HYDROLOGICAL AND HYDROGEOLOGICAL EVALUATION OF MASSIVE SALTY LAGOONS, (CASE STUDY: QATTARA DEPRESSION)

By

Heba T_Allah Salah Abdel Azeem

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirement for Degree of
DOCTOR OF PHILOSOPHY
In
Irrigation and Hydraulics Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

Hydrological and Hydrogeological Evaluation of Massive Salty Lagoons, (Case Study: Qattara Depression)

Key Words:

Qattara Depression; Density dependent modeling; Mass Balance; Nile Delta Drainage; Salty Lagoons.

Summary:

Hydropower generation has been proposed by utilizing the difference in the water levels between the Mediterranean Sea and the Qattara Depression released accumulated water level. The study objectives included: studying the salinity effect and the hydrogeological conditions of Qattara depression on the Delta drainage and the effect of the lagoon salinity on the underneath groundwater reservoir. The results have revealed that the saline lagoon does not affect the Nile Delta drainage. The lagoon accumulated salinity does not reach the Nile Delta and its effect on the underneath sandstone reservoir is minor due to the confining shale layer.

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I would like to endow this work to my father's soul, God bless him, Grateful acknowledgement for my mother who constantly prayed for me to accomplish this work.

Heba T_Allah Salah Abdel Azeem

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Abstract

At the beginning of the 20th century, several studies were performed to study the consequences of delivering the Mediterranean Sea water to the Qattara Depression through a canal for hydropower generation by utilizing the difference in the water levels. Main objectives of the current study are to: a) create a data bank for the depression, b) determine the expected evaporation from the accumulated saline water in the depression, c) study the hydrogeological conditions of Qattara as a drainage lagoon for the Delta, d) study the effect of saltwater lagoon on the Nile Delta, and the groundwater reservoir. The study methodology has been performed utilizing the recent tools, of analysis, that had not been available for the previous studies as; efficient numerical models, geographic information system (GIS), and Digital Elevation Models (DEM). The effect of salinity on evaporation, from the lagoon, was calculated. A number of twenty one boreholes, with average depth of 3900 m, were employed to construct the geological stratification. Hydraulic conductivity values and groundwater levels have been collected from the available boreholes and deep exploratory wells drilled by the oil companies. Mass balance of the lagoon saltwater was performed, every separate year during a period of 50 years. Density dependent model (SEAWAT) via MODFLOW has been employed for duration of fifty years. The simulation was done every separate year. The simulation was repeated for different water filling levels (50 m and 60 m below mean sea level).Several well fields are assumed between the lagoon and the Nile Delta. The wells screen was assumed in the Moghra, the limestone, and the deep sandstone aquifers. The results revealed that the lagoon does not affect the Nile Delta drainage efficiency; the lagoon accumulated salinity does not reach the Nile Delta. The study, also, showed that the effect of the lagoon salinity, on the lower sandstone reservoir, is minor because of the confining shale layer and the salinity does not disperse out reaching the Nile Delta.

Chapter 1: Introduction

1.1. General Outline

The investigated region is located in the northern part of the Western Desert of Egypt between longitudes 25º 00′ - 31º 00′ E and latitudes 27º 00′- 31º 00′ N, which extends from Rasheed branch in the East to Libyan Boundary in the West and extends from Mediterranean Sea in the North to 20 km away from the end of Qattara Depression in the South. The study area includes the Qattara Depression which is a major physiographic feature in the Sahara Desert, Wadi Al Natrun, and Siwa Oasis. The Qattara Depression covers area of about 19,500 km². It is 300 km in length and a maximum 145 km width. Its bottom is composed of uninhabited and impassable "sabkhas" or salt or salt marshes, dried up salt lake beds and shifting sands.

Its location below sea level offers the possibility of hydroelectric power production. Its realization requires the connection of the depression to the Mediterranean Sea through a canal and / or pipeline system. After water filling to its maximum extent, the flow rate and hence power production capability would have to be matched to the high solar evaporation rate, due to its location in an arid hot desert area, from the surface of the generated lake.

