Geo technical Investigation and Topographic Survey for Landfill Site in Gujranwala

Geotechnical Investigation Report

The report presents findings of the field investigation laboratory testing and geotechnical recommendations for Geo technical Investigation and Topographic Survey for Landfill Site in Gujranwala.

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Executive Summary

"Gujranwala Waste Management Company intends to build a landfill site in Gujranwala. The project site is located at about 4.5 km towards Bakhriyawali Village from Canal Crossing at Alipur Chatta Road. This is about 3.5 km off Gujranwala Pindi Bypass Road. The location of the site can be seen in the Site Location Map attached as AnnexureA.1.

Keeping in view the layout of the proposed structures, Gujranwala Waste Management Company provided the requirement of the Geotechnical Investigation to be implemented for the design and evaluation of the proposed structure.

For evaluation of sub-surface soil parameters and safe design of foundations, it was essential to carry out Geotechnical Investigations. M/s Lean & Green Private Limited carried out Geotechnical Investigations at the project site. The Scope of Work (SOW) was defined considering the current project requirements provided by the client. Four (4) boreholes of 30 m depth and five Auger holes of 10 m depth were planned to assess the ground condition for supporting the proposed structure .

Probabilistic Seismic Hazard Assessment (PSHA) carried out for revision of seismic provisions of the Building Code of Pakistan, shows that the site area falls in Zone 2A. It is therefore, recommended that the project structures should be designed to cater for the requirements of Zone 2Aof Building Code of Pakistan (2007).

The top surface comprises vegetative cover which is underlain by Lean Clay/Silt (Soft to firm), up to 1 m depth, the material is underlain by Silty Sand (Medium Dense to Dense) up to a maximum investigated depth of 30 m depth below NSL.

Groundwater was encountered at a depth of about 6 m in the boreholes drilled up to a maximum depth of 30 m below NSL. However, seasonal variation can result into increase of groundwater table, in the upper layer of soil.

The bearing capacity curves are provided in the Annexure B.3.

The evaluation of the bearing capacity of the Square/Rectangular Foundation has been done using approach given by Terzaghi, Elastic theory and other established correlations. The analysis has been carried out for a depth of foundation 1.5 m below NSL.

Similarly, the evaluation of the bearing capacity of the Strip Foundation has been done. The analysis has been carried out for a depth of foundation 1.5 m below NSL.

1. Introduction

1.1. Scope of Report

Gujranwala Waste Management Company (GWMC) has planned the construction of a Landfill Site in Gujranwala. The project site is located at about 4.5 km towards Bakhriyawali Village from Canal Crossing at Alipur Chatta Road, this is about 3.5 km off Gujranwala Pindi Bypass Road. Keeping in view the layout of the proposed structures GWMC provided the requirement of the Geotechnical Investigation to be implemented for the design and evaluation of the proposed structure.

For evaluation of sub-surface soil parameters and safe design of foundations, it was essential to carry out Geotechnical Investigations. M/s Lean & Green Private Limited was assigned the task to carry out Geotechnical Investigations at the project site. This Geotechnical Investigation report provides detail of current site conditions and interpretation of the investigation works carried out for the design and evaluation of proposed foundations. In addition, the report also delineates the guidelines and recommendations on geotechnical aspects to be used for structural design as well as considerations for construction activity.

1.2. Objectives of Investigations

The geotechnical investigation were undertaken to meet the following objectives:

- To delineate the subsoil conditions of the site area.
- To evaluate the geotechnical design parameters for various structures

1.3. Proposed Development

The proposed project involves Construction of Landfill Site in Gujranwala.

1.4. Scope of Work

The Scope of Work (SOW) was defined considering the current project requirements provided by the client. The Geotechnical Investigation was accordingly planned to assess the ground condition for supporting the proposed structure.

1.4.1. Field Investigations

The Scope of Work (SOW) was defined considering the current project requirements provided by the client. Four (4) boreholes of 30m depth and five Auger holes of 10 m depth were planned to assess the ground condition for supporting the proposed structure.

In addition to above three of the boreholes were converted in to piezometers, for long term monitoring of fluctuation of ground water table. Five (5) permeability tests were performed in the auger holes drilled at site up to maximum investigation depth of 10 m below NSL. The field investigations were performed as per the latest ASTM standards listed in Table 1-1

Table 1-1: List of Field Tests

No.	Field Test	ASTM / BS Standard
1.	Standard Penetration Tests (SPT)	ASTM D1586-11

1.4.2. Laboratory Tests

Samples collected from the boreholes were subjected to the following tests, as per latest ASTM, AASHTO, BS or equivalent Standards, as listed in Table 1-2:

Table 1-2: List of Laboratory Tests

No.	Laboratory Test	ASTM / BS Standard
1.	Grain Size Analysis (GSD)	ASTM D421-85(07), ASTM D422-63(07)
2.	Hydrometer Analysis (HMA)	ASTM D422-63(07)
3.	Atterberg Limits (ATL)	ASTM D4318-00
4.	Natural Moisture Content (NMC)	ASTM D2216-10
5.	Direct Shear Test (DST)	ASTM D3080-11
6.	Unconfined Compressive Strength (UCS)	ASTM D2166-13
7.	Oedometer Test (OED)	ASTM D2435-11
8.	Chemical Tests (CHM)	BS 1377-3:1990

2. Site Description

2.1. Location of the Project Site

The project site is located at about 4.5 km towards Bakhriyawali Village from Canal Crossing at Alipur Chatta Road, this is about 3.5 km off Gujranwala Pindi Bypass Road. The location of the site can be seen in the Site Location Map attached as AnnexureA.1

2.2. Geology and Seismicity of the Area

2.2.1. Geology

The project site is located in Punjab, which is a plain of Alluvial material and scattered rocks at deeper depth. A Geological Map showing the Geological distribution of the area is provided in Annexure A.3Geological Map of the Project Area.

2.2.2. Seismicity

Probabilistic Seismic Hazard Assessment (PSHA) carried out for revision of seismic provisions of the Building Code of Pakistan, shows that the site area falls in Zone 2A. It is therefore, recommended that the project structures should be designed to cater for the requirements of Zone 2Aof Building Code of Pakistan (2007).

A plan showing various zones of Pakistan as per Latest Seismic Microzonation as given in the Building code of Pakistan is attached with this report as Annexure A.4.

2.3. Current Use of Project Area

The site area is currently open, and partly in use as agriculture and mostly for borrowing the material for nearby earth works.

2.4. Topography of Project Area

The topographically the site area used to be a fairly plain. But after start of borrowing of soil, it has developed depressions of more than 6 m in the most of area which is now filled with water. The area under cultivation is fairly plain.

3. Subsurface Exploration

3.1. General

The field investigation was performed under full time supervision by our experienced geotechnical engineer who supervised drilling operation, sampling and logging and top supervised the laboratory testing. The field tests that were performed are listed in Table 1-1

3.2. Drilling

A total of nine (9) boreholes of maximum borehole depth of thirty meters (30 m) were planned at the project site. The field investigation was supported by relevant laboratory testing. The drilling and sampling work has been performed using the standards, procedures and equipment's recommended for engineering site investigation. The exact location of boreholes has been marked on the ground in the presence of the client's representative.

3.3. Standard Penetration Tests (SPT)

Standard penetration test is by far the most popular and economical method of obtaining subsurface information. It is carried out to assess the in-situ compactness of various soil layers. Significant numbers of foundation design procedures make use of SPT results.

Testing method essentially consists of driving split spoon sampler of specified dimensions up to a distance of 46cm into the soil at bottom of borehole. A 63.5kg hammer failing free from a height of 76cm is used to drive the sampler. Number of blows required to drive the sampler were carried out in accordance with the specification of ASTM D1586-11. Continuous standard penetration test is performed wherever possible.

The SPT's were carried out at an interval of 1m in boreholes. A total of one hundred sixteen (116) SPT's were performed. Annexure B.1 shows the variation of SPT blows with depth and the detail of SPT Results are given in the individual borehole logs in Annexure D.1.

3.4. Sampling

Collection of representative samples forms an essential part of investigation program. The following types of samples have been collected for this Project.

3.4.1. Disturbed Soil Samples

Disturbed soil samples were obtained either from the Auger/bailer as the borehole was advanced or from the spilt spoon sampler after performing Standard Penetration Test (SPT). Disturbed samples were used to classify the soil type and depth of occurrence of different layers, and were preserved, for laboratory testing. All the samples obtained from the boreholes were properly preserved in polythene bags and labelled as disturbed samples. The entire sampling, preservation and transportation of the samples were carried out as per latest ASTM standards.

3.4.2. Undisturbed Soil Samples

A total of four (4) undisturbed soil samples were recovered from the boreholes, using Pitcher samplers. After determining the in-situ density, the samples were properly waxed, labelled and preserved before transportation to the laboratory.

3.4.3. Ground Water Samples

The groundwater table was encountered at a depth of about 6m below NSL, during geotechnical investigations carried out at site. A total of four (4) water sample were collected from the boreholes.

The most of the exiting site area has been ponded apparently with the ground water and rain water accumulated in the deep excavated area more than 6 m.

3.5. Installation of Piezometers

A total of three auger holes were converted in to Piezometers for the purpose of ground water table monitoring in the long term. The auger holes were drilled up to a depth of 10 m below NSL and were converted in to piezometers by installing PVC slotted pipes wrapped with non-woven geotextile as a filter material. The observations of the water level at the time of field investigation are given in Table 3-1 - Ground Water Level Observation during Field Investigation

Table 3-1 - Ground Water Level Observation during Field Investigation

Borehole No.	Surface Elevation (m)	Bottom Elevation	Depth of Water	Water Elevation
BH-1	498.00	468.00	6.00	492.00
BH-2	495.62	465.62	4.00	491.62
BH-3	493.47	463.47	5.50	487.97
BH-4	495.78	465.78	4.50	491.28
BHA-1	496.38	486.38	6.00	490.38
BHA-2	496.61	486.61	6.00	490.61
BHA-3	492.79	482.79	5.00	487.79
BHA-4	498.52	488.52	7.60	490.92
BHA-5	490.26	480.26	4.50	485.76

3.6. Field Permeability Test

Five (5) field permeability tests were carried out at different depths in the overburden soils. This yielded preliminary information about the order of magnitude and variability of the coefficient of permeability. The method of falling of variable head is more appropriate for clays. Therefore, Constant Head method was adopted for these tests as most of the test horizons were encountering sandy soils. The tests were carried out as per BS 5930, BS 1377 P5 and ASTM D2434-68 (1994). In all the cases, the boreholes were cased from the ground surface to the top of the soil column to be tested. The borehole drilled and was washed with clean water in order to clear the test zone. In this test, the head of water was maintained, and the volume of flow was measured as a function of time. The results of these tests are as follows:

Borehole No.	Depth	Material	Coefficient of Permeability (cm/sec)
BH-01	5	Fine Sand	3.45E-04
BH-02	8	Fine Sand	3.81E-04
BH-03	3	Fine Sand	1.22E-04
BH-04	4	Fine Sand	7.15E-05
BH-05	8	Fine Sand	3.12E-04

4. Laboratory Test Results

In addition to field testing, a number of laboratory tests, as listed in Table 1-2, were also conducted on selected soil samples. Results of these tests are helpful in classification of soil, determining engineering properties such as classification, compactness and suitability for construction material; the same is given in the Annexure B.2.1, which contains laboratory test results.

Brief description of all the laboratory tests and testing standards is given in the following sections.

4.1. Grain Size Analysis

Soil is an uncemented aggregate of mineral grains and decayed matter with liquid and gas in the empty spaces between the solid particles, which consists of an assemblage of discrete of particles of various sizes and shapes. This analysis consists of shaking the soil sample through a set of sieves, which decrease in opening sizes from top to bottom. The object is to group these particles into separate size ranges and to determine the relative proportions by dry weight, of each size range.

Grain size analysis is been conducted in two stages. Particles size distribution of coarse-grained soils is performed by sieve analysis while hydrometer analysis is conducted to establish distribution of fine-grained soils. Grain size analysis is carried out as per ASTM D422-63(07).

Based on the results of these analyses and the Atterberg limits, the soil is classified into groups and sub-groups according to their engineering behaviour. Generally two elaborate classification systems are used which are the American Association of State Highway and Transportation Officials (AASHTO) classification system and the Unified Soil Classification System (USCS). The AASHTO classification system (AASHTO M145 or ASTM D3282-09) is used mostly by highway departments for road design, whereas the USCS system (ASTM D2487-11) is used by geotechnical engineers for foundation design etc.

A total of one hundred twenty three (123) sieve analyses were conducted on the samples collected from the site.

The classification test results indicate that the subsoil mostly comprises of CL, ML, SM, SP-SM/SW-SM groups on the basis of USCS System. The soils classified as granular indicated fines (passing # 200 sieve) ranging from 1% to 32%. The fine content in the cohesive soils were indicated as 80% to 98%.

4.2. Hydrometer Analysis

Hydrometer analysis is the process by which fine-grained soils, silts and clays, are graded. It is performed if the grain sizes are too small for sieve analysis. The basis for this test is Stoke's Law for falling spheres in a viscous fluid in which the terminal velocity of fall depends on the grain diameter and the densities of the grain in suspension and of the fluid.

The soil sample is mixed in water, along with a dispersing agent to separate individual soil particles. The density of the soil suspension is determined with a hydrometer calibrated to read in grams of solids per litre after the sand settles out and again after the silt settles. Corrections are made for the density and temperature of the dispersing solution, as defined in ASTM D422-63(07).

A total of two (2) hydrometer tests performed on the soil samples indicated that the percent passing from a 0.02mm size ranged from 24% to 48% and percent passing from a 0.002mm size varied from 6% to 22%.

4.3. Atterberg Limits

Atterberg limits, as described in ASTM D4318-00, are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit. As a dry, clayey soil takes on increasing amounts of water, it undergoes dramatic and distinct changes in behaviour and consistency. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state, the consistency and behaviour of a soil is different and consequently so are its engineering properties.

Plastic limit (PL) is the moisture content at which the soil passes from the semisolid to the plastic state, as the moisture content is increased. It is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface.

Liquid Limit (LL) is the moisture content at which a soil passes from the plastic state to a liquid state as the water content is increased.

Plasticity Index (PI) is the difference of moisture content at liquid and plastic limits (PI=LL-PL). A plot of Pi against LL provides the bases for classification of cohesive soils. It also provides insight into several soil characteristics such as compressibility and strength.

