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**Research Paper** 

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# Suggestion on Foundation Soil Layer Selection at Prabasi Palli: Constrained From Geological and Geotechnical Engineering Survey

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**Abstract:-** Environmental and Geospatial Solutions (EGS, Bangladesh) carried out a comprehensive geological and geotechnical engineering survey at the Prabasi Palli area, and submitted a soil test report to Geological Survey of Bangladesh (GSB). The purpose of this survey was to assess the feasibility of the site for building construction that at the same time was needed to be approved by GSB after evaluating the soil test report. Regionally, predominant occurrence of clay at very shallow depths, complex tectonic condition, and varied geomorphology, rendered the site for especial consideration and investigation. The occurrence of clay there corroborates the necessity of investigating the geological conditions as well as engineering properties of the soil layers, which is the preliminary concern for predicting sustainability of desired civil structures. EGS performed in situ Standard Penetration Test (SPT) along with sampling at different locations within the project area. The investigation strictly followed the GSB guideline. Two predominant geomporphologic units were identified there along with demarcating four major geotechnical units or soil layers, considering the collected soil samples and SPT N-value. Differing soil strength characteristics were recognized in either of the two geomorphologic units. The authors recommended on selection of foundation soil layer there by characterization of soil strength. They kept foundation design out of scope of this work.

Keywords: - Borehole, Standard Penetration Test, N value, Bearing capacity, Foundation soil layer

#### I. INTRODUCTION

Determination of subsurface geological and geotechnical properties is essential for an economic and intelligent design of foundation of civil structures, such as building, road, railway, dam, embankment, bridge etc. A reasonably accurate conception on the geological set-up in relation to the sedimentary history is a prerequisite to correlate or review the consistency of the subsurface section.

The Probasi Palli project was undertaken to raise some buildings in a planned way within the privately possessed area at the locality. Such works need GSB approval based on geological and geotechnical engineering survey report on the area. Therefore, EGS, as a client of Habitat Planning Associates Ltd. carried out the survey. The subsurface geological and geotechnical investigation works include identification and delineation of subsurface geological and geotechnical units using SPT borehole data. 13 boreholes up to 20m depth and 2 up to 30m along with standard penetration test (SPT) have been completed at different selected positions as per guidelines of GSB. Moreover, samples were collected at 1.5m interval for geotechnical laboratory tests with a view to preparing a complete geological and geotechnical engineering report on the site.

Probasi Palli Project area is situated in the Eastern periphery of Gazipur Sadar Thana and broadly within Dhaka-Tongi or Gazipur-Tongi region of Bangladesh that covers parts of Khilgaon and Kamaira village of Pubail Union. The area is nearly 45 km by road from Dhaka. It is bounded approximately by latitudes from 23°55′27.8472″N to 23°55′31.386″N and longitudes from 90°28′0.725″E to 90°28′3.961″E from North to South,

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and by latitudes from  $23^{\circ}55'27.8472''N$  to  $23^{\circ}55'26.526''N$  and longitudes from  $90^{\circ}28'0.725''E$  to from  $90^{\circ}28'17.645''E$  from West to East.



# Figure 1. Location map of the project area (red circle highlights the project area) (source: Rajdhani Unyayan Kortripakkha (RAJUK))

The area is of rugged topography and relief, comprising of characteristics of the Pleistocene terraces. Small discreet terraces with adjacent low and flat flood plains are distinguishable. Highest topography recorded is 11.89 m and the lowest is 7.01 m.

Nagda river, a distributary of Balu river, is adjacent to the are in the South. Natural small channels (most appropriately Khal in local name) in a cross-cutting manner occupies around the terraces of the area. They are dry in the dry season and water flows through them during wet season. Overall drainage pattern of the area is dendritic to trellis.

It is within a village area and density of population is medium. Not much structure have been raised. Flat lands are mainly used for irrigation and habitation is seen on the terraces.



Figure 2. Represents topography, drainage and landuse pattern at the locality.

#### II. METHODOLOGY

Standard penetration Test (SPT) was conducted at the site by 15 boreholes. Among them, 2 were up to 30m depth and the others were up to 20m depth. Standard of testing was ASTM D1586. Samples were collected at 1.5 m interval and SPT N value was determined from blow counts. Borehole log has been prepared by documenting the borehole data. This data has been used for subsoil stratification and foundation soil layer selection. Borehole layout map, N value correction and log sheets have been presented in Appendix II.

