THE USE OF GIS TOOL FOR THE EVALUATION OF DESALINATION NEEDS FOR SINAI

Magdy Abou Rayan*, Berge Djebedjian* and Ibrahim Khaled**

ABSTRACT

The development of non-conventional water resources in Egypt is a must in order to respond to the continuously increasing demand. Sinai has different water resources. An integrated water resources management (IWRM) is a must. The desalination is a major water resource for Sinai. The present paper presents the results of an investigation undertaken in order to evaluate technically and economically the installed desalination units. A geographical information system is used in order to evaluate the potential solar energy. The system calculates the corresponding solar desalination units in order to respond to the required demand. The GIS system can also predict the future demand forecasting for 15 years. This investigation was done within a mainframe of IWRM. The other sources of water are evaluated, the emphasis are put upon the desalination as a non-conventional water resource. All the installed units were scanned and investigated.

The objective of this research work is to offer recommendation in order to enhance the integrated water resource management strategy for Sinai.

Keywords: Sinai, Water resources, Desalination.

1. INTRODUCTION

The objective of the **I**ntegrated **W**ater **R**esources **M**anagement (**IWRM**) is to help in moving from sectoral development-based focus to an integrated management-based approach.

The IWRM is distributed on three levels as indicated in Figure (1). The first level is the policy formulation level, the Ministry of Irrigation and Water Resources (MIWR) is responsible of the general planning of water resources.

The Ministry of Housing, Equipment and New Agglomerations (MHENA) is responsible of policy formulation in domestic and tourist water use sectors and sanitary drainage. The water policy and the institutional framework are formulated at this level. A tied cooperation and coordination between (MIWR) and (MHENA) is achieved. The water policy; institutional development policies including human resources development is proposed at this level. This is the constitutional function.

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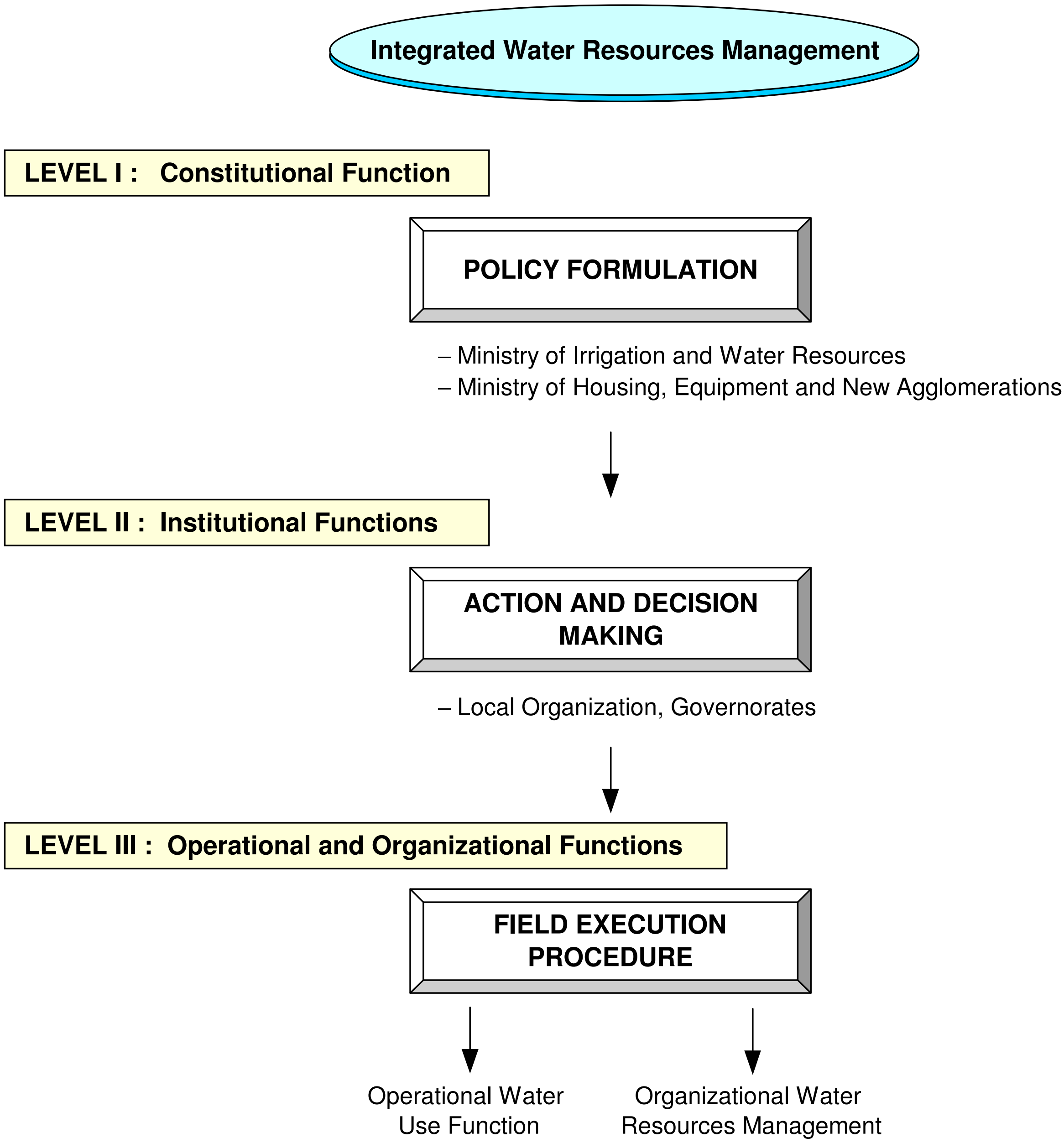

