Pioneering Action in Managing the Transboundary Nubian Sandstone Groundwater Aquifer

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Introduction

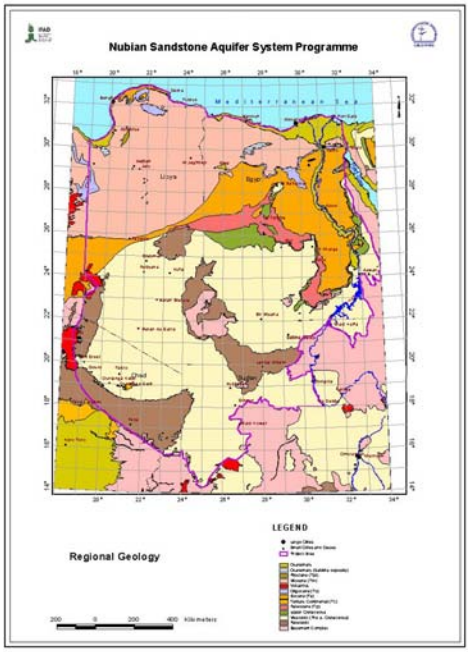
In the North Eastern part of Africa, lies the Nubian Sandstone Aquifer System (NSAS), which is shared between Egypt, Libya, Sudan and Chad. The aquifer system underlies an area of about 2.2 million km^2, 828,000 km^2 of which is in Egypt, 760,400 km^2 is in East Libya, 235,000 km^2 is in North Chad and 376,000 km^2 is in North Sudan. The area occupied by the aquifer extends between Latitudes 14 and 33 and longitudes 19 and 34.

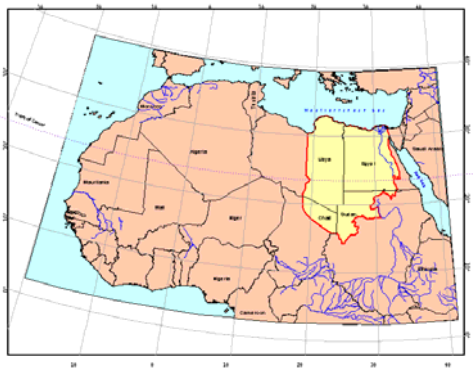
Water scarcity is an overwhelmingly important constraint to development in the region. The non-renewability of the Nubian Sandstone Aquifer, and the lack of information on great portions of the aquifer poses more complexity on the management of the aquifer. It is considerably important to employ rational principles in the utilization of the aquifer and to predict the aquifer response to different scenrios of groundwater utilization.

A Regional Programme was established for developing a shared vision for the aquifer's management. The Centre for Environment and Development for the Arab Region and Europe (CEDARE), the International Fund for Agricultural Development (IFAD) and the Islamic Development Bank (IDB) joined forces in 1997 to establish a programme for the formulation of a regional development strategy for the utilization of the Nubian Sandstone Aquifer.

Geography

The Nubian Sandstone Aquifer System (NSAS) is a transboundary aquifer underlying a total area of 2.2 million km^2 within the Eastern Sahara in Northeast Africa and is shared among Chad, Egypt, Libya and Sudan. In Egypt, the aquifer underlies an area of 828,000 km^2, in East Libya 760,000 km^2, in North Chad 235,000 km^2 and in North Sudan 376,000 km^2. The area occupied by the aquifer extends between latitudes 14 and 33 and longitudes 19 and 34.