#### SURFACE GEOLOGY

#### III. GENERAL GEOLOGY

The project area lies within Dhaka-Gazipur terrace, a part of Madhupur Tract, located in the central part of Bangladesh. The tract is a structural high that extends from the folded hills in the eastern fringe of Bengal basin. This elevated area is only a few meters above the surrounding rivers such as the Buriganga and Turag on the west and the Balu on the east (Alam and Aurangzeb, 1975). Locally, the Tract is subdivided into the Dhaka and Bhawal Garh terraces [1]. The terraces are parts of an inlier, a technical term for an elevated area surrounded by lowlands. The elevation of the Tract varies from 2 to 14 m above mean sea level. The terraces are surrounded by the Ganges-Meghna floodplain in the south, the old Brahmaputra floodplain in the east and the Jamuna floodplain in the west. It is formed of Madhupur Clay Residuum and is exposed as a monoclinal limb. Due to higher elevation than the surrounding plains, the terrace has become a seat of urban and industrial development [2]. A series of dendritic to trellis drainage system has developed on the terrace following the fractures or shear zones [1].

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Figure 3. Geological map of map of Dhaka-Tongi region—after EPC/ MMP 1991 and Khandoker 1987 (inset) (red circle in the figure shows the project area)

#### **TECTONIC SET-UP**

Stable shelf (SS) in the Northwestern region, Bengal Foredeep (BF) and hinge zone between SS and BF broadly describes the tectonic subdivision of Bangladesh. The Bengal basin is asymmetric; the thickness of the sediments increases toward the south and east to more than 16 km (Curray and Moore, 1971; Murphy, 1988). Interpretations of the tectonic setting of the basin are varied and rather convolute. Desikachar (1974) considered the Bengal basin as a pericratonic basin of the Indian plate. His proposition suggests that the deeply subsided central portion of the Bengal basin forms part of the Indian plate, whereas the eastern basin margin is actually part of the Burmese plate. In his view, the Burmese plate has moved toward the Indian plate beginning in the Miocene, and just east of the Ninety-East ridge (or its northern extension), where he inferred maximum subsidence, the Burmese plate overrode the Indian plate to form a subduction zone between the two plates [4]. Today most authors agree that convergence between India and Burma has resulted in subduction of oceanic crust beneath Burma, with the trailing margin of India currently passing obliquely into the foreland of the Indo–Burman ranges (Murphy, 1988; Mukhopadhyay and Dasgupta, 1988; Alam et al., 2003). This convergent margin has been complicated by right-lateral strike-slip motion (e.g., Kaladan fault, Sagaing fault), possibly throughout the history of the collision (e.g., Ni et al., 1989).

The project area lies within the Bengal foredeep or the deeper part of the Bengal basin. The deeper part of the Bengal basin, a zone of very thick sedimentary strata lying over deeply subsided basement, was subdivided based on gravity studies. The division is a northwestern platform flank just east of the Hinge zone, and an eastern folded flank that includes the Chittagong Hills and the Sylhet trough in the northeastern part of the Bengal basin (Khandoker, 1989; Khan, 1991). The platform flank shows small-amplitude, isometric or geographically equant anomalies, whereas the folded flank exhibits large-amplitude, linear or elongated anomalies (Bakhtine, 1966). The Sylhet trough is a conspicuous trough of thick sedimentary fill along the northeastern part of the Bengal basin (Holtrop and Keizer, 1970; Woodside, 1983). The Sylhet trough is a depositional low, located just south of the crystalline Shillong Plateau with a structural relief of about 20 km between the trough and the neighboring plateau (Murphy, 1988; Johnson and Nur Alam, 1991) [4]. The folded flank of the deeper basin is composed of elongated folds of north–northwest to south–southeast trend. Structural complexity of the folded flank increases from west to east and merges into the Indo– Burman ranges farther east (Khan, 1991).

88° 89° 90° 91° 92° 93° 94° E 87 27 N HIMALAYAS 27 Main Boundary Thrust Fault HIMALAYAN OREDEEP ASSAM BASIN MIKIR 2Ē - 11 ADDLE SHILLONG MASSIF ORTHERN FORELAND SHELL 25 SURMA INDIAN SHIELD B WESTERN F  $2\overline{4}$ TRIPURA FOLD BELT < ç 23 THE INDOBURMAN NTINENTAL CRUS S (PASSIVE CONTINENTAL MARGIN 22 H A T I Y A TROUGH OCEANIC CRUST 20 50 21 80 BENGAL FAN TECTONIC MAP OF BANGLADESH AND ADJOINING AREAS ŝ Depth in Metres 90 nn (1993

Figure 4. Regional tectonic map of Bangladesh (Source: Guha (1978); GSB (1990); Reimann, 1993).

