THE NORTH-WESTERN SAHARA AQUIFER SYSTEM

BASIN AWARENESS

DATA BASE AND GIS

VOLUME III

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PREFACE

Extending over an area of more than one million km², the North-Western Sahara Aquifer System—which is shared by Algeria, Tunisia and Libya—consists of continental deposits enclosing two major groundwater aquifers: the CI (Continental Intercalaire) and the CT (Complexe Terminal). The structural configuration and the climate of the region are such that the reserves are very little renewed: these are geological reserves whose natural outlets (springs and foggaras) had led to the development of oases where the centuries-old lifestyles have remained for a long time in perfect symbiosis with the Saharan ecosystem.

For the last century and, more particularly, for the past thirty years, exploitation by boreholes has seriously undermined this groundwater reserve. The water abstractions, used both for farming purposes (irrigation) as dug well as for drinking water supply and for industry, have soared from 0.6 to 2.5 billion m3/year, via water points (now numbering 8800), and, as the springs dried up, they were replaced by deeper drilled dug wells.

This intensification of water exploitation generates a certain number of problems of which, in particular, a steady drop in water level, an increase in pumping costs, a decrease in artesian exploitation, a drying up of natural outlets and an increasing risk of deterioration of water quality by salinisation ….

The three countries concerned have soon become aware of the problems related to the use of these aquifer resources from a sustainable perspective and have endeavoured to improve the state of knowledge relating to these resources, as dug well as their management. Accordingly, and as early as 1970, a major Algerian-Tunisian programme, known as ERESS and implemented by UNESCO, had led to establishing, based on a preliminary modelling which focused on the border zones of the two countries, an evaluation of the usable resources of this aquifer system, as dug well as forecasts concerning the evolution of their use. This programme was continued under UNDP in 1984.

Twenty years later, that is in 1992, the Sahara and Sahel Observatory (OSS) organised in Cairo (Egypt) the first workshop on “Aquifers of the Major Basins”, thus initiating the inception of its “Major Basins Aquifers” programme which was to pave the way for the advent of the “SASS Project” in September 1997, following a series of regional seminars and workshops. This SASS project was the first of its kind to take into consideration the basin as a whole, that is up to its natural boundaries.

Upon request by the three countries, OSS sought out and obtained financial support from the Swiss Cooperation Agency, IFAD and FAO for a first three-year phase which was officially initiated in May 1999 in Rome and whose main objective was to update the evaluation of the resources exploitable, as dug well as to set up a consultation mechanism between the three countries.
Compared with its predecessor, i.e. ERESS, the SASS project was to avail itself of a major asset: participation by Libya and use of the data compiled over the last thirty years. These data were to allow:

- the establishment of a joint data base for the three countries which was intended to enhance the value of the information gathered and to serve as an information exchange tool;
- the design of a model simulating the hydrodynamic behaviour of the aquifer system and making it possible to forecast the impact of increased exploitation.

These two activities have been carried out by eliciting, in a continuous manner, the contribution of national experts from the three countries. The results were presented to the three countries and have been enlightening to the decision-makers as to the development prospects and the related risks. This has also proved to be an occasion for the three countries to show interest in strengthening the sustainability of the updating, monitoring and information exchange programmes, as dug well as giving concrete expression to a gradually emerging concept of “basin awareness”.

What prospects for SASS at the conclusion of this first survey phase?

For Algeria, just as much as for Tunisia and Libya, the CT now and the CI very soon are set to be in such a state of exploitation that it would be necessary for the three countries at once to exercise control over abstraction rates, and thus give concrete expression to their mutual determination to secure the future of the region, in particular, by applying a jointly agreed policy for preserving their water resources.

The implementation of such a partnership, in the course of the SASS project, has made it possible to gradually build mutual trust among the technical teams, awareness that the problems faced by any of the parties depend to a certain extent on the actions undertaken by the other parties, and conviction that the exchange of information—which is the pillar of any form of solidarity—is an activity that is not only possible but also necessary.

Aware of the need for a sustained consultation and for conferring an institutional aspect on the cooperation initiated under the present project, the three SASS countries have expressed their agreement for the set up of a permanent tripartite consultation mechanism for a joint management of SASS. The need for a developed and sustainable institutional mechanism now being an established fact, its implementation has been designed according to a gradual approach. At the beginning, its prerogatives will be mainly focused on the development of data bases and models, promoting studies, research and training, designing monitoring indicators, as dug well as on considering the future development of the said mechanism. OSS welcomes the Coordination Unit entrusted with this mechanism, according to the will of the three countries.

By its activities and its outcomes, at both the scientific and the technical levels, the SASS project does represent an example in terms of approach to the study and management of non renewable water resources from a sustainable perspective. Through the exchange of information and the will to engage in consultation which it has elicited, the project may serve as a model for regional cooperation. This project stands, indeed, as a success story for South-South and North-South cooperation, which is perfectly in tune with the OSS objectives and mission.

I would like to acknowledge all those who have contributed to the implementation and the success of this first phase. First of all, I must express my gratitude to the Ministers in charge of water resources and the following national institutions: the National Agency for Water Resources (ANRH) in Algeria, the General Directorate for Water Resources (DGRE) in Tunisia, and the General Water Authority (GWA) in Libya, which have always been both ready and willing to exchange information, participate in scientific activities and take the appropriate decisions within the Steering Committee; their readiness and willingness have been, indeed, the key factor in the achievement of the project objectives. I would also like to thank the OSS cooperation partners which have not only provided financial assistance to the project but also shown particular interest in its implementation and offered insightful and enlightening remarks during the various Steering Committee meetings. Last but not least, I would like to thank the project team within the OSS Executive Secretariat: the permanent staff, the national teams and consultants, as dug well as the eminent specialists who have helped us validate the scientific findings of the project.

Chedli FEZZANI

Executive Secretary

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July 1999 – October 2002: The conducting of the study on the North-Western Sahara Aquifer System has claimed forty months of uninterrupted effort and cooperation—essential work which, though not always easy, was always indispensable, and a fine example of unwavering solidarity.

Alongside with the SASS permanent team, the project elicited the effort of a certain number of people whom we would like to wholeheartedly thank for their contribution to the success of this joint undertaking. Of these, we would like to mention in particular:

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FOREWORD

The present report relates to the "***Data Base & Geographic Information System***". It summarizes the various reports drafted for the phases of this action. It is composed of two main parts:

- The first part presents the architecture of this data base and of the software products made during the project ;
- The second part gives a detailed description of the data collected, both by the national teams of the countries and by the permanent SASS team.

The structure of the present report reflects the various steps of design and set up of the data base.

The first part proposes the following items:

- Synthesis of the data available at the inception of the study (structures and contents) ;
- Presentation of the organizational and technical solution that has been adopted ;
- Detailed description of final outputs produced, as dug well the possibilities in which they can be used for purposes of an integrated management within the basin.

The second part proposes the following items:

- Presentation of the process of data collection, control and entry ;
- Quantitative and qualitative description of the data collected and, more particularly, those impacting the outputs of the digital model.

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ACRONYMS

N°	NAME	DEFINITION
	ACSAD	**Arab Centre for Studies of Arid Zones and Dry Land**
1	**ANRH**	**Agence Nationale des Ressources Hydrauliques (National Water Resources Agency) (Algeria)**
2	**DB**	Data base
	BRL	**Compagnie d'aménagement de la région du Bas-Rhône et du Languedoc (Bas-Rhône and Languedoc Region Land Use Planning Company)**
3	**CI**	**Continental Intercalaire aquifer**
	CRDA	**Commissariat Régional au Développement Agricole (Regional Agricultural Development Commissionership) (Tunisia)**
4	**CT**	**Complexe Terminal aquifer**
5	**DGRE**	**Direction Générale des Ressources en Eau (General Directorate for Water Resources) (Tunisia)**
6	**DRS**	**Direction Régionale Sud (Southern Regional Directorate) (currently decentralized service in Ouargla, Algeria)**
7	**ERESS**	**North-Western Sahara Water Resources Study**
8	**GWA**	General Water Authority (Libya)
9	**DDM**	Data Design Model
10	**OSS**	Sahara and Sahel Observatory
11	**PM5**	Processing Mode Flow – version 5
12	**SASS**	**North-Western Sahara Aquifer System**
13	**IS**	Information System
14	**GIS**	Geographic Information System
15	**VBA**	Visual Basic for Application

LIST OF TABLES

INTRODUCTION

The SASS project includes two main components:

- Updating the SASS water resources knowledge ;
- Setting up a consultation mechanism.

The first part requires the collection, organization and homogenization of available data within the three countries concerned by the project. The second part implies securing the technical conditions necessary for a joint management of the basin water and, therefore, the establishment of a continuous system of data collection and processing with a view to facilitating future information updates.

This is why the SASS project has provided for an activity called “homogenization of hydro-geological and geodesic data” which was aimed mainly at collecting and organising the data available in the three countries, sharing the study area, in order to provide these data as an input to the digital model.

Such as designed, the project has considered that:

- Structured data are available within administrations entrusted with water resources ;
- The exclusive purpose of the database was to prepare the modelling activity: only the data directly related to the digital model had to be put together and homogenized.

At the inception of the SASS project, and after carrying out initial missions in the three countries concerned, the diagnosis of the situation was as follows:

- The three countries were still developing or restructuring their own data bases. A pressing need for a better management of information was expressed by all parties: a really relational data structure, dynamic DB-Model links, possibility of complex and synthesis enquiries, easy cartographic information display obtained directly from the DB ;
- The main part of information was scattered in heterogeneous files and even in written documents. Data used in the context of previously conducted studies in the region were not integrated in the respective DBs.

For the project proper, it was necessary to go further by securing the technical conditions necessary for a joint management of basin data and by setting up tools for facilitating future updates.

The establishment of the SASS data base has, accordingly, been started as a veritable project of design and set up of an integrated information system whose major objectives may be summed up as follows:

- to address the immediate needs of preparation of the data required by the digital model and help towards the gradual establishment of an updating mechanism allowing easy entry of new data and exchange of information between the countries ;
- to reconcile the needs of the SASS project with the specific needs of the countries which will be able to avail themselves of the methodological tools and the software used under this project. (One of the immediate outcomes of this objective is the standardization of the national DBs from a design point of view.) ;
- to allow the integration of geographic data, as dug well as automatic link with the digital model (data preparation and transfer of model results to the GIS).

The technological context allows an approach to the problem from this perspective and to implement the appropriate software solution fairly quickly. This context can be summarized as follows:

- high-performance DBMS which are dug well-interfaced with the GIS software,
- reusable components allowing rapid development of applications,
- also more open modelling software and which are henceforth adaptable to pre and post-processor levels.

However, the achievement of these objectives cannot obtain without a proven design methodology and an approach favouring efficient participation by the countries concerned in all the phases of implementation of this system: design and implementation, collection and validation of data.

The approach that has been adopted is based on the key element which the datum (static component) and not on the processing (dynamic aspect). This will endow the system with openness and an incremental character, thus allowing its subsequent use both by a concerted management structure and by the countries themselves—**information exchange having become possible**.

This is why a detailed examination of the systems and data bases existing in the countries concerned has been carried out. This in-depth analysis has led to the design of a hospitable architecture which includes, in addition to the items necessary for the project, any information managed by a hydrogeological service (possibility of use as national data base).

The execution of the system was divided into four steps:

- **Analysis of the information available** in the three countries and choice of the organizational solution in view of the project objectives, the countries specific needs and the current technological state-of-the-art (hardware and software) ;
- **Design of the information system** and description of the computer solution chosen jointly with the countries concerned: architecture of the common data base, identification of GIS layers, harmonization of Coding, definition of processing methods ;
- **Establishment of the data base and GIS:** installation of the hardware and software set up, implementation of the data base and GIS, transfer of the heterogeneous data available in the three countries and training of the teams (DBMS, GIS, spatial analysis tools) ;
- **Integration of the three components of the information system** (Relational data base, GIS and digital model): integration of the geographical data in the DB, establishment of the GIS-model links, development of the DB-model transfer modules (records by point or by mesh net), which has allowed the **collection of a considerable body of data** grouped within a homogeneous, consistent and incremental relational data base.

That was how the whole body of data available up to now on the zone (ERESS study, RAB project, data collected at country level, data collected in the context of regional studies...) has been entered in the system and has become accessible to the SASS project teams, as dug well as to the administrations of the three countries concerned by the project.

This system is complemented by user-friendly tools of data research and input, synthesis enquiries and procedures of addition of new data likely to be supplied by the three countries.

Data analysis tools have also been in order to facilitate the detection of anomalies and inconsistencies and to provide the digital model with valid data. These tools comprise enquiries, statistical processing and GIS based spatial analyses.

The use of the tools thus developed has considerably facilitated the progress of the SASS project.

To begin with, because, unlike the previous studies, an only one source of data was established for the various processing operations: **guarantee of consistency**.

Besides, through dug well-defined procedures, these processing operations are performed in the same way and, therefore, with the same level of **reliability**.

Finally, all basic tasks have been automated to allow greater **flexibility** of use, without which the handling of such a considerable amount of data would be difficult.

PART I

DESIGN AND EXECUTION OF THE INFORMATION SYSTEM

1- STUDY OF THE DATA AVAILABLE AND BASIC ALTERNATIVES FOR DEVELOPING THE NEW SYSTEM

1.1- Methodological approach

1.1.1. Definition of the terms used

Information System (IS): A set of dynamic interactive elements organized according to a purpose.

Database (DB) of an information system: structured information collection related to a given field and computer managed. A data base is controlled by a model and must meet a certain number of specifications:

- total independence between data and processing,
- non redundancy of information,
- integrity and consistency of the data.

DBMS: software allowing the handling, management and use of a database**.** Most existing DBMS on the market are of a relational type, that is based on the theory of groups and including all operations of the relational algebra (union, juncture, intersection…)

Design approach: the data base design process conception is generally divided into three steps: a design phase leading to the definition of a data model, a logical implementation phase, and a phase of implementation and machine based operating based on the DBMS chosen.

Design tools: the generalisation of relational data bases has led to the devising of methodological design tools which allow the establishment of high-performance and sustainable systems, since they rest on control over basic information. These tools are provided with operational rules, with a formalism and sometimes even with assistance software that facilitates data model development.

Data models: this is an intellectual tool allowing a representation of the real world through the managed information and the links likely to exist between them. A graphic schematisation is often offered by these tools for a better symbolisation of this representation.

Relational model: this was developed in the late 1970s for purposes of ensuring:

- total independence between data and processing operations - > sustainable and hospitable systems ;
- access to by high-level, non procedural languages ;
- mechanisms of “user” views that are different from those implemented. Every user can have his/her own view of the data base items.

Item: Object in the information system with properties. It is also designated by the term entity. In the case under consideration, a water point represents an item.

Relation (or association)**:** Link that can exist between two items and witch defines current management rules. The items “water point” and “administrative unit” are connected by the relationship of belonging.

Property or (attribute)**:** elementary information managed by the information system. It is connected to an item and, sometimes, to a relation. The name, altitude and coordinates of a water point are properties.

Identifier: particular property that makes it possible to identify an item in a unique way. The order number of a water point is an identifier.

1.1.2. Presentation of the approach

Inspired from the "MERISE" design method, the approach adopted is based mainly on:

- separation between data structures (stable component) and processing operations (dynamic aspects). These two areas are conducted in parallel and distinctly (guarantee of sustainability and hospitability) ;
- description of the system on three levels: design, organizational and physical, thus allowing methodical progress in understanding the problem and proposing the solutions that are suitable to the context.

Table 1: The three abstraction levels constituting the MERISE approach

Level	Data	Processing operations
Design What?	Items, association, property, identifier	Management rules, Operations on data, processes, events,
Organizational Where? How ? Who? When ?	Localization of data Access	Processing units **Operating mode** Degree of automation
Physical	Storage medium	Exploitation environment

The major task consists in developing a data model which best reflects reality. For so doing, it is necessary to conduct an exhaustive inventory of the current and future items belonging in the management of hydrogeological data. These items represent objects such as a water point, an aquifer, an administrative unit . . . The relations connecting these items are also listed and sorted out to the rules and procedures in force.

Once the model has been validated, the next step is to execute it according to the organizational and technical solution adopted.

The establishment of the SASS information system has, accordingly, required the following phases:

- **Diagnosis phase of the current situation and the development orientations:** during this phase, the needs, objectives and various possible options are identified. According to various criteria (costs, deadlines, technological trends . . .), an organizational and technical solution is selected ;
- **Design phase:** The outcomes of this phase consist in the Data Design Model (DDM) and the most suitable organizational and technical solution. This phase is independent of the computer means since it is mainly based on items that contain the information system and on relations linking these items.

- **Execution phase:** it results in the conversion of the DDM into a physical model depending this time on the DBMS (Data Base Management System) chosen according to the previously selected technical solution.
- **Implementation phase :** this takes place in the organizational environment adopted after transfer of the data available.

The design phase is the most important and determines the success of the other phases. Efforts have been focused on a perfect understanding of the field, the development of a representative data model and the definition of the best development solution possible.

Given the nature of the processing operations required, the system must have capacity to integrate several categories of information:

- Descriptive digital data ;
- Data of a spatial nature ;
- Records of measurements.

During the design phase, it has been decided to establish a hospitable structure that can be used both by the SASS teams as dug well as by the countries concerned for integrating future extensions and adaptations to their specific needs.

The functionalities of the system have been designed in such a way as to facilitate the utilization of the modelling software, to establish dynamic links between the digital and spatial data and automate the pre and post-model operations in order to allow the team entrusted with the model to multiply simulations.

On the organizational level, an adequate diagram for an exploitation that is in compliance with the internal organization of the three administrations has been defined. Procedures and rules of exploitation and administration of the system have been developed.

1.2- Analysis of the data available within the three countries

A detailed analysis of the hydrogeological data available in the three countries has been carried out. It has led to:

- Making an exhaustive inventory of the data available relating to the study zone, within each of the three administrations in charge of the management of water resources (GWA, DGRE, ANRH), as dug well as integrating them in the common SASS DB ;
- Getting acquainted with the Codings in use in each of the countries and proposing a harmonized Coding that meets the SASS objectives while observing the as much as possible the existing codes ;
- Defining the adaptations to be made on the national DBs, both with regard to design (standardized data model) and with regard to contents (grouping of disparate data) ;
- Listing and identifying the data to be transferred to the common data base, either by automatic entry or manual entry.

This diagnosis has involved not only the architecture of the data but also the contents proper.

It has led to highlighting the common concern of the three countries to undertake to improve their information system in order to bring together disparate data. The diagnosis has revealed that:

- GWA has developed a new data base under bilingual ACCESS (English-Arabic) with the help of ACSAD. This database had just been accepted ;
- DGRE has filed a project for a total recast of its hydro-geological information system according to a customer-server approach. A design study has already been conducted in the matter. For this institution, the SASS project was the opportunity to homogenize the many existing DBs within a single relational structure ;
- ANRH, which had already an ACCESS base developed in collaboration with BRGM, wished to have better tools allowing sophisticated enquiries which are difficult to conduct based on the existing tools. A project of a hydro-geological data base under SQL/SERVER had just been initiated.

The project of execution of the SASS data base coincided perfectly with the expectations of the three countries. It was, therefore, necessary to design a data structure taking into account all these concerns and specificities, and to obtain from it the common elements necessary to the SASS project.

1.2.1. Structure of existing data bases

1.2.1.1. ANRH: BADGE data base

i) Data base structure

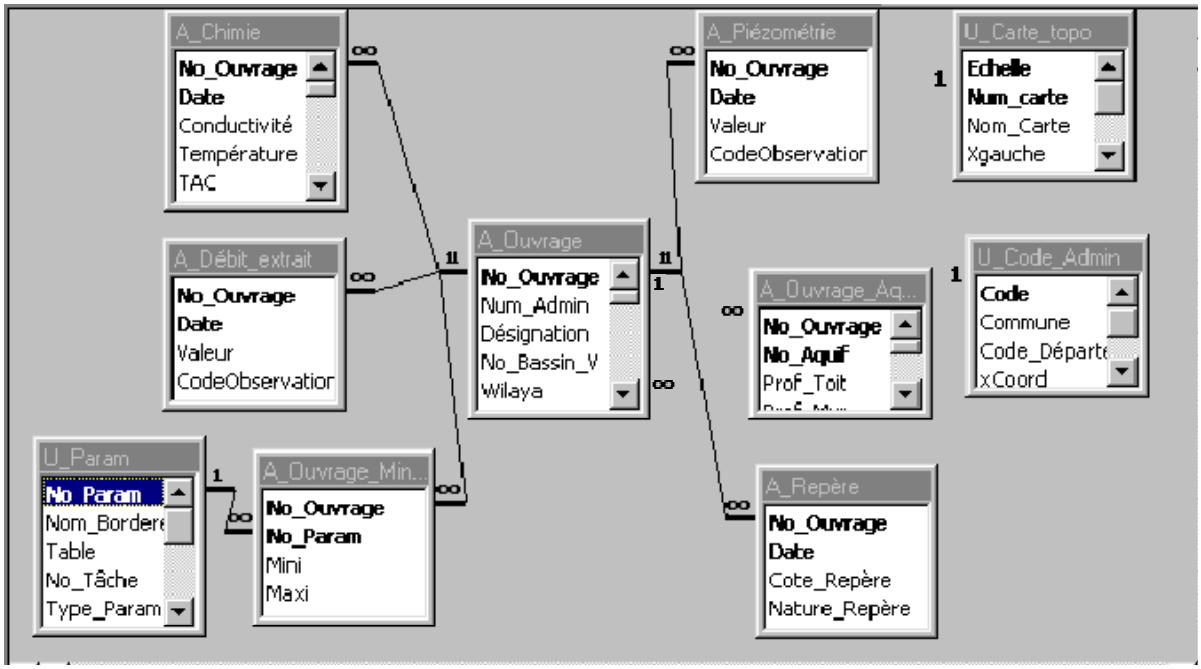
BADGE has been established within decentralized structures (regional agencies) responsible of data input. A copy of each of these bases is subsequently transmitted and then managed at headquarters. There are, accordingly, as many data bases as regional offices. For the SASS zone, the agencies concerned are that of Ouargla and, to a lesser extent, that of Adrar (more recently created).

The ACCESS base structure has been developed in collaboration with the firm ANTEA /BRGM based on an old DOS version, which did not manage the chronological data.

It is for this reason that the flow and level data are stored within the “water points” table itself. An updating of these data supplants those previously listed in the table.

The structure of the data base under ACCESS is as follows:

Figure 1: Diagram of the BADGE data base



This diagram is converted into the following ACCESS tables:

Table 2: BADGE tables list

Name	Designation	Identifier
A_structures	Features of the water points and location. Includes boreholes, dug wells, springs and foggaras	N° structure
A_structure_aquifer	Description of the aquifers tapped by the structure	N° structure + N° aquifer
U_Topog. Map	Topographic maps in various scales on which the water points are positioned	N° of map
U_Admin.	Administrative entities table (Wilaya)	Code_of admin.
U_Param.	Measured or recorded parameters list and their units	N° param
A_Flow tapped	Record of tapped rates	N°_structure + Date
A_piezometry	Record of piezometric levels	N°_structure + Date
A_chemistry	Chemical analyses	N°_structure + Date
U_Index	List of coded fields and their significance	Name_Index + Code

The analysis of the data structure reveals the following constraints:

- Certain important data are referenced only in the index of terms (which has exclusively a glossary role), while they should be considered as items in their own right. This is not compliant with the basic rules of relational data bases and does not favour the development of synthesis enquiries. This is, for instance, the case of such items as “Aquifer”, “Catchment”, “lithological layer”… ;

- Major fields, such as the nature of the coordinates, the projection system used or the precision of the units (ranks, degrees) do not figure on the "A_Structures" table, which makes it impossible to locate the water points by means of GIS without considerable prior processing ;
- The area is divided into several DBs: one by regional agency and by type of water point (springs, dug wells, boreholes). This does not allow synthetic processing and enquiries by spatial unit (administrative unit, aquifer, basin . . .). Besides, the boundaries of the regional agency do not coincide with the natural boundaries.

ii) Coding used

No_Structure: Water point classification N°. This is the unique identifier of the water point coded on 9 alphanumeric positions.

- A999: n° of the square in which the structure is located. **The squaring** adopted uses a numbering in letters for abscissa and in figures for ordinates. Note that a grid represents a side grade,
- '–': separation dash,
- 99999: sequential order N° in the grid.

Num_Admin: Code of the administrative unit composed of the n° of the Wilaya and the n° of the town in the Wilaya.

Wilaya: N° of wilaya (n° from 1 to 48)

Aquifer: Code of the aquifer (order n°); the CI and the CT are assigned, respectively, the codes 88 and 89

N° scale: Sequential N° of the scale as located in the table. It is of digital type

Example: 3 for 1/200 000 of the southern region

N°_map: N° of the sheet within this scale. These numerical values are assigned by INC (National Institute of Cartography)

Example: N° scale 1, n° map 12 => map at 1/500 000 of the El Goléa region.

Type_Structure: Nature of the water point (borehole, dug well, piezometer, foggara…)

Object_Structure: water point objective at construction time (exploitation, exploration …)

State_Structure: Condition of the water point (exploited, abandoned, closed, filled…)

Use_Structure: Purpose of the water point (Drinking water supply, irrigation, industry…)

iii) Summary of constraints

- Absence of a central DB grouping all the data. The storage by regional areas does not allow to conduct processing by aquifer, for instance ;
- Several tables must be created in order to observe the relational model and to allow for statistical and synthesis enquiries ;
- Codes need revision for a greater precision of the terms used and to avoid duplication.

1.2.1.2 GWA: LGWDBS Data Base

i) Data base structure

This is a database developed under ACCESS by ACSAD. This DB, known as LGWDBS, had just been accepted by GWA at the inception of the SASS project. It was not, therefore, supplied yet.

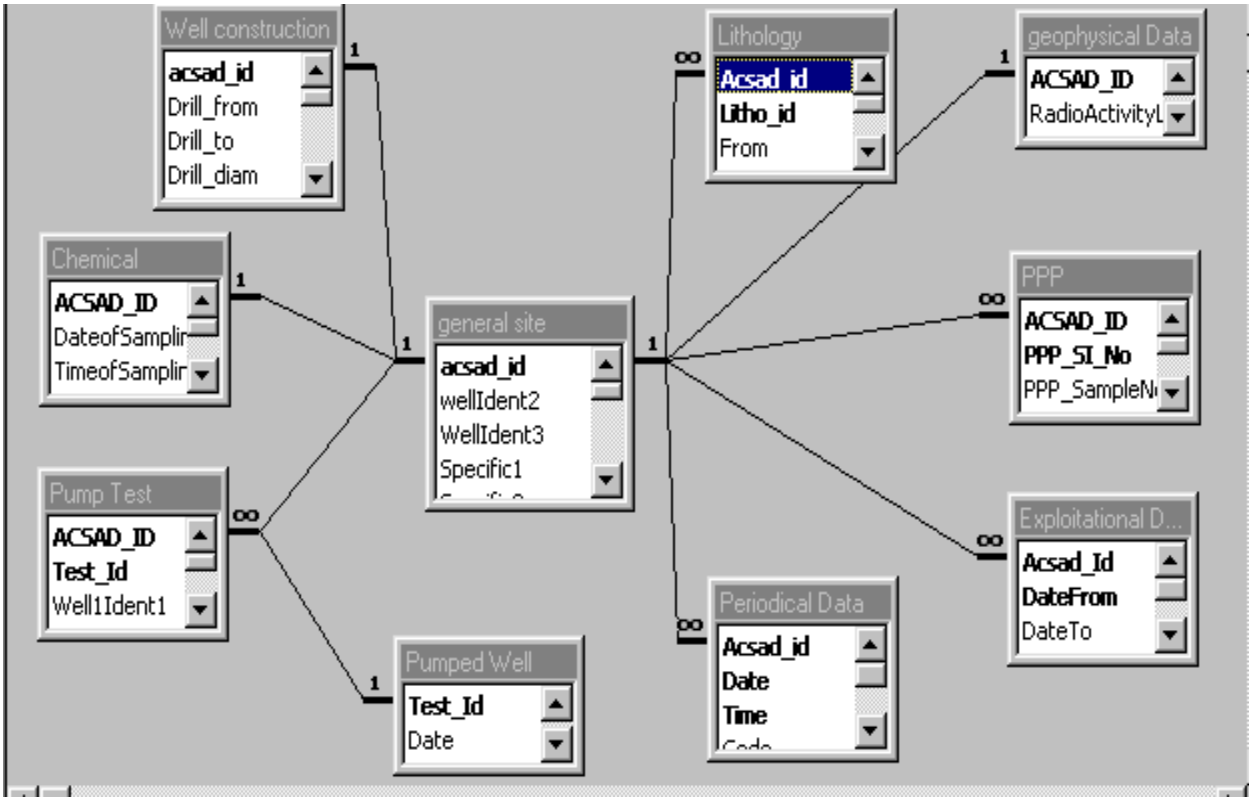


Table 3: GWDBS tables list

Table Title	Designation	Identifying
General Site	Identification and Features of water points	Acsad_Id
Dug well construction	Facilities of the water point	Acsad_Id
Geophysical Data	Geophysical data	Acsad_Id
Lithology	Lithological description	Acsad_Id + litho_id
Palaeontology - Petrography - Physical analysis	Palaeontology, petrography, physical analyses,	Acsad_Id + PPP_sample_no
Pump Test	Pump tests	Acsad_Id + Test_id
Pumped Dug well	Test borehole	Test_id + startDate
Periodical Data	Piezometric data	Acsad_Id + Date
Exploitation Data	Exploitation data	Acsad_Id+ dateFrom
Chemical	Chemical analyses	Acsad_Id + date of sampling

The structure is fairly complete; however, it focused exclusively on the water point. Other data of spatial nature are non existent, which does not allow the conducting of synthesis enquiries.

No procedures of automatic transfer of existing data have been developed: only manual entry of these data is allowed.

ii) Coding used

Water point Code : three different codings are utilized:

- N° of inventory related to the positioning map. Its structure is as follows:
  - N° of map, which may differ according to the scale (1/250000 or 1/50000)
  - Order N° within the map
- Specific N° written on the authorization of drilling
  - 1 alphanumeric position designating the place where the authorization is delivered (e.g.: T for Tripoli)
  - 1 numeric position designating the region (1 West, 2 Centre,…)
  - 1 alphanumeric position for the sub-region
  - 4 numeric positions for the order n°
  - 1 position which may take " 0" values for a new borehole and "1" for a replacement borehole
  - 2 positions designating construction year

Other number designating old codes: it is a free code of 10 alphanumeric positions.
Water points may have any of the three codes, but the primary key to the water points table is the field « Acsad_Id », a sequential number assigned by the DBMS every time a new water point is entered in the DB.

Type of water point: (1 borehole, 2 dug well, 3 spring)

Object of the water point: (1 exploration, 2 exploitation, 3 survey, . . .)

Owner: 1 Public, 2 private,

Use: (a Domestic, b Livestock, c irrigation, d desalinisation,)

iii) Summary of constraints

- The relational model is not fully observed: it lacks some important tables, and there is a need to revise the relations ;
- The fact that the primary key of the main "water points" table is an order number may result in problems of duplication:
- Certain synthesis enquiries are impossible to make for lack of certain important tables (e.g.: all water points concerned by the SASS project).

1.2.1.3. DGRE: description of data bases

i) Structures of data bases

In the case of the DGRE, several thematic data bases have been listed. Besides, the data input being largely decentralized at the level of the regional structures (CRDA), several copies of these bases are stored within the central services (sometimes several bases per aquiferor per year).

Four distinct databases are managed by the various DGRE services:

- Boreholes
- Deep groundwater exploitation
- Piezometry
- Water quality

"BOREHOLES" data base:

This base contains the features of all the boreholes drilled since 1991. It is envisaged to integrate the previous data within the framework of the SASS project.

Table 4: "Boreholes" data bases list

Table title	Designation	Identifier
Boreholes	Features of deep drilled wells	N° DRE
Delegations (sub-region)	List of "Delegations"	Coddel
Gouvernorate (region)	List of "Governorates"	Code

"Deep and shallow aquifer piezometry" data base:

Originally designed under DBASE, it was subsequently transferred under ACCESS in order to allow a processing of the data for purposes of an easy output of piezometric yearbooks.

Table 5: List of "Piezometric" data base tables

Table title	Designation	Identifier
PIEZIN	Piezometry measured during the previous year	
PIEZFIN	Piezometry of the current year	
GOUVERNORAT	List of gouvernorates	Code
CODNAP	List of aquifers	Codnap
SECTEUR	List of hydrological sectors	N° of sector
TYPE	Contains the list of types of structure	N° type
EQUIP	Nature of water point facilities	N° equip
ETAT	Contains the various conditions of the non supervised water points	N° condition

"EXPL" data base: Exploitation of deep aquifers

This was developed under DBASE and is intended for monitoring the data relating to the exploitation of the deep aquifers. Certain processing operations and enquiries are done by means of DBMS ACCESS. Data inputs take place at CRDA (Regional Agricultural Development Commissionerships).

List of tables of the "exploitation of the deep aquifers"

Table	Designation	Identifier
EXPL	Contains exploitation data	N° DRE
CODNAP	Aquifers list	CODNAP

The study of the various data bases available within DGRE reveals that considerable design work is necessary in order to bring together the various data within a same architecture and to devise procedures for information updating based on CRDA.

The recovery of the data available, whose quantity is appreciable (regular monitoring of the exploitation piezometric level of aquifers), requires the development fairly sophisticated enquiries and modules.

iii) Coding used:

CODNAP: Numerical code adopted for the various aquifers of the country.
Format: 99999

- 9: number of hydrological region (1-9)
- 9: number of hydrological sector in the region
- 9: number of hydrological basin in the sector
- 9: number of the aquifer in the basin under consideration
- 9: N° of the aquifer level (0: shallow aquifer, 1: level 1 deep aquifer)

Example: 65210

SECTOR: Coding of hydrological sectors: 6 numerical positions
- 9999: aquifercode
- 9: n° of sector in the aquifer

Example: 652101

IRH N°: Code assigned by the inventory office **:**
- 99999: Chronological N° in the region
- 9: N° of region

Example: 19007/5

ARR N°: District number: 2 numerical positions [from 1 to 23]

TYPE: Types of water points**.** 1 numerical position:
- 0: dug well
- 1: borehole or drilled well
- 2: piezometer
- 3: tunnel
- 4: well used for recharge survey
- 5: piezometer for recharge survey

EQUIP: Nature of measurement point equipment **:**
- 0: not equipped
- 1: level recorder
- 2: ADAS (Automatic Data Acquisition System) recorder
- 3: manometer

STATE: State of non supervised points coded as follows**:**

Table 6: Coding used for reasons of lack of piezometric measurements

Code	Significance	Code	Significance
777	pumped	11111	not created.
888	clogged	22222	difficult access.
999	dried up.	33333	water drawing.
1111	military zone.	44444	crumbled.
2222	dam zone.	55555	negative.
3333	abandoned.	66666	impassable land.
4444	newly constructed.	77777	not supervised.
5555	inaccessible.	88888	Reduced diameter for survey purposes
6666	not measured.	99999	plugged.
7777	closed.	666666	artesian.
8888	drilled.	777777	replaced.
9999	filled up.	888888	leakage
9999999	polluted	999999	damaged

NDRE: DRE number depending on the location of the water point and its type. It is coded based on 9 numerical positions:

- 9: Map Scale [1: 1/50000, 2: 1/100000]
- 999: n° of map
- 9: type of water point [1: borehole, 2: dug well, 3: spring, 4: emergence, 5: dug well with drilled tube in the bottom]
- 9999: N° of order on the map

Example: 207110001: Scale 1/100000, n° of map 071, type 1 (borehole), n° of order 0001

UTILISA: Code of use of water [10: drinking water, 20: agriculture, 30: industry, 40 hotel facility.]

DEB: nature of flow [0: pumped ,1: Artesian.]

1.2.1.4. Synthesis of the information available in terms of data structures

The following table synthesizes the situation of the architecture of the DBs existing in the three countries at the inception of the project:

Table 7: Synthesis of gaps in the DBs of the three countries

Country	Gaps and deficiencies
Algeria (ANRH)	Much information not taken into account by the DB are in disparate EXCEL files. The architecture of the DB does not allow certain advanced processing operations and complex enquiries The DB–GIS links have not been provided. Poor consideration of water points coordinates: - confusion between Lambert and UTM, between Southern and Northern Lambert - absence of a field for the geographical units - No zone n° UTMs
Libya (GWA)	The existing data base needed to be standardized: missing tables and relations, water points primary key not suitable, The major part of the data is under the form of written documents, as the data base has just been delivered by ACSAD GIS is not integrated in the DB. Problems with the UTMs coordinates (zone n° missing), coordinates
Tunisia (DGRE)	The various DBs are managed separately. Major risks of inconsistency Data Coding needs revision Difficulty of use and impossibility to conduct synthesis processing operations GIS is not integrated in the DB Only one type of coordinates is provided

1.2.2. State of information

With regard to contents, a detailed inventory of the data available has been carried out. The objective of this diagnosis operation is to identify the Coding used and to input the data transfer tools into the new data base. The situation at the beginning of the project can be presented as follows:

1.2.2.1. ANRH (Algeria)

i) BADGE base content:

The data base managed by the Ouargla regional services contains 4900 water points. The water points collecting the two main aquifers count 3000 and are distributed among in the following Wilayas: Adrar, Bechar, Biskra, El Oued, Ghardaia, Illizi, Laghouat, Ouargla, Tamanrasset, Tindouf,,.

Water points located in the Wilayas of Tebessa, Khenchela and Djelfa, and which belong in the SASS zone, are in data bases managed by the regional services of Constantine and Djelfa.

The existence of a central data base containing all water points would have allowed the obtaining of data about all those water points concerned by the project by means of simple enquiries, such as belonging to a given extension zone or collecting a given aquifer.

Such as they are presented, these data include a significant number of anomalies which prevent their direct use:

- **the coordinates are almost all erroneous or unexploitable:**
  - absence of a field for mentioning the projection system (there are several of them in Algeria)
  - inversion of longitudes and latitudes
  - absence of indication of zone for UTMs
  - omission of a column for mentioning “East” or “Ouest” with respect to the Greenwich meridian
  - Omission of units for geographical coordinates (grades or degrees).
- **values of flow, level and dry residue not always connected to dates**
- **major fields missing or not detailed** (aquifers, altitude, depth, stoppage date, heights of strainers,…).

The BRL (1998) study was an opportunity to do considerable work of data verification by the “modelling” team of ANRH, and major corrections were made. Some fields necessary to the digital model were also complemented (coordinates, flows and levels). This work having been executed under EXCEL, the outcome of this enhancement has not been reintroduced in BADGE.

ii) Foggaras File

The features of the foggaras (about 700) were stored in EXCEL files (a file by Wilaya). The computer department of ANRH has undertaken to transfer these files to BADGE, but corrections continue to be made on the EXCEL files.
The coordinates and flows are only partially detailed.

iii) Inventories data

The results of the latest inventories carried out in the SASS zone between 1991 and 1998, processed and validated as regards their identification-localization, are stored in EXCEL files. A major work of adjustment to the BADGE data has been undertaken by the ANRH team.

These inventories have been conducted either by ANRH, or by the Hydraulics Directorates of the Wilaya (DHW). However, in both cases, an considerable number of water points are not provided with the indispensable data for identification and localization of the water points:

- Identification number: the operation of assignment of an identifier is made based on positioning on a topographic map; it is the prerogative of the central administration (currently ANRH) ;

- Coordinates ;
- Date of inception and stoppage of a borehole in order to define the record period.

Various devices have been used by the ANRH team for purposes of reconstructing the records and positioning the water points. The same flow value has been assigned to years for which measurements are lacking (up to the date of stoppage of pumping where this date is mentioned).

iv) Other available data

- Files used in the context of the ERESS and RAB-80 studies: Covering also the Tunisian part, they are available on floppy disks, with variable length text format. The manual entry option has perhaps been chosen for being less costly. These data relate mainly to the records of abstractions and levels (1950 - 1981).
- Abstraction data from petroleum boreholes: These data were provided by SONATRACH. They have the same format as the inventory data and are also in EXCEL files .

1.2.2.2. DGRE (Tunisia)

In the case of DGRE, most of the all the data after the year 1990 are in Dbase or EXCEL format. These files are distributed by CRDA, which count 6 such regional offices for the SASS zone (Kebili, Tozeur, Tataouine, Gabès, Gafsa and Médenine), as dug well as by theme (boreholes features, exploitation and piezometry).

The data collected before the year 1990 have been entered manually by the DGRE team based on the files.

The DGRE data do not present any major problems and have been the easiest to be transferred. This is largely due to the fact that there is a yearly monitoring of flows and levels and that the yearbook are regularly issued.

Certain gaps were, nevertheless, observed:

- the IRH number does not appear in a uniform way ;
- coordinates expressed in degrees are difficult to locate ;
- data relating to inception and completion of works are not uniform (free text format).

1.2.2.3. GWA (Libya)

Being newly established (November 1999), the GWA data base did not contain any data. These are most often found in written documents (borehole records, study reports, …), and this in a synthetic way (for instance, the figures relating to abstractions are given by exploitation group and not by water points). Since the number of boreholes was relatively limited, manual data input by the SASS team was adopted.

i) Water points file

A EXCEL file containing the basic features of water points has been prepared for purposes of the project. This file also includes values for flows, static levels and dry residue.

This file is delivered with some gaps:

- With regard to coordinates:
  - the same columns present at the same time geographical coordinates and UTM ;
  - the zone number is not given.

- With regard to the dates of the measurements of flows, levels and dry residue.

Besides, it seems that flow units are expressed sometimes in l/s and at other times in m3/h, with nothing to help distinguishing them.

ii) Other available data

The data having served for the studies conducted by GEFLI (1978), GEOMATH (1994) and BRL (1997) were also recovered in the database from manual files.

1.2.3. Synthesis of data in terms of contents

The following table summarizes the nature and volume of the data relating to the SASS zone, and which are available at the inception of the project and at the very beginning of the collection operation.

Table 8: Synthesis of data provided by the countries at the inception of the project

Origin	Data available on computer	Number	Format
ANRH	-Features of the water points of the southern zone (DRS), not checked . - Data of inventories (91–98) - Basic data from the ACCESS table, with corrected coordinates and distributed by aquifer - SONATRACH water points - inventory of foggaras (by group)	3000 3000 140 176 groups	ACCESS EXCEL EXCEL
DGRE	- Water points features: a file by district concerned - Exploitation record 82–99. A file by district - Piezometric record 82–99: a file by district	500	Dbase Dbase Excel
GWA	Water points features, also containing hydrodynamic data, flow, level and dry residue	168	EXCEL

The data not yet computerized are generally found in study reports or in manual files. These data relate, for the major part, to the following studies:

- The ERESSS and RAB-60 studies, covering the Algerian and Tunisian parts
- The studies conducted on the Libyan part (GEFLI, GEOMATH, BRL)
- The BRL-1998 study relating to the development of Saharan regions Algerian part).

These data complement those supplied by the countries on computer support.

1.3- Basic development options

1.3.1. Organizational choices

In view of the current situation within each country, the objectives assigned to the project and the present technological context, an organizational global solution has been defined for the execution of the information system .

Broadly speaking, in order to collect and manage the SASS information, there are three levels of processing operation:

- **Regional level 1:** Regional service for ANRH, CRDA for DGRE, and region for GWA.
- **Central administration level 2:** Service in charge of national data base management
- **SASS level 3:** Where the data base common to the whole basin are managed.

Each level comprises data that are proper to it, in addition to the common data that is found in the upper level. In the context of this project, focus has been placed on the levels 2 and 3. It is up to the countries to define the structures of the regional DBs and the mechanisms for updating the national data bases.

The technical solution wished by all the teams consists, therefore, in adapting the structures of the national DBs (level 2) in order to make them really relational, to correct the inconsistencies observed and to improve the Codings in force so as to adapt them to the needs of SASS.

Accordingly, the SASS project is perfectly in tune with the activities of the countries in matter of data management. It represents some sort of a **pilot project for the organisation and processing of hydro-geological data**.

However, this choice requires an active involvement of the country teams and a more enhanced training so that they become able to appropriate the tasks of establishment of the system, of maintenance and adaptation to national needs.

The strategy of gradual establishment of the information system may be illustrated by the following diagram:

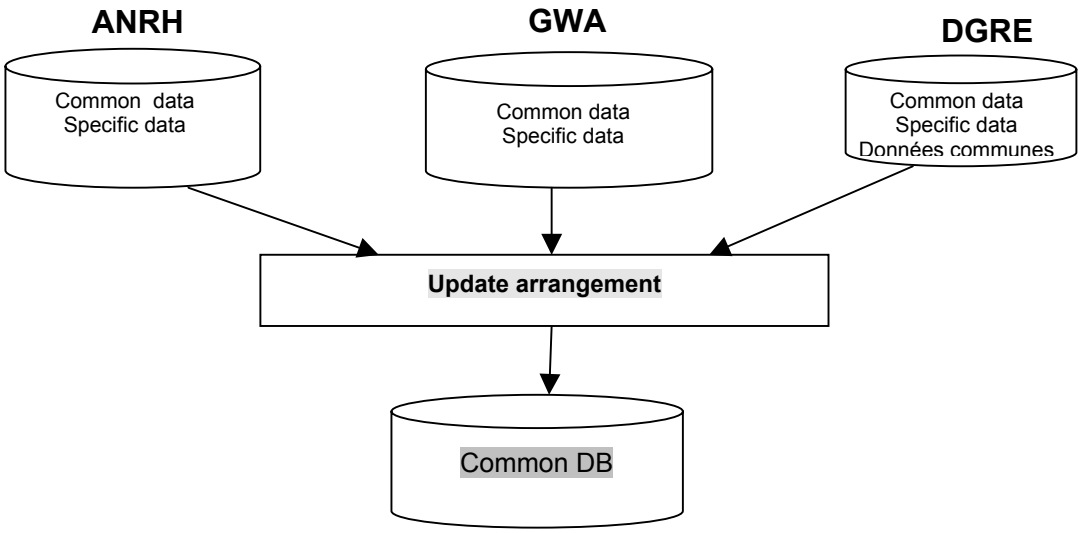
Table 9: Short and middle term phases of establishment of the IS

Phase	Regional level	National level	SASS level
For purposes of the model		- Improvement of the structure of the DBs -Harmonisation of Codings - Recovery of heterogeneous data	- Design of a common data base and a GIS on the SASS zone - Gathering of all data available to date - Design of tools allowing interfacing with the digital model
For purposes of the consultation mechanism	Establishment of compatible regional bases, with possibilities of central DBs update	- Devising of common data base update mechanisms - Integration of socio-economic data - More detailed GIS	- Design of basin level joint management tools

Key:

- *in blue: actions fully completed during the project time period*
- *in green: actions that are in advanced progress*
- *in black: tasks that it is desirable to conduct for a proper operating of the IS.*

In order to meet the immediate needs of the project, the following organizational solution has been selected:



The above diagram, which symbolizes the organizational solution selected by mutual agreement among the national teams, is translated into an identical global architecture for the three countries which can enter their specific data. Accordingly, the management and maintenance task is thus facilitated. At SASS level, a common base, whose structure issues from the global structure, is established to contain only the data necessary for the project.