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NSAS Regional Programme

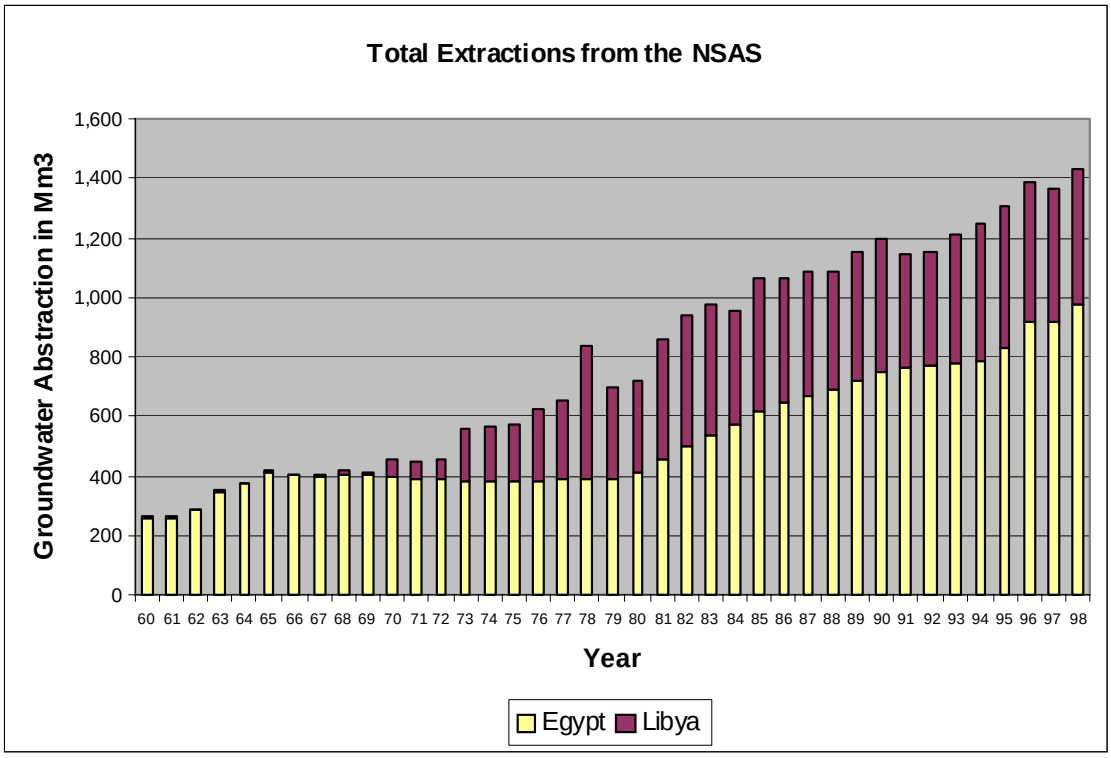
During the past four decades, countries sharing the aquifer have made separate attempts to develop the Nubian Aquifer and the overlying arid lands. Since early seventies, they have expressed their interest in regional cooperation to share their experience and to study and develop this shared aquifer. They agreed to seek international technical assistance to establish a regional project in order to develop a regional strategy for the utilization of the aquifer. Such assistance was provided by the Centre for Environment and Development for the Arab Region and Europe (CEDARE), the International Fund for Agricultural Development (IFAD) and the Islamic Development Bank (IDB) who joined forces in 1997 to establish a programme for the formulation of a regional development strategy.

Most recent isotope hydrogeological studies indicate that the Nubian Sandstone Aquifer System is non-renewable. Groundwater extractions lead to decline in water levels and in areas of intensive development, the upconing and/or the lateral flow of saline water endanger the good quality of the water.

In order to curb the danger and ensure sustainable utilization of the Nubian Sandstone Aquifer System, an enabling environment for the formulation of a regional development strategy was necessary. Capacity building of the groundwater management specialists in the National institutions of the four concerned countries was of utmost importance and a regional groundwater development strategy aiming at optimizing levels of groundwater withdrawal from the Nubian Aquifer in each country to avoid any negative reciprocal externalities was deemed imperative. Within these objectives, a regional programme steering committee as well as a regional technical review committee were formed. National coordinators in the four countries were appointed. A regional information system, thematic maps, and a mathematical model were developed. Capabilities of the national professionals in the four countries in groundwater modeling, GIS, database management, monitoring and EIA of groundwater projects were empowered through a number of training programs.

Groundwater Utilization

The Nubian groundwater has been used for centuries by the indigenous people living in the oases within the sahara. During the sixties of the last century, utilization of the Nubian waters has started by the governments and its development has been increasing gradually. The figure below shows the variation of the aquifer's utilization by country over the past four decades.



The figure shows that Egypt and Libya have been the only two countries utilizing the NSAS on the national scale. It should be noted that the utilization of the NSAS in Chad and Sudan was just limited to the use of the natives in the oases. It is also worthmentioning here that the area of the NSAS incorporated in the study in Sudan, is only the Sahara Nubian, whereas the Nile Nubian was not. The governments of Chad and Sudan have plans for future utlization of the NSAS, and these plans were reflected in the simulations of the mathematical model.

