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Evaporation from Salty Lagoons

(Case Study: Qattara Depression)

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ملخص عربي

تم إعداد العديد من الدراسات - في بداية القرن العشرين - لدراسة توصيل مياه البحر المتوسط من خلال قناة توصيل لمنخفض القطارة بهدف توليد الطاقة الكهربائية وذلك بإستغلال فرق المناسيب بين المنخفض والبحر المتوسط ، وتهدف الدراسة الحالية إلى :-أ) إنشاء منظومة معلومات هيدرولوجية للمنخفض ب) حساب معدلات البخر المتوقع من المياه المالحة المجمعة في بحيرة المنخفض. وقد تم إعداد منهج الدراسة باستخدام البرامج الحديثة التي لم تكن متاحة للدراسات السابقة للمشروع حينها، وهذه البرامج مثل النماذج العددية الفعالة، نظام المعلومات العددية (GIS) ، ونماذج الإرتفاعات الرقمية (DEM).

كلمات البحث: منخفض القطارة، البخر من المياه المالحة، الملوحة، الإتزان المائي.

Abstract

At the beginning of the 20th century, several studies were performed to deliver 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 hydrological data bank for the depression, and b) determine the expected evaporation rate from the accumulated saline water in the Lagoon. The study methodology has been performed utilizing the recent tools of analysis that had not been available for the previous studies of the project such as; efficient numerical models, geographic information system (GIS), and Digital Elevation Models (DEM).

Keywords: Qattara Depression, evaporation from saline water, salinity, mass balance.

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Introduction

The Qattara Depression is a desert basin within the northwestern desert of Egypt, in Matruh Governorate, lying within the triangle formed by El-Alamein, Mersa Matruh and the Siwa Oasis. It is 200 km west of Cairo, and 75 km east of Siwa Oasis as shown in Figure 1. The depression deepest floor level is 133 m below sea level. It contains the second lowest point in Africa (The lowest is Lagoon Assal in Djibouti). The depression covers a surface area of about 19,500 km² (7,000 square miles). Its maximum length is 298 km with width of 145 km. (Ezzat, M.A., 1977).

The bottom of the depression consists of a salt pan (sabkha). The floor of the Qattara Depression rests, predominantly, in the Lower Miocene Moghra formation, which consists of a complex sequence of relatively coarse sediments of tertiary age as shown in Figure 2. These sediments merge with the Western Plateau Complex in the north-western side of the Lagoon. (Ball, J., 1933).

Within the depression, there are saline marshes under the northwestern and northern escarpment edges. The major oasis in the depression is Moghra oasis, which is uninhabited and has 4 km² brackish zones (LAHMEYER, 1981). Salt marshes, also, occur and occupy, approximately, 300 km². It is situated in the eastern most part of the depression, forming a small, local depression within the main Qattara Lagoon. Windblown sands are encroaching in some areas.

The utilization of the Qattara depression (discovered at the beginning of the 20th century in the northern part of the Libyan desert) for the purposes mentioned here, was suggested for the first time by the Berlin geography specialist, Professor Penk in 1912, and later by Dr. Ball in 1927 (Dr. Ing. Giuseppe De Martino, 1973).

