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Integrating Geospatial and Geophysical Information for Mapping Groundwater Potential Zones – Case Study of Matrouh-Negilla Basin, North Western Coast, Egypt

Hasan El-Kadi*[1], Islam Abou El-Magd[2], Osama Abdel-Raouf[3], Osman Ebrahem[4]

*[1]Geophysical Department, Fac of Science, Azhar Univ. Egypt

[2]Environmental Studies Department. National Authority for Remote Sensing and Space Sciences, Egypt

[3]Professor of geophysics, Water Recourses Research Institute (WRRI), National Water Research Center (NWRC), Egypt

[4]Environment and Climate Changes Research Institute, National Water Research Center (NWRC), Egypt

Osman.ebrahem@yaho.com[4]

ABSTRACT

The area is considered one of the areas that are suffering from the decreasing of fresh surface water and insufficient rainfall particularly in summer months. Rainfall and surface runoff are the recharge resources, which should be taken into consideration in water resources planning and management in developing processes. In this research work all available techniques to investigate the facies change and depth of water bearing zones to describe the lateral and vertical distribution of different aquifers in the area. Vertical Electrical Sounding data collected from 86 locations was interpreted qualitatively and quantitatively to obtain layered resistivity parameters and water bearing aquifer. Qualitative interpretation of vertical electrical sounding (VES) data shows four-layered profiles in most of the locations. Also, to evaluate the ability of currently used GIS and remote sensing techniques to distinguish or delineate target features controlling groundwater occurrence and produce potentiality map of the area based on the available data interpretation and analysis that will be a good basis for detailed groundwater exploitation in the area. In this study a standard methodology is proposed to determine groundwater potential using integration of remotely sensed data and GIS techniques. The accurate information to obtain the parameters that can be considered for identifying the groundwater potential zone such as geology, slope, drainage density, geomorphic units and lineament density and soil and slope and land used are generated using the satellite data. The study has generated a final groundwater potential zone map that is categorized into five categories 1) poor, 2) low, 3) moderate, 4) good and 5) very good. This groundwater potential information will be useful for effective identification of suitable locations for extraction of water. Further details on the methodology and outcomes will be discussed in the paper.

Keywords : Mapping Groundwater Potential Zones, RS& GIS, Electric Resistivity, NWC, Egypt

I. INTRODUCTION

The Egyptian government has put a strategy to solve the problems of water deficiency. So, searching for groundwater is of great importance to face the expecting high-demand on water. This study is devoted to the investigation of the water potentiality in surface and sub-surface and water quality at area. There are several methods employed for delineating groundwater potential zones such as geological, hydrological, geophysical and remote sensing techniques. Integration of various data and thematic maps, such as terrain features derived from remote sensing images, such as, geology, slope, drainage density, geomorphic units and lineament density and soil and slope and land used are help in generation of groundwater potential zone maps which when complete with geophysical data i.e. VES data in GIS environment, facilitates effective evaluation of groundwater potential zones (Yousef Ali H. et al., 2015). Vertical electrical resistivity method can provide depth of occurrence of groundwater zone, thickness of the aquifer system and the probable location for well sites. This research adopts the integration of geophysical data and other remotely sensed data with GIS analysis to understand the groundwater resources in the area of study and provide precise maps and information about the groundwater potentiality that secure the sustainable development in the area.

