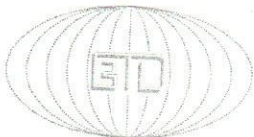


**REPUBLIC OF LEBANON**  
**MINISTRY OF ENERGY AND WATER**

**GEOLOGICAL AND HYDROGEOLOGICAL STUDY  
OF EN NAKHLE REGION  
(KOURA – NORTH LEBANON)**

**Final Report**

**May 2016**

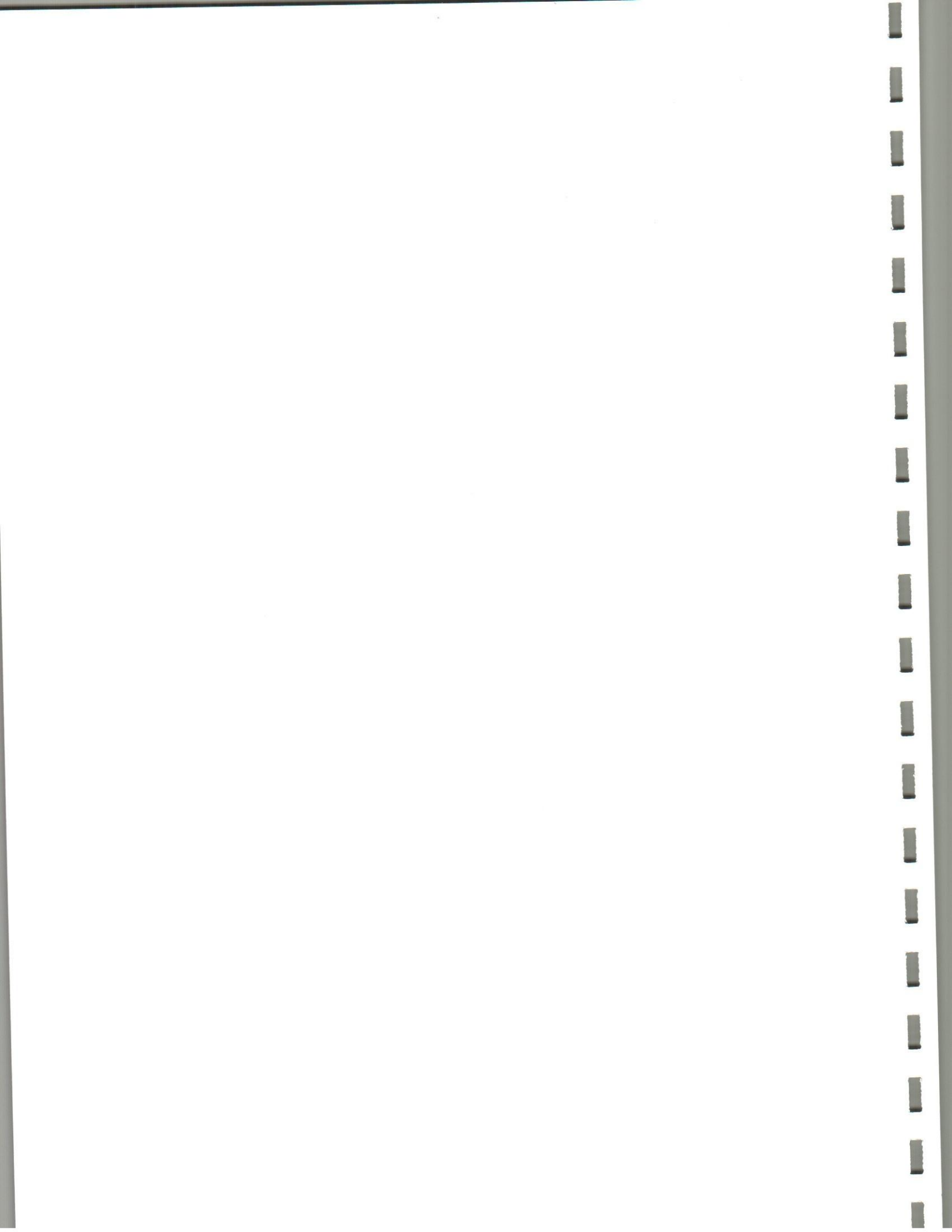


**Bureau Technique pour le Développement (BTD)**

Phone: 04-712157 / 712158

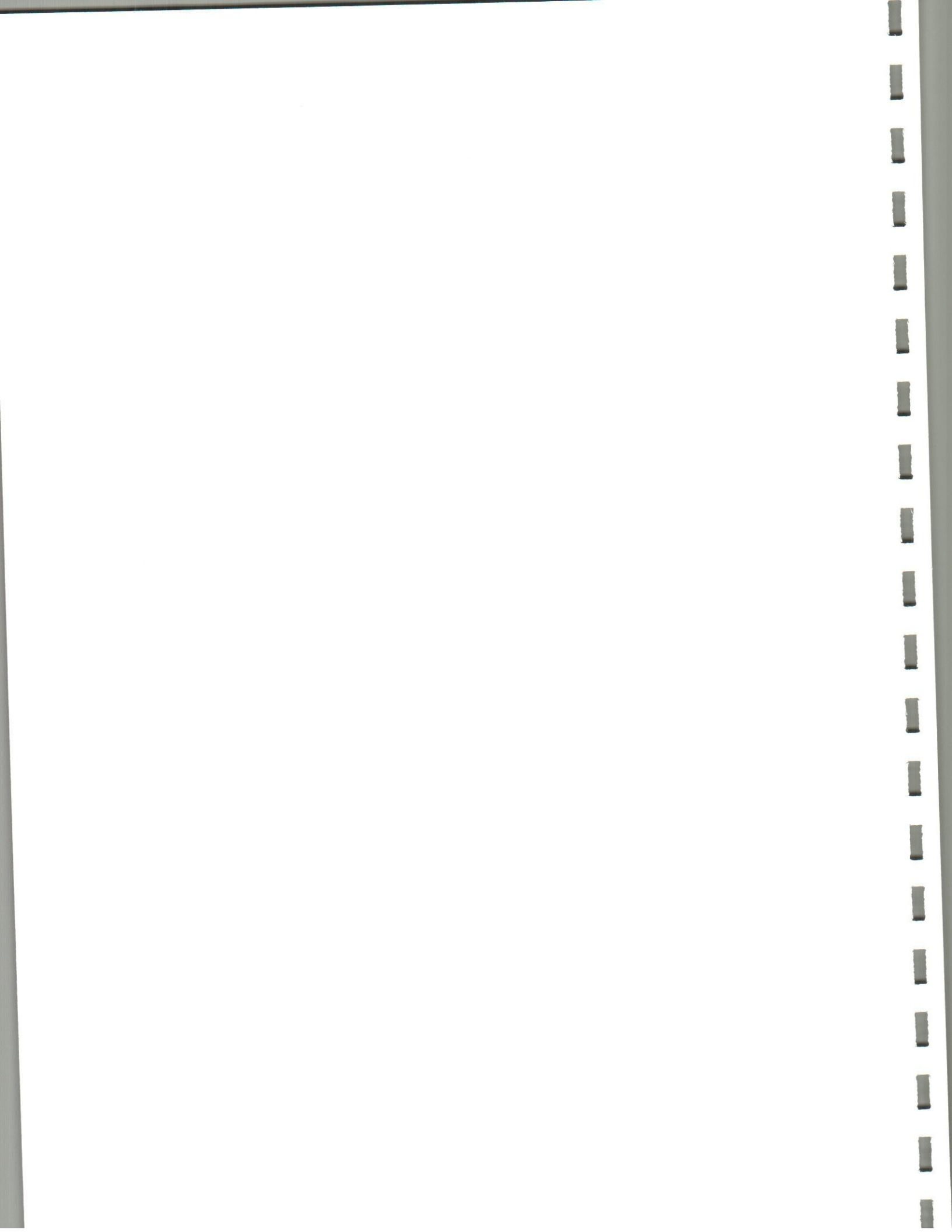
Fax: 04-712159

Email: [btdbtd@dm.net.lb](mailto:btdbtd@dm.net.lb)