Figure (1) Integrated water resources management distribution

The second level is the level of decision making where the governorates of Sinai (North and South) and development Organizations (North and South) are responsible. The action is taken at this level. In the third level, there are two functions for (IWRM) in field execution. The first is ***operational*** or water use function and the second is ***organizational*** or water resource management function, The water use includes the following sectors: agriculture, domestic, industry, tourism and recreational. An institutional frame is proposed from level (I) to control the interaction between these two functions; operational and organizational.

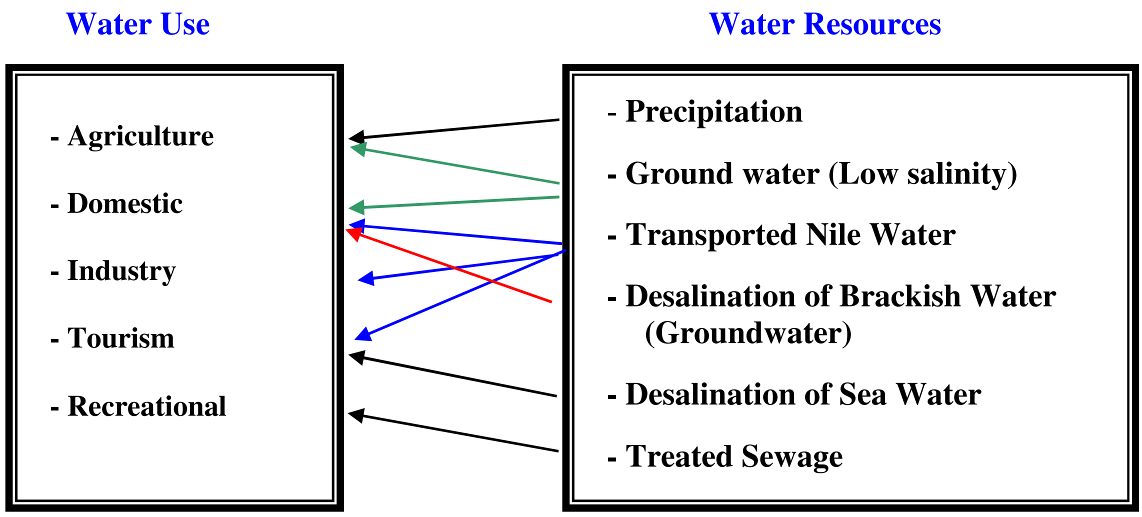

Figure (2) Interrelation between water use and water resources

The interaction between water resources and water use is shown in Figure (2). In the present investigation the water resources, which are controlled by the organizational function of IWRM are presented. The water use that is operational function of IWRM is also presented, and finally a proposition is made for the conditional framework in order to intensify the role of seawater desalination as a non-conventional water resource.

The objective of this paper is to recommend to the policy maker the necessary tools in order to emphasis the role of desalination as non-conventional water resources. The GIS tool is used in order to evaluate the potential of solar energy and sizing the required solar desalination unit. The emphasis is put upon the solar energy as a renewable and clean source of energy. The GIS tool can also predict the future need for water per region; the forecast is done for 15 years.

2. WATER RESOURCES IN SINAI (ORGANIZATIONAL)

This is the organizational or water resources management function. In this organizational level the objective is to:

- assess the present water resources.
- provide reliable information on the availability and quality of surface and groundwater.
- provide scenarios for the development and use of water.

Below is a general description of Sinai and the assessment of resources, its availability and quality.

The Sinai Peninsula has an area of 59,438 km^2, Figure (3). Sinai includes some plains and highlands, Figure (4). The weather in the plains is similar to other parts of Egypt, mainly dry and warm. The weather of the highlands differs from other parts of Sinai in the temperature and rainfall. It is colder, with a minimum of 10°C difference in temperature. In this district, the rainfall increases and reaches that of the Mediterranean district.