The eastern edge of the depression is the Mogra Oasis which is about 205 km from Cairo, and about 56 km from the Mediterranean Sea. The Kara Oasis is located on the western border of the depression. The southwestern border of the depression is at a distance of about 80 km from the Siwa Oasis. The North Western edge of the depression is formed by a steep rising mountain reaching height up to 230 meters above sea level. The slope of the depression, at this location, appears to be very steep and deep, while the slope on the North eastern side of the depression is mild. The s1opes disappear on the South Eastern borders and the floor of the depression on these two locations gradually increases till it reaches the levels of the desert, (Bassler, [1]).

The basic concept of the project is to channel the Mediterranean Sea water, either through tunnel's or open canal, to the depression, and to regulate this discharged water by water turbines, thus utilizing the difference of head between the sea 1evel and the depression water levels for power production. Since the depression is closed from each direction, a vast lake will be formed until its level reaches 60 meter below sea level.

At this level, the water flow, diverted from the sea, should be limited to the amount of water evaporated from the surface of the formed lake. Thus, it is clearly seen that the utilization of Qattara project depends on two basic natural phenomena, the first is the potential due to the difference of levels between the sea and the depression and the second is the solar energy which is the dominating factor on which depends the quantity of evaporation from the surface of the formed lake.

At the beginning of the 20th century, several studies were performed to study delivering the Mediterranean Sea water to the Qattara Depression through a canal utilizing the Qattara Depression for hydropower production that can be done by using the difference in the water level. The Qattara project includes; the Qattara Lake, the headrace canal and the reservoir, creating a massive hydroelectric power project in northern zone of Egypt. Thirty years ago, many studies were performed to evaluate the effect of the depression, after filling, on the Nile Delta and on the groundwater

sandstone reservoir. The results were negative ones for the Delta and the groundwater reservoir.

The proposed diversion of Mediterranean Sea water into the Qattara Depression for generation of electricity in northwestern Egypt could adversely affect the present hydrologic balance in surrounding aquifers. Among these aquifers, the Lower Miocene Moghra Aquifer is of particular importance because it constitutes most of the bottom area of the proposed Qattara Reservoir and is connected to both the Nile Delta aquifer in the east and the Lower Cretaceous (Nubian) artesian aquifer in the south. Flooding the Qattara Depression from the Mediterranean Sea would have the following benefits:

1) Alter the climate, in adjacent areas, in terms of temperature, humidity and evaporation,
2) Create a massive hydroelectric power project, in northern zone of Egypt,
3) Provide opportunities for work during construction and operation,
4) Create new living communities around the depression and on the sides of the filling canal which will be 80 km length between the depression and the Mediterranean Sea, and
5) Create new industrial communities in the region.

1.2. Research Objective

The objective of this thesis is to perform utilizing the new tools which had not been available thirty years ago when the project was proposed. The tools include numerical efficient models, programs of geographic information system, satellite images, and digital elevation models. The proposed research intends to accomplish the following objectives:

- Create a data bank for the depression using the Geographic Information System (GIS) including topography, meteorology, geology, hydrology, and hydrogeology.
- Determine the expected evaporation from the accumulated saline water.
- Study the current hydrogeological conditions of the depression as a drainage pool for the Delta.
- Study the effect of saltwater lagoon on the Nile Delta
- Evaluate the salinity effect on the groundwater reservoir, and
- Finally, evaluate the project feasibility using different scenarios of water levels in the lake.

1.3. Research Methodology

The thesis methodology is summarized through four phases in order to fulfill the target objectives.

Phase I:Data Collection and Data Analysis

Collect, analyze, and evaluate the data including:

- Topographical maps,
- Geological and hydrogeological maps,
- Satellite and areal maps,
- Digital elevation model (DEM), and