REPORT ON:

SUB-SOIL INVESTIGATION FOR THE CONSTRUCTION OF REGULATOR 1VENT AT DUMURIA CH. 28.550KM OVER DUMURIA KHAL IN POLDER NO-15 UNDER REHABILITATION OF POLDER 15 AT GPS POSITION E:- 0731861, N:- 2461640, THANA:- SHYAMNAGAR, DIST:- SATKHIRA.

PROJECT

REHABILITATION OF POLDER 15 AT SATKHIRA DISTRICT.

CLIENT:

SATKHIRA O&M DIVISION-1, BWDB, SATKHIRA.

NOVEMBER-2022

GEOTECH Boring & Engineering

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CONTENTS

1. Introduction:

A fairly accurate assessment of the characteristics and engineering properties of the soils at aside is essential for proper design and successful construction of any structure at the site. The field and laboratory investigations required to obtain the necessary data for the soils for this purpose are collectively called soil exploration. The choice of the foundation and its depth, the bearing capacity, settlement analysis and such other important aspects depend very much upon the various engineering properties of the foundation soils involved. Soil exploration may be needed not only for the design and construction of new structures, but also for deciding upon remedial measures if a structure shows signs of distress after construction. The design and construction of highway and airport pavements will also depend upon the characteristics of the soil strata upon which they are to be aligned. Sub-soil investigation and laboratory tests for proposed project were prepared by Geotech Boring & Engineering.

2. Client and Project:

The Name of the Client is **Satkhira O&M Division-1, BWDB, Satkhira**. The Sub-Soil Investigation For The **Construction of Regulator 1vent at Dumuria Ch. 28.550km Over Dumuria Khal In Polder No-15 Under Rehabilitation of Polder 15 at GPS Position E:- 0731861, N:- 2461640, Thana:- Shyamnagar, Dist:- Satkhira.**

3. Objective:

The objective of the exploration work was to determine the probable sub surface conditions such as stratification, denseness or hardness of the strata, position of ground water table etc. and to evaluate probable range of safe bearing capacity for the structure. To fulfill the objective, the work carried out is comprises of:

- Drilling the borehole up to the depth of 120ft below existing ground level in order to know the sub surface stratification, conducting necessary field tests and to collect disturbs and undisturbed soil samples for laboratory testing.

- Testing soil samples in the laboratory to determine its physical and engineering properties of the soil samples, and

- Analyzing all field and laboratory data to evaluate safe bearing capacity of the soil for given foundation sizes and necessary recommendations for foundation design and construction.

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4. Scope of Work:

The main scope of this investigation works are:

i. Drilling of exploratory boring BH1 to BH3 up to the maximum depth of 120ft from the existing ground surface.

ii. Performing of Standard Penetration Test (SPT) at 5 ft. intervals up to the required depth.

iii. Collection of disturbed (by thin walled Shelby tubes) and undisturbed sample for laboratory test and visual classification.

iv. Determining the ground water table in each borehole.

v. Determining the geotechnical properties of soil from various laboratory and field test.

vi. Preparation of final report with all works including detailed description of soil stratification.

5. Field Works:

Following field tests are performed to determine the properties of soil into the field:

1. Standard penetration test
2. Cone penetration test
3. Static Cone penetration test
4. Dynamic Cone penetration test
3. Vane shear test
4. Relative density test
5. Ground water table
6. Collection of disturbed soil samples
7. Collection of undisturbed soil samples
8. Field classification

5.1 Standard Penetration Test (SPT)

The Standard Penetration Test (SPT) is widely used to determine the parameters of the soil in-situ. The test is especially suited for cohesion less soils as a correlation has been established between the SPT value and the angle of internal friction of the soil. The test consists of driving a split-spoon sampler (Fig. 18.6) into the soil through a borehole 55 to 150 mm in diameter at the desired depth. A hammer of 140 lb (63.6 kg) weight with a free fall of 750 mm is used to drive the sampler. The number of blows for a penetration of 300mm is designated as the "Standard Penetration Value" or "Number" *N*. The test is usually performed in three stages. The blow count is found for every 150 mm penetration. If full penetrations obtained, the blows for the first 150 mm are ignored as those required for the seating drive. The number of blows required for the next 300 mm of penetration is recorded as

Geotech Boring & Engineering Khulna Date the SPT value. The test procedure is standardized by ISI and set out in “IS: 2131-1986—Standard Penetration Test”.

Usually SPT is conducted at every 1.5 to 2 m depth or at the change of stratum. If refusal is noticed at any stage, it should be recorded.

In the case of fine sand or silt below water-table, apparently high values may be noted for *N*. In such cases, the following correction is recommended for observed SPT value greater than 15 (Terzaghi and Peck, 1948):

$$N = 15 + 0.5 * (N' - 15)$$

Where *N'* = observed SPT value, and *N* = corrected SPT value.

For SPT made at shallow levels, the values are usually too low. At a greater depth, the same soil, at the same density index, would give higher penetration resistance. The effect of the overburden pressure on SPT value may be approximated by the equation:

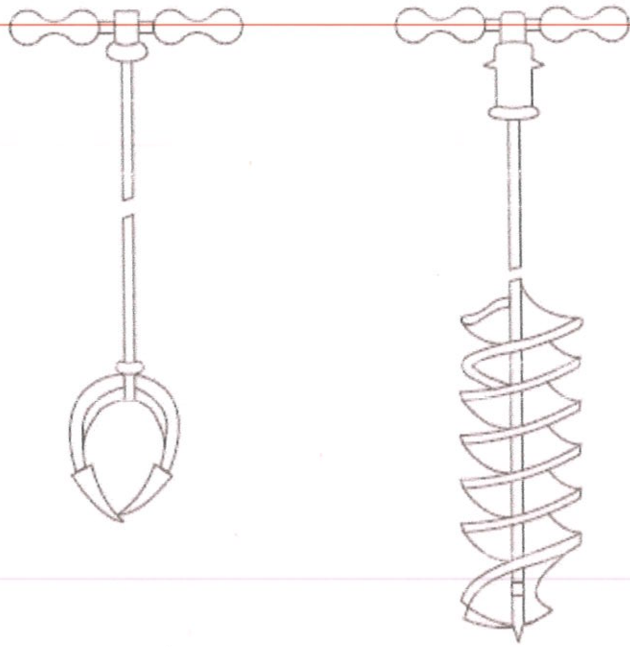
$$N = N' * \frac{350}{\sigma + 70}$$

Where *N'* = observed SPT value,

N = corrected SPT value, andσ = effective overburden pressure in KN/m2, not exceeding 280 KN/m2. This implies that no correction is required if the effective overburden pressure is 280 kN/m2.Terzaghi and Peck also give the following correlation between SPT value, Relative density, Dr, and Angle of friction, φ:

Table 5.1 Correlation between *N*, *Dr*and φ

S. No.	Condition	N	Relative density, Dr	Angle of friction, φ
1	Very Loose	0 – 4		
2	Loose	4 – 10		
3	Medium	10 – 30	35 – 65%	30° – 36°
4	Dense	30 – 50	65 – 85%	36° – 42°
5	Very dense	Greater than 50	Greater than 85%	Greater than 42°



(a) Post-hole auger(b) Helical auger

Fig. Soil augers

5.6.3 Wash Boring

Wash boring is commonly used for exploration below ground water table for which the auger method is unsuitable. This method may be used in all kinds of soils except those mixed with gravel and boulders. The set-up for wash boring is shown in Fig. 18.2.

