North Western Sahara Aquifer System (NWSAS) M&E Rapid Assessment Report

Misr Consult
Envir. & Infra Str. Studies

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Monitoring and Evaluation for Water In North Africa

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Executive Summary

This rapid assessment aims at providing information about the performance of existing transboundary aquifer management organizations as well as assessment of the monitoring and evaluation tools and practices. The North-Western Sahara Aquifer System (NWSAS) is one of the major North African transboundary groundwater basins shared by three North African countries belonging to the N-AMCOW (Algeria, Libya and Tunisia). The management organization of the NWSAS is the subject of this transboundary rapid assessment report. The NWSAS can be categorized as a multi-layered system of aquifers which embodies a huge stock of non-renewable groundwater. The exploitation of this resource has risen steeply, causing decline of the aquifer artesian pressure, groundwater salinization, and loss of natural oases. Such impacts could lead to the total depletion of the resource. Accordingly, it is important to establish an aquifer management organization that will coordinate the implementation of plans and management measures. Authorities in the three countries, well aware of the risks facing the Saharan Basin, have initiated joint studies under the supervision of the Observatory of the Sahara and the Sahel (OSS). In the framework of the joint studies, while no formal treaty has been signed, the three countries reached an agreement in 2002 to establish a “Consultation Mechanism” for the NWSAS. The Consultation Mechanism has been implemented in the form of a steering committee composed of representatives of the national agencies in charge of water resources. This Consultation Mechanism evolved into a permanent structure which has been endorsed by the ministers of water in the three NWSAS countries in 2006.

The permanent Consultation Mechanism is composed of: a Council of Ministers in charge of water resources in the three countries; a Steering Committee consisting of the national institutions in charge of water resources in the three countries; National Committees (including other institutions concerned with water resources, users associations, and non-governmental organizations); national and regional technical Working Groups; and a Coordination Unit led by a coordinator at the Tunis-based OSS. The NWSAS permanent Consultation Mechanism is managed through the regional Steering Committee, assisted by National Committee, the OSS Executive Secretary, and potential cooperating partners. The Steering Committee meets for one ordinary session each year, and extraordinary sessions may be requested. The meetings are held on a rotating basis, and the chairmanship is held by the host country. The secretariat of the permanent Consultation Mechanism, at the OSS, is secured with an adequate funding structure. However, explicit information on the level of financial contribution by country, and funding regularity could not be perceived in this assessment. The Consultation Mechanism is responsible to: i) Support the countries in implementing the main technical activities aimed at facilitating consultation, especially data collection by establishing joint networks and updating common databases and models; ii) Simplify the institutional process by identifying transboundary water resources challenges, formulating proposals for solution, and formalizing consents; and iii) Ensure information dissemination and organizing discussion at the level of decision-makers on development options in the basins, and promote participatory management.

The support provided from regional and international organizations plays a major role in sustaining mechanisms of regional cooperation for the joint management of the NWSAS. This is manifested by the support obtained from Swiss, German and French development cooperation agencies, as well as from IFAD, FAO, AWF, FFEM and GEF. In this respect, the OSS with the help of the three countries worked on

developing a strategic partnership with the regional and international organizations in terms of the NWSAS multi-phased project characterized by: Phase 1: (1999–2002) Knowledge improvement; Phase 2: (2003–2007) Consultation mechanism; and Phase 3: (2009–2014) Strategy for a sustainable management. NWSAS basin-scale monitoring and evaluation has been only considered in the framework of the multi-phased project under supervision of the OSS. The first phase of the project, through mathematical modeling, led to identification of risks associated with major future abstractions. Accordingly, emphasis has been placed on the need for monitoring and evaluation. In the second phase of the project, monitoring and evaluation have been explicitly addressed. This is manifested by setting up common monitoring networks and defining a set of monitoring indicators. However, because of the encountered technical and operational difficulties, the project recommendations suggest having a data acquisition protocol, formalization of the data exchange, dissemination of the annual status reports every three years, and having a pertinent task force within the Consultation Mechanism. With regard to the quality monitoring network, the project report pointed out that “the establishment of such a network is necessary and urgent. However, the water quality monitoring network has not yet been put in place.