The Madhupur tracts are broken into several fault blocks, the surfaces of which are a few meters higher than the nearby floodplain land. Most of the authors including Fergusson (1863), Hirst (1916), Morgan & McIntire (1959), Rizvi (1975), Khandoker (1987&1989), Huq et al. (1991), Coates et al. (1988, 1990 &1991), A1am (1988 & 1995) and Kamal (1998, 2005) believed that the Madhupur tracts represent tectonically uplifted surface. Some researchers including Monsur (1995) opined that the La1mai hills and the small portion of Madhupur (locality) represent tectonically uplifted blocks but the entire Barind and the major portion of the Madhupur tracts were originated by erosional processes, rather than structural. [3]

According to the second thought, during glacial and interglacial periods the combined effects of seaward subsidence and landward uplift have caused a warping of the alluvial terraces, which are called the 'Pleistocene terraces'. Afterwards these dissected valleys were filled up with alluvial sediments, generating a recent floodplain surface at lower position than the initial Pleistocene Terraces. [3]

A further research, therefore, is needed to bring forward the history of the formation, deformation of these tracts by using modern equipments, which may help to resolve the problems associated with origin and evolution of the tracts.

#### **Subsurface Geology**

The terraces are surrounded by the Ganges-Meghna floodplain in the south, the old Brahmaputra floodplain in the east and the Jamuna floodplain in the west [1]. Alam (1988) identified the following geological units in and around the Dhaka-Tongi area.

Age	Formation	Lithology	Thickness (meters)			
Holocene	Alluvium	Lowland: River bed deposit: Grey sand and silty	0-9			
		sand, medium to fine grained.				
		Local unconformity				
		5				
		Natural levee and interstream deposit: Sandy silt,	1.21-4.7			
		silt and loam, grey and friable.				
		Backswamp and depression deposits:				
		Clay and silty clay, grey, bluish grey to dark grey.	0.61-1.5			
		Highland: Silt and clay above the present flood	0-3.5			
		level.				
Pleistocene	Madhupur Clay	Red clay: Light brown to brick red and massive,	31			
		pisolitic with fossil wood, ferruginous and				
		calcareous nodules and surficial deposits of slag.				
		Mottled clay: Earthy grey with patches of orange,				
		brown colour, massive and containing calcareous				
		and ferruginous nodules				
		Unconformity				
Pliocene	Dupi Tila	Sandstone: Yellow to yellowish grey, massive,	90+			
		cross bedded, mostly fine to medium grained				
		containing scattered gravel lenses, moderately				
		consolidated.				

#### Table 1. Stratigraphic succession in and around Dhaka-Tongi area. [1]

Subsurface geology of the project area was studied using 15 boreholes up to 20m depth, two of which is of 30m depth. Geological lithologs and cross-sections obtained from the boreholes has been presented in figure 5. Clay, silty clay, organic clay with iron concretions and organic materials occupies the Lithology of the area. Reddish brown, yellowish brown, grey colors with mottling are prominent in the clays. Some localized sand deposits have also been found. The stratigraphic succession of the area along with geotechnical units, established from the borehole data is given in the following table.

	Table 2.	Generalized str	aligraphic succession of the Frobasin Fam project area	•
Age	Formati	Geotechnical	Lithology	Thickness
	on	Units		(m)
Holocene	Alluviu	Unit 1	Lowland: Floodplain deposit: Grey to light grey sand, fine	1.5
	m		grained.Local unconformity	
		Unit 2	Backswamp and depression deposits: Grey, light grey, dark	3-7
			grey, black clay and silty clay with organic materials	
	Madhup	Unit 3	Light brown to brick red mottled clay with some silt, organic	20+
Pleistoce	ur Clay		materials and iron concretions.	
ne			Light grey with patches of orange, brown, black color	
			containing silt, organic materials and iron concretions.	
			Unconformity	
Plio-	Dupi		Massive sand: Yellowish brown very fine grained micaceous	
Pleistoce	Tila		sand with silt and clay	
ne				
		Unit 4	1	3-7.5+

#### Table 2. Generalized stratigraphic succession of the Probashi Palli project area.









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Figure 5. Presents litho logs and geological and cross-sections obtained from the boreholes.

#### Geomorphology And Geologic History Of The Site

Geomorphologically, the area shows two clear units. One is the inlier type Pleistocene terraces and the other is the surrounding shallow valley type flat lands. These low lands remain under water during the monsoon season of Bangladesh and wet during the winter. The villages recognize the mound type terraces, and the adjacent low lands are recognized by farm lands.

The lower Dupitila Sandstone Formation was deposited in fluvial environment of Plio-Pleistocene time. The Madhupur Clay deposit of the project area is of early Pleistocene time and originated in fluvial environment (Md. Hussain Monsur, Banglapedia), which later suffered Neotectonic upliftment and Late Pleistocene dissecting events that remained in inlier form also popularly known as Pleistocene terraces or tracts. Unconformity between Dupi Tila and overlying Madhupur Clay Formation indicates a depositional break in the area. The adjacent low land of the area contains recent flood plain deposits.

#### IV. SUBSOIL STRATIFICATION

Soil layer belonging to the subsurface of the project site was investigated by boring and sampling; up to 30m depth in boreholes BH-P-02 and BH-P-06, and others were limited to 20m. From N value range and visual sample classification, we divided the soil layer there into 4 subsoil units and named as:

- 1. Unit 1 (sandy)
- 2. Unit 2 (organic clay)
- 3. Unit 3 and (clay)
- 4. Unit 4 (sandy)

These units also correlate well with our stratigraphic subdivision presented in the Table 2 and hence, the same names have also been adopted here.

