الجمهورية اللبنانية

وزارة الطاقة والمياه

# دراسة محطة معالجة مياه بحيرة المسيلحة ومحطات الضخ وخطوط النقل والدفع والخزانات وتصميم محيط الأشغال أسفل سد المسيلحة بما فيها القلعة – قضاء البترون

الجزء الأول: دراسة محطة معالجة المياه وضخها إلى الخزانات الرئيسية

1-2 استقصاءات وسبر أغوار لمنطقة محطة المعالجة

1-2-1 بئر (عمق ١٥ مترا)

1-2-2 التجارب المخبرية

**TENDER DOCUMENTS FOR DESIGN, BUILD, OPERATE AND MAINTAIN CONTRACT**

**VOLUME 6: Geotechnical Investigations**

حزيران ٢٠١٧

Founded 1956
DAR AL HANDASAH NAZIH TALEB & PARTNERS
دار الهندسة نزيه طالب وشركاه

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|---|---|---|
| QC | Ref: L1402 / 1855 | |
| | Revision: 01 | Date: June 07, 2017 |
| | Signature: | |

# 1 INTRODUCTION

This geotechnical engineering report has been prepared for the proposed Water Treatment Plant, Mseilha – North Lebanon (see Figure 1).

The Geotechnical Investigation was carried out in a manner to understand the subsurface geology of the chosen location and to determine the site conditions (including the groundwater table) from the geotechnical engineering point of view.


**Figure 1 Mseilha Water Treatment Plant.**

# 2 WATER TREATMENT PLANT

The project consists of a Water Treatment Plant (see Figure 2) including followings:

- Flash mixer (4), valve chamber (3), aerator (2), flow-meter (1) and pre/post chlorination rooms (12).
- Clariflocculators (6) and distribution box (5).
- Filters (7), chemical room (11) and sludge tank (13).
- Clear water tanks (8), high lift pump (9).
- Generator and transformer room (10).
- Store and workshop (14), administration building (16), guard house and guard room (15).

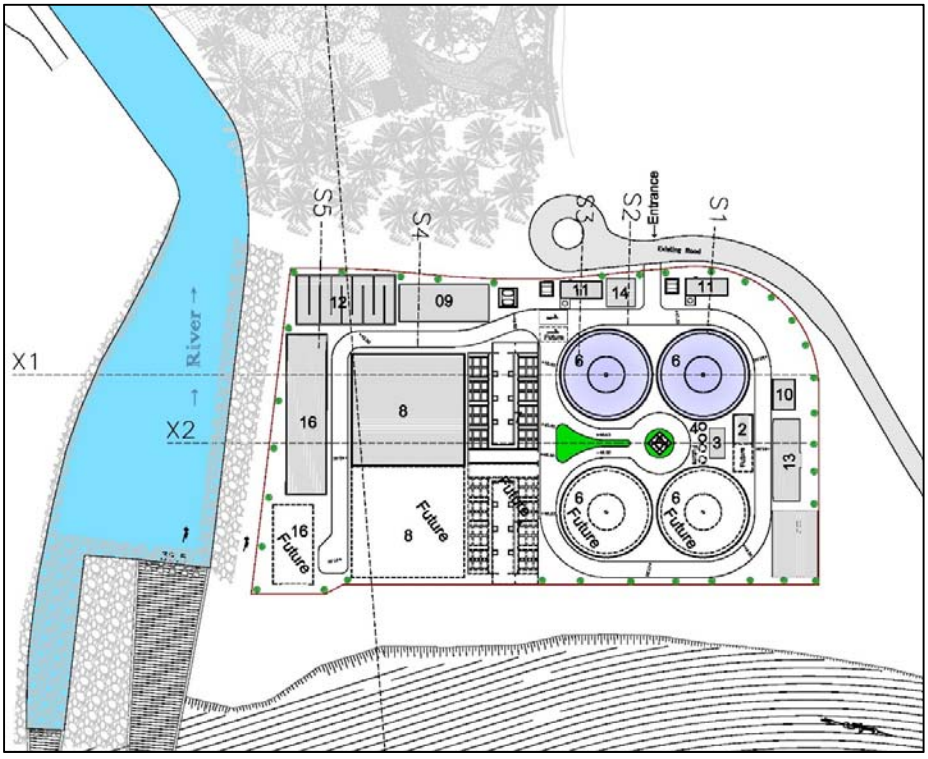


**Figure 2 Water Treatment Plant Installation.**

# 3 SITE DESCRIPTION

The proposed Water Treatment Plant is located on a valley floor downstream of the Mseilha Dam (see Figure 3) under construction. The existing ground is sloping to the South. The topography of the site increases in elevation Northward; its lowest point is about 36m above the sea level and reaches a maximum elevation of 53 (refer to Appendix 1). The site of the Water Treatment Plant is about 20,750 $m^2$.

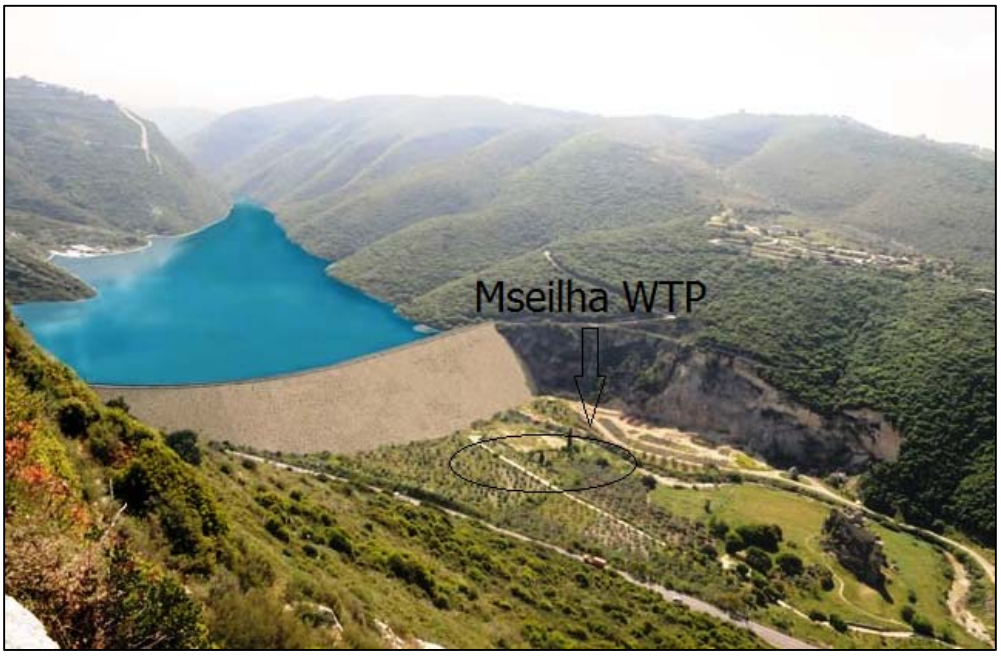


**Figure 3 Site of the project.**

# 4 GEOTECHNICAL INVESTIGATION

Five boreholes (continuous core drilling in soil and rock) 15 meters deep each, were drilled between October 09 and 14, 2015 at locations shown on attached drawing (Appendix 1), in a manner to determine geological stratigraphy of the site and geotechnical parameters of the subsurface soil and rock stratums that were used in engineering analysis.

Open standpipe piezometers were installed into the drilled boreholes for measuring the depth and fluctuations of the groundwater table.

A crawler mounted rotary drill rig as shown on Figure 4 was used in geotechnical investigation.

**Figure 4 Crawler mounted rotary drill rig.**

The scope of works of this geotechnical investigation consisted of the followings:

- Continuous core drilling in soil and rock.
- Performing Standard Penetration Test (SPT) in soil and obtaining disturbed samples.
- Performing Dynamic Cone Penetration Test (DCPT) in soils contain coarse gravels and cobbles.
- Installing open standpipe piezometers into the drilled borehole and measuring the depth and fluctuations of the groundwater table (piezometric survey) by using a water level meter (PLS 200 / Denmark, EU).
- Performing laboratory tests on representative soil and rock samples taken from the boreholes.