Models are useful tools for monitoring and evaluation because they allow probing the potential impacts of pumping variations on the overall groundwater-flow system. Comprehensive NWSAS regional modeling efforts were undertaken in the framework of the multi-phased project under supervision of the OSS. These efforts aimed to develop a model that could be used as a mutually accepted technical reference for discussions of transboundary issues among the three NWSAS countries. The modeling efforts have been instrumental in identifying new withdrawal potential and risks associated with major future abstractions with future prediction scenarios up to 2050. The modeling work undertaken in the multi-phased project made several important contributions to transboundary analysis and NWSAS evaluation. Modeling results can help to assess the regional monitoring network coverage and technical basis for cooperation between the sharing countries. Successful modeling is possible only if the methodology is properly integrated with data collection, data processing and other techniques/approaches for the evaluation of the groundwater system characteristics.

Groundwater management either within the national or in the shared transboundary context is very much about making informed decisions. Informed decisions can only be made by using up to date collected and analyzed groundwater data. Sound monitoring data is therefore an essential prerequisite to implementing any form of transboundary governance. The three NWSAS countries have already agreed on the Consultation Mechanism as the institutional mechanism to cooperate on information management. On the other hand, the activities of the multi-phased project bear also evidence of acceptance of the obligation to exchange and share available data and information. In the first phase of the NWSAS multi-phased project, activities comprised development of a database allowing standardizing of the hydrogeological data collected in the three countries, so as to meet the needs for the NWSAS modeling. The development of the NWSAS project, however, revealed the need to transform this database into an integrated information system including the database itself, a suit of mapping tools and the model. Fulfilling such an objective required that the national databases be adapted and homogenized. With the introduction of the Consultation Mechanism, the developed information system has been oriented towards monitoring of the concerted management, both on the technical and political levels. The management of the data is performed by the administrator at OSS. The data sets are validated through an exchange between the national experts and the central administrator. It is finally up to the OSS scientific managers to analyze the information and to draw the relevant conclusions, which will then be submitted to the decision makers in the three countries. Recently, in the framework of third phase of the NWSAS project, in early 2012, a call for tender has been announced by OSS for updating the NWSAS database.

Technical responsibilities of the Consultation Mechanism national committees comprise monitoring, collection and interpretation of data, and periodical reporting. Reporting information is the final step in the data management. Accordingly, recommended tasks remain to be undertaken by the Consultation Mechanism include: collating reports from the authorities in the three countries; preparation of briefing documents and publication of regular updates; and publication of periodic reports on the state of the aquifer system. However, the adoption of common standards and procedures for transboundary reporting require fully comparable information and compatible assessment methods and data management systems. The regional cooperation programs made important advances with respect to the development of inter-state understanding of transboundary monitoring and evaluation including NWSAS basin-scale technical reporting. However, despite the mutually acknowledged role of the Consultation Mechanism, the three countries continue monitoring and evaluation in a routine national context. Creation of an enabling environment for transboundary monitoring and evaluation remains a major concern. Apparently, the NWSAS countries and the permanent Consultation Mechanism adapt comfortably to monitoring and evaluation in a regional context only when it is carried out within a regional cooperation program facilitated with the involvement of regional and international organizations.

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Acronyms and Abbreviations

ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
ANRH	Agence Nationale des Ressources Hydrauliques (Algeria)
AWC	Arab Water Council
AWF	African Water facility
BGR	German Federal Institute for Geosciences and Natural Resources
CI	Continental Intercalaire
CRDAs	Commissariat Régional au Développement Agricole
CT	Complexe Terminal
DB	Database
DDC-Suisse	Direction du Développement et de la Coopération de la Suisse
DGRE	Direction générale des Ressources en Eau (Tunisia)
ERESS	Etude des Ressources en Eau du Sahara Septentrional
FAO	Food and Agriculture Organization of the United Nations
FFEM	Fond Français pour l'Environnement Mondial
GEF	Global Environment Facility
GIS	Geographic Information System
GMMR	Great Man-Made River Project (Libya)
GMRA	Great Man-Made River Water Utilization Authority (Libya)
GTA	Groupes de Travail Ad hoc
GWA	General Water Authority (Libya)
GWP	Global Water Partnership
IFAD	International Fund for Agriculture Development
INECO	Institutional and Economic instruments for sustainable water management in the Mediterranean region
IS	Information System
ISARM	Internationally Shared Aquifer Resources Management
IT	Information Technology
IWRM	Integrated Water Resources Management
MCM	Million Cubic Meters
M&E	Monitoring and Evaluation
N-AMCOW	Northern Region of the African Ministers' Council on Water
NGOs	Non-Governmental Organizations
NWSAS	North-Western Sahara Aquifer System
OSS	Observatoire du Sahara et du Sahel
SAGESSE	Système d'Aide à la Gestion des Eaux du Sahara Septentrional System of help to the Management of the Septentrional Sahara Waters
SASS	Système Aquifère du Sahara Septentrional
SWOT	Strengths, Weaknesses, Opportunities, Threats
UC	Unité de Coordination
UN/ECE	United Nations/ Economic Commission for Europe
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization

1. Background

Algeria, Egypt, Libya, Mauritania, Morocco and Tunisia constitute the Northern Region of Africa and are the member countries of the Northern Region of the African Ministerial Council on Water (AMCOW), commonly named N-AMCOW. The countries have decided to harmonize and standardize their Water Sector Monitoring and Evaluation (M&E) framework. The global objective of this assignment is assessment of existing M&E systems for the six N-AMCOW countries. This rapid assessment aims at providing information about the performance of existing transboundary aquifer management organizations and frameworks as well as assessment of the adopted ways to harmonize and standardize key indicators, and the existing M&E tools and practices.

A transboundary rapid assessment deals with the transboundary water resources that N-AMCOW countries share. Transboundary assessment essentially involves identification of the stage of the development of agreements on the use of the shared resources, description and evaluation of the status of the transboundary basin M&E system; and also includes diagnostic analysis of the shared basin and the relevant basin organization. The huge groundwater reservoir of the North-West Sahara Aquifer System (NWSAS) is shared by three North African countries belonging to the N-AMCOW countries (Algeria, Libya and Tunisia). The NWSAS is the subject of this transboundary rapid assessment report.

1.1 NWSAS Physical Setting

The North-West Sahara Aquifer System (NWSAS) also referred to as the Système Aquifère du Sahara Septentrional (SASS), is a large complex hydrogeological basin located in the desert North Africa area. It is one of the major North African transboundary groundwater basins. The NWSAS can be categorized as a multi-layered system of aquifers which embodies a huge stock of non-renewable, fossil water. It displays a mostly porous and fissured / fractured structure (Struckmeier and Richts 2012). The NWSAS, from the geological point of view, is made by sedimentary formations the oldest of them date back to the Carboniferous-Permian period and it includes two main aquifers with different hydrogeological features, the Complexe Terminal (CT) (*Terminal Complex*) and the Continental Intercalaire (CI) (*Intercalary Continental*). This System, as shown in Figure 1, covers an area of more than one million square kilometers, including 700,000 km^2 (69%) in Algeria, 250,000 km^2 (23%) in Libya, and 80,000 km^2 (8%) in Tunisia (Diallo and Dorsouma, 2008).

The Continental Intercalaire (CI) is defined as the set of sedimentary layers comprising mainly continental sandstone-clay formations of the lower Cretaceous, to which are associated post-paleozoic and ante-cenomanian marine or lagoon sediments. The CI is located on the lower level. It has a thickness of many hundreds of meters and is found in depths ranging from around 400 up to 2,000 meters below ground (Besbes et al. 2004). Some drilling wells exploiting the CI layer reached the depth of 2,800 m and over.

The CI contains a set of layers with very differing lithology, comprising mainly continental sandstone in alternation with marine limestones and clay formations (Zekster and Everett 2004). The Mio-Pliocene continental formations are in connection with aquifers of the Eocene, the Senonian and the Turonian. However, considering the whole scale of the Sahara, one can consider that these different levels form a unique aquifer, the aquifer of the 'Complexe Terminal' (Besbes et al. 2004). Accordingly, the Complexe Terminal (CT) is located on the upper level of the NWSAS. It designates limestones and continental, sandy and clayish formations, dating from the Upper Cretaceous to the Miocene and Pliocene (Besbes et al. 2004). The CT is a confined aquifer lying about 200 m deep in the Chotts region hosted by Superior Cretaceous limestones that, near the Algeria border, are dominated by Miocene's siliceous sands in a strong hydraulic continuity. Additionally shallow phreatic aquifers of local importance occur. Especially at the basin boundaries connections between them and the deeper aquifers occur.