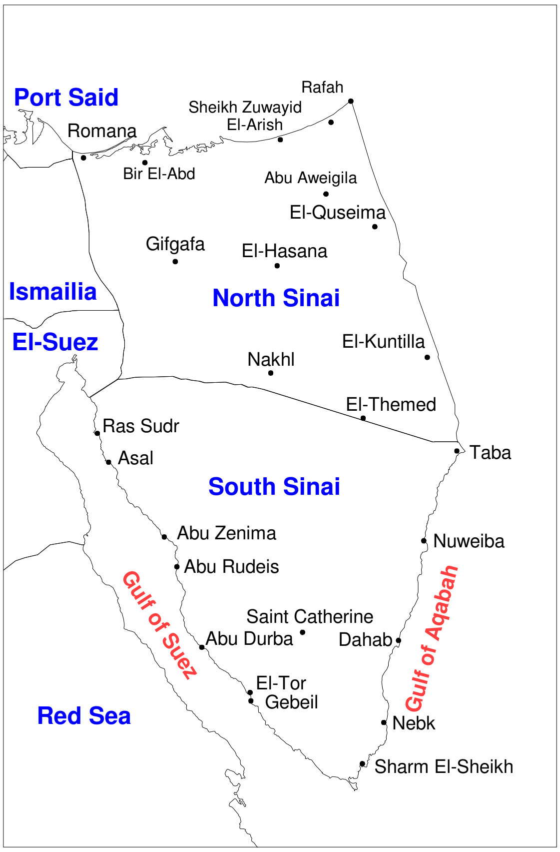

Figure (3) Sinai Peninsula and North and South Sinai governorates

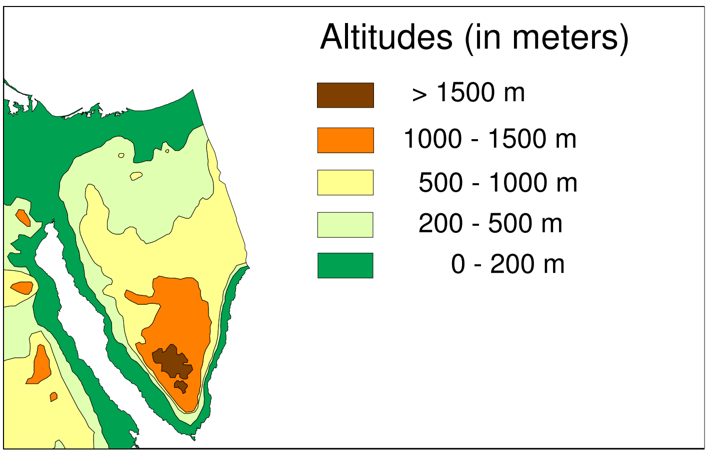

Figure (4) Topography of Sinai

The total population is 254,000 which is mainly Bedouin (60 %) and the rest are located in small cities as El-Arish, Sharm El-Sheikh. The population growth rate of 2.87 % is the highest in Egypt.

The water resources in Sinai can be classified into the following categories:

1- Renewable resources from rain,
2- Underground water,
3- Potable water transported by pipeline,
4- Desalinated water.

2.1. Renewable Resources from Rain (Precipitation)

Despite that in Sinai some places possess a reasonable precipitation rate of 200 mm/year; Figure (5); this rate is considered as the highest in Egypt. Significant intensities of rainfall are recorded during some years in the neighborhood of 500 mm/year.

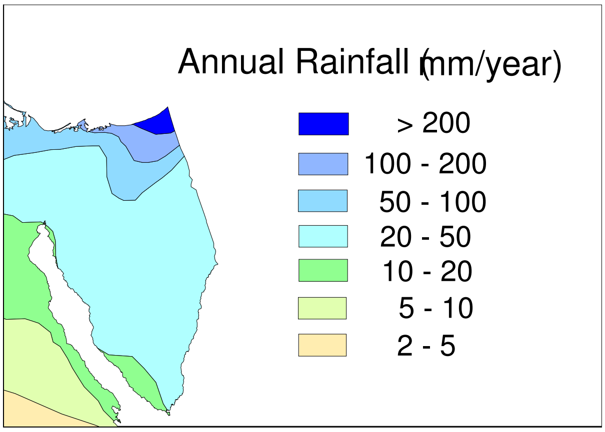

Figure (5) Annual precipitation in Sinai

The precipitation is not used efficiently in Sinai; most of the water goes to the sea, in some cases causes disaster in its way there. In any event the precipitation in Sinai is not counted as a water resource, despite the fact that the future strategy of the Ministry of Water Resources and Irrigation is based on the utilization of this water through the construction of some dams in order to accumulate water. For the moment this resource is not counted.

2.2. Underground Water

Underground water; Figures (6) and (7); is divided into two kinds: brackish and low salinity.

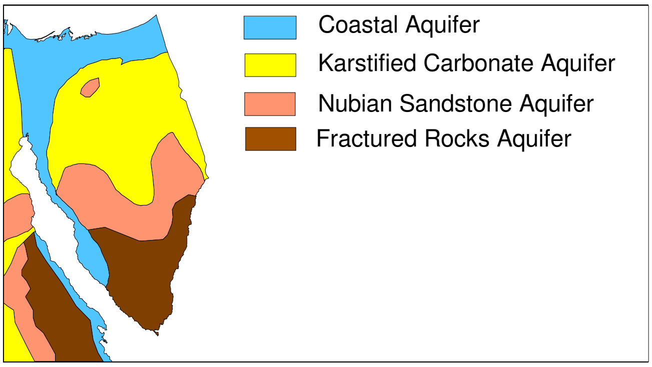

Figure (6) Main aquifers in Sinai

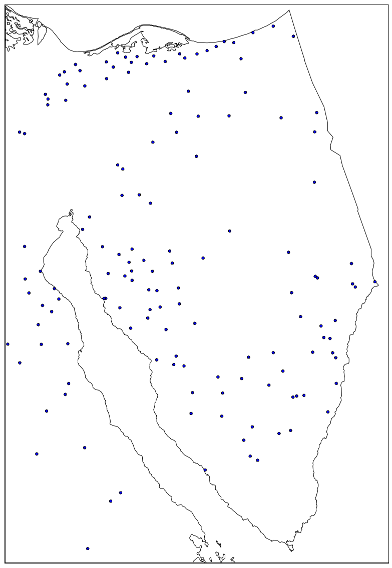

Figure (7) Location of wells and springs in Sinai

2.2.1. Brackish water

The brackish water supply is of salinity up to 20,000 P.P.M. The water delivered from the wells goes directly to agriculture if it is of low salinity. The rest is desalinated by reverse osmosis (RO) or electrodialysis (ED). Table 1 shows the number of wells and salinity. Table 2 shows the desalination units using brackish water.

