PART 2

DATA BOOK

I DRAWINGS

I. Drawings

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2. Entire Flow Monitoring System
3. General Layout Plan of Optical Fiber Cable
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7. Surge Tank 1 (from Intake to WTP)
8. WTP; General Layout Plan
9. WTP; General Plan and Section
10. WTP; Hydraulic Profile (Phase 1 &2)
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17. Battali Hill Reservoir(Phase 1 Project) and Location of Sector Inlet Chamber
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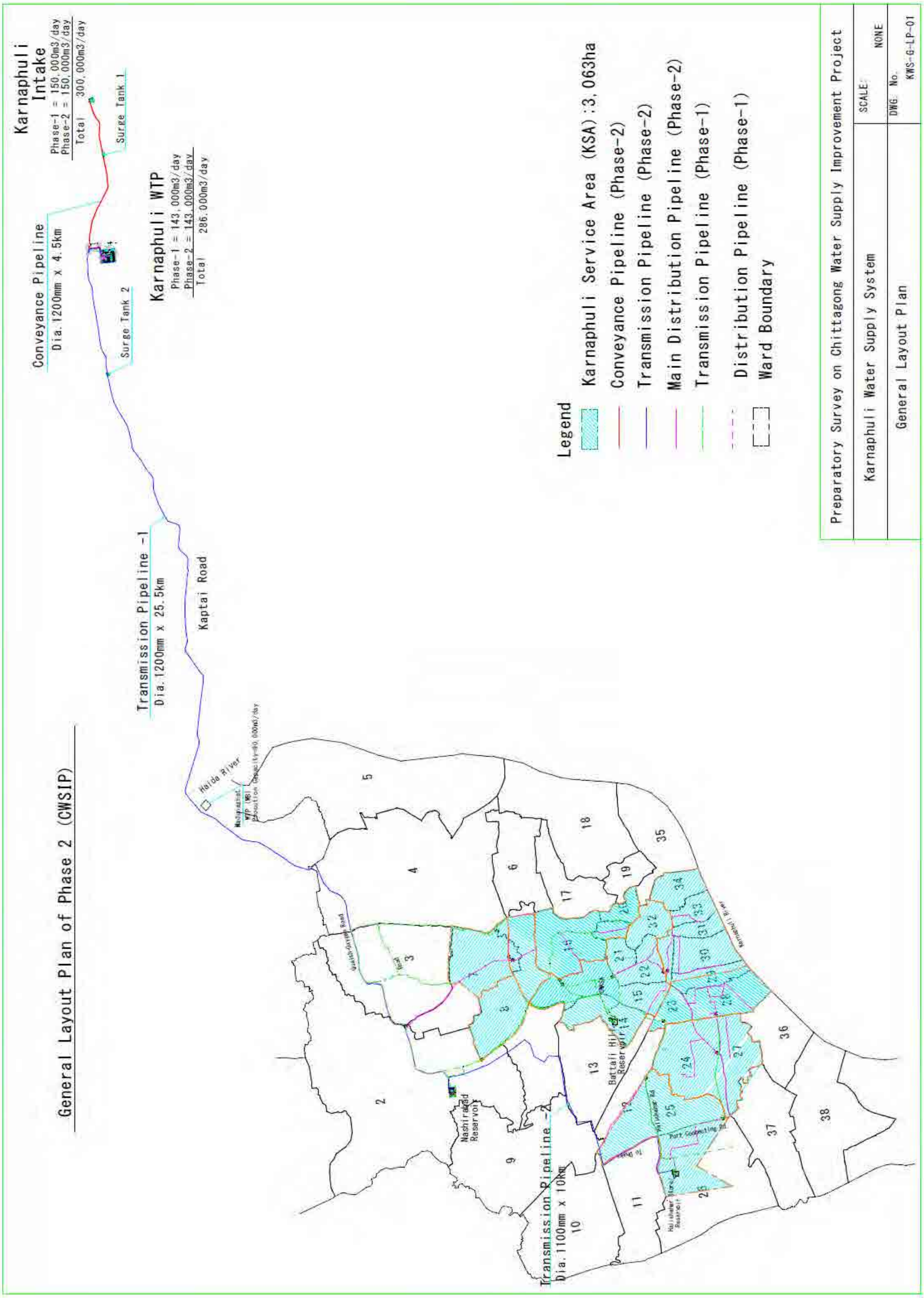
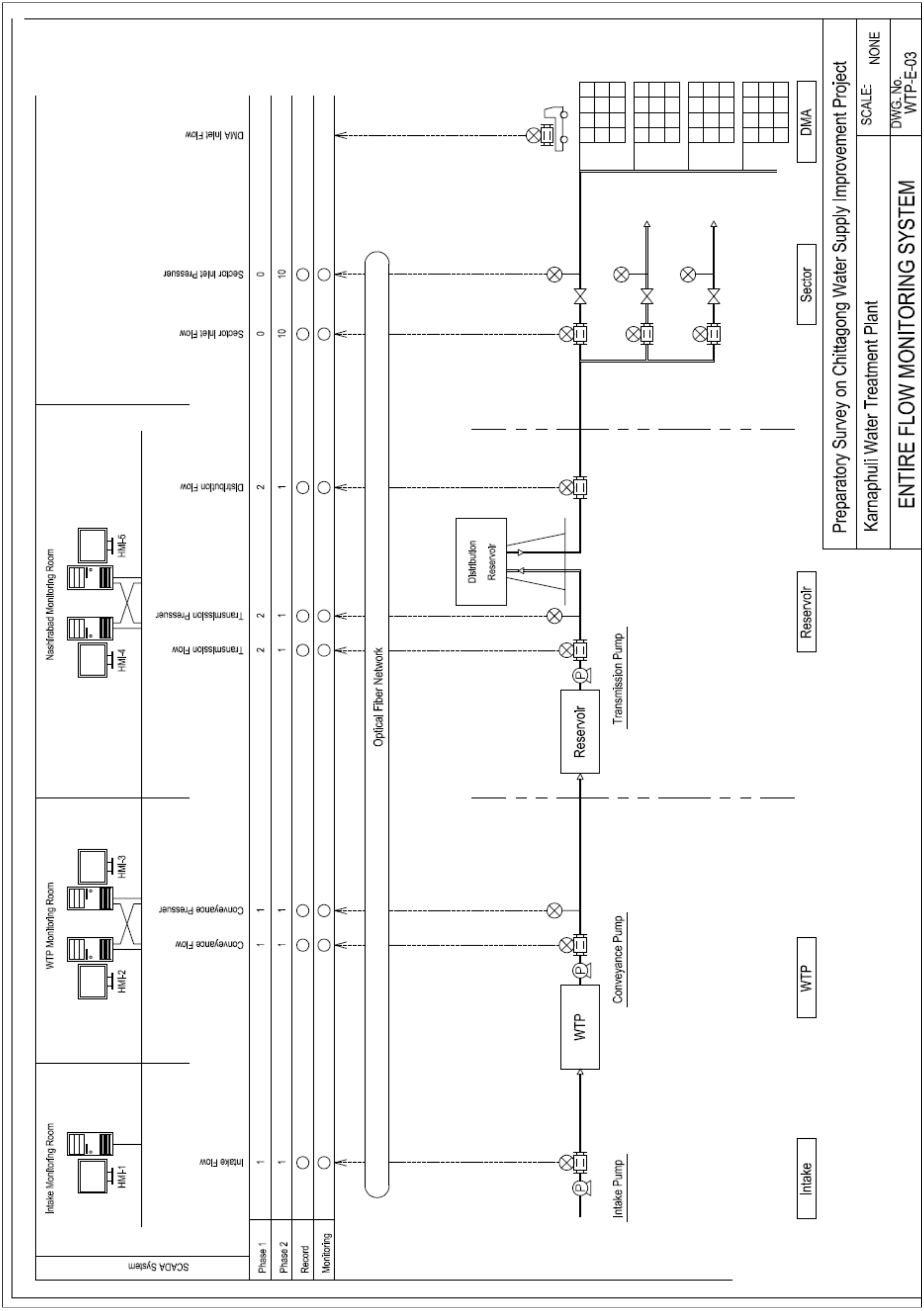
19. General Layout Plan of KSA
20. General Layout Plan of Sector
21. Sector and DMA Inlet Chamber
22. House Connection ; Section

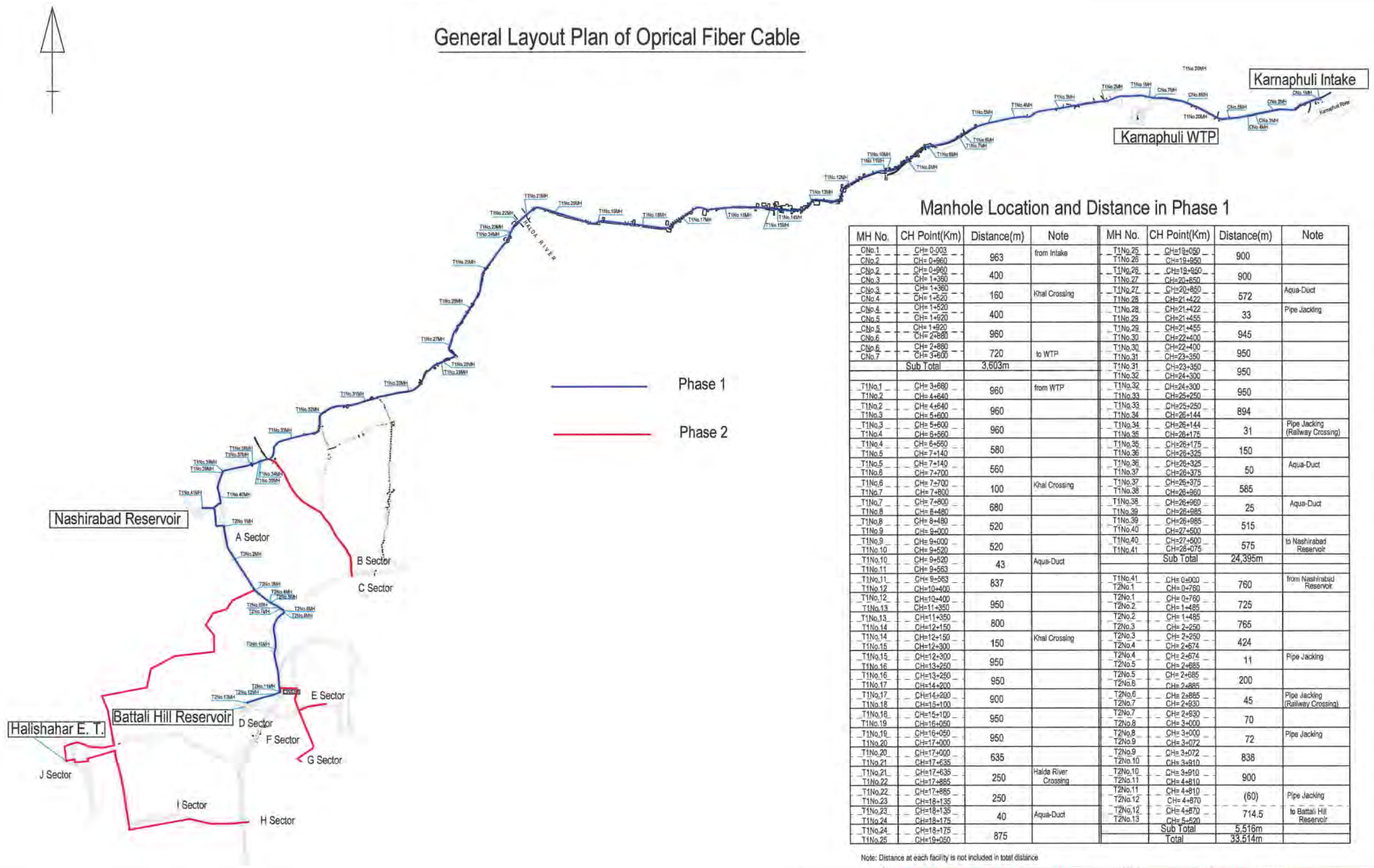
1. General Layout Plan



2. Entire Flow Monitoring System



3. General Layout Plan of Optical Fiber Cable



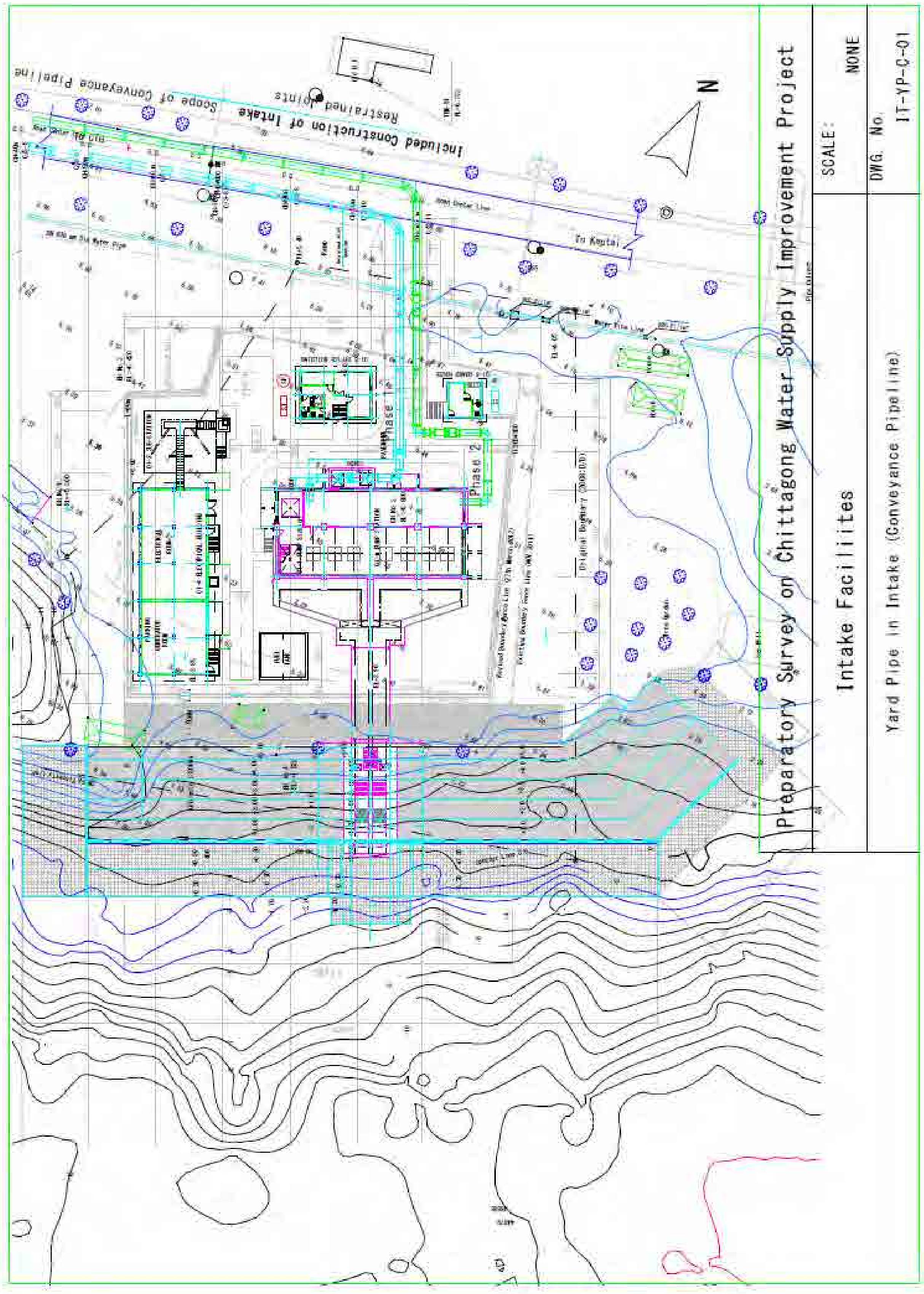
Manhole Location and Distance in Phase 1

MH No.	CH Point(Km)	Distance(m)	Note
CNo.1 CNo.2	CH= 0-003 CH= 0+960	963	from Intake
CNo.2 CNo.3	CH= 0+960 CH= 1+360	400	
CNo.3 CNo.4	CH= 1+360 CH= 1+520	160	Khal Crossing
CNo.4 CNo.5	CH= 1+520 CH= 1+920	400	
CNo.5 CNo.6	CH= 1+920 CH= 2+880	960	
CNo.6 CNo.7	CH= 2+880 CH= 3+600	720	to WTP
	Sub Total	3,603m	
T1No.1 T1No.2	CH= 3+680 CH= 4+640	960	from WTP
T1No.2 T1No.3	CH= 4+640 CH= 5+600	960	
T1No.3 T1No.4	CH= 5+600 CH= 6+560	960	
T1No.4 T1No.5	CH= 6+560 CH= 7+140	580	
T1No.5 T1No.6	CH= 7+140 CH= 7+700	560	
T1No.6 T1No.7	CH= 7+700 CH= 7+800	100	Khal Crossing
T1No.7 T1No.8	CH= 7+800 CH= 8+480	680	
T1No.8 T1No.9	CH= 8+480 CH= 9+000	520	
T1No.9 T1No.10	CH= 9+000 CH= 9+520	520	
T1No.10 T1No.11	CH= 9+520 CH= 9+563	43	Aqua-Duct
T1No.11 T1No.12	CH= 9+563 CH=10+400	837	
T1No.12 T1No.13	CH=10+400 CH=11+350	950	
T1No.13 T1No.14	CH=11+350 CH=12+150	800	
T1No.14 T1No.15	CH=12+150 CH=12+300	150	Khal Crossing
T1No.15 T1No.16	CH=12+300 CH=13+250	950	
T1No.16 T1No.17	CH=13+250 CH=14+200	950	
T1No.17 T1No.18	CH=14+200 CH=15+100	900	
T1No.18 T1No.19	CH=15+100 CH=16+050	950	
T1No.19 T1No.20	CH=16+050 CH=17+000	950	
T1No.20 T1No.21	CH=17+000 CH=17+635	635	
T1No.21 T1No.22	CH=17+635 CH=17+885	250	Halda River Crossing
T1No.22 T1No.23	CH=17+885 CH=18+135	250	
T1No.23 T1No.24	CH=18+135 CH=18+175	40	Aqua-Duct
T1No.24 T1No.25	CH=18+175 CH=19+050	875	
T1No.25 T1No.26	CH=19+050 CH=19+950	900	
T1No.26 T1No.27	CH=19+950 CH=20+850	900	
T1No.27 T1No.28	CH=20+850 CH=21+422	572	Aqua-Duct
T1No.28 T1No.29	CH=21+422 CH=21+455	33	Pipe Jacking
T1No.29 T1No.30	CH=21+455 CH=22+400	945	
T1No.30 T1No.31	CH=22+400 CH=23+350	950	
T1No.31 T1No.32	CH=23+350 CH=24+300	950	
T1No.32 T1No.33	CH=24+300 CH=25+250	950	
T1No.33 T1No.34	CH=25+250 CH=26+144	894	
T1No.34 T1No.35	CH=26+144 CH=26+175	31	Pipe Jacking (Railway Crossing)
T1No.35 T1No.36	CH=26+175 CH=26+325	150	
T1No.36 T1No.37	CH=26+325 CH=26+375	50	Aqua-Duct
T1No.37 T1No.38	CH=26+375 CH=26+960	585	
T1No.38 T1No.39	CH=26+960 CH=26+985	25	Aqua-Duct
T1No.39 T1No.40	CH=26+985 CH=27+500	515	
T1No.40 T1No.41	CH=27+500 CH=28+075	575	to Nashirabad Reservoir
	Sub Total	24,395m	
T1No.41 T2No.1	CH= 0+000 CH= 0+760	760	from Nashirabad Reservoir
T2No.1 T2No.2	CH= 0+760 CH= 1+485	725	
T2No.2 T2No.3	CH= 1+485 CH= 2+250	765	
T2No.3 T2No.4	CH= 2+250 CH= 2+674	424	
T2No.4 T2No.5	CH= 2+674 CH= 2+685	11	Pipe Jacking
T2No.5 T2No.6	CH= 2+685 CH= 2+885	200	
T2No.6 T2No.7	CH= 2+885 CH= 2+930	45	Pipe Jacking (Railway Crossing)
T2No.7 T2No.8	CH= 2+930 CH= 3+000	70	
T2No.8 T2No.9	CH= 3+000 CH= 3+072	72	Pipe Jacking
T2No.9 T2No.10	CH= 3+072 CH= 3+910	838	
T2No.10 T2No.11	CH= 3+910 CH= 4+810	900	
T2No.11 T2No.12	CH= 4+810 CH= 4+870	(60)	Pipe Jacking
T2No.12 T2No.13	CH= 4+870 CH= 5+520	714.5	to Battali Hill Reservoir
	Sub Total	5,516m	
	Total	33,514m	

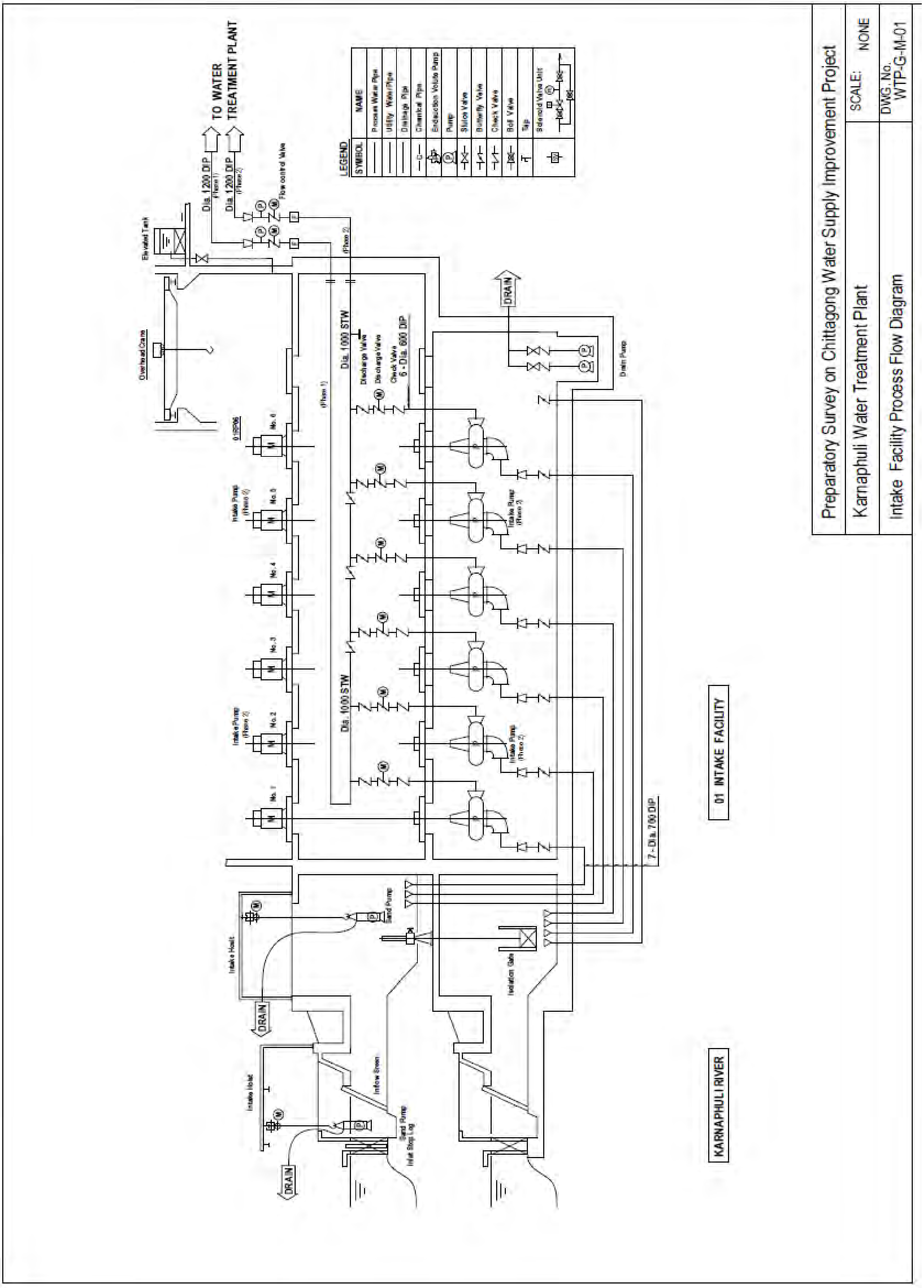
Note: Distance at each facility is not included in total distance

Preparatory Survey on Chittagong Water Supply Improvement Project	
Karnaphuli Water Supply System	SCALE NONE
General Layout Plan of Optical Fibre Cable	DWG. No. KWS-G-OP-01

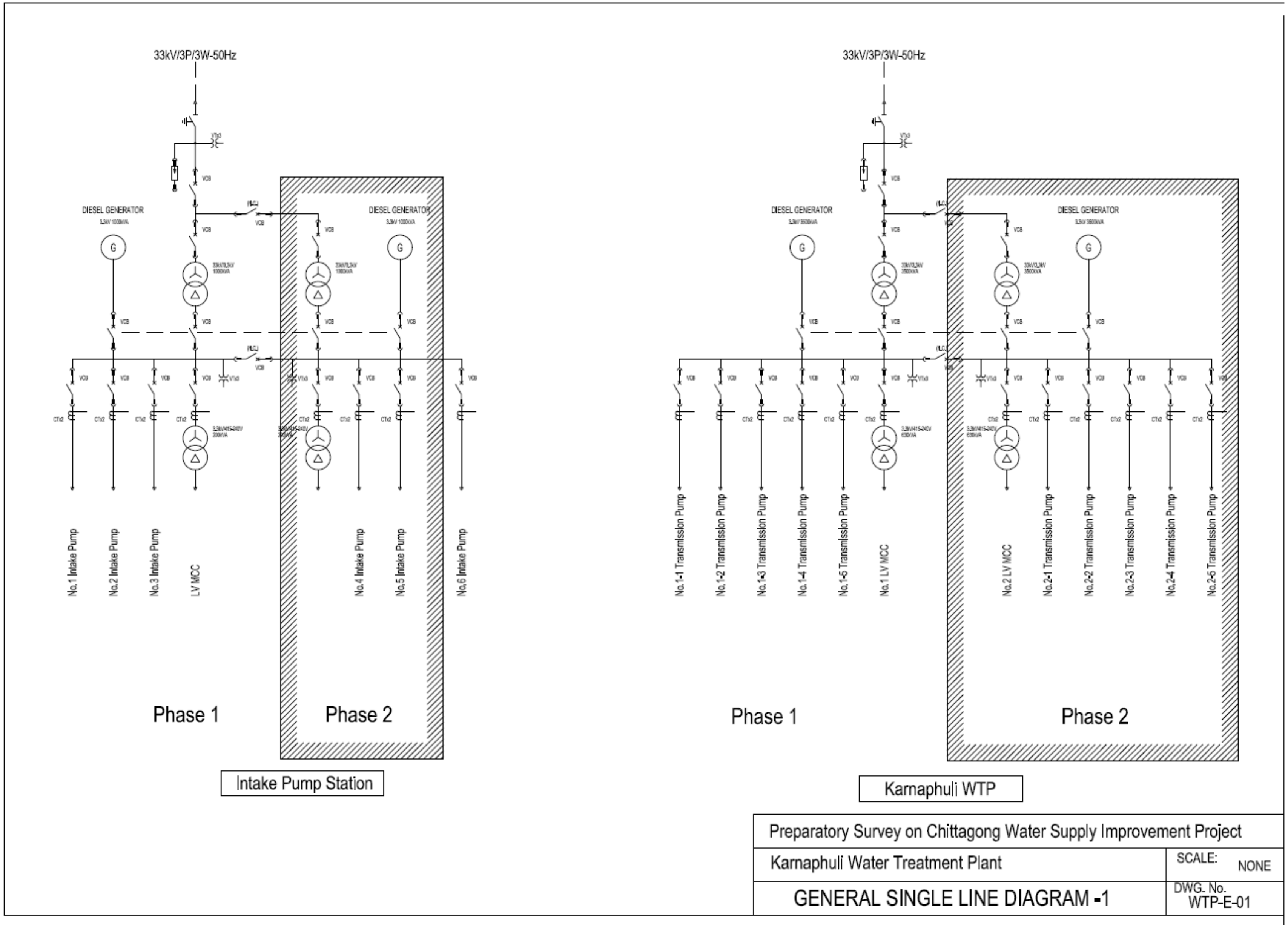
4. Intake Facilities; Yard Pipe (Conveyance Pipeline)



