Annexure-3

Geotechnical Report

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GEOTECHNICAL INVESTIGATION REPORT

NAME OF WORK : **REPORT ON THE RECOMMENDATION OF FOUNDATION FOR THE PROPOSED CONSTRUCTION OF 400 MLD CAPACITY REVERSE OSMOSIS DESALINATION PLANT AT PERUR ON ECR, CHENNAI**

CLIENT : **M/s AECOM India Pvt. Ltd., Gurgaon,**
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DLF Cyber City, DLF Phase II,
Gurgaon - 122002, Haryana

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JOB NO : SM&FE / 059 / Consultancy / MERIDIAN / 2014

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229

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REPORT ON THE RECOMMENDATION OF FOUNDATION FOR THE PROPOSED CONSTRUCTION OF 400 MLD CAPACITY REVERSE OSMOSIS DESALINATION PLANT AT PERUR ON ECR, CHENNAI

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Ref: The Team Leader Lr. No. PMS / AU / LR / 053 Dated, 10.10.2014, From M/s Prime Meridian Surveys Pvt. Ltd

1. INTRODUCTION

The CMWSSB, Government of Tamilnadu has proposed to construct a 400 MLD capacity Reverse Osmosis Desalination Plant at Perur on ECR, Chennai. The CMWSSB has appointed M/s AECOM India Pvt. Ltd, Gurgaon, Haryana as consultant for this project. The officials of M/s AECOM India Pvt. Ltd, Gurgaon, Haryana and Engineers of CMWSSB, Chennai have approached the Division of Soil Mechanics and Foundation Engineering, Department of Civil Engineering, Anna University, Chennai - 25 to carryout soil investigation in the proposed site and recommend the most suitable foundation system for the proposed construction of 400 MLD capacity Reverse Osmosis Desalination Plant. Accordingly, the work

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was taken up and Field Investigation was carried out by M/s VRR Engineering Consultancy, Chennai - 103 under the supervision of Professor, Division of Soil Mechanics and Foundation Engineering, Department of Civil Engineering, Anna University, Chennai - 25. The soil investigation work was carried out during 28th of October 2014 to 5th of November 2014. This report comprises the details of soil investigation, analysis of field and laboratory test results and recommendation of most suitable foundation system.

2. SITE CONDITION AND EXPERIMENTAL PROGRAM

The proposed site is located at Perur, ECR, Chennai. The site is having ECR road to its western side and 200 m from bay of bengal sea shore to its eastern side. The site is covered with lot of trees. The water table was located within 1.5 m to 2.0 m as can be seen from many small ditches found in the site, because of nearness of seashore. The total number of borehole locations has been decided as 5 numbers as agreed by the client and the Professor & Project Co-ordinator, Division of Soil Mechanics and Foundation Engineering, Department of Civil Engineering, Anna University, Chennai - 25. The location of bore hole is shown in figure 1. The nature of field tests includes standard penetration tests, disturbed soil sampling through split spoon sampler, identification of different soil layers, location of ground water table, complete logging of the borehole etc, Laboratory investigation consists of classification tests such as grain size distribution, Atterberg limits, specific gravity and free swell index of soil samples and point load strength index and geological classification of rock core samples.

After removing the top 0.25 m soil, the boreholes were advanced from the existing ground level using rotary boring technique supplemented by Bentonite mud circulation. Mud circulation was used to stabilize the sides and bottom of the boreholes and then to bring the soil

3. REVIEW OF FIELD AND LABORATORY TEST RESULTS OF SOIL PROFILE

3.1 Borehole Number 1 (BH 1)

Brown sand layer was encountered at top 7.5 m depths with 'N' values of 11, 18, 28, 24, 27, 36 and 14 respectively for 1 m, 2 m, 3 m, 4 m, 5 m, 6 m and 7.5 m depths. The sand and fine content (silt and clay) of this sand layer is 91% - 98% and 2% - 9% respectively (Table 1). In 9 m and 10.5 m depths, brown sand layer was observed with 'N' values of 28 and 21 respectively. The sand and fine content (silt and clay) of this sand layer is 81% and 19% respectively. Grayish silty sand layer was found at 12 m depth with 'N' = 23 whose sand and fine (silt & clay) content values are 75% and 25% respectively. Grayish clayey sand (CI) of 'N' value 24 was found in 13.5 m depth. The sand and fine content (silt and clay) of this clayey sand layer is 43% and 57% respectively. This clayey sand (CI type) is having liquid limit of 42%, plastic limit of 22% and free swell index of 60% (Table 1). In 15 m depth, grayish silty clay (CH) layer was observed with 'N' value of 38 whose sand and fine content (silt and clay) value is 48% and 52%. This silty clay (CH type) is having liquid limit of 51% and plastic limit of 24%. Grayish clayey sand (SC-CH) of 'N' value > 100 (Hammer was Rebound for 55 blows with 13 cm penetration) was found in 16.5 m depth with sand and fine content (silt and clay) of 73% and 27% respectively. This clayey sand (SC - CI type) is having liquid limit of 41%, plastic limit of 22% and free swell index of 140%(Table 1). The high swelling nature and plasticity characteristics of this clayey sand is may be attributed to the presence of degraded Feldspar rock minerals of the underlying weathered rock layer. Grayish weathered rock was encountered in the depth range of 18 m to 20 m with SPT 'N' > 100 (Hammer was Rebound for 54 blows with 2 cm penetration at 18 m depth and 54 blows with 1 cm penetration at 19.5 m

depth). The NX size double tube core barrel was used to drill and retrieve the rocky stratum from 20 m to 21.5 m depth. The observed rock layer is Pinkish Granite with more Feldspar mineral (Plate 5 and 9 of Annexure - 1). The weathering grade of this rock is II (slightly weathered and moderately strong) as per the ISI scale of weathering grade of rock mass. The Point Load Strength Index this pinkish granite is 1.18 MPa. The borehole was terminated at 21.5 m depth from the existing ground level. The index and shear strength properties of soils and rock samples collected at BH 1 in different depths are listed in table 1. The ground water table is located at a depth of 1.60 m from the existing ground level. Figure (a) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 1 location.

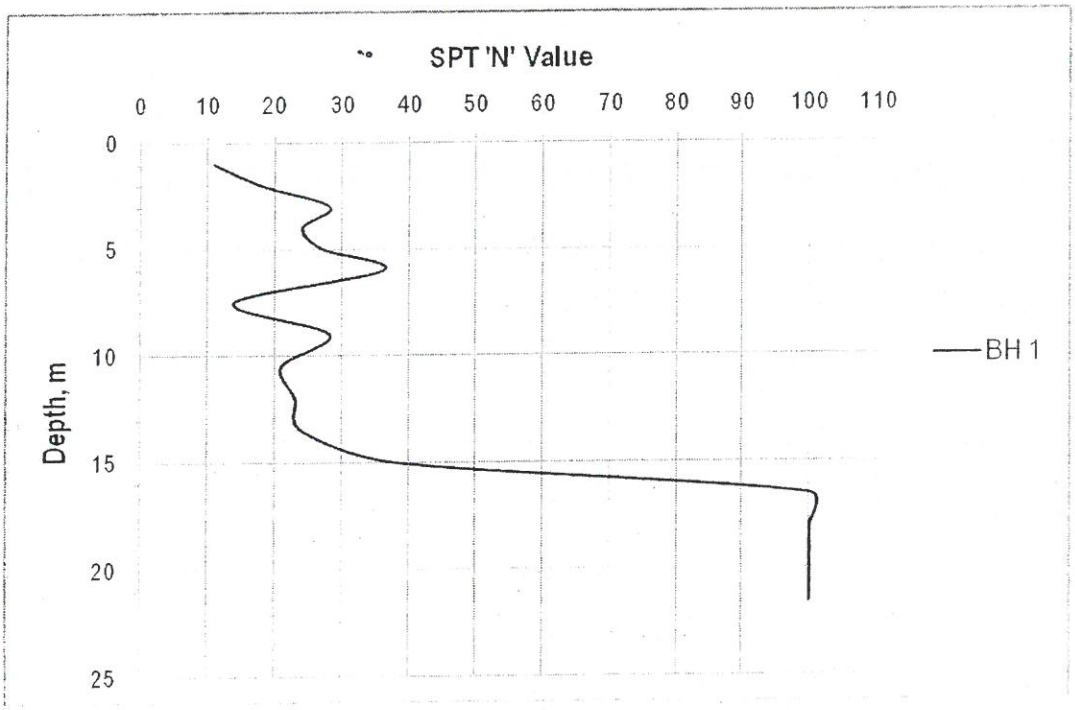

Figure (a) Variation of SPT 'N' value of different soil layers with respect to depth in BH 1

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3.2 Borehole Number 2 (BH 2)

In the top 9 m depth, brown sand layer was observed with 'N' values of 12, 18, 12, 33 , 36, 40, 33 and 24 respectively for 1 m, 2 m, 3 m, 4 m, 5 m, 6 m, 7.5 m and 9 m depths. The sand and fine content (silt and clay) of this sand layer is 96% - 99% and 1% - 4% respectively. Grayish brown clayey sand (SC) of 'N' value 27 and 21 was found in 10.5 m and 12 m depths with sand and fine content (silt and clay) of 58%-65% and 35%-42% respectively. This clayey sand (SC type) is having liquid limit of 37%, plastic limit of 17% and free swell index of 40%(Table 2). Grayish silty clay (CI) of 'N' value 22 was encountered in 13.5 m depth. The sand and fine content (silt and clay) of this silty clay layer is 23% and 77% respectively. This silty sand (CI type) is having liquid limit of 44%, plastic limit of 25% and free swell index of 55%. In 15 m depth, grayish silty clay (CH) layer was observed with 'N' value of 36 whose sand and fine content (silt and clay) value is 23% and 77%. This silty clay (CH type) is having liquid limit of 57%, plastic limit of 24% and free swell index of 120% (Table 2). Grayish brown clayey sand (SC-CI) of 'N' = 38 was observed in 16.5 m depth with sand and fine content (silt and clay) of 54% and 46% respectively. This clayey sand (SC - CI type) is having liquid limit of 41%, plastic limit of 22% and free swell index of 100%(Table 2). The high swelling nature and plasticity characteristics of this clayey sand is may be due the presence of degraded rock minerals of the underlying weathered rock layer. Grayish weathered rock was encountered at 17.9 m with SPT 'N' > 100 (Hammer was Rebound for 54 blows with 2 cm penetration). The borehole was terminated at 17.9 m depth from the existing ground level. The index and shear strength properties of soils and rock samples collected at BH 2 in different depths are listed in table 2. The ground water table is located at a depth of 1.70 m from the existing ground level. Figure (b)

shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 2 location.

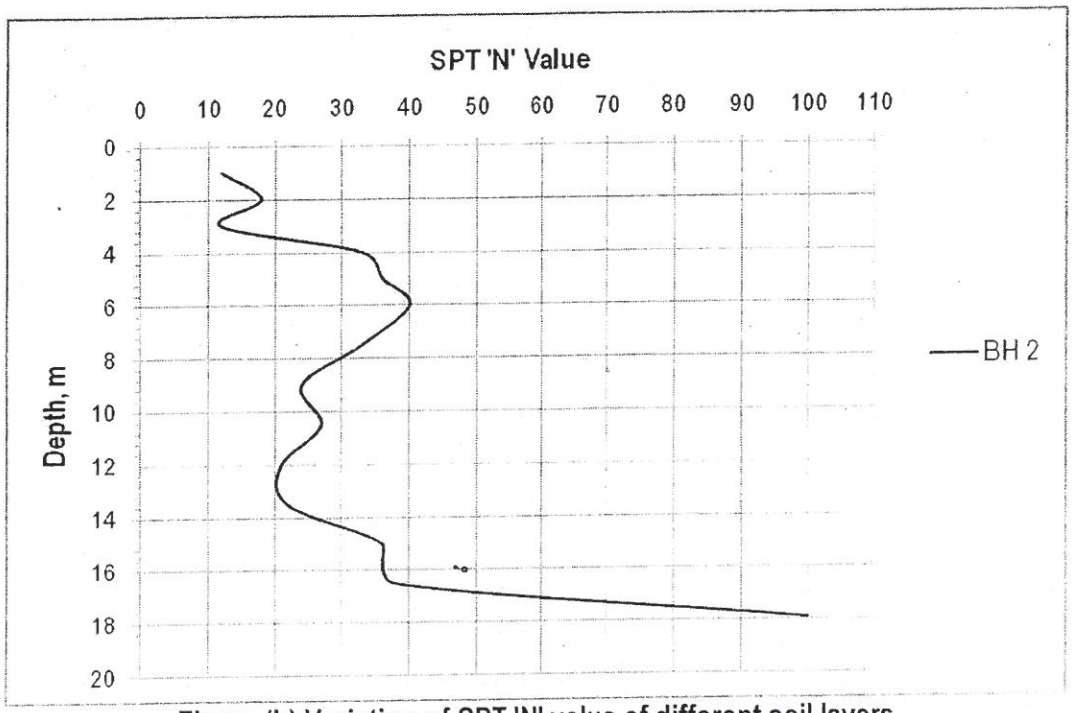

Figure (b) Variation of SPT 'N' value of different soil layers with respect to depth in BH 2