A total of five (5) Atterberg limit tests performed on the soil samples indicated that the liquid limit (LL) ranged from 30 to 31and plasticity index (PI) varied from 10 to 11, while three (3) samples showed a non-plastic (NP) behaviour.

4.4. Natural Moisture Content

Moisture content of soil is the ratio of the amount of water present in a soil sample to the solid mass of the soil. The knowledge of the in situ natural moisture content will give an idea of the state of soil in the field. It is essential in in establishing a correlation between soil behaviour and its index properties and determining the bearing capacity and settlement. The standard procedure is given in ASTM D2216-10.

The laboratory tests performed on four (4)relatively undisturbed soil samples extracted up to a maximum depth of 6m below NSL have yielded natural moisture content ranging from 16%to 31%.

4.5. Direct Shear Test

Direct shear test, according to ASTM D3080-11, is a laboratory to measure the shear strength properties of soil. It is performed on three or four specimens from a relatively undisturbed soil sample. A specimen is placed in a shear box which has two stacked rings to hold the sample; the contact between the two rings is at approximately the mid-height of the sample. A confining stress is applied vertically to the specimen, and the upper ring is pulled laterally until the sample fails, or through a specified strain. The load applied and the strain induced is recorded at frequent intervals to determine a stress-strain curve for each confining stress. This test is commonly used for dry or saturated sandy soils.

A total of four (4) direct shear tests were performed on the relatively undisturbed granular soil samples extracted from undisturbed soil samples extracted from boreholes using pitcher sampler. The results indicated angles of internal friction $(\emptyset)$ varying from 33° to 37° with the corresponding cohesion intercept of zero.

4.6. Unconfined Compressive Strength

The objective of the unconfined compression test is to determine the unconsolidated un-drained strength of a cohesive soil in an inexpensive manner. Fine-grained soils are usually tested in compression. Undisturbed specimens are cut from tube samples and disturbed specimens are loaded in compression, recording load and deflection measurements. The unconfined test uses axial loading without lateral confining pressures, making it the simplest and relatively quickest laboratory method of estimating strength of soil. Standard Procedure is given in ASTM D2166-13.

The project site area has a very thin cover of cohesive material in the upper 1 m only, therefore, no undisturbed soil sample was extracted from the cohesive material. Therefore, the unconfined compression test was not performed.

4.7. Oedometer Test (OED)

An oedometer test is a kind of geotechnical investigation performed in geotechnical engineering that measures a soil's consolidation properties. Oedometer tests, as described in ASTM D2435-11, are performed by applying different loads to a soil sample and measuring the deformation response. The results from these tests are used to predict how a soil in the field will deform in response to a change in effective stress.

Oedometer tests are designed to simulate the one-dimensional consolidation and drainage conditions that soils experience in the field. To simulate these conditions, rigid confining rings are used to prevent lateral displacement of the soil sample.

The project site area has a very thin cover of cohesive material in the upper 1 m only, therefore, no undisturbed soil sample was extracted from the cohesive material. Therefore, the unconfined compression test was not performed.

4.8. Chemical Tests

The chemical tests are performed, as per BS 1377 Part 3, to check the acidity of the soil and the quantities of aggressive materials in the ground, such as Sulphates, Chlorides and Organic materials which may attack buried concrete or metal.

Chemical tests carried out on two (2) water samples indicated that total soluble solids varied as 355 to 460ppm and chloride contents from 67 to 98ppm.

5. Ground Conditions and Engineering Properties

5.1. Lithology of Project Area

The top surface comprises vegetative cover which is underlain by Lean Clay/Silt (Soft to firm), up to 1 m depth, the material is underlain by Silty Sand (Medium Dense to Dense) up to a maximum investigated depth of 30 m depth below NSL

5.2. Ground Conditions

The ground conditions consist of the following general conditions summarized below in Table 5-1

Table 5-1: Summary of Ground Conditions

Borehole No.	Top Depth (m)	Bottom Depth (m)	Description Title	Description
1	0	1	1	SILT
1	1	4	3	SILTY SAND
1	4	10.11	6.10	FINE SAND
1	10.11	20.21	10.10	FINE SAND
1	20.21	30	9.8	FINE SAND
2	0	1	1	SILT
2	1	2	1	SILTY SAND
2	2	10.10	8.10	FINE SAND
2	10.10	20.21	10.10	FINE SAND
2	20.20	30	9.78	FINE SAND
3	0	1	1	SILT
3	1	2.5	1.5	SILTY SAND
3	2.5	10.10	7.6	FINE SAND
3	10.11	20.22	10.11	FINE SAND
3	20.22	30	9.78	FINE SAND
4	0	1	1	SILT
4	1	2	1	SILTY SAND

Borehole No.	Top Depth (m)	Bottom Depth (m)	Description Title	Description
4	2	10.11	8.11	FINE SAND
4	10.11	20.22	10.11	FINE SAND
4	20.22	30	9.78	FINE SAND

5.3. Groundwater Table

Groundwater was encountered at a depth of about 6 m in the boreholes drilled up to a maximum depth of 30 m below NSL. However, seasonal variation can result into increase of groundwater table, in the upper layer of soil

5.4. Geotechnical Design Parameters

5.4.1. Summary of Design Parameters

Table 5-2 summarizes the recommended layer thicknesses used in parameters selection and design recommendation evaluated.

Table 5-2: Summary of Design Parameters

Material Type	Depth below NSL D (m)	Bulk Density (g/cm^3)	Coefficient of Volume Compressibility (m_v)cm^2/kg	Angle of Internal Friction Phi (°)	Cohesion C (kg/cm^2)	Young's Modulus E (MPa)
Lean Clay/Silt	0.0-3.0	1.65	0.012	-	0.35	1.0
Silty Sand/Fine Sand	3.0-30.0	1.75	-	32.00	-	7.5

5.4.2. Discussion on Design Parameters

The design parameters have been evaluated considering results of field geotechnical investigation, laboratory testing, experience, and judgment of author of this report in the similar ground. The ground condition reveals mostly Cohesive (silt/Lean Clay)at the foundation laying depth of about 1.5m below NSL.

5.4.3. Geotechnical Design Criteria

The foundations of all the structures should meet the following design criteria:

- These should be safe against shear failure of the supporting ground. A factor of safety of 3 is adopted for this purpose.

- These should not settle excessively under the service loads. A limit of 25mm has been put on the total settlement of individual foundations. Similarly, the angular distortion between the two adjacent foundations should not exceed1/500.
- The bedding of pipelines should be rigid enough to remain stable. This should be attained by compacting the pipe bedding to at least 95% Modified Proctor Compaction (70% Relative density).
- If mat foundation is adopted, it should not settle beyond limits under the service loads. A limit of 50 mm has been put on the total settlement of foundations (corresponds to adifferential settlement of about 35 mm between the centre and edge of the mat foundation).

6. Engineering Considerations

6.1. Earthworks

6.1.1. Ground Preparation

The topsoil at site mostly belongs to vegetative material. Initial site preparation will require removal of such contaminated/vegetative topsoil. Such soil may be used in the landscaping.

6.2. Foundations

6.2.1. Proposed Structures

The proposed structures are expected to be low level loading as they will mostly comprise administration buildings etc. Usually this kind of buildings can be supported on shallow foundation. Considering the ground conditions, it is recommended to support these buildings on strip foundation with after recommended ground improvement in case any weak pocket observed during construction at site.

6.2.2. Design of Shallow Foundations

The evaluation of the bearing capacity of the Square/Rectangular Foundation has been done using approach given by Terzaghi, Elastic theory and other established correlations. The analysis has been carried out for a depth of foundation 1.5 m below NSL. The bearing capacity curves are presented in Annexure B.3.1.

Similarly, the evaluation of the bearing capacity of the Strip Foundation has been done. The analysis has been carried out for a depth of foundation 1.5 m below NSL. The bearing capacity curves are presented as Annexure.

6.2.3. Modulus of Subgrade Reaction

Modulus of sub-grade reaction K_s can be evaluated using the evaluated allowable bearing pressure, respective structural pressure, and factor of safety (FOS). The expression for its calculation is given below:

- For Strip and Square Footings with 25.4mm (1 inch) tolerable settlement

$$K_s = \frac{Evaluated\,Net\,Allowable\,Bearing\,Pressure}{Settlement\,(25.4mm)\,under\,maximum\,structural\,pressure} \times Factor\,of\,Safety$$

- For Raft / Mat Footings with 50.8 mm (2 inch) tolerable settlement

$$K_s = \frac{Evaluated\,Net\,Allowable\,Bearing\,Pressure}{Settlement\,(50.8\,mm)\,under\,maximum\,structural\,pressure} \times Factor\,of\,Safety$$

6.2.4. Placement of Granular Fill

If any soft and loose material encountered, at foundation excavation level, during construction, then it should be further excavated and replaced with suitable granular material in proper compaction.

The availability of the sound ground must be confirmed before placement of the foundation pad. An experienced engineer should confirm the soundness of the excavation base as the upper soil is weak.

The excavated surface must be proof compacted to at least 95% of the Modified AASHTO Dry Density before placement of foundation or pavement.

The suitable granular material, if used, should comprise granular material, free draining, well graded, non-plastic and having particle size in a range of 0.075 mm to maximum 75 mm. The maximum content of fines should be limit to 10%. The minimum compaction requirement for granular back fill or proof rolling below foundation base should be at least 95% Modified AASHTO dry density or 75 % Relative Density.

6.3. Lateral Earth Pressure

6.3.1. Static Earth Pressure Coefficients

In case of buried structures and retaining walls, use of cohesion-less backfill is recommended. The evaluation of static earth pressure on buried wall / retaining walls depends upon the movement allowed for in the design, configuration of the wall, backfill geometry and the type of soil used as backfill. For smooth vertical walls with horizontal backfill, the following simplified expressions can be used for determination of coefficients of Lateral Earth Pressure.

- Coefficient of Active Earth Pressure

$$K_a = \frac{(1 - Sin\,\emptyset')}{(1 + Sin\,\emptyset')}$$

- Coefficient of Earth Pressure at Rest

$$K_0 = (1 - Sin\ \emptyset')$$

- Coefficient of Passive Earth Pressure

$$K_p = \frac{(1 + Sin\emptyset')}{(1 - Sin\emptyset')}$$

Where Ø′ is effective Angle of Internal Friction of backfill soil.

The effective Angle of Friction of typical granular soils available in Punjab may be used as 30 degree.

6.3.2. Dynamic Earth Pressure Coefficients

For evaluation of earth pressure under earthquake conditions, the equations proposed by Mononobe-Okabe may be used.

6.4. Construction of Roads & Embankments

6.4.1. Formation of Subgrade and Embankment

Subgrade consisting of Silty Sand / Sandy Silt usually belongs to A4 material is found at site as per geotechnical investigation and visually inspected at site during site reconnaissance. However, there is presence of A-6 soil at surface as well. Therefore, it must be noted that only A-4 soils should be used for subgrade and embankment construction.

It is recommended to adopt an average design CBR of existing subgrade as 7, which is inline the above the minimum CBR value requirements of the subgrade material as per NHA Specifications.

6.4.2. Borrow Placement and Compaction

Before placement of the Earth fill/borrow fill, in-situ soil should be proof-rolled to achieve a minimum compaction level of 90% Modified AASHTO density.

The following maximum layer thickness, minimum compaction is recommended for various elements of embankment:

Table 6-1: Borrow Compaction Parameters

Material Type	Material Type	Maximum Compacted Layer Thickness (cm)	Recommended Modified AASHTO Compaction (%)
(a). A-4 as Embankment & Subgrade			
Top 30cm	A-4	15	95
30cm – 75cm	A-4	20	93
Below 75cm	A-4	20	90

6.5. Constraints and Risks

6.5.1. Damp Proofing and Surface Drainage

Principle constraints include following:

- Proper paving should be provided along the periphery of the Structure.
- All the backfilling of the foundation above concrete pad should be done with non swell cohesive material to avoid seepage of water in the foundation base. Alternatively, the top 30cm of any backfilling should be carried out with non-swelling cohesive soil.
- Adequate water proofing/damp proofing shall be provided for the structure. To avoid problem regarding moisture, it is recommended to adopt water-reducing admixtures in concrete.
- Cementitious coatings should also be provided to avoid moisture movement through the concrete.

6.5.2. Contaminated Land

The spillage of fuels, oils or other contaminants on the site should be prohibited and servicing of tools, plants, and machinery during the construction period should be managed to prevent pollution, while large numbers of machines are operating on the site.

6.5.3. Quality Control

The following precautions must be ensured for better quality control at site for construction stage:

- The water cement ratio of the concrete should be monitored properly for better quality of concrete.
- The compaction works should be supervised by experienced geotechnical engineer. The compaction of the area under foundation and other major load bearing locations should be certified by a licensed professional engineer for its laying as per specifications.

6.6. Design and Construction Aspects of Land Fill

6.6.1. Formation of Temporary and Final Cover

Soil or similar inert material should be used for the lifetime of the land fill site, to cover the waste on a regular basis. Extra thickness of "final cover" material shall also be required once the site has reached completion.

The simple spreading of daily cover is very effective way to reduce the attraction of waste to birds, suppress odours, prevent fly infestations, discourage rats and other animals, to reduce exposure to atmosphere conditions and to reduce wind blow litter.

Ideally, cover material should be taken from within the site, increasing the available space for waste disposal and reducing the need to bring material from elsewhere.

The material excavated from the site should be adequate for use a temporary and final cover material. Final confirmation should be made on remoulded permeability of the representative samples taken from the borrow source if adopted. At this time we expect that the soil removed during excavation will be used.

The soil should be compacted to at least 95 percent of the modified proctor density within a moisture content range of 0 to 3 percent wet of optimum.

6.6.2. Excavation at Site

The excavation required for the construction of foundation up to a shallow depth of about 3m, can be made without provision of any supporting system. The provision of dewatering must be kept in the scope of work of construction due to possibility of rainy season, during construction.

The excavation for the land fill area can be easily done with simple mechanical means, which is being practice currently at site. Since the adjacent areas are being used for agriculture purpose therefore, no major stability issues are anticipated to results in to property loss, however, it is recommended to excavate at a slope angle established by hit and trial method at site for an excavation of about 6 m, which is foreseen in the light of current ground conditions.

As a broad guideline it is suggested to adopt a slope angle of 2H:1V, however, based on hit and trial method adopted at site, the angle can be further steepened.