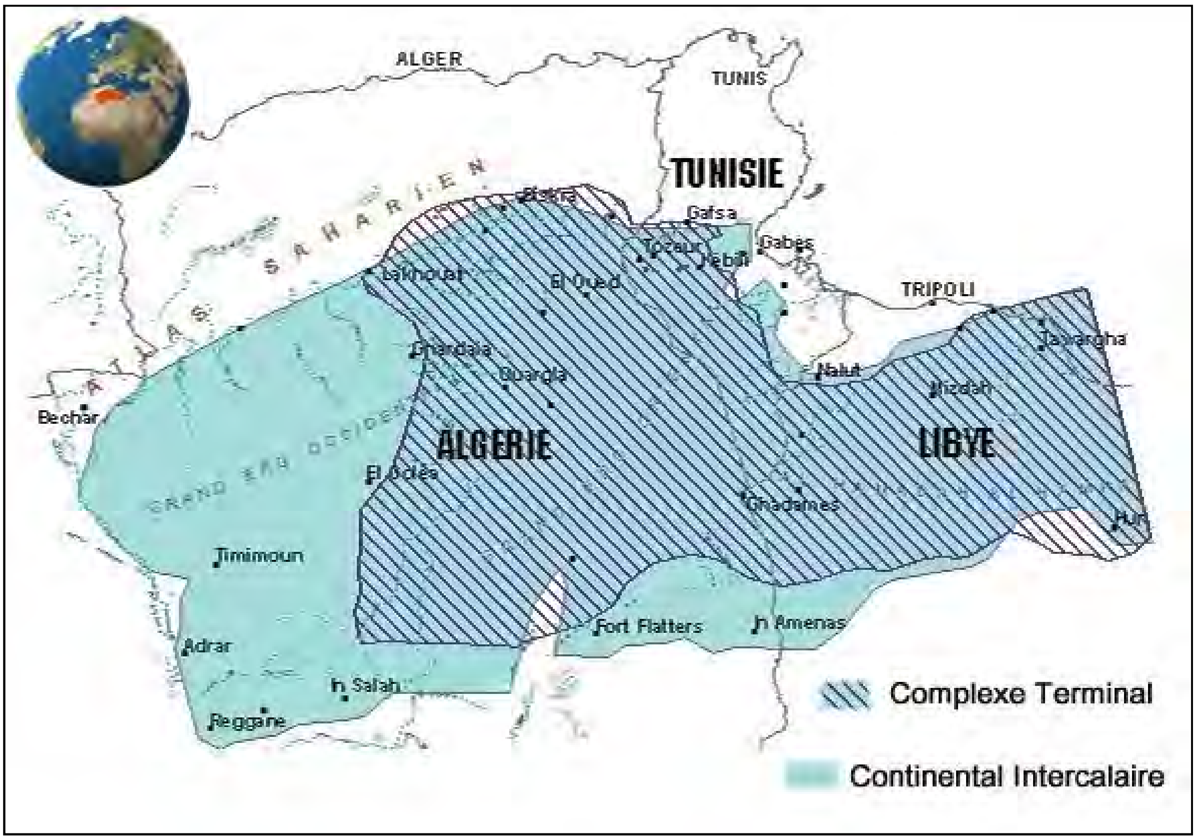

Figure 1. NWSAS Location Map

(Source: OSS, 2008, modified)

Given the arid to saharan climate conditions, these formations are slightly recharged. The formations in the aquifer system are recharged from the following areas: the Saharan Atlas piedmont plains in Algeria, the Dahar in Tunisia, and Djebel Nefoussa in Libya. However, the system extension and the layer thickness have facilitated the accumulation of considerable reserves over the past centuries.

1.2 NWSAS Development Patterns

Even though the NWSAS groundwater has been often considered as "fossil", recent studies (Ould Baba, 2005) found that in some regions in the mountains of Algeria Atlas there is a direct annual recharge by rainfall, which is estimated to reach one billion cubic meters per year (10^9 m^3/y). Nevertheless, the NWSAS hydrogeological features produce some very low filtration velocities justifying the average groundwater age of about 35.000-40.000 years. All these features show the typical nature of a non-renewable resource. Although the NWSAS was identified in the 50's, its exploitation started using water sources and foggaras located in the outlets of the aquifer until they were replaced by new drilling wells in the 80's after drop rate and drying. While the aquifer has remained substantially under stable conditions up to the 80's, in the last twenty years, because of the economic feasibility of the artesian flowing source and the increasing population growth in the NWSAS countries, the exploitation of this resource has risen steeply, especially for major agricultural projects. Growth of abstractions in the major development areas in the NWSAS during the period 1970 - 2000 are illustrated in Figure 2 (Mamou et al. 2006). As a consequence, some of NWSAS main hydro-environmental features have been affected including decline of the aquifer artesian pressure, groundwater salinization, and loss of natural oases (Zammouri et al., 2007). Such impacts could inescapably lead to the total depletion of the resource, such that it will not be available for future use.

