SPILE sample, the results gave liquid limit value around 40% and plastic index is 17%. At PCL, results gave liquid limit value is 38% and plastic index around 16%, these results of Atterberge limits indicate possibility of occurence medium potential for swelling.

Grain size distribution are the percentage of the various size of soil grains percent in a given dry soil sample is carried out by mechanical sieve analysis for coarse grain and whereas fine-grained soils are analysed by the hydrometer method. Graphs are shown in Appendix G.

Specific gravity results determined in Table (2) for the soil samples by using a pycnometer.

Samples No. (m)	Specific Gravity
SPILE	2.74
PCL	2.74

Table No.(2) Specific Gravity Test Results

Single Oedometer Collapse Test carried out for samples in four stages with different moisture content. **First**, by using 8% moisture content which is less than the optimum moisture content, and loaded in the conventional oedometer to a stress level 200kpa and then inundation by distilled water is applied to induce collapse. Two rings for test are taken, one at a Top of the mould other in the Bottom for samples SPILE and PCL separately. (disturbed sample compacted with 8% moisture content at the mould in three layers, then two consolidation rings pushed entire the samples, one at top side and other in bottom side)**.**

Second by using 13% of moisture content which is more than the optimum moisture content for two rings at top and bottom. Graphs and results are shown in appendix G.

The sample results which used 8% moisture content shows that, the difference between void ratio from saturation values Δe_c is high compared to that of moisture content 13%.

Table (3) shows the results of single oedometer test and results of collapse potential.

Sample	Case	e_o	e_1	e_2	C_P
SPILE	8% moisture content **(TOP)**	0.36817	0.33279	0.25166	5.90%
SPILE	8% moisture content **(BOTTOM)**	0.37301	0.27274	0.23016	3.12%
SPILE	13% moisture content **(TOP)**	0.30847	0.27689	0.27596	0.071%
SPILE	13% moisture content **(BOTTOM)**	0.25847	0.23317	0.23228	0.071%
PCL	8% moisture content **(TOP)**	0.62009	0.49638	0.43158	4.0%
PCL	8% moisture content **(BOTTOM)**	0.54476	0.50044	0.39621	6.74%
PCL	13% moisture content **(TOP)**	0.34157	0.30146	0.29861	0.212%
PCL	13% moisture content **(BOTTOM)**	0.31702	0.27339	0.27060	0.212%

Table(3) Single oedometer and Collapse potential Results

Double Oedometer Collapse Test is carried out by two identical samples are placed in oedometers; one tested at in-situ natural moisture content, and the other is fully saturated before the test begins, and then subjected to identical loading. These were taken for samples SPILE and PCL,

Two, stress versus strain curves are generated. The difference between the compression curves is the amount of deformation that would occur at any stress level at which the soil get saturated. Results for double oedometer collapse test are shown in Appendix G indicated low void ratio at the difference between natural moistue and added water to sample in collapse soil for samples SPILE and PCL. Also, at same initial void ratio of natural moisture content and water added curves at appendix G and Tables (4-1) and (4-2), the collapse potential C_p indicated medium to high collapse.

P KN/m^2	e_1	e_2	e_o	**C_P(%)**
80	0.421	0.459	0.501	2.532
160	0.392	0.438	0.501	3.051
320	0.361	0.420	0.501	3.924
640	0.318	0.392	0.501	4.930

Table (4-1) Double collapse Results of C_P for PCL sample

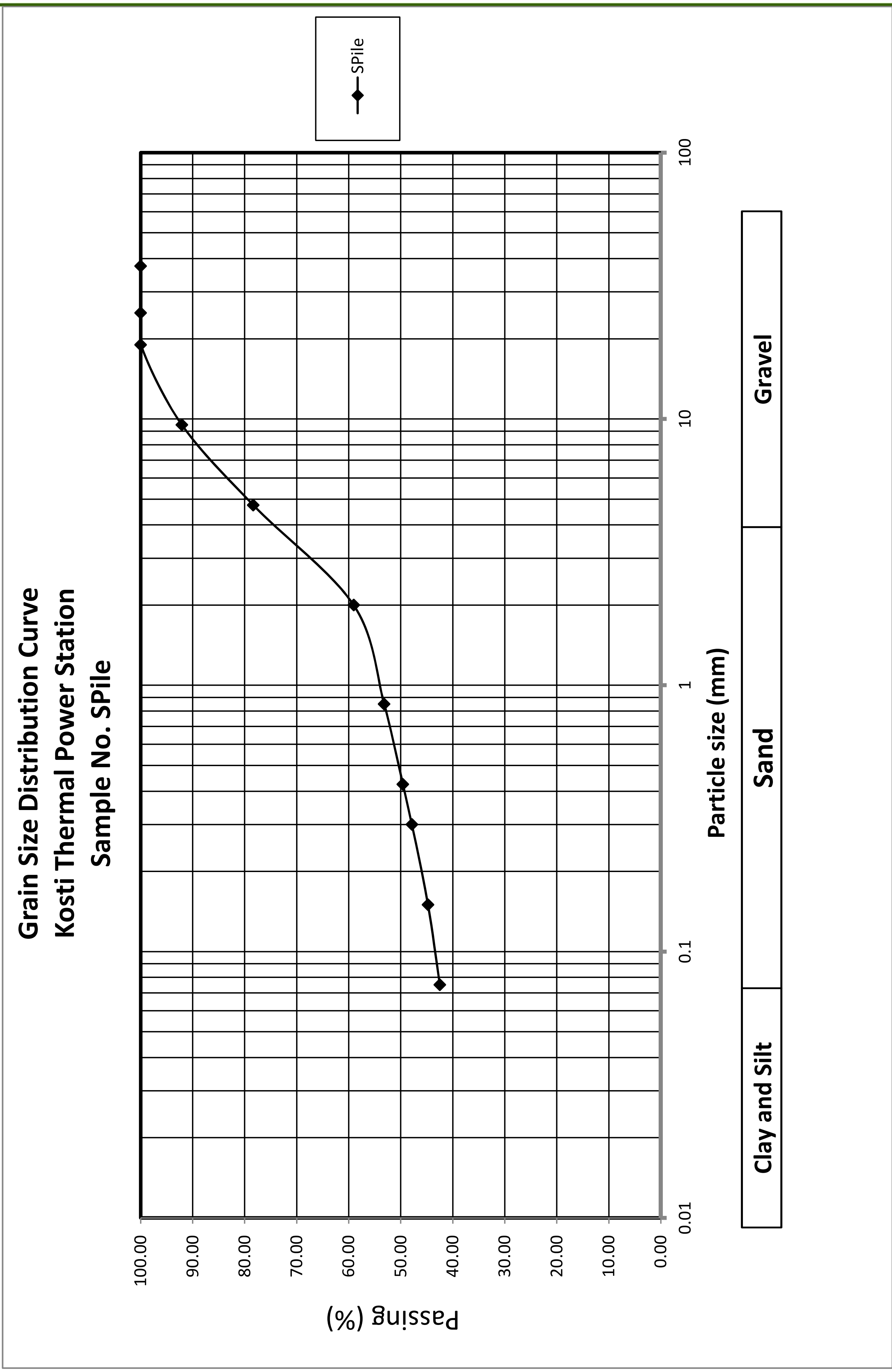
P KN/m^2	e_1	e_2	e_o	C_P(%)
160	0.3460	0.3530	0.3658	0.5125
320	0.3200	0.3390	0.3658	1.3911
640	0.2830	0.3200	0.3658	2.7090

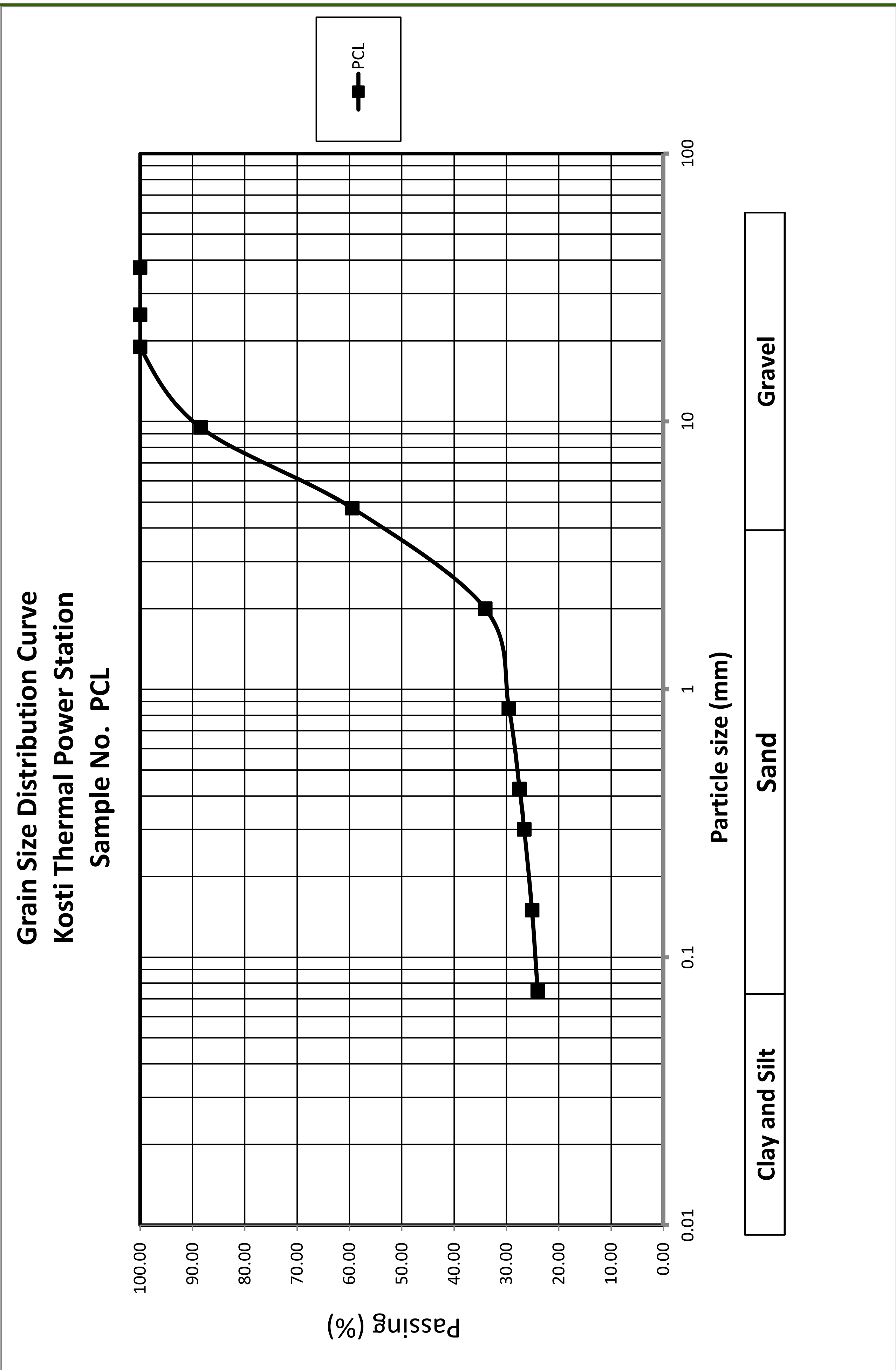
Table (4-2) Double collapse Results of C_p for SPILE sample

