Arab J. Nucl. Sci. Appl, Vol 51, 2, 58 -67 (2018)

Arab Journal of Nuclear Sciences and Applications

ISSN 1110-0451 | *Web site: ajnsa.journals.ekb.eg* | (ESNSA)

Evaluation of Potential Hazards Associated With Qattara Depression as a National Hydropower Project in Egypt

W.M. Moustafa, R.A. Hussien and N. Nassar
Egyptian Nuclear and Radiological Regulatory Authority

Received 20th Sep 2017
Accepted 22nd Oct 2017

The objective of this paper is to evaluate, assess and study the potential hazard associated with the proposed national hydropower project at Qattara Depression. To achieve this objective, the two elements of sustainable development of this vast area, water and power, were developed. The Old Delta lies in the Western Desert of Egypt. It begins from the west of Assiut aligning the western outskirts of El Minya and Al Faiyum and terminated by Qattara Depression in the northern portion. It is a natural depression that covers about 2% of Egypt area. The depression depth is about 134 m below the sea level. A Clean electric generation could be achieved from the net head of filling Qattara Depression. Qattara Depression has the super potentiality of generating clean hydropower during the filling period and also has a high potentiality after filling period. This hydropower can provide Egypt with future needs and could be exported to Eastern Nile countries. The hydropower generation from Qattara Depression does not need filling time, high cost building dam. Previously eleven sites comprising 76 core samples of Lower (sandstone) and Middle (limestone) Miocene age were collected from the northeastern tip of the Qattara Depression in the north of the Western Desert of Egypt. The majority of samples showed weak to very weak remnant magnetization with goethite, hematite and titan magnetite as the main magnetic carriers. However, with a careful, detailed thermal demagnetization, they yielded stable, probably primary, magnetization. The resulting overall mean direction corresponded to a palaeomagnetic which seems to agree with other known African Miocene poles. This result implies that the Qattara area has been stable at least since Early Miocene. The presence of goethite as the main magnetic carrier supports the assumption that weathering has been playing an important role in the development and shaping of the depression. The possible site hazards associated with this project could be evaluated from different points of view, in order to give an overview to this promising project. The Qattara Depression, as a national project in Egypt, can achieve some accomplishments such as ; defending the Nile River Delta and the Mediterranean countries from the sinking or inundation of the Sea Level Rise (SLR) and reduce the cost of protecting coastal shores , generate hydroelectric power between 1000 to 2000 MW (depending on the filling water rate) from Qattara Depression (under the sea level by depth of -60 (MSL) in average, desalinating water in large quantities; providing new areas, particularly for the refugee in case of the sinking or inundating of some parts of the Delta, due to the (SLR); Supporting housing, fish farming, tourism, and agriculture.

Keywords: Hazard assessment, Hydropower project, Qattara Depression.

Introduction

Egypt is highly vulnerable to climate change impacts, according to several national assessments. Coastal zones, water resources and agriculture are the most vulnerable sectors. Climate change risks may affect Egypt's future development plans. Egypt should, thus, start to implement adaptive strategies for managing climate risks in vulnerable areas [1]. For this reason, the present work was set

Corresponding Author: nagwa2009200@yahoo.com
DOI: 10.21608/ajnsa.2018.6511

in order to investigate the filling scenarios of the Qattara Depression to adapt to sea level rise. Recently, there has been a serious concern to use the Qattara Depression as a basin to discharge the extra water resulting from the global warming. The transformation of the Qattara Depression into inland sea could provide sea level adjustment, as well as generate energy, induce rainfall over some of the desert margin areas, reduce hot desert temperatures, and produce new fisheries and resorts. The above investigation phases are presented under the following headlines:

- Area description
- Geology of the study area
- Reviewing of literature in the field of climate change and Qattara Depression
- Evaluating the studied area
- Assembling data and implementing them
- Outlining the hydraulic characteristics of the study area.
- Designing the different scenarios and simulating them
- Hydrogeology and hydrochemistry

Area description

The Qattara Depression in the North Western Desert of Egypt, which is the largest natural closed depression of the eastern Sahara, is a region where salt weathering appears to be particularly effective (Fig. (1)). It is of an almost triangular shape, its head at Assuit Barrage and its base ends of the Mediterranean Sea. The climate of the area is arid with high temperature and low precipitation. .The temperature ranges between 35 ºC, in summer, and 20 ºC in winter. Participation ranges between 5 mm, in January, and 0.8 mm, in April. Evaporation ranges between 1.8 mm/day, in January, and 7.9 mm/day, in June. Relative humidity ranges between 56%, in May, and 66%, in December, wind speed ranged between 7 km/hr and 9 km/hr.