## TABLE OF CONTENTS

1	INTRODUCTION.....	1
2	GEOLOGY OF EN NAKHLE AREA .....	1
2.1	LITHO-STRATIGRAPHY .....	1
2.1.1	VINDOBONIAN (M2A).....	1
2.1.2	QUATERNARY DEPOSITS .....	1
2.2	STRUCTURAL GEOLOGY.....	2
3	HYDROGEOLOGY.....	2
3.1	THE MIOCENE AQUIFER.....	2
3.1.1	LOWER EOCENE AND QUATERNARY DEPOSITS AQUICLUDES .....	2
4	DESIGN OF THE WATER WELL .....	3
4.1	BOREHOLE LOCATION .....	3
4.2	ACCESS TO BOREHOLE .....	3
4.3	DEPTH .....	3
4.4	EXPECTED DISCHARGE.....	3
4.5	STATIC WATER LEVEL .....	3
4.6	LAYERS THAT WILL BE PENETRATED .....	3
4.7	SCHEDULE OF DRILLING, CASING AND GROUTING .....	3



# GEOLOGICAL AND HYDROGEOLOGICAL STUDY OF EN NAKHLE REGION (KOURA – NORTH LEBANON)

## 1 INTRODUCTION

En Nakhle town is located on the Koura Plain between the elevations of 200m and 250 m.a.s.l. It is surrounded by the following villages: Bdebba to the south, Batroumine to the west, Haret el Khasse to the north and Btouratij to the east.

The yearly average rain precipitation on En Nakhle area is 800 mm/year and it is characterized by hot weather in the summer and warm winter.

## 2 GEOLOGY OF EN NAKHLE AREA

The outcropping rocks in En Nakhle area belong to the third geological era (Cenozoic) but with the presence of recent Quaternary deposits.

The attached geological map (Map A) and its geological section give a clear picture about the stratigraphic succession prevailing in the area, as well as the geological structure.

The geological investigations in the study area are based on data obtained from Amioun geological map (scale 1/20000) done by Alain Guerre in 1969. To these maps have been added the new information obtained from the aerial photographs, satellite images and the detailed field investigations.

### 2.1 LITHO-STRATIGRAPHY

The Cenozoic rocks cover almost all the study area (Map A), while the Quaternary deposits cover the eastern part of the area.

The oldest rock formation in the study area are of the Middle Eocene (Vindobonian, m2a), with a complete absence of the Upper Eocene and Lower Miocene rocks, which means that the middle Miocene Layers are laid unconformably on the top of the Lower Eocene rocks.

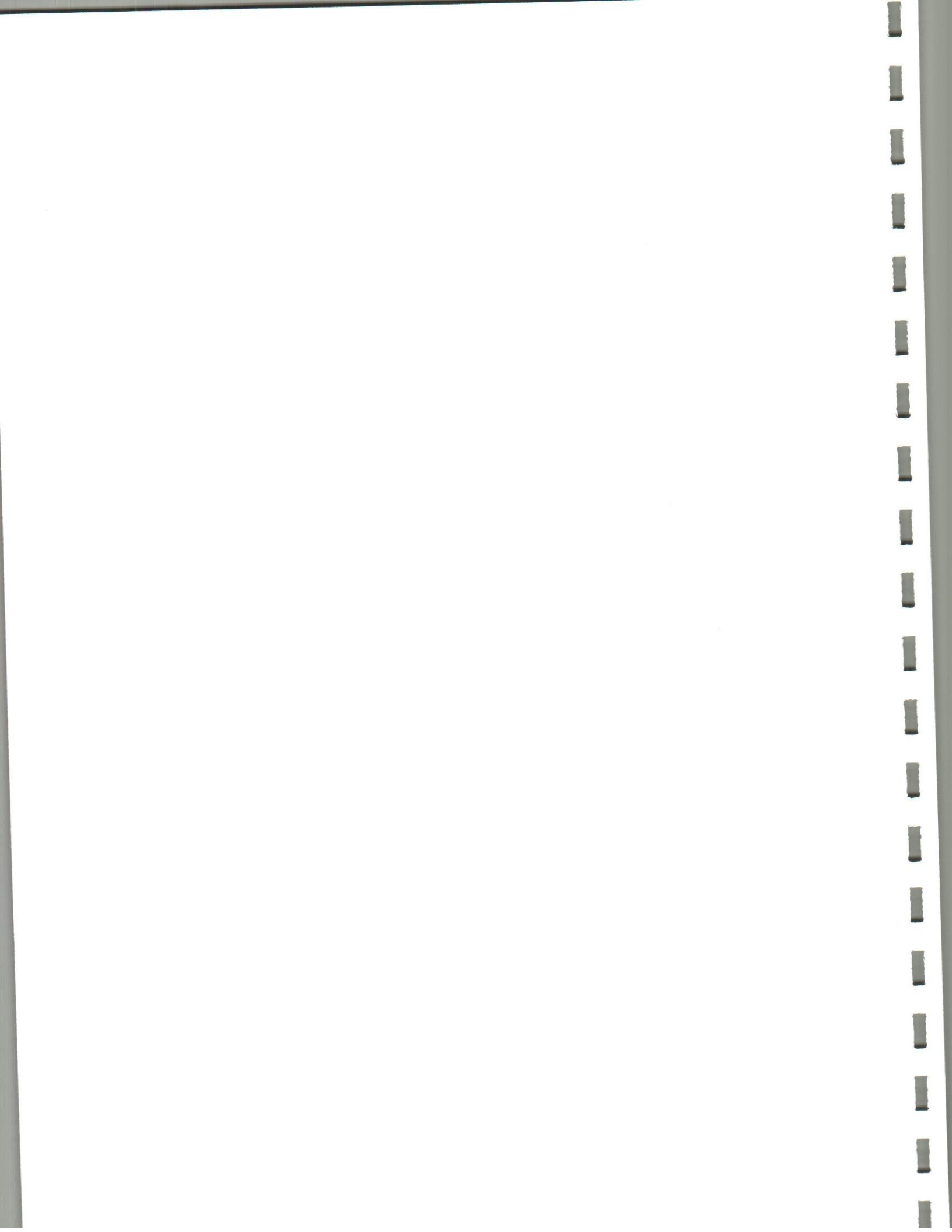
#### 2.1.1 Vindobonian (m2a)

