



**APPLICATION OF GEOGRAPHICAL INFORMATION
SYSTEMS (GIS) TECHNIQUE ON GEOPHYSICAL
EXPLORATION FOR GROUNDWATER
IN EL- ARISH-RAFAH AREA,
NORTHEAST SINAI,
EGYPT.**

BY

**NADIA ABD EL MONIEM ABD EL FATTAH
M. SC., GEOPHYSICS**

THESIS

**SUBMITTED FOR THE PH. D. DEGREE
OF SCIENCE**

IN

APPLIED GEOPHYSICS

To

**GEOPHYSICS DEPARTMENT
FACULTY OF SCIENCE
AIN SHAMS UNIVERSITY
CAIRO, EGYPT.**

2010

SUPERVISORS

PROF. DR. MAHDY M. A. ABDEL RAHMAN

Professor of Geophysics
Geophysics Department,
Faculty of Science, Ain Shams University

PROF. DR. MOHAMED A. MABROUK

Professor of Geophysics
Geophysics Department,
and vice president of Desert Research Center
for projects, *Cairo, Egypt*

PROF. DR. IBRAHIM MOHAMED NASR

Professor of Geophysics
Geophysics Department,
Desert Research Center,
Cairo, Egypt.

DR. ABDEL KHALEK EL WERR

Associate Professor of Geophysics
Geophysics Department,
Faculty of Science, Ain Shams University

ACKNOWLEDGMENTS

I always praise to Allah, the Lord of the world, by whose grace this work has been completed

I am indebted to express my deepest gratitude and appreciation to Prof. Dr. Mahdi Mohamed Abdul Rahman Professor of Geophysics, Department of Geophysics, Faculty of science, Ain Shams University, Cairo, Egypt, for supervising, critical reading and revising the manuscript.

My deep thanks, gratitude and appreciation are extended to Prof. Dr. Mohamed Abbas Mabrouk, vice president of Desert Research Center for projects and Prof. of Geophysics, for suggesting the point of research, supervising and planning the work, critical reading and revising the manuscript.

My deep thanks, gratitude and appreciation to Prof. Dr. Ibrahim Mohamed Nasr, Geophysics Department, Desert Research Center who suggests, planned and supervised all steps of this research. Field work and its interpretation have been done under his intimate guidance.

Also deeply thanks to Dr. Abdel El-Khalek, M. M. El-Werr, Associate professor of Geophysics, Geophysics Department, Faculty of Science, Ain Shams University, for supporting the work,

Special thanks to Prof. Dr. Ahmed Mohamed Ali Youssef, Prof of Geophysics and head of remote sensing and GIS unit for his help and continuous encouragements.

Also my deep thanks to all staff member of the Geophysics department and remote sensing & Geographic Information System unit, Desert Research Center. Finally, I wish to express my gratitude appreciation to my parents, husband and my kids for their patience and continuous encouragement.

ABSTRACT

The development of the hydrogeologic potentialities of North Sinai requires an understanding of geologic structure, stratigraphic and lithologic properties of aquifers for groundwater production.

The growing activities in this promising area have caused an ever-increasing need for water resources for new reclamation of many acres of land to increase the cultivated land and to attract new population to decrease the population density along the Nile-Valley.

The study area occupies a portion of the northeastern coast of Egypt and covers an area about 2100 Km². It lies between latitudes 30° 47' N & 31° 50' N and longitudes 33° 50' E & 34° 20' E.

The present work aims to deal with the application of the geophysical exploration techniques (deep reflection seismic and geoelectrical resistivity) and the application of geographical information systems (GIS), with the main objects of the impact of geological structural elements on groundwater occurrences in the study area.

To achieve this goal, Landsat ETM and Radarsat imagery were used and subjected to many processes to improve their appearance as principle component analyses, visual interpretation, unsupervised classification and merge of them. The results indicate the presence of three zones of sand dune trend which lead us to make interpretation of reflection seismic passing on these trend to show if these phenomena are related to subsurface structure or not.

The geoelectrical measurements in the study area were planned according to the results obtained from the interpretation of deep

reflection seismic profiles crossing the study area from north to south. The main target of the interpretation of these sections is to identify the highly disturbed zones that represent the favorable areas for groundwater accumulation according to the obtained results we distribute the vertical electrical sounding to detect the buried channel of wadi El Amr.