3.3 Borehole Number 3 (BH 3)

Brown sand layer was observed in top 6 m depths with 'N' values of 11, 12, 15, 18, 18 and 34 respectively for 1 m, 2 m, 3 m, 4 m, 5 m and 6 m depths. The sand and fine content (silt and clay) of this sand layer is 93% - 96% and 4% - 7% respectively (Table 3). In 7.5 m depth, grayish brown sand layer was observed with 'N' = 15. The sand and fine content (silt and clay) of this sand layer is 82% and 18% respectively. Grayish brown clayey sand (SC) of 'N' = 22 was found in 9 m depth with sand and fine content (silt and clay) of 67% and 33% respectively. This clayey sand (SC) is having liquid limit of 34%, plastic limit of 17% and free swell index of 40%(Table 3). At 10.5 m depth, grayish silty clay (CI) of 'N' value 23 was found with sand and

fine content (silt and clay) of 43% and 57% respectively. This silty clay (CI type) is having liquid limit of 39%, plastic limit of 19% and free swell index of 45% (Table 3). In 12 m depth, grayish silty clay (CH) layer was observed with 'N' value of 22 whose sand and fine content (silt and clay) value is 26% and 74%. This silty clay (CH type) is having liquid limit of 47%, plastic limit of 23% and free swell index of 50%. Grayish clayey sand (SC-CI) of 'N' value 27 and 42 was found in 13.5 m and 15 m depths respectively with sand and fine content (silt and clay) of 62% and 38% respectively. This clayey sand (SC - CI type) is having liquid limit of 42%, plastic limit of 22% and free swell index of 50% (Table 3). The high swelling nature and plasticity characteristics of this clayey sand is may be attributed to the presence of degraded Feldspar rock minerals of the underlying weathered rock layer. Grayish weathered rock was encountered in the depth range of 16.5 m to 17 m with SPT 'N' > 100 (Hammer was Rebound for 57 blows with 8 cm penetration at 16.5 m depth and 55 blows with 3 cm penetration at 17 m depth). The NX size double tube core barrel was used to drill and retrieve the rocky stratum from 17 m to 18.5 m depth. The observed rock layer is Fresh Granite with more Hypersthene mineral (Plate 6 and 10 of Annexure - 1). The weathering grade of this rock is I (Fresh, no visible sign of weathering and very strong) as per the ISI scale of weathering grade of rock mass. The Point Load Strength Index this grayish granite is 2.20 MPa. The borehole was terminated at 18.5 m depth from the existing ground level. The index and shear strength properties of soils and rock samples collected at BH 3 in different depths are listed in table 3. The ground water table is located at a depth of 1.54 m from the existing ground level. Figure (c) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 3 location.

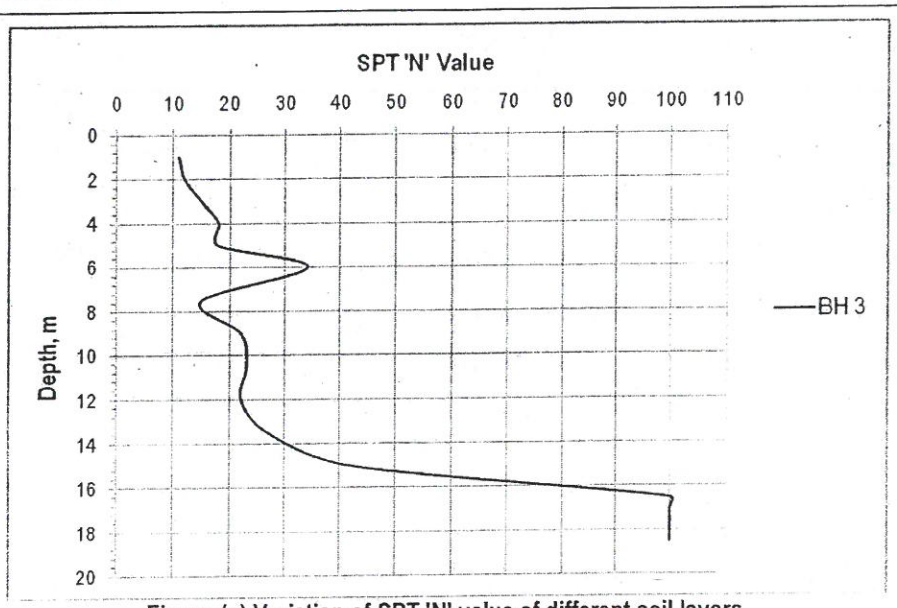

Figure (c) Variation of SPT 'N' value of different soil layers with respect to depth in BH 3

At 5 m, 6 m and 7.5 m depths, grayish brown sand layer was observed with 'N' values of 33, 36 and 18 respectively. The sand and fine content (silt and clay) of this sand layer is 83% - 89% and 11 - 17% respectively. Grayish brown clayey sand (SC) of 'N' = 24 was found in 9 m and 10.5 m depths with sand and fine content (silt and clay) of 70% and 30% respectively. This clayey sand (SC) is having liquid limit of 30%, plastic limit of 16% and free swell index of 30%(Table 4). In 12 m, 13.5 m and 15 m depths, grayish brown clayey sand (SC) of 'N' values 28, 58 and 67 was observed with sand and fine content (silt and clay) of 64% - 70% and 30% - 36% respectively. This clayey sand (SC type) is having liquid limit of 33%, plastic limit of 17% and free swell index of 40% (Table 4). Grayish weathered rock was encountered in the depth range of 16.5 m to 17 m with SPT 'N' > 100 (Hammer was Rebound for 55 blows with 5 cm penetration at 16.5 m depth and 53 blows with 2 cm penetration at 17 m depth). The NX size double tube core barrel was used to drill and retrieve the rocky stratum from 17 m to 18.5 m

depth. The observed rock layer is Fresh Granite with more Hypersthene mineral (Plate 7 and 11 of Annexure - 1). The weathering grade of this rock is I to II (slightly weathering and moderately strong) as per the ISI scale of weathering grade of rock mass. The Point Load Strength Index this grayish granite is 1.10 MPa. The borehole was terminated at 18.5 m depth from the existing ground level. The index and shear strength properties of soils and rock samples collected at BH 4 in different depths are listed in table 4. The ground water table is located at a depth of 1.65 m from the existing ground level. Figure (d) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 4 location.

3.5 Borehole Number 5 (BH 5)

Brown sand layer was found in top 7.5 m depths with 'N' values of 14, 18, 35, 33, 36, 35 and 20 respectively for 1 m, 2 m, 3 m, 4 m, 5 m, 6 m and 7.5 m depths. The sand and fine content (silt and clay) of this sand layer is 86% - 96% and 4% - 14% respectively (Table 5). In 9 m and 10.5 m depths, brown clayey sand (SC) layer was observed with 'N' values of 27 and 22 respectively. The sand and fine content (silt and clay) of this clayey sand layer is 67% and 33% respectively. This clayey sand (SC) is having liquid limit of 30%, plastic limit of 16% and free swell index of 30% (Table 5). Grayish brown silty sand of 'N' = 54 and 72 was found in 12 m and 13.5 m depths with sand and fine content (silt and clay) of 85% and 15% respectively. In 15 m depth, grayish brown clayey sand (SC) of 'N' = 63 was observed with sand and fine content (silt and clay) of 60% and 40% respectively. This clayey sand (SC type) is having liquid limit of 34%, plastic limit of 17% and free swell index of 40% (Table 5). Grayish weathered rock was encountered in the depth range of 16.5 m to 19.6 m with SPT 'N' > 100 (Hammer was Rebound for 54 blows with 1 cm penetration at 16.5 m depth, 58 blows with 1 cm penetration at 18 m depth and 54 blows with 0 cm penetration at 19.6 m depth).

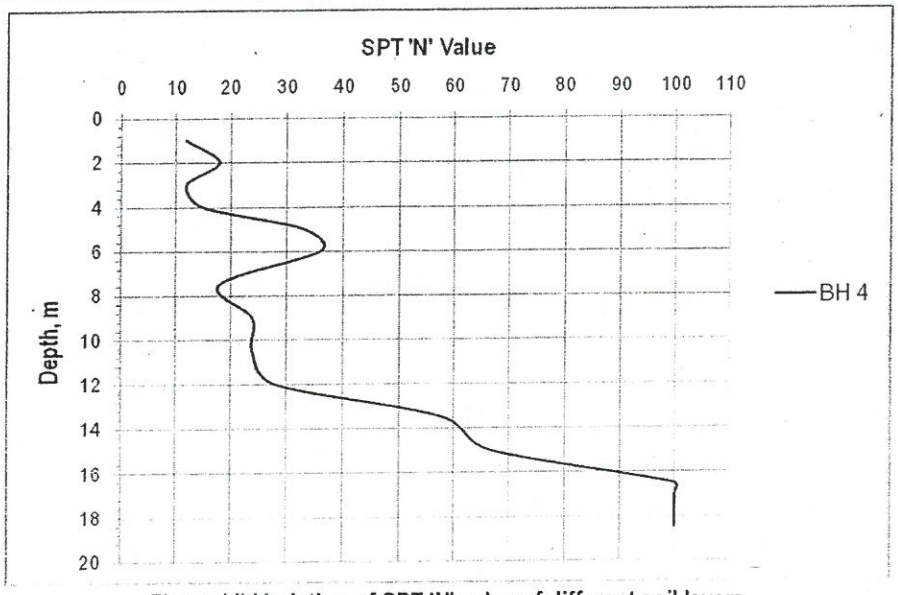

Figure (d) Variation of SPT 'N' value of different soil layers with respect to depth in BH 4

The NX size double tube core barrel was used to drill and retrieve the rocky stratum from 19.6 m to 21.1 m depth. The observed rock layer is Fresh Granite with more Hypersthene mineral (Plate 8 and 12 of Annexure - 1). The weathering grade of this rock is I (Fresh, no visible sign of weathering and very strong) as per the ISI scale of weathering grade of rock mass. The Point Load Strength Index this grayish granite is 1.78 MPa. The borehole was terminated at 18.5 m depth from the existing ground level. The index and shear strength properties of soils and rock samples collected at BH 5 in different depths are listed in table 5. The ground water table is located at a depth of 1.72 m from the existing ground level. Figure (e) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 5 location.

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Figure (f) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 1 to BH 5 of the proposed site. It is learnt that ground water level might raise to as high as 0.5 m to 1.5 m to 2 m normal water table fluctuation, especially during winter season.

4.0 COMPUTATION OF BEARING CAPACITY AND SETTLEMENT

In order to determine the bearing capacity and settlement of the *'shallow open foundation system'* at various depths of 2.0 m and 3.0 m depths, the location of ground water table is assumed at ground surface (submerged condition). Table I to Table V show the SPT'N' value, Correlated CPT 'q_c' value (IS 2911, Part 1, Sec.1), Correlated Elastic Modulus 'E_s' value (Schmertmann 1970) and Shear strength parameters of the borehole 1 to 5 of the proposed site. The geotechnical design parameters of engineering properties of soil layers which are required to determine bearing capacity and settlement are taken from Table I to Table V by considering the worst soil condition and least shear strength parameters below the foundation depth. The least 'N' values of soil layers were observed in BH - 3. Hence, safe bearing capacity and settlement computations were made for BH-3 data. The Safe Bearing Capacity is computed using Bureau of Indian Standard IS 6403-1981 equation. The Settlement of foundation is arrived based De Beer Method (IS 8009 (Part I) 1976 Sec. 9.1.2) using the correlated CPT 'q_c' value (IS 2911, Part 1, Sec.1), of the borehole number 3 of the proposed site.

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Figure (f) shows the variation of SPT 'N' value of different soil layers with respect to depth in BH 1 to BH 5 of the proposed site. It is learnt that ground water level might raise to as high as 0.5 m to 1.5 m to 2 m normal water table fluctuation, especially during winter season.