The base of the land fill site should be design for a permeability of existing base soil in a range of 3.12 to $3.18x10^{-4}$. For sealing of the base of the land fill site, a clay liner may be adopted, for which suitable soils would be high plastic clays, locally the areas near sambrial/Sialkot, material of high plasticity index (PI above 15 is usually available, which may be used blended with additives to improve the permeability values. Alternatively, geotextile based clay liner may be adopted.

6.6.3. Liquefaction Potential

Liquefaction is a loss of the shear strength of a soil that occurs when the ground experiences strong ground shaking. The phenomenon may result in large total and/or differential settlement beneath Structures founded on the liquefying soils. In order for the potential effects of liquefaction to be manifested at the ground surface, the soils generally have to be granular, loose to moderately dense, saturated relatively near the ground surface, and must be subjected to a sufficient magnitude and duration of shaking.

According to the grading plans for the proposed Landfill Site, surficial soils will be removed so that the proposed filling will be directly underlain by medium dense to dense Sands. With the removal of upper alluvium, the nearest groundwater will be on the order of 1 to 2m below the base of the landfill. Due to the lack of a week sandy soil, the relatively low design site acceleration being in zone 2A, and the competency of the Sands at about 6 m depth, the potential for significant, large-scale liquefaction effects and associated dynamic settlement to cause damage to the composite liner system and other site facilities is very low..

6.6.4. Cement Type

It is recommended to use Ordinary Portland Cement as per results of chemical tests performed at soil and water samples from site.

7. Conclusions

In summary it is concluded that

- The top surface comprises vegetative cover which is underlain by Lean Clay/Silt (Soft to firm), up to 1 m depth, the material is underlain by Silty Sand (Medium Dense to Dense) up to a maximum investigated depth of 30 m depth below NSL
- Groundwater was encountered at a depth of about 6 m in the boreholes drilled up to a maximum depth of 30 m below NSL. However, seasonal variation can result into increase of groundwater table, in the upper layer of soil
- The bearing capacity curves are provided in the Annexure B.3
- The evaluation of the bearing capacity of the Square/Rectangular Foundation has been done using approach given by Terzaghi, Elastic theory and other established correlations. The analysis has been carried out for a depth of foundation 1.5 m below NSL.
- Similarly, the evaluation of the bearing capacity of the Strip Foundation has been done. The analysis has been carried out for a depth of foundation 1.5 m below NSL.
- Proper paving should be provided along the periphery of the Structure.
- All the backfilling of the foundation above concrete pad should be done with non swell cohesive material to avoid seepage of water in the foundation base. Alternatively, the top 30cm of any backfilling should be carried out with non-swelling cohesive soil.
- Adequate water proofing/damp proofing shall be provided for the structure. To avoid problem regarding moisture, it is recommended to adopt water-reducing admixtures in concrete.
- If any soft and loose material encountered, at foundation excavation level, during construction, then it should be further excavated and replaced with suitable granular material in proper compaction.
- Cementitious coatings should also be provided to avoid moisture movement through the concrete.
- “The base of the land fill site should be design for a permeability of existing base soil in a range of 3.12 to 3.18×10^{-4}. For sealing of the base of the land fill site, a clay liner may be adopted, for which suitable soils would be high plastic clays, locally the areas near sambrial/Sialkot, material of high plasticity index (PI above 15 is usually available, which may be used blended with additives to improve the permeability values. Alternatively, geotextile based clay liner may be adopted.”

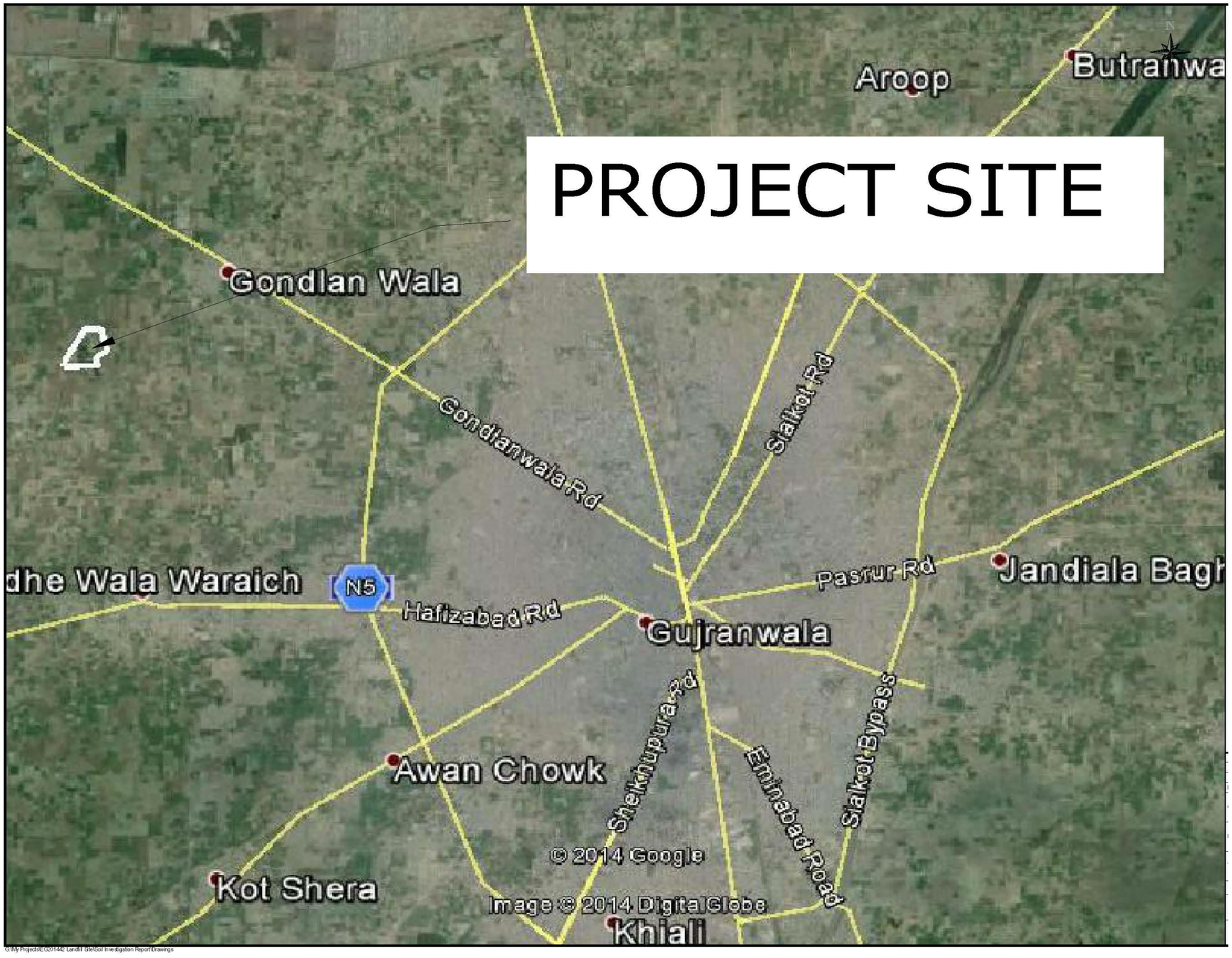
8. References

Following References and specialized Software have been utilized in the development of this report:

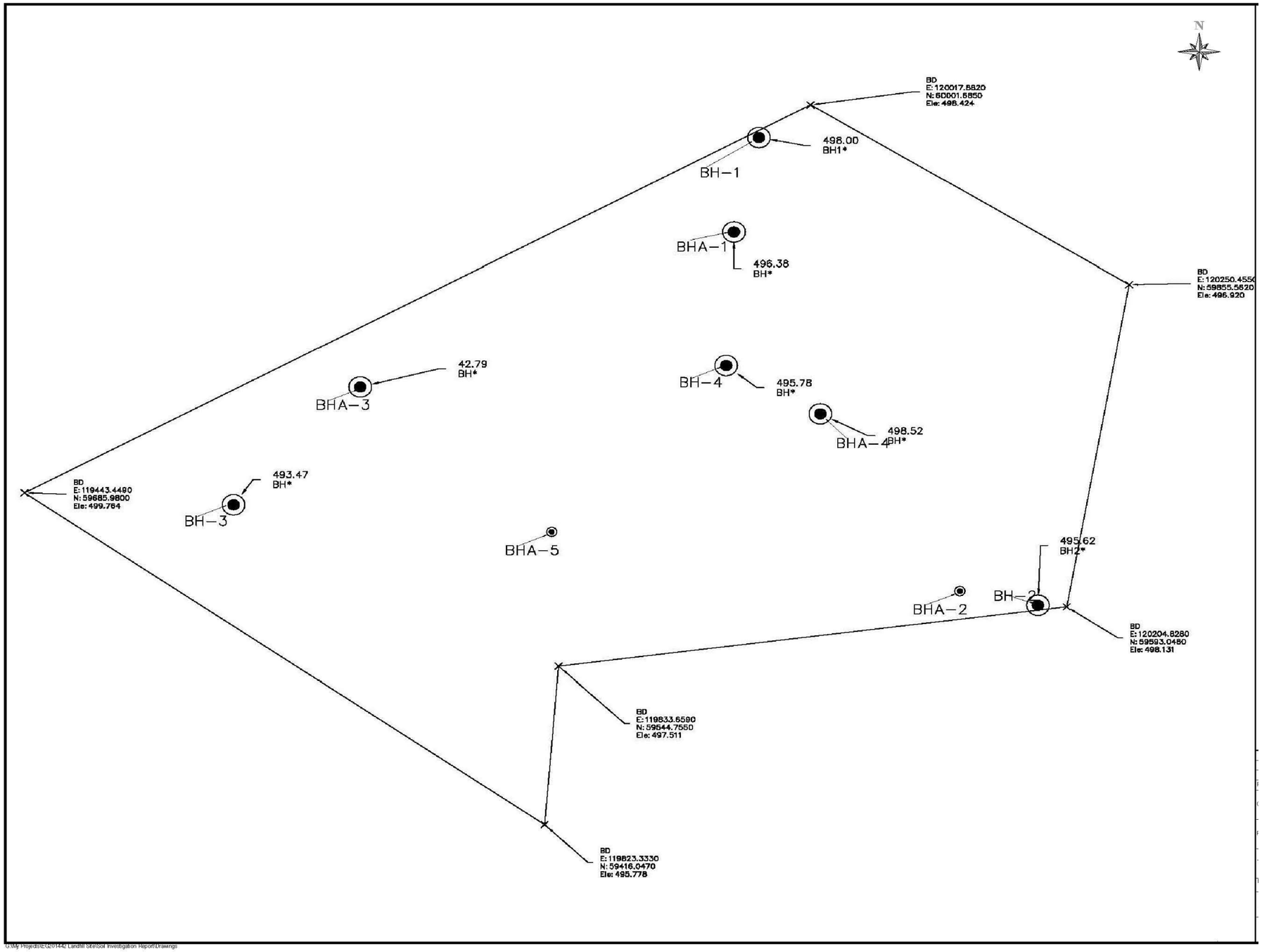
- Foundation Analysis and Design by Joseph E. Bowles
- Winlog & Winfence (softwares for generation of graphical borehole logs and subsurface profiles)
- NovoSPT a software from Novotech (for assessment and correlation of standard penetration resistance data for analysis and design)
- Building Code of Pakistan as given on Pakistan Engineering Council Website
- ASTM Book volume 4.08 (Soils and Rocks)
- Geotechnical Earthquake Engineering by Kramer

Annexure A. Drawings

A.1. Site Location Map


PROJECT SITE
Aroop
Butranwa
Gondlan Wala
Gondlanwala Rd
Sialkot Rd
dhe Wala Waraich
N5
Hafizabad Rd
Pasrur Rd
Jandiala Bagh
Gujranwala
Awan Chowk
Sheikhupura Rd
Eminabad Road
Sialkot Bypass
© 2014 Google
Image © 2014 DigitalGlobe
Kot Shera
Khiali
G:\My Projects\EG201442 Landfill Site\Soil Investigation Report\Drawings

A.2. Geotechnical Investigation Plan



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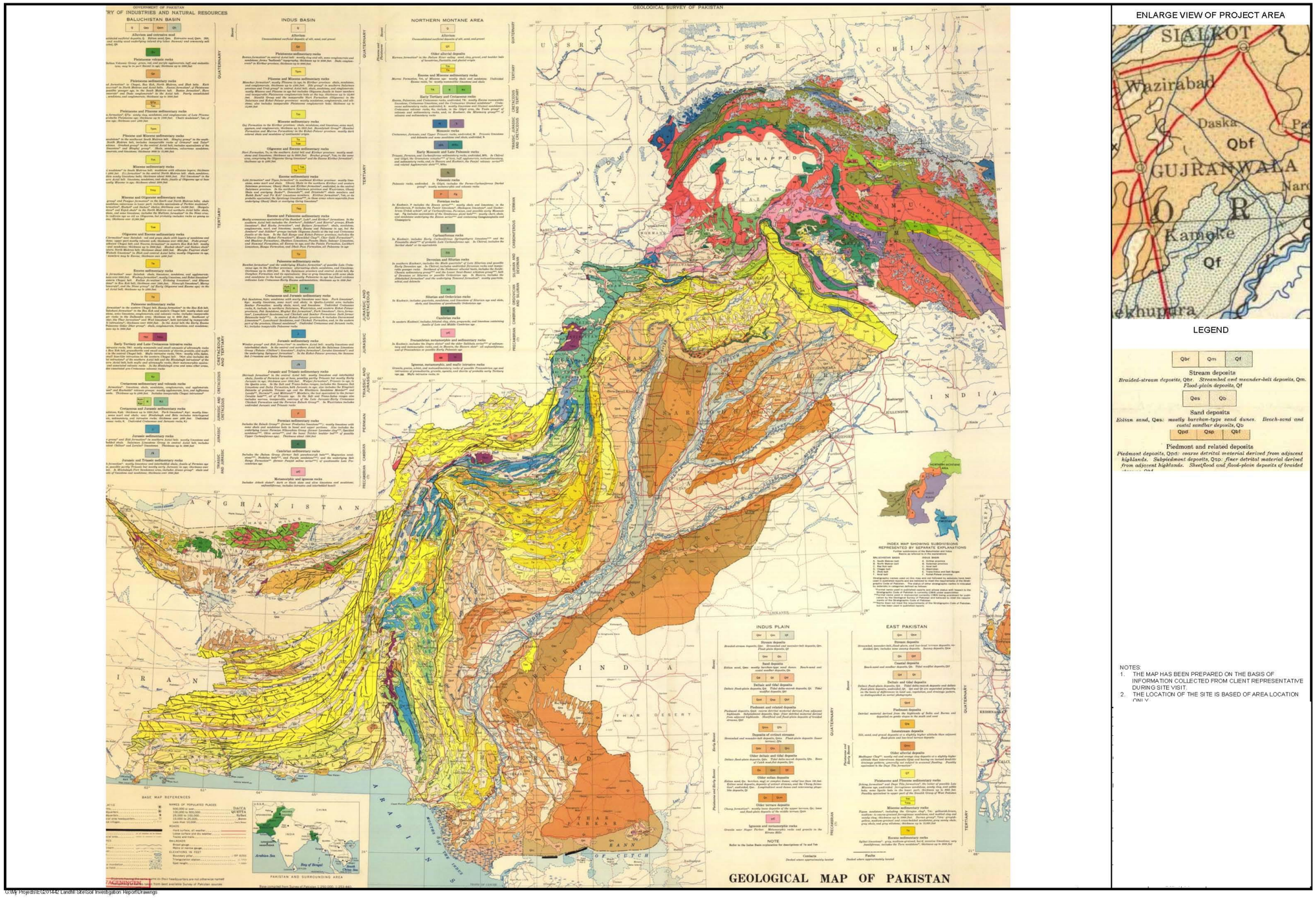
A.3. Geological Map of the Project Area



