Evaluation of Groundwater Potential and Proposed Scenarios for Development in the Eastern Desert of Egypt : (Case study; Wadi Qena)

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Abstract: Groundwater is the main source of water especially in the Egyptian deserts where surface water is not available. The eastern desert and its valleys are considered one of the priority areas for development based on the groundwater as a principal source for different activities. Wadi Qena is one of the most important valleys in the Eastern Desert, it lies on the axis El Saeed - the Red Sea, which was created to link between Asyut and Sohag cities. To achieve an integrated development plan for this valley, hydrogeological studies were applied for evaluating groundwater potential and assessment of the future development activities of this valley in the field of agriculture and land Reclamation. The main objective of this research is to investigate the hydrogeological characteristics of the study area, evaluate groundwater potential and to simulate the proposed development scenarios based on groundwater during the period of 50 years of operation. To achieve the objectives of the research, wells inventory include locations and extractions for all production wells have been carried out in the study area. The total amount of extraction concentrated in the south part of the study area. Evaluation of groundwater potential for the present two aquifers systems was based on the calculated hydraulic parameters from the pumping test of three experiment/production wells. A numerical groundwater flow package Visual modflow was used and the evaluation of the present conditions has been simulated. The modeling was used to test the proposed scenarios for groundwater development for 50 years. The results of the current research indicated that groundwater potentiality could be classified as medium (at the southern part) to low (at the northern part) and any further groundwater extraction should be controlled in future.

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Key words: Groundwater potential, modeling, Wadi Qena, development Scenarios.

1- Approach:

Aquifer potential may be defined as its ability to supply water with good quality and suitable rate at a certain time and place needed to sustain the required development. The main factor that may affect groundwater potential is the continuity of the source in both in terms of ***quality*** and ***quantity***. Quantity refers to the availability of the source, while quality refers to its suitability for a specific use.

Several options for groundwater management in Wadi Qena region can be initiated for agriculture development. The preference of one option over another depends on the hydrogeological conditions which represented mainly in the groundwater potential and the effect of aquifer discharge on the groundwater level during the period of development (50 years).

To satisfy the research objectives, the following approach has been adopted:

1. Data collection and evaluation of the available data.
2. Analyses and interpretation of field investigation.
3. Simulation of the study area for present hydrogeological conditions.
4. Test proposed scenarios for development for a period of 50 years.
5. Evaluation of groundwater potential for the aquifer systems

2. Description of the Site

Wadi Qena is located in Eastern Desert, between latitudes °26.10, 28°00 N, and longitudes 32° 15, 33° 30 E, and occupies an area about 15,000 km2. It extended from north to south parallel to Nile river with length 30km. Wadi Qena is situated within five governorates; Qena; Sohag; Assyut; Menya and Beni Swief, and links these governorates with The Red Sea Governorate. Figure (1) shows the general location of Wadi Qena region.

3. Hydrogeological Setting of the Wadi Qena

The hydrogeological setting of the study area was built up on the geological, geophysical investigations and the available data of old and recent drilled bore holes. The hydrostratigraphic units of the Wadi Qena could be divided into five horizons (Figure 2) in the following:

a) Quaternary aquifer, (first horizon)

The Quaternary aquifer lies on the top most part of the hydrogeological section. It consists of different types of deposits as; sandstone, gravels, conglomerate with silt and sand interbeded, with a thickness ranging between few meters to more than

75m, this thickness decreases in north, and these facies change to clay, shale and silt. These deposits considered as a shallow aquifer.