86mm diameter (bit set OD) double tube core barrel (T2 86, see Figure 5) equipped with tungsten carbide core bit was used in continuous core drilling with NW drill rods and HW casings.

**Figure 5 Double tube core barrel**

Core drilling was performed by using as minimum as possible amount of circulation water in a manner to increase the Total Core Recovery (TCR), only clean water was used during the drilling by taking into account the piezometers to be installed, water losses were recorded on site and indicated in logs of borings. The logs of borings are presented in Appendix 2.

Cores (soil and rock) taken from the boreholes were stored in standard wooden core boxes. All the necessary information related to the runs of coring and boreholes were indicated on the boxes and photos of core boxes were taken upon completion of the boreholes. The photos of core boxes are presented in Appendix 3.

TCR/SCR, Rock Quality Designation (RQD), Fracture Frequency, cavity detection and detailed logging were carried out during the core drilling and indicated in logs of borings.

In soil stratums, Standard Penetration Test (SPT) was performed at 1.5m intervals by using Split-Spoon SPT sampler (see Figure 6) in 2 inches outside diameter with a one way valve at the head of the sampler and a soil type basket lifter at the bottom end and disturbed samples (D) were obtained, labelled and stored in moisture-proof containers.

**Figure 6 SPT sampler.**

Where needed, Dynamic Cone Penetration Test (DCPT) was performed in soil stratums contain coarse gravels and cobbles. A solid cone (see Figure 7) having an apex angle of 60 degrees and an end diameter of 62.5mm was used in DCPT with SPT hammer.

**Figure 7 Solid cone.**

The dynamic penetration tests (SPT and DCPT) were performed to estimate the relative density / stiffness and consistency of the subsurface soil stratums.

Perforated (one third of the standpipe) UPVC pipes, 50mm diameter (OD) and 3.7mm thick, wrapped with geotextile (PP, 150 gr/m2) were installed into the boreholes as open standpipe piezometer with concrete heading and steel pipe protection as shown on Figure 8, in a manner to measure the depth and fluctuations of the groundwater table by using a water level meter.

**Figure 8 Open standpipe piezometer.**

All above mentioned works were performed according to ASTM and IS standards and were supervised by an engineering geologist.

- ASTM D6640: Core drilling in soil and rock.

- ASTM D1586: Standard Penetration Test.
- IS 4968: Dynamic Cone Penetration Test.
- ASTM D4750: Determining subsurface liquid level in a borehole.

Representative soil and rock samples from the boreholes (see Figure 9) were selected and tested in the laboratory to determine the geotechnical parameters of the subsurface soil and rock stratums. The laboratory test results are presented in Appendix 4.


**Figure 9 Selected soil and rock samples.**

# 5 SUBSURFACE GEOLOGY

According to outcrops within the area of the Water Treatment Plant and logs of borings (Appendix 2), the subsurface geology mainly consists of followings:

- Made Ground is found in all boreholes except BHWTP4. This stratum, 2m thick in average, is loose to medium dense.
- Rounded GRAVEL with subrounded Cobbles and Boulders of Limestone, in a sandy clay matrix (mix of alluvial and colluvial soil deposits), is found in all boreholes except BHWTP4. This stratum, 4.5m thick in average, is medium dense in general.
- Light brown silty CLAY of intermediate plasticity with occasional rounded and subrounded Gravels, Cobbles and Boulders of Limestone (lacustrine soil deposits occasionally mixed with alluviums and colluviums). This stratum, 7m thick in average, is firm to stiff.
- Bedrock (interbeddings of Cretaceous Limestone and Marly Limestone with Marl) is found in boreholes BHWTP1, BHWTP2 and BHWTP4 at a depth of 12m in average from the existing ground level. This stratum consists of light cream to beige and olive brown slightly weathered crushed medium strong to strong (intact rock strength) interbeddings of Cretaceous Limestone and Marly Limestone with Marl.

**BHWTP1:** 15 meters deep, X: -318373.5, Y: 13690.0, Z: +42.02

**0-3.5m:**

Loose to medium dense, coarsely fragmented (angular) limestone with fines (**made ground**), circulation-water loss at 3m

**3.5-9m:**

Loose to medium dense rounded **GRAVEL** with subrounded Cobbles and Boulders of Limestone, in a sandy clay matrix (mix of alluvial and colluvial soil deposits)

**9-12m:**

Light brown firm to stiff **CLAY** with occasional rounded and subrounded Gravels, Cobbles and Boulders of Limestone (lacustrine soil deposits occasionally mixed with alluviums and colluviums)

**12m-15m:**

Light cream to beige and olive brown slightly weathered crushed medium strong to strong (intact rock strength) interbeddings of Cretaceous Limestone and Marly Limestone with Marl (**bedrock/lower saprolite**).

**BHWTP2**: 15 meters deep, X: -318448.0, Y: 13671.5, Z: +39.9

**0-4.5m:**

Loose to medium dense, coarsely fragmented (angular) limestone with fines (**made ground**)

**4.5-11m:**

Medium dense rounded **GRAVEL** with subrounded Cobbles and Boulders of Limestone, in a sandy clay matrix (mix of alluvial and colluvial soil deposits), circulation-water loss at 6m

**11-15m:**

Light cream to beige and olive brown slightly weathered crushed medium strong to strong (intact rock strength) interbeddings of Cretaceous Limestone and Marly Limestone with Marl (**bedrock/lower saprolite**).

**BHWTP3**: 15 meters deep, X: -318428.0, Y: 13732.5, Z: +43.5

**0-0.5m:**

Medium dense, coarsely fragmented (angular) limestone with fines (**made ground**)

**0.5-10.5m:**

Light brown firm to stiff **CLAY** with occasional rounded and subrounded Gravels, Cobbles and Boulders of Limestone (lacustrine soil deposits occasionally mixed with alluviums and colluviums)

**10.5m-15m:**

Loose to medium dense rounded **GRAVEL** with subrounded Cobbles and Boulders of Limestone, in a sandy clay matrix (mix of alluvial and colluvial soil deposits), circulation-water loss at 12m

**BHWTP4**: 15 meters deep, X: -318381.5, Y: 13775.4, Z: +47.4

**0-13m:**

Light brown stiff **CLAY** with occasional rounded and subrounded Gravels, Cobbles and Boulders of Limestone (lacustrine soil deposits occasionally mixed with alluviums and colluviums), circulation-water loss at 12m

**13-15m:**

Light cream to beige and olive brown slightly weathered crushed medium strong to strong (intact rock strength) interbeddings of Cretaceous Limestone and Marly Limestone with Marl (**bedrock/lower saprolite**).

**BHWTP5**: 15 meters deep, X: -318417.2, Y: 13804.2, Z: +54.7

**0-1.5m:**

Loose to medium dense, coarsely fragmented (angular) limestone with fines (**made ground**)

**1.5-6.5m:**

Medium dense rounded **GRAVEL** with subrounded Cobbles and Boulders of Limestone, in a sandy clay matrix (mix of alluvial and colluvial soil deposits), circulation-water loss at 4m

**6.5-15m:**

Firm to stiff and stiff **CLAY** with occasional rounded and subrounded Gravels, Cobbles and Boulders of Limestone (lacustrine soil deposits occasionally mixed with alluviums and colluviums)

*No water table was detected in boreholes during the piezometric surveys on October 2015.*

# 6 LAND FORMING

According to the preliminary design drawings, the landforming will consist of excavating the existing ground to a depth of around 1m (clearing and grabbing) and then, filling the low level areas to the level of slab on grade (43.5 in average) as shown on Figure 10 and Appendix 1.

