REPUBLIC OF LEBANON

MINISTRY OF ENERGY AND WATER

GEOLOGICAL AND HYDROGEOLOGICAL STUDY WITHIN GHOUMA – MRAH EZ ZIATE REGION

Final Report

February 2013

Bureau Technique pour le Développement (BTD)

Phone: 04-712157 / 712158
Fax: 04-712159
Email: btdbtd@dm.net.lb

TABLE OF CONTENTS

1 GEOLOGY OF GHOUMA AREA

The geological investigation of the study area is originally based on the previous work done on north region. The bulk of information has been analyzed from stratigraphical work done by L. Dubertret. In addition, several techniques were utilized to modify the geological map and, hence, better understand the geology. These are particularly the remote sensing methods of MAPS photo satellite, aerial stereographic photographs with a scale 1/25000 (1963). Fieldwork also took an important share of the investigation. The final result is an up to date geological map with a 1/10000 scale (**Figure 1**) covering the study area and the proper understanding of the different geological aspects of this area such as: geomorphology, lithostratigraphy and structural geology.

1.1 GEOMORFOLOGY

The study area is characterized by a relatively moderate topography, and consists of the Senonian marl Formation, Turonian Formation and the Cenomanian Formation with an altitude between 250 and 500m above the sea level.

1.2 LITHO-STRATIGRAPHY

The outcropping rock formations in the study area extend from the Cenomanian Formation (C4) to the Senonian marl formation (C6) through the Turonian rock formation (C5).Furthermore, recent Quaternary alluviums and slope deposits especially in the plains, valleys, and along toes of the slopes.

1.2.1 Cenomanian Formation (C4)

This formation can be subdivided into 3 lithological units from bottom to top these are:

1) The lower Cenomanian rocks (C4a) which includes bioclastic limestones, yellowish marls and cherty limestones, thick bedded limestones, dolomites, and dolomitic limestones.
2) The middle Cenomanian rocks(C4b) that consists of a considerable limestone and dolomitic limestone block forming a cliff..
3) The upper Cenomanian rocks(C4c) which constituted of narrow beds of limestones with siliceous beds, thick beds of limestones and dolomitic limestones, and locally stratified light creamy limestones characterized by thin interbeds of cherty bands and nodules. The Upper Cenomanian formation outcrops on the Western part, and South Eastern part of the study area. The average thickness of this formation is about 550m.

1.2.2 Turonian Formation (C5)

The Turonian rock formation has been divided into two different units since the beginning of the 20th century (1910 Douville and 1955 Dubertret). The stratigraphical investigations by SAINT-MARC, led to the refining of these two subdivisions: Basal Turonian Member and Terminal Turonian Member.
The former consists of dolomitic marls, dolomitic rocks, and dolomitic limestone rocks. It is characterized by the presence of Ammonites mega fossils. The latter, on the other hand, is

characterized by the presence of Hippurites. In terms of lithology, the Terminal Member is made up of dolomites limestones and dolomitic limestone rocks. Limestone outcrops exhibit different facies: oolitic, detrital, crystalline, lensoid, and silicified. The dolostones are coarse grained, light-brown color, they have a sugary texture and are fairly compacted. Upon weathering they become friable and form dolomitic sand in several places. Turonian formation outcrops on very wide surface area in the middle south and northern part of the study area. The average thickness of this formation is about 150m.

1.2.3 Senonian formation (C6)

The Senonian formation outcrops on small patches, at the middle, and north eastern part of the study area. Lithologically speaking this formation consists of white marls, limy-marlstone, and marly limestone rocks. The average thickness of Senonian formation in the study area is about 100 m.

1.2.4 Quaternary Deposits (Q)

These deposits are recent in age and consists of loose sandy clay in the plains, and gravel sin the valleys and along the toes of the slope. These deposits originated from older formations by gravity and running water.

1.3 STRUCTURAL GEOLOGY

The general structure configuration describing the study area is related to the western flexure of Mount-Lebanon and the presence of Mrah ez Ziyate – Basbina syncline.

The axis of Mrah ez Ziyate – Basbina syncline is oriented SW-NE and it is located to the middle of Mrah ez Ziyate village.

The beds of the eastern flank of this syncline which consist of Turonian (C5) and Senonian (C6) formations are dipping by 6° toward the west, while the western flank of this syncline are dipping by 10° toward the east.

The Mrah ez Ziyate - Basbina syncline structure seem to be the dominant structural mechanism in the study area. Moreover the study area is crossed by a series of S-W, S-N trending faults.

1.4 HYDROGEOLOGY

The study area consists of different hydrogeological units. These are Cenomanian-Turonian aquifer, and Senonian aquiclude.

1.4.1 Cenomanian-Turonian Aquifer (C4)

The Cenomanian-Turonian aquifer represents one of the main aquifers in Lebanon and is the most productive aquifer in the Cretaceous sequence. It is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints, and channels which is a typical occurrence in karstic aquifers.