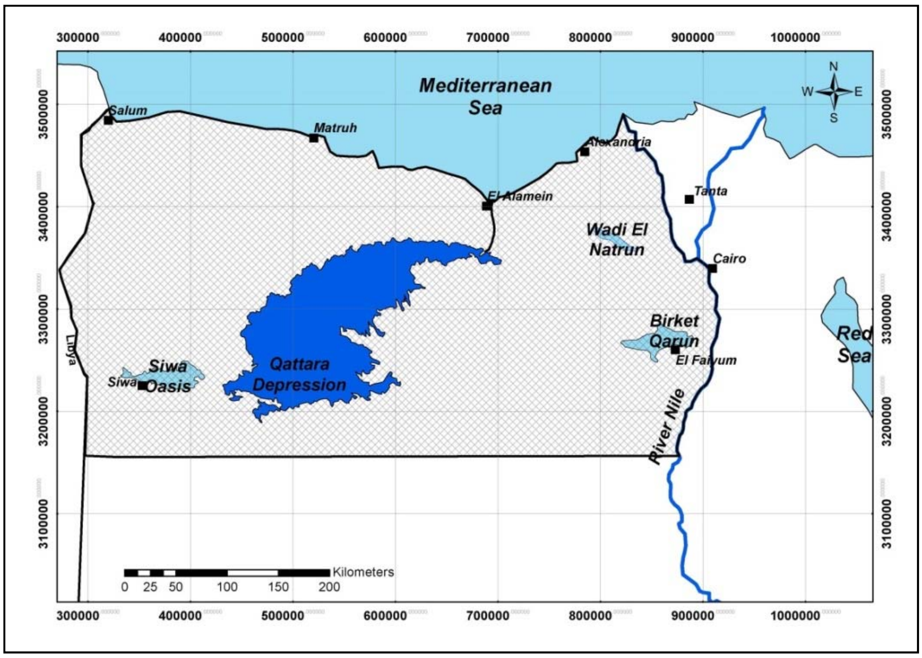

Fig. 1.Qattara Depression location in the investigated area

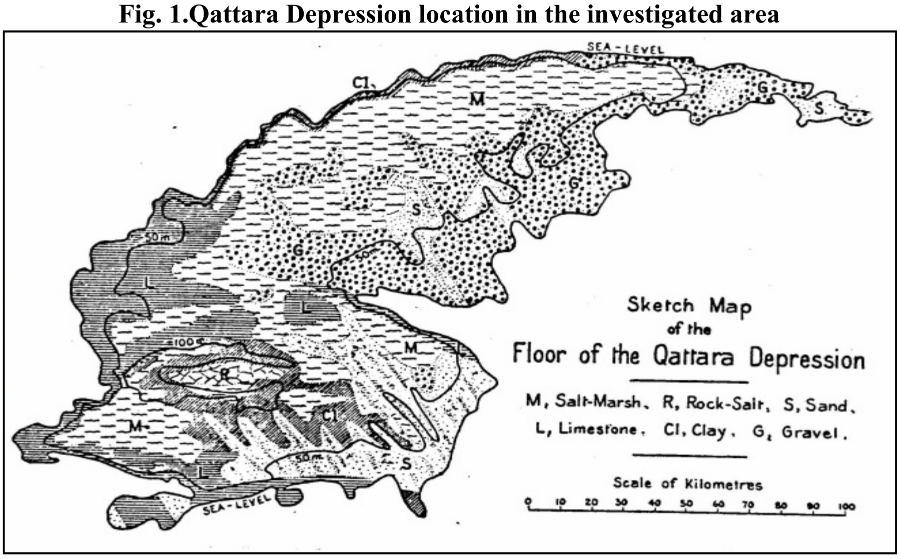

Fig. 2.The floor of Qattara Depression (Ball, J., 1933)

Morphology of Qattara Depression

By using the new tools that had not been available in the last decades, the topography of the Qattara Depression was identified as shown in Figure 3 using the Digital Elevation Models (DEM 30 m x 30 m). Several cross sections in the Lagoon (filled depression) were generated, using the Global Mapper software to identify the topography and the different bed levels as shown in Figure 4 through Figure 9. Surface area and accumulated volumes, for each level, of the Lagoon were calculated as shown in Figure 10 and Figure 11, respectively.