II. STUDY AREA

Matrouh governorate is located in the far north-west extending from the kilometer 61 west Alexandria governorate until the Egyptian – Libyan border, 450km along the Mediterranean Coast length, extending south into the desert in depth 400km south of Siwa Oasis and the total area of 166,563km2.The study area covers about 60km2 (Fig.1). The area extends in a W-E direction the Mediterranean Sea, (Matrouh and El-Negila basin) is a part of the Northwestern Coastal zone of Egypt. It is bounded by longitudes 26.30\ and 27. 30\ E, and by latitudes 31. 00\ and 31. 30\ N, The attitude of the study area slopes gently to the north, i.e., towards the Mediterranean Sea. The area has a semi-arid Mediterranean climate, characterized by a brief, mild, rainy winter and long warm summer months (May to September) of clear sky, high radiation, moderate temperature (from 8oC in January to 31oC in August), and considerably short rainfall storms during winter season. The rainy season is from October until January, at Matrouh, annual rainfall for the period 1990-2006 was 148mm of this quantity occurred in December and January, 61% occurred in January - February (winter. Most of the rainfall on the Southern plateau is running on the surface, causing water runoff, where the annual runoff in the study area (Fig.1). The Groundwater is considered the most available source for water supply besides rain water which acts as the main source of recharge to groundwater aquifers.

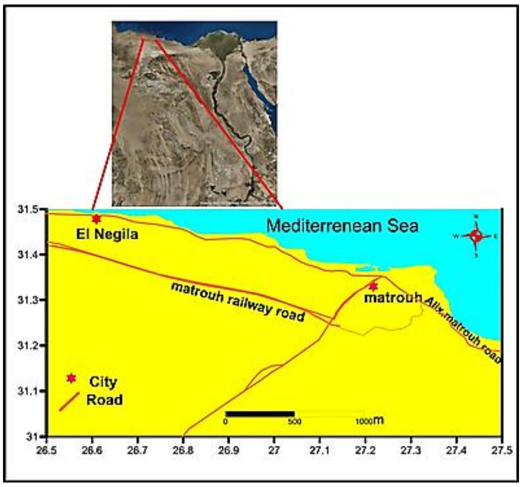


Figure (1): General Location Map for the Study Area

III. METHODOLOGY

Geophysical Survey

In the present study, vertical electrical sounding (VES) survey is applied to investigate the vertical distribution of the examined resistivity layers. The geophysical survey described in this work is represented by DC vertical electrical soundings (***VES***). Geoelectrical resistivity surveys in the form of eighty nine discrete vertical electrical soundings were carried out in selected area this ves's were arranged in measuring profiles as shown in(Fig.2), the well-known Schlumberger configuration with current electrode spacing (**AB/2**) starting from 1.5 m up to 700m,in successive steps, is selected and applied. Twelve profiles were constructed, to cover the area to explain the vertical and horizontal distribution of the physical properties of the sedimentary layers. The first layer was interpreted as wadi deposits with a resistivity range of 21-1973 Ohm. The second geoelectrical layer has resistivity ranging from 8 Ohm.m to 488 Ohm.m, and comprises limestone intercalation with clay. The third geoelectrical layer consists of fracture limestone with brackish water reflected resistivity range 1-115 Ohm m, with thickness ranging from 18 m to 125 m; this layer represents the main water bearing formation. The fourth layer consists of limestone with saline water which considered the base of the investigated section reflect low resistivity value of 0.4-176 Ohm.m (Figures (3) below shows the cross section A-A .

The identified aquifer system in the investigated area represented by two types of lithology as following: a Fracture limestone which represents the third geoelectrical layer (upper part of aquifer), its thickness increasing in the southeast and north east, of the coastal plain, and decreased in central part of area and fourth layer which represent the limestone with saline water (lower part of aquifer). Also, results of the interpretation of the vertical electrical soundings in the form of depth, thickness and true resistivity were indicated that the thickness of the aquifer varies along the area and the mean value of the thickness ranges from less than 15 to 125 meters. The true resistivity of third layer (fractured limestone), indicated that this layer is characterized dominant resistivity values ranging from 10 to 40 Ohm, all over the area.

