THE NORTH WESTERN SAHARA AQUIFER SYSTEM

BASIN AWARNESS

VOLUME 1

ACTIVITY REPORT

October 2002

SUMMARY

INTRODUCTION

This report summarises the accomplished work and the means of achieving the goals and managing the Project. It is divided into three parts:

In the **first part** with the title "Genesis of the Project", the issues pertaining to the Great Aquifer Basins across the OSS countries are briefly described. This account is followed by a review of the different phases leading to the creation of the SASS Project and by a description of the work procedure adopted in agreement with the countries and the co-operation partners until its launch in July 1999.

The **second part** describes how the different actions were carried out: updating the information, putting it into usable form and developing the tools needed to collect and manage the data.

In this part of the report, the technical and scientific results of the Project actions are exploited in accordance with the defined terms of reference. The procedures and results of each one of the Project actions are described. In this way, it is possible to obtain detailed information concerning each Project action, verify that it is carried out according to the defined plan and judge whether it has proved innovative and enriching or, on the contrary, insufficient.

The Project action has three main components:

- Information system: initially, the objective of this sub-project was to gather a minimum data set but it was transformed into a true information system. The results of this action show the degree to which the national engineers were involved in this phase and demonstrate, in particular, the dynamics of the interactions between the three countries as well as the data-analysis tools that were developed. The nascent databases in the three countries were improved, adapted and harmonised and can now be updated by any future data.

- Management model: in the Model section, a brief description is given of:
  - The development of the conceptual model and the different calibration stages,
  - The various versions of the model developed in accordance with the recommendations by the Evaluation Committee and the data added at the half-way stage of the Project,
  - The workshop organised to choose the computer code.

- Exploratory simulations: the process leading to a consensus between the three countries is described:
  - The requests by the countries were taken into account in the preliminary simulation scenarios and their impacts, particularly the negative ones, were defined and communicated to the countries,
  - On the basis of the results, the countries asked the SASS for an optimisation of the withdrawal rates. This prompted the Project to develop a micro-model (for simulation-optimisation around which the countries and the Project worked together in order to find a jointly agreed solution.

Concerning the organisation of the actions, the following should be noted:

- Establishment of a Model - DB - GIS link,
- Involvement of engineers from the three countries in the choice of the computer code and in all the phases of the Project work,
- Involvement of the decision-makers in the development of exploitation scenarios,
- Greatly increased importance of education and training

The third part of the report describes how the various Project actions were carried out. In this section, the following main points are discussed:

- **Comparison between the allocated budget and the actual expenditure**

The budget allocated by the partners includes five headings. For each heading, a comparison is shown between the allocated budget and the actual expenditure. This makes it possible to see if the expenditure conforms to the set budgets and objectives. Any deviations are discussed.

- **Acquisition of material and equipment**

The main equipment acquisitions (vehicles and computer tools) are listed in two tables. Equipment and costs per country are shown in appendix.

- **Recruitment of experts**

The modalities of expert recruitment are detailed, for long-term as well as short-term expert assistance.

- **Training**

A table listing the various workshops illustrates the training activity and training sessions organised by the Project. They were attended by around 100 engineers and specialised cadres.

- **Contributions by the countries**

The contributions by the countries are itemised and the contribution efforts compared to the initial objectives are highlighted. The exceptional contributions by the countries deserve to be stressed.

The **fourth part** of the report deals with **consultation mechanism**. This part of the Project started long after the technical one and is set to end in December 2002. To date, the actions within this mechanism framework have produced:

- An overview of the stakes and risks linked to the SASS,
- A report concerning the institutional and legal aspects linked to the SASS in the three countries,
- A preliminary report on the options defined by each one of the three countries

The organisation of the following events is planned for the end of December 2002:

- National workshops to discuss the chosen options,
- a regional workshop to approve the first blueprint of the consultation mechanism. This blueprint will be developed further in the second phase where the applications of the mechanism will be discussed, i.e.:
  - definition of evolution indicators
  - modalities of organisation and control
  - types of agreement to be reached.

1ST PART

ORIGIN OF THE PROJECT

NORTHERN SAHARA AQUIFER SYSTEM
" SASS "

ORIGIN OF THE PROJECT

I - FOR THE GREAT BASINS AQUIFERS PROGRAMME BY THE OBSERVATORY OF THE SAHARA AND THE SAHEL (OSS).

Throughout the Sahara-Sahel region, there are great sedimentary cross-border basins containing shared aquifer systems.

Together, these basins cover a surface area of around 4,000,000 km^2, i.e., a quarter of the area of the OSS Sahara-Sahel region.

The existing enormous reserves cannot, however, sustain intensive exploitation because of multiple constraints and limiting factors:

- Inaccessibility of large areas
- Existence of potentially contaminating salt-bearing formations
- Depth of wells and water temperature
- Occasionally mediocre chemical quality
- Risks of soil degradation
- High-cost investment

Apart from the complexity of great aquifer systems and the factors limiting their exploitation on a large scale, the situation is complicated by a lack of in-depth studies that take account of the natural boundaries of the basins.

Each one of the OSS countries has individually contributed to further the knowledge of its own water resources. However, in the special case of the cross-border resources, the unilateral efforts are hampered by the fact that these portions of the reservoirs and their development plans are not explicitly taken into account and may suffer greatly if the mutual effects of an intensive exploitation of the reservoirs are unknown.

On the basis of this observation, the OSS has undertaken to develop, within its programme called "the great basins aquifers", a technical and scientific co-operation between the countries concerned to further the awareness of these basin, i.e., **a consciousness of sharing a common resource and the need to act together in order to use it rationally.**

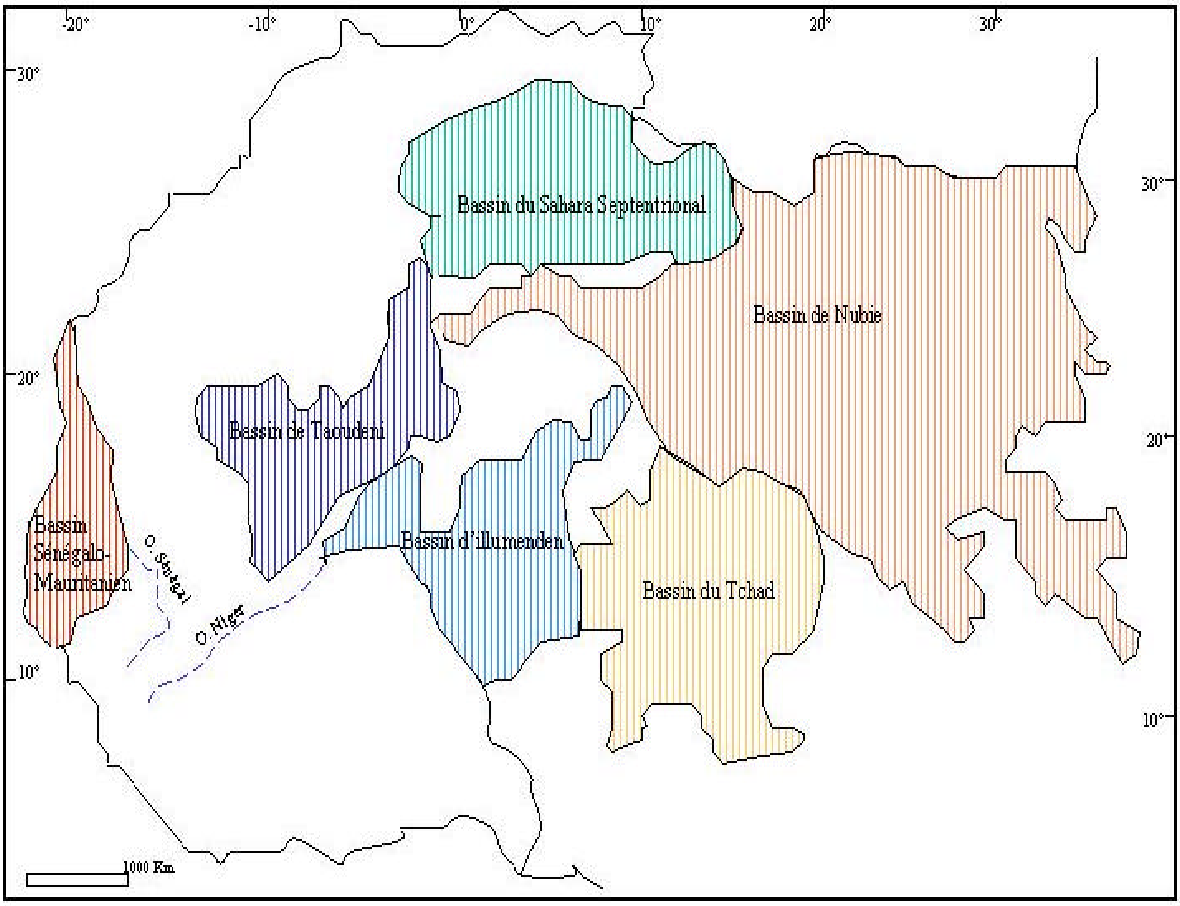
The action by the OSS therefore consists in creating favourable conditions that allow the scientists and decision-makers of the countries concerned and their institutions to work together to evaluate and manage these resources in order to assist the States in developing common strategies and co-ordinated planning initiatives.

Six specialised regional workshops for each basin as well as reports published by the OSS have contributed to define a programme for each aquifer whose principal objectives are:

- A study to estimate the exploitable resources and construct consensual scenarios.
- Creation of a common database destined to make information available and to authorise data exchanges.
- Organisation of thematic and educational seminars for technicians working on the same system to update information and exchange work experience.
- Updating of withdrawal states.
- Setting-up of a joint-planning mechanism in view of institutionalising the framework of co-operation and ensure the continuation of the programmes of monitoring and exchanges and updating of information throughout the basins.

In the Sahara-Sahelian part of Africa, most of the groundwater is contained in the huge reservoirs of the cross-border sedimentary basins.

Map showing the location of the main cross-border sedimentary basins



	basins	Countries	Surface area in km2
Northern Sahara	Nubian sandstone	Libya, Egypt, Sudan, Chad	2.000.000
	Northern Sahara	Algeria, Tunisia, Libya	1.000.000
Southern Sahara	Lake Chad	Chad, Niger, Cameroon, Nigeria	350.000
	Iulllemeden	Niger, Mali, Algeria	200.000
	Taoudeni	Mali, Mauritania, Algeria	500.000
	Senegal-Mauritania	Mauritania, Senegal, Guinea Bissau, Gambia	30.000

Besides the great cross-border sedimentary basins there are other groundwater aquifers in the Sahara-Sahelian region. They are smaller and less productive and found in:

- wadi underflows, particularly on the margins of the great basins
- bedrock zones in the Sahelian regions
- small sedimentary basins

These resources do not have a definite cross-border role.

Apart from the reports by the OSS concerning the Sub-Saharan basins presented and validated in the workshop organised at AGRHYMET/CILSS in Niamey in 1997, which, among other recommendations, advised that particular attention be given to the basins of Illumenden and Senegal-Mauritania, the research work by the OSS led to the launching of a programme for two aquifer systems:

- the Nubian Sandstone (NSAS - Nubian Sandstone Aquifer System)
- the Northern Sahara Aquifer System (SASS)

The choice of these two basins was motivated by:

- the desire of the countries involved to conduct joint studies in order to define the best development scenarios and to make joint decisions for a sustainable management of the resource,
- the considerable body of data collected during the last three decades in the course of numerous drillings carried out in formerly poorly investigated zones,
- the availability of several point and regional studies particularly in Libya
- a significant increase in withdrawals to supply both drinking-water and irrigation networks accompanied by large transfer projects,
- growing concerns as to the sustainability of the development and the negative impacts that have become manifest in recent years, i.e.,:
  - drying-up of springs
  - weakening artesian flow
  - increasing drawdowns
  - water-quality degradation

- the presence of all the conditions needed to put in practice the desired co-operation and to create a true mechanism for joint planning that may serve as a model for similar basins.

Thus, with financial assistance from Germany and France several meetings and special workshops were held, among others, in Cairo in 1992 and 1994 and in Tunis in 1997 with the participation of:

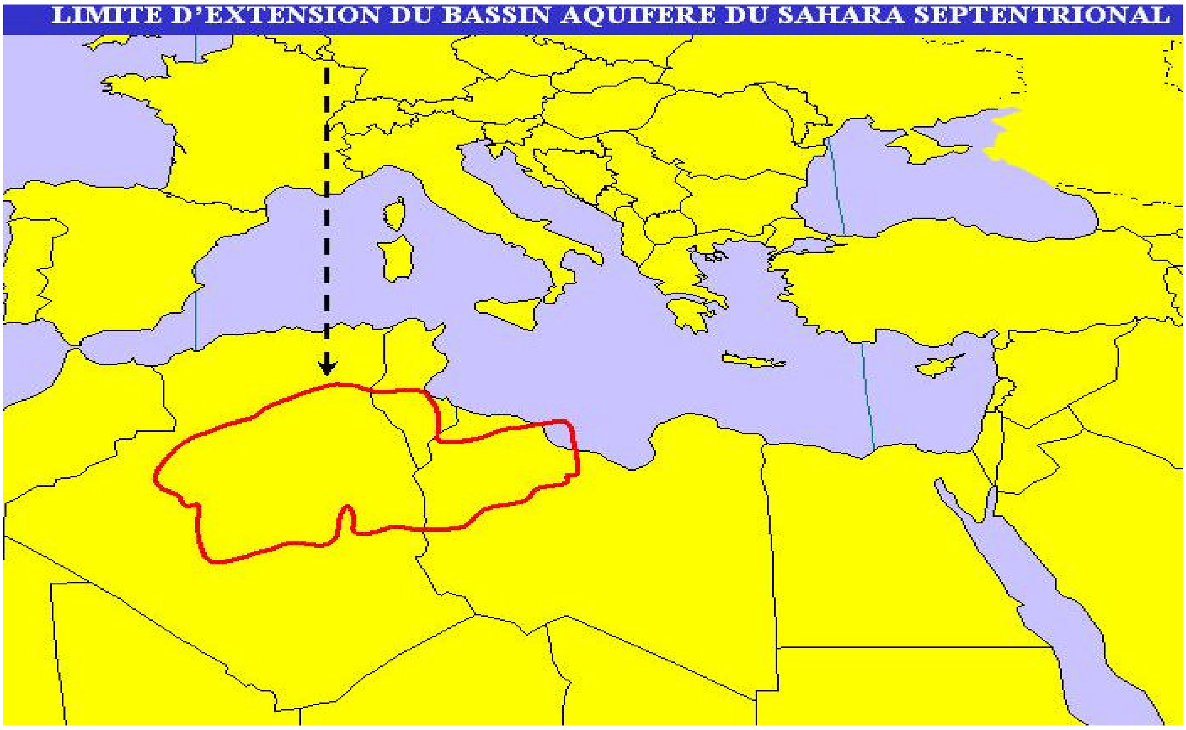
- the OSS
- the countries sharing the SASS and NSAS basins
- the international co-operation partners, in particular, UNESCO-FIDA-FAO and scientific organisations e.g., the OATC, BGR, BRGM, ACSAD, CEDARE and the CILSS/AGRHYMET.

In the periods between workshops, experts and national institutions in each country were asked to draw up technical work documents that would contribute to establish project documents for both basins.

Two preliminary plans were established:

- a technical document reviewing present knowledge and planned developments, particularly in agriculture
- a document comparing legislation and institutions in the countries.

Regarding the Nubian Sandstone, the vivid interest expressed by Egypt allowed the FIDA to entrust the subsequent OSS work to the CEDARE. For the SASS, a preparatory meeting concerning the Project document was held in Tunis in May 1997 with the institutions in charge of water in the three countries, the international organisations (UNESCO, FIDA, OATC) and the international experts presided by the OSS.



During this meeting, the planned actions and the programme were adopted. The countries asked the OSS to set out the terms of reference that would apply to the two lines of action:

- **Updating the estimates of the SASS water resources**

- **Setting up a mechanism for joint planning at the scale of the SASS**

This document was adopted by the countries at the meeting on September 8-10, 1997 in Tunis where they also entrusted the OSS with the task of raising external funds and act as "**overseer**" for the execution of the programme.

After wide-ranging efforts, the OSS managed to obtain funding from the FIDA, the DDC-Switzerland and the FAO and finalise the procedures at the meeting in Rome, on April 29-30, 1998.

At the meeting in Rome in May 1999, it was decided that the official launch of the SASS project would be planned for July 1st 1999.

II - LAUNCH OF THE "SASS" PROGRAMME

At the meeting in Rome, in May 1999, the OSS was officially designated by the countries and the financial partners as the Executive Agency of the Project.

For the execution of the Project, a Steering Committee presided by the OSS was set up. It is composed of:

- Co-operation partners: (FIDA, FAO, DDC-Switzerland)
- Partners from international and scientific organisations (UNESCO, ACSAD, BGR)
- General Directors of the national institutions in charge of water resources from the three countries
  - ALGERIA : ANRH (Agence Nationale des Ressources Hydrauliques)
  - LYBIA : GWA (General Water Authority)
  - TUNISIA : DGRE (Direction Générale des Ressources en Eau)

Main tasks of the Committee:

- assess the validity and the quality of technical results obtained during the preceding phase;

- discuss and approve, or modify, the action programmes of the work phases as well as the expenditure plans proposed by the regional co-ordinators of the programme and the OSS in reports that will be submitted to the members of the Steering Committee at least two weeks before the meeting;

- propose solutions to problems arising during the execution of the Programme.

In its capacity as Executive Agency the task of the OSS was to:

- manage the funds allocated to the Project;
- to hold a bid in order to select and recruit the regional and international expert of the program

- select and recruit, in co-operation with the regional Programme Co-ordinator, the required consultants according to the programme approved by the Steering Committee;
- acquire equipment and materials as agreed by the countries concerned and the co-operation partners;
- supply the regional Programme Co-ordinators with any logistical assistance required to ensure an efficient operation (premises - with the help of countries hosting the agency in charge - secretariat, printing of reports, etc.)
- organise an external financial audit of the management of the Programme funds;
- provide a scientific audit of the results.

Matters concerning the regional updating of the estimates of the SASS water resources

The OSS has obtained the necessary partnerships to support the implementation of the Programme, notably with UNESCO and the FAO, given the excellent co-operative relationships maintained with these institutions.

On the basis of the tasks assigned to the OSS, it selected, by common consent (at a meeting in Rome in May 1999 at the FIDA headquarters) together with the members of the Steering Committee, a team of co-ordinators composed of three experts;

- A regional co-ordinator
- A scientific and technical adviser
- An adviser for the mechanism of joint planning

This Project co-ordination team, subject to the control of the OSS, is responsible for the technical execution of the Programme **"Updating of the study of the SASS water resources"** with the following tasks:

- running of the Project,
- co-ordinating national contributions,
- setting out the terms of reference of the consultants,
- programming, organisation and monitoring of the work by the consultants,
- establishing the contracts of the consultants and of various services,
- validation of reports and technical results,
- writing technical statements and general reports
- organising meetings and training workshops
- directing the Project activities and monitoring results according to the recommendation by the Steering Committee and the OSS,
- preparing, with the national co-ordinators, progress reports to be submitted to the Steering Committee,
- preparing general reports as demanded by the Steering Committee
- acting as secretariat for the Steering Committee.

Setting-up of a joint-planning mechanism at the scale of the basin

The Regional Co-ordinator assisted by the expert/adviser actively contributes to consolidate the partnership between the FAO and the OSS who acts as executive agency and facilitates any action likely to further the progress toward the targeted objectives.

The co-ordinator has **a secretariat** responsible for logistics, operational management and follow-up of work programmes.

The SASS project started three years ago, on July 1st, 1999, on the basis of decisions by the Steering Committee (meeting in May, 1999, in Rome). The OSS has made all the arrangements with the three countries in order to detach the three experts selected to form the co-ordination team of the SASS project. They are: **Djamel LATRECH** (Algeria), **Ahmed MAMOU** (Tunisia) and **Sadok KADRI** (Libya).

The OSS has endeavoured to respect the schedule for the installation of the team and to set up the Project in accordance with the decided time-frame despite the efforts required to transfer its headquarters from Paris to Tunis.

2ND PART

UPDATING THE ESTIMATES OF WATER RESOURCES

Scientific and Technical actions

IMPLEMENTATION OF THE SASS PROGRAMME AND ITS RESULTS

Regarding the implementation, three different aspects are considered:

- Technical activities
- Project financing
- Project management

I - TECHNICAL ACTIONS

In accordance with the terms of reference, there are 30 specified actions. Their objectives and the completed work are described below.

The following manner of presenting the work illustrates the procedure and shows the obtained results as well as providing an opportunity to measure the conformity of the actions undertaken within the Project against those defined in the terms of reference and to evaluate potential deviations.

ACTION 1: Preparation of national reports describing the databases used for each country (format, scope, etc.) and the geographical information systems (type of data, expected products, users, computer codes, type of equipment, manpower capacity, etc.).

ACTION 2: Workshop led by an expert to define the minimum data set for the common base and the procedures for harmonising the databases.