This has resulted in the design of a data design model (DDM) which meets all the concerns and current and future objectives of the SASS project. This DDM has been later adapted to cover the needs of the three countries and to serve for purposes of obtaining an incremental common core installed at SASS.

Procedures of regular updating have been defined, together with the access rights and privileges of the various users with regard to this common base.

As the objective is to prepare data for the digital model, the common data base has been executed first of all after having validated the global design model.

The organization selected rests on:

- the establishment of a common data base at SASS level (which can become the future DB of the concerted management structure),
- the adaptation of the national DBs to make them compliant with the rules of relational bases, as dug well as to harmonize data for purposes of facilitating their updating,
- the definition of clear updating procedures in both directions,
- the set up of safety data mechanisms (authorizations of access, utilization levels . . .).

The three countries have benefited from these improvements at the design level and are able to pursue the extensions desired in order to use this system as a data management tool at the regional or central level (headquarters of the three administrations).

The updating mechanisms are based, in the event of modification, on the principle of replication which is provided in most DBMS available on the market.

1.3.2 Technical options

The technical solution has been adopted while taking into consideration the following aspects:

- format and mode of entry of the data for the digital model ;
- current technological trends ;
- the data available in the three countries ;
- easy use and control over the model by the national project teams.

The technological context, at the inception of the project, was characterized by the increasing capacity of “office automation” DBMSs, which was bringing them close in performance to veritable DBMSs. This option could not, therefore, be discarded and, more particularly, ACCESS which, in its recent version, offers interesting functionalities.

Indeed, in its 2000 version, ACCESS presents features that allow for the management of fairly sizeable data bases (of up to 2 Go) in network environment and even in Intranet. It is provided with such interesting utilities as:

- replication, which allows the updating of a central base by regional DBs: the updating of data, after modification by the countries’ teams or by SASS teams is carried out via a mechanism that synchronises the content of all the DBs, while maintaining the consistency of the data ;
- concurrent access to data under a multi-user environment ;
- an advanced data safety: possibility to create several groups, each of which having authorisations and access rights ;
- possibility of easy migration to larger systems, such as SQL/SERVER via a simple utility supplied with the product.

The choice of ACCESS was made based on the fact that the processing operations and the volume of data managed by the SASS project do not require a higher capacity DBMS. ACCESS is commonly used and the teams of the three countries have enough control over this system to exploit and manage the data base.

The hardware and software thus selected are as follows:

DBMS: **ACCESS**, for its being used and mastered in the three countries, as well as for the ease of its interfacing with GIS. The 2000 version allows, in addition, easy migration to the SQL-SERVER envisaged by DGRE and ANRH.

GIS software: **ARCVIEW**, for its simplicity, capacity, perfect compatibility with ACCESS and its fairly common use in the field of water resources. Fitted with a high-capacity development language, it allows the entry of the customised utilities necessary for performing GIS – Digital model links.

SPATIAL ANALYST extension, under Arcview, purchased for purposes of carrying out operations of interpolation and development of iso-values maps.

IMAGE ANALYSIS extension, under Arcview, for processing scanned maps and their digitalisation.

Hardware and software configurations have been defined on a case by case basis, according to the rule of observance of the minimum required to exploit the software nd the data base for purposes of the project. A few specific purchases have been made as support operations to the countries.

By means of this software, a data management and processing system will be developed based on a data model, an exhaustive inventory of the processing procedures, and the organisational mode selected.

The transition from the initial situation to the new system has been made by means of clearly defined manual or automatic procedures which provide, *inter alia*, for codification changes, validity controls, and type modification.

For a perfect mastery of this system and of its components, there were organised training workshops for the various teams: initiation into data bases, control over ACCESS, training on GIS, in general, and on the ARCVIEW software, in particular.

List of software and hardware as per country

Table 10: List of hardware and software purchased by the project

Institution	Hardware and software
ANRH	1 Pentium III: 256 Mo, DD 8Go, screen 19“, drive ZIP 250, Windows NT Professional Office 2000 (ACCESS DBMS) GIS software Arcview 3.2 Spatial Analyst Extension for Arcview Image Analysis Extension for Arcview 1 additional Pentium III (larger data volume)
DGRE	1 Pentium III: 256 Mo, DD 8Go, screen 19“, drive ZIP 250, Windows 98 Professional Office 2000 (SGBD ACCESS) GIS software ArcInfo (network version) Update for ARCVIEW version 3.0 to 3.2 Spatial Analyst Extension for Arcview Image Analysis Extension for Arcview
GWA	1 Pentium III: 256 Mo, DD 8Go, screen 19“, drive ZIP 250, Windows 98 Professional Office 2000 (together with ACCESS DBMS) GIS software Arcview 3.2 Spatial Analyst Extension for Arcview Image Analysis Extension for Arcview ArcView extension for handling Arabic
SASS office (Tunis)	1 Pentium III: 256 Mo, DD 8Go, screen 19“, drive ZIP 250, Windows 98 Professional Office 2000 (together with ACCESS DBMS) GIS software Arcview 3.2 Spatial Analyst Extension for Arcview Image Analysis Extension for Arcview ArcPress extension for ArcView

A draft version of the information system was developed during a workshop organised from 1 December to 4 December 1999 (see report for phase 1) which brought together the project teams. The digital and geographic data intended to make up this system were identified, as well as the codifications to be adopted. In sum, this workshop has made it possible to:

- identify the set of items intended to make up the information system, including the data of spatial character ;
- adopt a common codification for the SASS data base, which would be compatible with those used by the countries ;
- propose various development solutions according to the modelling software which would be selected ;
- set out a strategy for the transfer of the existing files and for the entry of manual data: old records (1950 – 1981), data found in studies reports . . .

1.3.3 Content of the information system envisaged

An exhaustive list of the various items intended to figure in the information system has been compiled in collaboration with the countries' teams. This list takes into consideration:

- the immediate needs of the model ;
- the problems found in the structures of the national DBs ;
- possibilities of development and extension ;
- integration of GIS within the information system.

This inventory has been made after initiation into the IS concepts and into the methodological approach.

Table 11: List of items composing the IS

Item	Significance
Water point or structure	Groundwater structure which may be a drilling, a dug well, a spring, a piezometer . . .
Hydrogeological unit or aquifer unit	Natural unit, demarcated in space according to hydrogeological criteria. This is a unit of evaluation and management of the resources.
Topographic map	Reference of the sheet on which the water point has been inventoried. The identifier of this item consists in the scale + map N°
Administrative region	First level administrative unit (Governorate, Wilaya, Province)
Geophysical zone	Demarcated expanse having formed the subject of a geophysical study. The access key being the study reference.
User	Denomination of the user of the water supplied by the structure: name of town, water distribution company, irrigated crop zone, industrial plant or tourist facility . . .
Purpose	Code and denomination of the purpose of the structure, once being operated.
Type	Type of structure/ equipment (drilling, dug well, spring . . .)
State	Current state of the water point
Subject	Subject of the water point at the time of its construction (exploration, exploitation . . .)
Use	Use of the water point: domestic, irrigation, tourism . . .
Formation	Geological formation of the layers crossed by the water point (international codification (nomenclature) is adopted followed by the local name where it exists)
Lithological layer	Features of the formations encountered whether aquiferous or not
Stratigraphy	Relation describing the stratigraphy of the layers crossed by the water point
Casing	Relation describing the water point equipment
Catchment area	Surface natural unit
Climatological station	Climatological parameters observation station
Climatological record	Relation comprising the record of climatological observation values
Pollution source	Location identified as likely to induce pollution: urban effluent, industrial plant, farming concern . . .
Date	Item intended to allow the establishment of relations with the water point. These relations consist in chronological records and measurements (piezometry, abstractions . . .)
Piezometry	Record of piezometric levels: The access key consists in the identifier of the water point followed by the measurement date.
Abstractions	Record of abstractions: The access key consists in the identifier of the water point followed by the measurement date.
Chemistry	Record of the findings of chemical analyses: The access key consists in the identifier of the water point followed by the measurement date.

2- DATA DESIGN MODEL (DDM) AND IMPLEMENTATION DOCUMENTS

2.1- Description of DDM

One of the characteristics of the approach adopted is a separation between the structure of the data and the processing operations applied to the data.

In other words, in order to achieve a hospitable and incremental information system, the method adopted consists in ignoring, at first, the processing procedures which themselves are subject to change. Emphasis is, therefore, laid on the more stable part which are the data, while identifying in a precise manner the following aspects:

- the data sets (items) ;
- the nature of the links existing between them ;
- the management rules related to these items.

This approach, which allows the development of a representation as close as possible to the reality observed, aims at the production of a data design model (DDM) that synthesises the items and the relations based on a formalism which derives from existing or envisaged rules:

- a water point may tap 1 or several aquifers ;
- a water point supplies, at a given date, a certain flow ;
- a water point may serve several users ;
- a user may be supplied by several water points ;
- a water point has a mesh net number within a given meshing.

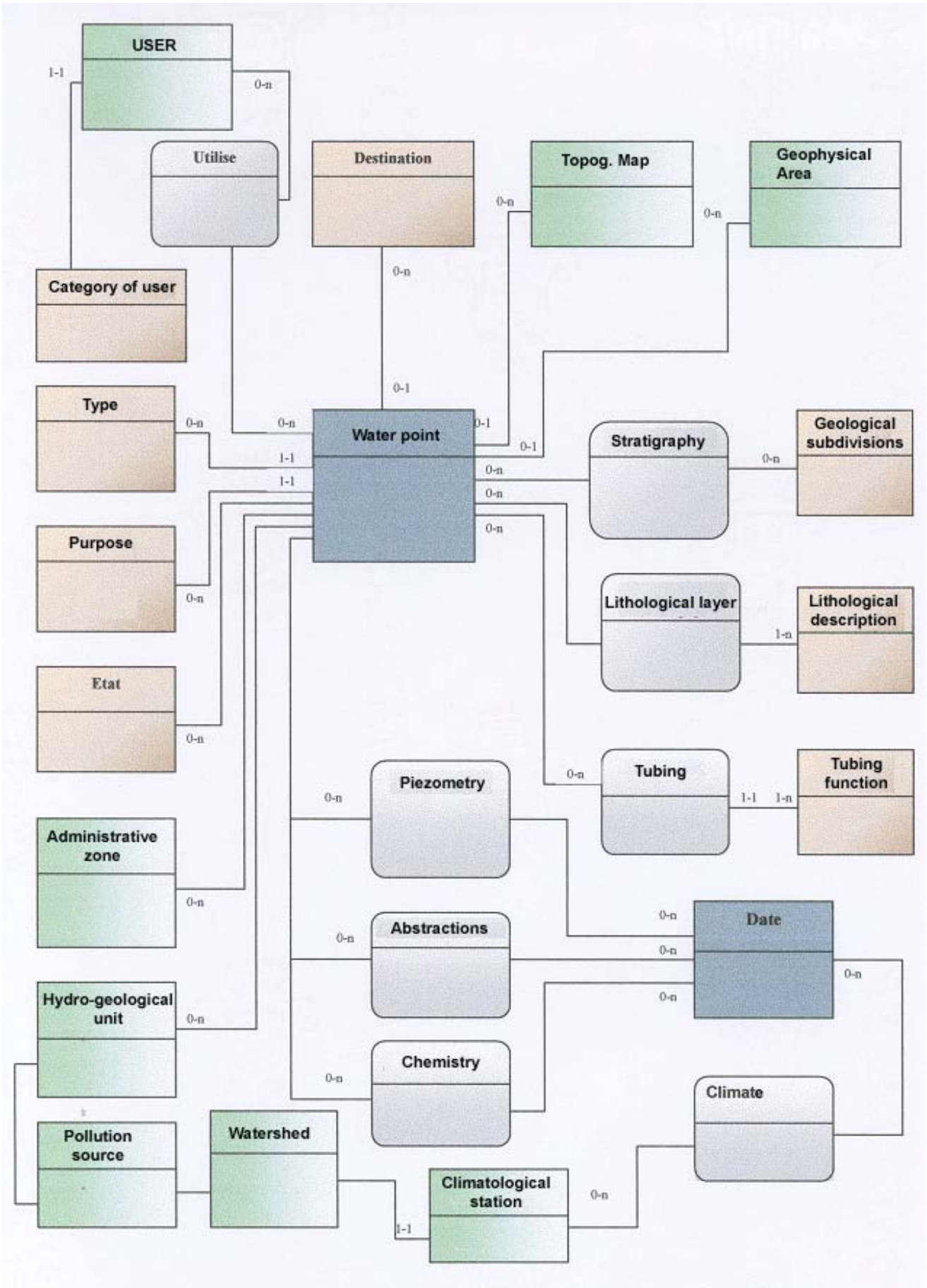
The modes of processing are addressed only after validation of the DDM by the countries.

Another workshop, organised in March 2000, has led to undertaking the validation of the DDM of SASS (which also covers the countries' concerns):

- identification of the items belonging under the IS and their identifiers ;
- relations and cardinalities ;
- detailed list of the properties of each item.

It should be noted that this DDM is independent of the machine and of the DBMS onto which the system will be installed. The rules for the transition to the relational model, then to a logical model on the DBMS, is made based on clear rules.

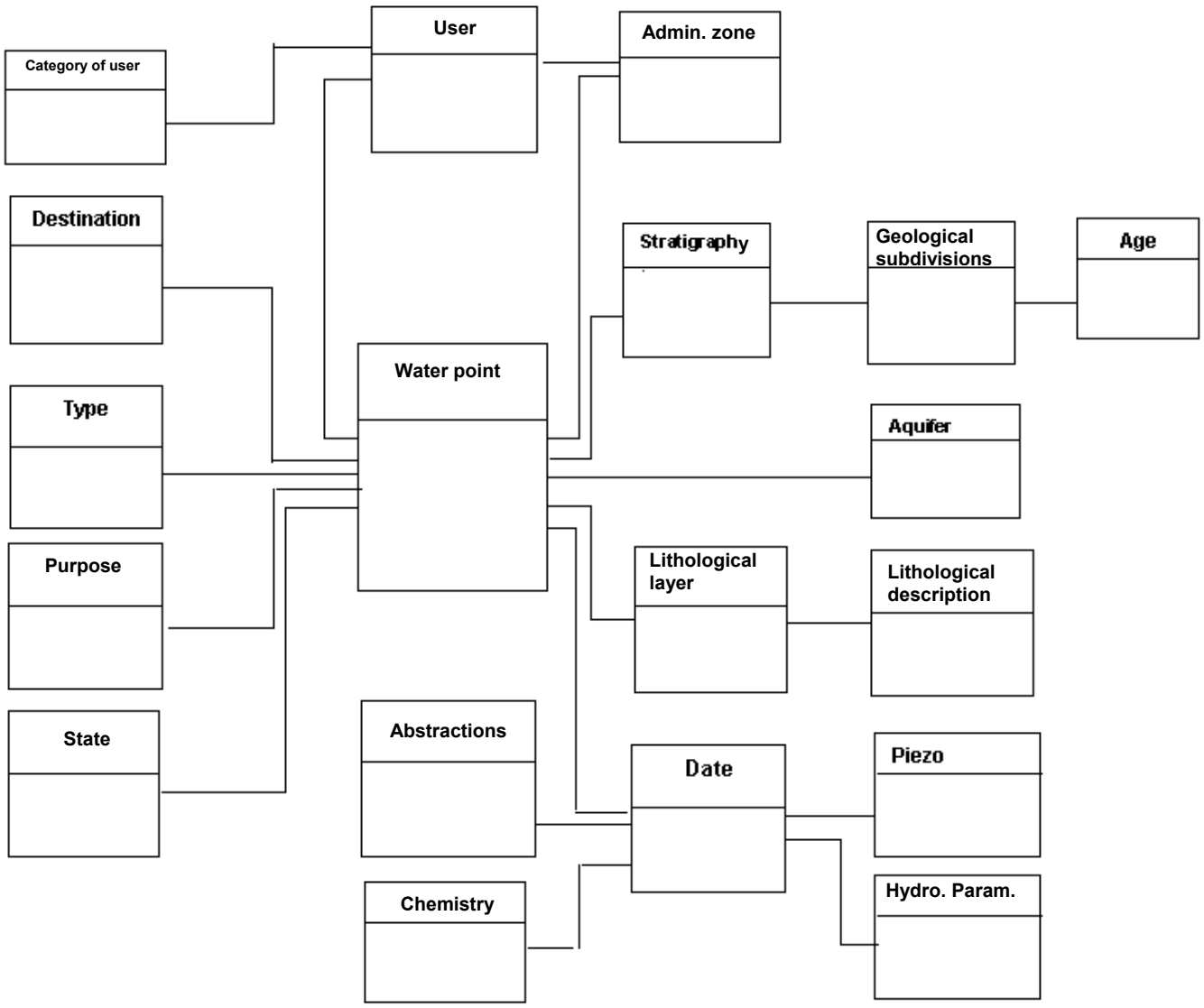
Global Design Model



Based on this design model, which is intended for very large needs, a smaller sub-model has been obtained in order to handle the data necessary to the SASS project, which constitutes a sub-set of the global model.

The architecture thus obtained is given in the following diagram:

Design model for the project needs



The items relating to the equipment of the wells and to the links with the hydrological data have been removed from the model since the project does not use them.

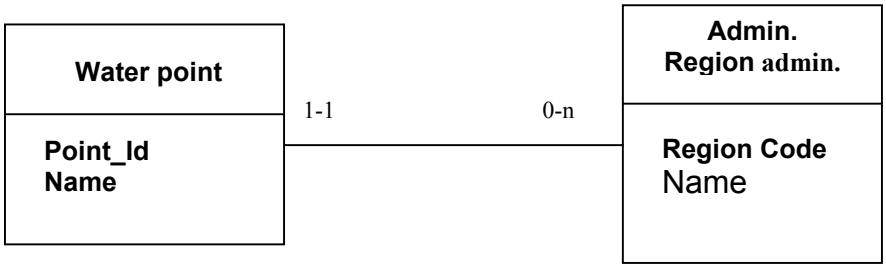
Their possible integration will not pose any problem. The same applies to other non provided items, since the same approach is applied.

2.2- Relational model

The transition to the relational model is a step which prepares for applying the DDM to the DBMS. According to the nature of the relations and according to the cardinalities obtaining from the management rules, transition procedures are applied.

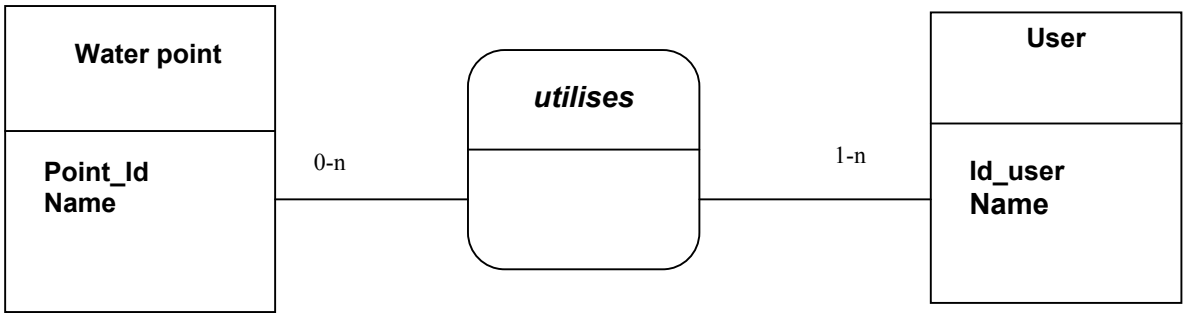
The types of relations between the items may be summed up as follows:

Case n° 1:



This relation translates that fact that an administrative region contains zero or several water points and that, consequently, a water point belongs necessarily to an administrative region.

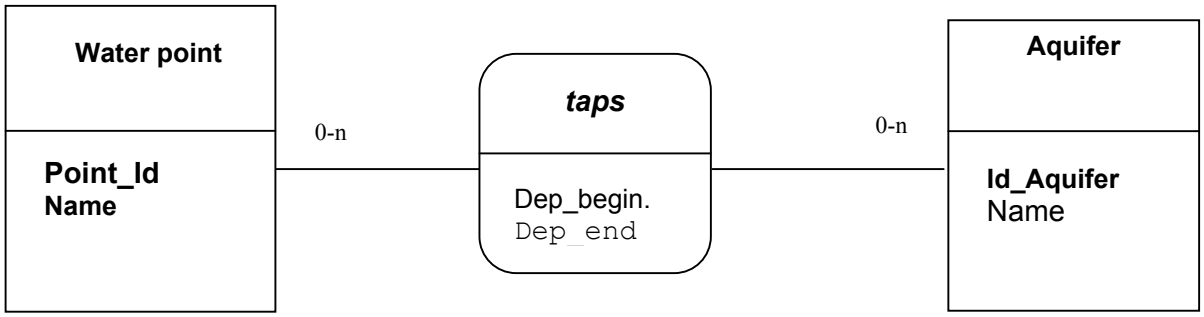
Case n° 2:



Between the items "*Water point*" and "*User*", the link may be expressed as follows:

- a same water point is intended for zero use (if it is not exploited) or for several uses ;
- a user may be supplied by one or several water points.

Case n°3:



Here, the relation "*taps*" itself contains attributes or properties.

The following rules are applied:

- all items become tables, and their attributes become fields ;
- for associations of type "*1-n*", the identifier of the main item migrates to the secondary item.

For the example illustrating Case n° 1, the transition to the relational model generates the creation of two tables: "Water points" and "Adm. region". The "Water points" table will comprise an additional field which is "region_code".

- the associations of the type 1-n (Case n° 2) are processed as follows:
  - apply rule n° 1 ;
  - create a third table which will comprise as an attribute the keys of the two other tables.

The example of Case n° 3 will translate, in addition to the creation of the tables "Water point" and "Users", into a third table "**Utilises**", containing the identifiers of the former two tables.

- The associations containing data (Case n° 3) are processed in the following way:
  - the associations become tables ;
  - for the keys, apply the preceding rules.

The output is identical to Case n° 2, except that the intermediate table thus created will comprise, in addition to the identifier, the attributes "depth_beg." and "depth_end".

2.3- Implementation under ACCESS

After the data model had been validated (workshop of 28 – 31 March 2000), it was converted into the ACCESS DBMS according to the rules outlined above.

2.3.1 Terms used

Table: set of data relating to a particular subject. A table presents a basic item of the ACCESS data base where the data are stored. The "Points" table contains the features of the water points. A detailed table contains several records (lines).

Linked (or connected) **table:** Table found in another data base (whether it is of ACCESS type or not).

Field: item of a table serving to contain data. A table comprises one or several fields (columns).

Primary key: unique identifier of each line in a table. A key may be either a field, or a mix of several fields.

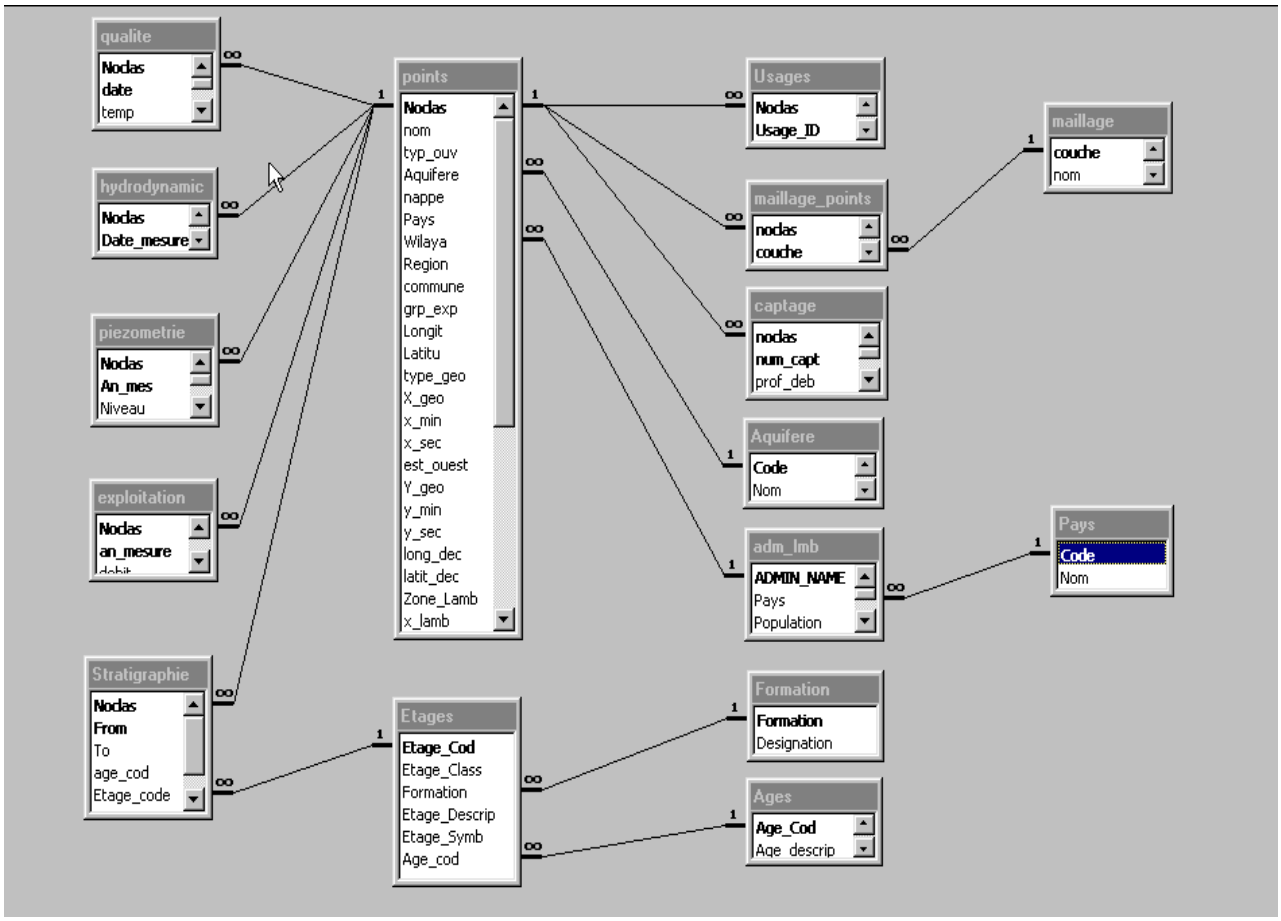
Referential integrity: mechanism preserving the relations defined between several tables when records are modified or cancelled. Referential integrity ensures the consistency of the values of the keys between the tables.

Query: object of an ACCESS base which allows a display, modification or analysis of data originating from one or several tables.

2.3.2 Diagram of the data base

The implementation of the system under the ACCESS DBMS has taken into consideration the specificities of the latter while integrating the data necessary for the DB-Digital model links. In fact, there were added to the DB structure certain specific tables, such as:

- “meshing”: describing the features of the net meshes (the possibility to execute more than one meshing is envisaged) ;
- “mesh-points”: comprising the mesh net number for each water point in the meshing under consideration.



The adding of these tables has been required by the choice of the PM5 software as a digital model.

Relations are established between the various tables according to the rules inventoried during the design study. These relations make it possible to maintain, upon each modification, the integrity of the system:

- it is not possible, for instance, to generate the record of a water point if the latter does not figure in the “**POINTS**” table ;
- if the identifier of a point has been modified, the set of related tables are automatically updated ;
- in the event of trying to cancel a Wilaya which comprises at least one water point, the system displays “error”.

These relations are basic to the development of queries and other data analyses.

This structure represents a sub-set of the global design model; only the data necessary to the SASS model have been taken into consideration. This has generated the tables described in Annex 1.

2.3.3 Consistency of the national DBs with the SASS DB

The common SASS data base, implemented under ACCESS, may be updated in various ways:

- by input forms ;
- by import queries from existing files ;
- by updating from the countries' data bases, in case the latter are perfectly compatible with the common DB.

In the framework of the project, and so as to meet the immediate needs of preparing the data for the digital model, the first two modes have been used:

- queries, conversion functions and modules have been developed for a transfer of the data supplied by the countries on computer medium ;
- input forms have served for entering the data collected by the SASS team from the documents and study reports conducted in the region.

It is, however, desirable that, as far as updates are concerned, the third process could be implemented in future.

It is for purposes of this objective that preliminary work of adaptation of the national data bases has been undertaken within the three administrations concerned, which aimed at making them more conform with the diagram adopted and facilitating the operation of data collection and transmission to SASS.

The structures of the three DBs have been reviewed and adapted so that they can be in perfect compatibility with the data model that has been designed.

Table 12: Correspondence between the SASS DB tables and those of the national DBs

Item designation	**Appellation in the three administrations**			
	ANRH	**DGRE**	**GWA**	Common DB
Geological ages	Ages	Ages	Ages	Ages
Geological stages	Etages	Etages		Stages
Aquifers	Unité_hydrog	nappe	Aquifer	Aquifer
Topographic_map	Carte_topo	Carte_topo	Topo_map	
Chemistry	A_chimie	Qualité	Chemical	Quality
Lithological descriptions	Litho_point	Litho_point	Lithology	Lith_point
Geological formations	Formation	Formation	Formation	
Abstraction records	A_Débits extraits	Exploitation	ExploitationalData	Exploitation
Lexis	U_lexique	Lexique	Lexique	Lexique
Hydrodynamic parameters	Param_hydro	Param_hydro	hydrodynamic	Hydrodynamic
Countries				Countries
Piezometry	A_piezométrie	Piézométrie	Periodical data	Piezometry
Water points	A_Ouvrage	Point d'eau	Wells	Points
Administrative regions	Wilaya	gouvernorat	Province	Admin_sass
1.1.1.1.1 Pollution source	Source_pollution	Source_pollution	Source_pollution	
Stratigraphy	Stratigraphie	Stratigraphie	Formation Members	Stratigraphy
Lithological unit	Lithologie	lithologie	Lith_Describ	Lithology
User	Utilisateur	Utilisateur	User	
Utilises	Utilise	utilise	Well-user	Usage

This table also shows the tables that have been created in the context of the SASS project, either entirely (shady colour) or based on fields figuring in other tables for purposes of observing the rules of relational bases (clearer colour). The “Lexis” table which groups all the codification tables, that is those comprising a code and a designation (usage, subject, user type, . . .), has been standardized.

This operation has involved the following aspects:

- More or less significant restructuring operations which may be summed up as follows:
  - addition of non existent tables ;
  - restructuring of tables and fields ;
  - modifications concerning the codification (lexis) ;
  - development of missing relations between tables (so that the DBMS could secure integrity controls).
- Global adaptations and harmonisation of codifications for the common data base ;
- Definition of a strategy for recovery of the existing data for purposes of facilitating the transition to the new situation.

This work remains, of course, in need of being complemented by actual implementation and by the transfer of all existing data. Similarly, procedures of updating the national DBs according to the regional DBs need to be established.

The following table gives a synthesis of the changes introduced in each of the DBs of the three countries.

Table 13: Adaptations and improvements introduced in the national DBs

Institution	Adaptations introduced
ANRH	- Adding of tables: construction, log, lithological unit, geological stages and ages, user, climatological station, climatological record; - Change of structure for almost all tables; - Arrangement of lexis and creation of separate tables: Wilaya, hydrogeological unit, basin, lithology and transfer of corresponding data (the latter being previously generated based on the lexis); - Deriving of hydrodynamic parameters previously figuring in the “A_Ouvrage” (Structures) table; - Adapting of codifications.
DGRE	- Grouping within a single base and making the disparate DBs consistent; - Creation of missing relations between the items for purposes of ensuring integrity controls; - Adding of “Aquifers”, “Hydrological Regions”, “Hydrological Sector”, “Catchment Areas”, “Governorates”, “Sub-regions”, “Districts” tables; - Revision of the structure of the table “*Water Points*” and import of available data relating to SASS; - Adapting the lexis to SASS needs, while taking into consideration the codifications existing at DGRE; - Conversion and transfer of exploitation and piezometry data to the new structure.
GWA	- Restructuring certain tables: “Water Point”, “Chemistry”, “Lithology”; - Adding of non existent tables: “Topographic Map”, “Users”, “Hydrogeological Unit”, “Hydrogeological Parameters”, “Climatological Station” and “Climatological Record”; - Standardisation of common lexis and establishment of correspondences between the French and English descriptions.

The improvements and adaptations thus made relate, therefore, only to the design aspects (structures of the DBs) even if, partially, certain data have been also transferred. It belongs to the country teams to make these DBs operational and to ensure their management. For so doing, an initiation into the ACCESS DBMS has been provided to the national experts (see contents in Annex).

2.4- Data safety strategy

Five broad groups of users have been identified, including the system manager, whether with regard to the national DBs or within SASS. These groups of users are:

- **The system manager**: who needs to have all authorisations and all full access ;
- **The team assigned to information updates**: rights of data addition and modification;
- **The modelling team**: possibility of updating the tables pertinent to the DB-Model links (net meshing, for instance) ;
- **Decision-makers**: guided browsing and synthesis queries ;
- **Other users (guest users)**: guided browsing (consultation only).

The SASS DB may be consulted by the three countries, but no updating is allowed (group 2 does not exist in this case).

The following table shows the nature of the processing operations allowed to each of the user groups:

Table 14: The different groups of users and their authorizations

Group	Rights
1. System manager	- modification of structure of the tables - updating of system tables - transfer of data from the three countries (or from the regional services, for national DBs)
2. Team assigned to information updates	- guided browsing ; - access to updating forms
3. Model team	- all selection queries: digital or spatial - updating of the tables relevant to the model - procedures of mesh net generation and assignment of mesh numbers to water points - inception of modules of preparation of data for PM5
4. Decision-makers	- other synthesis queries - thematic cartography, graphs, summary tables
5. Others	- guided browsing

Access accounts and codes have been assigned to each of the groups for purposes of ACCESS to the common DB.

As regards the national DBs, the designated manager will define himself the access authorisations according to context and organisation in place. He may extend them or limit them in view of the rules in force.

The inclusion of new data issuing from the countries may be done via a procedure using replication.

"Copy process of a data base so that two or more copies may exchange updates of information or forms, reports or other replicated items. This exchange bears the name ***synchronisation****. Each copy of the data base is called* ***replica*** *and contains a common set of tables, queries, reports, forms, macros and modules. Each replica may also comprise local items which exist only in the replica concerned."*

Definition supplied by MicroSoft

The problem of updating arises when one does not use a centralised single data base, but rather external copies, as is the case for SASS. When various users enter or modify data, the latter need to be synchronised so that they can work on the same base. So that this synchronisation becomes possible, the data base needs to be converted into a replica, which is established following a replication. The latter is a function offered by the data bases management systems. After several updates on a distant data base, a successful synchronisation will make all the replicas consistent. While it is possible to have as many replicas as necessary, there can only be a single master replica. These replicas contain all the information of the data base. However, in the event that we should need only part of the data, a solution is required: it consists in creating a partial replica by applying a filter of one or more tables in order to retrieve only the data needed.

Example: Each of the countries needs only the data relevant to the zone that it manages; in this case, a partial replica is made for it with, as a filter, the field "*Country*". This data base, thus replicated, will be used normally within these countries for their own needs and, at any moment, a synchronisation may be done at SASS level (where the master replica is located), which guards against variances and makes all the data mutually consistent.

In order that this synchronisation, which is executed automatically by the ACCESS DBMS, becomes reliable, the data common to the three countries need to be updated at master replica level by the SASS data base manager.

For future updates, there will therefore be no need to enter the data in the central data base: only the countries are eligible to do this each for the part that is relevant to it (partial replicas).

In the case where this possibility cannot be implemented, a withdrawal solution has been provided which consists in updating and entering new data directly in the common DB by means of forms and modules developed for this purpose. For so doing, entry files (see Annex) have been designed.

2.5- Description of GIS

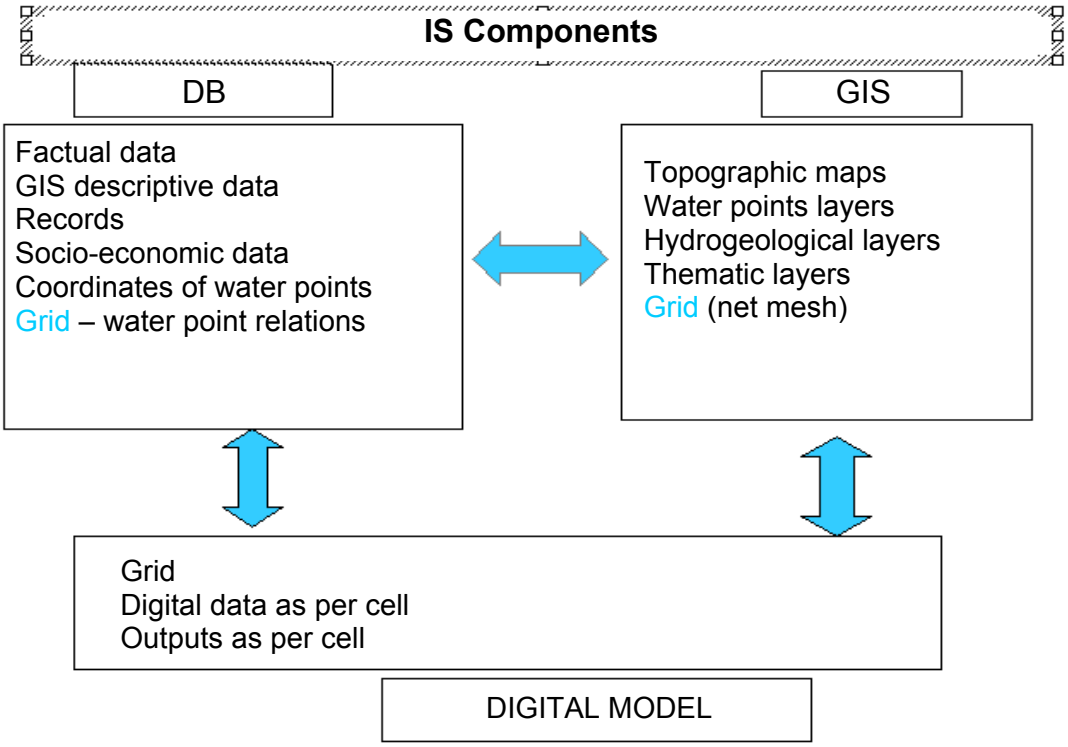
2.5.1 Integration of GIS within the global IS

GIS is designed to be an integral part of the global IS, insofar as the descriptive data of the geographic items are provided in the structure of the data base. The objective being that each item of information should be stored at a single location (no redundancy).

The second objective relates to the DB-Model and GIS-Model links which need to be executed in an automatic way and one that is transparent for the user.

The Information System thus comprises three main components which are: the DB, the GIS, and the digital model. The net meshing of the model, which is at the same time a table of the

DB and a layer of the GIS, makes it possible to provide these links, as illustrated by the following diagram:



The DB – GIS links translate into:

- an integration of the descriptive data relating to the geographical layers in the DB so that they can be used in queries even outside of the GIS. Redundancies are avoided, as the information is stored only in one location ;
- the creation of GIS layers for the whole set of data likely to be made into a map or to form the subject of spatial queries: when designing the DB, an inventory of these items was made (abstraction zone, aquifer, administrative units . . .).

Accordingly, any query made on the DB may, without difficulty, form the subject of a thematic cartography.

The DB-Model connections consist in preparing these input data, and are translated basically into:

- a calculation of the abstractions of each net mesh of the model ;
- the automatic constitution of basic files used by the PM5 software (the latter having been chosen as a modelling software).

Two solutions are possible to manage the whole set of data within the same data structure and to meet the project needs:

- within the ARCVIEW environment, where it is possible to access the information in the DB ;
- under ACCESS, and in this case it should be possible to visualise the GIS layers.

Whichever solution is adopted, interfacing modules are necessary to globally manage all the information and to ensure links between the geographic data and their descriptive attributes.

2.5.1.1. ARCVIEW solution

The ARCVIEW software 3.2 comes with, in addition to the integration of the DBASE and INFO formats in native mode, an access extension to data bases (*Data Base Access Extension*) which allows connection, via the ODBC protocol, to the whole set of DBMSs available on the market.

A user familiar with these procedures would be capable of performing this type of processing within the ARCVIEW software. There are, nevertheless, particular processing operations which cannot be performed without the development of specific modules, especially when these are repetitive.

In such a case, the use of the language "***AVENUE***", also supplied with ARCVIEW 3.2, becomes indispensable.

This solution presents the following disadvantages:

- this is a language that is not mastered by the country experts ➔ maintenance difficulties ;
- ESRI tends somewhat to abandon this language: with these new products, it is rather the language **Visual Basic** that is proposed ;
- the time periods for the execution of the interfaces are longer: it is not fitted with rapid development tools (user-friendly interface, items explorer, assistance software . . .).

2.5.1.2. ACCESS – MapObjects solution

This solution requires the purchase of a special utility that allows the development of access utilities to the GIS layers in order to make possible the main operations of display, selection and handling of geographic objects (items) outside of the GIS software.

ESRI proposes "MapObject", which is a set of components usable based on any other advanced language (VB, C++, DELPHI . . .) to execute the basic GIS tasks: visualisation of ARCVIEW layers, spatial queries, control of map windows . . .

Accordingly, it is possible to execute the DB – GIS – Model interfaces under ACCESS environment, that is while remaining within the data base which, it is worth mentioning, is the most commonly used.

The advantages of this solution are the following:

- the development language remains VBA which is common, easy to use and, therefore, makes maintenance easier ;
- the user is always within the data base environment where he/she performs the major part of the processing operations: consultation and updating of data, statistical and synthesis queries, multi-criteria searches . . .

The only disadvantage lies in the need to purchase "*MapObjects*". The "*MapObjectLT*" version, which is considerably less costly, has been selected and purchased for the SASS project.

Even though the latter version is limited, it does allow, nevertheless, the execution of all the operations required for the development of the interfaces:

- visualisations of ARCVIEW layers, with the control of map windows (Zoom, Pan, Identify . . .) ;
- geographic selections and queries of attributes ;
- development of thematic maps.

The only limitation relates to the impossibility to create SHP files, which is indispensable for generating net meshing, for instance.
In order to circumvent this constraint, there is a solution that consists in developing in VBA the function of read/ write of the files in SHP format whose detailed structure has been found in the ESRI documents.

The solution "*MapObjectsLT*" has, therefore, been selected for the development of the modules necessary for the DB – GIS – Model interfaces.

2.5.2- GIS coverage

The whole set of GIS layers developed under the project belong in the Lambert Sud (South) projection system with the following features:

Ellipsoid:	Clarke 1880
Central meridian:	2.7
Reference parallel:	33.3
Latitude south:	31.733928
Latitude north:	36.866072
False easting:	500135
False northing:	300090

The maps have been made according to ARCVIEW 3.2 SHP format. This involves the following layers:

2.5.2.1 Topography and basic maps

- Hydrographic network ;
- Level contours: equidistance 100 m ;
- Chotts and depressions ;
- Level elevation points ;
- Major towns, as obtaining from DCW and from the numbering of the ERESS maps ;
- Main roads ;
- Administrative units (Wilaya, Governorate, Province . . .) ;
- Boundaries of the communes, covering the Algerian part and obtained from INCT.

This map has been constructed, for the major part, by the IMAGIS (Algiers) and SOMAPHO (Tunis) Consultants.

2.5.2.2. Digital land model covering the study zone

- Grid (1 km side) processed by means of "*Spatial Analyst*" which features the possibility of obtaining level contours and level elevation points.

2.5.2.3. Hydrogeology

- Water points: direct connection with the DB ;
- Boundaries of main aquifer systems (IC and TC) ;
- Faults ;
- Initial piezometric map ;
- Boundaries of artesianism.

2.5.2.4. Hydraulic parameters

- Transmissivities map.

2.5.2.5. Abstraction zones

- Boundaries of exploitation groups.

The digitalisation of these items has been made in part for Libya and for Tunisia.