Initially, the hole is advanced for a short depth by using an auger. A casing pipe is pushed in and driven with a drop weight. The driving may be with the aid of power. A hollow drill bit is screwed to a hollow drill rod connected to a rope passing over a pulley and supported by a tripod. Water jet under pressure is forced through the rod and the bit into the hole. This loosens the soil at the lower end and forces the soil-water suspension upwards along the annular surface between the rod and the side of the hole. This suspension is led to a settling tank where the soil particles settle while the water overflows into a sump. The water collected in the sump is used for circulation again.

The soil particles collected represent a very disturbed sample and is not very useful for the evaluation of the engineering properties. Wash borings are primarily used for advancing bore holes; whenever a soil sample is required, the chopping bit is to be replaced by a sampler. The change of the rate of progress and change of color of wash water indicate changes in soil strata.

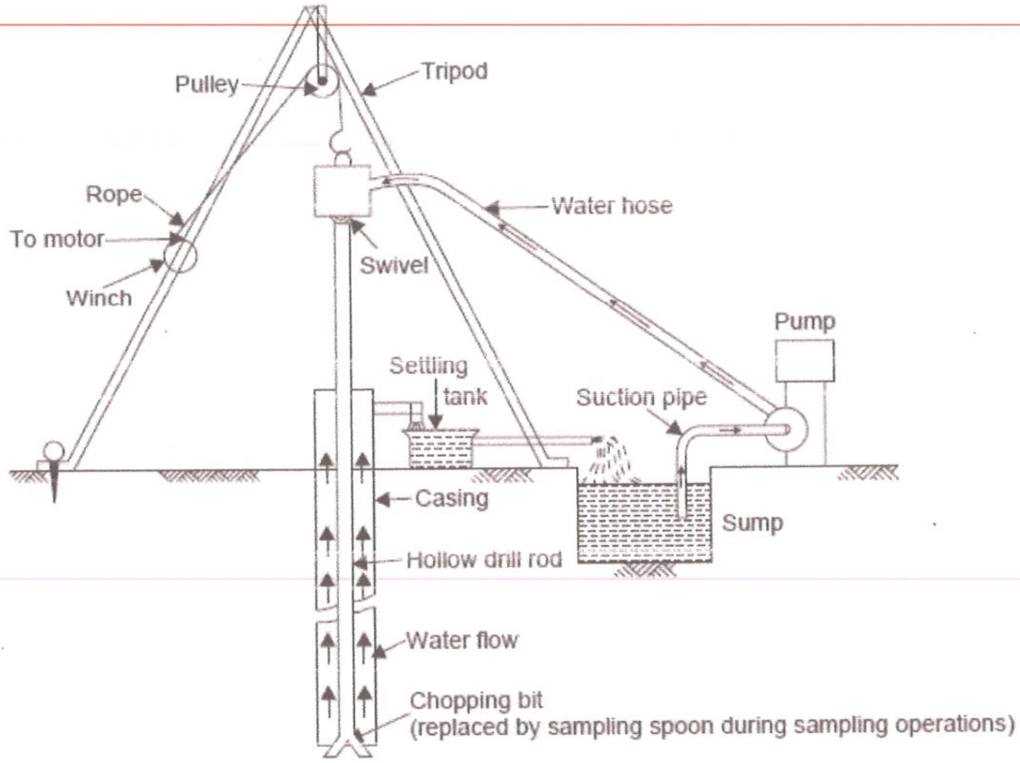


Fig. Sct-up for Wash Boring

5.6.4 Percussion Drilling

A heavy drill bit called 'churn bit' is suspended from a drill rod or a cable and is driven by repeated blows. Watcr is addcd to facilitatc thc brcaking of stiff soil or rock. Thc slurry of thc pulvcrizcd material is bailed out at intervals. The method cannot be used in loose sand and is slow in plastic clay. The formation gets badly disturbed by impact.

5.6.5 Rotary Drilling

This method is fast in rock formations. A drill bit, fixed to the lower end of a drill rod, is rotated by power while being kept in firm contact with the hole. Drilling fluid or betonies slurry is forced under prcssurc through thc drill rod and it comcs up bringing thc cuttings to thc surfacc. Evcn rock corcs may be obtained by using suitable diamond drill bits. This method is not used in porous deposits as the consumption of drilling fluid would be prohibitively high.

5.6.6 Planning an Exploration Program

The two important aspects of a boring program are 'spacing of borings' and 'depth ofborings'.

Table 5.3 Spacing of Borings (Sowers and Sowers, 1970)

Sl. No.	Nature of the project	Spacing of borings (meter)
1	Highway (Sub-grade survey)	300-600
2	Earth dam	30-60
3	Borrow pit	30-120
4	Multistory buildings	15-30
5	Single story factories	30-90
Note:For uniform soil conditions, the above spacing are doubled; for irregular conditions, theseare halved.		

For important and heavy structures such as bridges and tall buildings, the borings should extend to rock.E.De Beer of Belgium adopted this rule for determining the so-called 'critical depth of boring' (Hvorslev, 1949). Based on this, recommended depths of borings for buildings are about 3.5 m and 6.5 m for single- and two-storey buildings. For dams and embankments, the depth ranges between half the height to twice the height depending upon the foundation soil.

5.6.7 Boring Log

Information on subsurface conditions obtained from the boring operation is typically presented in the form of a boring record, commonly known as "boring log". A continuous record of the various strata identified at various depths of the boring is presented. Description or classification of the various soil and rock types encountered, and data regarding ground water level have to be necessarily given in a pictorial manner on the log.

5.7 SOIL SAMPLING

'Soil Sampling' is the process of obtaining samples of soil from the desired depth at the desiredlocation in a natural soil deposit, with a view to assessing the engineering properties of the soilfor ensuring a proper design of the foundation.

5.7.1 Types of Samples

Soil may be classified as: Disturbed samples, and undisturbed samples, depending upon the degree of disturbance caused during sampling operations.

A disturbed sample is that in which the natural structure of the soil gets modified partly or fully during sampling, while an undisturbed sample is that in which the natural structure and other physical properties remain preserved. 'Undisturbed', in this context, is a purely relative term, since a truly undisturbed sample can perhaps be never obtained as some little degree of disturbance is absolutely inevitable even in the best method of sampling devised till date.

Disturbed samples may be further subdivided as: (*i*) Non-representative samples, and(*ii*) Representative samples. Non-representative samples consist of mixture of materials from various soil or rock strata or are samples from which some mineral constituents have been lost or got mixed up. Soil samples obtained from auger borings and wash borings are non-representative samples. These are suitable only for providing qualitative information such as major changes in subsurface strata. Representative samples contain all the mineral constituents of the soil, but the structure of the soil may be significantly disturbed. The water content may also have changed. They are suitable for identification and for the determination of certain physical properties such as Atterberg limits and grain specific gravity.

5.7.2 Types of Samplers

Soil samplers are classified as 'thick wall' samplers and 'thin wall' samplers. Split spoon sampler(or split tube sampler) is of the thick-wall type, and 'Shelby' tubes are of the thin-wall type.

Depending upon the mode of operation, samplers may be classified as the open drive sampler, stationary piston sampler and rotary sampler.

Open drive sampler can be of the thick wall type as well as of the thin wall type. The head of the sampler is provided with valves to permit water and air to escape during. The check valve helps to retain the sample when the sampler is lifted. The tube may be seamless or may be split in two parts; in the latter case it is known as the split tube or split spoon sampler.

Stationary piston sampler consists of a sampler with a piston attached to a long piston rod extending up to the ground surface through drill rods. The lower end of the sampler is kept closed with the piston while the sampler is lowered through the bore hole. When the desired elevation is reached, the piston rod is clamped, thereby keeping the piston stationary, and the sampler tube is advanced further into the soil. The sampler is then lifted and the piston rod clamped0i in position. The piston prevents the entry of water and soil into the tube when it is being lowered, and also helps to retain the sample during the process of lifting the tube. The sampler is, therefore, very much suited for sampling in soft

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soils and saturated sands. Rotary samplers are of the core barrel type (USBR, 1960) with an outer tube provided with cutting teeth and a removable thin liner inside. It is used for sampling in stiff cohesive soils.