Questionnaires were set up to facilitate the analyses of existing data in the three countries. By studying the collected information it was possible to highlight a certain number of important constants:

- for their daily needs, the three countries were faced with problems of structuring the hydrogeological data and integrating the GIS into their overall data systems;

- most of the information concerning the SASS zone was dispersed between different files with heterogeneous formats (EXCEL, DBASE, etc.) or on paper;

- the data used in earlier studies had never been assembled in computer files; the original information had disappeared, only general data (by mesh, region, etc.) were recovered.

In the Project, three essential objectives were targeted:

- gathering and organisation of the data in order to prepare the modelling phase; this collecting and sorting of the data allowed the SASS Project to construct a reference base for all future studies;

- taking advantage of the SASS Project to help the countries better to structure the hydrogeological information and to facilitate future updating exercises and the preparation of favourable technical conditions for the joint-planning structure;

- progressive development of a tool to be used in basin water management and capable of handling numerous requests for overviews and of providing graphic and mapping displays. However, this will only be possible when data exchanges between the countries are allowed and facilitated (setting-up of updating procedures for the SASS database).

By approaching the problems in this way, it has been possible to involve the national teams in all the phases of the Project. The DB report describes in detail all the actions undertaken to this end.

As a result of the chosen orientations (Action 1), the following has been accomplished:

- the three countries received and filled out a questionnaire containing an inventory of the existing assets concerning systems, means, computer codes and processing modes;

- a visit was made to the three institutions to listen to their concerns and see how the Project fitted into their daily occupations;

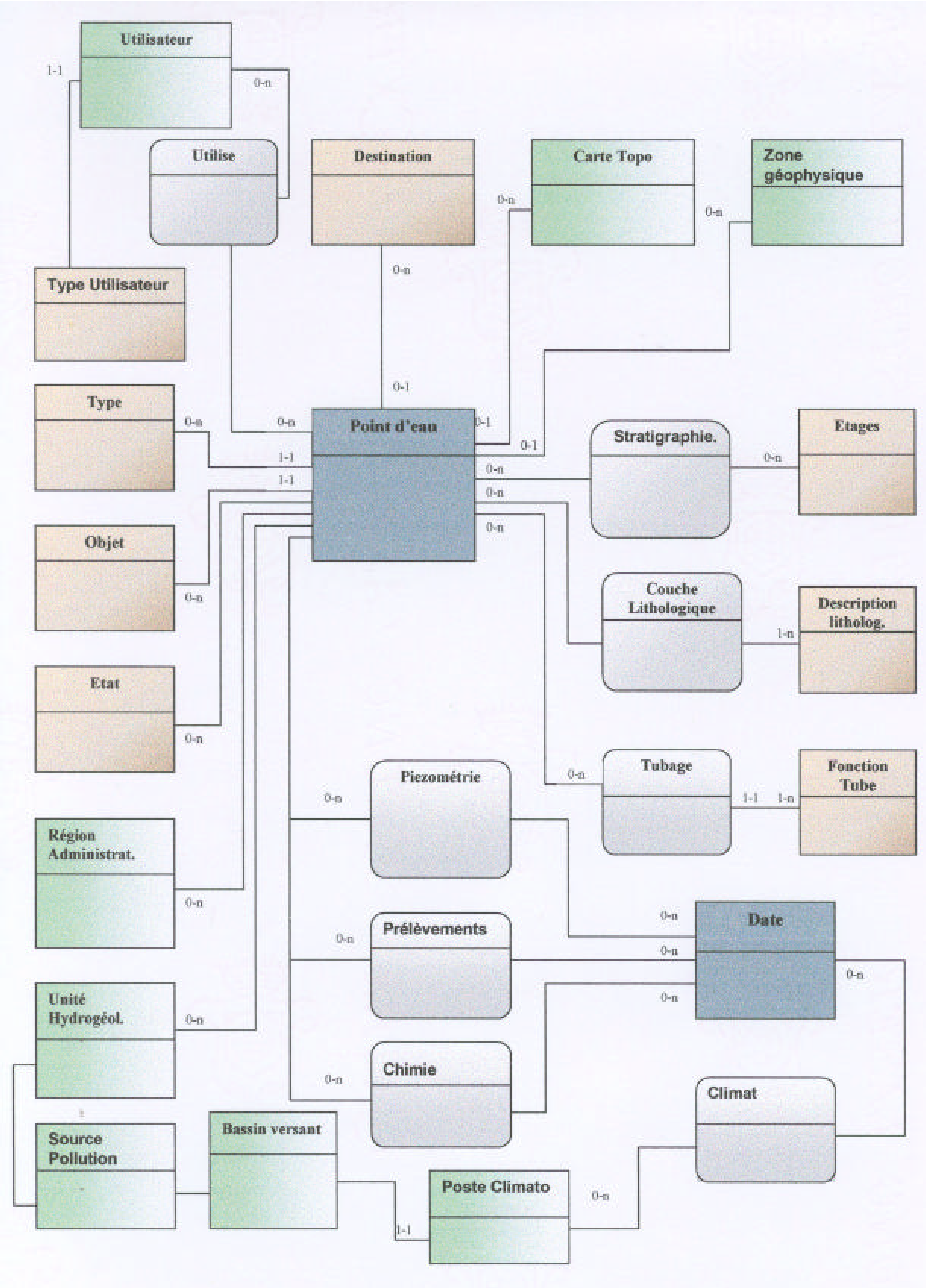
- two workshops were organised:
  - the first one (December 1 to 4, 1999) attended by the teams from the three countries and devoted to examining the existing data (nature, codification, management rules) and especially, to setting up an integrated system suited to the SASS Project and to the needs of the countries. This workshop also served to define how the GIS would be linked up to the database
  - the second one was organised from March 28 to 31, 2000 to validate the structure of the proposed system and to choose the best organisational and technical solution for the Project equipment and computer codes, organisation of data collection, ways of correcting the files.

On the basis of the proposed conceptual model (fig. 1) a core representing the blueprint of the common base was defined. The necessary adaptations of the bases of the respective countries were listed in order to be dealt with in the subsequent phase.

The new dimension acquired by the item "Database" required additional steps not initially planned in the Project. This is the reason why it was reorganised, as follows :

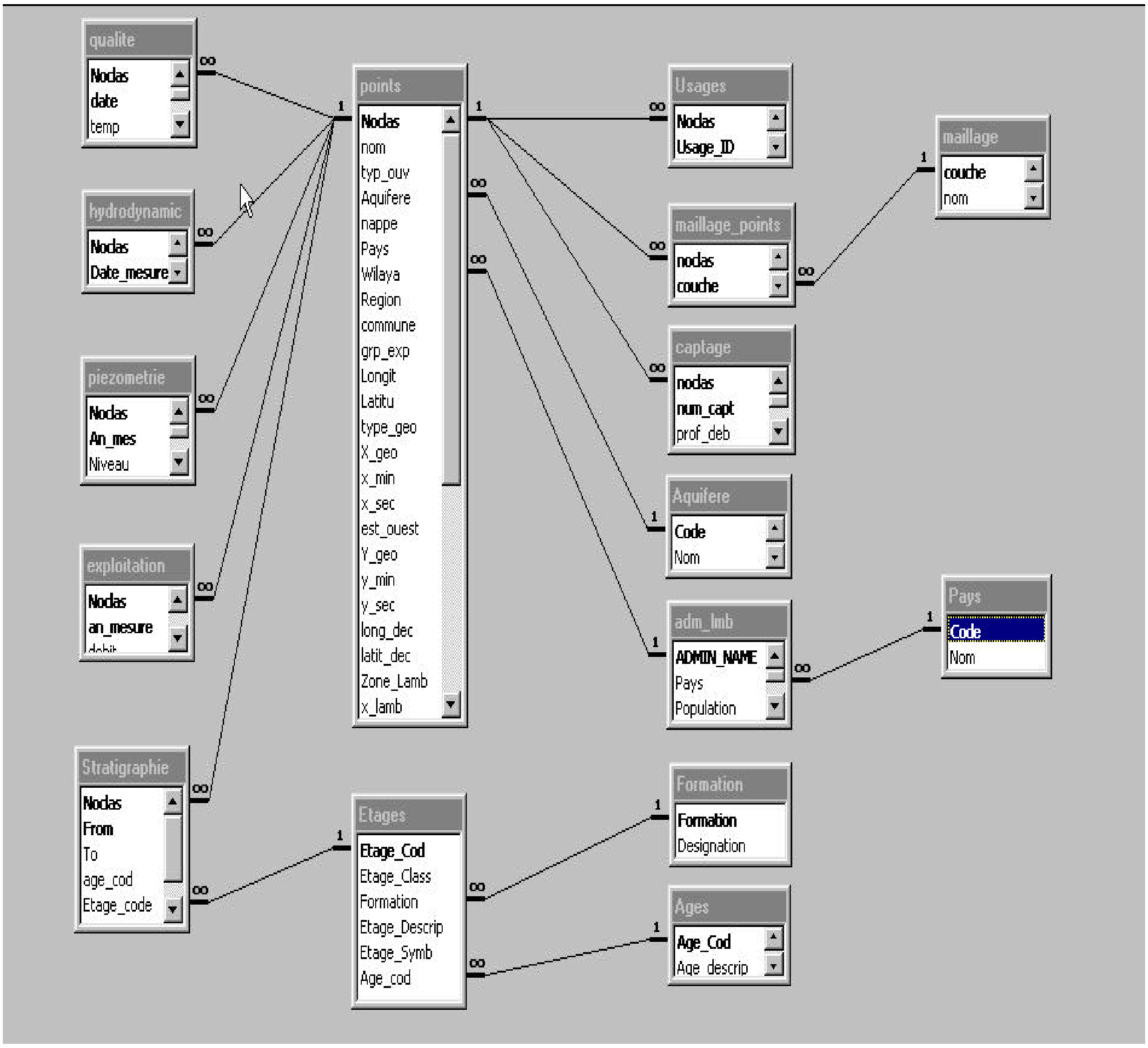
- ***phase 1 :*** **"Analysis of existing situation"** which consisted in examining in detail, the present situation in the three countries (including their specific needs outside the scope of the Project and working out an organisational and technical solution to suite the conditions and easily implemented,
- ***Phase 2:*** « **a common core useful to the SASS** » : Establishment of a data conceptual model as big as possible and that should be sufficiently open to allow the integration of additional entities. It should integrate the descriptive data of the SIG and the entities that are in relation with the data of the numerical model and that permit to extract from this model a common core useful to the SASS to be extracted and installed on the organisational solution defined above.

Figure 1. Overall conceptual model



- ***Phase 3*** « **Building the database** » : during this phase, the necessary database, entry programmes, data control and transfer procedures required by the Project were defined. A body of statistical and overview requests was also constituted to facilitate some verification processes (fig.2)

Figure 2: Diagram of the DB



- **Phase 4** « **installation of the GIS** » : the different layers constituting the GIS and their characterising data were defined. The spatial scale of digitalisation, transfer of existing data and the harmonisation of projection systems were also defined.

- **Phase 5** « **Establishment of DB-GIS-model links** » : Several solutions were proposed depending on which modelling code was chosen. A study was made of the different available options. The solutions range from a simple format adaptation to the development of interface by means of programming languages provided with the GIS code on the DBMS (Database management system) .

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The last phase assumes that the data are available in computerised form and that they only have to be harmonised in order to be introduced into the common data base. However, a preliminary examination revealed that:

- most of the computerised data are recorded in many different formats,

- much of the information is recorded on paper and had to be compiled from the study reports, codified and formatted before being included in the database;

- whatever their form, the available data were not exhaustive and had to be supplemented to be usable.

ACTION 3: Organisation of additional training sessions (two weeks per session per country).

Several types of training and internships were organised in the water authorities of the three countries:

- Training concerning the concepts of the information system, of GIS and the fundamental rules governing basic links;

- Initiation into the DBMS-ACCESS (tables, requests, forms).

- Initiation into the GIS code and particularly into the links with the database.

- Training in the use of the tools of data analysis: statistical requests, spatial requests with the help of the GIS, adding missing data with the help of the GIS.

A second series of visits (one weeks per country) was organised when all the data had been collected and introduced into the common database in order to:

- establish coherence between the data gathered by the countries and those introduced by the SASS team;
- validate the contents of the database, once the missing data had been added;
- allow the national teams to collect additional information.

Regarding the GIS, further training was organised in each country on the subject of the acquired software:

- ARC VIEW

- SPATIAL ANALYST.

Choice of equipment and software

The choice of the software was made jointly by the experts - national teams - Project team. The environment available in each country was taken into account.

DBMS

The choice of the DBMS code was discussed in the workshop attended by the engineers in charge of the databases in the countries and after an analysis of the various available systems:

- ACCESS
- ORACLE
- SQL-SERVER

The choice of ACCESS was motivated by:

- its availability in all the national institutions
- the more or less perfect ability of the nationals to handle the code as their bases were already on this DBMS
- its easy interfacing with the GIS, in particular on a PC.

GIS

The ARCVIEW code coupled to the SPATIAL-ANALYST was selected because:

- it is compatible with ACCESS,
- it is reliable,
- it is widely used in the field of Natural Resources,
- it is available in the countries and the engineers are familiar with it.

All these codes were acquired by the Project and made available to all the countries.

ACTION 4: Programmes of format conversion between the databases and support for the countries to ensure that the developed GIS function correctly.

All the inventoried heterogeneous data were transferred to the new structure of common data. The transfers were made with the help of requests and specific modules developed in close co-operation with the teams in all three countries (see Volume 1).

It was sometimes necessary to process the data before transferring them: change the type or format, add missing columns, harmonise the coding, etc.

ACTION 5: Validation workshop

A workshop to validate the programmes, followed by an official transfer of the database was organised in each country. The Project ascertained that in each national institution, the information system was well understood and functioned correctly.

ACTION 6: Harmonisation of geodesic data between the three countries

In order to harmonise the Geodesic Systems of reference, a workshop was organised in Tunis, on April 13-14, 2000.

This workshop assembled:

- the national Project co-ordinators,
- the institutions in charge of Cartography - Geodesics in each of the three countries,
- experts on Cartography and Geodesics.

At the end of this workshop, the following decisions had been made:

- to analyse the Libyan altimetric data and compare them to the common Algerian-Tunisian system in order to control any potential conversion of the altitudes so as to determine the deviation between the two reference systems and to adjust one of them as required to harmonise the levelling;

- to possibly use the GPS to obtain useful and rapid levelling data in view of the time frame allotted to the phase "altitude measurements" and to supplement existing measurements. On the basis of the above recommendations, geographic information was gathered from various sources:

- numerical model at the 1:a,000,000 scale from the USGS,
- maps produced during previous studies (e.g. ERESS)
- topographical maps provided by national cartography agencies
- the DCW made available to the OSS by the WRI-USA
- maps drawn up by the SASS team.

An analysis of their mathematical base and their contents made it possible to draw up a cartographic document at a scale of 1:2,000,000 covering the entire SASS basin in the conformal Lambert projection of southern Algeria.

This document was delivered to the countries in paper and CD form with a technical manual. Furthermore, according to instructions by the OSS Executive Secretary, the 25 maps and the ERESS documents, almost impossible to find, were digitalised and transferred in CD and printed-paper form to the three countries to allow them access to this valuable body of information. A CD was sent to UNESCO.

To make this material accessible, the main operations carried out by a firm specialising in cartography concerned:

- entry of basic topography map
- entry of the different hydrogeological layers, structured in ARC/INFO format,
- printing maps and documents on paper.

This operation represents a contribution by the OSS to the enrichment of the national information fund in these countries.

ACTION 7: Selection in each country of observation points that form a minimum observation network throughout the basin.

In all three countries, the measurement records are heterogeneous, often with gaps in the chronology and inadequate spatial distribution. In order to improve its knowledge of the piezometric situation, the Project team started by analysing the existing data. From a network of 1,164 measurement points, 194 points were selected as representative (because of available records) of a minimum common network.

Additional measurements were made in order to obtain a piezometric state updated to the year 2000. The distribution across the three countries is shown in the following table.

Number of wells with more than one piezometric measurement.

Aquifers	Country	Observed wells	Selected water points
CI	Algeria	273	64
	Tunisia	92	16
	Libya	137	30
CT	Algeria	378	50
	Tunisia	257	10
	Libya	27	24
	Total	**1164**	**194**

ACTION 8: Preparation of national reports on the methods for withdrawal estimates

Each country has established a state of withdrawal rates by using estimating methods or flow-rate monitoring.

ALGERIA
The withdrawal estimates were made by reference to the data obtained during field inventories of existing wells and springs.

TUNISIA
The withdrawal rates are estimated every year and published annually (piezometric annals).

LIBYA
The withdrawal rates are only measured during great regional studies. The survey carried out in 1999 by the GWA teams made it possible to partially update the information. The national reports by the three countries were analysed and demonstrated the difficulty of obtaining exhaustive information concerning withdrawals because of:

- the size of the basins
- the considerable number of wells and springs
- the equipment needed

The national reports were processed and analysed by the Project team who added to them by:

- targeted field studies by the national teams
- searching for and analysing information in various documents available in the countries

ACTION 9: Workshop to:

- **Present and approve the network of observation points and the measurement frequency**
- **Recommend methods allowing rapid estimates of the withdrawals.**

The approach developed by the Project consisted in first analysing the measurement and withdrawal data which enabled it to establish a document of "data analysis" which was communicated to the three countries.

To process, analyse and validate the considerable amount of collected data the Project developed tools capable of detecting the most striking anomalies and identify gaps.

These tools belong to two large categories: **statistical requests** that provide tables and lists of anomalies transmitted to the three authorities to be corrected and updated, **spatial requests** that use the GIS to show co-ordinate errors and other spatial-type fields.

Statistical requests

This involved extracting from the database information by country and/or administrative unit, by aquifer system or by installation type. These tables were compared to the results of the studies in order to detect anomalies that might remain in the database.

The following are examples of tables:

- Number of wells and springs per administrative unit, per aquifer and per period
- Sum of the withdrawals per country and per aquifer in a given year,
- Share of the withdrawal per aquifer in each administrative unit

Spatial requests

This type of request combines the GIS layers with the DB information:

- List of the wells and springs where one or several parameters fall outside a give interval
- List of the wells whose "wilaya" (administrative unit) field position is incompatible with the geographical boundaries of the administrative unit.
- Mapping of the points where the flow is assumed to be artesian and superimposing them on the layer of "artesian-flow limit".
- Map of the drawdown between two given dates
- Map of the divergence between the altitude of the wells recorded in the DB and that produced by the numerical field model of the USGS,
- Mapping of the depth of the wells extracted from the DB and comparison with the top and bottom of the aquifers.

Results

Altogether, the requests made it possible to identify several error sources in the databases for a number of wells:

- Lack of co-ordinates
- Errors in the co-ordinates
- Lack of classification number
- Pumping rate not mentioned or erroneous,
- Altitude lacking or erroneous
- Errors or gaps in the piezometric data
- Artesian boreholes outside the zone of artesian flow and vice versa
- Abnormal drawdowns

This analysis made it possible to:

- Better define the necessary additional field work

- Identify the gaps to be filled in the records of withdrawal rates and piezometric levels
- Detect errors and define corrective measures
- Obtain more efficient well inventories
- Better estimate withdrawals and drawdowns

After completion of the data analysis, several workshops were held (two per country) with the Project team and the national teams for the purpose of:

- Planning the field studies needed to validate and verify the information
- Ascertaining that the data introduced into the database were corrected and improved.

This approach, more suitable than a definition of withdrawal methods, made it possible to prepare validated and reliable data concerning, among others, withdrawal rates, measurements of heads and salinity in agreement with the national teams.

ACTION 10: Field measurements to establish an updated situation of withdrawals, piezometric heads and chemical water quality.

Given the results of the data analyses and the detected shortfalls, field studies were carried out in each one of the three countries to measure piezometric levels, confirm the location of the wells and springs and the TDS (total dissolved solids).

The targets of these field studies were:

In Libya:

- Measurements of the present flow rate of the Tawargha spring and of monitoring wells
- Piezometric heads
- Water sampling for chemical analyses

In Algeria:

- Updating of the withdrawals from the water wells in the oil fields
- Correction of the El-Oued inventory
- Additional piezometric measurements in Ghardaïa, Wargla and El Oued
- Updating of the piezometric state of the TC and CI for the year 2000

In Tunisia:

- Measurements of the flow rates in bored wells for the year 2000, in the Djerid, Nefzaoua and Gabes
- Water sampling for chemical analyses and conductivity measurements.

ACTION 11: Entry of the data into the common base

Once the data entry, verification and updating modules had been built, the data gathering tasks were distributed between the SASS team and the country teams as follows:

- To the SASS for data before 1981 found in the reports and elsewhere,

- Study documents
- To the country teams for the data after 1982 (characteristics of the wells, withdrawal records - piezometric heads and water quality)

In a subsequent phase, the coherence - validation was established for the three authorities. The collected data were introduced into the common database. Nearly 23,000 data were entered for over 3,000 wells and springs. The type of data and their distribution by aquifer and by country are listed in the following table.