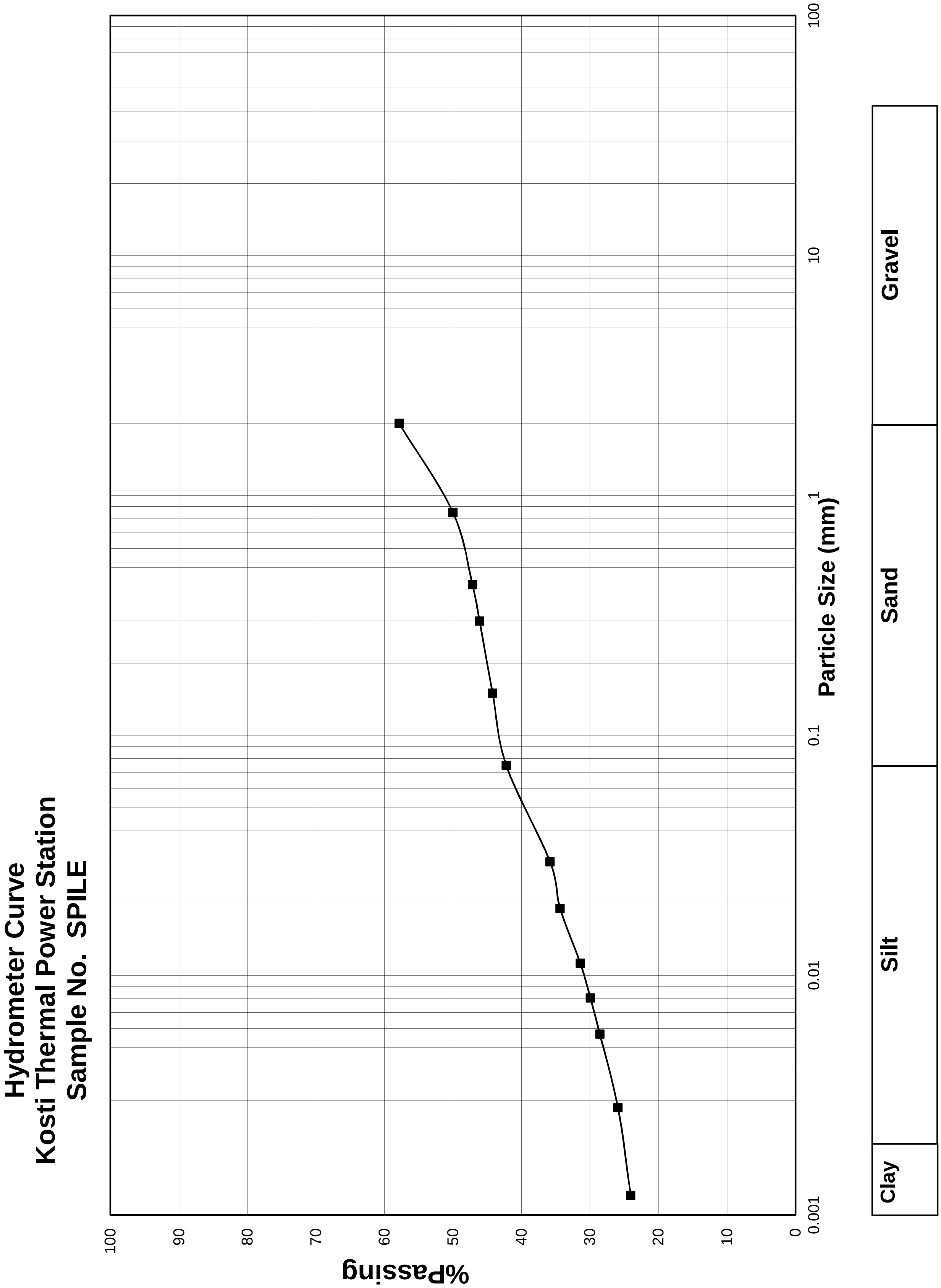
APPENDIX (G)