Unit 1, consisting of grey to light grey very loose to loose fine-grained sand, having high water content. This unit has been encountered in only two boreholes (BH-P-03 and BH-P-12) up to 1.5m depth. SPT "N" value range (3-4) has been reckoned for this unit. The deposits may be of recent flood plain origin.

Unit 2, mainly grey and dark grey clay and silty clay with organic content, has soft to very soft engineering property, and high water content. This unit is found in BH-P-02 and BH-P-06, BH-P-07, BH-P-08,. "N" value range (1-4) has been found for this unit. The unit displays very recent alluvial nature.

The geotechnical unit 3 is red and mottled in color, medium stiff to hard. Clays with higher SPT values are associated with iron concretions. From borehole observation, we got the occurrence of this unit throughout the project area at various depths with an average thickness of about 16m. The unit in most cases was found at the surface of the highlands of the area while found underlain by Unit 1 and Unit 2 at low lands, mostly at 7.5m depth from the surface. Maximum N value (44) was found in this unit 19.5m depth. From table 1 and table 2, it is discernible that Unit 3 represents the Madhupur Clay Formation, which has 31m of regional thickness (Alam, 1998). N-value range (3-44) has been reckoned at various depths.

Unit 4 is composed of yellowish brown medium dense to dense fine grained massive micaceous sand with silt and clay. The sand body is possibly equivalent to the Plio-Pliestocene (upper) Dupitila Formation; is medium dense to dense in its engineering property. The formation has regional thickness of more than 90m (Alam, 1998).. BH-P-01, BH-P-06, BH-P-13, BH-P-14, BH-P-15 are the boreholes where this unit has been encountered. SPT value range (10-41) was counted at various depths. This unit was found only within the inliers, underlain by the Unit 3; occurring from 9 to 16.5m below the surface.

There has been seen a general trend of increasing N value with depth. Subsoil stratification and there visual characteristics along with N value range has been summarized in the following table. The geotechnical units yielded from sub-soil stratification have been presented by geotechnical cross-sections in figure 6.

Unit	Soil description	Boreholes	Depth	SPT N value
	L L		range (m)	range
			0 ( )	0
Unit 1	Grey to light grey very loose to loose	BH-P-03; BH-	up to 1.5	3 to 4
	fine grained sand	P-12	_	
Unit 2	Mainly grey and dark soft to very soft	BH-P-02	0 to 7.5	1 to 4
	grey clay and silty clay with organic	BH-P-06	0 to 7.5	
	content	BH-P-07	0 to 4.5	
		BH-P-08	0 to 7.5	
Unit 3	Red, mottled medium stiff to hard clay	BH-P-01	0 to 7.5	3 to 44
	(Madhupur Clay) with rapid		9 to 16.5	
	occurrence of iron concentration.		19 to 19.5	
		BH-P-02	7.5 to 30	
		BH-P-03	1.5 to 19.5	
		BH-P-04	0 to 19.5	
		BH-P-05	0 to 4.5	
			7.5 to 19.5	
		BH-P-06	6 to 12	
			18 to 30	
		BH-P-07	4.5 to 19.5	
		BH-P-08	7.5 to 19.5	
		BH-P-09	0 to 19.5	
		BH-P-10	0 to 19.5	
		BH-P-11	0 to 19.5	
		BH-P-12	1.5 to 19.5	
		BH-P-13	0 to 9	
		BH-P-14	0 to 9	
		BH-P-15	0 to 13.5	
Unit 4	Yellowish brown medium dense to	BH-P-01	16.5 to 18	10 to 41
	dense fine grained massive micaceous	BH-P-06	12 to 19.5	
	sand with silt and clay	BH-P-13	9 to 19.5	
		BH-P-14	9 to 19.5	
		BH-P-15	12 to 19.5	

 Table 3. A summary of subsoil units with their N value range and boreholes of occurrence at Prabashi Palli project site.



Figure 6. Cross sections along line A-B & C-D showing four geotechnical units as identified at the project site

#### Soil Strength Characterization and Discussion

Consistency of cohesive soil deposits and relative density of cohesionless soil deposits have been described in accordance with internationally accepted terms, which give approximate indication of strength of soil strata encountered at different depths. For cohesive soil, consistency terms indicate the following approximate bearing capacity of the different soil strata estimated on the basis of SPT N-values.

Consistency	SPT N-value	Allowable bearing capacity (KPa)
Very soft	0-2	<25
Soft	2-4	25-50
Medium	4-8	50-100
Stiff	4-15	100-200
Very stiff	15-30	200-400
Hard	>30	>400

For cohesionless deposits, relative density terms give the following approximate strength characteristicsbased on SPT N-values.