Table 1. Brackish water resources

City	Number of Wells	Approximate Depth (m)	Capacity (m^3/day)	Salinity
El-Arish	50	40-60	52000	3000-5500
El-Hasana	12	12-1000	6250	1800-5000
Nakhl	7	17-1200	3600	1800-3000
El-Quseima	spring	-	1440	1200
Sheikh Zuwayid	25	30-80	5000	1200-4000
Rafah	35	35-90	10000	2700-3000

Table 2. Desalinated brackish water

City	Number of units	Capacity (m^3/day)	Process
El-Arish	7	2800	Electrodialysis
El-Hasana	1	300	Electrodialysis
Nakhl	2	200	Reverse Osmosis
El-Kuntilla	1	150	Reverse Osmosis
Abu Aweigila	1	100	Reverse Osmosis

The capacity of the brackish water desalination units is low since it is basically for small agglomeration except at El-Arish. These small units produce water for domestic use.

2.2.2. Low salinity water (300-700 P.P.M.)

This water is used in domestic purposes and agriculture. This resource is concentrated only in El-Qaa Plain. In the area of El-Tor City and Saint Catherine, there are 26 wells with a total capacity of 25,000 m^3/day. The population of these regions is 22,000 inhabitants. The water is more than the requirements for this population, and a part of it is transported to the neighboring areas as Sharm El-Sheikh and Abu Rudeis. Also, this area is an agriculture area due to the presence of these wells.

2.3. Potable Water Transported by Pipeline

The first pipeline was inaugurated 10 years ago to El-Arish, Figure (8), with a 158 km length and 700 mm diameter. The same pipeline continues to Sheikh Zuwayid and Rafah. The supply is given in Table 3.

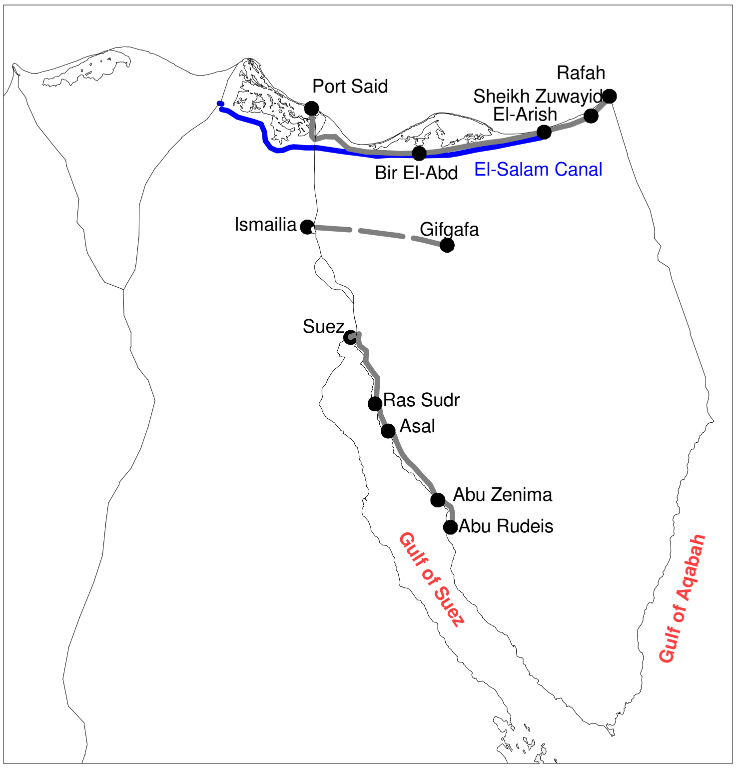

Figure (8) Water transportation to Sinai by pipelines

Table 3. Nile water supply to Sinai

City	Capacity (m^3/day)
Rumana	5,000
Bir El-Abd	10,000
El-Arish	20,000
Sheikh Zuwayid	5,000
Rafah	5,000
Total Supply	**45,000**

Future Projects:

There is a new 3-year project to supply water to Gifgafa (middle of Sinai) by a pipeline with a length of 182 km and a total capacity of 60,000 m^3/day, Figure (8). It is still in the planning stage for the future. The cost of this pipeline will be high particularly if it is to be extended to the Gulf of Aqaba. The cost will be certainly higher than desalination units.

2.4. Desalinated Water

Most of the Gulf of Aqaba region uses desalination to respond to water demand requirements. There are two categories of desalination units: first is government-owned units; second is the private-sector-owned units.

Table 4 presents the government-owned units and the technology used. The total amount of desalinated water is 9900 m^3/day or 3.6 million m^3/year.