6. Laboratory Works:

To know the characteristics of soil sample following tests are performed as per ASTM method are described below:-

6.1 Natural Moisture Content: (ASTM D 2216)

'Water content' or 'moisture content' of a soil has a direct bearing on its strength and stability. The water content of a soil in its natural state is termed its 'Natural moisture content', which characterizes its performance under the action of load and temperature.

The most accurate approach is that of oven-drying the soil sample and is adopted in the laboratory. A clean container of non-corrodible material is taken and its empty weight along-with the lid is taken. A small quantity of moist soil is placed in the container, the lid is replaced, and the weight is taken. The lid is taken removed and the container with the soil is placed in a thermostatically controlee dove for 24 hours, the temperature being maintained between 105-110°C. After drying, the container is cooled in a desiccators, the lid is replaced and the weight is taken. For weighing a balance with an accuracy of 0.0001 N (0.01 g) is used. Thus, the observations are:

Weight of an empty container with lid = $W1$
Weight of container with lid + wet soil = $W2$
Weight of container with lid + dry soil = $W3$
The calculations are as follows:
Weight of dry soil = $W3 - W1$
Weight of water in the soil = $W2 - W3$

Water content, $w = \frac{W2-W3}{W3-W1} \times 100\%$

6.2 Grain Size Distribution: (ASTM D 421 & D 422)

Mechanical analysis is the determination of the size range of particles present in a soil, expressed as a percentage of the total dry weight. Used methods are generally to find the particle-size distribution of soil: (l) sieve analysis-for larger than particle sizes 0.075 mm in diameter, and (2) hydrometer analysis –for particle sizes smaller than 0.075 mm in diameter.

A series of sieves having different-size openings (according to British Standard) are stacked with the larger sizes over the smaller. A receiver is kept at the bottom and a cover is kept at the top of the assembly. The soil sample to be tested is dried, clumps are broken if necessary, and the sample is passed through the series of sieves by shaking.

The material retained on any particular sieve should naturally include that retained on the sieves on top of it, since the sieves are arranged with the aperture size decreasing from top to bottom. The weight of material retained on each sieve is converted to a percentage of the total sample. The percentage material finer with respect to any sieve size is calculated by subtracting this from 100.

The soil particles less than 75–μ size can be further analyzed for the distribution of the various grain-sizes of the order of silt and clay is 'sedimentation analyses or 'wet analyses. The soil fraction is kept in suspension in a liquid medium, usually water. The particles descend at velocities, related to their sizes, among other things. The analysis is based on 'Stokes Law' for what is known as the 'terminal velocity' of sphere falling through an infinite liquid medium. If a single sphere is allowed to fall in an infinite liquid medium without interference, its velocity first increases under the influence of gravity, but soon attains a constant value. This constant velocity is maintained indefinitely unless the boundary conditions change, is known as the 'terminal velocity'. The principles obvious; coarser particles tend to settle faster than finer ones. By Stokes' law, the terminal velocity of the spherical particle is given by

$$v = \frac{1}{180} \frac{(\gamma_s - \gamma_w)}{\mu_w} . D^2$$

Here s_and γ_w are in kN/m^3, μ_w in N-sec/m^2, and D in mm; v will then be in cm/scathe sedimentation analysis may be conducted with the aid of hydrometer in the laboratory.

D = K√ (H/t)

H = fall in cm, and t = time in min. The factor K can be tabulated or graphically represented for different values of temperature and grain specific gravity.

"Particle-size distribution curve "or "Grain-size distribution curve" plotted on semi-log co-ordinates, where the particle size is on a horizontal 'logarithmic' scale, and the percentage by weight of the size smaller than a particular sieve-size is on a vertical 'arithmetic 'scale.

6.3 Atterberg Limits (ASTM D 4318)

In 1911, A. Waterberg, a Swedish scientist, developed a method for describing the limit consistency of fine-grained soils on the basis of moisture content. These limits are the liquid limit, the plastic limit, and the shrinkage limit. The liquid limit is defined as the moisture content, in percent, at which the soil changes from a liquid state to a plastic state. The moisture contents (in percent) at which the soil changes from a plastic to a semisolid state and from a semisolid to a solid state is defined as the plastic limit and the shrinkage limit, respectively. These limits are generally referred to as the Waterberg limits. The Waterberg limits of cohesive soil depend on several factors, such as amount and type of clay minerals and absorbed action.

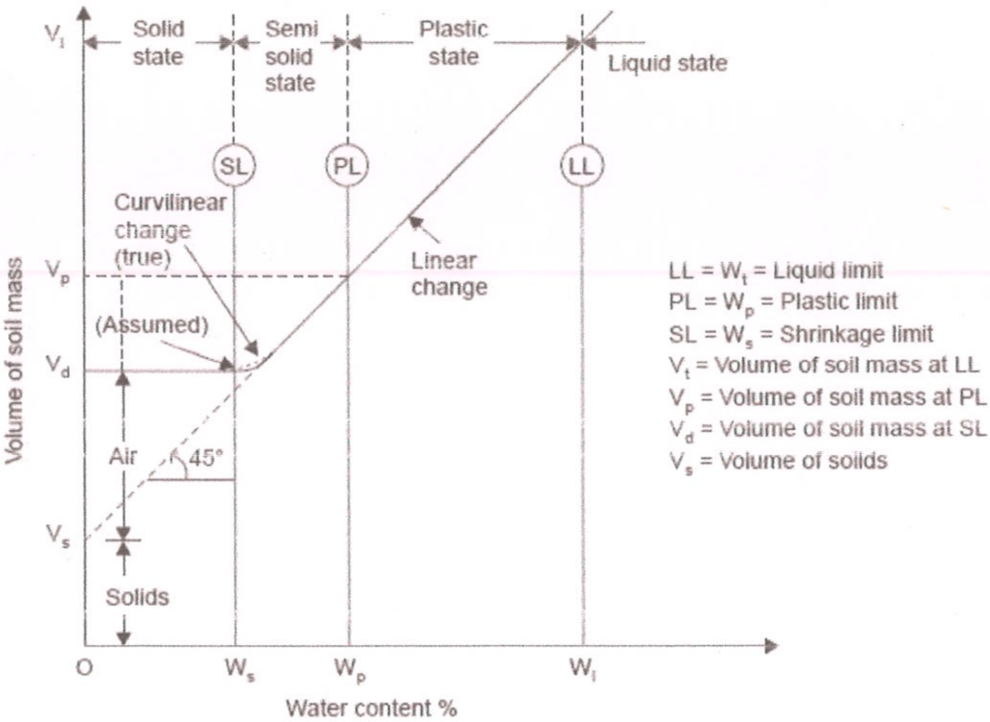

Fig. Variation of volume of soil mass with variation of water content

6.4 Specific Gravity (ASTM D 854)

Values for specific gravity of the soil solids were determined by placing a known weight of oven-dried soil in a flask, then filling the flask with water. The weight of displaced water was then calculated by comparing the weight of the soil and water in the flask with the weight of flask containing only water. The specific gravity was then calculated by dividing the weight of the dry soil by the weight of the displaced water. A 50-cc density bottle or a 500-cc Pycnometer may be used. With the aid of these four observations, the grain specific gravity may be determined as follows:

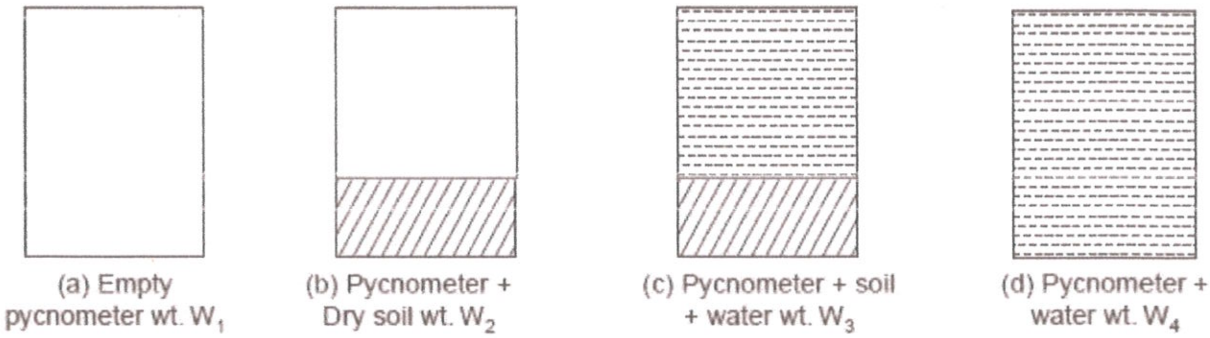

Fig. 3.3 Determination of grain specific gravity

From the readings, the wt of solids $Ws = W2 - W1$, from (a) and (b)

$$Sp.Gr.G = \frac{Ws}{Ws - (W3 - W4)}$$

6.5 Organic Content (ASTM D 2974)

The organic content of each soil was determined by first oven-drying a representative sample of each soil at 105°C for 24 hours, then recording the moisture content. The sample was then placed in a muffle furnace, heated to 440°C, then reweighed after a nearly constant mass was achieved. The ash content of the sample was then recorded as the weight loss due to ignition divided by the initial dry weight. The organic content was then calculated as 1 minus the ash content.

7. Corrected SPT Values

Corrected SPT Values for Bore Holes 1 to 3.

Bore Hole No:- 01			Bore Hole No:- 02			Bore Hole No:- 03		
Depth (ft)	N'	N	Depth (ft)	N'	N	Depth (ft)	N'	N
5	3	3	5	2	2	5	3	3
10	2	2	10	2	2	10	2	2
15	2	2	15	2	2	15	2	2
20	2	2	20	2	2	20	2	2
25	2	2	25	2	2	25	2	2
30	3	3	30	2	2	30	3	3
35	3	3	35	3	3	35	3	3
40	3	3	40	3	3	40	3	3
45	4	4	45	5	5	45	4	4
50	3	3	50	4	4	50	4	4
55	3	3	55	4	4	55	5	5
60	4	4	60	5	5	60	6	6
70	5	5	70	5	5	70	7	7
80	10	10	80	7	7	80	8	8
90	9	9	90	8	8	90	7	7
100	39	27	100	35	25	100	43	29
110	25	20	110	30	23	110	27	21
120	29	22	120	28	22	120	32	24

8. Physical and Engineering properties of Soil

8.1 Description of soil Composition:

The following terms are used in this report for description of soil composition

Trace: 1 to 10 %

Little: 11 to 20 %

Some: 21 to 35%

Sandy: 36 to 50% Sand

Clayey: 36 to 50 % Clay

Silty: 36 to 50 % Silt

Test results:

Table Physical and Engineering properties of Soil.

Bore Hole No: 01						
Depth (feet)	Moisture Content (%)	Sand Content (%)	Specific Gravity	Atterberg Limits		
				Liquid Limit (w_L)	Plastic Limit (w_p)	Plasticity Index (PI)
5	34.89		2.74	45.20	29.71	15.49
35			2.74	44.60	31.22	13.38
70	31.37			43.89	30.60	13.29
110		73	2.67			

Bore Hole No: 02						
Depth (feet)	Moisture Content (%)	Sand Content (%)	Specific Gravity	Atterberg Limits		
				Liquid Limit (w_L)	Plastic Limit (w_p)	Plasticity Index (PI)
10	41.92		2.74	48.89	32.32	16.57
30			2.74	44.60	30.32	14.28
60	32.19			42.30	28.71	13.59
100		75	2.67			

Bore Hole No: 03						
Depth (feet)	Moisture Content (%)	Sand Content (%)	Specific Gravity	Atterberg Limits		
				Liquid Limit (w_L)	Plastic Limit (w_p)	Plasticity Index (PI)
5	33.87		2.74	42.90	28.71	14.19
40	34.21			44.32	28.71	15.61
70		9	2.70	37.20	29.22	7.98
120		74	2.67			

9. Estimation of Allowable Bearing Capacity

9.1 Bearing Capacity for Shallow Foundation:

The soil must be capable of carrying the loads from any engineered structure placed upon it without a shear failure and with the resulting settlements being tolerable for that structure. This session will be concerned with evaluation of the limiting shear resistance.

9.1.2 Clay and Clayey Soil:

The ultimate bearing capacity of these soils depends upon its consistency (or shear strength). The consistency can be determined by standard penetration resistance. For small jobs where a better economy can be achieved by using a conservative design value based on simple test results, the standard penetration test is used. The relationship between the standard penetration resistances, the consistency in the accompanying table (Terzaghi and Peck, 1948) is very approximate.

Consistency of Soil	N(Standard penetration resistance)	Square footing (Allowable bearing pressure)* tons/sq ft	Continuous footing (Allowable bearing pressure) tons/sq ft
Very soft **	1	0.15	0.11
	2	0.30	0.22
Soft **	3	0.45	0.34
	4	0.60	0.45
Medium **	5	0.75	0.56
	6	0.90	0.68
	7	1.05	0.79
	8	1.20	0.90
Stiff ***	9	1.35	1.01
	10	1.50	1.12
	11	1.65	1.23
	12	1.80	1.35
	13	1.95	1.46
	14	2.05	1.57
	15	2.25	1.68
Very stiff ***	15-30	2.25-4.50	1.68-3.38
Hard	30+	4.50+	3.38+

* Ultimate bearing capacity is equal to three times the allowable.

** Settlement often large and should be determined.

*** Stiff clays often possess fissures and cracks which are weak planes in resisting shearing forces. Such clays must be kept from being softened by water, the shear strength on these planes may be as low as that of soft clays.

The load bearing capacities of different types of shallow foundation/footing at different depths are calculated as per field results that are bellows:

Bore Hole No:	Depth (Ft)	SPT	Bearing Capacity Ton/Sqft (F.S.-3.00)	
			Square Footing	Continuous Footing
01	5	3	0.492	0.388
	10	2	0.328	0.258
	15	2	0.328	0.258

Bore Hole No:	Depth (Ft)	SPT	Bearing Capacity Ton/Sqft (F.S.-3.00)	
			Square Footing	Continuous Footing
02	5	2	0.328	0.258
	10	2	0.328	0.258
	15	2	0.328	0.258

Bore Hole No:	Depth (Ft)	SPT	Bearing Capacity Ton/Sqft (F.S.-3.00)	
			Square Footing	Continuous Footing
03	5	3	0.492	0.388
	10	2	0.328	0.258
	15	2	0.328	0.258

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9.2 Settlement of Footing:

Footings on granular soils will not suffer detrimental settlement if the smaller value of two allowable pressures given by below equations is used.

For square footing:

$$q_{ult} = 2N^2BR_W + 6\,(100 + N^2)DR'_W$$

For very long footing:

$$q_{ult} = 3N^2BR_W + 5\,(100 + N^2)DR'_W$$

Where,

q_{ult} = net ultimate bearing pressure.