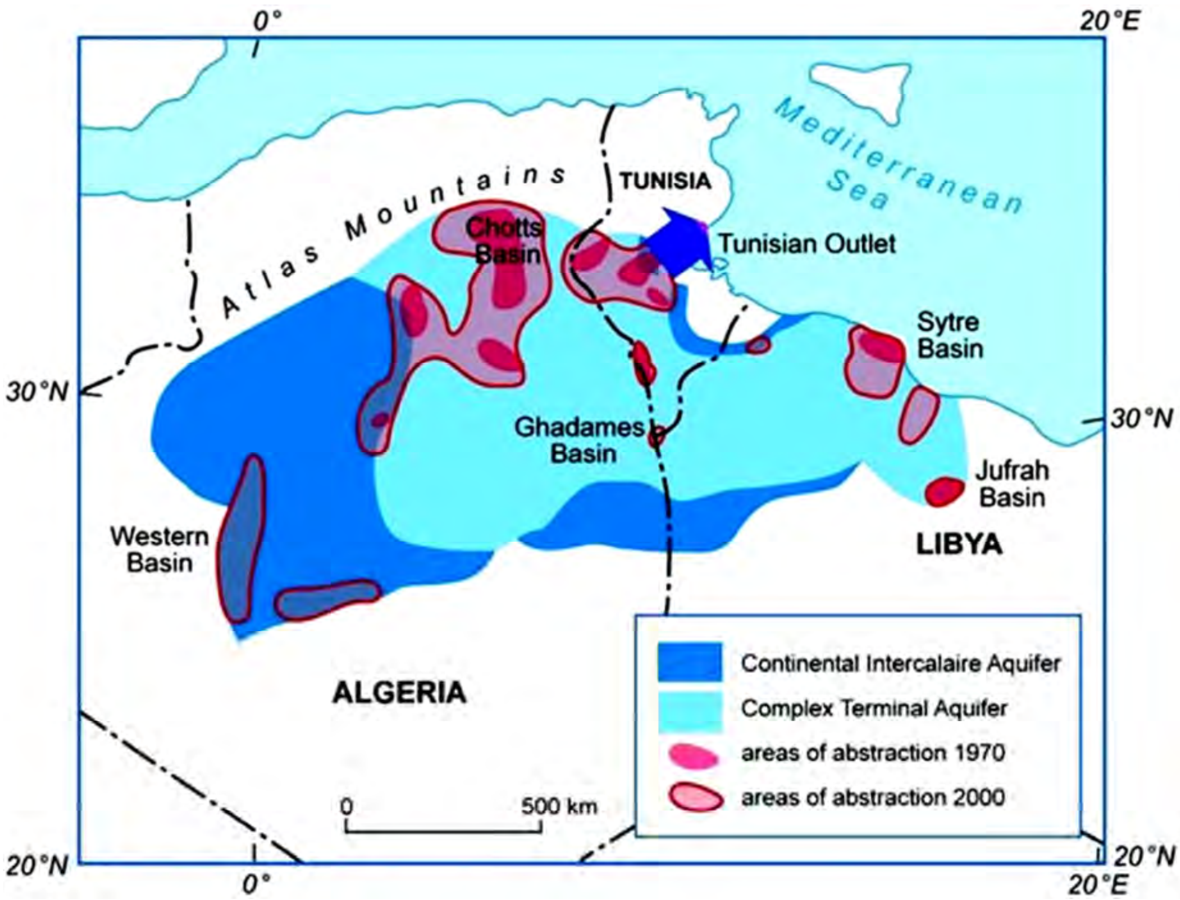

Figure 2. NWSAS Major Development Areas

(Source: Mamou et al. 2006)

A census conducted by the Observatory of the Sahara and the Sahel (OSS) in 2001 showed that the NWSAS is exploited by almost 8,800 withdrawal water points: 3,500 (39.8%) in the Continental Intercalary and 5,300 (60.2%) in the Complex Terminal. These points include 6,500 (73.8%) in Algeria, 1,200 (13.6%) in Tunisia, and 1,100 (12.6%) in Libya. The number of drilled exploitation wells has substantially increased during the last 20 years with predominance in the agricultural sector. In the census, the annual exploitation reaches over 2.2 billion m^3 in year 1990: 1.3 billion (59.1%) in Algeria, 0.55 billion (25%) in Tunisia and 0.33 billion (15.9%) in Libya (Figure 3 - Mamou et al. 2006). However the national consultants in the three countries indicate that the annual exploitation has been revised and corrected to 2.2 billion m^3 in year 2000 and 2.5 billion m^3 in year 2008. The three countries sharing the aquifer system are concerned about the future of the Saharan regions with such prolonged NWSAS withdrawal trend (Mamou et al. 2006).