Table 5 presents the private-sector-owned units. In fact, the major supply of desalinated water is from private sector. The total capacity of private sector production is 30,090 m^3/day or 11 million m^3/year distributed on 21 production plants owned mainly by hotels.

Table 4. Government-owned desalination units

Place	**Taba**	**Taba**	**Nuweiba**	**Dahab**	**Sharm El-Sheikh**	**Sharm El-Sheikh**	**Nuweiba**
System	R.O.	M.V.C.	E.D.	R.O.	V.V.C.	R.O.	M.E.D.
Date of start	1986	1996	1985	1995	1996	1998	1999
Total area, m^2	50000	42000	23600	30000	30000	30000	
Capacity, m^3/day	600	2000	300	500	500	4000	2000
Feed water salinity, PPM	48000	48000	2400	44000	44000	44000	45000
Product salinity, PPM	450	30	500	500	30	500	50
Power consumption, kW/m^3	13.5	9	4.3	8.5	9	6.5	
Total Cost/m^3, LE	6.21	6.64	2.78	7.51	4.75	6.34	NA

R.O. (Reverse Osmosis), M.V.C. (Mechanical Vapor Compression), E.D. (Electrodialysis), V.V.C. (Thermal Vapor Compression), M.E.D. (Multiple Effect Desalination)

Table 5. Private-sector-owned desalination units

Location	**Owner**	**Technology**	**Capacity (m^3/day)**	**Salinity**	**Product Salinity**	**Selling Price (LE/m^3)**
Taba	Golden Coast	R.O.	750	40,000	350	8
	Maleh Company	R.O.	4000	35,000	400	7.5
Nuweiba	Helnan	R.O.	240	44,000	400	8
	Hilton	R.O.	300	44,000	400	8
Sharm El-Sheikh	Pyramiza	R.O.	2000	44,000	400	9
	Ramo	R.O.	1000	44,000	400	9
	Metito	R.O.	500	44,000	400	9
	Raga	R.O.	2000	44,000	400	8
	Southern Water Co.	R.O.	7000	44,000	400	11
	Montazah	R.O.	2500	44,000	500	
	Residence	R.O.	500	44,000	600	
	Euro Palace	R.O.	500	44,000	400	
	Meridien	R.O.	500	44,000	400	
	Aqua Marina	R.O.	2000	44,000	400	
	Moevenpick	R.O.	1000	44,000	400	
	Marriott	R.O.	500	44,000	350	
Dahab	Sheik Zayed	R.O.	2500	44,000	400	
	Bacha Coast	R.O.	500	44,000	400	
	Ghazala	R.O.	500	44,000	400	
	Helnan	R.O.	800	44,000	400	
	Pullman	R.O.	500	44,000	400	

3. WATER USE (OPERATIONAL FUNCTION)

The effective operational function within an IWRM requires a management system that respond to societal needs. The water use in Sinai is classified as following:

3.1. Agriculture

The water for agriculture in Sinai is mainly supplied from precipitation. The agriculture is seasonal: 251,000 feddans (1 hectare = 2.38 feddans). It has no real impact on the national economy. The new plan for land reclamation is based on El-Salam canal, Figure (8). This project pretends to reclaim 0.7 millions feddans in Sinai. The required irrigation water is 4 billion cubic meter/year. Half of this water will come from the reuse of agriculture drains. As seen from the figure, the canal is planned to go to El-Arish City.

3.2. Domestic

The density of population in Sinai is very low. The supply of water for domestic use comes from the Nile water transported by pipeline. All North Sinai relies on Nile water treated at the Port Said water treatment plant. The discharge of the pipeline is 45,000 m^3/day. It satisfies all the need for the inhabitants in North Sinai cities and villages. In South Sinai the coastal area of the Suez Gulf relies on Nile water transported by pipeline at a discharge of 17,500 m^3/day. The city of El-Tor, the capital of South Sinai, relies on groundwater. The coastal area of the Gulf of Aqaba relies on desalination.

3.3. Tourism

Tourism activities are supplied mainly by desalinated water. The water consumption for tourism is as high as 500 lit/day per bed. The expansion of tourism is based on desalination.

3.4. Recreational

Recreational areas are irrigated by treated sewage water. A private sector company is in charge of treating the sewage and the selling of the treated water.

4. GIS TOOL

The Geographic Information System (GIS) platform of the MapInfo software is used to develop a decision making tool for the implementation of desalination units powered by the Renewable Energy Sources (RES). The tool is developed to analyze the water demand and supply situation, to monitor water shortage problems and to examine the application possibilities for the implementation of desalination schemes powered by (RES) in selected regions of the target countries.

The GIS-Decision Making Tool is based on three major levels of analysis:

- Identification of areas under water shortage problems,
- Site selection for the installation of RES/desalination plants,
- Design, sizing and cost estimation of RES/desalination systems.

Figure (9) presents the basic outline of the method.