A total of 111 vertical electrical soundings (VES's) were distributed in the area. The vertical electrical soundings were carried out to define the subsurface geoelectrical layers, their laterally and horizontally extension and to define the structure affecting them. The results of VES's data interpretation reveals the number of geoelectrical layers, the structural elements and the groundwater occurrence. The third geoelectrical layer was detected, that found to be the waterbearing formation to the north while in the southern part of the area this clastics layer changed to limestone as the effect of shear fault which, thrown to the north.

Finally by the use of GIS, decision support maps were established for new drilling groundwater potentialities, these maps helps the decision maker to locate the best places for new drilling water wells taking into consideration the economic aspect.

The integration of remote sensing, deep reflection seismic and the vertical electrical sounding shows that, the results are pointed to best conditions in the study area, which, are located in the northern and central part these locations were suggested as the best hydrogeological conditions because they have the maximum thickness of groundwater, vast plain, good soil suitable for agriculture and they also represent the path of the buried channel of wadi EL Amr was suggested.

CONTENTS

Subject	page
Acknowledgments	i
Abstract	ii
Contents	iv
List of Figures	viii
List of Tables	xi
Chapter I: Introduction	1
1.1 General outline	1
1.2 Location of the study area	1
1.3 Accessibility	2
1.4 Climate	2
1.5 Rainfall	2
1.6 Air temperature	2
1.7 Evaporation	4
1.8 Relative humidity	4
1.9 Previous work	5
1.10 Aim of the present work	6
Chapter II: Geomorphological, geological and hydrogeological settings	8
2.1 Geomorphological Setting	8
2.1.1 El Halal - El Amr tilted blocks	8
2.1.2 El Rawafaa - El Auga foot slopes	8
2.1.3 El Gora - El Massaid old coastal plain	9
2.1.4 El Arish - Rafah coastal belt	9
2.1.5 Drainage basins	11
2.1.6 Salt marshes (Sabkhas)	11
2.2. Geological Settings	11
2.2.1 Stratigraphy	11
1. Triassic rocks	12
2. Jurassic rocks	12
3. Cretaceous rocks	12
4. Paleocene deposits	17
5. Eocene rocks	18
6. Oligocene rocks	18

7. Miocene rocks	18
8. Pliocene deposits	19
9. Quaternary deposits	19
2.2.2 Geological structure	19
1. The stable foreland	20
2. The gently folded zone	20
3. The fractured or shear zone	20
4. The strongly folded province	21
2.3 Hydrogeological setting	24
2.3.1 Sand dune aquifer	24
2.3.2. Alluvium aquifer	25
2.3.3 Pleistocene aquifer	25
2.3.3.1 Calcareous sand stone (Kurkur) aquifer	25
2.3.3.2 Gravel aquifer	25
2.3.4 Eocene Limestone aquifer	26
2.3.5 Upper Cretaceous Limestone aquifer	26
Chapter III: Remote sensing application	27
3.1. Data types	27
3.1.1 Satellite image	27
3.1.2 Maps	29
3.1.3 Descriptive data	29
3.2. Image processing techniques	29
3.2.1 Rectification	30
3.2.2 Enhancement	30
3.2.3 Principal Component Analysis (PCA)	32
3.2.4 Histogram equalization techniques	36
3.2.5 Intensity, hue and saturation	36
3.2.6 Surface cover classification	36
3.2.7 Creation of digital elevation model	36
3.2.8 Enhancement of radar image	37
3.2.9 Merging radar with VIS/IR imager	37
Chapter IV: Seismic data interpretation	50
4.1. Available data	50
4.2 Seismic data interpretation	52
4.2.1 Seismic interpretation technique	52
4.3.2 Interpretive output versions	55
4.3.2.1 Interpreted seismic sections	55
4.3.2.2 Interpretation of the seismic maps	57
4.3.2.2.1 Time structural contour maps on the top of the interested formations	62