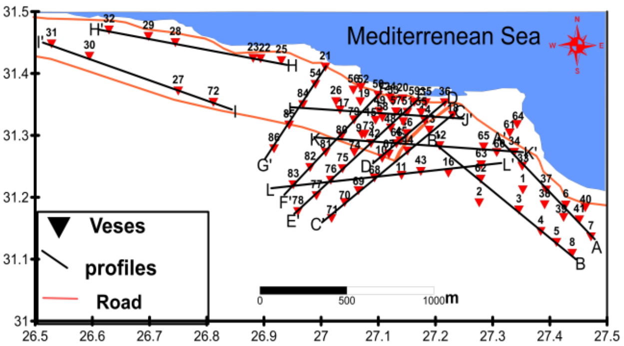


Figure (2) : Geoelectrical Profiles at the Studied Area

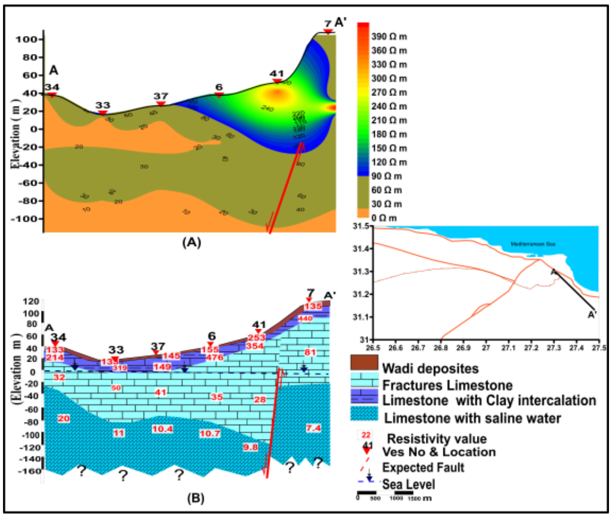


Figure (3): Geoelectric Cross-Section A-A'

Remote Sensing

Methodology for the investigation and study is summarized in following schematic diagram (Fig: (4) which is to be properly to obtain the desired final outputs and achieve research objectives. It involves catchment and drainage extraction using Arc-hydro module, digital image processing for the extraction of geomorphology, geology, slope, drainage density, and lineament density and soil and slope and land use/cover, Different classes were identified for each criterion and arranged in their decreasing order of weight. Appropriate weightage has been defined on the basis of their contribution to the groundwater potentiality (availability). The integration of these factors in a systematic method will result in a map showing potential zones for groundwater storage, with a number of categories. The available sentinel 2 imagery was acquired, provided in USGS data format. The software used in this research includes the follows: (ENVI 5.3) for georeferencing and image processing techniques of satellite images; also, (PCI Geomatica -2013) is used to create the lineament map and Arc GIS 10.3 is used with the plug-in Arc-hydro tools for hydrological processing.

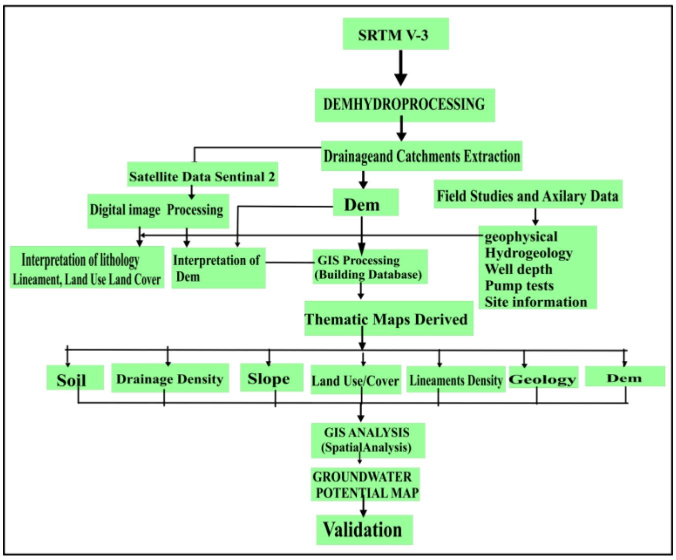


Figure (4) : Flow Chart Showing Data and Methods Employed for the Study

IV. RESULTS AND DISCUSSION

A: - Drainage Density

The drainage density is the most important parameter that control groundwater occurrence and distribution.

