Ain Shams University
Faculty of Engineering
Mechanical power department

"WATER RESOURCES MANAGEMENT BY APPLYING MATHEMATICAL MODELING TECHNIQUES IN NORTHEASTERN PORTION OF SINAI PENINSULA, EGYPT."

By

Eng. / SAID ABDEL-ALEEM FARAG HAWASH

(Researcher assistant).

A THESIS
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN MECHANICAL POWER ENGINEERING.
To
DEPARTMENT OF MECHANICAL POWER ENGINEERING,
Faculty of Engineering, Ain Shams University.

SUPERVISORS

Prof. Dr. M. A. El-Samanoudi
Prof. of Fluid mechanics,
Mechanical power depart.
Faculty of Engineering,
Ain Shams University,
Cairo, Egypt.

Prof. Dr. Gamal S. Ebied
Prof. of hydraulics,
Irrigation & hydraulic depart.,
Faculty of Engineering,
Ain Shams University,
Cairo, Egypt.

Prof. Dr. N. H. N. Rofail
Prof. of mathematical modeling,
Hydrology department,
Desert Research Center,
Cairo, Egypt.

Prof. Dr. Yehia L. Ismail
Prof. and Head of hydrology department,
Desert Research Center,
Cairo, Egypt.

Cairo, (2012)

لجنة الإشراف

الإسم والتوقيع	التعريف
أ.د / محمد أبوالعينين السمنودى	أستاذ ميكانيكا الموائع – قسم هندسة القوى الميكانيكية – كلية الهندسة – جامعة عين شمس
أ.د / جمـال صـادق عبيـد	أستاذ الهيدروروليكـا – قسم هندسة الرى والهيدروليكا – كلية الهندسة – جامعة عين شمس
أ.د / نبيل حسنى نجيب روفائيل	أستاذ تقنيات النمذجة الرياضية قسم الهيدرولوجيا – مركز بحوث الصحراء ج.م.ع
أ.د / يحيى لطفى إسماعيل	أستاذ و رئيس قسم الهيدرولوجيا مركز بحوث الصحراء ج.م.ع

القاهره- 2012

لجنة الإشراف

أ.د.م/ محمد ابو العينين السمنودى

أستاذ ميكانيكا الموائع
قسم هندسة القوى الميكانيكية
كلية الهندسة - جامعة عين شمس
ج.م.ع

أ.د.م/ جمال صادق عبيد

أستاذ الهيدروليكا
قسم الرى و الهيدروليكا
كلية الهندسة - جامعة عين شمس
ج.م.ع

أ.د.م/ نبيل حسنى نجيب روفائيل

أستاذ تقنيات النمذجة الرياضية
قسم الهيدرولوجيا –
مركز بحوث الصحراء
ج.م.ع

أ.د/ يحي لطفى إسماعيل

أستاذ و رئيس قسم الهيدرولوجيا
مركز بحوث الصحراء
ج.م.ع

القاهرة– (2012)

ABSTRACT

The groundwater resources play a tremendous important role in the different activities that carried out in the studied area and also similar areas. These activities include tourist, industrial and agricultural projects. Therefore, the Egyptian government does great efforts to establish these new communities and solve any problems, which may face the investors during their work. It is obvious that the most important problems are how to get cheap, good quality and a long life water resource. This target can be achieved by two ways; namely; the good design of the production well, and the continuous well-maintenance and characteristics observation. So, the present work has aimed to evaluate the water resources management of the study area through two approaches:

***** The First approach:*** Evaluation of water well characteristics and design criteria (well deterioration phenomena):

- Well performances and characteristics have been assessment by applying (41 step drawdown tests) and completely analyzed by two methods: 1. manual method *(manual calculation & graphical analysis method),* 2. G.W.W software *(Ground-Water under Windows; Version 1.10, Y 2005, Xp upgraded).*
- Water well productivities assessment have been deduced and graphically illustrated through out the study area, and then the future investment plan could be obtained or suggested.
- Design criteria of studied wells have been technically investigated, and compared with ideal ones to illustrate and explain failure phenomena.
- Finally; the results have been discussed and suitable suggestions are recommended, as best solutions to construct a more economic and efficient production wells more safety with along life to complete the water resources management..