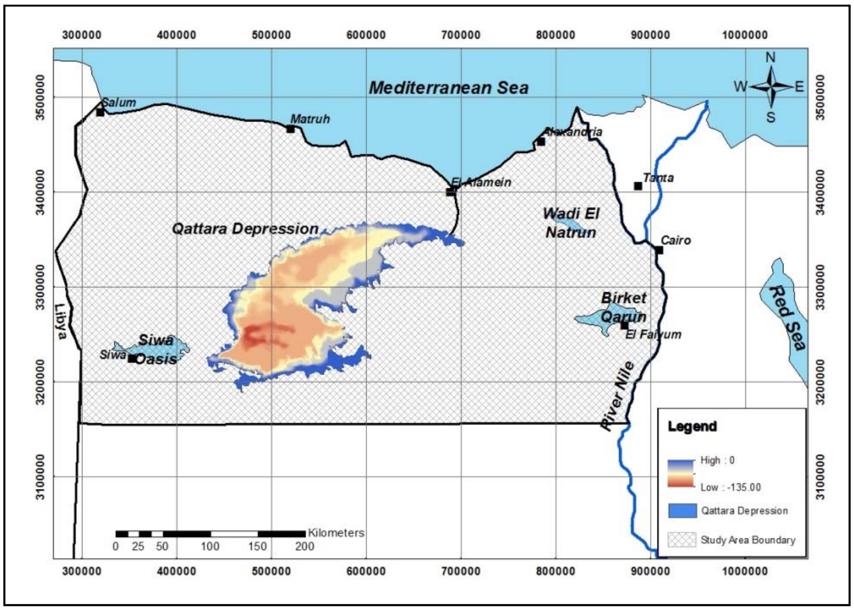

Fig. 3: Topography of Qattara Depression using Digital Elevation Models, DEM

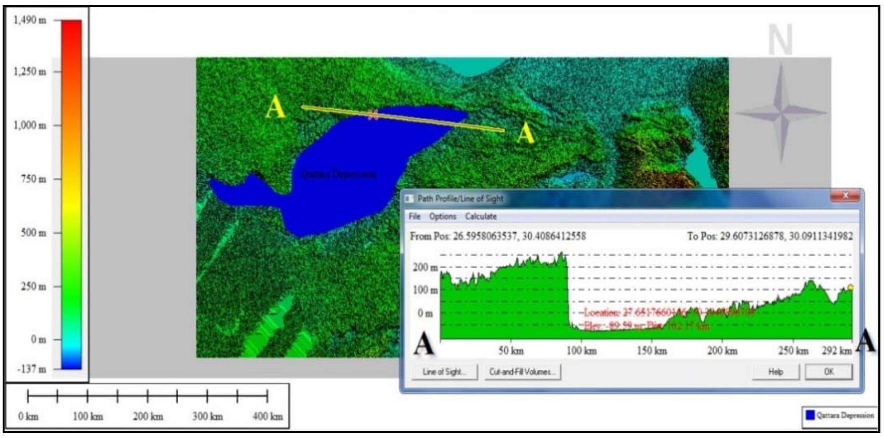

Fig.4: Transversal cross section (A-A) showing the bed level at - 89.60 m

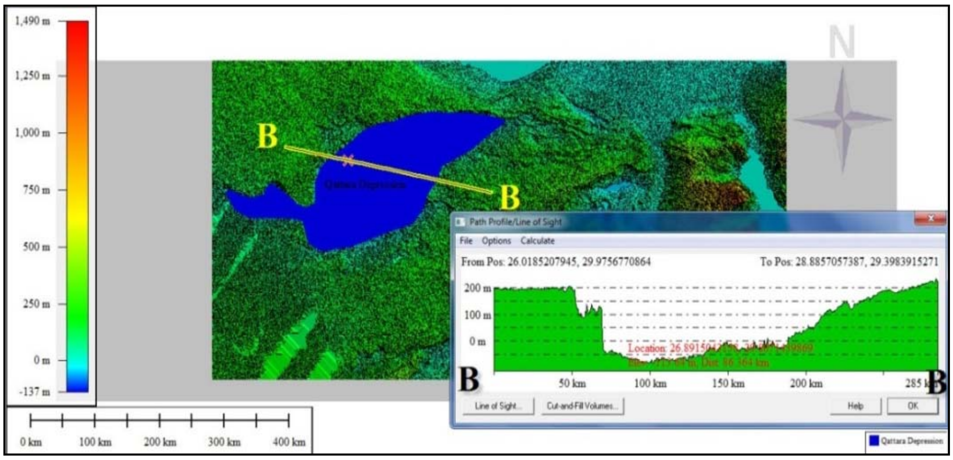

Fig.5: Transversal cross section (B-B) showing the bed level at - 113.64 m

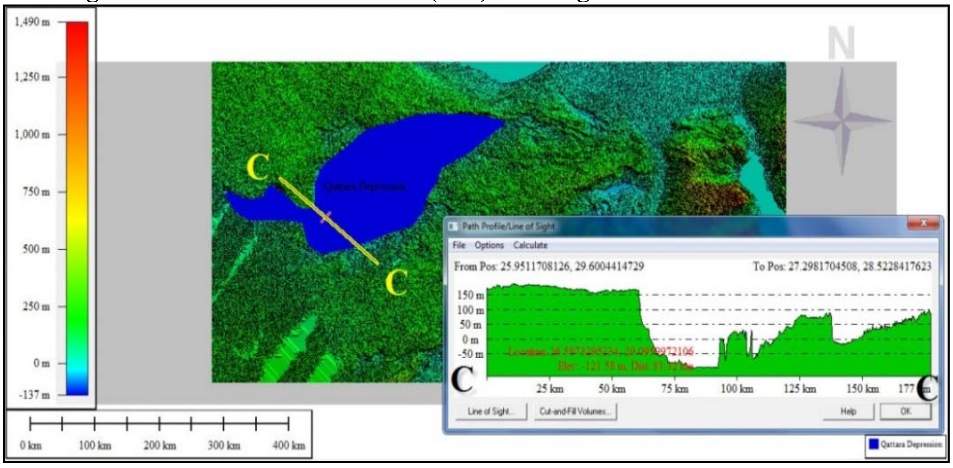

Fig.6: Transversal cross section (C-C) showing the bed level at - 121.60 m

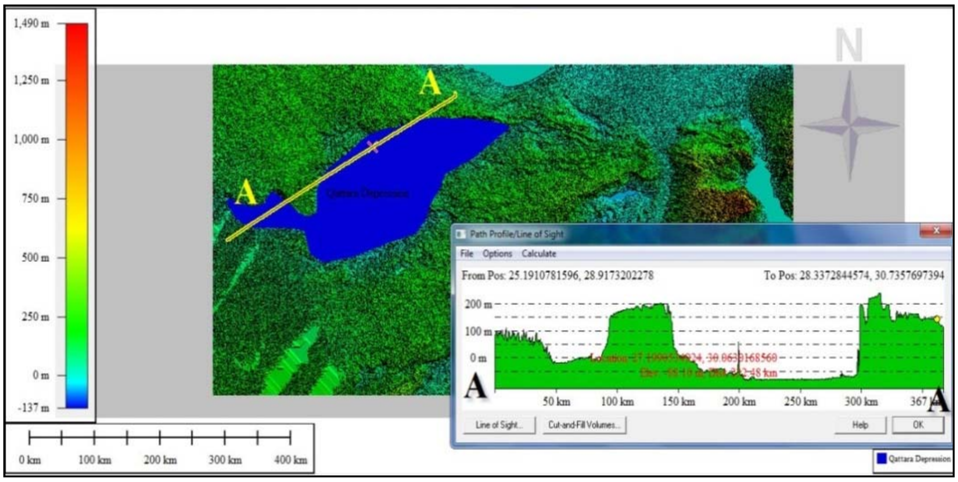

Fig.7: Longitudinal section (A-A) showing the bed level at - 88.10 m

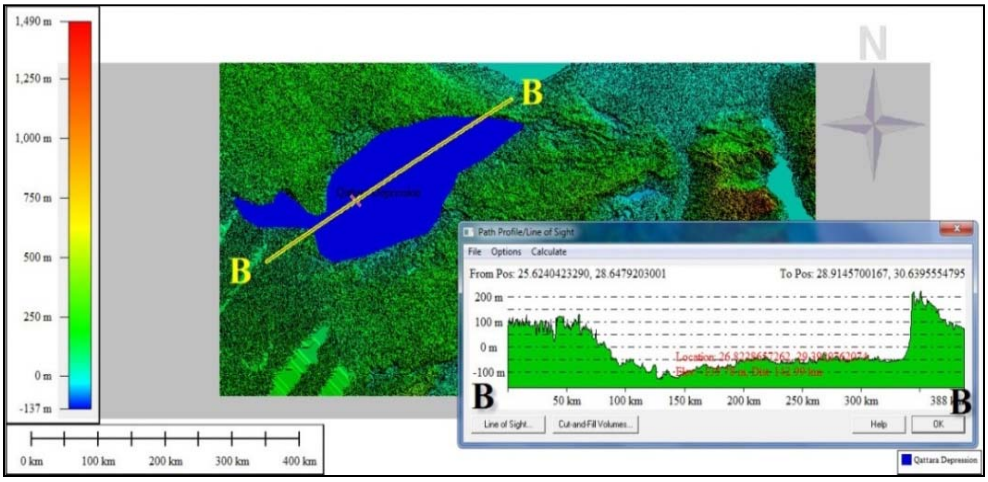

Fig.8: Longitudinal section (B-B) showing the bed level at - 133.00 m