Statistics concerning the database

Aquifer	Country	Number of wells	Number of static meas..	Number of flow meas.
CI	Algeria	676	753	2142
	Tunisia	120	321	1423
	Libya	183	407	457
CT	Algérie	1484	1623	3655
	Tunisia	352	1173	8560
	Libya	192	74	582
	Total	**3007**	**4351**	**16819**

ACTION 12: Analysis of geological and geophysical data from petroleum and hydraulic explorations (rock type, well-logs, geophysics) needed for the modelling and the description of the aquifer formations and for the understanding of the hydraulic functioning of the aquifer layers.

Petroleum drilling logs

Apart from surface geological data from which one can deduce, e.g., the extent of aquifer outcrops and the potential recharge areas, the structural analysis of the reservoirs and the lithostratigraphic correlations are based mainly on the study of well logs, particularly from petroleum drillings in Algeria, Tunisia and Libya.

The task of the SASS consisted in re-examining the well logs in Algeria and updating the information in Tunisia. The state of knowledge was improved by new data and by adding those from the Libyan wells. Data regarding the sub-surface geology published in previous studies were used to draw a 1:2,000,000 map of the outcrops at the basin scale.

The geological data of around 290 boreholes were taken into account in the study of the basin structure. They are distributed as follows:

	TC + CI
Algeria	163
Libya	106
Tunisia	21
Total	**290**

These data were used to:

- Establish correlations across the entire basin in the East-West and North-South directions,
- Drawing maps of the top, bottom and thickness of the aquifers

⇒ **Wells and springs:**

The records of the evolution over time of the well points in the SASS are shown in the figures below:

Figure 3: Number of well points in the CI

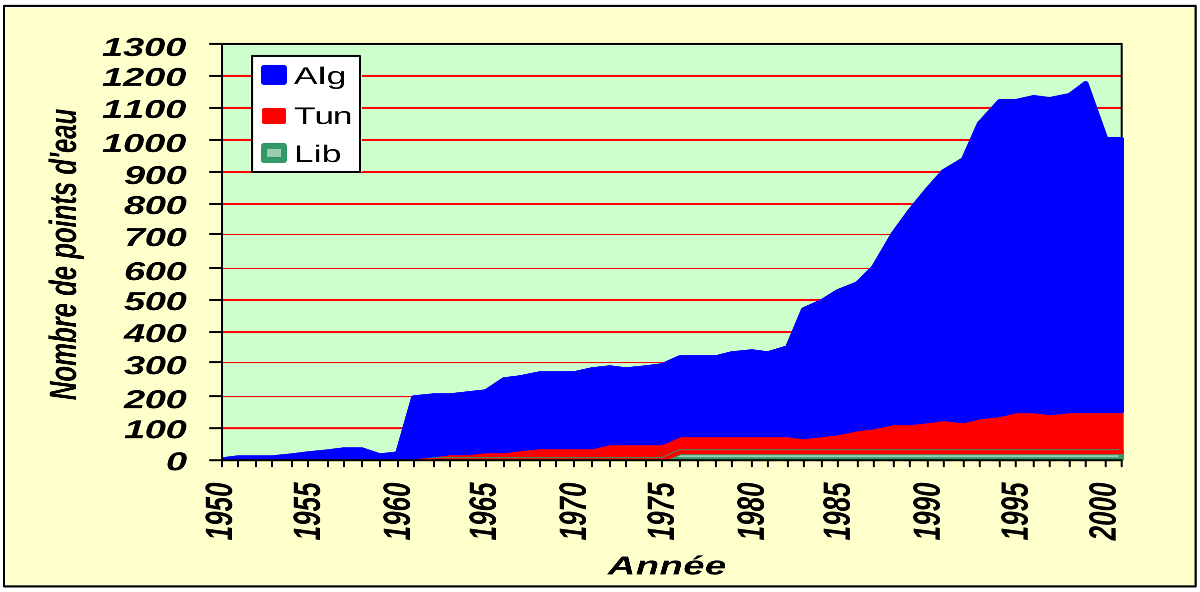
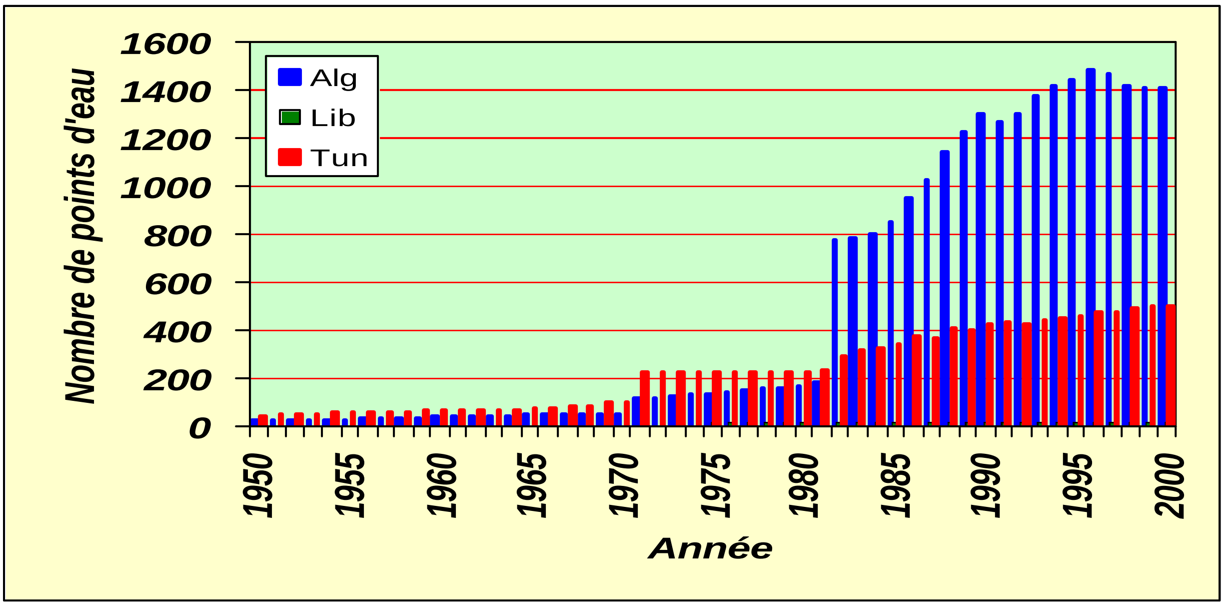


Figure 4: Number of well points in the TC



Since 1980, the increase in the number of wells has been significant in the tree countries where there are nearly 3,000 drilled wells. The information gained from these wells has extended our knowledge to new zones and provided access to monitoring updated to 2000.

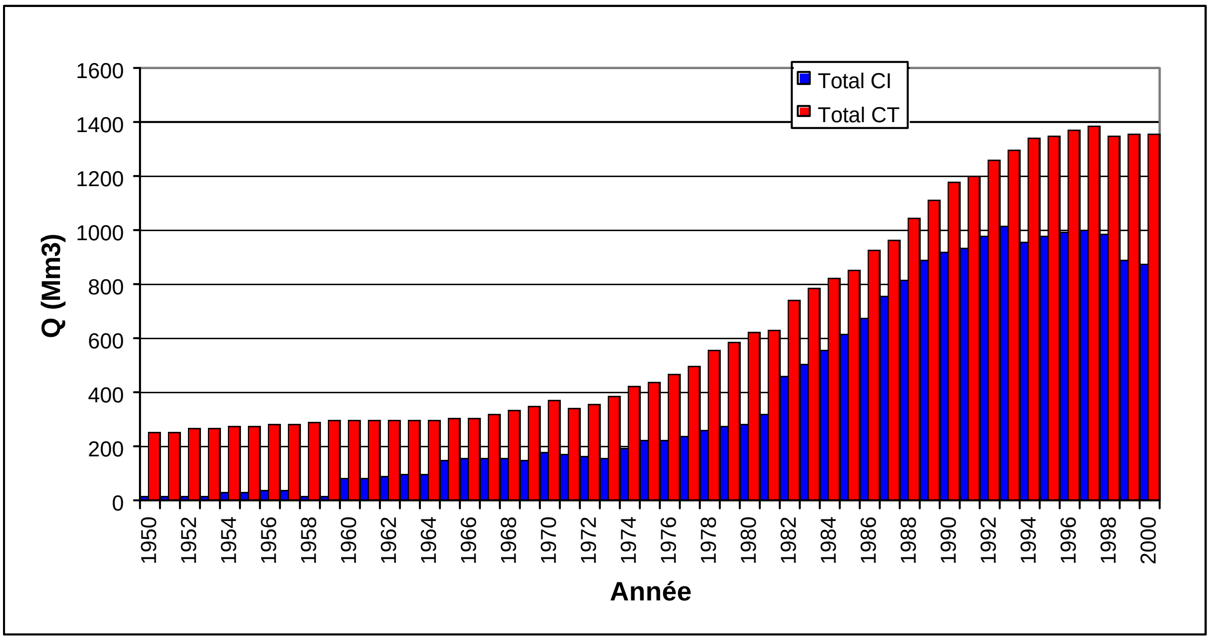
ACTION 13: Assembling information and data concerning the withdrawal rates, piezometric heads and water quality, gathered since 1950; establishing withdrawal and head records.

The assembled information concerns all the wells and springs since their creation and not only since 1970, although this period is appropriate for Algeria and Tunisia, whereas Libya has very useful data going back further than 1970.

With the objective of a calibration in steady state, at equilibrium, the collected information extends from 1950 to 2000.

The following figure shows a reconstruction of the withdrawal records from 1950 to 2000:

Figure 5: Overall withdrawal in the CI and TC aquifers



The piezometric levels and the water quality involve a considerable number of data whose past history is included in the DB; extracts are presented according to region and grouped together in the report **"Hydrogeological overview and Models".**

Distribution of the collected data according to country and aquifer.

WATER QUALITY			
Country	**CI**	**CT**	**Total**
Algeria	335	1236	1573
Tunisia	209	2008	2230
Libya	149	87	237
Total	**693**	**3331**	**4040**

Aquifer	PIEZOMETRIC MEASUREMENTS		
	Country	Number of wells	Numb. Meas. Stat. level
CI	Algeria	676	753
	Tunisia	120	321
	Libya	183	407
CT	Algeria	1484	1623
	Tunisia	352	1173
	Libya	192	74
Total		**3007**	**4351**

Around **9,000 data** were gathered for the piezometric and water-quality records.

ACTION 14: Levelling with GPS, if necessary.

The national teams to ascertain the altitude of some piezometric points carried out levelling studies. Most of the information concerning the altitude of the points was found in the archives of the three authorities. A basin-scale DEM was built based on the digitalised maps and the DCW to provide a verification system of the water-point altitudes.

ACTION 15: Assembling information on pumping tests and hydrodynamic characteristics of the aquifers, possibly by means of a few additional pumping tests.

All the information concerning the hydrodynamic parameters was gathered either by the national teams or by the Project team. Over 500 data were collected; their distribution by aquifer and by country is shown in the following table:

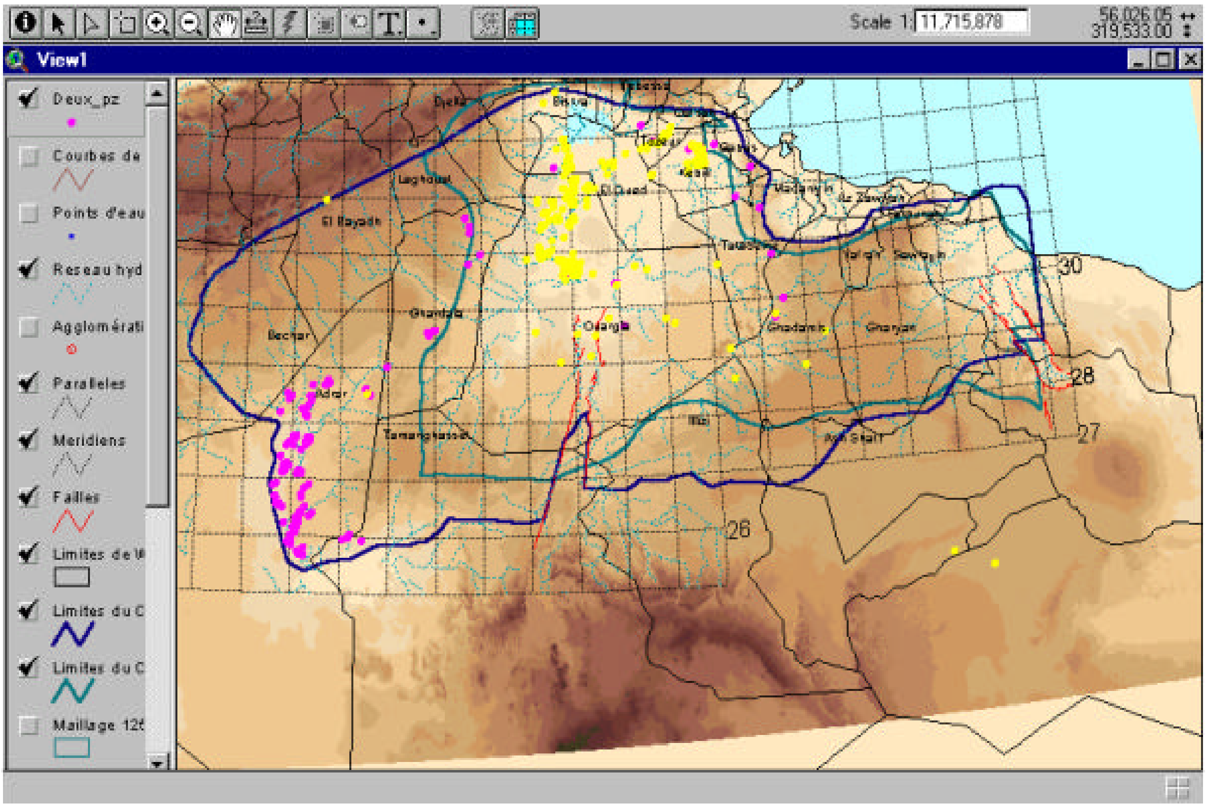
AQUIFER	COUNTRY	Number field meas.
CI	Algeria	12
	Tunisia	13
	Libya	190
CT	Algeria	79
	Tunisia	196
	Libya	-
	Total	**490**

ACTION 16: Introduction of the collected data into the geographic data base

Once the architecture of the GIS had been established (layers, codification, descriptive data) and the projection system defined, all the digitalised geographical data were converted into the ARCVIEW format (GIS code selected for the Project).

The other maps were digitalised by a consulting firm according to the directions laid down by the SASS in collaboration with the "database expert - GIS" (fig. 3).

Figure 6: Principal layers of the GIS



ACTION 17: Reconstitution of the piezometric maps from several periods in the exploitation history of the aquifers concerned.

To satisfy the needs of the models, the “initial state” and the “present state” are important for the different calibrations. The initial state was taken to be the one in 1950 and the present state to be the one in 2000. The maps describing past situations are those of the salinity and the piezometric heads. They were established for both aquifers (CI and TC) at these two dates.

The maps were controlled by referring to intermediate situations obtained from available records for the springs and wells and from partial maps in previous studies.

As the water salinity does not undergo any pronounced variations, the initial state is used. It was supplemented by records of salinity evolution at the points where the variation is most marked. A total of six maps were drawn up: four piezometric and two water-quality maps.

- Map of the initial piezometric levels in the Terminal Complex (1950),
- Map of the initial piezometric levels in the Intercalary Continental formation (1950),
- Map of the piezometric levels in the Terminal Complex (2000),
- Map of the piezometric levels in the Intercalary Continental formation (2000)
- Map of the salinity in the Terminal Complex (2000),
- Map of the salinity in the Intercalary Continental formation (2000).

ACTION 18: Building a conceptual model for each aquifer system describing its hydrodynamic functioning and the relations between the aquifers, which will constitute the basis of the mathematical model. Here, the conditions at the boundaries and inside the domain will be defined as well as the functioning of the aquifer system in steady state or with continuous emptying, etc., the time step, etc.

The main data and information acquired in the last thirty years are summarised in the following table; data from fundamental studies, petroleum drillings and the numerous springs and wells were analysed and processed.

Data acquired during the last thirty years

	1970-1981	2000	Results
Studied surface area	800.000Km^2 (Algeria + Tunisia) Artificial boundaries Partial studies	1.000.000Km^2 (Algérie + Tunisia + Libye) Natural basin boundaries Complete studies	
Studies and data	50 documents (reports, theses, ..) 160 drilling for oil	200 documents including (reports, theses, models, ..) 80 additional drilling for oil	More precise knowledge: - Geology - Geometry of the system
Withdrawals	800 springs and wells 600 Millions m^3	7000 springs and wells 2.5 billion m^3	Data recorded over 50 years : - quality - productivity - hydrodynamic parameters
Informatics	Fixed meshes and limited number	Efficient codes Multilayered model DB+ GIS	Meshes : large number and variable sizes and variable sizes Data-analysis

After this sorting and analysis, a general hydrogeologic structure was established for Northern Sahara (fig. 7). By examining the geology, lithostratigraphy, piezometric heads, chemical quality, drawdown records and flow balances, the Project obtained a sufficient mass of information to construct a pertinent conceptual model.

When this analysis had been completed and given that the geology was represented as four aquifer layers on the basis of the lithostratigraphic correlations, it was decided to:

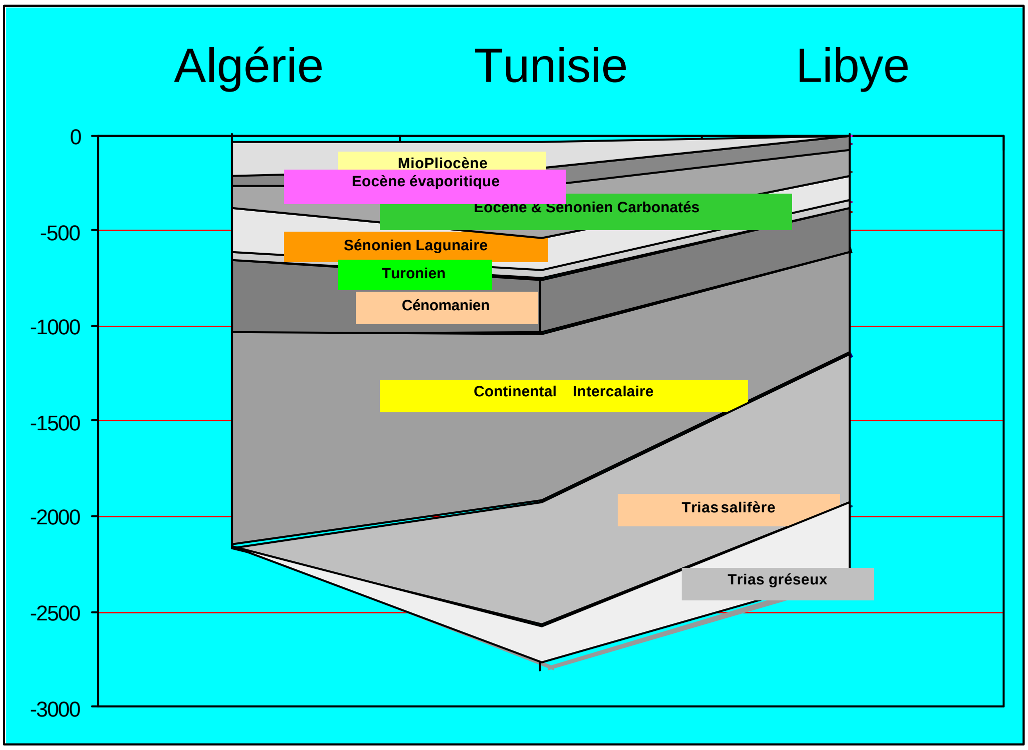
- consider the Intercalary Continental formation and its equivalent, the Kiklah formation, as the major SASS aquifer;

- consider the Terminal Complex, within the meaning of the ERESS (Mio-Pliocene coupled with the Senonian - carbonate Eocene) prolonged in Libya by the Mizda formation, as the second largest SASS aquifer;
- represent the Turonian permeable formation as an aquifer although there are only very localised piezometric data in Algeria and Tunisia, the reason being the risk that it might pose to the water of the Terminal Complex in some areas;
- represent the Cambrian-Ordovician as an aquifer formation, particularly in the Libyan part where these formations have a considerable potential which might, in the long term, interact with the IC.

Figure 7: Hydrogeological structure of the North Western Sahara

SCHEMA HYDROGEOLOGIQUE du SAHARA SEPTENTRIONAL		
ALGERIE	TUNISIE	LIBYE
Toit Imperméable	Toit Imperméable	
Nappe des SABLES	Nappe des SABLES du Djerid	Nappe du Mio Plio Quaternaire
Semi perméable	Semi perméable	semiperméable
Nappe des CALCAIRES	Nappe des Calcaires - Nefzaoua	Upper Cretaceous-Paleocene: MIZDA
Imperméable	Semi perméable	semiperméable
Nappe du TURONIEN	Nappe du TURONIEN	NALUT Aquifer
Imperméable	Imperméable	imperméable
CONTINENTAL INTERCALAIRE SL	CONT INTERCALAIRE & Jurassique	Jurass Lower Cretaceous - KIKLAH
Paléozoique	Imperméable	imperméable
		Trias : AZIZIA Aquifer
	Paléozoique	Paléozoique

Lithostratigraphical structure of the SASS



ACTION 19: Workshop preceding a meeting of the Project Steering Committee in order in order to:
- evaluate the proposed conceptual model,
- confirm the choice of the computer code and the decisions on possible modifications to take into account mapping deformations.