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TABLE I SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 1 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m^2)	Elastic Modulus 'E_s' Value (kN/m^2)	Shear Strength Parameters	
				'c' (kN/m^2)	Φ in Degrees
1.0	11	4400	8426	0	29^0
2.0	18	7200	13788	0	33^0
3.0	28	11200	21448	0	37^0
4.0	24	9600	18384	0	35^0
5.0	27	10800	20682	0	37^0
6.0	36	14400	27576	0	40^0
7.5	14	5600	10724	0	30^0
9.0	28	11200	21448	0	37^0
10.5	21	8400	16086	0	34^0
12.0	23	6900	17618	0	35^0
13.5	24	4800	18384	150	0^0
15.0	38	7600	29108	237	0^0
16.5	> 100	40000	76600	0	45^0
18.0	> 100	100000	76600	0	45^0
19.5	> 100	100000	76600	0	45^0
20 - 21.5	> 100	Point Load Strength Index = 1.18 MPa			

TABLE II SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 2 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m^2)	Elastic Modulus 'E_s' Value (kN/m^2)	Shear Strength Parameters	
				'c' (kN/m^2)	Φ in Degrees
1.0	12	4800	9192	0	29^0
2.0	18	7200	13788	0	33^0
3.0	12	4800	9192	0	29^0
4.0	33	13200	25278	0	39^0
5.0	36	14400	27576	0	40^0
6.0	40	16000	30640	0	42^0
7.5	33	13200	25278	0	39^0
9.0	24	9600	18384	0	35^0

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TABLE I SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 1 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m²)	Elastic Modulus 'E_s' Value (kN/m²)	Shear Strength Parameters	
				'c' (kN/m²)	Φ in Degrees
1.0	11	4400	8426	0	29⁰
2.0	18	7200	13788	0	33⁰
3.0	28	11200	21448	0	37⁰
4.0	24	9600	18384	0	35⁰
5.0	27	10800	20682	0	37⁰
6.0	36	14400	27576	0	40⁰
7.5	14	5600	10724	0	30⁰
9.0	28	11200	21448	0	37⁰
10.5	21	8400	16086	0	34⁰
12.0	23	6900	17618	0	35⁰
13.5	24	4800	18384	150	0⁰
15.0	38	7600	29108	237	0⁰
16.5	> 100	40000	76600	0	45⁰
18.0	> 100	100000	76600	0	45⁰
19.5	> 100	100000	76600	0	45⁰
20 - 21.5	> 100	Point Load Strength Index = 1.18 MPa			

TABLE II SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 2 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m²)	Elastic Modulus 'E_s' Value (kN/m²)	Shear Strength Parameters	
				'c' (kN/m²)	Φ in Degrees
1.0	12	4800	9192	0	29⁰
2.0	18	7200	13788	0	33⁰
3.0	12	4800	9192	0	29⁰
4.0	33	13200	25278	0	39⁰
5.0	36	14400	27576	0	40⁰
6.0	40	16000	30640	0	42⁰
7.5	33	13200	25278	0	39⁰
9.0	24	9600	18384	0	35⁰

(14/23)

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10.5	27	8100	20682	0	37^0
12.0	21	6300	16086	0	34^0
13.5	22	4400	16852	137	0^0
15.0	36	7200	27576	225	0^0
16.5	38	15200	29108	0	41^0
17.9	> 100	100000	76600	0	45^0

TABLE III SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 3 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m²)	Elastic Modulus 'E_s' Value (kN/m²)	Shear Strength Parameters	
				'c' (kN/m²)	Φ in Degrees
1.0	11	4400	8426	0	29^0
2.0	12	4800	9192	0	29^0
3.0	15	6000	11490	0	31^0
4.0	18	7200	13788	0	33^0
5.0	18	7200	13788	0	33^0
6.0	34	13600	26044	0	39^0
7.5	15	6000	11490	0	31^0
9.0	22	6600	16852	0	35^0
10.5	23	4600	17618	143	0^0
12.0	22	4400	16852	137	0^0
13.5	27	8100	20682	0	37^0
15.0	42	12600	32172	0	42^0
16.5	> 100	100000	76600	0	45^0
17.0	> 100	100000	76600	0	45^0
17 - 18.5	> 100	Point Load Strength Index = 2.20 MPa			

TABLE IV SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 4 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m²)	Elastic Modulus 'E_s' Value (kN/m²)	Shear Strength Parameters	
				'c' (kN/m²)	Φ in Degrees
1.0	12	4800	9192	0	29^0
2.0	18	7200	13788	0	33^0
3.0	12	4800	9192	0	29^0

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10.5	27	8100	20682	0	37^0
12.0	21	6300	16086	0	34^0
13.5	22	4400	16852	137	0^0
15.0	36	7200	27576	225	0^0
16.5	38	15200	29108	0	41^0
17.9	> 100	100000	76600	0	45^0

TABLE III SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 3 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m²)	Elastic Modulus 'E_s' Value (kN/m²)	Shear Strength Parameters	
				'c' (kN/m²)	Φ in Degrees
1.0	11	4400	8426	0	29^0
2.0	12	4800	9192	0	29^0
3.0	15	6000	11490	0	31^0
4.0	18	7200	13788	0	33^0
5.0	18	7200	13788	0	33^0
6.0	34	13600	26044	0	39^0
7.5	15	6000	11490	0	31^0
9.0	22	6600	16852	0	35^0
10.5	23	4600	17618	143	0^0
12.0	22	4400	16852	137	0^0
13.5	27	8100	20682	0	37^0
15.0	42	12600	32172	0	42^0
16.5	> 100	100000	76600	0	45^0
17.0	> 100	100000	76600	0	45^0
17 - 18.5	> 100	Point Load Strength Index = 2.20 MPa			

TABLE IV SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 4 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m²)	Elastic Modulus 'E_s' Value (kN/m²)	Shear Strength Parameters	
				'c' (kN/m²)	Φ in Degrees
1.0	12	4800	9192	0	29^0
2.0	18	7200	13788	0	33^0
3.0	12	4800	9192	0	29^0

(15/23)

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4.0	15	6000	11490	0	31^0
5.0	33	13200	25278	0	39^0
6.0	36	14400	27576	0	40^0
7.5	18	7200	13788	0	33^0
9.0	24	7200	18384	0	35^0
10.5	24	7200	18384	0	35^0
12.0	28	8400	21448	0	37^0
13.5	58	17400	44428	0	45^0
15.0	67	20100	51322	0	45^0
16.5	> 100	100000	76600	0	45^0
17.0	> 100	100000	76600	0	45^0
17 - 18.5	> 100	Point Load Strength Index = 1.10 MPa			

TABLE V SPT "N' values, Correlated CPT q_c Values, Shear Strength Parameters, Elastic Modulus (E_s) for BH 5 Location

Depth (m)	SPT 'N' Value	CPT 'q_c' Value (kN/m²)	Elastic Modulus 'E_s' Value (kN/m²)	Shear Strength Parameters	
				'c' (kN/m²)	Φ in Degrees
1.0	14	5600	10724	0	30^0
2.0	18	7200	13788	0	33^0
3.0	35	14000	26810	0	40^0
4.0	33	13200	25278	0	39^0
5.0	36	14400	27576	0	40^0
6.0	35	14000	26810	0	40^0
7.5	20	8000	15320	0	34^0
9.0	27	8100	20682	0	37^0
10.5	22	6600	16852	0	35^0
12.0	54	16200	41364	0	45^0
13.5	72	28800	55152	0	45^0
15.0	63	18900	48258	0	45^0
16.5	> 100	100000	76600	0	45^0
18.0	> 100	100000	76600	0	45^0
19.6	> 100	100000	76600	0	45^0
19.6 - 21.1	> 100	Point Load Strength Index = 1.78 MPa			

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4.1 Allowable Bearing Capacity

The average design 'N' value and shear strength parameters below foundation level up to the influence depth of 1B is used to determine the Safe Bearing Capacity. The Safe Bearing Capacity is computed using Bureau of Indian Standard IS 6403-1981 equation. The width of foundation is assumed as 2.5 m to determine the Safe Bearing Capacity for varying depth of foundation. The computed Safe Bearing Capacity for the proposed site is shown in Table VI.

TABLE VI Safe Bearing Capacity of the proposed Site at Perur, ECR, Chennai for 2.5 m width of Foundation

Depth of Foundation (m)	Design Shear Strength Parameters		Safe Bearing Capacity (kN/m²) IS 6403-1981 Equation
	'c' (kN/m²)	Φ in Degrees	
2.0	0	30^0	158
2.5	0	31^0	209
3.0	0	32^0	274

4.2 Settlement of Soil Layer

One of the important aspects of any foundation systems is to satisfy the settlement criteria apart from bearing capacity criteria. The total settlement of foundation is becoming very critical, especially if the foundation is located on clays, because the clay layer is expected to undergo excessive consolidation settlement over a period of time under sustained loadings which of course depends on the state of clay (initial water content / void ratio), whereas in the

case of loose sand layer, elastic or immediate settlement plays a crucial role. The Table VII shows the settlement of foundation computed based on De Beer Method (S 8009 (Part I) 1976 Sec. 9.1.2) with respect to safe bearing capacity of the 2.5 m x 2.5 m foundation at various depths. The settlement is computed up to the influence depth of "2B" below the foundation. ***The allowable settlement as per IS 1904 Table I 1986 is 50 mm.***

TABLE VII Settlement Values computed with Respect to the Safe Bearing Capacity of 2.5 m x 2.5 m Size Foundation

Size of Foundation	Depth of Foundation	Safe Bearing Capacity (kN/m^2)	Settlement as per De Beer Method - IS 8009 (Part I) 1976 Sec. 9.1.2 (mm)
2.5 m x 2.5 m	2.0 m	158	17.99
	2.5 m	209	20.99
	3.0 m	274	26.62

5.0 DETERMINATION OF SAFE PILE CARRYING CAPACITY

As the exact total structural load of the super structure has not been made available to this office of Division of Soil Mechanics and Foundation Engineering, CEG, Anna University, Chennai - 25, attempts are also made to suggest pile foundation for varying pile diameter apart from recommendation of shallow foundation. For computing the load carrying capacity of pile, Indian Standard IS 2911 (Part 1/Sec. 2) 2010 method and Meyerhof 1959 formula (Based on SPT 'N' Value) are used. The diameters of piles are assumed as 400 mm, 500 mm, 600 mm and 750 mm and the length of the pile is taken as 17 m to 20 m. The least shear strength parameters and least 'N' values were taken as the criteria from Table I to Table V out of the five

borehole locations for the design of pile foundation for the proposed site. Accordingly, the least shear strength parameters and least 'N' values of soil layers were observed in BH - 3. Hence, safe pile carrying capacity computations were made for BH-3 borehole data. The Indian Standard IS 2911 (2010) specifies that the base resistance should not exceed 1000 to 1100 t/m^2 for bored cast-in-situ piles and 1500 t/m^2 for precast driven piles. The end bearing capacity is also computed based on Cole and Stroud (1977) approach by providing 0.5 D in Granite Rock Strata as pile socketing (D is pile diameter in mm). The shear strength of rocky stratum (point bearing shear strength) is the point load strength index of the rock samples which is used to determine the ultimate end bearing resistance of the pile.

For calculating the skin friction along the pile length of 17 m to 20 m, the design 'N' values and shear strength parameters for respective depths were used. As seen from section 3.5, the water table may fluctuate significantly varying from 0.5 m to 2 m because of nearness of seashore. This instant fluctuations may induce settlement of surrounding soil which in turn may cause negative skin friction. Hence, the safe frictional capacity were computed beyond 2 m depth. The safe end bearing capacity and safe skin frictional capacity are together added for different pile diameter and the total safe load carrying capacity of pile thus computed is shown in Table VIII. The factor of safety of 3 has been used for determining safe end bearing and also frictional capacity of bored cast-in-situ piles.

The uplift capacity of a pile is given by sum of the frictional resistance and the weight of the pile (buoyant or total as relevant) as per Section 6.3.2 of IS 2911 (Part 1/Sec. 2) 2010. The recommended factor of safety is 3.0 in the absence of any pull out test results and 2.0 with pullout test results. Uplift capacity can be obtained from static formula by ignoring end-bearing

but adding weight of the pile (buoyant or total as relevant). The safe uplift capacity of pile varying diameter is given in Table IX.

TABLE VIII Safe Load Carrying Capacity of Pile for varying Diameter for the Length of 17 m to 20 m

Pile Diameter	Safe Pile Capacity (Tons) Meyerhof 1959	Safe Pile Capacity (Tons) (IS 2911 Part-I 2010 Static Formula)	Safe Pile Capacity (Tons) Cole and Stroud (1977) Formula) - 0.5 D Socketed into Granite Rock Strata
400 mm	79	87	90
500 mm	95	104	107
600 mm	129	140	145
750 mm	191	204	213

TABLE IX Safe Uplift Capacity of Pile for varying Diameter for the Length of 17 m to 20 m(IS 2911 (Part 1/Sec. 2) 2010

Pile Diameter	Safe Uplift Capacity (Tons) IS 2911 (Part 1/Sec. 2) 2010
400 mm	41
500 mm	47
600 mm	58
750 mm	76

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6. CONCLUSIONS

Upon Consideration and closer examination of the discussions of section 4 and 5, the following conclusions are made for the proposed construction of 400 MLD capacity Reverse Osmosis Desalination Plant at Perur on ECR, Chennai.

- ✓ The recommended safe bearing capacity of the proposed site for '*shallow foundation*' is shown in Table X for varying depth. The minimum width of foundation shall be 2.5 m.

Table X Recommended Safe Bearing Capacity of the proposed site at Perur, ECR, Chennai

Size of Foundation	Depth of Foundation	Safe Bearing Capacity (kN/m^2)	Settlement as per De Beer Method - IS 8009 (Part I) 1976 Sec. 9.1.2 (mm)
2.5 m x 2.5 m	2.0 m	158	17.99
	2.5 m	209	20.99
	3.0 m	274	26.62

- ✓ As an alternative to the shallow foundation, the recommended safe vertical pile carrying capacity and uplift capacity of the 17 m to 20 m length of 'bored cast in-situ pile' for varying diameter is shown in Table XI.

- ✓ The bored cast in-situ pile shall be terminated at about 17 m to 20 m depth on the rocky stratum.

