

Regional Strategy for the Utilisation of the Nubian Sandstone Aquifer System

Administration

Volume IV



**CENTRE FOR ENVIRONMENT & DEVELOPMENT FOR THE
ARAB REGION AND EUROPE**



INTERNATIONAL FUND FOR AGRICULTURAL DEVELOPMENT

Programme for the Development of a Regional Strategy for the Utilisation of the
Nubian Sandstone Aquifer System

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Preface

Throughout history, access to water has been essential to social and economic development and stability of cultures and civilizations. Water is an indispensable commodity of life. Groundwater is considered as one of the principal fresh water resources. Under the thrust of the ever-increasing population in the world, there happens to be a notable deficiency in the fresh water supplies. This state of affairs urged individuals, communities, authorities and international agencies to search for groundwater in an attempt to keep pace with the continually increasing demand for water.

The countries of Northeast Africa, Egypt, Libya, Chad and Sudan share The Nubian Sandstone Aquifer System (NSAS), which represents a huge fresh water reserve. The four countries have expressed their interest to share their experiences and to develop this regional Aquifer System.

With this in mind The Centre for Environment and Development for the Arab Region and Europe (CEDARE) developed a programme for The Development of The Nubian Sandstone Aquifer System. The Programme was then funded by the International Fund for Agricultural Development (IFAD) and executed by CEDARE.

The results of the study presented in this report have produced a Regional Strategy for the utilization of this huge common resource, which hopefully will facilitate consultation between the concerned countries and create a sense of sharing a common resource in order to exploit it rationally.

This detailed study has been conducted by a team of experts guided by Dr. Mohamed Bakhbaki NSAS Regional Coordinator.

May I avail myself to this opportunity to thank the collaborating national institutions for their efforts and cooperation. Last but not least I wish to express, on behalf of the governments concerned, and on behalf of CEDARE, our deep appreciation and gratitude to IFAD for financing the project.

Dr. Kamal A. SABET
Executive Director

Acknowledgments

The “Programme for the Development of a Regional Strategy for the Utilisation of the Nubian Sandstone Aquifer System (NSAS)” is funded by the International Fund for Agricultural Development (IFAD). The execution of the Programme is the primary responsibility of CEDARE. The NSAS Programme team wish to extend their thanks and appreciation to IFAD who has funded this programme and made this publication and the associated study possible. They wish also to express their gratitude to CEDARE for hosting the Programme and making its implementation come true. The guidance and support of Dr. Kamal Sabet, Executive Director of CEDARE is highly appreciated.

The NSAS Programme wish also to convey its gratefulness to the consultants of the Programme whose valuable inputs are highly appreciated, namely Dr. Abdou Shata, Senior Geology Consultant, Mr. Philippe Pallas, Dr. G. Pizzi and Eng. Saleh Nour.

The Programme acknowledges the involvement and the effective contribution of the National Institutions of the four concerned countries whose cooperation, interaction and provision of information throughout the implementation of the Programme was of ultimate benefit and utmost importance towards the forwarding and accomplishment of this study. Special vote of thanks are to the National Coordinators; Dr. Moussa Terap – Chad, Dr. Fatma Attia – Egypt, Dr. Omar Salem – Libya and Dr. Idris M. Idris – Sudan. Appreciation is extended to all the members of the Steering Committee and the Regional Technical Review Committee for their constructive input and time.

Special recognition to Ms. Sahar Ezz El Arab, Secretary of the Programme for typing the report.

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Forward

This study on the development of a regional strategy for the utilization of the Nubian Sandstone Aquifer System has been prepared by Dr. Mohamed Bakhbakhi (CEDARE Regional Programme Coordinator), the Programme's team of consultants, Professor Dr. A. Shata, Mr. Phillippe Pallas, Dr. G. Pizzi and Engineer Saleh Nour and the staff of The Programme Engineer Amr Abdel-Meguid and Engineer Omar Elbadawy.

In the preparation of this study numerous reports, studies, documents, briefs and write up have been consulted. Below is a partial list of these reports:

- 1) The final reports of the "special research Project in Arid areas period 1984 – 1987" and on "Hydrogeological investigations in the Nubian Aquifer System", Eastern Sahara prepared by Klitzsch et al, 1987, as well as research on modeling of the Nubian Aquifer System by Heintl and Binkman (Published in 1989), the hydrogeological investigation carried out by Heintl and Thorweihe in Northern Sudan, 1983 and S.W. Egypt, 1993. (annex 1),
- 2) Bretschneider, H., Heintl, M., Brinkmann, P.J., Hollander, R. (1987) Groundwater Model for the Nubian Aquifer System. Technical University of Berlin.
- 3) The many technical reports prepared by the Technical University of Berlin and ACSAD upon request of OSS,
- 4) P.J. Brinkman, M. Heintl, R. Hollander and G. Reich, 1987. Retrospective simulation of groundwater flow and transport in the Nubian Aquifer System, Berliner Geowiss. Abh (A) 75.2, 465-516 Berlin.
- 5) JVQ, Joint Venture Qattara (1978): study Qattara-Depression, special volume: Regional geology and Hydrogeology, unpublished report of Lahmeyer GmbH, Salzgitter consult GmbH, Deutsche Projekt Union GmbH.
- 6) Pallas P. (1978) water resources of the socialist People's Libyan Arab Jamahiriya. 2nd Symposium of geology of Libya-Tripoli.
- 7) El Ramly, I. (1983), Water Resources Study of Zone V (Al Kufrah and Sirt Basins) unpublished report, Socialist People's Libyan Arab Jamahiriya, Secretariate of Agricultural Reclamation and Land development, water and Soil Department.
- 8) The technical reports prepared by the National institutions and regional organizations (annex 1),

- 9) Ali Hissene Mahmoud (1986) geologie Und Hydrogeologie des Erdis-bechen, NE-Tschad. Berliner Geowiss. Reihe A/B 76, Berlin.
- 10) EZZAT, M.A. (1974): Groundwater series in the Arab Republic of Egypt; Exploitation of groundwater in ElWadi El-Gadid Project Area. Part I to IV, General Desert Development Authority/ Ministry of Irrigation Cairo.

The results achieved during our study are included in a final report made up of four volumes and two annexes.

This is Volume 4 of 4 volumes and 2 annexes report

Volume 1: Executive summary

Volume 2: Hydrogeology

Volume 3: Groundwater Model

Volume 4: Administration

Annex 1: Information System

Annex 2: Bibliography

Note: The denomination used and the boundaries shown on any map or graphical appendices to this document do not imply, on the part of IFAD, CEDARE or any other party associated with the preparation of this document, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

List of Abbreviations

ACSAD	Arab Center for Studies of Arid zones & Dry Lands
Bm³/y	Billion cubic meters per year (10 ⁹ m ³ /y)
CEDARE	Centre for Environment and Development For the Arab Region and Europe
EIA	Environmental Impact Assessment
GIS	Geographic Information System
GWA	General Water Authority, Libya
IFAD	International Fund for Agricultural Development, Rome
IDB	Islamic Development Bank
m.b.g.l	meters below ground level
m.a.s.l	meters above mean sea level
m.b.s.l	meters below mean sea level
MSL	mean sea level
mg/l	milligrams per liter
g/l	grams per liter
Mm³/y	Million cubic meters per year
Mm³/day	Million cubic meters per day
GMS	Ground water Modeling System
AQUQA3D	Ground water Modeling Software
NSAS	Nubian Sandstone Aquifer System
NAS	Nubian Aquifer System
PNAS	Post Nubian Aquifer System
RC	Regional Coordinator
RIGW	Research Institute for Groundwater – Egypt
RPSC	Regional Programme Steering Committee
RTRC	Regional Technical Review Committee
SSO	Sahara & Sahel Observatory
TDS	Total Dissolved Solids
TUB	Technical University of Berlin
UNEP	United Nations Environmental Programme
UNDP	United Nations Development Programme
U.S.G.S	United State Geological Survey
mcm	Million Cubic meters
PPM	Parts per Million
GL	Ground Level

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Foreword

In order to pave the way for the formulation of a regional NSAS development strategy, two of the Programme's specific objectives which are (i) creating an enabling environment for the formulation of a regional strategy; and (iii) assisting in the capacity-building of national institutions, were achieved through a number of activities. These activities comprise institutional arrangements, equipment purchase and training courses. Details are described in this volume.

Institutional Arrangements

At the aim of enabling the environment for the development of a regional strategy for the utilisation of the NSAS, the following institutional arrangements were carried out:

1.1 Revitalizing the Nubian Sandstone Aquifer System Joint Authority

The Joint Authority on the Nubian Sandstone Aquifer that was previously formed between Egypt, Libya, and later Sudan was revitalized again. Chad was invited to attend as an observer at the first meeting of the revitalized Joint Authority in February 1998. The Joint Authority acted as the Regional Programme Steering Committee (RPSC). The Joint Authority in its first rotation during the Programme was chaired by Dr. Mona ElKady who was delegated by H.E. Dr. Mahmoud Abu-Zeid, Minister of Public Works & Water Resources of Egypt.