4.3.2.2.2 Average velocity maps of the top of the two interested horizon	66
4.3.2.2.3 Depth structural contour maps on the tops of interested horizons	67
Chapter V: Application of geoelectrical exploration	73
5. Electrical resistivity sounding	73
5.1. Data acquisition	73
5.2. Interpretation technique of electrical resistivity data	73
5.2.1 Qualitative interpretation	75
5.2.2. Quantitative interpretation	76
5.3 Result and discussion	81
1. The first geoelectrical layer (A)	82
2. The second geoelectrical layer (B)	82
3. The third geoelectrical layer (C)	90
4. The fourth geoelectrical layer (D)	92
5. The fifth geoelectrical layer (E1& E2)	94
5.4 Illustration of the interpreted data	94
5.4.1 Geoelectrical cross section	94
5.4.2 Water level contour map	109
5.4.3 Structure contour map of the top of Pliocene-Miocene clay	109
Chapter VI: Ground water occurrence	114
6.1 Definition of the aquifers system	114
6.2 Aquifer Potentiometry	119
6.3 Aquifer hydraulic characteristics	119
6.4 Formulation of the problem	123
6.5 Estimation of the aquifer parameters	125
6.6 evaluation of the data	125
Chapter VII: Geographical Information Systems application	136
7.1 Building GIS data base	136
1. data input	136
2. Geo-referencing the spatial data	137
3 Spatial data sources	137
7.2 Spatial data analysis	137
7.3 Application of GIS in the study area	138
7.3.1 Resistivity GIS map for the waterbearing layer	138
7.3.2 Depth to the waterbearing formation GIS map	138
7.3.3 Saturated thickness of the waterbearing formation	141

GIS map	
7.3.4 Transmissivity of waterbearing formation GIS map	144
7.4.5 Hydraulic conductivity of waterbearing formation	144
GIS map	
7.4 Modeling process	147
Scenario 1	147
Scenario 2	150
Scenario 3	150
Summery and conclusions	152
References	162
Arabic Summary	

List of Figures

Figures	Page
Figure (1-1): Location map of the study area	3
Figure (1-2): Average annual rainfall.	4
Figure (1-3): Maximum temperature	5
Figure (2-1): Geomorphologic map of the study area.	10
Figure (2-2): Generalized geologic column of North Sinai.	13
Figure (2-3): Surface geologic map of the study area	15
Figure (2-4): Lithofacies distribution across the hinge belt Fault	16
Figure (2-5): Structural map of North and Central Sinai.	22
Figure (2-6): Major tectonic elements of the study area.	23
Figure (3-1): False color composite band 7 5 1.	31
Figure (3-2): Two band scatterplot.	33
Figure (3-3): First Principle .Component.	34
Figure (3-4): Second Principle .Component.	34
Figure.(3-5):First Principle Component analysis of the study area.	35
Figure.(3-6): ETM image enhancement by histogram Equalization.	38
Figure (3-7): Trace of different trend of sand dune on ETM image.	39
Figure (3-8): Trace of natural vegetation and cultivated areas.	40
Figure (3-9): Hue, intensity saturation of ETM image.	41
Figure (3-10): Unsupervised classification on ETM image	42
Figure (3-11): The Digital Elevation Model (DEM) of the study area.	44
Figure (3-12): Ground elevation of the study area.	45

Figure (3-13): The Drainage pattern of the study area.	46
Figure (3-14): Radarsat image	47
Figure (3-15): The resolution merge of Radarsat and ETM image of the study area.	48
Figure (3-16): Trace of covered and uncovered stream.	49
Figure (4-1): Shot point location map.	51
Figure (4-2): Time-depth curves of the well distributed in the study area.	56
Figure (4-3): Interpreted seismic section NS-84-121 in the dip direction.	58
Figure (4-4): Interpreted seismic section NS-84-129 in the dip direction.	59
Figure (4-5): Interpreted seismic section NS-84-110 in the strike direction.	60
Figure (4-6): Time structural map on the top of Cretaceous.	64
Figure (4-7): Time structural contour map on the top of Jurassic.	65
Figure (4-8): Average velocity contour map on the top of Cretaceous.	69
Figure (4-9): Average velocity contour map on the top Jurassic.	70
Figure (4-10): Depth structure contour map on the top of Cretaceous.	71
Figure (4-11): Depth structure contour map on the top of Jurassic.	72
Figure (5-1): Location map of Vertical Electrical Sounding station	74
Figure (5-2): Example of the field resistivity sounding curves.	77
Figure (5-3): Interpreted VES 9 beside the drilled well Abu Mesafer.	79
Figure (5-4): Well logging and lithological data of Abu Mesafer well.	79
Figure (5-5): Interpreted results at sounding station 38.	80
Figure (5-6): Composite log and lithological data of Gora well No.1.	80
Figure (5-7): Iso- resistivity contour map of the first -	88