2.5.2.6. Geology

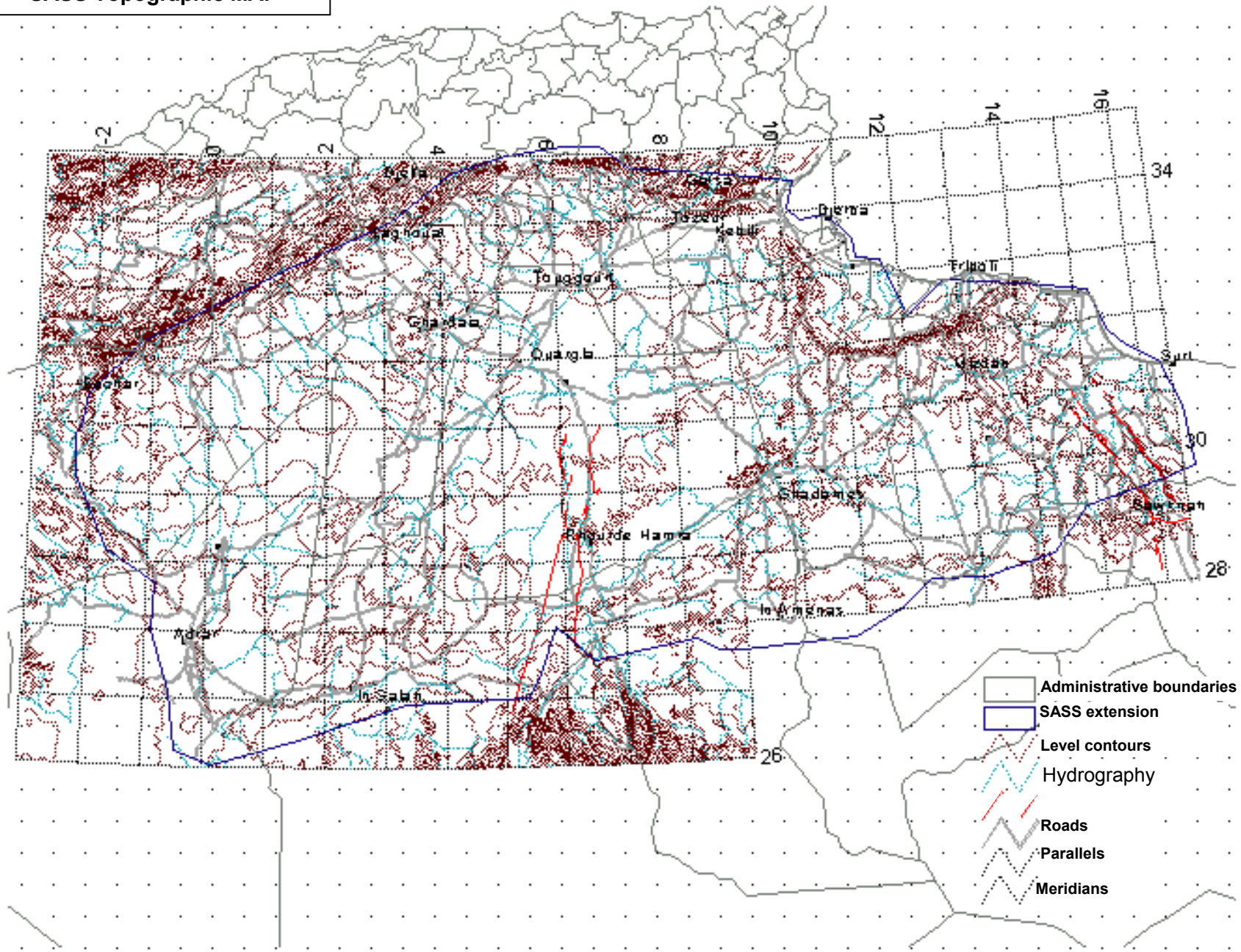
- Geological map of SASS zone at scale of 1/2 000 000:

This map has been made in the framework of the project. It represents the synthesis of the whole geological data on the outcrops of the various layers.

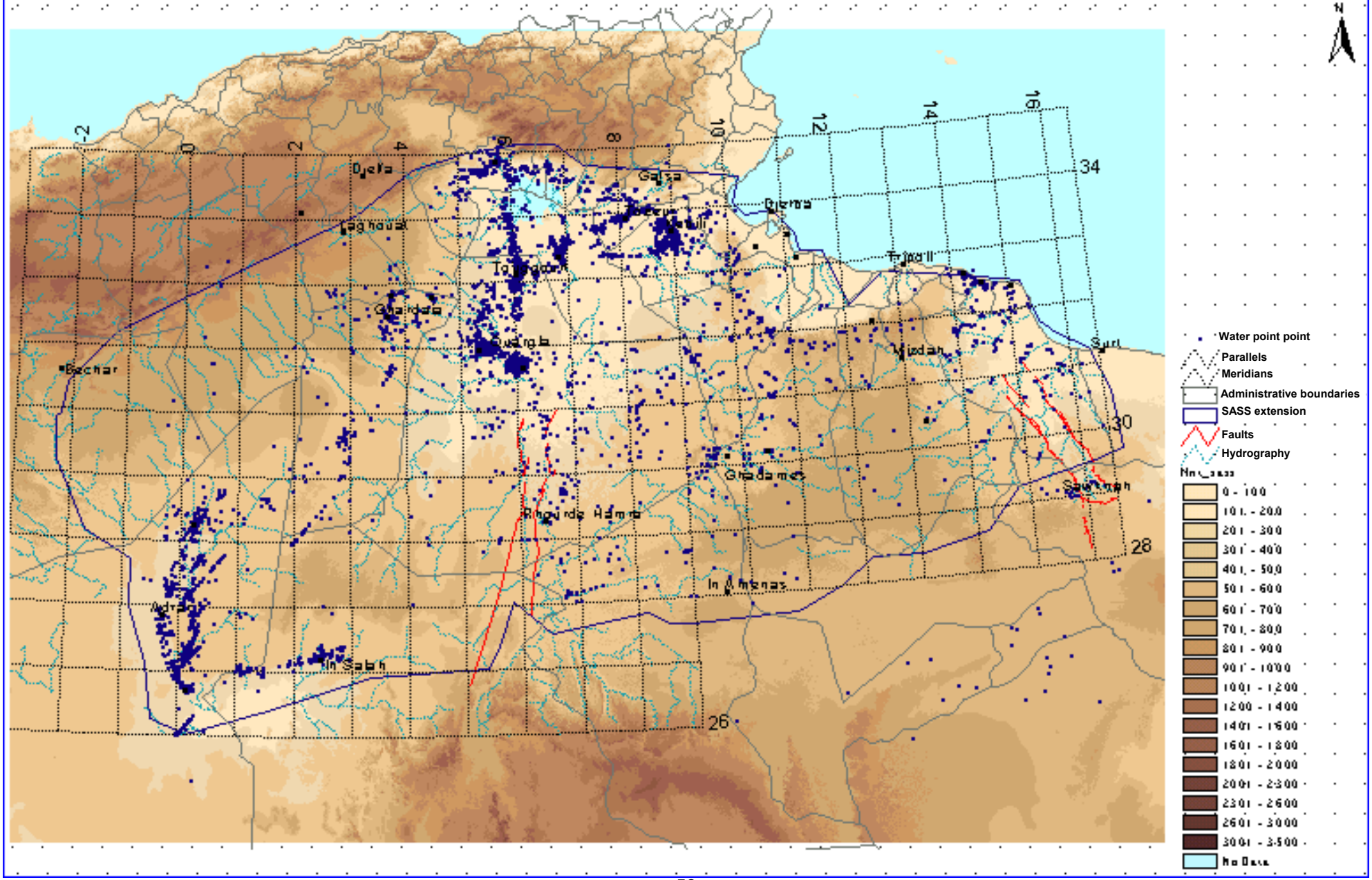
- Grid (net mesh) of the MP5 model:

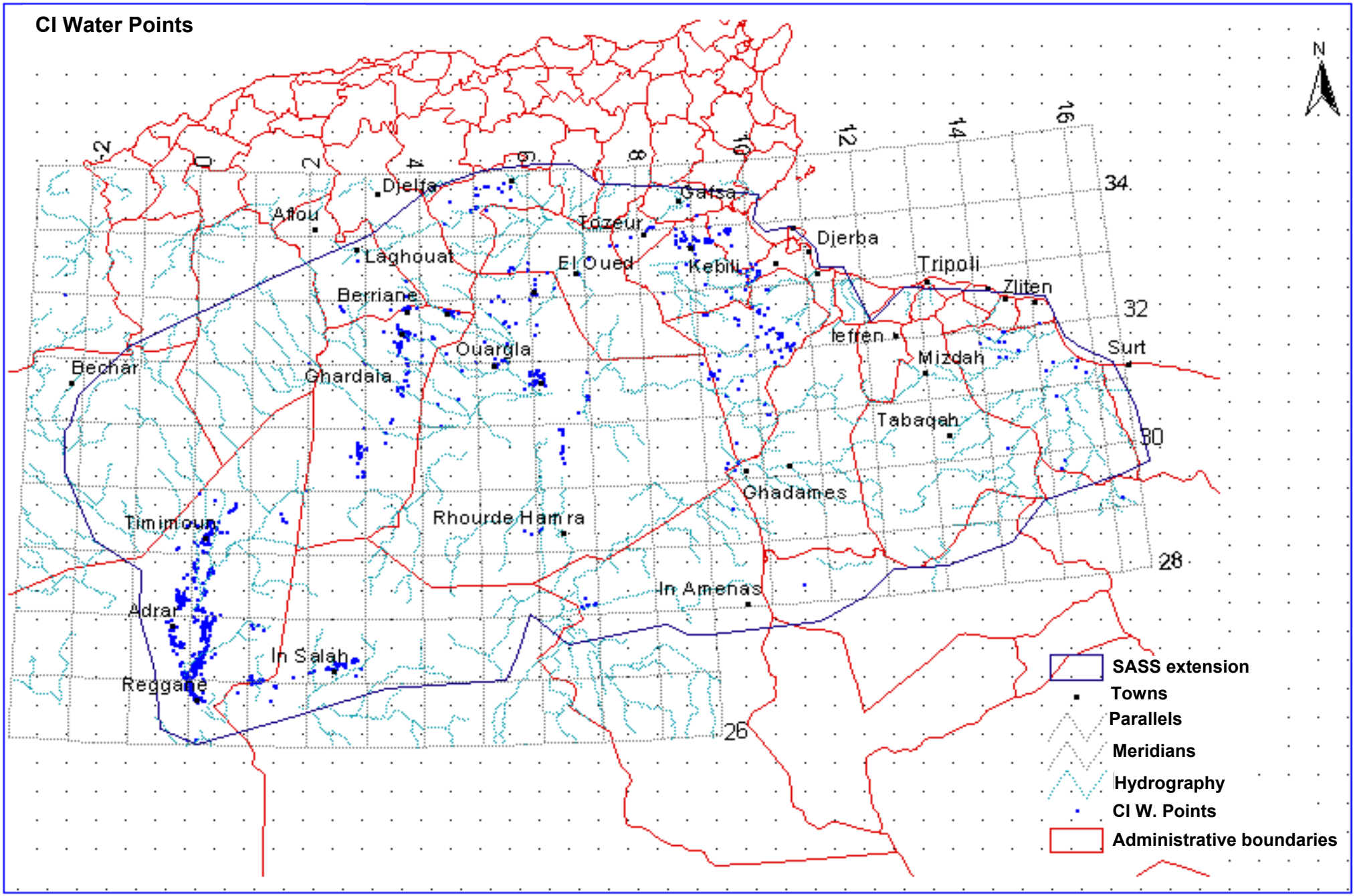
A grid (net mesh) for each layer of the model: IC, TC, “Grès Supérieurs” (Upper Sandstone) and Turonian.

SASS Topographic MAP

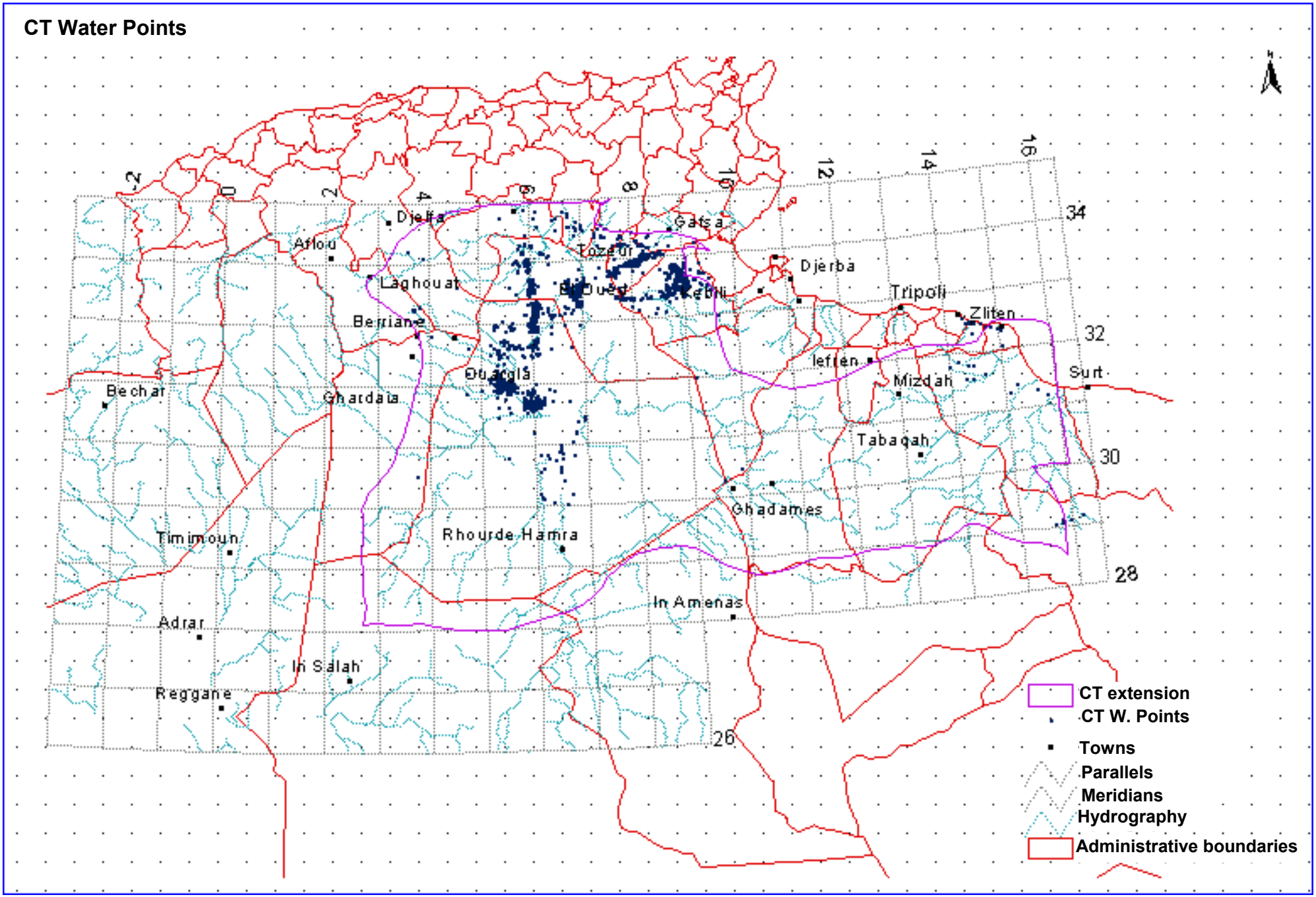


Digital Land Model

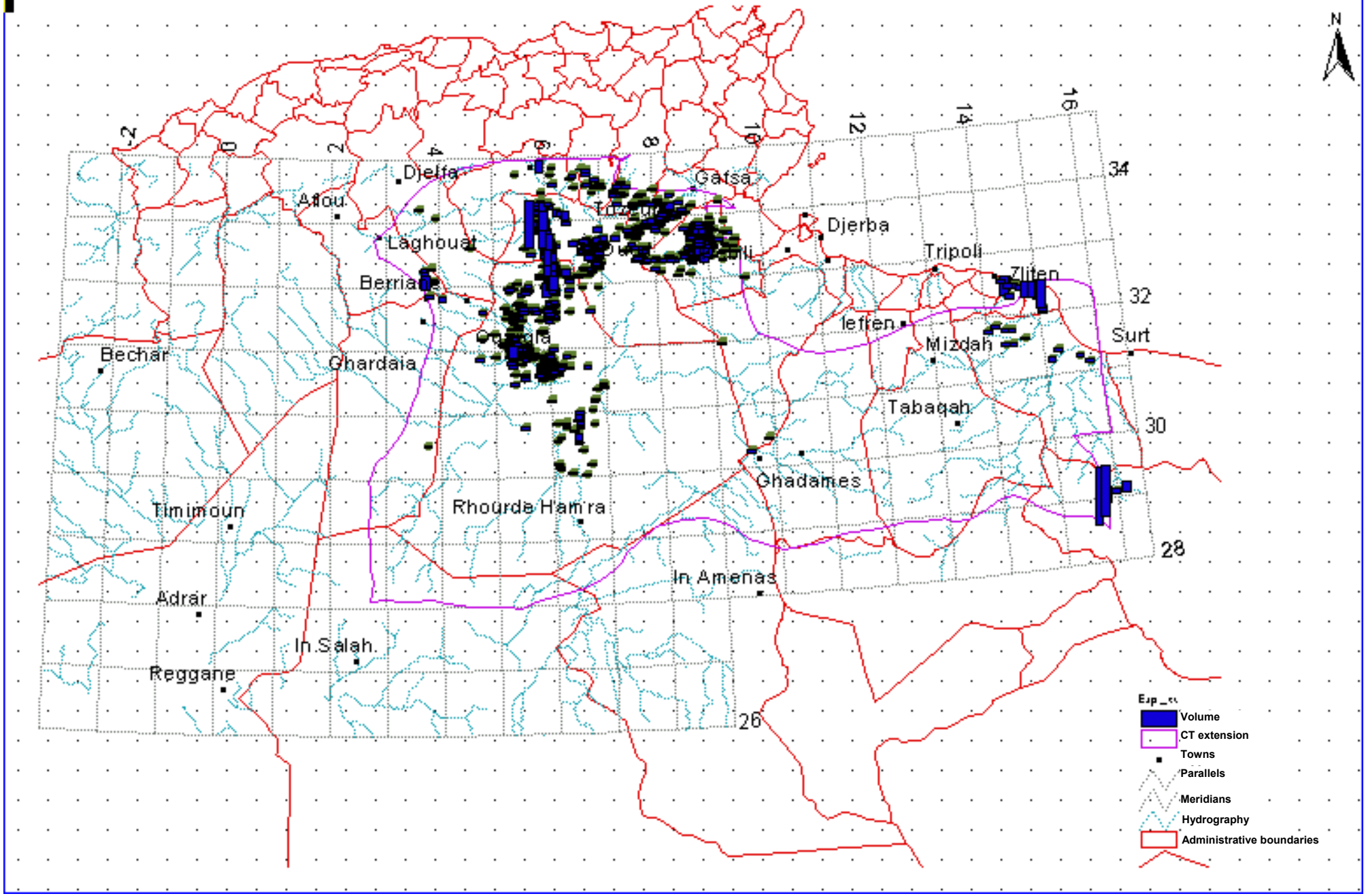


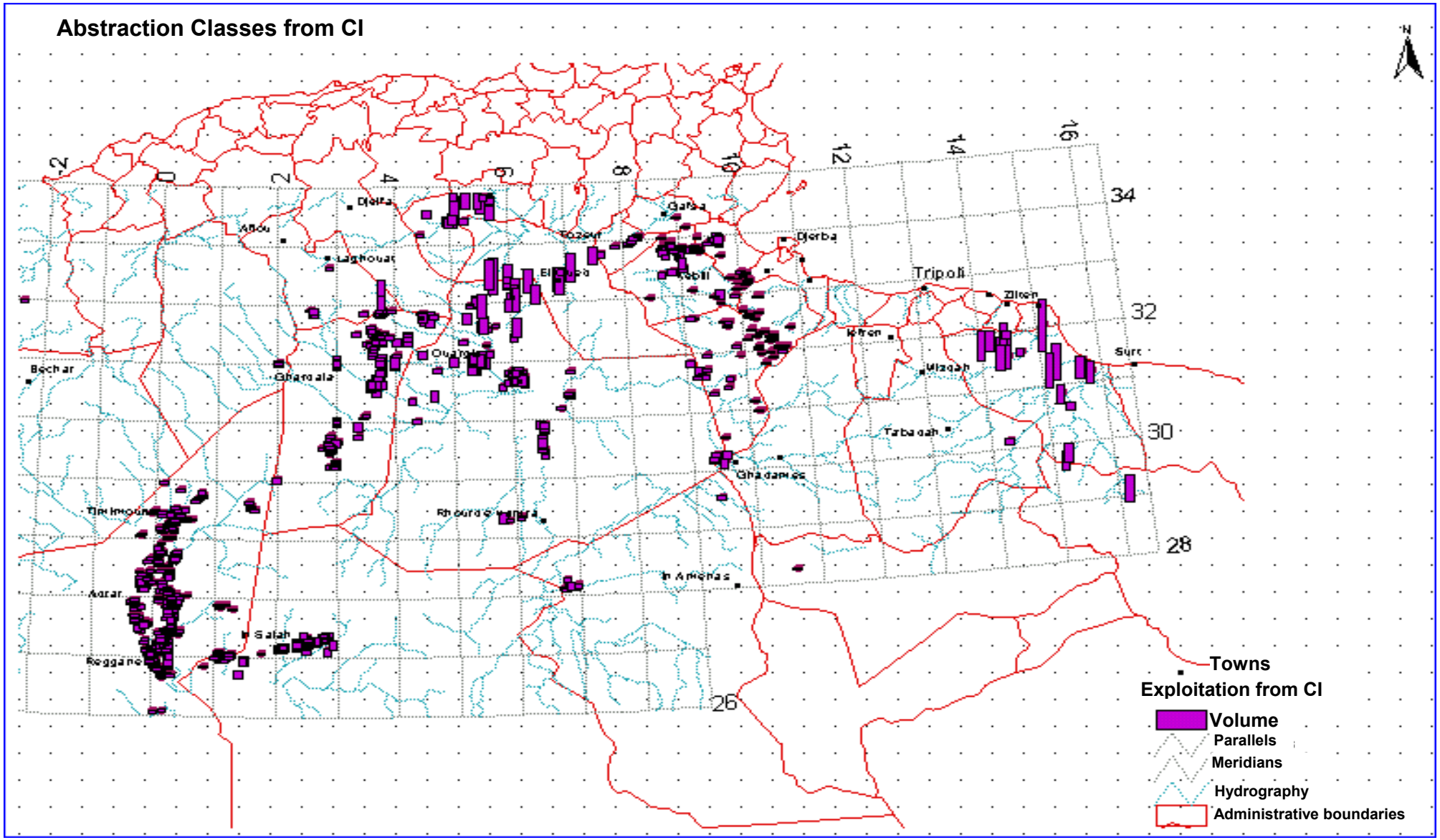

CI Water Points
N
Djelfa
Aflou
Laghouat
Berriane
Ouargla
Ghardaia
Bechar
Timimoun
Adrar
In Salah
Reggane
Rhourde Hamra
In Amenas
Ghadames
Tozeur
Gafsa
El Oued
Kebili
Djerba
Tripoli
Zliten
Nefren
Mizdah
Tabaqah
Surt
34
32
30
28
26
SASS extension
Towns
Parallels
Meridians
Hydrography
CI W. Points
Administrative boundaries

CT Water Points



Abstraction Classes from CT




Abstraction Classes from CI
N
0
2
4
6
8
10
12
14
16
34
32
30
28
26
Djelfa
Laghouat
Ouargla
Bechar
Ghardaia
Tinghoud
Adrar
Reggane
In Salah
Rhourde Nouss
In Amenas
Ghadames
Nalut
Djerba
Tripoli
Zliten
Khoms
Misrata
Tarhouna
Sirt
Towns
Exploitation from CI
Volume
Parallels
Meridians
Hydrography
Administrative boundaries

3- DESCRIPTION OF FINAL PRODUCTS PRODUCED

The execution of the SASS data base and of the management and processing tools has generated operational final products that have been tested and used in the context of the project. These products are described in summary fashion in the present chapter (for further details, please refer to Annexes 2 and 3):

- the data base and the management procedures ;
- the GIS and the scripts developed for the project's specific needs ;
- the processing tools composed of statistical queries, the DB – PM5 interface and the DB – GIS links.

3.1- The data base

In order to allow a flexible use of the system, it was decided to breakdown the ACCESS data base into two parts:

- a first part comprising exclusively the tables gathered in a single data base file, namely the part "***Data***" ;
- a second part comprising the management tools, queries and reports, as well as the specific modules and functions, gathered in another ACCESS file, namely the part "***Programmes***".

This process offers various advantages, among which:

- a greater protection of the data against possible handling errors ;
- the possibility of sharing the base containing the data and, therefore, using it in a Multi-user environment: centralised data base ;
- greater possibilities of advancement and development of specific tools ;
- the possibility of using a DBMS other than ACCESS to manage the central data base.

Table 15: ACCESS files making up the SASS DB

ACCESS file	Contents	Observations
SAGESSE_data.mdb	Data tables	May be shared Only a system manager may access it directly
SAGESSE.mdb	Specific forms, procedures and functions Queries, reports	May be installed in several customer stations (network) Possible addition of specific functions
System_sag.mdw	Users groups Access rights	Managed by the DBMS Maintenanced by system manager

The "Programmes" – "Data" link is made by means of a connection mechanism which consists in accessing and updating the information existing in a distant base of ACCESS type or other (SQL SERVER, ORACLE . . .).

Several users may share one same and sole data base ➔ uniqueness of the data source. Besides, each user may develop specific programmes and queries in addition to those that have been developed in the course of the project.

The protection of the data is secured, since no one can have direct access to the tables of the “Data” base except the system manager.

Via the “Programme” base, access is regulated by the authorisations granted by the system manager to the various groups, each of which having an account and a password.

3.1.1. Presentation of the data tables

The “Data” part is composed of the following data, classified by class:

- Identification, location and features of the water points ;
- Lithological description, geology, top and bottom of the layers collected ;
- Descriptive data on the spatial units (administrative region, abstraction zone, aquifer . . .) ;
- Records: levels, exploitation, quality ;
- Summary data on water use ;
- Codification glossary ;
- Utility tables used by the system for its operating.

3.1.1.1. “Points” table

This is a table that contains all the data relating to the identification and the location of the water points.

The identifier, or primary key, of each record is the classification number (“*NoClas*”). The codification already existing in the countries concerned has been kept for practical reasons. There are no duplication risks, since the way a field is codified differs from one country to another.

Besides, the adoption of a SASS specific codification would have required a renumbering of the water points and ensuring a “national code” – “SASS code” correspondence.

Codification in force

ANRH: the code comprises 9 alphanumeric positions having the format “A999-99999”, where:

- A999: represents the number of the square in which the structure is located within a grid of 1 square grade in the Lambert Paris system. The ordinates are expressed by means of a letter (A to V) and the abscissa are expressed in figures ;
- 99999: is the sequential n° of a water point in the grid.

DGRE: the NRH n°, code assigned by the inventory office, is expressed in 8 numerical positions according to the 99999-99-9 format, where:

- 99999: chronological n° in the region ;
- 99: 00, 01, 02 or 03, serving to indicate the successive replacements ;
- 9: n° of region.

GWA: the codification used is of the type *T/2B/0030/0/85*. This code is distributed as follows:

- letter representing the location where the authorisation has been delivered (T for Tripoli, for instance) ;
- 9A, code of the sector in the region ;
- 9999, being the sequential n° of the water point ;
- 9 is assigned value 1, in case of a replacement drilling, 0 otherwise ;
- 99: these two figures designate the water point construction year.

The water points that are not provided with a national identifier have been codified at SASS.

3.1.1.1.1. Coordinates

The location data have been enriched and made consistent. Two classes of coordinates are possible: decimal and Lambert degrees. For this purpose, the following fields have been created:

- "**Type géo**" (Geographical type): which may be assigned "*D*" values if the coordinates are expressed in degrees, "*G*" if they are expressed in grades and "*L*" if they are given directly in Lambert ;
- "**Long_dec**" and "**latid_dec**": which contain the coordinates in decimal degrees. These fields are automatically calculated upon entry of the data ;
- "**Zone_UTM**": in order to indicate the UTM zone (value in the range of 29 to 33).

3.1.1.1.2. Type of water point

The following water point types have been listed: drilling, spring, foggaras, piezometer, artesian well, oil well, hand operated borer (DGRE).

For purposes of the project, other types have been created: exploitation group, foggaras group.

*3.1.1.1.3. AquiferThis field provides a connection with the "*Aquifer*" table, and may contain he following values:*

Table 16: Codification of the aquifers and PM5 numbering

Code	Name	Model layer
CI	Intercalary Continental	5
CT	Terminal Complex	2
GS	Upper Sandstone	4
IN	Indeterminate	0
TU	Turonian	3

3.1.1.2. "Exploitation" table

Two fields contain abstractions data: the flow expressed in l/s and the annual volume expressed in m3/year. The entry of any of the two fields triggers the automatic calculation of the other.

The table comprises the annual abstractions records. To each datum is related the information source that supplies it:

Table 17: List of the various sources of abstraction records

Origin	Significance
ERESS:	Records used in the ERESS study
Invent. Foggara:	Data obtained from inventories of foggaras
Invent. ANRH:	Inventories conducted by ANRH or by the DHW, and under ANRH control
RAB:	Records used in the context of the RAB project
SASS:	Data collected and entered by the SASS team
DGRE:	Records made by DGRE
GWA:	Data supplied by GWA

3.1.1.3. « Piezometry » table

Two fields have been provided for the storage of data: the static level and the piezometric level. This situation has been required by the fact that certain level values have been found only under the form of piezometric levels.

At data input time, an only one datum is entered, the other being automatically calculated when the altitude of the water point is provided.

Similarly to the case of abstractions, a field intended to contain the origin of the information has been created:

Table 18: Origins of the piezometric data

Origin	
Piezometry Yearbook	DGRE piezometric yearbooks
ANRH	Data supplied by ANRH
ARMINES_ENIT	Records of levels used in the context of the ARMINES/ENIT study
BRL	BRL study (1994): Libyan part
BRL (1998)	BRL study (1998): Algerian part
DRE_1981	Records made by DGRE
ERESS	ERESS study
GEOMATH	GEOMATH study (Libyan part)
GWA	Data supplied by GWA
RAB	Records used in the context of the RAB project
DGRE unpublished reports	Collected in unpublished reports

3.1.1.4. Geology related tables

The organisation of geological data is made by means of tables:

- « *Ages* »: this table contains the geological ages codified as follows:

Table 19: Contents of the « Geological Ages » table

Age_Cod	Age_descrip
02	Quaternary
03	Quaternary - Neogene
04	Neogene
05	Neogene Palaeogene
06	Palaeogene
07	Cretaceous
08	Jurassic Cretaceous
09	Triassic Jurassic
10	Trias
11	Carboniferous
12	Devonian
13	Silurian
14	Ordovician
15	Cambrian Ordovician
16	Precambrian

- « *Stages* »: this table contains a list of the stages relevant to a given geological age.

Table 20: Example of Neogene stages and formations

Stage_Cod	Stage_Class	Formation	Age_cod
0400	N	MP	04
0401	N2	MP	04
0402	N1	MP	04
0403	N13	MP	04
0404	N12	MP	04
0405	N11	MP	04
0406	N-Pg	MP	04

- « *formation* »: this is a table which presents the appellation of the litho-stratigraphic formations existing in the SASS zone. For example, the table below presents the stages belonging in the Secondary:

Formation	Designation
SenC	Carboniferous Senonian
SenL	Lagoon Senonian
Trias	Triassic
Tu	Turonian

- « *stratigraphy* »: this table contains the description of the various layers crossed by the drilling.

A module has been developed for the automatic transfer of the geological data derived from the « ROCKWORKS » software. It gives the tables relevant to the “Geology” domain.

The data of the EXCEL table generated by ROCKWORKS are distributed across the ACCESS tables provided for this purpose, as illustrated by the following table:

ID	X	Y	Z	MP	Em	Ei	Pal	Sen	Sen	Tu	Ce	CIK	LIK	Tria	Palz	Td
Ab 2	-	185	679	679	659	659	659	659	659	659	609	529	-538	-538	-538	-538
Al 1	-	-	440	440	440	440	440	370	370	370	350	327	-251	-251	-251	-351
Aj 1	-	105	540	540	540	540	540	540	540	540	540	468	-658	-758	-758	-758
AMg	-	16	659	659	499	499	499	499	499	499	499	499	169	169	169	169
Arb 1	265	2	175	175	-40	-40	-40	-40	-200	-500	-	-784	-1532	-	-	-
Baa	3	220	430	430	300	300	300	300	130	-70	-	-366	-1225	-	-	-

BAR	283	302	46	46	-	-	-	-	-534	-624	-	-	-2989	-	-	-

Noclas	From	To	Age_cod	Stage_code	Formation
Ab 2	0	20	06	0613	Em
Ab 2	20	70	07	0710	Cen
Ab 2	70	150	07	0711	CIK
Ab 2	150	1217	08	0801	LIK

Stratigraphy Table

In addition to the lines series relevant to stratigraphy, a record is generated in the « *Points* » table. The fields « *Noclas* », « *X_lamb* », « *Y_lamb* » and « *depth* » are automatically updated by the transfer model.

3.1.1.5. Link tables via the PM5 model

The DB – Model connection is provided via the following tables:

- « *aquifer* » by including in it the field « PM5 layer n° » ;
- « *Points-maillage* » (points grid (net mesh)) which contains for each water point its net mesh n° ;
- « *Aliment* » (recharge) where the aquifers recharge values are given in m3/s in the middle of the net meshes.

« *Points-maillage* » (points grid (net mesh)) table:

This table provides the link between the water point and its net mesh number within a given net meshing. The assignment is made automatically by the system, by means of a procedure that is developed further off, according to the water point coordinates.

It is actually the table which performs the interface between the DB and the PM5 model at the time of preparation of the input data.

This approach allows a better flexibility in the data management and updating, since the basic information is no longer the net mesh but rather the water point: a net meshing change does not affect at all these data bases (original information). It henceforth becomes possible, thanks to this architecture, to reuse the whole data

collected and organised during the SASS project, which is not the case for the other studies conducted so far.

«*Aliment*» (recharge) table

This table has been created in order to contain the aquifers recharge values, since the PM5 model does not distinguish between abstraction and recharge (it needs the algebraic sum of the two values).

Its structure resembles that of the « *points* » table, but contains only the identifier (which may be the n° of the cell, for instance), the aquifer, the coordinates and the recharge value in m3/s.

3.1.2 The «programs» part

As to the « Programmes » part, it groups the other ACCESS items necessary for data management and processing. A certain number of tools have been developed in order to make it possible:

- to enter data, visualise them and introduce corrections ;
- to query the system in order to obtain synthetic and crosscheck tables, as well as to prepare modelling process procedures ;
- to automatically execute changes of coordinates, as well as to prepare cartographic representations ;
- to update the system and to introduce consistency in the data collected by the country teams.

3.1.2.1. Data entry and modification forms

In order to execute the entry and updating of the information, a certain number of forms have been designed. However, they have not been actually used as the entire body of data has been transferred by means of queries. They are, nevertheless, useful for the display of the of the whole data related to a given water point, for performing graphic visualisations and for retrieving records that meet a given criterion.

They may be adapted and complemented for exploitation at the level of the national DBs.

A multi-tab form has been designed to contain the whole set of data concerning a given water point. A common area comprises the identification number and the name of a flowing water point (see Annex 2).

There are many advantages to be obtained by using forms, of which:

- entry of controlled and, therefore, more reliable data ;
- possibility to act simultaneously on data originating from several related tables (sub-forms) ;
- greater flexibility offered by the controls (streaming lists, buttons . . .).

3.1.2.2. Queries

The queries made during the SASS project may be classified into four groups relating to:

- data updates: these are by far the largest in number, as they have made it possible to convert, transfer and organise the data originating from existing files ;
- statistics and synthesis: these are used for purposes of data control ;
- specific: these prepare for pre-model processing operations and DB – GIS links ;
- selection and display of various data.

3.1.2.3. Modules

The major processing operations relate to the DB – SIG and DB – PM5 interfaces:

- procedure for setting up the «*well.dat* » file ;
- automatic generation of the grid (net mesh) according to criteria supplied by the user ;
- DB – GIS synchronisation in case of modification of the coordinates of water point at the level of the data base ;
- Automatic assignment of PM5 cell numbers to all points provided with coordinates.

However, many procedures and functions have been developed via the VBA language for the execution of specific tasks. They are called for by the forms and by the queries (see Annex 2, for further details).

3.2- Data analysis tools

3.2.1. Statistical queries

Table 21: Percentage of gaps concerning the identification – location fields

Field	Designation	Non zero values	Percentage of gaps
NoClas	Identification number	5598	25,14%
nom	Name of water point	7202	3,69%
typ_ouv	Type of water point	7467	0,15%
Aquifere	Aquifer code	7172	4,09%
Pays	Country code	7469	0,12%
Wilaya	Administrative region	6241	16,54%
long_dec	Longitude in decimal degrees	6575	12,08%
latit_dec	Latitude in decimal degrees	6580	12,01%
x_lamb	X Lambert	7061	5,58%
y_lamb	Y Lambert	7061	5,58%
Datfin	Construction date	5192	30,57%
Altitu	Altitude	2651	64,55%
ProInv	Total depth of water point	5064	32,28%

3.3- The SAGESSE software

The building of the SASS data base has led to the establishment of a considerable number of tools having served for:

- transferring the data made available by the countries for purposes of the project ;
- entering new data ;
- undertaking the necessary checks and corrections by data entry form and in an interactive manner ;
- developing statistical and synthesis queries allowing permanent control of the reliability of the data collected ;
- executing the interface with the PM5 model and thus automating the preparation of the data for purposes of the latter model ;
- ensuring the DB – GIS connections by means of the specific functions.

These tools, which have been developed in ACCESS environment as the contents of the data base were being made, have been grouped within a single package dubbed « *SAGESSE* » (**S**ystème d'**A**ide à la **G**estion des **E**aux du **S**ahara **Se**ptentrional) (North-Western Sahara Waters Management Assistance System).

The initiative to develop such a package is a response to the wish to gradually establish a permanent arrangement for the collection and management of data related to the SASS basin. Indeed, « *SAGESSE* » comprises all the basic components necessary to make up a veritable control panel for monitoring the exploitation of the basin waters.

Intended mainly for SASS users (decision-makers, team entrusted with the digital model, Data Base manager . . .), SAGESSE has been designed as an explorer that displays the data collected during the project under tabular or geographic form. The toggling between these two modes, as well as the control of GIS layers, are made by a mere click, and this without exit from the ACCESS environment.

SAGESSE has been developed in order to bring together and enhance the value of the work done in matter of organisation and management of the data collected, as well as of the various processing operations conducted in the context of the project.

This product, which initially was intended to meet the sole objective of ensuring an interface with the PM5 model, has been enriched and gradually turned into a veritable management tool that may be of precious service not only for the countries concerned, but also for the consultation structure which would be set up.

3.3.1. General features

SAGESSE has been developed for data consulting and updating operations, for the preparation of inputs to the PM5 model, as well as for the visualisation of synthesis tables.

Its hospitable architecture allows for software guided exploration and for the possibility to develop additional, non provided queries and processing operations, and this directly in ACCESS environment.

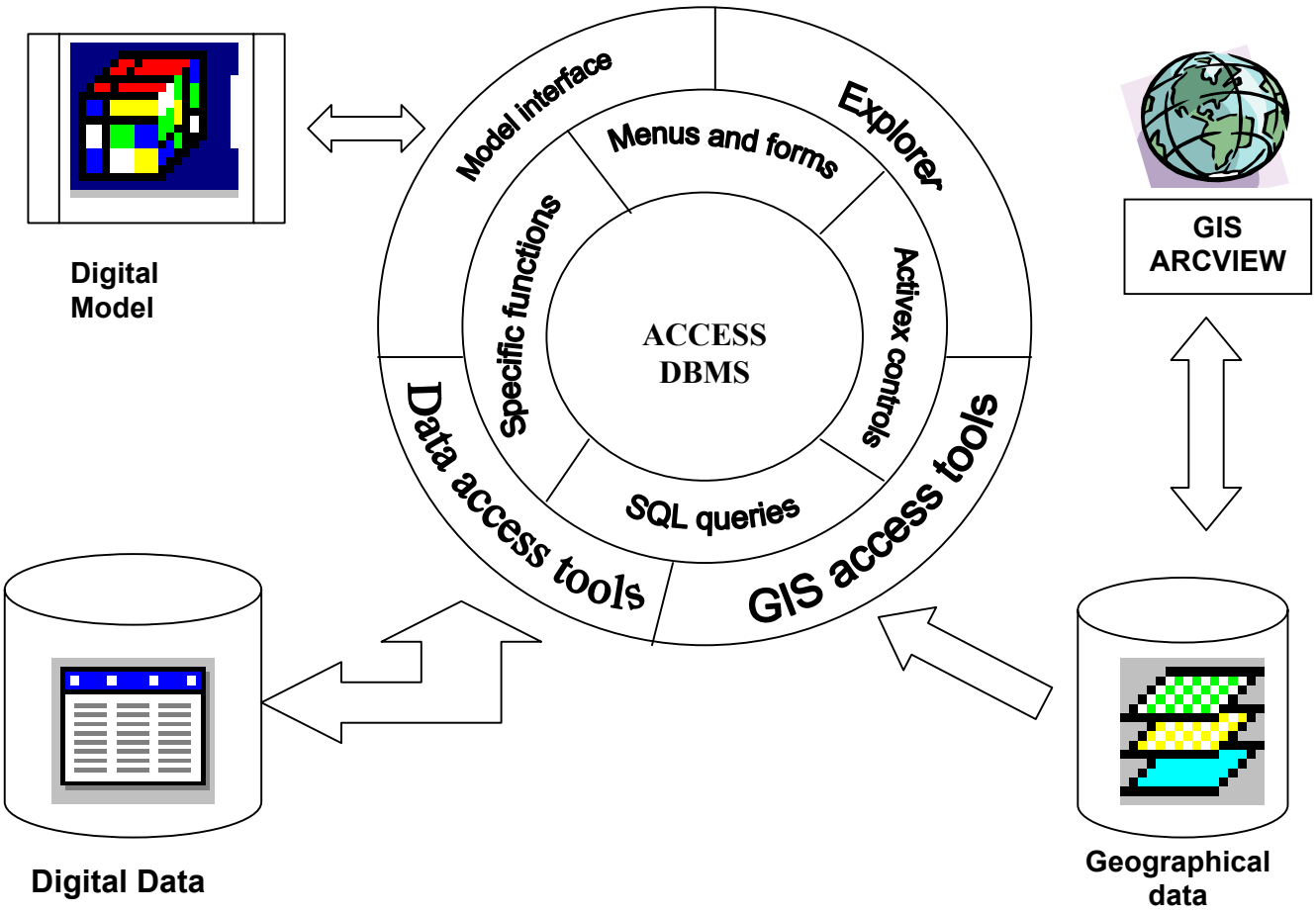
Among the innovative features of the system, the following are worth mentioning:

- the data necessary for the digital model originate directly from the data base, which offers the following advantages:
  - the data collected are reusable for future updating studies ;
  - the system developed is used both for modelling (main objective) and for purposes of meeting the needs of decision-makers: statistics, synthesis tables, thematic maps ;
  - the user does not have to worry about the format of the "input" files to the "Model" software, nor about the "outputs" ➔ less dependence with respect to modelling software ;
  - the data are not entered by cell, but by water point: this ensures greater flexibility. The grid (net mesh) is dynamic.
- The GIS integrates judiciously with the data base, thus allowing:
  - cartographic visualisations of the basic themes without exiting ACCESS ;

- automatic updating of the “water point” line each time the coordinates are modified, or after entry of new water points ;
- automatic assignment, by spatial query, of a cell number to the water points.

3.3.2 Structure of the system

This is both a hospitable and incremental system developed by means of standard tools in ACCESS environment: ACTIVEX components developed by Microsoft and ESRI, VBA programming language. This offers the advantages of a non costly management of the system, as well as an incremental and fairly easy maintenance.



Around the DBMS and its core functions, a certain number of additions have been made via the language VBA and thanks to dedicated components (dialogue boxes, GIS access functions . . .).

These functions make it possible mainly to:

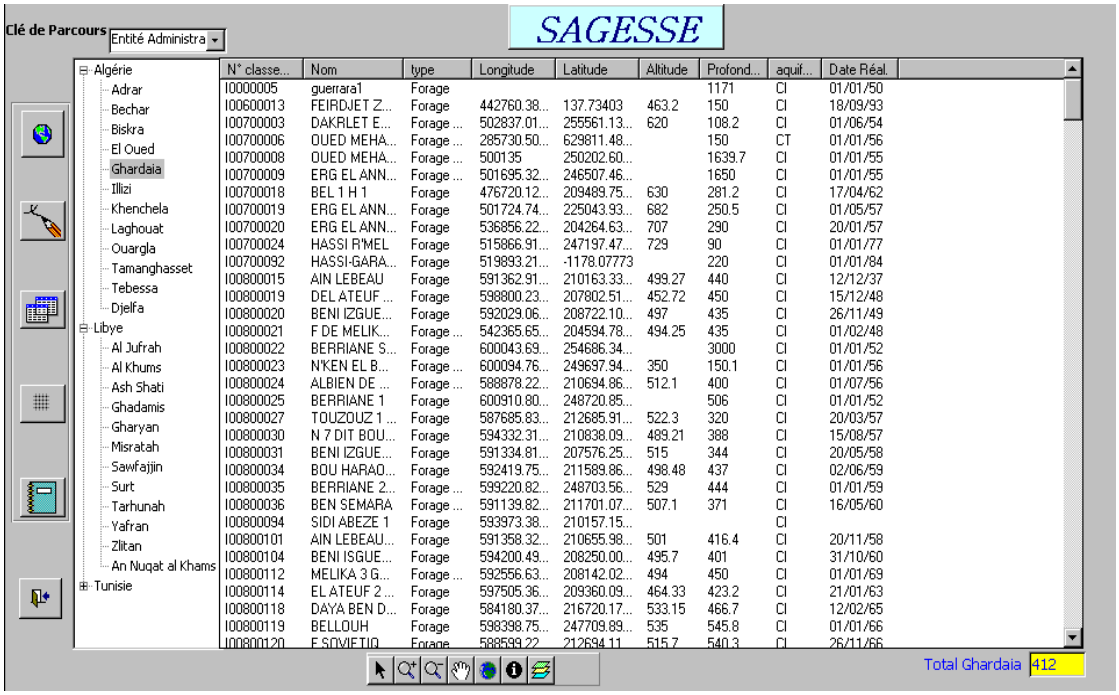
- access the GIS functionalities without loading the latter in order to perform most operations of cartographic visualisation ;
- explore the content of the DB based on various entry keys ;
- prepare, without difficulty, the data necessary to the model.