The drainage density point data is classified into five groups based on logical reasoning considering the variation of drainage density that affect groundwater occurrences of the area, to evaluate the

recharge property can be realized by detailed morphometric analysis of the drainage network. The drainage network order to a large extent depends on lithology, which provides an important indication of the percolation rate. 70% of the study area falls under low to moderate drainage density category. K.V.Suryabhagavan (2017). Figure(5) below shows the drainage density of the study area, where the dark below color indicate for higher density (up to 4) and dark brown color indicate for lower drainage density up to 0. The analysis shows that the higher density nears the coastal zone.

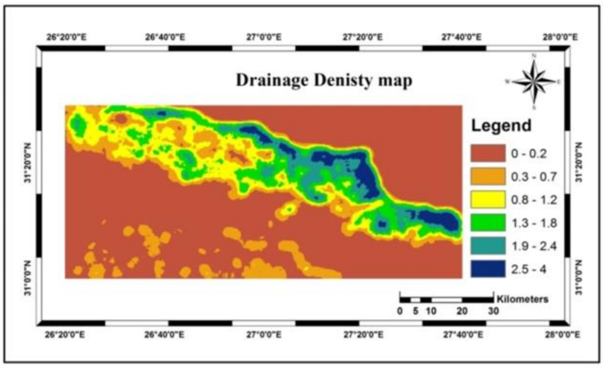


Figure (5): Drainage density map

B: - Lithologic Map

Lithology influences both the porosity and permeability of aquifer, and it has a direct impact on the occurrence and allocation of groundwater. The study area consists mainly of wadi and playa deposits, and their good permeability makes these areas a good place for groundwater accumulation and movement; thus, these areas were assumed to have good groundwater potential; however other areas consist mainly of limestone, shale and dolomite. Groundwater production in this system is mostly poor, except in some places with good joint development, where there may be a good abundance of fissured water. As a result of the fieldwork surveys we classify a weight factor of 20 of the total explanation (table 1). Besides, a score was given to each lithotype described in correspondence with their geological and hydrogeotechnical features (Figure :(6) shows the surface lithotypes map that has been generated, from geological map. It generally shows that the area is mainly covered with three different lithotypes categories (1) calcareous arenite; (2) Wadi and playa deposits; (3) clasic gypsum and carbonate. (Hsin-Fu Yeh 2008).

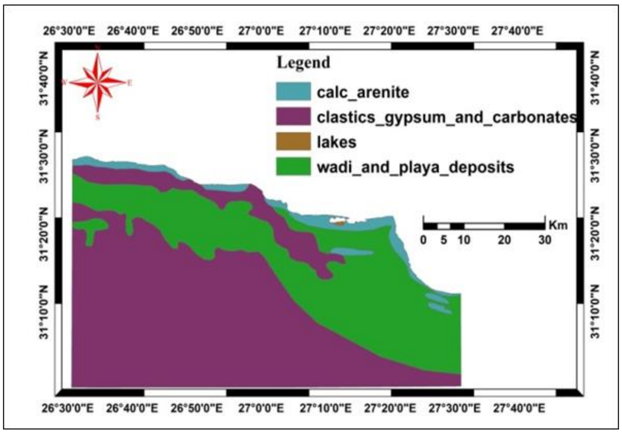


Figure (6). Lithology Map

C: - Land Use Map

Understanding of land use/land cover is needed for optimal management of natural resources and it provides important indicators to the extent of groundwater requirement. Therefore, land use and land cover classes were delineated from the interpretation of of remotely sensed data; this was primarily based on visual interpretation, unsupervised classification, and supervised classification. The land use classes identified are, water body, cultivated land, barren land, sand dune, sabkat, urban, based on medium resolution satellite images of sentinel 2 (1D. C. Jhariya, (2015), (Figure (7).