ENLARGE VIEW OF PROJECT AREA

LEGEND

Qbr | Qm | Qf

Stream deposits

Braided-stream deposits, Qbr. Streambed and meander-belt deposits, Qm. Flood-plain deposits, Qf

Qes | Qb

Sand deposits

Eolian sand, Qes: mostly barchan-type sand dunes. Beach-sand and coastal sandbar deposits, Qb

Qpd | Qsp | Qbf

Piedmont and related deposits

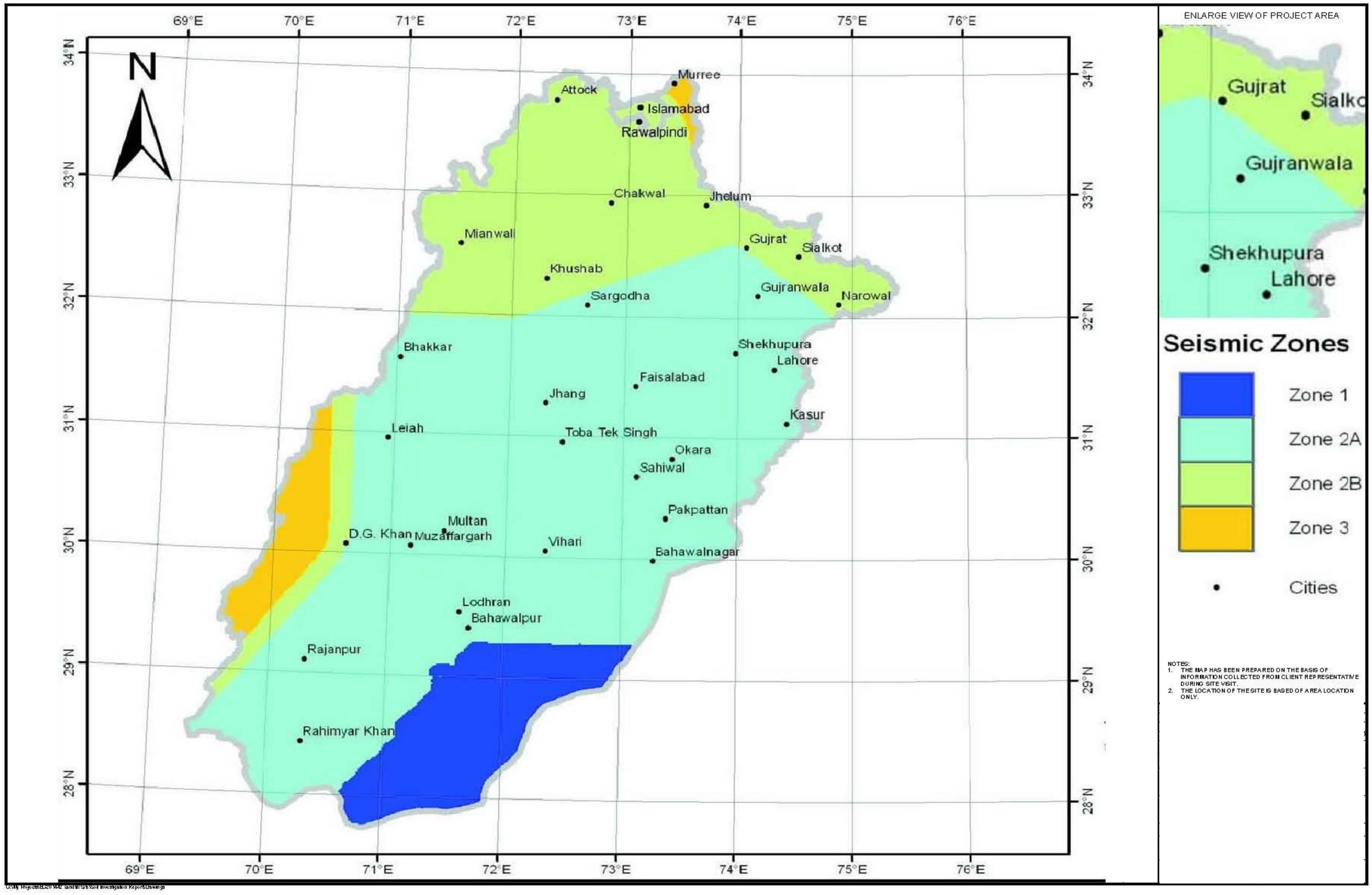
Piedmont deposits, Qpd: coarse detrital material derived from adjacent highlands. Subpiedmont deposits, Qsp: finer detrital material derived from adjacent highlands. Sheetflood and flood-plain deposits of braided

NOTES:

1. THE MAP HAS BEEN PREPARED ON THE BASIS OF INFORMATION COLLECTED FROM CLIENT REPRESENTATIVE DURING SITE VISIT.
2. THE LOCATION OF THE SITE IS BASED OF AREA LOCATION ONLY.

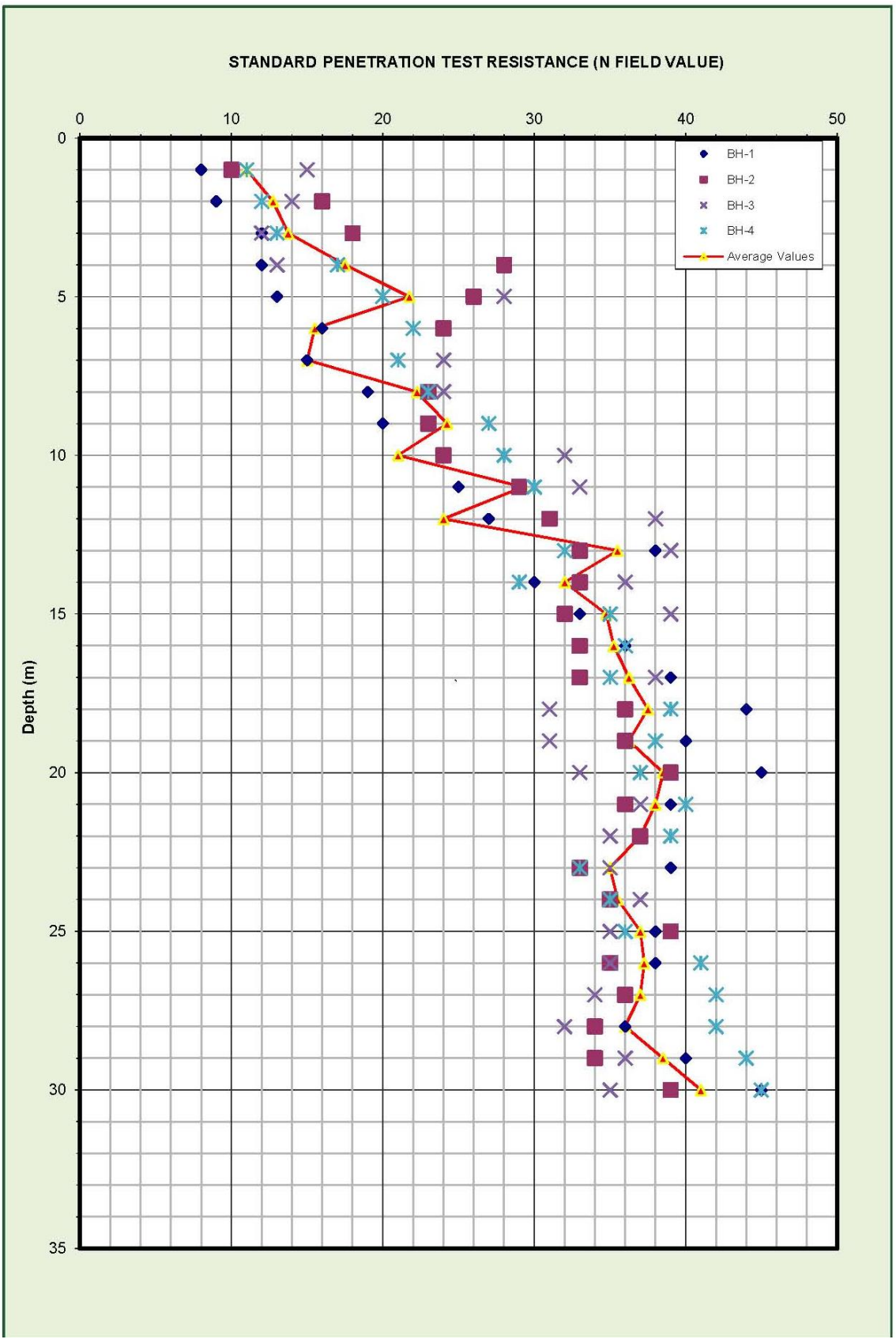
G:\My Projects\EG01442 Landfill Site\Soil Investigation Report\Drawings

A.4. Seismic Map of Punjab


69°E
70°E
71°E
72°E
73°E
74°E
75°E
76°E
34°N
33°N
32°N
31°N
30°N
29°N
28°N
N
Murree
Attock
Islamabad
Rawalpindi
Chakwal
Jhelum
Mianwali
Gujrat
Sialkot
Khushab
Sargodha
Gujranwala
Narowal
Bhakkar
Shekhupura
Lahore
Faisalabad
Jhang
Kasur
Leiah
Toba Tek Singh
Okara
Sahiwal
Pakpattan
Multan
D.G. Khan
Muzaffargarh
Vihari
Bahawalnagar
Lodhran
Bahawalpur
Rajanpur
Rahimyar Khan
ENLARGE VIEW OF PROJECT AREA
Gujrat
Sialko
Gujranwala
Shekhupura
Lahore
Seismic Zones
Zone 1
Zone 2A
Zone 2B
Zone 3
Cities
NOTES:
1. THE MAP HAS BEEN PREPARED ON THE BASIS OF INFORMATION COLLECTED FROM CLIENT REPRESENTATIVE DURING SITE VISIT.
2. THE LOCATION OF THE SITE IS BASED OF AREA LOCATION ONLY.

Annexure B. Figures

B.1. Variation of SPT Blows with Depth


STANDARD PENETRATION TEST RESISTANCE (N FIELD VALUE)
0
10
20
30
40
50
0
5
10
15
20
25
30
35
Depth (m)
BH-1
BH-2
BH-3
BH-4
Average Values

B.2. Summary of Laboratory Test Results

B.2.1. Laboratory Classification Testing

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

Contractor: Lean & Green (Pvt.) Ltd.

Client Name: Urban Unit, Lahore

Date: Monday, September 29, 2014

Sample with "*" are classed on the basis of Atterberg limit test of the similar or adjacent sample.

Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
1	BH-1	SPT-1	1.00	100	100	98	80	31	20	11	80	20	-	(CL)	Lean Clay with Sand	(A-6) Clayey Soils
2	BH-1	SPT-2	2.00	100	100	97	32	-	-	-	32	68	-	(SM)	Silty Sand	(A-2-4) Silty and Clayey Gravel and Sand
3	BH-1	SPT-3	3.00	100	100	100	22	-	-	-	22	48	-	(SM)	Silty Sand	(A-2-4) Silty and Clayey Gravel and Sand
4	BH-1	SPT-4	4.00	100	100	90	3	-	-	-	3	97	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

5	BH-1	SPT-5	5.00	100	100	92	2	-	-	-	2	98	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
6	BH-1	SPT-6	6.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
7	BH-1	SPT-7	7.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

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				#4	#10	#40	#200									
8	BH-1	SPT-8	8.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
9	BH-1	SPT-9	9.00	100	100	92	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
10	BH-1	SPT-10	10.00	100	100	100	-	-	-	-	-	100	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
11	BH-1	SPT-11	11.00	100	100	95	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

12	BH-1	SPT-12	12.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
13	BH-1	SPT-13	13.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
14	BH-1	SPT-14	14.00	100	100	87	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

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				#4	#10	#40	#200									
5	BH-1	SPT-15	15.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
16	BH-1	SPT-16	16.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
19	BH-1	SPT-17	17.00	100	100	89	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
21	BH-1	SPT-18	18.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
22	BH-1	SPT-19	19.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

23	BH-1	SPT-20	20.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
24	BH-1	SPT-21	21.00	100	100	95	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

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				#4	#10	#40	#200									
25	BH-1	SPT-22	22.00	100	100	92	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
26	BH-1	SPT-23	23.00	100	100	93	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
27	BH-1	SPT-24	24.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
28	BH-1	SPT-25	25.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
29	BH-1	SPT-26	26.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

30	BH-1	SPT-27	27.00	100	100	89	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
31	BH-1	SPT-28	28.00	100	100	94	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

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Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

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				#4	#10	#40	#200									
32	BH-1	SPT-29	29.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
33	BH-1	SPT-30	30.00	100	100	92	5	-	-	-	5	95	-	(SW-SM)	Well Graded Sand with Silt	(A-2-4) Silty and Clayey Gravel and Sand
34	BH-2	SPT-1	1.00	100	100	98	3	-	-	-	3	97	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
35	BH-2	SPT-2	2.00	100	100	95	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
36	BH-2	SPT-3	3.00	100	100	94	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

37	BH-2	SPT-4	4.00	100	100	93	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
38	BH-2	SPT-5	5.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

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				#4	#10	#40	#200									
39	BH-2	SPT-6	6.00	100	100	92	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
40	BH-2	UDS-1	7.00	100	100	-	-	-	-	-	-	100	-	(SW)	Well Graded Sand	(A-1-b) Gravel and Sand
41	BH-2	SPT-8	8.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
42	BH-2	SPT-9	9.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
43	BH-2	SPT-10	10.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
44	BH-2	SPT-11	11.00	100	100	90	2	-	-	-	2	98	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

45	BH-2	SPT-12	12.00	100	100	92	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

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				#4	#10	#40	#200									
46	BH-2	SPT-13	13.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
47	BH-2	SPT-14	14.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
48	BH-2	SPT-15	15.00	100	100	87	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
49	BH-2	SPT-16	16.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
50	BH-2	SPT-17	17.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

51	BH-2	SPT-18	18.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
52	BH-2	SPT-19	19.00	100	100	82	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

Contractor: Lean & Green (Pvt.) Ltd.