The graphic interface is composed of a main consultation form which also serves as general menu, thus allowing access to the other windows:

- «*general data* » form, for purposes of entry and correction of data ;
- « *exploitation graphs* », « *piezometry graph*» and « *Total Dissolved Salts (DRS) graph* » forms ;
- window for the preparation of data for purposes of the PM5 model or Wingép.

The « *main* » form which is executed automatically at starting time serves to guide the user in exploring the DB. The visualisation may be either digital or geographic.

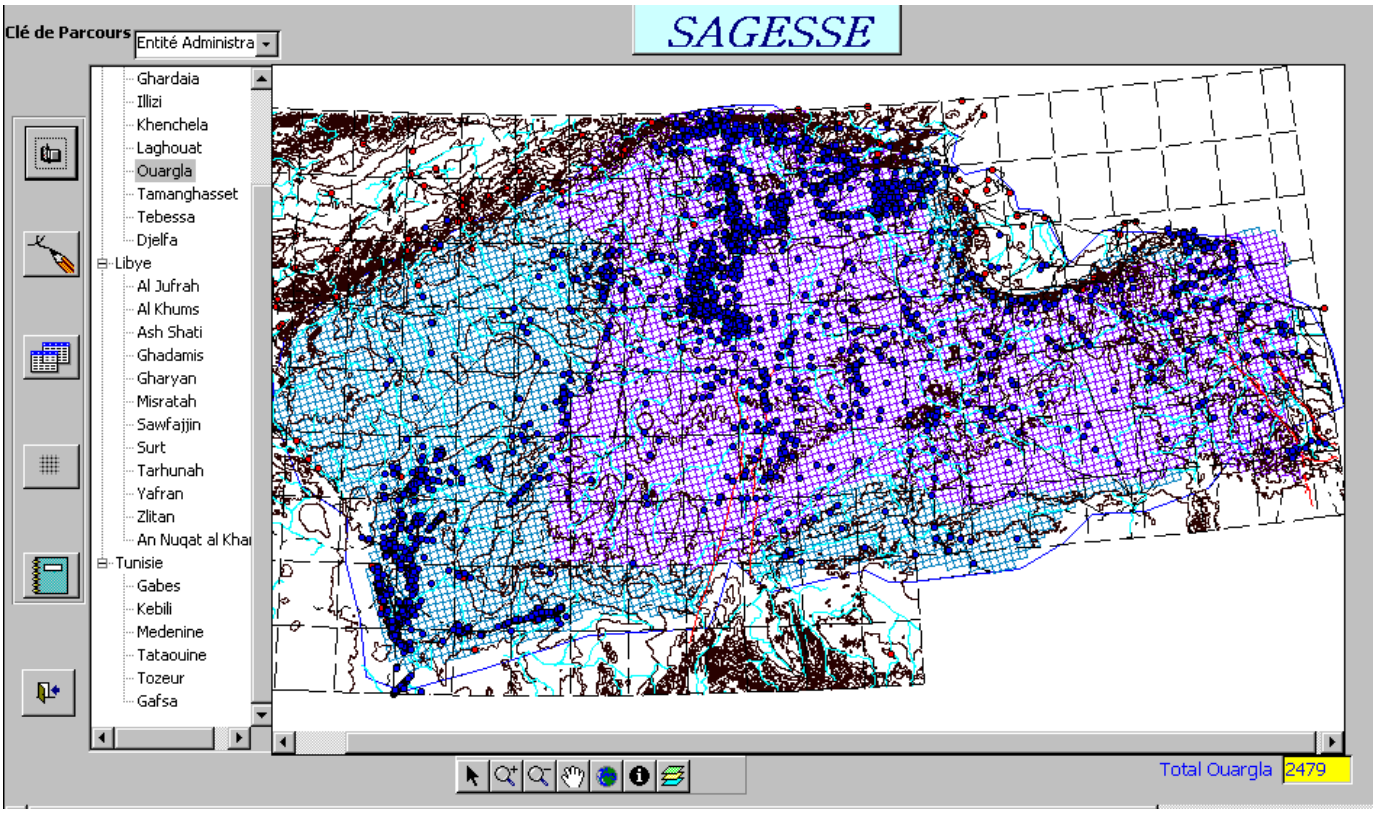
Main form



The exploration window is at the same time a main menu based on which it is possible to access all the functionalities of the software. Tabular exploration is made, at present, in two ways: by administrative unit (country, Wilaya) and by aquifer (layer and type of water point) ; it is, however, possible to add other selection keys or to further develop the existing keys (example: addition of a level called « *commune* » to the key « *wilaya* »).

The button  allows a shift to the geographic mode which displays a map window comprising the main GIS layers.

Visualisation of the map window



Buttons corresponding to the most common GIS tasks have been incorporated: Zoom, Pan, control of layers and possibility to access the information relating to a water point via the button « *info* » after having done sufficient zooming.
Geographical selection and access to the information of the DB currently focus on the water points only: the only active layer of the map window. More sophisticated cartographic processing must be done under ARCVIEW.

The button allows a control of the loaded up layers: visibility or not, colour, display of labels or not.

Main GIS layers

For cartographic display, SAGESSE uses part of the SHP files compiled in the context of the project.

- the topographic map: level contours, major towns, hydrographic network ;
- the administrative boundaries ;
- the layers representing the grid (net mesh) of the various model layers ;
- the water points in perfect synchronisation with the data base.

3.3.3. Functionalities of the software

3.3.3.1 Brouwsing and consultation of the data

The explorer is a flexible and user-friendly tool for the visualisation of data. Toggling between digital mode and geographic mode constitutes an additional facility for the users.
Several criteria for scrolling through the data are available: by administrative region, by aquifer, by type of water point. Other keys may be integrated after slight changes in the forms.

3.3.3.2. Edition of data and controls

The updating of the information is made by means of adapted interfaces which facilitate the entry procedure. The major fields are controlled, and the system accepts only valid data.
The relational structure rejects any data that do not meet the criteria of consistency.
The tasks of adaptation to other needs are possible: adding of fields to the forms, specific data controls, inclusion of other forms.

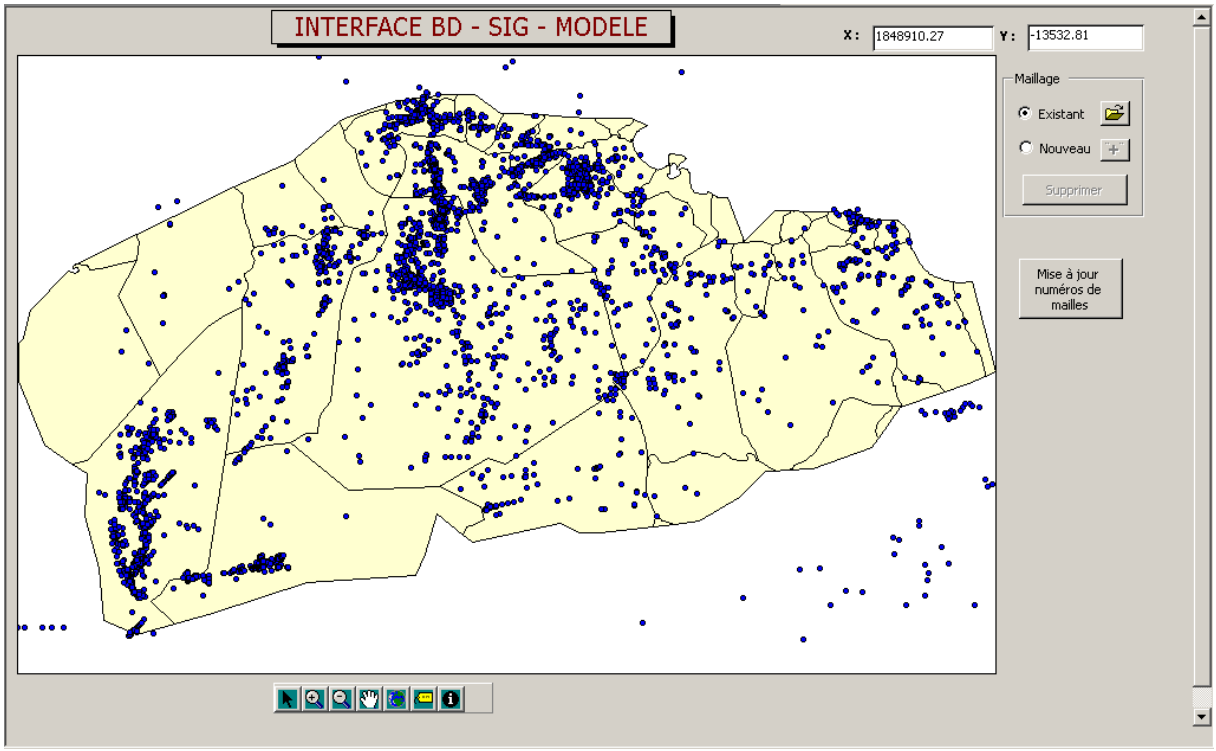
3.3.3.3. DB – GIS – Model links

One of the innovative features of the SASS project consists in not considering the celll as the elementary unit of data entry in the digital model. It is to the water point that the quantitative data concerning abstractions, piezometry, etc, are related, and it is at this level that the user performs the modifications. As to the groupings and totals, they are performed by means of queries that are executed automatically during the preparation of the data for the model.

Thus, changes at the level of the grid (net mesh) parameters no longer constitute a problem.

This vision allows greater flexibility, but requires that a permanent connection be established between the data base and GIS, so that any modification concerning the water points is immediately reflected, and in a transparent way, on the level of the data arranged as per net mesh.

A form has been designed for purposes of carrying out these connection operations, as well as to ensure DB – GIS – Model synchronisation.



Based on this form, three basic tasks may be initiated by the user:

- generation of a grid (net mesh) for the model ;
- automatic assignment of a net mesh number to all water points comprising Lambert coordinates ;
- permanent synchronisation DB – GIS, in order to maintain consistency between the « *points* » table and the corresponding GIS layer.

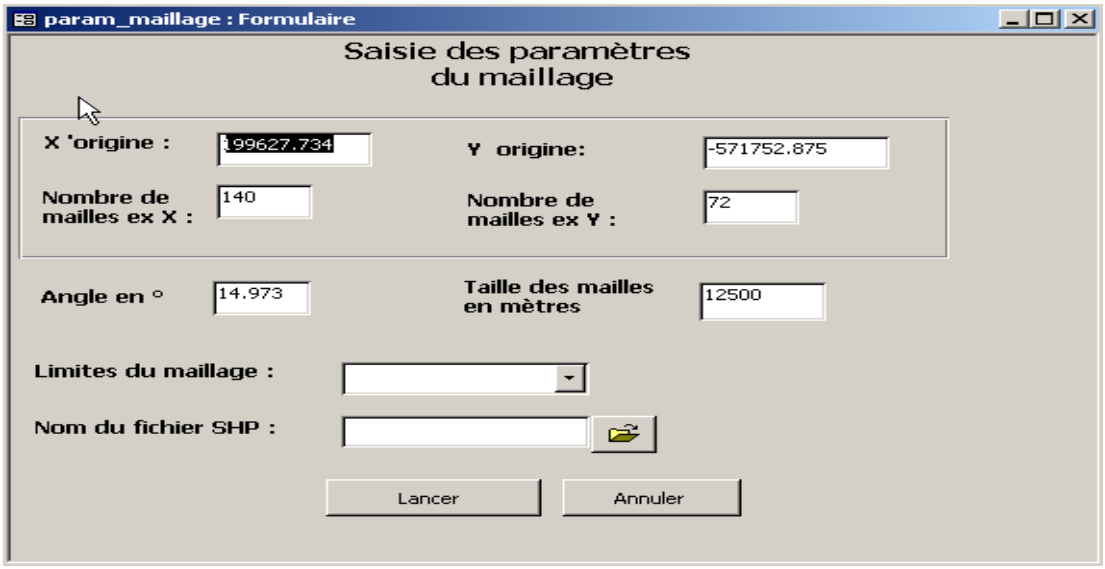
3.3.3.3.1 Automatic generation of grid (net mesh)

The first processing operation consists in generating a grid (net mesh) that is adapted to the PM5 model and which would be sufficiently configured to provide greater flexibility for the user.

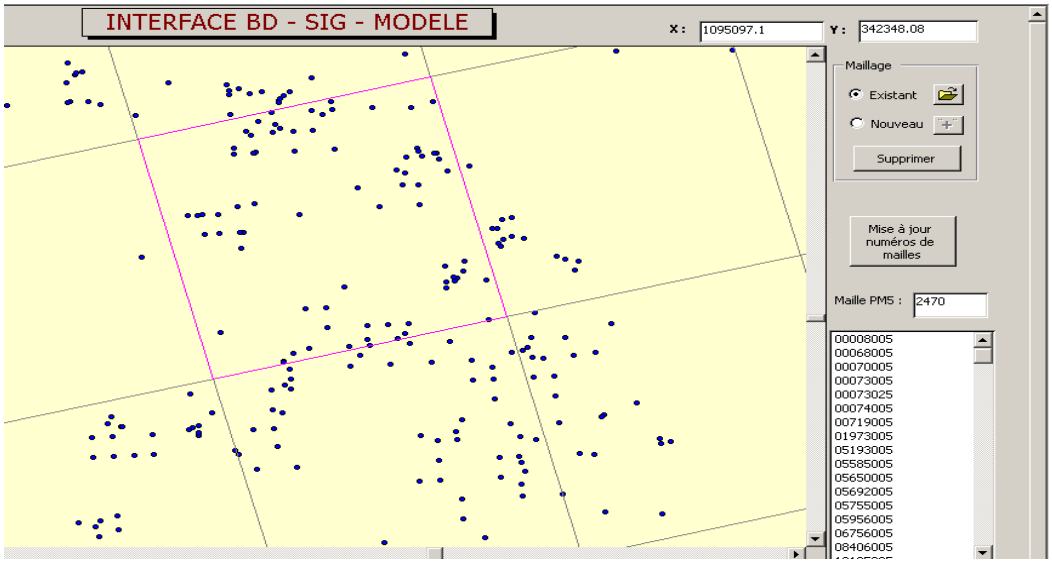
A module has been developed within SAGESSE to produce a regular grid (net mesh) with the following parameters: size of cell metres, number of X and Y cells, origin of starting point, positioning angle.

This grid (net mesh) may or may not be circumscribed within a polygon representing the boundaries of a zone (CI extension, for instance). Once created, this grid is recorded as a GIS layer under SHP format. This allows the development of various queries by net mesh and facilitates the transfer of data to the PM5 model.

Entry form for grid parameters



Once created, the grid may be loaded up onto the map window and it will be possible to undertake visualisations by cell:



When a cell is selected, the latter is highlighted, and it is possible, for example, to list all the water points that it contains.
The selection of any given point in the list causes the point to appear in another colour within the window to better show it.

3.3.3.3.2. Assignment of a cell number to the water points

The DB – Model link is made by the assignment, via a VBA procedure, of a cell number to each water point within the grid (net mesh) under consideration. These values are automatically updated within the data base.

This operation is necessary each time an update of the cells numbers is needed, that is after the following events:

- change at the level of the water points coordinates ;
- addition of new water points ;
- creation of a new grid (net mesh) or modification of the parameters of a given grid.

The procedure is initiated by clicking on the button 

3.3.3.3.3. Preparation of the PM5 files

This operation is based on:

- ACCESS queries involving the « *points* », « *exploitation*» / « *piezometry* », « *grid (net mesh)* » tables ;
- Functions written in VBA which transcribe these queries in the format required by PM5.

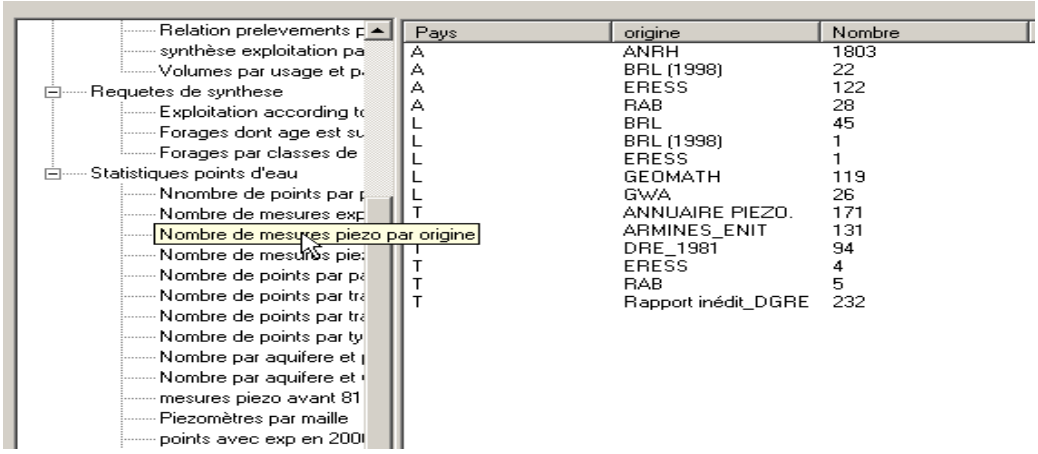
Several files are thus generated, covering the needs of the team in charge of the digital model:

- Sum of the abstractions as per cell;
- Drilling marks for piezometry ;
- Piezometric level records at certain spots.

Procedures of retrieval of outputs and their storage in the DB or in the GIS are also possible. The latter will allow the listing of the various maps of hydraulic parameters calculated by the model.

3.3.3.4 Queries explorer

A considerable number of queries and synthesis processing operations, which were conducted during the project, have been grouped within a queries explorer for easy use, as illustrated by the following image:



It is possible to include other queries within this explorer: only the system managers are eligible to carry out such additions.

3.3.3.5 Conversion of coordinates

At the time of data entry, the system computes automatically the coordinates in decimal degrees.

Conversion into Lambert is made by a utility developed in the framework of the SASS project based on the language « *Avenue* ».

This extension performs directly on the « Points » table the conversion of the geographical coordinates into Lambert and automatically updates the corresponding fields.

PART II

ANALYSIS AND SYNTHESIS OF THE DATA COLLECTED UNDER SASS

4. AVAILABLE DATA COLLECTED BY THE PROJECT AND ADDITIONAL DATA GATHERED

A considerable body of data relevant to the SASS zone is assumed to be available in view of the number of studies conducted since 1970. However, these data are, in fact, very disparate and, therefore, not usable without prior organisation and processing operations. This situation is due to various factors:

- often the data collected during these studies are not stored and are scattered in reports ;
- the data bases have not been designed properly enough to handle the modelling process operations ;
- the initial data by water point are difficult to locate since all the data were expressed by net mesh.

4.1- Organisation of data collection

Two main sources have been used for data collection ; these are:

- the files existing in the above-mentioned countries ;
- data originating from previous studies and which are found in EXCEL files or in written documents.

As regards the first set of data, automatic queries and procedures were used in order to import them into the DB. As for the second set of data, manual entry was used.

For both cases, procedures were developed for the organisation and control of the data, and their integration within the common data base.

The diversity of the information sources and the operation of transfer to the data base have required major checking, correction and homogenisation work in order to make these data exploitable.

The collection operation was carried out in two phases with regard to the data available in the three countries concerned. The first phase consisted in setting out the query based updating procedures. The second phase was above all of a qualitative nature, since it followed upon the findings of the data analysis and error detection operation.

4.1.1. Initial collection

This procedure, which was started before the establishment of the data entry interfaces under ACCESS, has led to activating the operation of establishment of the contents of the DB. However, an analysis and validation phase was necessary in order to detect and correct any possible errors resulting from the diversity of the collection sources and the absence of control at data entry time.

4.1.1.1. ANRH files

Three types of data were supplied by ANRH, with regard to the two main aquifers (the CI and the CT):

- Characteristics of the water points: one EXCEL file as per aquifer ;
- Inventory and flow records data ;
- Piezometric records.

Table 22: List of files supplied by ANRH

Name of file	Description	Number of lines
Forage CI unique	Characteristics of the water points of the CI aquifer	898
Forage CT unique	Characteristics of the water points of the CT aquifer	1750
Ciunique	Inventories conducted in the CI	1830
Ctunique	Inventories conducted in the CT	1900
Fic1piezCI	Piezometric records in the CI	1320
Fic1piezCT	Piezometric records in the CT	2296

i) Characteristics of the water points:

This file contains, in addition to the information relating to the identification of the water points, data on the collections and chemical analyses.

Column	Significance	Processing operations conducted	Destination ACCESS table
Wilaya	Wilaya where the water point is located	Standardisation of names	Points
Aquifère	CT or CI		
NOCLAS	Water points classification N°	Standardisation of the « L999-99999 » representation format	
LOG	Existence of LOG (yes or no)		
DATFIN	Date of construction completion	Conversions into data type	
LONGIT	Longitude in text format expressed in Deg/. Min./ Sec.	Correction of degrees, minutes, seconds separators	
LATITU	Idem	Idem	
ALTITU	Altitude of water point	Cancelling of non digital characters	
PROINV	Total depth in m	Cancelling of non digital characters	
DEBEXP	Exploitation flow in l/s		
ANEXPL	Year of measurement of this exploitation flow	Conversion into date	
NIVREP	Static level		
NIVREP	Levels adjusted in consideration of sign (artesianism)	Conversion into values	Piezometry
DATPOM	Date of pumping test		Hydrodynamic parameters
débit (l/s)	Test flow	Cancelling of characters other than digital	
rabattement	Drawdown		
TR(m2/s)	Transmissivity or permeability	Manual correction	
	Storage coefficient	Scanty data	

Column	Significance	Processing operations conducted	Destination ACCESS table
RS(mg/l)	TDS (Total Dissolved Salts)	Conversion into digital values	Quality
ANMESUR	Year of TDS measurement	Conversion into date	
Ca			
Mg			
K			
Na			
Cl			
So4			
Co3			
Co2			
pH			
temp°C			
Date	Date of the chemical analysis		
Haut crépinée	Screen depths (beginning and end in m)	Unification of separators, then extraction of the various layers and conversion of depths into digital values	Collection
Formation captée	Name of tapped formation	Assignment of an identical name to the same formation	
DEBPOM	Rated flow		Exploitation
DEBEXP	Exploitation flow in l/s		
ANEXPL	Year of measurement of this exploitation flow	Conversion into date	

The first step consisted in importing these two files (« CI wells » and « CT wells ») with a view to building a table for the water points having a unique identifier transcribed in the same way.

Once the import into ACCESS has been made, several « update » queries had to be conducted, particularly for purposes of:

- Splitting the LONGIT and LATITU columns, after their conversion to digital values, into three headings (degrees, minutes and seconds). These three attributes will serve for computing the coordinates into decimal degrees, then into Lambert (links with GIS) ;
- Inclusion of the additional fields as the table will contain data originating from the three countries (country, type of coordinates, East or West), and automatic assignment of values to these fields.

ii) Inventory files:

These files constitute a complementary part to the water points table and contain the flow records for the period 1982 - 2000. Particular processing has been conducted with regard to these files:

- similar processing as for the « *characteristics »* file ;
- reconstruction of the classification numbers wherever possible ;
- comparison with the water points file (seeking out correspondence to avoid duplicates).

This third item is particularly complex, since many inventoried water points lack name, classification n° and coordinates. A list of these wells has been transmitted to ANRH. Wherever any of these items exists, a connection has been made with the « *points* » table.

The structure of the file is as follows:

Table 23: Structure of the inventory files

Column	Significance	Processing operations conducted	Destination table
Nom	Name of water point		Points
N° BIRH	Classification number	Format standardisation	
Année de Réalisation	Construction year or date	Conversion into date (in case of « year » only, complementing by month and day as follows « 01/01/ »	
Nappe	CI or CT		
Région	Wilaya or "Gouvernorat" (Gopvernorate/ Province)	Cancel « foggara ». These values are placed in a column « type_ouv » (type of structure)	
WILAYA	Name of the wilaya	Standardization of names	
Longitude(géo)	Longitude (deg-min-sec)	Arrange separators	
Latitude(géo)	Latitude (deg-min-sec)	Idem	
Longitude(déc)		Ignore (does not consider negative longitudes)	
Latitude(déc))		Ignore	
Altitude	Altitude		
Profondeur	Depth		
Débit initial	Initial flow (at construction date)	Conversion into digital values and into annual volume	Exploitation
Débit actuel	Current flow (in inventory year)	Idem	
Année d'inventaire	Inventory year or period	In case a period comprises beginning and end, extract the end year. Conversion into digital data	
Source d'inventaire	Institution or person having conducted the inventory		
1982	Flow for the year 1982 in l/s	Conversion into annual volume	
…	…		
2000	Flow for the year 2000 in l/s		
Niveau statique	Static level	Static level read	Piezometry
Année d'inventaire			
Heures	Number of hours of pumping		None
Jours	Days		
Mois	Months		
Débit annuel saisi	Annual volume recorded in situ		
Débit annuel calculé	Calculated annual volume, using the hours, days and months columns		
Diff. de débit (saisi-calculé)	Difference recorded – calculated		
Débit fictif continue	Volume converted into l/s		
Etat du forage	Condition of well	Has not been imported (has served for constructing the record)	

This third part of the table has not been dealt with and will be considered within ANRH own data base. Only the outputs originating from these headings and made up of the « 1982 » to « 2000 » columns have been exploited, since, for SASS purposes, the annual level is quite sufficient.

The import of these « *inventories* » files has been carried out in several steps: the first step consisted in seeking out correspondence with the « *points* » table, as well as in the transfer of the data to the latter table, and this according to the following rule:

- if the water point figures in the two files (identical classification number): the data of the « inventory » file serve to update the « *Points SASS* » (SASS water points) data table ;
- if the water point does not have an inventory number, then in this event:
  - a) either it has a correspondence at the level of the name and, in this case, the n° is extracted from the water points table and rule (a) is applied ;
  - b) or else the name does not exist, and a fictitious classification number is assigned to the water point. The record is, afterwards, added to the « *point* » table. This is a new water point.

This rule may, however, give rise to duplicates as it does not take into consideration a comparison of the coordinates. Yet, the risk of having duplicates has been preferred over that of loss of information. Besides, coordinates are not always exact as a result of their prior conversion into Lambert or UTM with respect to the degrees. A systematic verification by ANRH has been scheduled in order to refine the data base and remove all redundant water points.

Afterwards, an import of the data under ACCESS has been conducted in the three tables concerned, namely:

- « *points* », for the identification – location data ;
- « *exploitation* », as regards the records. These records include the initial flows, the flows recorded during the inventory and the series constructed by the ANRH team (1982 - 2000) ;
- « *piezometry* », within which there has been added the value of the « static level » column, with the year of this measurement being the inventory year.

iii) « Piezometry » files

They almost have the same structure as the inventory files. The task has consisted in comparing the piezometric values contained in this file with those of the « *characteristics* » file, which are found to be identical. The only values transferred are those of the « *SONATRACH* » wells.

4.1.1.2. DGRE files

Three types of files have been supplied by DGRE. These files are all in DBASE format and the structure is homogeneous:

i) Characteristics of the water points

Identification – location files relevant to the water points located in the Governorates (regional administrative departments) of Tozeur, Kebili, Gabes and Tataouine. These files present the following structure:

Table 24: Structure of the DGRE files

Column	Significance	Processing operations conducted	Destination table
NIRH	Identification number	Arranging for the standard 8 digit number format	Points
NOM	Name of water point		
NAPPE	Name of aquifer		
LATI	Latitude in grades	Standardization of separators	
LONG	Longitude in grades	Idem	
ALTI	Altitude in m		
DATDEB	Construction inception date	Conversion into date type	
DATFIN	Construction completion date	Idem	
PROF	Depth		
ARRONDIS	District number	Designation instead of n°	
FORMCAPT	Formation tapped		Collections
COT_DEB	Elevation beginning in m		
COT_FIN	Elevation end in m		
DATE	Test date		Hydrodynamic parameters
DEBIT	Test flow		
RABAT	Drawdown		
NS	Static level		
RS	Total Dissolved Saltss (TDS)	Conversion into mg/l in the Tozeur file	Quality

The import of these files has been made after the creation of common headings and homogenization with the water points file originating from DGRE data.

- creation of common headings (country, aquifer (CI or CT), type of coordinates), and updating of corresponding values ;
- extraction of the grades, minutes and seconds attributes and computation of decimal degrees (after conversion and application of the corrector coefficient **2,5969213** for longitudes corresponding to the Paris longitude with respect to Greenwich) ;
- organisation of the « date » fields.

The « *DATFIN* » (construction completion date) field has been reconstructed as follows wherever it is not filled out:

- equal to « *DATDEB* » (construction inception date) whenever available ;
- equal to *DATE* (test date)

ii) «Exploitation » files

These are Dbase format files for Tozeur and Kebili, and EXCEL format files for Gabes – Tataouine. Their structure is as follows:

Column	Significance	Processing operations conducted	Destination table
NIRH	Identification number	The n° has been set by DGRE	Exploitation
NOM	Name of water point		
NAPPE	Name of aquifer table		
Q_1982	Volume in 1982 (m3)		
…	…		
Q_1999	Volume in 1999 (m3)		

iii) « Piezometry » files

Column	Significance	Processing operations conducted	Destination table
NIRH	Identification N°	The n° has been set by DGRE	Piezometry
NOM	Name of water point		
TN	Elevation of natural ground		
NS_1982	Static Level in 1982 (m)		
NS_1999	Static Level in 1999 (m)		

4.1.1.3. GWA files

GWA has transmitted to SASS an EXCEL file comprising the features of 168 wells. This file does not present any anomalies and has not, therefore, formed the subject of any major processing operations, except for the water points lacking an identifier and to which a fictitious classification n° has been assigned.
The file comprises the following columns:

Column	Significance	Processing operations conducted	Destination table
well no	Identification of the water point		Points
Other_no	Second identifier		
location	Locality		
xd	Degrees		
xm	Minutes		
xs	Seconds		
Long_dec	Longitude in decimal degrees		
Yd	Latitude degrees		
Ym	Minutes		
Ys	Seconds		
Lat_dec	Latitude in decimal degrees		

T.D	Depth		
G.L (m.a.s.l)	Altitude		
Compl. Date	Construction completion date	Standardization and conversion	
Tapped from	Depth Collected from	Adding of separators and standardization	
Tapped To	Depth Collected to		Collection
S.W.L	Static level		
Yield	Flow		
D.D	Drawdown		Hydrodynamic parameters
Tp	Transmissivity obtained during pumping time		
Tr	Transmissivity obtained during rise time		
T.D.S	Total Dissolved Salts (TDS)		Quality
T	Temperature		

Two major fields are missing: aquifer (CI or CT) and administrative region where the well is located. The “aquifer” field has been filled out manually by means of the entry form. As for the « Wilaya » field, it has been reconstructed by means of GIS for the water points provided with coordinates.

4.1.2. Additional data supplied in March 2001

4.1.2.1. ANRH files

The following modifications have been made following the recommendations of the expert in charge of the model:

- Revision of the abstractions data which, after simulation, have been found to be faulty in certain locations. It should be pointed out that these values have been reconstructed by the ANRH team as they originate from imprecise inventories ;
- Elimination of duplicates induced by inventories conducted in the same locations by DHW (Direction de l’Hydraulique de Wilaya/ Regional Hydraulics Directorate) ;
- Integration of new inventories conducted in 98 and 99 ;
- Identification of water points whose classification number has not been initially transmitted ;
- Checking of all coordinates ;
- Addition of the « *usage »* column.

4.1.2.2. DGRE files

DGRE has undertaken to check the data relating to the Tunisian part, which have been processed at SASS. These data are related to abstraction and piezometric records.

New water points have been reported: water points located in the Governorates of GABES, GAFSA, and MEDENINE + the water points located in TOZEUR and KEBILI which had not been transmitted initially.

Major correction work has been done to assign the proper classification numbers and to adjust the coordinates.

It is worth mentioning that DGRE has transmitted the data directly under the form of ACCESS tables.

4.1.2.3. GWA files

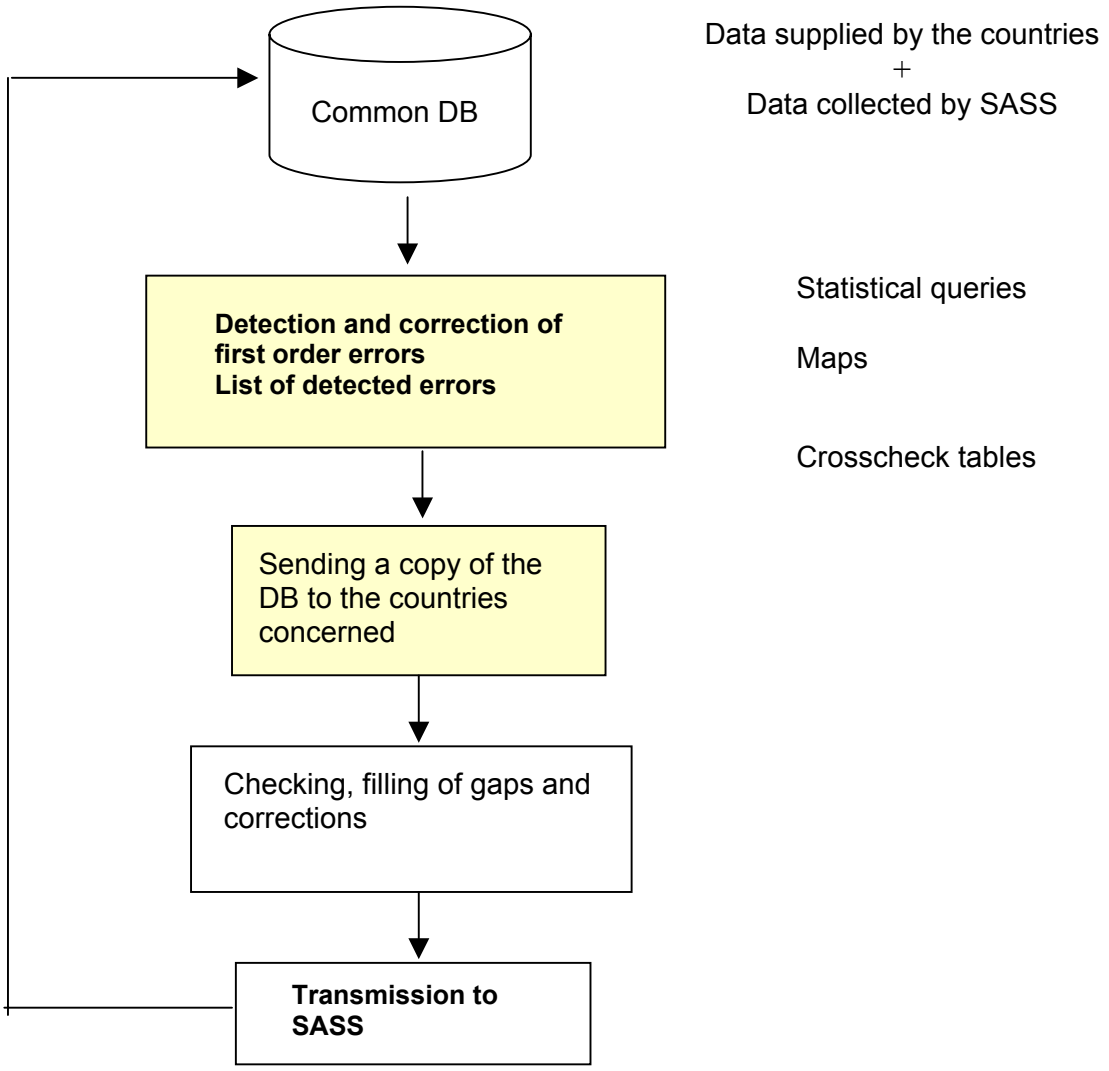
For the Libyan part, additional information has been transmitted under the form of written documents and was entered in the common DB by means of the entry forms.

This information is related to:

- the abstraction data as per exploitation group ;
- the piezometric records originating from the national network ;
- the salinity records (Total Dissolved Salts (TDS)).

Certain UTM coordinates have been converted into geographic coordinates by the GWA team, then updated in the DB.

4.2- Validation procedure



This procedure has served during the project for the various updates: corrections, adding of various data, filling of gaps . . . EXCEL files are less and less used, and new practices have been gradually established, which consisted in operating directly on the data base and not on loose files.

Future updates will be even less cumbersome, thanks to the following aspects in particular:

- to the quite considerable reduction of aberrant errors ;
- to the homogenisation of the formats, codes and procedures ;
- to the new procedures of updating and correcting the data at the time of entry ;
- to the replication mechanism (guarantee of consistency between the DBs).

4.3- Data collected

4.3.1. ANRH data

Three types of data were supplied by ANRH, which relate to the two main aquifers (the CI and the CT):

- Characteristics of the water points: one EXCEL file as per aquifer ;
- Inventory and flow records data ;
- Piezometric records.

Two major sources of data were provided by ANRH:

- Data prepared for purposes of the BRL study ;
- Latest inventories conducted during the period 91 – 99 ;

all of which was proposed in EXCEL format.

The ANRH data were those that had presented the greatest difficulties. This is due, first of all, to the larger volume of data and, secondly, to the way according to which the inventories were conducted:

- absence of classification number for most wells ;
- many fields have not been filled out ;
- presence of duplicates by coordinates and by names of wells ;
- reconstruction of flow records, as regular measurements were not available ;
- absence of regular measurements of levels.

Several corrections have proved necessary so that these data could be imported in the ACCESS data base (see Annex 2):

- standardisation of columns: in order to group these files. It has proved necessary to place at the same location the columns bearing the same information (the heading « *level* », for instance, was not placed at the same location for all files) ;
- correction of the types of data: this relates mainly to columns of the type « date » and « digital value » (date of completion of well construction, date of pumping test and Total Dissolved Salts (TDS) measurement, flow, level, altitude, …), which were all supplied in text format ;
- homogenisation of the classification number which constitutes the primary key to the data base and which has to be presented in the same way (L000-00000) ;
- correction of the values of the coordinates and standardisation of their format with a view to their importing to ACCESS.

4.3.1.1. Data validation

The complex nature of the problems, added to the very large volume of data, have led to seeking out, as a first step, methods and tools based on statistical processing and on GIS based spatial queries. (See report entitled « Analysis of SASS Hydrogeological Data ».)

Broadly speaking, the procedure has involved the fields that have a direct impact on the digital model, namely:

- location of the water points ;
- their hydraulic characteristics ;
- the piezometric records ;
- the abstractions.

Identification and location of the water points:

The cartographic representation of the water points has made it possible to unveil certain deficiencies:

- absence of coordinates ;
- errors relating to the geographical units (degrees/ grades) ;
- inversion of longitudes and latitudes.

Besides, many water points are not provided with coordinates at all (water points obtained from the inventories). A list of these water points was established, then transmitted to the ANRH team. Priority order was granted to those which are provided with an abstraction record. This list also comprises the water points affected by information gaps at the level of the main fields which are:

- Identification number,
- Name of water point,
- Administrative unit,
- Type of water point,
- Aquifer,
- Construction date,
- Depth,
- Tapped depth,
- Altitude of the water point,
- Hydrogeological data: level, flow, drawdown, TDS (Total Dissolved Salts).

Case of inventory data

Most of the water points appearing in the inventory files are not provided with an identification number, nor with coordinates. The following approach has been adopted for purposes of their transfer to the DB:

> Manual search and connection by means of the fields: name, aquifer, construction date, depth, altitude. If the water point exists in the DB, its data are updated by those of the inventory. Otherwise, it is assigned a numbering under the form « **X000-00000** », as if it was a new well.

This approach presents the advantage of using the whole data collected, but presents the risk of giving rise to duplicates.

A certain number of digital and spatial queries have been developed in order to mitigate these impacts: searches by name, coordinates and depth, when such data exist.

As they could not be conducted in a systematic manner, these processing operations were carried out manually on a case by case basis.

Once they had been organised, these data were transmitted to ANRH to complement the missing data relating to the major water points and which have an exploitation record. The coordinates of these water points have been reconstructed for purposes of the model.

4.3.2. DGRE data

Three types of files were supplied by DGRE. These files are all in DBASE format and their structure is homogeneous (see Annex 2).

- **Characteristics of the water points**

Identification – location files for the water points located in the Governorates of Tozeur, Kebili, Gabes, Tataouine and Gafsa.

In order to allow their import, these files underwent preliminary processing operations which involved:

- adaptation of formats and types of data ;
- corrections of the columns containing the coordinates ;
- splitting of the columns that were initially presented under grouped form.

It has also proved necessary to undertake a correction of the coordinates and their conversion into decimal degrees: standardisation of the positions and separation symbols, then grades – decimal degrees conversion (with addition of the corrector coefficient « **2,5969213**» which corresponds to the change of origin Paris – Greenwich).

- **« Exploitation » files**

These are the EXCEL format files related to the Governorates concerned. These data are relevant to the 1981 – 1999 records, as the previous data have been taken in charge by SASS.

- **« Piezometric » files**

They relate to the records of levels for the period 1981 - 2000 (one measurement per year).

The files generated by the « *exploitation* », « *piezometry* » DBs have been transferred via ad hoc programmes, while the data relevant to the characteristics of the water points have been integrated by means of queries.

4.3.3. GWA data

The largest part of the data were entered at SASS level, since they originate from various sources and are not available in the Libyan DB: studies reports, manual files . . .

A file comprising the characteristics of the water points was supplied by GWA. Its transfer did not present any major problems, except for the fact that certain coordinates expressed in the UTM system do not include the zone number..

The abstraction records were supplied by exploitation group, rather than by water point.

As for the piezometric records, they were supplied under the form of manual files, then entered at SASS level.

4.3.4. Contribution by the project team

charge by the country teams. These data relate mainly to the following fields:

4.3.4.1. Geological data

- establishment and interpretation of the wells cross-sections and entry of the geological data in the data base ;
- development of the geological map.

The geological data processed and transferred to the DB relate to 83 wells distributed over the whole SASS zone.

4.3.4.2. The « abstraction » and « piezometry » records

The abstraction and piezometry data related to the period 1950 - 1981 have been, for the major part, collected and entered by the project team.

The following sources were used:

- the ERESS study, complemented by the RAB study and the ARMINES/ENIT study ;
- the recent studies conducted by BRL (1994 and 1998), GEFLI and GEOMATH.

Once they had been grouped within the DB, these data were sent to the countries for control and validation.

4.3.4.3. The water quality (salinity) data

The salinity records have been, for the major part, entered by the SASS team. Various sources were consulted for this purpose (see Volume 2 – SASS).

4.4- Synthesis of the data collected in the framework of the project

After various trips between SASS and the three administrations for corrections and filling of gaps, the data reached a maximum reliability level. For so doing, all possibilities have in fact been used:

- checking and error detection tools ;
- manual corrections ;
- crosschecks between various types of data ;
- visits by the national teams to the regional structures for purposes of validating certain data.

The following tables indicate the volume of data collected to date.

General characteristics:

Country	Characteristics of the water points	Hydrodynamic parameters	Collection depths	Usages
Algeria	6147	4176	1009	893
Libya	1054	374	116	29
Tunisia	1172	240	157	146
Total	**8373**	**4790**	**1282**	**1068**

Records:

Country	Exploitation		Piezometry		Salinity	
	Number of points	**Period**	**Number of points**	**Period**	**Number of points**	**Period**
Algeria	1654	1950-2000	2135	1950-2000	1091	1889-2000
Libya	36	1980-2000	184	1970-2000	237	1970-2000
Tunisia	837	1950-2000	420	1950-2000	365	1947-2000
Total SASS	**2527**		**2739**		**1693**	

4.4.1. Distribution by origin

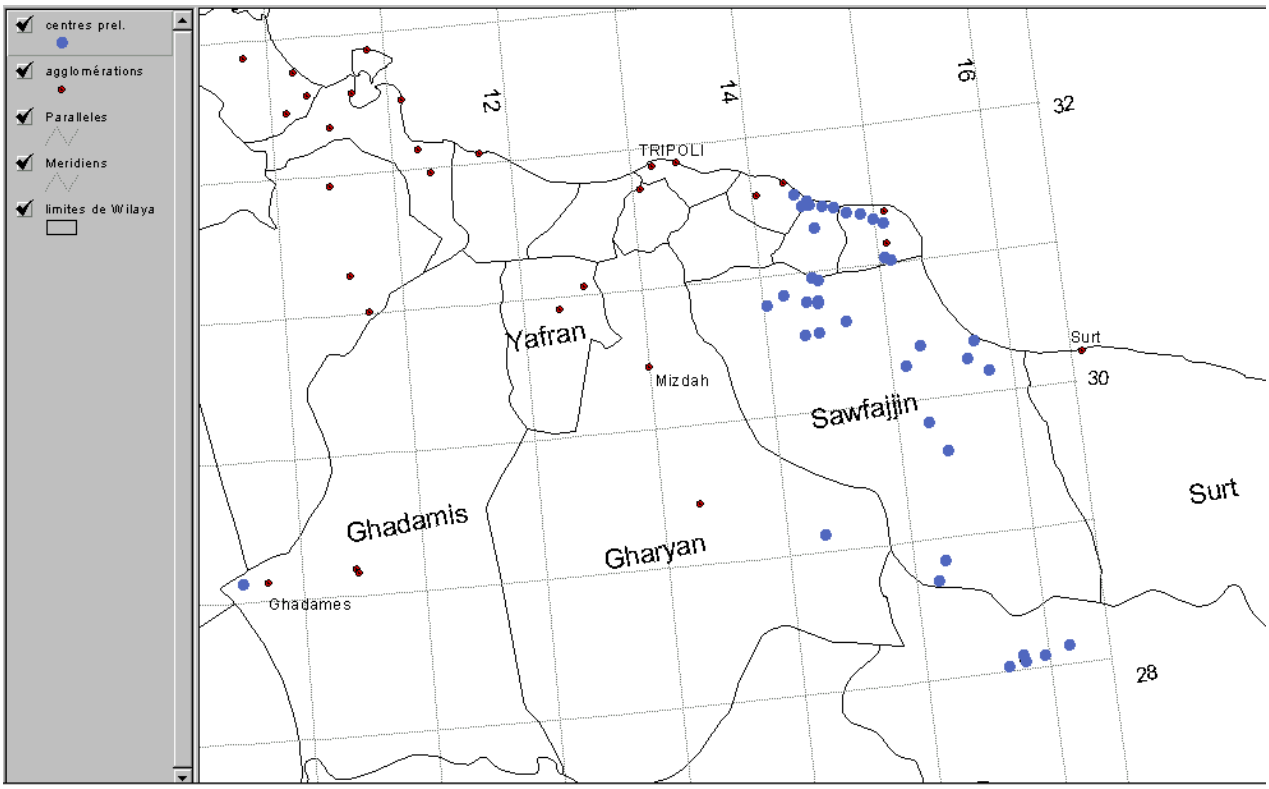
Several information sources have been used for purposes of data collection:

- National DBs for the characteristics of the water points ;
- EXCEL files containing inventory data (ANRH) ;
- Manual entry at SASS for the following records: exploitation, piezometry and dry residue related to the periods that are not covered by the countries DBs.