I uble of	Sti engen enai aet	eristies of conclision	
Relative density	SPT N-value	Estimated	Strength characteristics
		shearing angles	
Very loose	>4	28°	Very poor
Loose	4-10	30°	Poor to fair
Medium dense	10-30	32°	Fair to good
Dense and very dense	>30	34°	Good to excellent

Table 6. Strength characteristics of cohensionless soils

Both geological and geotechnical cross-section has been prepared using lithological and SPT data of the fifteen boreholes at the project site. It is remarkable that soils of high land and low land show different

strength characteristics. Unit 1 and Unit 2 were encountered only in the low lands overlying Unit 3. The upper two units are completely absent in the Pleistocene tracts. Again, soil units of the low lands show low consistency ( the N value was less than 30 in all of the boreholes at the low lands); on the other hand, soil units in the terraces show higher consistency (N value 44 and 41 was found at Unit 3 and Unit 4 respectively). Overall trend of SPT values showing increasing trend with depth, except in the Unit 3 of the higher ground. Unit 4 was not found in the low lands.

From geological and geotechnical point of view, it is clear that the soil subdivision Unit 1 has low SPT value, very loose to loose nature, and has very poor strength. Again, clayey Unit 2 is rich in organic matter, very soft to soft in nature, and has very limited allowable bearing capacity. Moreover, organic matter in soil highly attributes rapid settlement after getting exposure to any load. Hence, shallow foundation should be discarded there unless top soil improvement. Unit 3 of the low lands consists of very stiff clay, allowable bearing capacity of which varies from 200-400KPa. Therefore, we suggest that Unit 3 can be chosen as foundation soil layer there.

Only Unit 3 and Unit 4 were encountered in the tracts. Unit 3 there consists of hard clay mostly, 16.5 m below the surface, which has bearing capacity of over 400KPa. Again, Dense to very dense sand was found in the Unit 4 that has good to excellent strength. So both of these units can be chosen as foundation soil layer, depending on where maximum N-value occurred.

#### V. CONCLUSIONS

Probasi Palli Project area presents two distinct geomorphological subdivisions, Pleistocene terrace, and adjacent low lying shallow valley type lands, each showing difference in strength of the soil units. A comprehensive geological and geotechnical engineering survey was conducted there; primarily by 15 boreholes. Depth of two SPT boreholes was 30m whereas others were 20m. Based on borehole samples and SPT blow counts, 4 soil layers were identified each of which having distinguished lithology, depositional environment, engineering properties, and soil strength. Considering the strength characteristics of soils, we suggested to discard shallow foundations at the low lying lands unless top soil improvement, while to select the Madhupur Clay equivalent Unit 3 as the foundation layer. On the other hand, we recommended both Unit 3 and Unit 4 (Dupitila Sandstone Formation equivalent) as foundation soil layer, where maximum strength occurs. Further detailed study could be conducted by the geotechnical engineering laboratory test data. Also seismicity of the area and soil response should be taken care of.

#### ACKNOWLEDGEMENT

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#### APPENDICIES APPENDIX I



Figure 7. Topographic map of the project area (source: Habitat Planning Associates Ltd.)



Figure 8. Existing landuse map of the site.



Figure 9. Exploratory boreholes layout map.

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#### **N Value Correction**

Even after standardization, many variations still are significant, which means the test has a poor repeatability. The principal variants are:

- Method of drilling •
- Cleanliness of the bottom of the hole (lack of loose dirt) before the test •
- Presence or lack of drilling mud •
- Diameter of the drill hole •
- Height difference of falling hammer •
- Number of turns of the rope around the cathead. •
- Mass of the anvils that the hammer strikes
- Friction in rope guides and pulleys
- Wear in the sampler drive shoe •
- Straightness of the drill rods .
- Presence or absence of liners inside the samplers •
- Rate at which the blows are applied. .

So, the authors feel the necessity to correct the N-value for the selected17 boreholes. The variations in testing procedures may be at least partially compensated by converting the N recorded in the field to  $N_{60}$  as follows (Skempton, 1986):

 $N_{60} = \frac{E_m C_B C_S C_R N}{2}$ 

(1)

 $N_{60} = \frac{1}{0.60}$  (1) Where,  $N_{60} = SPT$  N- value corrected for field procedures

Em = hammer efficiency = 0.45 (for Dount hammer)