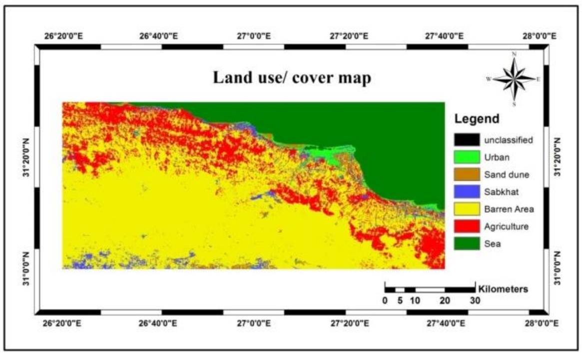


Figure (7). Land Use Map of Study Area

One of the parameters that influence the occurrence of sub-surface groundwater occurrence is the present condition of land cover and land use of the area. The effect of land use / cover is manifested either by reducing runoff and facilitating, or by trapping water on their leaf.

Land use/cover may also affect groundwater negatively by evapotranspiration, assuming interception to be constant.

D: - Lineament Density Map

Lineaments have often been recognized as canals of groundwater flow, and were used for the site selection of the potential wells. Many researchers found that areas with high lineaments density are good for groundwater development (Feifan Deng 2016) (Figure: (8). Many short lineaments are found as groups of uncertain direction, thus representing intensive fracture systems of fissures and joints, which is probably due to geological structures of dome or anticline. We noticed that the lineaments appear discontinuous (as short linear) due to the existence of human activities along a lineament straight of theses lineaments

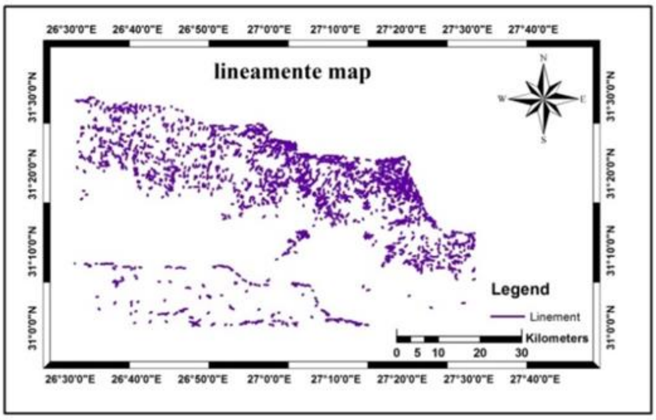


Figure (8). Lineament Density Map

E: - Soil Map

Soil properties influence, the relationship between runoff and infiltration rates, which controls the degree of permeability, that defines the groundwater potential (Abdul-Aziz 2016)). The prevailing soil types in the study area were classified into five groups, namely Sandy to loamy sand, Rocky escarpments, coastal limestone ridges, Gravelly sand , brown loamy as shown in Fig(9). The soil map shows that Gravelly sand soils comprises the most dominant soil type in the area of study. It is also more determinant in groundwater occurrence and movement as compared to Gravelly sand and Sandy to loamy.