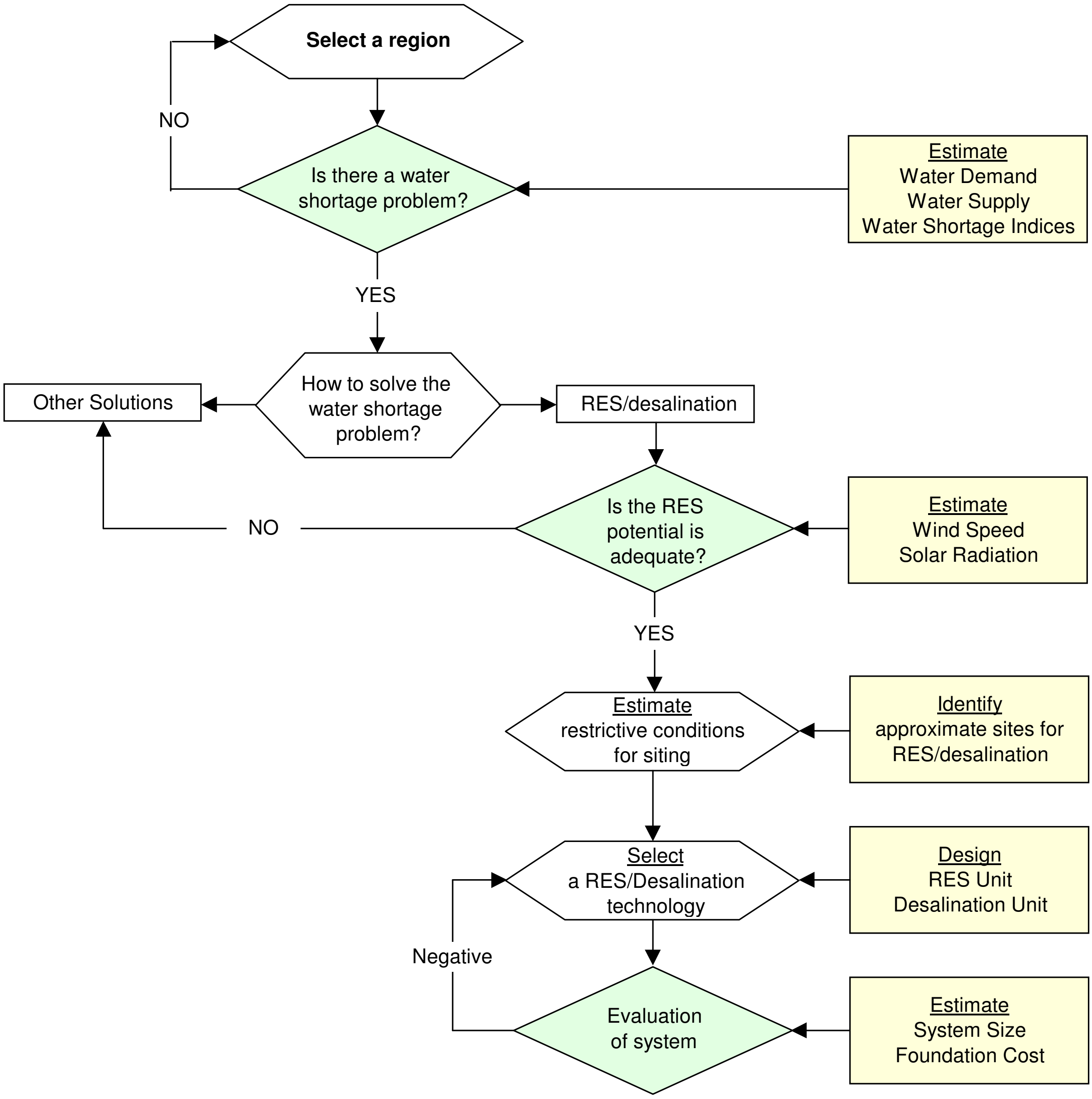

Figure (9) Overview of the decision-making procedure

A wide variety of maps and data sets are handled by the tool using advanced data management methods and incorporating important geographic characteristics of the regions under consideration.

The precise estimation of the water needs for domestic, irrigation and industrial use and the monthly variation of water demand in Sinai are performed by the GIS-Decision Making Tool. The estimation procedure is presented in Figure (10).