***** The Second approach:*** Water bearing formation evaluation:

- Quantitatively the water bearing formation in the area has been evaluated by applying several pumping tests, step drawdown tests and the MODFLOW software *(Version 3.0, Y 2006).*

- Qualitatively, the groundwater is evaluated by an iso-salinity distribution, zonation and contour maps.

■ Hydrological data base bank has been constructed by using Microsoft Excel (Version 2007) and GIS program such as ArcGIS, and ArcInfo *(Versions, 9.0 & 9.2).*

■ Moreover; the hydraulic parameters of the water bearing formations were determined and evaluated through 46 pumping tests and 39 recovery tests carried out on selected drilled wells. Also, data collected of 17 pumping tests which carried out from previous studies.

■ On the other hand the ground elevation of the study area is illustrated by a Digital Elevation Model (DEM).

■ Due to the groundwater depths *(46.1m – 186.45m from the ground surface)* of middle and southern portions (whole of the study area except coastal zone), the rainfall replenishment is nearly absent.

■ Based on the output results of mathematical model, the northern and northwestern portions are characterized by reasonable potentiality of groundwater. Moreover, the eastern and southern portions reflect limited aquifer potentials.

■ Finally, the obtained results and suitable suggestions have been discussed and recommended.

ACKNOWLEDGMENTS

First, Thanks to ***ALLAH*** for granting me health and patience to complete this thesis.

I wish to express my deep gratitude and appreciation to:

***** Prof. Dr. Mohamed Abul-Eneen El-Samannoudi, Prof. of Fluid Mechanics, Mechanical Power Department, Faculty of Engineering, Ain Shams University,*** for supervising, Kindly advices, and for critical reading the work.

***** Prof. Dr. Gamal Sadek Ebid, Prof. of Hydraulic and Irrigation Hydraulic Department, Faculty of Engineering, Ain Shams University,*** for supervising, fruitful suggestions during the work.

***** Prof. Dr. Nabil Rofail***, ***Prof. of hydrology and mathematical Modeling, Hydrology Department, Desert Research Center*** for proposing the theme of this research, planning and supervising the thesis.

******** Special thanks to ***Prof. Dr. Yehia Lotfy Ismail, head of Hydrology department, Desert Research Center,*** for his continuous advising during the field work, for his help during the interpretation of the data, encouragement me and revising the thesis.

** I‘d express my deepest thanks to ***spirits of both Prof. Dr. Ahmed Safwat Swedan, Prof. Dr. Mahmoud El-Hefnawy, Dr. Mohamed Ali Abdel-Basier,*** due to teaching me how can I be a researcher and helpful for others.

** Author is also deeply thanks ***Dr. Eng. Sawsan Moselhy*** and ***Dr. M. S. El-Sabri*** for their fruitful advices and helping me in office and field works.

** I wish to great thanks for ***Dr. Y. R. Gedamy, Geologist R. Abdel-Hafeez, Geologist M. M. Hussien and Mr. Zaiet Hassan*** for their encouragement and help in field and/or lab. works.

** Special thanks to the ***staff members of Hydrology Department***, ***Desert Research Center***, for their help and encouragement .

** So Special thanks to the ***staff members of the Mechanical and Electrical Institute, National Water Research Center***, for their encouragement and help during the progress of the thesis.