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Table XI Recommended Safe Load Carrying Capacity and Uplift Capacity of Pile for varying Diameter for the Length of 17 m at Perur, ECR, Chennai

Pile Diameter	Pile Capacity (Tons)	Uplift Capacity (Tons)
400 mm	86	41
500 mm	102	47
600 mm	138	58
750 mm	203	76

- ✓ Pile load test has to be conducted to ensure the designed pile carrying capacity. The minimum grade of concrete for pile foundation is M25.

- ✓ Because of the proximity of seashore to the proposed site, there is every possibility for sea water intrusion during open excavation, if shallow foundation is proposed. Enough care may be taken to design a suitable dewatering system while construction of foundation is in progress.

14/11/14

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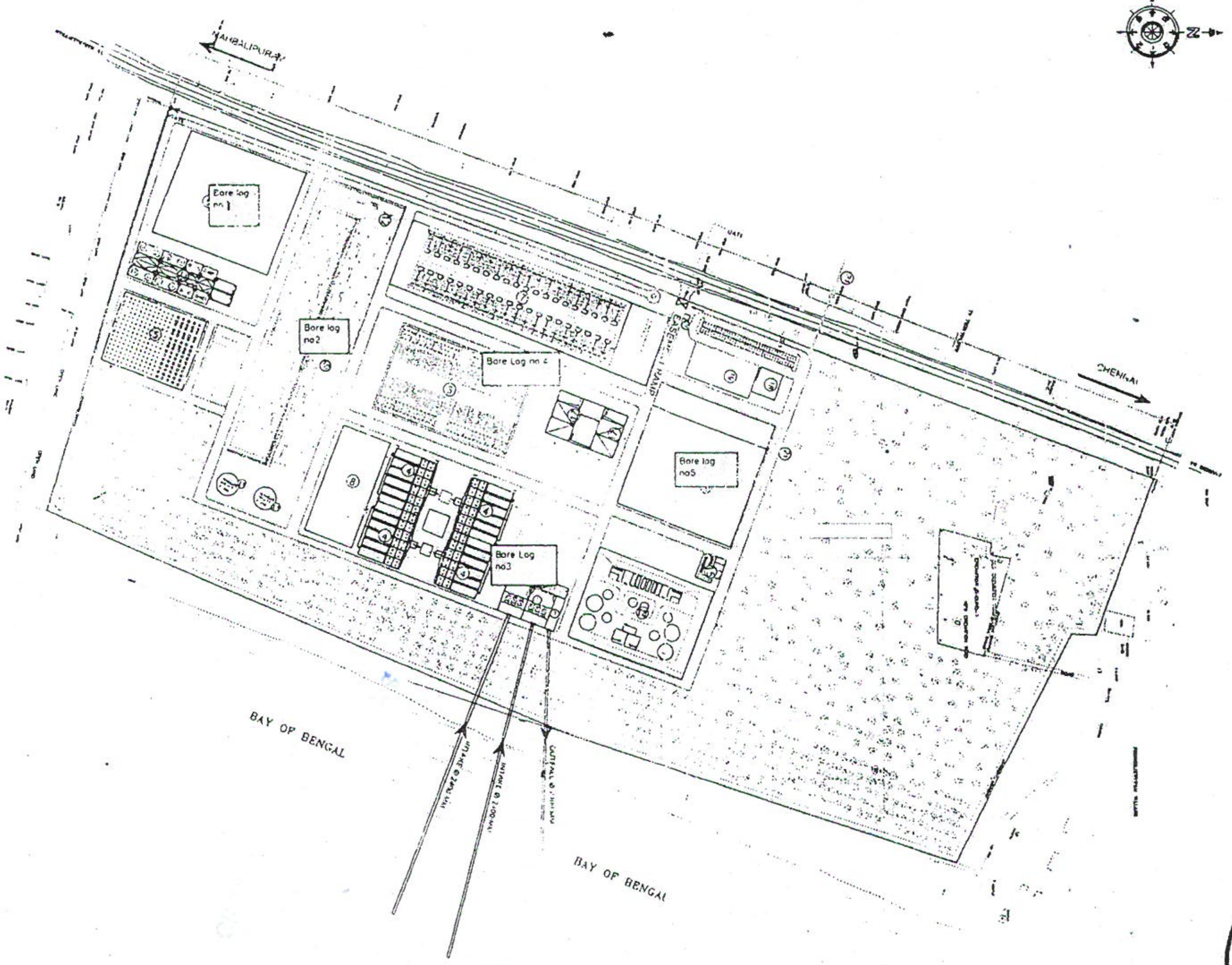

Figure 1 Location of Boreholes

LIST OF UNITS

1. INLET ONSHORE SCREENS
2. INTAKE PUMP STATION
3. OUTFALL CHAMBER
4. LAMELLA CLARIFIER
5. PRE TREATMENT STORAGE
6. DISSOLVED AIR FLOATATION
7. DUAL MEDIA GRAVITY FILTER
8. RO FEED TANK
9. ELECTRICAL SUBSTATION
10. RO BUILDING
11. RO PERMEATE TANK
12. CIP
13. CHEMICAL STORAGE FOR RO
14. POTABILIZATION
15. POST-CHLORINATION BUILDING
16. PRODUCT WATER TANK
17. FILTER BW HOLDING TANK
18. ADMINISTRATION BUILDING
19. MAINTENANCE WORKSHOP
20. GUARD HOUSE
21. PRODUCT WATER MAIN

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CONSULTANT	CLIENT	PROJECT TITLE -	CONSULTANCY TO CONDUCT PREFEASIBILITY STUDIES INCLUDING FINANCIAL VIABILITY PREPARATION OF DETAILED PROJECT REPORT BID SETTING UP OF [illegible] CAPACITY SEA WATER REVERSE OSMOSIS DESALINATION PLANTS FOR CHENNAI CITY ALONG ECR ROAD, CHENNAI, TAMILNADU, INDIA
AECOM WATEK AECOM INDIA Private Limited in Association with GHD Pty Limited and WATEK Engineering	Chennai Metro Water Supply and Sewerage Board	DRAWING TITLE -	LAYOUT
		SCALE - AS SHOWN	DWG. NO. 12138/CI/VSSB/SWRO/001 · SIZE A3

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FIELD BORE LOG PROFILE

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR			
BH NO	1	DATE OF START	03.11.2014
SITE	Perur	DATE OF COMPLETION	04.11.2014
DIA OF BORING	150 mm	GROUND WATER LEVEL	1.60 m
TYPE OF BORING	Rotary (Calyx)	RL	-

Depth below EGL (m)	Soil / Rock Profile	Description / Classification of Soil / Rock	Standard Penetration Test (SPT) / UDS / Core Drilling				Relative Density/ Consistency
			15	30	45	N	
1.00		Brown Sand	3	5	6	11	Medium Dense
2.00		Brown Sand	6	7	11	18	Medium Dense
3.00		Brown Sand	10	10	18	28	Medium Dense
4.00		Brown Sand	9	10	14	24	Medium Dense
5.00		Brown Sand	10	12	15	27	Medium Dense
6.00		Brown Sand	12	18	18	36	Medium Dense
7.50		Brown Sand	9	7	7	14	Medium Dense
9.00		Brown Sand	11	13	15	28	Medium Dense
10.5		Brown Sand	8	10	11	21	Medium Dense
12.0		Grayish Silty Sand	9	11	12	23	Medium Dense
13.5		Grayish Clayey Sand	8	12	12	24	Medium Dense
15.0		Brown Silty Clay	11	18	20	38	Hard
16.5		Grayish Brown Clayey Sand	21	55 (13 cm) Rebound		> 100	Hard
18.0		Grayish Brown Weathered Rock	54 (2 cm) Hammer Rebound			> 100	Hard
19.5		Grayish Brown Weathered Rock	54 (1 cm) Hammer Rebound			> 100	Hard
20 - 21.5		Pinkish Gray Granite Rock	CR = 60%, RQD = 20%			> 100	Hard

Borehole Termination Depth is 21.5 m from the Existing Ground Level

Figure 2

FIELD BORE LOG PROFILE

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR								
BH NO	2		DATE OF START	01.11.2014				
SITE	Perur		DATE OF COMPLETION	02.11.2014				
DIA OF BORING	150 mm		GROUND WATER LEVEL	1.70 m				
TYPE OF BORING	Rotary (Calyx)		RL	-				
Depth below EGL (m)	Soil / Rock Profile	Description / Classification of Soil / Rock	Standard Penetration Test (SPT) / UDS / Core Drilling				Relative Density/ Consistency
			15	30	45	N	
1.00		Brown Sand	4	6	6	12	Medium Dense
2.00		Brown Sand	6	8	10	18	Medium Dense
3.00		Brown Sand	3	6	6	12	Medium Dense
4.00		Brown Sand	6	15	18	33	Dense
5.00		Brown Sand	15	18	18	36	Dense
6.00		Brown Sand	17	18	22	40	Dense
7.50		Brown Sand	13	15	18	33	Dense
9.00		Brown Sand	11	11	13	24	Medium Dense
10.5		Grayish Brown Clayey Sand	12	13	14	27	Medium Dense
12.0		Grayish Brown Clayey Sand	9	10	11	21	Medium Dense
13.5		Grayish Silty Clay	10	11	11	22	Very Stiff
15.0		Grayish Silty Clay	9	18	18	36	Very Stiff
16.5		Grayish Brown Clayey Sand	11	15	23	38	Dense
17.9		Grayish Brown Weathered Rock	54 (2 cm) Hammer Rebound			> 100	Hard
Borehole Termination Depth is 17.9 m from the Existing Ground Level							

Figure 3

FIELD BORE LOG PROFILE

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR			
BH NO	3	DATE OF START	05.11.2014
SITE	Perur	DATE OF COMPLETION	05.11.2014
DIA OF BORING	150 mm	GROUND WATER LEVEL	1.54 m
TYPE OF BORING	Rotary (Calyx)	RL	-

Depth below EGL (m)	Soil / Rock Profile	Description / Classification of Soil / Rock	Standard Penetration Test (SPT) / UDS / Core Drilling				Relative Density/ Consistency
			15	30	45	N	
1.00		Brown Sand	2	5	6	11	Medium Dense
2.00		Brown Sand	3	6	6	12	Medium Dense
3.00		Brown Sand	4	7	8	15	Medium Dense
4.00		Brown Sand	5	8	10	18	Medium Dense
5.00		Brown Sand	6	8	10	18	Medium Dense
6.00		Brown Sand	11	15	19	34	Dense
7.50		Grayish Brown Sand	7	7	8	15	Medium Dense
9.00		Grayish Brown Clayey Sand	7	11	11	22	Medium Dense
10.5		Grayish Silty Clay	7	11	12	23	Very Stiff
12.0		Grayish Silty Clay	8	10	12	22	Very Stiff
13.5		Grayish Brown Clayey Sand	9	10	17	27	Medium Dense
15.0		Grayish Brown Clayey Sand	11	18	24	42	Dense
16.5		Grayish Brown Weathered Rock	57 (8 cm) Hammer Rebound			> 100	Hard
17.0		Grayish Brown Weathered Rock	55 (3 cm) Hammer Rebound			> 100	Hard
18.5		Grayish Granite Rock	CR = 25%, RQD = 7%			> 100	Hard

Borehole Termination Depth is 18.5 m from the Existing Ground Level

Figure 4

FIELD BORE LOG PROFILE

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR			
BH NO	4	DATE OF START	30.10.2014
SITE	Perur	DATE OF COMPLETION	31.10.2014
DIA OF BORING	150 mm	GROUND WATER LEVEL	1.65 m
TYPE OF BORING	Rotary (Calyx)	RL	-

Depth below EGL (m)	Soil / Rock Profile	Description / Classification of Soil / Rock	Standard Penetration Test (SPT) / UDS / Core Drilling				Relative Density/ Consistency
			15	30	45	N	
1.00		Brown Sand	5	5	7	12	Medium Dense
2.00		Brown Sand	6	9	9	18	Medium Dense
3.00		Brown Sand	4	6	6	12	Medium Dense
4.00		Brown Sand	6	7	8	15	Medium Dense
5.00		Grayish Brown Sand	8	12	21	33	Medium Dense
6.00		Grayish Brown Sand	9	16	20	36	Dense
7.50		Grayish Brown Sand	6	8	10	18	Medium Dense
9.00		Grayish Brown Clayey Sand	8	11	13	24	Medium Dense
10.5		Grayish Brown Clayey Sand	9	12	12	24	Very Stiff
12.0		Grayish Brown Clayey Sand	10	12	16	28	Very Stiff
13.5		Grayish Brown Clayey Sand	16	25	33	58	Very Dense
15.0		Grayish Brown Clayey Sand	17	33	34	67	Very Dense
16.5		Grayish Brown Weathered Rock	55 (5 cm) Hammer Rebound			> 100	Hard
17.0		Grayish Brown Weathered Rock	53 (2 cm) Hammer Rebound			> 100	Hard
18.5		Grayish Granite Rock	CR = 20%, RQD = 7%			> 100	Hard