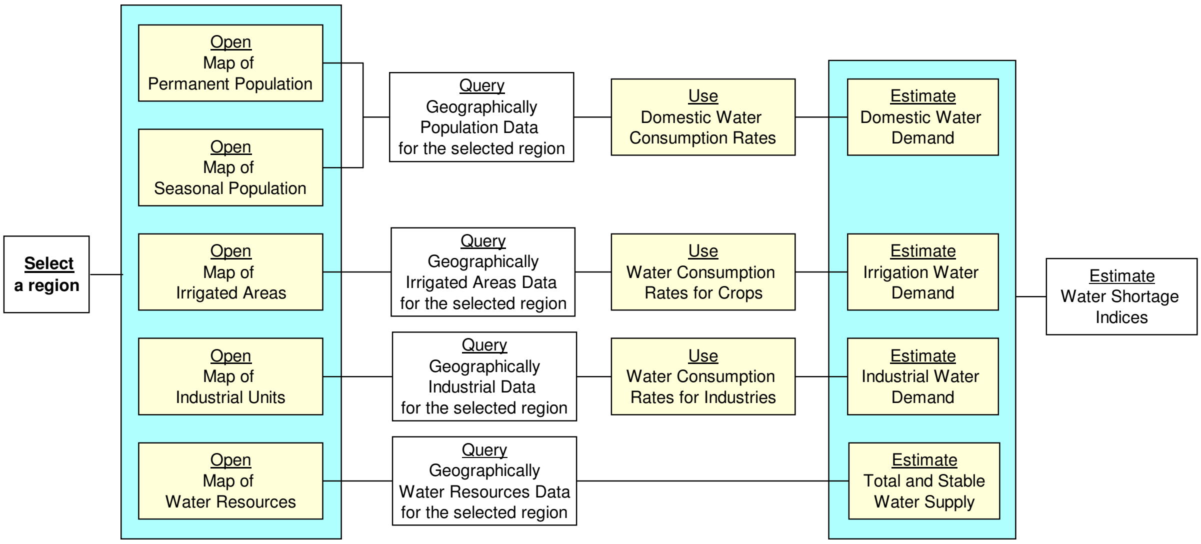

Figure (10) Water situation analysis using the GIS tool

The necessary data are related to water demand/availability, RES availability, technology solutions and cost estimations and should be first introduced in the geographically referenced database of the tool, which allows for effective geographic data management.

The capacity of the desalination plant and the daily and seasonal operation are determined by the water demand. The desalination process is selected taking into account the capacity of the plant, the feed water quality and the product water requirements. The energy requirements of each desalination process are presented in [3].

The design of the appropriate RES-park to power a desalination project is based on the energy needs of the desalination plant, the exploitable RES potential and the area siting restrictions for the installation of the RES converters. The required area for the installation of photovoltaic cells and the annual energy production are given in [3].

The financial analysis of the proposed investment involves the capital and operational costs; the estimation of the overall discounted costs and the evaluation of the expected water-selling price. The definitions of different costs are presented in [3].

5. SCENARIOS

Based on available information and forecasting for the future, the expected major activities in Sinai will be:

- Agriculture, and
- Tourism.

Agricultural activities will be covered by the El-Salam canal; it is worthwhile to develop any real agricultural activities away from El-Salam canal.

For the development of the Gulf of Aqaba coastal zone, besides desalination there is a future project to erect a pipeline to transport water to the Gulf of Aqaba. This project suffers from two main disadvantages:

1. The high cost of installation, added to the running cost is approximately 4 LE/m^3.
2. Egypt suffers from water insufficiency problems; water is recycled in order to meet the ever-increasing demand. This pipeline will increase the demand that is satisfied with difficulties.

According to these disadvantages, the scenario for development of the Gulf of Aqaba region must be based on seawater desalination to satisfy all demands - tourism or domestic.

In the institutional level, it is required to encourage private sector participation in the field of water production by desalination and reuse of treated sewage water. In level (I) legislation is required in order to encourage these activities. An incentive as tax exemption for investment in this sector is required. Only two companies are active in this field with no other competitors. The competition will bring the price down.

5.1. Importance of Desalination in order to Respond to Water Shortage Problems

The data obtained from the governmental units are shown in Table 4, which enables economic analysis. As a general rule, the dominating technology is the Reverse Osmosis technology. The private sector uses only this technology. The Sharm El-Sheikh vapor compression unit gives low total cost per cubic meter because part of the funds used in the erection of the plant is a donation from abroad. Thus, this figure can not be considered since the capital cost is not accurate. But in general, the cost of the water produced by Reverse Osmosis and vapor compression are similar at LE 6.2 to 6.34 for RO and 6.64 for vapor compression. The difference does not justify the use of one technology or the other.

Detailed investigation and site visits reveal that RO technology expenses are elevated because of the intake in most cases. An example is the Sharm El-Sheikh plant where the beach wells were not operated, as they should be. An open intake was designed to compensate for the lake of feed water.

The international tender now for RO units is as low as less than one $US, ($ 0.7 the last year 2000 price) which is equivalent to LE 3.86, approximately half of the actual operating costs in Sinai. That is why the new unit will be RO and the private sector understands these results.

The advantage of reverse osmosis is that its maintenance work is less sophisticated than vapor compression. The two units of vapor compression suffer from maintenance problems and deliver less than the nominal capacity. Other advantages of RO units are their reliability and compactness in size. This is important for the tourist area where the surface area is limited.

5.2. Water Requirement by the Year 2010

Variation in water requirements under the alternative development strategies depends primarily on the area under consideration and the scenario for the development. The primary activity in this region is tourism. Three scenarios in this region can be expected for the development of tourism. The actual demand for the coming 3 years is a 35 % increment, which corresponds to a yearly increment rate of 11 %.

- High scenario (actual) 11 %
- Moderate scenario 8 %
- Low scenario 5 %

The actual scenario is the high scenario. There was a sudden increment this year for the demand of hotel licenses. Most of them are located on the Taba-Nuweiba coast. The rate will decrease because there are no more places available in this area. It is completely booked. The expected areas for construction are Dahab and Sharm El-Sheikh.

5.3. Market Potential

The global market potential for the Gulf of Aqaba area is 65 hotels for the period of two to three years. This is the number of licenses demanded to the governorate. The distribution is given in Table 6.