Evaluation of the proposed conceptual model:

The conceptual model, presented to and validated by the national experts from the three countries and the Steering Committee was also subjected to a scientific evaluation at a meeting on the 17th and 18th of September 2001, composed of:

- the five international experts possessing a wide experience of the SASS or of other similar basins,
- the directors general of each institution in the three countries and their engineers,
- the SASS Executive Secretary and Project team.

In order to obtain an outside view and validation of its work, the OSS has created an evaluation committee composed of prominent scientists specialising in the field. After having analysed the work, the evaluation committee produced a report in which it approved the choices made and commended the modelling expert for the scientific quality of his work.

Choice of computer code:

To choose the computer code, a 5-day workshop was organised in February 2000 with the participation of:

- the modelling engineers from each institution in the three countries (6 engineers),
- the SASS Project team
- the modelling expert

- representatives of 7 international institutions with experience of developing hydrogeological modelling codes.

OSS procedure for choosing the software

The computer-programme market is expanding fast and the number of available products increases every day. The problem was to distinguish between what was merely new and what was truly innovative. The SASS/OSS embarked on this long and perilous course, which finally led to the choice of the code that would be most appropriate for modelling the SASS.

Among the welter of codes proposed on the Internet, the SASS/OSS team examined only the best known with the most operationally efficient products, judging from their applications and the publications that have made them known. It was therefore decided to make a preliminary selection of five or six codes and to present them in a workshop where they would be applied to a previously prepared case study for which the constructors had provided copies of the code to the OSS. Because the time to prepare the workshop was too short, almost half of the consultations had to be made by "direct link".

Whatever the chosen code, it is clear that this process was a great achievement by the SASS apart from being a valuable educational experience. In fact, beside the world-wide survey by the International Ground Water Modelling Centre, IGWMC, at the beginning of the 1980s, there are very few known efforts to compare hydrogeological models and codes. The success of this effort is proved not only by the quality of the presented products but also by the reputation of the organisations and the standing of the persons taking part.

- **GMS** (Groundwater Modelling System):
- Engineering Computer Graphics Laboratory, Brigham Young University & US Army Engineer Waterways Experiment Station, USA.
- **MARTHE** (Modélisation d'Aquifère par un maillage Rectangulaire en régime Transitoire pour le calcul Hydrodynamique des Ecoulements), Département Eau du BRGM, Orléans, France.
- **MULTIC**, Laboratoire de Modélisation en Hydraulic et Environnement, ENIT, Tunis, Tunisia.
- **NEWSAM,** Centre d'Informatique Géologique de l'Ecole des Mines de Paris, Fontainebleau, France.
- **PMWIN** (Processing Modflow for Windows), W.H. Chiang & W. Kinzelbach, ETH - Zürich, Switzerland *
- **VISUAL MODFLOW**, Waterloo Hydrogeologic Inc., Ontario, Canada*.
- **WINGEO** (Geolab for Windows) Geolab, Sophia-Antipolis, France.

*MODFLOW family

TECHNICAL SELECTION CRITERIA	
1	**Ease of use**
2	**Quality of the documentation** • Reference manual • Mathematic model • Description of input-output files
3	**Space discretisation**
4	**Modification of the discretisation**
5	**Quality of the presentation of results** • Spatial representation • Chronological series
6	**Export on other media**
7	**Import of pre-developed files**
8	Access to source code - intervention on the programmes
9	Computation speed
10	Representation of boundary conditions
11	**Special conditions :** • Movement from unconfined to confined • Desaturation • Faults • Density flow
12	**Integrated spatial interpolar**
13	**Transport modules**
14	**Aquitard storage**
15	**Optimisation of withdrawals**
COMMERCIAL CRITERIA	
16	User help line
17	cost

Results

According to the adopted criteria, WINGEO is clearly the winner but it was not chosen for two major reasons:

- the dominant role given to the geographic modelling has the effect of obscuring that of the hydrogeology. This situation is ideal for discussions with the decision-maker but frustrates and even handicaps the modeller when evaluating the effects of different hypotheses. This might be particularly detrimental when a model is being constructed or calibrated but it is not an obstacle when predictive simulations are made.

- WINGEO still has a few “bugs” and describes conditions that are not particularly relevant to the Sahara. Some of these were reported to the code developers who immediately repaired or corrected them but others were not detected.

It was suggested that WINGEO be acquired for educational purposes and possibly used for some predictive simulations. However, in order to guard against the two above-mentioned weaknesses, it was decided rather to embark on the development stages of the model (from the conceptual to the digital model) and its calibration in steady and transient state with a more hydrogeologically “transparent” code. From this point of view, the ideal tool was without a doubt NEWSAM: its only flaw is that it is so far in advance of its time that it has refused the

Windows monopoly. Moreover, it is necessary to be able to immediately transfer the SASS model to the three countries and therefore, to install it on a PC and run it on a Windows system.

At present, the best available tool that fulfils all these conditions is the PMWIN system, in particular its PM5 version. This version was given free of charge to the SASS project by Professor Kinzelbach from Zürich, one of the two authors of the code.

Instead of a meeting with the Steering Committee (approximately 1 day), the Project organised two different workshops for the national teams, one over two days, the other for a week.

However, the Project acquired NEWSAM for the three countries in order to allow them to observe any further developments introduced by its author.

ACTION 20: Additional information in the fields identified above required to adjust the simulation models.

Given that new data were sometimes acquired long after the first model calibration and because of recommendations by the Model Scientific Evaluation Committee, the Project decided to undertake:

- A new data analysis
- a revision of the hydrogeological structure at the Tunisian outlet,
- a redrawing of the eastern boundary (Libya)

Although the new data and the recommendations arrived near the end of the Project, the OSS decided to adopt them despite the financial consequences and the delay incurred.

1 - Critique and Validation of the Hydrogeological data:

In hydrogeology, the complexity of a problem is generally measured rather by the degree of geological complexity of a system than by the number, diversity and heterogeneity of the data to be handled. In consequence, there are no traditions and therefore no proven tools of systematic analysis, critical evaluation and validation of large numbers of hydrogeological data. From this standpoint, the problem of the SASS was exemplary and a text-book example because of the quantity, the diversity and the heterogeneity of the data gathered by the Project. These data are of varying quality and some of them showed anomalies that made them impossible to use as such.

It was therefore necessary, when the information had been introduced into the SASS database, to find suitable methods and tools to systematically analyse and validate the data. With the help of these tools it was possible to identify and correct the erroneous data, when detected. The tools in question concerned in particular:

1-1-The piezometric data

When all the initial corrections had been made, i.e., systematic corrections, (inventory of “possible” records, the detection and correction of aberrant values, such as systematic corrections of signs, verification of the reliability of corrected piezometric heads), it was still not certain that all the piezometric data were reliable and usable. It was therefore necessary

to estimate their reliability through filtering procedures and according to precise criteria. To this end, they were analysed by means of the following four processes:

- Plotting on different maps and graphs according to their value
- Tracing of contour curves
- Coherence of the declared altitude and that obtained by the MTL,
- Coherence with the overall piezometric map

The information on the evolution with time of the piezometric heads, from 1950 to the present, is very unevenly distributed in space. Several hundreds of piezometric series have been recorded so far in the SASS database but their quality is variable and sometimes quite mediocre. In order to make these data usable and better adjust the model, the data were grouped into homogenous geographical sectors. It was then possible by visual comparison to fill the gaps in the "type" series of the group which is the longest one and the one that is judged to be the most coherent with the regional record. This is done by "borrowing" data from other piezometers or boreholes in the same group. This procedure produces "synthetic series", generally one series per group or geographical sector.

The procedure can be used to advantage and without much risk on the "densest" series but is not very efficient for "sparse" ones containing very few measurements.

1-2-Withdrawals and their evolution

The withdrawals, their distribution in space and evolution with time constitute, together with the recharge, the source term of the mathematical model. Unlike the transmissivities, this term not calibrated by trial and error and must therefore be totally free from uncertainty and discontinuity. As this rule is, however, often violated where recharge flow is concerned, it is all the more vital to devote the utmost attention and rigour to the preparation of withdrawal data.

Several months of hard work by the Project and the national teams were necessary to compile, verify and validate the withdrawal records for each one of the springs and wells over a continuous period of fifty years, from 1950 to 2000. The result is a considerable volume of data, on the order of 70,000 annual flow-rate measurements (around 1,400 "active" wells in the CI and 2,200 in the TC with an average production period of 20 years). It was, of course, unthinkable to introduce all these data manually into the model as they were already adapted and stored in the database. This is why the Project developed an original interface Database/Model compatible with MODFLOW.

2- Revision of the flow rates in Algeria

Further surveys, carried out in the spring of 2001 in Algeria, led to a substantial revision of the Algerian withdrawal records which resulted in an overall decrease, for 2000, on the order of **15%** as compared to previous estimates (the withdrawal rates fell from **52 m^3/s to 45.6 m^3/**s). The model therefore had to be revised regarding Algeria to take into account the new data.

3- Additional information on the CI in southern Tunisia

After the initial calibration phase of the model, it became clear that it was necessary to revise the very structure of the model in southern Tunisia. It was therefore decided to review all the existing well stratigraphies and produce a new synthesis of the hydrogeology data in order to obtain a more adequate picture of the main CI formations. The resulting lithostratigraphical data, gathered from one hundred and fifty boreholes, form a geologic database specific to southern Tunisia.

These geological cross-sections were used to establish the continuity of each one of the identified aquifers. The new structural scheme of the SASS model includes an additional aquifer: the Upper Sandstone aquifer. Moreover, the new delineation of the CI in the Gabès region has a large gap corresponding to the Melaab dome where the aquifer is considered to be totally absent.

4-Redrawing of the eastern boundary

In its report of January 2002, the evaluation committee of the SASS model made a certain number of recommendations regarding the stages of the model construction and its calibration. The redrawing of the East-North-East boundary of the model, which was done in May 2002, allowed the well fields of Soknah and Waddan in the south-east to be included in the Terminal Complex, the deep well in Waddan to be linked to the CI and the Khoms-Zliten well fields to be represented in their entirety.

In addition, the records of the withdrawal evolution were reviewed and corrected and the model reconfigured to include the new data.

This required a great deal of work: reconfiguring of the boundaries and of some boundary conditions, recalibration in steady and then, transient state, recalculation of all the exploratory simulations carried out during the autumn of 2001 in order to update the results in Libya.

ACTION 21: Defining the model meshes and drawing them on the GIS

In order to facilitate the transfer of data from the older models (mainly the ERESS one whose project possessed digitalised data) to the SASS one, a discretisation grid identical to that of the Continental Intercalary (ERESS, 1972) was chosen; it so happens that this model is the one that covers most of the SASS space. This grid is composed of regular square 25x25 km meshes. During the calibration, it was decided to cut these meshes into four with the result that the final meshes are 12.5x12.5 km, which represents for each layer:

- Terminal Complex 4,128 meshes
- Turonian 4,128 meshes
- Continental Intercalary 6,439 meshes
- Cambrian-Ordovician 1,423 meshes

a total of over **16,000 meshes** representing a surface area of nearly 2,500,000 km^2.

The aquitards are represented by the vertical flows that cross them due to the different heads in the superposed aquifer layers, i.e., leakage fluxes (see model report).

ACTION 22: Establishing the GIS-model links, programmes to automatically determine the withdrawals per mesh.

The information system built for the SASS is based on an integration of the three essential components: the DB, the GIS and the numerical model. The latter is considered only from the aspect of input data and produced results (possibility of transfer to the DB and the GIS). Thus, the model grid is at the same time a layer in the GIS, a basic data table and the model input mechanism (Fig. 8).

Diagram of the links between the three components

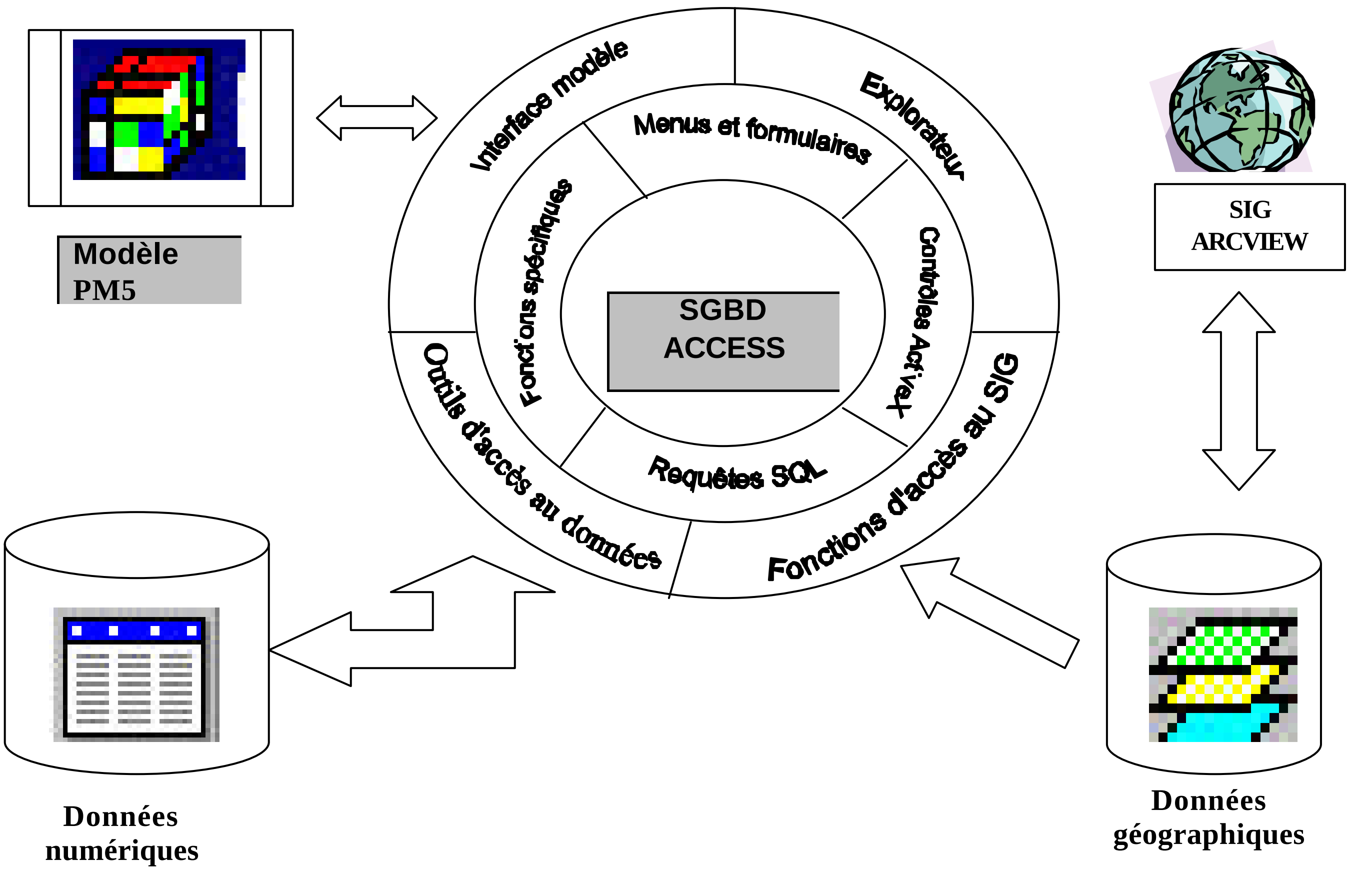


Figure 8: Structure of the code

Therefore, the data are put into the base not by mesh but by well (which is more natural). This approach offers a flexibility that did not previously exist (a change of grid is no longer a constraint).

To obtain this flexibility, it was necessary to develop interface modules that make it possible to:

- construct a grid from parameters provided by the user (origin, mesh size, orientation, etc.) while staying within the database environment,

- at any moment, attribute a flow rate to each mesh of the model and automatically prepare the entry file required by the PM5 code,

- ensure a permanent synchronisation between the DB and the grid in its capacity as a GIS layer: any change in the well table is automatically reflected onto the “well” layer in the GIS and consequently onto the withdrawals by mesh.

This flexibility allowed a great number of changes to be made in the course of the Project.

Figure 9: Explorer
diagram of the window of dynamic grid construction + transfer screen to PM5.

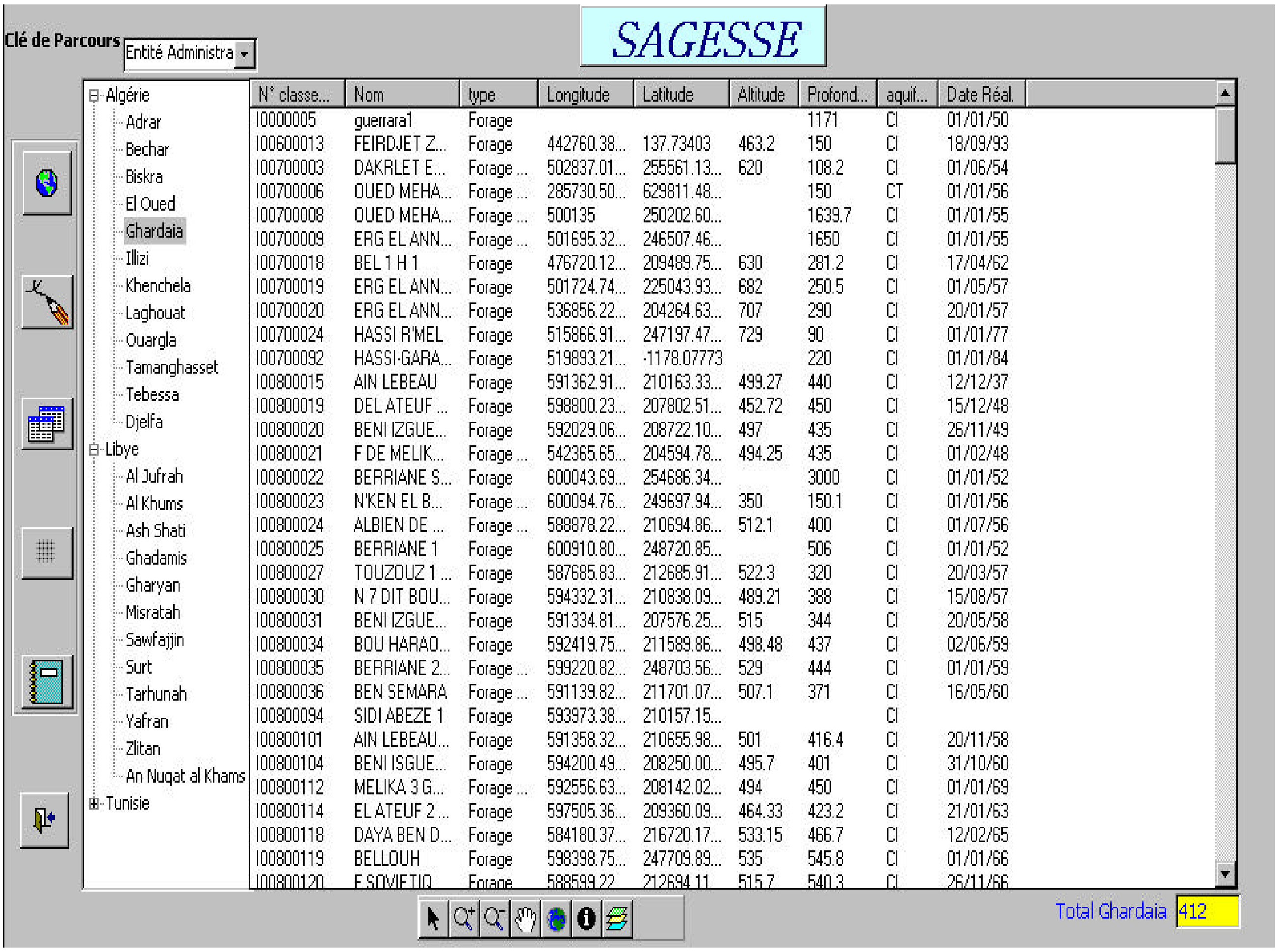
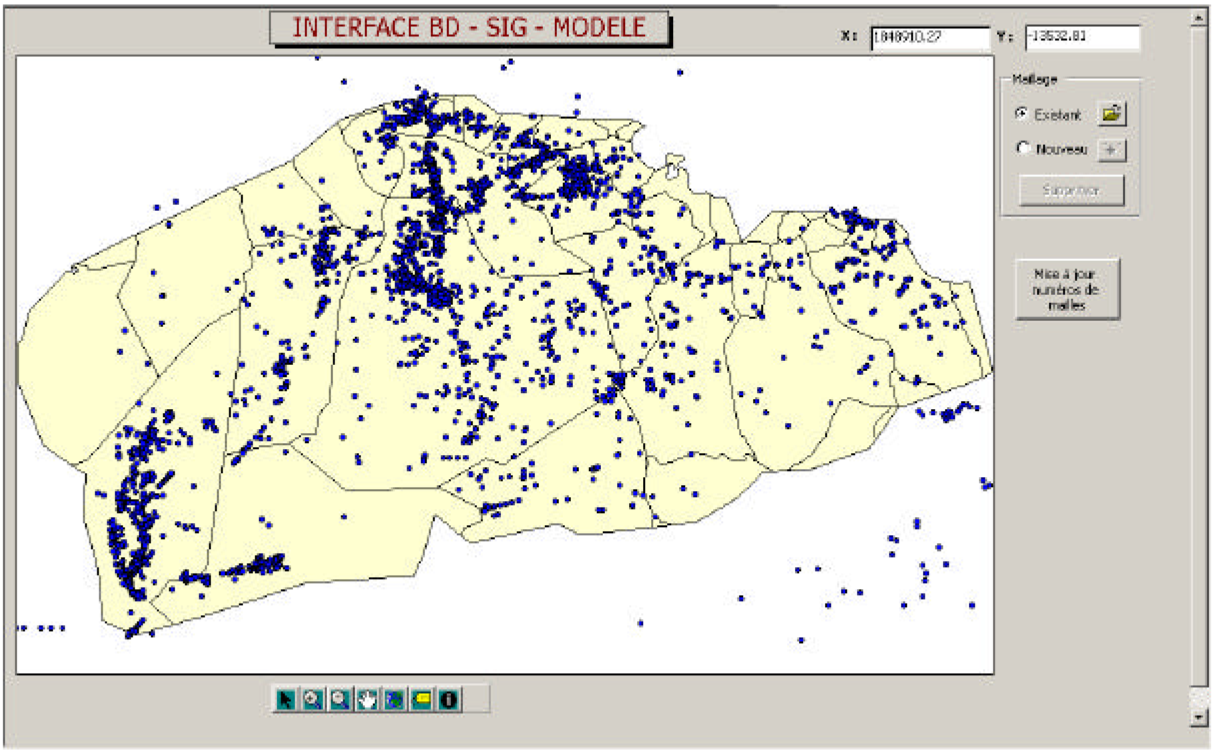


Figure 10: DB-GIS-Model synchronisation



ACTION 23: Preparation of the terms of reference for the model calibration

The terms of reference for the model calibration were defined by the Project team after many months of data analysis and processing.