Borehole Termination Depth is 18.5 m from the Existing Ground Level

Figure 5

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FIELD BORE LOG PROFILE

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR			
BH NO	5	DATE OF START	28.10.2014
SITE	Perur	DATE OF COMPLETION	30.10.2014
DIA OF BORING	150 mm	GROUND WATER LEVEL	1.72 m
TYPE OF BORING	Rotary (Calyx)	RL	-

Depth below EGL (m)	Soil / Rock Profile	Description / Classification of Soil / Rock	Standard Penetration Test (SPT) / UDS / Core Drilling				Relative Density/ Consistency
			15	30	45	N	
1.00		Brown Sand	4	7	7	14	Medium Dense
2.00		Brown Sand	5	8	10	18	Medium Dense
3.00		Brown Sand	10	14	21	35	Dense
4.00		Brown Sand	11	15	18	33	Dense
5.00		Brown Sand	12	18	18	36	Dense
6.00		Brown Sand	12	15	20	35	Dense
7.50		Brown Sand	6	10	10	20	Medium Dense
9.00		Brown Clayey Sand	9	12	15	27	Medium Dense
10.5		Brown Clayey Sand	8	10	12	22	Medium Dense
12.0		Grayish Brown Silty Sand	18	23	31	54	Very Dense
13.5		Grayish Brown Silty Sand	20	30	42	72	Very Dense
15.0		Grayish Brown Clayey Sand	21	30	33	63	Very Dense
16.5		Grayish Brown Weathered Rock	54 (1 cm) Hammer Rebound			> 100	Hard
18.0		Grayish Brown Weathered Rock	58 (1 cm) Hammer Rebound			> 100	Hard
19.6		Grayish Brown Weathered Rock	54 (0 cm) Hammer Rebound			> 100	Hard
19.6 - 21.1		Grayish Granite Rock	CR = 20%, RQD = 0%			> 100	Hard

Borehole Termination Depth is 21.1 m from the Existing Ground Level

Figure 6

259

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Table 1

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH 1 — **Ground Water Level** — **1.60 m from EGL**

LABORATORY TEST RESULTS

SPT 'N' Value	Depth (m)	Soil Description / Classification	Index Properties						Specific Gravity	Grain Size Analysis (%)						~~Triaxial Shear / UCC Test / Direct Shear Test Results~~ / Correlated Values*		Consolidation Test Results	
			Natural Moisture Content (NMC), %	Bulk Density (kN/m³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines		Cohesion (c) kN/m²	Angle of Friction (Φ)	Co-efficient of Consolidation (C_v) x 10^{-3} cm²/sec	Compressibility Index, (C_c)
														Silt	Clay				
11	1.00	Brown Sand	19	18	Non Plastic				2.63	0	3	40	55	2		0	29⁰	-	-
18	2.00	Brown Sand	15	19	Non Plastic				2.63	0	4	34	56	6		0	33⁰	-	-
28	3.00	Brown Sand	13	21	Non Plastic				2.64	0	3	31	62	4		0	37⁰	-	-
21	4.00	Brown Sand	19	20	Non Plastic				2.63	0	2	21	72	5		0	35⁰	-	-
21	5.00	Brown Sand	19	21	Non Plastic				2.64	0	2	22	71	5		0	37⁰	-	-
36	6.00	Brown Sand	20	22	Non Plastic				2.62	0	3	14	80	3		0	40⁰	-	-
14	7.50	Brown Sand	14	18	Non Plastic				2.63	0	15	39	37	9		0	30⁰	-	-
28	9.00	Brown Sand	12	21	Non Plastic				2.62	0	42	24	15	19		0	37⁰	-	-
21	10.5	Brown Sand	17	20	Non Plastic				2.62	0	12	14	55	19		0	34⁰	-	-
23	12.0	Grayish Silty Sand	20	20	Non Plastic				2.66	0	0	4	71	25		0	35⁰	-	-
24	13.5	Grayish Clayey Sand (CI)	15	20	42	22	20	45	2.60	0	4	11	28	57		150	0⁰	-	-
38	15.0	Brown Silty Clay (CH)	17	22	51	24	27	60	2.60	0	7	11	30	52		237	0⁰	-	-
> 100	16.5	Grayish Clayey Sand (SC - CI)	14	22	41	22	19	140	2.67	2	21	23	27	27		0	45⁰	-	-
> 100	18.0	Grayish Brown Weathered Rock	Washed Sample													0	45⁰	-	-
> 100	19.5	Grayish Brown Weathered Rock	Washed Sample													0	45⁰	-	-

Note: * Shear strength parameters were derived as per Terzaghi and Peck Correlation (1974).

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Table 2

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR																						
BH 2																		Ground Water Level		1.70 m from EGL		
LABORATORY TEST RESULTS																						
SPT 'N' Value	Depth (m)	Soil Description / Classification	Index Properties						Specific Gravity	Grain Size Analysis (%)						~~Triaxial Shear / UCC Test / Direct Shear Test Results~~ / Correlated Values*		Consolidation Test Results	
			Natural Moisture Content (NMC), %	Bulk Density (kN/m³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines		Cohesion (c) kN/m²	Angle of Friction (Φ)	Co-efficient of Consolidation (C_v) x 10^{-3} cm²/sec	Compressibility Index, (C_c)
														Silt	Clay				
12	1.00	Brown Sand	16	18	Non Plastic				2.64	0	5	44	49	2		0	29⁰	-	-
18	2.00	Brown Sand	16	19	Non Plastic				2.64	0	3	48	47	2		0	33⁰	-	-
12	3.00	Brown Sand	17	18	Non Plastic				2.63	0	0	25	73	2		0	29⁰	-	-
33	4.00	Brown Sand	17	22	Non Plastic				2.64	0	7	18	71	4		0	39⁰	-	-
36	5.00	Brown Sand	18	22	Non Plastic				2.63	0	30	39	27	4		0	40⁰	-	-
40	6.00	Brown Sand	18	22	Non Plastic				2.63	0	31	40	28	1		0	42⁰	-	-
33	7.50	Brown Sand	17	22	Non Plastic				2.62	0	28	41	30	1		0	39⁰	-	-
24	9.00	Brown Sand	13	20	Non Plastic				2.61	0	20	29	34	17		0	35⁰	-	-
27	10.5	Grayish Brown Clayey Sand (SC)	12	21	37	17	20	40	2.60	0	17	18	30	35		0	37⁰	-	-
21	12.0	Grayish Brown Clayey Sand (SC)	21	20	37	17	20	40	2.60	0	9	8	41	42		0	34⁰	-	-
22	13.5	Grayish Silty Clay (CI)	21	20	44	25	19	55	2.66	0	0	2	21	77		137	0⁰	-	-
36	15.0	Grayish Silty Clay (CH)	19	22	57	24	33	120	2.66	0	0	2	21	77		225	0⁰	-	-
38	16.5	Grayish Brown Clayey Sand (SC - CI)	17	22	41	22	19	100	2.67	0	10	11	33	46		0	41⁰	-	-
> 100	17.9	Grayish Brown Weathered Rock	Washed Sample													0	45⁰	-	-

Note: * Shear strength parameters were derived as per Terzaghi and Peck Correlation (1974).

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261

Table 3

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH 3 — **Ground Water Level** — **1.54 m from EGL**

LABORATORY TEST RESULTS

SPT 'N' Value	Depth (m)	Soil Description / Classification	Index Properties						Specific Gravity	Grain Size Analysis (%)						~~Triaxial Shear / UCC Test / Direct Shear Test Results~~ / Correlated Values*		Consolidation Test Results	
			Natural Moisture Content (NMC), %	Bulk Density (kN/m³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines		Cohesion (c) kN/m²	Angle of Friction (Φ)	Co-efficient of Consolidation (C_v) x 10^{-3} cm²/sec	Compressibility Index, (C_c)
														Silt	Clay				
11	1.00	Brown Sand	20	18	Non Plastic				2.62	0	3	45	46	6		0	29⁰	-	-
12	2.00	Brown Sand	23	18	Non Plastic				2.62	0	2	36	58	4		0	29⁰	-	-
15	3.00	Brown Sand	22	19	Non Plastic				2.63	0	2	35	58	5		0	31⁰	-	-
18	4.00	Brown Sand	19	19	Non Plastic				2.63	0	0	47	49	4		0	33⁰	-	-
18	5.00	Brown Sand	19	19	Non Plastic				2.64	0	2	43	48	7		0	33⁰	-	-
34	6.00	Brown Sand	19	22	Non Plastic				2.62	0	47	13	35	5		0	39⁰	-	-
15	7.50	Grayish Brown Sand	12	19	Non Plastic				2.64	0	29	23	30	18		0	31⁰	-	-
22	9.00	Grayish Brown Clayey Sand (SC)	12	20	34	17	17	40	2.63	0	7	22	38	33		0	35⁰	-	-
23	10.5	Grayish Silty Clay (CI)	19	20	39	19	20	45	2.61	0	0	0	43	57		143	0⁰	-	-
22	12.0	Grayish Silty Clay (CH)	19	20	47	23	24	50	2.61	0	0	0	26	74		137	0⁰	-	-
27	13.5	Grayish Brown Clayey Sand (SC - CI)	13	21	42	22	20	50	2.65	0	23	14	25	38		0	37⁰	-	-
42	15.0	Grayish Brown Clayey Sand (SC - CI)	15	22	42	22	20	50	2.65	0	32	8	22	38		0	42⁰	-	-
> 100	16.5	Grayish Brown Weathered Rock	Washed Sample													0	45⁰	-	-
> 100	17.0	Grayish Brown Weathered Rock	Washed Sample													0	45⁰	-	-

Note: * Shear strength parameters were derived as per Terzaghi and Peck Correlation (1974).

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Table 4

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH 4 — **Ground Water Level** — **1.65 m from EGL**

LABORATORY TEST RESULTS

SPT 'N' Value	Depth (m)	Soil Description / Classification	Index Properties						Specific Gravity	Grain Size Analysis (%)						~~Triaxial Shear / UCC Test / Direct Shear Test Results~~ / Correlated Values*		Consolidation Test Results	
			Natural Moisture Content (NMC), %	Bulk Density (kN/m³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines		Cohesion (c) kN/m²	Angle of Friction (Φ)	Co-efficient of Consolidation (C_v) x 10^{-3} cm²/sec	Compressibility Index, (C_c)
														Silt	Clay				
12	1.00	Brown Sand	15	18	Non Plastic				2.63	0	0	32	59	9		0	29⁰	-	-
18	2.00	Brown Sand	16	19	Non Plastic				2.64	0	0	25	64	11		0	33⁰	-	-
12	3.00	Brown Sand	18	18	Non Plastic				2.64	0	0	18	71	11		0	29⁰	-	-
15	4.00	Brown Sand	16	19	Non Plastic				2.64	0	3	28	58	11		0	31⁰	-	-
33	5.00	Grayish Brown Sand	14	22	Non Plastic				2.63	0	3	28	58	11		0	39⁰	-	-
36	6.00	Grayish Brown Sand	16	22	Non Plastic				2.63	0	5	25	59	11		0	40⁰	-	-
18	7.50	Grayish Brown Sand	11	19	Non Plastic				2.63	0	2	39	42	17		0	33⁰	-	-
24	9.00	Grayish Brown Clayey Sand (SC)	11	20	30	16	14	30	2.66	0	0	7	63	30		0	35⁰	-	-
24	10.5	Grayish Brown Clayey Sand (SC)	11	20	30	16	14	30	2.66	0	0	10	60	30		0	35⁰	-	-
28	12.0	Grayish Brown Clayey Sand (SC)	12	21	33	17	16	40	2.66	0	0	9	61	30		0	37⁰	-	-
58	13.5	Grayish Brown Clayey Sand (SC)	12	22	33	17	16	40	2.68	0	2	14	51	33		0	45⁰	-	-
67	15.0	Grayish Brown Clayey Sand (SC)	12	22	33	17	16	40	2.68	0	1	20	43	36		0	45⁰	-	-
> 100	16.5	Grayish Brown Weathered Rock	Washed Sample													0	45⁰	-	-
> 100	17.0	Grayish Brown Weathered Rock	Washed Sample													0	45⁰	-	-

Note: * Shear strength parameters were derived as per Terzaghi and Peck Correlation (1974).