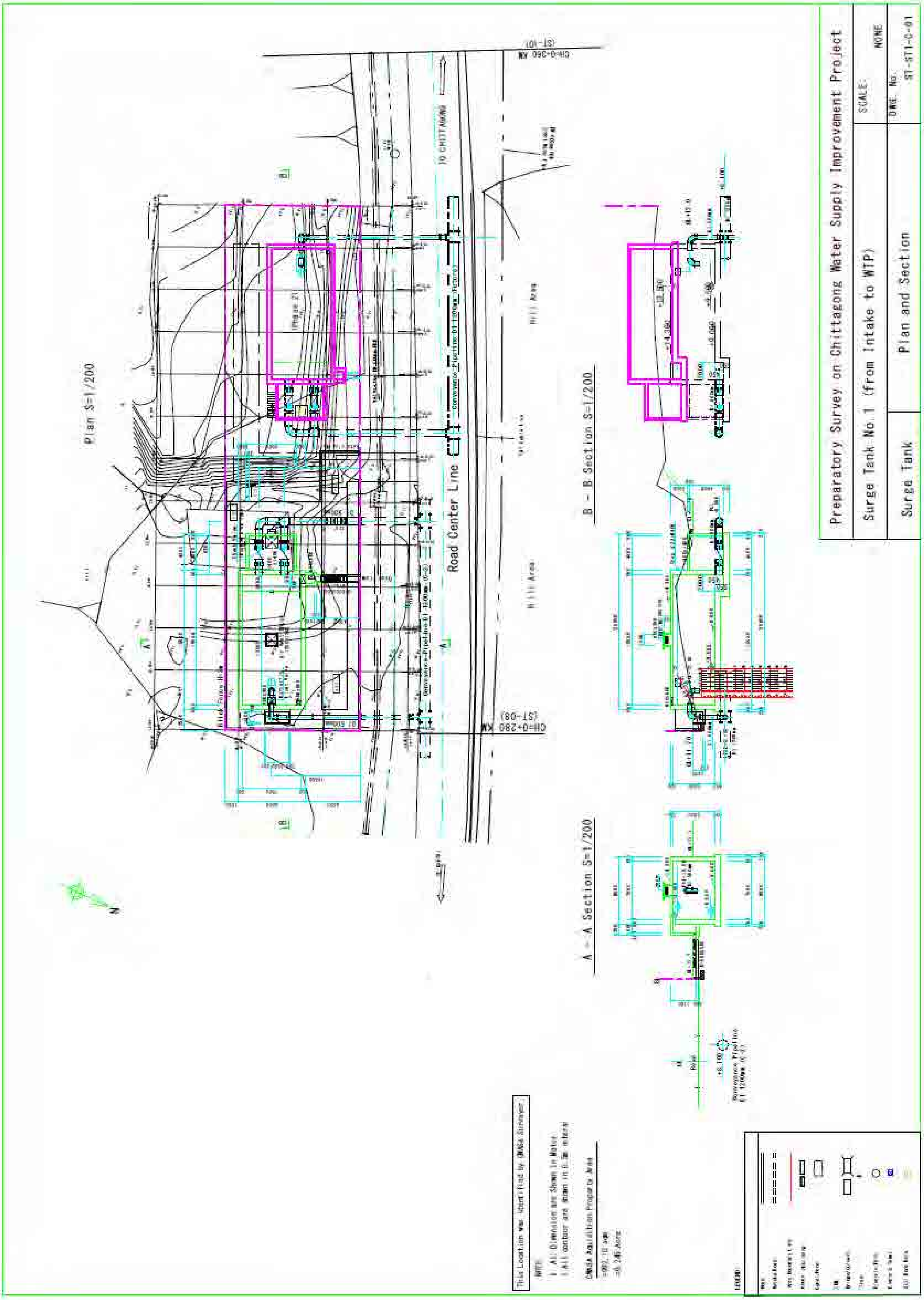
5. Intake Facilities; Process Flow Diagram



6. Intake / WTP Facilities; General Single Line

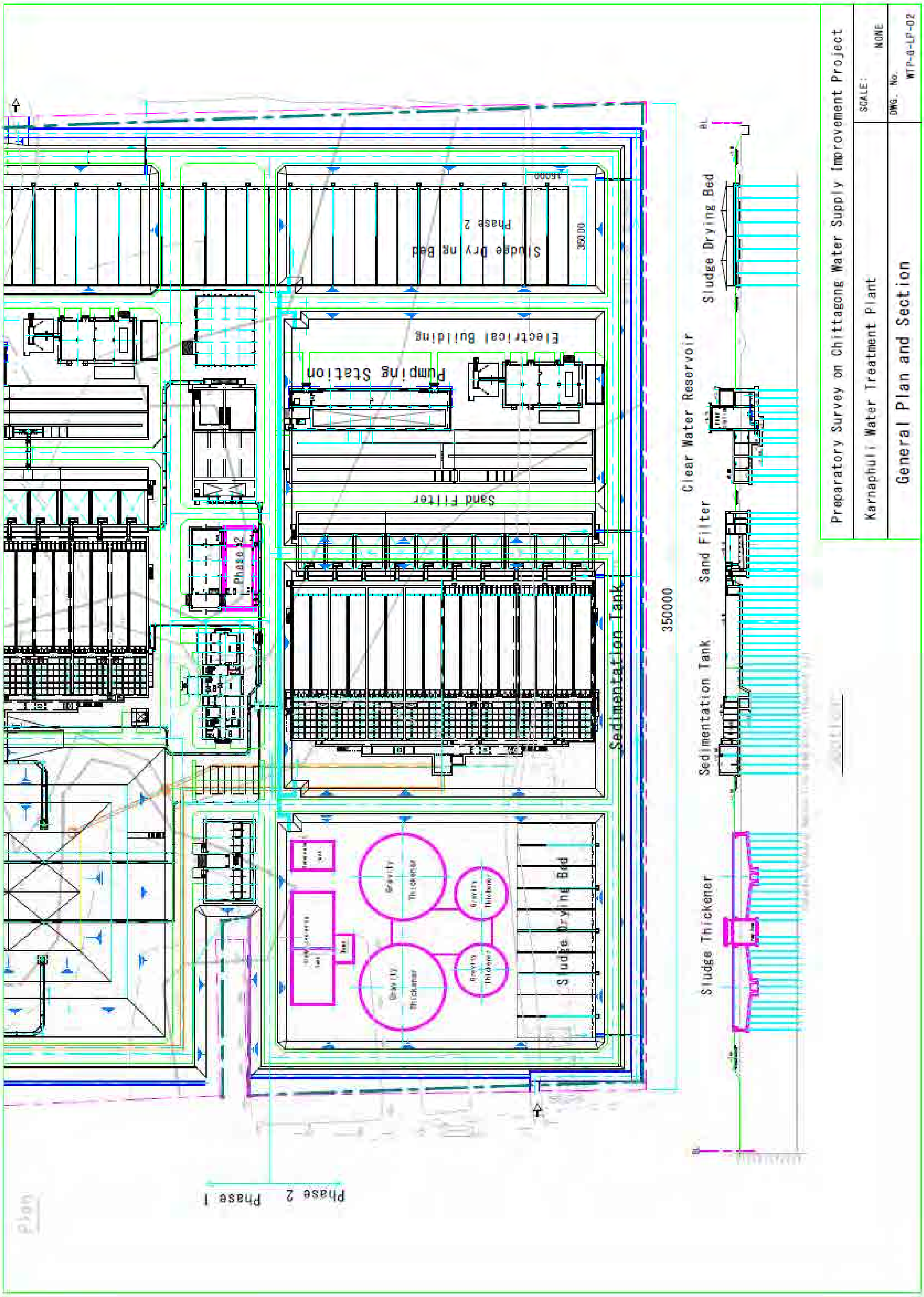


7. Surge Tank 1 (from Intake to WTP)

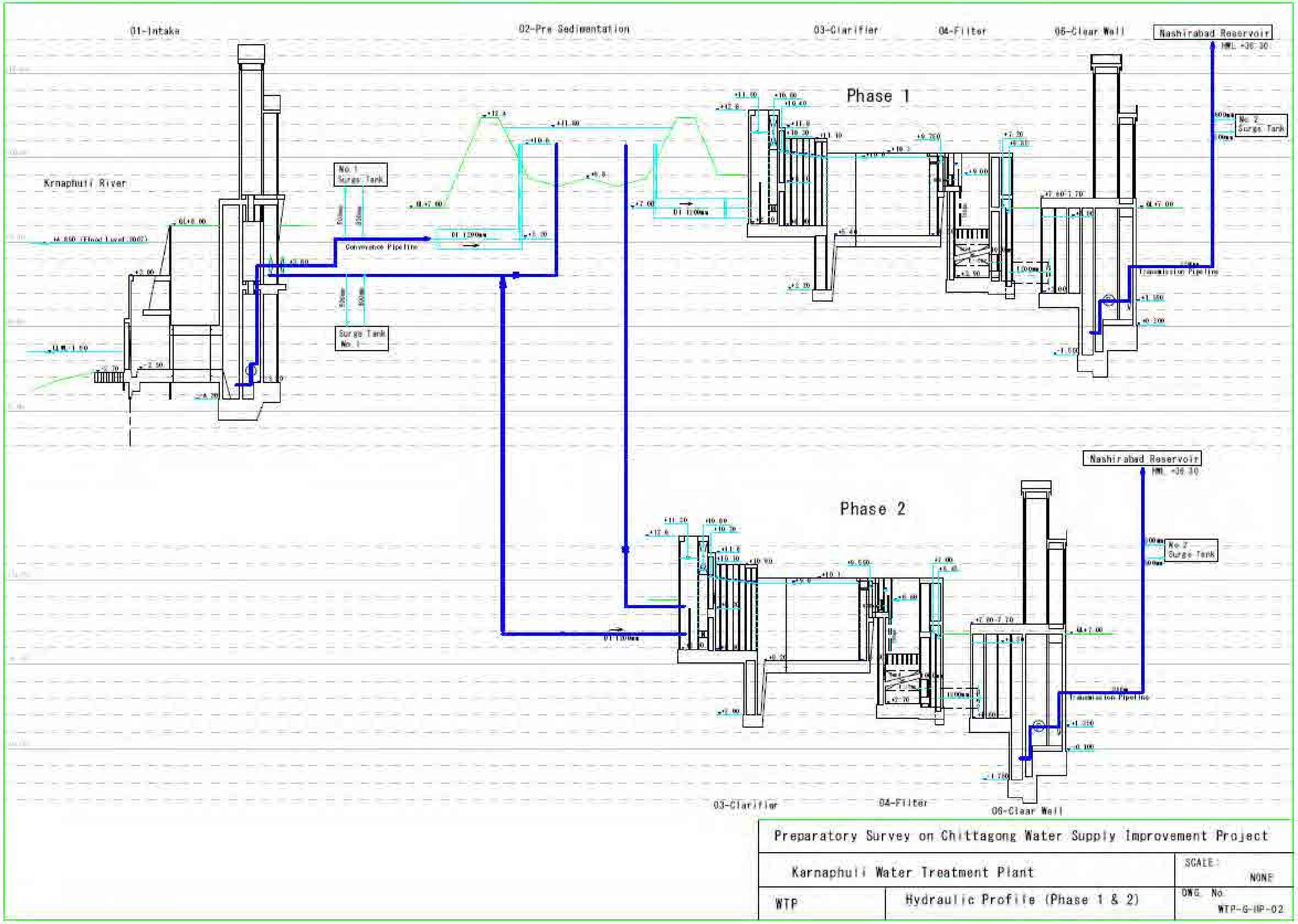


8. WTP; General Layout Plan

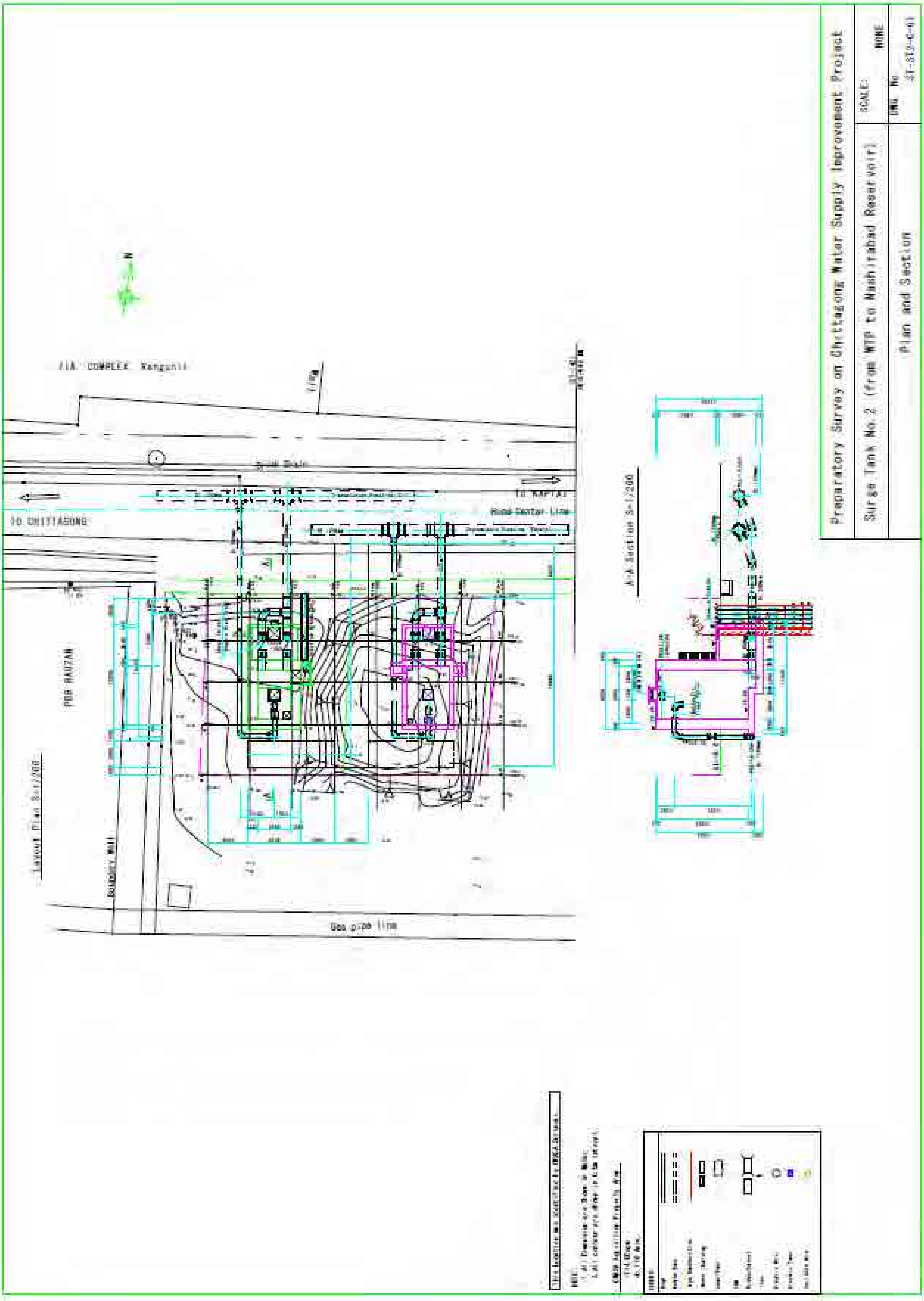
9. WTP; General Plan and Section



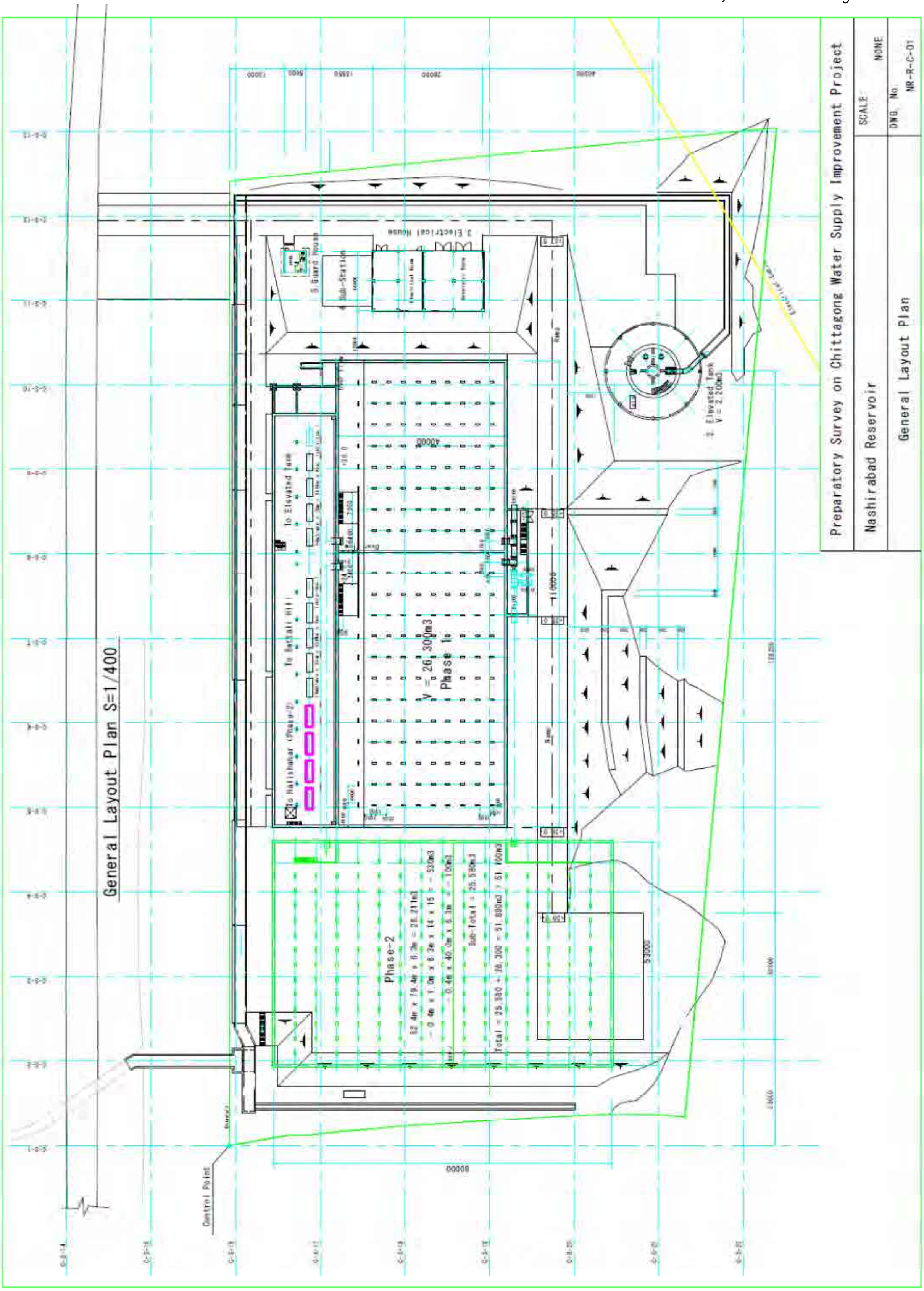
10. WTP; Hydraulic Profile (Phase 1&2)



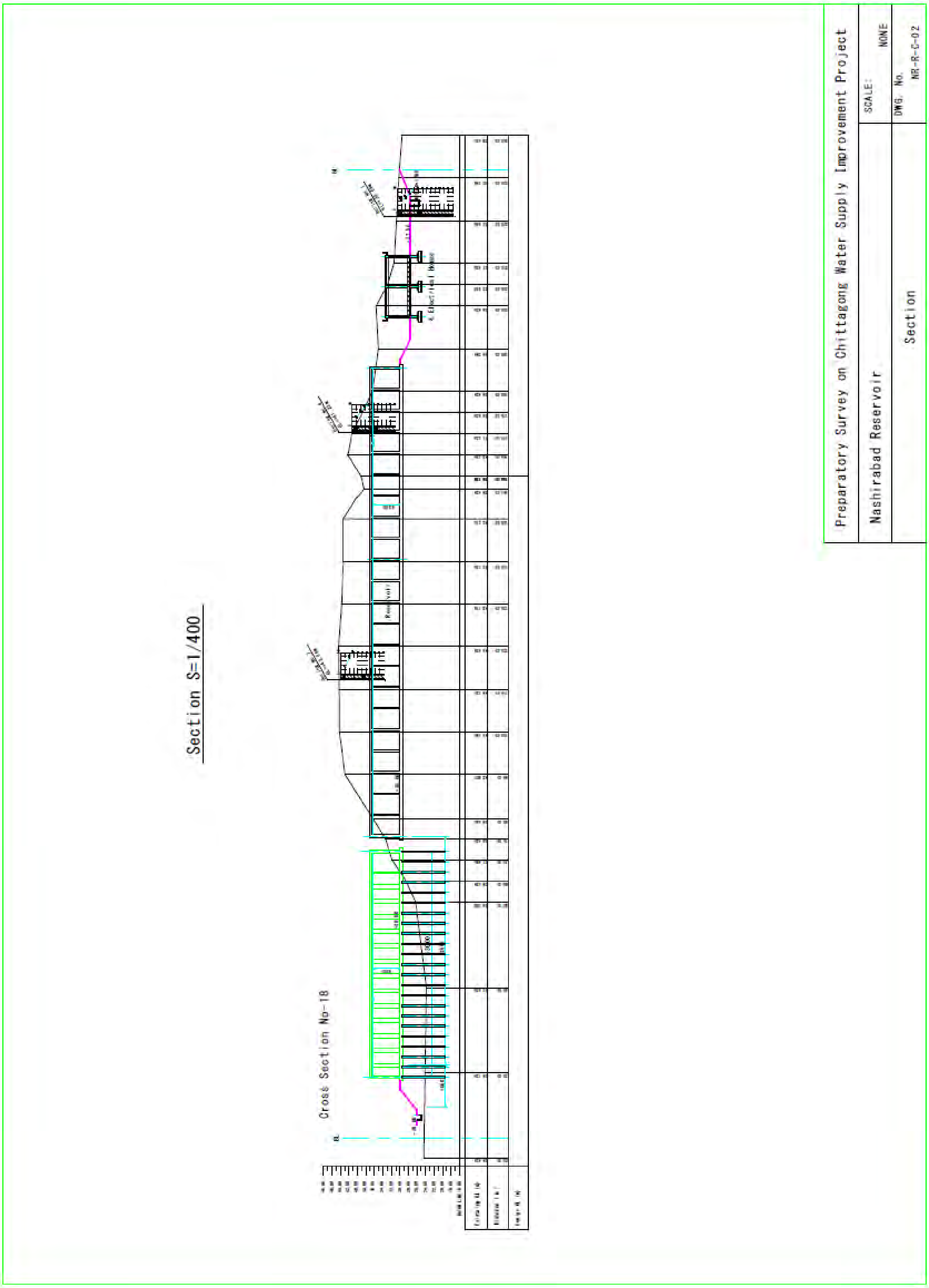
11. Surge Tank 2 (from WTP to Nashirabad Reservoir)



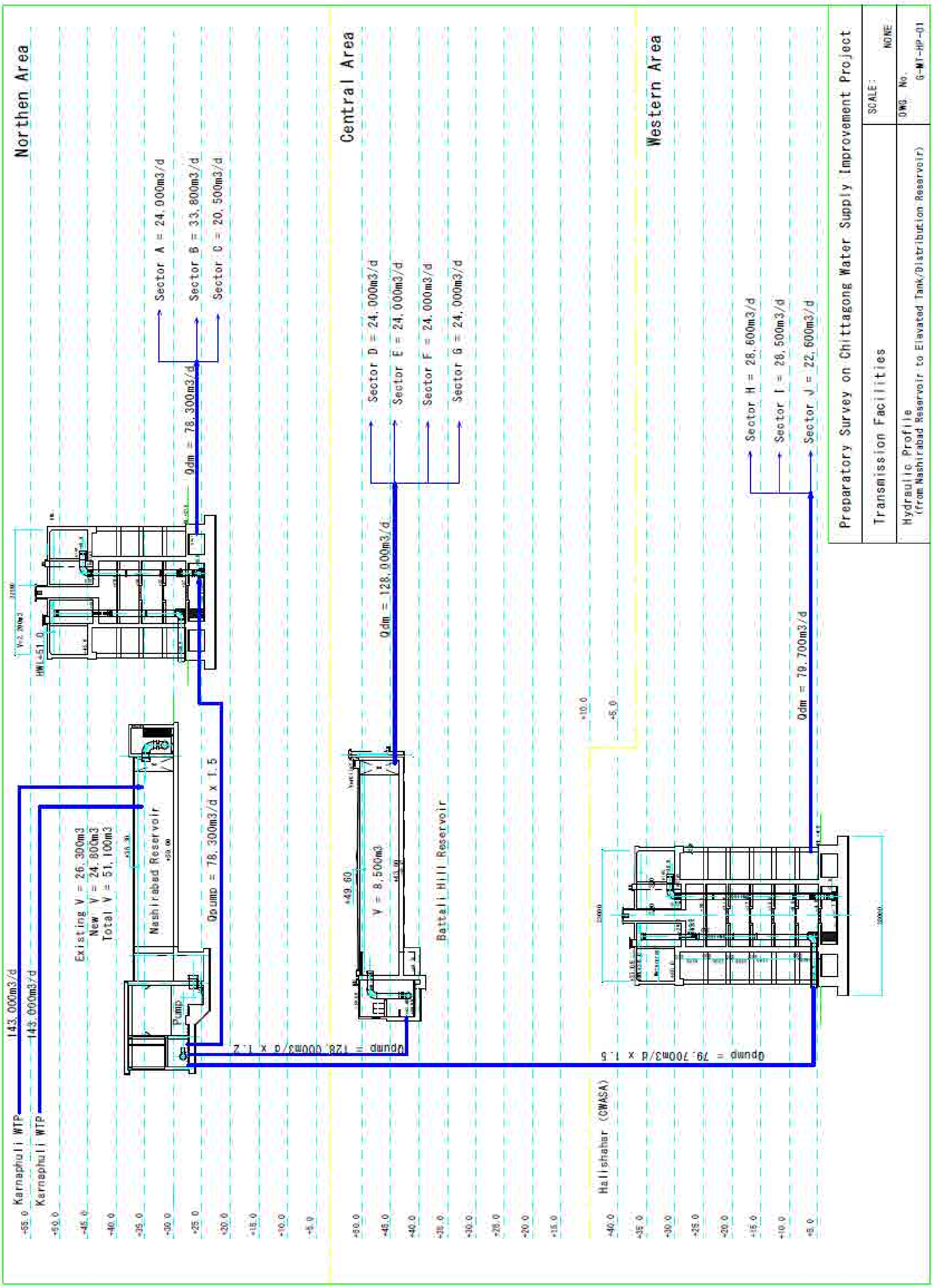
12. Nashirabad Reservoir; General Layout Plan