The Middle Miocene Layers, specially the Vindobonian (m2a), cover almost all the study area, and are composed of limestones, marly limestones and sandy limestones interbedded with marly layers.

The average thickness of these layers is around 300 m. They form the most important aquifer in the Koura plain and extend to Tripoli and Mount Terbol to the north.

#### 2.1.2 Quaternary Deposits

Above the Miocene layers stratigraphically, and in the structural depression that has been formed to the east of Btouratij village, different Quaternary deposits have been deposited as follows (Map A):



- a- Conglomerates of the old Quaternary ( $q_{cg}$ )
- b- Confluvial red clays of the Middle Quaternary ( $q_{ar}$ )
- c- Diverse fluvial alluviums of the recent Quaternary ( $q$ ): sands, gobbles and clays.

These deposits have covered in variable ways and thicknesses the underneath limestone layers, so that the thickness of these deposits exceed sometimes 50 m, which make them suitable places for olive cultivation in Koura region.

## 2.2 STRUCTURAL GEOLOGY

The study area is related to the western flank of En Nakhle syncline. The Miocene beds in En Nakhle dip toward the east or north-east. The dip of the layers ranges between  $7^\circ$  and  $10^\circ$  (Map A). To the South, in Amioun, the beds dip toward the North of about  $60^\circ$ . Consequently a syncline is present in the area because, eastward, outside the study area, the Eocene and Miocene layers dip westward. The axis of this syncline would have a NE-SW trend. This geological structure reflects the importance of the tectonic factors that took place in the third geological age.

In addition, the study area is crossed by a series of east-west trending faults, that appear especially in the north-western part of the study area in the Miocene layers.

## 3 HYDROGEOLOGY

The study area consists of different hydrogeological units. These are the Miocene aquifer and the Lower Eocene and Quaternary aquicludes.