293

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Table 5

PROJECT : Proposed Construction of Desalination Plant at Perur, ECR

BH 5 — **Ground Water Level** — **1.72 m from EGL**

LABORATORY TEST RESULTS

SPT 'N' Value	Depth (m)	Soil Description / Classification	Index Properties						Specific Gravity	Grain Size Analysis (%)					~~Triaxial Shear / UCC Test / Direct Shear Test Results~~ / Correlated Values*		Consolidation Test Results	
			Natural Moisture Content (NMC), %	Bulk Density (kN/m³)	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %	Free Swell Index		Gravel	Coarse Sand	Medium Sand	Fine Sand	Fines				
														Silt	Clay	Cohesion (c) kN/m²	Angle of Friction (Φ)	Co-efficient of Consolidation (C_v) x 10^{-3} cm²/sec	Compressibility Index, (C_c)
14	1.00	Brown Sand	15	18	Non Plastic				2.64	0	0	7	84	9		0	30⁰	-	-
18	2.00	Brown Sand	15	19	Non Plastic				2.63	0	0	23	68	9		0	33⁰	-	-
35	3.00	Brown Sand	18	22	Non Plastic				2.63	0	11	30	50	9		0	40⁰	-	-
33	4.00	Brown Sand	18	22	Non Plastic				2.64	0	0	4	90	6		0	39⁰	-	-
36	5.00	Brown Sand	18	22	Non Plastic				2.64	0	0	9	87	4		0	40⁰	-	-
35	6.00	Brown Sand	13	22	Non Plastic				2.64	0	0	11	85	4		0	40⁰	-	-
20	7.50	Brown Sand	13	20	Non Plastic				2.64	0	6	26	54	14		0	34⁰	-	-
27	9.00	Brown Clayey Sand (SC)	14	21	30	16	14	30	2.62	0	7	28	42	33		0	37⁰	-	-
22	10.5	Brown Clayey Sand (SC)	14	20	30	16	14	30	2.62	0	7	28	42	33		0	35⁰	-	-
54	12.0	Grayish Brown Silty Sand	14	22	Non Plastic				2.66	0	1	30	54	15		0	45⁰	-	-
72	13.5	Grayish Brown Silty Sand	14	22	Non Plastic				2.66	0	1	30	54	15		0	45⁰	-	-
63	15.0	Grayish Brown Clayey Sand (SC)	12	22	34	17	17	40	2.60	0	2	21	37	40		0	45⁰	-	-
> 100	16.5	Grayish Brown Weathered Rock	Washed Sample													0	45⁰	-	-
> 100	18.0	Grayish Brown Weathered Rock	Washed Sample													0	45⁰	-	-
> 100	19.6	Grayish Brown Weathered Rock	Washed Sample													0	45⁰	-	-

Note: * Shear strength parameters were derived as per Terzaghi and Peck Correlation (1974)

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Annexure - 1 (Site Photographs)

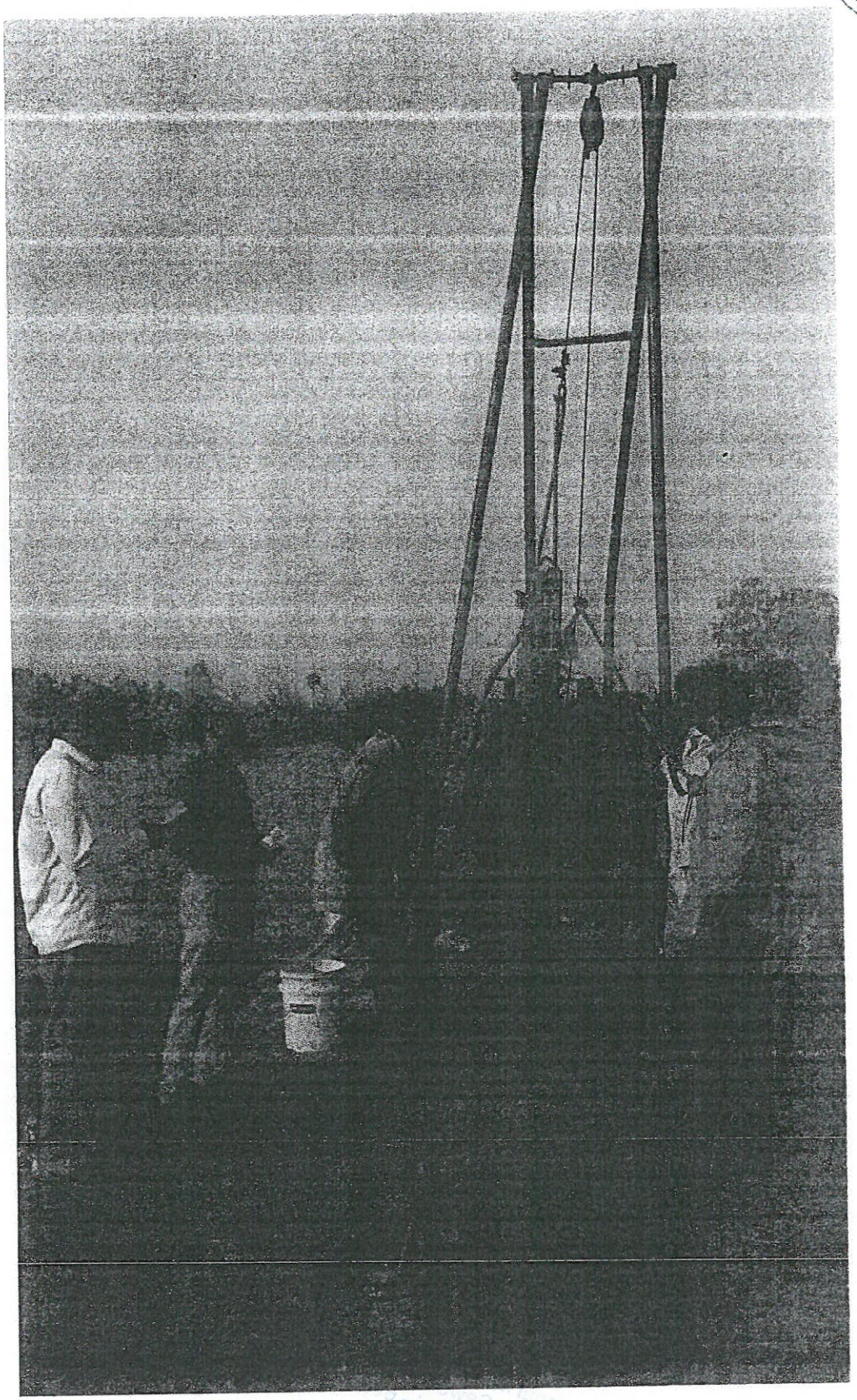
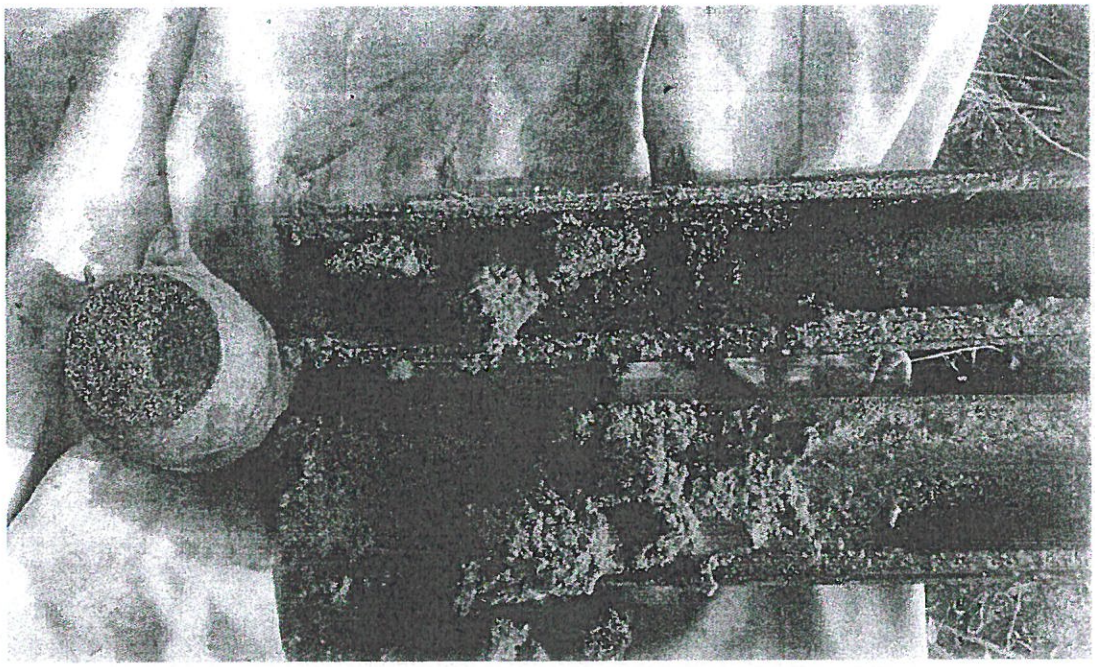


Plate 1 View of SPT in Progress at the proposed Site



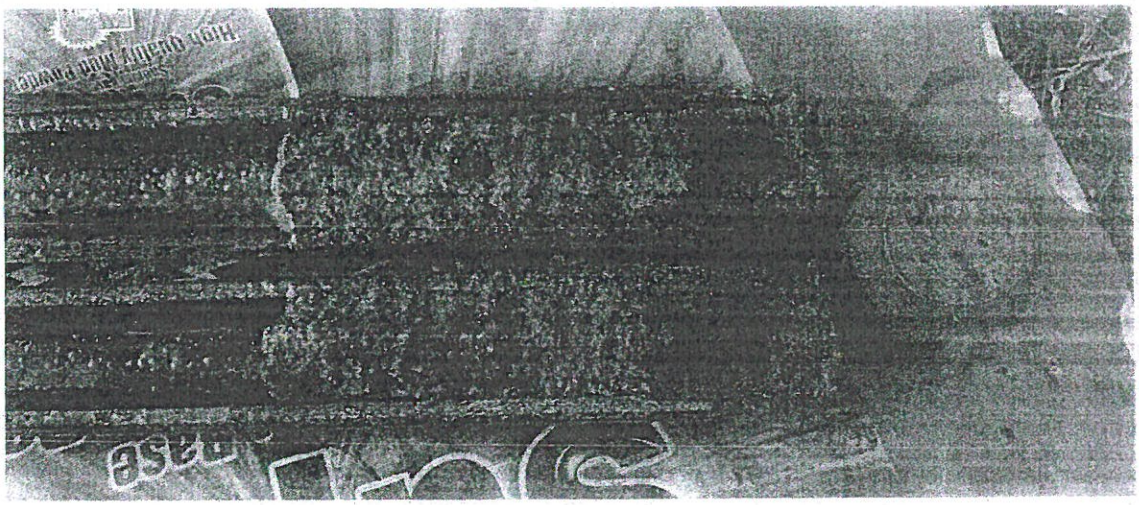


Plate 2 View of Soil Sampling through Split Spoon Sampler at the proposed Site

Plate 3 Inspection by the Faculty Member of Department of Civil Engineering, CEG, Anna University, Chennai - 25 on 01.11.2014 at proposed Site

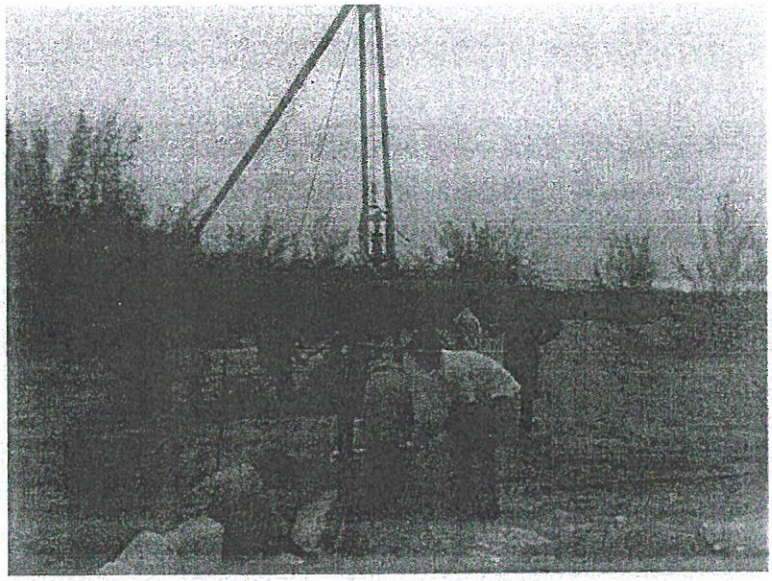


Plate 4 Inspection by the Faculty Member of Department of Civil Engineering, CEG, Anna University, Chennai - 25 on 01.11.2014 at proposed Site

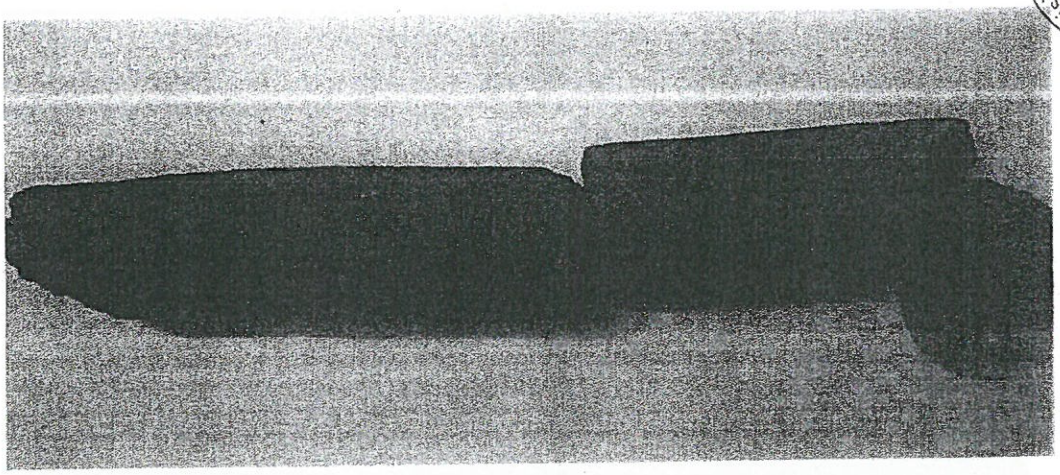


Plate 5 View of Pinkish Granite Core Sample found at BH 1 in 20.0 to 21.5 m Depth