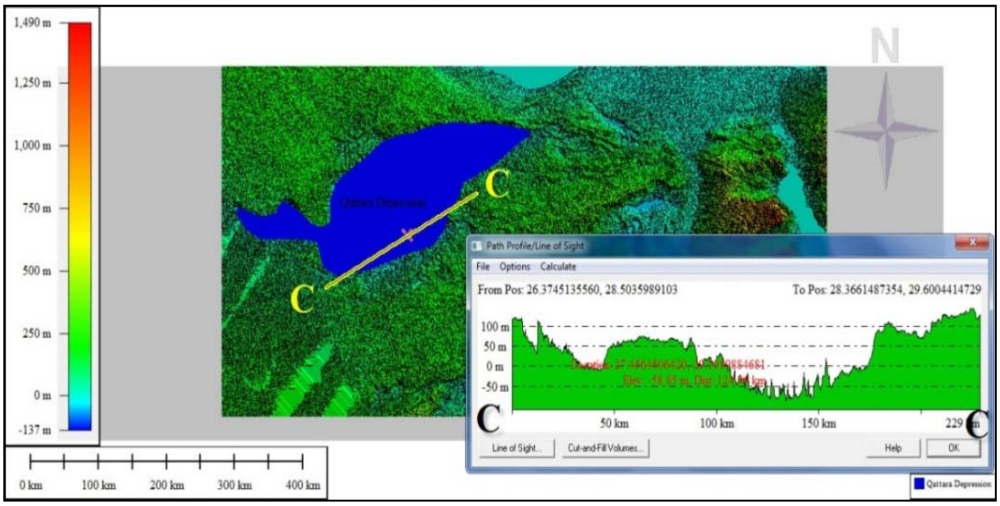

Fig.9: Longitudinal section (C-C) showing the bed level at - 58.85 m

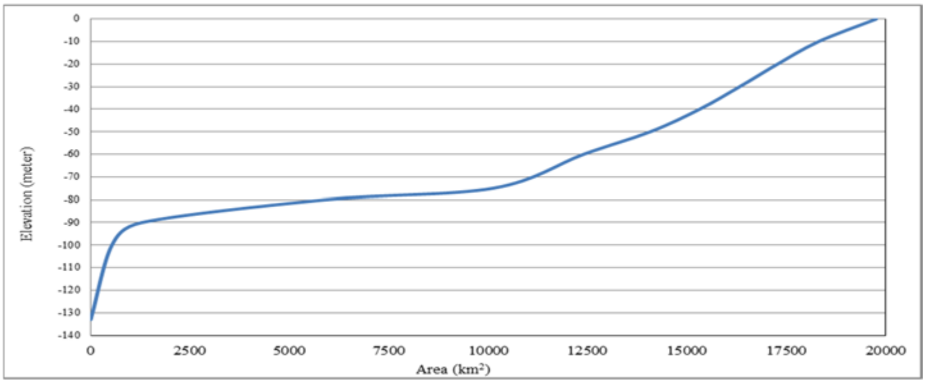

Fig.10: Water surface area (km^2) versus Lagoon levels

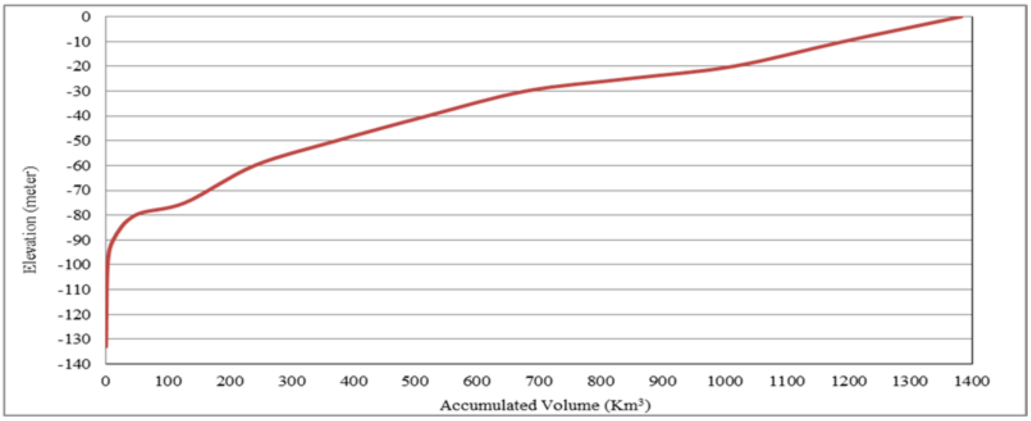

Fig.11: Accumulated volume (km^3) versus Lagoons levels

Climate in the region of Qattara Lagoon

The region is described as being arid one, with low rainfall, and high summer temperature and moderately low winter temperature. The yearly rainfall at the sea coast varies between 110 mm and 190 mm and it decreases to about 20 mm at the northern boundary of the lagoon. Further south, the rainfall is less (Shata A., et al., 1962).