Thus, the Joint Authority included Dr. Mona ElKady from Egypt, Chairperson, Dr. Fatma AbdelRahman Attia, and Dr. Taher Mohamed Hassan from the Ministry of Water Resources and Irrigation of Egypt, Dr. Omar Mohamed Salem, Dr. Mohamed AbuElqassem Bakhbakhi, and Dr. Salem Rashrash from the Secretariat of Agriculture of the Libyan Arab Jamahiriya, and Dr. Mohamed Kheir Saleh from the Ministry of Irrigation and Water Resources of Sudan. Mr. Moussa Tchitchaou, Directeur de l'Hudraulique, le Ministere de l'Environnement et de l'Eau of Chad participated in the Joint Authority's third meeting (first during the Programme) as an observer and was supposed to discuss with the Ministry of Environment and Water in Chad the possibility of joining the Authority. In this meeting, the Joint Authority decided to officially invite Chad to be an active member of the Authority. In March 1999, Chad officially joined the Authority. During their meeting on 6 June 2000, the members of the Joint Authority elected Dr. Omar Salem, chairman of the Authority for its new rotation.

1.2 Forming the Regional Programme Steering Committee-RPSC

The Regional Programme Steering Committee (RPSC) was formed of the Joint Authority members. Its role was to approve the Plan of Work and Budget proposed by the NSAS Programme and the Regional Technical Review Committee and to review their recommendations. Also to discuss any other issues related to the NSAS Programme and its regional setup. The RPSC met once a year or whenever necessity arised.

1.3 Forming the Regional Technical Review Committee-RTRC

CEDARE called for the first meeting of the Regional Technical Review Committee to which a provisional list of committee members were invited. The list included representatives of IFAD, the four countries sharing the aquifer, namely Egypt, Chad, Libya, and Sudan, Technical University of Berlin, Sahara & Sahel Observatory (OSS), UNESCO, the Islamic Development Bank (IDB), ACSAD, UNDP, the Italian

Government, the Netherlands, and other Egyptian organizations and experts since the meeting took place in Egypt. The meeting was held on 4-5 February 1998.

At the end of the meeting the RTRC was formed including representatives of Egypt, Libya, Sudan, CEDARE, IFAD, IDB, UNESCO, ACSAD, OSS, and the Technical University of Berlin (TUB).

1.4 Appointment of National Coordinators

Members of the Joint Authority and the Regional Programme Steering Committee (RPSC) of the Programme appointed in their first meeting the Focal point Institutions and the National Coordinators. In Egypt, the Ministry of Public Works and Water Resources of Egypt appointed the Research Institute for Groundwater as the Programme Focal Institution and Dr. Fatma Abdel-Rahman as the Egyptian National Coordinator. In Libya, the Secretariat of Agriculture for the Libyan Arab Jamahiriya appointed the General Water Authority as the Focal Institution and Dr. Omar Salem as the Libyan National Coordinator. In Sudan, the Ministry of Irrigation and Water Resources appointed the Non-Nile Waters Directorate as the Focal Institution and Dr. Mohamed Kheir Saleh as the Sudanese National Coordinator. The National Coordinators are the representatives of their corresponding countries and meet once a year as members of the RTRC. At the beginning of the second year of the project and during the second RTRC meeting, Chad officially joined the Joint Authority of the Nubian Sandstone Aquifer. In Chad, The Ministère de l'Environnement et de l'Eau, Direction de l'Hydraulique is the focal Institution, with Dr. Moussa Tchitchaou as the National Coordinator. In the year 2000 Dr. Moussa Terap replaced Dr. Tchitchaou as the Directeur de l'Hydraulique in Chad and Chad's National Coordinator. In January 2001, Mr. Mahamat Kher Salah replaced Dr. Terap. In the year 2000 the Non-Nile Waters Directorate of Sudan was renamed to be the Groundwater and Wadis Directorate and Dr. Idris Mohamed Idris was appointed its Director and hence the Sudanese National Coordinator.

1.5 Regional Technical Review Committee Meeting -1

The first meeting of the RTRC took place during the period of 4 - 5 February 1998, at CEDARE premises in Cairo-Egypt. Since there were no activities in 1997, the RTRC recommended to consider the 1st of February 1998 as the official starting date of the project. The main objectives of the meeting were to:

- ? review the work plan, budget, and schedule of activities
- ? select a Regional Coordinator for the Programme
- ? review the current utilization and monitoring of the Aquifer
- ? define the extension of the Nubian Sandstone Aquifer System (NSAS)
- ? decide on means for the NSAS information consolidation
- ? define problems to be solved by the Programme
- ? recommend possible NSAS modeling Environments

The RTRC endorsed the Work Plan and Budget for the first fiscal year of the Programme (1998) and presented it to the RPSC. The RTRC highlighted the fact that the programme will have to be shifted to February 1998. It was agreed that the countries will discuss among themselves their equipment needs and submit them to CEDARE. The RTRC recommended that the national databases should be

strengthened. Essential and required data should be made accessible to CEDARE for verification, storing and eventually made available to the concerned countries. A commercial software was recommended to ensure the sustainability and maintenance of any regional model that may be developed during the Programme. A user friendly interface for pre and post processing was needed for that simulation model to be linked with the geo-referenced database on GIS. Scientific Visualization was deemed important for better understanding of the Aquifer behavior. Density dependent modeling was recommended to be utilized whenever possible. Geostatistics tools were recommended to be utilized to evaluate the data whenever possible. The second day of the meeting was dedicated to a seminar on the review of existing and possible Nubian Sandstone Aquifer System Modeling environments.