1.4.2 Senonian (C_6) aquiclude

The clay and marl horizons within the Senonian formation act as relatively impermeable zones that minimize the flow between the different underlying and overlying aquifers.

As it has been said previously, the syncline axis of Mrah ez Ziyate - Basbina crosses the middle of Mrah ez Ziyate village with the Turonian (C5) Formation outcropping at its top and on its flanks. The beds on the eastern flank of this syncline are dipping by 6° toward the west, and the western flanks are dipping by 10° toward the east.

We have to remind here, that the project area lies on the Turonian Cenomanian dolomitic limestone formation. These rocks are highly fissured and the density of fissures increases in the vicinity of the major faults.

In addition, the trend of the syncline flanks give an idea of the ground water flow direction since the ground water has a tendency to flow to the areas of least resistance.

As a result, the water precipitation that falls on the limestones of the Turonian formation infiltrates underground follows the fractured and faulted zones and moves eastward and westward toward the syncline axis and forms what we call an aquifer.

Therefore, the best productive site for the water well to be drilled is on the syncline axis or to its western flank.

1.5 DESIGN OF THE WATER WELLS

1.5.1 Ghouma well

1.5.1.1 Borehole location

The well is located on plot No. 151 to the left side of the road leading to Jrane el Hara locality in Mrah ez Ziyate, at the following coordinates (Fig. 2):

X = -317,722 km
Y = +7848 km
Z = 385 m
(Bejje map, 1/20.000)

1.5.1.2 Access to Borehole

Access to the site is easy on a secondary road. Some clearing and excavation for the well site is necessary in order to park the drilling machine.

1.5.1.3 Depth

600 m

1.5.1.4 Expected discharge

432-605 m^3/day (or 5-7 l/s).

1.5.1.5 Static water level

250 m below ground level.

1.5.1.6 Geology

The syncline axis of Mrah ez Ziyate - Basbina, crosses the middle of Mrah ez Ziyate village with a Turonian (C5) formation outcropping at its top and on its flanks. The beds on the eastern flank of this syncline are dipping by 6° toward the east. The well has been located on the western flank of the syncline. It will cross at the beginning the reefy limestones of the Turonian (C5). These limestones are highly karstified and might contain many karstic voids.

The beds that will be penetrated by the drilling rig are:

a) The limestones and marly limestone of the Turonian (C5) Formation (150 m).
b) The limestones and dolomitic limestones of the Upper Cenomanian (C4c) Formation (150 m).
c) The marls and marly limestones of the Middle Cenomanian (C4b) Formation (200 m).
d) The dolomites and limestones of the Lower Cenomanian (C4a) Formation (100 m).

1.5.1.7 Schedule of drilling, casing and grouting

The Contractor shall present the schedule for drilling in order to have a final casing and screen diameter of 12". The well is to be drilled with a rotary rig and provide for all additional equipment such as water and fuel, as well as treating collapsing rocks at his own expense.

Nevertheless, the schedule of the proposed works could be as follows (Fig. 3):

- Drilling by rotary methods with a 22" bit from 0 to 20m, with samples collection as described in the general specifications from this depth and onwards.

- Installing 18" I.D. casing (black steel, thickness 5mm)

- Grouting the annular space as described in the general specifications, from the bottom to the surface, then waiting between 36 to 48 hours for the cement to set, and then continue the drilling works.

- Drilling with a 17.5" bit from 20 to the depth of 200 m.

- Installing 15.5" ID casing (black steel, thickness 5mm).

- Drilling with 14.75" bit from 200 to the total depth of 600 m.

- Installing 12" casing and screens as shown below:
  a) Casing:
     Diameter: 12" ID
     Type: Carbon steel
     Thickness: 6 mm
     Total length: 550 m

b) Screens:
Diameter: 12" OD
Type: Carbon steel, bridge slotted 12.2% void, 1.5-2mm slots.
Thickness: 6 mm
Total length: 550 m.

The installation of the casing and screens will be in accordance with the general specifications, and in particular, the welding and closure of all openings such that the water only enters the well through the screen openings, in order to minimize the pollution from zones above the SWL.