4.4.1.1. Abstraction records

Country	Origin of the data	Number of measurements	Entry mode in the DB
Algeria	ERESS RAB ANRH inventories Foggaras inventories	120 298 2490 176	Entry by SASS Idem Transfer via programme Idem
Libya	SASS	37	Entry by SASS
Tunisia	ERESS RAB DGRE network	290 280 964	Entry by SASS Idem Transfer via programme

The Libyan data are estimated based on information about irrigated areas. They are provided by abstraction centre ; the latter accordingly count 37 in the two aquifers together. They are located as follows:



4.4.1.2. Piezometry records

Country	Origin of the data	Number of measurements	Entry mode in the DB
Algeria	ERESS RAB ANRH files BRL 98	131 30 2050 22	Entry by SASS Idem Transfer via programme Entry by SASS
Libya	ERESS GEOMATH BRL GWA	1 119 45 26	Entry by SASS Automatic transfer
Tunisia	ERESS RAB ARMINES / ENIT DGRE network Unpublished DGRE reports	4 5 131 265 232	Entry by SASS Idem Idem Transfer via programme Entry by SASS

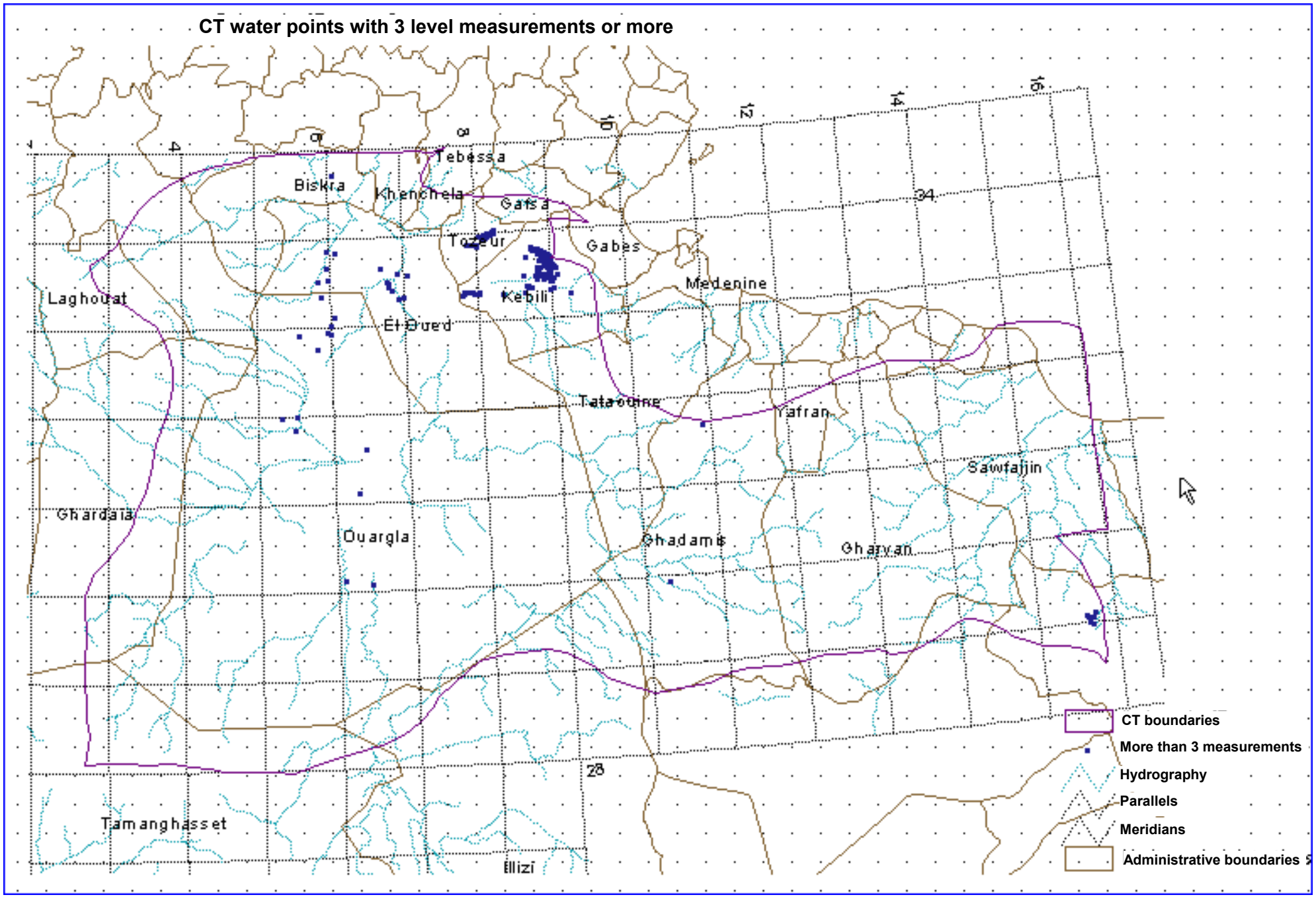
The following table shows the time distribution of the piezometric measurements collected for each of the two main aquifers:

Aquifer	1950	1960	1970	1981	1990	2000
CI	04	13	77	20	56	202
CT	19	60	219	87	146	66

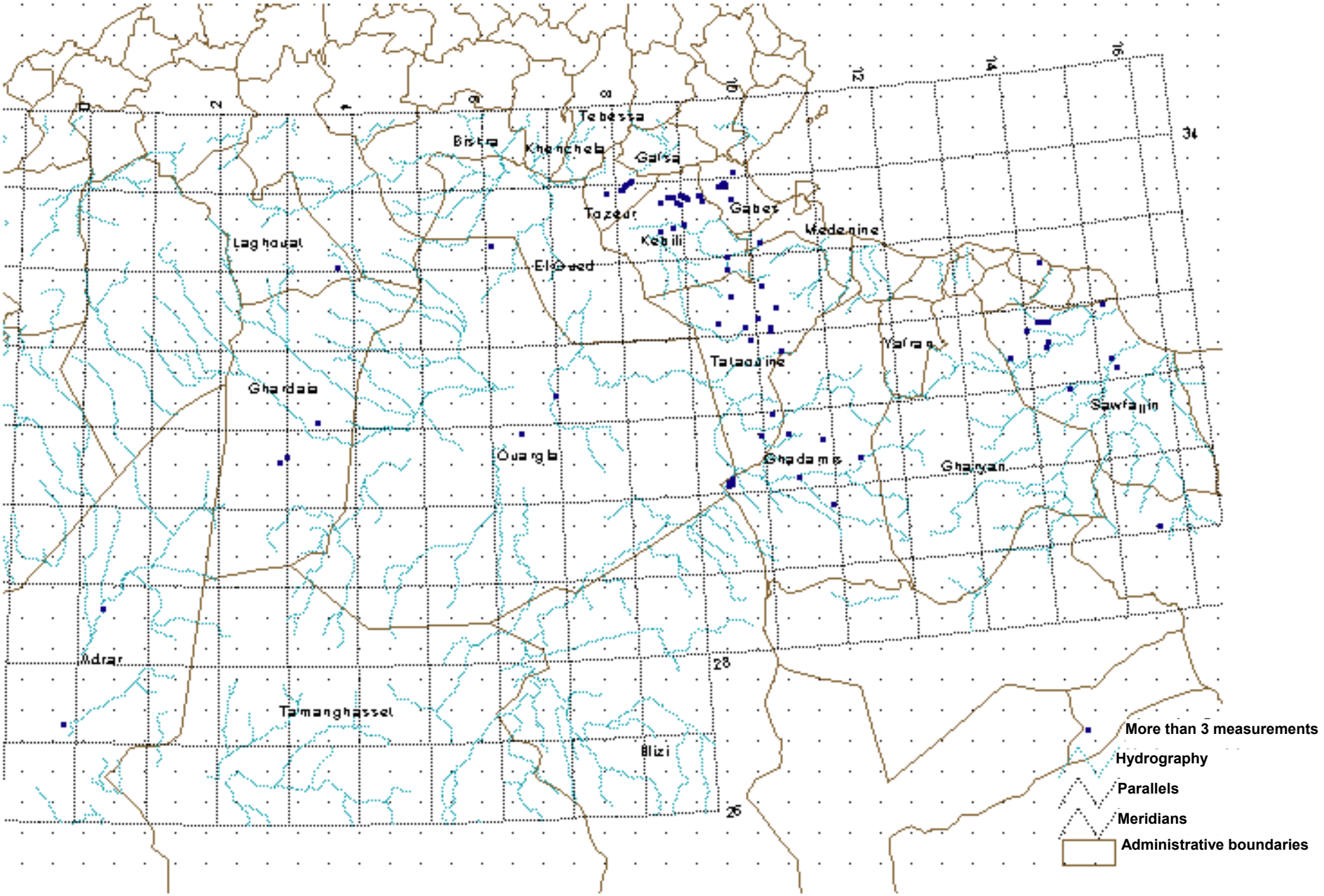
DGRE and GWA carry out regular monitoring of the levels by means of a network ; this is not the case for ANRH which collects these data on the occasion of inventories or in the context of studies.

Few water points have a long duration record, except for the Tunisian water points. The following table shows the scope of the piezometric series:

Country	Longest series (years)	Number of points with 3 or more measurements
Algeria	7	48
Libya	16	39
Tunisia	25	225


CT water points with 3 level measurements or more
Tebessa
Biskra
Khenchela
Gafsa
Tozeur
Gabes
Medenine
Laghouat
Kebili
El Oued
Tataouine
Yafran
Sawfajjin
Ghardaia
Ouargla
Ghadames
Gharyan
Tamanghasset
Illizi
CT boundaries
More than 3 measurements
Hydrography
Parallels
Meridians
Administrative boundaries

Cl water points with 3 level measurements or more



4.4.1.3. Salinity (Total Dissolved Salts) record

Country	**Number of points with TDS (Total Dissolved Salts) measurement**	**Origin of data**
Algeria	1294	ANRH data base Data from previous studies
Libya	175	Water points files
Tunisia	365	Data base Previous studies

The following table gives a synthesis of the evolution of the number of TDS records as per period:

Period **Aquifer**	**Before 1972**	**Between 1972 and 1981**	**Between 1982 and 1990**	**After 1990**
CI	165	256	262	73
CT	803	1853	803	347

5- DATA PROCESSING AND VALIDATION

Three broad sets of digital queries have been developed for enquiry, control and updating of the data:

- Statistical tables on the state and volume of the data collected ;
- Synthesis surveys and cross tables ;
- Control and analysis statistical queries.

These queries are sometimes complemented by graphic and cartographic representations for better interpretation.

5.1- Statistical queries

A set of statistical queries has been developed in order to evaluate the state of the data collected in the DB. These queries have made it possible to unveil the gaps and detect the anomalies found in the data collected.

It is worth pointing out that this is probably the first time, within the three administrations, that data control and correction operations take place straight in the Data Base and not in work files as was the case in the past.

This represents a major achievement for SASS future updates and is a sure contribution towards the validation of the data about the zone.

The set of tools having been available to the countries, their use for the processing of data in other regions is possible.

5.1.1. Statistics on the rate of filling out of the major fields

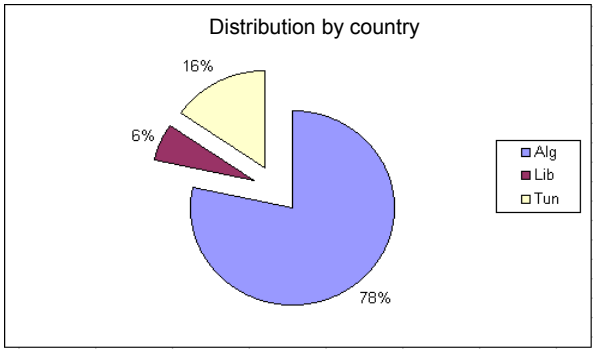
These fields are those which allow the identification, location and characterisation of a water point.

Field	Classification n°	Name	Aquifer	Wilaya	Longitude	Latitude	Construction date	Altitude	Depth
Filled out	8072	7708	7775	6691	7241	7244	5821	3178	5530
Percentage	100,00%	95,49%	96,32	82,89%	89,71%	89,74%	72,11%	39,37%	68,51%

The figures above represent the situation upon completion of the data collection task, after a long control, correction and gap filling operation of operation conducted by the national project teams and by the SASS team.

Still in this same area, the number of water points whose fields above have all been filled out (100% on the whole) is fairly considerable, as illustrated by the following table:

Aqquifer	Alg	Lib	Tun	The 3 countries
CI	418	79	59	**556**
CT	1315		196	**1511**
Total	1733	79	255	**2067**



The total number of water points being about 8000.

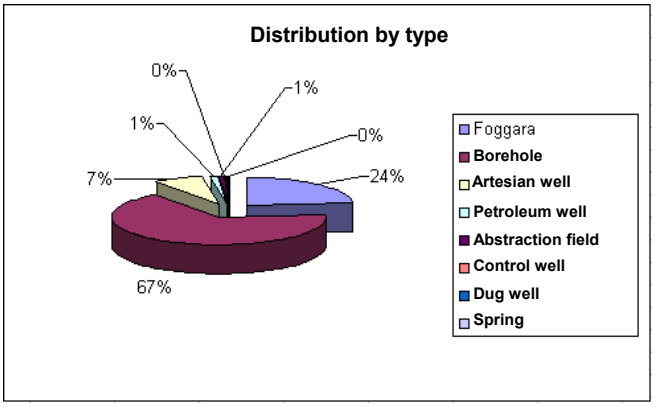
5.1.2. Number of water points as per Wilaya and per aquifer

Aquifer	Country	Wilaya	1950	1960	1970	1980	1990	2000
CI	ALG.	Adrar		176	176	177	450	412
		Biskra		1	1	5	19	19
		El Oued	1	1	2	5	13	13
		Ghardaia	3		39	47	119	210
		Illizi					22	29
		Ouargla		1	16	25	83	85
		Tamanghasset	1			1	66	72
	LIB.	Al Jufrah					1	1
		Ghadamis			1	1	1	1
		Gharyan				1	1	1
		Misratah				1	1	1
		Sawfajjin				17	18	18
	TUN.	Gabes	3	2	3	3	11	13
		Kebili	9	4	10	12	31	42
		Medenine					4	11
		Tataouine	6	8	31	36	26	45
		Tozeur					10	12
Total CI			**23**	**193**	**279**	**331**	**876**	**985**
CT	ALG.							
		Biskra	4	7	7	7		
		El Oued	7	12	21	43	297	396
		khenchela					22	22
		Ouargla	16	20	21	113	966	979
		Tebessa					16	14
	LIB.	Al Jufrah	3	3	5	5	5	5
		Al Khums	1	1	1	2	2	2
		Misratah	4	4	6	6	6	6
		Sawfajjin				2	11	11
		Zlitan	3	3	3	4	5	5
	TUN.	Gafsa					6	5
		Kebili	34	48	65	126	290	341
		Tataouine					1	2
		Tozeur	9	17	37	102	127	151
Total CT			**81**	**115**	**166**	**410**	**1754**	**1939**

The water points missing are those whose field is not filled out.

5.1.3. Distribution of the number of wells as per type

Code	CI	CT	Total
Foggara	679		679
Borehole	1918	4316	6234
Artesian well	214	156	370
Petroleum well	33	87	120
Abstraction field	24	19	43
Control well	7	12	19
Dug well		3	3
Spring	8	19	27
Total	2883	4612	**7495**



5.1.4. List of gaps and anomalies

- Water points without altitude and having piezometric measurements ;
- List of duplicates by coordinates ;
- Water points located outside of the net meshing and having an exploitation record ;
- …

5.1.5. Number of wells as per construction period

Four periods have been defined:

0 - Indeterminate (water points without construction date) ;

1 - Before 1972

2 – 1972 - 1982

3 – 1983 - 1990

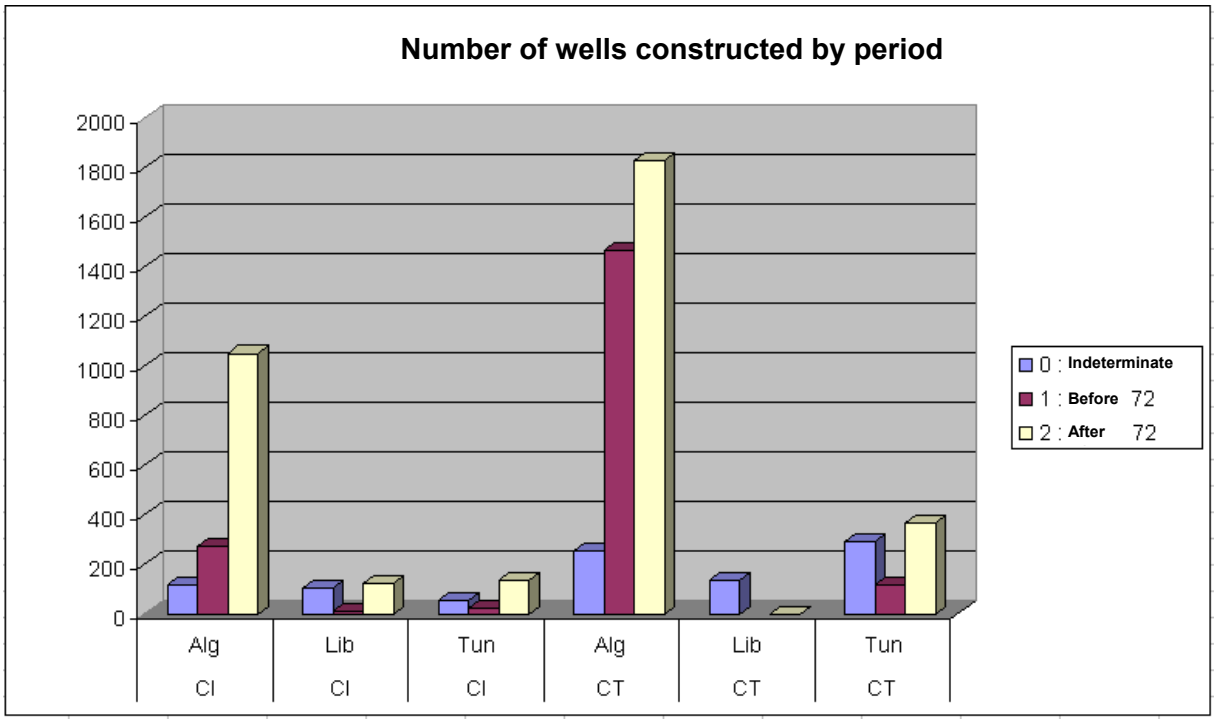
4 – 1991 - 2000

Microsoft Access - [R01_nombre par periode : Requête Analyse croisée]

Fichier Edition Affichage Insertion Format Enregistrements Outils Fenêtre ?

Aquifère	Pays	0	1	2	3	4
	A	114	274	183	483	384
CI	L	107	9	60	60	4
CI	T	57	25	16	80	42
CT	A	257	1465	429	905	491
CT	L	136			1	
CT	T	293	117	144	134	88

The number of wells whose period is indeterminate is quite large. One notices also that the period 83 – 2000 presents a high increase rate which may be due to the development of agriculture.



The grouping of the periods shows the large number of wells constructed after the ERESS study in 1972.

5.2- Synthesis queries

Statistics of wells by age-group

The following age-groups have been defined:

1: <= 20 years
2: > 20 and <= 40 years
3: > 40 and <= 60 years
4: > 60 and <= 80 years
5: > 80 and <= 100 years
6 > 100 years

Microsoft Access - [R02_nombre de points par tranche age : Requête Analyse croisée]

Fichier Edition Affichage Insertion Format Enregistrements Outils Fenêtre ?

Pays	Aquif	1	2	3	4	5	6
A	Cl	891	263	129	5	26	36
A	CT	1492	1024	490	161	116	85
L	Cl	117	147			2	1
L	CT	2	86				
T	Cl	129	30	10			1
T	CT	239	193	43	11	3	

The well stoppage date has never been filled out: this explains perhaps the presence of wells of over a century of age. In the following example, the query is based also on the exploitation data (a well not having abstraction data has most probably been stopped).

State of abstractions from wells of over 80 years of age

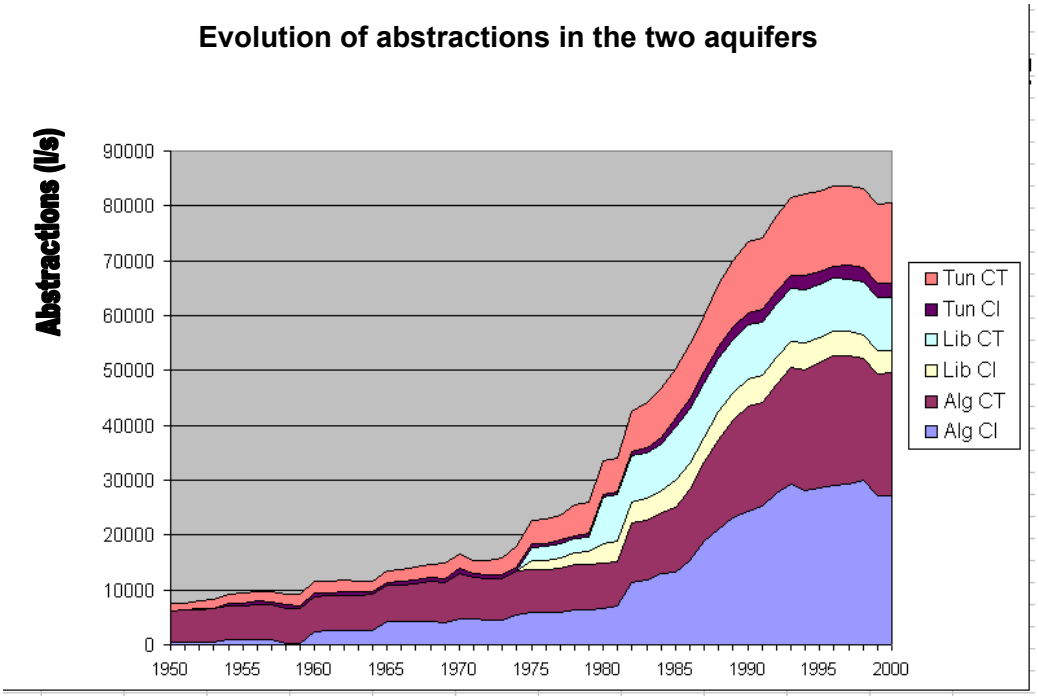
Microsoft Access - [R02_Exploitation des forages selon age : Requête Sélection]

Fichier Edition Affichage Insertion Format Enregistrements Outils Fenêtre ?

Pays	Aquifere	Noclas	age	débit (l/s)	Datfin
A	CI	X00100484	116	30	01/01/1885
A	CI	K00700021	110	6	01/01/1891
A	CI	L00700002	110	23	02/12/1891
A	CI	I00800146	101	25	01/01/1900
A	CI	J00800088	101	40	01/01/1900
A	CI	J01000814	101	100	01/01/1900
A	CI	J01100114	101	33	01/01/1900
A	CI	J01100116	101	7	01/01/1900
A	CI	J01100135	101	17	01/01/1900
A	CI	J01100136	101	40	01/01/1900
A	CI	K00700049	101	3	01/01/1900
A	CI	K00700056	101	17	01/01/1900
A	CI	K00700057	101	25	01/01/1900
A	CI	K00700058	101	11	01/01/1900
A	CI	K00800018	101	15	01/01/1900
A	CI	K00800019	101	33	01/01/1900
A	CI	K00800023	101	12	01/01/1900
A	CI	L00700034	101	13	01/01/1900
A	CI	L00700036	101	7	01/01/1900
A	CI	L00700082	101	15	01/01/1900
A	CI	L00700084	101	45	01/01/1900
A	CT	H01100639	101	39	01/01/1900
A	CT	H01100642	101	1	01/01/1900
A	CT	H01100649	101	3	01/01/1900
A	CT	H01100650	101	4	01/01/1900
A	CT	K01100046	101	2	01/01/1900
A	CT	L01100047	101	3	01/01/1900

The number of wells of over a century of age counts only 21 wells for the two aquifers together, which is markedly less than the figures of the preceding table (>120). Note the high flow (yield) of the well **J01000814.**

Graph relating to the evolution of the abstractions as per aquifer and per country



Total flows by Wilaya in 2000

Evolution of abstractions as per aquifer and per Wilaya (10^6 M3/year)

Aquifer	Country	Wilaya	1950	1960	1970	1980	1990	2000
CI	Alg	Adrar		0	0	0	163	200.5
		Biskra		3.2	3.2	14.7	51.3	51.3
		El Oued	5.5	6.8	13.9	21.8	71.7	71.7
		Ghardaia	4.9		27.2	39.4	144.2	252.8
		Illizi					22.9	32.5
		Ouargla		0.3	34.9	54.5	145.6	148
		Tamanghasset	5			0.1	84.8	100.4
	Lib	Al Jufrah					5	14
		Ghadamis			0.1	4.3	4.3	4.3
		Gharyan				1.6	1.6	0
		Misratah				0	20	6
		Sawfajjin				45	117.6	64.7
	Tun	Gabes		2.2	7.5	3.4	14.8	24.9
		Kebili		2.8	5.4	2.1	26.6	38
		Medenine					0.1	0.1
		Tataouine	0.1	1.6	14.2	12.2	8	9.1
		Tozeur					8.4	9.3
	Total CI		**15.5**	**16.9**	**106.4**	**199.1**	**889.9**	**1027.6**
CT	Alg	Biskra	3.7	10.1	13.1	10.5		
		El Oued	94.9	95.7	135.2	127.9	201.6	294.2
		khenchela					9	9.6
		Ouargla	83.4	93.9	110.6	112.9	387.6	391.3
		Tebessa					8.1	7.2
	Lib	Al Jufrah	2	3	10	94	130	107.8
		Al Khums	0.5	0.5	1	12	13	14
		Misratah	28.9	24.7	16.9	58	55.9	57.4
		Sawfajjin				1	7	27
		Zlitan	2	3.1	4.6	6	21.2	26.2
	Tun	Gafsa					4.9	2.8
		Kebili	30.6	50.4	56.5	111.1	240.2	318.2
		Tataouine					1.4	1.5
		Tozeur	10.1	15.8	26.9	80	159.1	132.5
	Total CT		**256.1**	**297.2**	**374.8**	**613.4**	**1239**	**1389.8**
		Grand total	**271.6**	**314.1**	**481.2**	**812.5**	**2129**	**2417.4**

Relation age - depth - abstractions

Country	Aquif	age	Mean Depth	Abs. (MM3)
Alg	CI	1	307,87	15,523
		2	768,62	4,327
		3	494,56	1,181
		4	440	0,024
		5	70,5	0,016
		6	692,54	0,443
	CT	1	142,99	7,422
		2	140,91	6,384
		3	144,41	2,357
		4	130,51	0,406
		5	96,19	0,125
		6	77,37	0,009
Tun	CI	1	1023,49	1,928
		2	719,51	0,368
		3	1143,75	0,086
	CT	1	395,19	4,805
		2	221,78	1,935
		3	157,94	0,229
		4	109,17	0,005
		5	120	0,001

Age-groups:

1: ≤ 20 years
2: ≤ 40
3: ≤ 60
4: ≤ 80
5: ≤ 100
6: > 100

This comparison relates only to Algeria and Tunisia, since the abstractions data for Libya are provided by exploitation group (depth non existent).

5.3- Data control and analysis queries

These queries have been developed for purposes of testing and detecting any inconsistencies induced by the transfer of data from heterogeneous files. On the whole, these queries prepare for the making of maps or graphs, which are more convenient for this type of processing.

Among such queries, which will be revisited in the next section devoted to GIS, the following are worth mentioning:

- Extraction of those water points which have formed the subject of at least one abstraction measurement ;
- Water points having at least one piezometric value, but of which one, the field « *altitude* », is missing ;
- Preparation of the drawdowns map (two level measurements: before 72 and after 90) ;
- List of water points supposed to belong to a Wilaya but located outside of it ;
- Preparation of the map relating to water points located outside of the net meshing and having an abstractions record.

5.4- GIS and spatial queries

The GIS layers consist of the topographic map processed and homogenised by IMAGIS and SOMAPHO, as well as the hydrogeological layers originating from the ERESS digitisation and complemented by the SASS team.

To these layers, there were added the coverage of the water points originating from the DB, the net meshings related to the model layers and, obviously, the whole set of thematic maps made based on the ACCESS or ARCVIEW queries.

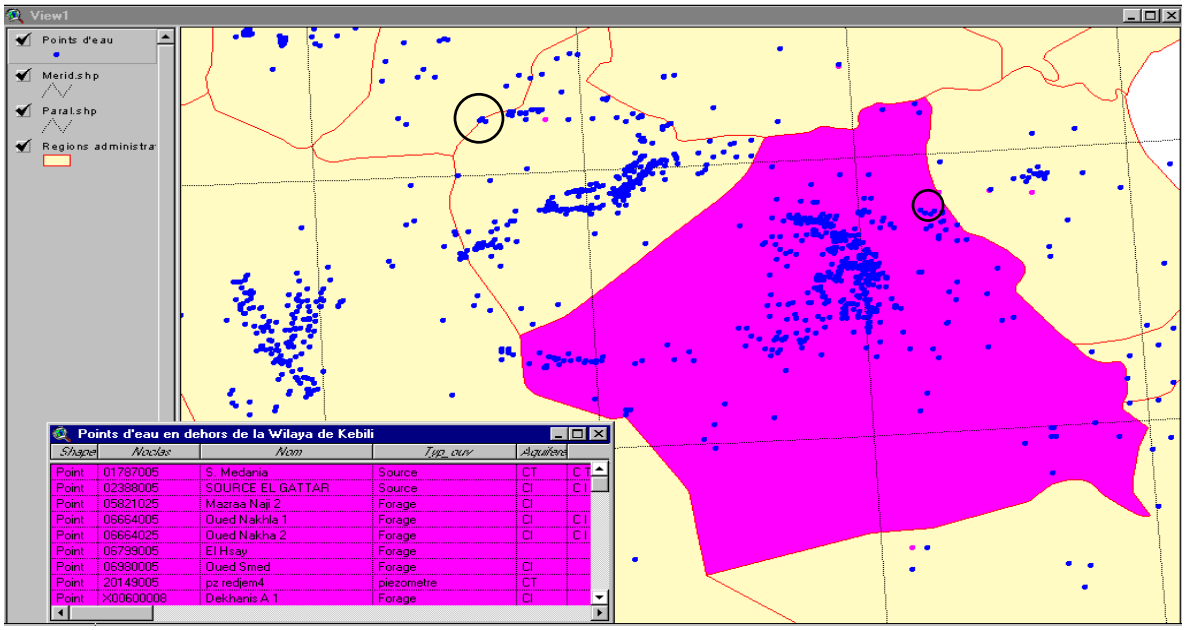
GIS plays a major part in the system that has been set up in the sense that it is used at each step during the operation of data processing:

- correction or reconstruction of certain parameters ;
- special queries for error detection ;
- generation of the net meshing via the language incorporated in the GIS software ;
- connection with the digital model.

5.4.1. Data control spatial queries

These are procedures allowing a detection of anomalies in the location of the water points (coordinates, belonging to a spatial unit).

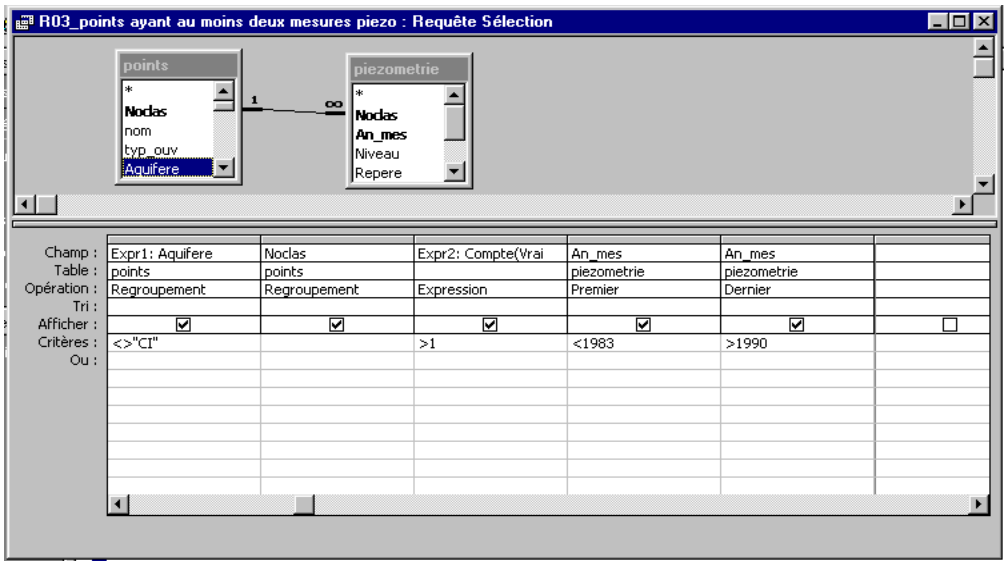
Anomalies relating to coordinates or to belonging to a unit



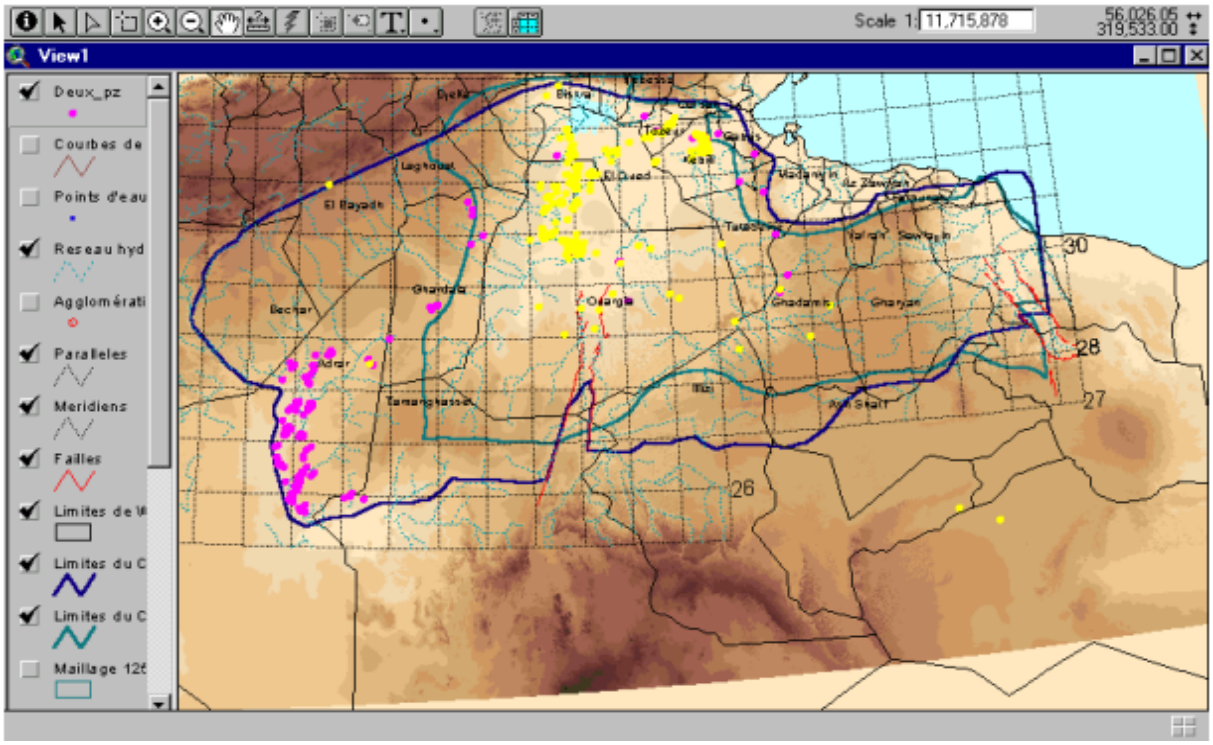
Here, the water points supposed to belong to the Governorate of Kébili, but actually located outside of the Governorate, are identified. A list of all these water points in need of checking may be recorded in all standard formats (Dbase, Excel, …) .

Map of the points requiring measurements of level or of altitude

This query has been developed for purposes of defining the additional field work necessary to obtain reference piezometric maps for the model. The operation consists in extracting from the DB the whole set of water points lacking a level value and, among them, those requiring a measurement of altitude in situ.



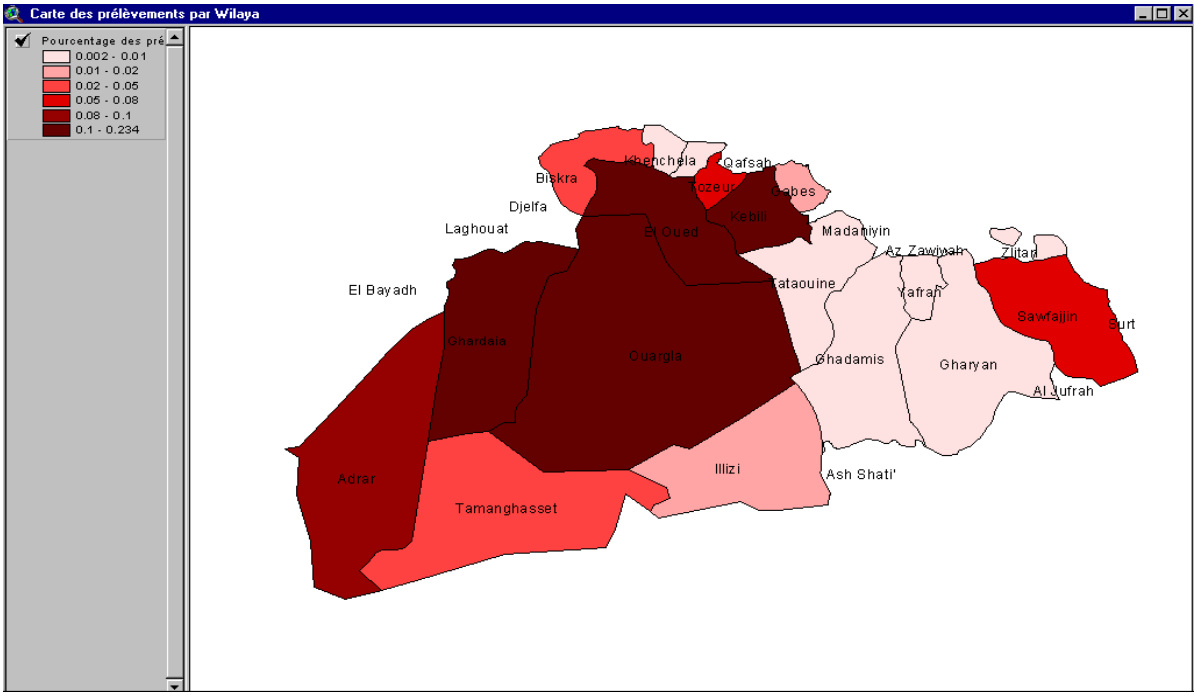
The result of the query is taken up again under ARCVIEW for the development of the map below:



In yellow, the water points meeting the criteria set.

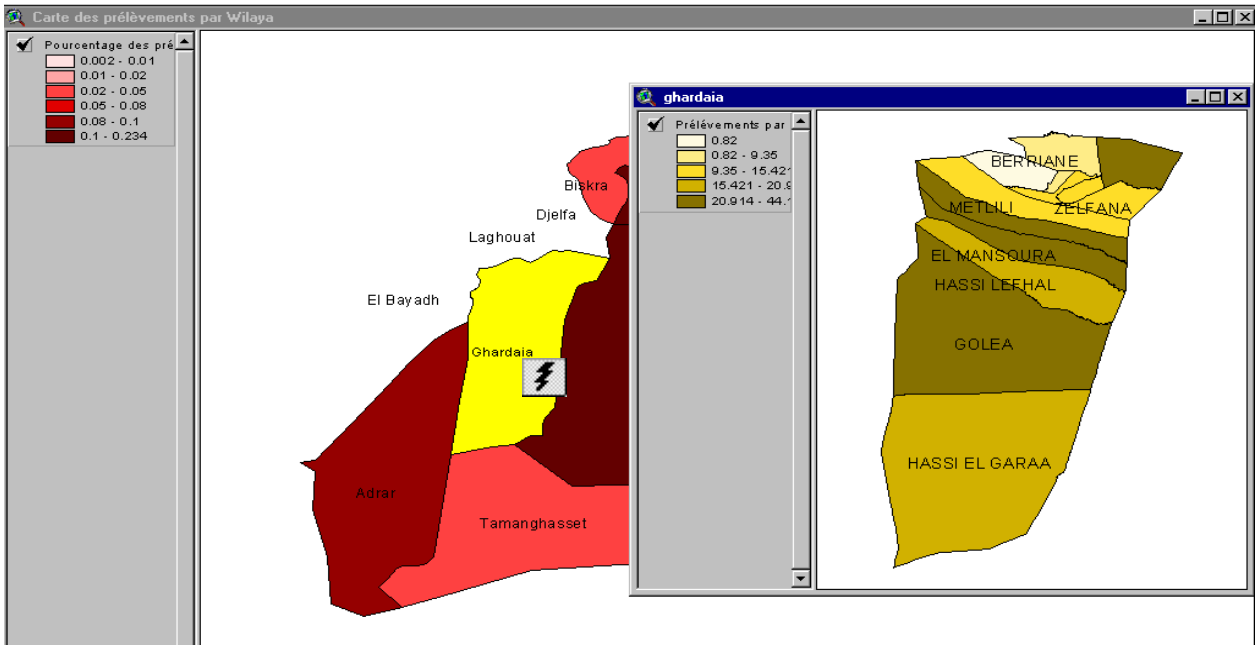
5.4.2. Synthesis queries and various thematic maps

Distribution of the total abstractions as per Wilaya in 2000



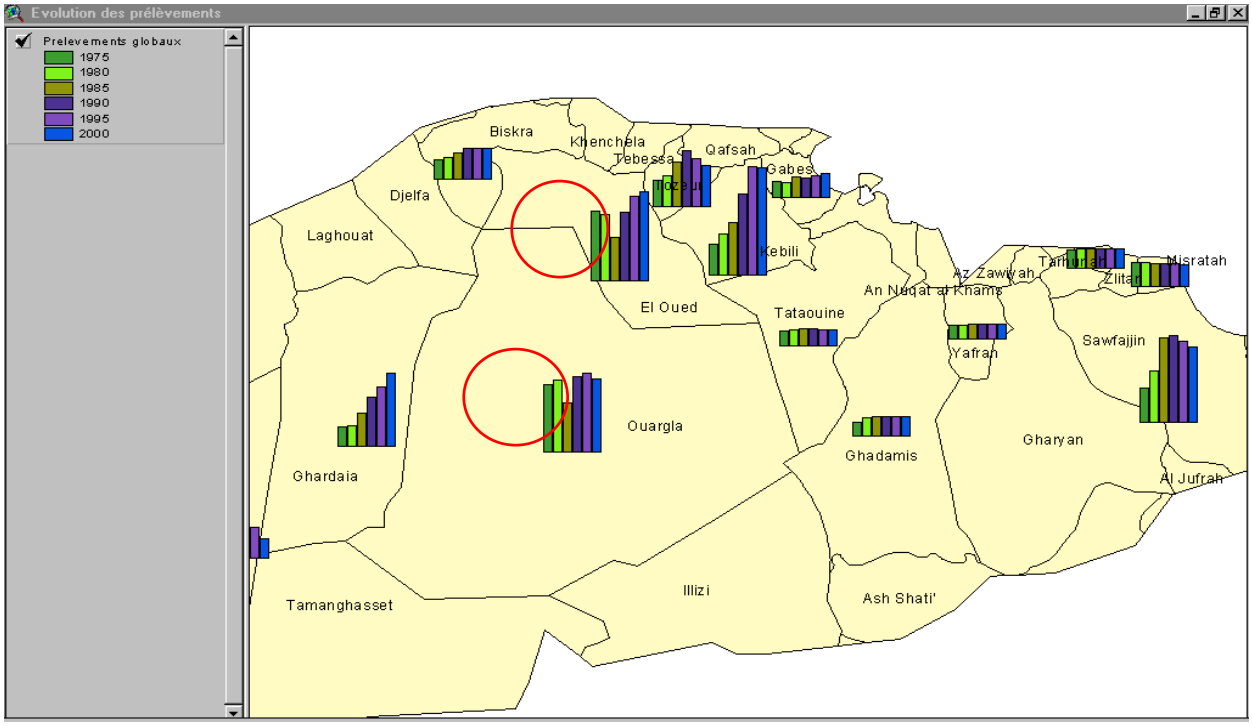
The use of queries offers the invaluable advantage of an automatic updating of the map each time a change occurs with respect to the basic data (addition of new exploitation values, changes in the boundaries of the Wilaya . . .).