1.6 Regional Programme Steering Committee Meeting-1

The Joint Authority for the Studies and Development of the Nubian Sandstone Aquifer held its Third Board Meeting on February 4th, 1998 at the premises of CEDARE. The meeting was attended by the representatives of Egypt, Libya, and Sudan, and Chad representative in observer capacity. The main items discussed in the meeting included:

- ? Admission of Sudan to the Joint Authority
- ? Invitation of Chad to the Joint Authority
- ? Administrative and financial aspects
- ? Appointment of an executive director and directors of regional offices
- ? Coordination of national and regional activities
- ? Approval of the Work Plan, Budget and Schedule of Activities as proposed by the RTRC.

1.7 Appointment of Regional Coordinator

CEDARE sent the Terms of References and required qualifications for the Regional Coordinator's post to the concerned countries to nominate their candidates for the post. Five nominations for candidates (two from Sudan, two from Egypt, and one from Libya) were received.

During the First Regional Technical Review Committee Meeting, the participants formed a sub-committee composed of the representatives of CEDARE (Dr. Kamal Sabet), IFAD (Dr. Philippe Pallas), and UNESCO (Dr. Abdin Saleh) to evaluate the nominated candidates for the post of the Regional Coordinator.

Dr. Mohamed Bakhbakhi from Libya was selected to be the Regional Coordinator. His name was then proposed to IFAD for final approval. IFAD approved and CEDARE offered the post for Dr. Bakhbakhi who accepted the offer and joined CEDARE as a Regional Coordinator on August 12th 1998.

1.8 Support Staff

A Water Resources Management Specialist (Eng. Amr AbdelMeguid), and a Senior Secretary (Ms. Sahar Darwish) were hired in June 1998. On December 25th, 1998 the secretary left and a new Senior Secretary (Sahar Ezz-Elarab) was hired on March 1st,

1999. A Senior GIS Specialist (Eng. Omar Elbadawy) was hired as a part timer then was involved as a full timer since January 2000.

1.9 Regional Technical Review Committee Meeting-2

The meeting was held on 17-18 March 1999, and was attended by the committee members including the representatives of Egypt, Libya, Sudan, Chad, CEDARE, IFAD, UNESCO, ACSAD, OSS and the Technical University of Berlin. The main objectives of the meeting were to:

- ? Review and adopt the Plan of Work and Budget for the second year prepared by the NSAS Programme
- ? Review the activities implemented during the first year of the Programme on the regional and national levels
- ? Discuss the modeling approach and the aquifer's boundary conditions
- ? Discuss data collection and monitoring activities
- ? Discuss the development of a regional information system and the mechanism of data sharing among countries
- ? Discuss the extension of the Programme's duration

The RTRC endorsed the Plan of Work and Budget and presented it to the Regional Programme Steering Committee (RPSC). The RTRC approved the boundary conditions proposed by the NSAS Programme and highlighted the importance of the development of a regional information system to facilitate data exchange and information sharing.

1.10 Regional Programme Steering Committee Meeting-2

The second Regional Programme Steering Committee (RPSC) meeting of the NSAS Programme was held on 17-18, March, 1999. The meeting was attended by the committee members which were the members of the Joint Authority on the Nubian Sandstone Aquifer. The main items discussed in the meeting included:

- ? Official admission of Chad to the Joint Authority and the RPSC
- ? Approval of the Plan of Work and Budget as proposed by the RTRC

1.11 Regional Technical Review Committee Meeting-3

The meeting was held on 5-6 June, 2000, and was attended by the committee members including the representatives of Egypt, Libya, Chad, CEDARE, IFAD and IDB. The representative of Sudan was not able to attend the meeting. The main objectives of the meeting were to:

- ? Review the modeling progress achieved and discuss the modeling approach, calibration results, new aquifer boundaries and delineation acquired in the model and other technical aspects concerning the modeling activity.
- ? Review and adopt the Plan of Work and Budget for the IDB funded phase of the NSAS Programme
- ? Discuss the participation of Chad and the needs for its capacity building and equipment supplies.

The RTRC endorsed the Plan of Work and Budget for the IDB funded phase and presented it to the Regional Programme Steering Committee (RPSC). The RTRC approved the new boundary conditions proposed by the NSAS Programme and the calibration results. Two countries (Libya and Chad) provided the Programme with their future development scenarios to be simulated by the model. Egypt promised to submit its future plans within a month from the date of the meeting. The RTRC approved the extension of the Programme till the end of year 2000 due to the expansion of the model's scope and boundaries to the Mediterranean territories which lead to the involvement of extra time, effort and data collection. During the meeting, the representative of IFAD requested the submission of an interim report. In prompt response to his request, the NSAS Programme submitted the interim report in July 2000.