Client Name: Urban Unit, Lahore

Date: Monday, September 29, 2014

Sample with "*" are classed on the basis of Atterberg limit test of the similar or adjacent sample.

Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
53	BH-2	SPT-20	20.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
54	BH-2	SPT-21	21.00	100	100	93	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
55	BH-2	SPT-22	22.00	100	100	87	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
56	BH-2	SPT-23	23.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
57	BH-2	SPT-24	24.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

58	BH-2	SPT-25	25.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
59	BH-2	SPT-26	26.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

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Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
60	BH-2	SPT-27	27.00	100	100	92	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
61	BH-2	SPT-28	28.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
62	BH-2	SPT-29	29.00	100	100	98	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
63	BH-2	SPT-30	30.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
64	BH-3	SPT-1	1.00	100	100	97	13	-	-	-	13	87	-	(SM)	Silty Sand	(A-2-4) Silty and Clayey Gravel and Sand

65	BH-3	SPT-2	2.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
66	BH-3	SPT-3	3.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

Contractor: Lean & Green (Pvt.) Ltd.

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Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
67	BH-3	SPT-4	4.00	100	100	95	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
68	BH-3	SPT-5	5.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
69	BH-3	UDS-1	6.00	100	100	-	-	-	-	-	-	100	-	(SW)	Well Graded Sand	(A-1-b) Gravel and Sand
70	BH-3	SPT-7	7.00	100	100	92	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
71	BH-3	SPT-8	8.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
72	BH-3	SPT-9	9.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

73	BH-3	SPT-10	10.00	100	100	93	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

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Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
74	BH-3	SPT-11	11.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
75	BH-3	SPT-12	12.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
76	BH-3	SPT-13	13.00	100	100	87	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
77	BH-3	SPT-14	14.00	100	100	91	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
78	BH-3	SPT-15	15.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

79	BH-3	SPT-16	16.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
80	BH-3	SPT-17	17.00	100	100	83	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

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Client Name: Urban Unit, Lahore

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Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
81	BH-3	SPT-18	18.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
82	BH-3	SPT-19	19.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
83	BH-3	SPT-20	20.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
84	BH-3	SPT-21	21.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
85	BH-3	SPT-22	22.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

86	BH-3	SPT-23	23.00	100	100	87	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
87	BH-3	SPT-24	24.00	100	100	86	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

Contractor: Lean & Green (Pvt.) Ltd.

Client Name: Urban Unit, Lahore

Date: Monday, September 29, 2014

Sample with "*" are classed on the basis of Atterberg limit test of the similar or adjacent sample.

Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
88	BH-3	SPT-25	25.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
89	BH-3	SPT-26	26.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
90	BH-3	SPT-27	27.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
91	BH-3	SPT-28	28.00	100	100	87	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
92	BH-3	SPT-29	29.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

93	BH-3	SPT-30	30.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
94	BH-4	SPT-1	1.00	100	100	90	3	-	-	-	3	97	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

Contractor: Lean & Green (Pvt.) Ltd.

Client Name: Urban Unit, Lahore

Date: Monday, September 29, 2014

Sample with "*" are classed on the basis of Atterberg limit test of the similar or adjacent sample.

Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
95	BH-4	SPT-2	2.00	100	100	88	2	-	-	-	2	98	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
96	BH-4	SPT-3	3.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
97	BH-4	SPT-4	4.00	100	100	82	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
98	BH-4	SPT-5	5.00	100	100	80	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
99	BH-4	SPT-6	6.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

100	BH-4	SPT-7	7.00	100	100	82	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
101	BH-4	SPT-8	8.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

Contractor: Lean & Green (Pvt.) Ltd.

Client Name: Urban Unit, Lahore

Date: Monday, September 29, 2014

Sample with "*" are classed on the basis of Atterberg limit test of the similar or adjacent sample.

Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
102	BH-4	SPT-9	9.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
103	BH-4	SPT-10	10.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
104	BH-4	SPT-11	11.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
105	BH-4	UDS-1	12.00	100	100	-	-	-	-	-	-	100	-	(SW)	Well Graded Sand	(A-1-b) Gravel and Sand
106	BH-4	SPT-13	13.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
107	BH-4	SPT-14	14.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

108	BH-4	SPT-15	15.00	100	100	82	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

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Date: Monday, September 29, 2014

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Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
109	BH-4	SPT-16	16.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
110	BH-4	SPT-17	17.00	100	100	80	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
111	BH-4	SPT-18	18.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
112	BH-4	SPT-19	19.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
113	BH-4	SPT-20	20.00	100	100	89	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

114	BH-4	SPT-21	21.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
115	BH-4	SPT-22	22.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

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Client Name: Urban Unit, Lahore

Date: Monday, September 29, 2014

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Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
116	BH-4	SPT-23	23.00	100	100	92	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
117	BH-4	SPT-24	24.00	100	100	87	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
118	BH-4	SPT-25	25.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
119	BH-4	SPT-26	26.00	100	100	89	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
120	BH-4	SPT-27	27.00	100	100	90	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

121	BH-4	SPT-28	28.00	100	100	88	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand
122	BH-4	SPT-29	29.00	100	100	87	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SOIL CLASSIFICATION BY ASTM D2487 AND AASHTO SYSTEM

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

Contractor: Lean & Green (Pvt.) Ltd.

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Date: Monday, September 29, 2014

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Sr. No.	Borehole/Testpit No.	Sample No.	Depth (m)	% Passing				LL	PL	PI	% Silt/clay	% Sand	% Gravel	SOIL CLASSIFICATION AS PER USCS REFERENCE ASTM D2487		SOIL CLASSIFICATION AS PER AASHTO
				#4	#10	#40	#200									
123	BH-4	SPT-30	30.00	100	100	85	1	-	-	-	1	99	-	(SW)	Well Graded Sand	(A-2-4) Silty and Clayey Gravel and Sand

SUMMARY OF CHEMICAL TEST RESULTS PERFORMED ON SOIL/WATER SAMPLES

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

Contractor: Lean & Green (Pvt.) Ltd.

Client Name: Urban Unit, Lahore

Date: Monday, September 29, 2014

Sr. No.	Borehole/ Testpit No.	Sample No.	Depth (m)	Organic Matter Content (%)	Sulphate Contents (%)	Chloride Contents (%)	PH	TDS (PPM)
1	BH-1	WS	-	-	-	0.092	-	445.000
2	BH-2	WS	-	-	-	0.098	-	460.000
3	BH-3	WS	-	-	-	0.089	-	435.000
4	BH-4	WS	-	-	-	0.067	-	355.000

B.2.2. Summary of Strength Related Test Results

SUMMARY OF STRENGTH/SETTLEMENT RELATED TESTS RESULTS

Project Name: Geotechnical Investigation for Landfill Site in Gujranwala

Contractor: Lean & Green (Pvt.) Ltd.

Client Name: Urban Unit, Lahore

Date: Monday, September 29, 2014

Sr. No.	Borehole No.	Sample No.	Depth	Moisture Density Results		Unconfirmed Compression Test		Direct Shear Test		Consolidation		
			(m)	NMC	Dry Density	Compressive Strength	Failure Strain	C	Φ	"cv"	initial void ratio "e_0"	Swell Pressure
				%	g/cc	kg/cm^2	(%)	kg/cm^2	(Degree)	cm^2/sec	(%)	(%)
1	BH-1	UDS-1	10.00	31.36	1.45	-	-	-	33.50	-	-	-
2	BH-2	UDS-1	7.00	15.91	1.63	-	-	-	37.30	-	-	-
3	BH-3	UDS-1	6.00	20.91	1.63	-	-	-	35.70	-	-	-
4	BH-4	UDS-1	12.00	22.38	1.57	-	-	-	36.90	-	-	-

B.3. Allowable Bearing Capacity Curve

B.3.1. Square/Rectangular Foundation

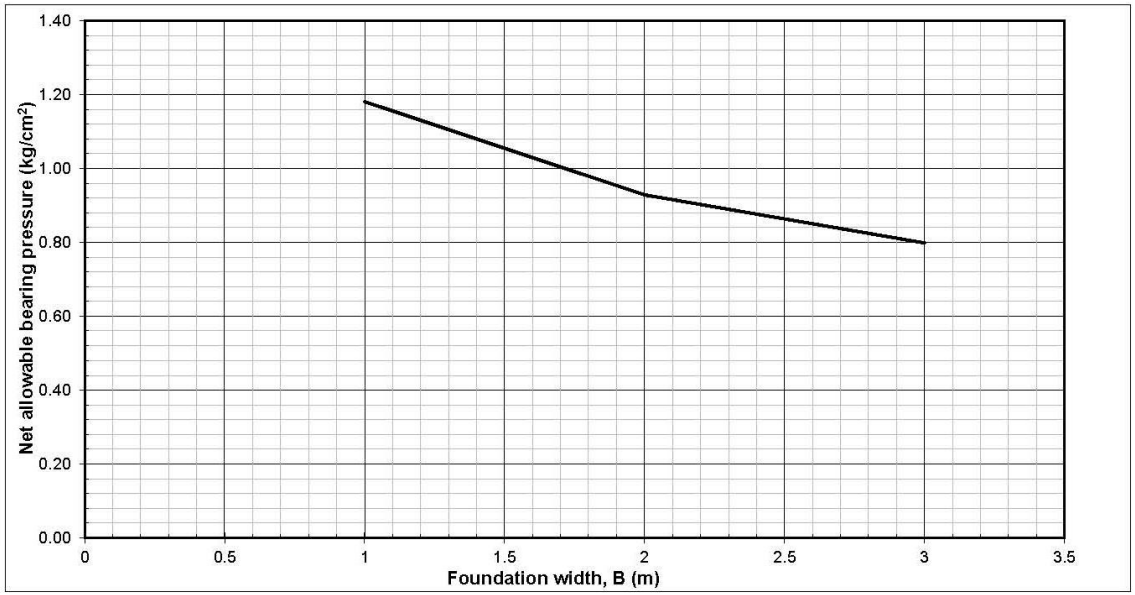
CALCULATIONS OF BEARING CAPACITY FOR LANDFILL SITE AT GUJRANWALA

Figure B.3.1

Foundation Type		
Foundation Width B (m)	1.00	OK
Foundation Length (m)	1.00	
Foundation Depth, D (m)	1.5	
Depth of Influence (Di) (m)	1.50	
Factor of Safety FOS	3.00	
Depth of Water Table (Dw) m	10.00	
Vertical Reaction (V) KN	-	
Horizontal Reaction (H) KN	-	
Moment (M) KN.m	-	
Load due to Embedment (Ve) KN	32.09	

Total Tolerable Settlement = 25 mm Square/Rectangular Foundation

Special Notes: The Foundation must be inspected by Experienced Geotechnical Engineer, and must be placed on sound ground. The Grannular Cushion if required to be placed as per specification mentioned in the Section 6.5 of the Geotechnical Investigation Report.



B.3.2. Strip Foundation

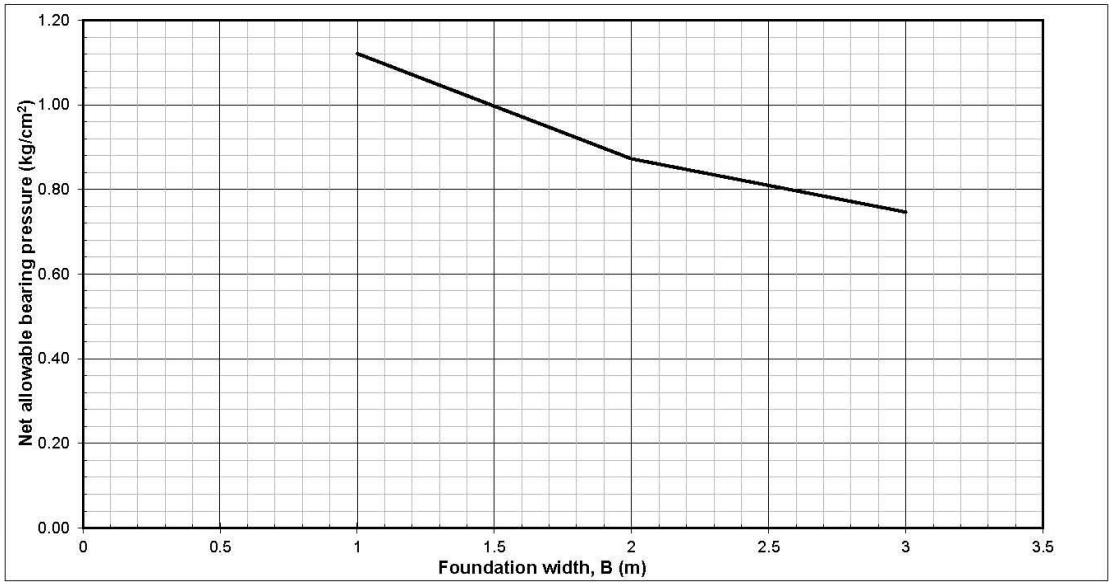
CALCULATIONS OF BEARING CAPACITY FOR LANDFILL SITE AT GUJRANWALA

Figure B.3.2

Foundation Type		
Foundation Width B (m)	1.00	OK
Foundation Length (m)	2.00	
Foundation Depth, D (m)	1.5	
Depth of Influence (Di) (m)	1.50	
Factor of Safety FOS	3.00	
Depth of Water Table (Dw) m	10.00	
Vertical Reaction (V) KN	-	
Horizontal Reaction (H) KN	-	
Moment (M) KN.m	-	
Load due to Embedment (Ve) KN	32.09	

Total Tolerable Settlement = 25 mm Strip Foundation

Special Notes: The Foundation must be inspected by Experienced Geotechnical Engineer, and must be placed on sound ground. The Grannular Cushion if required to be placed as per specification mentioned in the Section 6.5 of the Geotechnical Investigation Report.