- Calibration in steady state

The steady-state calibration was defined by the 1950 state. This date was that of steady state as defined for ERESS, i.e., the period during which the two aquifers were at equilibrium in Algeria - Tunisia. After analysis of available data, the same date (1950) was adopted for the Libyan sector.

- Calibration in transient state

An analysis of the withdrawals and piezometric heads, including the most recent ones, led to the adoption of the year 2000 as the reference date for the transient calibration.

ACTION 24: Model calibrations

Classically, the first step in a model calibration is the one in steady state so as to minimise the number of parameters to be adjusted. The objective is to ensure that the all the introduced data are coherent as to boundary conditions, piezometric heads and transmissivities.

The second phase of the calibration consists in verifying that the model functions in transient state over a period during which the system state has evolved significantly in terms of withdrawals and observed drawdown.

The parameters adjusted during the second verification phase are the spatial distribution of storage coefficients and the evolution in time of the recharge rates. However, in the case of the SASS, it is clearly impossible to make changes over time of the recharge because, on the one hand, it is still poorly known and, on the other, the recharge zones are so far away from the pumping zones that precise knowledge of such changes would not influence the model predictions.

In reality, a much broader calibration procedure was used for the SASS: in addition to the calibration of the parameters, among which the transmissivities were also included during the calibration in transient state, reputedly certain elements had, in some cases, to be questioned during the calibration: this was true for the withdrawal rates, the actual shape of the eastern boundary of the aquifer layers and the very structure of the aquifer system itself (see model report).

The geological complexity of the system and the difficulty in obtaining precise data concerning the present withdrawal rates and the piezometric heads prompted several modifications of the model.

In order to stress the attention devoted to the calibrations and the need to make a number of changes in the model before the final calibration, it was considered useful to briefly describe the different previous versions in order to demonstrate that the Project has taken into account:

- All recent data until 2001
- All the recommendations (particularly to extend the model), even those dating from April 2001 regarding the Libyan sector.

The 8 versions are shown in order to illustrate the changes made from one version to the next.

Main stages of the calibration (extract from the "Model" report).

1-Tripoli, or June 2001, model

This model represents the first complete attempt to take into account all the hydrogeological information in the SASS model. The quasi three-dimensional structure of the model contains three aquifers (TC, Turonian, CI) over the entire space where these aquifers are present, separated by two aquitards (lagunar Senonian and Cenomanian). The model has two layers with prescribed heads at the top and bottom which represent the Algerian and Tunisian chotts and the Gulf of Sidra (upper layer) and the Cambrian-Ordovician aquifer (bottom layer).

The hydraulic parameters (transmissivity and storage) of the TC and CI aquifers are almost the same as those used in previous models (ERESS, GEOMATH and GEFLI).

The hydraulic parameters of the Turonian aquifer and the vertical hydraulic conductivity in the aquitards were determined by trial-and-error calibration, starting from an initial value estimated from a few tests on the Turonian made by Sonatrach in the Hassi Messaoud region and from data found in the literature for the vertical conductivity in the aquitards.

The calibration of this model in steady state is very satisfactory; the calculated hydraulic heads and water balance are in fairly good agreement with the observations.

Unfortunately, this model proved unable to describe the transient behaviour of the CI aquifer in the region of the Tunisian chotts (Chott Fedjej, Chott Djerid). On the basis of these results, the structure of the CI in southern Tunisia was completely revised.

2- Impact of the changes in Algerian withdrawal rates

After a final series of verifications carried out by the ANRH teams in Algiers and Ouargla, some errors were corrected and the total withdrawal from all aquifers in Algeria, in 1998, was found to amount to 45.6 m^3/s instead of 52 m^3/s. Without any modification of the structure or parameters of the model, the new Algerian withdrawal figures were used in simulations on the Tripoli model.

This procedure did not include any calibration, only a simple calculation of the piezometric heads and new balances.

The result, in terms of calculated drawdowns compared to “Tripoli” drawdowns and of flow balances calculated in 2000, showed the extent of the variations induced by these changes in prescribed pumping and therefore, the need to revise the model at several points in Algeria.

These model revisions were carried out concurrently with the modifications required by the new representation of the Tunisian outlet of the CI.

3- Initial effects of the new structural configuration of the CI

The new structure adopted for the CI in southern Tunisia includes two aquifers: **the lower aquifer** represents the formations belonging strictly to the CI, **the upper aquifer** represents the “Upper Sandstone”.

The division of the CI into two layers is justified by the great difference in hydraulic heads in these aquifers. For the Upper Sandstone, the piezometric reference map for 1950 was reconstituted.

The withdrawal records of both the Upper Sandstone and the CI over the period 1950 - 2000 were also revised.

The quasi three-dimensional structure of the model of August 20 is the result of adding the Upper Sandstone layer to the Tripoli model and of reconfiguring the CI boundary in the Gabès region where the Melaab dome was excluded from the aquifer.

Preliminary calculations taking into account the updated withdrawal rates in Algeria and Tunisia (the latter in order to account for the re-affectation of withdrawals from one layer to another in the CI) showed that the rates calculated in steady state at the Tunisian outlet of the CI cannot, in this case, exceed 1.8 m^3/s (whereas the generally admitted one at this outlet is 3.6 m^3/s). With the transmissivity field used here, the new delineation of the dome and the prescribed-head conditions at the recharge boundaries, the recharge of the CI by the Dahar falls to **0.6 m^3/s** whereas it was **2.6 m^3/s** in the Tripoli model and **1.99 m^3/s** in that of the ERESS.

4- Model of August 20, 2001

When it became obvious that it was impossible to make a high flow rate pass through the Tunisian outlet with the ERESS transmissivity field, it was decided to depart somewhat from this distribution, particularly in the regions where the absence of wells and therefore of *a priori* transmissivity values made this option admissible.

It became necessary to modify the transmissivity field in order to reproduce a flow rate on the order of 3.6 m^3/s at the Tunisian outlet (actually 3.9, if the percolation in Shott Fedjej is taken into account).

To reproduce this increase, it was, in fact, necessary to create an approximately 100 m-wide stream tube running from Touggourt to the El Hamma fault inside which the CI transmissivity was increased to 2.10^{-2} m^2/s: the highest increases in transmissivities (up to ten times those of the ERESS) were located in the region of the Eastern Erg where there were no measurements.

This increase may seem arbitrary in the absence of any references but the SASS is not the first to be obliged to raise the transmisssivities considerably in this sector: GEOMATH (in BRL, 1997) who built a cross-border model of the CI was forced to adopt high transmissivites (2.10^{-2} m^2/s) in the same area, doubtless to “compensate the loss” to the Tunisian outlet of the fluxes that in the ERESS model were coming from Libya and therefore to include more recharge from the Atlas in the West. However, the comparison with GEOMATH does not go any further as this model assumed the entire Tunisian-Libyan Djeffara to be the CI outlet.

Another major modification of the hydraulic parameters (as compared to the Tripoli model) concerns the leakage coefficients for which a “window” was created underneath Shott Djerid between the Upper Sandstone and the Turonian, on the one hand, and the Turonian and the Terminal Complex, on the other.

It was decided that before proceeding further with the calibration, the predictive capacity of the model should be put to the test by a calculation where the 2000 withdrawal rates were maintained constant.

The preliminary results clearly show that the piezometric heads in the TC are “maintained” by the Chotts which stay connected to the aquifers even in case of de-saturation because of the prescribed-head conditions adopted for the Chotts. Thus they contribute to “recharge” the aquifer as soon as the piezometric head falls below the level of the chotts.

This phenomenon is particularly evident underneath Chott Djerid where a large circular area of weak drawdown appears which may, in the first analysis, be due to either:

- recharge flow from the Chott to the aquifer,
- excessive leakage from the Turonian, enhanced by the “window” of shott Djerid, or
- an overestimate of the storage coefficients adopted for the unconfined aquifer, or simply to the fact that there is no working well within the Chott.

In order to make a well-informed evaluation of the effects of the above-mentioned parameters, it was decided to construct a new version of the model where:

- the meshes of the Chott are automatically disconnected from the TC as soon as the piezometric head in the aquifer falls below the level of the Chott,

- the leakage window of shott Djerid (Upper Sandstone - Tur. - TC) disappears in favour of a spatially more diffuse and homogeneous leakage,
- the calibration of the head records in transient state must allow a possibly substantial decrease in the storage coefficients of the “unconfined aquifer”, particularly in the Terminal Complex sectors where the earlier values were considered excessive over large areas lacking any measurements or tests (the Great Eastern Erg).

5- Model of September 10, 2001

Compared to the previous one, this model was modified as follows:

- disappearance of the leakage “window” of shott Djerid, replaced by diffuse leakage,
- substantial reduction of the transmissivities in the Upper Sandstone,
- modification of the structure of the Upper Sandstone whose “piezometric depression” is no longer represented as the result of percolation toward the Djerid but of drainage toward the Fedjej shott considered as a drain,
- change of the boundary conditions prescribed on the Algerian-Tunisian chotts: from being a layer of prescribed-head meshes, as represented in the August 20 model, the chotts become a drain with a no-flow boundary which prevents any recharge of the TC by the chotts,
- readjustment of the CI transmissivity field made necessary by all the previous changes: in general, the present transmissivities are 20 to 25% higher than those in the August 20 model,
- revision of the flow rate at the Tunisian outlet, increasing it from 2.75 m^3/s to 3.3 m^3/s which is much closer to the generally admitted estimates,
- substantial reduction in the storage coefficients of the unconfined zones in the Terminal Complex. (The storage coefficient in an unconfined aquifer has an important role in the long-term behaviour of the aquifer system. In the TC, contrary to the CI, there are unfortunately no measured storage-coefficient values in the unconfined aquifer nor a sufficient number of reliable control points allowing the S values to be corrected by calibration based on the drawdown records).

6- Model of September 23, 2001 - review of the transmissivity structure

The September 23 model was built after the recommendations made by the Model Evaluation Committee: the CI transmissivities in the September 10 model were replaced by those in the Tripoli model (the same as those in ERESS). The calibration results are of the same quality as those of the September 10 model (note, in particular, the excellent agreement between the measured and calculated drawdowns in Shott Fedjej). As expected, the steady-state flow rate at the Tunisian outlet of the CI is only 1.9 m^3/s.

This model satisfies the choice to attribute greater confidence to transmissivity estimates based on field data than to the natural flow rate at the Tunisian outlet, which has been extensively studied but still remains uncertain.

7- Model of September 30, 2001

The September 30 model is derived from the September 23 one but doubles the CI transmissivities in the regions of Biskra, El Oued and Nefzaoua. The results of the model calibration are excellent and the steady-state flow rate at the Tunisian outlet is 3.1 m^3/s which is very close to the previous estimates.

The September 30 model is therefore a synthesis, a compromise between the two options discussed above. In fact, the geologic information is scarce on the Biskra - El Oued, - Nefzaoua triangle and the decision, taken for the ERESS model, to double the transmissivities in this area is not contrary to the experimental data.

The September 30 model can therefore be considered to be an acceptable final state of the SASS model calibration phase. This model is the one that best responds to the criteria and the constraints imposed on the calibration. Consequently, it appears to be the most suitable one for predictive simulations of water-resource development in the Northern Sahara Aquifer System.

8- Revision of the model in the eastern basin

To take into account the new data gathered in Libya, during the first semester of 2002, it was necessary to update the model. This was due to the redrawing of the eastern and north-eastern boundary of the modelled area. The evolution of the withdrawal records was also reviewed and corrected. The model was reconfigured to take account of the new information which entailed a vast amount of work: reconfiguring the boundaries and some boundary conditions, re-calibration in steady and then, transient state. **Thus, this last version of the model is definitely the one that will be used to simulate future water-resource exploitation in the Northern Sahara Aquifer System (see model/SASS report).**

ACTION 25: Scenarios of future aquifer exploitation

With the aim of defining the aquifer-exploitation scenarios and including national institutions in the validation process, one expert from each country was selected jointly by the OSS and the national institutions.

The three experts worked on the development scenarios in accordance with the terms of reference set out by the Project team and each one wrote a report discussing the following issues:

- the present state of the withdrawals, distributed between different uses: Drinking-water supply - Agriculture - Industry,
- present population and forecast for 2050,
- present irrigated surface area and predicted evolution until 2050

The three reports made it possible to identify the amounts needed in 2050 for drinking-water supply, agriculture and industry.

Country	Withdrawal in 2000	Additional demand in 2050
ALGERIA	1,3 million de m3/y	Scenario I : 2 billion m3/yr Scenario II :3 billion m3/yr
LIBYA	400 million m3/yr	840 million m3/yr
TUNISIA	510 million m3/yr	No change

Population growth in the studied areas of the three countries

Population	1970	2000	2030
Algeria	420,000 inhab	2.600,000 inhab	5.300.000 inhab
Tunisia	37,000 inhab	376,00 inhab	900,000 inhab
Libya	160,000 inhab	1.000.000 inhab	2.300,00 inhab
Total	**617,000 inhab**	**3.970,000 inhab**	**8.500,000 inhab**

Development of surface area irrigated by water from the CI and CT in the three countries

Unity : 1000 ha

Surface area	1970	2000	2030
Algeria	11 000 ha	92 000 ha	212 000 ha
Tunisia	9.000 ha	15.000 ha	26.000 ha
Libya		44.000 ha	103.000 ha
Total	**20.000 ha**	**151.000 ha**	**341.000 ha**

These development scenarios, approved by the countries, were presented and debated in a workshop organised at the OSS headquarters on June 1-2, 2002 and attended by:

- The three Directors General
  - ANRH - Algeria
  - GWA - Libya
  - DGRE - Tunisia
- the three experts, authors of the national reports,
- the Executive Secretary of the OSS and the SASS team

At the end of this workshop, the development scenarios were adopted and now form the basis on which the exploratory simulations will be constructed.

ACTION 26: Exploratory simulations of the scenarios

A report was produced based on the development scenarios adopted by the three countries. It defined the character of the exploratory simulations and consisted of:

The calculation conditions

The objective of the exploratory simulations is to investigate the capacities of the system, up to its very limits; at this stage, the limits of resource development will be defined keeping in mind the remaining uncertainties concerning the hydrogeological, social and economical

parameters which might create totally skewed working hypotheses and therefore, results. It was deemed useful to carry out the calculations over a period that is:

- sufficiently long to allow impulses, whose effects are to be determined, to reach their peak and to extend as far as possible in space,
- not too long, however, to prevent it from exceeding the boundaries of significance of the tool with regard to the above-mentioned uncertainties

From this point of view, a simulation period of fifty years seemed reasonable. The exploratory simulations will therefore be made over fifty years and the initial reference state will be the one in 2000 as established by the model.

To explore the aquifer system up to its extreme reactions and capacities keeping in mind the objective of sustainability, a constant flow rate will be used throughout the calculation period. This flow rate will represent the maximum one foreseen by the plan or the scenario in question so as to approach a quasi-steady state regime in 50 years.

- **Expected results**

Each simulated scenario or development plan will provide the following results:

- Drawdown map for 2000 to 2050 calculated across the entire aquifer of interest
- Time curve of the drawdown (2000-2050) established at a certain number of test wells, one per large hydraulic region and large exploitation area (i.e. arount 12 test wells),
- Principal terms of the 2050 balance, in particular the calculated flow rate at the three main outlets: Ain Tawargha, the Foggaras and the Tunisian outlet,
- Estimate in numbers that makes it possible to evaluate, in terms of additional drawdown, the impact of the simulated scenario on each of the neighbouring countries that might be affected,
- Map of the depth of the piezometric level, calculated for 2050, below that of the ground,
- Depth of the piezometric level below the surface of the chotts in Algeria and Tunisia which can be translated into risk assessment of potential salinisation.

- **Reference scenario: maintaining the present situation or simulation zero**

This scenario is very unlikely but must be simulated in order to compare and fully understand the effects of the various development scenarios. It consists in maintaining constant the withdrawals recorded in 2000 and calculating the corresponding evolution of the system during the coming 50 years.

- **Recapitulation of the exploratory simulations**

Finally, the exploratory simulations carried out at this stage of the SASS study can be summarised as follows:

- Maintaining the present state (withdrawals in 2000) or "simulation zero"
- Algeria : weak hypothesis
- Algeria : strong hypothesis

- Libya : deficits made up in 2030
- Libya : Ghadames field
- Libya : Impact of pumping in Jebel Hassaouna
- Tunisia: withdrawals in 2000 maintained

The following table shows the pumping rates represented in SASS model for each simulation:

SCENARIO	Wells CI M3/s	wells CT M3/s	Total wells SASS m3/s
Simulation zero			
Algeria (1)	21.3	20.9	42.2
Libya (2)	3.2	3.8	7.0
Tunisia (3) upper sand included in CI	2.7	14.5	17.2
Total SASS	**27.2**	**39.2**	**66.4**
Additional debit rates			
Algeria_weak hyp. (4)	36.4	26.1	62.5
Algeria strong hyp. (5)	59.6	41.8	101.4
Libya deficits made up (6)	5.1	4.7	9.8
Libya Ghadames field (7)	2.9	0.0	2.9
Libya_Jbel Hassaouna	0.0	0.0	0.0
Totals débits SASS			
Total case Algeria weak hypothesis = (1) + (2) + (3) + (4)	**63.3**	**65.3**	**128.9**
Total case Algeria strong hypothesis = (1) + (2) + (3) + (5)	**86.8**	**81.0**	**167.8**
Total Libyan deficits made up = (1) + (2) + (3) + (6)	**32.3**	**43.9**	**76.2**
Total Lybia Ghadames field = (1) + (2) + (3) + (7)	**30.1**	**39.2**	**69.2**

Results of the exploratory simulations: maintaining the present withdrawals until 2050

- **In the Continental Intercalary**

Simply continuing the present withdrawals would, in 2050, have caused considerable drawdown (as compared to the 2000 levels) in the entire lower Algerian Sahara, in excess of 40 m over a surface area of almost 200,000 km^2 with a central axis running approximately from El Oued to Hassi Messaoud. Elsewhere in Algeria, particularly in the CI outcrop zones, the drawdown is weak ,e.g., in the Adrar administrative unit where the maximum drawdown is on the order of 15 m in the Touat.

In Tunisia, the drawdown exceeds 20 m everywhere and 40 m in the sector of the Ksar Ghilane; it is on the order of 25 m around the Fedjej shott.

In Libya, the drawdown approaches 25 m in a 100 x 300 km-band surrounding the major exploitation sites: Bani Walid, Wadi Zamzam, Wadi Ninah and Sufajin. Elsewhere, the calculated drawdown is around 10 m throughout the Hamada El Hamra.

The calculation of the depth of piezometric levels shows that the boundaries of artesian flow calculated for 2050 are not very different from those of today. The loss of artesian flow is limited to the El Borma and Ghadames sectors.

