Integrated Study for Environment, Hydrology and Water Resources Challenges of Red Sea Resort

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Abstract. The study area is Abu Soma Bay, which is located between the cities of Hurghada and Safaga. The objective of this study was to identify the hydrogeological conditions of the area to evaluate the available water supply, the impact of flash flood on the proposed infrastructure in the area and impact of touristic development on the environment surrounding. To cover the objectives, several studies have been carried out, these studies, can be summarized as follows: Field investigations which include, Survey, Topography and Geology, Hydrological Study, Hydrogeological study and water quality conditions in the coast of the study area as a development coastal resort lies in the Red Sea Coast. The results of the hydrologic study showed that the maximum discharge was about 56.6 m$^3$/s with runoff volume about 559600 m$^3$ for 50-year return period. The calculated velocity at the effective basin outlet is about 0.375 m/s for maximum discharge. Consequently, it's concluded that the flood has no harm effect on any of the study area buildings. It's clear from The Hydrogeological study that, the study area is suffering from the lack of fresh water, but the water supply is restricted only on the presence of saline and vary saline water.

Keywords: Water Resources, Hydrology, Development Coastal Resorts, Water Quality, Environmental Challenges, Red Sea Coast

1. Introduction

Historically, The Red Sea has a strategic importance as a point of contact between East and West. It is the eastern gate of Egypt with a coastline stretching over 1080 km as reported by Djebedjian and co-worker [1]. After implementing Egyptian development strategies in various fields, the Red Sea Governorate has become one of the investment areas and one of the touristic attractions in the world and thus a major source of national income. [2- 9] reported that More than 95% of the marine protected areas in Egypt located in the Red Sea Governorate and thus monitoring and investigating the challenges of water resources and the quality of the Red Sea is a vital and necessary issue. The area investigated is Abu Soma Bay, which is located between the cities of Hurghada and Safaga on the Red Sea Figure 1. Abu Soma is an important Egyptian tourist resort on the Red Sea, away from the Nile. It has an attractive beach and a very beautiful coastline for marine tourism activities. There is an ongoing need to expand and develop the infrastructure to provide drinking water. There are three sources of potable water: long-distance tanker trucks, water pipelines and desalination plants [10-11].
Djebedjian et al. [1] studied, Abu Soma Bay as an investigated area located along the Red Sea coast and assessing the costs of water desalination and transportation for the Abu Soma region as a case study of the Red Sea Governorate for tourist buildings and human settlements. Three desalination plants were built, producing 4,500 cubic meters per day. He concluded that moving water horizontally is relatively cheap while the main cost is pumping it. While the concept of a new pipeline to supply Abu Soma with water is technically feasible and the choice of the water source should remain in the future, it may become less able to desalinate water due to the lower cost in new desalination technologies. Although not all the areas connected by pipeline so investigations should continue for water resources and desalination alternative. In this study it was investigated Soma Bay area that was not investigated before and a solution was found for water resources also study the area for touristic development in addition monitor Red Sea water quality surrounding the study area and indicate its quality for marine life and touristic activities.

2. Objective of the Research
The Red Sea has gained strategic importance throughout history as the focal point between East and West as the Red Sea Governorate has automatically become associated with this privilege. Based on its historical, economic, political and geophysical dimensions, it has become conservative at all times; past, present and future. It is the eastern gate of Egypt with the coastline stretching over 1080 kilometre. Moreover, the vast area of the province is rich in oil, minerals and fishery resources. This is in addition to its beautiful and talented nature along with the wonderful weather all year. It is one of the coastal and border governorates in Egypt [4-5]. The objective of this study is to identify the hydrogeological conditions of the area under consideration to evaluate the available water supply and the impact of flash flood on the proposed infrastructure in the area and the impact of the project in the environment surrounding. To cover the objectives, several studies have been carried out, these studies, can be summarized as follows: Field investigations
which include, Survey, Topography, Geology, Hydrological Study, Hydrogeological study, water resources and water quality conditions in the coast of the study area.