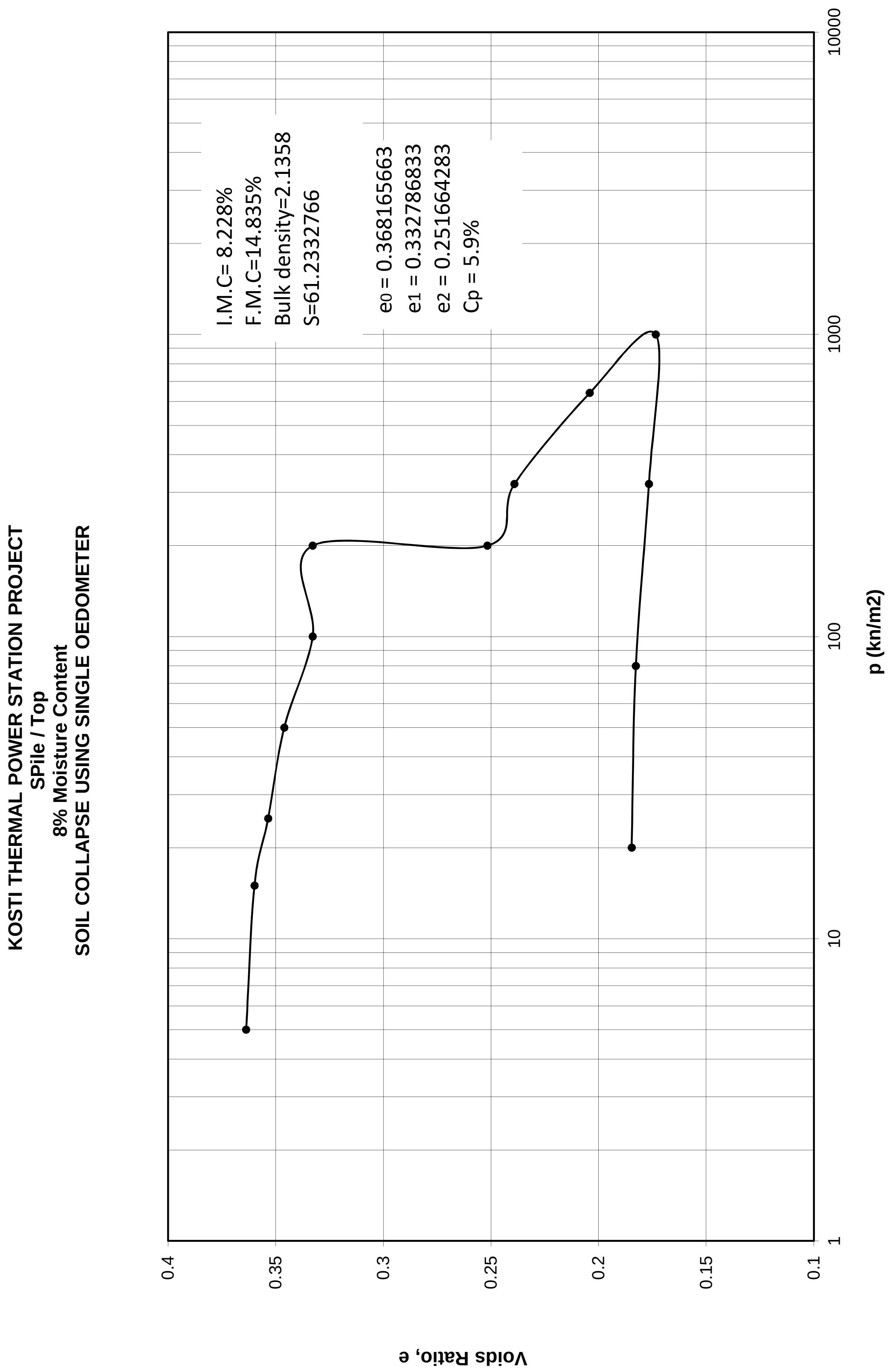
RESULTS FOR TESTS OF SAMPLES

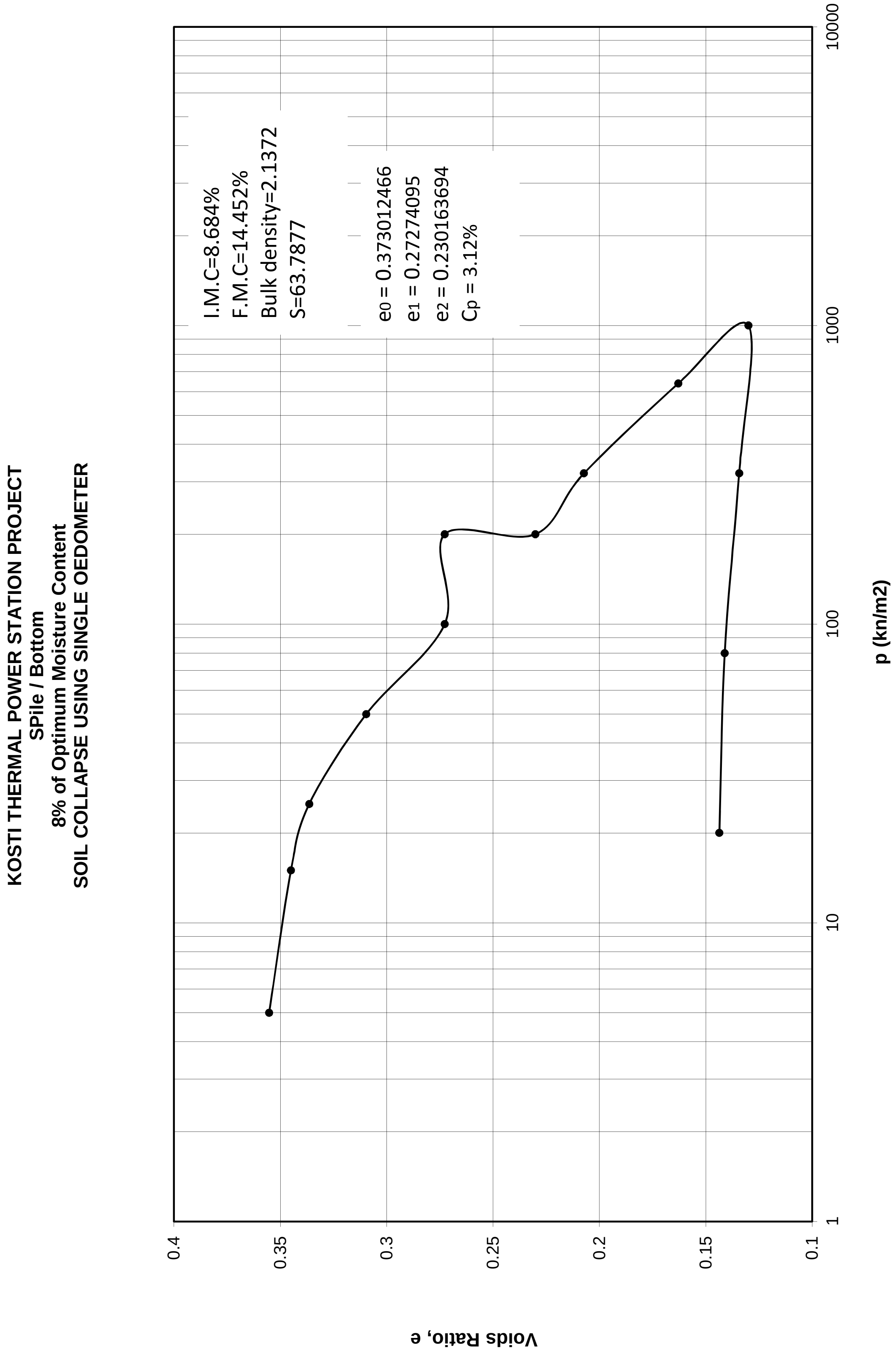
SPILE AND PCL

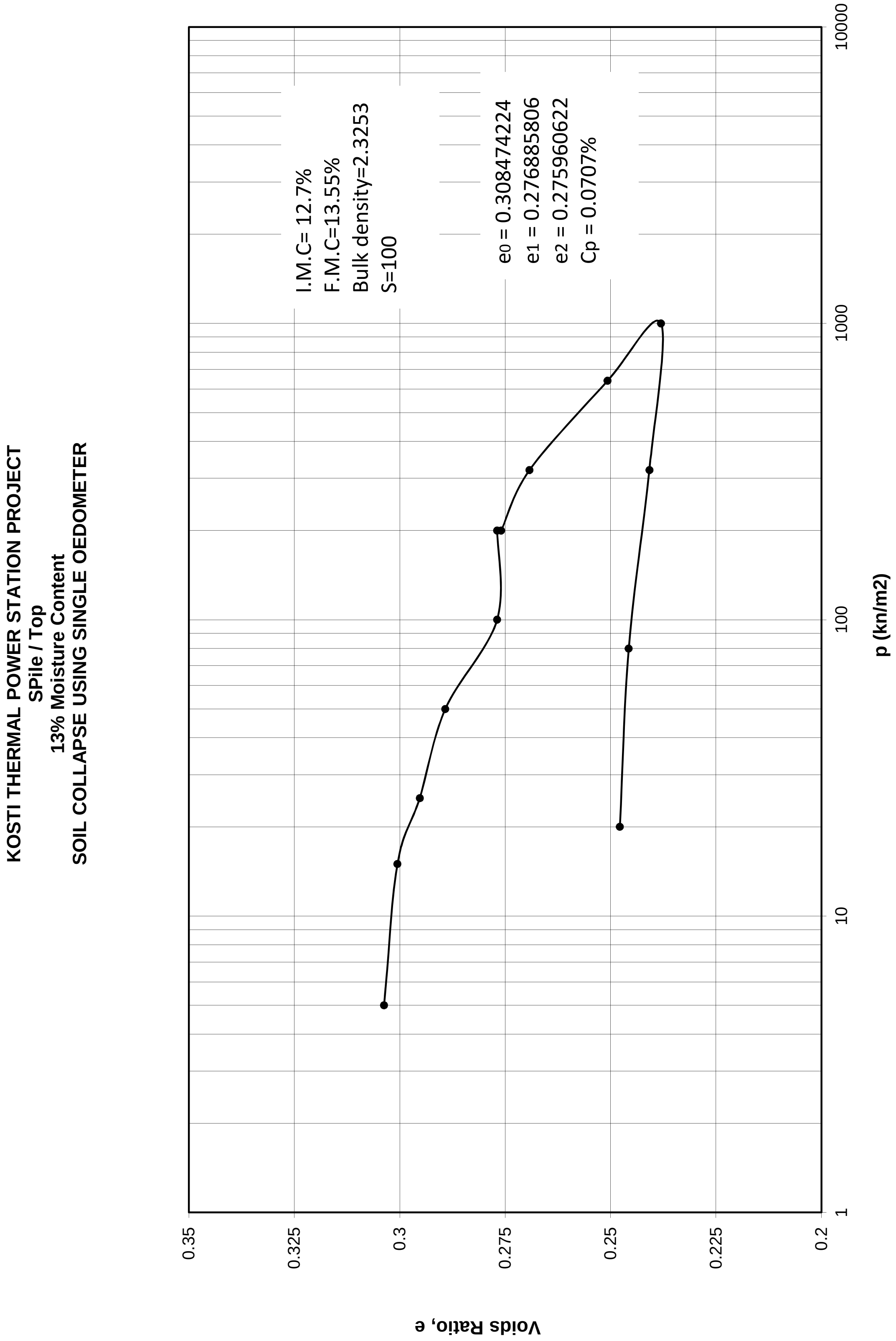

Grain Size Distribution Curve
Kosti Thermal Power Station
Sample No. SPile
SPile
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

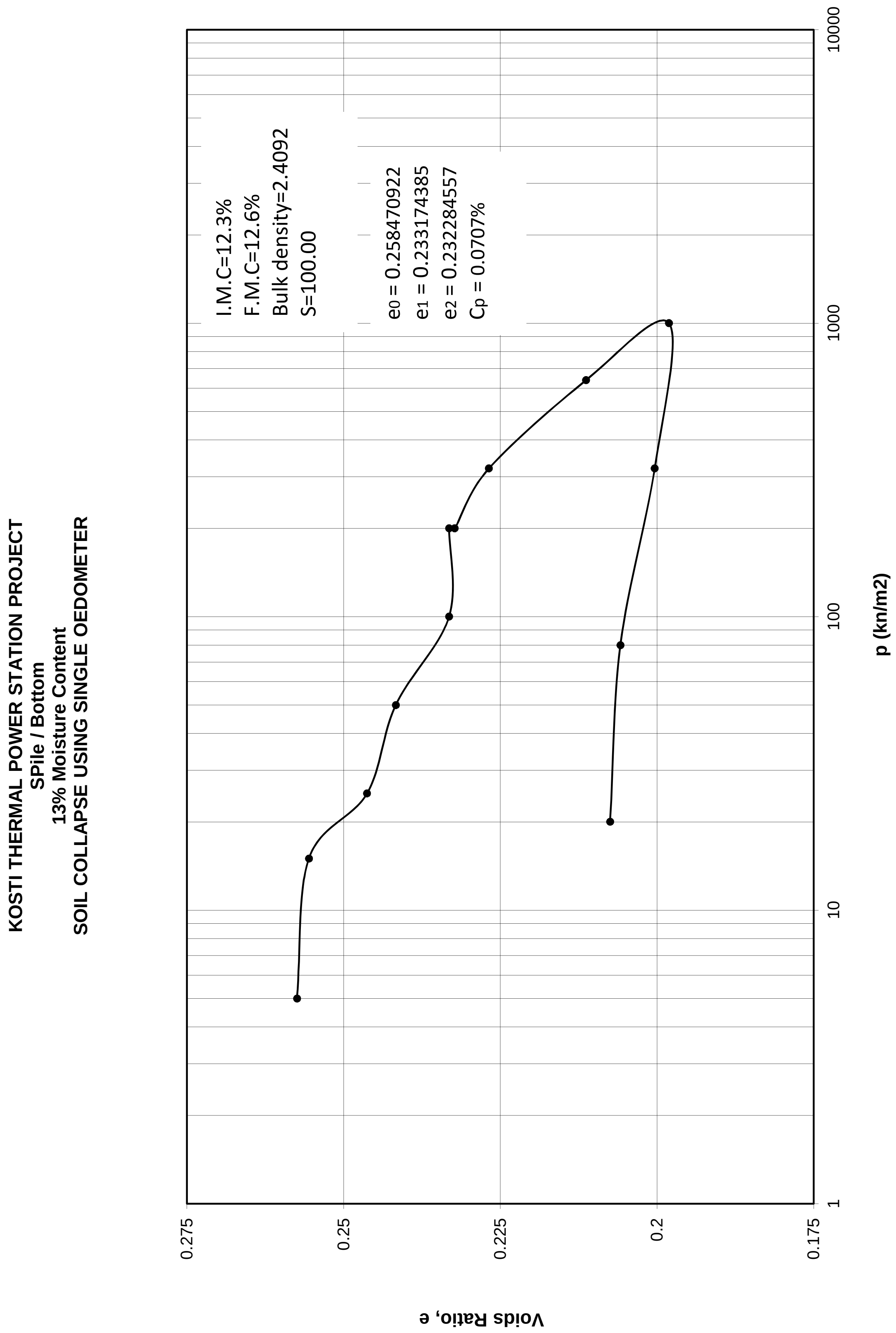

Grain Size Distribution Curve
Kosti Thermal Power Station
Sample No. PCL
PCL
Passing (%)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.01
0.1
1
10
100
Particle size (mm)
Clay and Silt
Sand
Gravel

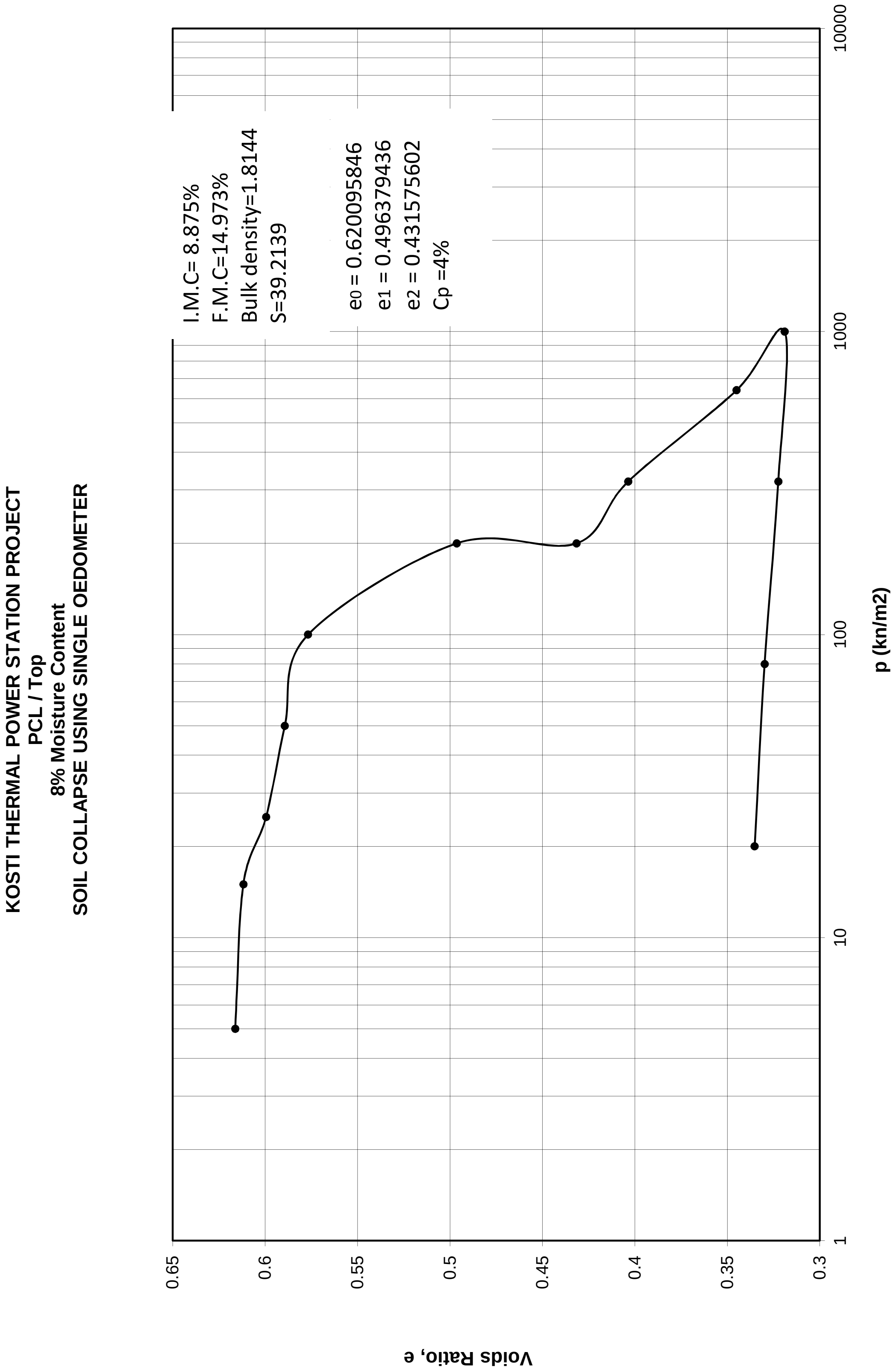

Hydrometer Curve
Kosti Thermal Power Station
Sample No. SPILE
%Passing
0
10
20
30
40
50
60
70
80
90
100
Particle Size (mm)
0.001
0.01
0.1
1
10
100
Clay
Silt
Sand
Gravel