A common origin by wind deflation to a base level controlled by the groundwater table has been the generally accepted explanation [2, 3, and 4]. Other explanations include solution, mass-wasting followed by wind deflation [5], or the depression was originally excavated as a stream valley, subsequently modified by karstic activity, and was further deepened and extended by mass-wasting, deflation and fluviatile processes .It has been recently suggested that the depression is of a structural control origin [6]. Although most studies have noted the presence of an extensive sheet of sabkha that covers the floor of the Qattara Depression, a salt-weathering origin for the Qattara Depression had not been proposed. A previous paper described the results of field studies of evaporite sediments in recent sabkhas and in scattered, isolated hills at elevations of 25, 75 and 100 m below sea level (b.s.l.) in the Qattara Depression and petrographic descriptions of core samples. The purpose of the study was to assess the rate and nature of weathering in this environment. It proposes that, rapid erosion of the depression is favored by the high sodium chloride content of the near surface groundwater, combined with alternating wetting and drying cycles caused by sporadic groundwater seepage and occasional rainfall and evaporation.

The Qattara Depression forms one of the most significant morphological features of the North Western Desert of Egypt. The depression is a closed inland basin that is bounded from the north and west by steep escarpments, with an average elevation of about 200 m above sea level (a.s.l.). Towards the south and east the floor of the depression rises gradually from 60 m b.s.l. to the general desert level at 200 m a.s.l. (Fig. (1c)). The depression has an area of some 19500 km2, its length is about 300km, and width varies between 50 and 150 km. The total storage capacity of the depression is 197 billion cubic meters (BCM). Its lowest depth is -142 m. The depression is estimated to have an excavated volume of 3200 km3 [7].Within the depression, cones, towers, mushrooms and plateau- like hills, ranging in height from 5 to 30 m, are common, especially, near the western scarp of the depression.

Geology of the study area

The Qattara Depression is excavated into northerly dipping Miocene and Eocene rocks (Fig. (1d) and Fig. (1e)). Sandy and clayey layers of the Lower Miocene Moghra Formation form the bottom and the surroundings of the depression (Fig. (1B)), where the elevation ranges from 50 to 80 m b.s.l. In some areas, the Moghra sediments occur as small plateau and dissected hills within the sabkhas. Middle Eocene calcareous sediments of the Mokattam Formation form the southern scarp of the depression. The Upper Eocene–Oligocene

Dabaa Formation underlies the southwestern part of the depression, including all areas below 100 m b.s.l. It consists of black shales and contains abundant gypsum veins and shark bones and teeth. The northern steep escarpment is associated with the Middle Miocene calcareous sediments of the Marmarica Formation, with a thickness of a few meters at the rim of the depression, increasing to several hundred meters at the coast, where Pliocene carbonate rocks are exposed. Over large areas of the floor, the bedrock is covered by younger deposits, including windblown sand, sabkhas and Quaternary evaporite sediments. The sands that cover most of the depression is associated with moist sand sheets with adhesion ripples at the surface in the northeastern part of the depression and large parallel, longitudinal, lunette, seif and complex dune belts in the southern part of the depression. The dune axes trending north–northwest– south–southeast, parallel with the prevailing wind direction. The dunes are composed mostly of quartz sand mixed with minor carbonate, mud, shale and gypsum fragments. Near the southwestern part of the depression, the dunes are black due to their high content of black shale fragments derived from the Dabaa Formation.

The sabkha sediments also cover large areas of the floor and lower slopes of the depression (about 5800 km^2), generally occurring at or below the elevation of 50 m b.s.l. At the northeastern part of the depression, the sabkha is commonly moist, and consists of loose windblown sand and silt that contains sporadic halite and gypsum crystals. In the western and southwestern part of the depression, the sabkha sediments are wet or dry in many places and have a rough granular salt crust that grows within the bedrock of the Moghra and Dabaa Formations.

The Quaternary evaporite sediments cover isolated, scattered hills, 5–30 m in height, at the lower slopes of the western scarp as well as isolated plateau at the ground elevations 25, 75 and 100 m b.s.l. in the southwestern part of the depression. The hills are scattered around the wet and dry sabkhas and consist of the clastic facies of the Pliocene/Pleistocene Kalakh Formation or the Lower Miocene Moghra Formation or the shaley facies of the Upper Eocene–Oligocene. These facies are encrusted with an up to 50 cm thick, hard, indurated gypsum/anhydrite crust or contain up to 30 cm in size, gypsum/anhydrite nodules near the top.