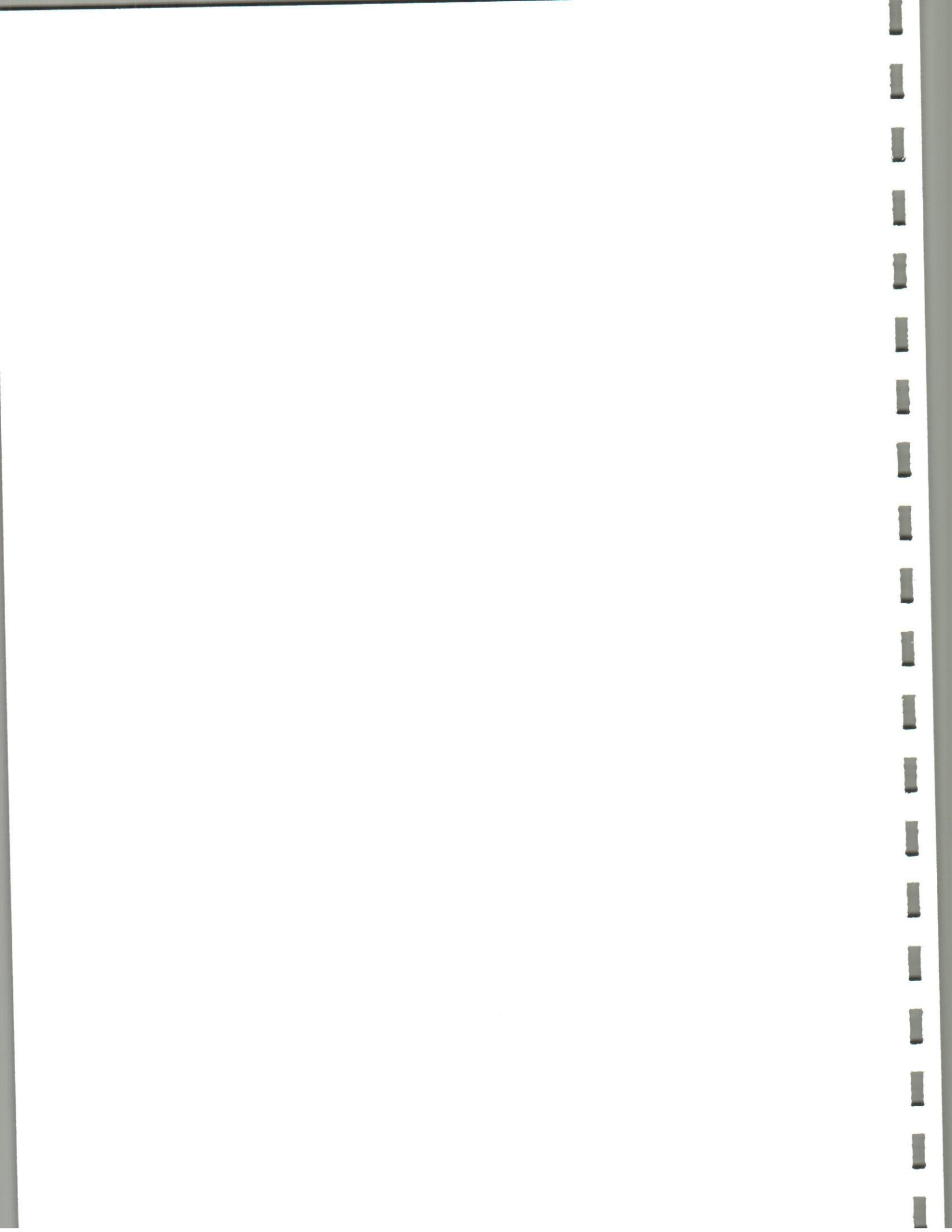
### 3.1 THE MIOCENE AQUIFER

The limestones of the Miocene formation form the major aquifer in En Nakhle and its surroundings. These limestones are in good tectonic position (syncline), which allows the water to store inside the karstic limestone layers so that the syncline that present in the area forms since the seventies – a rich ground water area that has been tapped by more than 100 private wells.

The ground water stored in this aquifer, which is recharged annually in the rainy seasons, allows drilling a new well to a depth of 350 m. It should be noted that the sead new aquifer which is the limestone layers related to the Upper Turonian (C5b), is at a depth exceeding 900m. These karstic limestone layers are very deep and there are many difficulties to reach them due to the presence of these marly layers of the whole Eocene and Senonian formations (C6); which will create caving in problems while drilling.

#### 3.1.1 Lower Eocene and Quaternary Deposits Aquicludes

The clay and marl horizons within the Lower Eocene and Quaternary deposits act as relatively impermeable zones that minimize the flow between the different underlying and overlying aquifers, and consequently characterized by no exploitable yield.





## 4 DESIGN OF THE WATER WELL

### 4.1 BOREHOLE LOCATION

The proposed well is located in a plot No. 1853 belonging to En Nakhle municipality in Boustane el Kbir locality to the north of En Nakhle village at the following coordinates:

X = -305282 m  
Y = +24186 m  
Z = 245 m  
(Dedde map, Q-6, 1/20.000)

### 4.2 ACCESS TO BOREHOLE

The access of the site is easy because of the presence of a secondary road. Excavating a pool in order to receive the drilling cuttings is necessary not to harm the nearby plots.