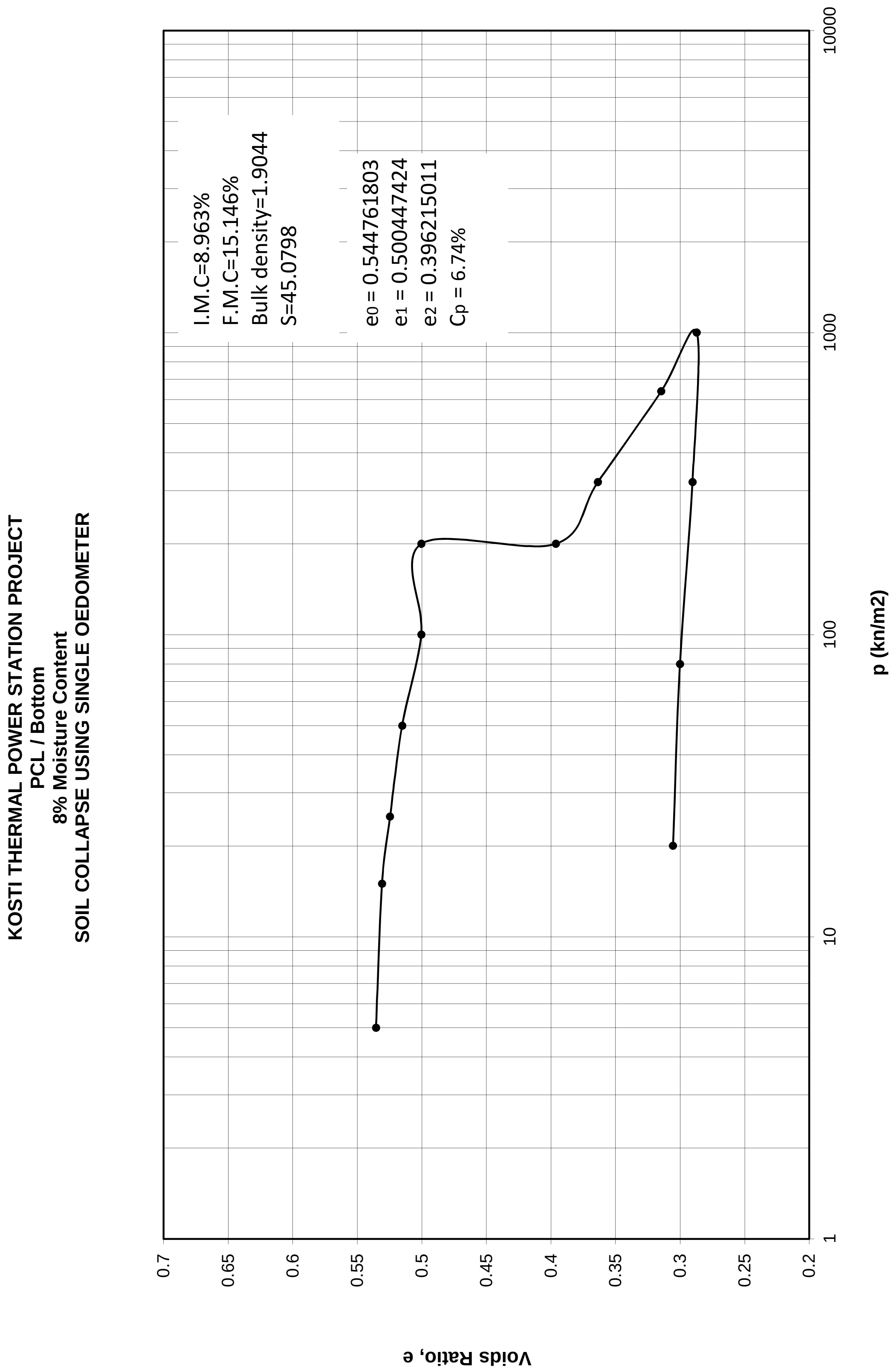

KOSTI THERMAL POWER STATION PROJECT
SPile / Top
8% Moisture Content
SOIL COLLAPSE USING SINGLE OEDOMETER
I.M.C= 8.228%
F.M.C=14.835%
Bulk density=2.1358
S=61.2332766
e0 = 0.368165663
e1 = 0.332786833
e2 = 0.251664283
Cp = 5.9%
Voids Ratio, e
p (kn/m2)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
1
10
100
1000
10000

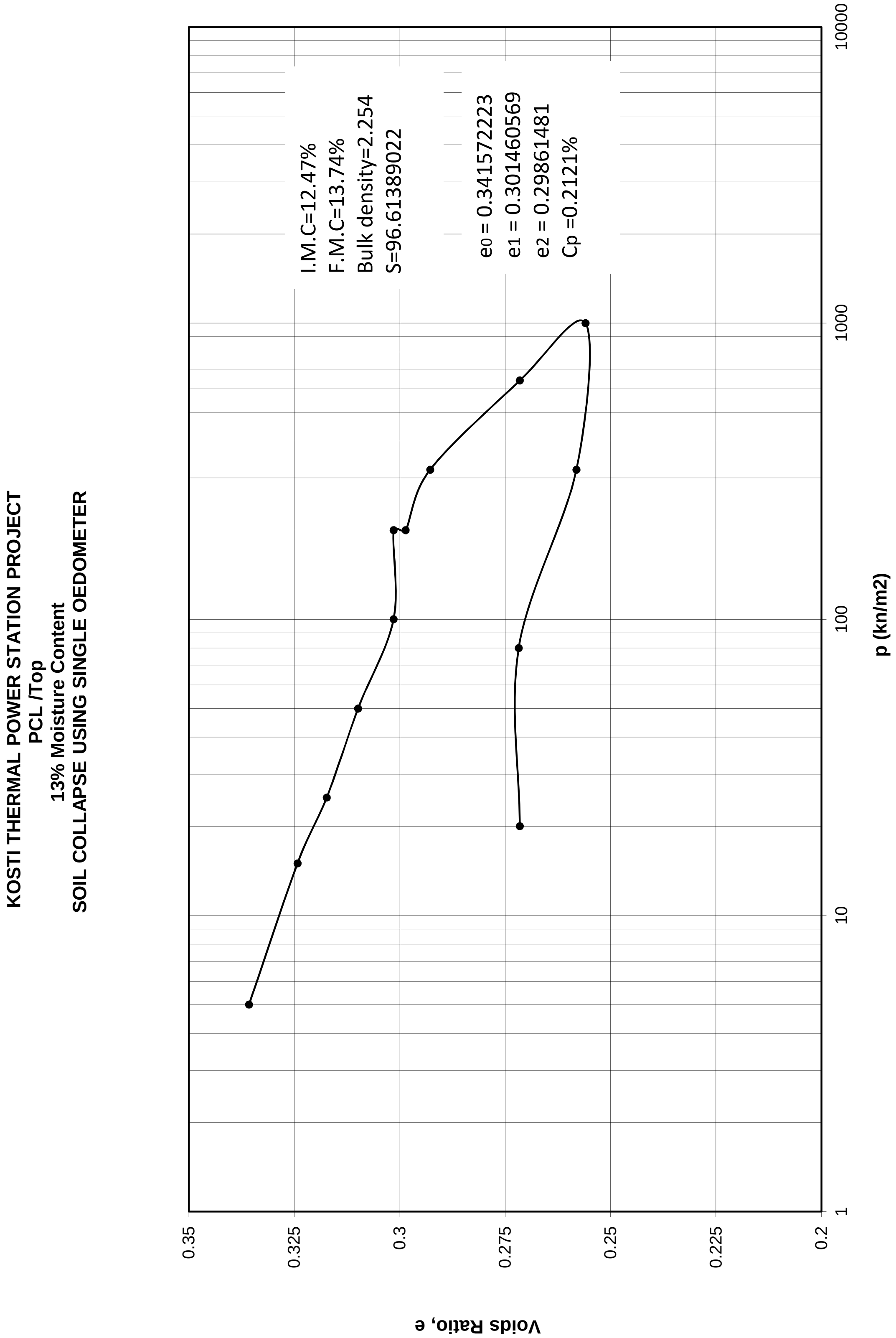

KOSTI THERMAL POWER STATION PROJECT
SPile / Bottom
8% of Optimum Moisture Content
SOIL COLLAPSE USING SINGLE OEDOMETER
I.M.C=8.684%
F.M.C=14.452%
Bulk density=2.1372
S=63.7877
e_0 = 0.373012466
e_1 = 0.27274095
e_2 = 0.230163694
C_p = 3.12%
Voids Ratio, e
p (kn/m2)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
1
10
100
1000
10000

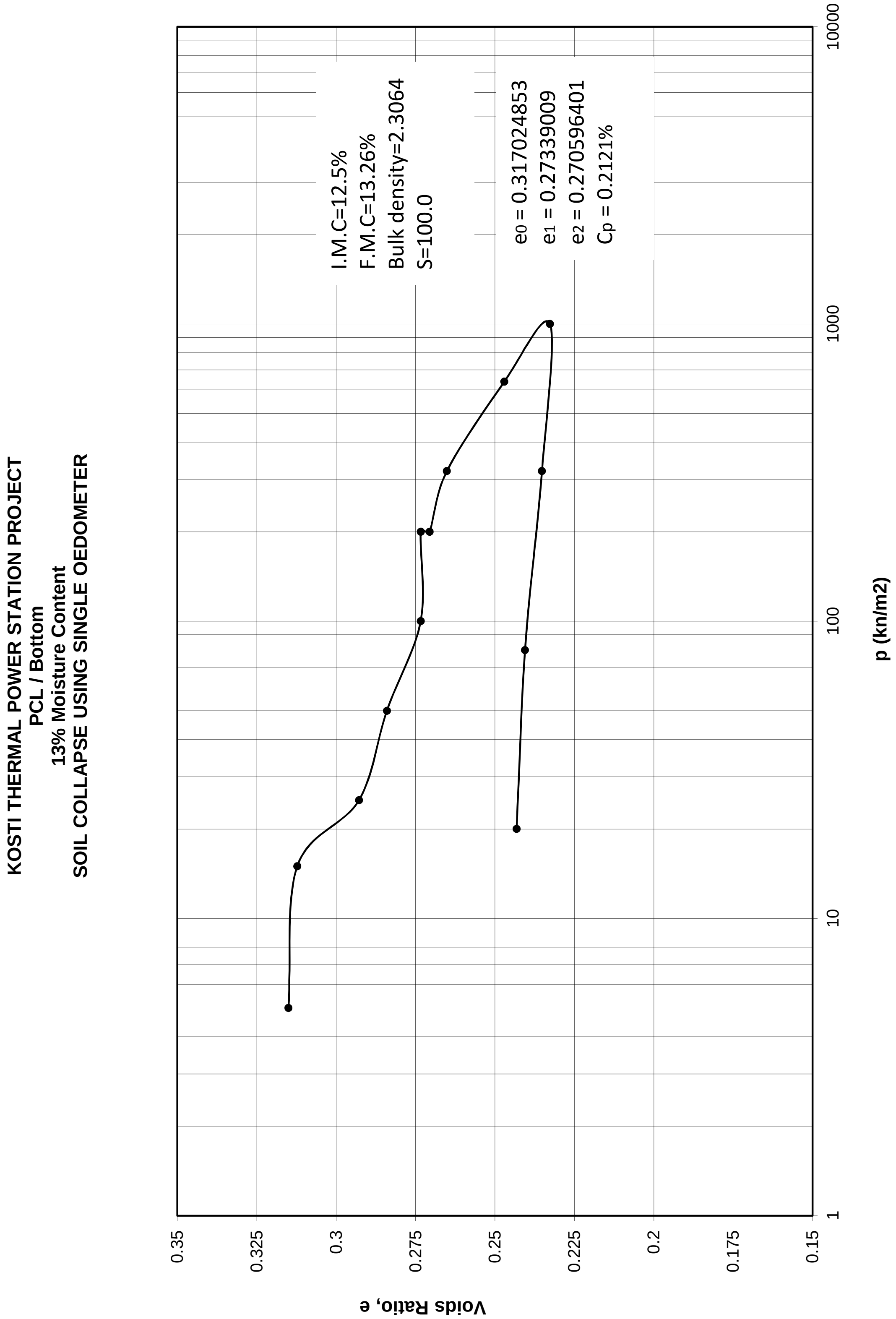

KOSTI THERMAL POWER STATION PROJECT
SPile / Top
13% Moisture Content
SOIL COLLAPSE USING SINGLE OEDOMETER
I.M.C= 12.7%
F.M.C=13.55%
Bulk density=2.3253
S=100
e0 = 0.308474224
e1 = 0.276885806
e2 = 0.275960622
Cp = 0.0707%
Voids Ratio, e
p (kn/m2)
0.35
0.325
0.3
0.275
0.25
0.225
0.2
1
10
100
1000
10000