** Finally, I wish to express my gratitude and appreciation to ***my great father*** and to ***spirit of my compassionate mother.***

*** So thanks to ***my kindly wife*** and to ***my lovely daughters*** for their patience and continuous encouragement.

APPROVAL SHEET

THESIS TITLE : *" WATER RESOURCES MANAGEMENT BY APPLYING MATHEMATICAL MODELING TECHNIQUES IN NORTHEASTERN PORTION OF SINAI PENINSULA, EGYPT."*

PRESENTED BY: *SAID ABDEL-ALEEM FARAG HAWASH*

DEGREE NAME: *DOCTOR OF PHILOSOPHY IN MECHANICAL POWER ENGINEERING.*

DISCUSSION COMMITTEE:

NAME, TITLE AND AFFILIATION	.....	*SIGNATURE*
1.. PROF. DR. RIADH H. AL-DABBAGH *AJMAN UNIVERSITY..*	.....	
2.. PROF. DR. EL-ADL A. A. EL-KADY *FACULTY OF ENGINEERING, AL-AZHAR UNIVERSITY.*	.....	
3.. PROF. DR. MOHAMED A. EL-SAMANOUDI *FACULTY OF ENGINEERING, AIN SHAMS UNIVERSITY.*	.....	
4.. PROF. DR. GAMAL SADEK EBEED *FACULTY OF ENGINEERING, AIN SHAMS UNIVERSITY.*	.....	

INTRODUCTION

General outlines:

Various hydrogeological studies have been made in the investigated area since 1950. The importance of Sinai is referred to its location, where it constitutes the eastern border of Egypt. The groundwater is the main source for agricultural, municipal, domestic and drinking purposes. The rapid growth of Sinai Peninsula population in the last decades has increased the water demands. The present groundwater supplies in the Sinai Peninsula are generally insufficient to meet the expected increases in water demands. Therefore, serious strategies for water development have been established to fully utilize the surface and groundwater resources at economic costs. So the advisement future development of Sinai Peninsula requires detailed studies about the water resources of the study area.

1.1. Location of the study area:

The study area is located in the northeastern portion of Sinai Peninsula, Egypt. This area is bounded by Omm Shehan-EL Ouga road to the south, El Arish-Rafah coastal road to the north, eastern boundary of wadi El-Arish to the west, and International border (between Egypt and Palestine) to the east. The investigated area occupies a part of the Sinai Peninsula of about 1382.5 km^2, (Fig.1.1).

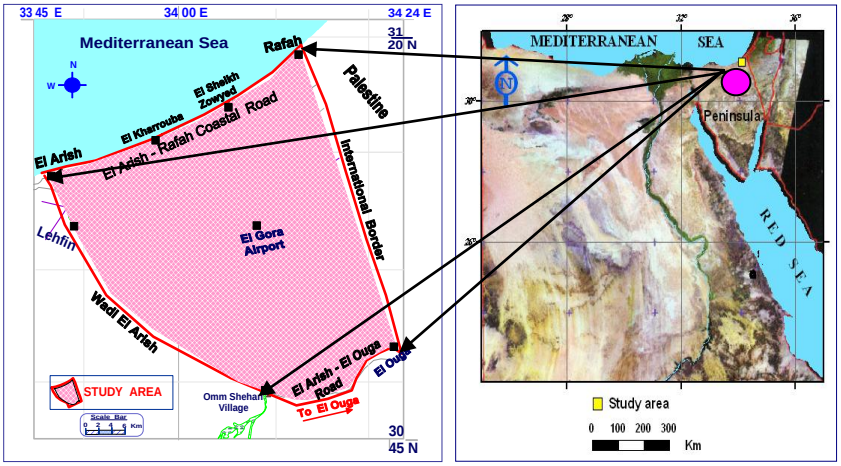

Fig. (1.1) Key map of the study area.