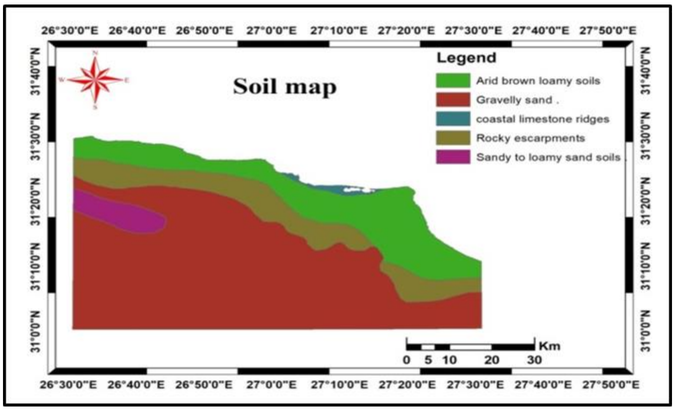


Figure (9). Soil Map of Study Area

F: - Digital Elevation Model

The Digital Elevation Model (DEM) of the study area (Figure .10) was extracted from the SRTM data (30 m resolution). DEM was employed to offer varieties of data that assist in produced landforms map and hydrology information and parameters. where the results indicated that elevations of the study area ranged between -8 to 237 m above Sea level, coastal plain zone elevation is ranged between -8 and 56 m, while the piedmont plain is varies between 56 to 141m, also plateau elevation ranges between 80 and 230 m, the L.S plateau is characterized by three units varying in elevation between 114- 155 unit 1, 155- 192m (unit 2) and 192 – 237 m unit 3, the surface water seepages with the slopes towards, the low area to the north in general.

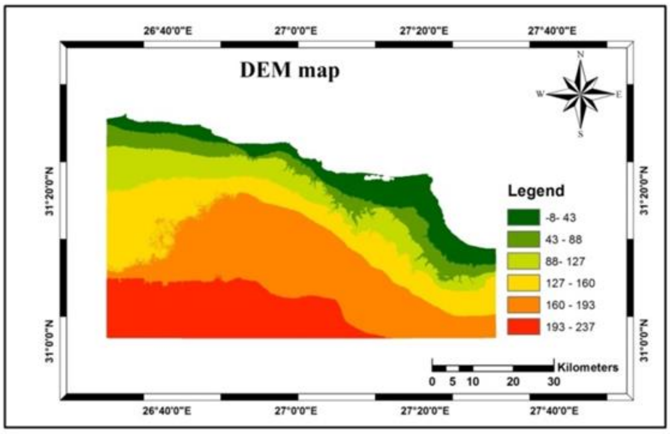


Figure (10). Dem Map of Study Area

J: -Slope Map

Slope plays an important role in influencing the recharge of groundwater depending on the degree of gradient of the landscape. The study area lies topographically at higher elevation and having flat to dissected sloppy

Thematic layers	**Features/Categories**	**Rank**	**Weightage**
Lithology	wadi playa deposits calc_arenite clasitc gypsum carbonate lake	6 5 4 3 2 1	20%
Slope	0 - 0.6° 0.7°-1.2° 1.3°-2.1° 3.8°-6.2° 6.3°-14°	6 5 4 3 2	10%
Land use	sand dune agriculture barren area sabkhat urban	5 4 3 2 1	5%
Drainage density	0-0.2 0.3-0.7 0.8-1.2 1.3-1.8 1.9-2.4 2.4-4	6 5 4 3 2 1	15%
Soil	Gravel sand Sand to loamy sand Loamy soil Limestone Rocky escarpment	6 5 4 3 2	20%
Dem	-8-43 43-88 88-127 127-160 160-193 193-237	6 5 4 3 2 1	10%
lineament	0-0.2 0.2-0.4 0.4-0.8 0.8-1.3 1.3-2.5	1 2 3 4 5	20%

Table (1) Assigned Rank and Weightage for Various Thematic Layers

morphology. The most majority of the study area is flat having slope degree value of 0–0.5 The area with slope values of o.5-2 is classified as gentle and moderate that covers 97% of the study area, respectively, which is covered by barn and cultivation land. The study showed that slopes with flat <0.5 and gentle slope areas (0.5-2) are more suitable for groundwater occurrence as compared to steep slope. This is because gentle and flat slope areas permit less runoff and the water infiltration and have very good potential. Finally the topographic setting gives an idea about the general direction of groundwater flow and its influence on groundwater recharge and discharge (Figure 11).