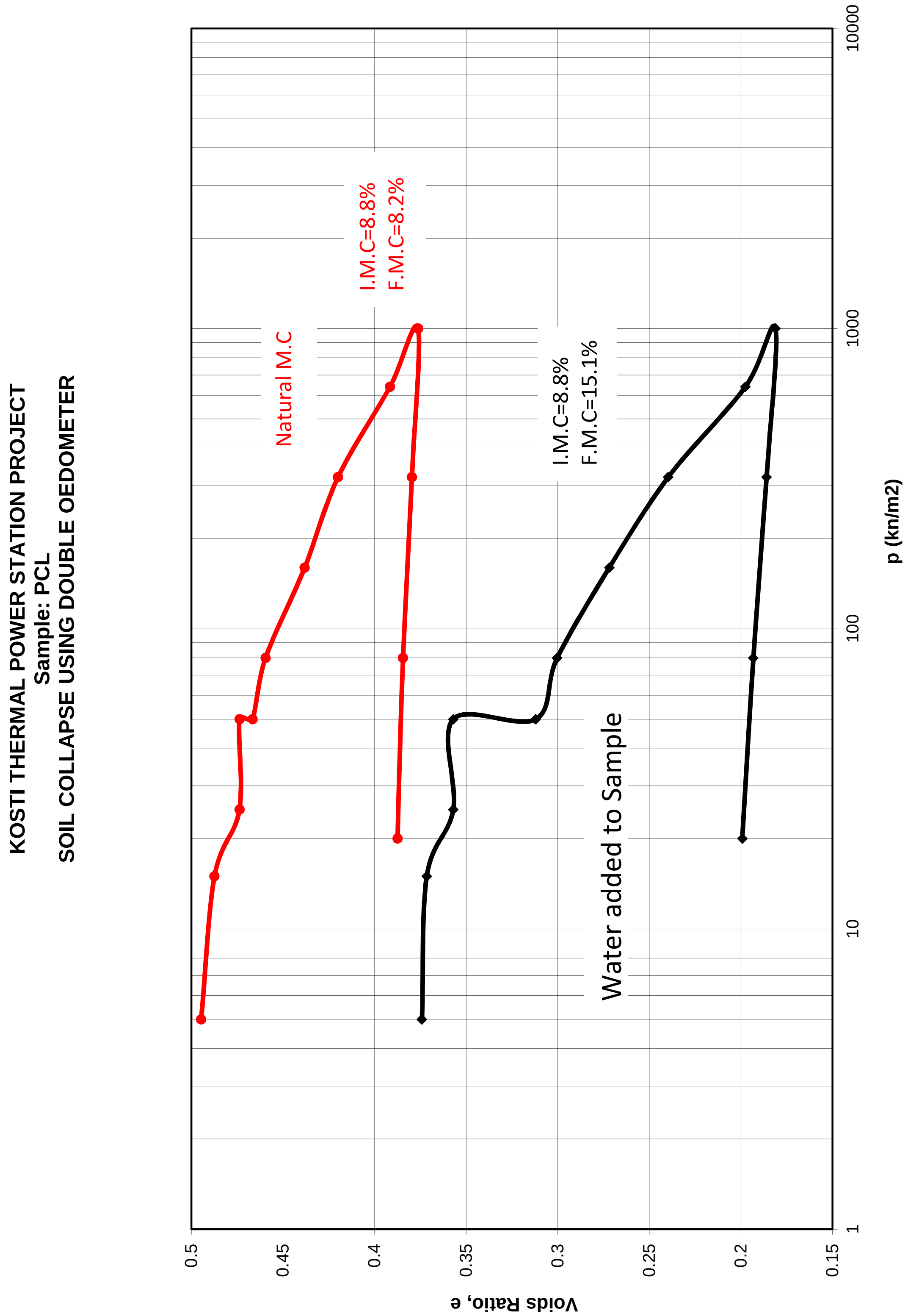

KOSTI THERMAL POWER STATION PROJECT
SPile / Bottom
13% Moisture Content
SOIL COLLAPSE USING SINGLE OEDOMETER
I.M.C=12.3%
F.M.C=12.6%
Bulk density=2.4092
S=100.00
e0 = 0.258470922
e1 = 0.233174385
e2 = 0.232284557
Cp = 0.0707%
Voids Ratio, e
p (kn/m2)
0.275
0.25
0.225
0.2
0.175
1
10
100
1000
10000

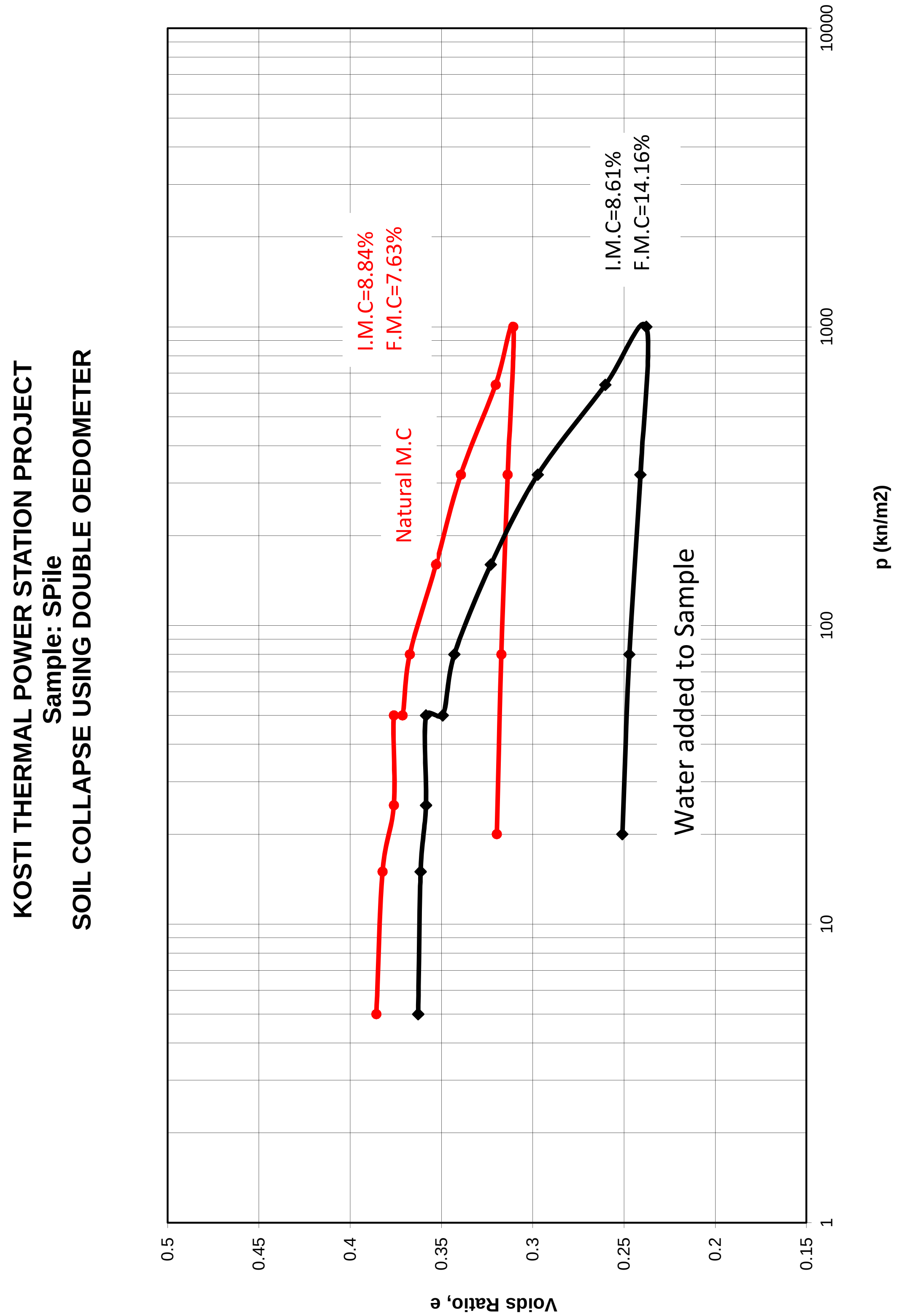

KOSTI THERMAL POWER STATION PROJECT
PCL / Top
8% Moisture Content
SOIL COLLAPSE USING SINGLE OEDOMETER
I.M.C= 8.875%
F.M.C=14.973%
Bulk density=1.8144
S=39.2139
e0 = 0.620095846
e1 = 0.496379436
e2 = 0.431575602
Cp =4%
Voids Ratio, e
p (kn/m2)
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
1
10
100
1000
10000

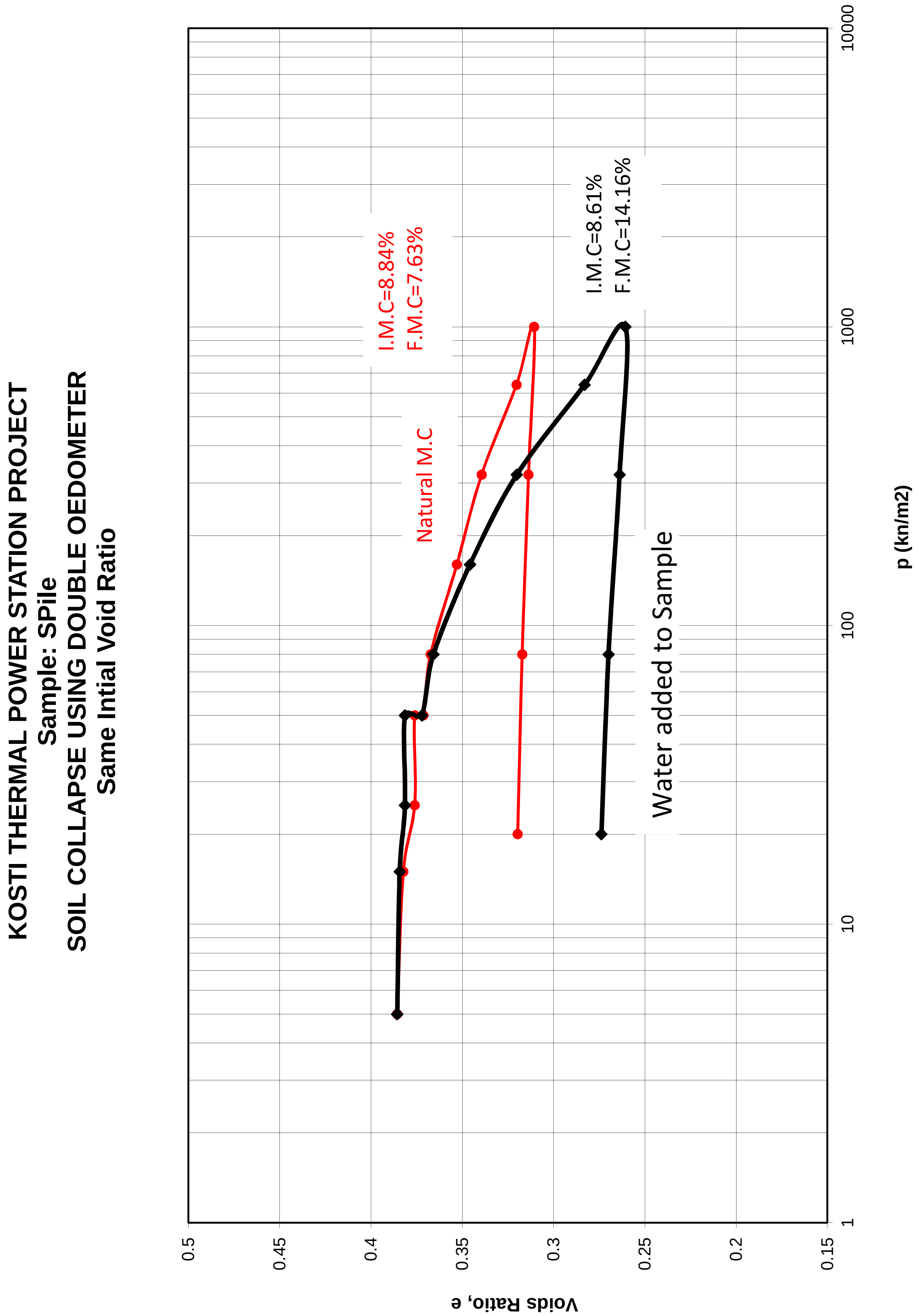

KOSTI THERMAL POWER STATION PROJECT
PCL / Bottom
8% Moisture Content
SOIL COLLAPSE USING SINGLE OEDOMETER
I.M.C=8.963%
F.M.C=15.146%
Bulk density=1.9044
S=45.0798
e0 = 0.544761803
e1 = 0.500447424
e2 = 0.396215011
Cp = 6.74%
Voids Ratio, e
p (kn/m2)
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
1
10
100
1000
10000