N = standard penetration resistance,

B = width of footing, ft

D = depth of footing, ft measured from ground surface to bottom of footing

R_w & R'_w = correction factors for position of water level.

Allowable bearing pressure has been established empirically (Terzaghi & Peak, 1948) and may be expressed by the equation:

$$q_a = 720\,(N-3)\,\left(\frac{B+1}{2B}\right)^2 R'_W$$

Where,

q_a = net allowable bearing pressure in psf for maximum settlement of 1 inch.

Footing on stiff clay, hard clay & other firm soils generally require no settlement analysis if the design provides a minimum factor of safety of 3. Soft clay, compressible silt and other weak soils will settle even under moderate pressure and therefore settlement analysis is necessary.

The total settlement of a footing on clay may be considered to consist of three parts (Skempton and Bjerrum, 1957):

$$S = S_i + S_C + S_S$$

Where,

S = total settlement

S_i = immediate settlement.

S_C = settlement due to consolidation of clay.

S_S = settlement due to secondary consolidation of clay.

9.2.1 Immediate settlement:

Immediately upon application of load on the footing, elastic compression of the underlying soil takes place causing a settlement of the footing. The amount can be computed by elastic theory. However, it is usually very small and can be neglected for all practical purposes.

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9.2.2 Settlement due to consolidation:

The settlement caused by consolidation is due to the slow extrusion of water from the pores of the fine particles of clay. The amount of final consolidation settlement S_C can be calculated by the following equation:

$$S_C = S_o \beta$$

Where,

β = the coefficient depending on the geometry of the footing and the loading history of the clay.

S_o = settlement calculated by Terzaghi theory of consolidation;

$= m_v \Delta p H$

$= \frac{C_c}{1+e_0} H \log_{10} \frac{p_0+\Delta p}{p_0}$

Where,

m_v = coefficient of volume compressibility of clay. This value is determined by consolidation test.

Δp = vertical stress due to footing.

H = thickness of the compressible clay. The clay thickness should be divided into several layers to obtain reasonably accurate settlement of a thick layer.

C_C = compression index, also determined by consolidation test.

P_0 = vertical effective pressure due to soil overburden.

9.2.3 Settlement due to secondary consolidation:

When an undisturbed soil sample is tested in the consolidometer (or odometer) the rate of volume decrease checks very closely with the theory. However, when the sample is one hundred percent consolidated (according to the theory of consolidation) the volume decrease does not stop according to the theory, but instead the sample continues to compress at a reduced and rather constant rate. The amount of consolidation that can be computed by the theory is called primary consolidation; whereas the slow consolidation the takes place afterwards is called secondary consolidation.

$$S = \frac{e_0 - e}{1+e_0} H$$

$$= C_C \frac{H}{1+e_0} log \frac{p_0+\Delta p}{p_0}$$

$$t = \frac{T_V}{C_v} H^2$$

Where,

S = settlement due to consolidation

H = thickness of clay layer. If the soil is drained on top and bottom as in the consolidation test, Half-thickness should be used.

e_0 = natural void ratio of the steel in place.

P_0 = weight of soil above mid height of the consolidating layer.

Δp = net additional pressure = consolidation pressure.

T_v = time factor, a coefficient depending upon the percentage of consolidation.

t = time required to reach a certain percentage of consolidation. The percentage of consolidation is the ratio of the amount of compression at the certain time during the process of consolidation to the total calculated compression S.

C_C = compression index, to be determined by consolidation test.

C_V = coefficient of consolidation to be determined from the results of the consolidation test.

(Ref. Book: Foundation Design by Wayne C. Teng, page no.61, 62, 118, 129 & 130)

9.3 Determination of Bearing Capacity for Pile:

A pile is supported in the soil by the resistance of the toe to further penetration plus the frictional or adhesive forces along its embedded length.

Ultimate bearing capacity = Ultimate base resistance + Ultimate skin friction

$Q_u = Q_b + Q_s$

9.3.1 Cohesive Soil:

Q_b for piles in cohesive soils is based on Meyerhof's equation (1951):

$Q_b = N_c c_b A_b$ Where,

N_c = bearing capacity factor, widely accepted as 9.0

C_b = undisturbed untrained shear strength at the base of the pile

A_b = the area of the pile base

$Q_s = \alpha c_u A_s$

Where, α = Adhesion factor (Table .... Ref. Peck, Hanson &Thornburn, 1973)

c_u = undisturbed untrained shear strength of soil adjoining pile

A_s = surface area of embedded length of pile

Table. Adhesion Factor α for Cohesive Soil (Peck, Hanson &Thornburn, 1973

q_u (tsf)	A	q_u (tsf)	α	q_u (tsf)	α	q_u (tsf)	α
0.1	0.99	0.6	0.943	1.1	0.80	1.6	0.657
0.2	0.986	0.7	0.92	1.2	0.78	1.8	0.62
0.3	0.98	0.8	0.89	1.3	0.75	2.0	0.565
0.4	0.97	0.9	0.87	1.4	0.72	2.2	0.535
0.5	0.957	1.0	0.836	1.5	0.674	2.4	0.550

9.3.2 Cohesion less Soil:

With cohesion less soil it is possible to make reasonable estimates of the values of q_b and f_s from in-situ penetration test. Meyerhof (1976) suggests the following formulae to be used in conjunction with the standard penetration test.

Sand and gravel $q_b = 400ND/B \leq 400N$ kN/m^2

$= 0.4ND/B \leq 4N$ tsf

Large diameter driven pile $f_s = 2N < 100$ kN/m^2

$= N/50 \leq 1$ tsf

9.3.3 Bearing Capacity of piles from the SPT and soil parameters:

Table 9. The skin friction and end bearing capacities of piles (F. S. = 3.0):

Bore Hole No: 01			
Depth (ft)	N	F_s(tsf)	F_b(tsf)
5	3	0.058	0.54
10	2	0.039	0.36
15	2	0.039	0.36
20	2	0.039	0.36
25	2	0.039	0.36
30	3	0.058	0.54
35	3	0.058	0.54
40	3	0.058	0.54
45	4	0.077	0.72
50	3	0.058	0.54
55	3	0.058	0.54
60	4	0.077	0.72
70	5	0.094	0.90
80	10	0.156	1.80
90	9	0.144	1.62
100	27	0.205	4.86
110	20	0.168	3.60
120	22	0.180	3.96

Bore Hole No: 02			
Depth (ft)	N	F_s(tsf)	F_b(tsf)
5	2	0.039	0.36
10	2	0.039	0.36
15	2	0.039	0.36
20	2	0.039	0.36
25	2	0.039	0.36
30	2	0.039	0.36
35	3	0.058	0.54
40	3	0.058	0.54
45	5	0.094	0.90
50	4	0.077	0.72
55	4	0.077	0.72
60	5	0.094	0.90
70	5	0.094	0.90
80	7	0.125	1.26
90	8	0.134	1.44
100	25	0.195	4.50
110	23	0.184	4.14
120	22	0.180	3.96

Bore Hole No: 03			
Depth (ft)	N	F_s(tsf)	F_b(tsf)
5	3	0.058	0.54
10	2	0.039	0.36
15	2	0.039	0.36
20	2	0.039	0.36
25	2	0.039	0.36
30	3	0.058	0.54
35	3	0.058	0.54
40	3	0.058	0.54
45	4	0.077	0.72
50	4	0.077	0.72
55	5	0.094	0.90
60	6	0.110	1.08
70	7	0.125	1.26
80	8	0.134	1.44
90	7	0.125	1.26
100	29	0.212	5.22
110	21	0.174	3.78
120	24	0.190	4.32

10. CONCLUSIONS AND RECOMMENDATIONS:

10.1 CONCLUSIONS:

The Sub-Soil Investigation For The **Construction of Regulator 1vent at Dumuria Ch. 28.550km Over Dumuria Khal In Polder No-15 Under Rehabilitation of Polder 15 at GPS Position E:- 0731861, N:- 2461640, Thana:- Shyamnagar, Dist:- Satkhira.**

Three bore holes were drilled up to the maximum depth of 120ft from the existing ground level. On the basis of the information of the investigated site the following conclusions may be drawn:

1. The bearing capacity of the sub-soil of shallow foundation at normal foundation level is low.
2. On the basis of the field and laboratory information, shallow foundation may not be suitable in this site due to presence of soft clay layer.