1.12 Regional Programme Steering Committee Meeting-3

The third Regional Programme Steering Committee (RPSC) meeting of the NSAS Programme was held on 6 June 2000. The meeting was attended by the committee members who were the members of the Joint Authority on the Nubian Sandstone Aquifer. The main items discussed in the meeting included:

- ? Election of chairperson of the Joint Authority for its coming year
- ? Approval of the Plan of Work and Budget as proposed by the RTRC

1.13 Technical Meeting of the National Coordinators

Upon the recommendations of the Regional Technical Review Committee in its third meeting, a technical meeting of the National Coordinators was held in Tripoli, Libya on 3-4 October 2000. The objective of the meeting was to review the results of the simulated scenarios of the mathematical model. During the meeting the National coordinators approved the simulated scenarios. Also, the Nubian Aquifer Regional Information System developed by the NSAS Programme was presented. The representatives of the four countries signed two agreements; the first one for the monitoring and exchange of groundwater information of the NSAS through which it was agreed to share the information consolidated throughout the project and the second agreement for monitoring and data sharing through the regional Information System within an internet environment through which the updated and monitored data will be online exchanged by the four countries. (Agreements shown in Appendix II).

1.14 Regional Technical Review Committee Meeting-4 and Seminar on Development Strategies

The meeting was held on 28-29 January 2001, and was attended by the committee members including the representatives of Egypt, Libya, Sudan, CEDARE, IFAD, ACSAD and OSS. The representative of Chad was not able to attend the meeting. The main objectives of the meeting were to:

- ? Review the achievements and outcomes of the NSAS Programme
- ? Review the development strategies and scenario simulations of the mathematical model developed and presented by the NSAS Programme
- ? Review the Nubian Aquifer regional information system

The RTRC approved the modeling results and simulations of development strategies and emphasized the fact that the findings of the Programme, the developed information system and the calibrated model should be provided to the four countries to be used for further simulation of scenarios on both local and regional levels. The RTRC also recommended that further studies should be carried out to tackle the water quality issues and that the regional monitoring network should be augmented. It also recommended that during the year where CEDARE would be hosting the Regional Information System, the Joint Authority should establish the necessary arrangements for regionally maintaining and updating it.

1.15 Regional Programme Steering Committee Meeting-4

The fourth Regional Programme Steering Committee (RPSC) meeting of the NSAS Programme was held on 28-29, January, 2001. The meeting was attended by the committee members which were the members of the Joint Authority on the Nubian Sandstone Aquifer, except for Chad's member who was not able to attend. The main items of the meeting included:

- ? Endorsement of the two agreements of monitoring and data sharing and information exchange that were signed during the National Coordinators meeting held in October 2000
- ? Timeframe for the transfer of the calibrated model and the Information System from CEDARE to the Joint Authority

(Minutes of the RPSC Meeting-4 (The Joint Authority Meeting-6) is shown in Appendix III)

1.16 International Conferences

- 1- "Regional Aquifer Systems in Arid Zones - Managing Non-renewable Resources"

The NSAS Programme co-sponsored the above mentioned conference which was held in Tripoli, Libya on 20-22 November 1999. The Regional Coordinator prepared and presented two key papers titled "Updating Knowledge of the Nubian Sandstone Aquifer System Water Resources" and "Why the Great Man-made River Project".

- 2- The Programme Coordinator presented the NSAS Programme experience in ESCWA meeting, held in Beirut, Lebanon in April, 1999.

1.17 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.

Therefore, the NSAS Programme had the National Coordinators of the four countries sign two agreements for the data sharing, monitoring and exchange of information.

Within the context of the first agreement the four countries will share the data that was consolidated throughout the implementation of the Programme and that was

incorporated in the Regional Information System. Within the framework of the second agreement they will update the information by continuous monitoring of the aquifer and updating the Information System.

The NSAS Programme 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 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 which are shown in Appendix II.

The regional monitoring network included existing locations as well as proposed ones to cover the gaps of information. For the Nubian, the existing wells are 42 and the recommended new ones are 5. For the Post Nubian, the existing wells are 18 and the recommended new ones are 9.

Purchase of Equipment

At the aim of the capacity building of the National Institutions, hardware and software were purchased for them. Upon assessment of the needs of these Institutions equipment were purchased and provided as described below.

2.1 Computers and Hardware Purchase

It was decided to provide the focal institutions as well as CEDARE with 2 computers each. Computer specifications were prepared according to the technical needs to allow for groundwater modeling, GIS, data storage, data analysis, data presentation, Internet communication, file sharing, and report writing. Computers were also loaded with a basic word processing, spreadsheet, and presentation package. Request for quotations have been sent out and offers were received. The most suitable offer technically and financially was chosen and purchase order was sent out. Micron Millennia 400 computers were purchased, tested and delivered to the focal institutions during the month of October 1998.