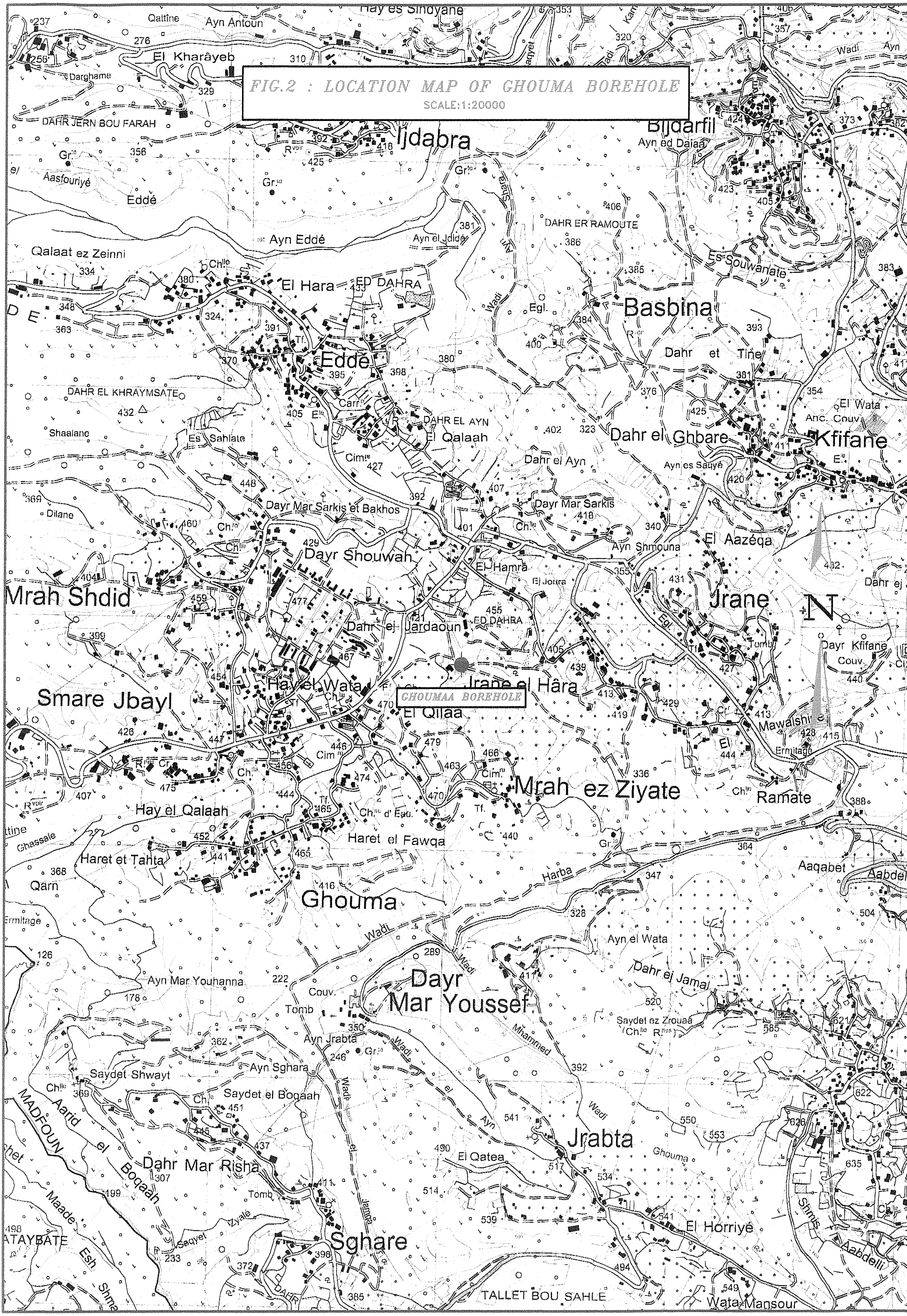
FIG.2 : LOCATION MAP OF GHOUMA BOREHOLE
SCALE:1:20000
GHOUMAA BOREHOLE
N
Ijdabra
Edde
El Hara
ED DAHRA
Basbina
Bijdarfil
Kfifane
Dahr el Ghbare
Dahr el Ayn
El Qalaah
Dayr Shouwah
Mrah Shdid
Smare Jbayl
Hay el Wata
Dahr el Jardaoun
Jrane el Hâra
El Qilaa
Jrane
El Aazéqa
Mrah ez Ziyate
Ramate
Hay el Qalaah
Haret el Fawqa
Haret et Tahta
Ghouma
Dayr Mar Youssef
Jrabta
Sghare
Dahr Mar Risha
Saydet Shwayt
Saydet el Boqaah
Ayn Sghara
Ayn Jrabta
Ayn Mar Youhanna
Ayn el Wata
Dahr ej Jamal
Saydet ez Zrouaa
El Qatea
El Horriye
Wata Mansour
TALLET BOU SAHLE
MADFOUN
Aarid el Boqaah
DAHR JERN BOU FARAH
DAHR EL KHRAYMSATE
DAHR ER RAMOUTE
DAHR EL AYN
Qalaat ez Zeinni
Ayn Eddé
Ayn el Jdide
Ayn Antoun
El Kharâyeb
Dayr Mar Sarkis et Bakhos
Dayr Mar Sarkis
Ayn Shmouna
Dayr Kfifane
Mawalshi
Aaqabet
Es-Souwanate

FIG. 3 : VERTICAL CROSS SECTION OF GHOUMA BOREHOLE