 $C_B$ = borehole diameter correction = 1.0

Cs= Sampler Correction = 1.20

 $C_R$  = rod length correction 0.75 N= SPT blow counts recorded in the field

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4.000		DF		4.0			8.0		0			0.68	/	78					
4.8m	-	00			Light gray , black, very and organic (0,AV		4.5	•	•			0.68		78					
a.on		D4		1.5	Skels sell organic GLAV		6.0	1	x	2		2.03		315					
T deet		06		1.5	Light gray very self filly QLAV		7.6	3	3	2		2.03		115					
- 0.0en		D6			Yorkowich tenzes - 6458 gray and CLAY base the		9.0	3	5	-	13	6.70		394					
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12.000		DØ			Recklark brown - halfd grou shafely reckland warg all CLAY brace ISB, organic		12.0	5	7	10	17	11.0		214					
13.844	-	D9		9,0	- Coloris		14	5	•	10	18	12.2		218					
15.00		D10			Planking broken have apply		15.0			12	20	13.5		227					
10.000		011			and the organic control		17	z	10	33	23	19.0		238					
18.024		D12			Tolowent brown . light gray easy sill CLAY.		10.0	2	9	16	25	10.9	1	246					
10.000	-	013			Brownian policials brown vory off CLAY		19.5		11	27	28	18.9		256					
_01.0m		D14			Brownight, method very effectively, organic		21.0	6	٠	35	23	19.0		238					
22.0**		D15			Vellowish beyon very still GLAV		22.5	6	*	13	21	14.2		231					
24.031	-	018		1	Yolkasish kerveri i kglil gray very still GLAY trace DB		24.0	9	7	3.8	20	10.5		227					
16.0m		D17			Vicilization forward , Sight group very still GLAY with Sat		29.0	6	*	3.2	20	13.5		227					
#7.0m		D10					27.0	5	7	33	1.0	12.2		218					
28.0+1		019			Televent brown very stat		28.5	1	10	2.8	28	18.6		238					
30.00		000		1.0	Light grey very slit CLAY		00.0		7	10	17	11.0	/	21.4					

Propert: Probast Path Propert Size Hole No. 1894-P-04 Societion: Probast Path Kernera, Puthal, Cazasury							Chent: HABITAT PLANNING ABSOCIATES LTD Ground Water Level 12.500181											
Sovenillir Depth of	tation Efforts	1 22-	10.0	1.070	8'N 90'28'0.725'E		L	Legend Land Can Invata										
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1.0en	-	D1					1.6	3				6.08		170				
aem	-	02	8.5ee	7.0	Valuetan trown, tabl proy , mothad stiff CLAY with e8, organic content		2.0	4		7	12	0.1		189				
4.5m		D3					4.5	з	4	6	10	6.78		377				
a.om		D4			Light groy sill CLAY with		6.0	a	•	-		5.4		163				
7.8m		D5					7.6	*	•	7	12	8.1		189				
9.0m	F	D6					9.0	4	6	•	34	9.45	1	200				
10.8m	F	07			Light grou bill to voly stiff CLAV Bills with		.,	3	•	•	35	10.1		205				
12.0**	F	DB		9.0			12.0	4	•	2	32	<u>0</u> :1		189				
13.500		09					14	2		•		6.08		170				
18.0=		D10			Volument trong total and		15.0	4	8	•	10	6.75		177				
10.5m		Dii			pathoniah herizer esailare 4881 CLAY Source at tergelete sourcest		17		*		*	5.4		163				
18.0-1		D12		3.5	Yohosish trown slightly repliced self! CLAY with self		18.0	4	5	6	н	7.43		183				
			L		Light grey stiff GLAY with		1		L.,	L.,			N N					

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Project: Project Patti Project							Client: HABITAT PLANNING ASSOCIATES LTD														
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1.0200		DI			Black very soft organic CLAV, many site		1.0	,	0	•		0.68		_				78	1		
3.0m	-	122		8.8	machineli group very east		3.0	,	0	•		0.68		_	_			78	- (	-	_
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		011		3.0	Pedaratal largers, restants around using this gradient using states		17	6	10	10	123	16.5		-	5		-	206		-	
10.00-		018		1.0	Variansials termine, tagin gray sharasa vary first sifty 0.404D, 80h clay		18.0	10	10	2.5	.41	87.7		-	-		5	242	-	-	f
10.6m		013			Freeman - Annual - An		18.5	16	21	23	44	20.7		-	-	-	1	303		+	-
11.038		014		4.5	valuesing, to resident brown		21.0	1.2		22	40	87		-	-		1	291		+	-
er ben		015			Publicated Systems In Split prov		27.5	12	3.0	20	30	24.3		-	-	1		200		+	1
64.000		010	11		Lage gray very still CLAV.		24.0		•	1.0	32	14.0			6			236		+	+
24. fem		0.52			table and		25.5	10	85	10	25	16.9		-	>	-	-	246		+	$^{+}$
#7.6m		018		6.0	or by very will CLAV, Elle		27.0	6	10	1.0	53	10.5		-	1	-		2.18		+	t
28.31		010			brown onth ICLAY with an		28.8	7	11	1.0	23	14.0		-	(	-	-	235		+	t