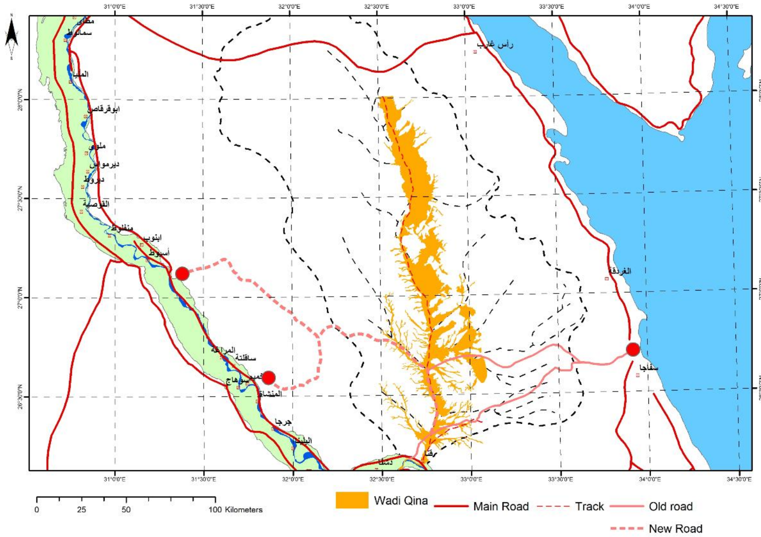

Figure1. Location Map for the Study Area.

The subsurface aquifers are generally recharged by direct infiltration from precipitation and surface water run off that scuttle down from the eastern mountains Plateau of the Red Sea (Figure 2) along almost EW and NE wadies.

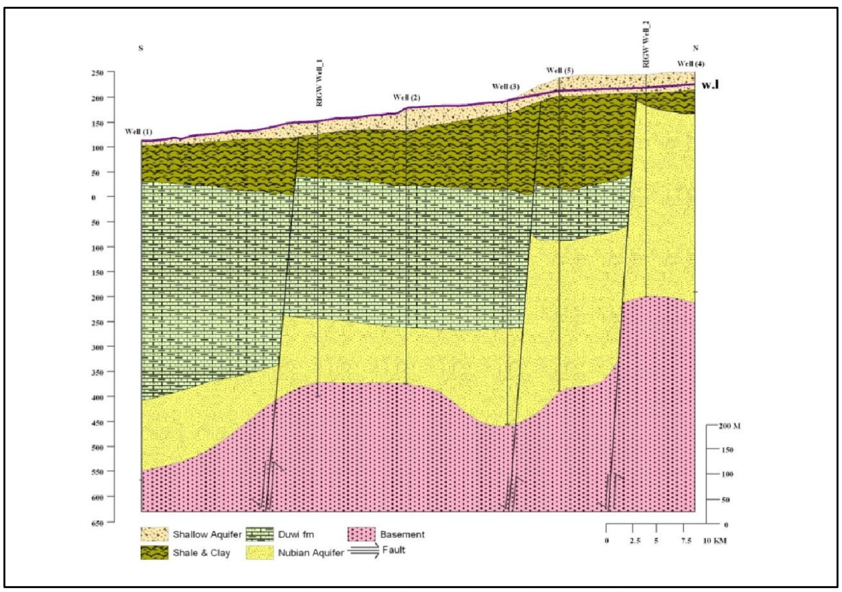

Figure 2. Aquifer configuration of Wadi Qena

b) Shale or clay: (second horizon),

It consists of different types of clay, shale with a thickness ranging between 50 to more than 100m. These impervious deposits considered as aquiclude horizon.

c) Fracture limestone and dolomite: (third horizon)

It consists mainly from fractured limestone and dolomite with marl and gypsum intercalations. The thickness of this deposits ranging between 100 to 250m, it considered as moderately productive aquifer, belonging to Upper Cretaceous age.

d) Lower Cretaceous sandstone: (Nubian sandstone)

It is considered the main sandstone aquifer in the area and composed of sandstone with clay intercalations, the thickness of this horizon ranges from 100 to 350m (the lower Cretaceous aquifer).

e) The basement complex: (igneous and metamorphic horizon)

It consists of different types of igneous rocks. These rocks usually contain joints and cracks which are considered as conduits and very important for recharging all the aquifers in the Wadi area (lateral recharge). This type of rocks considered an aquifuge horizon with thickness of more than 2000 m.

Water Quality

9 water samples were collected from the observed and production wells for the shallow and deep aquifers in the study area and analyzed for major elements and salinity. The results of the analyses indicates that the groundwater salinity of the deep aquifer is ranging between 1600 ppm and 2200 ppm from south to north of wadi area respectively. While groundwater salinity of the shallow aquifer is ranging between 3000ppm to 5000ppm, due to the limited aquifer recharge.