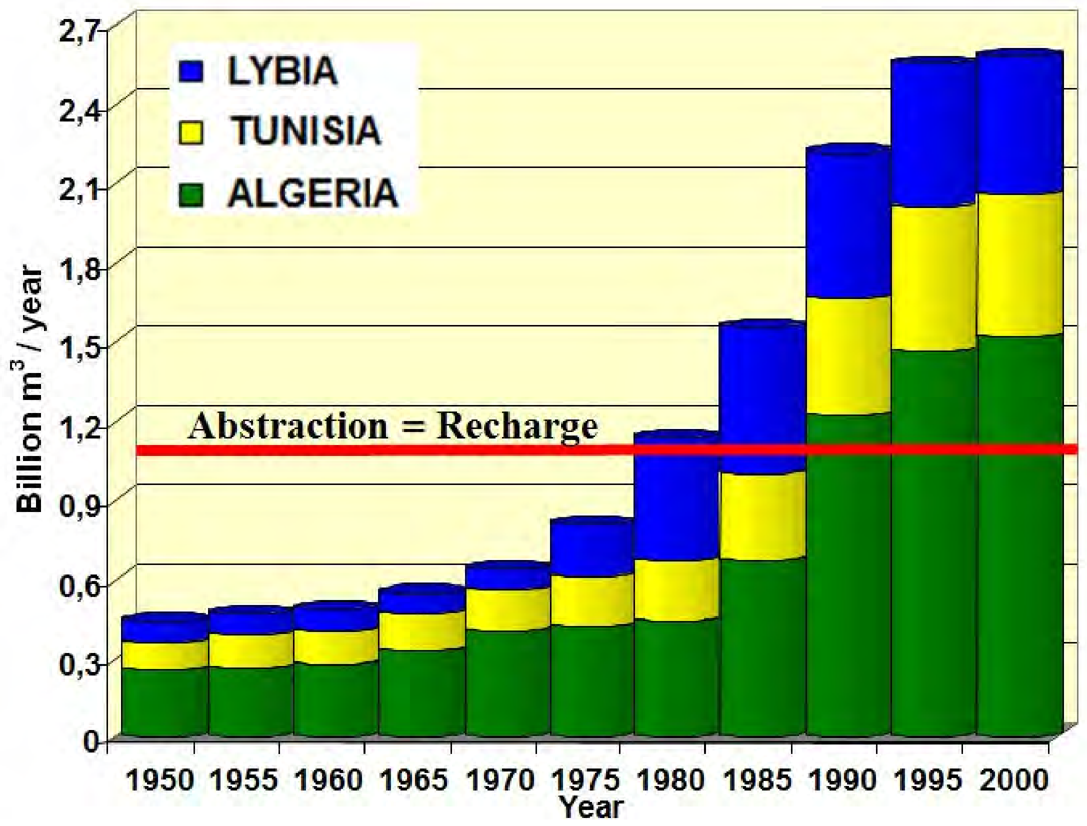

Figure 3. Evolution of NWSAS Withdrawal Trend
(Source: Mamou et al. 2006)

The NWSAS is only slightly recharged by around one billion m^3/year in total. The groundwater potential of the NWSAS has been estimated to be about 60 000 billion m^3 (ERESS, RAB, SASS projects, Dj. Latrech (OSS) presentation in Gestion concertée d'une ressource partagée, cas du système aquifère du Sahara Septentrional: Gestion de la rareté de l'eau dans la région MENA. FIDA Rome 18-19 Février 2004). Analogous with the growth of the riparian populations and the growth of their economies it is anticipated that the exploitation of the NWSAS will grow even further. In fact, Algeria and Libya are presently planning to increase their shares, and Tunisia plans to stabilize its extraction at its current rate in traditional areas (Mamou et al. 2006), but new sites that would be favorable for exploitation in the future without risks or harmful effects were being identified, and it remains possible to relocate the exploitation towards these new sites in the coming decades. In Tunisia, it is possible to take additional withdrawals of 178 Mm^3/year from the NWSAS in 2050.