3. Methodology

The study area is located at Red Sea coast between Hurghada and Safaga cities (about 47 km from Hurghada). The study area is contained by three roads and Red Sea coast. The site is contained from the north by the Suma Bay road, from south by Abu Suma Resort road, from west by Hurghada – Safaga road, and from east by Red Sea coast. The study area is located between the long 33° 45" & 34° 00 E and lat. 26° 45' & 26° 55' N along the western coast of the Red Sea. The area is bounded by the basement rocks in the west and the Red Sea in the east.

3.1. Topography of the Study Area

Topographic maps that cover the study area have been collected and analyzed. A topographic map of scale 1:50000 is used to create the Digital Elevation Model (DEM) for study basin using Geographical Information System (GIS). Geographic Information System (GIS) has been used to convert the topographic maps, with a suitable scale, to digital maps using the information of the Spot Heights (SH) and the Digital Elevation Model (DEM). This model is used to delineate wadi boundary based on the Digital Elevation Model (DEM) of the area. The Digital Elevation Model (DEM) of effective basin is shown in Figure 2.

![Figure 2. The Digital Elevation Model (DEM) of the effective basin](image)

Topographic Surveys

The study area is a Tourist village which is located at the Red Sea coast, north of Safaja at Ras Abu Suma, near Hurgada/Safaja coastal road at km 18 from Safaja. The area lies east of Red Sea Mountains, which are dissected by a series of valleys, the highest of these mountains is Shayeb Mountain, the valleys flow toward the coastal plain and then to the sea causing damage to the main infrastructure located at the coast [12][13]. This depends on the seriousness of the valleys due to the morphological characteristics of the valley. The topographic map shows that Wadi Abo Murrat affects the study area and the need to study its impact on the tourist village and to determine if there was a danger to the tourist village is a must. The study area was surveyed where all required data are collected from preparing a contour map and sections of the study area. The study area is associated with moderately
flat coast and sand hills. The landscape is generally a plateau and the land gently rises towards the sand
hills and the coastal Hurgada/Safaja road. The study site is at elevation levels of about 40 m from 0 to
100 m above sea level detailed topographical survey of the proposed site has been done

3.2. Geology of Ras Abu Suma Area-Red Sea

The regional geology of the area represents that the area is characterized by the presence of the oldest
rocks of the Pre-Cambrian, Tertiary, Quaternary and recent deposits. The geologic map of Egypt which
is prepared by [13], scale 1: 500.000 was used to define the different geologic units from older to
younger.

3.3. Hydrologic Analysis

Due to the absence of the runoff hydrographs measurements, synthetic unit hydrograph methods are suitable
for calculating the flood characteristics. The synthetic unit hydrograph of the Soil Conservation Service
(SCS) is one of the recommended methods. HEC-1 is one of the most famous hydrologic models has been
used, which was developed by the U.S. Army Corps of Engineers. Hydrologic Engineering Center.
Hydrologic Modelling System (HEC-HMS) and Watershed Modelling System (WMS) were developed
as comprehensive environment for hydrologic analysis by using the HEC-1 in cooperation with the U.S.
Army Corps of Engineers Waterways Experiment Station. WMS uses three primary data sources for
model development; Geographic Information Systems (GIS) Vector Data. Digital Elevation Models
(DEMs) or Gridded Elevation Sets. Triangulated Irregular Networks (TINs). Once boundaries have
been created, geometric attributes such as area, slope and runoff distances could be computed
automatically as shown in Figure 3. A topological tree representation of the watershed is created, and all
data necessary to define an HEC-1 and/or HMS model can be entered by selecting basins and outlet
points. Also, the location of rain gauge station is defined to compute the average rainfall over the basin.
Different hydrologic data are used to feed the program to get the basin hydrograph for 25 and 50-
year return periods. The result of the hydrologic analysis showed that for 25-year sol index min
time was 225 min with volume 105513.3 m$^3$, and flow 11.08 m$^3$/sec. Also, for 50-year sol index
minimum time was 225 minutes with volume 238544.1 m$^3$, and flow 24.9 m$^3$/sec as showed in
Figure 4.

![Figure 3. Effective basin geometric parameters](image-url)
A hydrological study has been carried out where different data are collected such as; topography, morphology, meteorology and rainfall losses.