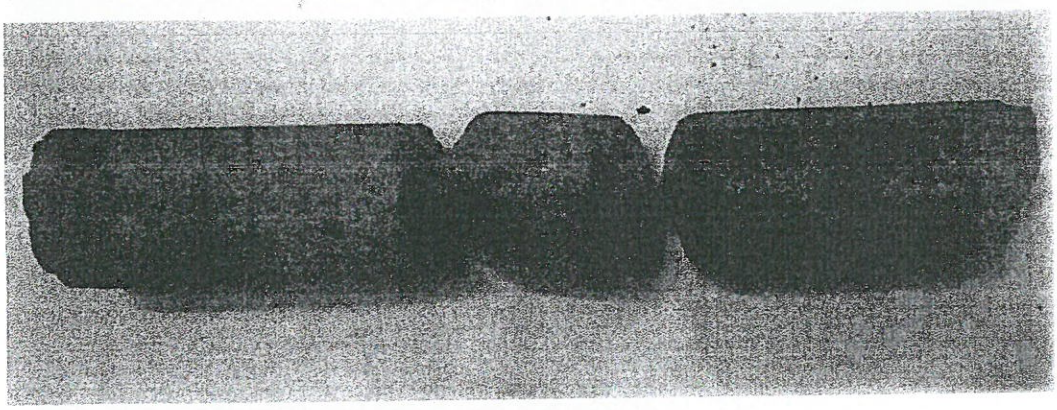


Plate 6 View of Grayish Granite Core Sample found at BH 3 in 17.0 to 18.5 m Depth

Plate 7 View of Grayish Granite Core Sample found at BH 4 in 17.0 to 18.5 m Depth

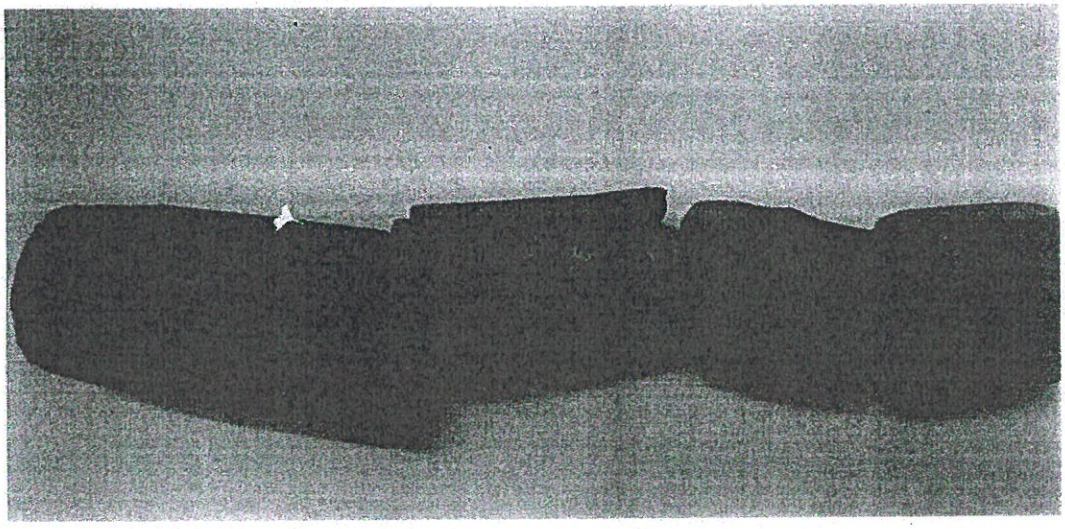


Plate 8 View of Grayish Granite Core Sample found at BH 5 in 19.6 to 21.1 m Depth

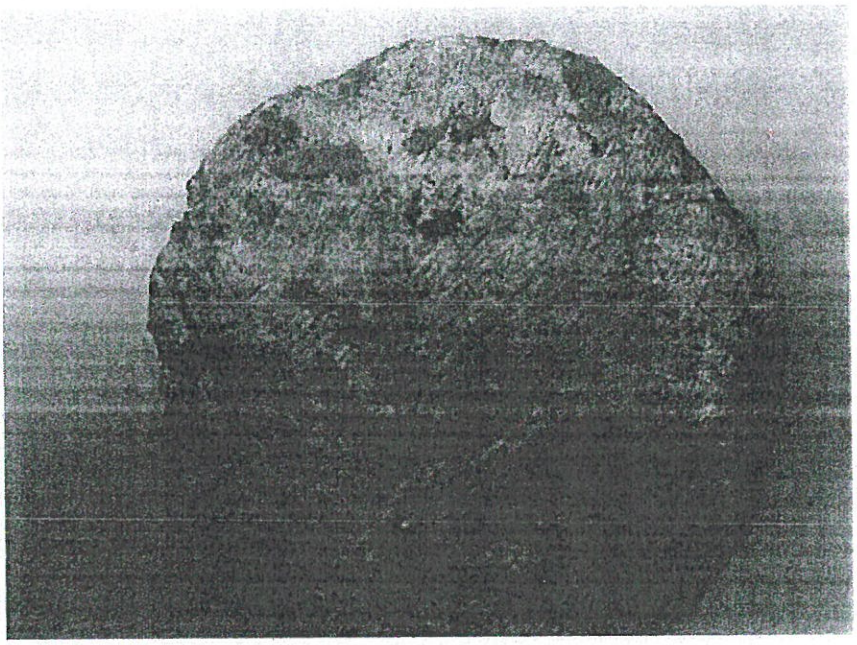


Plate 9 Texture of Pinkish Granite core sample at BH 1 in 20.0 to 21.5 m Depth

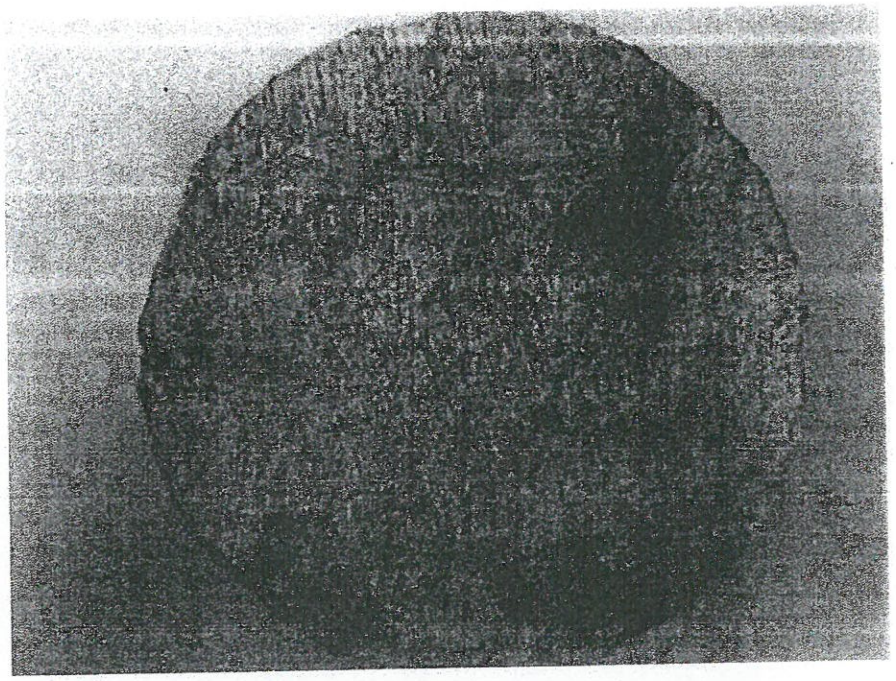


Plate 10 Texture of Grayish Granite core sample at BH 3 in 17.0 to 18.5 m Depth

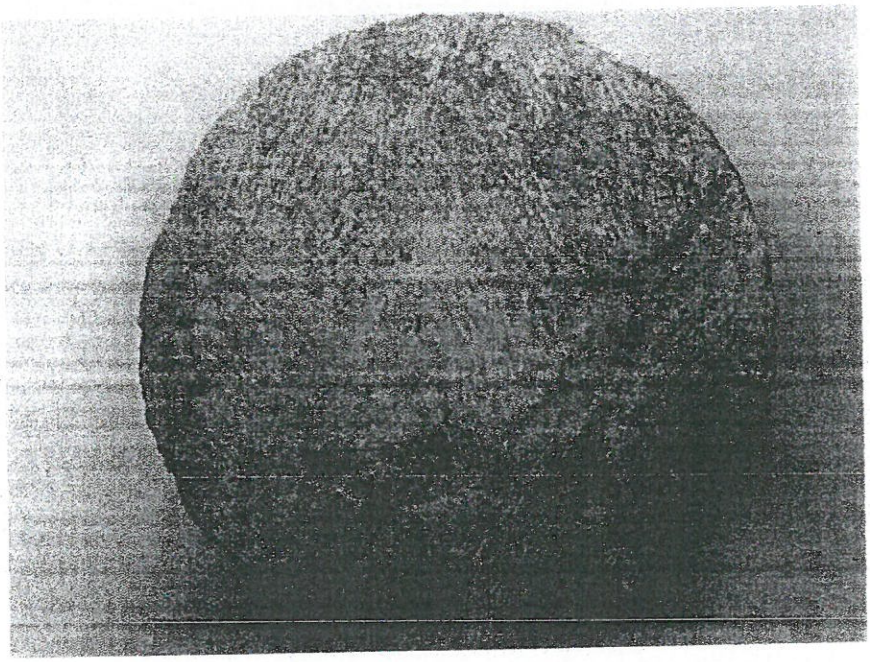


Plate 11 Texture of Grayish Granite core sample at BH 4 in 17.0 to 18.5 m Depth

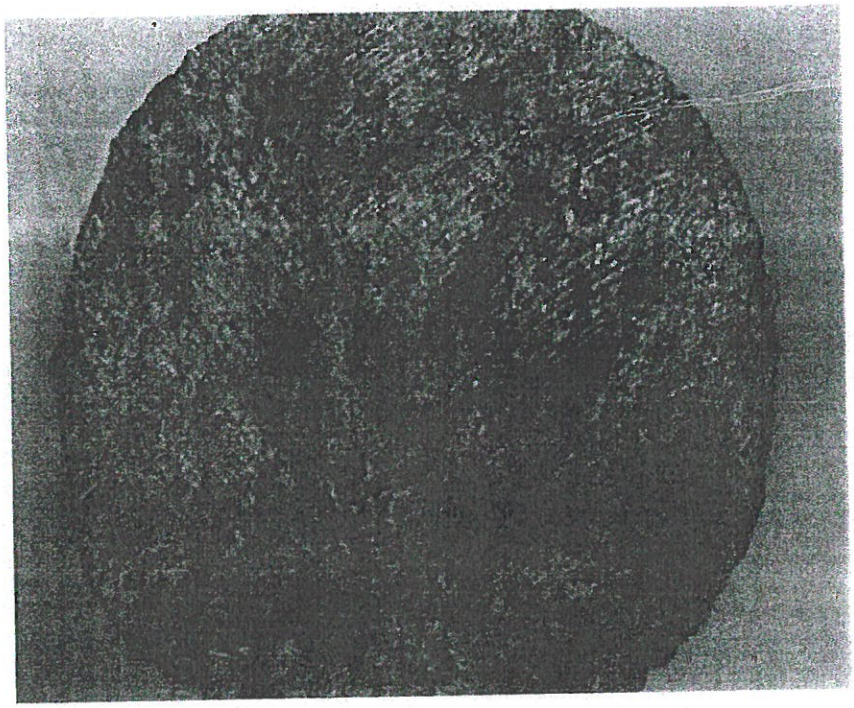


Plate 12 Texture of Grayish Granite at BH 5 core sample in 19.6 to 21.1 m Depth

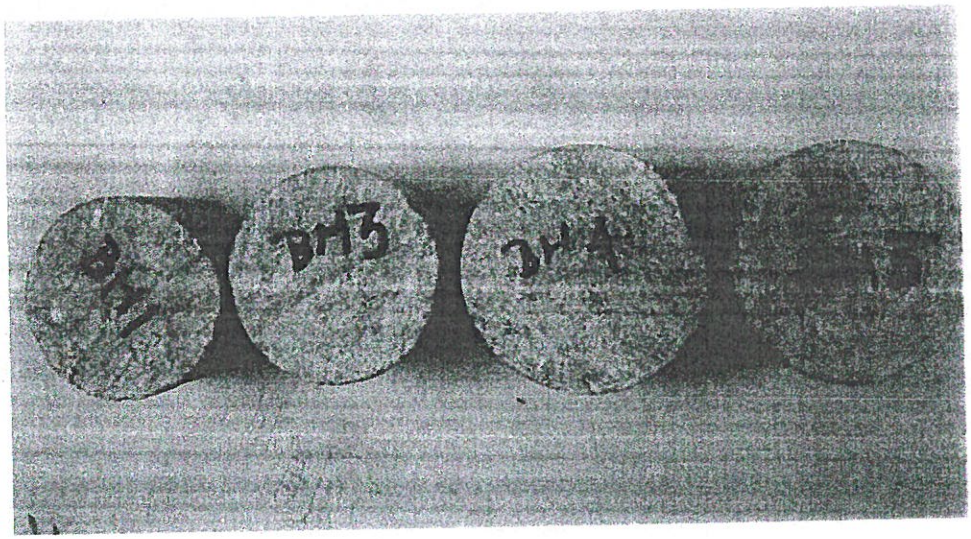


Plate 13 View of Rock Core Samples prepared for conducting Point Load Strength Index Test in Department of Civil Engineering, CEG, Anna University, Chennai - 25

Annexure-4

Wind Velocity, Direction, Lithological Drift, Wave Velocity and Other Site Data

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Methods of data collection and analysis

1. Physical

Wind: To understand the wind pattern prevailing in the project region, the data on daily variation of wind speed and direction at 0830 hours and 1730 hours available for Chennai region were compiled from the *Bay of Bengal Pilot (1978).*

***Storm*:** The information on cyclonic storm is essential for the environmental assessment. Occasional occurrence of severe cyclonic storm is found to occur in this region. Based on the IMD data on the Tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea, (1979), and the Addendum (1996) published by IMD, the details on the storms occurred between 1877 and 1990 were compiled.