1.2. Main objectives of present study:

The present study concentrates on the following main targets:

1.2.1. Evaluation of the well deteriorations through the following:

(a) Actual well design parameters,
(b) Well performances (well characteristics),
(c) Water chemical analysis of representative samples,
(d) Evaluating well failure cases,
(e) Overcoming of well failure conditions,
(f) Ideal design criteria,

1.2.2. Studying water management through:

(a) Collecting all the previous data about geomorphology, geology, hydrogeology and hydrology of the study area as a data bank for future studies.
(b) Carrying out pumping tests to define different aquifer characteristics.
(c) Surveying all water points to evaluate historical fluctuation of groundwater quantity and quality.
(d) To discuss groundwater problems such as deterioration in water productivity & water salinity.
(e) Applying suitable Mathematical model to propose integrated groundwater management through proposing future scenarios

1.3. Scope of present work:

Many emphases are given in the present study in reviewing and reanalyzing well data. Great efforts are made to create and construct new data base bank. Theses efforts are specified into two main types:

1.3.1. Field works. ***1.3.2. Office & Lab. works.***

1.3.1. Field works which include:

- Collection of main well data (Well locations, well local name and owner, well construction, well lithology, well elevation and available water samples).
- Carrying out several hydrological field tests like (pumping tests, step drawdown tests, and infiltration tests).
- Monitoring of water well (drawdown, discharge, pH and salinity).

1.3.2. Office & Lab. works cover the following items:

- Constructing data base bank by documenting the main well data (well locations, well local name and owner, well construction, and well lithology, well elevation), also available measurements of

(water well drawdown, water well discharge, well elevation and both water salinity and pH values).

- Analysis of field tests data (pumping tests, step drawdown tests, and infiltration tests) by using several methods and software.
- Chemical analysis of available field samples to define (water Total Dissolved Solids TDS, water pH, iron (Fe) contents).
- Studying well design criteria and well failure parameters.
- Mathematical model procedures (conceptual model preparing & input data in forms tabulating and mapping calibrating, running, practical prediction, assuming several favorable scenarios.
- Revealing both of conclusions and recommendations.

1.4. Data of the existing water wells (water points):

During the present study, data of represented water wells (water points) were collected from different locations and different sources for studying the groundwater resources. These water points represent the investigated aquifers of the study area (especially along El-Arish - Rafah road). The location of these water points is given in Fig. (1.2).

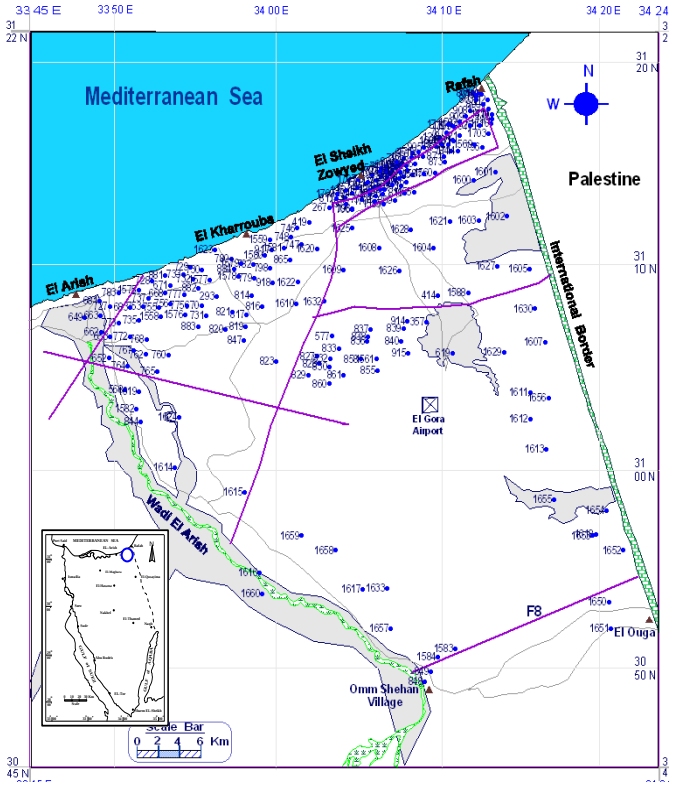

Fig. (1.2) Water points distribution map of the study area.

1.5. Research Activities:

The present thesis includes field, laboratory and office activities.

1.5.1. Present field activities:

In the field, the following activities were carried out through eight field trips by the team work of Desert Research Center (D.R.C.) during the periods from March 2006 to April 2009 to include:

(a) Carrying out sixteen infiltration tests at different sites of various types of soils.