The exposed stratigraphic section around the study area is composed of a sedimentary sequence ranging in age from the middle Eocene to the Quaternary (Fig. (2)). The middle Eocene calcareous sediments of the Mokattam Formation form the southern scarp of the depression. The upper Eocene Qasr El Sagha Formation is composed of black shales with coquina and oyster intercalations [9]. The Miocene rocks in the study area are represented by two formations: a lower Miocene fluvio-marine Moghra Formation and a middle Miocene shallow marine Marmarica Formation [10]. Sandy and clayey beds of the lower Miocene Moghra Formation form the bottom and the surroundings of the Qattara Depression, where the ground level reaches 50 to 80 m below sea level.

In parts of the study area, the Moghra sediments occur as small plateaux and residual hills within the Quaternary sabkhas. The Quaternary deposits are represented by unconsolidated eolian sands, sabkhas and wadi filling unconformably overlying the Miocene rocks [11, 12]. The eolian sands occur as seif dunes that are composed of very fine sands with few detrital carbonates. The sabkha sediments cover large areas of the floor and lower slopes of the Qattara Depression, occurring at or below the elevation of 50 m below sea level. In the Qattara Depression distinguished three types of evaporates based on their relative age and ground elevation, in relation to the groundwater level. Type 1 evaporite sediment is the oldest, representing the earliest record of the Quaternary aridity in the Qattara Depression. The evaporite sediments are present as random, isolated or dense, 2–15 cm evaporite nodules that grow dis-placively within the top of the Moghra clastics. Type 1 evaporite sediment is regarded as an erosional remnant of a sabkha deposit that was formed at a time when the floor of the depression stood 5–30 m higher than at present. This type also represents the former level of the groundwater table which may coincide with the arid episodes of the Quaternary [13], or may have controlled by the groundwater discharge pattern during the Quaternary. Type 2 evaporite sediment forms an indurated rough sabkha surface. It consists of gypsum/ anhydrite or halite crusts. Type 3 evaporite sediment is recorded as levels lower than types 1 and 2 evaporite sediments, as wet, rough sabkha surface. It represents the last stages of a lowering groundwater table, where the sabkha surface is recorded in the capillary evaporation zone of near surface groundwater.

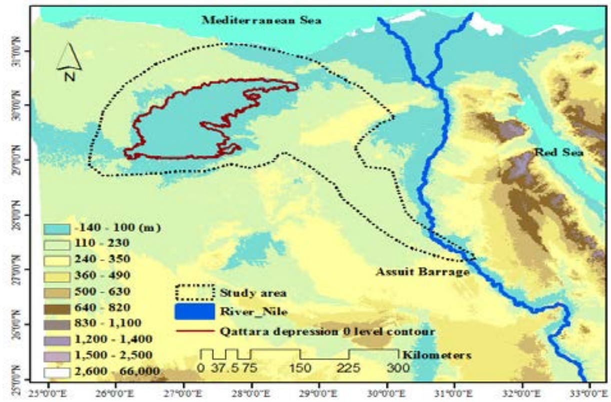


Fig. 1. (a) Qattara map

Fig. 1. (b) Photo of Qattara Depression

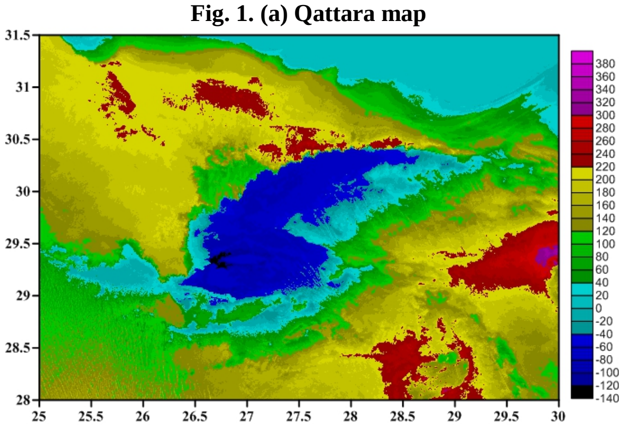


Fig.1(c) Digital Elevation Model (DEM) for the study area.