Hydrogeology

The area of the Nubian Sandstone Aquifer System is composed of different water bearing strata that are differentiated into two systems, namely the Nubian Aquifer System (NAS) and the Post Nubian Aquifer System (PNAS). The NAS underlies almost all the area of Egypt, Eastern Libya, Northern Sudan and Northern Chad. The NAS comprises the Paleozoic and the Mesozoic deposits and overlies the Pre-Cambrian basement complex. The PNAS occurs to the north of the 26th parallel overlying the NAS in the North of the Western Desert of Egypt and North Eastern Libya. The PNAS comprises the Tertiary continental deposits in Libya and Egypt and the Tertiary carbonate rocks in Egypt. A low permeability layer belonging to the Upper Cretaceous and the lower Tertiary sediments separates the two systems.

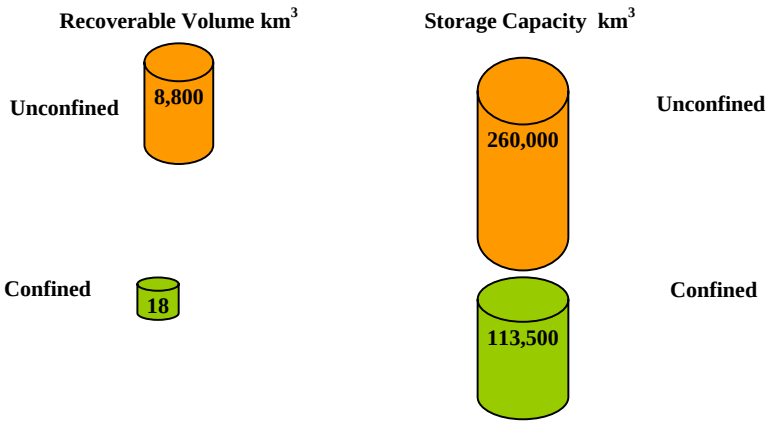
In the Nubian Aquifer System the hydraulic conductivity of the Paleozoic deposits is estimated at 10^{-5} to 10^{-6} m/s and that of the Mesozoic deposits is estimated at 10^{-4} to 10^{-6} m/s. For the confining layer separating the two systems, the horizontal hydraulic conductivity is estimated at 10^{-7} m/s and the vertical hydraulic conductivity is estimated at 10^{-10} to 10^{-11} m/s. In the Post Nubian Aquifer System (PNAS) the hydraulic

conductivity ranges from $3.6x10^{-5}$ m/s in the area between West Delta and Qattara Depression to $6.4x10^{-5}$ m/s in the Northwestern part of the Western Desert in Egypt. The hydraulic conductivity in the PNAS in Sarir, Libya, ranges from $3.1x10^{-4}$ m/s to $8x10^{-5}$ m/s.

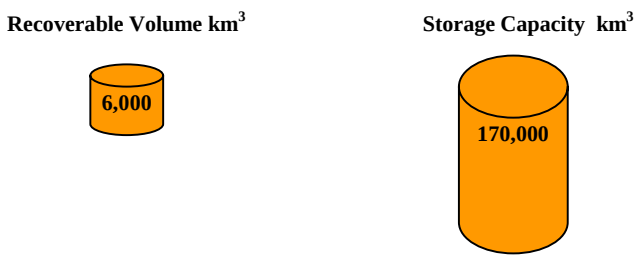
Assessment of Groundwater in Storage

The volume of water in storage is assessed based on 100m drawdown in the unconfined aquifer and 200m drawdown in the confined aquifer, and the estimated water in storage is about 15,000 km^3.

Nubian Aquifer Groundwater Assessment (confined / unconfined)



Post-Nubian Groundwater Assessment (unconfined)



Regional Mathematical Model

One of the outputs of the regional project executed by CEDARE was the development of a regional mathematical model. A finite element groundwater flow model was used. The model is a regional one and does not intend to provide a detailed local prediction of the aquifer's response to water development scenarios. It has rather been designed to analyze the regional behavior of the aquifer system, simulate various development scenarios and predict approximate regional aquifer response.