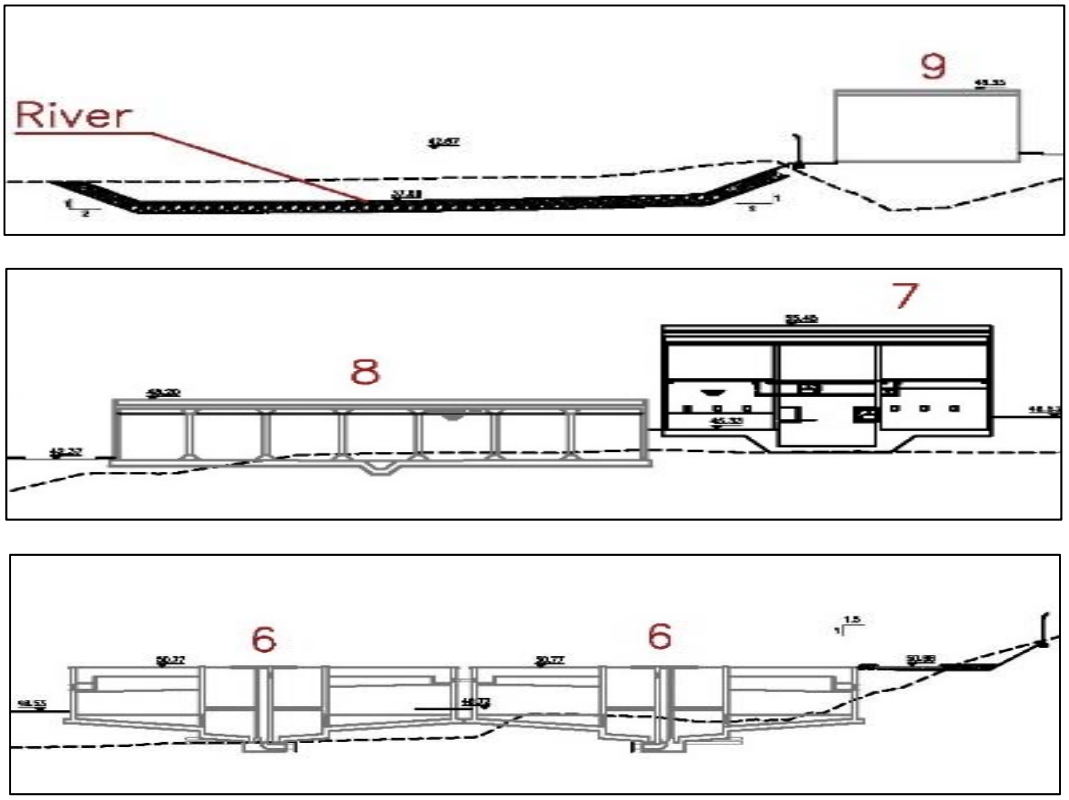


**Figure 10 Land forming.**

In view of the findings, the following slope ratios shall be used for preliminary design purpose.

**Temporary soil cuts (made ground / mix of alluvial and colluvial soil deposits):**

1V:1H to a maximum vertical height of 4.5m as a single cut.

Soil cuts higher than 4.5 meters, should be benched by using the above given slope ratio and height, with benches not less than 4m wide.

The width of the benches should be determined in accordance with height of the soil cut and the minimum deformation conditions (Rankine Active Earth Pressure).

**Engineering fill slope** (coarsely fragmented limestone and sand, with non-plastic fines passing sieve number 200 less than 15%):

1V:1.5H

**However, above given presumed slope ratios should be replaced with specific slope ratios in accordance with actual site and material conditions.**

# 7 BEARING STRATUM

According to the land-forming and logs of borings (subsurface geology within the area of interest); the proposed Water Treatment Plant will be founded on multi-layered foundation soil mainly consists of followings:

- Loose to medium dense made-ground, 2m thick in average.
- Medium dense mix of alluvial and colluvial soil deposits, 4.5m thick in average.
- Firm to stiff lacustrine soil deposits occasionally mixed with alluviums and colluviums, 7m thick in average.

The bearing capacity of a layered soil can be estimated by using the theory of elasticity (elastic settlement of a foundation).

In view of the findings, the following soil parameters may be used in bearing capacity analysis. **However, below given values should be checked with further geotechnical investigations (Menard Pressiometer Test and/or CPTu Sounding).**

Made ground (unsaturated):

Modules of elasticity: 17250 kN/m2

Poisson's ratio: 0.25

Mix of alluvial and colluvial soil deposits (unsaturated):

Modules of elasticity: 27600 kN/m2

Poisson's ratio: 0.3

Lacustrine soil deposits occasionally mixed with alluviums and colluviums (unsaturated):

Modules of elasticity: 20700 kN/m2

Poisson's ratio: 0.2

As per above, an ultimate bearing capacity of 150 kN/m2 shall be used for **preliminary design purpose.**

**It is necessary to mention that densifying the multi-layered foundation soil with deep dynamic compaction, to a depth of reaching the lacustrine soil deposits, may be needed for heavy structures, to increase the safe bearing capacity.**

# 8 CONCLUSIONS & RECOMMENDATIONS

The project consists of a Water Treatment Plant including followings:

- Flash mixer, valve chamber, aerator, flow meter and pre/post chlorination rooms
- Clariflocculators and distribution box.
- Filters, chemical room and sludge tank.
- Clear water tanks, high lift pump.
- Generator and transformer room.
- Store and workshop, administration building, guard house and guard room.

The proposed Water Treatment Plant is located on a valley floor downstream of the Mseilha Dam under construction. The topography of the site increases in elevation Northward; its lowest point is about 36m above the sea level and reaches a maximum elevation of 53. The site of the Water Treatment Plant is about 20,750 m2.

According to outcrops within the area of the Water Treatment Plant and logs of borings, the subsurface geology mainly consists of followings:

- Loose to medium dense **Made Ground** (2m thick in average)
- Medium dense rounded **GRAVEL** with subrounded Cobbles and Boulders of Limestone, in a sandy clay matrix (mix of alluvial and colluvial soil deposits, 4.5m thick in average).
- Light brown firm to stiff **CLAY** of intermediate plasticity with occasional rounded and subrounded Gravels, Cobbles and Boulders of Limestone (lacustrine soil deposits occasionally mixed with alluviums and colluviums, 7m thick in average).
- **Bedrock** (interbeddings of Cretaceous Limestone and Marly Limestone with Marl, at a depth of 12m in average).

*No water table was detected in boreholes during the piezometric surveys.*

According to the preliminary design drawings, the landforming will consist of excavating the existing ground to a depth of around 1m (clearing and grabbing) and then, filling the low level areas to the level of slab on grade (43.5 in average).

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**Engineering-fill slope** (coarsely fragmented limestone and sand, with non-plastic fines passing sieve number 200 less than 15%):

1V:1.5H

**However, above given presumed slope ratios should be replaced with specific slope ratios in accordance with actual site and material conditions.**

According to the land-forming and logs of borings (subsurface geology within the area of interest); the proposed Water Treatment Plant will be founded on multi-layered foundation soil mainly consists of followings:

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- Firm to stiff lacustrine soil deposits occasionally mixed with alluviums and colluviums, 7m thick in average.

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In view of the findings, the following soil parameters may be used in bearing capacity analysis. **However, below given values should be checked with further geotechnical investigations (Menard Pressiometer Test and/or CPTu Sounding).**

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Modules of elasticity: 27600 kN/m2

Poisson's ratio: 0.3

Lacustrine soil deposits occasionally mixed with alluviums and colluviums (unsaturated):

Modules of elasticity: 20700 kN/m2

Poisson's ratio: 0.2

As per above, an ultimate bearing capacity of 150 kN/m2 shall be used for **preliminary design purpose.**