2.2 Groundwater Flow & Transport Model Purchase

After the presentation of the user-friendly and powerful Groundwater Modeling System (GMS) at the RTRC meeting-1, and the recommendation of the RTRC for using a commercial groundwater model and a user-friendly pre and post processor for the groundwater model, it seemed like GMS could be a potential software for groundwater modeling of the NSAS. Further investigation of the capabilities of GMS was carried out. A training course on the groundwater modeling using GMS was organized by CEDARE and the developers of GMS through professional trainers on GMS (Environmental Modeling Systems Inc.). It was the joint decision of CEDARE and the participants of the course from the countries sharing the NSAS that GMS is the software of choice for groundwater modeling of the Aquifer. The fact that GMS uses a number of well known, well documented, and verified groundwater simulation models such as MODFLOW and MT3D, supported the decision of selecting GMS. A discounted price of the software was offered to CEDARE for group purchasing of the software. CEDARE purchased the GMS software and provided each country as well as the Regional Programme with a copy including several modules namely, Subsurface Characterization, Map, Grid, MODFLOW, MT3D, and Geostatistics together with the associated manuals. The GMS packages arrived to CEDARE and were installed on the purchased computers and sent to the three countries (Egypt, Libya and Sudan).

In the beginning of year 2000, the new version of the GMS (v. 3.0) was released. The upgrading of the GMS software from version 2.1 to version 3.0 was carried out. Hardware keys were received from the national institutions in Egypt, Libya and Sudan and were sent out to the software developers (Environmental Modeling Systems Inc.) in Utah, USA, to be upgraded, received back and sent to the relevant institutions.

Due to the modeling activity requirements which is mentioned in detail later in this report, it was deemed necessary to shift the modeling approach from the Finite Difference Method to the Finite Element Method. The groundwater software AQUA3D which is a Finite Element Model was found appropriate for the modeling of the NSAS. AQUA3D was purchased for the Programme with which the model was developed. Four licenses of the software were purchased for the four concerned countries. The four copies arrived to CEDARE on 25 June 2000 and then were provided to the countries.

2.3 GIS Modules Purchase

Analysis of Geographic Information Systems (GIS) capabilities in each focal institution took place. With the objective of standardizing databases and to facilitate future exchange of experience and information and based on the needs assessment of the Programme, some GIS modules were thought to be of higher priority at this stage of the Programme. GIS modules were selected to provide Data Automation, Mapping, Viewing spatially varying Information Layers, and Spatial Analysis of Information Layers. Training on these GIS modules took place. Requests for quotations, and analysis of offers took place. Purchase orders of the GIS modules were sent out. These packages were actually delivered to the three countries. A GIS unit was established in each focal institution.

2.4 GIS Digitizers

Requests for quotations and analysis of offers for GIS digitizers took place according to technically set digitizer specifications. Purchase orders for one A₀ digitizer per focal institution were sent out, and the three digitizers were received by CEDARE and sent to the concerned countries. The digitizers constituted an integral part of the GIS units.

2.5 A3/A4 Color Printers

Requests for quotations and analysis of offers for inkjet color printers size A3/A4 took place. Four A3/A4 inkjet color printers were purchased; one for each focal institution in addition to one for the Regional Programme in CEDARE.

2.6 A₀ Plotter

Requests for quotations and analysis of offers for an A₀ Plotter took place. Purchase order for the A₀ plotter was sent out. The plotter was delivered and is centrally located in CEDARE to serve in printing the final products and large maps of the Nubian Sandstone Aquifer that any of the focal institutions may request.

2.7 GPS

Specifications were put down and sent out to dealers and suppliers. Eight Global Positioning Systems were purchased and delivered; two for Egypt, two for Sudan and four for Libya.

2.8 Monitoring Equipment

The purchase order for twenty six water level data loggers, four water level probes, as well as four EC/Temp/PH probes was sent out in December 1998. These monitoring equipment were distributed and divided among the three countries.

- Eight dataloggers, two water level probes and two sets of the quality probes for Egypt.
- Eight dataloggers, two water level probes and two sets of the quality probes for Sudan.
- Ten dataloggers for Libya.

The distribution of the monitoring equipment and the GPS's as listed above, makes the equipment distributed among the three countries of equal cost.

2.9 Field Computers

It was also deemed necessary for the effective data collection activity carried out by the national institutions to provide them with field computers. Having investigated their needs and upon their responses requesting the field computers, the purchase of these equipment was done. Using these field computers, the data recorded in the water level dataloggers could be easily retrieved and transferred in the field, without having to miss any data. Three field computers which are characterized by their high resistance to harsh field conditions (heat, rain, etc.) were provided to the three countries; Egypt, Libya and Sudan.