Geoelectrical layer.	
Figure (5-8): Iso- resistivity contour map of the second geoelectrical layer.	89
Figure (5-9): Iospach contour map of the second geoelectrical layer .along the study area.	91
Figure (5-10): Iso – resistivity contour map of the third geoelectrical layer.	93
Figure (5-11): Iso - resistivity contour map of the fourth geoelectrical layer along the study area.	95
Figure (5-12): Geoelectrical cross sections along the study area.	96
Figure (5-13): Geoelectrical cross section A-A'.	98
Figure (5-14): Geoelectrical cross section C-C'.	99
Figure (5-15): Geoelectrical cross section D-D'.	100
Figure (5-16): Geoelectrical cross section G-G'.	101
Figure (5-17): Geoelectrical cross section H-H'.	102
Figure (5-18): Geoelectrical cross section I-I'.	103
Figure (5-19): Geoelectrical cross section J-J'.	104
Figure (5-20): Geoelectrical cross section K-K'.	105
Figure (5-21): Geoelectrical cross section L-L'.	106
Figure (5-22): Geoelectrical cross section M-M'.	107
Figure (5-23): Geoelectrical cross section N-N'.	108
Figure (5-24): Water level contour map of Pliocene sand and Eocene limestone.	110
Figure (5-25): Structure contour map of the top of Pliocene -Miocene clay.	111
Figure (5-26): Inferred Structure from seismic and electric study	112
Figure (4-27): Inferred path of the buried channel of wadi El Amr	113
Figure (6-1): Location map of the wells	116
Figure (6-2): Isopach map of the saturated thickness of Kurkur Formation	119
Figure (6-3): Depth to water contour map of Kurkur Formation.	121
Figure (6-4): Aquifer Hydraulic characteristic.	122
Figure (6-5): Location map of pump wells.	124
Figure (6-7): Iso–hydraulic conductivity contour map of the Kurkur Formation (m/day).	134
Figure (6-8): Iso-transmissivity contour map of the Kurkur Formation (In m ² /day).	135

Figure (7-1): Resistivity map of waterbearing formation.	139
Figure (7-2): The Depth to water bearing formation (kurkur).	140
Figure (7-3): The saturated thickness of water bearing formation (Kurkur).	142
Figure (7-4): Iso-Transmissivity map of the water bearing formation.	144
Figure (7-5): Iso-hydraulic conductivity of the water bearing formation.	145
Figure (7-6): Flow chart shows the inputs and the output of the raster calculation.	147
Figure (7-7): Decision support map of groundwater investments (Scenario 1).	148
Figure (7-8): Decision support map of groundwater investments (Scenario 2).	150
Figure (7-9): Decision support map of groundwater investments (Scenario 3).	151

List of Tables

Table	Page
Table (4-1): Depths, two-way times and average velocities derived from VSP logs on the tops of the interested formations.	54
Table (5-1): Resistivity and thickness of the geoelectrical layer.	83
Table (6-1): Well no. and name of the investigated area	117
Table (6-2): pumping test results.	125
Table (6-3): Aquifer electrical and hydraulic parameters.	126
Table (6-4): Hydraulic parameter Calculated from both pumping tests and VES'es.	127
Table (6-5): Electrical transverse resistance (T_p), transverse resistivity (ρ_t), and calculated transmissivity (T), hydraulic conductivity (K).	130
Table (7-1): The different class of each layer	142
Table (7-2): The model and the weight of each layer.	146

INTRODUCTION

1.1 General outline

In the last few decades, great attention had been paid for the establishment of new settlements, land reclamation and preservation of our land. For these purposes, favorable effort had been given in several integrated fields of study. Essentially a great consideration is given for reclamation projects. In the last two decades, studies had been conducted in the fields of geology, hydrogeology and geophysics by several governmental organizations and private sectors. These studies had been done to secure proper evaluation of new settlements. Example of these areas, prevailing locations in the northeastern part of Egypt (Sinai area). This area needs to explore more groundwater potentialities which would have its importance in any forthcoming development of the area.

The selected study area comprises a part of the desert area to the northeastern corner of Sinai Peninsula. The groundwater occurrences in northeastern Sinai have great importance for sustainable development of that remote arid and semiarid area. For this reason, the present work deals with the application of integrated geophysical techniques (deep seismic reflection, geoelectrical resistivity, and Geographic Information Systems (GIS), with the main objectives of exploring the groundwater as well as delineating the structural elements to clarify its impact on the distribution of the different aquifers.

1.2 Location of the study area

The area under investigation (El-Arish - Rafah) located in the northeastern part of Sinai Peninsula between wadi El Arish and the