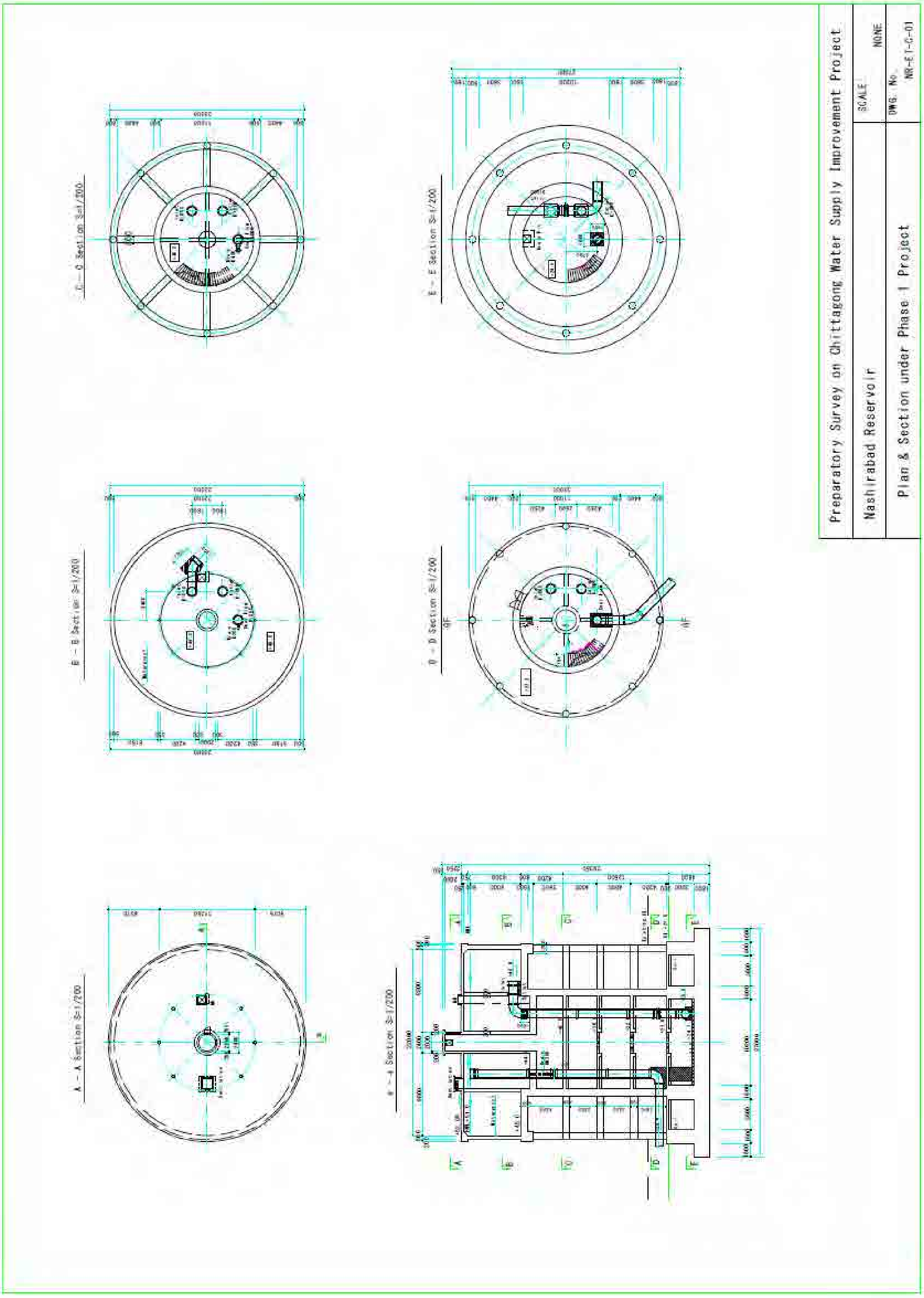
13. Nashirabad Reservoir; Section



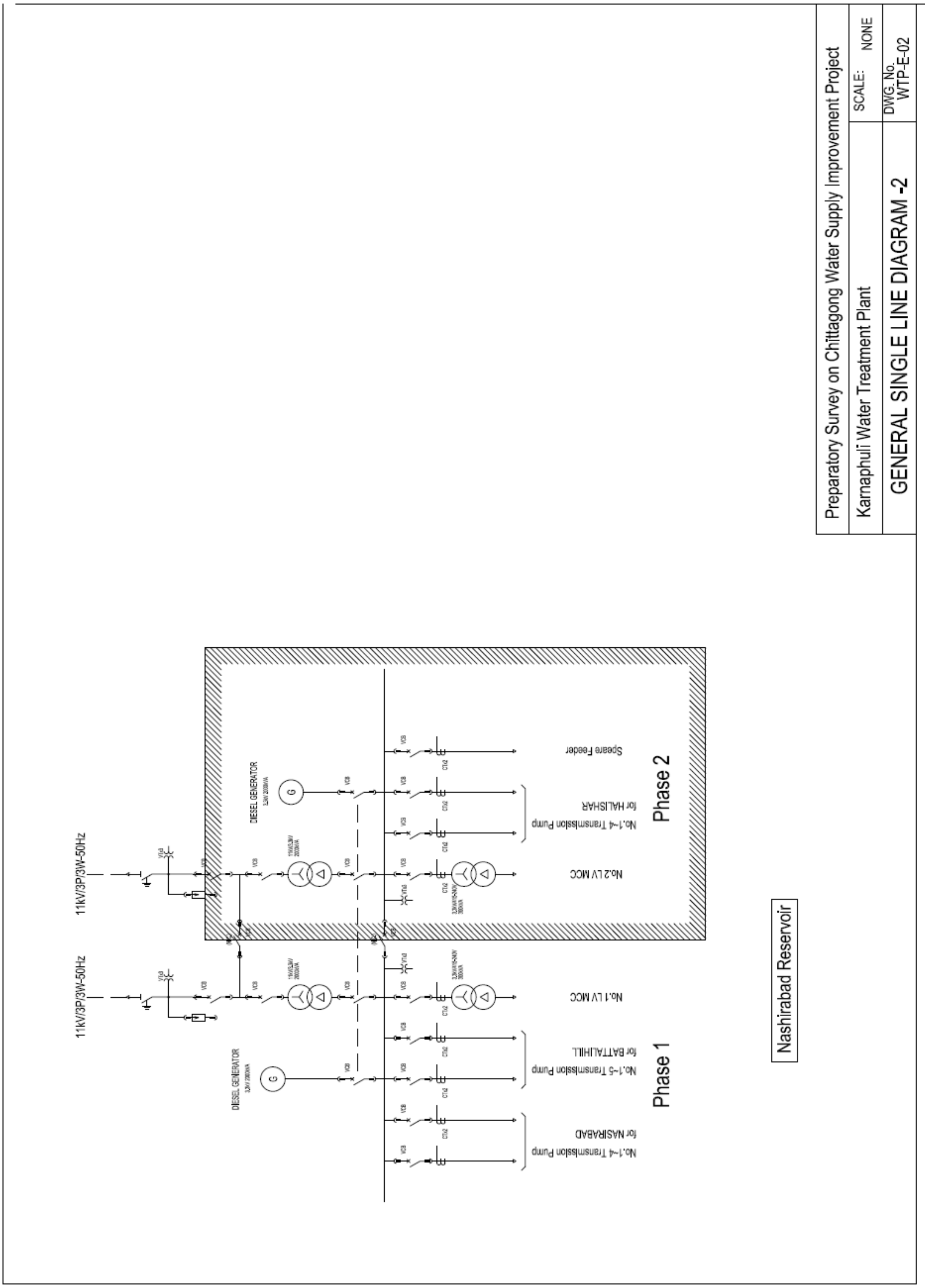
14. Hydraulic Profile from Nashirabad Reservoir to each Elevated Tank/Distribution Reservoir



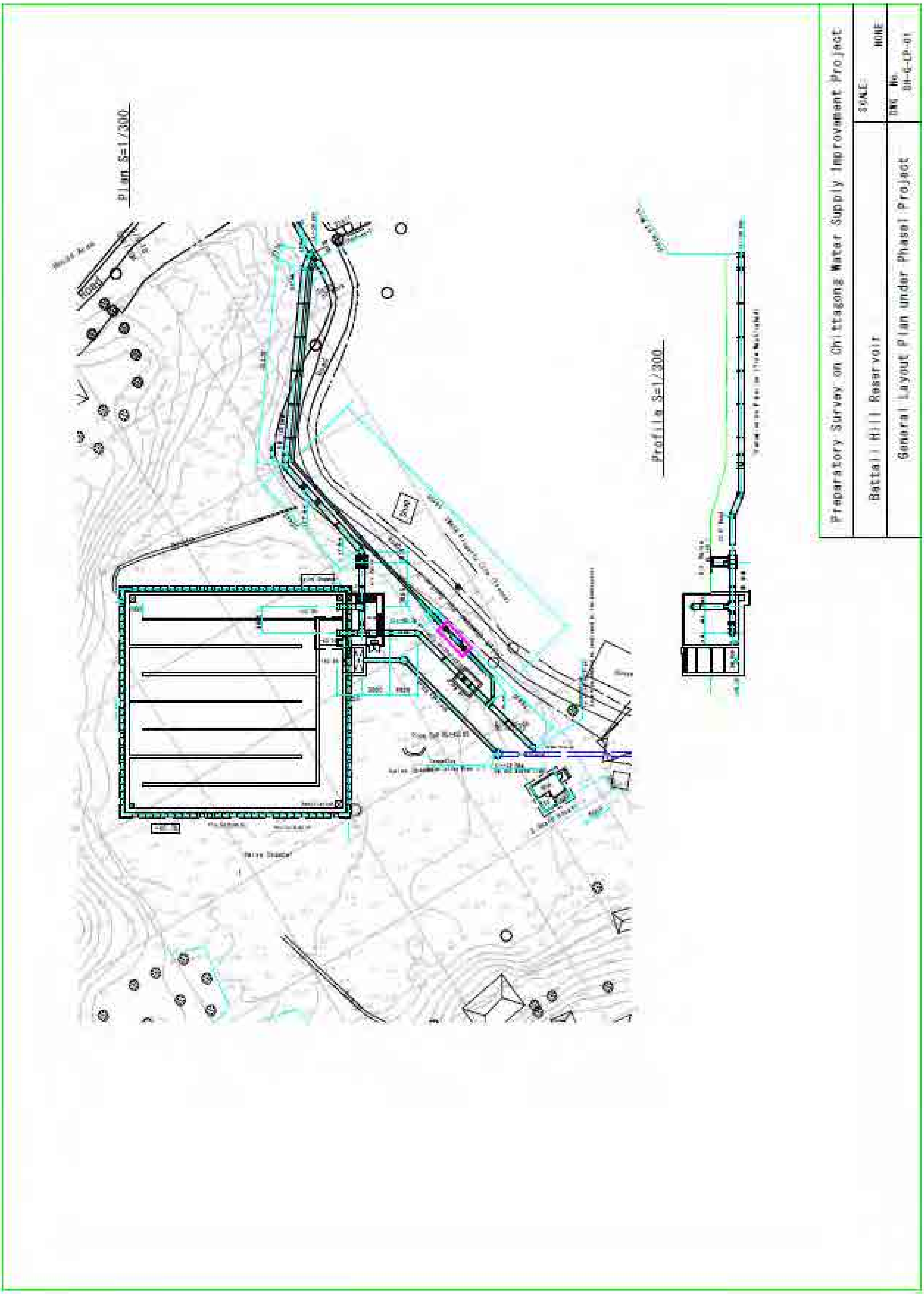
15. Nashirabad Elevated Tank (Phase 1 Project)



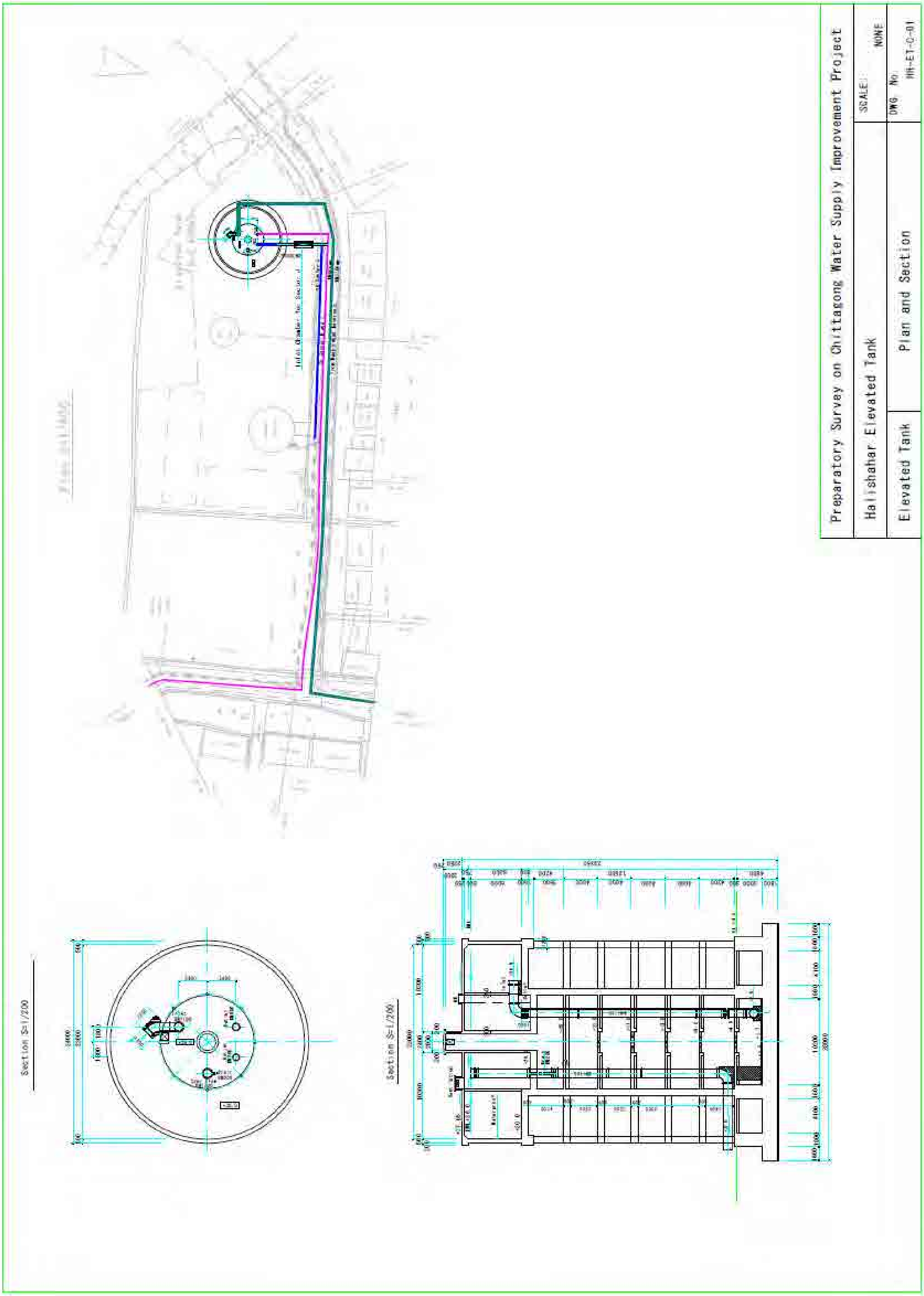
16. Nashirabad Reservoir; General Single Line Diagram



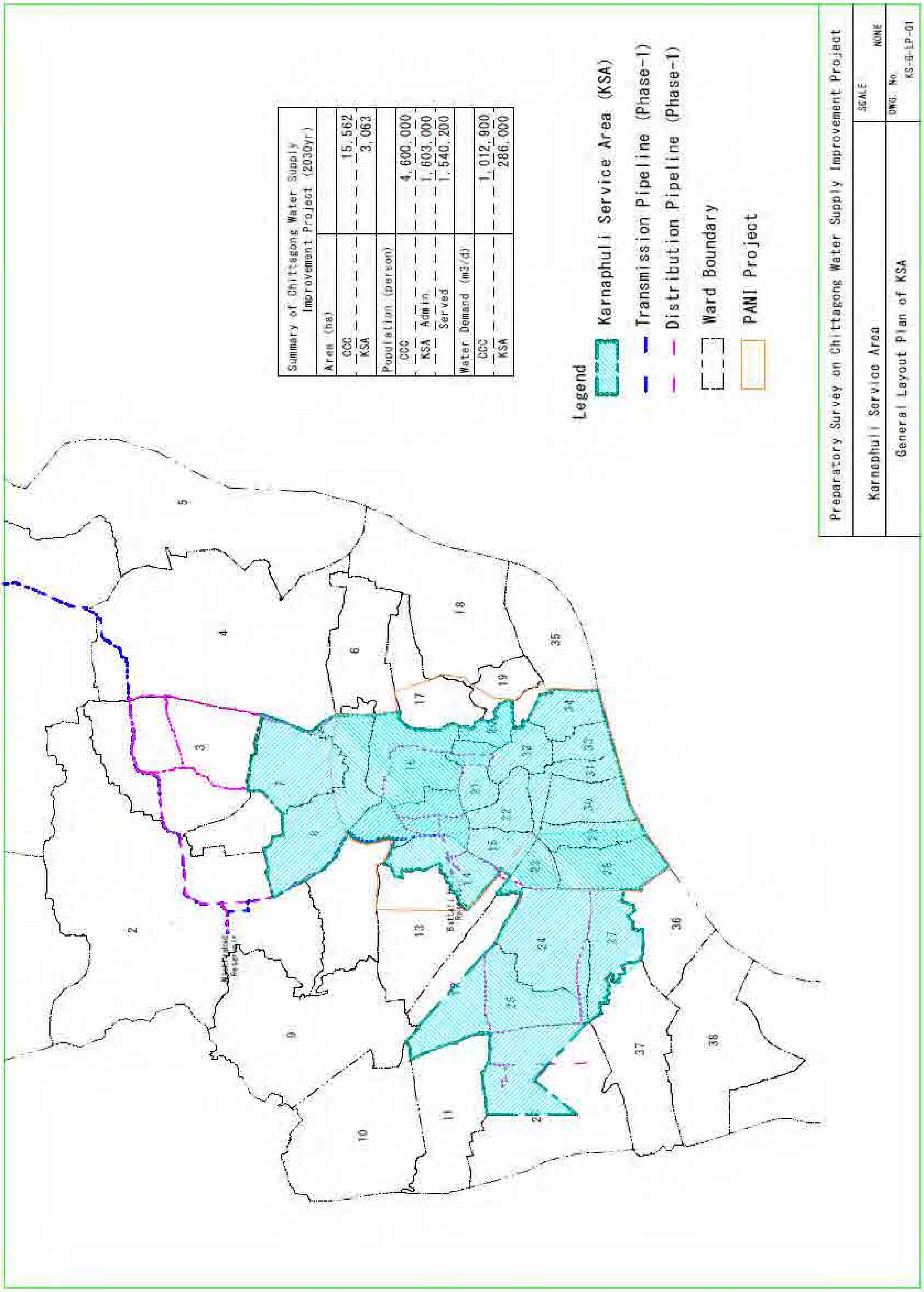
17. Battali Hill Reservoir (Phase 1 Project) and Location of Sector Inlet Chamber



18. Halishahar Elevated Tank; Plan and Section



19. General Layout Plan of KSA



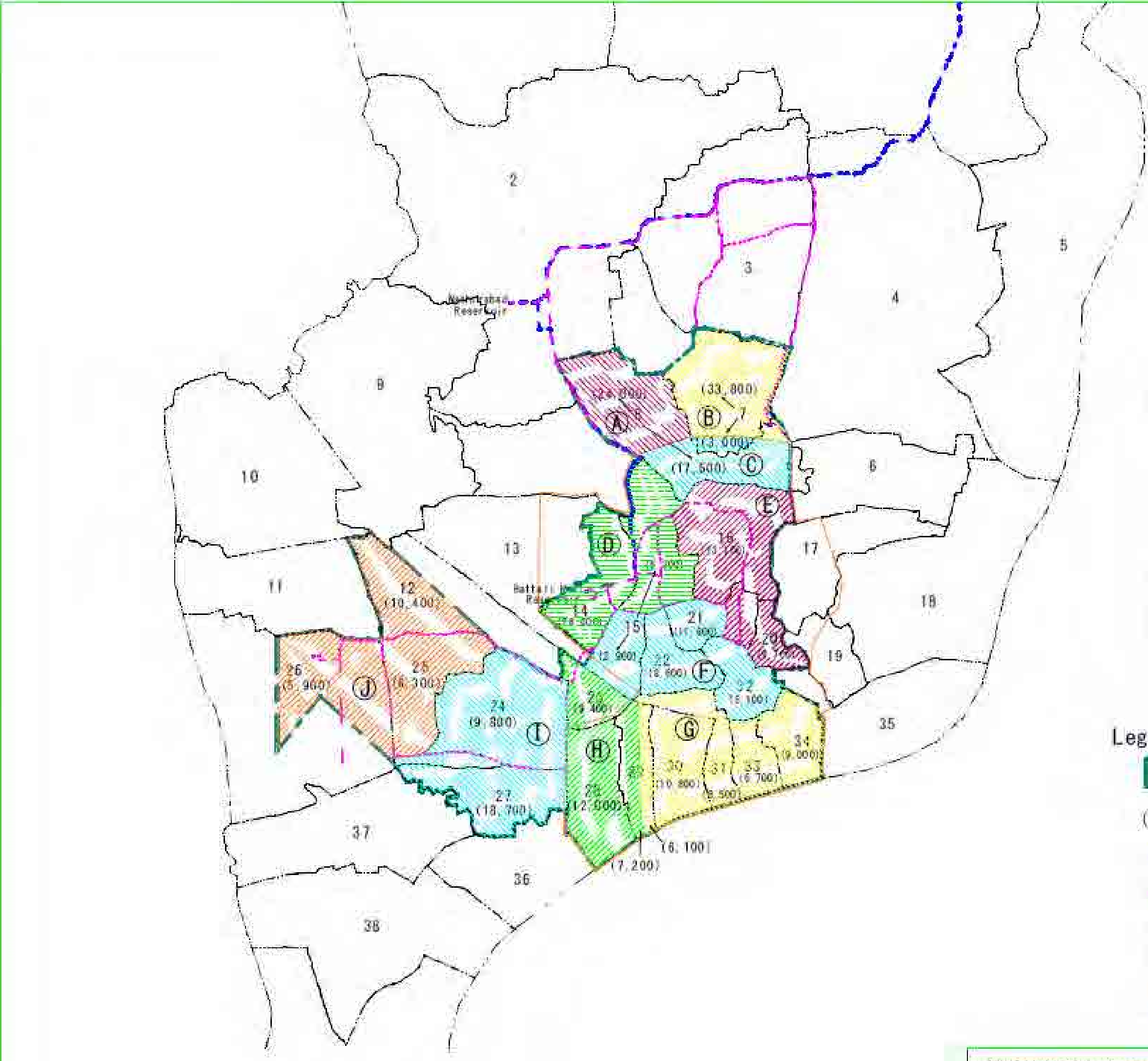
Summary of Chittagong Water Supply Improvement Project (2030yr)

Area (ha)		
CCC		15,562
KSA		3,063
Population (person)		
CCC		4,600,000
KSA	Admin	1,603,000
	Served	1,540,200
Water Demand (m3/d)		
CCC		1,012,900
KSA		286,000

Preparatory Survey on Chittagong Water Supply Improvement Project

Karnaphuli Service Area	SCALE NONE
General Layout Plan of KSA	DWG. No KS-G-LP-01

20. General Layout Plan of Sector



Water Demand in Sector (2030yr) (m3/d)