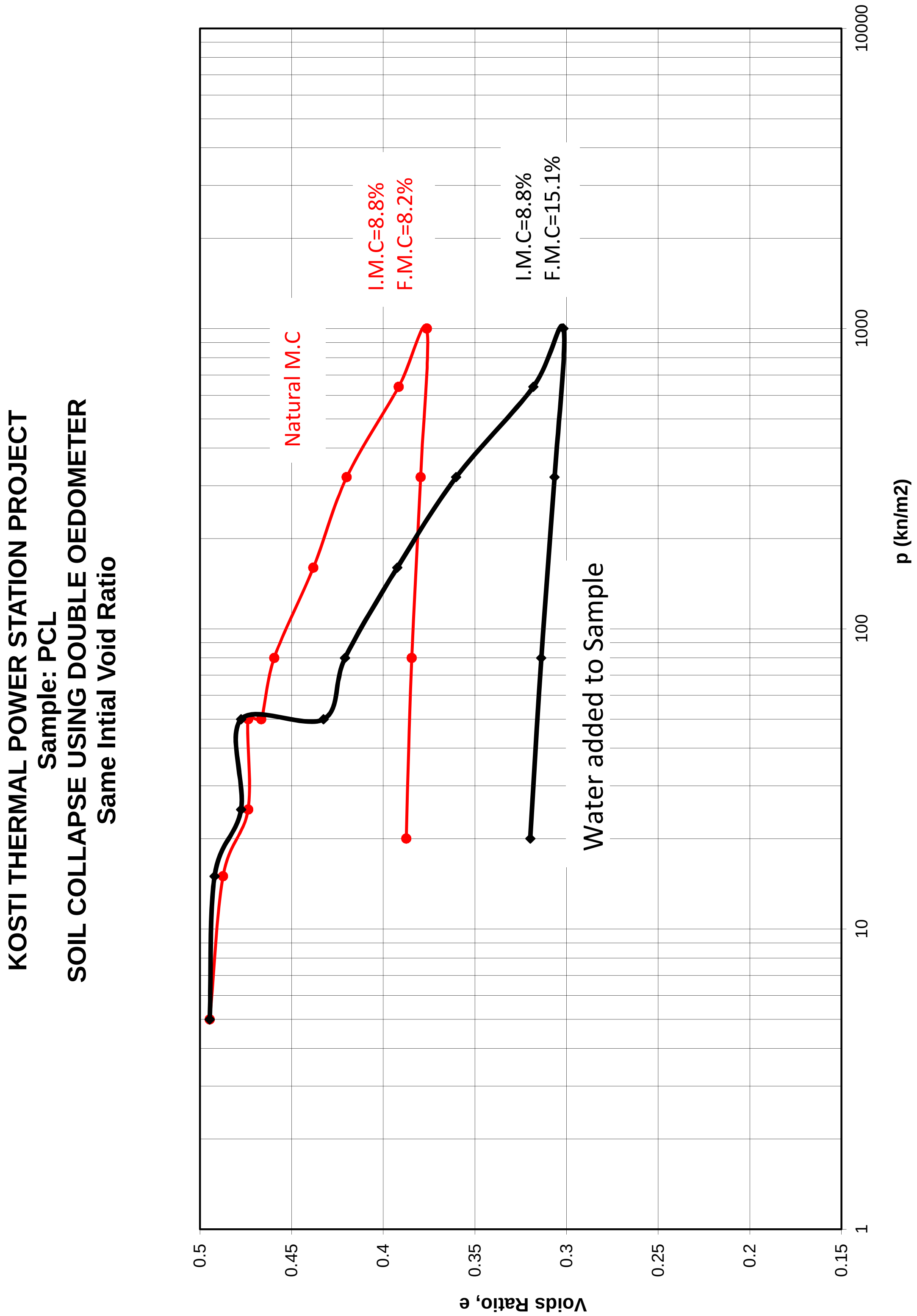

KOSTI THERMAL POWER STATION PROJECT
PCL /Top
13% Moisture Content
SOIL COLLAPSE USING SINGLE OEDOMETER
I.M.C=12.47%
F.M.C=13.74%
Bulk density=2.254
S=96.61389022
e0 = 0.341572223
e1 = 0.301460569
e2 = 0.29861481
Cp =0.2121%
Voids Ratio, e
p (kn/m2)
0.35
0.325
0.3
0.275
0.25
0.225
0.2
1
10
100
1000
10000


KOSTI THERMAL POWER STATION PROJECT
PCL / Bottom
13% Moisture Content
SOIL COLLAPSE USING SINGLE OEDOMETER
I.M.C=12.5%
F.M.C=13.26%
Bulk density=2.3064
S=100.0
e0 = 0.317024853
e1 = 0.27339009
e2 = 0.270596401
Cp = 0.2121%
Voids Ratio, e
p (kn/m2)
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
1
10
100
1000
10000


KOSTI THERMAL POWER STATION PROJECT
Sample: PCL
SOIL COLLAPSE USING DOUBLE OEDOMETER
Natural M.C
I.M.C=8.8%
F.M.C=8.2%
I.M.C=8.8%
F.M.C=15.1%
Water added to Sample
Voids Ratio, e
p (kn/m2)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
1
10
100
1000
10000


KOSTI THERMAL POWER STATION PROJECT
Sample: SPile
SOIL COLLAPSE USING DOUBLE OEDOMETER
I.M.C=8.84%
F.M.C=7.63%
Natural M.C
I.M.C=8.61%
F.M.C=14.16%
Water added to Sample
Voids Ratio, e
p (kn/m2)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
1
10
100
1000
10000


KOSTI THERMAL POWER STATION PROJECT
Sample: SPile
SOIL COLLAPSE USING DOUBLE OEDOMETER
Same Intial Void Ratio
I.M.C=8.84%
F.M.C=7.63%
Natural M.C
I.M.C=8.61%
F.M.C=14.16%
Water added to Sample
Voids Ratio, e
p (kn/m2)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
1
10
100
1000
10000


KOSTI THERMAL POWER STATION PROJECT
Sample: PCL
SOIL COLLAPSE USING DOUBLE OEDOMETER
Same Intial Void Ratio
Natural M.C
I.M.C=8.8%
F.M.C=8.2%
I.M.C=8.8%
F.M.C=15.1%
Water added to Sample
Voids Ratio, e
p (kn/m2)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
1
10
100
1000
10000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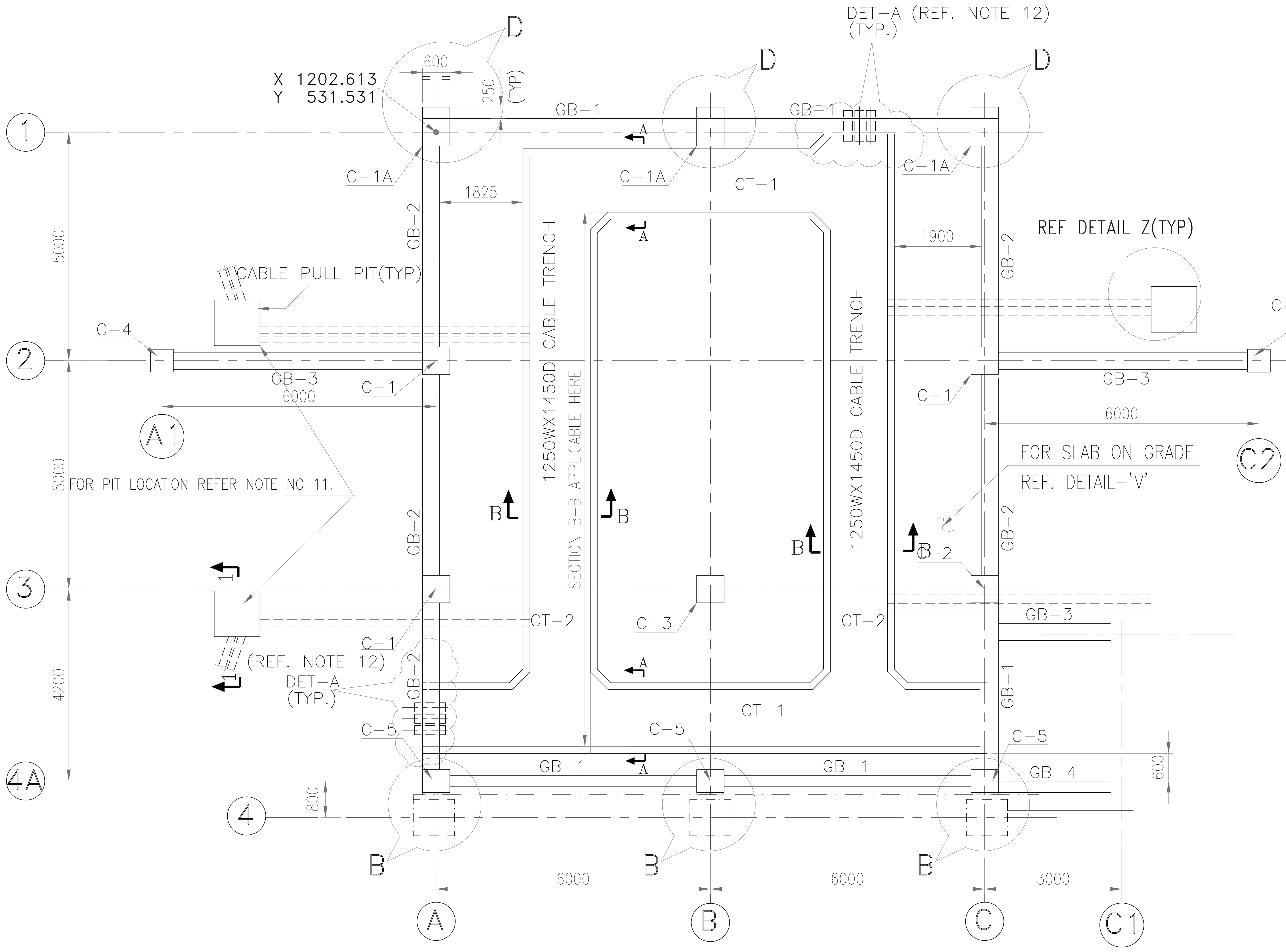
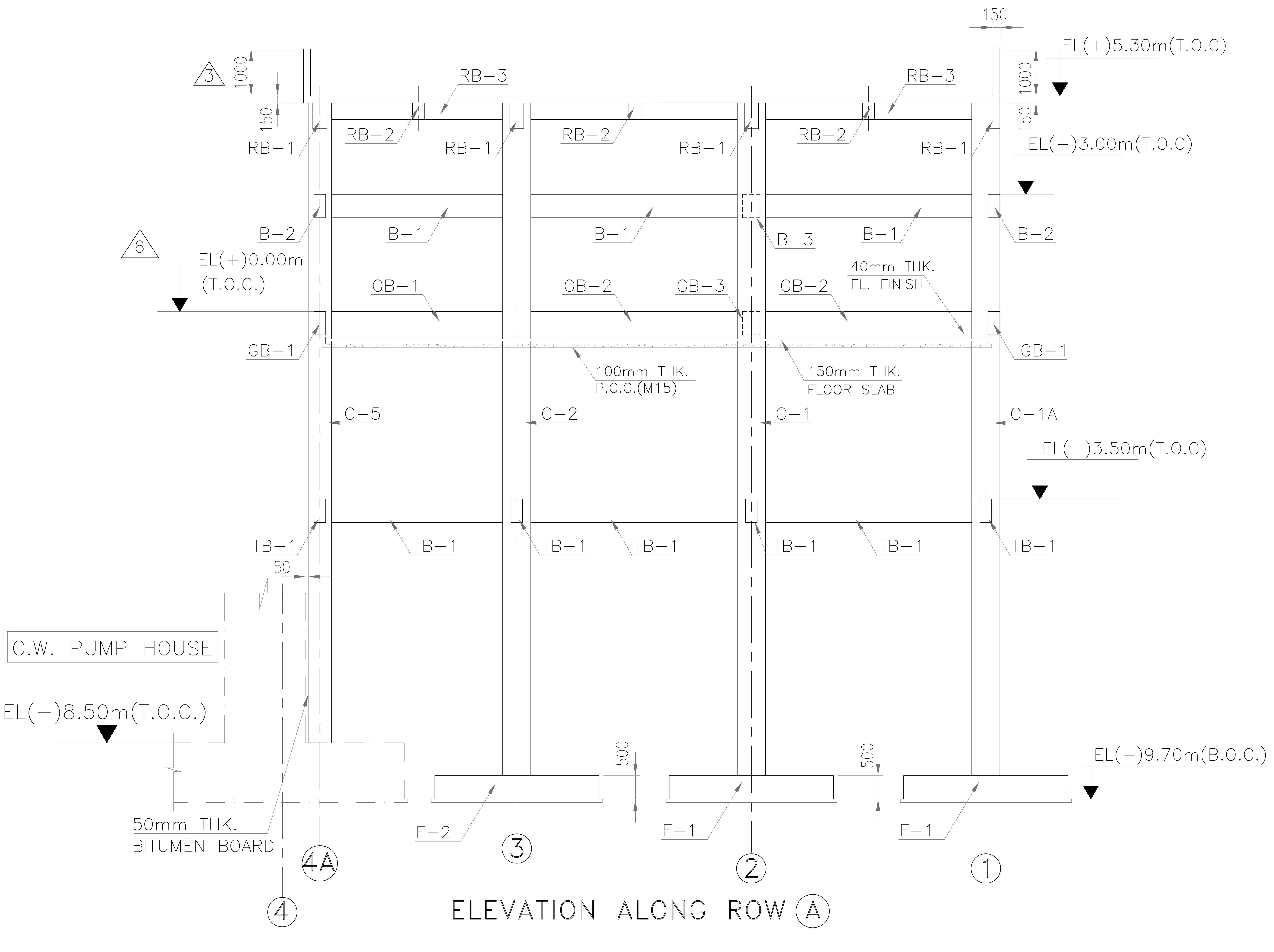
it must not be used directly or indirectly in any way detrimental to the interest of the company.
ELECTRONIC FILE NAME: 250-M001_R1
RABAK SINNAR RAILWAY
RABAK SINNAR HIGHWAY
RABAK SINNAR HIGHTENSION
TRANSMISSION LINE
UNDERGROUND WATER & OIL PIPE
GEOGRAPHICAL NORTH
PLANT NORTH
HOUSING AREA
FUEL OIL AREA
RAW WATER RESERVOIR
CHEMICAL HOUSE
PT PLANT
CLARIFIED WATER STORAGE
PIPE/CABLE CORRIDOR
DM PLANT
EFFLUENT TREATMENT PLANT
DM STORAGE TANKS
CHLORINATION BUILDING
AREA FOR TEMP. LABOUR COLONY (STAGE-I)
FUTURE UNITS (4X250MW)
TRANSFORMER YARD
SWITCHYARD
CW PIPES
COOLING TOWER(UNIT-1)
COOLING TOWER(UNIT-2)
COOLING TOWER(UNIT-3)
COOLING TOWER(UNIT-4)
BHEL/SUB. CONTRACTOR'S SITE OFFICES AND TEMP. STORAGE/PRE. ASSLY. AREA (STAGE-I)
Switch yard Area
MCC ROOM-CW PUMP HOUSE
KEY PLAN
SCALE 1:50000
KOSTI Thermal Power Station 4x125 MW
NATIONAL ELECTRICITY CORPORATION (NEC)
THE REPUBLIC OF THE SUDAN
FICHTNER
Fichtner GmbH & Co. KG
Stuttgart, Germany
BHARAT HEAVY ELECTRICALS LTD
POWER SECTOR
PROJECT ENGINEERING MANAGEMENT
NEW DELHI
PLOT PLAN
DRAWING NO.
PE-DG-250-100-M001