Table 6. Number of licenses for hotel construction to the year 2003

Location	No. of Licenses
Nuweiba	3
Nuweiba – Dahab	2
Dahab	6
Dahab – Sharm El-Sheikh	9
Sharm El-Sheikh	18
Taba	2
Taba – Nuweiba	25
Total	**65**

The expected number of beds is about 65 x 500 assuming each hotel of 500 beds.

The total expected growth in water market demand = 65 x 500 x 0.54 = 17,550 m^3/day, which represents an increment of 33.75 % of actual capacity, distributed over three years at 11 % per year. This is considered as the high scenario of demand increment. This study has been done using the GIS tool. The analysis of shortage according to the region was done using three scenarios: high 11 %, moderate 8 % and low 5 %. The results are shown in Figures (11) - (13) for the Nuweiba, Dahab and Sharm El-Sheikh subregions, respectively. The calculation was done up to the year 2010. The only way to respond to this shortage is the desalination of seawater.

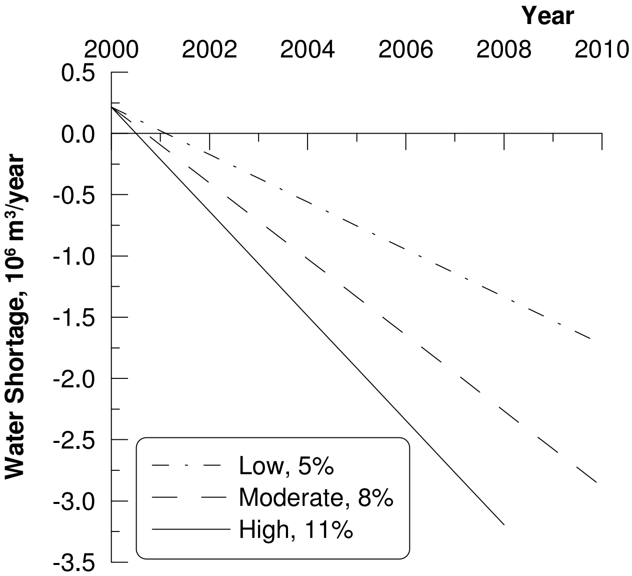

Figure (11) Scenarios for water requirements (*10^6 m^3/year) for Nuweiba subregion

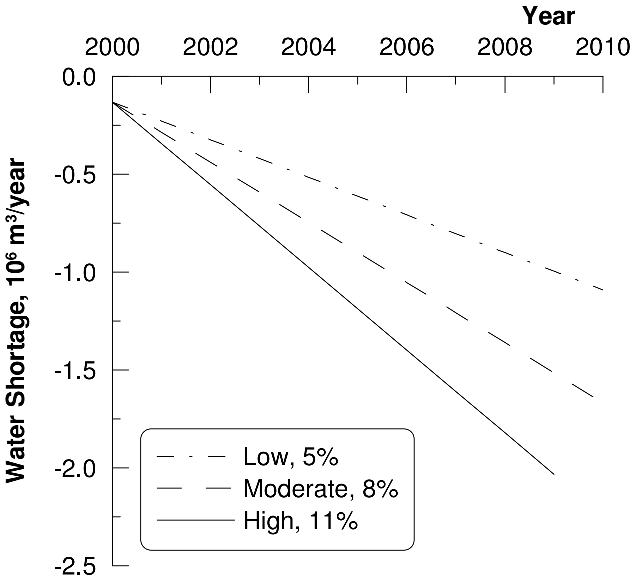

Figure (12) Scenarios for water requirements (*10^6 m^3/year) for Dahab subregion

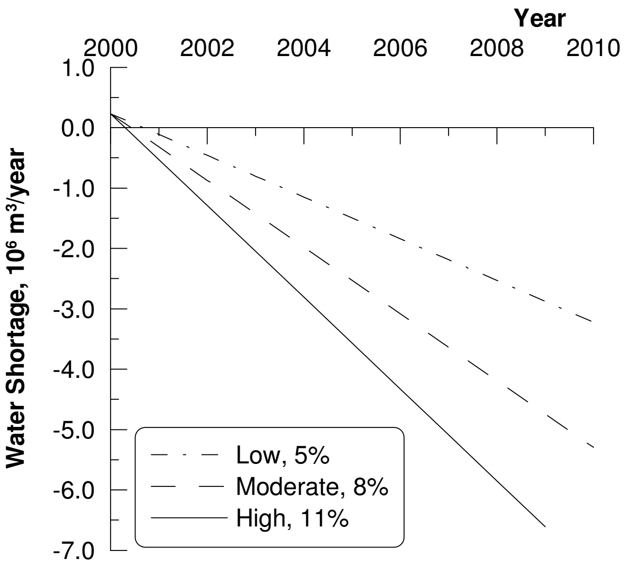

Figure (13) Scenarios for water requirements (*10^6 m^3/year) for Sharm El-Sheikh subregion

6. CONCLUSIONS

The desalination option is the most appropriate in order to respond to the water shortage problems in South Sinai. Based on the present study, the Reverse Osmosis is the appropriate technology for the development of the Sinai and Gulf of Aqaba region. Solar energy can be used in order to power these units using photovoltaic units instead of diesel generators where diesel is used. The photovoltaic panels can be installed on the neighboring mountains. The GIS tool is reliable mean for forecasting and sizing of the required desalination units.

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