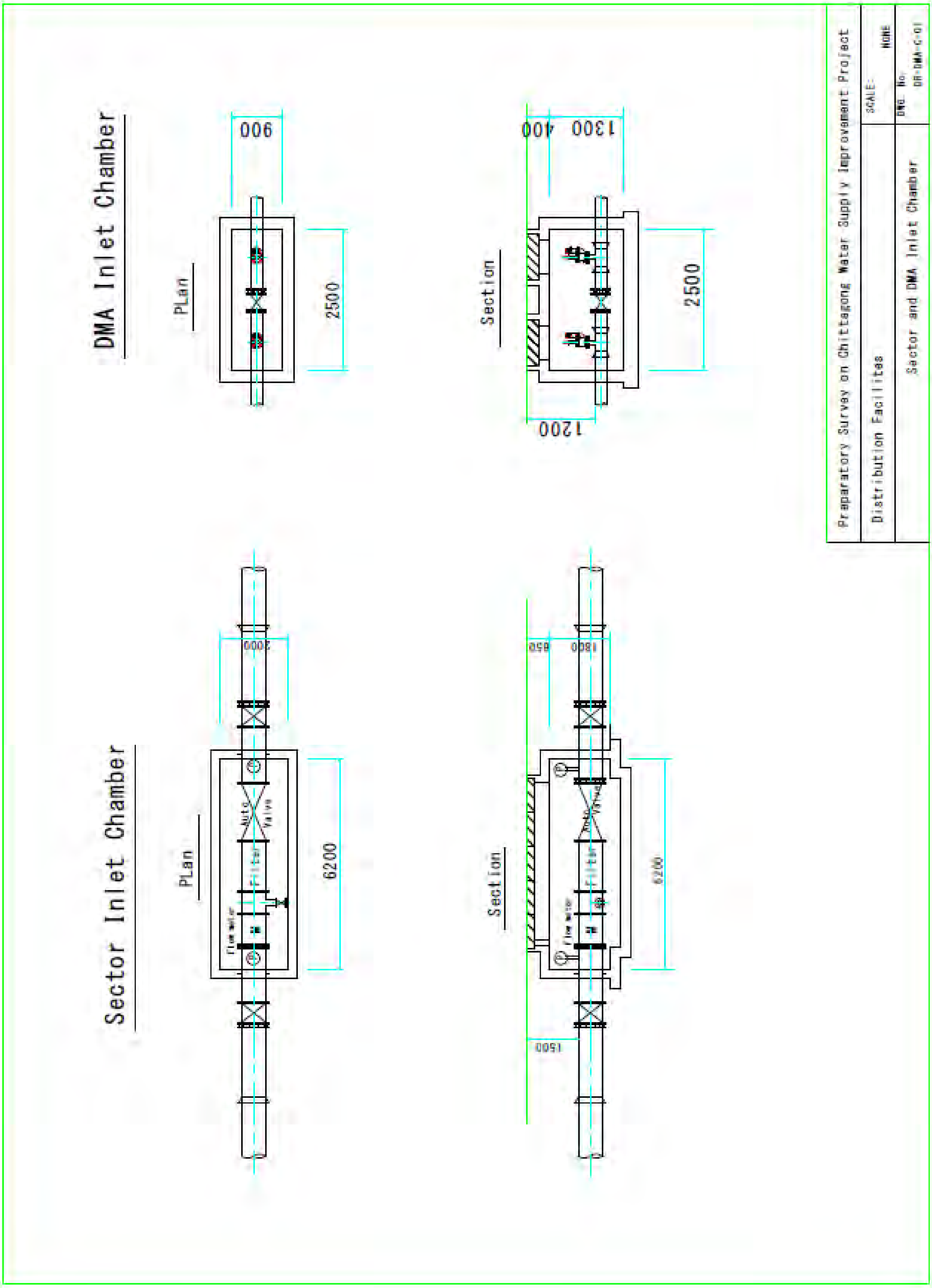
Sector	Ward Number	Qdmax	Qhmax
Ⓐ	8 (Part)	24,000	36,000
Ⓑ	7 (Part)	33,800	50,700
Ⓒ	7 (Part), 8 (Part)	20,500	30,750
Ⓓ	14, 15 (Part)	34,900	52,350
Ⓔ	16, 20	22,800	34,200
Ⓕ	15 (Part), 21, 22, 32	29,200	43,800
Ⓖ	29 (Part) 30, 31, 33, 34	41,100	61,650
Ⓗ	23, 28, 29 (Part)	28,600	42,900
Ⓘ	24, 27	28,500	42,750
Ⓙ	12 (Part), 25, 26 (Part)	22,600	33,900
Total		286,000	429,000

Legend

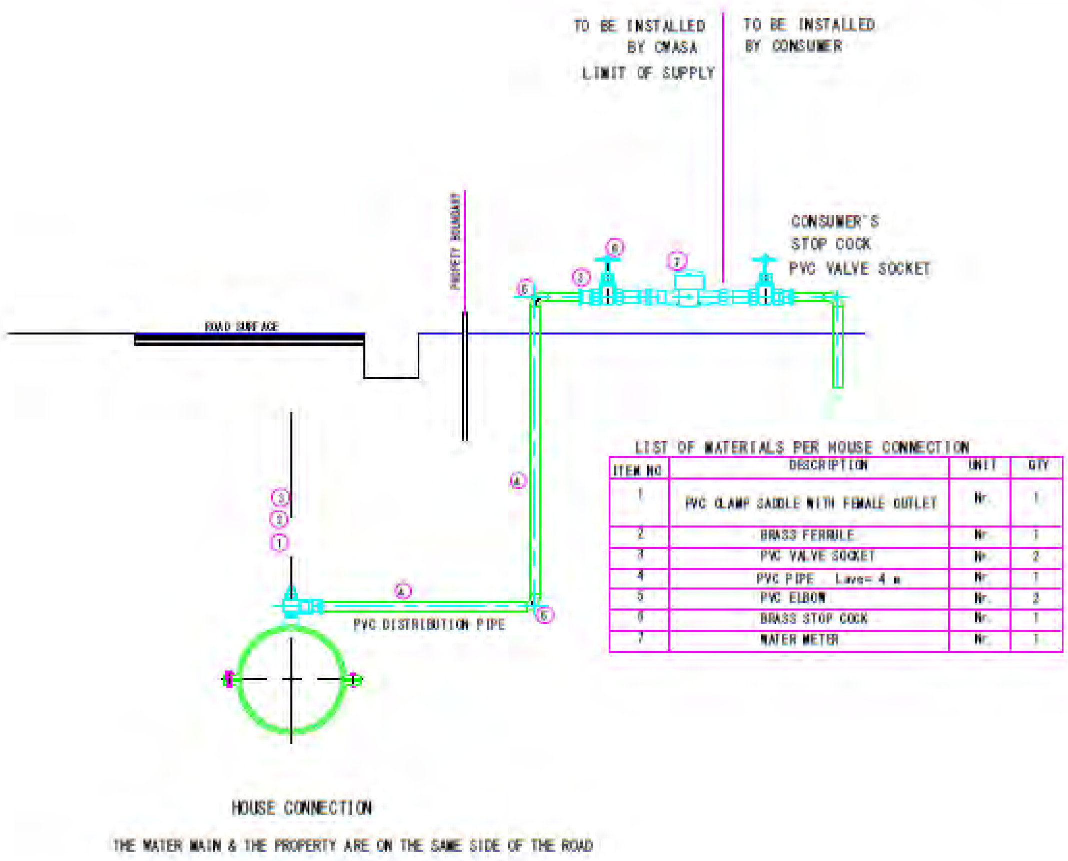
- ▭ Karnaphuli Service Area
- (36,800) (Daily Maximum Water Demand: m3/d)
- — — Transmission Pipeline (Phase-1)
- — — Distribution Pipeline (Phase-1)
- ▭ Ward Boundary
- ▭ PAN Project

Preparatory Survey on Chittagong Water Supply Improvement Project	
Karnaphuli Service Area	SCALE: NONE
General Layout Plane of Sector	DWG. No. KSA-G-KS-02

21. Sector and DMA Inlet Chamber



22. House Connection; Section



HOUSE CONNECTION

THE WATER MAIN & THE PROPERTY ARE ON THE SAME SIDE OF THE ROAD

LIST OF MATERIALS PER HOUSE CONNECTION

ITEM NO	DESCRIPTION	UNIT	QTY
1	PVC CLAMP SADDLE WITH FEMALE OUTLET	Nr.	1
2	BRASS FERRULE	Nr.	1
3	PVC VALVE SOCKET	Nr.	2
4	PVC PIPE Lave= 4 m	Nr.	1
5	PVC ELBOW	Nr.	2
6	BRASS STOP COCK	Nr.	1
7	WATER METER	Nr.	1

Preparatory Survey on Chittagong Water Supply Improvement Project

Distribution Pipeline

House Connection : Section

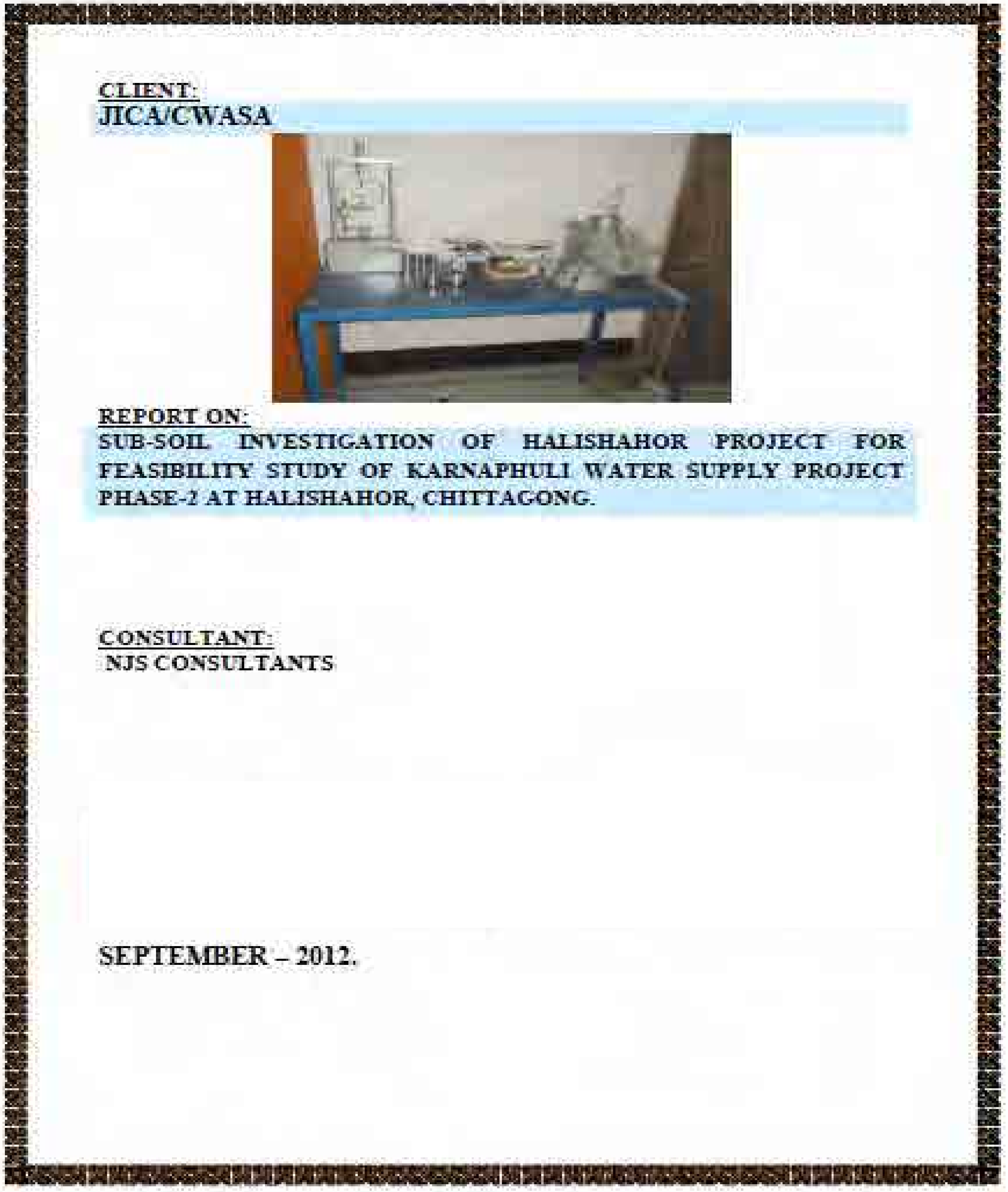
SCALE: NONE

DWG. No. DP-HC-C-01

II SOIL INVESTIGATION

II. Soil Investigation

II.1 Halishahar Site



CLIENT:
JICA/CWASA

REPORT ON:
SUB-SOIL INVESTIGATION OF HALISHAHOR PROJECT FOR FEASIBILITY STUDY OF KARNAPHULI WATER SUPPLY PROJECT PHASE-2 AT HALISHAHOR, CHITTAGONG.

CONSULTANT:
NJS CONSULTANTS

SEPTEMBER – 2012.

REPORT ON SUB-SOIL INVESTIGATION (Halishahar Site)

1.0 INTRODUCTION:

A reasonably accurate conception about the subsoil parameters of any project site is an essential priority for proper planning and designing the foundation of the concerned structure, So that the structure after its construction would remain safe and stable throughout its service period. Paying due considerations to JICA Survey Team**,** was agreed to offer the sub-surface investigation work of the same in favour of **BETS Consulting Services Ltd.**, Engineering Consultant, a well reputed geotechnical firm in Dhaka, Bangladesh.

According to work order of representative of the client, a detailed sub-soil study comprising execution of **3 (Three)** number borings up to **19.5-21.0m**deep, including the different field and laboratory tests was carried out and results analysis, report preparation & report submission etc had been undertaken and all official correspondence carried out by BETS, during the period of **SEPTEMBER-2012.**

2.0 METHODOLOGY:

BETS sent one SPT Test team for field test at the site. According to the work order, Team Leader of SPT Test team contacted with representative of client forrecognizing the selected land and locations for field test. The location of bore holes was selected in presence of the representative of client.

3.0 CLIENT:

JICA Survey Team.
NJS CONSULTANTS

4.0 LOCATION:

HALISHAHOR, CHITTAGONG.

5.0 SCOPE OF WORK:

The main scopes of this investigation work are:

a. Execution of exploratory borings, recording of sub-soil stratification and position of ground water table.
b. Execution of standard penetration test (**SPT**) at an interval of **1.5m** depth with collection of disturbed soil samples up to final depth exploration of each boring.
c. Collection of 1 nos. undisturbed soil samples by thin walled Shelby tubes for each bore hole.
d. Preparation of final report with all works including detailed description of soil stratification sub-soil.
e. From the field tests and laboratory tests, scope of calculation for bearing capacity values for design shallow foundation.
f. For loose and soft strata, from the field test and laboratory tests, scope of calculation for skin friction and bearing values for design deep foundation.

6.0 FIELD WORKS:

All the field works and field tests were conducted as per standard procedure as laid down in ASTM specification are as follows:

6.1 EXPLORATORY BORING DRILLING:

Drilling was executed by wash boring method. A hole was started by driving vertically a 4” diameter steel casing into the ground to some depth and then the formation ground casing was broken up by repeated drops of a chopping bit attached to the lower and of drilling pipe. The upper end of the same was forced at high pressure through pressure pipe. Forced slurry or water emerges at high velocity through the pores of the chopping bit, and returns to the surface through the annular space between drilling pipe and the side of the casing or hole, carrying with it the broken-up soil. In this way drilling is advanced up to a level of 6” above the depth, where SPT has to be executed.

6.2 STANDARD PENETRATION TEST:

Standard penetration Tests have been executed in all the bore holes at 1.5m. intervals of depth up to the final depth of in this test, a split spoon sampler of 2” out diameter and 1-3/8” inner diameter, is made to penetrate 18”, for boring. Into the soil by drops of a hammer weighing 140lb. failing freely for a height of 30 inches. Number of blows of hammer required for penetration of each 6” length of the sampler is recorded. The number of blows last 12” penetration of the total 18” is know as the standard penetration value (N-values) as specified by ASTM and is plotted the SPT value of the particular depth.

6.3 EXTRACTION OF SOIL SAMPLE:

The Disturbed soil samples were collected at 1.5m. intervals and at every change of soil strata split spoon sampler. These soil samples were studied visually and the soil classification were done to prepare strata chart of soils up to the explored depth. Before collection of samples, the hole is washed and cleaned the drill pipe with the help of an adapter and is lowered into the hole. The sampler is then pressed down into the ground in one rapid continuous movement until the tube, except 4inches from the top is filled with soil sample.

Undisturbed soil samples were collected at a depth where layer of soil is changed such as 8ft to 12ft.Undisturbed soil samples area collected by means of thin walled sharp ended 3inch dia.stationary piston sampler from the cohesive soil formation. The collected tubes were then labeled with detailed job designation, date and shifted the laboratory for testing.

7.0 LABORATORY TESTS:

All Laboratory Tests conducted on soil samples collected either in the disturbed or in the undisturbed state. All tests were done as per ASTM procedures, are as follows:

7.1 NATURAL MOISTURE CONTENT:

The water content of a soil sample is the ratio of the weight of the water in the sample to its dry weight. It is usually expressed as a percentage. The soil sample is weight both in natural state and in over dry state and the moisture content is calculated by dividing the loose of weight of the sample by its dry weight.

7.2 COMPLETE GRAIN SIZE ANALYSIS:

The object of grain size analysis is to determine the size of the soil grains, and the percentage by weight of soil particles of different particles size, comprising a soil sample. The process consists of either sieve analysis or hydrometer analysis or both. The hydrometer analysis is adopted for sample passing sieve No. 200. For hydrometer analysis, a 40 gms of the over dry sample, is thoroughly mixed with required quantity of water in a calibrated glass cylinder. In order to avoid flocculation, a little dispersing agent is added. The density of the suspension is measured at specified time intervals, by means of a hydrometer or special design. At any particular time the size of the largest particle remounting in suspension at the level of the hydrometer can be computed by means of stocks Law, where as he weight of the particles finer than that size, can be computed from the density of the suspension at the same level.

The mixture is washed through U.S standard sieve No. 200 and the fraction retained is dried. The fraction retained on each sieve is weighed for calculation of the percentage of different fraction. The results are represented by cumulative curves plotted on semi-logarithmic graph paper.

7.3 ATTERBERG LIMITS:

Physical properties of clay are greatly influenced by water content. A given soil behave as a fluid or a soil or, as a plastic materials, depending on how much water its contains. The water contents that correspond to the boundaries between the states of consistency are called as the Atterberg limit.

Liquid Limit is the minimum water content at which a clay soil just starts behaving like a fluid. It is determined with the help of a standard limit device which consists of brass cup and an arrangement to impart blows to cap at a uniform rate. The water content at which 25 blows are required is termed as the limit.

The plastic limit is the minimum water content at which a soil is just plastic and is determined by rolling out a soil sample at slowly decreasing water content until, the desired water content is reached, at which a thread of 3mm diameter just begins to crumble. The thread is rolled on glass plate with hand.

7.4 SPECIFIC GRAVITY TEST:

The specific gravity of soil particles (Gs) is defined as the ratio of the mass of given volume of soil particles to the mass of an equal volume of water at 40C. The specific gravity of a solid for most natural soils falls in general range of 2.60 to 2.80. To determine the specific gravity of soil sample, 25 grams of over dried soil sample is thoroughly pulverized and is placed in a calibrated psychomotor. Water is poured inside the pycnometer until its top is slightly below the calibrated mark. The mixture is then boiled thoroughly in order to eliminate all the air bubbles. More water is then added to the mixture till it over-night, the temperature is then recorded and the bottle is weighed.

The specific gravity Gs is given by:

$$Gs = \frac{\mathbf{Gt . Ws}}{\mathbf{Ws - W_1 + W_2}}$$

Where,

Gt = Specific gravity of water at TOC.
W_S = The weight of over dry soil (25gms.)
W_1 = Weight of flask + soil + water.
W_2 = Weight of flask + water.

7.5 DIRECT SHEAR TEST:

Direct shear test can be performed for both cohesion less & cohesive soil to determine shear strength, angle of internal friction, cohesion c, volume change etc. The test is done in a direct shear machine which consists of a normal loading device; shearing displacement of approximately 10mm per minute is often for a sample used for a sample thickness of about 1.2cm.

The results of a direct shear test on a cohesion less & cohesive soil can be presented in a summary table & by stress-strain curve. A stress-strain curve normally consists of shear stress, various shear displacement for both the undisturbed and the remolded test under a specified normal load the normal load usually varies from 1/3kg/cm^2 to 1kg/cm^2. Another curve of normal stress verses shearing stress will give angle of internal and cohesion for cohesive soil.

7.6 UNCONFINED COMPRESSION TEST:

Unconfined compression test is a simple method for determination of shearing strength of cohesive soil which is important to determine the bearing capacity of soil. As the name implies, the lateral confining pressure in an unconfined compression test is kept zero, unsupported specimen and at failure is measured. The specimen is prepared from the undisturbed soil sample by carefully trimming it to a cylindrical shape of 7cm height and 3.5cm dia. The specimen is then placed on the level pedestal of the unconfined compression apparatus in a vertical position. The load is applied axially on the top of the specimen an is distributed uniformly over surface of the specimen with the help of double providing ring assembly fitted with a strain gauge, fitted with the apparatus. The load is applied at such a rate that the vertical deformation of the sample is nearly 2% (two percent) per minute in order to avoid and drainage during compression. The load is kept increasing until the specimen fails along shearing plane. The maximum load at failure knows as the unconfined compressive strength of the sample the shearing strength of the sample is half of the unconfined compressive strength.

7.7 CONSOLIDATION TEST:

The gradual process of compression of soil under the action of static load and with decrease of void ratio due to expulsion of water from the soil pores is termed consolidation The phenomenon compressibility characteristics of a soil as the period and magnitude of settlement of a foundation depends on these characteristics. The test is performed on a specimen of circular shape of 6.35cm dia and 2.54cm thickness, the specimen is prepared from the undisturbed sample by carefully trimming it to the required dimension with the help of a cutting edge and wire saw.

The specimen is then placed in the consolidation ring and its top and bottom are trimmed off level with that of the ring .The specimen along with the ring on the top and the other at the bottom of the specimen. The load is then applied on porous stone and on the specimen with the help of a level arrangement with the apparatus.

Decreases in volume of specimen are read from a strain gauge attached to the consolidation unit at specified time intervals the consolidation unit is always kept full with water in order to avoid evaporation of the specimen. The load increment is allowed after each twenty four hours, The observed reading are then plotted on semi-logarithmic graph paper to give the pressure-void ratio curve from which compression index, Cc Can be calculated. Cc is important factor governing the settlement process of underlying soils.

8.0 SOIL COMPOSITION:

8.1 DESCRIPTION OF SOIL COMPOSITION:

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

Trace fine sand	: 1 to 10% fine sand.
Little silt	: 11 to 20% silt.
Some clay	: 20 to 35% clay.
Sandy silt	: 35 to 50% sand & 50 to 70% silt.
Clayey silt	: 35 to 50% clay & 50 to 70% silt.
Silty sand	: 35 to 50% silt & 50 to 70 % sand.

9. 0 CORRELATION TABLE OF SOILS BASED ON SPT-VALUES:

Two tables for Cohesion-less and cohesive soils based on N- Values as below:

9.1 values of Unit Weight and Angle of Internal Friction of Cohesion-less soil Based on N-Values (After K. Terzaghi and R. B. Peck):

Table No. 1.

N-Values	Condition	Relative Density	Angle of Internal Friction	Moist Unit Wt. in gm/cc.
0-4	Very loose	0.0-0.2	25^0-30^0	1.12-1.60
4-10	Loose	0.2-0.4	30^0-35^0	1.44-1.84
10-30	Medium	0.4-0.6	35^0-40^0	1.76-2.08
30-50	Dense	0.6-0.85	40^0-45^0	1.76-2.24
Over 50	Very dense	1.00	45^0	2.08-2.40

The tabulated values apply for dry/moist cohesion less sand. For silty sands the bearing capacity values must be reduced by study of grain size classification and applying judgment. Correction for water table close to bottom of foundation the bearing values should be reduced to half. The bearing values are, however, not affected by the water table at a depth greater than 1.5B below foundation level, B being least dimension of the bottom of foundation. Bearings values for intermediate position of water table may be reduced by liner interpolation.

9.2 Values of approximate Unconfined Compressive Strength Based on N-Values for Cohesive Soil (After K. Terzaghi and R.B. Peck):

Table No.- 2.

N-Values	Condition	Unconfined compressive Strength in Kg/cm^2.
Below 2	Very soft	Below 0.25
2-4	Soft	0.25-0.50
4-8	Medium	0.50-1.00
8-16	Stiff	1.00-2.00
16-32	Very stiff	2.00-4.00
Over 32	Hard	Over 4.00

In the above table the shear strength of cohesive soil is equal to 1/2 of unconfined compressive strength and the angle of shearing resistance is equal to zero. It should be remembered that the correlation for cohesive soil is always much reliable.

10.0 PHYSICAL PROPERTIES:

Physical Properties of the subsoil formation of the project area have been evaluated by the execution of **3(Three)** number borings of **19.5-21.0m** deep (firm strata). The overall physical properties may be summarized as follows:

10.1 STRATIFICATION OF SOIL:

The top soil is light brown soft to medium clay, some silt the underlying soil is grey coarse sand, trace silt.

10.2 CONSISTENCY/COMPACTNESS:

Up to the depth of EGL to 6.0m, consistency of the top soil usually varies from soft to medium consistency of soil, however, gradually increase the consistency. The subsequent deep layers stiff to medium stiff soil state.

10.3 GROUND WATER TABLE:

The position of Ground Water Table (GWT) is about (-) **0.0-0.60m** from existing ground level.

10.4 Natural Moisture Content, Unit Weight, Specific Gravity and Liquid Limit:

Table No .3 Name of the Laboratory Test:

Name of the Soil Test
Natural Moisture Content
Natural Unit Weight
Dry density
Specific Gravity
Liquid Limit
Plasticity index
Grain Size Distribution
Direct shear test
Consolidation test
Unconfined compressive test

11.0 ENGINEERING PROPERTIES:

The engineering properties of soil, including the cohesion, compressibility and the angle of internal granular friction have been determined by performing laboratory tests on the soil samples collected during field investigation. These are as follows:

11.1 COHESION: The values of cohesion, as reported from the performance of unconfined compression tests from Laboratory Test Sheet.

11.2ANGLE OF INTERNAL FRICTION:
The angle of internal friction values of the investigated of soil, as reported form the performance of direct shear test from Laboratory Test Sheet.

11.3 COMPRESSIBILITY: The top layer of plastic silty soil usually has been observed moderately compressible in nature by consolidation tests from Laboratory Test Sheet.

12. 0 EVALUATION OF BEARING CAPACITY:

12.1 BEARING CAPACITIES OF THE SHALLOW CONDITION FROM THE SPT:

The Bearing capacities of the shallow foundation particularly for the top layer of cohesive soil may be estimated from the SPT values, as suggested by Terzaghi, according to the following table.

Table No.- 4: Bearing Capacities of the shallow foundation (Values in kg/cm^2, F. S. =2.50):

SPT range	Allowable Bearing Capacity (Tsf)	
	Continuous Footing (B=4ft)	Isolated Column Footing (B=8ft)
0-2	0.00 - 0.225	0.00 - 0.30
2-4	0.225 - 0.45	0.30 - 0.60
4-8	0.45 - 0.90	0.60 - 1.20
8-15	0.90 - 1.80	1.20 - 2.40
15-30	1.80-3.60	2.40-4.80
>30	> 3.60	> 4.80

Note:
a. width = 4ft for strip footing and width = 8ft for isolated footing respectively.
b. The above values are the net allowable Bearing capacities.
c. The cohesive soil has been considered in a saturated condition.