### 4.3 DEPTH

350 m

### 4.4 EXPECTED DISCHARGE

432-605 m<sup>3</sup>/day (or 5-7 l/s).

### 4.5 STATIC WATER LEVEL

100 m below ground level.

### 4.6 LAYERS THAT WILL BE PENETRATED

The layers that will be penetrated by the drilling are:

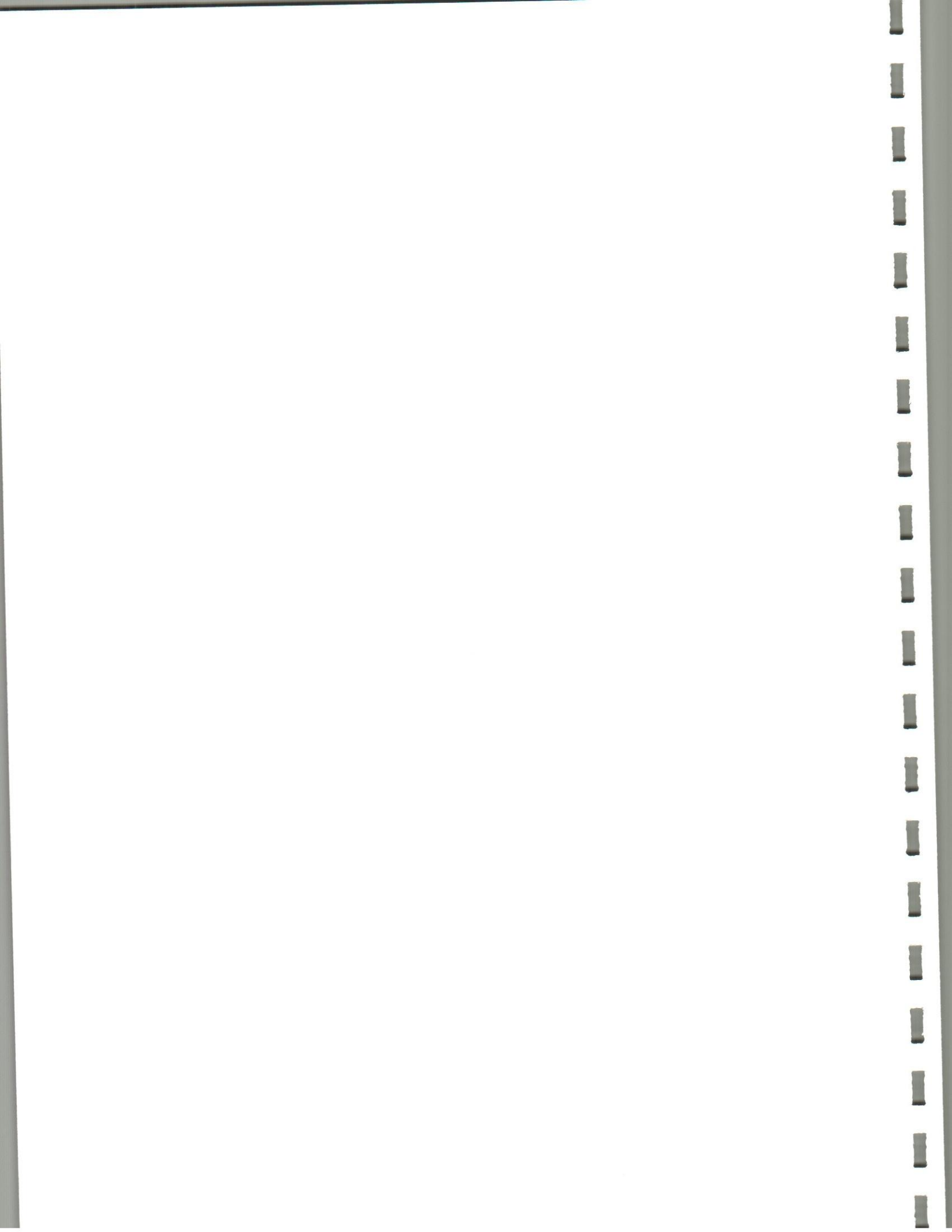
- a) The clays of the Quaternary deposits (qar) to the depth not more than 20 m.
- b) The limestones and marly limestones of the Middle Micoene (Vindobonian m2a) to the depth of around 300 m.