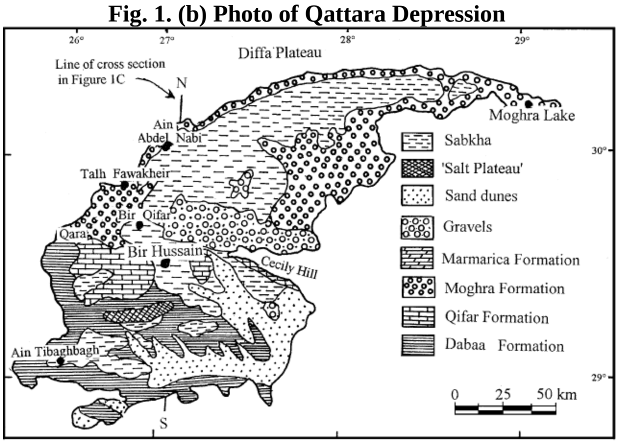


Fig. 1 (d) Geologic map of the Qattara Depression [8].

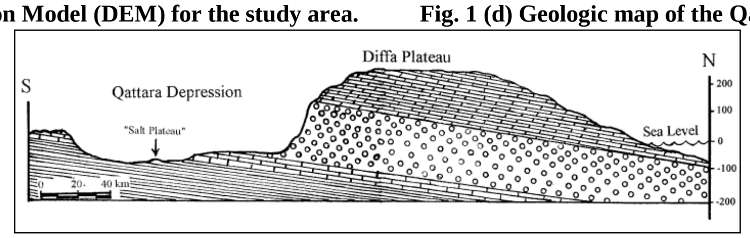


Fig. 1 (e) Geologic cross-section of the Qattara Depression

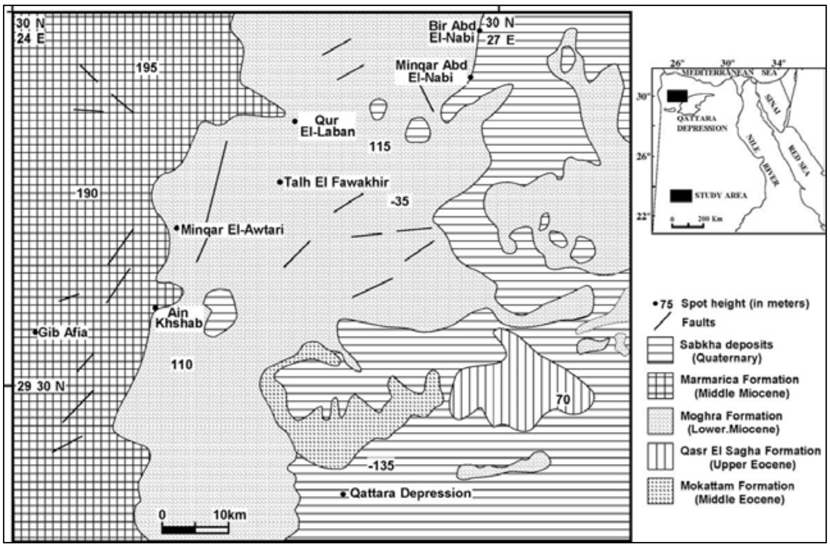


Fig. (2) Map showing location and geology of the study area [14].

Literature review

Primarily, literature, in the field of flood risks, was reviewed. Many articles in the different journals, Periodicals and magazines were assembled and reviewed. Also, many reports from the different authorities and organization were studied. Based on the revised literature, it was found that many researchers investigated the flood risks due to climate changes and Qattara Depression, locally and worldwide.

Evaluation of the study area

The main target of this evaluation is to detect the deeper subsurface structures and to investigate their possible relationships with earthquake activity. The RTP aeromagnetic map was used to detect the regional extension of the structures interpreted from the land magnetic survey. The RTP land and aeromagnetic maps were interpreted by the filtering technique, least-squares separations, tectonic trend analysis, spectral analysis, Werner method, Euler method, and 2D techniques. The results show that the main tectonic trends are 35° N–45° W, 45° N–65° E, E–W, and Aqaba. Moreover, two seismic lines, WQ85-31B and 127 were interpreted, and their location was matched with the deduced tectonic map. The results show great matching between the location of the faults deduced from both the geomagnetic and seismic data. They agree completely with the well logging data. Furthermore, these structures correlate with the earthquake activities recorded by the Egyptian National Seismological Network (ENSN).

The recent seismicity maps (Fig.(3)), developed by the ENSN (1997–2003), and indicates that the study area shows very low, almost missing, seismic activity. This explains why surface faults are absent or rare. This indicates also that the recent tectonics of the study area have been more stable than those of other adjacent areas close to the Mediterranean Sea or the Nile Delta. Dealing with the flood hazard, there are two probabilities of flooding risks, in Egypt.

- The first risk might occur in the coastal area in the Nile Delta due to Sea Level Rise (SLR) and Delta subsidence ,and
- The second risk might occur due to high flood over the Nile River banks.