12.2 BEARING CAPACITY OF THE SHALLOW FOUNDATION FROM THE SOIL PARAMETERS:

The bearing capacities of the shallow foundation may more appropriately be determined from the parameters of soil such as the values of cohesion and the angle of internal friction as obtained from the performance of laboratory tests. These have been done considering the general equations of the Bearing capacity of the foundation as suggested by Terzaghi. The evaluated values are provided in the following Table no. 5, and Table no.6

Table No. 5. Bearing Capacities of the Shallow Foundation from Field and Laboratory Test (Values in kg/cm^2, F. S. = 2.50):

Bore Hole	**Depth in m**	**Field SPT**	**Cohesion kg/cm^2**	**Bearing Capacity (kg/cm^2)**	
				For strip Foundation	**For circular or square footing**
BH-01	1.5	5	0.23	0.56	0.75
	3.0	1	0.05	0.11	0.15
	4.5	4	0.18	0.45	0.60
	6.0	7	0.32	0.79	1.05

BH-02	1.5	2	0.09	0.23	0.30
	3.0	1	0.05	0.11	0.15
	4.5	1	0.05	0.11	0.15
	6.0	12	0.55	1.35	1.80
BH-03	1.5	4	0.18	0.45	0.60
	3.0	3	0.14	0.34	0.45
	4.5	2	0.09	0.23	0.30
	6.0	14	0.64	1.58	2.10

Table No.6: The Skin Friction and the End Bearing Capacities of Piles (F.S. =2.50)

Depth m	BH-01					BH-02				
	N	N_{cor}	Cu kg/cm^2	f_s kg/cm^2	f_b kg/cm^2	N	N_{cor}	Cu kg/cm^2	f_s kg/cm^2	f_b kg/cm^2
1.5	5	-	0.23	0.03	-	2	-	0.09	0.01	-
3.0	1	-	0.05	0.01	-	1	-	0.05	0.01	-
4.5	4	-	0.18	0.03	-	1	-	0.05	0.01	-
6.0	7	-	0.32	0.05	-	12	-	0.55	0.08	-
7.5	14	-	-	0.10	6.24	15	-	-	0.10	6.69
9.0	25	20	-	0.14	10.70	18	17	-	0.11	8.83
10.5	28	22	-	0.15	13.42	21	18	-	0.12	11.23
12.0	35	25	-	0.17	17.85	24	20	-	0.13	13.92
13.5	43	29	-	0.20	23.29	35	25	-	0.17	20.08
15.0	50	33	-	0.22	28.99	40	28	-	0.19	24.53
16.5	50	33	-	0.22	31.88	40	28	-	0.19	26.98
18.0	50	33	-	0.22	34.78	47	31	-	0.21	33.17
19.5	50	33	-	0.22	37.70	50	33	-	0.22	37.70
21.0						50	33	-	0.22	40.59

Depth m	BH-03				
	N	N_{cor}	Cu kg/cm^2	f_s kg/cm^2	f_b kg/cm^2
1.5	4	-	0.18	0.03	-
3.0	3	-	0.14	0.02	-
4.5	2	-	0.09	0.01	-
6.0	14	-	0.64	0.10	-
7.5	12	-	-	0.08	5.35
9.0	17	16	-	0.11	8.56
10.5	21	18	-	0.12	11.23
12.0	16	16	-	0.11	11.07
13.5	27	21	-	0.14	16.86
15.0	43	29	-	0.20	25.87
16.5	35	25	-	0.17	24.53
18.0	48	32	-	0.21	33.71
19.5	50	33	-	0.22	37.70
21.0	50	33	-	0.22	40.59

Note:

- N=Blows/ft, Cu=C
- f_s = Allowable value of the skin friction.
- f_b = Allowable value of the pile end bearing capacity.
- SPT (N) values are corrected within calculation.
- The values of f_s and f_b have been making preliminary estimate about the carrying capacity of a Bored R.C.C. pile.
- In the case of plastic silty soil, the values of the cohesion have been obtained from the SPT values.

13.0 FORMULA USED FOR COMPUTATION:

FOR COHESIVE SOIL:

The ultimate bearing capacity:

$$Q_{ult} = CN_c = \frac{Q_u .N_c}{2} \text{ (J. E. Bowles)}$$

$$q_{all} = \frac{q_u . N_c}{2X3} + \gamma D_f = \frac{q_u N_c}{6} + \gamma D_f \text{ (Factor of safety = 2.50)}$$

Where, q_u = Unconfined Compressive Strength in kg/cm^2.

N_c = Bearing Capacity Factor
= 6.8 square footing.
= 5.7 continuous footing.

FOR COHESION-LESS SOIL:

$Q_{ult} = C\ Nc\ Sc + \gamma D_f\ Nq + 0.5\gamma\ BN\gamma\ S\gamma$ (J. E. Bowles)
Where, C = Cohesion, γ = Unit weight of soil
D_f = Depth of footing, B = Width of footing
N_C, N_q & $N\gamma$ = bearing capacity factors = f (Φ) = f (N)
Sc, $S\gamma$ = Shape Factors = f (B, D_f)
$Q_{allowable} = q_{ult}/F.S.$ (F.S. = 2.5)
(Ref. Book: Foundation Analysis and Design by J. E. Bowles, page No. 213-277)

ULTIMATE SKIN FRICTION (f_s) AND END BEARING (f_b)

FOR COHESIVE SOIL :

$f_s = FC_d$ (M. J. Tomlinson)
Where, $C_d = q_u/2$;
q_u = Unconfined Compressive strength of soil and
F= Bearing Capacity Factor (Ranges between 0.45 to 0.60)

FOR COHESION-LESS SOIL:

For high displacement piles, $f_s = 2.0\ N\ kN/m^2$
For low displacement $f_s = 1.0\ N\ kN/m^2$
Where, N average of corrected N- value along the length of the pile.
For bored piles in sand, $f_b = 14\ N\ (D_b/B)\ kN/m^2$
Where D_b = actual penetration into the granular soil.
For bored pile in sand, the unit frictional resistance (f_s) is given by
$f_s= 0.67\ N\ kN/m^2$ (K . R. Arora).

CONSOLIDATION SETTLEMENT:

$S= C_c / (1+e_o) * H * \log (p_o + \Delta p) / p_o.$
(Ref. Book: Soil Mechanics and Foundation Engineering by K. R. ARORA, Page NO. - 383-450, 638-647 & 1003-1006).

STANDARD PENETRATION TEST:

N correction=15+0.5(N'-15)
Where, N correction =Corrected N- value
N'=SPT value from the field
(Ref. Book: Theory and Practice of Foundation Design by N.N. SOM & S.C. DAS. Page no-42.)

LOAD CALCULATION FOR ANY DIAMETER/ANY LENGTH OF PILE:

$$\mathbf{P= \pi DLf_s + \pi D^2/4f_b}$$

Where,
P =Allowable working Load
f_s =Average Allowable value of the skin friction=Kg/cm^2
f_b =Allowable value of the pile end bearing capacity =Kg/cm^2
π = A constant=3.1416
D =Pile Diameter
L =Required length of pile = m

14.0 COMPUTATION FOR CONSOLIDATION SETTLEMENT:

The vertical downward movement of the base of a structure is called settlement and its effect upon the structure depends on its magnitude, its uniformity, the length of the time over which it takes place, and the nature of the clay soils. The consolidation settlement can be calculated form test result of unit weight and consolidation tests. The average settlement depends on column load of structure.

15.0 CONCLUSIONS:

On the basis of above analysis and discussions, the following conclusions may be drawn regarding the sub-soil condition of the project area.

a. The overall soil formation of the investigated site are more or less regular in between the Bore hole locations.
b. The top layers of the investigated site have been encountered with comprising light brown soft to medium clay, some silt (Ref. Bore logs).
c. The underlying soil is grey coarse sand, trace silt. (Ref. Bore logs).
d. Bearing capacities for shallow foundation including isolated column footings are may not be suitable (Ref. **-** Table – 5)
e. Shallow foundation as isolated column footing may not be provided at the project site.
f. **R. C. C. Cast-In-Situ Pile** may be provided for all borings at project site.

16.0 RECOMMENDATIONS:

On the basis of aforesaid conclusions, the following recommendations are suggested for **PROJECT: GEOTECHNICAL INVESTIGATION OF FEASIBILITY STUDY OF KARNAPHULI WATER SUPPLY PROJECT PHASE-2 AT HALISHAHOR, CHITTAGONG.**

R.C.C CAST-IN-SITU PILE:

The average bearing capacities (F.S=2.50) of different or same diameter piles with embedment length up to **50.0ft or 15.0m** from **EGL** for each bore hole**,** may be considered as follows:

31.16 Ton for 400 mm or 16 inch.dia pile
37.10 Ton for 450 mm or 18 inch.dia pile
43.50 Ton for 500 mm or 20 inch.dia pile
57.67 Ton for 600 mm or 24 inch.dia pile

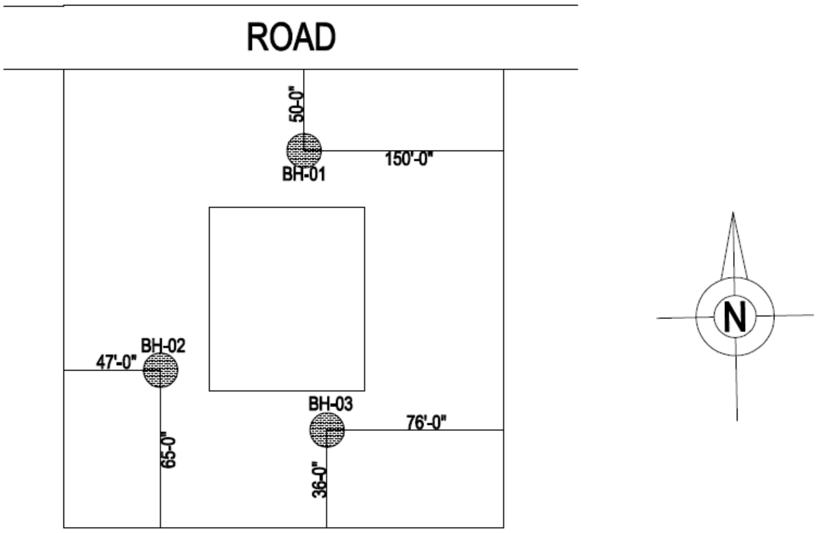
Note:

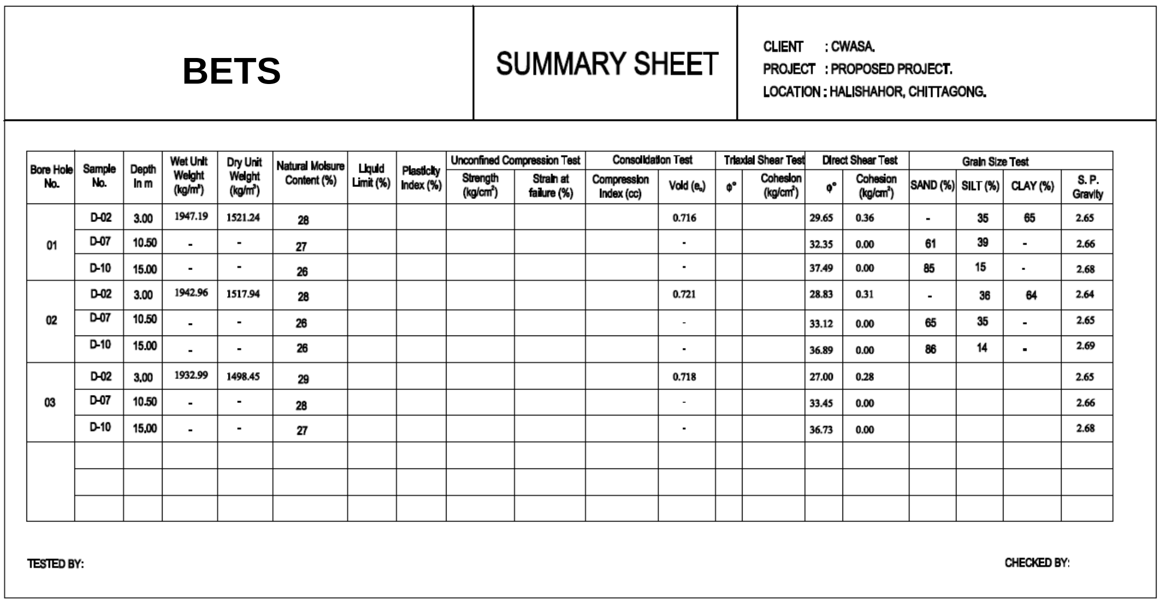
a. 1 Tsf = 1 kg/cm^2 = 2ksf, 1 Ton = 2000 lbs = 9.81 kN, 1m = 3.28ft, EGL = Existing Ground level & F. S. = Factor of Safety.
b. The designer may select any other alternative type, depth as well as the bearing capacity of the foundation in the light of information provided in this report.
c. Foundation base should be kept dry during construction period.

BETS

BORE HOLE LOCATION

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : HALISHAHOR, CHITTAGONG.





BETS

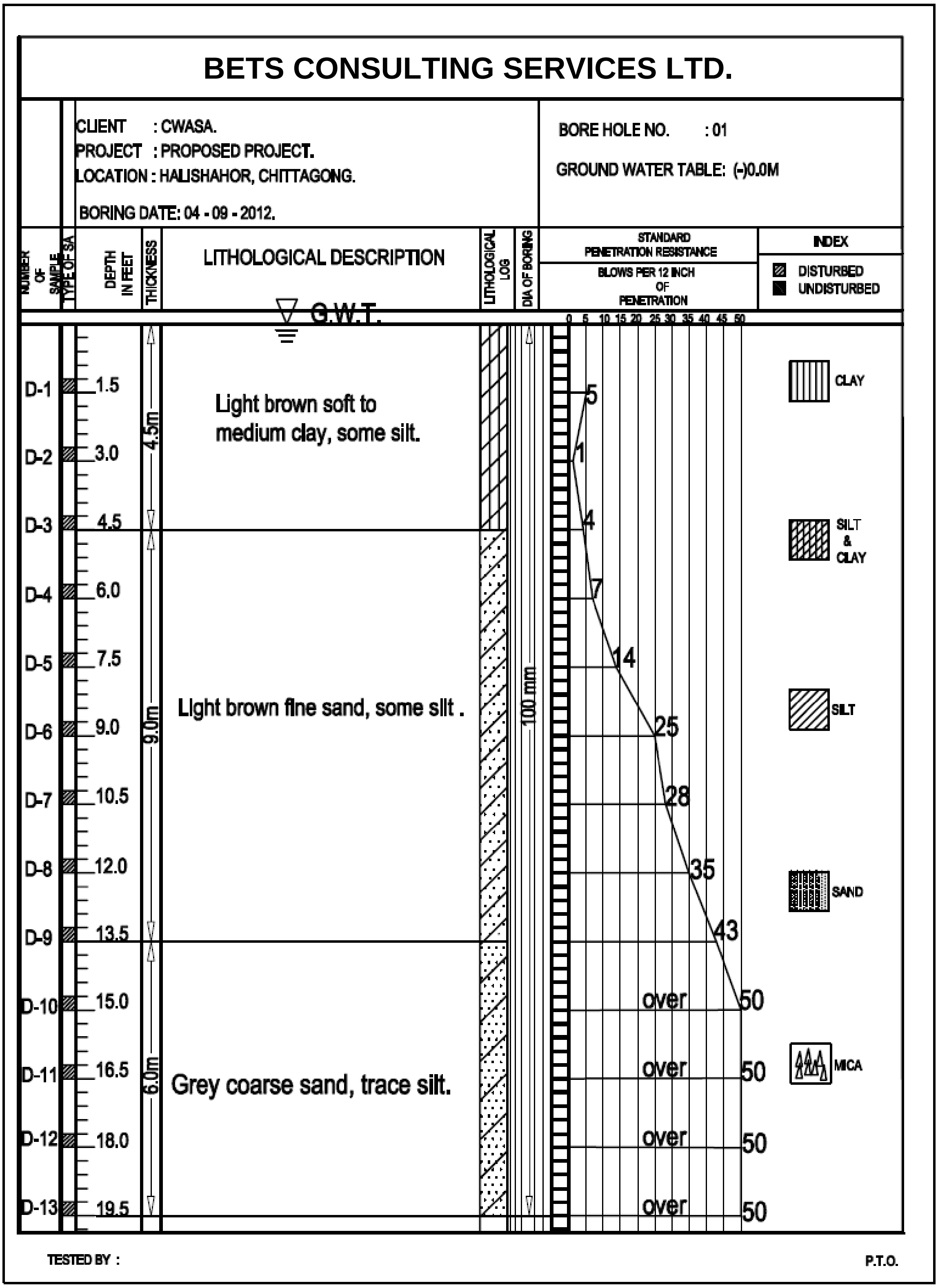
SUMMARY SHEET

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : HALISHAHOR, CHITTAGONG.

Bore Hole No.	Sample No.	Depth in m	Wet Unit Weight (kg/m^3)	Dry Unit Weight (kg/m^3)	Natural Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Unconfined Compression Test		Consolidation Test		Triaxial Shear Test		Direct Shear Test		Grain Size Test			
								Strength (kg/cm^2)	Strain at failure (%)	Compression Index (cc)	Void (e_o)	ϕ°	Cohesion (kg/cm^2)	ϕ°	Cohesion (kg/cm^2)	SAND (%)	SILT (%)	CLAY (%)	S. P. Gravity
01	D-02	3.00	1947.19	1521.24	28						0.716			29.65	0.36	-	35	65	2.65
	D-07	10.50	-	-	27						-			32.35	0.00	61	39	-	2.66
	D-10	15.00	-	-	26						-			37.49	0.00	85	15	-	2.68
02	D-02	3.00	1942.96	1517.94	28						0.721			28.83	0.31	-	36	64	2.64
	D-07	10.50	-	-	26						-			33.12	0.00	65	35	-	2.65
	D-10	15.00	-	-	26						-			36.89	0.00	86	14	-	2.69
03	D-02	3,00	1932.99	1498.45	29						0.718			27.00	0.28				2.65
	D-07	10.50	-	-	28						-			33.45	0.00				2.66
	D-10	15,00	-	-	27						-			36.73	0.00				2.68

TESTED BY:

CHECKED BY:



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CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : HALISHAHOR, CHITTAGONG.
BORING DATE: 04 - 09 - 2012.

BORE HOLE NO. : 01
GROUND WATER TABLE: (-)0.0M

NUMBER OF SAMPLE	TYPE OF SA	DEPTH IN FEET	THICKNESS	LITHOLOGICAL DESCRIPTION	LITHOLOGICAL LOG	DIA OF BORING	STANDARD PENETRATION RESISTANCE BLOWS PER 12 INCH OF PENETRATION
				▽ G.W.T.			
D-1	▨	1.5	4.5m	Light brown soft to medium clay, some silt.		100 mm	5
D-2	▨	3.0					1
D-3	▨	4.5					4
D-4	▨	6.0	9.0m	Light brown fine sand, some silt .			7
D-5	▨	7.5					14
D-6	▨	9.0					25
D-7	▨	10.5					28
D-8	▨	12.0					35
D-9	▨	13.5					43
D-10	▨	15.0	6.0m	Grey coarse sand, trace silt.			over 50
D-11	▨	16.5					over 50
D-12	▨	18.0					over 50
D-13	▨	19.5					over 50

INDEX
▨ DISTURBED
■ UNDISTURBED

CLAY
SILT & CLAY
SILT
SAND
MICA

TESTED BY :

P.T.O.

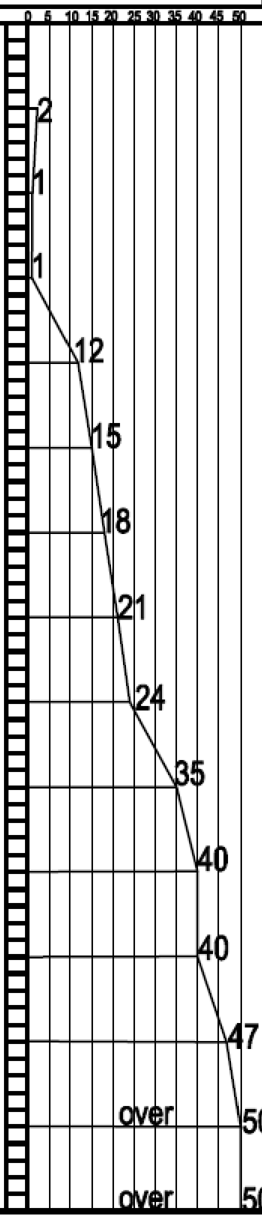
BETS CONSULTING SERVICES LTD.

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : HALISHAHOR, CHITTAGONG.
BORING DATE: 05 - 09 - 2012.

BORE HOLE NO. : 02
GROUND WATER TABLE: (-)0.0M

NUMBER OF SAMPLE	TYPE OF SA	DEPTH IN FEET	THICKNESS	LITHOLOGICAL DESCRIPTION	LITHOLOGICAL LOG	DIA OF BORING	STANDARD PENETRATION RESISTANCE BLOWS PER 12 INCH OF PENETRATION
D-1	▨	1.5	4.5m	Light brown soft to medium clay, some silt.	▨	100 mm	2
D-2	▨	3.0					1
D-3	▨	4.5					1
D-4	▨	6.0	9.0m	Light brown fine sand, some silt .	▨		12
D-5	▨	7.5					15
D-6	▨	9.0					18
D-7	▨	10.5					21
D-8	▨	12.0					24
D-9	▨	13.5					35
D-10	▨	15.0	7.5m	Grey medium sand, little silt.			40
D-11	▨	16.5					40
D-12	▨	18.0					47
D-13	▨	19.5					over 50
D-14	▨	21.0					over 50

▽ G.W.T.



INDEX
▨ DISTURBED
■ UNDISTURBED

▥	CLAY
▩	SILT & CLAY
▨	SILT
░	SAND
⩓	MICA

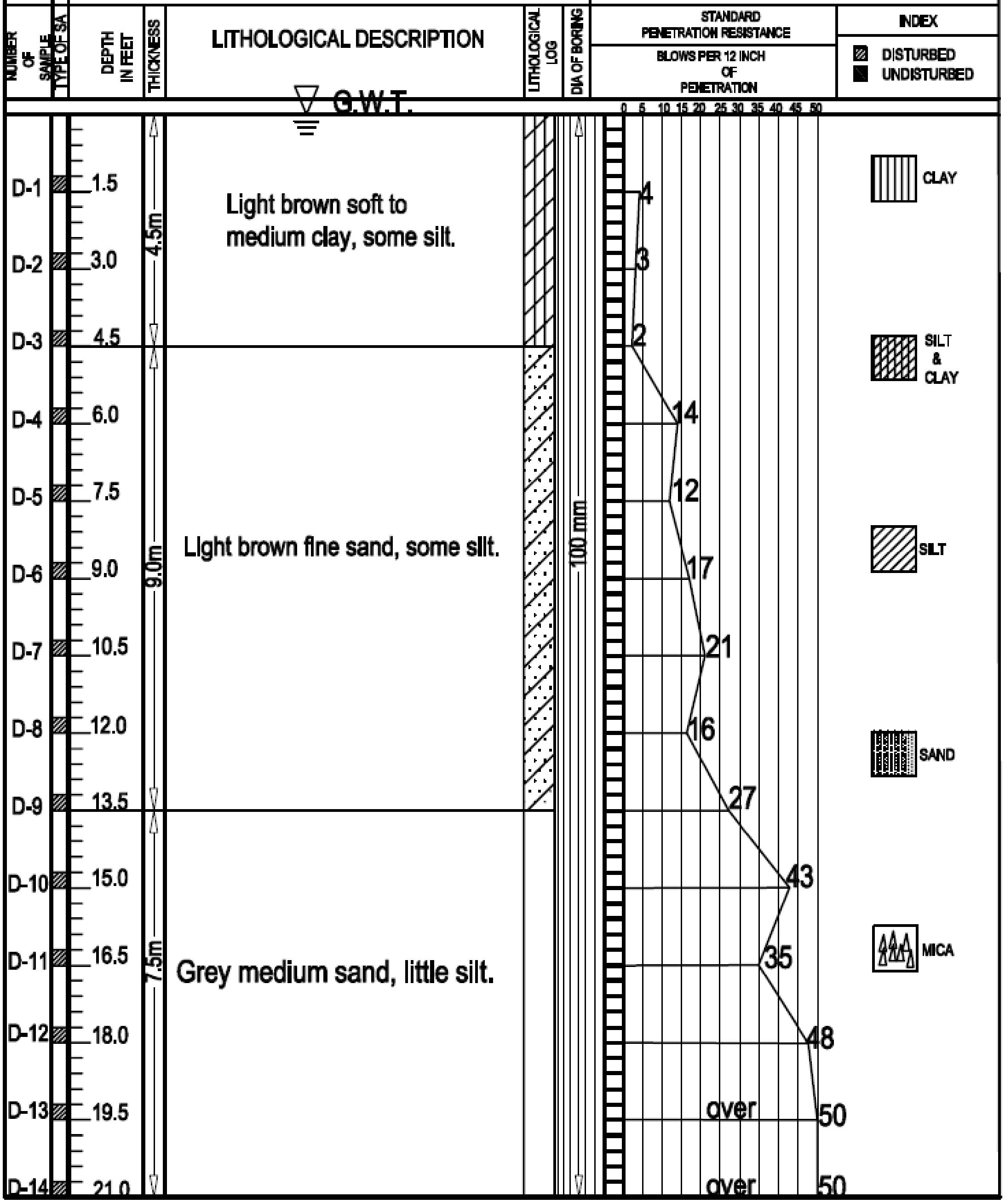
TESTED BY :

P.T.O.

BETS CONSULTING SERVICES LTD.

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : HALISHAHOR, CHITTAGONG.
BORING DATE: 05 - 09 - 2012.

BORE HOLE NO. : 03
GROUND WATER TABLE: (-)0.0M



Light brown soft to medium clay, some silt.

Light brown fine sand, some silt.

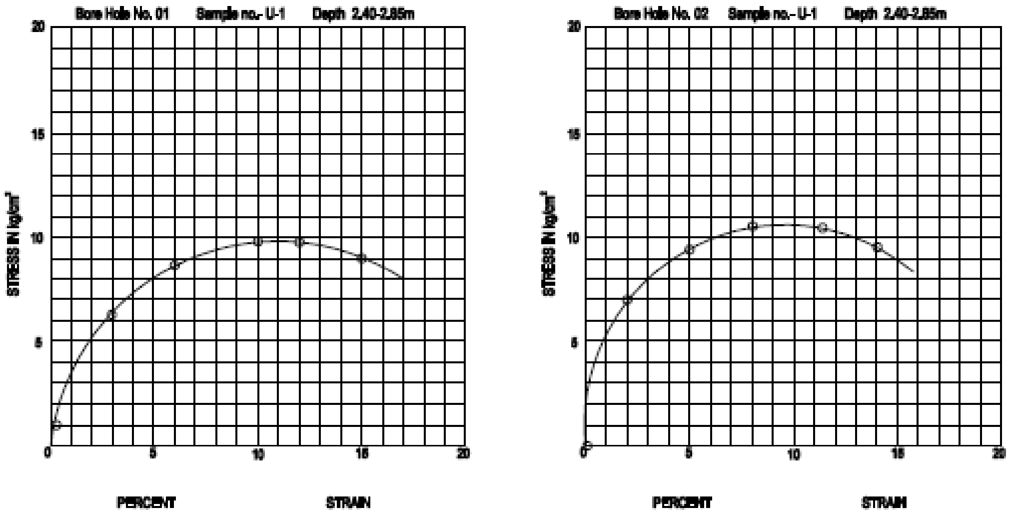
Grey medium sand, little silt.