The « *HOTLINK* » functionality of the « *ARCVIEW* » software make is possible to ***zoom*** on a given Wilaya in order to obtain a detailed distribution of these abstractions at the level of the communes, such as illustrated by the following example::



In this example, a click on the Wilaya of Ghardaia displays a map relating to the distribution of the volumes tapped by commune. It is, thus possible to define several levels of links corresponding to increasingly larger scales.

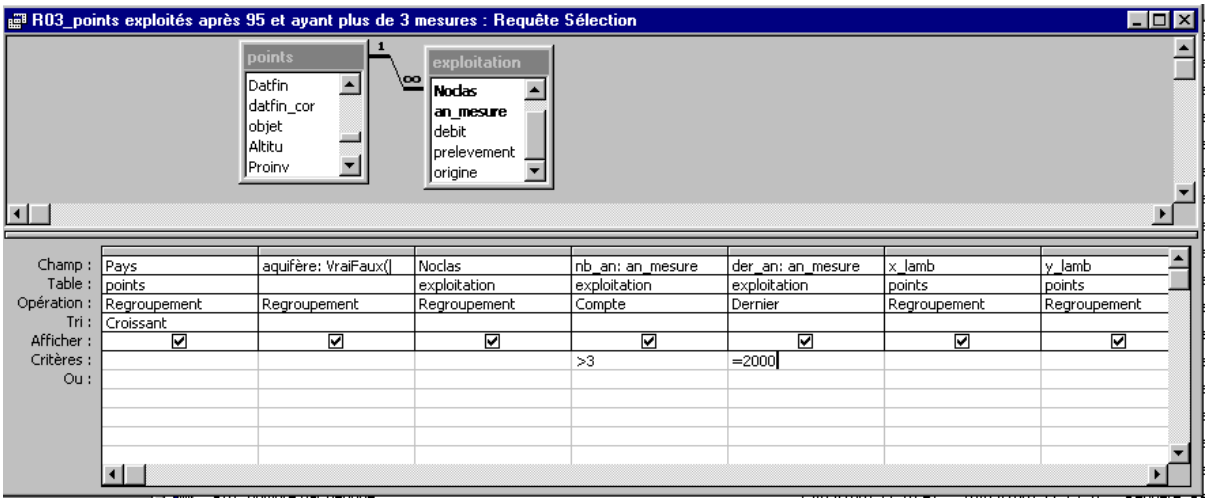
Evolution of the total abstractions from 1975 to 2000



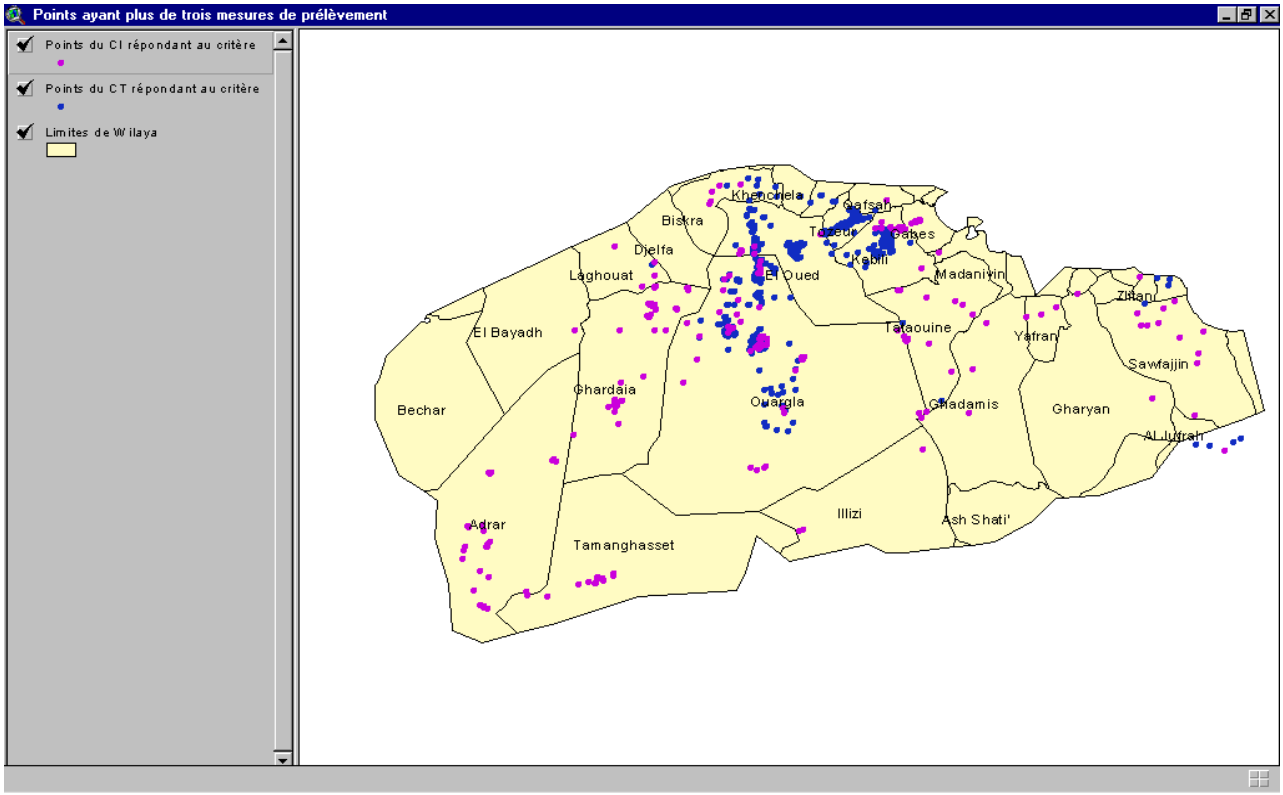
It is soon noted that, for the Wilayas of « *Ouargla* » and « *El Oued* », the abstractions for 1985 need checking.

Water points still exploited, and provided with an abstraction record (>3 values)

This map, which presents in magenta the CI water points that meet this criterion, is the output of a ACCESS query involving the « *water points* » and « *exploitation* » tables. The query is illustrated below:



This query is taken up again directly under ARCVIEW:



Such a processing may serve to select, for instance, the water points to be included in the future network for the measurement of extracted flows.

PART III

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

The establishment of the SASS data base has made it possible to collect and homogenise the whole body of data available to date about the zone, and this within a relational and consistent structure.

Without this hospitable architecture, it would have been difficult to imagine the performance of all the processing operations, queries and thematic maps that the project has managed to produce.

The investment and the effort made are already cost-effective and profitable in the framework of this project, considering, for instance, the time it used to take, only a few years ago, in order to update a model following a change in the net meshing, the integration of new data or the inclusion of a new abstraction scenario.

The system developed during the project, which revolves around DB – GIS – Model links, has proved to be of great usefulness and constitutes, for the countries, a non negligible basis for the development of high-performance management tools.

As regards the contents, much has been done ; however, certain anomalies still exist:

- a good number of wells are still lacking an identifier or coordinates ;
- the space and time distribution of the data is not homogeneous ;
- the abstractions are still in need for greater mastery.

If the purpose is to achieve a level of reliability sufficient enough to ensure error free data, it is required to do further work on these collected data and to define clear procedures for the collection of new data.

The former task can only be carried out by the countries themselves, using the tools and means made available to them by SASS. As for the latter task, i.e. future updates, they cannot be made reliable unless the collection, coding and control processes are undertaken at local level.

A decentralisation of the management and processing needs will need to be provided and promoted in order to facilitate future (and why not regular) updates of the information.

Yet, the most urgent task remains that of « *clearing »* and stabilising the present DB so that it can better reflect the current situation. Such operation needs to involve mainly the country teams.

The tasks to be carried out by the countries are summed up in the following table:

Table 25: Tasks to be carried out with regard to the contents of the national DBs

Country	Tasks
Algeria	- Checking the inventory data, assigning an identification number and elimination of duplicates - Entry of missing data: coordinates, depth, collected formation, altitude, dates of well construction and stoppage, condition … - Crosschecking the abstraction records with the data available to at the level of the users - Constructing the table of the exploitation groups and relating them to the water points - Checking the data related to geology - Precise demarcation of the exploitation zones and their cartography
Libya	- Crosschecking the data entered at SASS level with the wells actually existing, elimination of duplicates and assignment of identifiers - Construction of abstraction records as per well - Construction of the table of the exploitation groups and relating them to the water points - Checking the data related to geology - Precise demarcation of the exploitation zones and their cartography
Tunisia	- Checking the characteristics of the water points and complementing the missing data - Constructing the table of the exploitation groups and relating them to the water points - Checking the data related to geology - Precise demarcation of the exploitation zones and their cartography

Within a second phase, it will be perhaps necessary to integrate the data relevant to the well equipments and related installations (pumps, motors . . .), at least for the major wells.

As far as GIS is concerned, it is important to develop a more precise digital cartography of the zones presenting particular hydrogeological potential: large scale topographic map, more precise MNT, boundaries of crop zones and of the extensions envisaged . . .

And yet, technical tools are not enough by themselves to ensure proper operating of the information system's collection and updating mechanism. It is, indeed, necessary to set up an appropriate organisation and working procedures that are compatible with those already established in each of the project countries.

It is this component which needs to be developed so that the consultation structure could play fully its role of production of reliable decision-making tools for a rational management of the basin waters.

The set up of an information exchange channel and of organised processing procedures is a key factor for the success of the consultation mechanism. It is these aspects, which were often ignored in the past, that make it possible to support and sustain the technical tools developed in the context of the study, as well as to enhance their efficiency.

ANNEXES

ANNEX 1

Description of the tables and fields of the common DB

Table: *ADMIN_SASS*: Administrative units (Wilaya, Governorate, Province)

Field	Designation	Type	Size
Admin_name	Name of administrative unit	Text	42
Pays	Country code: A,L or T	Text	1
Population	Population of the latest census	Full length	4
SuperfiICe	Area in km²	Real double number	8
nom_loc	Local appellation	Text	20

Table: *AQUIFERE*: Major aquifers (CI, CT, Turonian)

Field	Designation	Type	Size
Code	Aquifer code: CI, CT, TU	Text	2
Nom	Full name	Text	30

Table: *CAPTAGE*: Strained depths of the wells

Field	Designation	Type	Size
noclas	Classification number	Text	14
Num_capt	Sequential number of layer	OTCet	1
prof_deb	Depth of beginning of screen (m)	Real single number	4
prof_fin	Depth of end of screen (m)	Real single number	4
formation	Formation	Text	40

Table: *COUCHES SIG*: GIS layers used in the map window

Name	Designation	Type	Size
layer_id	Layer number (sequential)	Full	2
nom	Name of layer (name of SHP file)	Text	12
description	Description of layer in light	Text	30
affichage	Displayed or not in the map window	Yes/No	1
étiquette	Visibility of labels	Yes/ No	1
color_back	Background colour	Full length	4
color_out	Line colour	Full length	4
style	Fill style	Full	2
symb_pt	Symbol for point items	Full length	4
chp_etiq	Field used for label	Full	2

Table: *EXPLOITATION*: Record of flows or abstractions

Name	Designation	Type	Size
Noclas	Classification number	Text	14
an_mesure	Year of measurement of the flow or the abstraction	Full	2
débit	Flow in l/s	Real single number	4
prélèvement	Annual volume abstracted in m3	Real double number	8
origine	Origin of the measurement or of the data	Text	20

Table: *HYDRODYNAMIC*: Values of hydrodynamic parameters

Name	Designation	Type	Size
Noclas	Classification number	Text	14
Date_mesure	Date of measurement	Date/Hour	8
Duree	Duration of pumping test	OTCet	1
NS	Static level in m	Real single number	4
Debit	Flow in l/s	Real single number	4
Rabattement	Drawdown in m	Real single number	4
Transmiss	Transmissivity	Real double number	8
Permeab	Permeability	Real single number	4
Coeff_emmag	Storage coefficient	Real single number	4

Table: *PAYS*: List of countries involved in the zone

Name	Designation	Type	Size
Code	Country code: A, L or T	Text	1
Nom	Full name	Text	20

Table: piezometrie: Record of piezometric measurements

Name	Designation	Type	Size
Noclas	Classification number	Text	14
An_mes	Year of measurement	Full	2
Niveau	Piezometric level in m	Real single number	4
Rpere	Altitude of marker in m	Real single number	4
Alt_np	Altitude of piezometric level	Real single number	4
Origine	Origin of measurement	Text	20
Observation	Observation on measurement quality (lexis)	Text	10

Table: points: Characteristics of the water points

Name	Designation	Type	Size
Noclas	Classification number of water point	Text	14
Nom	Name	Text	40
typ_ouv	Type of water point (lexis)	Text	20
Aquifère	Aquifer code	Text	2
Nappe	Formation	Text	40
Pays	Country code	Text	1
Wilaya	Administrative unit	Text	30
Region	Economic region	Text	30
grp_exp	Exploitation group	Text	20
Longit	Longitude such as collected	Text	12
Latitu	Latitude	Text	12

type_geo	Type of coordinates (lexis)	Text	1
X_geo	Longitude degrees	OTCet	1
x_min	Longitude minutes	OTCet	1
x_sec	Longitude seconds	OTCet	1
est_ouest	East or West of Greenwich (E or W)	Text	1
Y_geo	Latitude degrees	OTCet	1
y_min	Latitude minutes	OTCet	1
y_sec	Latitude seconds	OTCet	1
long_dec	Longitude in decimal degrees	Real double number	8
latit_dec	Latitude in decimal degrees	Real double number	8
x_lamb	X Lambert in m	Real double number	8
y_lamb	Y Lambert in m	Real double number	8
LOG	Existence of drilling log	Logic	1
Datfin	Year of construction completion	Date/Hour	8
Objet	Subject of water point (lexis)	Text	30
Altitu	Altitude in m	Real double number	8
Proinv	Depth of structure in m	Real double number	8
Etat	State of water point (lexis)	Text	20

Table: qualité: Values of chemical parameters

Name	Designation	Type	Size
Noclas	Classification number	Text	14
date	Date of measurement	Date/Hour	8
RS	Total Dissolved Saltss (TDS)	Real single number	4
Ca	Calcium	Real single number	4
Mg	Magnesium	Real single number	4
K	Potassium	Real single number	4
Na	Sodium	Real single number	4
Cl	Chlorine	Real single number	4
So4	Sulphates	Real single number	4
Co3		Real single number	4
Co2		Real single number	4
pH		Real single number	4
temp	Water temperature in °C	Real single number	4

Table: *LITHOLOGIE*: Codes and description of the lithological formations crossed

Name	Designation	Type	Size
code_litho	Code of lithological formation	Text	4
Description	Description in light	Text	50

Table: Litho_point: Lithology at water point

Nom	Designation	Type	Size
Noclas	Classification number of water point	Text	14
Code_Litho	Code of lithological layer	Text	4
Prof_deb	Depth beginning in m	Real single number	4
Prof_fin	Depth end in m	Real single number	4
media_cond	Conditions of the medium (lexis)	OTCet	1
type_aquifer	Aquifer type (lexis)	OTCet	1
Porosité	Porosity	Real single number	4
Perméabilité	Permeability	Real single number	4

Table: *MAILLAGE*: List and characteristics of the net meshings created

Name	Designation	Type	Size
maillage	Grid (net mesh) number	OTCet	1
X_orig	X of starting point in m	Real single number	4
Y_orig	Y of starting point in m	Real single number	4
Size	Size of the net mesh in m	Full	2
nb_grille_x	Number of cells in X	Full	2
nb_grille_y	Number of cells in Y	Full	2
Angle	Direction angle in °	Real single number	4

Table: maillage_points: Net mesh - points relation

Name	Designation	Type	Size
noclas	Classification number pf water point	Text	14
maillage	Grid (net mesh) number	Text	10
maille	Cell number in the grid under consideration	Text	12

The cell number is updated based on a procedure that requires a spatial query.

This procedure needs to be initiated each time a change of coordinates occurs.

Table: ***ALIMENT***: Recharge zone (in this version, this is a point item). The present table has been added for purposes of the PM5 which processes the flow at net mesh location as an algebraic sum [*alimentation* + *prélèvements*] (recharge + abstractions)

Name	Designation	Type	Size
Couche	Model layer	Text	50
Aquif	Aquifer number (PM5 number)	Real double number	8
Noclas	Identification number of recharge zone	Text	255
X	X Lambert of the zone in m	Real double number	8
Y	Y Lambert in m	Real double number	8
Alim	Recharge in m3/s	Real double number	8

Table: *ALIM_MAILLAGE*: Recharge – net meshin relation

Name	Designation	Type	Size
Noclas	Classification number for recharge zone	Text	254
Maille	Cell number	Text	10

The cell number is automatically updated based on a procedure using a number assignment spatial query. This procedure is initiated each time there is a change in coordinates or on the occasion of a new net meshing.

Table: *LEXIQUE*: Contains the significance of the coding used

Name	Designation	Type	Size
Nom	Name of lexis	Text	25
Code	Code of lexical item (sequential number)	OTCet	1
Description-Fr	Description in French language	Text	50
Description-Eng	Description in English language	Text	50
Observation	Observations	Text	20

ANNEX 2

Instructions of use of SAGESSE

INTRODUCTION

SAGESSE has been developed for purposes of bringing together and capitalizing the whole set of computer developments conducted in the framework of the SASS project. The intention was to gradually design a data management tool that would be of use not only to the countries concerned for their own needs, but also to the basin management consultation structure envisaged for the post-project phase.

The set up of this system has allowed, among other outcomes:

- A synthesis of the data available (data collected by the countries, data collected in the context of the studies conducted in the zone) which have been brought together and organised under the form of an exhaustive, relational data base that will allow in future a considerable saving of costs and of time with regard to the data collection phase ;
- A set of tools facilitating the preparation of entry data for the digital model have been developed. These tools have allowed, and will continue to allow, an easier implementation of the exploitation scenarios ;
- A set of information updating and transfer processes which facilitate the model updating operations as result of a standardisation of the data likely to originate from the three countries.

SAGESSE is, therefore, in sum:

- A relational data base designed to meet, in a sustainable way, the requirements pertaining in the management of the basin and likely to offer a concrete response to the concerns of the three countries ;
- A set of modules sparing the tedious tasks of preparing the data for the model and offering the possibilities for the model designer to integrate more hypotheses ;
- A user-friendly interface for browsing, query and selection, as well as updating of information ;
- An arsenal of statistical queries liable to be enriched and customised according to the needs in hand.

The processes used for the development of this system offer a sustainable technological solution and an easy migration to top-of-the-range systems should such migration prove to be necessary (DB volume, increased use by several users, multiplication of parties to the system, integration of additional data . . .). These state-of-the-art techniques may be summed up as follows:

- Use of the ACTIVEX technology ;
- Use of GIS tools for interfacing with the digital model ;
- A configuration allowing easy maintenance of the system.

SAGESSE comprises, accordingly, three main components which are:

- The DB proper: this is the tables and queries structure ;
- The user interface: browser, entry forms ;
- The modules allowing connection with the digital model and the customisation and GIS connection VB functions.

Installation

Required Configuration

SAGESSE has has been designed to operate in standalone under Windows 9x, 2000 or NT. It operates in optimal manner with the hardware purchased under the project for each of the three countries and at SASS head office in Tunis, that is Pentium III with:

- 128 Mb RAM
- A 17'' screen
- 1 ZIP drive

The following software is required for operating the SAGESSE system:

- Professional OFFICE 2000, including ACCESS
- ARCVIEW 3.2
- SPATIAL ANALYST

Installation procedure

The installation is done manually by mere copy of the files comprised in the CDROM. It is required to create two files within a same drive:

- The «***SAGESSE***» file which should include the data base ;
- The «***CARTES_SASS»*** (SASS_MAPS) file where the cartographic files will be copied.

Files supplied with the software:

- The «SAGESSE» file which comprises the following files:
    - Sagesse_data: File comprising the data only (tables)
    - Sagesse.mdb: File comprising the other items of the data base
    - Sagesse.mdw: File comprising information on the work groups

    - Book03.ico: Icons file
    - Earth.ico
    - Pm5.bmp
    - Search.avi

    - Init_lamb.ave: Initialisation of the extension «*Maj_DB_Lamb*»
    - Maj_DB_Lamb.avx: extension for the geographic - Lambert conversion and updating of the DB
    - gen_maille_clip.mbx: generation of the net meshing
    - histo_maille.mbx: assignment of net mesh numbers to the water points.

- The «***CARTE_SASS***» (SASS_Map) file which comprises the following ARCVIEW files:

  - admin_sass.dbf
  - admin_sass.sbn
  - admin_sass.sbx
  - admin_sass.shp
  - admin_sass.shx

  Administratives boundaries

  - courbes_niv.dbf
  - courbes_niv.sbn
  - courbes_niv.sbx
  - courbes_niv.shp
  - courbes_niv.shx

  Level contours

  - ext_ci.dbf
  - ext_ci.shp
  - ext_ci.shx

  CI extension

  - ext_ct.dbf
  - ext_ct.shp
  - ext_ct.shx

  CT extension

  - ext_sass.dbf
  - ext_sass.sbn
  - ext_sass.sbx
  - ext_sass.shp
  - ext_sass.shx

  Extension of zone

  - Failles.dbf
  - Failles.shp
  - Failles.shx

  Faults

  - grille_ci.dbf
  - grille_ci.sbn
  - grille_ci.sbx
  - grille_ci.shp
  - grille_ci.shx

  IC grid

  - grille_ct.dbf
  - grille_ct.shp
  - grille_ct.shx

  IC grid

  - hydro.dbf
  - hydro.sbn
  - hydro.sbx
  - hydro.shp
  - hydro.shx

  Hydrographic network

  - merid.dbf
  - merid.shp
  - merid.shx

  Meridians

- paral.dbf
- paral.shp
- paral.shx

Parallels

- points_sass.dbf
- points_sass.sbn
- points_sass.sbx
- points_sass.shp
- points_sass.shx

Water points

- routes.dbf
- routes.sbn
- routes.sbx
- routes.shp
- routes.shx

Main roads

villes_1.dbf

- villes_1.sbn
- villes_1.sbx
- villes_1.shp

Main towns

Installation procedure

Step 1:

- Copy the files cited above into the respective files. One basic condition: the same disk unit must accommodate both the *« SAGESSE*» and «*CARTE_SASS*» (SASS_Maps) files ;
- Creation of the shortcut via the following properties:

"C:\Program Files\Microsoft Office\Office\MSACCESS.EXE" U:\sagesse\sagesse.mdb /wrkgrp U:\sagesse\sagesse.mdw »

With the start repertory : *U:**sagesse*

The letter U represents the letter of the drive where the files have been copied.

Step 2: Copy the annexed modules

This operation concerns the «Avenue» and «Mapbasic» programmes developed for purposes of ensuring the BD - SIG – PM5 connection functions.

- «Avenue» files:
  - Init_lamb.ave in the repertory *«**Sagesse** »*
  - Maj_DB_Lamb.avx in the file «***U:\esri\AV_GIS30\ARCVIEW\EXT32***»

With U designating the drive where the ARCVIEW software is installed:

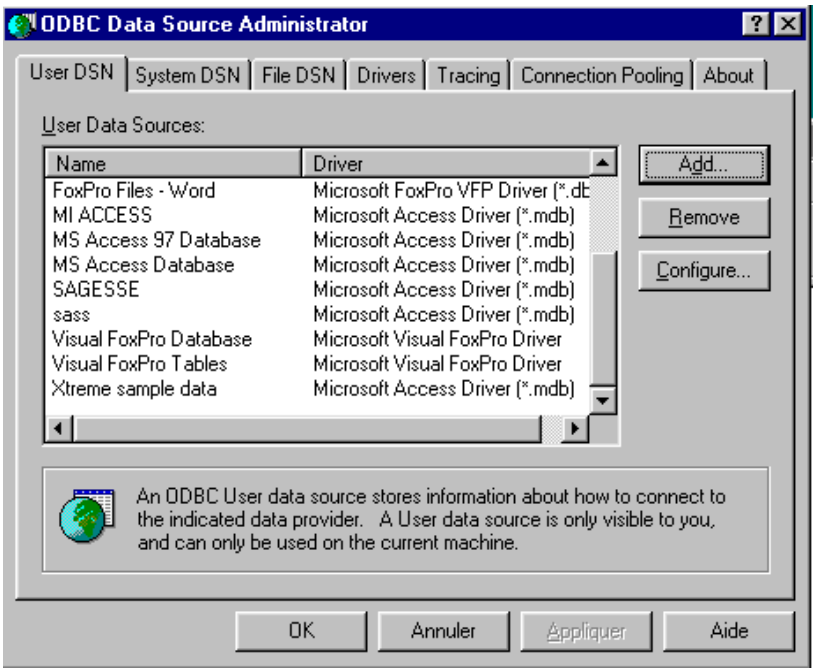
- «Mapbasic» files:
  - gen_maille_clip.mbx: in the repertory «***Sagesse** »*
  - histo_maille.mbx also in «Sagesse»

Step 3: ODBC configuration

For this purpose, initiate the module «*Odbc 32* » from the configuration panel:

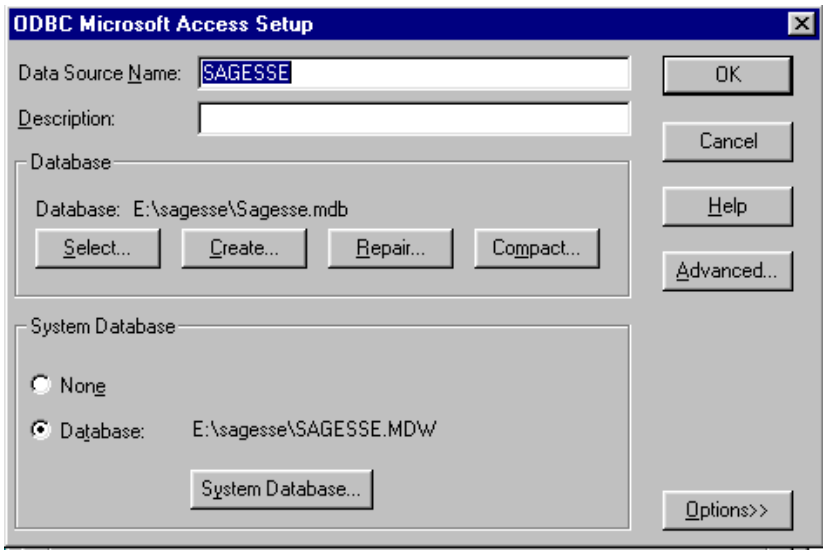
The purpose of this operation is to add a «***SAGESSE***» data source in order to be able to connect to it from Arcview .

The following screen view is displayed:



- When this is displayed, click on the button «***Add***» after having selected the drive «***MS ACCESS DATABASE***». Afterwards, type on the following screen:

The name of the data source: «***SAGESSE***» and select the name of the system base copied previously in the appropriate file (which contains the DB).



Click on OK and close the configuration panel window.

Information on the working groups:

Three groups have been set up each of which having access privileges and rights. A password and an account are assigned to each of these groups.

The “system manager” group

This group enjoys full rights of updating of the information and of modification of the other items in the data base. A single “system manager” is based for the time being (SASS headquarters in Tunis).

The “Project teams” group

These are the users among the national teams of the three countries each of which having their own account and their own password. Only the data could be updated by this group which is not eligible to modify certain items, such as the utility tables and the common and configuration forms.

Each of the countries may access the data proper to the other two,; however, only the modifications pertaining to the data of the country concerned are taken into consideration in updating the common base hosted by SASS.

The “Model team” group

The latter group enjoys « read only » access rights over the whole body of data, and may modify certain items of the DB relevant to the digital model.

Groups list:

- SASS (System manager)

- ANRH
- DGRE
- GWA
- Model:
- Guest: Consultation only.

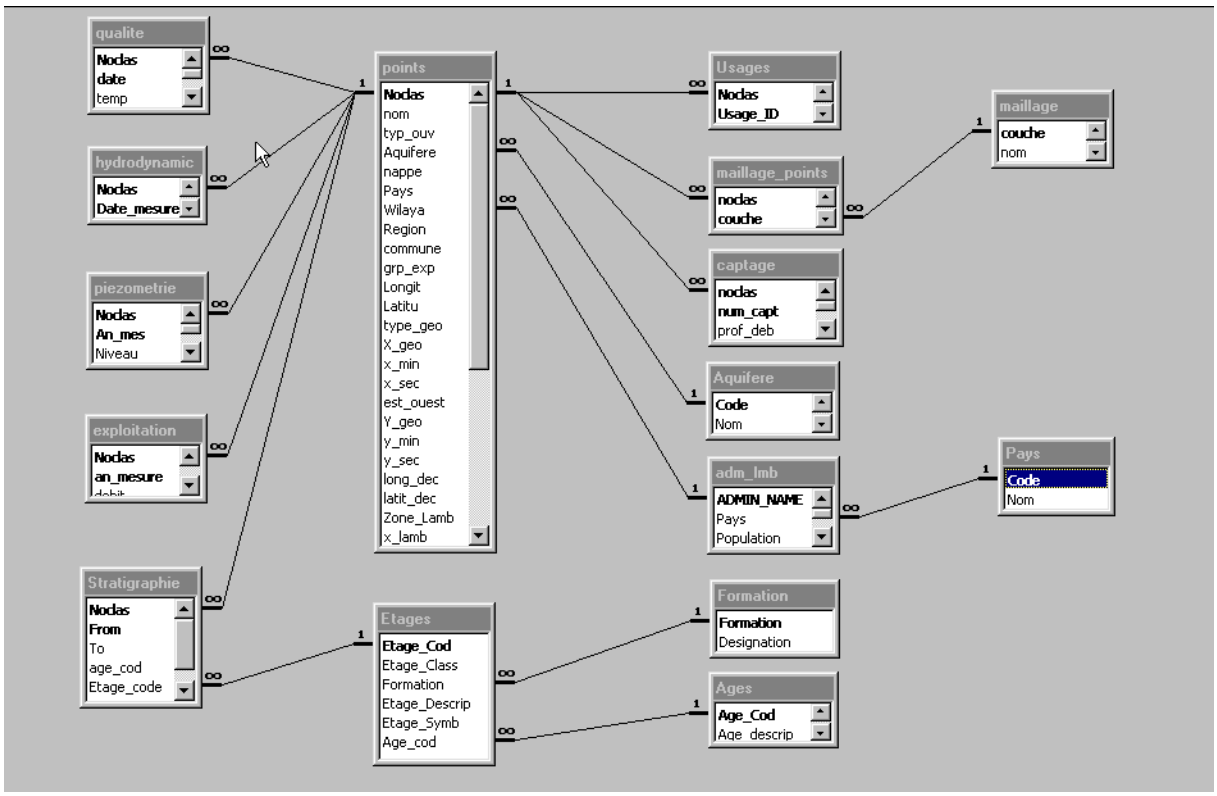
Presentation of the data base

Items of the DB

Like any ACCESS base, the SASS base is made up of system and users items:

- The tables where the basic data are stored ;
- The queries which comprise the controls allowing a visualisation of part of the data originating from one or several types and meeting certain criteria ;
- The forms allowing the display and entry of data ;
- The reports serving to present under the form of query or table output statements in order to print them or to send them to other office automation software ;
- Lthe macros which perform pre-defined actions in response to certain events (click on a button, for instance) ;
- And, finally, the modules where the specific programmes developed in VBA language are kept for purposes of executing the functions not provided under ACCESS (specific functions or procedures).

Diagram of the DB:



Relations are established between these various tables according to the rules listed during the design study. These relations make it possible to preserve, after each modification, the integrity of the system:

- Thus, it is not possible, for example, to create a record for a water point that is not yet in the «**POINTS**» table ;
- If the identifier of a water point is modified, all related tables are automatically updated ;

- In case one tries to remove a Wilaya that comprises at least one water point, the system displays an error message.

These relations are also of great relevance for the development of queries (connections).

This structure derives from the data design model, of which it represents a sub-set, since only those data necessary for the project have been taken into consideration. This has yielded the following tables, classified below as per class:

The tables:

Statistical data tables:

- ***Points***: Characteristics of the water points, identified by a unique code which is the field «NOCLAS» (classification number). This field is duplicated under the same form according to which it exists at the level of each of the countries (identical coding).
- ***Adm_Imb*** and ***Pays***: representing respectively the administrative units (Wilaya or municipalities) and the countries.
- ***Captage*** and ***Aquifère*** containing the data relevant to the layers tapped.
- ***Maillage*** and ***Maillage-points:*** the former comprises the characteristics of the cells (it is possible to have many of them, according to the size of the cells, the extension, the consideration or not of an aquifer layer). The latter is an intermediate table making the connection between the two (a water point belongs in a given cell within a grid (net mesh) under consideration).
- **Usages**: main uses of the water points (drinking water supply, irrigation, …). A water point may have several purposes.
- **Ages, étages** and **Formations:** these tables comprise, respectively, the geological ages, the stages and the various litho-stratigraphic formations existing in SASS.
- **Stratigraphie:** Description of the various geological layers of the points having served for the plotting of the contours.

Records tables:

- ***Piézométrie:*** series of piezometric values by water point and per year. The value is either a static level, or a piezometric level. The conversion is performed by the system when the field « a*ltitude*» is filled out.
- ***Exploitation***: record of abstractions, also made by year. Two fields are accepted: the flow in l/s or else the volume in m³/year ; the conversion of one into the other is made automatically in the course of the entry.
- ***Qualité***: contains the values of the chemical analyses by date and by water point.
- ***Hydrodynamic***: record of the values of the hydraulic parameters. It has been preferred to add a date to this type of data, even though, currently, an only one measurement at most is related to each water point.

Utility tables:

These are the tables used by the system for its operating. On the whole, these tables can only be updated by the « system manager ».:

- ***Lexique***: contains all the coding used in the base. It is displayed under the form of a dictionary Code – Significance in bright.
- ***Couches_SIG:*** list of GIS coverage and of related attributes.
- ***Liste_requete:*** list of all the queries that may be performed via the explorer (button ).

Model link tables:

These annex tables are created and updated by programmes and serve exclusively for operations of data preparation for the digital model. Their presence is indispensable for a proper operating of the system.

- ***Aliment***: comprises the recharge data by cell in m³/s. The recharge data are entered by cell and not by water point.
- ***Alim_maillage***: relation between *Point* and *Aliment* (water point and recharge).

The forms:

They constitute the user interface for scrolling through and modifying the data in a simple and user-friendly way. The indispensable forms are as follows:

- ***«Principal»***: this is the form which is automatically initiated when loading to the DB and which displays the explorer. It serves as main menu and as browser of water points data.
- ***«Données générales»:*** (general data): This is the form which allows the entry of data relevant to the water points. It is displayed under the form of several page indexes each of which comprising a class of data for a given water point.
- ***«Rechercher par Noclas»:*** (retrieve by classification number): This allows the entry of a water point n° for retrieval.
- ***«Import_géeologie»:*** This is a procedure for the import of the data originating from the «ROCKWORKS» software.

The sub-forms related to the «données générales» (general data) form

- «***sf_hydro***»: for entry of the hydraulic parameters ;
- «***sf_captage***»: for entry of tapped levels ;
- «***sf_usage***»: for entry of the data relevant to water uses ;
- «***sf_exploit***» for the entry of exploitation records ;
- «***sf_piezo***»: for entry of levels records ;
- «***sf_qualite***»: for entry of water quality related data ;
- «***sf_strati***»: for entry of stratigraphic contours.
- ***«Graphique exploitation»***: (exploitation graph): This displays the graph of evolution of abstractions at the level of a water point ;
- ***«Graphique NS»*** «***graphique piézométrie***»: graphs for the series of static levels and piezometric levels, respectively ;
- «***Graphique Salinité***»: curve of the Total Dissolved Saltss (TDS) for a water point under consideration.
- ***«maj liste requete***»: Explorer of the various queries performed and classified by class.
- «***Controle couches***»: allows the configuration of the parameters of the map window.
- «***Vers mapinfo***»: transfer of data to the GIS for purposes of assignment of a cell number ;
- «***Vers mapinfo_alim***»: same as for the preceding item, but relevant to the recharge data ;

- «***De mapinfo***»: retrieval of the outputs of the spatial query for purposes of assignment of cell numbers ;
- «***De mapinfo_alim***»: same as for the preceding item, but for recharge data ;
- «***Pre_modele***»: entry window for the parameters and for carrying out the procedure of data transfer to the digital model (PM5 format).

The queries:

A large number of queries have been conducted during the project. The major ones have been grouped within a catalogue (*liste_requete* table) for purposes of offering the user the possibility to initiate them by simple click on a queries explorer.

The classification of these queries may be revised or adapted to specific needs, and the adding of other queries to the catalogue is an easy operation (Cf. description further down), which should be carried out, let it be remembered, by the "DB manager".

Contents of the queries catalogue:

Group	Name
Water points statistics	Number of points per period
	Number of exploitation measurements by origin
	Number of piezometric measurements by orgin
	Number of piezometric measurements by period
	Number of points being used, by country
	Number of points by age group
	Number of points by flow groups
	Number of points by type of structure
	Number by aquifer and by country
	Number by aquifer and by Wilaya
	Piezometric measurements before 1981 and after
	Piezometers by cell
	Piezometry by origin
	Points with exploitation in 2000
	Points having 1 abstraction record before 1982 and another after 1982
	Points having at least two piezometric measurements
	Points having collections records
	Points having hydrodynamic data
	Points well-furnished in data
	Points exploited after 1995 and having more than 3 measurements
	Points by country having an exploitation record
	Points by country having a water quality record
	Points by country having a piezometric record
	points by Wilaya and Aquifer
	Points that all provided with data
	Rate of filling out of fields
	Abstractions records
	Abstractions from CI as per Administrative Unit and per year
	Abstractions compared in 2000

Group	Name
Abstractions	Abstractions compared in 1982
	Abstractions from CT as per Administrative Unit and per year
	Total abstractions as per year and per Wilaya
	Total abstractions as per Administrative Unit and per year
	Abstractions by aquifer, year and Wilaya
	Abstractions records by cell
	Sum of abstractions as per country and per aquifer in 2000
	Sum of abstractions per Wilaya
Piezometry	Relation Abstractions - Depth - Age by year
	Synthesis of exploitation by cell and by year
	Volumes by use and by country
Synthesis queries	Exploitation according to age
	Wells whose age is higher than a given value and which are exploited
	Wells by class of depth

Only the selection queries figure in this catalogue. The action queries must be initiated via the data base window or, for certain of them, via programme.

Hereafter, we propose the list of those that need to absolutely exist in «***SAGESSE***» so that the latter could operate:

Type	Name of query	Function
Intermediate queries	Affecter période (Assign a period)	Assign a number of period for each water point (*)
	Age des forages (Age of wells)	Calculate the age of wells
	Calcul ratio (Ratio calculation)	Calculation of the «Number of wells»/ «Sum of abstractions» ratio
	Tranches débits (Flows age group)	Assignment of a flow group to water points (*)
	Exploitation distinct	Water points with an exploitation record
	piezo distinct	Water points with a piezometry record
	qualite distinct (Quality)	Water points with a water quality record
	usages distinct	Water points with data on usage
PM5 – Connection queries	bd_mapinfo	Retrieval of water points having Lambert coordinates for transfer to GIS
	bd_mapinfo_alim	Retrieval of abstraction data having Lambert coordinates for transfer to GIS
	historique exploitation par maille (Exploitation record by cell)	Reconstruction of abstractions records by aquifer and by cell. Only the water points having a cell number are considered

* Cf. Annex 3

Update Queries	calcul NP par altitude (Calculation of piezometric level by altitude)	Updating of piezometric level by the value of the static level. No zero altitude
	calcul NS par altitude (Calculation of Static Level (NS) by altitude)	Updating of static level by the value of the piezometric level. No zero altitude
	conversion en degrés décimaux DGRE (Conversion into decimal degrees DGRE)	Adjustment of longitudes by shift of **2,5969213** + conversion into decimal degrees for the DGRE water points whose coordinates are expressed in Paris grades.
	Conversion en degrés décimaux (Conversion into decimal degrees)	Conversion into decimal degrees for the other points.
	maj_Prelev_parDebit	Updating of annual volume by continuous fictive flow
	maj_Debits_parPrelev	Updating of continuous fictive flow by annual volume

The other queries having served for the transfer of heterogeneous data originating from the three countries have been cancelled since they are not of any use (other transfer procedures have been developed based on the DB installed within the countries concerned).

The Macros:

The macros are on the whole used for purposes of executing performing operations in ACCESS as a response to certain events.

«Autoexec»: macro for initiating «*SAGESSE*» which starts the explorer;

«***Editer points d'eau***»: (Edit water points) allows loading the form for entering the water points after clicking on the button 

«***grades ou degrés***»: (Grades or degrees) displays the text «*Degré*» or «*Grad*» according to the choice made by the user for controlling the «*unité geog*.» (geographical unit).

«***graphique exploitation***»: loads to the form that allows a display of the exploitation graph ;

«***graphique piézométrie***»: same as for the “piezometric level” graph ;

«***graphique ns***»: displays the « static level » graph ;

«***graph_RS***»: shows the “TDS” evolution graph for the water point under consideration ;

«***ouvrir formulaire requêtes***»: displays the queries explorer (button )

«***vers mapinfo***»: opens the dialogue window for entry of the denomination of the export file to Mapinfo ;

«***de mapinfo***»: same as for import..

The modules:

The modules are Visual Basic Application (VBA) programmes that allow the performing of specific or complex tasks which could not be performed via macros.

There are two classes of modules:

- procedures related to controls (objects of the user interface) in response to events ;
- the VBA programmes bookshop where SAGESSE own functions and procedures are grouped, and which have been developed in the framework of the project.

Hereinafter, we propose the SAGESSE functions likely to be adapted or improved by the DB managers:

The «proced et fonct» Module comprises the common general procedures and functions:

Type	Name	Returned value
Functions	Function piquer_code	Wording of a lexis based on a code
	tranche_age	Age group for a given age
	tranche_prof	Depth group for a given depth
	affecter_periode	Assign a period to a water point (before 1972, 72-82, 82-90, > 1990).
	Tranche_debits	Flow group
	former_noclas	Reconstruct a classification number in the format required by the DB
	Degrees_dec	Conversion into decimal degrees of the coordinates expressed in DMS
	X_grades_to_DD	Conversion of grades into decimal degrees while taking into consideration the origin (Paris or Greenwich)
	dd_to_dms	Conversion of decimal degrees into DMS format
	cadrer_dec	Edit a number written on a certain length and a desired decimal number

«Maths» Module common mathematical functions

Type	Name	Returned value
Functions	arrondisup	Rounds up a whole number
	interpolin	Returns a value by linear interpolation
	Deg_2_Rad	Returns the degree – radian conversion constant

«Liens modele» Module: functions used in programmes of interfacing with the PM5 model

Type	Name	Returned value
Functions	de_mapinfo	Returns the name of the Mapinfo file comprising the cell numbers
	versMapinfo	Name of export file to Mapinfo
	ligne_colonne	Returns the line, column numbers within a grid (net mesh)
	pm5_dat	Returns the name of the PM5 file which will host the abstraction records by cell
	aquif_couche	Aquifer – Model layer relation

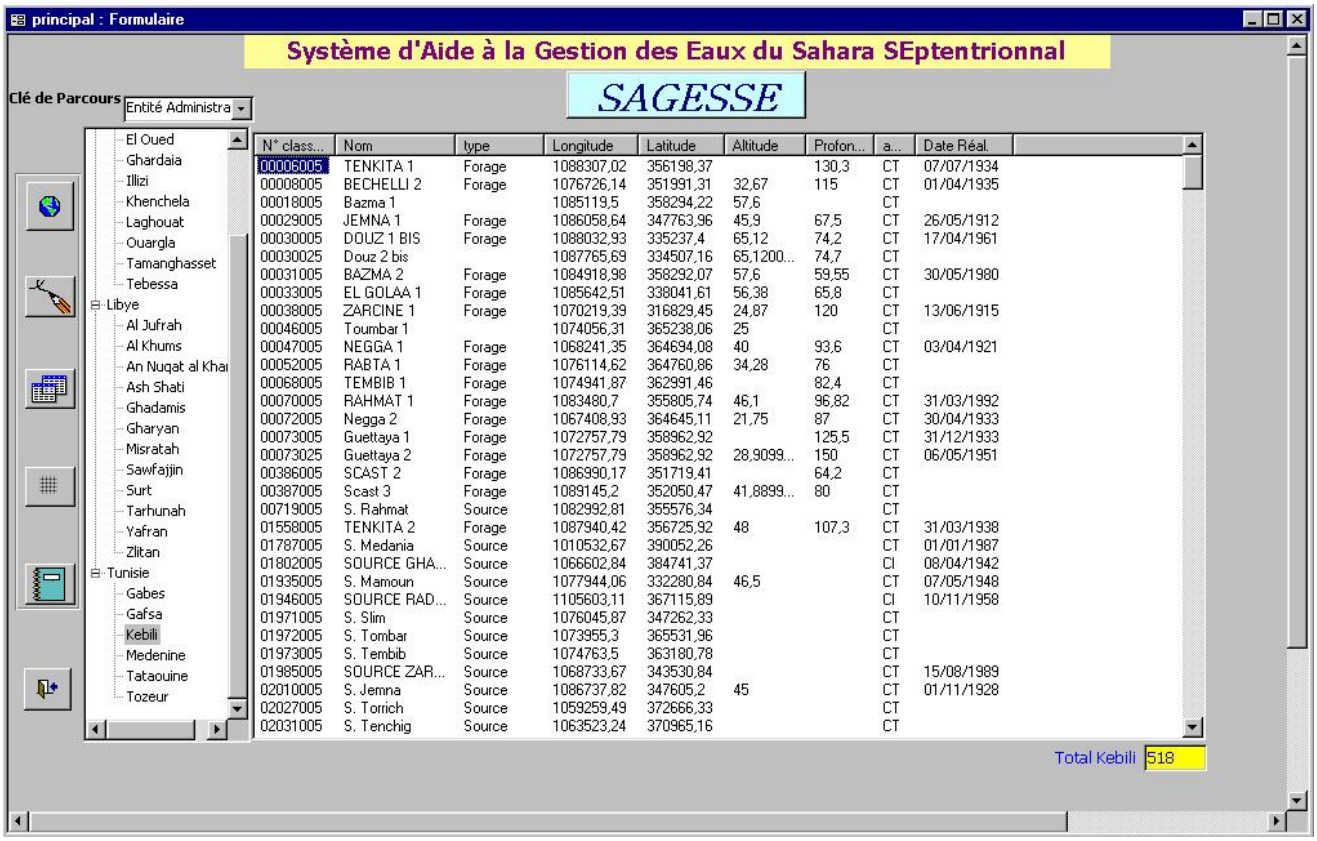
«**Importations**» **Module:** Procedures and functions used for automatic transfer of old DGRE data

Type	Name	Returned value
Procedures	importer_expl	Imports the exploitation data which are in Dbf format.
	importer_piezo	Imports the piezometry data
	import_hist_qual	Transfers the water quality data entered at SASS level
Functions	arrange_irh	Converts the DGRE water points number into conform IRH number
	aquif_couche	Aquifer – Madel layer relation

«**Lancer_debits» Module**: being connected with the «pre_modele» form, this procedure allows the calculation of the «Alimentation – prélèvement» (recharge – abstraction) algebraic sum for each cell based on the «Exploitation» , «Points» and «aliment» (exploitation, water points, and recharge) tables..