Annexure C. Field Permeability Test Data

Basic Test Data

BOREHOLE NO.	BH-01	**TEST NO.**	1	**LOCATION**	Bakhriyawali
DEPTH OF TEST (m)	5	**CASING DIA(cm)**	9	**BOTTOM OF CASING**	5.00
WATER TABLE(cm)	600	**CASING ABOVE NSL(cm)**	30	**METHOD OF TEST**	Constant Head
TYPE OF SOIL	Fine Sand	**TESTED BY**	Umair		

Observations

Elapsed Time	Flow (Liter)	Head (cm)
1.0	0.396	
1.0	0.396	
1.0	0.396	
1.0	0.368	
1.0	0.368	
2.0	0.735	
2.0	0.707	
2.0	0.679	
2.0	0.679	
2.0	0.622	
5.0	1.555	
5.0	1.583	
5.0	1.555	
10.0	3.195	
10.0	3.054	
10.0	3.082	
60.0	19.368	

Calculations

$for\ Constant\ Head\ Test = \ k = \frac{q}{FH_c}$ = **3.45 E-04** **cm/sec**

$for\ Variable\ Head\ Test = \ k = \frac{A}{FT}$ = **NA** **cm/sec**

or $k = \frac{A}{F(t_2 - t_1)} log_e \frac{H_1}{H_2}$

k is the Permeability of Soil

q is the Rate of Flow

F is the intake factor

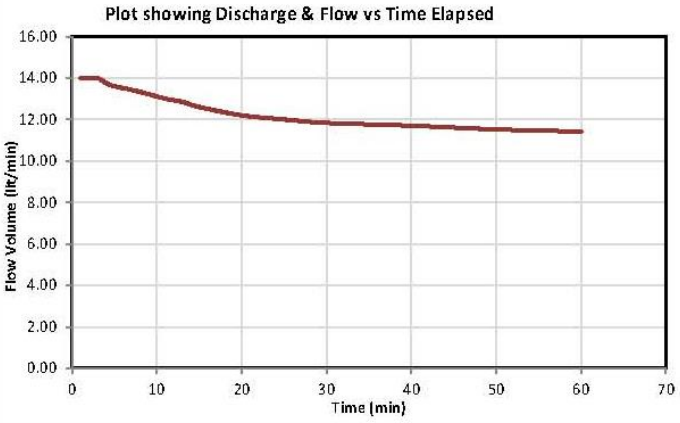
H_c is the constant head

H_1 is the variable head measured at time t_1 after commencement of test

H_2 is the variable head measured at time t_2 after commencement of test

A is the cross-sectional area of casing or standpiple as appropriate

T is the basic time factor



Basic Test Data

BOREHOLE NO.	BH-02	**TEST NO.**	2	**LOCATION**	Bakhriyawali
DEPTH OF TEST (m)	8	**CASING DIA(cm)**	9	**BOTTOM OF CASING**	8.00
WATER TABLE(cm)	600	**CASING ABOVE NSL(cm)**	30	**METHOD OF TEST**	Constant Head
TYPE OF SOIL	Fine Sand	**TESTED BY**	Umair		

Observations

Elapsed Time	Flow (Liter)	Head (cm)
1.0	0.198	
1.0	0.170	
1.0	0.141	
1.0	0.141	
1.0	0.141	
2.0	0.339	
2.0	0.368	
2.0	0.339	
2.0	1.696	
2.0	1.979	
5.0	1.555	
5.0	1.696	
5.0	1.753	
10.0	4.241	
10.0	3.252	
10.0	3.393	
60.0	21.404	

Calculations

$for\ Constant\ Head\ Test = k = \frac{q}{FH_c}$ = **3.81 E-04** **cm/sec**

$for\ Variable\ Head\ Test = k = \frac{A}{FT}$ = **NA** **cm/sec**

or $k = \frac{A}{F(t_2 - t_1)} log_e \frac{H_1}{H_2}$

k is the Permeability of Soil

q is the Rate of Flow

F is the intake factor

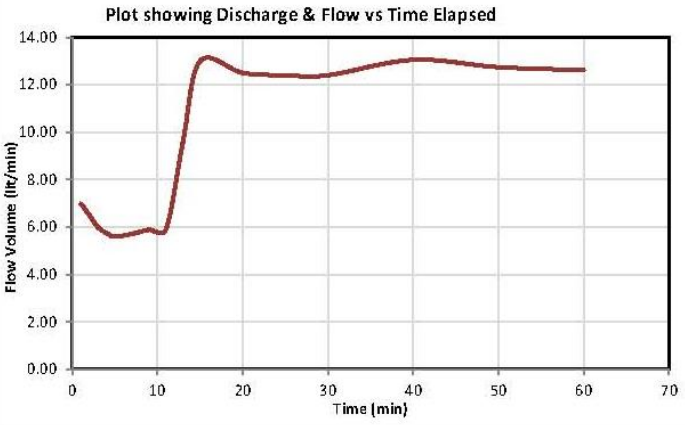
H_c is the constant head

H_1 is the variable head measured at time t_1 after commencement of test

H_2 is the variable head measured at time t_2 after commencement of test

A is the cross-sectional area of casing or standpiple as appropriate

T is the basic time factor



Basic Test Data

BOREHOLE NO.	BH-03	**TEST NO.**	3	**LOCATION**	Bakhriyawali
DEPTH OF TEST (m)	3	**CASING DIA(cm)**	9	**BOTTOM OF CASING**	3.00
WATER TABLE(cm)	600	**CASING ABOVE NSL(cm)**	30	**METHOD OF TEST**	Constant Head
TYPE OF SOIL	Fine Sand	**TESTED BY**	Umair		

Observations

Elapsed Time	Flow (Liter)	Head (cm)
1.0	0.113	
1.0	0.113	
1.0	0.113	
1.0	0.141	
1.0	0.141	
2.0	0.311	
2.0	0.311	
2.0	0.311	
2.0	0.339	
2.0	0.311	
5.0	0.311	
5.0	0.622	
5.0	0.565	
10.0	1.074	
10.0	1.074	
10.0	1.018	
60.0	6.871	

Calculations

$for\ Constant\ Head\ Test = k = \frac{q}{FH_c}$ = **1.22 E-04** **cm/sec**

$for\ Variable\ Head\ Test = k = \frac{A}{FT}$ = **NA** **cm/sec**

or $k = \frac{A}{F(t_2 - t_1)} log_e \frac{H_1}{H_2}$

k is the Permeability of Soil

q is the Rate of Flow

F is the intake factor

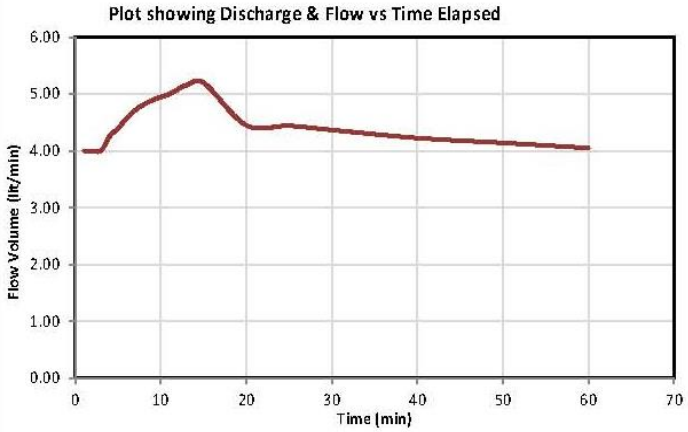
H_c is the constant head

H_1 is the variable head measured at time t_1 after commencement of test

H_2 is the variable head measured at time t_2 after commencement of test

A is the cross-sectional area of casing or standpiple as appropriate

T is the basic time factor



Basic Test Data

BOREHOLE NO.	BH-04	**TEST NO.**	4	**LOCATION**	Bakhriyawali
DEPTH OF TEST (m)	4	**CASING DIA(cm)**	9	**BOTTOM OF CASING**	4.00
WATER TABLE(cm)	600	**CASING ABOVE NSL(cm)**	30	**METHOD OF TEST**	Constant Head
TYPE OF SOIL	Fine Sand	**TESTED BY**	Umair		

Observations

Elapsed Time	Flow (Liter)	Head (cm)
1.0	0.113	
1.0	0.085	
1.0	0.085	
1.0	0.085	
1.0	0.085	
2.0	0.170	
2.0	0.141	
2.0	0.141	
2.0	0.141	
2.0	0.141	
5.0	0.141	
5.0	0.368	
5.0	0.368	
10.0	0.650	
10.0	0.650	
10.0	0.650	
60.0	4.015	

Calculations

$for\ Constant\ Head\ Test = \ k = \frac{q}{FH_c}$ = **7.15 E-05** **cm/sec**

$for\ Variable\ Head\ Test = \ k = \frac{A}{FT}$ = **NA** **cm/sec**

or $k = \frac{A}{F(t_2 - t_1)} log_e \frac{H_1}{H_2}$

k is the Permeability of Soil

q is the Rate of Flow

F is the intake factor

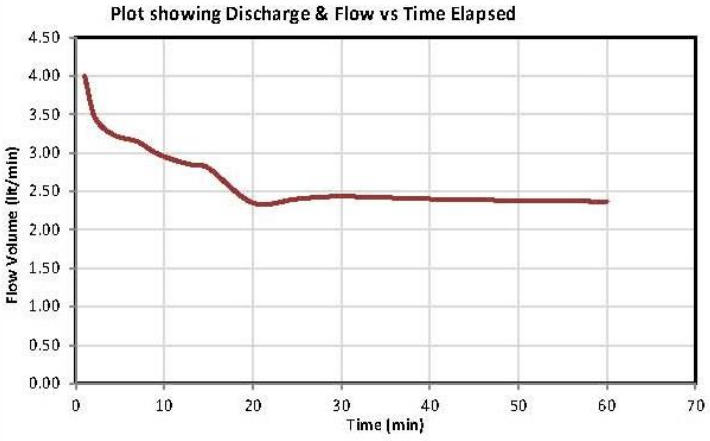
H_c is the constant head

H_1 is the variable head measured at time t_1 after commencement of test

H_2 is the variable head measured at time t_2 after commencement of test

A is the cross-sectional area of casing or standpiple as appropriate

T is the basic time factor



Basic Test Data

BOREHOLE NO.	BH-06	**TEST NO.**	5	**LOCATION**	Bakhriyawali
DEPTH OF TEST (m)	8	**CASING DIA(cm)**	9	**BOTTOM OF CASING**	8.00
WATER TABLE(cm)	600	**CASING ABOVE NSL(cm)**	30	**METHOD OF TEST**	Constant Head
TYPE OF SOIL	Fine Sand	**TESTED BY**	Umair		

Observations

Elapsed Time	Flow (Liter)	Head (cm)
1.0	0.339	
1.0	0.368	
1.0	0.396	
1.0	0.368	
1.0	0.368	
2.0	0.763	
2.0	0.735	
2.0	0.707	
2.0	0.707	
2.0	0.650	
5.0	1.725	
5.0	1.753	
5.0	1.696	
10.0	3.393	
10.0	3.110	
10.0	0.424	
60.0	17.502	

Calculations

$for\ Constant\ Head\ Test = k = \frac{q}{FH_c}$ = **3.12 E-04** **cm/sec**

$for\ Variable\ Head\ Test = k = \frac{A}{FT}$ = **NA** **cm/sec**

or $k = \frac{A}{F(t_2 - t_1)} log_e \frac{H_1}{H_2}$

k is the Permeability of Soil

q is the Rate of Flow

F is the intake factor

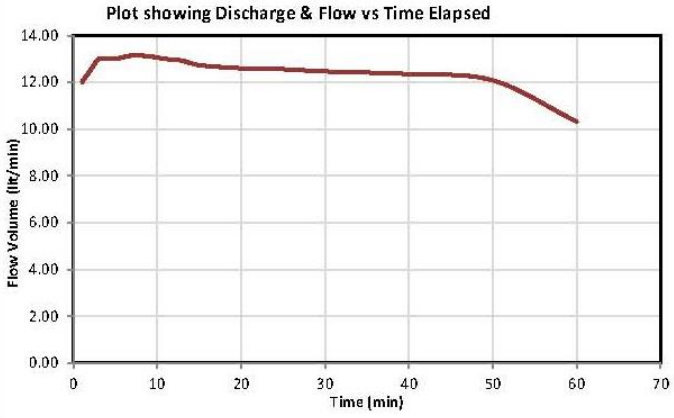
H_c is the constant head

H_1 is the variable head measured at time t_1 after commencement of test

H_2 is the variable head measured at time t_2 after commencement of test

A is the cross-sectional area of casing or standpiple as appropriate

T is the basic time factor



Annexure D. Site Investigation Logs

D.1. Borehole Logs

Start Date: 02-09-2014	End Date: 03-09-2014	Elevation: 100 (Assumed)
Easting: N.A	Northing: N.A	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 6.0 m	Drilling Method: Straight Rotary	

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Graphic Log	Sample No.	Depth (m)	Sample Symbol	1st 15 cm	2nd 15 cm	3rd 15 cm	N Value	Sample Type
0.0	0	Ground Surface			0						
		SILT Brown, Stiff, Silt, Low to Medium Plastic									
-1.0	1	**SILTY SAND** Grey, Loose to Medium Dense, Silty Sand, Trace Mica		1	1		3	4	4	8	SS
-2.0	2			2	2		3	2	5	9	SS
-3.0	3			3	3		4	5	7	12	SS
-4.0	4	**FINE SAND** Grey, Medium Dense, Fine Sand, Trace Mica, Trace Concretion at Depth of 6m		4	4		4	6	6	12	SS
-5.0	5			5	5		5	6	7	13	SS
-6.0	6			6	6		6	7	9	16	SS
-7.0	7			7	7		6	6	9	15	SS
-8.0	8			8	8		7	8	11	19	SS
-9.0	9			9	9		8	9	11	20	SS
-10.0	10				10						