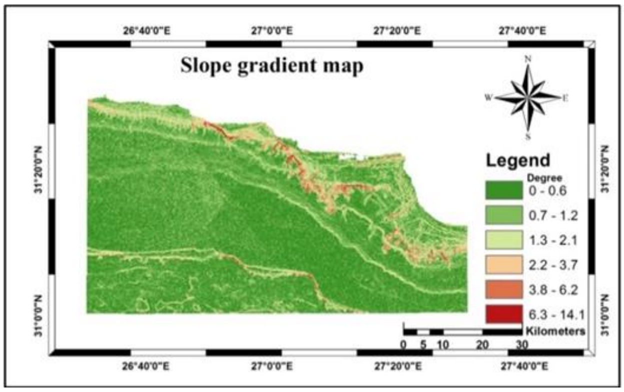
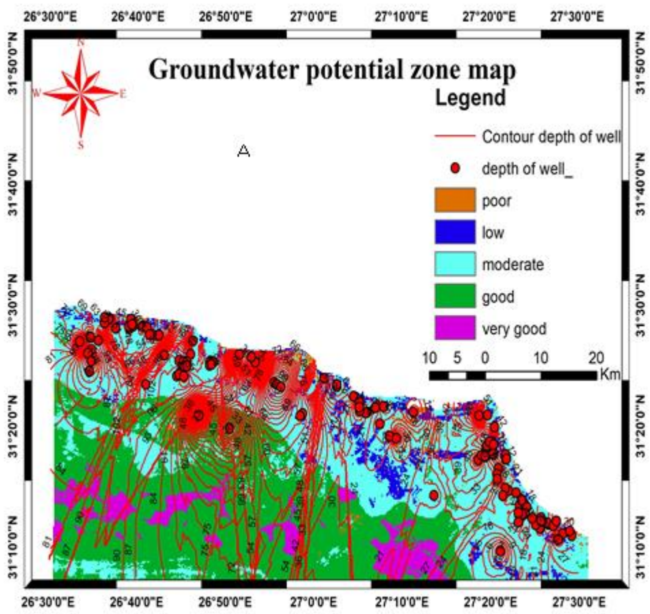