The drilling operation shall be stopped when reaching the marly grey layers of the Lower Eocene (e<sub>1-2a</sub>).

### 4.7 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 10". 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. 2):



- Drilling by rotary methods with a 22" bit from 0 to 20m, with samples collection from this depth and onwards.
- Installing 18" I.D. casing (black steel, thickness 5mm)
- Grouting the annular space 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 12.25" bit from 20m to the depth of 350 m.
- Installing 12" casing and screens as shown below:
  - a) Casing:
    - Diameter: 10" OD
    - Type: Carbon steel
    - Thickness: 6 mm
    - Total length: 250 m
  - b) Screens:
    - Diameter: 12" OD
    - Type: Carbon steel, touch-cut slotted 12.2% void, 1.5-2mm slots.
    - Thickness: 6 mm
    - Total length: 100 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.

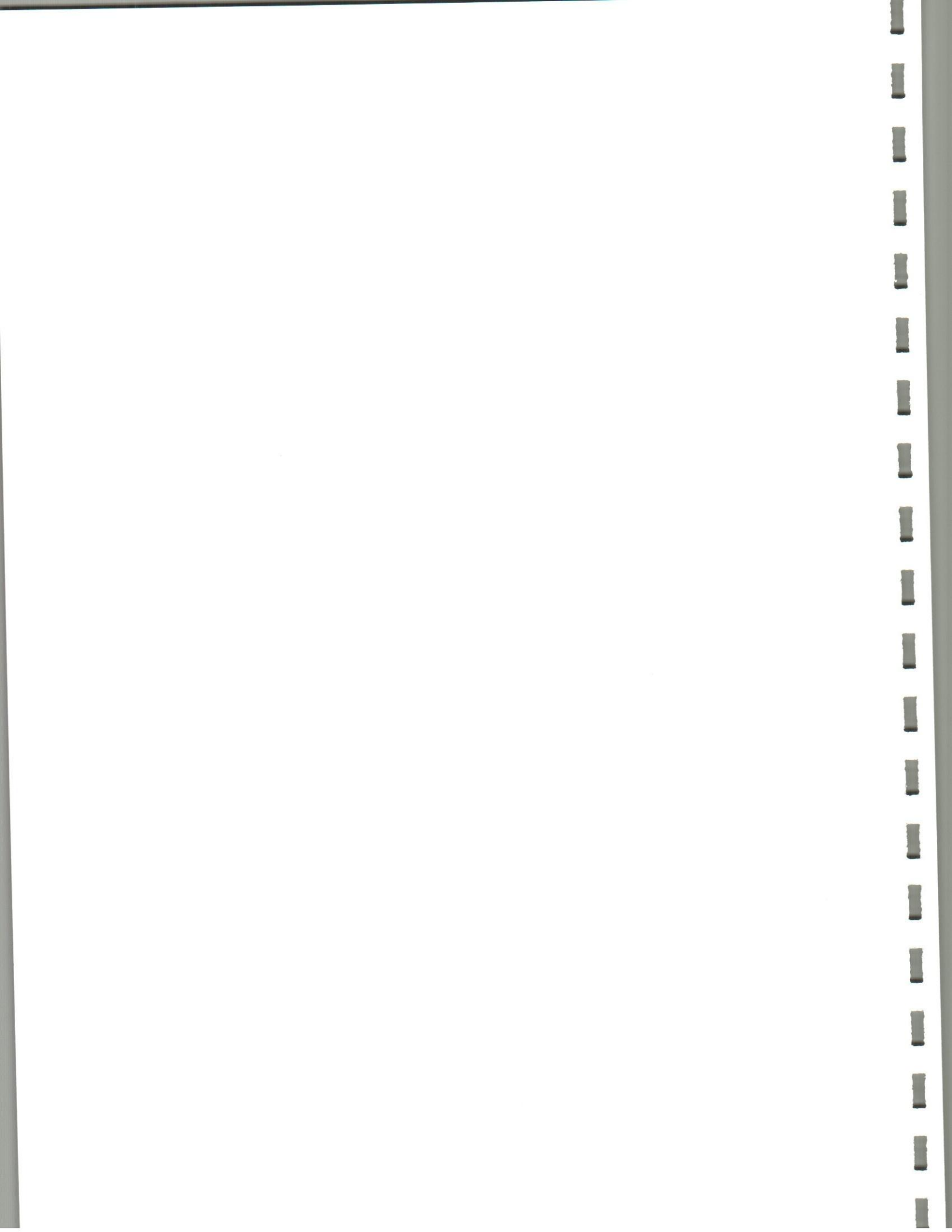


FIG.1 : LOCATION MAP OF EN NAKHLE BOREHOLE

SCALE: 1:20000



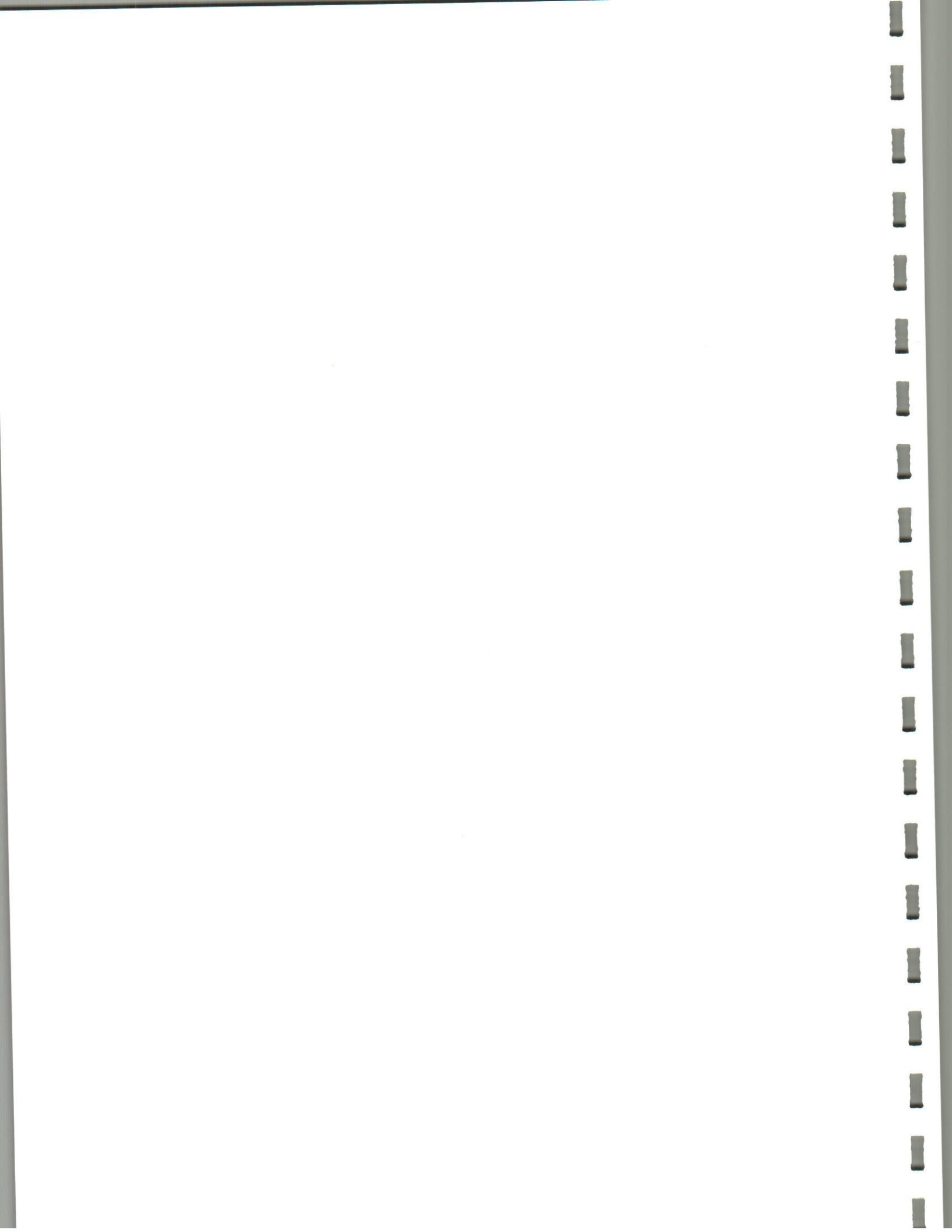


FIG. 2 : VERTICAL CROSS SECTION OF EN NAKHLE BOREHOLE