10.2 RECOMMENDATIONS:

Based on the above conclusions the following recommendations are suggested for the constructions of the proposed sites.

1. For the construction of shallow foundation may be used.
2. For the construction of mat, pile or pile raft foundation may be provided.

However the consultant or design engineer should take any alternative decision about the type, depth and dimension of foundation.

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The Pile capacity of different diameter piles with different depths are calculated as per field results that are bellows:

The skin friction and end bearing capacities of piles (F. S. = 3.0):

Length of pile from EGL (ft)	Bearing capacity of pile for different dia. Pile (tone/ Pile)		
	Pile Dia.=18″	Pile Dia.=20″	Pile Dia.=22″
50	14	15	17
55	15	17	19
60	18	20	22
70	22	25	28
80	29	32	36
90	36	40	44
100	50	57	63
110	58	65	73
120	66	75	83

NOTE:

a) Tsf=2ksf=95.78kN/ m^2 , 1 Ton=2000lbs =1000kg.

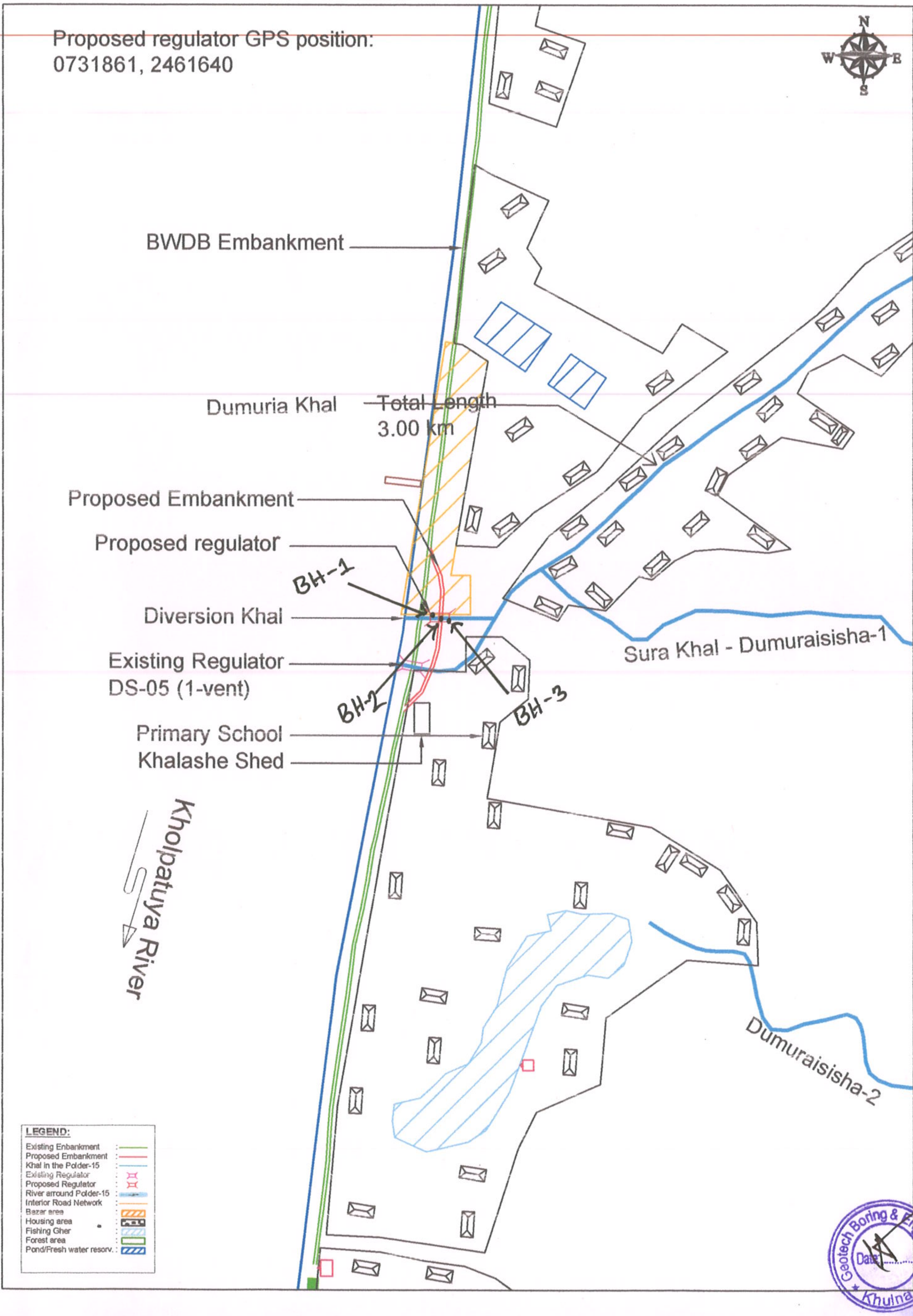
1m=3.28ft,EGL=Existing Ground Level & F.S=Factor of Safety

b) The designer may select any other alternative type, depth as well as the bearing capacity of the foundation in the light of information provided in this report.

c) Foundation base should be kept dry during construction period.

d) Pile load test should be performed. If pile load test is not performed than the value of pile capacity should be considered half.

Site Plan for Construction of Regulator 1vent at Dumuria km 28.550 over Dumuria khal in polder no-15 under "Rehabilitation of polder 15 at satkhira district" project under satkhira O&M Division-1, BWDB, Satkhira during the year 2021-22.



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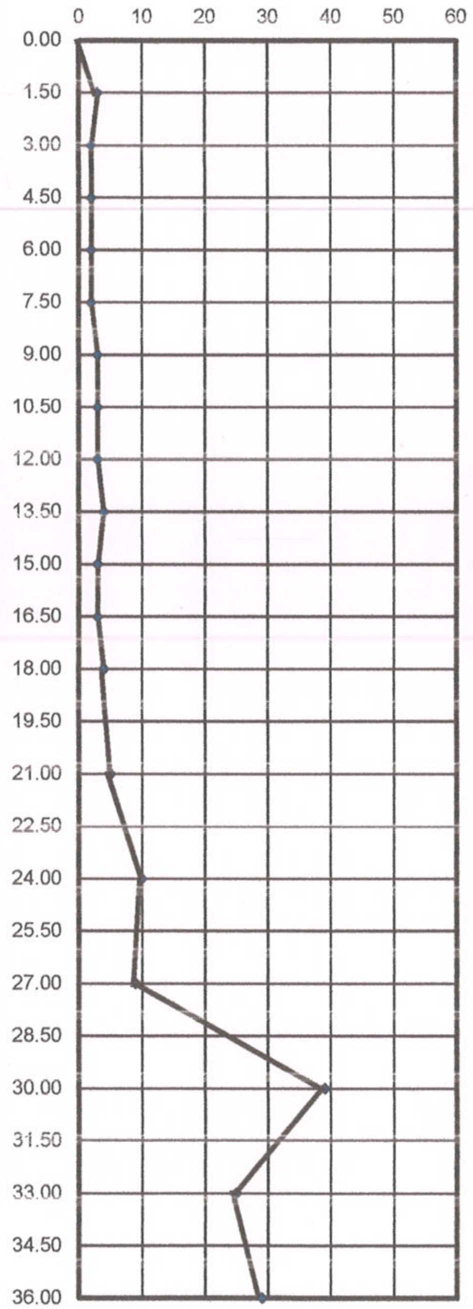
Bore Hole No.01	Project:- Construction of Proposed Rehabilitation of Polder 15 at Satkhira District.
Date:- 03.11.2022	Land Detail:- Dumuria at Ch. 28.550km Over Dumuria Khal, GPS Position E:- 0731861, N:- 2461640, Thana:- Shyamnagar, Dist:- Satkhira.
Client:- Satkhira O&M Division-1, BWDB, Satkhira.	GWL: (-)2.50m