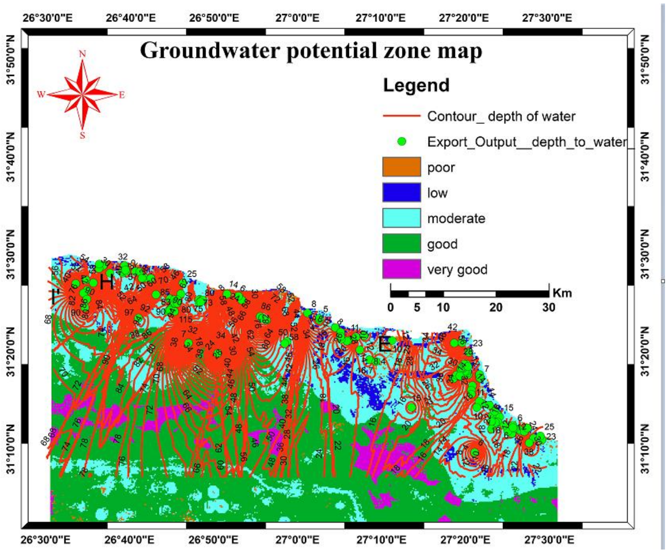
Figure (11). Slope Map of Study Area

H-Assigning Rank, Weight and Validation

The groundwater potential zones are obtained by overlaying all the thematic maps in phrase of weighted overlay method using the spatial analysis tool in ArcGIS 10.2. During the weighted overlay analysis, the ranks have been given for each individual parameter of each thematic map and the weight is assigned according to the influence of the different parameters (M.L.Waikar1, etal (2014) (table 1). Finally the weighted overlay is seven input thematic layers were allotted varying influence accord in to their favorability for groundwater. The resultant model has five classes obtained by summation of the weighted classes (Figure (12). The very good and good potential zones correspond to alluvial deposits, and low drainage density, and the fracture valleys, and valley fills, which coincide with the low slope at areas. Also, the moderate potential is characterized by structural hills foots of plain in northern part, and almost flat to gently slope toward the north, and composed of alluvial deposits and dune sand which are run parallel the foreshore, these zones cover large an areas and most of the wells were dug in it. Low potential zones mainly comprise structural hills and escarpments which contributes high run off. Poor groundwater potential zones are present in the escarpments with steep cliff, where low fractured rocks undifferentiated. The groundwater potential zone map was compared with the existing dug well in the study area. The comparison showed that the groundwater potential zones are in agreement with the existing well data. The result of validation showed that the moderate zones in the computed map using the proposed method coincide with areas of confirmed and expected GPZ (Nahla A Morad1 2014). In the same context, the poor and low potential zones agree well with previous hydrological maps of the study area. Furthermore, the result of spatial analysis showed that the highest number of groundwater wells is located within moderate and good and potential zones suggesting a positive correlation. Through 140 groundwater wells, 109 were found to be located within moderate, and 6 good, 17 low classes and no well is found in the very low and very good GWP zone (Figure.B.A).



(A)



(B)

Figure (13). Validation of Groundwater Potential Zones Map by Depth to Water (B) and Well (A)

V. CONCLUSION

It could be concluded that the integrated approach of "Geological-Hydrological Geophysical – Drilling - Satellite Image" is an effective tool for managing ground water resources for sustainable development in our area of study. The study reveals that integration of seven thematic maps such as drainage density, slope, geology, geomorphology, lineament density and land use/land cover and soil gives first-hand information to local authorities and planners about the areas suitable for groundwater exploration, the study area is classified in to very good, good, moderate, low and poor groundwater potential zones and Produced ground water potential zone map were compared and validated by existing discharge data obtained from different localities of the study area. The result showed fairly significant correlation or agreement with the discharge data. Also, the result of validation showed that the moderate zones in the computed map using the proposed method coincide with areas of confirmed and expected (GPZ) i.e (groundwater potential zone). In the same context, the poor and low potential zones agree well with previous hydrological maps of the study area.

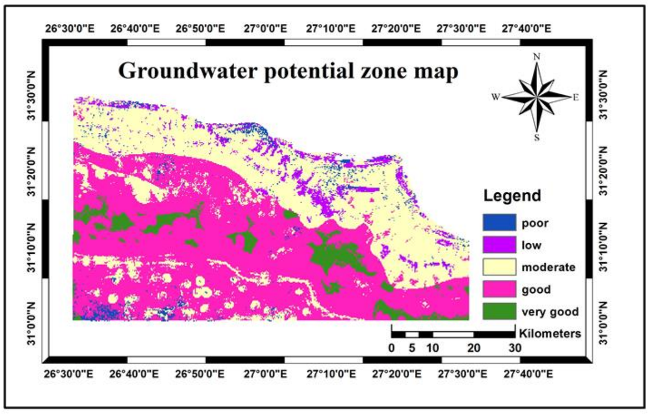


Figure (12). Groundwater Potential Zones Map of Area

According to the results derived from the interpretation of the geoelectrical measurements; the vertical geoelectric sections reflected the presence of four main geoelectric resistivity layers. The first layer was interpreted as wadi deposits and second was limestone with intercalation with clay, while the third layer was the main water bearing water formation(upper part of aquifer) and fourth layer is hard limestone with saline water which considered the(lower part of aquifer). Also, it can be noted that the water surface in the study area appears within the investigated depth of 15-125 meters. The thickness of the aquifer varies ranges from less than 20 to 100 meters, the true resistivity of third layer (fractured limestone), and values ranging from 10 to 40 Ohm, all over the area. The groundwater potentiality of this aquifer increases toward southeast and has a great effect on the groundwater quality in the area.

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