4- Ground Water Flow Model

The numerical modeling is a powerful and helpful tool for the analytical solution, especially when the area of model has variability and complicated in the hydrogeological conditions as acquired in the study area. In addition, it is good tool for testing the development proposed scenarios and its effect on the groundwater levels after 50 years and also determine the safety distance between the production wells to avoid overlapping cone of depression. To satisfy this objective the latest version of numerical modeling software (Visual Modflow 4.2) was used.

4.1 The Simulation Code

Visual MODFLOW 4.2 is a multi-dimensional, finite difference, block-centered, saturated groundwater flow code. It is a fully integrated package combine Modflow, Modpath and MT3D, where MT3D is used to forecast future concentrations of TDS.

4.2 Geometry of Modeling Area and input data

The regional groundwater model covers Wadi Qena with longitudinal length 82 km. The modeled area was divided into 200 cell in north south direction and 200cell in east west direction, with total cell 40000, and include four layers represented in (Figure 4):

- -layers (1,2) (Quaternary): represented in the upper unconfined aquifer with average thickness varies from 60 to 120m.
- layer 3: represented with semi pervious layer between upper and lower aquifers
- Layer 4 represented in the deep aquifer, its thickness varies from 70m south to 200m north of study area.

4.3 Recharge

The upper unconfined aquifer was recharged mainly through the infiltration of rainfall and floods where its rate reaches to 6mm/year. While the deep aquifer is recharged from seepage from surface water in the eastern part of the study area, where the aquifer is semi confined in this part.

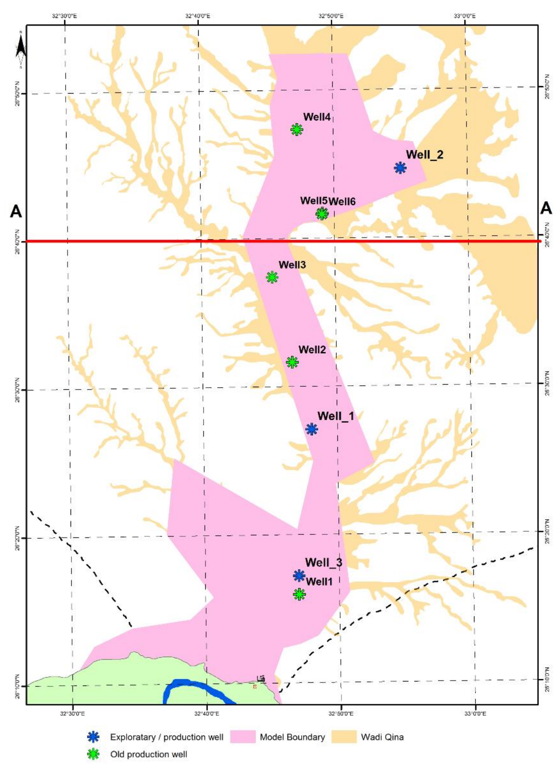

Figure3. Boundary of the Modeled Area

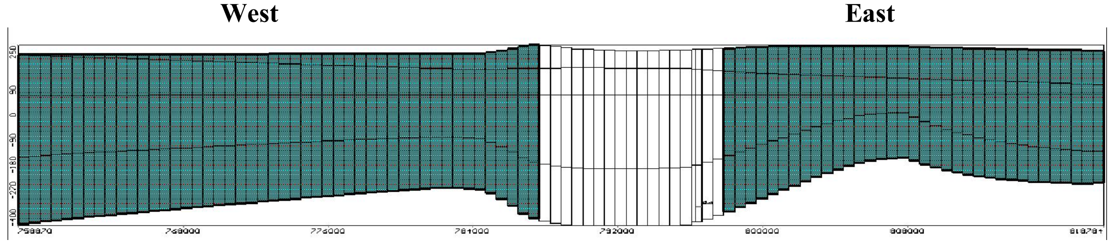

Figure 4. cross section illustrate the four layers of the study area (A-A)

4.4 Calibration

The Calibration Process is distinguished into two steps: 1) the first step, the calibration is in steady state condition for the regional model against the historical peizomrtric head of the production wells (6 wells) in addition to the new executed production wells by RIGW (3wells). The calibration process has been done through several trials by adjusting the topographic levels; recharge parameters and hydraulic resistance to generate piezometric head, which are in agreement with measured values. The second step represents in testing the proposed development scenarios for the study area.