STD. PENETRATION TEST DATA (blows/.30m) — 1 … 100

LEGEND

SAMPLER TYPE

SS - Split Spoon
ST - Shelby Tube
AWG - Rock Core, 1-1/8"
NQ - Rock Core, 1-7/8"
UDS - Undisturved Sample
CT - Continuous Tube

DRILLING METHOD

HA - Hand Auger
Rotary
HA/LP - Hand Auger/Light Percussion
HP - Heavy Percussion
SR - Straight
RC - Rock Core

Start Date: 02-09-2014	End Date: 03-09-2014	Elevation: 100 (Assumed)
Easting: N.A	Northing: N.A	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 6.0 m	Drilling Method: Straight Rotary	

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Graphic Log	Sample No.	Depth (m)	Sample Symbol	1st 15 cm	2nd 15 cm	3rd 15 cm	N Value	Sample Type
		FINE SAND Grey, Medium Dense to Dense, Fine Sand, Trace Mica		10							UDS
-11.0	11			11	11		9	11	14	25	SS
-12.0	12			12	12		10	12	15	27	SS
-13.0	13			13	13		11	15	23	38	SS
-14.0	14			14	14		10	12	18	30	SS
-15.0	15			15	15		13	16	17	33	SS
-16.0	16			16	16		14	17	19	36	SS
-17.0	17			17	17		16	18	21	39	SS
-18.0	18			18	18		17	21	23	44	SS
-19.0	19			19	19		16	19	21	40	SS
-20.0	20			20	20		18	21	24	45	SS

STD. PENETRATION TEST DATA (blows/.30m)

1 100

LEGEND

SAMPLER TYPE		DRILLING METHOD	
SS - Split Spoon	NQ - Rock Core, 1-7/8"	HA - Hand Auger	SR - Straight Rotary
ST - Shelby Tube	UDS - Undisturved Sample	HA/LP - Hand Auger/Light Percussion	RC - Rock Core
AWG - Rock Core, 1-1/8"	CT - Continuous Tube	HP - Heavy Percussion	

Client: M/s Lean and Green (Pvt.) Ltd. Multan

Start Date: 02-09-2014	End Date: 03-09-2014	Elevation: 100 (Assumed)
Easting: N.A	Northing: N.A	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 6.0 m	Drilling Method: Straight Rotary	

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Graphic Log	Sample No.	Depth (m)	Sample Symbol	1st 15 cm	2nd 15 cm	3rd 15 cm	N Value	Sample Type
		FINE SAND Grey, Medium Dense to Dense, Fine Sand, Trace Mica								45	
-21.0	21			21	21		16	19	20	39	SS
-22.0	22			22	22		16	17	20	37	SS
-23.0	23			23	23		16	19	20	39	SS
-24.0	24			24	24		14	17	18	35	SS
-25.0	25			25	25		15	18	20	38	SS
-26.0	26			26	26		16	19	19	38	SS
-27.0	27			27	27		16	17	19	36	SS
-28.0	28			28	28		15	17	19	36	SS
-29.0	29			29	29		18	19	21	40	SS
-30.0	30	BOTTOM OF BOREHOLE		30	30		15	20	25	45	SS

STD. PENETRATION TEST DATA (blows/.30m) 1 — 100

LEGEND

SAMPLER TYPE

SS - Split Spoon
ST - Shelby Tube
AWG - Rock Core, 1-1/8"
NQ - Rock Core, 1-7/8"
UDS - Undisturved Sample
CT - Continuous Tube

DRILLING METHOD

HA - Hand Auger
HA/LP - Hand Auger/Light Percussion
HP - Heavy Percussion
SR - Straight Rotary
RC - Rock Core

Start Date: 30-08-2014	End Date: 31-08-2014	Elevation: 218 m
Easting: 740641.4	Northing: 321122.3	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 4.0 m	Drilling Method: Straight Rotary	

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Graphic Log	Sample No.	Depth (m)	Sample Symbol	1st 15 cm	2nd 15 cm	3rd 15 cm	N Value	Sample Type
0.0	0	Ground Surface			0						
		SILT Brown, Stiff, Silt, Low to Medium Plastic									
-1.0	1	**SILTY SAND** Grey, Medium Dense, Silty Sand, Trace Mica		1	1		3	4	6	10	SS
-2.0	2	**FINE SAND** Grey, Medium Dense, Fine Sand, Trace Mica		2	2		3	8	8	16	SS
-3.0	3			3	3		5	8	10	18	SS
-4.0	4			4	4		8	12	16	28	SS
-5.0	5			5	5		7	11	12	23	SS
-6.0	6			6	6		8	12	12	24	SS
-7.0	7			7	7						UDS
-8.0	8			8	8		7	10	13	23	SS
-9.0	9			9	9		8	11	12	23	SS
-10.0	10			10	10						

STD. PENETRATION TEST DATA (blows/.30m) — 1 to 100

LEGEND

SAMPLER TYPE

SS - Split Spoon
ST - Shelby Tube
AWG - Rock Core, 1-1/8"
NQ - Rock Core, 1-7/8"
UDS - Undisturved Sample
CT - Continuous Tube

DRILLING METHOD

HA - Hand Auger
Rotary
HA/LP - Hand Auger/Light Percussion
HP - Heavy Percussion
SR - Straight
RC - Rock Core

Start Date: 30-08-2014	End Date: 31-08-2014	Elevation: 218 m
Easting: 740641.4	Northing: 321122.3	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 4.0 m	Drilling Method: Straight Rotary	

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Graphic Log	Sample No.	Depth (m)	Sample Symbol	1st 15 cm	2nd 15 cm	3rd 15 cm	N Value	Sample Type
		FINE SAND Grey, Medium Dense to Dense, Fine Sand, Trace Mica		10			8	12	12	24	SS
-11.0	11			11	11		9	12	17	29	SS
-12.0	12			12	12		11	14	17	31	SS
-13.0	13			13	13		12	15	18	33	SS
-14.0	14			14	14		12	16	17	33	SS
-15.0	15			15	15		13	16	16	32	SS
-16.0	16			16	16		14	16	17	33	SS
-17.0	17			17	17		16	16	17	33	SS
-18.0	18			18	18		17	15	21	36	SS
-19.0	19			19	19		16	19	17	36	SS
-20.0	20			20	20		18	19	20	39	SS

STD. PENETRATION TEST DATA (blows/.30m) 1 — 100

LEGEND

SAMPLER TYPE

SS - Split Spoon
ST - Shelby Tube
AWG - Rock Core, 1-1/8"
NQ - Rock Core, 1-7/8"
UDS - Undisturved Sample
CT - Continuous Tube

DRILLING METHOD

HA - Hand Auger
Rotary
HA/LP - Hand Auger/Light Percussion
HP - Heavy Percussion
SR - Straight
RC - Rock Core

Start Date: 30-08-2014	End Date: 31-08-2014	Elevation: 218 m
Easting: 740641.4	Northing: 321122.3	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 4.0 m	Drilling Method: Straight Rotary	

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Graphic Log	Sample No.	Depth (m)	Sample Symbol	1st 15 cm	2nd 15 cm	3rd 15 cm	N Value	Sample Type
		FINE SAND Grey, Medium Dense to Dense, Fine Sand, Trace Mica								39	
-21.0	21			21	21		16	16	20	36	SS
-22.0	22			22	22		16	17	20	37	SS
-23.0	23			23	23		16	13	20	33	SS
-24.0	24			24	24		14	17	18	35	SS
-25.0	25			25	25		15	19	20	39	SS
-26.0	26			26	26		16	16	19	35	SS
-27.0	27			27	27		16	17	19	36	SS
-28.0	28			28	28		15	17	17	34	SS
-29.0	29			29	29		18	17	17	34	SS
-30.0	30	BOTTOM OF BOREHOLE		30	30		15	19	20	39	SS

STD. PENETRATION TEST DATA (blows/.30m)

1 — 100

LEGEND

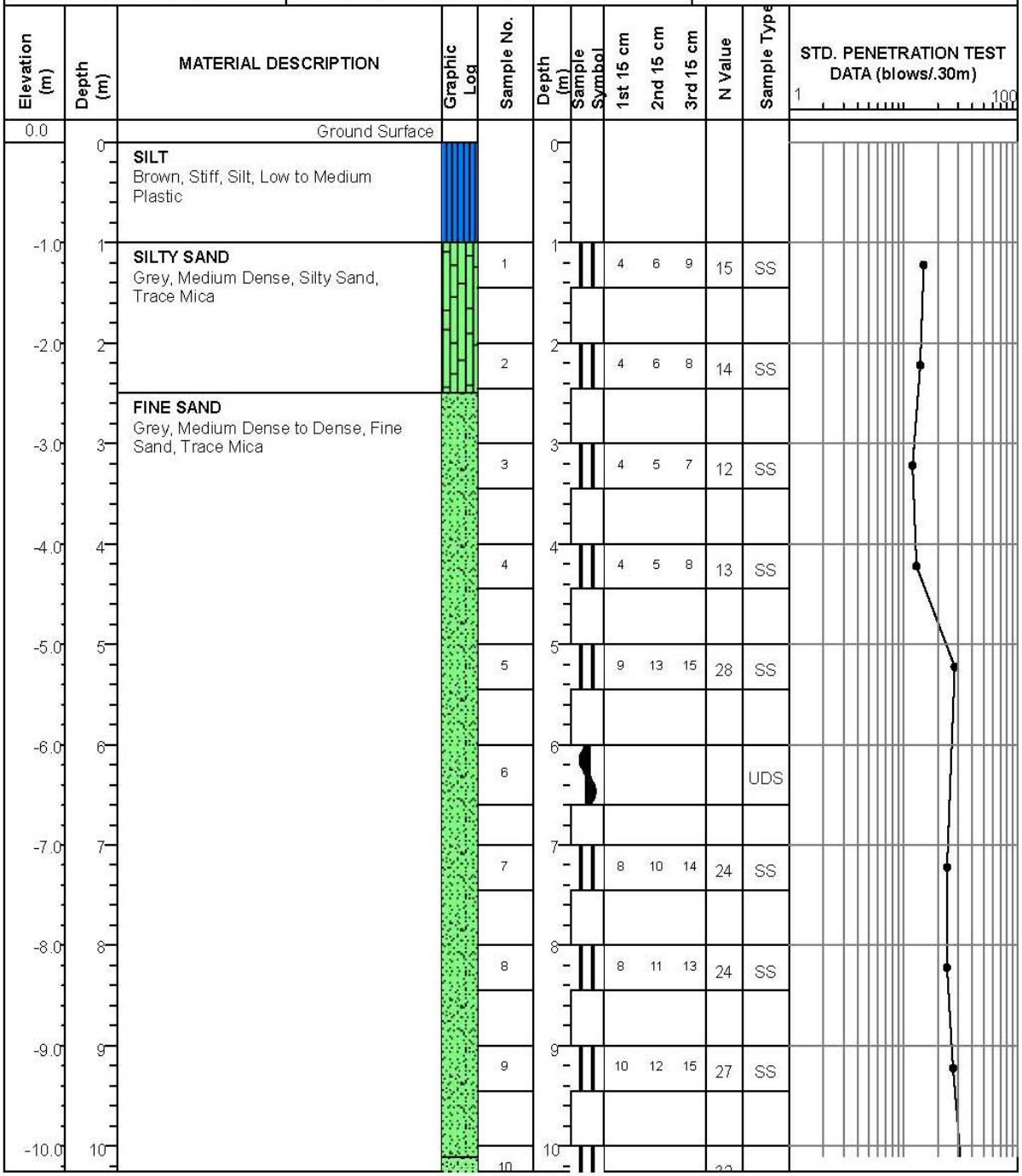
SAMPLER TYPE

SS - Split Spoon
ST - Shelby Tube
AWG - Rock Core, 1-1/8"
NQ - Rock Core, 1-7/8"
UDS - Undisturved Sample
CT - Continuous Tube

DRILLING METHOD

HA - Hand Auger
Rotary
HA/LP - Hand Auger/Light Percussion
HP - Heavy Percussion
SR - Straight
RC - Rock Core

Start Date: 29-08-2014	End Date: 29-08-2014	Elevation: 259 m
Easting: 740620.8	Northing: 321113.7	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 5.5 m	Drilling Method: Straight Rotary	



LEGEND

SAMPLER TYPE			DRILLING METHOD	
SS - Split Spoon	NQ - Rock Core, 1-7/8"		HA - Hand Auger	SR - Straight Rotary
ST - Shelby Tube	UDS - Undisturved Sample		HA/LP - Hand Auger/Light Percussion	RC - Rock Core
AWG - Rock Core, 1-1/8"	CT - Continuous Tube		HP - Heavy Percussion	

Start Date: 29-08-2014	End Date: 29-08-2014	Elevation: 259 m
Easting: 740620.8	Northing: 321113.7	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 5.5 m	Drilling Method: Straight Rotary	

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Graphic Log	Sample No.	Depth (m)	Sample Symbol	1st 15 cm	2nd 15 cm	3rd 15 cm	N Value	Sample Type
		FINE SAND Grey, Dense, Fine Sand, Trace Mica		10			11	14	18	32	SS
-11.0	11			11	11		12	15	18	33	SS
-12.0	12			12	12		13	19	19	38	SS
-13.0	13			13	13		15	18	21	39	SS
-14.0	14			14	14		14	17	19	36	SS
-15.0	15			15	15		14	18	21	39	SS
-16.0	16			16	16		15	17	21	36	SS
-17.0	17			17	17		15	18	20	38	SS
-18.0	18			18	18		14	15	16	31	SS
-19.0	19			19	19		13	14	17	31	SS
-20.0	20			20	20		13	15	18	33	SS

STD. PENETRATION TEST DATA (blows/.30m)

1 — 100

LEGEND

SAMPLER TYPE

SS - Split Spoon
ST - Shelby Tube
AWG - Rock Core, 1-1/8"
NQ - Rock Core, 1-7/8"
UDS - Undisturved Sample
CT - Continuous Tube

DRILLING METHOD

HA - Hand Auger
Rotary
HA/LP - Hand Auger/Light Percussion
HP - Heavy Percussion
SR - Straight
RC - Rock Core