The Nubian Aquifer System Boundaries

The boundary conditions of the Nubian Aquifer System are**:**

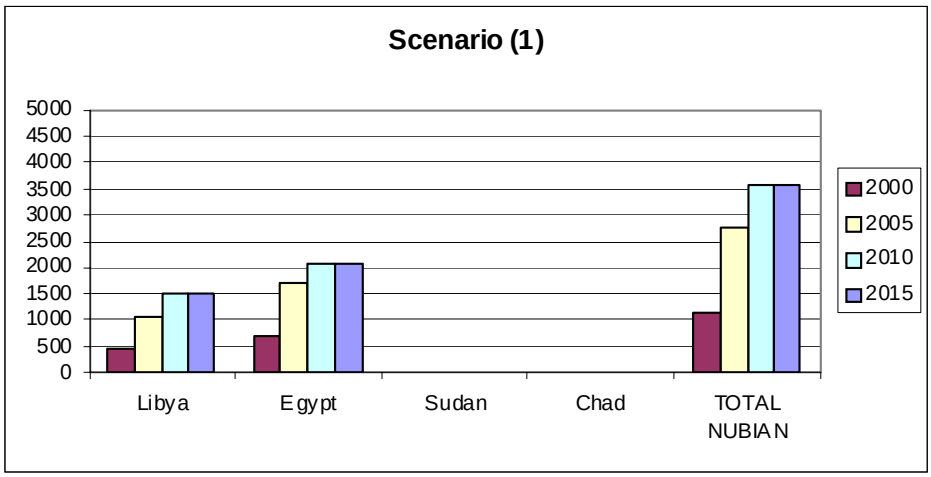
1. The eastern boundary is designed as a no-flow boundary along the impervious Pre-Cambrian basement complex of the mountain ranges of the Red Sea and northwards the Suez Canal.
2. The southern boundary is designed as a no-flow boundary stretching along the outcrops of the basement rocks of Southern Sudan (Kordofan and Darfur blocks) and Chad (Tibesti and Ennedi Mountains). In the southeastern part, the Nile is represented at Nasser Lake and Dongola by a fixed head boundary. Another fixed head boundary is taken at the southeastern part of the aquifer's boundary in Chad.
3. The western boundary is a groundwater divide extending from Tibesti mountains in the south northwards along the 19° Meridian. This boundary was designed as a no-flow boundary.
4. The northern boundary coincides with the Mediterranean coast line, representing a fixed-head boundary.
5. The base of the aquifer is taken at the surface of the Pre-Cambrian Basement complex. The basement surface elevations fall regionally from sea level in the southern part of the aquifer to over 5000 m.b.s.l. along the northern boundary. The top of the aquifer is represented by the water table in the area south of Latitude 25°, where the system is unconfined. Northwards, the aquifer is overlain by the low permeability confining layer (aquitard) of shales and carbonates with its bottom forming the top of confined part of the NAS.

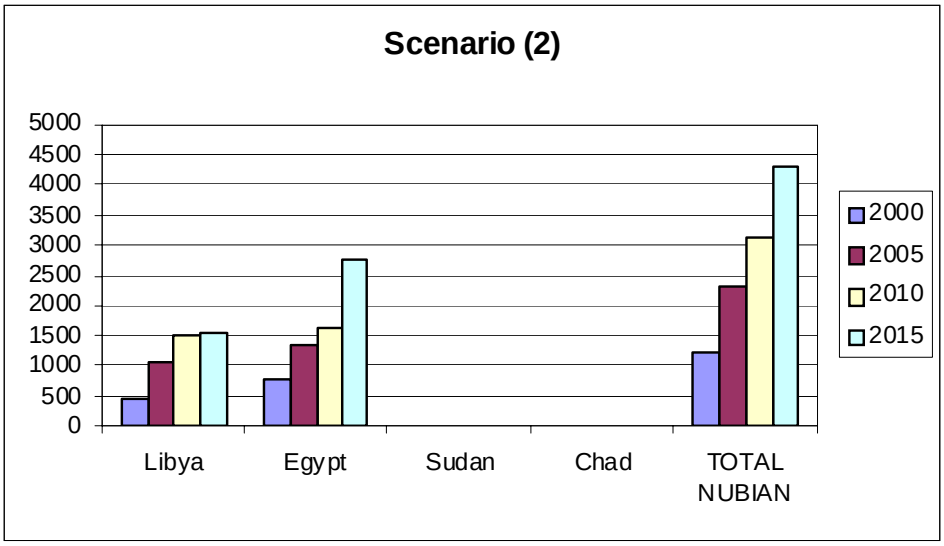
The Post Nubian Aquifer System Boundaries