Capacity Building

Within the objective of the capacity building of the National Institutions of the countries sharing the NSAS, training courses were conducted in the fields of groundwater modeling and Geographic Information Systems as well as the installation and use of monitoring equipment. Introductory and advanced levels in those fields were provided to empower human skills to master the tools for the management of groundwater resources. Within this context, five training courses were held as described below;

3.1 Training Course on Geographic Information Systems (GIS)

A training course for nine professionals from the focal institutions in the countries involved were trained on the use of GIS in Cairo-Egypt during the period of July 4th-10th, 1998. Three participants from each of Egypt, Libya and Sudan attended the course. This training included lectures and computers hands-on training on digitizing using the Data Automation Kit 3.5.1, Arc View 3.0a, and Spatial Analyst 3.0a. A GIS team was formed, which represented the nucleus of a GIS unit in each country sharing the Aquifer. They were all trained on the same software and could communicate easily and exchange information and experience in a standard manner in the future.

3.2 Training Course on GroundWater Modeling Using GMS

A training course on Groundwater Modeling Using the Groundwater Modeling System (GMS) took place in Cairo-Egypt June 28th-30th, 1998. This training was provided for nine professionals from Egypt, Libya, and Sudan, three from each country. Some refreshing lectures on the theoretical background of groundwater modeling were provided. GMS included a number of well known and widely used groundwater modules (MODFLOW, MT3D, ...) that are integrated into one user friendly interface. The participants were provided a Demo Version of GMS and the training manuals. They were given computers hands-on training where they actually practiced groundwater modeling on practical exercises. Later on, the participants were provided with working versions of the software to start modeling in their respective institutions. A team of groundwater modeling was formed for the Nubian Sandstone Aquifer.

The training course was followed by a study tour to the Siwa Oasis located in Northern Egypt where groundwater from the NSAS is being utilized. The study tour was during the period July 1st-3rd, 1998. It was interesting for experts from Libya who have similar utilization close by across the border to share their experience and information on the aquifer with the Egyptian groundwater experts in Siwa. The tour was equally interesting for the experts from Sudan as well.

3.3 Advanced Training Course on GMS and GIS Applications

An advanced training course on Geographic Information Systems (GIS) and Groundwater Modeling System (GMS) was conducted during the period 26-30 September 1999 in CEDARE, Cairo, Egypt. The course included hands-on-training using the real data of the Programme and addressed the issues and problems faced by the specialists in the relevant Institutions in the concerned countries through out the implementation of the Programme. It also focused on the interaction between the GIS and GMS, and the facilitation of inputting and outputting files between the two systems. The course was attended by ten hydrogeologists from the four countries sharing the aquifer; i.e. Chad, Egypt, Libya and Sudan; three participants from each of Egypt, Libya and Sudan and one from Chad.

3.4 Training Course on the installation and use of the monitoring equipment

A training course was held in the Netherlands during the period of 6-9 September 1999, covering installation, operation and maintenance procedures of the monitoring equipment that was purchased by the NSAS Programme. It also incorporated procedures for data collection, data transfer and data visualization through field computers. The training was provided by the manufacturer and was attended by three participants, one from each of Egypt, Libya and Sudan under the supervision of the Programme Regional Coordinator.

Upon their arrival to their countries, the monitoring equipment were installed under their supervision and the regular monitoring of the aquifer's behavior (quantity and quality) started at new locations within the aquifer where these equipment were installed.

3.5 Training Course on “Multilayer Groundwater Modeling using AQUA3D and GIS”

A training course on Multilayer Groundwater Modeling using AQUA3D and GIS was held in Libya and Egypt in order to enable as many professionals as possible to benefit from the training course. The course was held in the General Water Authority, Tripoli, Libya during the period from 25 September till 4 October 2000. Twenty one participants from Chad and Libya attended the course in Libya.

The same training course was then held in CEDARE, Cairo, Egypt during the period from 8 October till 16 October 2000. Ten participants from Egypt and Sudan attended it in Egypt.

During the course, the participants had hands on training on the groundwater finite element model “AQUA3D” as well as GIS, using the Nubian Sandstone Aquifer's data and development simulations. This course efficiently prepared the groundwater management professionals in the four countries for the use and modification of the

NSAS mathematical model since the calibrated and working model was provided to the four concerned National Institutions. It would enable them to carry out further simulations and to provide them with local boundaries for local models.

Administrative Backstopping

4.1 Administrative Backstopping

CEDARE being the executing agency of the Programme provided continuous administrative backstopping throughout the Programme. This was in the form of communication with the national coordinators, members of the RPSC, consultants, sister organisations, etc.

Other administrative matters include financial arrangements, hotel reservations, publications, reporting and scheduling work plans and budget.