Qattara Depression in Egypt, could supply new safe area for future development plans and could minimize the risk of floods, these areas are:-

- A canal could be dug from the Mediterranean Sea to the depression to save the water due to the SLR.
- A canal could be dug from the Nile River Nile to the depression to save the high floods of the river.

Assembling and implementing data

The digital elevation model (DEM) was used to generate triangulated irregular Network (TIN) map of the study area. Stream lines of canals, bank, flow paths, Qattara Lake storage, cross sections, land use, and hydraulic parameters were generated and digitized into the GIS and HEC-RAS environment. HEC-RAS is used to define the main topology, lengths, elevations, station name, and Manning roughness coefficients of all generated features. HEC-GeoRAS is used to generate geometric file as input for the Hydrologic Engineering Centres River Analysis System HECRAS. It is prepared by the US corps of Engineers, Fig. (4).

Outlining the hydraulic information of the study area

From the assembled and analyzed data, the following hydraulic information, about the study area, could be outlined:

Once the high flood water is discharged from Assuit barrage to Qattara Depression, rather than Toshka Depressions, the bed level depth of Assuit barrage will increase (i.e Not less than 15 m). Also the Nile velocity will increase.

Larger cross section areas of open channel canals and the flows were designed according to Table (1).

Designing and simulating of scenarios

Three scenarios were designed and simulated. These scenarios were as follows:

1st scenario was designed to connect the Mediterranean Sea to the depression to fill it with saline water

2nd scenario was outlined in digging a canal from the Nile River to the depression to collect the water during the high flood season

3rd scenario was designed to desalinate the water and use it together with the groundwater to develop the area around the depression.

Evaluating the results of scenarios

The designed scenarios were simulated and results were obtained. These results were analyzed. The results of the three scenarios were evaluated.

Conveying part of the storage from Nasser Lake to Qattara Depression (Second Scenario) might reduce the flood risk and might reduce the evaporation loss from Nasser Lake. This is emphasized by Shafik N M, 2010 who studied evaporation loss from Nasser Lake. It was stated that 1 billion cubic meters (BCM) could be saved if HAD level was reduced by 2 m. The water level decreases at the upstream of HAD will increase the Nubian Aquifer discharge to Nasser Lake by about 1.5 BCM, annually. The evaporation loss from branched khores will be reduced.

This was also emphasized by El-Sherbini [15], who studied HAD and the Qattara Depression. It was further hinted at the beginning of a new delta formation (i.e. 250 km long, it starts from Tunjur Village, 30 km south of Wadi Halfa, and extends till the Toshka area). This delta will reshape the river to discharge its water into new side branches on both banks of the lake. The study recommended the storage in Qattara Depression. On the other hand, this was further emphasized by Hanaa Nother [16], who studied the environmental changes in the area of Nasser Lake. Despite the large size of the lake, its water is almost closed, thus limiting the ability of self-purification. The lake is subjected to a complex indoor water cycle that overlaps with other cycles occurring in its sub margins (i.e. 228 Khores). Large numbers of khores makes small boats to be lost in the lake, and large ships lose their way. There are many shallow side khores. These increase the water losses by evaporation. Mixing of khores water with the lake water is very limited; as a result, if pollution reached the khores it would remain inside them to be transmitted into the lake at low level periods.

Nasser Lake is exposed to thermal stratification phenomenon in summer where the lake is classified into 3 layers. The middle layer prevents the passage of the bottom layer to the upper layer. Once pollution reached the bottom layer, the anaerobic reactions due to lack of oxygen will happen, thus, emitting nitrogen and phosphorus gases. As a result, fish will die emitting hydrogen sulphide, methane, and ammonia gases, which would deteriorate water quality. The withdrawal from the lake is mainly from bottom layer in front of the HAD. This causes major threat to the main course of the Nile in Egypt. Arid weather conditions increase water needs for agriculture. Each feddan, around Nasser Lake, needs 18600 m^3/feddan/year with irrigation efficiency system of 90% (i.e. drip irrigation systems); while each feddan, in the Delta and Nile Valley in Egypt, needs 6700 m^3/feddan/year of water.

The high temperature and high light intensity, reduces the growth of many plant and animal breeds, they reduce the nitrogen fixation efficiency in leguminous crops; they lower the sugar concentration in beets and increase the infertility in Egyptian Buffalo factions.