The relative humidity in the region is comparatively high, because of the northerly winds which carry moisture from the Mediterranean Sea. At the coast, the relative humidity is close to 60 percent, but at the southern edge of the lagoon it seldom falls below 30 percent. This is important ecological feature because the dew point is reached quite frequently during the nights in the winter seasons (Shata A., et al., 1962).

After filling the depression, because of evaporation, the relative humidity of the air crossing the lagoon will increase considerably. Consequently, dew formation during nights will also be greater than at present. Filling the Qattara Depression with continuously running sea water could significantly moderate the temperature by about 3-5 degrees centigrade. The high rate of the evaporation can also be a beneficial factor in terms of enhancing the rainfall. (Maher Kelada, 2010).

Before discussing the approach, used in the present study, to determine evaporation from the Qattara salty Lagoon, brief summary of the climatic conditions that affect the evaporation is presented as shown in Figures 12 through to 16. Meteorological data of Qattara Region are obtained from **Water& Climate Atlas** (www.iwmi.org). These data are used in calculating the evaporation from freshwater that follows the Penman's approach. It will be latter, modifed to evaporation values from saline water. Mean monthly precipitation from three different meteorological stations are collected and analyzed. The meteorological stations are Wadi El Natrun, Dabaa, and Siwa. The records of these stations are from the year 1970 through to the year 2000 as shown in Figure 17 (Eizeldin, M. A.; Khalil, M. B, 2006).

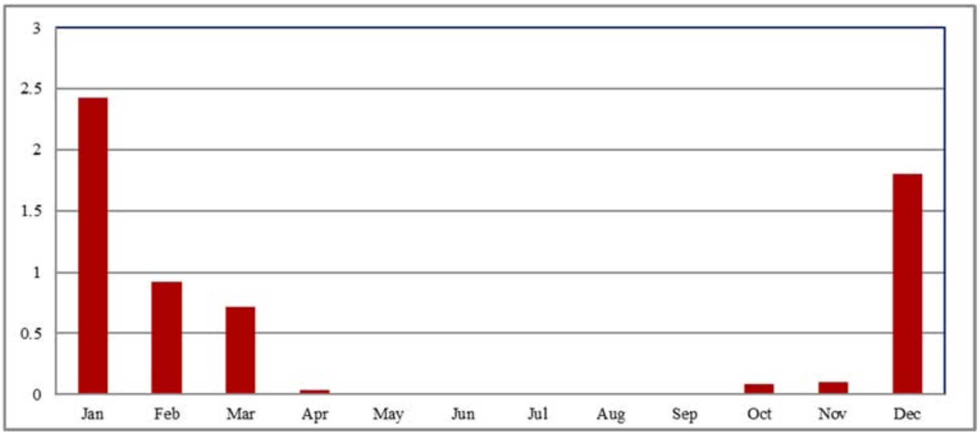

Fig. 12: Mean monthly rainfall (mm)
Water and Climate Atlas [(www.iwmi.org)](http://www.iwmi.org)

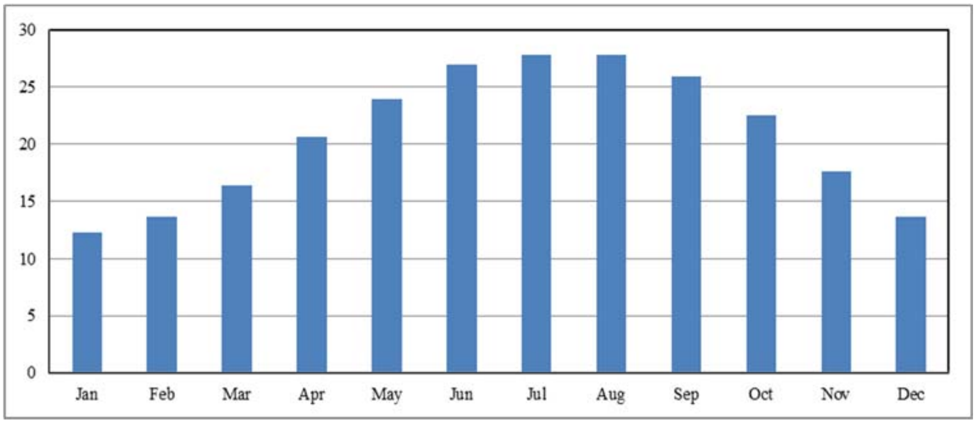

Fig.13: Mean monthly temperature (C°)
Water and Climate Atlas [(www.iwmi.org)](http://www.iwmi.org)