(b) Performing sixty-three pumping, thirty-nine recovery tests, and forty-three step drawdown tests, through the whole area especially in the north portion.

(c) Monitoring of water well depth and water well discharge through available drilled wells periodically and seasonally, as well as collecting of representative water samples for chemical analysis and well construction data.

(d) Field survey to determine the locations and ground elevations for 1714 water points by using a GPS instrument.

1.5.2. Laboratory activities:

In the laboratory, the following activities were carried out:

** Chemical analysis procedures for all the collected water samples were carried out in the laboratory of Desert Research Center, (Appendix 6 presents the respective data), including:

- Major cations and anions.
- Total Dissolved Solids (TDS) and pH values.
- Iron (Fe) contents of representative water samples.

1.5.3. Office activities:

The office activities comprise:

(a) Preparing hydrological maps, diagrams, cross-sections, tables and interpretation of the results.

(b) Evaluation and calculations of the different hydraulic parameters.

(c) Applying the MODFLOW (mathematical model software under windows) for predicting the future hydrological setting.

(e) Representing the chemical data using standard methods.

1.6. Climatic conditions:

To study the different climatic features, the necessary data have been collected from Cairo Meteorological Authority and the Research Institute of Water Resources. These data have been analyzed and evaluated. The obtained results revealed that the climatic conditions have played an effective role on the prevailing hydrogeological situation.

1.6.1. Climatic Elements:

A- Rainfall:

In the area under consideration, the amount of rainfall is significant through the year. Table (1.1) shows the mean rainfall precipitated over certain areas of Northern Sinai. It can be noticed that most of the rainfall over Northern Sinai is precipitated during winter time. The average minimum rainfall depth reaches 0, 0, 0 and 0 mm/month in El-Arish, Rafah, El-Maghara and El-Quseima stations based on the records during the period (1936-1993). The average maximum rainfall depth reaches 22.89, 94.20, 12.30 and 22.50 mm/month at El-Arish, Rafah, El-Maghara and El-Quseima station records respectively during the period (1936-1993), (Fig. 1.3).

Table (1.1) Mean rainfall (mm/month) over North Sinai by Egyptian Meteorological Authority (1936-1994).

Month	El-Arish	Rafah	El-Maghara	El-Quseima
Jan.	22.89	31.30	12.00	21.30
Feb.	15.41	37.20	9.70	22.50
Mar.	13.58	34.60	8.00	10.20
Apr.	3.82	14.20	0.00	2.60
May	1.51	0.10	0.00	0.10
Jun.	0.01	0.00	0.00	0.00
Jul.	0.00	0.00	0.00	0.00
Aug.	0.07	0.00	0.00	0.00
Sep.	0.20	0.00	0.00	0.00
Oct.	3.03	2.20	1.70	5.00
Nov.	7.84	94.20	0.00	13.20
Dec.	15.00	90.00	12.30	22.20