**Morphology**

The morphological analyses are concerned with the determination of the physical characteristics of the selected basin, such as their lengths, areas and slopes. The analysis was done using the information of the Spot Heights (SH) and the Digital Elevation Model (DEM), the direction and characteristics of each basin. Also, the morphological analyses are concerned with the determination of unit hydrographs parameters such as the Lag time (Lag), Concentration Time ($T_C$) and Storage Coefficient ($R$), as listed in Table 1.

**Table 1. General morphologic characteristics of the basin**

| Wadi Name  | Area (km$^2$) | Length (km) | Lag Time (hr) | Concentration Time (hr) | Storage |
|------------|--------------|-------------|---------------|-------------------------|---------|
| Abu Murrat | 50           | 13.4        | 1.81          | 7.89                    | 2.23    |

**Groundwater Condition**

The topography of the study area is characterized by gradation slope where the elevation ranges between 10-20 m towards the sea. Consequently, the regression and transgression process lead to deposit some layers or disappear of others which effect on the groundwater occurrence. It's clear from the available hydrogeological data that, the depth to water ranges from 1 m to 10 m at the wells drilled to feed the desalination plants located beside the study area. While the depth to Water reaches to about 88 m below the ground level to the North of the study area (Sahel Hashesh) and the productivity ranges from 100 to 120 m$^3$/h. Normally in the coastal aquifer there is a hydraulic connection to the sea. The area under investigation is far from the shore line by about 500 m. According to the geophysical investigation and the lithologic log of the study area there is a thick column of reefal fracture limestone which considered the main water bearing formation.
3.6. Water Resources and Water Quality in the Study Area

3.6.1. Water Quality WQ in the Study Area

The study area overlooking the Red Sea coast reflects the impact of seawater intrusion along the coast. The major cations (K, Ca, Na and Mg) and the main anions (Cl, HCO₃ and So₄) comprise about 99% of seawater salts. Chlorine ion constitutes 55% of the salt in seawater, the total dissolved solids range from 41,000 to 42,000 (ppm) and the water type is generally the sodium chloride type.

3.6.2. Water Resources in the Study Area

The Egyptian Government did a plan for establishing a water pipeline from the Nile River to supply all the cities that lie on the Red Sea Coast and now the pipeline supplies the area until Hurghada and still working to feed the other areas to the south until Halayeb area. There are two main lines Figure 5, the first is Qena-Safaga pipeline with total length of 180 km. There are three parallel lines with different diameters: 200, 300 and 400 mm. They are supported by 13 pumping stations distributed on the distance from Qena to Safaga. The total capacities of the lines are 17,000 m³/d distributed on three cities: Hurghada, Safaga and El-Quseir. The second line is the Koraimat pipeline with diameter 1000 mm until Ras Ghareb and 600 mm to Hurghada [1, 10-12]. The total capacity of the pipeline is 28,000 m³/d distributed on three cities: Zafarana, Ras Ghareb and Hurghada. There are seven pumping stations on the pipeline.

![Figure 5. Water transportation to the Red Sea Governorate by pipelines, [1].](image)

According to the annual report of the Environmental Information and Monitoring Program EIMP, visual observations in the coastal waters of the Gulf of Suez, the Gulf of Aqaba and the Red Sea in 1999/2000. The coastal waters of the Red Sea proper and the Gulf of Aqaba region were found to be clean except in a few locations such as Safaga in the Red Sea. The area is found clean except for some locations such as Safaga in the Red Sea, Sharm El Sheik Port and Sharm El-Sheikh Naama Bay in the Gulf of Aqaba. These may be due to human activities and the increasing number of ships. Water Quality in the study area was studied by monitoring 20 coast samples as shown in Figure and analysis the Physiochemical, major cations, major anions, trace metals and micro biological parameters results as shown in figures below.
3.6.3. Water Quality International Standards for Coastal Waters and Marine Outfalls

In the coastal part, marine waters are exposed to several types of uses. Depending on the types of uses and activities, water quality standards were determined to determine their suitability for a particular purpose [14-17]. Figure 6, shows Satellite Photo of the area showing water quality samples.