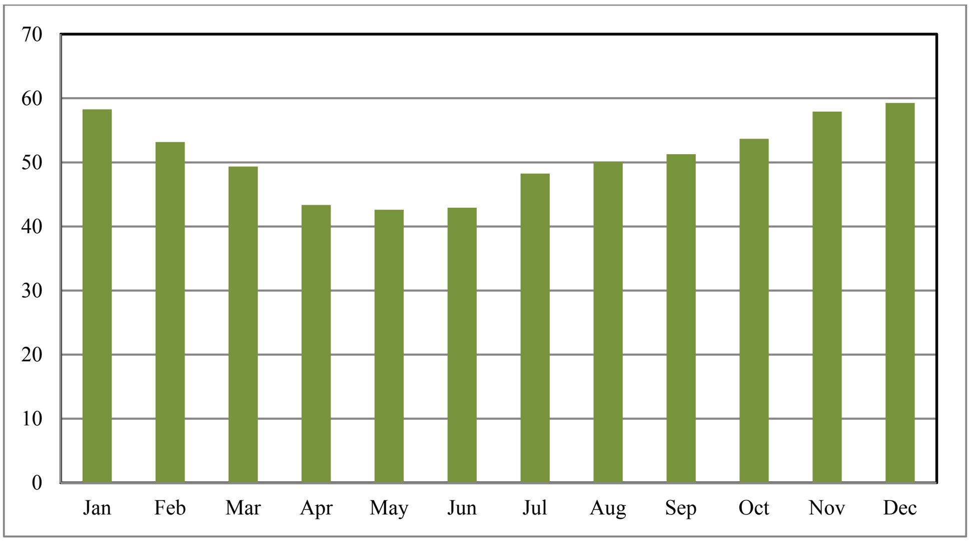

Fig.14: Relative humidity (%)
Water and Climate Atlas [(www.iwmi.org)](http://www.iwmi.org)

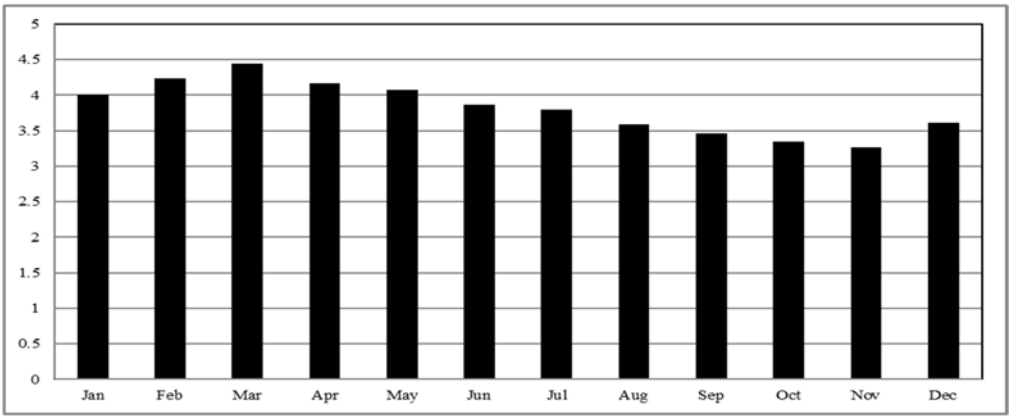

Fig.15: Wind speed (m/s)
Water and Climate Atlas [(www.iwmi.org)](http://www.iwmi.org)

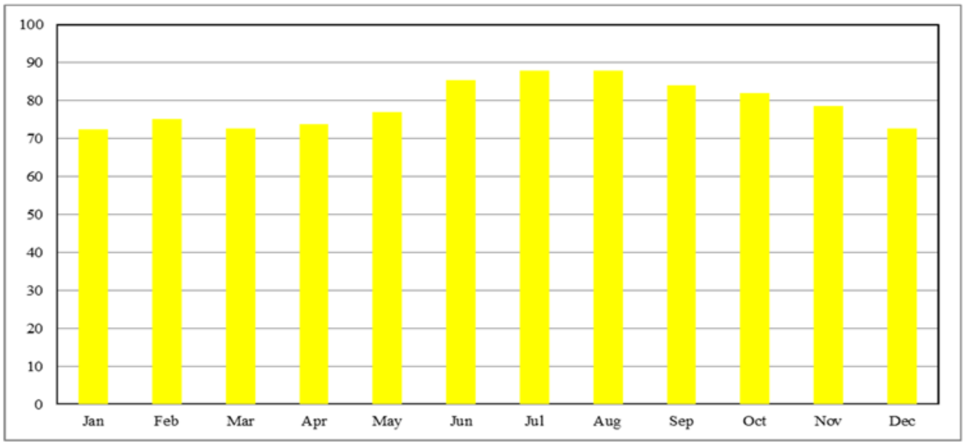

Fig.16: Sunshine hours (% of max.)
Water and Climate Atlas [(www.iwmi.org)](http://www.iwmi.org)

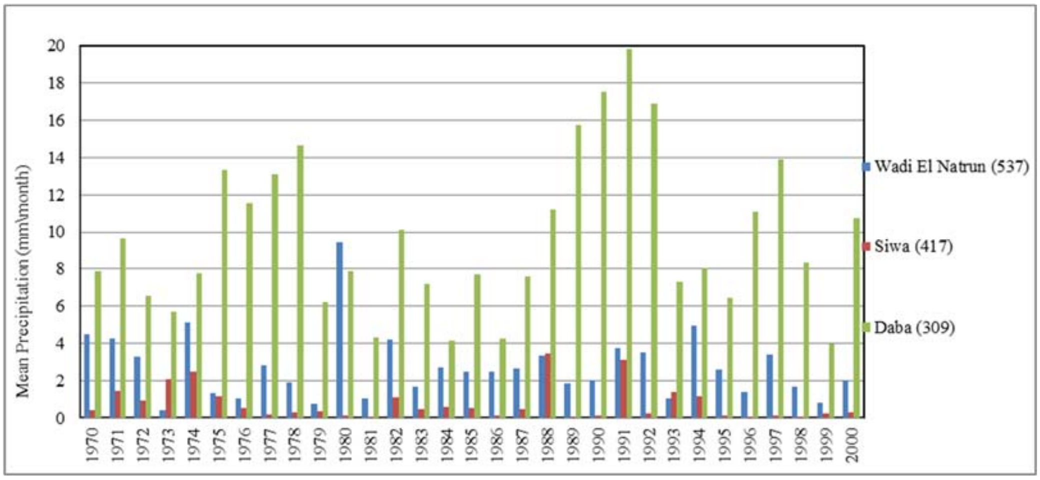

Fig. 17: Mean precipitation (mm) from three different meteorological stations
Eizel-Din, M. A.; Khalil, M. B, 2006