Sand dune around Nasser Lake spread by wind covering the plantings or uprooting it during stages of flowering and growth. Sand dunes sedimentation into the lake is about 1.5 million m^3/year. Low soil slopes leads to the difficulty of water access to higher land allocated for agriculture on Nasser Lake. Fish farming, inside Khores (i.e. in floating cages or concrete ponds) transfers dead or alive algae and industrial feed waste used as nutrients that pollute Nasser Lake Water.

The General Authority for Rehabilitation Projects and Agricultural Development in Egypt studied the groundwater sources in the area southeast Qattara Depression. It was stated that the main aquifer in this area is the Nubian Sandstone Aquifer, which has a high productivity. 3 test wells were dug in this region where their productivity were 70 m3/s, self-flow, and 350 m3/s using pumps. Salinity of the water is 650 mg/l which is safe for all purposes of agriculture, irrigation and drinking. Each well can irrigate 220 feddan with 300 m^3/s for 16 hours and 20 m^3/day per feddan. It was stated that the aquifer depth is about 1800 m starting at a depth of 800 m with a thickness of 1000 m.

The groundwater sources were studied in the area south of the Qattara Depression by digging 3 other wells where their productivity were 400 m^3/s, self-flow.The Salinity of the water was 192 mg/l, which is safe for all purposes of agriculture, irrigation and drinking. Each well can irrigate 3000 feddan with 300 m^3/s for 16 run hours and 20 m^3/day per feddan. Aquifer Depth is about 2000 m that starts at about 800 m with a thickness of about 1200 m. Sodium carbonate adsorption ratio reflects that the groundwater is safe for all purposes of agriculture and irrigation in all 6 wells.

RIGWA company consultancy studied the groundwater in Egypt. Aquifer thickness ranges between 70 and 700 m at discharge 25 of m3/day in Freij Valley to less than 1 m3/day near the Qattara Depression [17].

The soil, Water and Environment Research Institute (SWERI) studied land classification around Qattara Depression. The soil, climate, and water sources are possible to allow the establishment of agricultural projects. This area is characterized by vast continuous land close to the northwest coast. The desert road near Alamein City in northwestern coast goes through this vast area to the southern oases in the western desert. Also, there are some internal asphalt roads that connected this area by Wadi Natrun road. Most of this land area is sedimentary and similar to soil and climate of many successful agricultural projects in the western desert in Egypt.

Hydrogeology and hydrochemistry

Since the Qattara Depression forms the deepest point in the Western Desert of Egypt, groundwater flow in all aquifers bordering this area is consequently directed to this final base level [18]. Most of the groundwater that evaporates in the depression comes from the Moghra Aquifer system which is recharged from four sources; the Nubian sandstone aquifer in the south, Nile water in the east, saline water from the Mediterranean Sea to the north, and rain water. In contrast, in the western part of the depression, groundwater seepage is recharged from Nubian and Upper Cretaceous–Eocene aquifer systems]. The Moghra aquifer water is of the sodium chloride type (Qattara Project Authority, 1979), it increases in salinity from a relatively fresh water zone (1650 ppm chlorides) at a depth of 1000 m to a relatively saline water zone (100,000 ppm) at the depth 2200 m [19]. The estimated amount of groundwater flow to the depression is 3.2 m^3/s, while the total evaporation from the depression is 7.2 m^3/s (Qattara Project Authority, 1979. Upon evaporation, the groundwater seepage to the Qattara Depression increases in salinity. The near surface groundwater ranges in salinity from 3.3 g/l around the Moghra Lake at the east, to 38.4 g/l at the center to about 300 g/l in the sabkha area to the west. An exception to this east–west increase in salinity is found around fresh water springs such as at Bir Qifar area. El Bassyony (1995) interpreted the east–west increases in salinity from 43.6 to 421.0 g/l to the leaching of salts by surface water and groundwater, and due to excessive evaporation of groundwater at or slightly below the surface in the lowest part of the depression. The results of the chemical analyses performed by the Qattara Project Authority of the near surface groundwater in the Qattara Depression are shown (Fig. (4)). This data can be used to determine the origin of groundwater. The data show that most of the water samples are of the chloride type ($MgCl_2$ and $CaCl_2$) of marine origin. A few samples are, usually, of the $NaHCO_3$ and Na_2SO_4 types of meteoric origin. This indicates either the large influence of original seawater invasion, or the dissolution of the Moghra aquifer water of salts from the host rocks or preexisting salts. The westward increase in salinity of the chloride-type groundwater allows excessive crystallization of a near-surface thick halite crust in the western part, in contrast to the eastern part of the depression.