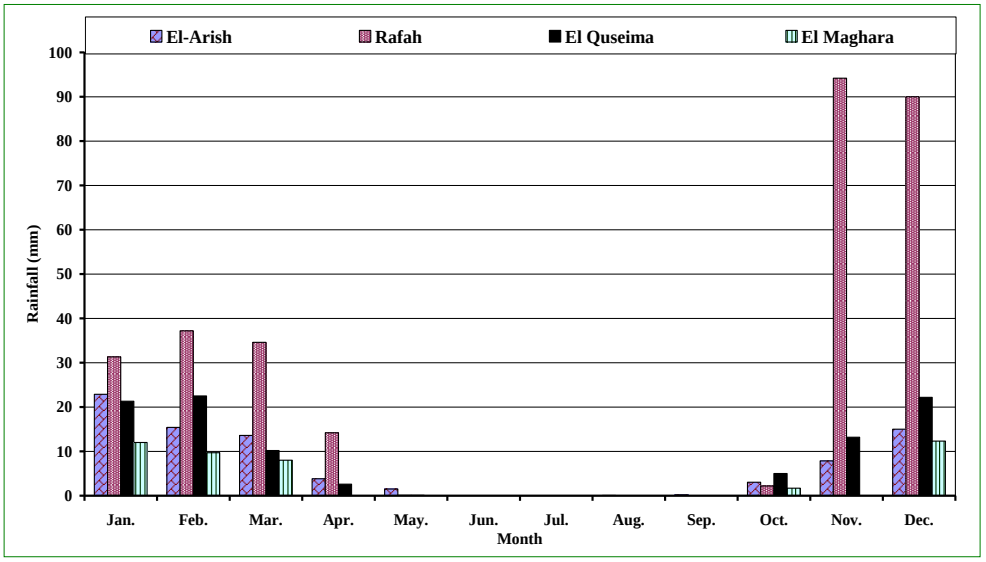

Fig. (1.3) Mean annual rainfall histogram in selected metrological stations (after Hassan, 2009).

B- Air Temperature: In the study area, the maximum air temperature at El-Arish is 31.6°C and the minimum is about 7.7°C. At Rafah, the maximum and minimum air temperatures are about 31.5°C and 7.8°C, respectively. Temperature is generally lower at the coastal areas than other parts of Sinai during the winter. The average monthly values over the area were shown in Tables (1.2&1.3) and Figs (1.3&1.4).

C- Wind Velocity: The mean monthly value of wind velocity over the study area estimated from the data offered by the Meteorological Authority, was found to be about 6.9 knots, (Mohamed, 1994) (kont = 1.85 km/hr).

D - Relative Humidity: The relative humidity (r) of air is the ratio between the pressure of water vapor (e) contained in the air and the saturation pressure of vapor at temperature (E), expressed in percent.

$$r = e / E * 100 \quad \text{.....(1.1)}$$

The most important climatic features (e.g. evaporation, evapotranspiration, and dew condensation are affected by the relative humidity which increases in winter time. In the study area, the relative humidity is generally higher in winter than in summer. At El Arish, which represents a portion of the northern coastal zone, it is of high values in summer, where it reaches about 75% (Nasr, 1993).The relative humidity decreases southwards where it ranges in the central

part of Sinai between 62% and 41 %. However, at the southern part of Sinai, it averages 61%, Gedamy (2004).

Table (1.2) Average monthly Maximum temperature over North Sinai by Egyptian Meteorological Authority (1936-1994).

Month	El-Arish	Rafah	El-Maghara	El-Quseima
Jan.	18.60	20.20	19.00	17.5
Feb.	19.30	21.80	19.40	19.10
Mar.	21.20	21.50	21.80	22.10
Apr.	24.90	23.90	28.30	26.40
May	27.40	26.70	29.40	30.20
Jun.	30.00	29.20	32.90	33.50
Jul.	31.30	30.90	33.20	34.00
Aug.	31.60	31.50	33.30	34.00
Sep.	30.20	30.40	30.20	31.20
Oct.	28.60	28.70	28.70	29.30
Nov.	24.90	24.40	27.30	24.40
Dec.	20.60	19.90	19.30	19.30

Table (1.3) Average monthly Minimum temperature over North Sinai by Egyptian Meteorological Authority (1936-1994).

Month	El-Arish	Rafah	El-Maghara	El-Quseima
Jan.	7.70	7.80	8.70	6.30
Feb.	8.10	9.50	9.70	7.60
Mar.	9.80	9.60	10.40	8.90
Apr.	12.50	12.60	14.20	12.00
May	15.10	14.90	16.20	14.70
Jun.	18.10	18.40	18.90	17.90
Jul.	20.60	20.50	19.50	19.80
Aug.	21.10	21.20	20.40	20.00
Sep.	19.50	19.00	18.70	18.10
Oct.	16.80	17.60	17.70	15.90
Nov.	12.80	13.20	16.20	12.70
Dec.	9.20	9.30	10.00	8.40