D-1	1.5	4
D-2	3.0	3
D-3	4.5	2
D-4	6.0	14
D-5	7.5	12
D-6	9.0	17
D-7	10.5	21
D-8	12.0	16
D-9	13.5	27
D-10	15.0	43
D-11	16.5	35
D-12	18.0	48
D-13	19.5	over 50
D-14	21.0	over 50

TESTED BY :

P.T.O.

BETS	**UNCONFINED COMPRESSION TEST**	CLIENT : CWASA. PROJECT : PROPOSED PROJECT. LOCATION : HALISHAHOR, CHITTAGONG.



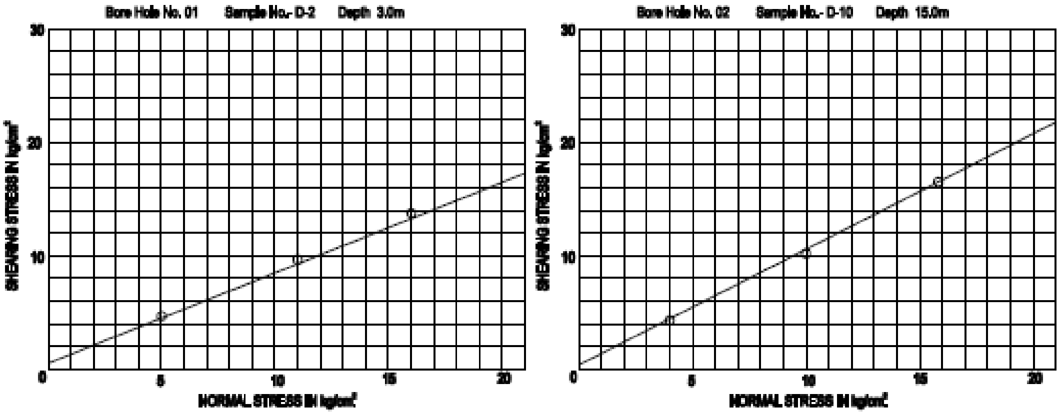
UNCONFINED COMPRESSIVE STRENGTH (kg/cm^2) : 0.78
PERCENT STRAIN AT FAILURE : 11.00
MOISTURE CONTENT (%) : 28
WET DENSITY (kg/m^3) : 1947.19
DRY DENSITY (kg/m^3) : 1521.34

UNCONFINED COMPRESSIVE STRENGTH (kg/cm^2) : 0.78
PERCENT STRAIN AT FAILURE : 11.00
MOISTURE CONTENT (%) : 28
WET DENSITY (kg/m^3) : 1943.56
DRY DENSITY (kg/m^3) : 1517.04

Tested By:

Checked By:

BETS	**DIRECT SHEAR TEST**	CLIENT : CWASA. PROJECT : PROPOSED PROJECT. LOCATION : HALISHAHOR, CHITTAGONG.

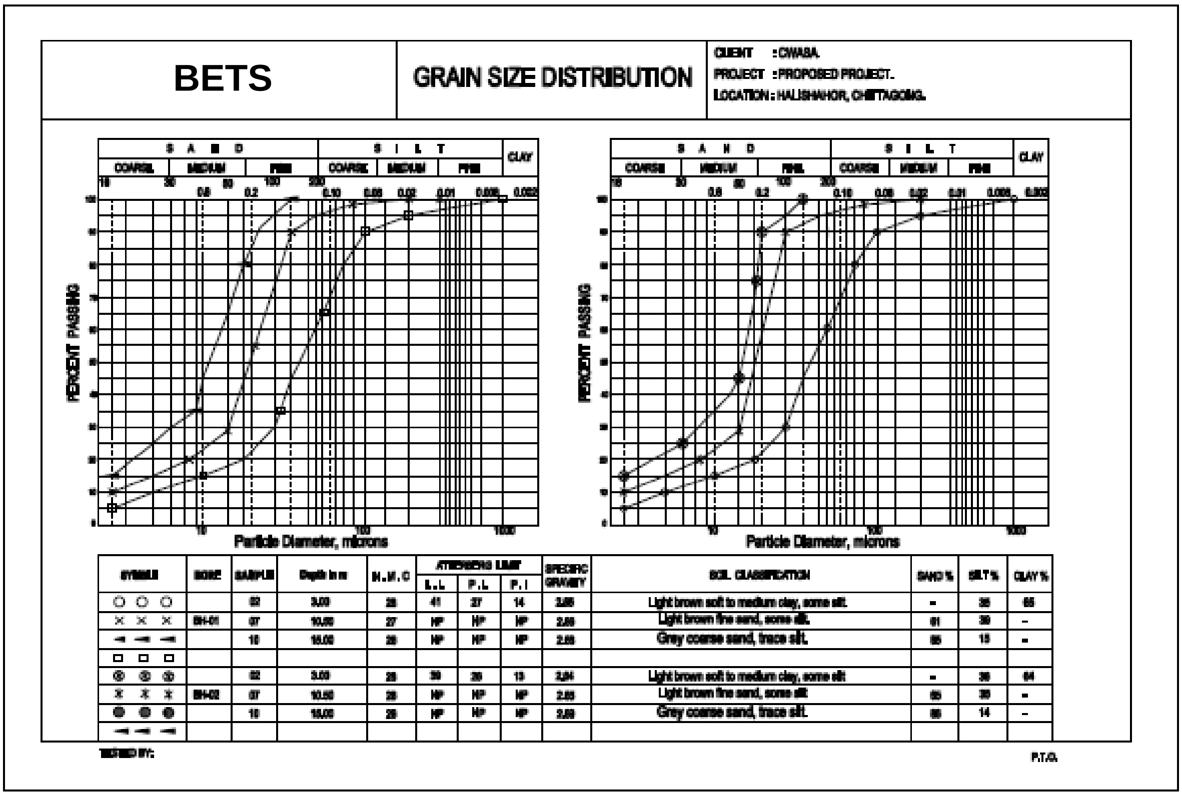


SHEARING ANGLE, ϕ (Degree)	29.65°
COHESION, C (kg/cm^2)	0.38

SHEARING ANGLE, ϕ (Degree)	36.89°
COHESION, C (kg/cm^2)	0.00

Tested By:

Checked By:



BETS

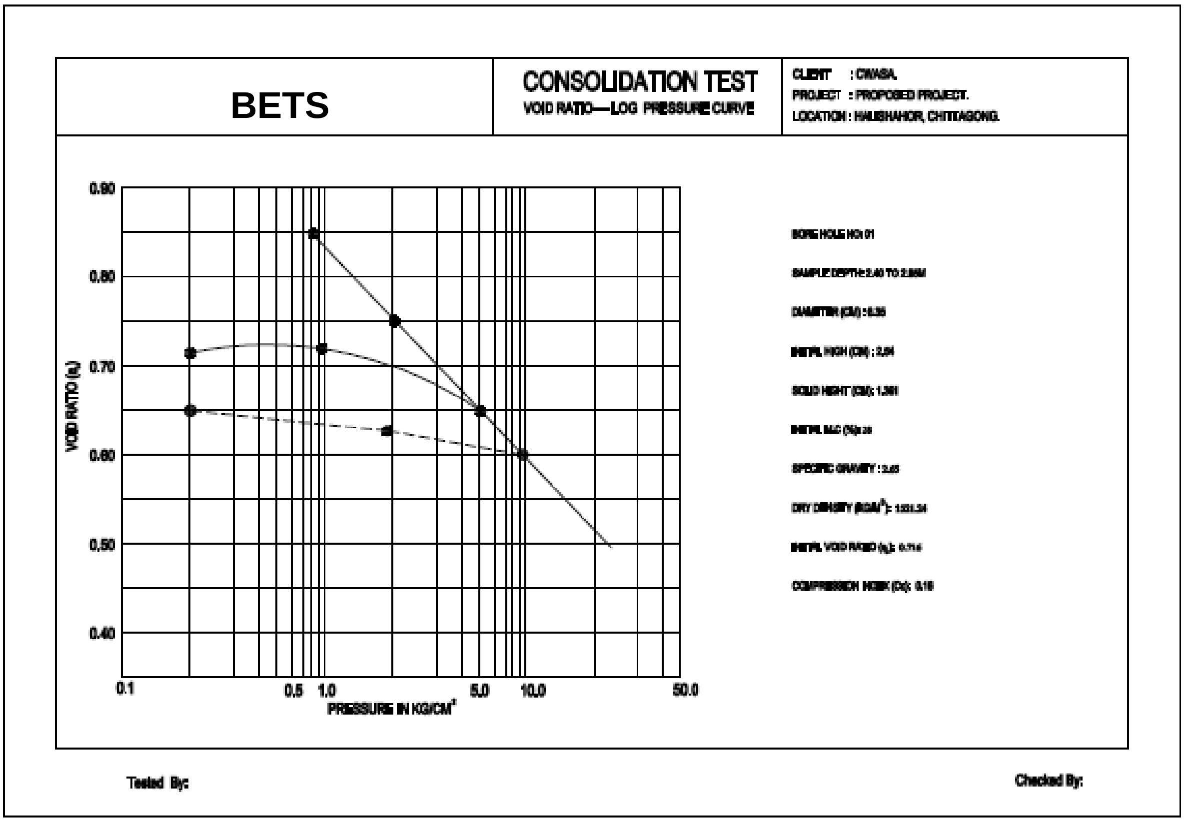
GRAIN SIZE DISTRIBUTION

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : HALISHAHOR, CHITTAGONG.

SYMBOLS	BORE	SAMPLE	Depth in m	N.M.C	ATTERBERG LIMIT			SPECIFIC GRAVITY	SOIL CLASSIFICATION	SAND %	SILT %	CLAY %
					L.L	P.L	P.I					
○ ○ ○		02	3.00	28	41	27	14	2.65	Light brown soft to medium clay, some silt.	-	35	65
× × ×	BH-01	07	10.50	27	NP	NP	NP	2.60	Light brown fine sand, some silt.	61	39	–
⟞ ⟞ ⟞		10	15.00	28	NP	NP	NP	2.65	Grey coarse sand, trace silt.	85	15	-
□ □ □												
⊗ ⊗ ⊗		02	3.00	28	39	26	13	2.64	Light brown soft to medium clay, some silt	-	36	64
⋇ ⋇ ⋇	BH-02	07	10.50	28	NP	NP	NP	2.65	Light brown fine sand, some silt	65	35	-
● ● ●		10	15.00	28	NP	NP	NP	2.60	Grey coarse sand, trace silt.	86	14	–
⟞ ⟞ ⟞												

TESTED BY:

P.T.O.



BETS

CONSOLIDATION TEST
VOID RATIO—LOG PRESSURE CURVE

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : HALISHAHOR, CHITTAGONG.

BORE HOLE NO: 01

SAMPLE DEPTH: 2.40 TO 2.85M

DIAMETER (CM) : 6.35

INITIAL HIGH (CM) : 2.04

SOLID HIGHT (CM): 1.201

INITIAL M.C (%): 28

SPECIFIC GRAVITY : 2.65

DRY DENSITY (KG/M³): 1551.34

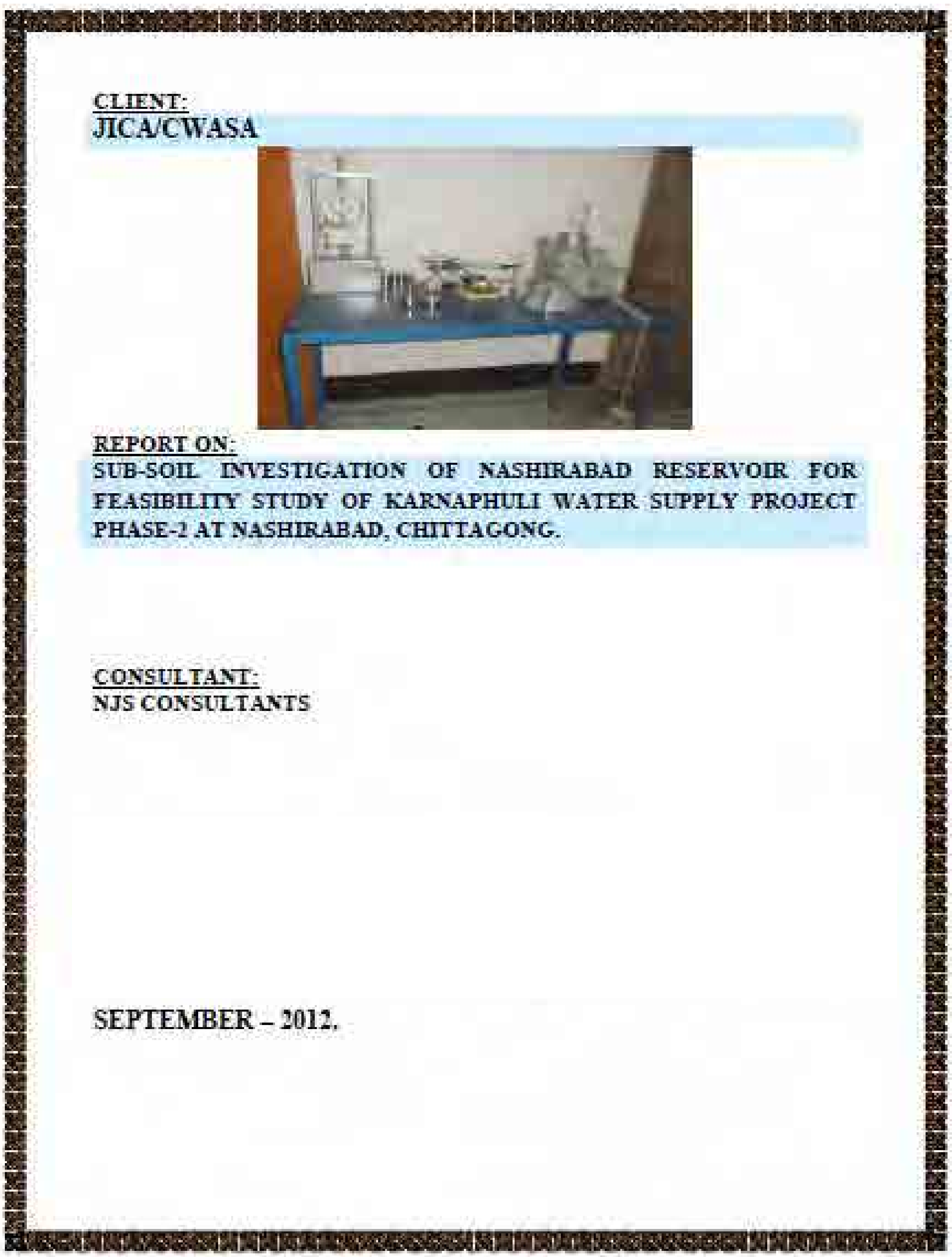
INITIAL VOID RATIO (e_0): 0.716

COMPRESSION INDEX (Cc): 0.18

Tested By:

Checked By:

II.2 Nashirabad Site



CLIENT:
JICA/CWASA

REPORT ON:
SUB-SOIL INVESTIGATION OF NASHIRABAD RESERVOIR FOR FEASIBILITY STUDY OF KARNAPHULI WATER SUPPLY PROJECT PHASE-2 AT NASHIRABAD, CHITTAGONG.

CONSULTANT:
NJS CONSULTANTS

SEPTEMBER – 2012.

REPORT ON SUB-SOIL INVESTIGATION (Nashirabad Site)

1.0 INTRODUCTION:

A reasonably accurate conception about the subsoil parameters of any project site is an essential priority for proper planning and designing the foundation of the concerned structure, So that the structure after its construction would remain safe and stable throughout its service period. Paying due considerations to JICA Survey Team**,** was agreed to offer the sub-surface investigation work of the same in favour of **BETS Consulting Services Ltd.**, Engineering Consultant, a well reputed geotechnical firm in Dhaka, Bangladesh.

According to work order of representative of the client, a detailed sub-soil study comprising execution of **4(Four)** number borings up to **13.5-19.5m**deep, including the different field and laboratory tests was carried out and results analysis, report preparation & report submission etc had been undertaken and all official correspondence carried out by BETS, during the period of **SEPTEMBER-2012.**

2.0 METHODOLOGY:

BETS sent one SPT Test team for field test at the site. According to the work order, Team Leader of SPT Test team contacted with representative of client for recognizing the selected land and locations for field test. The location of bore holes was selected in presence of the representative of client.

3.0 CLIENT:

JICA Survey Team.
NJS CONSULTANTS

4.0 LOCATION:

NASIRABAD, CHITTAGONG.

5.0 SCOPE OF WORK:

The main scopes of this investigation work are:

a. Execution of exploratory borings, recording of sub-soil stratification and position of ground water table.
b. Execution of standard penetration test (**SPT**) at an interval of **1.5m** depth with collection of disturbed soil samples up to final depth exploration of each boring.
c. Collection of 1 nos. undisturbed soil samples by thin walled Shelby tubes for each bore hole.
d. Preparation of final report with all works including detailed description of soil stratification sub-soil.
e. From the field tests and laboratory tests, scope of calculation for bearing capacity values for design shallow foundation.
f. For loose and soft strata, from the field test and laboratory tests, scope of calculation for skin friction and bearing values for design deep foundation.

6.0 FIELD WORKS:

All the field works and field tests were conducted as per standard procedure as laid down in ASTM specification are as follows:

6.1 EXPLORATORY BORING DRILLING:

Drilling was executed by wash boring method. A hole was started by driving vertically a 4” diameter steel casing into the ground to some depth and then the formation ground casing was broken up by repeated drops of a chopping bit attached to the lower and of drilling pipe. The upper end of the same was forced at high pressure through pressure pipe. Forced slurry or water emerges at high velocity through the pores of the chopping bit, and returns to the surface through the annular space between drilling pipe and the side of the casing or hole, carrying with it the broken-up soil. In this way drilling is advanced up to a level of 6” above the depth, where SPT has to be executed.

6.2 STANDARD PENETRATION TEST:

Standard penetration Tests have been executed in all the bore holes at 1.5m. intervals of depth up to the final depth of in this test, a split spoon sampler of 2” out diameter and 1-3/8” inner diameter, is made to penetrate 18”, for boring. Into the soil by drops of a hammer weighing 140lb. failing freely for a height of 30 inches. Number of blows of hammer required for penetration of each 6” length of the sampler is recorded. The number of blows last 12” penetration of the total 18” is know as the standard penetration value (N-values) as specified by ASTM and is plotted the SPT value of the particular depth.

6.3 EXTRACTION OF SOIL SAMPLE:

The Disturbed soil samples were collected at 1.5m. intervals and at every change of soil strata split spoon sampler. These soil samples were studied visually and the soil classification were done to prepare strata chart of soils up to the explored depth. Before collection of samples, the hole is washed and cleaned the drill pipe with the help of an adapter and is lowered into the hole. The sampler is then pressed down into the ground in one rapid continuous movement until the tube, except 4inches from the top is filled with soil sample.

Undisturbed soil samples were collected at a depth where layer of soil is changed such as 8ft to 12ft.Undisturbed soil samples area collected by means of thin walled sharp ended 3inch dia.stationary piston sampler from the cohesive soil formation. The collected tubes were then labeled with detailed job designation, date and shifted the laboratory for testing.

7.0 LABORATORY TESTS:

All Laboratory Tests conducted on soil samples collected either in the disturbed or in the undisturbed state. All tests were done as per ASTM procedures, are as follows:

7.1 NATURAL MOISTURE CONTENT:

The water content of a soil sample is the ratio of the weight of the water in the sample to its dry weight. It is usually expressed as a percentage. The soil sample is weight both in natural state and in over dry state and the moisture content is calculated by dividing the loose of weight of the sample by its dry weight.

7.2 COMPLETE GRAIN SIZE ANALYSIS:

The object of grain size analysis is to determine the size of the soil grains, and the percentage by weight of soil particles of different particles size, comprising a soil sample. The process consists of either sieve analysis or hydrometer analysis or both. The hydrometer analysis is adopted for sample passing sieve No. 200. For hydrometer analysis, a 40 gms of the over dry sample, is thoroughly mixed with required quantity of water in a calibrated glass cylinder. In order to avoid flocculation, a little dispersing agent is added. The density of the suspension is measured at specified time intervals, by means of a hydrometer or special design. At any particular time the size of the largest particle remounting in suspension at the level of the hydrometer can be computed by means of stocks Law, where as he weight of the particles finer than that size, can be computed from the density of the suspension at the same level.

The mixture is washed through U.S standard sieve No. 200 and the fraction retained is dried. The fraction retained on each sieve is weighed for calculation of the percentage of different fraction. The results are represented by cumulative curves plotted on semi-logarithmic graph paper.

7.3 ATTERBERG LIMITS:

Physical properties of clay are greatly influenced by water content. A given soil behave as a fluid or a soil or, as a plastic materials, depending on how much water its contains. The water contents that correspond to the boundaries between the states of consistency are called as the Atterberg limit.

Liquid Limit is the minimum water content at which a clay soil just starts behaving like a fluid. It is determined with the help of a standard limit device which consists of brass cup and an arrangement to impart blows to cap at a uniform rate. The water content at which 25 blows are required is termed as the limit.

The plastic limit is the minimum water content at which a soil is just plastic and is determined by rolling out a soil sample at slowly decreasing water content until, the desired water content is reached, at which a thread of 3mm diameter just begins to crumble. The thread is rolled on glass plate with hand.

7.4 SPECIFIC GRAVITY TEST:

The specific gravity of soil particles (Gs) is defined as the ratio of the mass of given volume of soil particles to the mass of an equal volume of water at 40C. The specific gravity of a solid for most natural soils falls in general range of 2.60 to 2.80. To determine the specific gravity of soil sample, 25 grams of over dried soil sample is thoroughly pulverized and is placed in a calibrated psychomotor. Water is poured inside the pycnometer until its top is slightly below the calibrated mark. The mixture is then boiled thoroughly in order to eliminate all the air bubbles. More water is then added to the mixture till it over-night, the temperature is then recorded and the bottle is weighed.

The specific gravity Gs is given by:

$$Gs = \frac{Gt \, . \, Ws}{Ws - W_1 + W_2}$$

Where,

Gt = Specific gravity of water at TOC.

W_S = The weight of over dry soil (25gms.)

W_1 = Weight of flask + soil + water.

W_2 = Weight of flask + water.

7.5 DIRECT SHEAR TEST:

Direct shear test can be performed for both cohesion less & cohesive soil to determine shear strength, angle of internal friction, cohesion c, volume change etc. The test is done in a direct shear machine which consists of a normal loading device; shearing displacement of approximately 10mm per minute is often for a sample used for a sample thickness of about 1.2cm.

The results of a direct shear test on a cohesion less & cohesive soil can be presented in a summary table & by stress-strain curve. A stress-strain curve normally consists of shear stress, various shear displacement for both the undisturbed and the remolded test under a specified normal load the normal load usually varies from 1/3kg/cm^2 to 1kg/cm^2. Another curve of normal stress verses shearing stress will give angle of internal and cohesion for cohesive soil.

7.6 UNCONFINED COMPRESSION TEST:

Unconfined compression test is a simple method for determination of shearing strength of cohesive soil which is important to determine the bearing capacity of soil. As the name implies, the lateral confining pressure in an unconfined compression test is kept zero, unsupported specimen and at failure is measured. The specimen is prepared from the undisturbed soil sample by carefully trimming it to a cylindrical shape of 7cm height and 3.5cm dia. The specimen is then placed on the level pedestal of the unconfined compression apparatus in a vertical position. The load is applied axially on the top of the specimen an is distributed uniformly over surface of the specimen with the help of double providing ring assembly fitted with a strain gauge, fitted with the apparatus. The load is applied at such a rate that the vertical deformation of the sample is nearly 2% (two percent) per minute in order to avoid and drainage during compression. The load is kept increasing until the specimen fails along shearing plane. The maximum load at failure knows as the unconfined compressive strength of the sample the shearing strength of the sample is half of the unconfined compressive strength.

7.7 CONSOLIDATION TEST:

The gradual process of compression of soil under the action of static load and with decrease of void ratio due to expulsion of water from the soil pores is termed consolidation The phenomenon compressibility characteristics of a soil as the period and magnitude of settlement of a foundation depends on these characteristics. The test is performed on a specimen of circular shape of 6.35cm dia and 2.54cm thickness, the specimen is prepared from the undisturbed sample by carefully trimming it to the required dimension with the help of a cutting edge and wire saw.

The specimen is then placed in the consolidation ring and its top and bottom are trimmed off level with that of the ring .The specimen along with the ring on the top and the other at the bottom of the specimen. The load is then applied on porous stone and on the specimen with the help of a level arrangement with the apparatus.

Decreases in volume of specimen are read from a strain gauge attached to the consolidation unit at specified time intervals the consolidation unit is always kept full with water in order to avoid evaporation of the specimen. The load increment is allowed after each twenty four hours, The observed reading are then plotted on semi-logarithmic graph paper to give the pressure-void ratio curve from which compression index, Cc Can be calculated. Cc is important factor governing the settlement process of underlying soils.

8.0 SOIL COMPOSITION:

8.1 DESCRIPTION OF SOIL COMPOSITION:

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

Trace fine sand	: 1 to 10% fine sand.
Little silt	: 11 to 20% silt.
Some clay	: 20 to 35% clay.
Sandy silt	: 35 to 50% sand & 50 to 70% silt.
Clayey silt	: 35 to 50% clay & 50 to 70% silt.
Silty sand	: 35 to 50% silt & 50 to 70 % sand.

9. 0 CORRELATION TABLE OF SOILS BASED ON SPT-VALUES:

Two tables for Cohesion-less and cohesive soils based on N- Values as below:

9.1 values of Unit Weight and Angle of Internal Friction of Cohesion-less soil Based on N-Values (After K. Terzaghi and R. B. Peck):

Table No. 1.

N-Values	Condition	Relative Density	Angle of Internal Friction	Moist Unit Wt. in gm/cc.
0-4	Very loose	0.0-0.2	25^0-30^0	1.12-1.60
4-10	Loose	0.2-0.4	30^0-35^0	1.44-1.84
10-30	Medium	0.4-0.6	35^0-40^0	1.76-2.08
30-50	Dense	0.6-0.85	40^0-45^0	1.76-2.24
Over 50	Very dense	1.00	45^0	2.08-2.40

The tabulated values apply for dry/moist cohesion less sand. For silty sands the bearing capacity values must be reduced by study of grain size classification and applying judgment. Correction for water table close to bottom of foundation the bearing values should be reduced to half. The bearing values are, however, not affected by the water table at a depth greater than 1.5B below foundation level, B being least dimension of the bottom of foundation. Bearings values for intermediate position of water table may be reduced by liner interpolation.

9.2 Values of approximate Unconfined Compressive Strength Based on N-Values for Cohesive Soil (After K. Terzaghi and R.B. Peck):

Table No.- 2.

N-Values	Condition	Unconfined compressive Strength in kg/cm^2.
Below 2	Very soft	Below 0.25
2-4	Soft	0.25-0.50
4-8	Medium	0.50-1.00
8-16	Stiff	1.00-2.00
16-32	Very stiff	2.00-4.00
Over 32	Hard	Over 4.00

In the above table the shear strength of cohesive soil is equal to 1/2 of unconfined compressive strength and the angle of shearing resistance is equal to zero. It should be remembered that the correlation for cohesive soil is always much reliable.