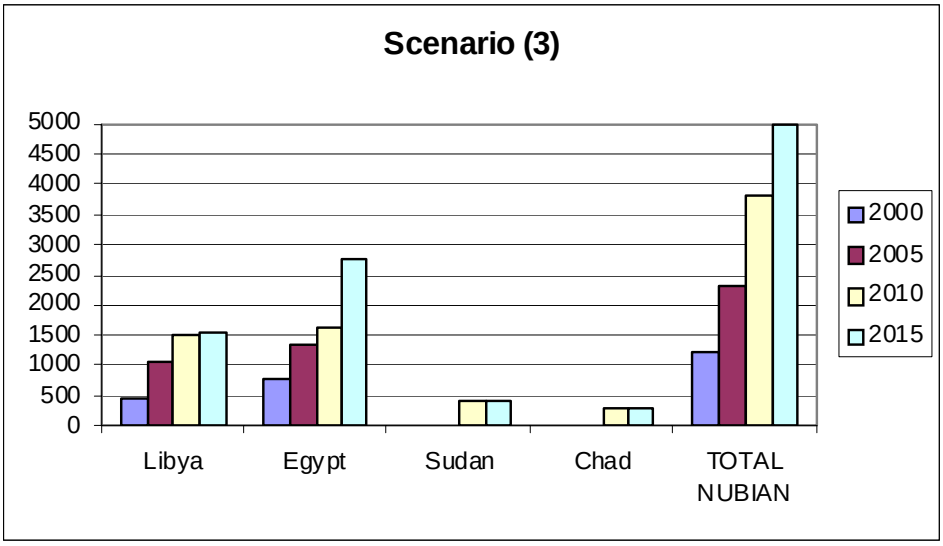
The boundary conditions of the Post Nubian Aquifer System (PNAS) are:

1. In the south, at latitude 26, the limit of the deposition was considered to be a no flow boundary.
2. In the west, at longitude 19 north of Tibesti, a no flow boundary was considered.
3. In the east, the Red Sea basement mountains were represented by a no flow boundary.
4. In the north, the Mediterranean Sea was represented by a fixed head boundary at mean Sea level.
5. The base of the PNAS coincides with the top of the confining layer of the Nubian Aquifer System underneath. The top of the PNAS is represented by its water table.

A number of scenarios were simulated, some of which are given below, followed by the impacts of such scenarios in terms of drawdown control maps.