hare th ocatio Second Depth o	de No s: Pro nation d Barir	na. Pultali. Gazipuur "N 90" 28" 11.028" 8		Grau Date L	- 100	er ee na	er La	Tieres	1.0met						
Dep Ci la	n de	farme to	(Clerks	Town (	Lithologic Description	3	14 Percent	3	1	5	No.	Const.	Graphical Representation	200	
1.54		D1		8.5	Backish groy sell CLAY, organic sortant		2	•	ŀ	2	9	2.09	115	+	
3.800	E	08	0.000	F				,	ŀ			1.35		+	
4.5m		0ð						•	0		1	0.68	78	+	
		D4		7.0	Dark gray very soft CLAV, organic contains			*	÷	x	á	1.05	99	_	
7.8m		06						•	÷	x	÷	1.05		_	
8.20x		De			Grey very solt CLAY; trace util			ä	x	x.	÷	1.38		_	
10.8et		D7			Ught grey soft silty CLAY, Iron parcetons		,		×	2	×	2.03	115	-	
10.000		De					•	s	6	10	16	10.0	209		
13.24		DB							7	12	19	12.8	223		
18.6m		010			Venovian brown very and any QLAY		2	•	z	9	36	10.8	209		
16.54		DII							2	3.0	3.2	17.6	23.4		
18-245		DIR			Velicesish brown very astholity OLAV, clay concretions		0				16	10.8	209		
10.04		013			Yellowish brown very stiff sitty CLAY		7			10	1.8	12.2	210		

floria Ho Location	Project: Probast Path Project (vo Hole He) (BHLEO) obston: Probast Path Kamare, Publit, Castaur o coltation (221-25) 21,466 (H) 90" 28" 13,084 (E)							Clienti HABITAT FLANNING ARSOCIATES LTD Ground Water Lewis 2 Conster Data 22 Logend 24 Ltd 2012											
	1.2	1	1	I.	LINGSON DESCRIPTION	1	N N	1	1	1	-	11	Graphical Representation	a velocity					
1.044		01	5		Open previo mentano. Interne very sub CLAV		1.0			3		0.68							
0.044		Di8	2.500		Blunch groy matture.		8.0	٩		•		*.05		3.47					
4.5m		D3			Inter CLAY with all		8.0			3		10.0		247					
7.8m		120		3.0	Valorateb Issuer, very MIR OLAY with six		7.8		,	-	2.0	10.8		200					
8.511		06			Valuestale Sciences and GLAX		9.0	2	•	•	10	6.75		- 177					
10.8mt		107		+.6	Victorials income, resolution terms, and party moduled using abilition, AV mode will		**	•	*	10	3.8	12.2							
13.84		0.0					12.0		•			7.43		103					
	_	010		0.0	Velowest Scown, restrict brown and CLAV with site		15.0				10	6.75		127					
18.844		011					17	•	•	-	3.4	8.48		200					
		012		2.0	Verbrands Armen, realisted Brown, very all CLAY with all		18.0		2	10	32	11.5		214					
10.000	1.0	013	_	_			19.5	31	. 7		3.5	10,1		295					

Heren Here	Parti Project		Client: HABITAT PLANNING ASSOCIATES LTD											
Location	Seaton: Probat Path Kamara, Putrat, Castputr So-ordination : 23" 55" 25.2084 "N 99" 28" 12.961 "K									-		24.11	2012	
Depth of	Burn		10.5			<u> </u>	1.			_	Ind		Chay Stratte Streetly	
R R	10.9	ji ji	10 here	Î	Lithologie Description	1	6	1	5 3	n ĝ	1 Use	n n	Graphical Representation	Velocity Curve
1.000		61		-	Lagita genes, resolution termany, mentioned some dama well CLAV wells and		1.6	•		•		54	103	
3.0m		132	***	⊢			3.0				10	0.78	177	
*.7m	0	09		3.0	Lapit group verboeten bronen, recalish bronen, invelsor oph CLAV with sale		4.5	•				2.42	283	
6.0=		194		F	Light group, yeikisalah Arman, neikkish taraya, mulikad alih sitiy CS AV		8.0	•		*	8	4.73	3100	
T dans		100			Laph aros: vellostati brown: rediktr/brown: mothed with CLAV with all		7.6	*	•	*	٠	5.4	363	
8.0m		08					9.0	1		6	10	6.78	177	
10.8m		627			CLAY HID DE			×	•	×	10	6.75	177	
18.001		120		12	Light gross peritowers between reservations, woothing perif CLAY with all		12.0			•	3.4	0.45	200	1
1.8.Am		100			Lagid grap modelich brown, and CLAV, take unit		14	4			3.0	0.78	194	
18.000		010			Visikowski krown, reaktale brown, akaf By roothed wary stiff CLAY, blie off		18.0	•	7	10	17	11.8	214	
38.541		011			Light gross very still CLAY.			5	•	10	10	12.8	218	
18.001		012			Vakewat terminency corr		18.0		,	•	15	10.1	205	
		1213		1.0	NRY OLAY		110.0		١.		17	11.0	1	