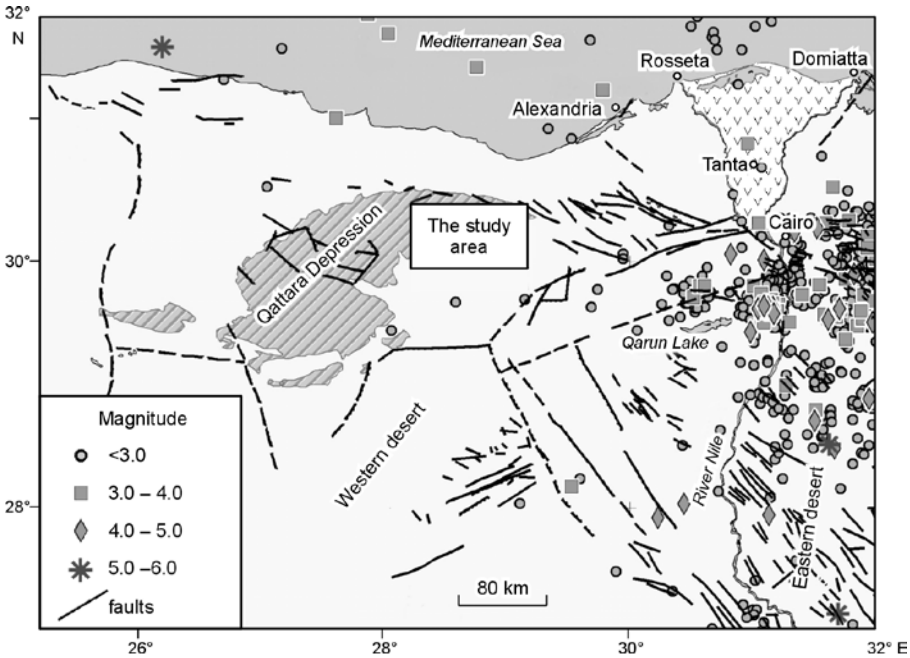


Fig. (3) Recent earthquake activities (1997–2003) in the northwestern part of Egypt, recorded by the Egyptian National Seismological Network (ENSN).

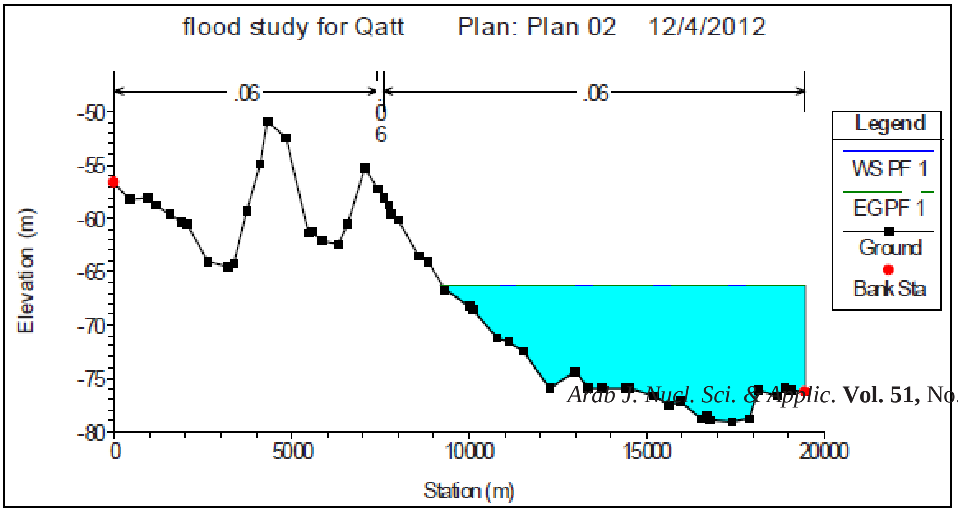
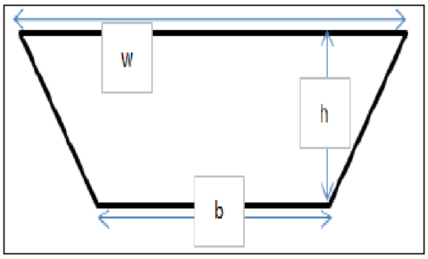


Fig. (4) Geometry of a cross section in study area

Table (1) Canal characteristics

	discharge *(m^3/s)*	*velocity* *(m/s)*	*h* *(m)*	*w* *(m)*	b (m)
Upper reach (intake)	800	0.5	15	115	100
Lower reach	600	0.5	12	112	100
Sub lower reach	200	0.5	8	58	50