The explorer

The explorer is the key component of the software based on which all the other functions are activated. It is automatically initiated upon loading of the data base and makes it possible to visualise and scroll down the whole set of data available under various forms and according to multiple entry points.
Being displayed continuously (up to shutting by the user), it provides a view of the location, number and distribution of the water points that represent the main component of the DB.



Two representation modes are offered: the digital mode (main attributes) and the cartographic mode (geographic location).

This browser, which also serves as main menu, comprises the buttons that iactivate each a pre-defined function within ***SAGESSE***.

Allows to choose a sorting criterion of water points by country and administrative unit, or else by aquifer and type of water point.

Used for toggling between the digital mode and the cartographic mode.

 Opens the «***donnees generales***» (general data) form in order to edit the water points (creation of updating).

 Allows an exploration of the outputs of the queries developed in the context of the project.

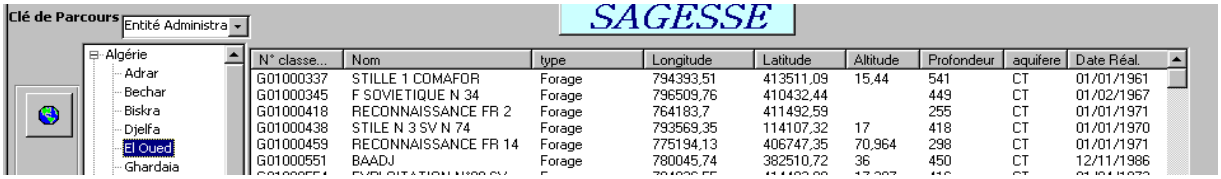
 Initiates the module which allows the transfer of the data to ***PM5***: flows by cell, piezometry.

 Provided for initiating the output list of outputs. Hardly used in the context of the project.

 Leaves the explorer to return to the Data Base window.

The right hand side window may contain either a table comprising the major characteristics of the water points belonging in the selected unit, or a water points map on a background comprising the GIS layers. In both cases, a double click on a water point shows a form comprising the detailed data relevant to the water point selected. .

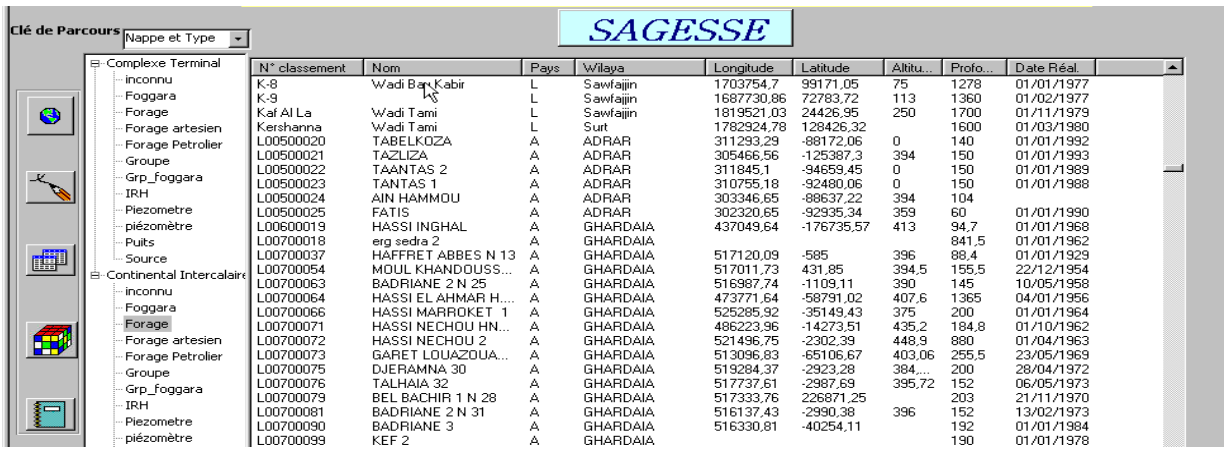
In the case of a digital table, the characteristics displayed differ according as to whether we choose the «*entité administrative*» (administrave unit) key or the «*par aquifère et type*» (by aquifer and type) key. In the first case, the following data are displayed:



N° classe...	Nom	type	Longitude	Latitude	Altitude	Profondeur	aquifere	Date Réal.
G01000337	STILLE 1 COMAFOR	Forage	794393,51	413511,09	15,44	541	CT	01/01/1961
G01000345	F SOVIETIQUE N 34	Forage	796509,76	410432,44		449	CT	01/02/1967
G01000418	RECONNAISSANCE FR 2	Forage	764183,7	411492,59		255	CT	01/01/1971
G01000438	STILE N 3 SV N 74	Forage	793569,35	114107,32	17	418	CT	01/01/1970
G01000459	RECONNAISSANCE FR 14	Forage	775194,13	406747,35	70,964	298	CT	01/01/1971
G01000551	BAADJ	Forage	780045,74	382510,72	36	450	CT	12/11/1986

The columns *Classification N°, denomination, type of structure (equipment), Lambert coordinates, altitude, depth, aquifer and construction date* are displayed.

On the other hand, if the entry criterion is the “aquifer” and “water point”, the table is modified:

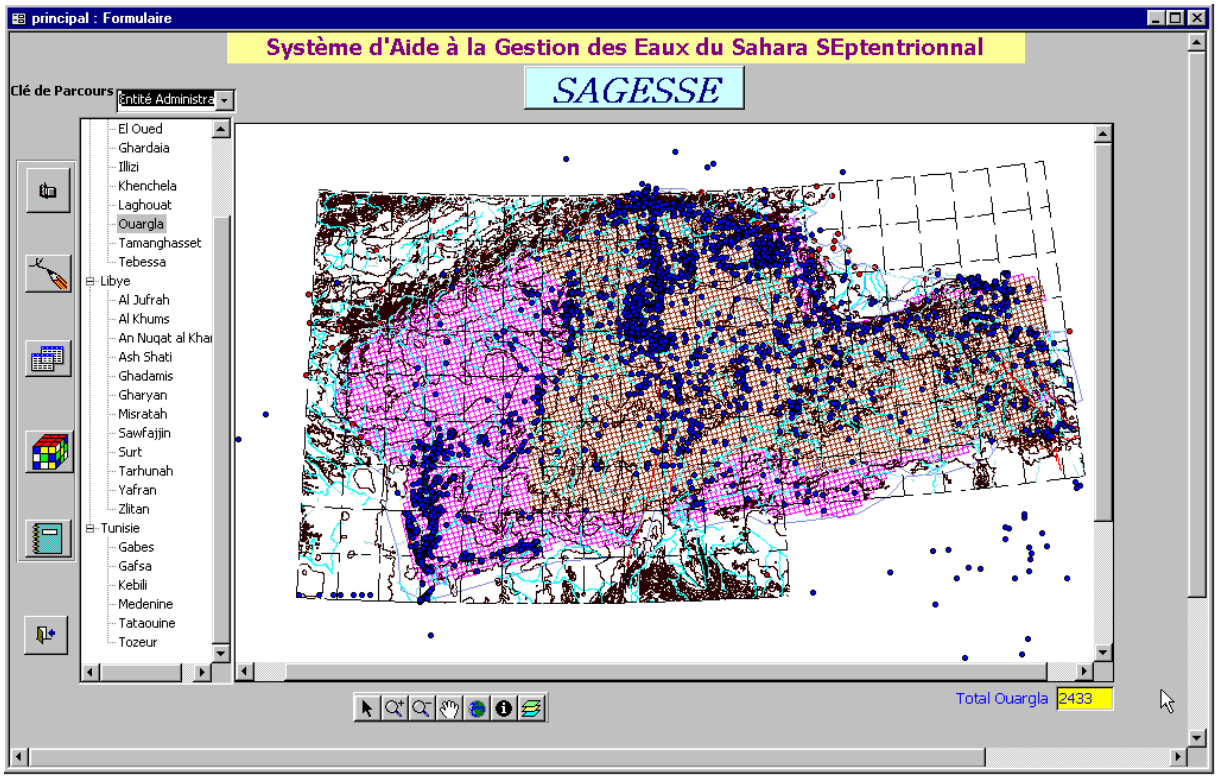


N° classement	Nom	Pays	Wilaya	Longitude	Latitude	Altitu...	Profo...	Date Réal.
K-8	Wadi Bar Kabir	L	Sawfajjin	1703754,7	99171,05	75	1278	01/01/1977
K-9		L	Sawfajjin	1687730,86	72783,72	113	1360	01/02/1977
Kaf Al La	Wadi Tami	L	Sawfajjin	1819521,03	24426,95	250	1700	01/11/1979
Kershanna	Wadi Tami	L	Surt	1782924,78	128426,32		1600	01/03/1980
L00500020	TABELKOZA	A	ADRAR	311293,29	-88172,06	0	140	01/01/1992
L00500021	TAZLIZA	A	ADRAR	305466,56	-125387,3	394	150	01/01/1993
L00500022	TAANTAS 2	A	ADRAR	311845,1	-94659,45	0	150	01/01/1989
L00500023	TANTAS 1	A	ADRAR	310755,18	-92480,06	0	150	01/01/1988
L00500024	AIN HAMMOU	A	ADRAR	303346,65	-88637,22	394	104	
L00500025	FATIS	A	ADRAR	302320,65	-92935,34	359	60	01/01/1990
L00600019	HASSI INGHAL	A	GHARDAIA	437049,64	-176735,57	413	94,7	01/01/1968
L00700018	erg sedra 2	A	GHARDAIA				841,5	01/01/1962
L00700037	HAFFRET ABBES N 13	A	GHARDAIA	517120,09	-585	396	88,4	01/01/1929
L00700054	MOUL KHANDOUSS...	A	GHARDAIA	517011,73	431,85	394,5	155,5	22/12/1954
L00700063	BADRIANE 2 N 25	A	GHARDAIA	516987,74	-1109,11	390	145	10/05/1958
L00700064	HASSI EL AHMAR H....	A	GHARDAIA	473771,64	-58791,02	407,6	1365	04/01/1956
L00700066	HASSI MARROKET 1	A	GHARDAIA	525285,92	-35149,43	375	200	01/01/1964
L00700071	HASSI NECHOU HN...	A	GHARDAIA	486223,96	-14273,51	435,2	184,8	01/10/1962
L00700072	HASSI NECHOU 2	A	GHARDAIA	521496,75	-2302,39	448,9	880	01/04/1963
L00700073	GARET LOUAZOUA...	A	GHARDAIA	513096,83	-65106,67	403,06	255,5	23/05/1969
L00700075	DJERAMNA 30	A	GHARDAIA	519284,37	-2923,28	384,...	200	28/04/1972
L00700076	TALHAIA 32	A	GHARDAIA	517737,61	-2987,69	395,72	152	06/05/1973
L00700079	BEL BACHIR 1 N 28	A	GHARDAIA	517333,76	226871,25		203	21/11/1970
L00700081	BADRIANE 2 N 31	A	GHARDAIA	516137,43	-2990,38	396	152	13/02/1973
L00700090	BADRIANE 3	A	GHARDAIA	516330,81	-40254,11		192	01/01/1984
L00700099	KEF 2	A	GHARDAIA				190	01/01/1978

The coliumns “Type” and “Aquifer” are replaced by “Country” and “Wilaya”.

As per default, the data are sorted out by “classification n°”. However, by clicking on a column heading, the data are sorted out according to the heading under consideration.

A click on the toggle button  makes it possible to display the most important GIS layers figuring in the file «*CARTE_SASS*» (SASS maps).



The ARCVIEW coverages cannot be modified except by means of the GIS software ; however, these updates are automatically reflected on the contents of this window.

A set of buttons have been created so that each could perform the main GIS functions, namely:

 Button for the selection of a water point or for zooming in by rectangle:

 Zoom in: factor 2.

 Zoom out: factor 0.5.

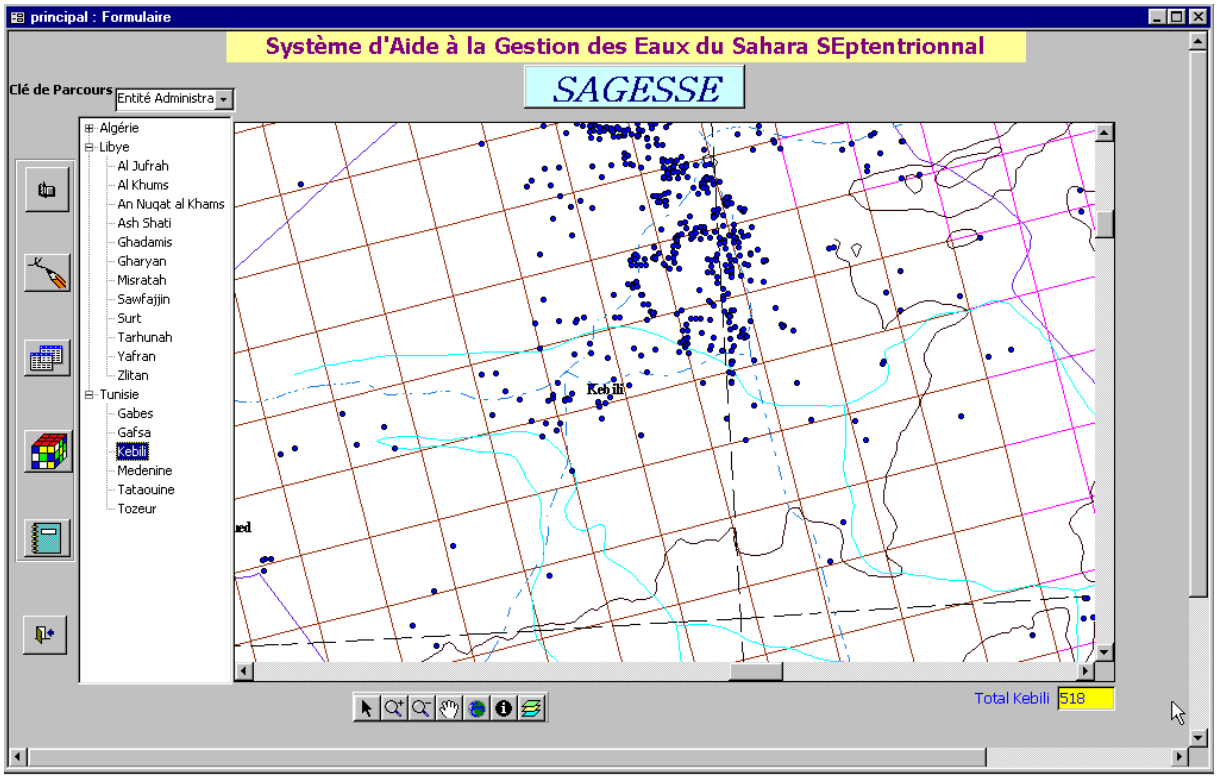
 Pan: does not operate in full extent.

 Full extent: Total view.

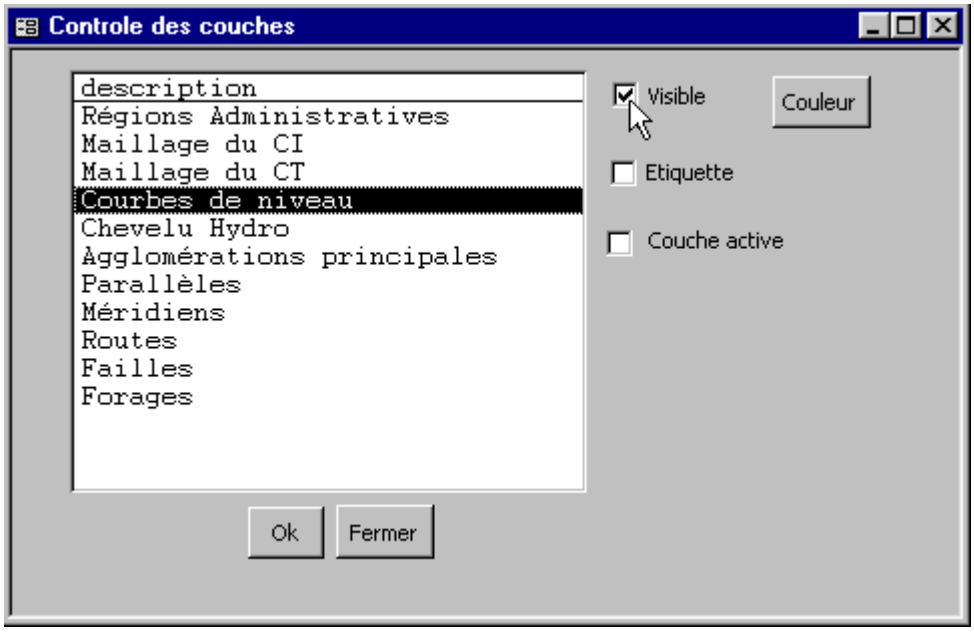
 *Identify*: button: a button that serves to display the «***Données générales***» form (« General data » form) which contains the detailed data about the water point.

 Control of layers: makes it possible to initiate the control window of the map window (visibility of coverages, colour of the objects, display of the labels (file tags))

When a zoom is performed, clicking on a Wilaya makes it possible to focus the zoom within the map window.

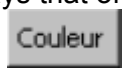


The button  makes it possible to act on the control of layers. By clicking on the button, the following window is displayed:



The list of the various layers is displayed, and opposite them the boxes to be ticked for the properties:

- Visible: that is figuring in the window ;
- Label: an activated box means that the labels of the objects of the layer in question are displayed ;
- Active layer: this makes it possible to specify the selected priority layer. This option has been provided, but is for the time being without any effect (the active layer is always that of the water points).

The button 

(colour) allows a change of the colours of the objects of the layer selected in the list.

The «Couleurs» (colours) dialogue window is called in to facilitate such a selection:

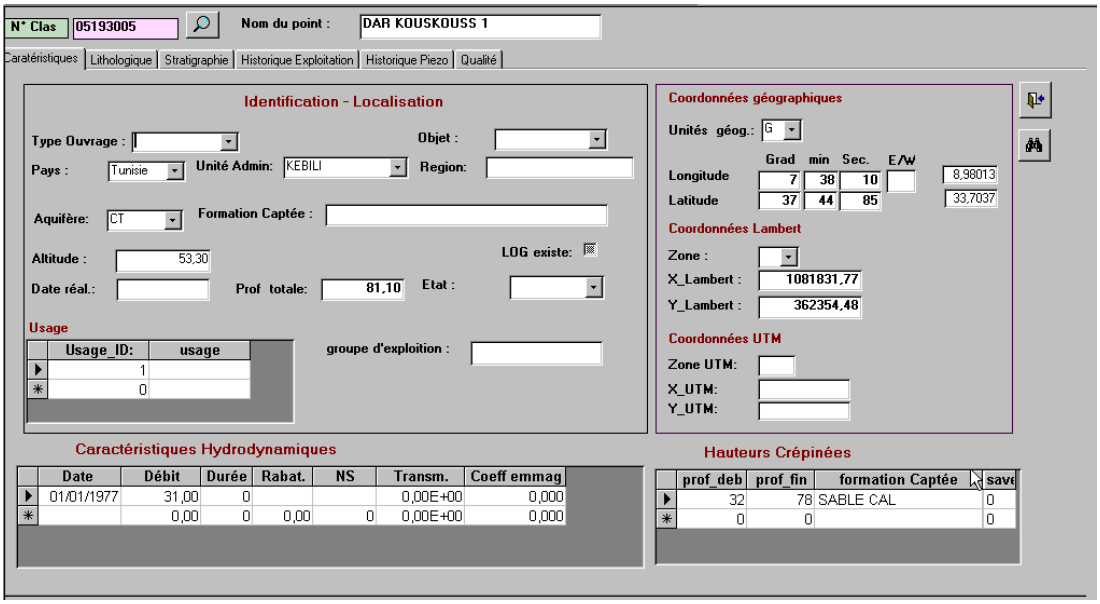
Use of the software

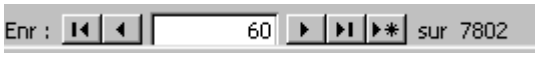
Data editing:

This option makes it possible to consult and edit the data relating to the water point. There are two ways of accessing the form that performs this procedure:

- either by double-clicking on the water point in the brshing (exploration) window (map or data window)
- or else by clicking on the button 

The difference between the two modes consists in the fact that, in the first case, the form contains a filter which allows the display only the current point, and hence it is not possible to consult the other points. The second mode, however, makes it possible to scroll through, retrieve and modify the set of the DB water points.





The form is displayed as a multi-page window tab comprising the following data:

Page 1: data on the identification and location of the water points, the hydraulic characteristics, the data on uses (usages) and, finally, a description of the screened lengths ;
Page 2: data on the lithological levels crossed ;
Page 3: Stratigraphy ;
Page 4: Exploitation record ;
Page 5: Record of piezometric measurements ;
Page 6: Record of quality.

The « heading » part of the form comprises the identifier of the water point, which is common to all pages: classification N° and display of the denomination.
The browsing buttons located at the bottom of the page make it possible to scroll through the data and to generate new water points (▶✱).

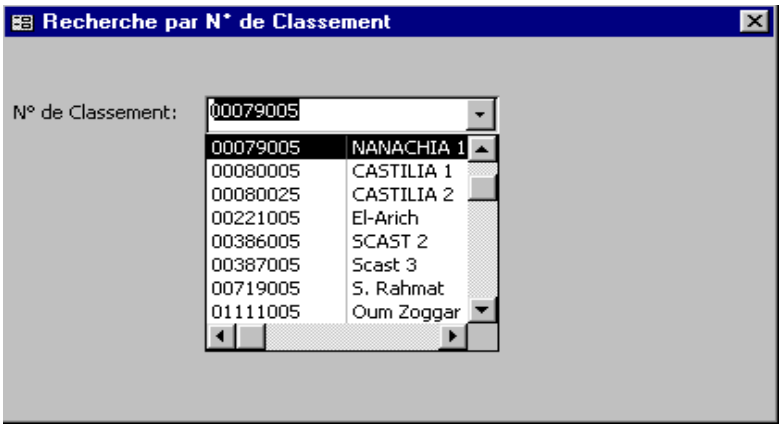
General characteristics:

Heading of the form:

When opening the form, the data relevant to the first water point are displayed according to the key (which is the classification N°). The shift buttons subsequently allow to scroll through the records (next, previous, first, last).

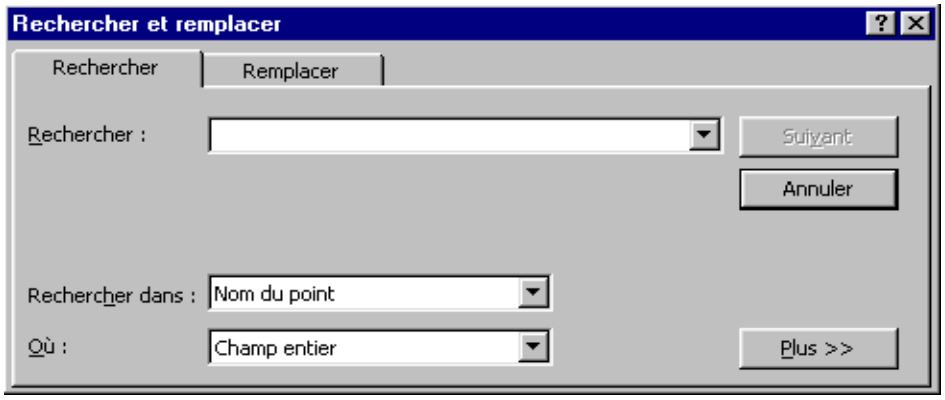
In the SAGESSE software, an additional button has been added in order to search (i.e., retrieve) a water point by recognising its classification number: this is the button 🔍.

By clicking on the latter button, a window is displayed to help perform this search (i.e., retrieval):



Once the selection is done, the pointer is positioned, within the form «***données générales***» (general data), on the water point chosen.

If we want the search to be performed based on any other criterion, another button may be used (). It is the ACCESS DBMS which triggers the display of the next window according to the current field in the form (location where the cursor is found at the moment of pressing on the button):



The next step is to type, in the seek area, the term to be retrieved and, in the «***où***» (where) area, the comparison mode:

- Whole field: seeking the full expression ;
- Bof (beginning of file): comparison for the first n characters typed ;
- Anywhere in the field: existence of the string typed in the field under search.

It is possible to leave the seek window open and scroll down the entire data which answer the search criterion, and this by means of the button «***Suivant***» (Next). The data displayed in the form are those of the water point found. To close the window, click on «***Ignorer***» (Ignore)..

Notes on the entry of fields:

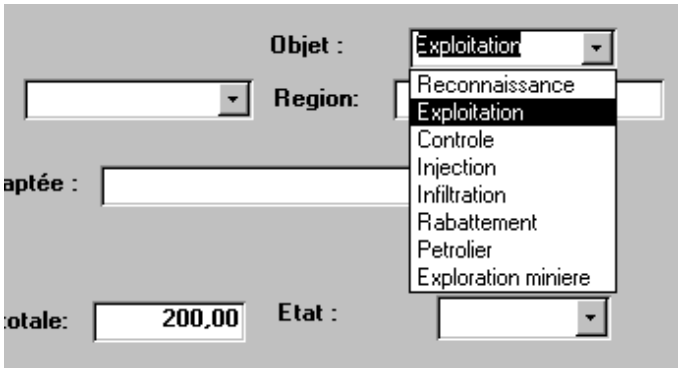
The fields represented in Combo boxes are of two types:

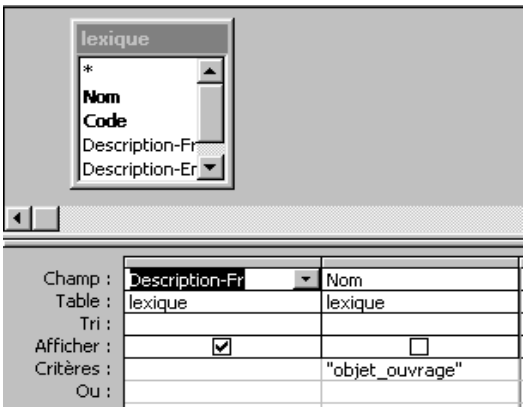
- Data originating from the lexis ;
- Data originating from another table that is in relation with the «***Points***» table.

For instance, the data pertaining in the fields: «***Type ouvrage***» (type of structure/ equipment), «***Objet»*** (object/ item) and «***Etat»*** (condition) originate from the lexis. On the other hand, the «***Wilayas***» relating to a country are entered via a query that retrieves all the Wilayas of a given country.

Here is an example illustrating each of the cases:

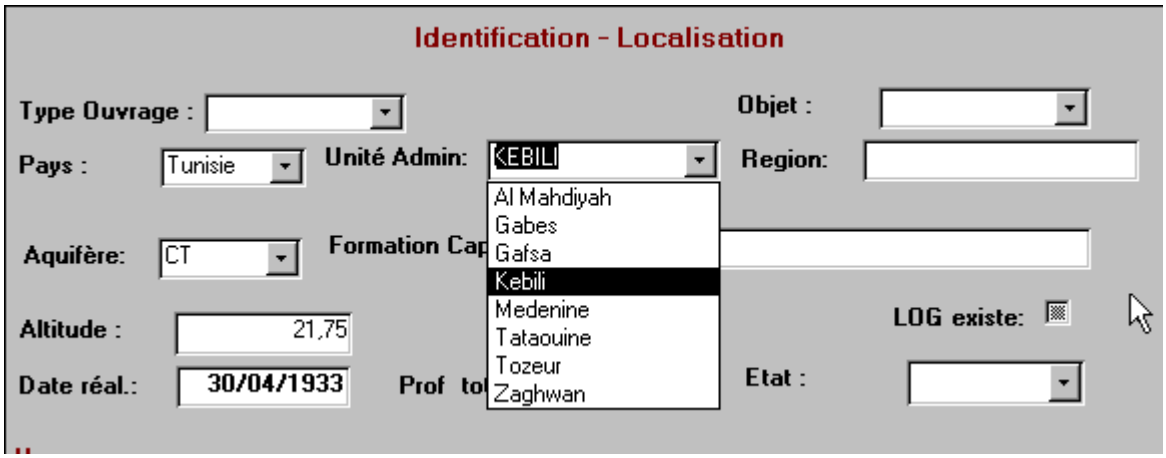
- Based on the lexis:



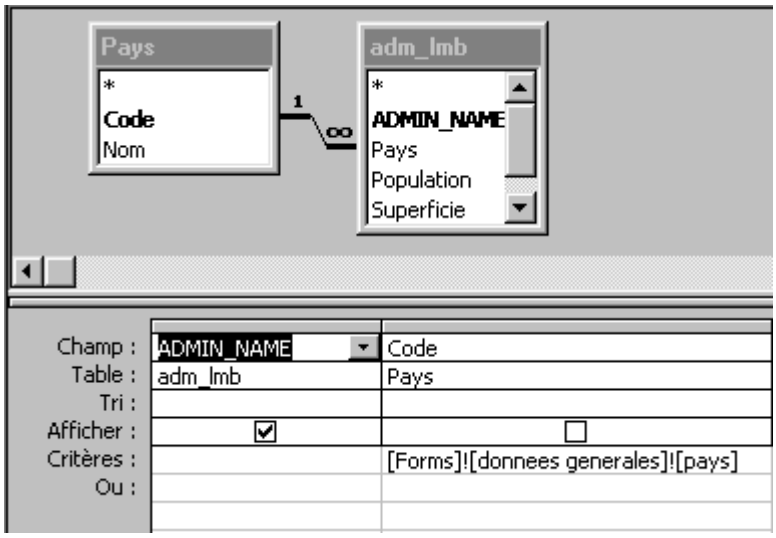


In order to obtain this output, it was necessary to input to the property «***contenu***» (content) of the combo box the query proposed on the right hand site.

- Based on a table: List of the Wilayas of a given country.



This time, the property «Contenu» (content) of the Combo has been defined as follows:



A procedure was added to the control «***Pays***» (Country) which makes it possible to refurnish the list of Wilayas when the value of the latter is changed (in order to propose to the user the Wilayas belonging to a given country).

```
Private Sub pays_BeforeUpdate(Cancel As Integer)
        Me.wilaya.Requery
End Sub
```

CONTROLS CONDUCTED IN PROCESS OF ENTRY:

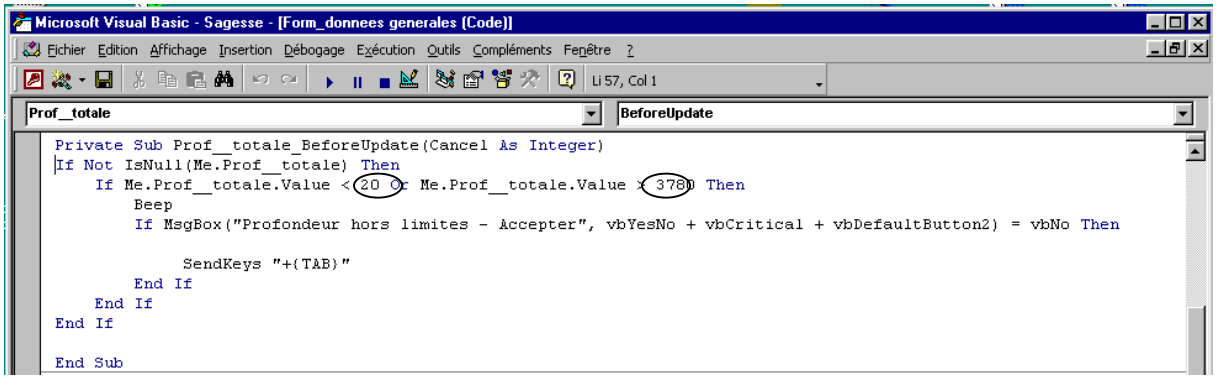
The controls conducted in process of entry of major fields, such as dates, coordinates, altitudes and depths, have been comprised. Upper and lower delimiters for these fields have been calculated based on statistics relating to the values collected for each country.

For the sake of illustration, we propose below the lower and upper delimiters for the DGRE data:

Field	**Min value**	**Max value**
Depth	30	3780
Altitude	0	640
Construction date	1910	Current year
Longitude (degrees)	7.5	12
Latitude (degrees)	30	35
Abstraction	0	1000
Levels	-350	390
Temperature	25	85
TDS*	14	15900
Year of piezometric measurement	> Construction date if the latter item has not been filled out => 1950	Current year
Year of flow measurement	> Construction date if the latter item has not been filled out => 1950	Current year

* TDS = Total Dissolved Salts

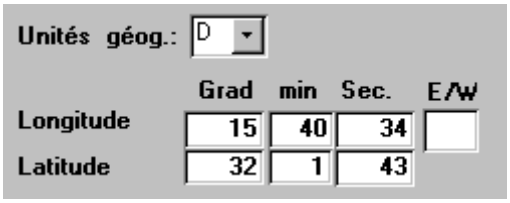
These may be modified by opening the form in design mode, then acting on the events « *Before_Update* » of the controls concerned, as shown by the following example:



Invisible calculated fields:

Certain items need to be calculated automatically and, hence, cannot be handled by the user. These are mainly:

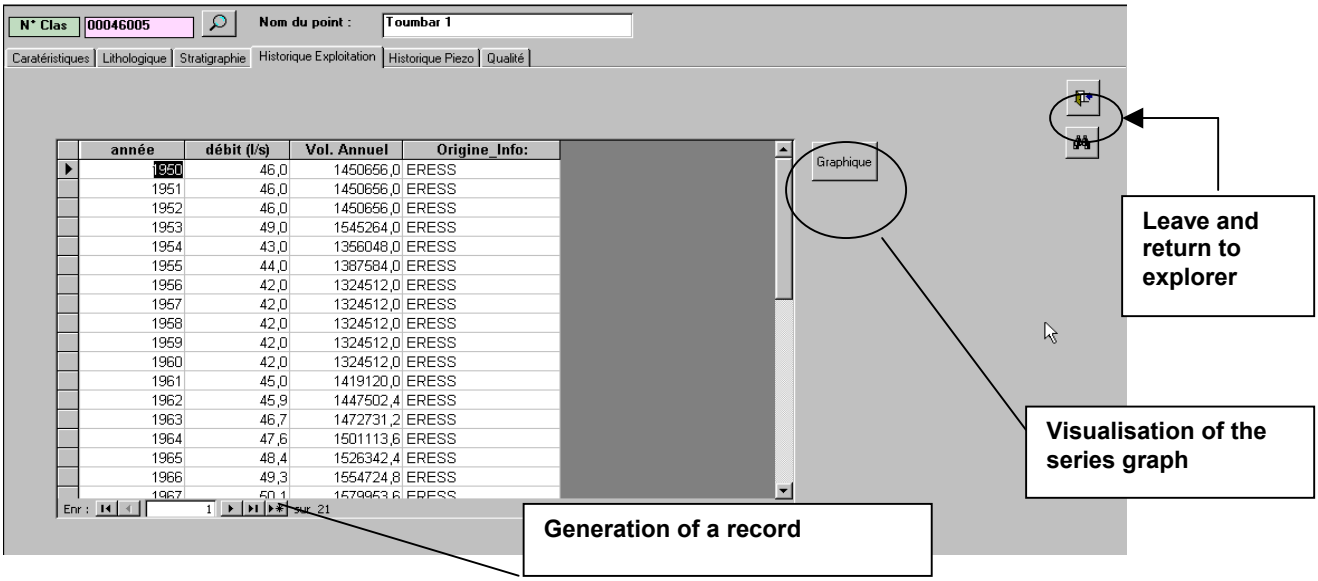
- The date on which the data has been updated: this is necessary for updating the SASS data base based on the national data bases ;
- The longitude and latitude fields in «decimal degrees»: the calculation of these fields is made upon each change in coordinates.



This operation eases the fairly difficult tasks of updating the coordinates for purposes of locating water points by means of GIS.

Exploitation records:

This is a sub-form of the form «***Donnees generales***» (general data), with the link being made by means of the classification n°..



visible columns displayed on the previous screen plus an invisible field which the

An invisible field which is the classification N° (the latter takes up automatically the value of the current water point).

We have kept the columns «***débits***» (flows) and «***prélèvement***» (abstraction) since, often, the exploitation data are at times expressed as m3/year, while at other times they are expressed as l/s. In order to avoid simultaneous entry of the two columns, an automatic calculation of one column based on the other has been integrated.

année	débit (l/s)	Vol. Annuel	Origine_Info:
1950	18,0	567648,0	ERESS
1951	15,0	473040,0	ERESS
1952	12,0	378432,0	ERESS
1953	12,0	378432,0	ERESS
1954	12,0	378432,0	ERESS
1955	12,5	394200,0	ERESS
1956	13,0	409968,0	ERESS
1957	12,8	403660,8	ERESS

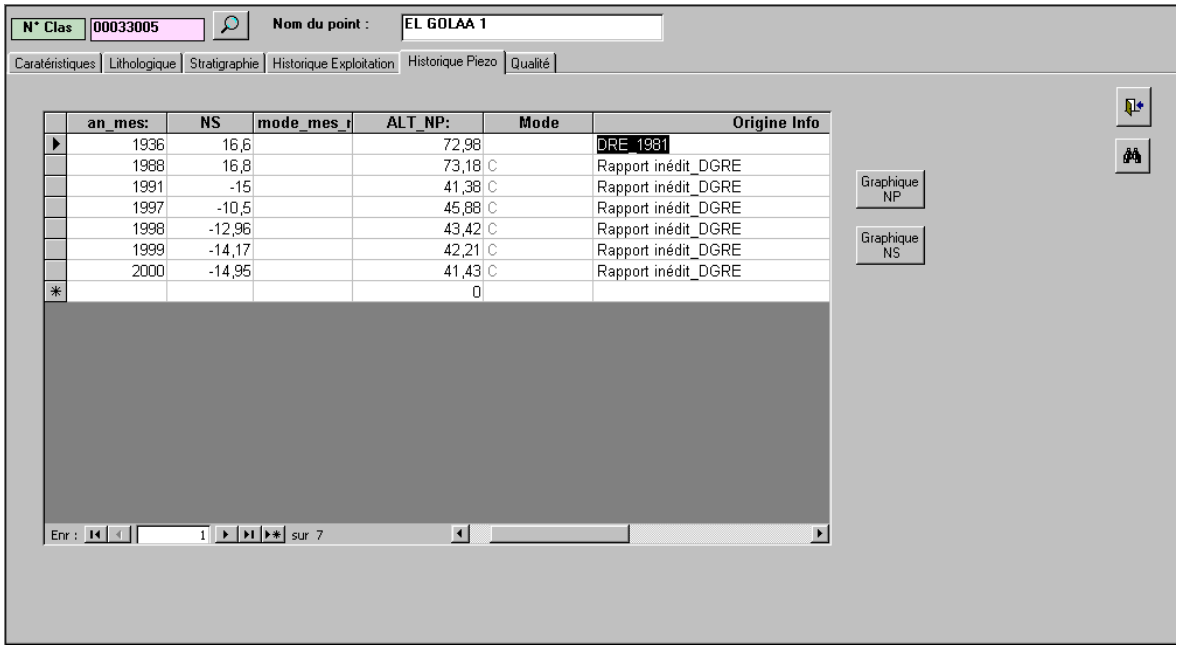
As shown by the example above, if the field «***débit***» (flow) is entered by the user, the field «***Vol.Annuel***» (annual volume) is calculated by the programme (the cursor does not stop at the level of entry to this field). The opposite situation is equally provided.

In the event that a change or addition of data has to be cancelled, one would press on the key «***Echap***» (Escape). This applies to all forms.

The value of the column «***Origine_Info***» (data origin) is selected within a list whose values originate from the table «***Lexique***» (Lexis).

Under its current version, only representation under the form of a histogramme is available for the graph.

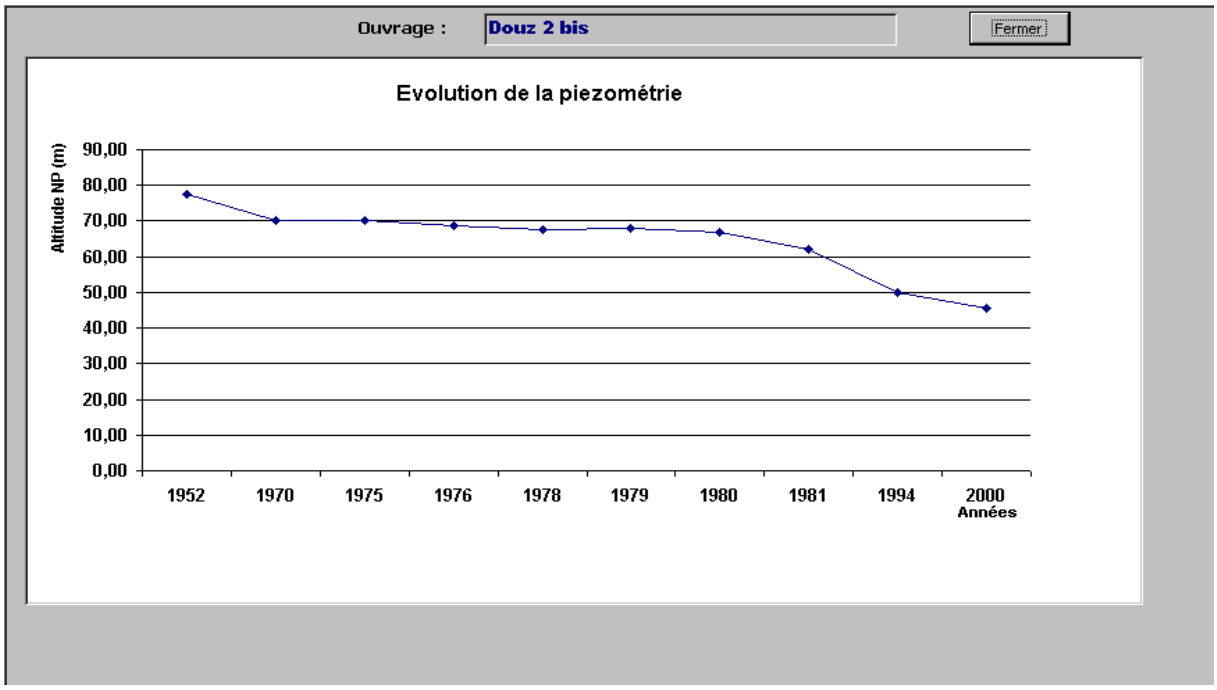
Piezometric record:



Similarly as for the exploitation data, and given the various data sources, a column denominated «**Origine_Info**» (Data origin) has been generated. The same applies to the existence of the fields «***NS***» and «***NP***» which represent, respectively, the static levels (SL) and piezometric levels (PL).

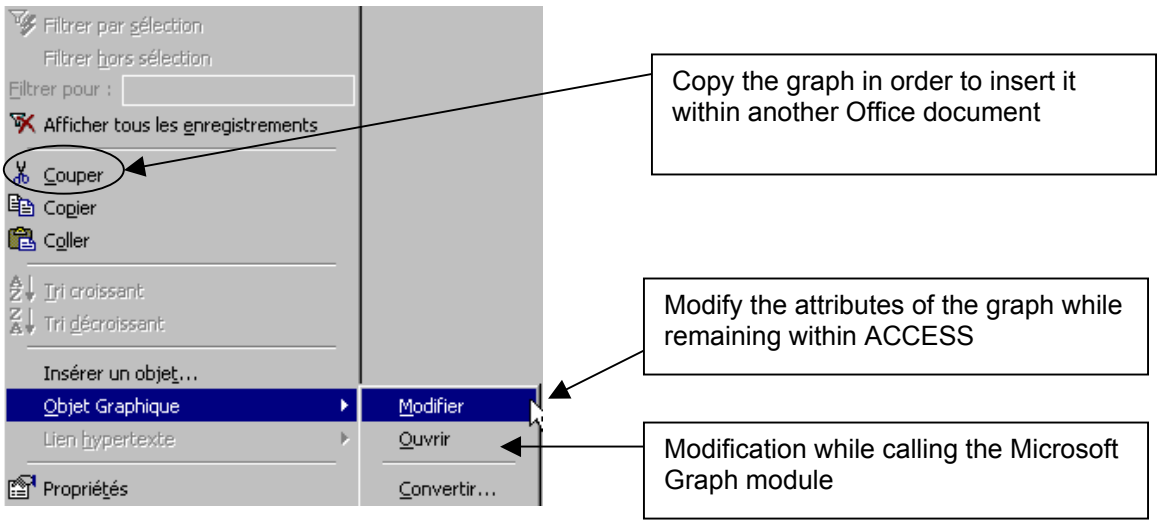
The updating of a field based on knowing the other is ensured by the programme, with, in addition, the assignment of value «***C***» to the columns «***Mode_mes_NS***» (static level measurements mode) or «***Mode_mes_NP***» (piezometric levels measurements mode), according to the case under consideration (calculated SL or calculated PL). This calculation is not possible unless the field «***altitude***» has been filled out.