- **In the Terminal Complex**

In Algeria, the 2050 drawdown exceeds 30 m in the entire Oued Rhir valley north of Toggourt. In Tunisia, it ranges between 20 and 30 m throughout the Djerid and Nefzaoua. In Libya, its maximum (on the order of 60 m) is located in the south-east, around the Soknah, Hammam and Ferjan well fields.

Compared to the present situation, the map of piezometric heads and depths below ground level clearly indicates that all artesian flow will disappear from the Algerian and Tunisian chotts. Furthermore, it shows that the Merouane and Melrhir chotts are completely "suspended" above the piezometric surface of the TC. This is also true in Tunisia regarding the southern margin of the Djerid sector and the Kebili peninsula with all that this special situation, hitherto unknown in the region, may imply regarding the risks of "recharge" to the TC aquifer by the shott water.

Simulation of the scenarios for the three countries:

- **Algeria - strong hypothesis**

  - ***In the Continental Intercalary***

The regions of Ghardaia, Oued Rhir, El Oued and Wargla will experience drawdowns of 300 to 400 m. In the principal Tunisian well fields, the drawdown will be 200 to 300 m.

Artesian flow will disappear almost totally. The effects on Libya are minimal.

  - ***In The Terminal Complex***

In Algeria itself, this scenario causes great additional drawdown, particularly around the sites of intense additional withdrawal:

- in the Oued Rhir (4 m^3/s) and the Souf, in the north (10 m^3/s)
- at Ouargla (10 m^3/s) and Hassi Messaoud-Gassi Touil, in the South (19.5 m^3/s).

The calculated additional drawdowns in these zones range from 70 to 150 m.

In Libya, this scenario has no effect.

In Tunisia, the situation is as follows:

- the additional drawdowns are on the order of 50 m in the Djerid and from 20 to 40 m in the Nefzaoua

- all the chotts (Djerid and Rharsa) are in a position to recharge the TC aquifer and the piezometric-level differences are, on average, 50 m.

This piezometric-level difference, which is the **main risk indicator**, is still greater in Algeria where it exceeds 100 m beneath the Melrhir and Merouane chotts and reaches 200 m at Mghaier and Djamaa.

The impacts of the weak Algerian hypothesis are no different from those of the strong hypothesis: **instead of 300 to 400 m, the drawdown is 250 m.**

- **Effects of the "Ghadames field" scenario:**

In the TC, the drawdown calculated by this scenario is negligible. As to the Continental Intercalary, the calculated net drawdown is on the order of 100 m in the Ghadames-Derj well field. It gradually decreases with the distance and is practically zero within a radius of 200 to 300 km. In Tunisia, all of the extreme south is naturally influenced by the withdrawals at Ghadames. In the Debdeb region in Algeria, the drawdowns are on the order of 60 m.

- **Effects of the "Djebel Hassaouna field":**

In the TC, the net drawdown created by the wells at Djebel Hassaouna is relatively small and shows a maximum of 10 to 20 m at the centre of the Hun graben.

In the CI, the influence of Djebel Hassaouna stops at the Hamada El Hamra basin and does not reach the Algerian and Tunisian borders. In Libya, the calculated drawdowns form a halo surrounding the well field with a maximum of 50 m in the south.

- **Effects of the "Making up the deficits" scenario in Libya:**

  - ***In the Continental Intercalary***

The net drawdown reaches a maximum of around 80 m with a large zone of 50 m around Wadi Zamzam. The influence on Tunisia and Algeria is negligible, less than 10%.

  - ***In theTerminal Complex***

Net drawdowns (in addition to simulation zero) are 100 m at Soknah, Hammam and Ferjan (the gross drawdowns are 160 m) and on the order of 30 to 50 m around the well fields in the north: Bani Walid, Wadi Zamzam, Wadi Washka.

- **Superimposition of the three Libyan scenarios:**

For the Continental Intercalary, the only aquifer concerned by all three scenarios, the result is shown of superimposing the net drawdowns calculated by the three Libyan simulations: Ghadames, Djebel Hassaouna, Making up the deficits.

This superimposition does not produce any significant change compared to the individual drawdown maps as the centres of withdrawals in each of the scenarios are, in fact, quite far from each other, i.e., several hundreds of kilometres.

The document containing the simulation results were communicated to the countries for analysis and recommendations. In view of the impact of the first scenarios**, Libya maintained its original predictions, Tunisia proposed additional withdrawals whereas Algeria**, given the magnitude of the drawdowns, **asked the Project to identify additional available hydraulic resources** as these resources condition the agricultural and industrial development as well as transfers between regions.

Main constraints listed by the countries concerned:

  - Safeguarding artesian flow
  - Preservation of the foggaras and the Tunisian outlet

➢ Preservation of the water quality in the vicinity of the chotts
➢ Admissible additional drawdown

On the basis of the answers by the countries, the Project identified all the potential withdrawal zones and developed a micro-model that can be used by the national agents with immediate results.

To exploit this micro-model, a workshop attended by the three directors general and the Project team was organised on April 1-2, 2002 at the OSS headquarters in Tunis.

All these results are extensively discussed in the Model report.

Figure 11: Potentially exploitable zones in the Terminal Complex

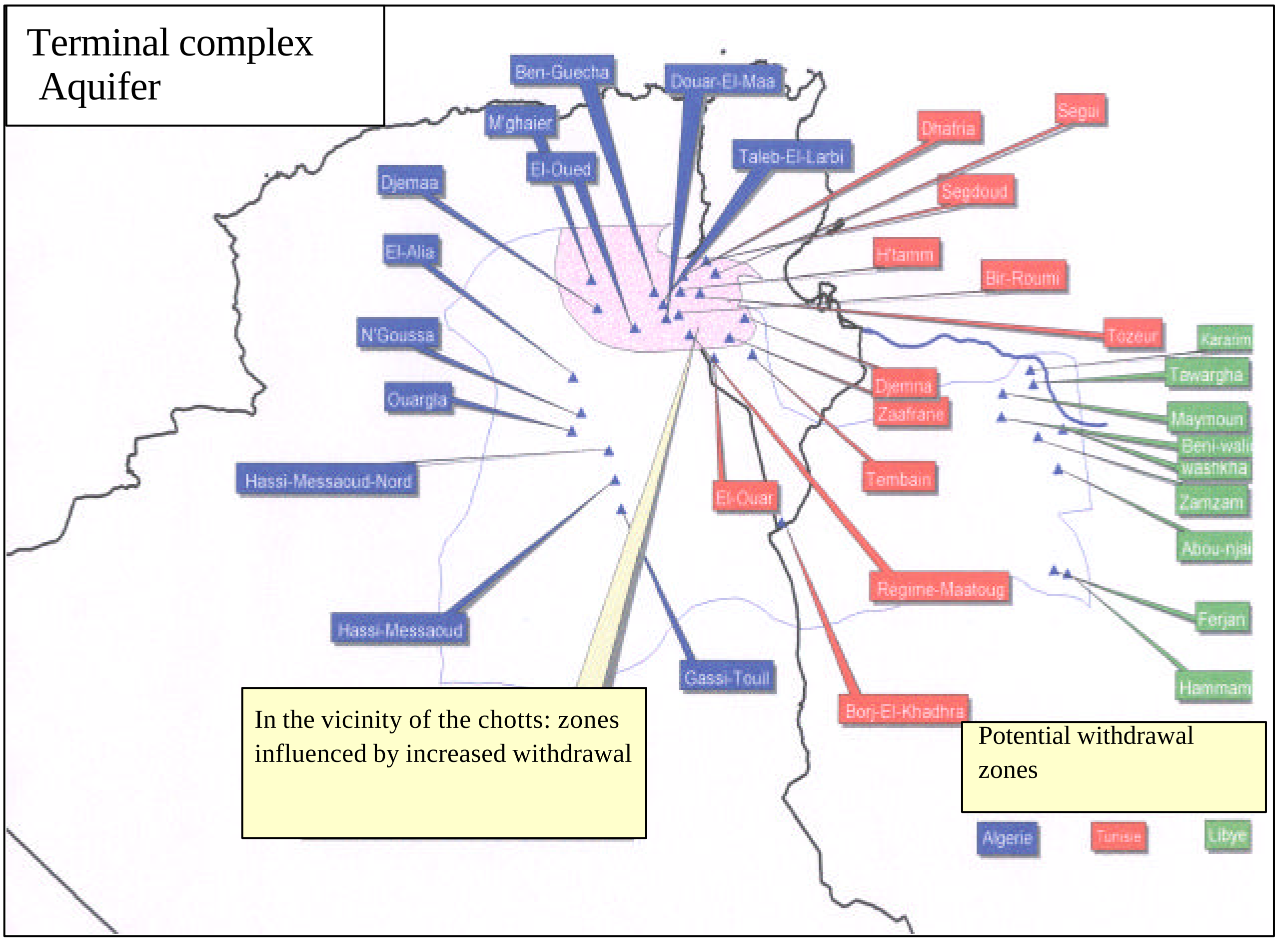


Figure 12: Potentially exploitable zones in the Continental Intercalary

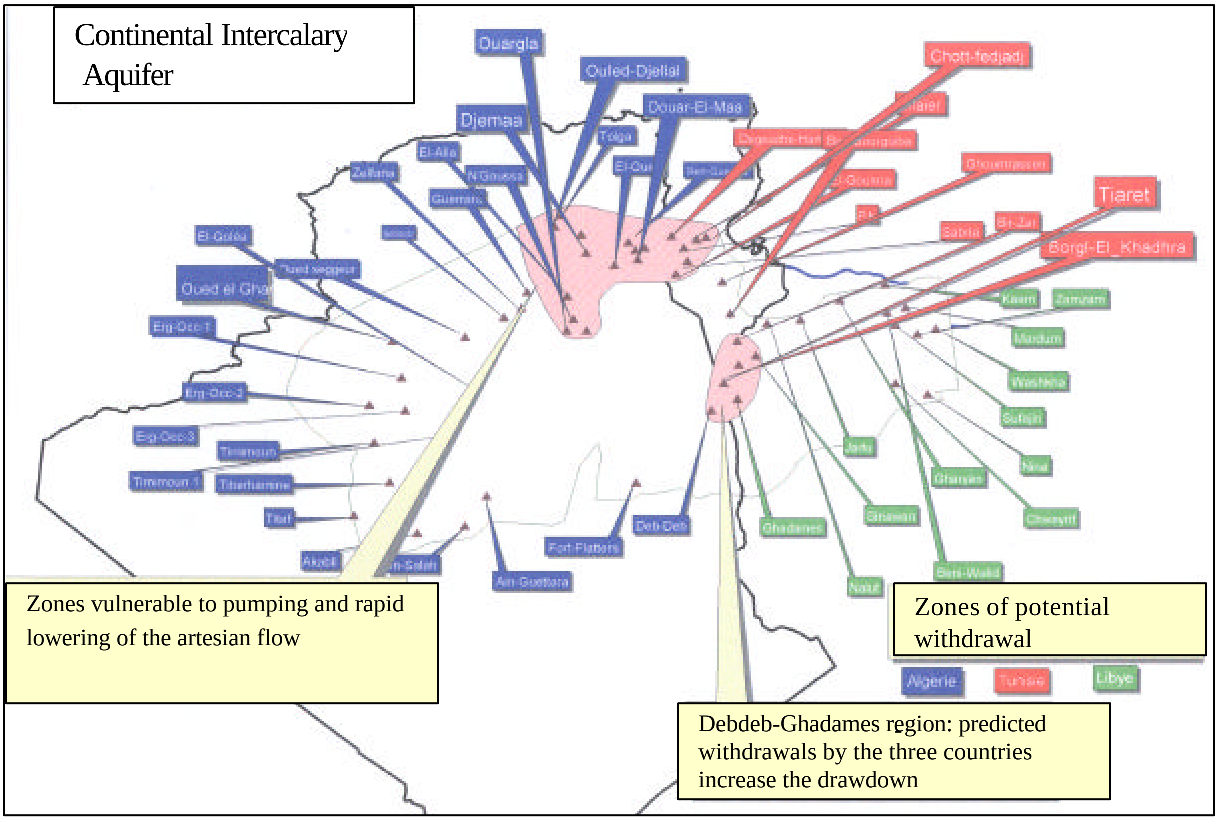


Table 1: Influence coefficients in metres: nominal flow rate - 10 m³/s. End time : 2050. Initial conditions: 2000.

	Champ de Pompage			Titaf	Akabli	Timimoun	Ouled Djallal	Tolga	El - Oued	Ben Guecha	Djemaa	M'ghaier	Taleb El Larbi	Douar El Maa	Sebseb	El Golea	Guerrara	Zelfana	Al Alia	N'Goussa	Ouargla	Hassi MessNord	In - Salah	DebDeb	Fort Flatters
Num zon	Nomzon	col,lin	sim0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Titaf	8-55	4	328	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Akabli	20-62	4	0	317	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Timimoun	16-41	2	0	0	353	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Ouled Djallal	64-6	42	0	0	0	534	356	157	160	199	252	149	143	28	1	73	51	103	74	59	63	0	1	0
5	Tolga	66-4	43	0	0	0	355	629	175	183	216	285	170	162	27	1	71	50	103	75	59	65	0	1	0
6	El - Oued	74-17	51	0	0	0	146	166	577	290	228	208	290	295	21	1	54	40	104	82	62	80	0	1	0
7	Ben Guecha	78-13	46	0	0	0	143	168	284	489	206	209	372	338	17	1	46	33	84	65	49	63	0	2	0
8	Djemaa	69-13	48	0	0	0	195	213	235	218	498	272	206	200	28	1	71	52	124	91	70	81	0	1	0
9	M'ghaier	69-9	46	0	0	0	248	282	214	222	272	531	206	197	26	1	69	49	111	81	63	72	0	1	0
10	Taleb El Larbi	79-15	45	0	0	0	130	153	282	370	191	192	493	386	16	1	42	31	78	62	47	61	0	2	0
11	Douar El Maa	79-17	46	0	0	0	124	145	287	336	185	183	386	544	16	1	41	30	78	62	47	62	0	2	0
12	Sebseb	49-22	32	0	0	0	28	27	22	19	28	27	18	18	224	3	60	82	43	42	44	33	0	0	0
13	El Golea	39-35	6	0	0	0	1	1	1	1	1	1	1	1	3	187	2	3	2	3	5	3	0	0	0
14	Guerrara	55-18	41	0	0	0	73	71	58	52	73	70	49	48	60	2	277	114	99	82	76	64	0	0	0
15	Zelfana	53-21	40	0	0	0	51	50	43	38	53	50	36	35	82	3	114	261	80	76	77	60	0	0	0
16	Al Alia	63-21	52	0	0	0	103	105	113	97	127	114	93	92	43	2	99	80	444	172	130	132	0	0	0
17	N'Goussa	63-26	58	0	0	0	75	76	88	74	93	83	72	72	42	3	82	76	172	577	243	249	0	0	0
18	Ouargla	61-28	55	0	0	0	59	60	66	56	72	65	54	54	44	5	76	77	130	243	541	235	0	0	0
19	Hassi MessNord	65-29	67	0	0	0	63	66	86	72	82	74	71	72	33	3	64	60	132	249	235	981	0	0	0
20	In - Salah	30-63	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	329	0	0
21	DebDeb	86-52	10	0	0	0	1	1	2	2	1	1	2	2	0	0	0	0	0	0	0	0	0	561	0
22	Fort Flatters	67-63	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1045
23	Chott fedjadj	94-16	26	0	0	0	75	94	199	264	125	126	285	285	7	0	19	14	37	29	22	30	0	2	0
24	Tozeur	85-15	38	0	0	0	104	124	235	308	157	159	330	327	12	0	32	23	59	47	36	47	0	2	0
25	Rigime Maatouk	84-20	40	0	0	0	98	117	229	288	150	150	313	322	11	0	30	22	58	47	35	48	0	3	0
26	El Borma 204	89-36	33	0	0	0	25	30	63	79	40	39	86	88	3	0	8	5	16	14	10	17	0	31	0
27	Kebili	90-18	33	0	0	0	86	104	210	274	136	136	296	296	9	0	24	18	46	37	28	38	0	3	0
28	Kseur Ghilane	94-25	41	0	0	0	37	45	92	120	58	58	131	133	4	0	11	7	21	17	13	19	0	7	0
29	Ghadamès	90-52	10	0	0	0	1	1	2	3	1	1	3	3	0	0	0	0	0	0	0	0	0	261	0

The operations carried out on the micro-model during the above-mentioned workshop indicated a certain number of scenarios responding to the development objectives while minimising the risks of degradation by observing the imposed constraints. The scenarios, summarised in the following table, were simulated on the numerical model which produces complete results and makes it possible to measure *a posteriori* the degree of success in attaining the objectives and obeying the constraints.

Additional withdrawals in the Continental Intercalary in m^3/s								
SCENARIO	CI-1	CI-2	CI-3	CI-4	CI-5	CI-6	CI-7	CI-8
ALGERIA	*8.5*		*2*	*8.5*	*38.5*	*80*		*118.5*
TUNISIA		*2.2*	*1.4*	*2.2*				*2.2*
LIBYA			*2.9*	*3.6*			*5.2*	*8.35*
Total	8.5	2.2	6.3	14.3	38.5	80	5.2	129.

Additional withdrawals in the Terminal Complex in m^3/s					
SCENARIO	CT-1	CT-2	CT-3	CT- 4	CT- 5
ALGERIA	*14.7*				*14.7*
TUNISIA		*3.3*			*3.3*
LIBYA			*11.*		*11.*
Algeria - OUED MYA				*18.0*	*18.0*
Total	14.7	3.3	11.	18.0	47.

The final result is that the additional withdrawals may be greater than those announced, provided that the spatial distribution is revised. Thus, the following zones were identified:

- high-potential zones without interference
- zones with limited inter-regional or cross-border influence
- vulnerable zones where withdrawal must be restricted or, in some areas, reduced.

ACTION 27: Social and economic evaluation of the simulation results

In the first phase, the Project analysed the reports on the predictions by the countries. When the final results of the scenarios had been approved during the last meeting of the Steering Committee and considering the new orientations decided by the countries, the OSS plans to undertake not simply an analysis of the results but rather a predictive study aiming at a sustainable development of the basin. This study will be conducted jointly and by consensus by the three countries during the second phase of the SASS (if adequate financial means are provided).

The social and economical evaluation will be based on the definitive scenarios approved by the countries after having constructed regional sub-models as recommended by the scientific committee in order that the social and economic component be founded on the most reliable and consensual results.

ACTION 28: Workshop linked to the last meeting of the Programme Steering Committee to present the results of the simulation scenarios

A report of the results of the last simulations was sent to the countries. These results will also be presented at the Steering Committee meeting at the end of October 2002. At this meeting, point 27 dealing with social-economic evaluation within the framework of sustainable management will be debated.

ACTION 29: Installation of the models in the countries

The models were installed in all the countries together with:

- a PM5 code with a user's manual
- CD Rom of the models
- Presentation by model experts

The procedure was the same for the geographical information system.

ACTION 30: Final Programme Report

In the course of the project, several progress reports were produced:

- Database and GIS
- Data analysis
- Conceptual model
- Choice of code
- Steady and transient state calibration
- Tunisian outlet
- Exploratory simulations
- Model revision (eastern basin)
- Predictive simulations
- Scientific Evaluation of the model

These 10 reports describe explicitly the obtained results. The final report was planned to require a month but because of the expansion of the Project, the final report has four parts:

- Presentation of the results
- Hydrogeological overview
- Information System
- Models

The final report is produced on paper and on a CD, format PDF.
A review panel was set up composed of the Executive Secretary (Chedli FEZZANI) and international experts (G. de MARSILY, J. MARGAT).

RECAPITULATION OF
THE PLANNED/COMPLETED PROGRAMME

Planned programme	Completed programme
Harmonisation of the Hydrogeological and geodesic databases	- rather than harmonise incomplete database, the Project undertook to: ▪ Build a rational common DB ▪ Integrate a GIS ▪ Establish DB - GIS links - A workshop was organised to harmonise geodesic data between the three countries.: The project undertook to: - choose a co-ordinate system and a projection system: - Convert the data - Draw up a 1:2,000,000 topographical base map on paper and digitalised maps.
Selection of a monitoring network and measurement exercises in the field	The Project undertook to : - inventory the springs and wells and withdrawal rates - make levelling and piezometric measurements - select a calibration network and a common network for future monitoring - introduce all the data into the common database
Collection and analysis of geologic and hydrogeologic information after the 1970 overview	The gathered and analysed information concerns: - 3 fundamental studies in Libya - 80 oil wells - 200 documents (reports, theses, etc…) - 7000 springs and wells A conceptual model was built An evaluation workshop and a workshop on the choice of code were organised The ERESS body of information was made available to the countries
Adjustment and calibration of the new Models and simulation of exploitation scenarios	- Development of an integrated information system: DB - GIS - model link - Model calibration in steady and transient state - Exploratory simulations - Workshop presenting and evaluating the results - Presentation of the results to the Steering Committee - Installation of the models in the 3 countries - Preparation of a final model report

3RD PART

ESTABLISHMENT OF THE PROJECT

III. COORDINATION AND MANAGEMENT OF THE SASS PROJECT

The SASS Project is funded from the following sources:

- DDC-Switzerlan d
- FIDA
- FAO
- The three countries : Algeria, Libya, Tunisia

The distribution of the funding is shown in Table 1.