Evaporation from Qattara salty Lagoon

The evaporation rate in mm\day, from fresh water, was calculated, using Penman Equation, for each month for each lagoon level as shown in Figure 18. The evaporation increases as by going down because of the increase of temperature. The yearly evaporation from freshwater was calculated to get the evaporation from lagoon saline water after filling. Effect of salinity on evaporation rate has been considered in the study.

For different values of salinity, the specific gravity is calculated (from where). Using the specific gravity, the ratio Es/Eo is obtained from Figure 19 (Eizeldin, M. A.; Khalil, M. B, 2006) where E_s and E_o are the evaporation from saline and fresh water, respectively.

Specific gravity of salt water concentration in Qattara Lagoon is less than 1.150 (check that number), thus the ratio of evaporation rate from saline water to the evaporation from fresh water is a function of specific gravity as shown in Equation 1, Eizeldin, M. A and Khalil, M. B, (2006).

The higher the lagoon salinity concentration, the higher the specific gravity values, the smaller evaporation rate from saline water. The relationship between lagoon salinity concentrations (PPM) and their corresponding values of specific gravity are shown in Figure 20. Figure 21 shows the relationship between the ratio of evaporation from saline water and evaporation from fresh water (Es/Eo) and the specific gravity (S.G.).

$$\frac{E_S}{E_O} = 8.2322 \times S.G.^3 - 32.543 \times S.G.^2 + 39.826 \times S.G. - 14.524 \quad (1)$$

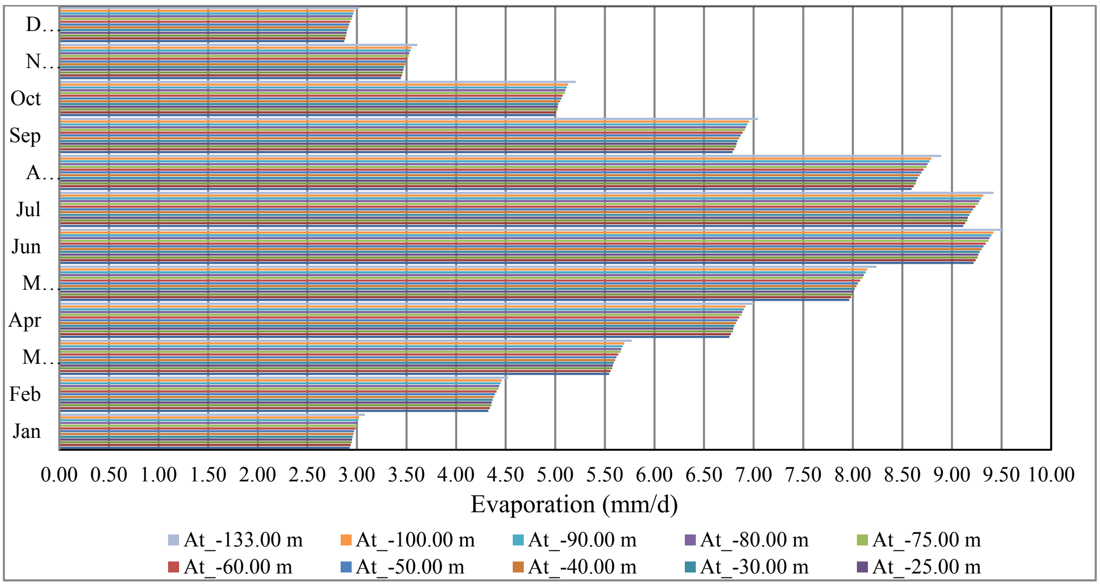

Fig.18: Evaporation rate for different Lagoon levels, at the different months

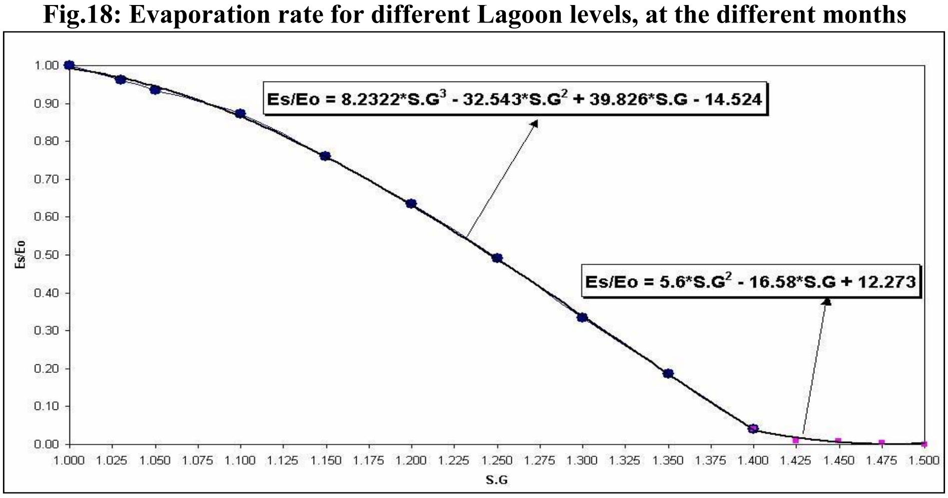

Fig.19: Effect of water specific gravity on evaporation rate (Eizeldin, M. A.; Khalil, M. B, 2006)