Two graphs may be developed for the current series: SL curve or PL curve, as shown by the following example:



To return to the form, press on the button «***Fermer***» (Close).

It is also possible to act on the graph by clicking on the right hand side button of the mouse in order to display a contextual menu as follows:



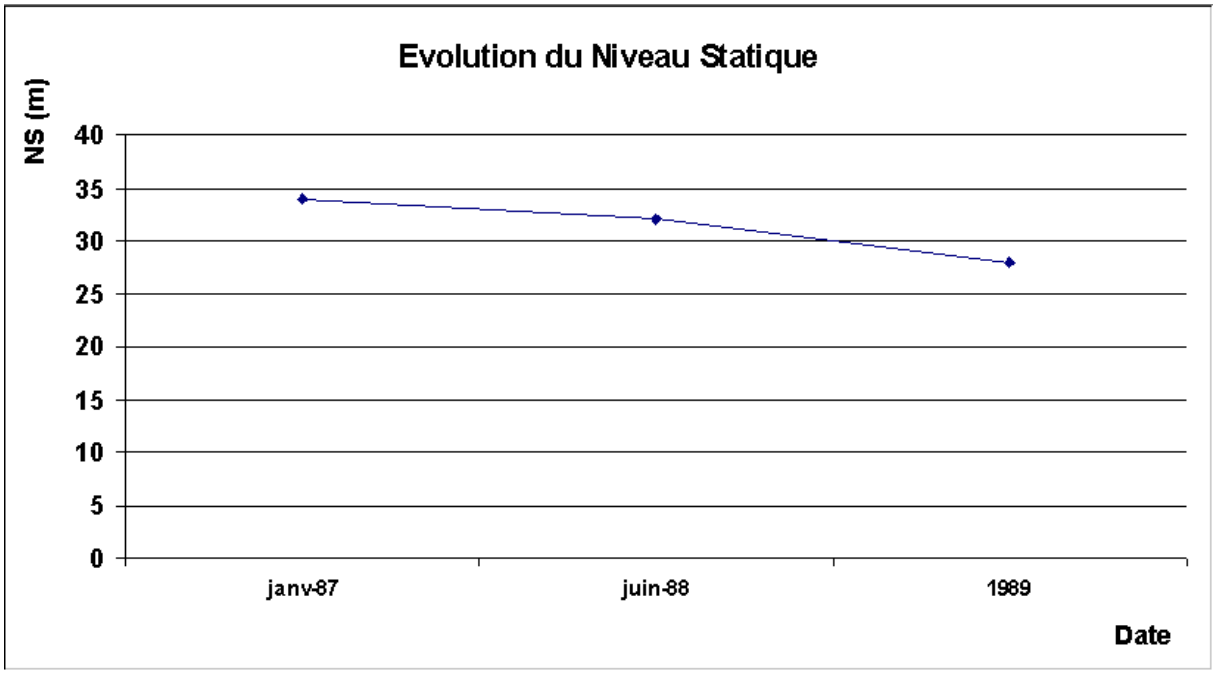
In the context of the project, an only one annual piezometric record has been collected for each water point. However, in order to meet the needs of the countries concerned, we have added an option that allows for the storage of several values per year, and by modifying certain features as follows:

a) The structure of the table «*piezometrie*» (piezometry): addition of a field denominated «*mois*» (month) and changing the primary key:

	Nom du champ	Type de données
🔑	Noclas	Texte
🔑	An_mes	Numérique
🔑	mois	Numérique
	Niveau	Numérique
	mode_mes_ns	Texte
	Alt_np	Numérique
	Mode_mes_np	Texte
	origine	Texte
	Observation	Numérique
	date_maj	Date/Heure

b) The form «sf_piezo» which takes into consideration the new field ;

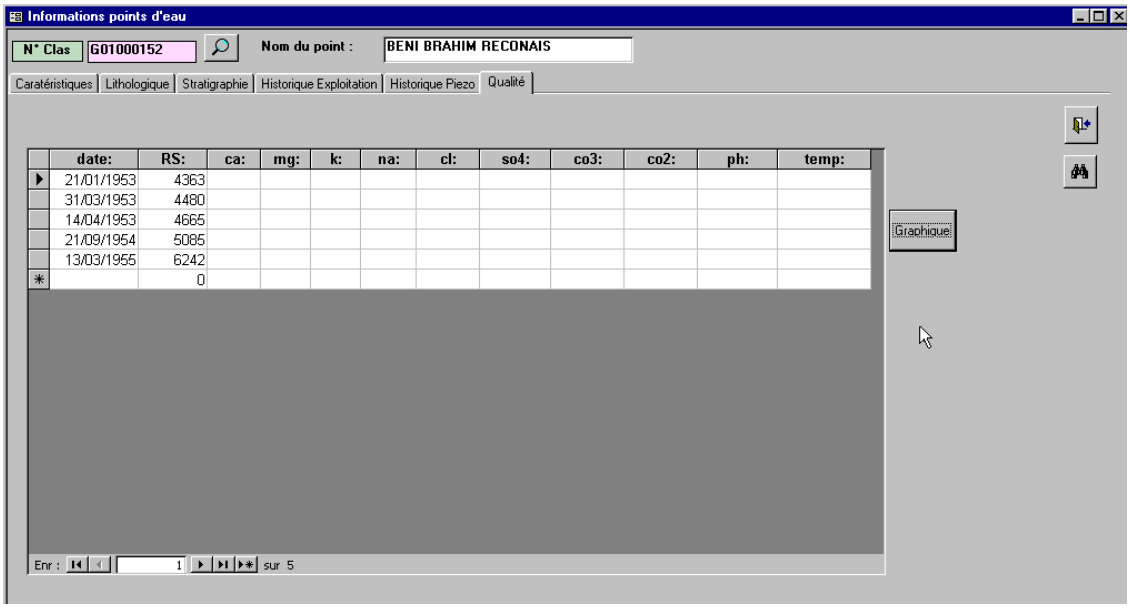
c) The two related graphs which display, in case the field has been filled out, the month when the piezometric measurement was carried out, as shown by the following example:



If the month is entered (filled out), it figures in the abscissa label.

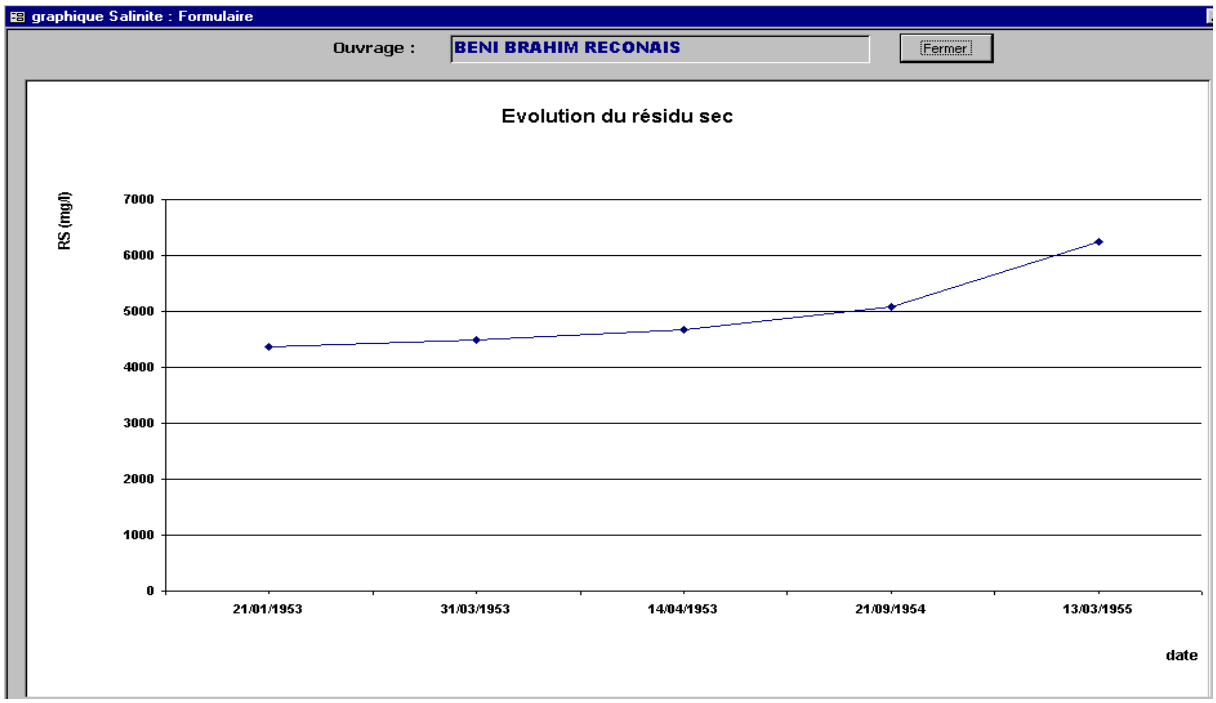
Quality record:

The quality data are stored under the form of a multi-parameter table in order to facilitate entry operations. In view of the data collected, only the («***RS***») TDS (Total Dissolved Salts) parameter and, to a lesser extent, the («***Temp***») (Temperature) parameter are entered (filled out).



The entry is made in the same way as for the exploitation and piezometry records.

Only the graph «***Résidu Sec***» (TDS: Total Dissolved Salts) has, therefore, been comprised, since it is of relevance to the project. The adding of other graphs is, however, possible following the pattern in which other graphs have been developed.



DB – GIS – Digital Model link

Three phases are necessary to provide and synchronise the Data Base – GIS – PM5 Model links/ connections. These are:

- A phase of generating the grid (net mesh) based on the parameters supplied by the user ;
- A phase of assigning a cell number to each of the water points which are provided with coordinates ;

- And, finally, a phase of preparation of the data for generating a file in «***.dat»*** format which is directly usable by PM5. Other file types have also been made (piezometric data: water points + records), but have not been used in the context of the project.

An interactive graphic interface has been generated in order to allow the user to perform those tasks: form « ***BD-SIG-Modele*** » (DB – GIS – Model form).

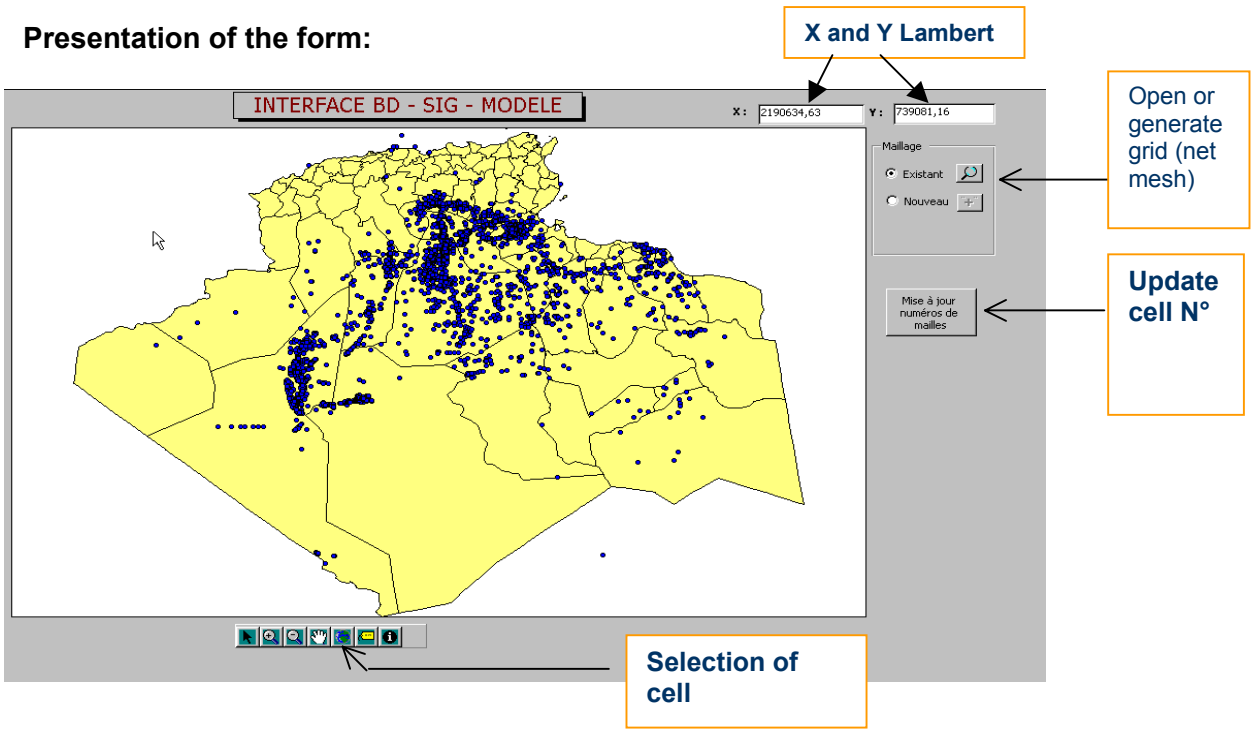
This form has been added in order to handle the links between the "Points" table, the GIS layer (representing the water points) and the digital model grid (net mesh). It should be noted that this grid (net mesh) may be modified any time: generation or import of a DXF file.

Functionality 1: the cartographic representation of the water points is automatic: it is made upon each load of the form and it uses, for so doing, the updated «*points*» table. The related shapefile is itself automatically updated, which ensures total and permanent synchronisation between the DB and the GIS.

Functionality 2: The grid (net mesh) is generated within SAGESSE environment and is better configured: taking into consideration the presence or not of a polygonal extension, size of the cells and direction of the grid (net mesh), denomination of the backup file.

Functionality 3: the possibility of graphic selection of a cell and listing all the water points that it contains. It is possible to display the data relevant to this point by mere double clicking on its number (similar to the way this is done in the «*principal*» (main) form). This represents, indeed, a precious tool for checking the data prior to initiating the PM5 model.

Presentation of the form:



The map window first displays the administrative boundaries file «*Admin_sass*» found in the file *carte_sass*) (SASS map).

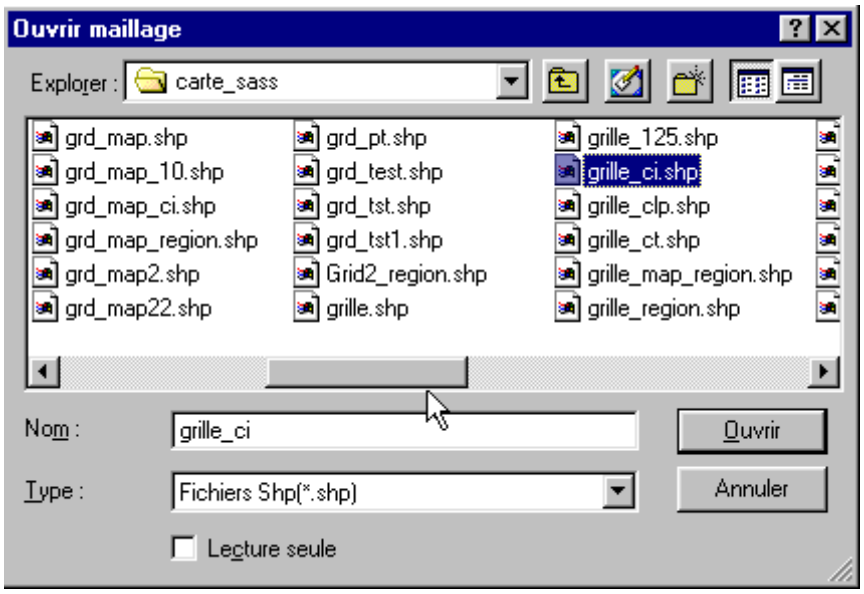
Then, the «*Points*» table may be scrolled down and each water point provided with Lambert coordinates is projected on this window. Two fields X and Y have been added in order to permanently display the coordinates corresponding to the position of the mouse on the map.

The buttons  and  make it possible to open an existing grid (net mesh) or to generate a new grid (net mesh), respectively.

Stage 1: Generation of the grid (net mesh) or loading an existing mesh

Opening of an existing grid (net mesh):

By clicking on the control button , the following screen is displayed for selecting the name of the file based on the file «*carte_sass*» (SASS map).



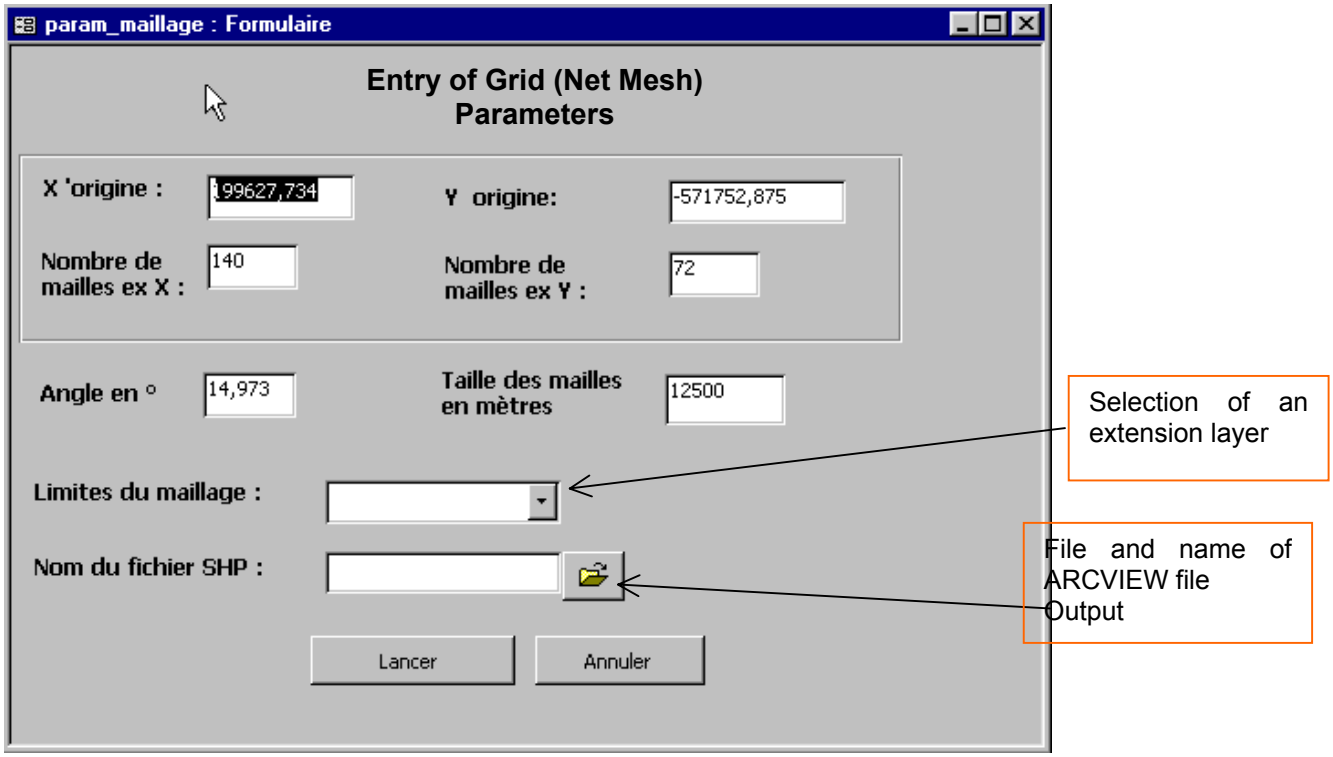
Two types of files may be selected: «*shp*» (SHP) and «*dxf*» (DXF).

After selecting the file, click on «*Ouvrir*» (Open)..

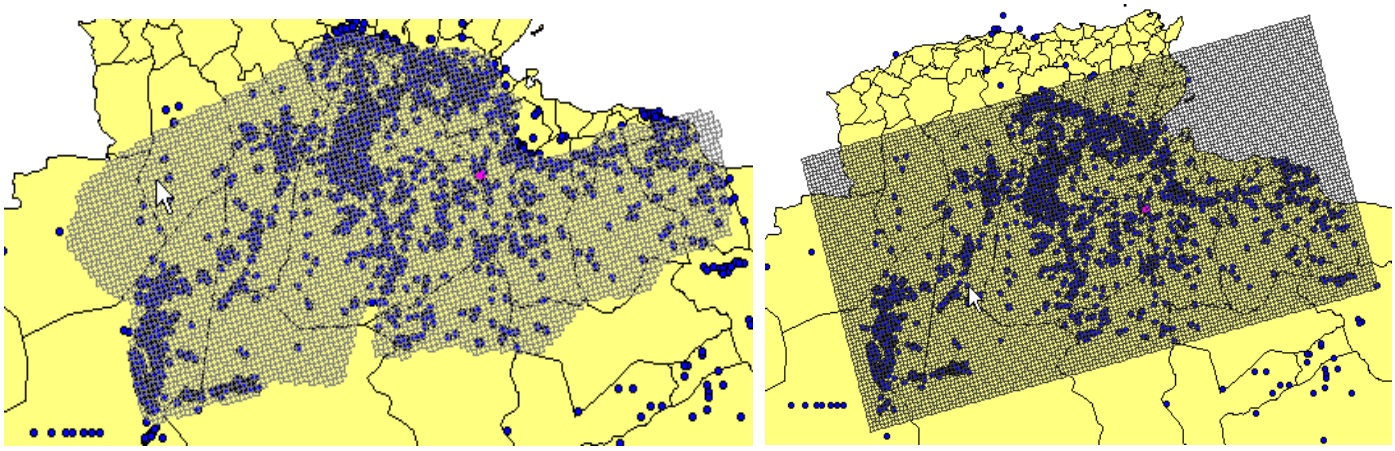
A control operation is performed before loading the file in order to check whether it is conform to a grid (net mesh) file. In case it is not, the file is not opened.

Generation of a new grid (net mesh)

The button initiates the form «Param_maillage» (grid (net mesh) parameter) which makes it possible to introduce the grid (net mesh) parameters and to generate it, then display it on the map window.



Choice of an extension layer: it is possible to input an extension (polygonal boundary) in order to select only the cells found inside this extension. The examples below show the two possibilities:



With extension **Without extension**

For so doing, either the extension is loaded and, therefore, proposed in the zone list, or else we need to click on «*Autre*» (other) and choose the name of a file via a dialogue box of file opening. One needs to make sure, of course, that this layer is in the same projection system.

Such an action must necessarily be done in the following cases:

- modification of grid (net mesh) ;
- change of the coordinates of the water points ;
- addition of new points.

Handling of the tool bar:

Once the net mesh is displayed, the user may proceed to the following operations:

- select a cell and display the water points that it contains ;
- update the cell numbers for each water point ;
- cancel the grid (net mesh) out of view (to generate or load another grid).

The tool bar, located below the map window, makes it possible to perform the more extended operations: Zoom, Pan, selection,

 Zoom rectangle performed by means of the mouse ;

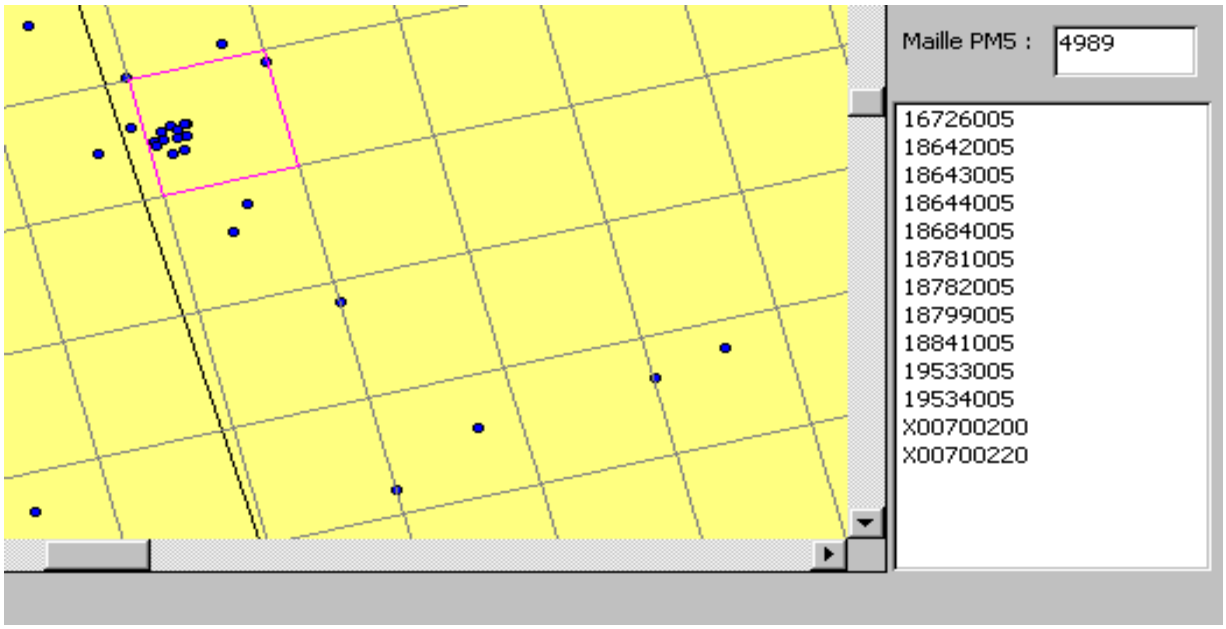
 Zoom In factor 2

 Zoom Out factor 0.5

 Pan in case of Zoom

 Full extent

 This button makes it possible to select a cell within a view. The selection of a cell gives the following output:

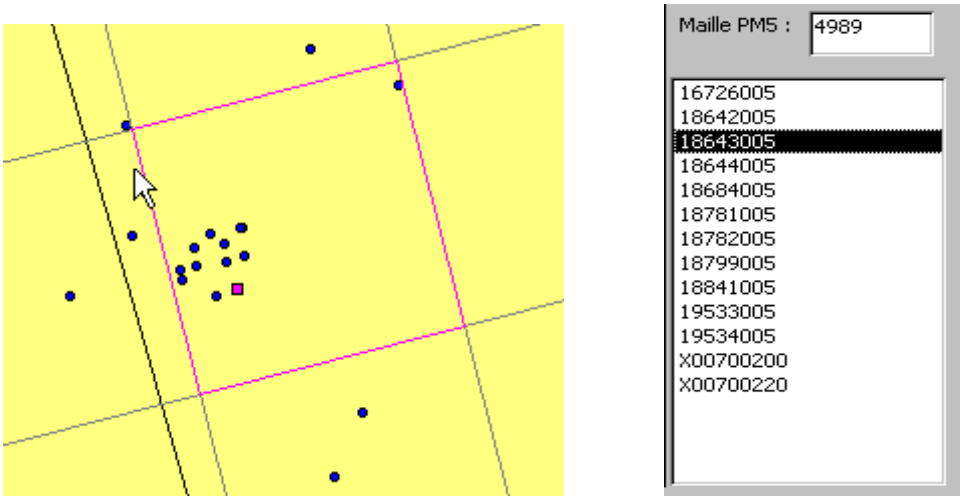


The selected cell is highlighted, and a list of the water points it contains is displayed.

The user may then choose:

- to double click on a number of a point in the list, in order to display the form «*Données générales*» (General data), and thus visualise the whole set of data relating to this water point ;
- to highlight a point on the map, by single click on the number of this point in the list.

Exemple:



The point selected in the list is highlighted on the view (magenta colour).

Double click in order to obtain further details on the water point.

Cancelling a net mesh:

The button 

(Cancel) makes it possible to remove the net mesh layer from the map window. It should be noted that this cancelling operation does not affect the SHP file stored in the «*carte_sass*» (SASS map) file.

Stage 2: Updating the cells numbers

This function allows a link between the data base and the model with a view to preparing the entry data for input into the PM5 (flows by cell) or to retrieve the inputs supplied by the latter.

A procedure has been developed in «*Mapobject*» language so that this function could be performed without leaving the SAGESSE environment: easy implementation and guarantee of reliability.

The button 

(Update cells numbers) initiates the procedure which consists in a spatial query performed on each cell, as well as the updating of the field « *Maille*» (Cell) of the «*Points*» table by applying the following rule:

- if a water point is located in a cell, its number is updated ;
- otherwise, zero value is assigned to this field.

It is for this reason that the net mesh should cover all the layers of the model (this ensures that all points have a cell number).

Stage 3: Initiating the procedure of transfer of data to PM5

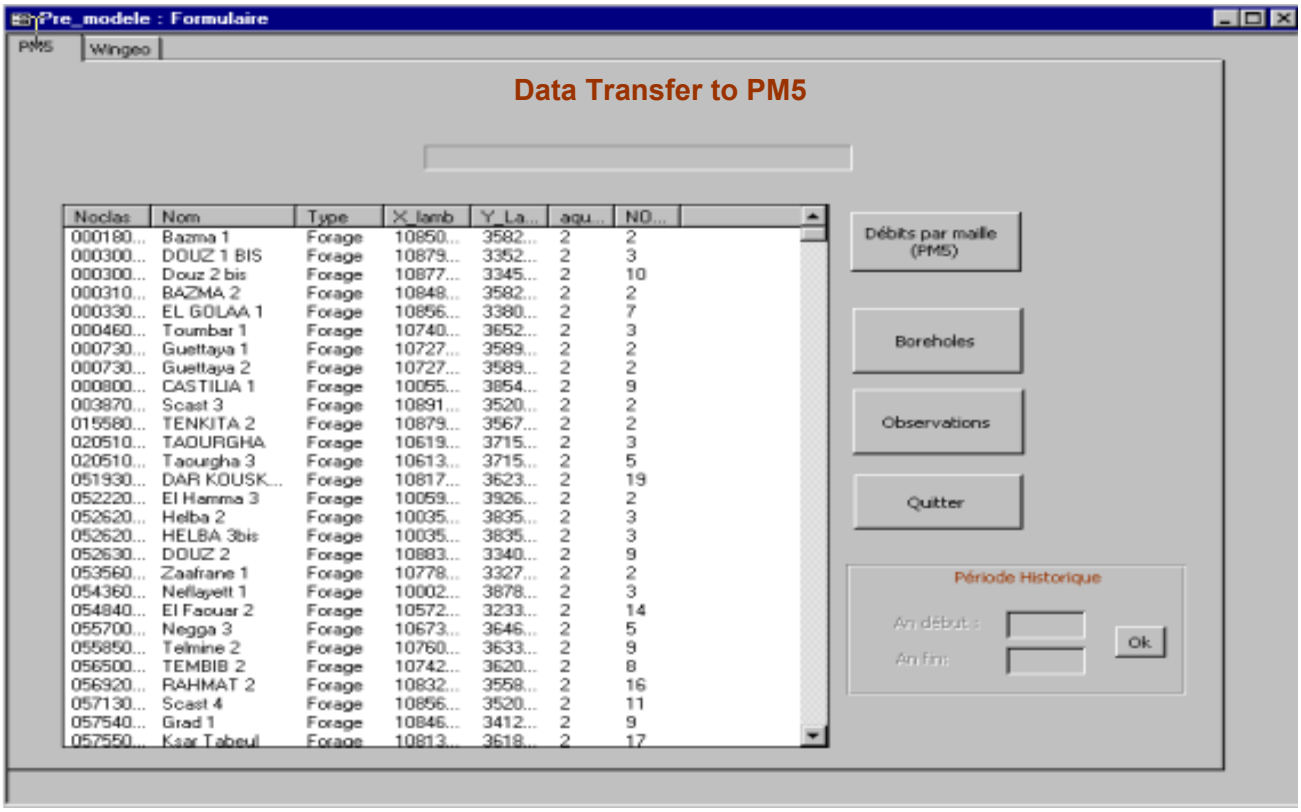
The preparation of the data is the operation that is most difficult to conduct manually. The development of the automatic transfer procedure allows not only to facilitate the task of the model designer, but also to ensure consistency between the data and to reduce errors.

A greater flexibility is offered the user who is now concerned about the water points exclusively without having to bother about the cell where the point is located. The operation of grouping by cell having become a mere query, the model designer may multiply hypotheses (assumptions) by:

- modifying the exploitation data (action is limited to the water points) ;
- or by generating fictive points (forecast simulations).

In order to access this option, the following steps must be followed:

- at the level of the main explorer, press the following button 
- in the data base window, initiate the form «*Pre_modele*».



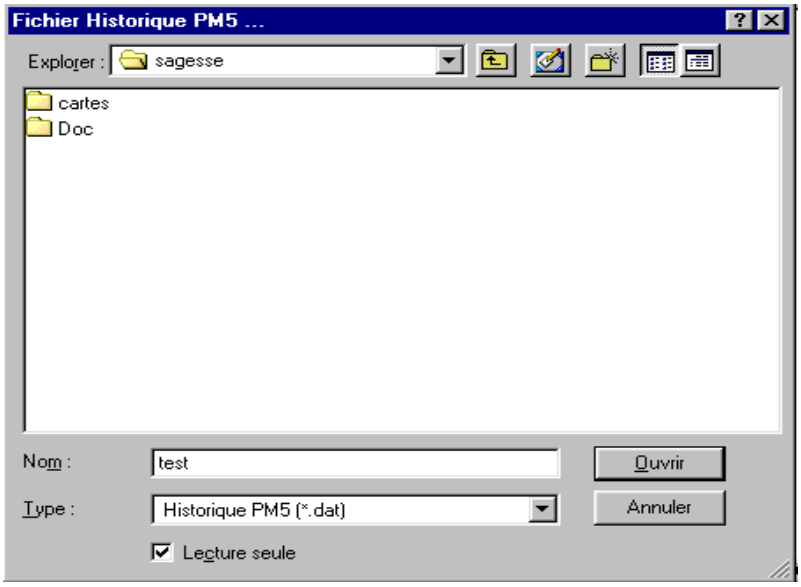
Three types of transfer are possible:

- marker piezometers (necessary for model calibration) ;
- level records related to these parameters ;
- flow records (algebraic sum of recharge – abstraction).

Although functional, the former two types have not been used in the context of the project. It is based on the third option that all simulations have been made.

By clicking on the button «*Débits par maille (PM5*)» (Flows by cell), the programme allows the user to input the beginning and end years (for permanent flow, supply the same values for the two years).

Click on OK to start the generation of abstractions by cell after having supplied the name and location of the PM5 file that you wish to generate.



The system then initiates the processing operation based on the cell numbers assigned, during the previous stage, to the water points having an exploitation record.

A file with a « Well.dat » format is generated. The latter may be directly used via PM5.

Conversion of data and updating of the DB

The conversion of coordinates is an operation that is necessary each time these coordinates are modified or when new water points are added.

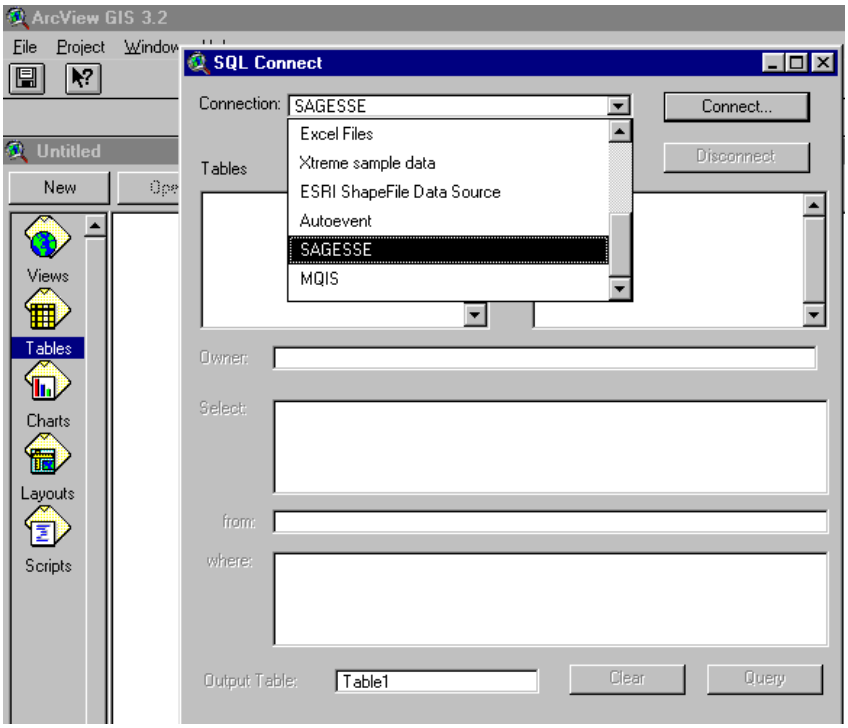
In process of entry, a conversion into decimal degrees is ensured by the entry programme and updating is automatic.

On the other hand, the conversion into Lambert coordinates may be carried out only by the GIS software. For this reason, and in order to simplify this procedure, we have developed an ARCVIEW extension that makes it possible to perform this conversion and to update the columns «***X_Lamb***» and «***Y_Lamb***» of the «***Points***» table.

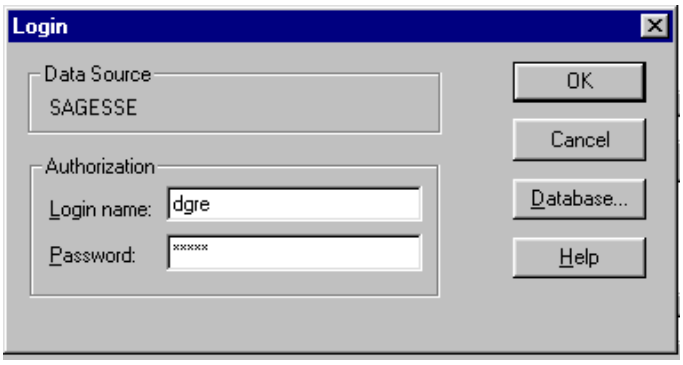
Procedure

1. Connection stage:

- Close SAGESSE and initiate ARCVIEW ;
- Load the extension « Conversion Lambert »: menu « fichier » (files), « extension » ;
- Connect to the « SAGESSE » data source by following the procedure below:



Select « SAGESSE », then click on the button « Connect » ; the following window is displayed:



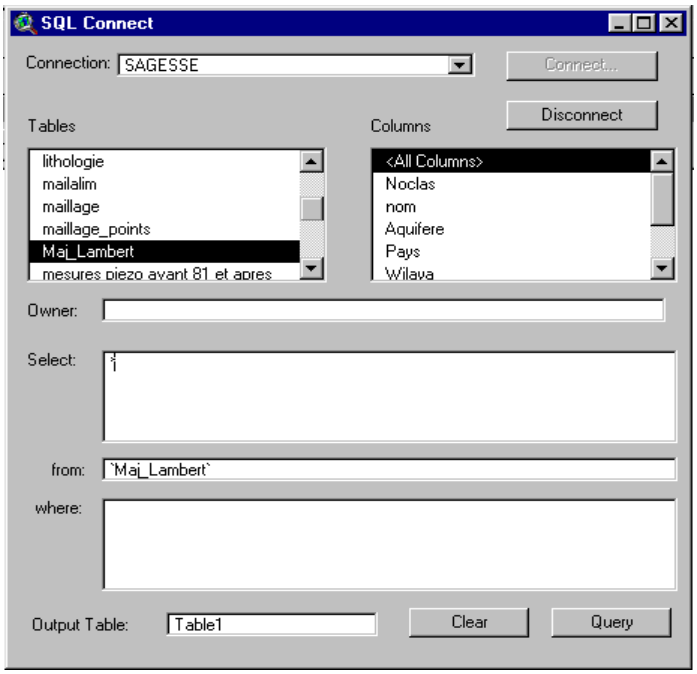
Enter account and password.

2. Stage of conversion of coordinates and updating the « points » table:

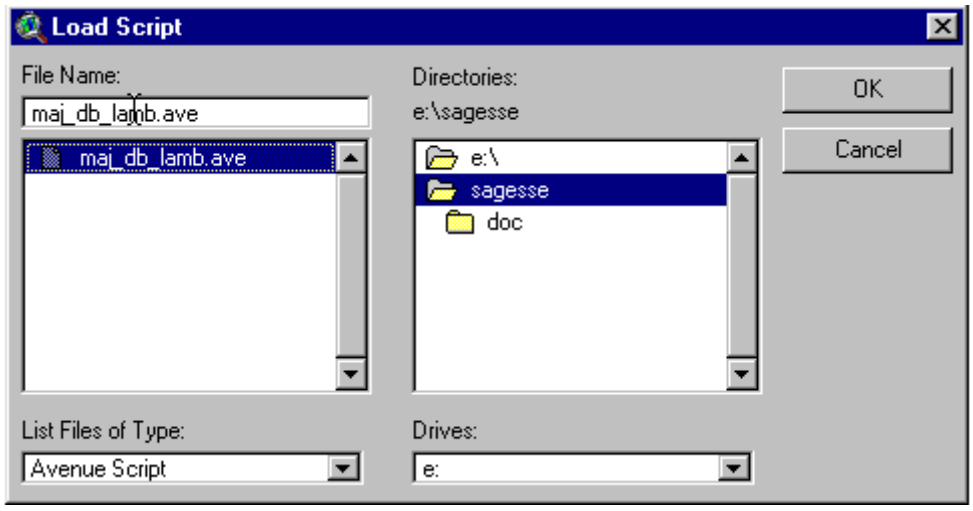
- Open the query « ***Maj_Lambert*** » by a double click ;
- Also double click on « ***all columns*** »

You may supply a name to the table which, by default, will be called « ***Table1*** ».

Click on OK to load the content of the query.

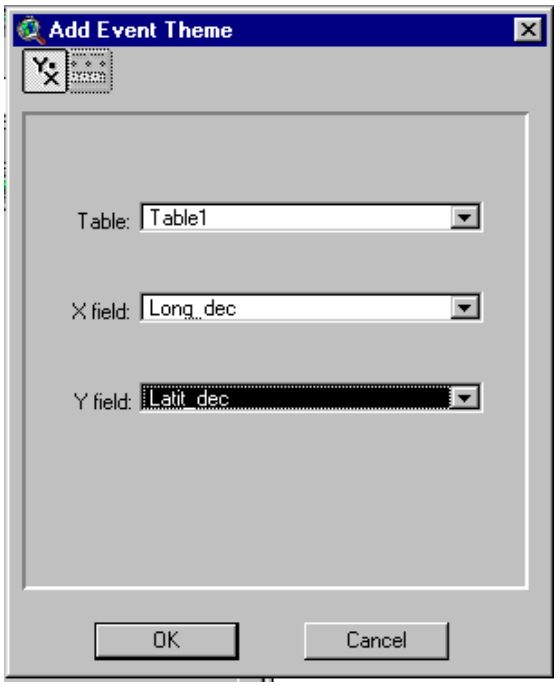


This query contains all the points that require an update: that is, all those that contain valid decimal degrees and whose field « Type_geo » is different from « **L** »:



- Generate a view comprising these points:

  Vew, New and menu « *Add Event Theme* » as follows: for the moment, the view is in decimal degrees (this is necessary).



- Load and initiate the script « ***init_lamb***» which initialises the process (generation of the button )

If this button is not displayed, click on view (otherwise, close view and restart it).

Last stage:

Click on the button to initiate the extension.

A warning message is displayed to confirm the updating of the « *points* » table.
Note that the projection will have changed by the end of the processing (this is Lambert Sud (South)).

In this way, the procedure of conversion into Lambert and of updating the DB has been made easier and less cumbersome:

- no fastidious entry of projection parameters, which would also be likely to result in errors ;
- less stages than before (conversion into Shape File), initiating a script which generates a DBF, manual transfer to the Points table …
- Non existent risk of errors.

Design and realization of the cover: Faiez Taarit

THE NORTH-WESTERN SAHARA AQUIFER SYSTEM

BASIN AWARENESS

DATA BASE AND GIS, VOLUME III - FEBRUARY 2004

Serving as a driving and facilitating force, OSS, in carrying out the SASS Programme, relies first and foremost on the expertise available in specialised, well experienced institutions of the three countries as well as on broad international partnership.

The North-Western Sahara Aquifer System, (NWSAS), shared by Algeria, Tunisia and Libya, has considerable water reserves that cannot be totally exploited and are only very partially renewed. The NWSAS stretches over a million km2 and is composed of two major water-bearing layers, the Continental Intercalary and the Terminal Complex. Over the last thirty years, abstraction by drilling has risen from 0.6 to 2.5 billion m3/yr. This rate of abstraction involves many risks: strong impact on neighbouring countries, salinisation, elimination of artesianism, drying up of outlets, etc. Simulations on the NWSAS Model have enabled OSS to pinpoint the location of the most vulnerable areas and map the risks facing the aquifer system. The three countries concerned by the future of the NWSAS will need to work together to develop a joint management system for the basin. A consultation mechanism needs to be instituted and gradually put into operation.

The present report relates to the "Data Base & Geographic Information System". It summarizes the various reports drafted for the phases of this action. It is composed of two main parts:

- The first part presents the architecture of this data base and of the software products made during the project ;

- The second part gives a detailed description of the data collected, both by the national teams of the countries and by the permanent SASS team.

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