Table 1: General Budget ($US)

Type of expenditure	Defrayed by the 3 countries	FIDA	SWITZERLAND	FAO
Updating of SASS water resource estimates				
➢ Staff or expertise, travel and running costs…………	517.500	763.900	272.000	
➢ Equipment …………	75.000	213.100	76.000	
➢ Additional logistic and administrative support………	-	88.000	32.000	
Sub-total 1	**592.500 (29,1 %)**	**1.065.000** (52,3%)	**380.000** (18,6 %)	
Sub-Total 2		**1.445.000**		
Consultation mechanism	**119.000** (30,4%)			**272.000** (69,6 %)
Grand total	**711.500 (29,3 %)**	1.717.000 (70,7 %)		

The contributions by the FIDA and the DDC-Switzerland were entrusted to the OSS in its capacity as Executive agent. The FAO managed its contribution directly: a portion was entrusted to the OSS ($US 75,000) to match its contribution. The contributions by the countries reflect their support for the Project.

III.1. Contributions by the cooperation partners

The technical activities of the SASS were funded by the FIDA and the DDC-Switzerland. The distribution among the donors and the various expenditure headings is shown in Table 2 below:

Table 2: Budget of the contributions by the co-operation partners

Expenditure	Total	FIDA	DDC
1 - Staff	786.900	579.900	207.000
2 - Travel	114.000	84.000	30.000
3 - Equipment			
Computer and field equipment	154.100	178.100	76.000
vehicles	135.000	135.000	0
Sub - total	**289.100**	**213.100**	**76.000**
4 - Sub-contract	20.000	15.000	5.000
5 - Running costs	115.000	85.000	30.000
6 - Additional logistic and administrative support by the OSS	120.000	88.000	32.000
TOTAL GENERAL	**1.445.000**	**1.065.000**	**380.000**
Percentage	100,00 %	73,70 %	26,30 %

In addition to the financial balance presented in a separate document, a statement detailing the work done under each heading as well as an analysis of the discrepancies are established below. This procedure makes it possible to evaluate, for each heading, the extent to which the objectives have been observed, justify the deviations and explain the modes of expenditure adopted by the OSS in conformity with existing financial regulations.

HEADING 1 : Staff

Allocated budget	Expenditure
786.000 $ US	

This budget was destined to cover the expenses for:

- The project co-ordination team
- The international consultants
- The national staff
- The assistants and support staff

Project team:

At the first meeting of the Steering Committee it was decided to recruit a Regional Co-ordinator for the duration of the Project (36 months) assisted by a Scientific and Technical Adviser (24 months) and an adviser on the “Consultation mechanism”.

In fact, the technical workload was such that it required the presence of both the Regional Co-ordinator and the Scientific Adviser for a period of 42 months each, i.e., a total of 84 months as opposed to the planned 60 months. The need to prolong the presence of the Project team beyond the initially designated period is explained by:

- The need to carry out a number of unplanned technical tasks, which cropped up as the work progressed.
- The size of the final report, which was initiated and, to a large extent, written, corrected and finalised by the Project.

The co-ordination team was also increased by the addition of an assistant and a driver as well as a Mauritanian Ph.D. student on a part-time basis.

International consultants :

The original plan was for 27 consultant man/months to develop:

- a database with a minimum data set
- a model - including all its stages: construction - calibration - simulations
- a final report requiring the equivalent of one consultant man/month.

In reality, as described in the second part of Chapter 1 (Project actions), the provisions for consultant man/months did not foresee the amount of work required by the various Project actions:

- Establishing a common topographical base map at the 1:2.000.000 scale.
- Establishing an adequate information system and installing it in all three countries.
- Analysing data.
- Re-calibrating the model several times as new data belatedly reached the Project.
- Organising the scientific and technical audit of the model, which required the intervention of several consultants.
- Setting up review committees for the final reports.

Furthermore, the nature of the final report, initially intended to be published as one technical volume on paper, changed as the Project expanded and became 4 volumes:

Volume 1 - Action report
Volume 2 - Hydrogeological overview
Volume 3 - Information system and data base
Volume 4 - Models

In addition to its paper version, the report also exists on CD-Rom, in PDF format. It is written in two languages (French and English). A sub-project to develop an interactive CD for a broader public was started with the help of a contribution by the GTZ.

Although many actions were added to the original programme, the previsions of consultant/months were adhered to. This was possible because of the strong involvement of the co-ordination team and the consultants in some of the tasks and of the optimisation of consultant/time (see Appendix 1: list of consultants and national-team engineers).

Instead of the **27 consultant man/months** planned for the model-database activities, no fewer than **38 man/months** were necessary.

In addition, expert work was required to:

- develop maps
- advise on scientific aspects of the work
- review the final report.

The fact that the amount of man/months exceeded the forecast without adding to the expenditure is due to a reduction in the fees of the three consultants, with their agreement, to the diligent participation of all the team members (co-ordination, consultants, national teams) and the continuous efforts by the Executive Secretary to accomplish the work within the set time frame.

Selection of the consultants:

On the basis of the action programme set out in May 1999, the terms of reference were formulated so as to require the experts and consultants to establish a detailed tender that took into account the link between the two main tasks, i.e., the database and the models. In particular, great expertise in databases was demanded in order to ensure scientific familiarity with the subject and avoid delays. For the modeller and the database consultant, experience of the GIS (specialising in the integrated water-resource management system) was required.

The terms of reference were defined while keeping in mind the complexity of the aquifer systems and the great diversity of the data figuring in the database and the GIS in the three countries. The terms of reference were communicated to the three countries together with a request to distribute them widely among the scientists and institutions concerned (national and international).

This procedure was used especially for the two principal experts (information system and models) of the Project; for short-term interventions, the procedure was not the same but the terms of reference were always defined and a contract signed.

National staff:

National staff was employed in several capacities:

- National experts were recruited in order to produce one document per country estimating the present and forecasting the future demands for water. These national experts were selected jointly by the OSS and the national institutions,

- engineers were received at the SASS headquarters in order to participate in:
    - developing scenarios
    - analysing data
    - validating results
    - support of some field work

HEADING 2: Travel

Allocated budget	Expenditure
114.000,00 $ US	

This heading is divided into 3 parts:

a) **International staff:**

The travels by the Project team, international consultants and national staff (engineers, national co-ordinators, consultants, etc.) were paid by the OSS according to the regulations in force and according to the most economical fares.

The OSS entrusts its travel arrangements to a travel agency (GTA) for all air-ticket purchases except when the tickets departing from the countries are less expensive in which case the OSS authorises experts to buy their own and be reimbursed on the basis of a bill from the ticketing agency. For each mission, a detailed report is submitted, which allows the administrative and financial file, opened for this purpose, to be closed and keeps all the members of the SASS-OSS team informed.

b) **Meetings and training workshops:**

In the chapter dealing with training, the initial reference terms provided:

- for the database work:
    - a workshop to define the data (0,25 expert man/month)
    - training sessions (1,5 expert/month)
    - one validation workshop (0,25 expert man/month)

- for the model work:
    - a workshop to choose the code (0,25 expert man/month)

which amounted to a total of 3 workshops for 4 engineers per country and 2.25 expert man/months.

The Project organised **4 workshops** and **7 training sessions** attended by over 90 engineers in the three countries.

The reasons for the large number of engineers are:

- the desire of the OSS to allow the engineers of the three countries to participate in all the phases of the validation of the results
- the selection process of the computer code
- the necessary training in the use of the tools acquired for the models, the GIS, etc..

Description of the training workshops

Theme	Type*	Contents	Date Duration	Nbre of engineers	Lieu
Harmonisation of geodesic data		Harmonisation of topographic base map	April 2000	3	Tunis
mathematic Model	F	Further training in modelling	May - june 2001 1 month	6	Zurich Polytechnique
	F	Training on PWIN code	Aug 2000 0,25 month	8	SASS Tunis
	A	Choice of code	Feb. 2000 0,25 month	6	SASS Tunis
Information System	A	Existing in the 3 countries and IS rough draft	Dec 1 - 4 1999	8	Tunis
	A	Validation of conceptual model - data base	March 2000 0,25 month	6	Tunis
	F	Initiation to data control tools	Nov.2000 0,75 month	6	Tunis Tripoli -Algeria
	F	DBMS ACCESS	June - July 2001 0,75 month	18	Tripoli Algiers -Tunis
	F	ARCVIEW	June 2001 - 0,25 month September 2001-0,25 month September 2001- 0,25 month	18	Tripoli Alger Tunis
	F	Initiation to installation, exploitation, administration of the DB	0,3 month	9	Tunis Algiers Tripoli
Well logs	F	Well logs Nov. 1999	0,25 month	6	Tunis

This action required the equivalent of 5 expert man/months, i.e., double that initially planned (see table “Workshop-training”).

To ensure the participation of engineers from the three countries, the per diems and the travel costs were paid by the Project.

Justification for the number of initiation workshops and further training sessions

A programme of initiation workshops and further training sessions was organised in order to:

- include the engineers appointed by each country in the workshops on the databases and the models, at all the stages of the Project work, in particular those dealing with the choice of codes and with the construction and validation of databases and models;

- involve in the workshops and re-training sessions all the engineers who work within the regional structures of the water authorities throughout the Sahara basin and who contribute directly to the Project by their field work.

The training sessions are short and their aims are essentially:

- to update knowledge and to inform the participants of recent progress in data processing,

- to instruct participants in the use of the tools, particularly the model codes and information systems, made available to the countries,

- to motivate the experts involved to search for and collect the data and the studies needed by the Project.

C - National co-ordinators:

Over and above the meetings by the national co-ordinators, under this heading the Project accepted to fund the planned meetings of the Steering Committee and those related to the evaluations of the work and the development of jointly agreed withdrawal scenarios. A substantial contribution was made by Algeria and Libya to the organisation of the first two meetings of the Steering Committee (organisation, funding, etc.).

- **Steering Committee:**

Three meetings of the Steering Committee were planned:

  - Algiers (june2000)
  - Tripoli (june 2001)
  - Tunis (October 2002)

- **National Co-ordinators:**

The National Co-ordinators were called to 6 meetings:

  - 4 in Tripoli
  - 2 in Tunis

These meetings were planned to be held in Tunis but the organisation of seminars on issues concerning the SASS (deep shared basins) in Tripoli led the Project to combine them with two meetings of the National Co-ordinators.

These meetings dealt with the following tasks:

  - review of interim evaluations of Project actions
  - co-ordinaton of the tasks entrusted to the national teams
  - presentation of progress reports by the national teams

- definition of future actions both by the national teams and the Project team

- **Scientific evaluation:**

A meeting devoted to the scientific evaluation of the model results was held in September 2001. The participants were:

- The Directors General
- The five experts
- The project team
- The Executive Secretary of the OSS

- **Meetings focusing on the simulations:**

Two meeting were held in June 2001 and May 2002 with:

- The project team
- The Directors General
- The model expert

Their objective was to report on the predicted needs and to develop jointly agreed scenarios.

In all, twelve (12) meetings were held, either totally funded by the Project or with contributions by the host countries to those of the Steering Committee.

HEADING 3: equipment

Allocated budget	Expenditure
289.100,00 $ US	

Provision was made for the following equipment:

- to collect additional field measurements (per country):
  - 1 field vehicle
  - portable laboratory
  - hydrologic measurement tools (probes, manometers, devices for measuring conductivity, pH, etc.)
  - GPS rents
  - Maps, serial photographs, satellite images etc.

- to construct databases, develop models and run the GIS (per country):
  - high-power computer processing unit (printer and graphic printer)
  - processing code (for the models and the GIS)
  - two portable micro-computers for the regional teams

- to co-ordinate the Project tasks within the OSS:
  - equipment of the secretariat (computer, fax, modem, etc.)

- liaison vehicle

Given the magnitude of the task to collect and analyse the data, the Project team did not strictly adhere to the original material list but rather reviewed what was already available in the national institutions or in decentralised (regional) structures and acquired, at the request of the countries, additional equipment as needed to carry out field work and data processing.

The survey discovered that a great deal of field equipment was available including GPSs in the three countries.

As technical data-collecting equipment was available for the field work, the OSS concentrated on acquiring, for the countries:

- computer equipment (micro-computers, work stations) for the regional operational structures
- computer codes to enable the decentralised structures of the national institutions to function more efficiently and to allow as many engineers as possible to become familiar with the data-analysis and modelling tools.

Computer and office equipment

Computer equipment

Main acquisitions for the countries

ORGANISMS	MATERIAL	SOFTWARES
ANRH Algeria	2 Pentium III micro-computers 8 portable Micro -computers 1 printer	Model: 1 PM-5 licence 1 Wingeo licence GIS: ARCVIEW 3.2 Spatial Analyst extension Image Analysis extension Log-Geology : ROCK WORKS
GWA Lybia	2 Pentium III micro-computers 1 Scanner 1 printer 1 Data show 1 disk writer 1 Graphic printer	ModEL: 1 PM-5licence 1 Wingeo licence GIS : Arc-view 3.2 Spatial Analyst Extension Image Analysis extension Log-Geology : ROCK WORKS
DGRE Tunisia	4 Pentium I4 Micro-computers 1 work station 6 printers 3 Scanners	Model: 1 PM-5licence 1 Wingeo licence SIG : Arc-view 3.2 Spatial Analyst extension Image Analysis extension Log-Geology : ROCK WORKS ARC-INFO network version

Equipment acquired for the Project team

- 5 micro-computers including 2 work stations
- 2 portable micro-computers
- 5 printers
- 1 scanner
- codes: MAPOBJETC, ARCVIEW, ARCPRESS, SPATIAL ANALYST, ROCK WORKS
- see appendix for the detailed list which includes:

  - acquired equipment
  - serial numbers
  - cost
  - invoice numbers
  - purpose
  - OSS coding

Office equipment:

This equipment was strictly reserved for the SASS.

Equipment acquired for the Project team

The office equipment consisted mainly of:

- Desks and chairs
- Cupboards
- Photocopy machine
- Telephone extensions
- fax

See appendix for an inventory showing:

- detailed list
- cost
- serial number
- purpose

Vehicles:

The original plan was to acquire three field vehicles (1 per country) with FIDA funds. An analysis of the actual needs of the countries showed that this plan did not correspond to the configuration and regional structures of the countries:

- in Algeria : 3 regional authorities covering an area of over 600.000 km^2
- in Tunisia: 3 regional authorities
- in Libya : 2 regional authorities

Each country undertook to provide the Project with one field vehicle from its own fleet per regional structure, i.e., 7 field vehicles.

Given this undertaking, the OSS procured light vehicles in exchange and within the limits of the allocated budget defined in the Project document.

This proposition was presented to the FIDA who approved it. In addition, 2 vehicles were acquired for the SASS headquarters.

Project team	2 utility vehicles
ALGERIA	3 utility vehicles
TUNISIA	1 utility vehicle 1 field vehicle
LIBYA	3 utility vehicles

Purchase procedure:

For all purchases (equipment and vehicles), the Project entered into negotiations and based its choice on at least three offers. These offers were analysed and a report on the choice was produced and approved by the countries.

HEADING 4: Sub contracts

Allocated budget	Expenditure
20.000,00 $ US	

This heading concerned, in particular:

- processing of the geodesic data
- sub-contracting to a consulting firm of the topographical base map with a user's manual and CD-Rom
- drawing of larger-scale maps in the vicinity of the chotts
- reproduction of the ERESS document
- translation

The divergence between the allocated budget and the actual expenditure is due to the unforeseen dimensions of the ERESS reproduction and to the fact that copying and translation were not taken into account at the outset.

HEADING 5: Running costs

Allocated budget	Expenditure
115.000,00 $ US	

The running costs were intended to cover:

- reproduction of overview documents for the Steering Committee meetings
- recruitment of an assistant and a driver
- current expenditure (consumer goods, etc.)
- rent of Project office
- miscellaneous: telephone, internet, maintenance, fees, insurance, etc.
- Progress reports requested by the countries

The Project benefited from the diplomatic advantages accorded the OSS and from the support of its services.

HEADING 6: Logistic support by the OSS

Allocated budget	Expenditure
120.000,00 $	

The expenditure concerned:

- The assistance by the OSS, in particular, with keeping and verifying accounts and with the financial audit.

Budget recapitulation

Allocated budget	Expenditure
1.445,00 $	

N.B.: the budget will be closed on October 31, 2002 when the state of the expenditures will be presented.

III.2 Contribution by the countries

The contributions by the countries, although they have been calculated, consist essentially in seconding engineers and field technicians to the Project, as shown in Table 3.

Table 3: Budget of Government contributions in $US

Expenditure	Unit	Unit cost	Quantity			Total USD		
			Algeria	Lybia	Tunisia	Algeria	Libya	Tunisia
National staff								
Engineers	H/m	2000	48,25	48,25	48,25	96.500	96.500	96.500
Topographical team	H/m	4000	2	2	2	8.000	8.000	8.000
Hydrogeological team	H/m	4000	11	5	8	44.000	20.000	32.000
Sub-total						**148.500**	**124.500**	**136.500**
Travel expenses of national staff						**16.000**	**16.000**	**16.000**
Equipment								
Field equipment						15.000	15.000	15.00
Computer equipment						10.000	10.000	10.000
Sub total						**25.000**	**25.000**	**25.000**
Other running costs						**20.000**	**20.000**	**20.000**
					Total	**209.500**	**185.500**	**197.500**
					GRAND TOTAL	**592.500**		

In reality, the contributions were much greater than those initially defined in the Project. When the Project started, each institution seconded five engineers to the Project for its duration, i.e., in total 60 persons/month as opposed to the planned 48.5 persons/moth.

These engineers worked mainly on:

- Collecting, analysing and validating data
- Writing specific reports and overviews
- Contributing to the scientific validation of the work

The field technicians carried out the following tasks:

- Completing the inventory of springs and wells
- Making piezometric measurements and estimating pumping rates
- Making additional levelling
- Verifying some well characteristics in the field

The technical equipment (measurement probes, GPS devices, manometers, etc.) and other running costs (driver, petrol, etc.) were funded by the national institutions.

III.3 Project management

The Project was managed according to the existing regulations within the OSS.

Expert advice

On the basis of the action programme set out in May 1999, the terms of reference were formulated so as to require the experts and consultants to establish a detailed tender that took into account the link between the two main tasks, i.e., the database and the models. In particular, great expertise in databases was demanded in order to ensure scientific familiarity with the subject and avoid delays. For the modeller and the database consultant, experience of the GIS (specialising in the integrated water-resource management system) was required.

The terms of reference were defined while keeping in mind the complexity of the aquifer systems and the great diversity of the data figuring in the database and the GIS in the three countries. The terms of reference were communicated to the three countries together with a request to distribute them widely among the scientists and institutions concerned (national and international).

This procedure was used especially for the two principal experts (information system and models) of the Project; for short-term interventions, the procedure was not the same but the terms of reference were always defined and a contract signed.

Workshops for initiation and further training

A programme of initiation workshops and further training sessions was organised in order to:

- include the engineers appointed by each country in the workshops on the databases and the models, at all the stages of the Project work, in particular those dealing with

the choice of codes and with the construction and validation of databases and models;

- involve in the workshops and re-training sessions all the engineers who work within the regional structures of the water authorities throughout the Sahara basin and who contribute directly to the Project by their field work.

The training sessions are short and their aims are essentially:

- to update knowledge and to inform the participants of recent progress in data processing,
- to instruct participants in the use of the tools, particularly the model codes and information systems, made available to the countries,
- to motivate the experts involved to search for and collect the data and the studies needed by the Project.

The ten workshops organised in the course of the Project were attended by 90 engineers. The Project was entrusted with the organisation of the workshops, the consultants were selected on the basis of their C.V.s and in close collaboration with the national institutions.

Scientific and technical audit.

The two main tasks of the Project - the database and the models - were complex ones, accomplished in several stages. They required the advice of scientists with specific capabilities in these fields, in particular to approve the reports and the choice of consultants.

As the Project team was concerned to obtain the views of scientists with acknowledged expertise in the field, it arranged for:

- A preliminary technical evaluation of the Project actions which was carried out by a international expert (Jean Margat)
- A workshop to evaluate the model, held in September 2001 and attended by 5 international experts as well as by the directors of the national institutions
- A model evaluation by an expert working at the OSS.

Steering Committee and National Co-ordinators

Steering Committee

Three meetings of the Steering Committee were held in:

- Algiers (June 2000)
- Tripoli (June 2001)
- Tunis (October 2002)

National Co-ordinators

The national co-ordinators were called to six meetings:

- 4 in Tunis
- 2 in Tripoli

The purpose of these meetings was to:

- Carry out a periodic evaluation of the Project actions
- Co-ordinate the tasks entrusted to the national teams
- Present the results of the work by the national teams

Accounting

The accounts are managed by:

- A full-time accountant within the OSS
- A certified accountant to analyse and monitor the accounts
- A financial audit office for a yearly audit

A financial balance sheet has been installed according to the budget lines of the observers (FIDA + DDC-Switzerland).

4TH PART

CONSULTATION MECHANISM

The aim of the joint-agreement mechanism is to organise a shared management of the SASS basin.