Table 1. NWSAS withdrawals in 2000 and the possible withdrawals evolution in 2050

Countries	Withdrawals (Year 2000) Mm^3/year	Future withdrawals (Year 2050) Mm^3/year
Tunisia	542	720
Algeria	1328	6100
Libya	340	950
Total	**2210**	**7770**

Inordinate pumping in the NWSAS could have serious effects on the future and the economy of the region. An overview is given below for the patterns of groundwater development from the NWSAS in Algeria, Libya and Tunisia.

Algeria is the biggest economy among the three riparian, with population of 37.1 million inhabitants (FAO, AQUASTAT database, 2011). Compared to the other two riparian, Algeria holds access to the largest amount of renewable surface water in proportion to its total water resources. Surface water makes up for around 50% of the overall current water supply of the country. Renewable groundwater is estimated at around 40%, whereas non-renewable groundwater makes up only about 9% of the total supply and 1% from desalination (OSS 2004c). Accordingly, Algeria is classified as having “a predominance of internal, renewable reserves without any downstream reserve constraints”. These figures may imply that Algeria is quite well-sustained in terms of renewable water resources. However, this is not the case since the total renewable water resources per capita of 324.3 m^3/year is well below the water poverty line (FAO, AQUASTAT database, 2007). In Algeria, approximately 69% of the NWSAS areal extent lies in the country (Mamou et al. 2006). As indicated in Figure 3, Algeria exploits the largest share of the NWSAS resources ranging at about 59% of the total extraction. It is expected that the exploitation of the NWSAS will grow even further. In this regard, Algeria suggests two scenarios for increasing its extraction (OSS 2008). The first one, a so called “weak hypothesis” scenario, opts for an increase from 1.3 billion m^3/year in 2000 to 3.3 billion m^3/year in 2030. The second one, a so called “strong hypothesis” scenario, expands extraction to reach 4.5 billion m^3/year in 2030 (OSS 2008). Apart from its inter-riparian relations in the NWSAS, Algeria shares five additional transboundary aquifers with other neighbor states. It is assumed that this fact influences the country’s behavior as a transboundary riparian, because the concern and motivation for international cooperation is expected to be higher in countries sharing several transboundary aquifers (Struckmeier and Richts 2006).

Libya relies nearly completely on resources that will be depleted at some stage, where majority of its water requirements are met from non-renewable groundwater (Foster and Loucks 2006). With only 6.4 million inhabitants Libya is smallest in population numbers compared to the other two riparian (FAO, AQUASTAT database, 2011). Libya displays a distribution of its water supply completely different from its riparian neighbors. Renewable surface water makes up for only about 3% of the overall current water supply of the country. Renewable groundwater is estimated at around 7%, whereas non-renewable groundwater makes up for 77% of the total supply. Libya is already engaged in re-use of wastewater and desalination to a considerable extent (OSS 2004c). The total amount of renewable water accessible to the country is only 0.6 billion m^3/year (FAO, AQUASTAT database, 2007). The annual per capita demand in Libya is about 809 m^3/year (OSS 2004c). Compared to the other two riparian, Libya holds the greatest reserve of exploitable non-renewable groundwater. Its current reserves are estimated at 4,000 billion m^3. Accordingly, Libya is classified as having a predominance of internal, non-renewable resources (OSS

2004c). In Libya, approximately 23% of the NWSAS areal extent lies in the country (Mamou et al. 2006). As indicated in Figure 3, Libya exploits about 16% of the total extraction from the NWSAS. It is expected that the exploitation of the NWSAS will grow even further. In this regard, Libya plans to increase extraction from 0.4 billion m^3/year in 2000 to 0.9 billion m^3/year in 2030 (OSS 2008). Apart from its inter-riparian relations in the NWSAS, Libya shares two additional transboundary aquifers with its neighboring countries, of which the Nubian Sandstone Aquifer System is the most important for Libya's groundwater resources.