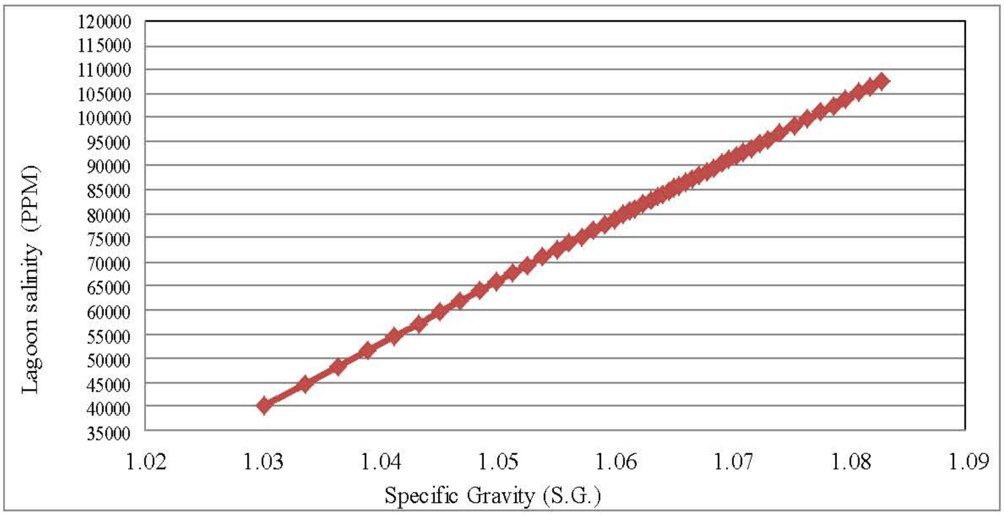

Fig. 20: Relationship between lagoon salinity and corresponding values of specific gravity

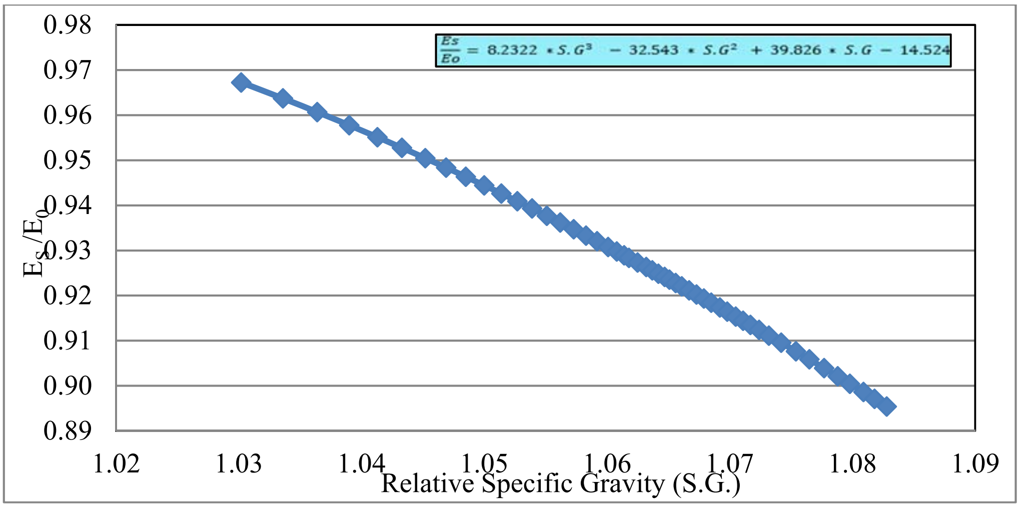

Fig.21: Relationship between the ratio (E_S/E_O) and specific gravity (S.G.)

Mass Balance of Qattara Lagoon

The salinity of the lagoon can be evaluated by taking the mass balance of the lagoon water into account. By referring to the volume of water contributed by rainfall, sea water inflow, and inflow of groundwater together with evaporation and outflow of groundwater, the accumulated salt concentration, after evaporation, in the lagoon water at t+Δt is calculated from Equation 2:

$$C_{i+1} = \{(V_o * C_i) + (V_R * C_o)\} + (V_{in} * C_{in}) - (V_{evap.} * C_o) \pm (V_{Groundwater} * C_{Groundwater})\} / V_o \quad (2)$$

Where V_o is the volume of the lagoon, C_{i+1} is the lagoon salt concentration in the year i+1, V_R is the volume of rainfall on the lagoon, C_o is the freshwater concentration; V_{in} is the inflow volume from sea water into the lagoon, C_{in} is the salt concentration of sea water, $C_{Groundwater}$ is the concentration out of the lagoon, $V_{evapo.}$ is the evaporation volume out of the lagoon (evaporartion form saline water), and $V_{Groundwater}$ is the volume recharged by inflowing/ outflowing groundwater into/ from the lagoon (K. Fujinawa et al., 2009). (from groundwater modeling in Abdel Azim in review for publication)

Conclusions:

A data bank, for Qattara Depression characteristics, has been built, using GIS, including morphological, meteorological, and hydrological characteristics. Evaporation from the salt accumulated water, in the depression, is calculated, annually, for fifty years.

Acknowledgments

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