4.5 The proposed development Scenarios:

Proposed scenarios are divided into 2 parts: **the first part is** represented in testing the safety distance between the production wells to avoid overlapping of cone of depression. ***The Second part is*** represented in testing the proposed development scenarios and its effect on the groundwater levels after 50 years, as follows:

Distance between production wells

Through groundwater flow model different distances between production wells with average discharge $70m^3$/hour were tested to evaluate its effect on groundwater levels allover the study area (table 1). The result of this scenarios illustrated that safety distance between wells should not exceed 1600m with maximum drawdown 18.7m.

The Proposed development scenarios

Five scenarios were tested to determine the maximum rate of groundwater discharge from surface and deep groundwater aquifers and its effect on groundwater drawdown as follows:

1- **Scenario 1;** this scenario is based on the extraction from the deep aquifer with an average rate of $70m^3$/h through well field **(G1)** contains 10 wells which distributed in the middle part of the study area. The result of this scenario illustrates that the average draw down after 50years ranges from 5m to 30m.
2- **Scenario 2;** this scenario based on the extraction from the deep aquifer with an average rate of $70m^3$/h through well field **(G2)** contains 12 wells which distributed in the north part of the study area. The result of this scenario illustrates that the average draw down after 50years ranges from 50m (in the edge of well field) to 100m (in center of well field).
3- **Scenario 3;** this scenario is based on the extraction from the deep aquifer with an average rate of $70m^3$/h through well field **(G3)** contains 10 wells which distributed in the south part of the study area. The result of this scenario illustrates that the average draw down after 50years ranges from 66m (at the edge of well field) to 100m (in center of well field).
4- **Scenario 4;** this scenario is based on the extraction from the deep aquifer with an average rate of $70m^3$/h through well fields which distributed allover the study area (total extraction equal = extraction from scenarios1,2,3). The result of this scenario illustrates that the average draw down after 50years ranges from 20m (at the edge of well field) to 100m (in center of well field).
5- **Scenario 5;** this scenario is based on the extraction from the deep aquifers as scenario 4, in addition to the extraction from surface aquifer **(G4)** (Figure 5). The results of this scenario, after 50years are illustrated in the table (1).

5- Evaluation of Groundwater Potential

Groundwater potential map is being an important tool for planners and decision makers in order to allocate, develop and manage the groundwater in wadi Qena region. The groundwater potential based on the hydrogeological conditions (aquifer type, rate of recharge, hydraulic characteristics, depth to groundwater and groundwater extraction) in addition to the results of the tested groundwater development scenarios through groundwater model of the study area.

5-1 Quantitative Potential

Quantitative groundwater potential was calculated using the analytical equations for the shallow and deep aquifers and based on extension of the aquifer, productivity and rate of recharge for shallow aquifer. While for deep aquifer it is based on saturated thickness, hydraulic parameters, and expected drawdown after 50 years.

The results of these parameters indicate that total groundwater potential for shallow aquifer reachs to 7.5 mcm/year, while it reachs to 100 mcm/year for deep aquifer (considering the max. period of development is 50years)

5-2 Qualitative potential

Based on the previous mentioned parameters, groundwater potential was evaluated qualitatively using different facilities of GIS. Figure 6 illustrates qualitative groundwater potential map for the deep aquifer in the study area, where the region was classified into 3 zones ranging between low potential (Zone II) to medium potential (Zone III).