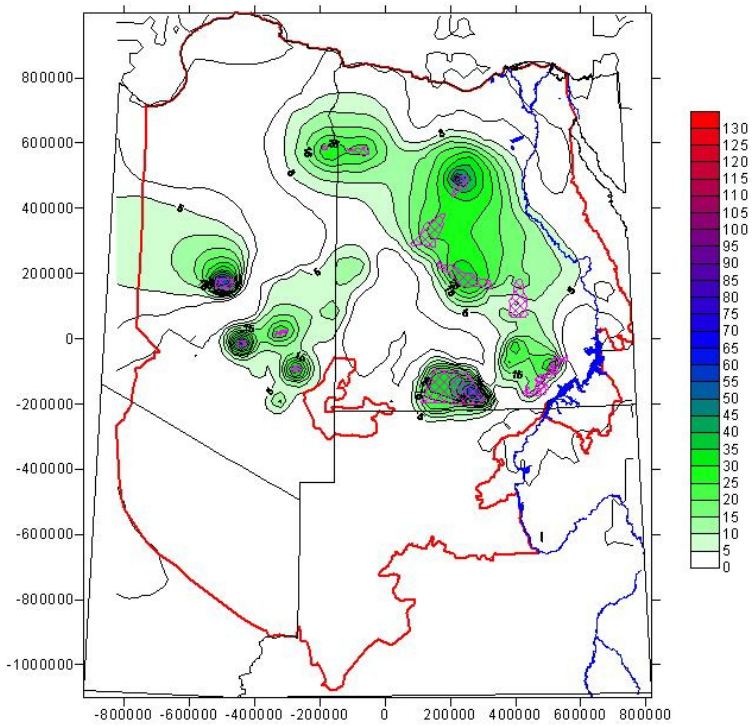


Figure (1): Scenario (1) Nubian 2000 - 2060 Draw-down

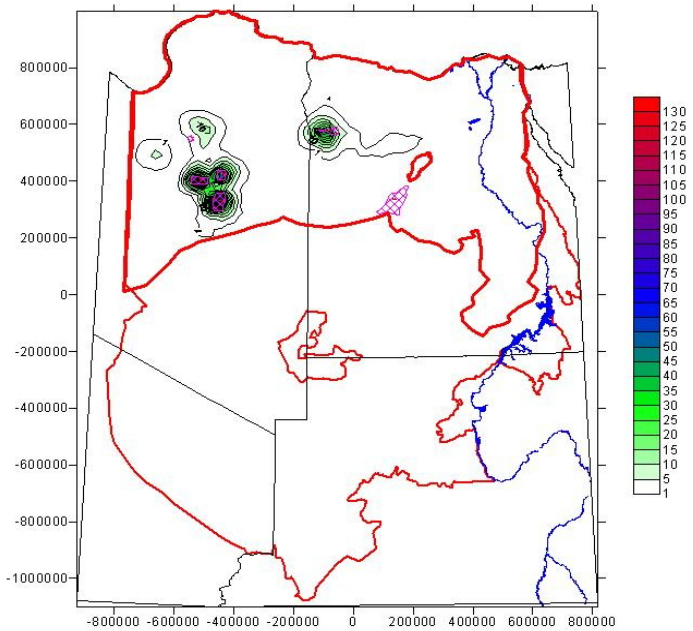


Figure (2): Scenario (1) Post-Nubian 2000-2060 Draw-down

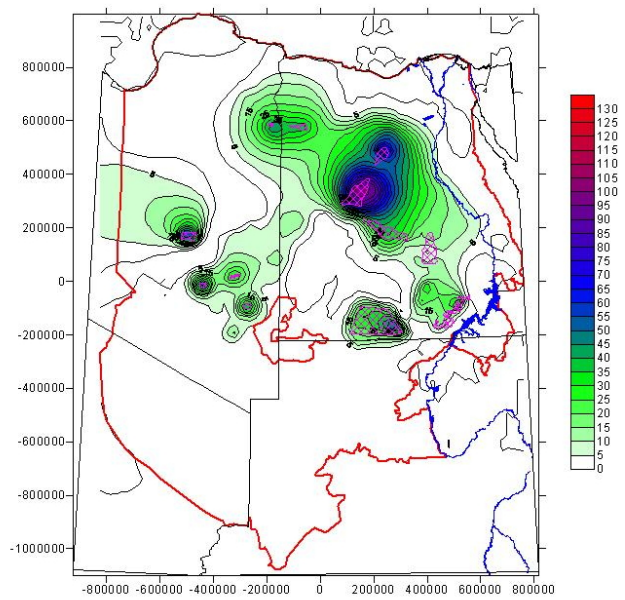


Figure (3): Scenario (2) Nubian 2000-2060 Draw-down