10.0 PHYSICAL PROPERTIES:

Physical Properties of the subsoil formation of the project area have been evaluated by the execution of **4(Four)** number borings of **13.5-19.5m** deep (firm strata). The overall physical properties may be summarized as follows:

10.1 STRATIFICATION OF SOIL:

The top soil is light brown medium clay, some silt, the underlying soil is grey coarse sand, trace silt.

10.2 CONSISTENCY/COMPACTNESS:

Up to the depth of EGL to 6.0m, consistency of the top soil usually varies from soft to medium consistency of soil, however, gradually increase the consistency. The subsequent deep layers stiff to medium stiff soil state.

10.3 GROUND WATER TABLE:

The position of Ground Water Table (GWT) is about (-) **0.0-4.50m** from existing ground level.

10.4 Natural Moisture Content, Unit Weight, Specific Gravity and Liquid Limit:

Table No .3 Name of the Laboratory Test:

Name of the Soil Test
Natural Moisture Content
Natural Unit Weight
Dry density
Specific Gravity
Liquid Limit
Plasticity index
Grain Size Distribution
Direct shear test
Consolidation test
Unconfined compressive test

11.0 ENGINEERING PROPERTIES:

The engineering properties of soil, including the cohesion, compressibility and the angle of internal granular friction have been determined by performing laboratory tests on the soil samples collected during field investigation. These are as follows:

11.1 COHESION: The values of cohesion, as reported from the performance of unconfined compression tests from Laboratory Test Sheet.

11.2ANGLE OF INTERNAL FRICTION:

The angle of internal friction values of the investigated of soil, as reported form the performance of direct shear test from Laboratory Test Sheet.

11.3 COMPRESSIBILITY: The top layer of plastic silty soil usually has been observed moderately compressible in nature by consolidation tests from Laboratory Test Sheet.

12. 0 EVALUATION OF BEARING CAPACITY:

12.1 BEARING CAPACITIES OF THE SHALLOW CONDITION FROM THE SPT:

The Bearing capacities of the shallow foundation particularly for the top layer of cohesive soil may be estimated from the SPT values, as suggested by Terzaghi, according to the following table.

<u>Table No.- 4:</u> Bearing Capacities of the shallow foundation (Values in kg/cm^2, F. S. =2.50):

SPT range	Allowable Bearing Capacity (Tsf)	
	Continuous Footing (B=4ft)	Isolated Column Footing (B=8ft)
0-2	0.00 - 0.225	0.00 - 0.30
2-4	0.225 - 0.45	0.30 - 0.60
4-8	0.45 - 0.90	0.60 - 1.20
8-15	0.90 - 1.80	1.20 - 2.40
15-30	1.80-3.60	2.40-4.80
>30	> 3.60	> 4.80

Note:
a. width = 4ft for strip footing and width = 8ft for isolated footing respectively.
b. The above values are the net allowable Bearing capacities.
c. The cohesive soil has been considered in a saturated condition.

12.2 BEARING CAPACITY OF THE SHALLOW FOUNDATION FROM THE SOIL PARAMETERS:

The bearing capacities of the shallow foundation may more appropriately be determined from the parameters of soil such as the values of cohesion and the angle of internal friction as obtained from the performance of laboratory tests. These have been done considering the general equations of the Bearing capacity of the foundation as suggested by Terzaghi. The evaluated values are provided in the following Table no. 5, and Table no.6

<u>Table No. 5.</u> Bearing Capacities of the Shallow Foundation from Field and Laboratory Test
(Values in kg/cm^2, F. S. = 2.50):

Bore Hole	Depth in m	Field SPT	Cohesion kg/cm^2	Bearing Capacity (kg/cm^2)	
				For strip Foundation	For circular or square footing
BH-01	1.5	4	0.18	0.45	0.60
	3.0	7	0.32	0.79	1.05
	4.5	12	0.55	1.35	1.80
	6.0	20	0.92	2.25	3.00

BH-02	1.5	4	0.18	0.45	0.60
	3.0	3	0.14	0.34	0.45
	4.5	41	1.88	4.61	6.15
	6.0	50	2.29	5.63	7.50
BH-03	1.5	5	0.23	0.56	0.75
	3.0	18	0.83	2.03	2.70
	4.5	9	0.41	1.01	1.35
	6.0	12	0.55	1.35	1.80
BH-04	1.5	6	0.28	0.68	0.90
	3.0	7	0.32	0.79	1.05
	4.5	11	0.50	1.24	1.65
	6.0	18	0.83	2.03	2.70

Table No.6: The Skin Friction and the End Bearing Capacities of Piles (F.S. =2.50)

Depth m	BH-01					BH-02				
	N	N_{cor}	Cu kg/cm^2	f_s kg/cm^2	f_b kg/cm^2	N	N_{cor}	Cu kg/cm^2	f_s kg/cm^2	f_b kg/cm^2
1.5	4	-	0.18	0.03	-	4	-	0.18	0.03	-
3.0	7	-	0.32	0.05	-	3	-	0.14	0.02	-
4.5	12	-	0.55	0.08	-	41	28	1.28	0.19	-
6.0	20	18	0.80	0.12	-	50	33	1.49	0.22	-
7.5	25	20	-	0.14	8.92	50	33	-	0.22	14.50
9.0	27	21	-	0.14	11.24	50	33	-	0.22	17.39
10.5	24	20	-	0.13	12.17	50	33	-	0.22	20.28
12.0	18	17	-	0.11	11.78	50	33	-	0.22	23.21
13.5	28	22	-	0.15	17.26	50	33	-	0.22	26.10
15.0	43	29	-	0.20	25.87					
16.5	50	33	-	0.22	31.88					
18.0	50	33	-	0.22	34.78					
19.5	50	33	-	0.22	37.70					

Depth m	BH-03					BH-04				
	N	N_{cor}	Cu kg/cm^2	f_s kg/cm^2	f_b kg/cm^2	N	N_{cor}	Cu kg/cm^2	f_s kg/cm^2	f_b kg/cm^2
1.5	5	-	0.23	0.03	-	6	-	0.28	0.04	-
3.0	18	17	0.76	0.11	-	7	-	0.32	0.05	-
4.5	9	-	0.41	0.06	-	11	-	0.50	0.07	-
6.0	12	-	0.55	0.08	-	18	17	0.76	0.11	-
7.5	14	-	-	0.10	6.24	21	18	-	0.12	8.03
9.0	20	18	-	0.12	9.36	27	21	-	0.14	11.24
10.5	50	33	-	0.22	20.28	40	28	-	0.19	17.16
12.0	50	33	-	0.22	23.21	50	33	-	0.22	23.21
13.5	50	33	-	0.22	26.10	50	33	-	0.22	26.10
15.0						50	33	-	0.22	28.99

Note:

- N=Blows/ft, Cu=C
- f_s = Allowable value of the skin friction.
- f_b = Allowable value of the pile end bearing capacity.
- SPT (N) values are corrected within calculation.
- The values of f_s and f_b have been making preliminary estimate about the carrying capacity of a Bored R.C.C. pile.
- In the case of plastic silty soil, the values of the cohesion have been obtained from the SPT values.

13.0 FORMULA USED FOR COMPUTATION:

FOR COHESIVE SOIL:

The ultimate bearing capacity:

$Q_{ult} = CN_c = \frac{Q_u . N_c}{2}$ (J. E. Bowles)

$q_{all} = \frac{q_u . N_c}{2X3} + \gamma D_f = \frac{q_u N_c}{6} + \gamma D_f$ (Factor of safety = 2.50)

Where, q_u = Unconfined Compressive Strength in kg/cm^2.

N_c = Bearing Capacity Factor
= 6.8 square footing.
= 5.7 continuous footing.

FOR COHESION-LESS SOIL:

$Q_{ult} = C\ Nc\ Sc + \gamma D_f\ Nq + 0.5\gamma\ BN\gamma\ S\gamma$ (J. E. Bowles)

Where, C = Cohesion, γ = Unit weight of soil

D_f = Depth of footing, B = Width of footing

N_C, N_q & $N\gamma$ = bearing capacity factors = f (Φ) = f (N)

Sc, $S\gamma$ = Shape Factors = f (B, D_f)

$Q_{allowable} = q_{ult}$/F.S. (F.S. = 2.5)

(Ref. Book: Foundation Analysis and Design by J. E. Bowles, page No. 213-277)

ULTIMATE SKIN FRICTION (f_s) AND END BEARING (f_b) FOR COHESIVE SOIL :

$f_s = FC_d$ (M. J. Tomlinson)

Where, $C_d = q_u/2$;

q_u = Unconfined Compressive strength of soil and

F= Bearing Capacity Factor (Ranges between 0.45 to 0.60)

FOR COHESION-LESS SOIL:

For high displacement piles, f_s = 2.0 N kN/m^2

For low displacement f_s = 1.0 N kN/m^2

Where, N average of corrected N- value along the length of the pile.

For bored piles in sand, f_b = 14 N (D_b/B) kN/m^2

Where D_b = actual penetration into the granular soil.

For bored pile in sand, the unit frictional resistance (f_s) is given by

f_s= 0.67 N kN/m^2 (K . R. Arora).

CONSOLIDATION SETTLEMENT:

$S= C_c / (1+e_o) * H * \log (p_o + \Delta p) / p_o.$

(Ref. Book: Soil Mechanics and Foundation Engineering by K. R. ARORA, Page NO. - 383-450, 638-647 & 1003-1006).

STANDARD PENETRATION TEST:

N correction=15+0.5(N'-15)

Where, N correction =Corrected N- value
N'=SPT value from the field

(Ref. Book: Theory and Practice of Foundation Design by N.N. SOM & S.C. DAS. Page no-42.)

LOAD CALCULATION FOR ANY DIAMETER/ANY LENGTH OF PILE:

$$P= \pi DLf_s + \pi D^2/4f_b$$

Where,

P =Allowable working Load

f_s =Average Allowable value of the skin friction=Kg/cm^2

f_b =Allowable value of the pile end bearing capacity =Kg/cm^2

π = A constant=3.1416
D =Pile Diameter
L =Required length of pile = m

14.0 COMPUTATION FOR CONSOLIDATION SETTLEMENT:

The vertical downward movement of the base of a structure is called settlement and its effect upon the structure depends on its magnitude, its uniformity, the length of the time over which it takes place, and the nature of the clay soils. The consolidation settlement can be calculated form test result of unit weight and consolidation tests. The average settlement depends on column load of structure.

15.0 CONCLUSIONS:

On the basis of above analysis and discussions, the following conclusions may be drawn regarding the sub-soil condition of the project area.

a. The overall soil formation of the investigated site are more or less regular in between the Bore hole locations.
b. The top layers of the investigated site have been encountered with comprising light brown medium clay, some silt (Ref. Bore logs).
c. The underlying soil is grey course sand, trace silt. (Ref. Bore logs).
d. Bearing capacities for shallow foundation including isolated column footings are may not be suitable (Ref. - Table – 5)
e. Shallow foundation as isolated column footing may not be provided at the project site.
f. **R. C. C. Cast-In-Situ Pile** may be provided for all borings at project site.

16.0 RECOMMENDATIONS:

On the basis of aforesaid conclusions, the following recommendations are suggested for **PROJECT: GEOTECHNICAL INVESTIGATION OF FEASIBILITY STUDY OF KARNAPHULI WATER SUPPLY PROJECT PHASE-2 AT NASIRABAD, CHITTAGONG.**

R.C.C CAST-IN-SITU PILE:

The average bearing capacities (F.S=2.50) of different or same diameter piles with embedment length up to **50.0ft or 15.0m** from **EGL** for **BH-01,** may be considered as follows:

28.08 Ton for 400 mm or 16 inch.dia pile
33.42 Ton for 450 mm or 18 inch.dia pile
39.17 Ton for 500 mm or 20 inch.dia pile
51.88 Ton for 600 mm or 24 inch.dia pile

The average bearing capacities (F.S=2.50) of different or same diameter piles with embedment length up to **25.0ft or 7.5m** from **EGL** for **BH-02,** may be considered as follows:

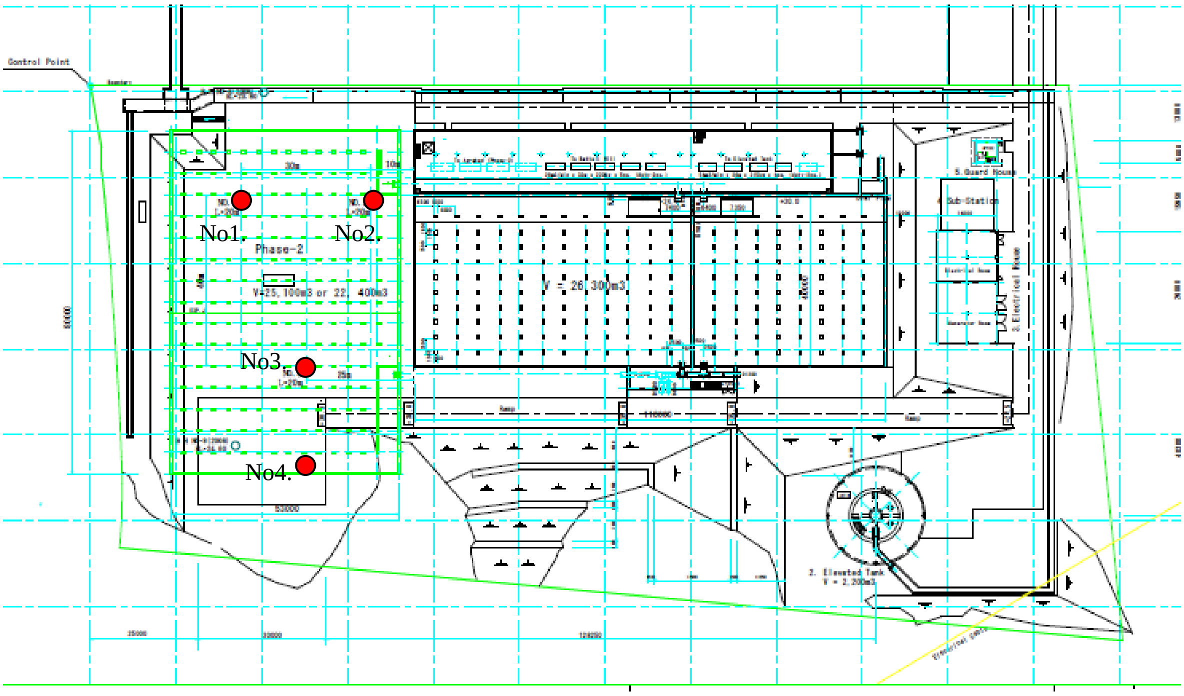
15.58 Ton for 400 mm or 16 inch.dia pile
18.56 Ton for 450 mm or 18 inch.dia pile
21.76 Ton for 500 mm or 20 inch.dia pile
28.84 Ton for 600 mm or 24 inch.dia pile

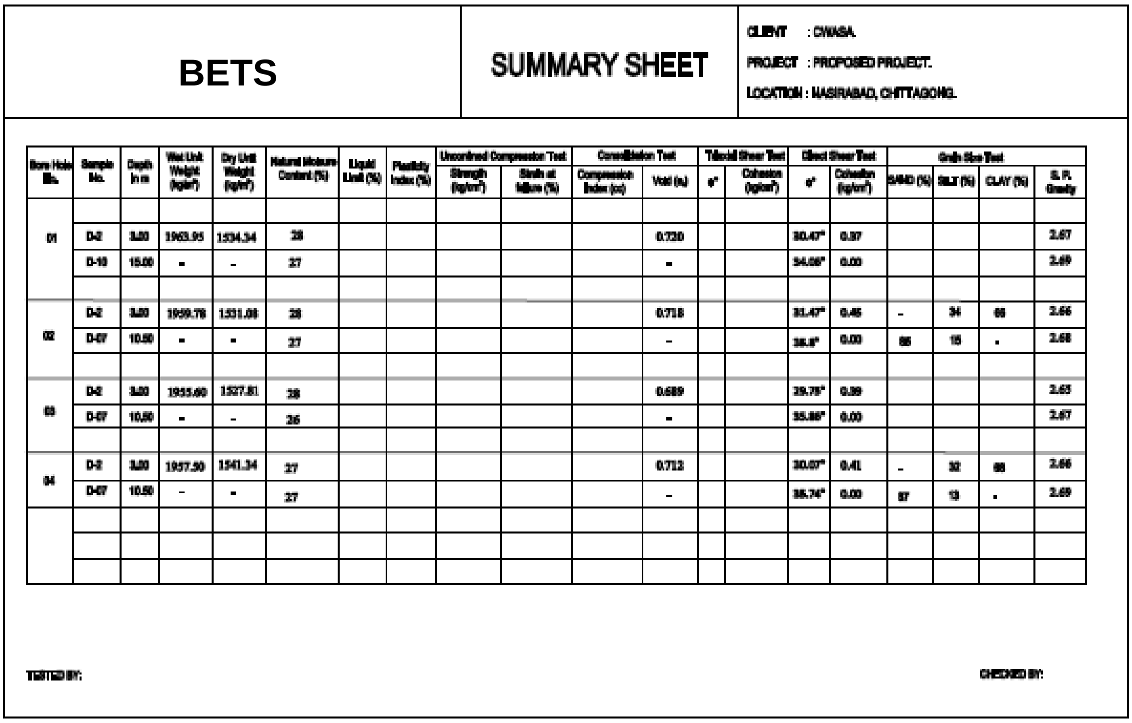
The average bearing capacities (F.S=2.50) of different or same diameter piles with embedment length up to **35.0ft or 10.5m** from **EGL** for **BH-03 & BH-04,** may be considered as follows:

21.81 Ton for 400 mm or 16 inch.dia pile
25.96 Ton for 450 mm or 18 inch.dia pile
30.44 Ton for 500 mm or 20 inch.dia pile
40.35 Ton for 600 mm or 24 inch.dia pile

Note:

- a. 1 Tsf = 1 kg/cm^2 = 2ksf, 1 Ton = 2000 lbs = 9.81 kN, 1m = 3.28ft, EGL = Existing Ground level & F. S. = Factor of Safety.
- **b. The designer may select any other alternative type, depth as well as the bearing capacity of the foundation in the light of information provided in this report.**
- c. Foundation base should be kept dry during construction period.





BETS

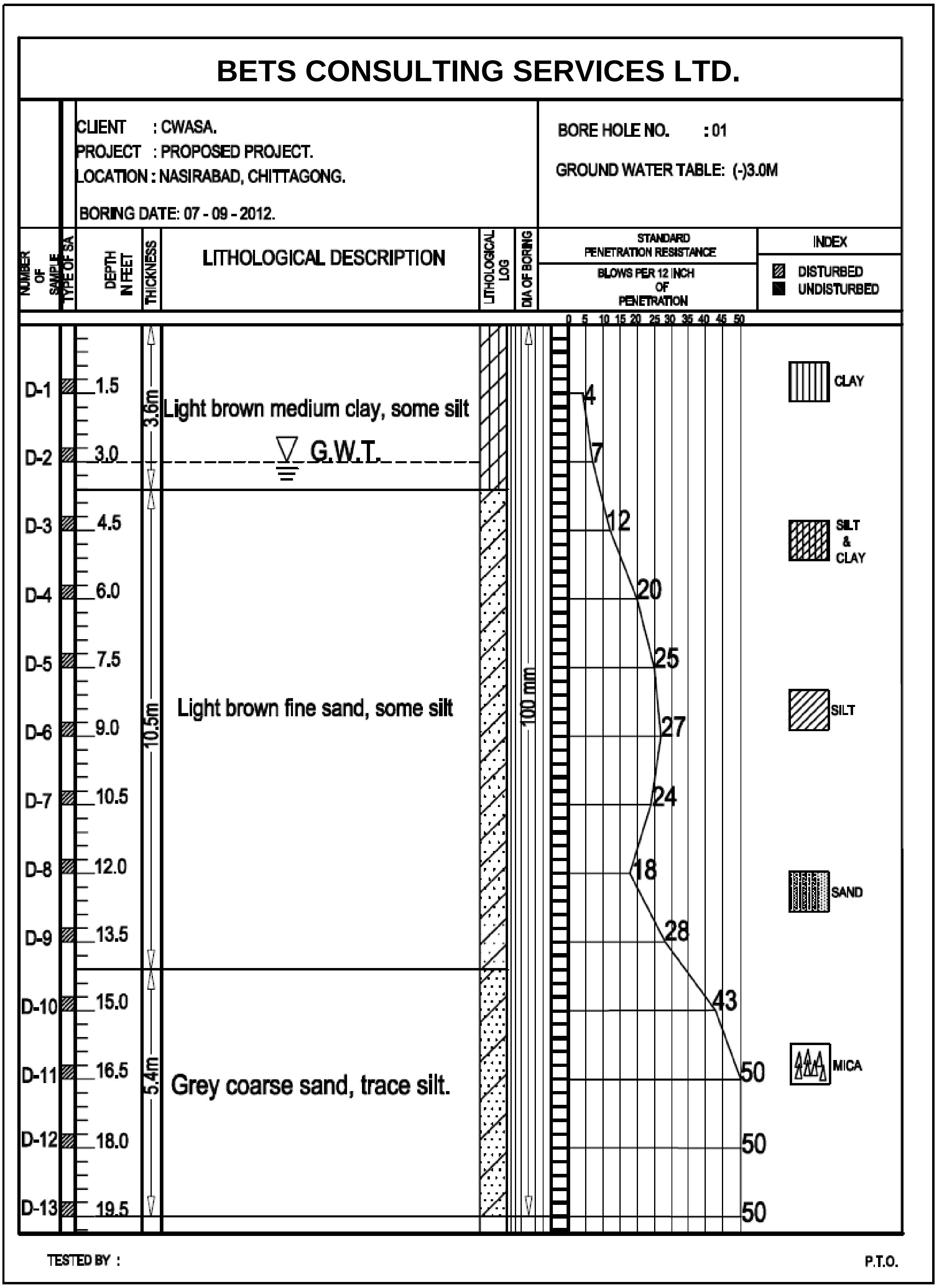
SUMMARY SHEET

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : NASIRABAD, CHITTAGONG.

Bore Hole No.	Sample No.	Depth in m	Wet Unit Weight (kg/m³)	Dry Unit Weight (kg/m³)	Natural Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Unconfined Compression Test		Consolidation Test		Triaxial Shear Test		Direct Shear Test		Grain Size Test			
								Strength (kg/cm²)	Strain at failure (%)	Compression Index (cc)	Void (e)	φ°	Cohesion (kg/cm²)	φ°	Cohesion (kg/cm²)	SAND (%)	SILT (%)	CLAY (%)	S.P. Gravity
01																			
	D-2	3.00	1963.95	1534.34	28						0.720			30.47°	0.37				2.67
	D-10	15.00	-	-	27						-			34.08°	0.00				2.69
02	D-2	3.00	1959.78	1531.08	28						0.718			31.47°	0.45	-	34	66	2.66
	D-07	10.50	-	-	27						-			36.8°	0.00	85	15	.	2.68
03	D-2	3.00	1955.60	1527.81	28						0.689			29.78°	0.39				2.65
	D-07	10.50	-	-	26						-			35.86°	0.00				2.67
04	D-2	3.00	1957.50	1541.34	27						0.712			30.07°	0.41	-	32	68	2.66
	D-07	10.50	-	-	27						-			36.74°	0.00	87	13	.	2.69

TESTED BY:

CHECKED BY:



BETS CONSULTING SERVICES LTD.

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : NASIRABAD, CHITTAGONG.

BORING DATE: 07 - 09 - 2012.

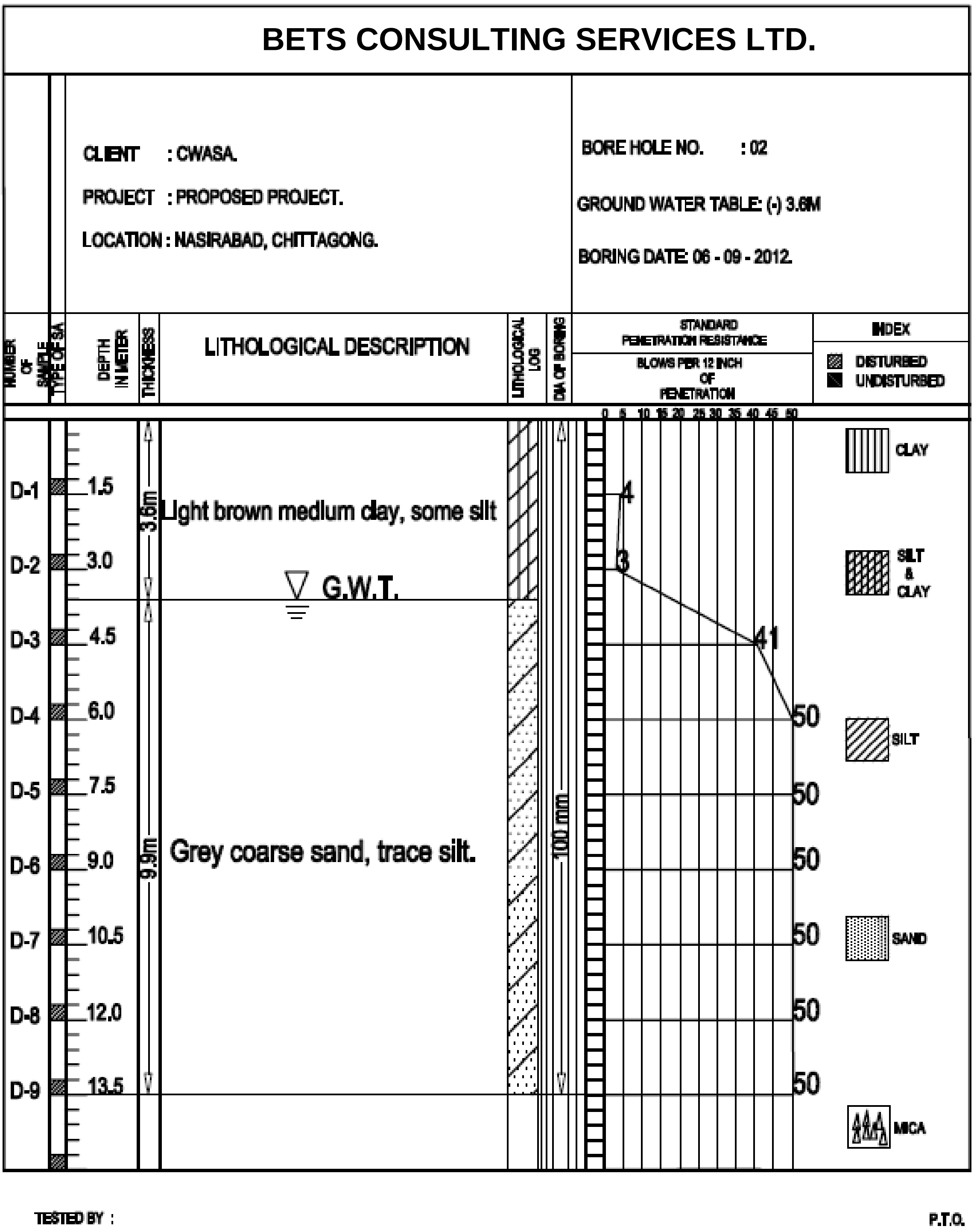
BORE HOLE NO. : 01
GROUND WATER TABLE: (-)3.0M

INDEX
▨ DISTURBED
■ UNDISTURBED

NUMBER OF SAMPLE	TYPE OF SA	DEPTH IN FEET	THICKNESS	LITHOLOGICAL DESCRIPTION	LITHOLOGICAL LOG	DIA OF BORING	STANDARD PENETRATION RESISTANCE BLOWS PER 12 INCH OF PENETRATION
D-1	▨	1.5	3.6m	Light brown medium clay, some silt		100 mm	4
D-2	▨	3.0		G.W.T.			7
D-3	▨	4.5	10.5m	Light brown fine sand, some silt			12
D-4	▨	6.0					20
D-5	▨	7.5					25
D-6	▨	9.0					27
D-7	▨	10.5					24
D-8	▨	12.0					18
D-9	▨	13.5					28
D-10	▨	15.0	5.4m	Grey coarse sand, trace silt.			43
D-11	▨	16.5					50
D-12	▨	18.0					50
D-13	▨	19.5					50

TESTED BY :

P.T.O.