Proposed Regional Well Monitoring Network

(A) NUBIAN SYSTEM AQUIFER

I. Egypt

1.1. Exiting Wells

#	Well Name	Location Coordinates	
		long.	lat.
1	EL-Kifar	26.936	29.531
2	El-Heiz	28.720	27.900
3	Sheikh Marzouk T.W.I	27.856	26.824
4	Qur El-Malek	27.925	26.062
5	South Mut	29.096	24.946
6	Malaab El-Kheil	30.321	25.270
7	West Sand Dune	30.279	24.989
8	North Abu-Bayan	30.626	24.386
9	Toshka Observation No. 4	31.643	22.739
10	East Oweinat No.7	28.033	22.500
11	One of Siwa Observation Wells	25.430	29.250

1.2. Recommended New Observation Wells

#	Well Name	Location Coordinates	
		long.	lat.
1	Darb El-Arbaiin	30.170	23.400
2	Kharga-Armant Road	31.800	24.700
3	North El-Gilf El-Kebir	26.000	25.000

II. Libya

2.1. Exiting Wells

#	Well Name	Location Coordinates	
		long.	lat.
	Kufra		
1	P-6	23.277	24.135
2	P-10	23.451	23.890
3	P-16	23.463	24.109
4	P-20	23.322	24.179
5	P-26	23.256	24.073
6	P-31	23.153	23.690
7	P-33	23.670	23.977
8	P-34	23.657	24.215
9	P-37	23.084	24.116
10	PZ-6	28.033	22.500
11	PZ 10	25.430	29.250
12	PZ 16	23.463	24.109
13	PZ 18	23.374	24.193

II. Libya

2.1. Existing Wells

#	Well Name	Location Coordinates	
		long.	lat.
	Tazerbo		
1	TE-02	21.034	25.663
2	TE-03	21.064	25.681
3	TE-04	21.070	25.688
4	TE-05	22.363	25.466
5	TE-07	21.500	24.931
6	S-01	21.839	26.007
7	S-02	21.195	25.680
8	S-03	20.875	25.503
9	S-10	21.965	25.076
10	PZ-218	21.910	25.550
11	PZ-618	21.910	25.360

2.2. Recommended New Observation wells

#	Well Name	Location Coordinates	
		long.	lat.
1	South Al Jaghubub	24.500	29.000
2	SKD - 24 (El Kufra Basin)	21.850	21.500

III. Sudan

3.1. Existing Observation Wells

#	Well Name	Location Coordinates	
		long.	lat.
1	Al Atrun	26.750	18.200
2	Qaab El-Bab	30.225	18.717
3	West Slima	28.420	21.320
4	Um Hilal	30.133	19.092

IV. Chad

4.1. Existing Observation Wells

#	Well Name	Location Coordinates	
		long.	lat.
1	Gouro	19.570	19.530
2	Ouvra Geisole	20.492	19.050
3	Gaour	21.186	18.356

(B) POST NUBIAN AQUIFER SYSTEMS**I. Egypt****1.1. Existing Wells**

#	Well Name	Location Coordinates	
		long.	lat.
1	One of Siwa Observation Wells	25.430	29.250

1.2. Recommended New Observation Wells

#	Well Name	Location Coordinates	
		long.	lat.
1	El-Diffa Western Plateau	26.300	30.250
2	South Qattara Sitra Area	29.000	27.500
3	Wadi El-Moweileh (South Wadi El-Rayar)	29.000	30.500
4	Kharga - Armant Road	31.800	24.700
5	Wadi El-Fareigh	30.500	30.450

II. Libya**2.1. Existing Wells**

#	Well Name	Location Coordinates	
		long.	lat.
	<u>Sarir North</u>		
1	PZ-3	22.310	27.675
2	PZ-6	22.046	27.533
3	PZ-9	22.090	27.948
4	PZ-15	21.652	27.770
	<u>Sarir South</u>		
1	PZ-33DP	22.008	27.344
2	PZ-35DP	22.016	26.450
3	PZ-39DP	21.606	26.786
4	PZ-41DP	22.250	26.836
5	PZA130/01	21.863	26.980
	<u>Sarir West</u>		
1	54d	21.340	27.228
2	55d	21.456	27.460
3	59d	21.340	27.717
4	62d	21.035	27.550
5	64d	20.910	27.380
	<u>Jalu/Awjlah</u>		
1	A-01-A		
	<u>Jabal Al Akhdar</u>		
1	PZ-3389 (El-Hawari)	20.200	32.000
2	PZ-3489 (El-Marj)	20.900	32.500

2.2. Recommended New Observation Wells

#	Well Name	Location Coordinates	
		long.	lat.
1	El Bayda	21.750	32.800
2	Al Makhili	22.260	32.200
3	Darnah	22.630	32.875
4	South Ajdabia	20.220	32.733