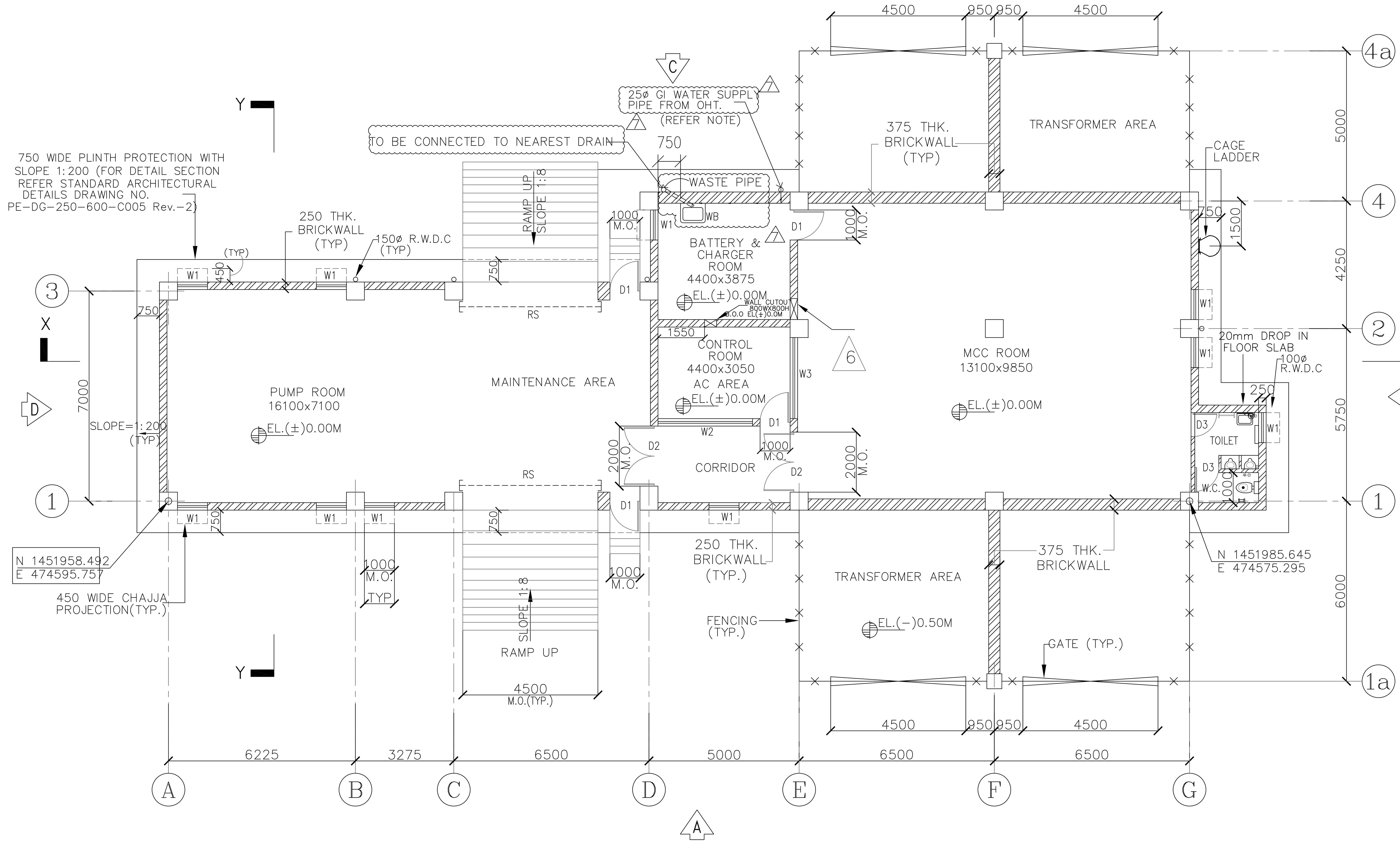


PLAN AT EL(±)0.00m

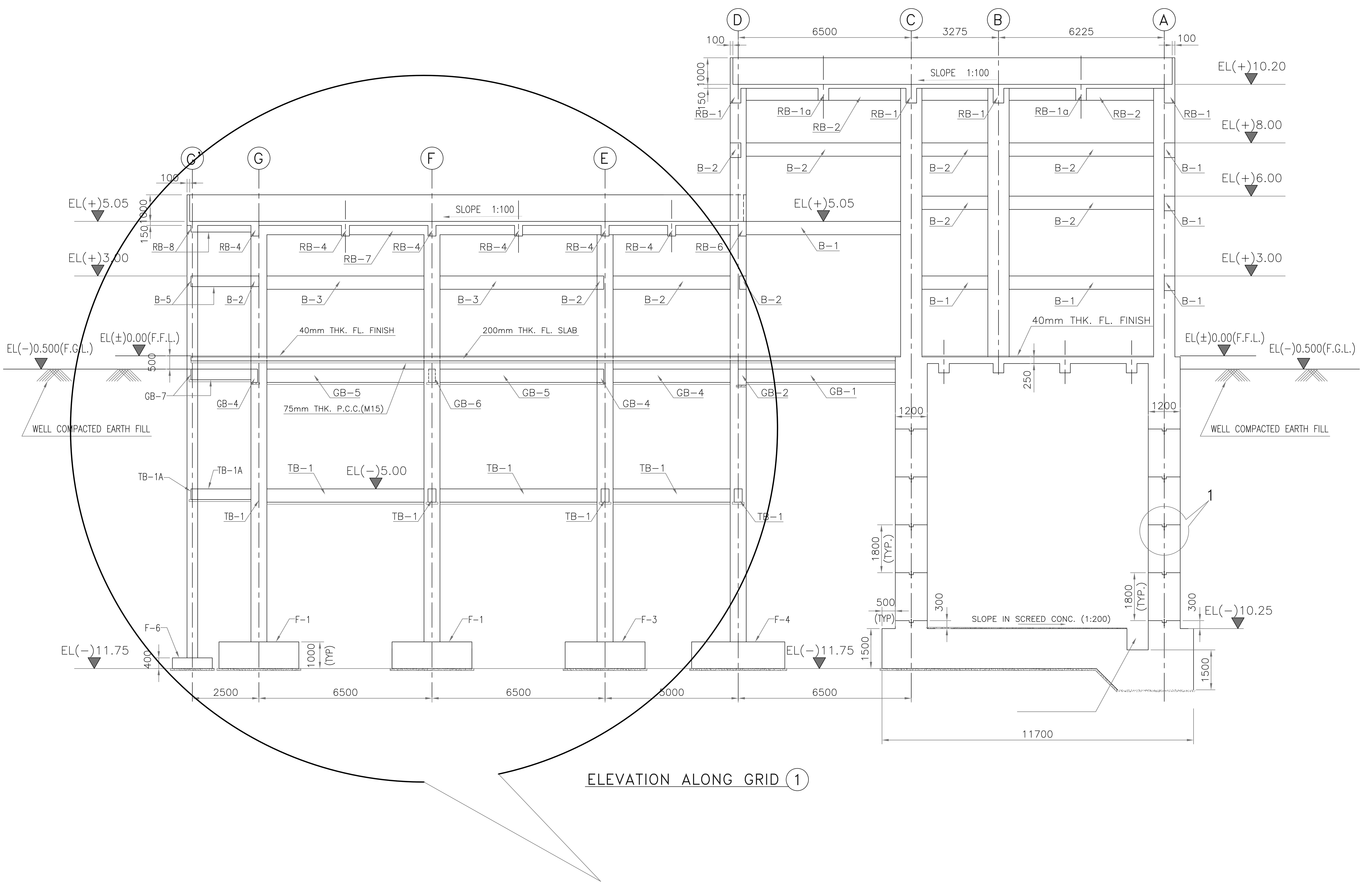


ELEVATION ALONG ROW A

MCC ROOM-CW PUMP HOUSE



PLAN AT EL.(±)0.00M.