Its objectives are:

- to create a permanent tri-partite decision framework involving the three countries

- to support the above structure by analysing the expectations of the countries while taking into account the individual capacities of the national institutions responsible for groundwater issues.

These two mutually complementary objectives are set in a perspective of a jointly agreed long-term management of a resource shared by the three countries.

The expected results are:

A the end of the action programme, the terms of an inter-state joint-decision framework specific to the Northern Sahara basin, including the creation of a permanent tri-partite structure, will be defined. These terms will be submitted by the FAO, in agreement with the OSS, to the relevant authorities in the three countries in order to be examined, amended and potentially, adopted.

1. **Budget**

The FAO has provided funding for Project actions amounting to $US 293,000 which are intended to cover the cost of:

- International consultants
- National consultants
- Technical support services
- OSS services
- Official travel
- Running costs
- Training costs

The budget of the joint-agreement mechanism is managed directly by the FAO. The share made available to the OSS amounts to $US 75,000 and is intended to cover:

- The salary of the joint-agreement mechanism adviser within the SASS
- Part of the assistant's salary
- Travel expenses of the SASS team in connection with the joint-agreement mechanism
- OSS expenditure for producing documents and organising meetings

2. **Inventory of the actions**

The actual work started in January 2001 and was planned to last for 18 months. The accomplished tasks include:

- approval of the Project document by the three countries
- organising of a meeting attended by the FAO, the OSS and the national decision-makers in January 2001 for the official launch of the Project

- visits to the three countries in order to define the conditions for the implementation of the Project and the selection of two national consultants (technical and institutional) per country
- signing of contracts by the national consultants and by the international legal consultant with the FAO
- a meeting, held in Rome in July 2002, between the national technical experts, the SASS Project team, the FAO and the international legal adviser;
- at this meeting, the national experts presented technical reports from each of the three countries and the following timetable was established:

    - A general report by the SASS was to be established, highlighting the orientations defined by each country concerning the appropriate mechanism to be used. Result: the report was finished in late September 2002
    - A preliminary report proposing options for the creation of a tri-partite joint-agreement mechanism together with an analysis of the implications of each option, relevant legal texts and the ranked preferences of the international consultant was to be produced. Result: the report was ready in October 2002.
    - Meeting in Rome on October 24-25 2002 to discuss and approve the preliminary report.
    - Organisation of a national workshop in each country (November 2002) to discuss and approve the proposals made in the previous phase
    - Organisation of a regional workshop with participation from the three countries to discuss and approve the option(s) chosen by the national workshops and express final recommendations on this basis

At the end of this procedure, the first blueprint of the joint-agreement mechanism will have been drawn up and approved by the three countries.

All the actions will be completed in December 2002 and approved by the three countries in January-February 2003.

CONCLUSION

To end this progress report, the following conclusions can be drawn:

- in the technical and scientific field, the Project has pursued its defined objectives. However, achieving these objectives was made more difficult by:

    - the considerable volume of data collection long after the first calibration,
    - taking into account the recommendations by the evaluation committee, created by the SASS
    - changes in the initial exploitations plans.

The numerous revisions of the model and the increased importance assumed by the information system have led to:

- development of data-management and processing tools capable of making the data more reliable in the future.
- Creation of dynamic co-operation and exchange between the three countries,
- Construction of a model able to take into account data collected until June 2001,
- Development of an optimisation model (micro-model) allowing decision-makers and experts to work together in the search for a jointly agreed exploitation scenario of the SASS resources.
- Organisation of training workshops attended by around one hundred engineers.

Moreover, although the accomplished work exceeds the objectives, it has all been done within the allocated Project budget.

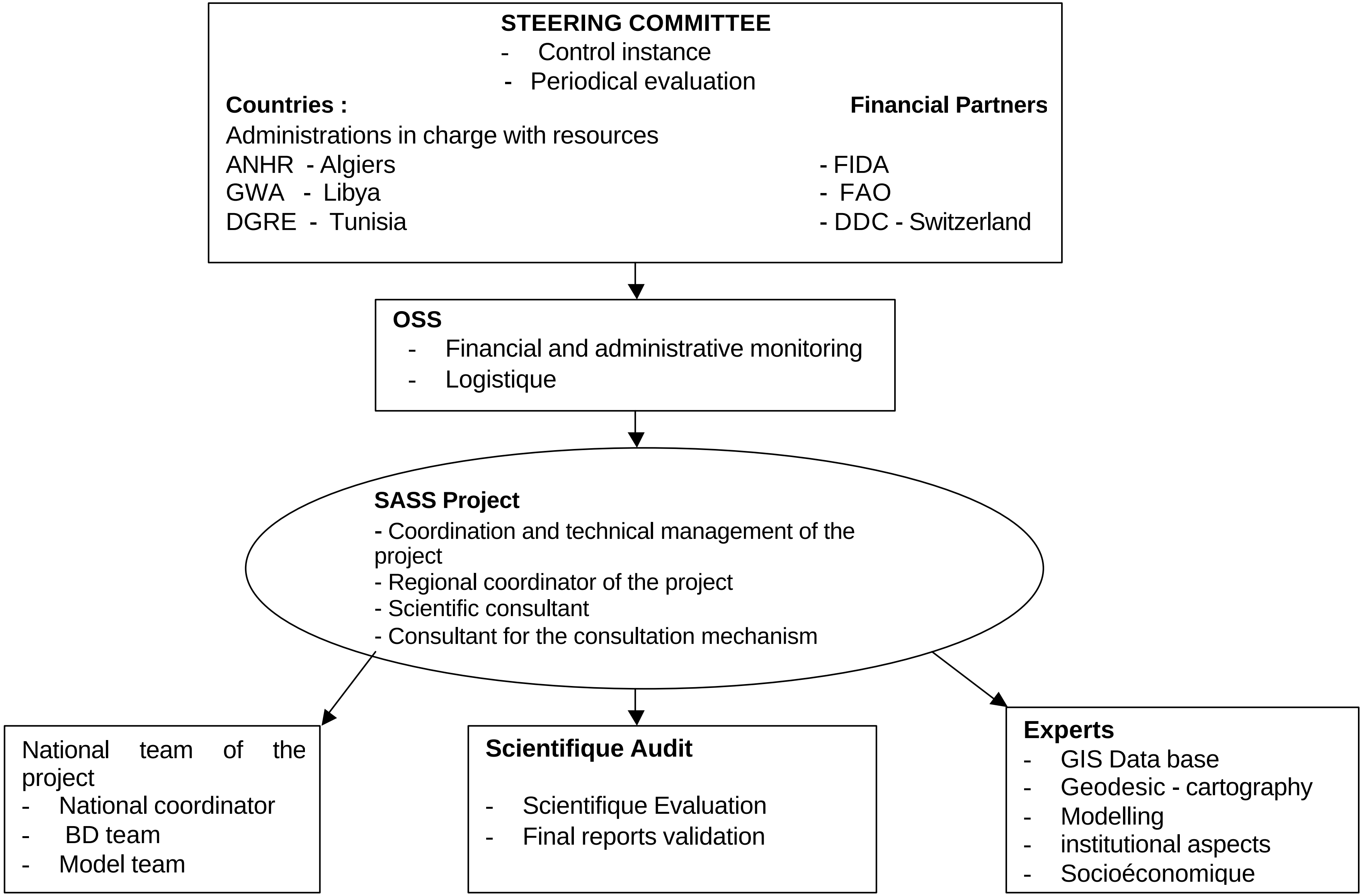
However, although by constructing the model it was possible to obtain results across the whole basin and to create an extraordinarily dynamic co-operation between the three countries (as they communicated to the Project all the documents and data from both water and petroleum drillings), it proved necessary, in order to pursue the SASS work, to build three sub-models for the following reasons:

- These sub-models represent regions with intensive exploitation which have to be treated on a large mesh to enhance the precision of the results produced by the basin-scale model which covers one million km^2,
- The results of the sub-models will provide the decision-makers and the politicians with elements to aid their decisions that are devoid of uncertainties and concern the most vulnerable zones, involving the three countries as to population, agriculture and irrigated surface areas,
- These results are determining and will form the basis of further in-depth discussions held by decision-makers and politicians.

ANNEXES

ANNEXE	Organisation of the project
ANNEX 2	List of national consultants and engineers
ANNEX 3	list of acquired material

ANNEX 1 : Project organisation



ANNEX 2 : List of the national consultants and engineers of the project

- **Data base and GIS consultant**

Belkacem Abdous (Algérie)

- **Numerical model consultant**

Mustapha Besbes (Tunisie),
Mounira Zammouri (Tunisie)

- **Algerian team(ANRH)**

Abdelmalek Ayad
Abderrazak Khadraui
Abderrazak Zahrouna
Ali Larbes
Djida Khiati
Fatima Biout
Ghania Aggoun
Mimi Bafou

- **Tunisian team (DGRE)**

Abderrazak Daoud
Brahim Ben Baccar
Brahim Labidi
Faten Horriche
Lahmadi Moumni
Rachid Khanfir
Yousra Ben Salah

- **Libyan team (GWA) :**

Ali Douma
ASEM AlUB
Lotfi Madi
Mehdi el-Mejerbi

- **Evaluation Committee**

Ghislain De Marsily
Giuseppe Pizzi
Jean Margat
Philippe Pallas
Wolfgang Kinzelbach

- **National Institutions**

Agence Nationale des Ressources Hydrauliques (ANRH) : Rachid Taibi , Directeur Général
Direction Générale des Ressources en Eau (DGRE) : Djemili el Batti, Directeur Général
General Water Authority (GWA) : Omar Salem, Secrétaire du Comité Populaire

- **Reading Committee**

Chedli Fezzani
Ghislain de Marsily

ANNEX 3 : List of acquired material

ALGERIA

Agence Nationale des Ressources Hydrauliques									
Provisional Budget in FF	in Euros	Expenses						Solde Budget	
		Date	Qty	Designations	Sum in FF	Sum in Euros		In FF	in Euros
				I/ Matériel de Transport					
220 552,00	**33 622,94**								
		09/05/2000	2	RENAULT KANGOO	154 768,00	23 594,23			
				Frais bancaire	91,64	13,97			
				Complément voiture	1 589,00	242,24			
				Frais bancaire	89,93	13,71			
		2001	1	RENAULT KANGOO	62 291,97	9 496,35			
				Frais bancaire	90,33	13,77			
				Carburant	1 712,77	261,11			
220 552,00	**33 622,94**				**220 633,64**	**33 635,38**		**-81,64**	**-12,45**
				II/ MATÉRIEL INFORMATIQUE					
239 416,00	**36 498,73**								
		15/11/2000	1	**Yves Emsellem:**	7 380,00	1 125,07			
				Licence Wingeo					
					7 380,00	**1 125,07**			
				IMAGIS: BOUCHIBI					
239 416,00	**36 498,73**	05/06/2000		Logiciel ArcView GIS pour Windows avec documentation d'origine (Anglais)	10 000,00	1 524,49			
				comprenant:					
				01 clé type Hardware					
				01 CD ROM (installation Arcview)					
				Documentation (05 volumes)					
				01 Pack (4 CD ROM ESRI Data and Maps)					
				Supplément documentation en Français	1 200,00	182,94			
				01 CD ROM (Interface ArcView en Français)					
				Documentation (02 volumes)					
				Logiciel extension ArcView Spatial Analyst	26 000,00	3 963,67			
				01 Clé type Hardware					
				01 CD ROM (Installation ArcView)					
				Documentation (02 volumes)					
				Logiciel Extension ArcView Image Analyst	26 000,00	3 963,67			
				01 Clé type Hardware					
				01 CD ROM installation					
				Documentation 3 volumes					
				Micro-ordinateur UNIKA, Processeur	19 125,00	2 915,59			
				Intel Pentium III, 600 Mhz					
				Mémoire de 256 Mo SDRAM					
				Disque Dur 1 de 10.2 Go					
				Disque Dur 2 de 8.4 Go					
				CD ROM 48x					
				2 HP 80w					
				Ecran 19"					

Budget Prévisionnel		Dépenses					Solde Budget	
en FF	**en Euros**	**Date**	**Qté**	**Désignations**	**Montant FF**	**Montant Euros**	**en FF**	**en Euros**
				Micro-ordinateur UNIKA, Processeur	13 200,00	2 012,33		
				Intel Pentium III, 600 Mhz				
				Mémoire de 128 Mo SDRAM				
				Disque Dur de 8.4 Go				
				CD ROM 48x				
				2 HP 80w				
				Ecran 17"				
				Lecteur ZIP	1400,00	213,43		
				Imprimante couleur de format A2	5800,00	884,20		
		24/07/2000		Onduleurs APC (American Power Company)	2400,00	365,88		
				Cartes Réseaux	700,00	106,71		
				Cassettes d'enregistrement ZIP	2100,00	320,14		
					107 925,00	**16 453,06**		
		17/04/2001	1	Documentation	1 000,00	152,45		
					1 000,00	**152,45**		
		07/05/2002	8	Portables Compaq	93 277,09	14 220,00		
		22/05/2002	1	Logiciel Rockware 2002	5 121,12	780,71		
					98 398,21	**15 000,71**		
239 416,00	**36 498,73**			**Total dépenses matériel informatique**	**214 703,21**	**32 731,29**	**24 712,79**	**3 767,44**
220 552,00	**33 622,94**			**Total Dépenses voitures**	**220 633,64**	**33 635,38**	**-81,64**	**-12,45**
459 968,00	**70 121,67**			**Dépenses Générales**	**435 336,84**	**66 366,68**	**24 631,16**	**3 755,00**

TUNISIE

Direction Générale des Ressources en Eaux

Budget Prévisionnel en FF	en Euros	Dépenses					Solde Budget	
		Date	Qté	Désignations	Montant FF	Montant Euros	en FF	en Euros
				VOITURE				
220 552,00	**33 622,94**							
		22/05/2000	1	MITSUBISHI				
				PAJERO	158 970,38	24 234,88		
				Frais Bancaire	3,11	0,47		
		2001	1	RENAULT MEGANE	83 017,00	12 655,86		
				Frais Bancaire	90,33	13,77		
				Carte Grise	1219,29	185,88		
				Transite	1699,58	259,10		
				Visite Technique	30,96	4,72		
				Vignette	412,47	62,88		
220 552,00	**33 622,94**				**245 443,12**	**37 417,56**	**-24 891,12**	**-3 794,63**
				MATERIEL INFORMATIQUE				
239 416,00	**36 498,73**							
		15/11/2000	1	**Yves Emsellem:**	7 380,00	1 125,07		
				Licence Wingeo				
					7 380,00	**1 125,07**		
		12/07/2000	1	Arc View 3.2	15 399,64	2 347,66		
		12/07/2000	1	Spatial Analyst	20880,87	3 183,27		
		29/06/2000	1	Onduleur Merlin Gerin Pulsar	7 311,51	1 114,63		
		12/07/2000	1	PC ARC INFO version 3.5.2	42 022,77	6 406,33		
		12/07/2000	1	Station de travail Kayak XM 600	20 495,42	3 124,51		
		12/07/2000	1	Lecteur ZIP externe	1 879,83	286,58		
		12/072000	1	Écran HP couleur 21"Trinitron	9 148,95	1 394,75		
		12/07/2000	10	Disquette ZIP 250MO	1 905,94	290,56		
					119 044,93	**18 148,28**		
		11/04/2002	4	Micro Ordinateur HP Vectra VL 420 *Processeur:Intel Pentium 4 1,5 GHZ *Disque Dur: 40 Go *Mémoire RAM: 256 Mo extensible à 512 Mo *Mémoire cache: 512 Mo *Mémoire Vidéo: 16 Mo NVIDIA *Lecteur Disquette: 3"1/2 à 1,44 Mo *Lecteur DVD 16X	39 898,78	6 082,53		

Budget Provisional		Dépenses					Solde Budget	
en FF	en Euros	Date	Qté	Désignations	Montant FF	Montant Euros	en FF	en Euros
				*Carte son intégré sur la carte mère				
				*Carte réseau 10/100 BT				
				*Kit multimédia complet				
				*Clavier, souris, tapis				
				*Système d'exploitation windows				
				XP préinstallé + CD				
				*Ecran couleur HP 17 pouces				
			4	mise à jour windows 2000 Professionnel	7 493,65	1 142,40		
				multilingue				
			4	Enceintes 2x250 Watts	607,61	92,63		
			6	Imprimantes Epson Stylus Couleur 1160	15 493,70	2 362,00		
			3	scanner Perfection 1640SU avec carte	6 000,04	914,70		
				et câble SCSI				
			4	Onduleur ellipse 650 réf: 66194	5 873,21	895,40		
		22/05/2002	1	Logiciel Rockware 2002	5 104,21	778,13		
				Total Dépenses	**80 471,21**	**12 267,76**		
239 416,00	**36 498,73**			**Total dépenses matériel informatique**	**206 896,14**	**31 541,11**	**32 519,86**	**4 957,62**
220 552,00	**33 622,94**			**Total Dépenses voitures**	**245 443,12**	**37 417,56**	**-24 891,12**	**-3 794,63**
459 968,00	**70 121,67**			**Dépenses Générales**	**452 339,26**	**68 958,68**	**7 628,74**	**1 162,99**

LIBYE

General Water Authority

Budget Prévisionnel		Dépenses					Solde Budget	
en FF	en Euros	Date	Qté	Désignations	Montant FF	Montant Euros	en FF	en Euros
I/ Matériels de Transport								
				RENAULT:				
		2001	3	RENAULT KANGOO	200 093,97	30 504,13		
				Frais bancaire	90,33	13,77		
				Frais de convoyage	8 595,00	1 310,30		
				Frais bancaire	91,05	13,88		
220 552,00	**33 622,94**				**208 870,35**	**31 842,08**	**11 681,65**	**1 780,86**
II/ Matériels Informatique & Logiciels								
				GAMMA SIC:				
239 416,00	**36 498,73**	18/12/2000	2	HP KAYAK XM Réf: P1649N	74 763,10	11 397,56		
				Processeur Intel Pentium III 800 EB				
				Disque Dur 9,1 GO ultra SCSI				
				256 Mo Rambus Memory				
				Carte graphique 32 MO				
				Carte réseau 10/100 BT				
				Lecteur DVD ROM 8x/32x				
				Moniteur HP Couleur 21 pouces				
				Trinitron P 1110				
				Lecteur ZIP externe 250 MO				
			1	Scanner couleur HP Scanjet 6350C	4 456,09	679,33		
				Format A4				
			1	Imprimante jet d'encre A3 HP	10 241,52	1 561,31		
				Deskjet				
			10	Disquette ZIP 250Mo	2 048,30	312,26		
					91 509,01	**13 950,46**		
		15/11/2000		**Yves Emsellem:**				
			1	Licence Wingeo	7 380,00	1 125,07		
					7 380,00	**1 125,07**		
				GRAPHTEC:				
		30/06/2000	1	ARC VIEW-Gis	15 399,64	2 347,66		
			1	ARC VIEW-Image Analysis	28 711,20	4 376,99		
			1	ARC VIEW-Spatial Analyst	20 880,87	3 183,27		
			1	ARC Press for ARC VIEW	3 393,15	517,28		
					68 384,86	**10 425,20**		
		30/11/2000	1	ZIP DRIVE	1 440,00	219,53		
					1 440,00	**219,53**		
		30/06/2001		**GAMMA SIC:**				
			1	Windows 2000 serveur professionnel	8 775,99	1 337,89		

Budget Prévisionnel		Dépenses					Solde Budget	
en FF	en Euros	Date	Qté	Désignations	Montant FF	Montant Euros	en FF	en Euros
				produit complet avec 5 utilisateurs une licence Version anglaise				
			2	Windows 2000 professionnel produit complet, licence version anglaise	2 856,00	435,39		
			3	Arabic View GIS	4 330,00	660,10		
					15 961,99	**2 433,39**		
				GAMMA SIC:				
		19/04/2002	1	DATA SHOW EPSON EMP 51	38 481,16	5 866,42		
			1	LECTEUR ZIP 250	1 594,93	243,15		
			1	GRAVEUR CD EXTERNE	2 278,47	347,35		
			1	ANTI VIRUS	430,37	65,61		
					42 784,93	**6 522,52**		
				GAMMA SIC:				
		16/04/2002	1	Traceur HP Design jet couleur 500 ps Format:AO Résolution:1200x600 dpi	27 848,21	4 245,43		
			1	Carte HPGL2	2 658,24	405,25		
				Frais de transport	1 822,79	277,88		
		28/05/2002	1	Barrette mémoire SIMM pour traceur HP	2 182,89	332,78		
					34 512,13	**5 261,34**		
		22/05/2002	1	Logiciel Rockware 2002	5 121,12	780,71		
					5 121,12	**780,71**		
239 416,00	**36 498,73**			**Total dépenses matériel informatique**	**267 094,04**	**40 718,22**	**-27 678,04**	**-4 219,49**
220 552,00	**33 622,94**			**Total Dépenses voitures**	**208 870,35**	**31 842,08**	**11 681,65**	**1 780,86**
459 968,00	**70 121,67**			**Dépenses Générales**	**475 964,39**	**72 560,30**	**-15 996,39**	**-2 438,63**