BETS CONSULTING SERVICES LTD.

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : NASIRABAD, CHITTAGONG.

BORE HOLE NO. : 02
GROUND WATER TABLE: (-) 3.6M
BORING DATE: 06 - 09 - 2012.

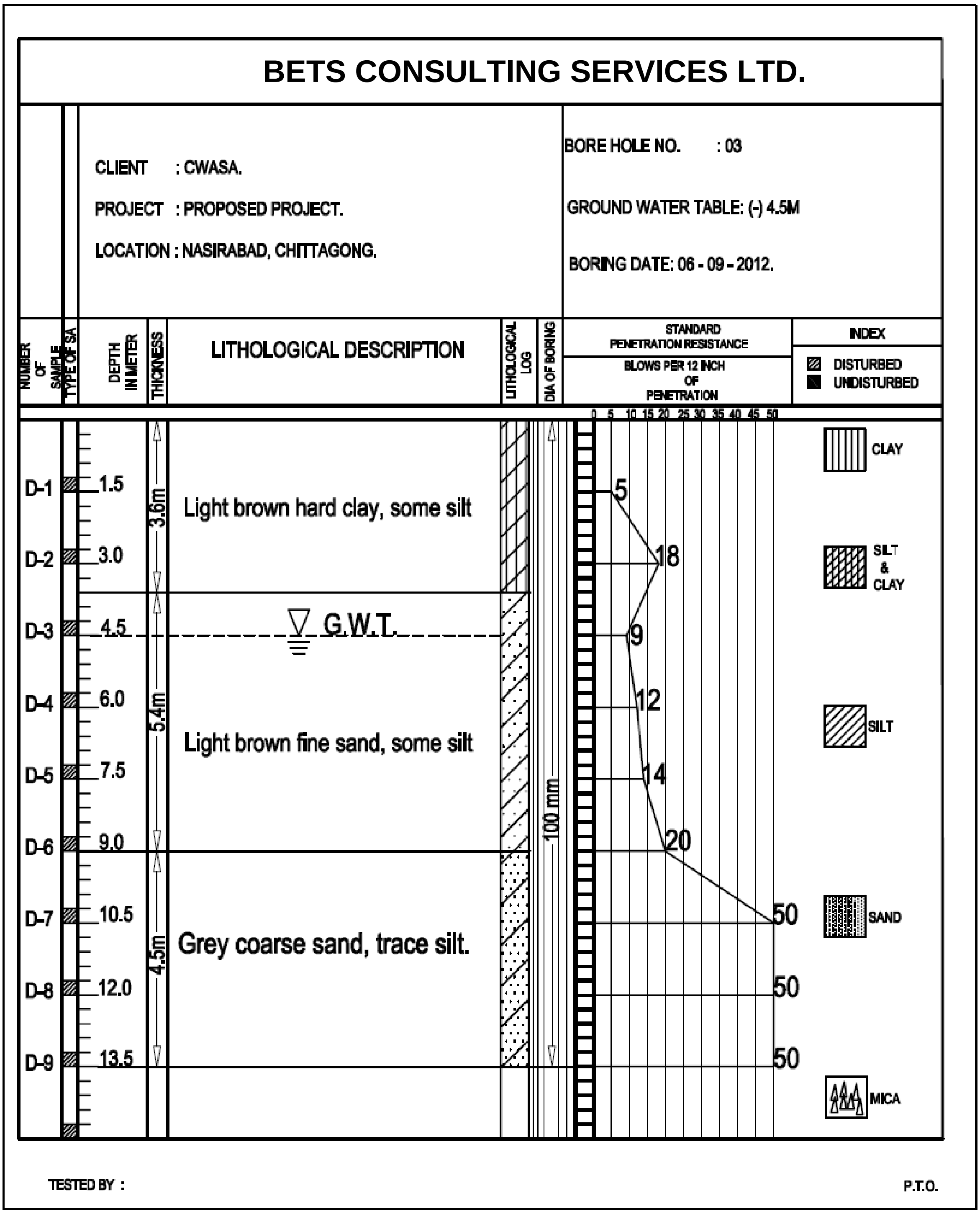
NUMBER OF SAMPLE	TYPE OF SA	DEPTH IN METER	THICKNESS	LITHOLOGICAL DESCRIPTION	DIA OF BORING	STANDARD PENETRATION RESISTANCE BLOWS PER 12 INCH OF PENETRATION
D-1	▨	1.5	3.6m	Light brown medium clay, some silt	100 mm	4
D-2	▨	3.0		▽ G.W.T.		3
D-3	▨	4.5	9.9m	Grey coarse sand, trace silt.		41
D-4	▨	6.0				50
D-5	▨	7.5				50
D-6	▨	9.0				50
D-7	▨	10.5				50
D-8	▨	12.0				50
D-9	▨	13.5				50

INDEX
▨ DISTURBED
■ UNDISTURBED

CLAY
SILT & CLAY
SILT
SAND
MICA

TESTED BY :

P.T.O.



BETS CONSULTING SERVICES LTD.

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : NASIRABAD, CHITTAGONG.

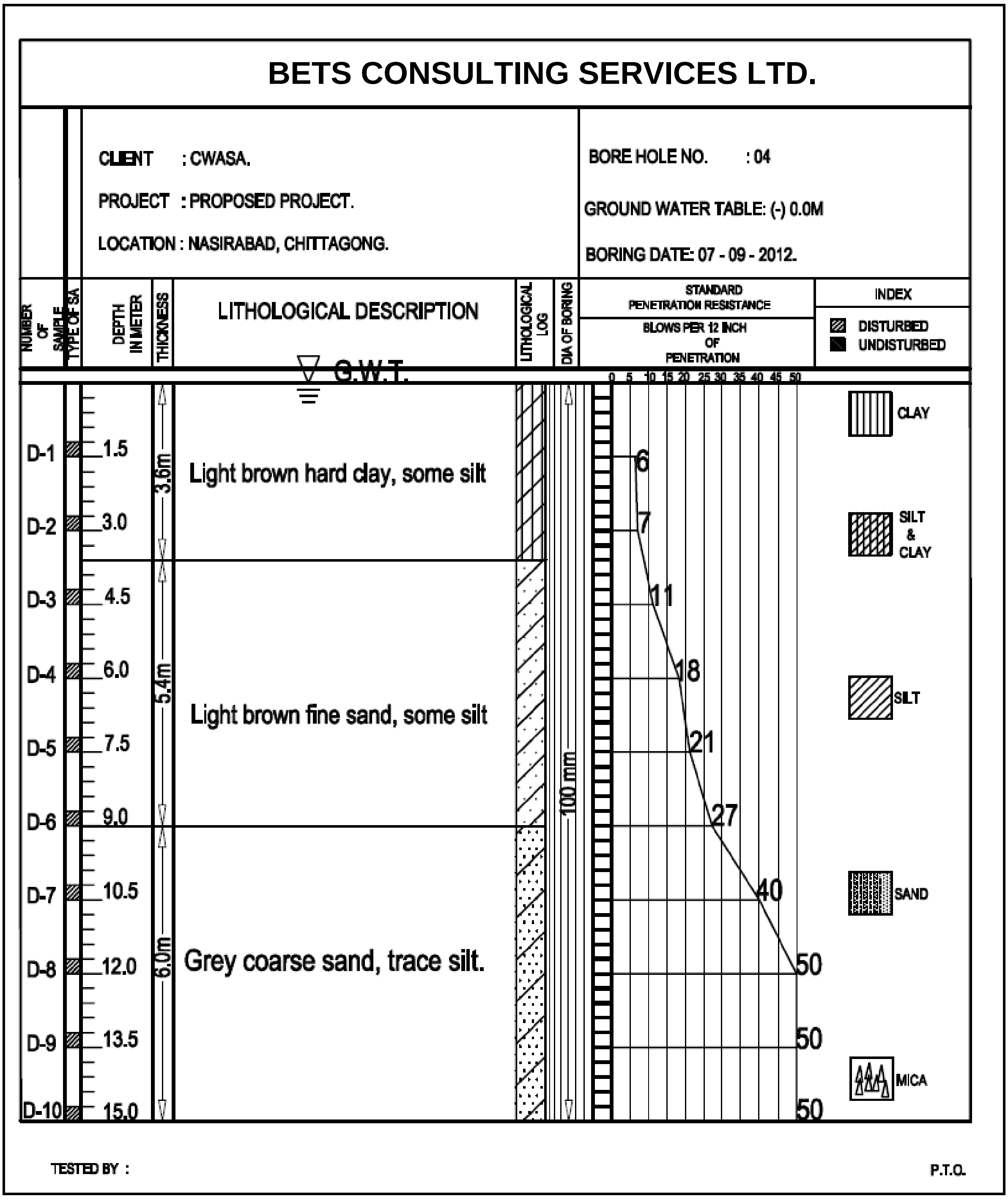
BORE HOLE NO. : 03
GROUND WATER TABLE: (-) 4.5M
BORING DATE: 06 - 09 - 2012.

NUMBER OF SAMPLE	DEPTH IN METER	THICKNESS	LITHOLOGICAL DESCRIPTION	STANDARD PENETRATION RESISTANCE BLOWS PER 12 INCH OF PENETRATION
D-1	1.5	3.6m	Light brown hard clay, some silt	5
D-2	3.0			18
D-3	4.5	5.4m	Light brown fine sand, some silt	9
D-4	6.0			12
D-5	7.5			14
D-6	9.0			20
D-7	10.5	4.5m	Grey coarse sand, trace silt.	50
D-8	12.0			50
D-9	13.5			50

G.W.T.

TESTED BY :

P.T.O.



BETS CONSULTING SERVICES LTD.

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : NASIRABAD, CHITTAGONG.

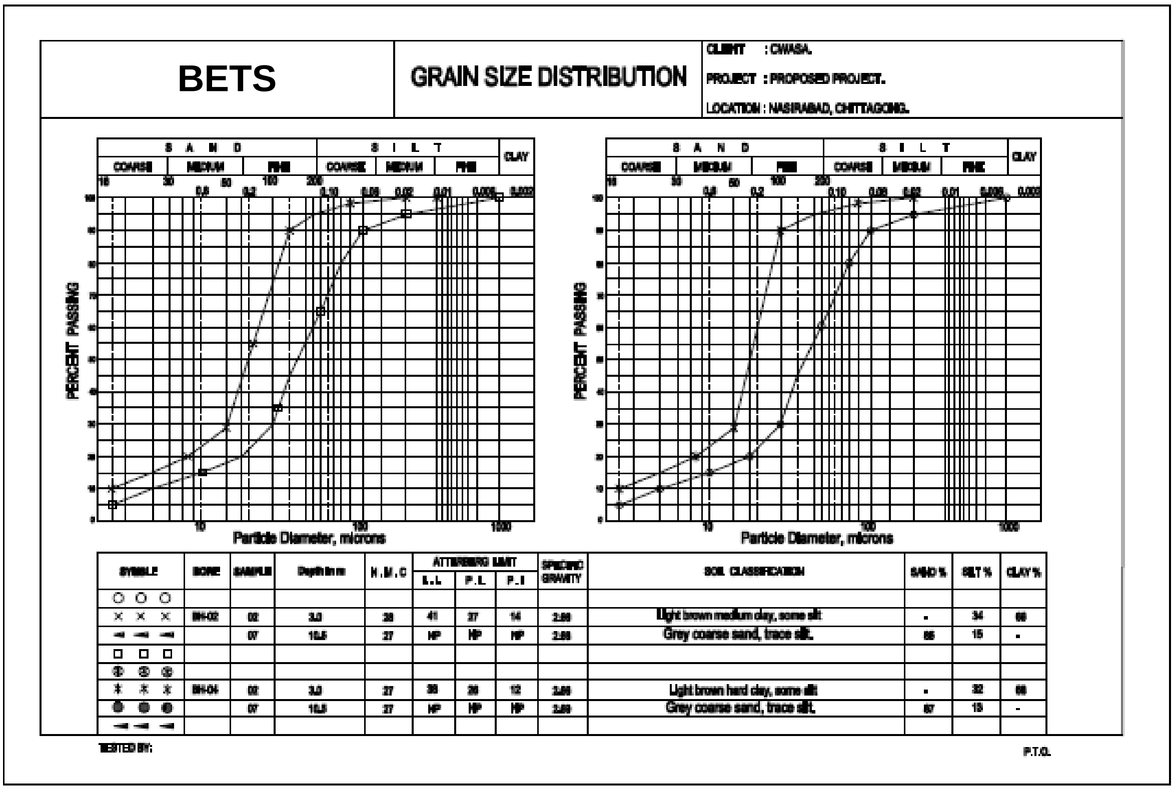
BORE HOLE NO. : 04
GROUND WATER TABLE: (-) 0.0M
BORING DATE: 07 - 09 - 2012.

INDEX
▨ DISTURBED
■ UNDISTURBED

NUMBER OF SAMPLE	TYPE OF SA	DEPTH IN METER	THICKNESS	LITHOLOGICAL DESCRIPTION	DIA OF BORING	STANDARD PENETRATION RESISTANCE BLOWS PER 12 INCH OF PENETRATION
D-1	▨	1.5	3.6m	Light brown hard clay, some silt	100 mm	6
D-2	▨	3.0				7
D-3	▨	4.5	5.4m	Light brown fine sand, some silt		11
D-4	▨	6.0				18
D-5	▨	7.5				21
D-6	▨	9.0				27
D-7	▨	10.5	6.0m	Grey coarse sand, trace silt.		40
D-8	▨	12.0				50
D-9	▨	13.5				50
D-10	▨	15.0				50

TESTED BY :

P.T.O.



BETS

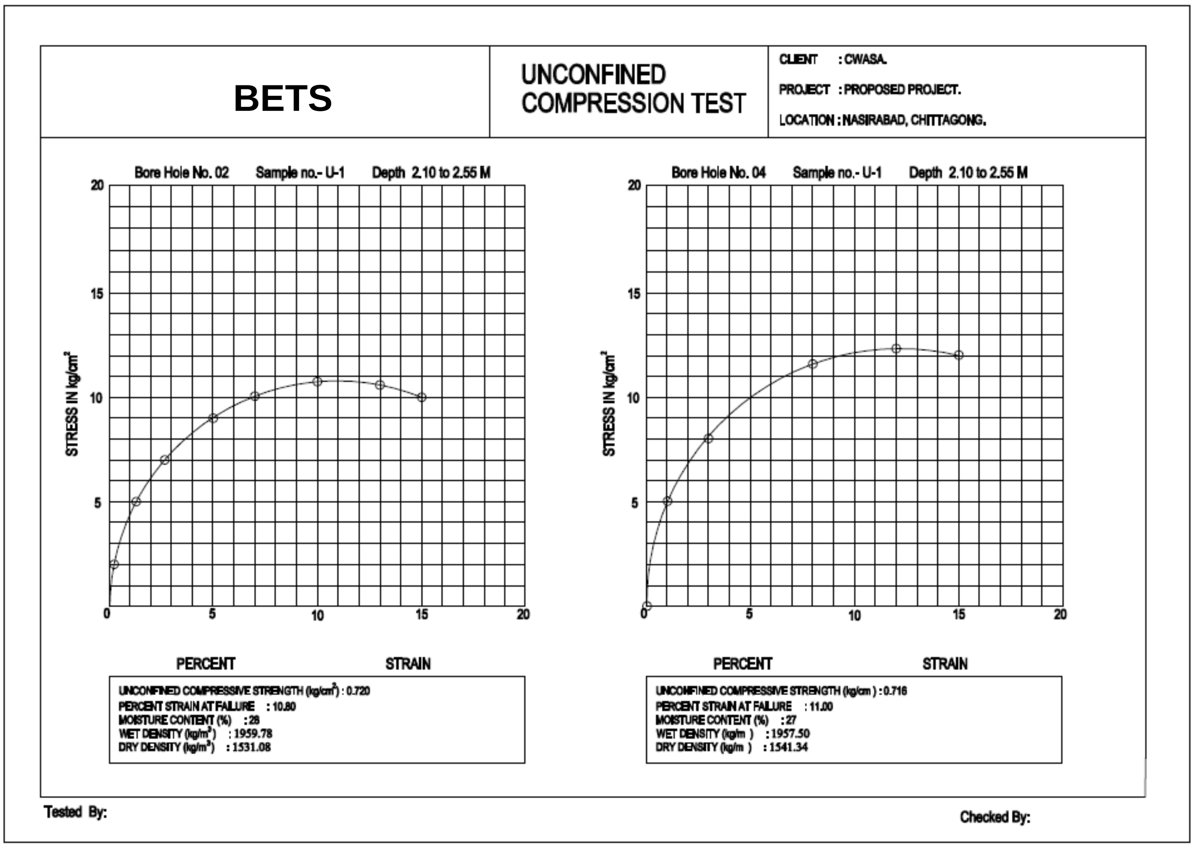
GRAIN SIZE DISTRIBUTION

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : NASIRABAD, CHITTAGONG.

SYMBLE	BORE	SAMPLE	Depth in m	N.M.C	ATTERBERG LIMIT			SPECIFIC GRAVITY	SOIL CLASSIFICATION	SAND %	SILT %	CLAY %
					L.L	P.L	P.I					
○ ○ ○												
× × ×	BH-02	02	3.0	28	41	27	14	2.66	Light brown medium clay, some silt	-	34	66
⇥ ⇥ ⇥		07	10.5	27	NP	NP	NP	2.66	Grey coarse sand, trace silt.	85	15	-
□ □ □												
⊕ ⊕ ⊕												
* * *	BH-04	02	3.0	27	38	26	12	2.66	Light brown hard clay, some silt	-	32	68
● ● ●		07	10.5	27	NP	NP	NP	2.66	Grey coarse sand, trace silt.	87	13	-
⇥ ⇥ ⇥												

TESTED BY:

P.T.O.



BETS

UNCONFINED COMPRESSION TEST

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : NASIRABAD, CHITTAGONG.

Bore Hole No. 02 Sample no.- U-1 Depth 2.10 to 2.55 M

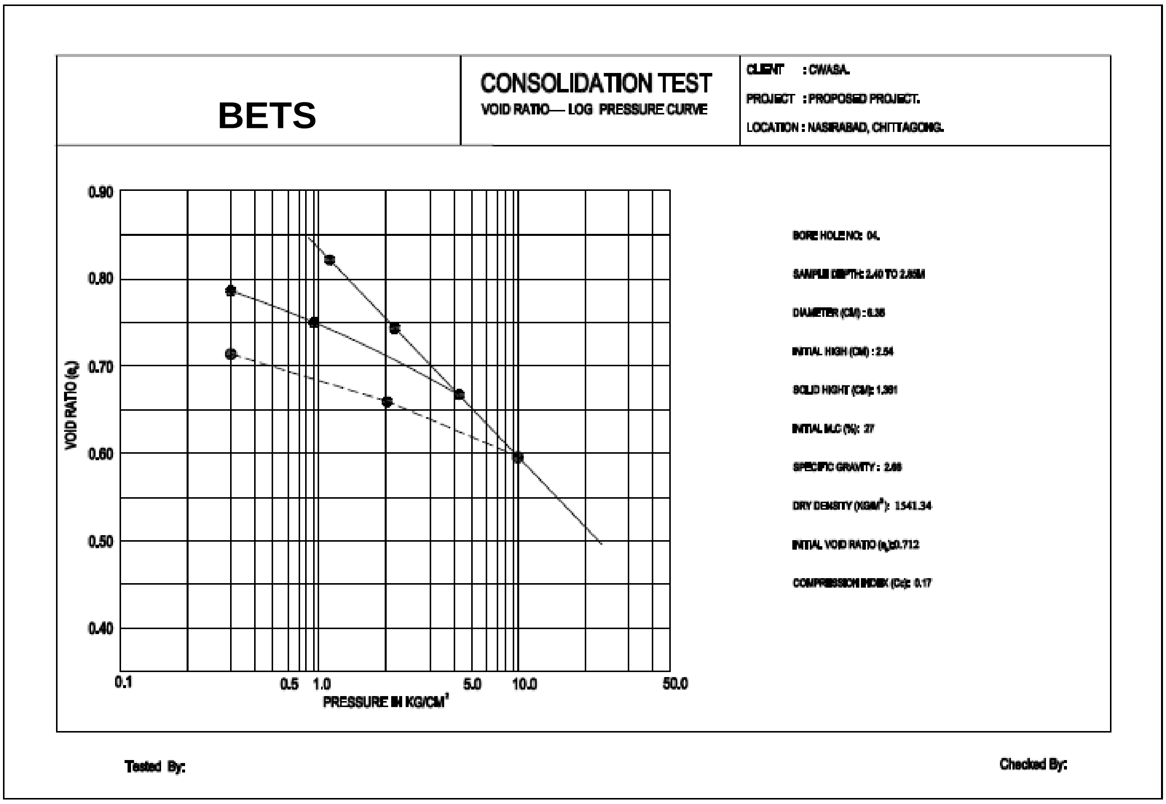
UNCONFINED COMPRESSIVE STRENGTH (kg/cm^2) : 0.720
PERCENT STRAIN AT FAILURE : 10.80
MOISTURE CONTENT (%) : 28
WET DENSITY (kg/m^3) : 1959.78
DRY DENSITY (kg/m^3) : 1531.08

Bore Hole No. 04 Sample no.- U-1 Depth 2.10 to 2.55 M

UNCONFINED COMPRESSIVE STRENGTH (kg/cm) : 0.716
PERCENT STRAIN AT FAILURE : 11.00
MOISTURE CONTENT (%) : 27
WET DENSITY (kg/m) : 1957.50
DRY DENSITY (kg/m) : 1541.34

Tested By:

Checked By:



BETS

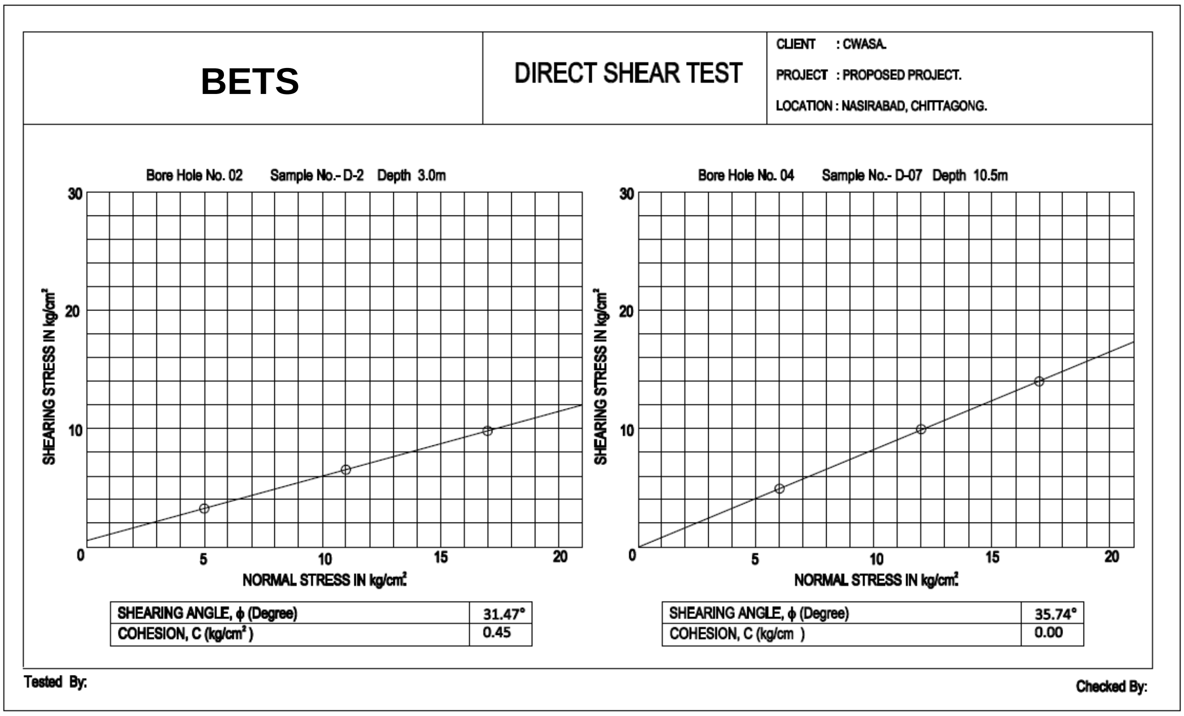
CONSOLIDATION TEST
VOID RATIO— LOG PRESSURE CURVE

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : NASIRABAD, CHITTAGONG.

BORE HOLE NO: 04.
SAMPLE DEPTH: 2.40 TO 2.85M
DIAMETER (CM) : 6.35
INITIAL HIGH (CM) : 2.54
SOLID HIGHT (CM): 1.381
INITIAL M.C (%): 27
SPECIFIC GRAVITY : 2.66
DRY DENSITY (KG/M^3): 1541.34
INITIAL VOID RATIO (e_0):0.712
COMPRESSION INDEX (Cc): 0.17

Tested By:

Checked By:



BETS

DIRECT SHEAR TEST

CLIENT : CWASA.
PROJECT : PROPOSED PROJECT.
LOCATION : NASIRABAD, CHITTAGONG.

Bore Hole No. 02 Sample No.- D-2 Depth 3.0m

SHEARING ANGLE, ϕ (Degree)	31.47°
COHESION, C (kg/cm^2)	0.45

Bore Hole No. 04 Sample No.- D-07 Depth 10.5m

SHEARING ANGLE, ϕ (Degree)	35.74°
COHESION, C (kg/cm)	0.00

Tested By:

Checked By:

III GROUND LEVEL SURVEY

III Ground Level Survey