Well Field	Draw down (m)
G1	27
G2	80
G3	100
G4	16

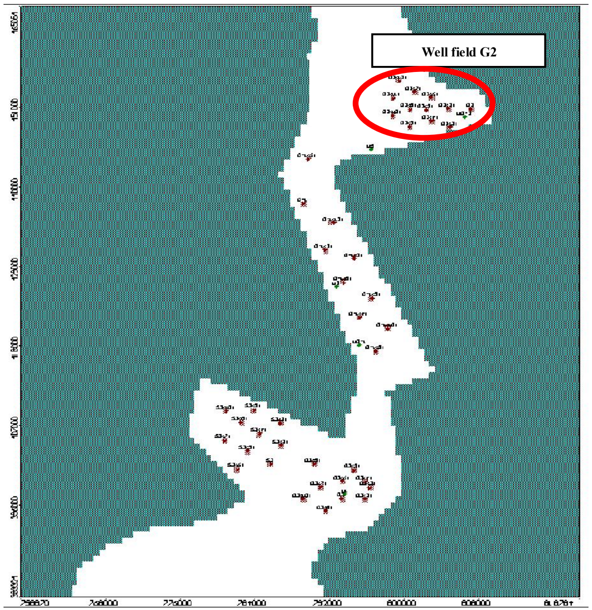

Figure (5) illustrates the Change in the Piezometric Heads under the Five Scenarios

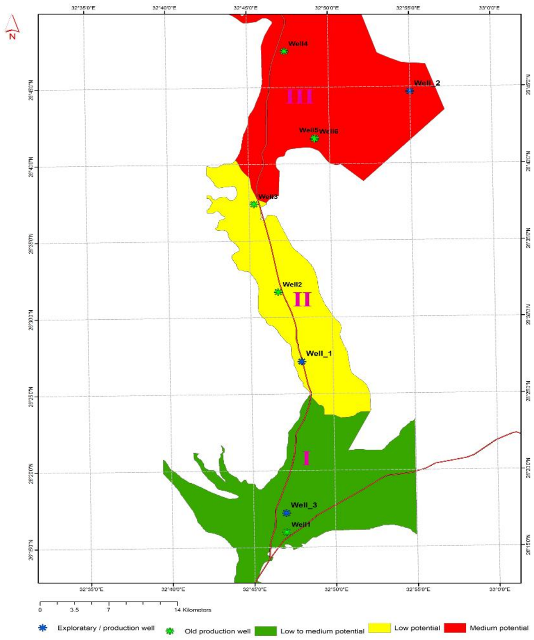

Figure 6 Groundwater potential map of the study area

6- Conclusion and Recommendations

6-1 Conclusion

- Wadi Qena is one of the most important valleys in the eastern desert, where it passes through 5 governorates.
- The geology and geomorphology of wadi Qena is very complicated due to the occurrence of igneous rocks which are scattered in the east of study area.
- The area is covered by two aquifers:
  1- **Shallow aquifer:** It is composed of sandstone and gravels and varies in thickness from 0 m (north) to about 75m (south). The salinity of the groundwater is very high and reaches to about 5000ppm.
  2- **Deep aquifer:** it consists of sandstone and shale and its thickness varies from 80m (south) to 200m (north). The groundwater flow direction is from north to south and the groundwater salinity varies from 1800 to 2100 ppm.
- The results of Groundwater flow model revealed the following:

1- 5 scenarios were tested to evaluate the effect of groundwater extraction on groundwater levels after 50 years.
2- The average distance between wells should not less than 1600m
3- The maximum discharge for the well should not exceed 80m3/h for 14hours per day
4- The average draw down through different development scenarios varies from 66m to 100m.

- The Groundwater potential for shallow aquifer reaches to about 7.5mcm/year, while it reach to 100mcm/year for deep aquifer.
- Through Hydrogeological conditions of the study area qualitative groundwater potential map was classified using GIS into three zones varies from medium to low potential.

Recommendations

- Continuous Monitoring is required to follow up the change in groundwater levels and quality through the proposed development steps.
- The recent methods for irrigation should be applied.
- The average distance between wells should not less than 1600m
- The maximum discharge for the well should not exceed 80m^3/h for 14hours per day to achieve a sustainable development for groundwater in the study area.

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