Start Date: 29-08-2014	End Date: 29-08-2014	Elevation: 259 m
Easting: 740620.8	Northing: 321113.7	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 5.5 m	Drilling Method: Straight Rotary	

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Graphic Log	Sample No.	Depth (m)	Sample Symbol	1st 15 cm	2nd 15 cm	3rd 15 cm	N Value	Sample Type
		FINE SAND Grey, Medium Dense to Dense, Fine Sand, Trace Mica								33	
-21.0	21			21	21		14	17	20	37	SS
-22.0	22			22	22		16	15	20	35	SS
-23.0	23			23	23		16	15	20	35	SS
-24.0	24			24	24		14	17	20	37	SS
-25.0	25			25	25		15	15	20	35	SS
-26.0	26			26	26		16	16	19	35	SS
-27.0	27			27	27		16	15	19	34	SS
-28.0	28			28	28		15	13	19	32	SS
-29.0	29			29	29		18	18	18	36	SS
-30.0	30	BOTTOM OF BOREHOLE		30	30		15	20	15	35	SS

STD. PENETRATION TEST DATA (blows/.30m) 1 — 100

LEGEND

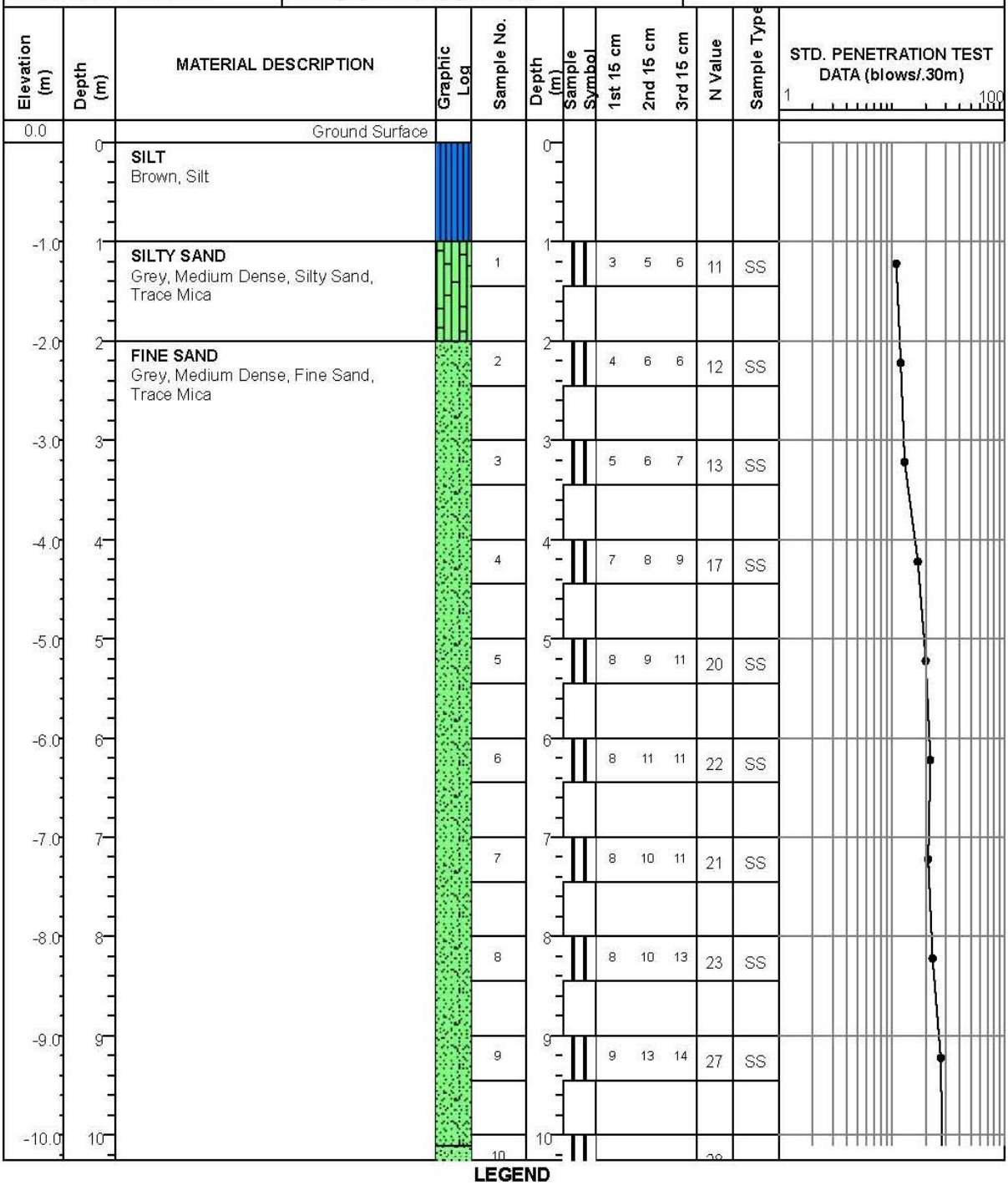
SAMPLER TYPE

SS - Split Spoon
ST - Shelby Tube
AWG - Rock Core, 1-1/8"
NQ - Rock Core, 1-7/8"
UDS - Undisturved Sample
CT - Continuous Tube

DRILLING METHOD

HA - Hand Auger
HA/LP - Hand Auger/Light Percussion
HP - Heavy Percussion
SR - Straight Rotary
RC - Rock Core

Start Date: 31-08-2014	End Date: 01-09-2014	Elevation: 100 (Assumed)
Easting: N.A	Northing: N.A	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 4.5 m	Drilling Method: Straight Rotary	



LEGEND

SAMPLER TYPE		DRILLING METHOD	
SS - Split Spoon	NQ - Rock Core, 1-7/8"	HA - Hand Auger	SR - Straight Rotary
ST - Shelby Tube	UDS - Undisturved Sample	HA/LP - Hand Auger/Light Percussion	RC - Rock Core
AWG - Rock Core, 1-1/8"	CT - Continuous Tube	HP - Heavy Percussion	

Start Date: 31-08-2014	End Date: 01-09-2014	Elevation: 100 (Assumed)
Easting: N.A	Northing: N.A	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 4.5 m	Drilling Method: Straight Rotary	

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Graphic Log	Sample No.	Depth (m)	Sample Symbol	1st 15 cm	2nd 15 cm	3rd 15 cm	N Value	Sample Type
		FINE SAND Grey, Medium Dense to Dense, Fine Sand, Trace Mica		10			11	13	15	28	SS
-11.0	11			11	11		10	14	16	30	SS
-12.0	12			12	12						UDS
-13.0	13			13	13		11	13	19	32	SS
-14.0	14			14	14		11	12	17	29	SS
-15.0	15			15	15		13	16	19	35	SS
-16.0	16			16	16		15	17	19	36	SS
-17.0	17			17	17		14	16	19	35	SS
-18.0	18			18	18		16	18	21	39	SS
-19.0	19			19	19		13	17	21	38	SS
-20.0	20			20	20		15	18	19	37	SS

STD. PENETRATION TEST DATA (blows/.30m) 1 — 100

LEGEND

SAMPLER TYPE

SS - Split Spoon
ST - Shelby Tube
AWG - Rock Core, 1-1/8"
NQ - Rock Core, 1-7/8"
UDS - Undisturved Sample
CT - Continuous Tube

DRILLING METHOD

HA - Hand Auger
Rotary
HA/LP - Hand Auger/Light Percussion
HP - Heavy Percussion
SR - Straight
RC - Rock Core

Start Date: 31-08-2014	End Date: 01-09-2014	Elevation: 100 (Assumed)
Easting: N.A	Northing: N.A	Notes:
Supervisor: Umair	Construction Contractor: N.A	
Groundwater Level: 4.5 m	Drilling Method: Straight Rotary	

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Graphic Log	Sample No.	Depth (m)	Sample Symbol	1st 15 cm	2nd 15 cm	3rd 15 cm	N Value	Sample Type
		FINE SAND Grey, Dense, Fine Sand, Trace Mica								37	
-21.0	21			21	21		17	19	21	40	SS
-22.0	22			22	22		16	17	22	39	SS
-23.0	23			23	23		14	16	17	33	SS
-24.0	24			24	24		12	16	19	35	SS
-25.0	25			25	25		14	17	19	36	SS
-26.0	26			26	26		17	19	22	41	SS
-27.0	27			27	27		16	20	22	42	SS
-28.0	28			28	28		17	19	23	42	SS
-29.0	29			29	29		18	21	23	44	SS
-30.0	30	BOTTOM OF BOREHOLE		30	30		15	21	24	45	SS

STD. PENETRATION TEST DATA (blows/.30m) 1 — 100

LEGEND

SAMPLER TYPE		DRILLING METHOD	
SS - Split Spoon	NQ - Rock Core, 1-7/8"	HA - Hand Auger	SR - Straight Rotary
ST - Shelby Tube	UDS - Undisturved Sample	HA/LP - Hand Auger/Light Percussion	RC - Rock Core
AWG - Rock Core, 1-1/8"	CT - Continuous Tube	HP - Heavy Percussion	

Urban Sector Planning & Management Services Unit (Pvt.) Ltd. — A Public Sector Company — Government of the Punjab

Lean & Green Private Limited Company

Annexure E. Site Photographs

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Soil Description Explanation Sheet (1 of 2)

DEFINITION:

In engineering terms soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil. Other materials are described using rock description terms.

CLASSIFICATION SYMBOL & SOIL NAME

Soils are described in accordance with the Unified Soil Classification (UCS) as shown in the table on Sheet 2.

PARTICLE SIZE DESCRIPTIVE TERMS

NAME	SUBDIVISION	SIZE
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

MOISTURE CONDITION

Dry Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.

Moist Soil feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.

Wet As for moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

TERM	UNDRAINED STRENGTH s_u (kPa)	FIELD GUIDE
Very Soft	<12	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	>200	The surface of the soil can be marked only with the thumbnail.
Friable	–	Crumbles or powders when scraped by thumbnail.

DENSITY OF GRANULAR SOILS

TERM	DENSITY INDEX (%)
Very loose	Less than 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	Greater than 85

MINOR COMPONENTS

TERM	ASSESSMENT GUIDE	PROPORTION OF MINOR COMPONENT IN:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: <5% Fine grained soils: <15%
With some	Presence easily detected by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 - 12% Fine grained soils: 15 - 30%

SOIL STRUCTURE

ZONING		CEMENTING	
Layers	Continuous across exposure or sample.	Weakly cemented	Easily broken up by hand in air or water.
Lenses	Discontinuous layers of lenticular shape.	Moderately cemented	Effort is required to break up the soil by hand in air or water.
Pockets	Irregular inclusions of different material.		

GEOLOGICAL ORIGIN

WEATHERED IN PLACE SOILS

Extremely weathered material	Structure and fabric of parent rock visible.
Residual soil	Structure and fabric of parent rock not visible.

TRANSPORTED SOILS

Aeolian soil	Deposited by wind.
Alluvial soil	Deposited by streams and rivers.
Colluvial soil	Deposited on slopes (transported downslope by gravity).
Fill	Man made deposit. Fill may be significantly more variable between tested locations than naturally occurring soils.
Lacustrine soil	Deposited by lakes.
Marine soil	Deposited in ocean basins, bays, beaches and estuaries.

Soil Description Explanation Sheet (2 of 2)

SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 60 mm and basing fractions on estimated mass)							USC	PRIMARY NAME
COARSE GRAIINED SOILS More than 50% of materials less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.0 mm	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.			GW	GRAVEL
				Predominantly one size or a range of sizes with more intermediate sizes missing.			GP	GRAVEL
			GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)			GM	SILTY GRAVEL
				Plastic fines (for identification procedures see CL below)			GC	CLAYEY GRAVEL
		SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes missing			SW	SAND
				Predominantly one size or a range of sizes with some intermediate sizes missing.			SP	SAND
			SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).			SM	SILTY SAND
				Plastic fines (for identification procedures see CL below).			SC	CLAYEY SAND
FINE GRAINED SOILS More than 50% of material less than 63 mm is smaller than 0.075 mm			IDENTIFICATION PROCEDURES ON FRACTIONS <0.2 mm.					
			DRY STRENGTH	**DILATANCY**	**TOUGHNESS**			
		SILTS & CLAYS Liquid limit less than 50	None to Low	Quick to slow	None		ML	SILT
			Medium to High	None	Medium		CL	CLAY
			Low to medium	Slow to very slow	Low		OL	ORGANIC SILT
		SILTS & CLAYS Liquid limit greater than 50	Low to medium	Slow to very slow	Low to medium		MH	SILT
			High	None	High		CH	CLAY
			Medium to High	None	Low to medium		OH	ORGANIC CLAY
HIGHLY ORGANIC SOILS			Readily identified by colour, odour, spongy feel and frequently by fibrous texture.				Pt	PEAT

• Low plasticity – Liquid Limit W_L less than 35%. • Modium plasticity – W_L between 35% and 50%.

COMMON DEFECTS IN SOIL

TERM	DEFINITION	DIAGRAM
PARTING	A surface or crack across which the soil has little or no tensile strength. Parallel or sub parallel to layering (eg bedding). May be open or closed.	
JOINT	**A surface or crack across which the soil** has little or no tensile strength but which is not parallel or sub parallel to layering. May be open or closed. The term 'fissure' may be used for irregular joints <0.2 m in length.	
SHEARED ZONE	Zone in clayey soil with roughly parallel near planar, curved or undulating boundaries containing closely spaced, smooth or slickensided, curved intersecting joints which divide the mass into lenticular or wedge shaped blocks.	
SHEARED SURFACE	A near planar curved or undulating, smooth, polished or slickensided surface in clayey soil. The polished or slickensided surface indicates that movement (in many cases very little) has occurred along the defect.	

TERM	DEFINITION	DIAGRAM
SOFTENED ZONE	A zone in clayey soil, usually adjacent to a defect in which the soil has a higher moisture content than elsewhere.	
TUBE	Tubular cavity. May occur singly or as one of a large number of separate or inter-connected tubes. Walls often coated with clay or strengthened by denser packing of grains. May contain organic matter	
TUBE CAST	Roughly cylindrical elongated body of soil different from the soil mass in which it occurs. In some cases the soil which makes up the tube cast is cemented.	
INFILLED SEAM	Sheet or wall like body of soil substance or mass with roughly planar to irregular near parallel boundaries which cuts through a soil mass. Formed by infilling of open joints.