![Satellite Photo](image)

**Figure 6.** Satellite Photo of the area showing water quality samples

4. Results

From the above integrated Geology, Hydrological, Hydrogeological, and water quality conditions in the coast of the study area results it can have resulted that:

- The study area which was investigated to depth of about 150m is composed of sands gravels and limestone in some parts, which differ in the groundwater probability as a result of its fracture density.
- Groundwater occurs in the third and fourth geo electric layers in most sections which was interpreted as sand and gravel with some clay intercalations.
- The resistivity of rock units in the study area decreases towards the east which means that, there is sea water intrusion.
- The groundwater aquifer in the study area is expected to be unconfined aquifer because of absence of natural barriers between sea and discontinuity of impervious layer.
- The depth to water ranges from 25 meters and 55 meters depending on the topography.
- The results of the hydrologic model showed that the maximum discharge is about 56.6 m3/s with runoff volume about 559600 m3 for 50-year return period. The calculated velocity at the effective basin outlet is about 0.375 m/s for maximum discharge. Consequently, it's concluded that the flood has no harm effect on any of the study area buildings.
- Desalinated water may be a solution for some water-stress regions, but not for places that are poor, deep in the interior of a continent, or at high elevation. The costs of desalination still remain higher than other alternatives for most regions of the world. Desalination processes are accompanied by some negative impacts on the environment such as production of concentrated brine and carbon dioxide emissions.
4.1. Results of the Water Quality Monitoring in the study area

Figure 7 part (a) PH for 20 samples in the site location ranged from 8.1-8.36 for all samples it is accepted range as its guideline ranges for marine water between 6.5-8.5 this range does not cause skin or eye irritation and is also conducive for propagation of aquatic life. While, Figure 5 part (b) for carbonate showed that the first 8 samples show that there is no Carbonate. There a sudden peak in Carbonate from sample 9 and followed by a consistent availability of Carbonate up until the last sample (Sample 20).

![Figure 7](image)

**Figure 7.** (a) PH concentrations for 20 samples in the site location and (b) Carbonate mg/L concentrations for 20 samples in the site location

Figure 8 part (a) Electrical conductivity EC mohoms/cm for 20 samples in the site location ranged from 60-60.8 mohoms/cm and Figure 6 part (b) Total dissolved solids TDS mg/L for 20 samples in the site location ranged from 42000 to 72700 mg/L.

![Figure 8](image)

**Figure 8.** (a) EC mohoms/cm concentrations for 20 samples in the site location and (b) TDS mg/L concentrations for 20 samples in the site location

Figure 9 Part (a) represents Ammonia (NH₃) mg/L concentrations for 20 samples in the site location which ranged from 0.17934 to 1.07604 mg/L. ammonia normal ranges according to surface water regulations [1989] 0.2-4 mg/L, when ammonia increase in water it is highly affect aquatic organisms. Figure 9 part (b) Biochemical Oxygen Demand (BOD) mg/L for 20 samples in the site location ranged from 0 to 1 mg/L, this range is acceptable and causes no stress on aquatic organisms as nitrate and phosphate in a water body contribute to high level of BOD in water which means decreases of dissolved oxygen, while there is no appearance for Oil and Grease in all samples.

![Figure 9](image)
Figure 9. (a) Ammonia mg/L Concentrations for 20 samples in the site location and (b) BOD mg/L concentrations for 20 samples in the site location

Figure 10 Part (a) Calcium (Ca) for 20 samples in the site location ranged from 450 to 550 mg/L, this range is acceptable as calcium concentration in red sea ranges between 225-400 mg/L, while Figure 10 Part (b) represents Potassium (K) for 20 samples in the site location that ranges 220-300 mg/ L while red sea potassium concentrations ranges between 210-380 mg/ L.