Properti Probasi Pathi Propert dere Hole No. (884-97.1 Lobitori: Probasi Path Kamain, Puthal, Gaujaur Go-ordination : 221'55' 28.0272'N .90'28'17-281''E Depth of Doing. 110.5 Million									Client: HARTAT PLANNING ASSOCIATES LTD Cround Water Level 1 2 Creater Date (24-11-0012 Legend and the Res Links (14-10-12) Legend and the Res Links (14-10-12)									
tan hote 51, p	1000 j	Sample.	ut Serger	Times I	Lithologis Description	Speed	1/1 Interest	1	a and	Associate	N 100	County N	Graphical Representation	August Vielaute Curve 100 200 A				
		<b>D</b> 1		40	Yadawish brown , light gray elightly mothes					•		5.4		169				
-3.0m	H	09		4.0	with SR		0.0		5	•	14	9.45		200				
4.0-		DB		3.0		light gray stift CLAY		4.5	2	4	6	10	6.75		177			
8.0×		04			Yatowah brown . ligte gray digitiy motiod medium still CLAY		6.0	8	*	6	*	0.05		170				
-7.8m		Do			Hite GH		7.6	э	4	Ŷ.	13	7.43		183				
9.84		De		3.0	Vellowish brown skill SILT with sand		0.0				15	10.1	)	205				
110.8em		07			Links over antimately					6	10	6.75		177				
12.0+1		De			Velowish brown still CLAY with still		12.0	3	×	6		6.08		170				
10.5m		09					14		6	7	18	8.1		189				
16.0m		D10		0.5	Velowish brown still CLAV trace all tran concretion		15.0		.6		13	8.78		194				
19.5m		DII					17		6	6	12	8.1		189				
18.01		DIR			Yelseesh brown stiff CLAY Strie SH		18.0			7	18	8.1		189				
		DID					19.5				13	0.76		194				

Project: Project Parliani Palli Project Bare Hole Pic BM P-11 Localion: Project Palli Permana, Pulsel, Cestiguour							Client: HABITAT PLANNING ASSOCIATES LTD Cliviand Water Level 1 2 Science Date: 25 11 2012										
Go-entir Depth o	intion thorn	1.99*	55' 2	8.027 Moto	5M 00.59.15.591.	•		ede	ne			1	Cost Bit	Services Fromme			
R R	3.8	÷.	100	Total	Unheinger Desertation	£	ĸĮ	2 3	1	a ĝ	1 in	1	Graphical Represent	40 200 200 200			
	-	D1			Yellowish brown , Tark grey slightly method		1.0	ie.	a.			0.4					
11.0+++		138		20	web Site		3.0	4	*	•	14	8.45		200			
-4.5ve	-	103			SQRE GRAY SHE CLAY		4.5	*	•	•	10	6.75					
H den		D4		3.0	Yellowish Brown , Egra gray alightly matteel meduate ash OLAY		6.0	8	*		u	8.09		170			
- P. Arm		05					7.6	•		*	"	7.43					
-0.0ee		De		9.9	Vellowish brown ablf BR,T with same		0.0	ä	0	•	10	10.1		205			
10.8=		D7			Light gray, yellowish		"	a	•	•	10	6.75		177			
12.040		108			BROWN VOLY JEET CLAY		12.0	3				6.08		\$20			
10.00		00			Vellowish brown still OLAY with sit		14	4	9	*	38	8.0		1.85			
18.000	-	010			Volowali Brown all CLAV trace all tree concetter		18.0		•	•	1.3	8.76		330			
10.0-		811					17	ä	ï		12	8.5		180			
-18,040		012			Vellowish krown sill OLAV life oil		18.0	2		2	12			199			
-			L	1					1.		1.3	1000					



Project: Probasi Palli Project Saro Hole No. 38449-14 Problem Probasi Palli Parmana, Pubali, Gazipuor								Client: HABITAT PLANNING ASSOCIATES LTD												
								Contar (24.11-2012												
is-ondi	Portinglian (23'36'36'7872'N 80'38'15.864'E									Lagend Lagend Lagend Lagend										
tepin :	Phone	2	10.5	Mote	1	-	-	<u> </u>	<u> </u>	1	2444	1	Saley .			In I				
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	L		1	E											N					
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10.600	1	011		L			17		155	1.0	3.5	22.3			1/1	229				
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10.07		1011	1	E			10.0	10				10.0		_		233				
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			· ·				1.0.0			1.66		100.7				2.04				



Figure 10. Log sheets of the 15 SPT boreholes completed at Prabasi Palli

#### **APPENDIX III**



Figure 11. Map showing lines A-B, B-C, C-D, D-E, E-F and F-G taken for geological Cross-sections as in figure 5.

#### APPENDIX IV



2014

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Figure 11. Maps showing line A-B and C-D taken for geotechnical cross-sections as in figure 6.