AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Irrigation & Hydraulics Department

Sustainable Groundwater Management Using Solar Energy

A Thesis submitted in partial fulfillment for the requirements of the degree of

Doctorate of Philosophy in Civil Engineering

[Irrigation & Hydraulics]

By

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Master Degree, Civil Engineering - [2016]

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STATEMENT

This thesis is submitted to Ain Shams University in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Civil Engineering "Irrigation and Hydraulics Department".

The work included was carried out by the author.

No part of this thesis has been submitted for a degree or a qualification at any other institute or university.

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SUMMARY

Sustainable Groundwater Management Using Solar Energy

Both energy and water are the two major pillars for developments all over the world. Due to the variation in accessibility and utilization of groundwater in many countries of the world, is its management becomes complex and a great challenge. Groundwater modeling has been an effective way to face this challenge. Egypt is considered one of the countries of the Sun Belt with high solar radiation which gives it one of the greatest potentials for solar energy application. Accordingly, Photovoltaic panels are being frequently used to pump groundwater to provide water for various proposes. As groundwater is the main source of water in the Western Desert of Egypt, and solar radiation is one of the renewable sources of energy. Therefore, it has become important to study and analyze the capabilities of these alternative sources.

The current study presents the application of solar energy in the groundwater management in Moghra Oasis (region that lies in North-East corner of Western Desert, and includes El-Dabaa, Moghra lakes and part of Qattara Depression). Moghra region is one of the areas of 1.5 Million Feddan land Reclamation Projects in Egypt.

The main aim of this thesis is to achieve the sustainable development based on groundwater and solar energy in the Moghra region. To realize this goal, a Multi Criteria Analysis was applied to determine the best location of solar energy plants used for

groundwater pumping, the applied multi-criteria layers include topography, solar radiation, depth to water, salinity, accessibility and land-use.

In order to simulate the different management scenarios, a three dimensional model using the MODFLOW software was constructed and calibrated using the available data. The scenarios include suggesting of proper extraction plan that could achieve the sustainable groundwater management, taking into consideration the impacts of climate change on Moghra aquifer groundwater in terms of temperature increase and sea level rise. The Moghra aquifer model is used to test the effects of nine proposed scenarios on groundwater levels decline in the study area after 100 years. Also, the impacts of climate change on groundwater in terms of sea level rise and temperature increase were investigated, the power needed for delivering the water demands and the required area of Photovoltaic (PV) plants were determined in Moghra region.

The model results led to the following conclusion: the best location for PV panels is close to the Nile Delta and outside the boundary of oil fields, Moghra Lake and Qattara Depression (restricted areas) where the depth to water is less than 100 m and the salinity is less than 5000 ppm. As well as the best management scenario is to pump a total rate of 1.2 Mm^3/d of water using 1000 wells serving a total area of 85,714 Feddan. The maximum drawdown of about 91.94 m will occur after 100 years. This scenario matches the maximum drawdown recommended by the MWRI for the next 100 years. Also, Sea Level Rise (SLR) has mild effects on groundwater levels due to the vast aquifer dimensions and when the

temperature increases by 2°C and 4°C, reference crop Evapotranspiration (ET_o) is expected to increase by around 5.14 %, and 10.29 %, respectively. Finally, the power needed for delivering the water demands and the required area of Photovoltaic (PV) plants will continuously increase due to the expected increase in water level drawdown.

As a general conclusion, a 3-D hydrogeological model was developed that can be used in for evaluating the groundwater management scenarios to determine the most sustainable strategy that can be implemented in the new reclamation projects using the renewable solar energy and taking into consideration the climate change. The developed model was applied to Moghra region as a part the ambitious project "1.5 Million Feddan" and can be applied to any other similar projects.

Keywords:

ArcGIS; Climate Change; Groundwater Management; MODFLOW/GMS; Moghra Aquifer; Solar Energy.

TO SPIRIT OF MY FATHER

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