Conclusions

The deduced fault structures do not cut Quaternary or near-surface rocks. This is also indicated by the seismicity map of northwestern Egypt, compiled by the ENSN. The correlation with the earthquake implies that the studied area is more stable than other adjacent areas in the northern parts of Egypt close to the Mediterranean Sea and the Nile River Delta. The obtained results suggest that, since the Early Miocene, tectonics have either played no significant role in the formation of the depression or resulted in movements that could not be detected palaeo-magnetically. Preferably, the weathering processes seem to have been strong and could have played the principal role in the development of the depression. This work is considered a guideline during any exploration process and for establishing any new towns or strategic projects in the area. GIS and HEC-RAS were used to study the filling scenarios of Qattara Depression. ***Based on the investigations, it was found that:*** From the hydraulic point of view, there is no significant difference between filling the Qattara Depression from Mediterranean Sea or from River Nile, as the Depression can store huge amounts of water.

It was thus recommended to

- Reduce the storage level in front of the HAD. This will secure Egypt in the event of high flood of the High Dam, and transfer part of the storage to the Qattara Depression.
- Reduce the level of the Nile River, thus the canals can accommodate the flood in the high seasons, which is sinking islands and return to agricultural drains beginning from Aswan.
- Reduce the rate of evaporation from Nasser Lake and increase the power of the HAD and the Aswan Old Dam.
- Use the groundwater and desalination of brackish groundwater to cultivate strategic crops as wheat, which is cultivated by brackish or fresh water.
- Use clean and renewable energy to reduce the costs of pumping water and wastewater treatment.

References

1- Albritton, C.C., Brooks, J.E., Issawi, B., Swedan, A. Origin of the Qattara Depression, Egypt. Geological Society of America Bulletin 102, 952–960(1990).
2- Ball, J.,Problems of the Libyan Desert. Geographical Journal 70, 21– 38(1927).
3- Ball, J. The Qattara Depression of the Libyan Desert and the possibility of its utilization for

power production. Geographical Journal 82, 289–314(1933).

4- Squyres, C.H., Bradley, W. Notes on the Western Desert of Egypt. Conference ,Petroleum Exploration Society, Libya, pp. 99– 105(1964).

5- Said, R. New light on the origin of the Qattara Depression. Societe de Geographie d'Egypte Bulletin 33, 37– 44(1960).

6- Gindy, A.R. Origin of Qattara Depression—discussion. Geological Society of America Bulletin 103, 1374–1375(1991).

7- Peel, R.F. The landscape in aridity. Institute British Geographers Trans 38, 1 – 23(1966).

8- El Bassyony, A.A. Introduction to Qattara Depression. Journal of Electrical Energy 5, 4 – 12(1990)

9- Said R. Cenozoic. In: Said R, editor. The Geology of Egypt. AA. Balkema Publ; p. 451– 86(1990).

10- Said R. The geology of Egypt. Amsterdam7 Elsevier; 377 pp(1962).

11- El Bassyony, A.A. Sabkhas of Qattara Depression, Western Desert, Egypt—a survey. Sedimentology of Egypt 3, pp. 13– 26(1995).

12- Aref M, El-Khoriby E, Hamadan M. The role of salt weathering in the origin of the Qattara Depression, Western Desert, Egypt. J Geomorphol 45:181– 95(2002).

13- Haynes C. Geological evidence of pluvial climates in the Nabta area of theWestern Desert, Egypt. In: Wendrof F, Schild R,editors. Prehistory of the Eastern Sahara. Academic Press; p. 353– 71(1980).

14- Conoco Coral. Geological map of Egypt, NH 35 Siwa Oasis; 1:500,000(1986).

15- El-Sherbini M I. High Dam and the Qattara Depression. Geology Department. Faculty of science. Mansoura University.Egypt; (2005).

16- Hanaa Nother. Environmental changes in the area of Lake Nasser. Egypt: PhD thesis. Faculty of Arts. Alexandria University; (1999).

17- Soil ,Water and Environment Research Institute (SWERI). Land survey classification in Qattara Depression, Marsa Matrouh governorate. Ministry of Agriculture. Agriculture Research Center. Egypt; (2011).

18- Qattara Project Authority, Study Qattara Depression—Draft Feasibility Study-3, Topography, Regional Geology and Hydrogeology. Ministry of Electricity and Energy, Egypt, 118 pp(1979).

19- Ezzat, M.A., Groundwater Series in the A.R.E.—Exploration of Groundwater in El-Wadi El-Gedid Project Area (New Valley).Ministry of Agriculture and land reclamation, Cairo, 121 pp(1974).