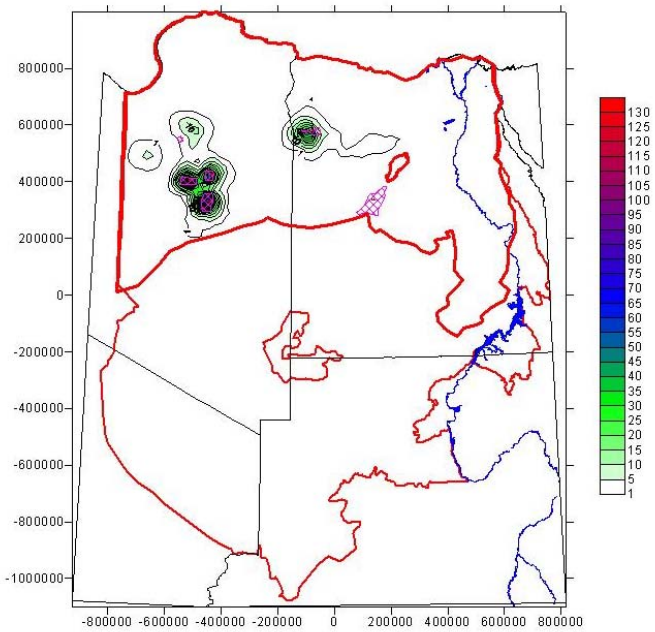


Figure (4): Scenario (2) Post-Nubian 2000-2060 Draw-down

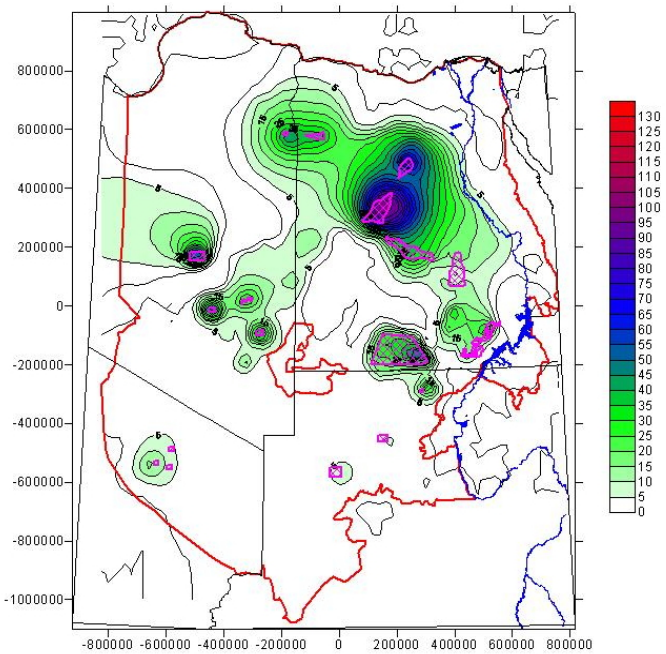


Figure (5): Scenario (3) Nubian 2000-2060 Draw-down

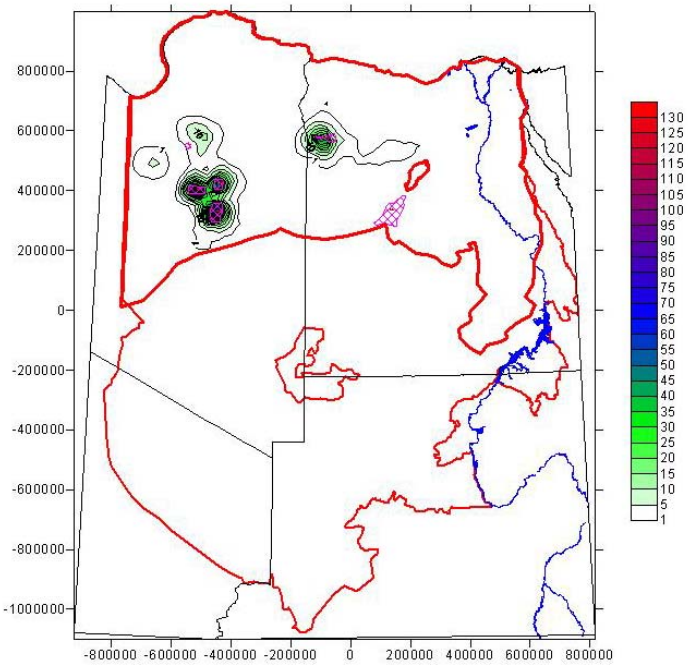
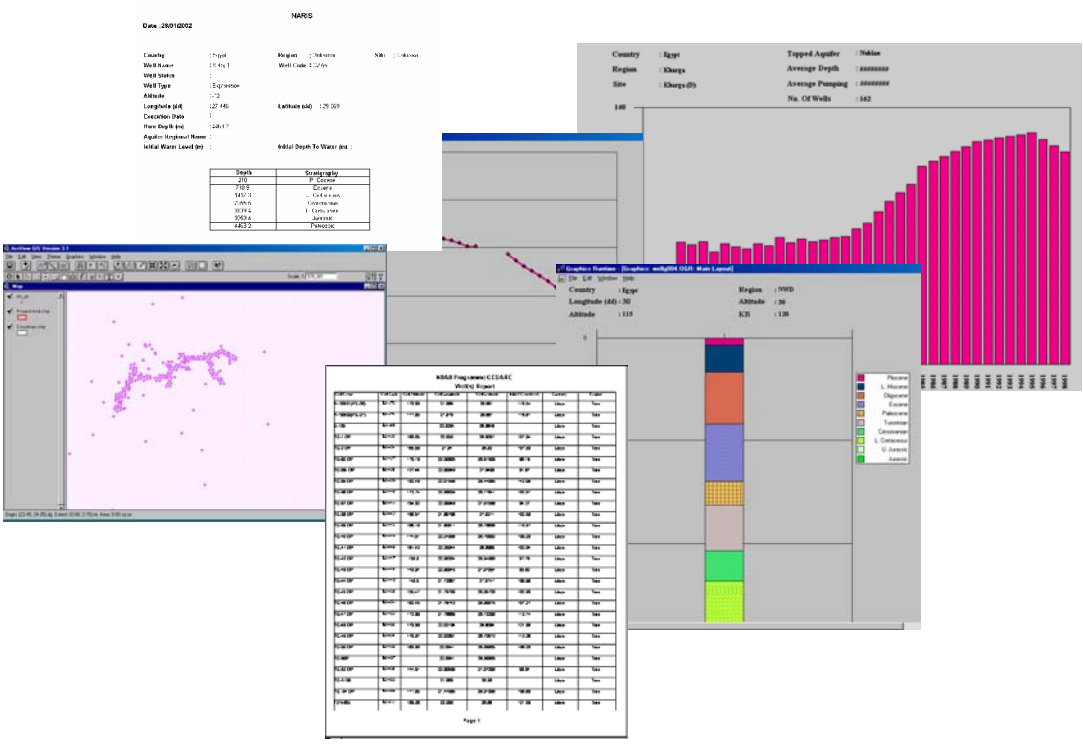