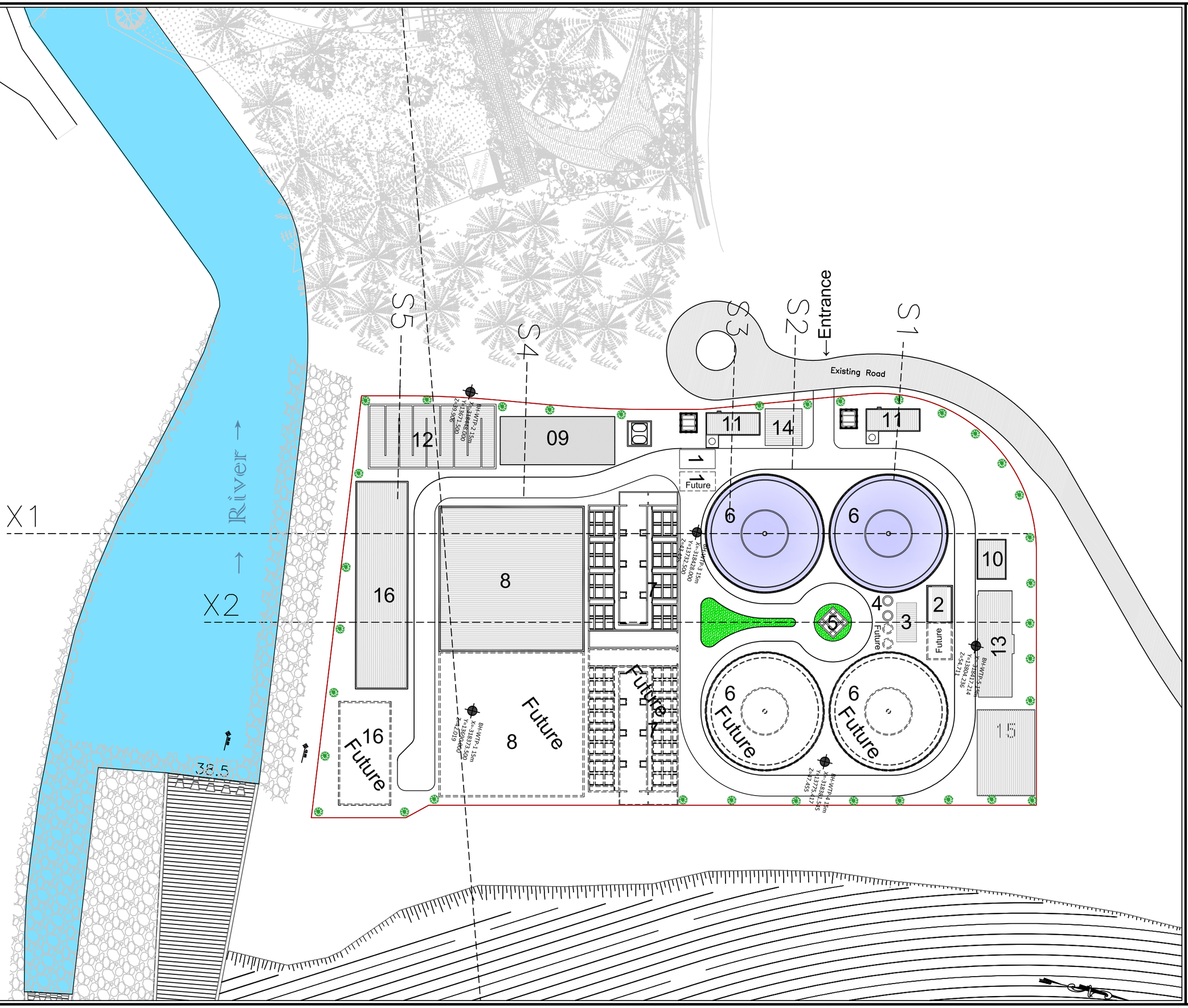
**It is necessary to mention that densifying the multi-layered foundation soil with deep dynamic compaction, to a depth of reaching the lacustrine soil deposits, may be needed for heavy structures, to increase the safe bearing capacity.**

# 9 CLOSURE

The conclusions and recommendations presented in this report are based on the assumption that the subsurface stratums and conditions do not deviate appreciably from those disclosed in the borings. There may be conditions pertaining to the site which were not disclosed by this subsurface soil survey, and thus could not be taken into account.

Therefore; above given conclusions and recommendations are valid under this assumption only and they should be updated with further geotechnical investigations prior to star execution.

# Appendix 1 Borehole Locations & Section X1




LEGEND

01—Flow Meter
02—Cascade Aerator
03—Valve Chamber
04—Flash Mixer
05—Distribution Box
06—Clariflocculator
07—Filters
08—Clear Water Tanks
09—High Lift Pumps
10—Generator & Transformer Room
11—Chemicals Room
12—Pre & Post Chlorination Room
13—Sludge Tank
14—Store & Workshop
15—Guard House & Guard Room
16—Administration Building

| No | DATE | REVISIONS | ARCH | CIVIL | MECH | ELEC |
|---|---|---|---|---|---|---|
| | | | | | | |

CLIENT:
Ministry of Energy and Water

# DOWNSTREAM OF MSEILHA DAM
## FOR POTABLE WATER

DAR AL HANDASAH NAZIH TALEB & PARTNERS
دار الهندسة نزيه طالب وشركاه
Founded 1956

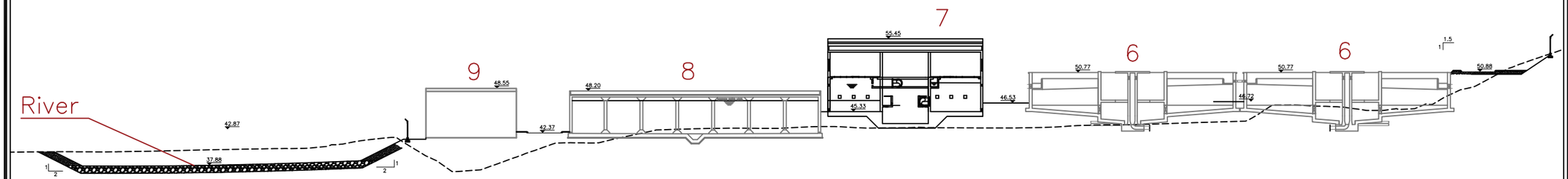
| GEOMETRIC | PAVEMENT | DRAINAGE | STRUCTURAL | PROJ.MANAGER |
|---|---|---|---|---|
| . | . | . | . | . |

WATER TREATMENT PLANT

Borehole Locations

| | |
|---|---|
| DRAWN : | |
| CHECKED : | |
| APPROVED : | |
| DATE : | June 2017 |
| SCALE : | 1:600 |
| FILE NAME | WTP-SS-BH.dwg |

| PROJECT | DIVISION | SUB-DIVISION | SHEET | REVISION |
|---|---|---|---|---|
| L1402D | WTP | SS | BH | 00 |




LEGEND

01—Flow Meter
02—Cascade Aerator
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| No | DATE | REVISIONS | ARCH | CIVIL | MECH | ELEC |
|---|---|---|---|---|---|---|
| | | | | | | |
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CLIENT:

Ministry of Energy and Water

# DOWNSTREAM OF MSEILHA DAM
## FOR POTABLE WATER

DAR AL HANDASAH NAZIH TALEB & PARTNERS
دار الهندسة نزيه طالب وشركاه

Founded 1956

| GEOMETRIC | PAVEMENT | DRAINAGE | STRUCTURAL | PROJ.MANAGER |
|---|---|---|---|---|
| . | . | . | . | . |

WATER TREATMENT PLANT

Section X1

| | |
|---|---|
| DRAWN : | |
| CHECKED : | |
| APPROVED : | |
| DATE : | June 2017 |
| SCALE : | N.T.S |
| FILE NAME | |
| WTP-SS-101.dwg | |

| PROJECT | DIVISION | SUB-DIVISION | SHEET | REVISION |
|---|---|---|---|---|
| L1402D | WTP | SS | 101 | 00 |

# Appendix 2 Logs of Borings

**SATCON**
SOIL STUDIES

# BORING LOG

| | | | | | |
|---|---|---|---|---|---|
| **CLIENT:** | MINISTRY OF ENERGY AND WATER | **FILE NO.:** | 15-028 | **BOREHOLE NO.:** | BHWTP1 |
| **PROJECT:** | MSEILHA WATER TREATMENT PLANT | | | | |
| **LOCATION:** | Mseilha - North Lebanon | **Elevation (m):** | 42.02 | **SHEET:** 2 | **OF:** 2 |
| **EQUIPMENT:** | CMV 800 | **METHOD:** | Continuous coring, T2 86 | **BOREHOLE DEPTH (m):** | 15.0 |
| **HOLE DAM. (mm):** | 114mm | **CORE DIAM. (mm):** | 72 | **DATE STARTED:** | 10/12/2015 |
| **ENGINEER:** | K.S. | **DRILLER:** | A.A. | **DATE FINISHED:** | 10/12/2015 |

| DEPTH (m) | SYMBOL | ST | SPT N blows | LT | DESCRIPTION OF MATERIAL | % FINES | TCR (%) | SCR (%) | R.Q.D (%) | UCS N/mm2 | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | 4,9,22 N=31 | | ditto | | 74 | 0 | 0 | | Lab. sample |
| | | | | | | | 106 | 0 | 0 | | |
| 12 | | | 4,4,8 N=12 | | | | | | | | |
| 13 | | | | | Light cream to beige and olive brown slightly weathered crushed medium strong to strong (intact rock strength) interbeddings of Cretaceous Limestone and Marly Limestone with Marl (bedrock/lower saprolite). | | 29 | 19 | 0 | | Casing:13.5m |
| 14 | | | | | | | 52 | 6.7 | 0 | | CPT 3,26,9 N=35 |
| 15 | | | | | | | | | | | |
| 16 | | | | | **End of borehole at 15.0m**<br><br>**No water table was detected in borehole during the piezometric surveys.** | | | | | | |
| 17 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |

SPT Standard Penetration Test
UCS Unconfined Compressive Strength
LT Layer Thickness
N Number of blows from SPT. Where full 0.3m has not been achieved, the number of blows for the quoted penetration is given

TCR Total Core Recovery
RQD Rock Quality Designation
SCR Solid Core Recovery

ST Sample Type
SYM Symbol
WT Water Table

**SATCON**
SOIL STUDIES

# BORING LOG

| | | | | | |
|---|---|---|---|---|---|
| **CLIENT:** | MINISTRY OF ENERGY AND WATER | **FILE NO.:** | 15-028 | **BOREHOLE NO.:** | BHWTP2 |
| **PROJECT:** | MSEILHA WATER TREATMENT PLANT | | | | |
| **LOCATION:** | Mseilha - North Lebanon | **Elevation (m):** | 39.9 | **SHEET:** | 2 **OF:** 2 |
| **EQUIPMENT:** | CMV 800 | **METHOD:** | Continuous coring, T2 86 | **BOREHOLE DEPTH (m):** | 15.0 |
| **HOLE DAM. (mm):** | 114mm | **CORE DIAM. (mm):** | 72 | **DATE STARTED:** | 10/12/2015 |
| **ENGINEER:** | K.S. | **DRILLER:** | A.A. | **DATE FINISHED:** | 10/12/2015 |

| DEPTH (m) | SYMBOL | ST | SPT N blows | LT | DESCRIPTION OF MATERIAL | % FINES | TCR (%) | SCR (%) | R.Q.D (%) | UCS N/mm2 | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | 12,13,22 N=35 | | ditto | | 29 | 0 | 0 | | |
| 12 | | | 50/11cm Refusal | | | | 48 | 4.8 | 0 | | Lab. sample |
| 13 | | | | | Light cream to beige and olive brown slightly weathered crushed medium strong to strong (intact rock strength) interbeddings of Cretaceous Limestone and Marly Limestone with Marl (bedrock/lower saprolite). | | 43 | 0 | 0 | | |
| 14 | | | | | | | | | | | CPT 50/11cm Refusal |
| 15 | | | | | | | 41 | 5.8 | 0 | | Casing:15.0m |
| 16 | | | | | **End of borehole at 15.0m**<br><br>**No water table was detected in borehole during the piezometric surveys.** | | | | | | |
| 17 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |

SPT Standard Penetration Test
UCS Unconfined Compressive Strength
LT Layer Thickness
N Number of blows from SPT. Where full 0.3m has not been achieved, the number of blows for the quoted penetration is given

TCR Total Core Recovery
RQD Rock Quality Designation
SCR Solid Core Recovery

ST Sample Type
SYM Symbol
WT Water Table

**SATCON**
SOIL STUDIES

# BORING LOG

| | | | | | |
|---|---|---|---|---|---|
| **CLIENT:** | MINISTRY OF ENERGY AND WATER | **FILE NO.:** | 15-028 | **BOREHOLE NO.:** | BHWTP3 |
| **PROJECT:** | MSEILHA WATER TREATMENT PLANT | | | | |
| **LOCATION:** | Mseilha - North Lebanon | **Elevation (m):** | 43.5 | **SHEET:** | 2 **OF:** 2 |
| **EQUIPMENT:** | CMV 800 | **METHOD:** | Continuous coring, T2 86 | **BOREHOLE DEPTH (m):** | 15.0 |
| **HOLE DAM. (mm):** | 114mm | **CORE DIAM. (mm):** | 72 | **DATE STARTED:** | 10/9/2015 |
| **ENGINEER:** | K.S. | **DRILLER:** | A.A. | **DATE FINISHED:** | 10/10/2015 |

| DEPTH (m) | SYMBOL | ST | SPT N blows | LT | DESCRIPTION OF MATERIAL | % FINES | TCR (%) | SCR (%) | R.Q.D (%) | UCS N/mm2 | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | 20,27,40 N=47 | | ditto | | 78 | 0 | 0 | | |
| 12 | | | | | Loose to medium dense rounded GRAVEL with subrounded Cobbles and Boulders of Limestone, in a sandy clay matrix (mix of alluvial and colluvial soil deposits). | | 50 | 0 | 0 | | Water loss at 12m |
| 13 | | | | | | | 43 | 0 | 0 | | CPT 12,13,6 N=19 |
| 14 | | | | | | | 25 | 0 | 0 | | CPT 10,4,7 N=11 |
| 15 | | | | | | | | | | | Casing: 15.0m |
| 16 | | | | | **End of borehole at 15.0m**<br><br>**No water table was detected in borehole during the piezometric surveys.** | | | | | | |
| 17 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |

SPT Standard Penetration Test
UCS Unconfined Compressive Strength
LT Layer Thickness
N Number of blows from SPT. Where full 0.3m has not been achieved, the number of blows for the quoted penetration is given

TCR Total Core Recovery
RQD Rock Quality Designation
SCR Solid Core Recovery

ST Sample Type
SYM Symbol
WT Water Table

**SATCON**
SOIL STUDIES

# BORING LOG

| | | | | | |
|---|---|---|---|---|---|
| **CLIENT:** | MINISTRY OF ENERGY AND WATER | **FILE NO.:** | 15-028 | **BOREHOLE NO.:** | BHWTP4 |
| **PROJECT:** | MSEILHA WATER TREATMENT PLANT | | | | |
| **LOCATION:** | Mseilha - North Lebanon | **Elevation (m):** | 47.4 | **SHEET:** | 2 **OF:** 2 |
| **EQUIPMENT:** | CMV 800 | **METHOD:** | Continuous coring, T2 86 | **BOREHOLE DEPTH (m):** | 15.0 |
| **HOLE DAM. (mm):** | 114mm | **CORE DIAM. (mm):** | 72 | **DATE STARTED:** | 10/13/2015 |
| **ENGINEER:** | K.S. | **DRILLER:** | A.A. | **DATE FINISHED:** | 10/13/2013 |

| DEPTH (m) | SYMBOL | ST | SPT N blows | LT | DESCRIPTION OF MATERIAL | % FINES | TCR (%) | SCR (%) | R.Q.D (%) | UCS N/mm2 | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | 15,16,26 N=42 | | | | 60 | 0 | 0 | | |
| 12 | | | | | ditto | | 76 | 0 | 0 | | Water loss at 12m |
| 13 | | | | | | | 62 | 20 | 0 | | CPT 19,50/11cm<br>Refusal<br>Lab. sample |
| 14 | | | | | Light cream to beige and olive brown slightly weathered crushed medium strong to strong (intact rock strength) interbeddings of Cretaceous Limestone and Marly Limestone with Marl (bedrock/lower saprolite). | | 73 | 7.3 | 0 | | Casing: 13.5m<br>CPT 50/13cm<br>Refusal |
| 15 | | | | | | | | | | | |
| 16 | | | | | **End of borehole at 15.0m**<br><br>**No water table was detected in borehole during the piezometric surveys.** | | | | | | |
| 17 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 19 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |

SPT Standard Penetration Test
UCS Unconfined Compressive Strength
LT Layer Thickness
N Number of blows from SPT. Where full 0.3m has not been achieved, the number of blows for the quoted penetration is given

TCR Total Core Recovery
RQD Rock Quality Designation
SCR Solid Core Recovery

ST Sample Type
SYM Symbol
WT Water Table

**SATCON**
SOIL STUDIES

# BORING LOG

| | | | | | |
|---|---|---|---|---|---|
| **CLIENT:** | MINISTRY OF ENERGY AND WATER | **FILE NO.:** | 15-028 | **BOREHOLE NO.:** | BHWTP5 |
| **PROJECT:** | MSEILHA WATER TREATMENT PLANT | | | | |
| **LOCATION:** | Mseilha - North Lebanon | **Elevation (m):** | 54.7 | **SHEET:** | 1 **OF:** 2 |
| **EQUIPMENT:** | CMV 800 | **METHOD:** | Continuous coring, T2 86 | **BOREHOLE DEPTH (m):** | 15.0 |
| **HOLE DAM. (mm):** | 114mm | **CORE DIAM. (mm):** | 72 | **DATE STARTED:** | 10/13/2015 |
| **ENGINEER:** | K.S. | **DRILLER:** | A.A. | **DATE FINISHED:** | 10/14/2015 |

| DEPTH (m) | SYMBOL | ST | SPT N blows | LT | DESCRIPTION OF MATERIAL | % FINES | TCR (%) | SCR (%) | R.Q.D (%) | UCS N/mm2 | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | 3,5,4 N=9 | | Loose to medium dense, coarsely fragmented (angular) limestone with fines (made ground) | | 50 | 0 | 0 | | |
| 2 | | | | | | | 57 | 0 | 0 | | |
| 3 | | | 30,42,50/11cm Refusal | | | | | | | | |
| 4 | | | | | Medium dense rounded GRAVEL with subrounded Cobbles and Boulders of Limestone, in a sandy clay matrix (mix of alluvial and colluvial soil deposits). | | 73 | 0 | 0 | | Water loss at 4m |
| 5 | | | | | | | 54 | 0 | 0 | | CPT 13,9,27 N=36 |
| 6 | | | | | | | | | | | CPT 4,9,6 |
| 7 | | | | | Firm to stiff and stiff CLAY with occasional rounded and subrounded Gravels, Cobbles and Boulders of Limestone (lacustrine soil deposits occasionally mixed with alluviums and colluviums) | | 57 | 0 | 0 | | CPT 3,5,13 N=15 |
| 8 | | | | | | | 69 | 0 | 0 | | CPT 2,3,10 N=18 |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | 74 | 0 | 0 | | Casing: 9.0m N=13 |

| | | | | | |
|---|---|---|---|---|---|
| SPT | Standard Penetration Test | TCR | Total Core Recovery | ST | Sample Type |
| UCS | Unconfined Compressive Strength | RQD | Rock Quality Designation | SYM | Symbol |
| LT | Layer Thickness | SCR | Solid Core Recovery | WT | Water Table |

N Number of blows from SPT. Where full 0.3m has not been achieved, the number of blows for the quoted penetration is given

# Appendix 3 Photos of Core Boxes


Msaytha
BH.WTP01 Box01
0 → 8.00 (m)


Msaytha
BH.WTP01 Box02
8.00 → 15.00 (m)


Msaytha
BH.WTP02 Box01
0 → 10.5 (m)


Msaylha
BH.WTP02 Box02
10.5 → 15.00 (m)


Msaylha
BH.WTP03 Box01
0 → 6.5 (m)


Msaylha
BH.WTP03 Box02
6.5 → 15.00 (m)


Msaylha
BH.WTP04 Box01
0 → 7.5 (m)


Msaylha
BH.WTP04 Box02
7.5 → 14.00 (m)


Msaylha
BH.WTP04 Box03
14.00 → 15.00 (m)


Msaytha
BH.WTP05 Box01
0 → 10.5 (m)


Msaytha
BH.WTP05 Box02
10.5 → 15.00 (m)

# Appendix 4 Laboratory Test Results

**ASSACO S.A.R.L**

أساكو ش.م.م.

*ENGINEER BILAL ASSAAD MELHEM ASSAAD & Co.*

المهندس بلال اسعد ملحم اسعد وشركاه

DESIGN & SUPERVISION - GEOTECHNICAL CONSULTANCY -MATERIALS TESTING

دُروس وإشراف - إستشارات جيوتقنيّة - فحص مَواد

***CLIENT: MINISTRY OF ENERGY & WATER***

***PROJECT: MSEILHA WATER TREATMENT PLANT***

***DESIGNER: DAR AL HANDASA NAZIH TALEB & PARTNERS***

# *LABORATORY TESTING OF SOIL & ROCK SAMPLES (BHWTP1- BHWTP2 – BHWTP4)*

***OCTOBER 2015***

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خليوي : ٢٧٣٤٤٥ /٠٣ - فاكس : ٦٤٦٩٣١ (٩٦١-١)
ص.ب : ٩٢١٧ / ١١ بيروت - لبنان

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# Table of Contents




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**Client:** Ministry of Energy and Water
**Project:** Mseilha Water Treatment Plant
**Designer:** Dar Al Handasa Nazih Taleb & Partners
**Location:** -
**Date:** 28-10-15

# TEST DATA SUMMARY ROCK - ASTM Designation C97 - 90

| Sample No. | Depth m | Moisture content % | Unit weight g/cm$^3$ | Absorption % | Point load index Mpa | U.C.S. kg/cm$^2$ | CaCO3 cont. % |
|---|---|---|---|---|---|---|---|
| BHWTP2 | 12.00 | - | 2.68 | - | 4.24 | - | - |
| | | | | | | | |
| BHWTP4 | 13.50 | - | 2.72 | - | 4.31 | - | - |
| | | | | | | | |

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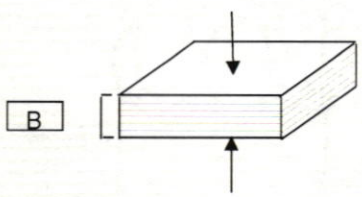
**Client:** Ministry of Energy and Water
**Project:** Mseilha Water Treatment Plant
**Designer:** Dar Al Handasa Nazih Taleb & Partners
**Location:** -
**Date:** 28-10-15

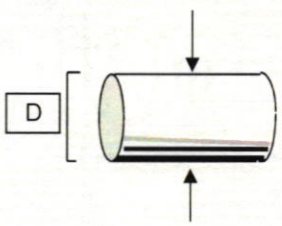
## POINT LOAD STRENGTH INDEX TEST
## Franklin & Brooch

| Test Pit no. | Sample depth m | Type of test | Dia.or Thic of sample ( mm ) | Gauge pressure ( KN ) | Point load index (Is;MPa) | Correction factor ( F ) | Corrected P.L.I Is(50);Mpa |
|---|---|---|---|---|---|---|---|
| BHWTP2 | 12.00 | B | 55.00 | 12.30 | 4.07 | 1.04 | 4.24 |
| BHWTP4 | 13.50 | B | 64.00 | 15.80 | 3.86 | 1.12 | 4.31 |
| | | | | | | | |

**Remark :** The estimated unconfined compressive strength was calculated using a factor K=24.
However the K factor is variable , depending on rock type and other factors.
The formula for the estimated unconfined compressive strength is : $\sigma = K \times Is(50)$

**Type of test :** D: Diametral. A:Axial. B:Block

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**Client:** Ministry of Energy and Water
**Project:** Mseilha Water Treatment Plant
**Designer:** Dar Al Handasa Nazih Taleb & Partners
**Location:** -