ELEVATION ALONG GRID 1

MCC ROOM-RIVER SIDE INTAKE PUMP HOUSE

FIRST ANGLE PROJECTION

ALL DIMENSIONS ARE IN MM

DRAWING NO. PE-250-DG-100-MSK25A

COMPUTER FILE NAME: -DG-100-MSK25A_R0

REFERENCE DRGS.:-

1.	KOSTI POWER PLANT CONTOUR	DRG. No. -NIL- (CUST.)
2.	RIVER SITE CONTOUR	DRG. No. -NIL- (CUST.)
3.	KOSTI POWER PLANT PROJECT (LOCATION OF POWER STATION & NILE RIVER)	DRG. No. -NIL- (CUST.) PE-DG-250-100-M001
4.	PLOT PLAN	PE-DG-250-100-N001
5.	P&ID PLANT WATER SYSTEM	PE-DG-250-172-N101
6.	G.A. OF RAW WATER INTAKE PUMP HOUSE	PE-DG-250-172-N105
7.	RAW WATER INTAKE PUMP	GA/670 03 10 2K7(G)

NOTES

1. RAW WATER INTAKE PUMP HOUSE FINISHED FLOOR LEVEL IS EL.(±)0.0M WHICH CORRESPONDS TO RL 383.50M.

FOUNDATION RESTING ON VIRGIN SOIL

TABLE-C(INTAKE PUMP HOUSE FENCING AREA)

NO	EASTING	NOORTHING	ELEVATION
F1	474667.246	1451927.596	RL+383.0
F2	474582.992	1452039.405	RL+383.0
F3	474507.121	1451982.233	RL+383.0
F4	474591.375	1451870.424	RL+383.0

TABLE-C(INTAKE PUMP HOUSE PLOT AREA)

NO	EASTING	NOORTHING	ELEVATION
D1	474723.727	1451929.695	RL+383.0
D2	474604.010	1451839.509	RL+383.0
D3	474363.330	1452158.998	RL+383.0
D4	474483.047	1452249.184	RL+383.0

KOSTI Thermal Power Station 4x125 MW

NATIONAL ELECTRICITY CORPORATION (NEC)
THE REPUBLIC OF THE SUDAN

FICHTNER

Fichtner GmbH & Co. KG
Stuttgart, Germany

JOB NO.	250
STATUS	CONTRACT
DISTRIBUTION	

REV.	DATE	ALTD	CHD	APPD	REV.	DATE	ALTD	CHD	APPD

BHARAT HEAVY ELECTRICALS LTD
POWER SECTOR
PROJECT ENGINEERING MANAGEMENT
NEW DELHI

DEPT CODE		NAME	SIGN	DATE
M	DRN	SUNIL		18.11.08
	DESN	AM HUSSAIN		18.11.08
	CHD	AM HUSSAIN		18.11.08
	APPD	SUNIL		18.11.08

TITLE
PLOT PLAN LOCAL TO INTAKE PUMP HOUSE AREA

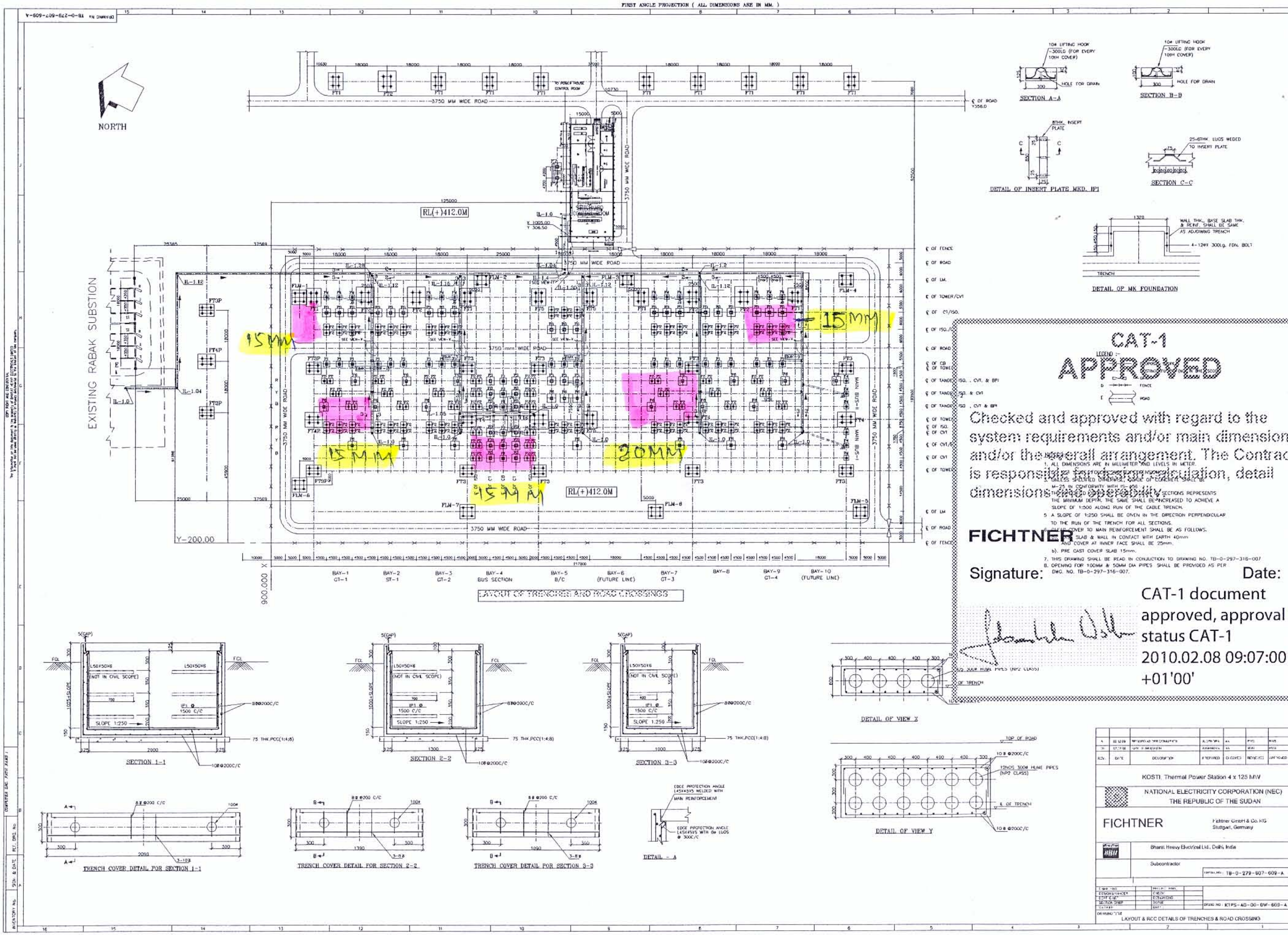
DEPT. SCALE
SIGN
DATE

DRAWING NO.
PE-250-DG-100-MSK25A

SHEET 1 OF 1 REV. 0

SIZE-A1

Settlement in MCC Room in River Water Intake Pump House - Ground floor including cable trenches



CAT-1

APPROVED

Checked and approved with regard to the system requirements and/or main dimensions and/or the overall arrangement. The Contractor is responsible for design, calculation, detail dimensions and operability.

FICHTNER

Signature: Date:

CAT-1 document approved, approval status CAT-1
2010.02.08 09:07:00 +01'00'

KOSTI Thermal Power Station 4 x 125 MW

NATIONAL ELECTRICITY CORPORATION (NEC)
THE REPUBLIC OF THE SUDAN

FICHTNER — Fichtner GmbH & Co. KG, Stuttgart, Germany

Bharat Heavy Electricals Ltd., Delhi, India

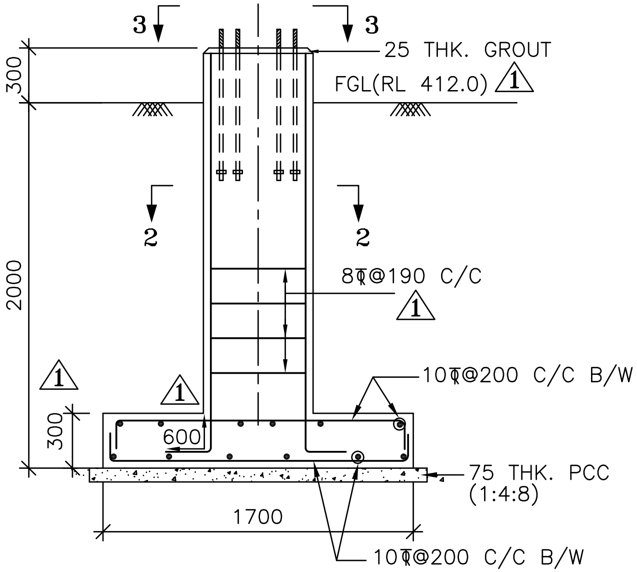
Subcontractor

TB-0-279-607-609-A

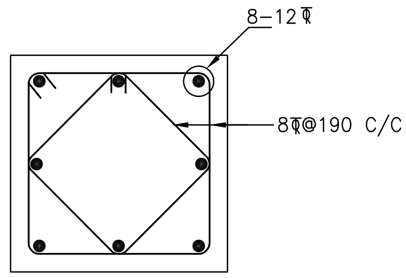
KTPS-40-00-DW-609-A

LAYOUT & RCC DETAILS OF TRENCHES & ROAD CROSSING

DRAWING No. TB-3-279-607-608-7-A



SECTION 1-1



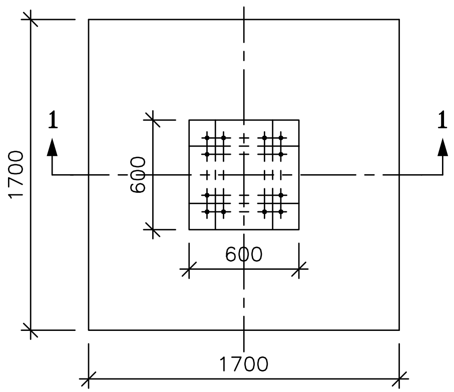
SECTION 2-2

NOTES:-

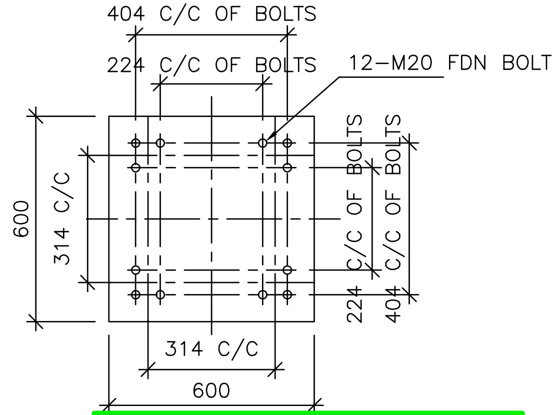
1. ALL DIMENSIONS ARE IN MILLIMETRE.
2. DO NOT SCALE THE DRAWING, FOLLOW WRITTEN DIMENSIONS ONLY.
3. GRADE OF RCC SHALL BE M25.
4. ALL REINFORCEMENT (DENOTED ASΦ) SHALL CONFIRM TO IS:1786-1985 OF GRADE Fe415.
5. CLEAR COVER TO MAIN REINFORCEMENT SHALL BE AS FOLLOWS:-

	ITEMS	TOP	BOTTOM	SIDE
a)	RAFT	50	50	50
b)	COLUMN	50	-	50

6. FOR FOUNDATION LAYOUT PLAN REFER DWG. NO. TB-1-279-607-604
7. FOR DETAILS OF TOWER FOUNDATION BOLTS REF. DWG. NO. TB-3-279-607-602-2



PLAN



VIEW 3-3

CAT-1
APPROVED

Checked and approved with regard to the system requirements and/or main dimensions and/or the overall arrangement. The Contractor is responsible for design calculation, detail dimensions and operability.

FICHTNER

Signature: Date:

REV.	DATE	DESCRIPTION	PREPARED	CHECKED	REVIEWED	APPROVED
A	14.12.09	REVISED AS PER FCE COMMENTS	JUGENDRA	AA	BVG	RMS
00	29.10.09	FIRST SUBMISSION	JUGENDRA	AA	BVG	RMS

KOSTI, Thermal Power Station 4 x 125 MW

NATIONAL ELECTRICITY CORPORATION (NEC)
THE REPUBLIC OF THE SUDAN

FICHTNER — Fichtner GmbH & Co. KG, Stuttgart, Germany

Bharat Heavy Electrical Ltd., Delhi, India

Subcontractor

DRWG. NO : TB-3-279-607-608-7-A

CHIEF. ENG.		PEOJECT ENG.	
DESIGN MANAGER		CHECK	
DEPT. CHIEF		DESIGN ENG.	
SECTION CHIEF		SCALE	
CAD-FILE		DATE :	

DRWG. NO : KTPS-AD-00-DW-608-7-A

DRAWING TITLE : RCC DETAILS OF EQUIPMENT FOUNDATION FOR 220KV PI (MIDDLE LEVEL) MKD. F6A