Depth in meter	Depth in feet	Graphics	Discription of Classification (Visual)	N- Values	Sample Type
1.50	5		Silty-Clay-Gray	3	DS
3.00	10			2	DS
4.50	15			2	DS
6.00	20			2	DS
7.50	25			2	DS
9.00	30			3	DS
10.50	35			3	DS
12.00	40			3	DS
13.50	45			4	DS
15.00	50			3	DS
16.50	55			3	DS
18.00	60			4	DS
19.50	65				DS
21.00	70		Silty-Clay-Gray	5	DS
22.50	75				DS
24.00	80		Clayey-Silt-Little Sand-Gray	10	DS
25.50	85				DS
27.00	90		Clayey-Silt-Little Sand-Gray	9	DS
28.50	95				DS
30.00	100		Silty-Sand-Trace Clay-Gray	39	DS
31.50	105				DS
33.00	110		Silty-Sand-Trace Clay-Gray	25	DS
34.50	115				DS
36.00	120		Silty-Sand-Trace Clay-Gray	29	DS

SPT Graph



Note: Undisturbed Soil=US, Disturb Soil=DS.

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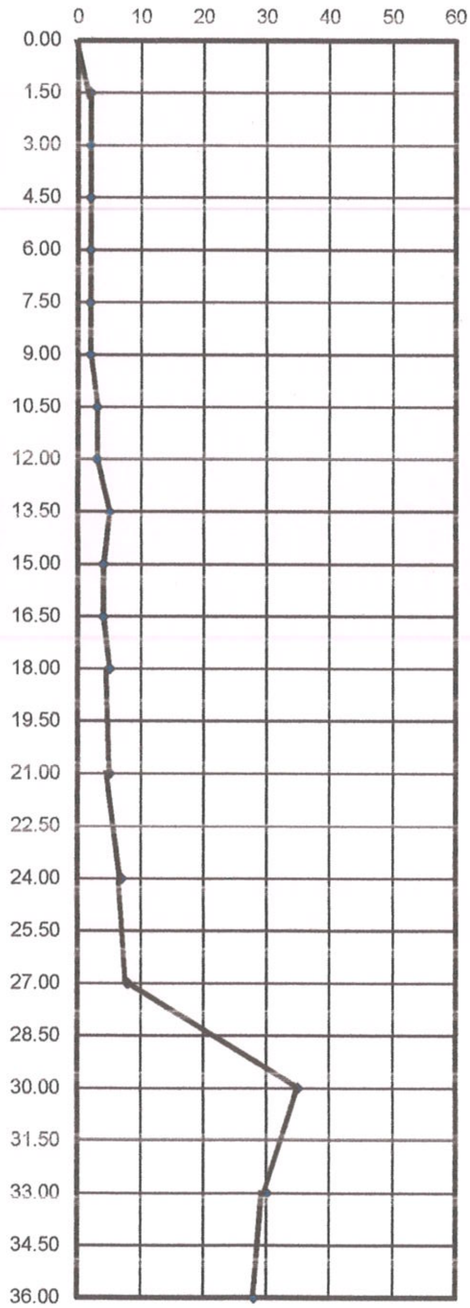
Bore Hole No.02	Project:- Construction of Proposed Rehabilitation of Polder 15 at Satkhira District.
Date:- 03.11.2022	Land Detail:- Dumuria at Ch. 28.550km Over Dumuria Khal, GPS Position E:-0731861, N:- 2461640, Thana:- Shyamnagar, Dist:- Satkhira.
Client:- Satkhira O&M Division-1, BWDB, Satkhira.	GWL: (-)2.60m

Depth in meter	Depth in feet	Graphics	Discription of Classification (Visual)	N- Values	Sample Type
1.50	5		Silty-Clay-Gray	2	DS
3.00	10			2	DS
4.50	15			2	DS
6.00	20			2	DS
7.50	25			2	DS
9.00	30			2	DS
10.50	35			3	DS
12.00	40			3	DS
13.50	45			5	DS
15.00	50			4	DS
16.50	55			4	DS
18.00	60			5	DS
19.50	65				DS
21.00	70		Silty-Clay-Gray	5	DS
22.50	75				DS
24.00	80		Clayey-Silt-Trace Sand-Gray	7	DS
25.50	85				DS
27.00	90		Clayey-Silt-Trace Sand-Gray	8	DS
28.50	95				DS
30.00	100		Silty-Sand-Trace Clay-Gray	35	DS
31.50	105				DS
33.00	110		Silty-Sand-Trace Clay-Gray	30	DS
34.50	115				DS
36.00	120		Silty-Sand-Trace Clay-Gray	28	DS

SPT Graph



Note: Undisturbed Soil=US, Disturb Soil=DS.

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Date:
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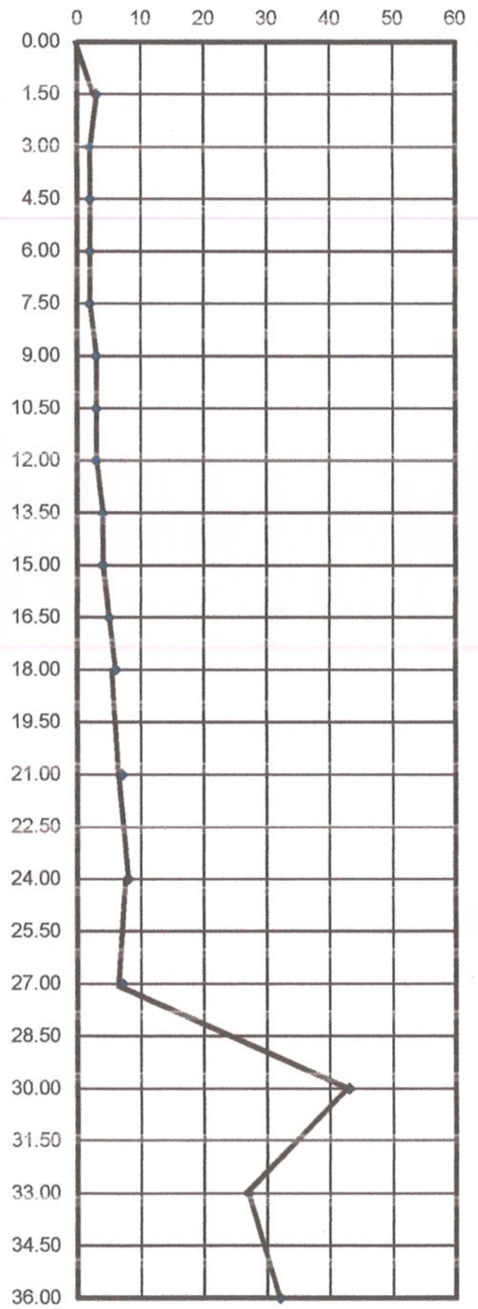
Bore Hole No.03	Project:- Construction of Proposed Rehabilitation of Polder 15 at Satkhira District.
Date:- 03.11.2022	Land Detail:- Dumuria at Ch. 28.550km Over Dumuria Khal, GPS Position E:- 0731861, N:- 2461640, Thana:- Shyamnagar, Dist:- Satkhira.
Client:- Satkhira O&M Division-1, BWDB, Satkhira.	GWL: (-)2.40m