**Date:** 28-10-15

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**TEST DATA SUMMARY - ASTM Designations D422 / D2216 / D3080 / D4318 / D1556 / 4944 / D2435 / D4318 - AASHTO T267-86**

| Sample I.D | Depth | Grain Size distribution | | | | | Atterberg | | Moist. | Bulk | dry | Sat. | Shear box | | Triaxial / CU+U | | Unconfined Test | | Perm- | Organic | $SO_4^{--}$ | $CL^-$ | PH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gravel | Sand | Fines | Silt | Clay | LL | PL | cont. | dens. | dens. | dens. | C | ϕ | C | ϕ | Cu | E | eability | Content | cont. | cont. | |
| | m | % | % | % | % | % | % | % | % | $g/cm^3$ | $g/cm^3$ | $g/cm^3$ | $kg/cm^2$ | Degree | $kg/cm^2$ | Degree | $Kg/cm^2$ | $Kg/cm^2$ | cm/s | % | ppm | ppm | |
| BHWTP1 | 10.0 - 10.5 | 1 | 36 | 63 | 25 | 38 | 37 | 26 | 26.6 | 1.89 | - | - | - | - | - | - | 0.30 | 115 | - | 1.26 | - | - | - |
| BHWTP4 | 4.0 - 4.5 | 5 | 9 | 87 | 17 | 70 | 57 | 36 | 42.6 | 2.03 | - | - | - | - | - | - | 0.51 | 168 | - | 1.31 | - | - | - |
| | | | | | | | | | | | | | | | | | | | | | | | |

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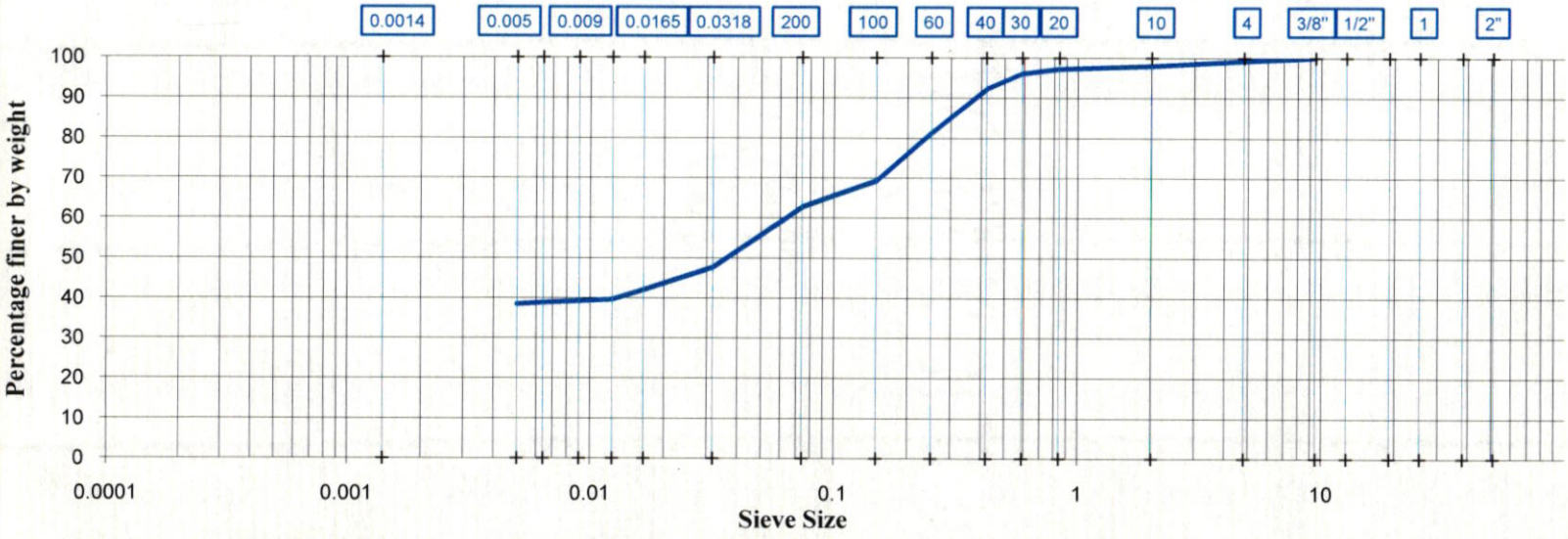
# PARTICLE SIZE DISTRIBUTION
## ASTM D-422




| CLAY | SILT | Fine | Medium | Coarse | Fine | Coarse | Cobbles |
|---|---|---|---|---|---|---|---|
| | | SAND | | | GRAVEL | | |

| Sample I.D | - | | Client: Ministry of Energy and Water | Location: - | ASSACO |
|---|---|---|---|---|---|
| BH / TP | Nr | Depth (m) | Project: Mseilha Water Treatment Plant | | |
| BHWTP1 | - | 10.0 - 10.5 | Designer: Dar Al Handasa Nazih Taleb & Partners | | |

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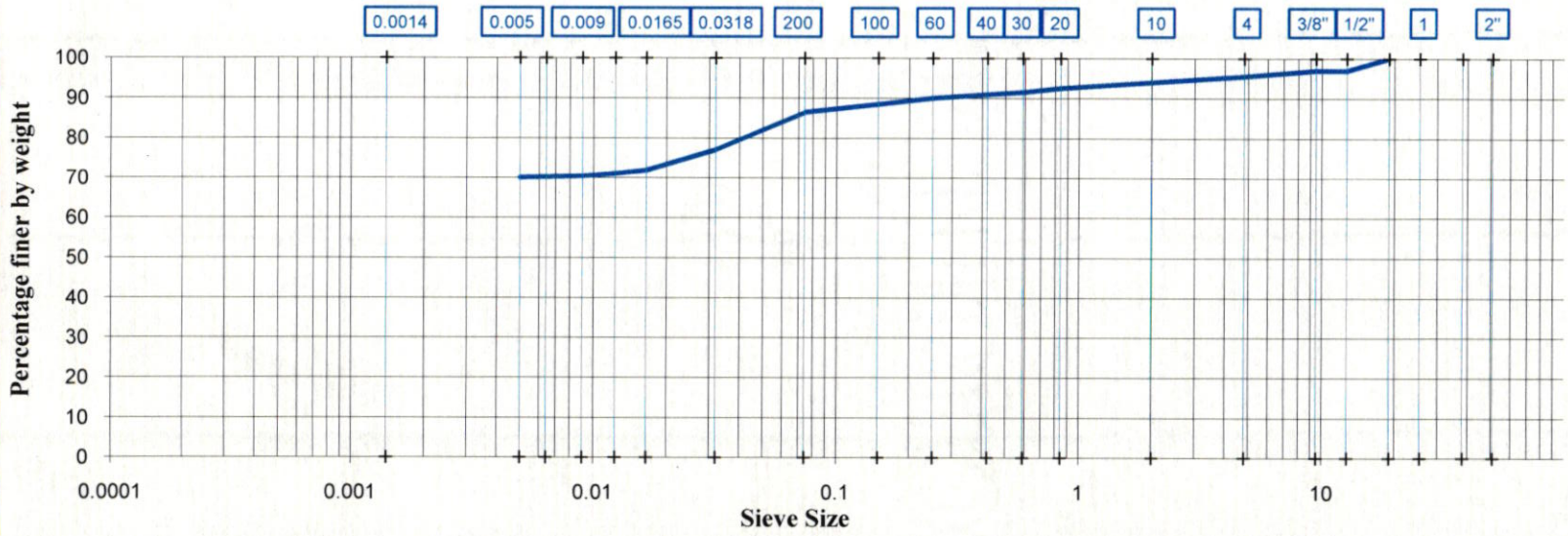
## ASTM D-422




| CLAY | SILT | Fine | Medium | Coarse | Fine | Coarse | Cobbles |
|---|---|---|---|---|---|---|---|
| | | SAND | | | GRAVEL | | |

| Sample I.D | - | | Client: Ministry of Energy and Water | Location: - | ASSACO |
|---|---|---|---|---|---|
| BH / TP | Nr | Depth (m) | Project: Mseilha Water Treatment Plant | | |
| BHWTP4 | - | 4.0 - 4.5 | Designer: Dar Al Handasa Nazih Taleb & Partners | | |