Waves: The ship reported visual observations documented in Indian Daily Weather Reports (IDWR) published by the India Meteorological Department, Pune, compiled over the period from 1968 to 1986 were used for the base line data. The data reported for the region between the latitude 10°N - 15°N, and longitude 80°E - 85°E were considered for the present project (Chandramohan, et.al., 1990).

***Tides*:** Tide measurement was carried at Fishing harbor using Aanderaa WTR9 Wave and Tide Recorder for a period of 19 days from 27.07.2013 to 15.08.2013. The tide data were recorded at 30 min interval. The Tides are measured at site. The details of measurements are:

Location	Geographical Co-ordinates		UTM - Zone 44		Duration	
	Latitude, N	Longitude, E	X (m)	Y (m)	From	To
Stn. T1	13°07'33"	80°17'53"	0423938	1451168	27.07.13	15.08.13

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273

Currents: Variations of current speed and direction were measured at one location off the project region using Aanderaa Seaguard SW RCM current meter (Stn. C1). The measurements were carried out in 15 minutes interval from 10.08.13 to 25.08.13. The measurement location is shown in Fig. 5. The details of measurement location, depth and duration are:

Location	Geographical Co-ordinates		UTM - Zone 44		Distance offshore (km)	Water depth (m)	Duration	
	Latitude, N	Longitude, E	X (m)	Y (m)			From	To
Stn.C1	12°37'30"	80°12'31"	0414063	1395804	1.5	8.5	10.08.13	25.08.13

Littoral Drift: Based on the ship reported wave data, the longshore sediment transport rate at the study region was estimated using the following equation (Shore Protection Manual, CERC, US Army, 1975).

$$Q = 1290(\frac{\rho g^2}{64\pi})T(H_0 K_r)^2 \sin 2\alpha_b$$

Where,

Q	=	longshore sediment transport rate in m^3/year,
ρ	=	mass density of the sea water in kg/m^3,
g	=	acceleration due to gravity,
H_o	=	deep water wave height in m,
T	=	wave period in seconds,
K_r	=	refraction coefficient, and
α_b	=	wave breaking angle.

Results

1. Physical

Wind: The month wise distribution of wind speed and direction are shown in Table 1. It is observed that during April, May, June and December wind speeds were around 10-11 knots and during the remaining months wind speeds were varying between 7 and 9 knots. During April to September, the morning wind mostly prevailed from SW and W, and during November to February, it mostly prevailed from NW. The wind patterns during morning hours and evening hours show the influence of land-sea breeze system in this region. During the days of depressions and cyclones, the wind speed commonly exceeds 50 kmph.

Table 1: Monthwise distribution of wind speed and direction

Month	Speed (knots)	Predominant direction from	
		0830 hrs	1730 hrs
January	8	NW	NE
February	8	W-NW	E-SE
March	9	SW-W	SE
April	10	S-SW	SE
May	11	S-SW	SE
June	10	SW-W	SE-S
July	9	SW-W	SE-S
August	8	SW-W	SE-S
September	7	SW-W	SE
October	7	SW-NW	N-SE
November	9	NW	N-SE
December	10	NW	N-SE

Storm: The tracks of cyclones which have crossed the coast near Chennai (within 150 km on either side) during 1877 to 1990 are presented in Table 2. It indicates that totally 58 storms had occurred within 300 km off the project region. The occurrence of storms in this region are more frequent in November (23) and in October (19). Among them about 37 number of storms had crossed the coast within 300 km distance during 1877 to 1990.

Table 2 : Tracks of cyclones passed Chennai region - 1877 to 1990

Month	Occurred in the vicinity	Crossed in the vicinity
January	3	--
February	-	
March	-	-
April	2	1
May	7	3
June	-	-
July	-	-
August	-	-
September	-	-
October	19	13
November	23	19
December	4	1

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275

Tides: The various tide levels with respect to Chart Datum for Chennai as presented in *Indian Tide Table 2013* are shown below:

Mean High water Spring	:	1.15 m
Mean High Water Neap	:	0.84 m
Mean Sea Level	:	*0.65 m*
Mean Low Water Neap	:	0.43 m
Mean Low Water Spring	:	0.14 m

The measured tide levels reduced to chart datum for the period 27.07.2013 to 15.08.2013 are shown in Fig. 1 below. It showed a spring tidal range of 0.95 m and a neap tidal range of 0.33 m.

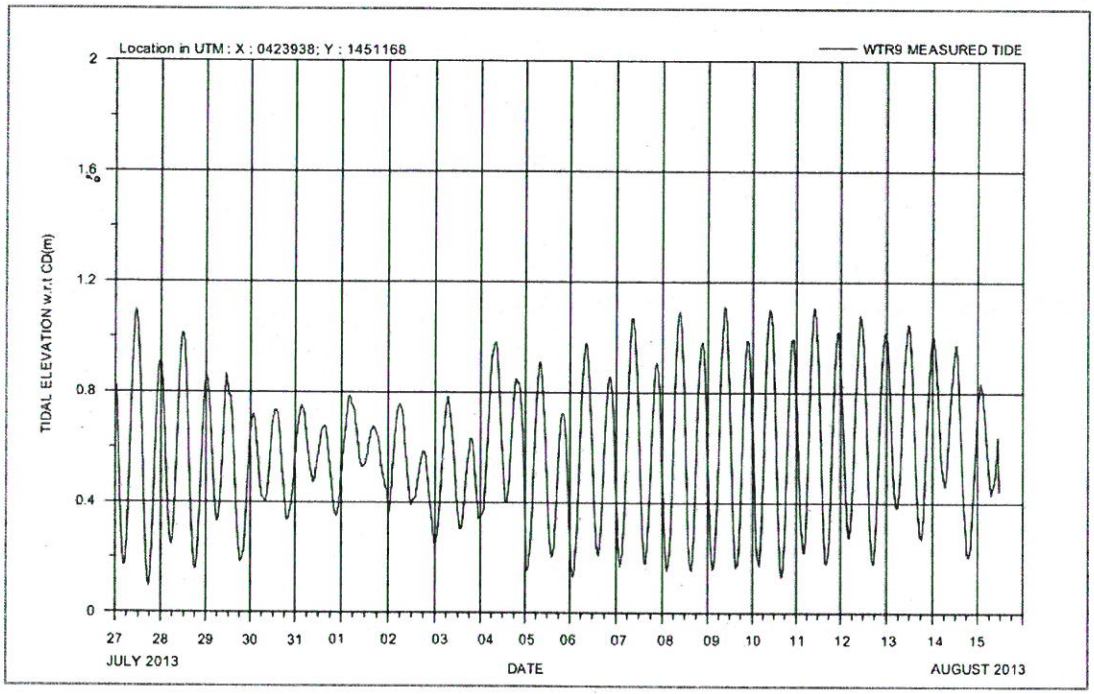

Fig. 1 : Variation of Measured Tide

Currents: The variation of surface current speed and direction measured at 1500 m offshore (stn. C1) is shown in Fig. 2 below. The current speed reached upto 0.33 m/s and the current direction was shifting with tides showing the variation within the sector of 330° – 90°.

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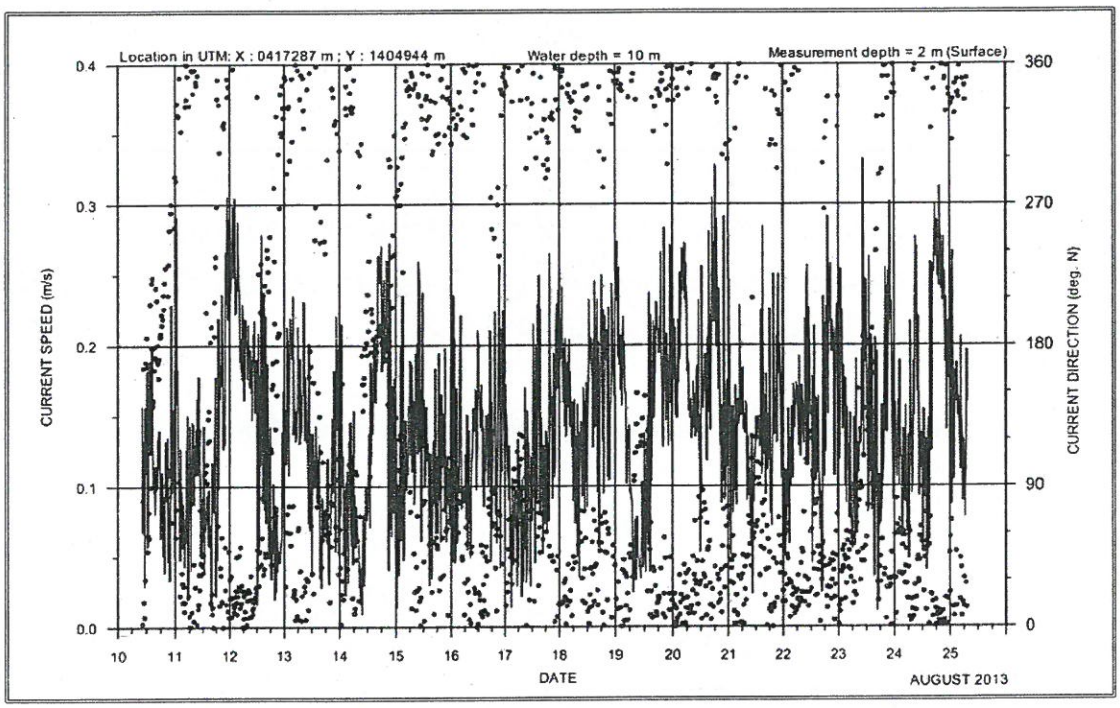

Fig. 2 : Variation of Current Speed and Direction of proposed Site

Waves: The data compiled based on the ship observed deep-water waves over the region between the latitude 10°N - 15°N, and longitude 80°E - 85°E is considered for the present project. It is observed that the significant wave heights varied between 0.5 and 1 m during February to April, 1 and 3.0 m during May to September and, between 1 and 2 m during rest of the year. The zero crossing periods of the waves varied between 5 and 8 s. The project region is located on the region which is significantly influenced during the northeast monsoon. The wave climate remains rough from May to November. The occurrence of storms and depressions during northeast monsoon often increase the wave activity in this region.

Tsunami: The occurrence of a Tsunami along the Indian coast is an extremely rare event with a very low frequency of less than once in 500 years. One worst tsunami event was witnessed on 26th December 2004 along the Tamil Nadu coast. From records of tide gauge data during the 2004 tsunami event, the run up due to tsunami at different stretches along the coast was observed to vary between 1 m and 3.5 m. The water level rise due to this Tsunami near the project region was around 2.0 m and the run-up crossed over the highways (ECR). Eye - witness accounts say that each high tsunami wave that approached the coast was like a solitary surging / tidal bore wave, and the rise in water level near the coast due to such surging wave existed for a short duration of nearly 30 minutes.

Littoral drift: The monthly volume of littoral drift at project region is shown in Table 3. The sediment transport rates were high (>1.98 x 10^5 m^3/month) in May and December. It was lowest (< 0.75 x 10^5 m^3/month) in March. The littoral drift was towards north from April to October and towards south during the remaining months of the year. The annual northerly transport is 0.98 x 10^6 m^3/year and the annual southern transport is 0.51 x 10^6 m^3/year.

Table 3 : Longshore sediment transport rate along Chennai coast

Month	Quantity (m^3 / month)
January	155790
February	84199
March	7376
April	-91894
May	-198016
June	-178516
July	-125861
August	-149160
September	-157813
October	-76053
November	68486
December	196906
(-) Transport in northerly direction	

Executive Engineer (Desal)
Chennai Metropolitan Water Supply &
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Chennai - 600 002.

Annexure-5

HTL & LTL Line Demarcation

Executive Engineer (Postal)
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Sewerage Board
Chennai - 600 002.