Depth in meter	Depth in feet	Graphics	Discription of Classification (Visual)	N- Values	Sample Type
1.50	5		Silty-Clay-Gray	3	DS
3.00	10			2	DS
4.50	15			2	DS
6.00	20			2	DS
7.50	25			2	DS
9.00	30			3	DS
10.50	35			3	DS
12.00	40			3	DS
13.50	45			4	DS
15.00	50			4	DS
16.50	55			5	DS
18.00	60		Clayey-Silt-Trace Sand-Gray	6	DS
19.50	65				DS
21.00	70		Clayey-Silt-Trace Sand-Gray	7	DS
22.50	75				DS
24.00	80		Clayey-Silt-Trace Sand-Gray	8	DS
25.50	85				DS
27.00	90		Clayey-Silt-Trace Sand-Gray	7	DS
28.50	95				DS
30.00	100		Silty-Sand-Trace Clay-Gray	43	DS
31.50	105				DS
33.00	110		Silty-Sand-Trace Clay-Gray	27	DS
34.50	115				DS
36.00	120		Silty-Sand-Trace Clay-Gray	32	DS

SPT Graph



Note: Undisturbed Soil=US, Disturb Soil=DS.

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178, KDA Majid Sarani, 1st Floor (Khan Cort Building), Sibbari more, Khulna. Date:- 03/11/2022

Mob No: 01714940302, 01775664866

Client Name/Project: - Rehabilitation of polder-15 at Satkhira district under ckt Satkhira O&M Division-1, BWDB Satkhira.)

Site Location: -

Bore Hole (BH):-

Thana: - Shyamnagar

Dist.:- Satkhira.

ch = 28.550km

Client Mobile No: - 01717566130

Water Table: (-)2.5 m

Mouza:- Dumuria.

J.L No:-

Khatian No:-

R.S Dag No:-

S.A Dag No:-

GPS position
N = 2461640
E = 0731861

Depth	6"	6"	6"	N Value	Un-disturb Soil	Disturb Soil	Soil Description (Type & Color)
5'	1	1	2	3			Silty Clay — Gray
10'	1	1	1	2			" " "
15'	1	1	1	2			" " "
20'	1	1	1	2			" " "
25'	1	1	1	2			" " "
30'	1	1	2	3			" " "
35'	1	1	2	3			" " "
40'	1	1	2	3			" " "
45'	1	2	2	4			" " "
50'	1	1	2	3			" " "
55'	1	1	2	3			" " "
60'	1	2	2	4			" " "
70'	2	2	3	5			" " "
80'	3	5	5	10			Clayey Silt, little Sand - Gray
90'	3	4	5	9			" " " " "
100'	10	17	22	39			Silty Sand, trace Clay - Gray
110'	5	11	14	25			" " " " "
120'	6	12	17	29			" " " " "

Name (Site Engr.)

Name & Signature (Owner/Engineer/Project Manager.)

Geotech Boring & Engineering Date........ Khulna

20/11/22.
(Md. Zakir Hossain)
Sub-Divisional Engineer
ID No-710218001
Shyamnagar O&M Sub-Division
BWDB, Shyamnagar, Satkhira.

03/11/22
Md. Sazzadul Haque
Sub-Assistant Engineer/SO
Nowabenki O&M Section
BWDB, Shyamnagar, Satkhira

GEOTECH *Boring & Engineering*

178, KDA Majid Sarani, 1st Floor (Khan Cort Building), Sibbari more, Khulna. Date:- 03/11/2022

Mob No: 01714940302, 01775664866

Client Name/Project: -

Site Location: - Dumunia get

Bore Hole (BH):- 02 ch = 28.550km

Thana: - Shyamnagar

Dist.:- Satkhira.

Client Mobile No: -

Water Table: (-)2.6 m

Mouza:-

J.L No:-

Khatian No:-

R.S Dag No:-

S.A Dag No:-

Depth	6"	6"	6"	N Value	Un-disturb Soil	Disturb Soil	Soil Description (Type & Color)
5'	1	1	1	2			Silty clay — Gray
10'	1	1	1	2			〃 〃 〃
15'	1	1	1	2			〃 〃 〃
20'	1	1	1	2			〃 〃 〃
25'	1	1	1	2			〃 〃 〃
30'	1	1	1	2			〃 〃 〃
35'	1	1	2	3			〃 〃 〃
40'	1	1	2	3			〃 〃 〃
45'	2	2	3	5			〃 〃 〃
50'	2	2	2	4			〃 〃 〃
55'	2	2	2	4			〃 〃 〃
60'	2	2	3	5			〃 〃 〃
70'	2	2	3	5			〃 〃 〃
80'	2	3	4	7			Clayey Silt, trace Sand - Gray
90'	2	4	4	8			〃 〃 〃 〃 〃
100'	9	15	20	35			Silty ~~clay~~ Sand, trace clay - Gray
110'	7	14	16	30			〃 〃 〃 〃 〃
120'	7	13	15	28			〃 〃 〃 〃 〃

Name (Site Engr.)

Geotech Boring & Engineering * Khulna * Date:

Name & Signature (Owner/Engineer/Project Manager.)

29/11/22.
(Md. Zakir Hossain)
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BWDB, Shyamnagar, Satkhira.

GEOTECH *Boring & Engineering*

178, KDA Majid Sarani, 1st Floor (Khan Cort Building), Sibbari more, Khulna. Date:-03/11/2022

Moh No: 01714940302, 01775664866

Client Name/Project: -

Water Table:- (-) 2.40 m

Site Location: - Dumunia set

Mouza:-

Bore Hole (BH):- 03

ch= 28.550km

J.L No:-

Thana: - Shyamnagar

Khatian No:-

Dist.:- Satkhira

R.S Dag No:-

Client Mobile No: -

S.A Dag No:-

Depth	6''	6''	6''	N Value	Un-disturb Soil	Disturb Soil	Soil Description (Type & Color)
5'	1	1	2	3			Silty Clay — Gray
10'	1	1	1	2			" " "
15'	1	1	1	2			" " "
20'	1	1	1	2			" " "
25'	1	1	1	2			" " "
30'	1	1	2	3			" " "
35'	1	1	2	3			" " "
40'	1	1	2	3			" " "
45'	1	2	2	4			" " "
50'	1	2	2	4			" " "
55'	2	2	3	5			" " "
60'	2	3	3	6			Clayey Silt, trace Sand, Gray
70'	2	3	4	7			" " " " "
80'	2	4	4	8			" " " " "
90'	2	3	4	7			" " " " "
100'	13	20	23	43			Silty Sand, trace Clay - Gray
110'	6	12	15	27			" " " " "
120'	9	14	18	32			" " " " "

Name (Site Engr.)

Name & Signature (Owner/Engineer/Project Manager.)

Geotech Boring & Engineering, Khulna. Date.......

29-11-22

(Md. Abul Khaer)
Executive Engineer
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Satkhira O&M Division-1
BWDB, Satkhira.

29/11/22.

(Md. Zakir Hossain)
Sub-Divisional Engineer
ID No-710218001
Shyamnagar O&M Sub-Division
BWDB, Shyamnagar, Satkhira.

03/11/22

Md. Sazzadul Haque
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BWDB, Shyamnagar, Satkhira.