Figure 11 Part (a) represents Magnesium (Mg) for 20 samples in the site location that ranged from 870 to 950 mg/L, while magnesium in red sea ranges 742-1262 mg/l this range is in acceptable limits, while Figure 11 Part (b) Sodium (Na) for 20 samples in the site location ranged from 12120 to 12495 mg/L, red sea ranges between 10556-14255 mg/l.
Figure 11. (a) Magnesium mg/L concentrations for 20 samples in the site location and (b) Sodium mg/L Concentrations for 20 samples in the site location

Figure 12 Part (a) shows that the Nitrite (N\textsubscript{2}O\textsubscript{4}) concentration for 20 samples in the site location is 0.2 mg/L as increases of nitrite concentration indicate to wastewater pollution, but this limit is acceptable . Figure 12 Part (b) represents Phosphate (PO\textsubscript{4}) concentration for 20 samples in the site location which are 0.2 mg/L for all samples this range is acceptable as according to surface water regulation [1989] its range between 0.5-7 mg/L, phosphate increase in water indicate that animal waste exists ,and Fig. 12: Part (c) represents Sulfate (SO\textsubscript{4}) for 20 samples in the site location ranged from 2630 to 2648 mg/L , decreases of sulfate to zero mg/L may cause odour , and excess of sulfate could attach the surface concrete bodies .

Figure 12. (a) Nitrate mg/L concentrations for 20 samples in the site location, (b) Phosphate mg/L concentrations for 20 samples in the site location and (c) Sulfate mg/L concentrations for 20 samples in the site location.
5. Conclusions and Recommendations
Integrated Geology, Hydrological, Hydrogeological and water quality conditions in the coast of the study area concluded that the study area which was investigated to depth of about 150 m is composed of sands gravels and limestone in some parts, which differ in the groundwater probability as a result of its fracture density. Also, the results of the hydrologic model showed that the maximum discharge is about 56.6 m$^3$/s with runoff volume about 559600 m$^3$ for 50-year return period. The calculated velocity at the effective basin outlet is about 0.375 m/s for maximum discharge. Consequently, it's concluded that the flood has no harm effect on any of the study area buildings. In addition, the topography of the study area is characterized by gradation slope where the elevation ranges between 10-20 m towards the sea. Consequently, the regression and transgression process lead to deposit some layers or disappear of others which effect on the groundwater occurrence. It's clear from the available hydrogeological data that, the depth to water ranges from 1 m to 10 m at the wells drilled to feed the desalination plants located beside the study area. While the depth to Water reaches to about 88 m below the ground level to the North of the study area (Sahel Hashesh) and the productivity ranges from 100 to 120 m$^3$/h. Normally in the coastal aquifer there is a hydraulic connection to the sea. The area under investigation is far from the shore line by about 500 m. According to the geophysical investigation and the lithologic log of the study area there is a thick column of reefal fracture limestone which considered the main water bearing formation. Finally, the study area overlooking the Red Sea coast reflects the impact of seawater intrusion along the coast. The major cations (K, Ca, Na and Mg) and the main anions (Cl, HCO$_3$ and So$_4$) comprise about 99% of seawater salts. Chlorine ion constitutes 55% of the salt in seawater, the total dissolved solids range from 41.000 to 42.000 (ppm) and the water type is generally the sodium chloride type. It is highly needed an intensive environmental studies in the area surrounding and the touristic villages activities affected the environment and should highly restricted by Egyptian environmental affairs agency to report all activities especially related to the coast line and sea shore coast. Water quality study of the Red Sea Coast in the study area showed that all the samples lies within regulations and it is recommended to monitor the samples location within project operation to maintain the quality within limits. It is recommended to study the marine environment in the study area and surrounded to keep the marine environment safe from touristic development negative impact that is an important goal of the Egyptian Sustainable development strategy 2030. All national regulation concerning the coat water did not mention the regulation with respect to the sea water usage, it should mention according to sea usage. In a coastal segment marine water is subjected to several types of uses. Depending of the types of uses and activities, water quality criteria should have specified to determine its suitability for a particular purpose. Also Coastal and Fresh Waters provides a review and assessment of the health hazards encountered during recreational use of coastal and freshwater environments. As it addresses a wide range of types of hazard, including hazards leading to drowning and injury, water quality, exposure to heat, cold and sunlight, and dangerous aquatic organisms; and provides background information on the different types of recreational water activity (swimming, surfing, etc.). With regard to water quality, separate chapters’ address fecal pollution, free-living microorganisms, freshwater algae, marine algae and chemical aspects should have addressed in the Egyptian regulations.

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