Figure (6): Scenario (3) Post-Nubian 2000-2060 Draw-down

The Nubian Aquifer Regional Information System (NARIS)

The regional strategy for the utlization of the NSAS was presented to a regional body which is the *Joint Authority for the Study and Development of the Nubian Sandstone Aquifer System*, whose mandate is to collaborate and develop co-operative activities for the development of the Aquifer. In this respect, a Nubian Aquifer Regional Information System (NARIS) was developed to assist decision-makers and facilitate sharing of information between the riparian countries. This information system comprises information on water points characteristics, groundwater levels (historical), water quality, groundwater extractions (historical), lithology information, in addition to a bibliographic database. The system ensures harmonization, integration and standardization of information, facilitates data storage, data processing, and analysis. It also allows displaying of basic data such as water points characteristics, water levels, salinity, extractions, etc. as well as facilitating the preparation of data for models' inputs and calibrations at different scales. This Regional Information System provides a link between the concerned countries through a system ensuring the easy exchange and flow of data and information. In addition, regional thematic maps were developed for and delivered to the four countries. These maps provide a unified spatial base paving the way for easy exchange of data amongst the concerned parties. Two agreements were signed by the four countries for regular monitoring of the aquifer and the sharing and exchange of data to unveil unknowns about the aquifer beyond the borders of each country.



Output samples of the NARIS

Also a bibliographic database was developed including more than 800 references about

the NSAS. Also a socio-economic study was carried out and a socio-economic indicators system was developed.

MECHANISM FOR CONTINUED REGIONAL COOPERATION AND SUSTAINABLE DEVELOPMENT

In order to assure the sustainable development and the continued mechanism of regional cooperation for the proper management of the Nubian Sandstone Aquifer, it was deemed imperative to share the information, monitor the aquifer regionally, and exchange updated information on the behavior of that shared resource.

Under the umbrella of the regional Programme, CEDARE prepared two agreements which were signed and endorsed by the representatives of the four countries.

Within the context of the first agreement the four countries agreed to share the data that was consolidated throughout the implementation of the Programme and that was incorporated in the Regional Information System. It was also agreed to share the information that would be collected (according to the terms of the second agreement) by updating the Regional Information System which would be implemented in an Internet environment that enables the on-line view of updates. However, this Internet environment for data sharing and exchange is not yet implemented due to lack of funds.

Within the framework of the second agreement they agreed to update the information by continuous monitoring and sharing of the following information;

1. Yearly extraction in every extraction site, specifying geographical location and number of producing wells and springs in each site.

2. Representative Electrical Conductivity measurements (EC), taken once a year in each extraction site, followed by a complete chemical analysis if drastic changes in salinity is observed.

3. Water level measurements taken twice a year in locations specified in maps and tables.

CEDARE also proposed a regional monitoring network, indicating representative sites that should be monitored, the parameters and the frequency of monitoring of these parameters. These included the yearly extraction in every extraction site, yearly measurement of the quality in each extraction site in addition to the water level measurements in specified locations which should be recorded twice a year. The monitoring network was designed to provide as much areal coverage as possible of the two layers of the aquifer, i.e. the Nubian as well as the Post Nubian aquifers. The four countries sharing the resource represented by their National Coordinators adapted the regional network and agreed to continue the monitoring of the aquifer through a mechanism specified in the two agreements. The regional monitoring network included existing locations as well as proposed ones to cover the gaps of information. The four countries were provided with equipment for monitoring the quantity and quality of groundwater, to maintain the collection and share of data.

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