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انساكو

# Unconfined Compressive Strength of Cohesive Soil

ASTM Designation D2166 - 91

**Client** : Ministry of Energy and Water
**Project** : Mseilha Water Treatment Plant
**Location** -
**Date** : 28/10/15

Borehole No. : BHWTP1
Depth : 10.0 - 10.5 m

Initial Diam. Do = 7.2 cm
Initial Area Ao = 40.7 cm²
Initial Height Ho = 9.9 cm

Wet Density : 1.89 g/cm³
Water content : 26.6 %
Dry Density : 1.49 g/cm³

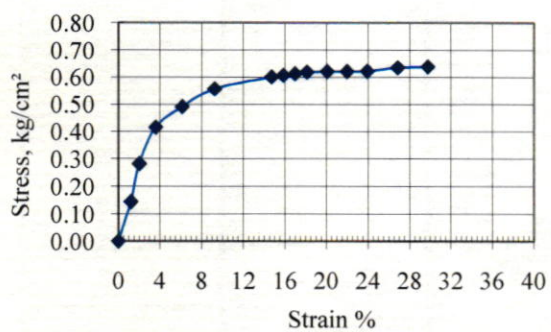
Description of Sample : **Brown, fine to medium, Silty Sandy CLAY.**

Proving Ring No. = 24534

Axial strain rate = 1.35 mm/min (1.5%)

| Elapsed Time | | Load Dial | Strain Dial | Axial Strain | Corr. Area | Load | Axial Stress |
|---|---|---|---|---|---|---|---|
| min. | sec. | 0.0001" | 0.01 mm | % | cm² | kg | kg/cm² |
| 0 | 0 | 0 | 0 | 0.00 | 40.72 | 0 | 0.00 |
| 0 | 5 | 14 | 119 | 1.20 | 41.21 | 5.9 | 0.14 |
| 0 | 10 | 28 | 198 | 2.00 | 41.55 | 11.7 | 0.28 |
| 0 | 15 | 42 | 356 | 3.60 | 42.23 | 17.5 | 0.41 |
| 0 | 20 | 51 | 607 | 6.13 | 43.37 | 21.3 | 0.49 |
| 0 | 25 | 60 | 915 | 9.24 | 44.86 | 25.0 | 0.56 |
| 0 | 30 | 69 | 1457 | 14.72 | 47.74 | 28.7 | 0.60 |
| 0 | 35 | 71 | 1570 | 15.86 | 48.39 | 29.4 | 0.61 |
| 0 | 40 | 72 | 1683 | 17.00 | 49.05 | 30.0 | 0.61 |
| 0 | 45 | 74 | 1795 | 18.13 | 49.73 | 30.8 | 0.62 |
| 0 | 50 | 76 | 1986 | 20.06 | 50.93 | 31.6 | 0.62 |
| 0 | 55 | 78 | 2177 | 21.99 | 52.19 | 32.5 | 0.62 |
| 1 | 0 | 80 | 2368 | 23.92 | 53.52 | 33.3 | 0.62 |
| 1 | 10 | 85 | 2658 | 26.85 | 55.66 | 35.4 | 0.64 |
| 1 | 20 | 89 | 2947 | 29.77 | 57.97 | 37.0 | 0.64 |

Unconfined Compression Test




Failure condition : Typical

Failure Stress = - kg/cm²
Failure Strain = - %

Stress at 15% strain = 0.6 kg/cm²

Undrained Shear strength= 0.3 kg/cm²
Modulus of Elasticity = 115 ~~Kpa~~ kg/cm²

Head of Laboratory Section

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Material Testing - Geotechnical Study


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# Unconfined Compressive Strength of Cohesive Soil

ASTM Designation D2166 - 91

**Client** : Ministry of Energy and Water
**Project** : Mseilha Water Treatment Plant
**Location** -
**Date** : 28/10/15

Borehole No. : BHWTP4
Depth : 4.0 - 4.5 m

Initial Diam. Do = 7.2 cm
Initial Area Ao = 40.7 cm²
Initial Height Ho = 7.4 cm

Wet Density : 2.03 g/cm³
Water content : 42.6 %
Dry Density : 1.42 g/cm³

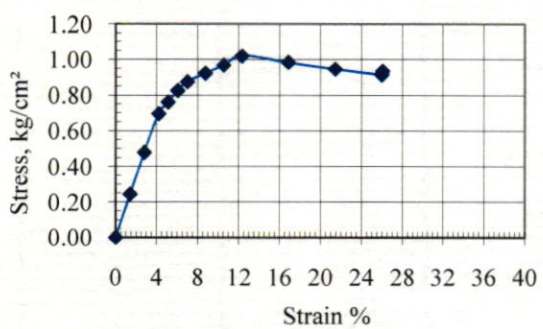
Description of Sample : **Light brown to gray, fine to medium, Silty slightly Sandy CLAY with fine to medium gravel.**

Proving Ring No. = 24534

Axial strain rate = 1.35 mm/min (1.5%)

| Elapsed Time | | Load Dial | Strain Dial | Axial Strain | Corr. Area | Load | Axial Stress |
|---|---|---|---|---|---|---|---|
| min. | sec. | 0.0001" | 0.01 mm | % | cm² | kg | kg/cm² |
| 0 | 0 | 0 | 0 | 0.00 | 40.72 | 0 | 0.00 |
| 0 | 5 | 24.0 | 104 | 1.41 | 41.30 | 10.1 | 0.24 |
| 0 | 10 | 48.0 | 208 | 2.81 | 41.89 | 20.0 | 0.48 |
| 0 | 15 | 71.0 | 311 | 4.20 | 42.50 | 29.5 | 0.70 |
| 0 | 20 | 78.5 | 380 | 5.14 | 42.92 | 32.7 | 0.76 |
| 0 | 25 | 86.0 | 449 | 6.07 | 43.35 | 35.8 | 0.83 |
| 0 | 30 | 92.0 | 518 | 7.00 | 43.78 | 38.3 | 0.87 |
| 0 | 35 | 99.0 | 649 | 8.77 | 44.63 | 41.2 | 0.92 |
| 0 | 40 | 106.0 | 780 | 10.54 | 45.51 | 44.1 | 0.97 |
| 0 | 45 | 114.0 | 912 | 12.32 | 46.44 | 47.4 | 1.02 |
| 0 | 50 | 116.0 | 1249 | 16.88 | 48.98 | 48.2 | 0.98 |
| 0 | 55 | 118.0 | 1586 | 21.43 | 51.82 | 49.0 | 0.95 |
| 1 | 0 | 121.0 | 1922 | 25.97 | 55.00 | 50.3 | 0.91 |
| 1 | 10 | 122.0 | 1926 | 26.03 | 55.04 | 50.7 | 0.92 |
| 1 | 20 | 124.0 | 1929 | 26.07 | 55.07 | 51.5 | 0.94 |

Unconfined Compression Test




Failure condition : Typical

Failure Stress = 1.02 kg/cm²
Failure Strain = 12.32 %

Stress at 15% strain = - kg/cm²

Undrained Shear strength= 0.51 kg/cm²

Modulus of Elasticity = 168 ~~Kpa~~ kg/cm²

Head of Laboratory Section

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Material Testing - Geotechnical Study


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ASSACO
انساكو

**Client:** Ministry of Energy and Water
**Project:** Mseilha Water Treatment Plant
**Designer:** Dar Al Handasa Nazih Taleb & Partners
**Location:** -
**Date:** 28-10-15

## Determination of Organic Content in Soils by Loss On Ignition

AASHTO DESIGNATION T 267-86 (1993)

| Sample No. | Sample Depth (m) | A | B | C | Percent Organic Matter, % |
|---|---|---|---|---|---|
| BHWTP1 | 10.0 - 10.5 | 44.21 | 43.86 | 16.54 | 1.26 |
| | | | | | |
| BHWTP4 | 4.0 - 4.5 | 45.34 | 44.97 | 16.87 | 1.31 |
| | | | | | |

A = Weight of crucible or evaporating dish and oven dried soil, before ignition, in g.
B = Weight of crucible or evaporating dish and oven dried soil, after ignition, in g.
C = Weight of crucible or evaporating dish,to the nearest 0.01 g.
Percent Organic Matter = (A-B)/(A-C)*100

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