Tunisia displays a similar distribution of its water supply to that of its neighbor Algeria. Renewable surface water makes up for 40% of the overall current water supply of the country. Renewable groundwater is estimated at around 50%, whereas non-renewable groundwater makes up for 10% of the total supply (OSS 2004c). Accordingly, Tunisia is as well classified as having "a predominance of internal, renewable reserves". It is also classified as "not suffering from any downstream reserve constraints" (OSS 2004c). The total amount of renewable water accessible to the country is only about 4.6 billion m^3/y (FAO, AQUASTAT database, 2007). With a population of 10.59 million, the annual per capita demand in Tunisia is about 248 m^3/y (OSS 2004c). Respective estimations lie at 1,700 km^3 (OSS 2004c). The country receives 0.1 km^3 inflow from Algeria annually. No water leaves the country to neighboring states (OSS 2004c). In Tunisia, the smallest share of approximately 8% of the NWSAS areal extent lies in the country (Mamou et al. 2006). As indicated in Figure 3, Tunisia exploits about 25% of the total extraction from the NWSAS. Though Algeria and Libya have plans to expand exploitation of the NWSAS; Tunisia plans to stabilize its extraction at its current rate in traditional areas (Mamou et al. 2006), but new sites that would be favorable for exploitation in the future without risks or harmful effects were being identified, and it remains possible to relocate the exploitation towards these new sites in the coming decades. It is possible to take additional withdrawals of 178 Mm^3/year from the NWSAS in 2050.Tunisia has also an access to Djeffara Transboundary Aquifer, shared by Tunisia and Libya with area extent is 21000 km^2 (48%) in Tunisia and 23000 km^2 (52%) in Libya.

1.3 NWSAS Transboundary Management

Management measures in terms of scientific characterization studies of the NWSAS had started in the 1960s, and developed in 1980 mainly between Algeria and Tunisia. Libya joined later. The technical cooperation has gradually led to mutual confidence and recognition of the problems and risks affecting the aquifer system (OSS, 2008). Authorities in the three countries have decided in 1997 to carry out a joint study programme to ensure control over possible transboundary impacts (Mamou et al., 2006). In 1999, the project was launched and the Sahara and Sahel Observatory (OSS) was named as the Executive Agency in charge of the project. The first phase of the programme ended in December 2002 with an agreement to establish a "Consultation Mechanism" for the joint management of the NWSAS (Mamou et al., 2006). This mechanism further evolved in 2008 towards a permanent structure composed of: A Council of Ministers in charge of water resources in the three countries; A Steering Committee composed of the national institutions in charge of water resources in the three countries; National Committees including other institutions concerned with water resources, users associations, and non-governmental organizations; National and regional technical working; and A coordination unit led by a coordinator at the OSS.

2. Scope of the Report

The North-West Sahara Aquifer System (NWSAS) is a large complex hydrogeological basin located in the North Africa desert area. It is one of the major North African transboundary groundwater basins, shared by three North African countries (Algeria, Libya and Tunisia). The management organization of the NWSAS is the subject of this transboundary rapid assessment report. Transboundary assessment involves identification of the status of agreements on the use of the NWSAS, description and appraisal of the transboundary Monitoring and Evaluation (M&E) system; and also includes diagnostic analysis (SWOT) of the shared basin and the relevant aquifer management organization. In the context of transboundary assessment, the objective of the “Background” introductory section is not to provide a detailed description of the geology and the hydrogeology of the NWSAS but rather to point out background information on the physical setting and groundwater development patterns from the NWSAS countries. Such background information is required for identification of the NWSAS-specific challenges associated with Integrated Water Resources Management (IWRM). In this report, transboundary assessment is conducted through an IWRM analytical framework considering the NWSAS and its regional management organization. The NWSAS multi-phased project and the pertinent activities including establishment of NWSAS institutional arrangements, have been the primary source of information for this report. In this respect, the report includes four main sections, namely, ‘IWRM: Transboundary Aquifers’, ‘Monitoring and Evaluation’, ‘Information Management’, and ‘SWOT Analysis’.

The section on ‘IWRM: Transboundary Aquifers’ includes sub-sections on ‘Governance’, ‘Key Players’, and ‘Finance’. The sub-section on ‘Governance’ introduces an overview of national and transboundary NWSAS related institutional arrangements for groundwater management in Algeria, Libya and Tunisia. It also provides comparative information on various institutional aspects of the NWSAS Permanent Consultation Mechanism covering the organogram, mission, mandate, and management of the organization. The sub-section on ‘Key Players’ summarizes the evolution of involvement and support provided to the NWSAS through regional and international organizations. The sub-section on ‘Finance’ describes the processes of budget, accounts and financial resources of the NWSAS’s Consultation Mechanism. It also outlines relevant executive regulations for mobilizing financial resources needed to implement the NWSAS multi-phased cooperation project. The section on ‘Monitoring and Evaluation’ includes sub-sections on ‘Parameters and Indicators’, and ‘Regional Modeling’. The sub-section on ‘Parameters and Indicators’ presents the conceived parameters and indicators associated with monitoring of the NWSAS. It also presents an overview of the regional efforts on information exchange and monitoring. The sub-section on ‘Regional Modeling’ discusses the role of NWSAS applied models as a mutually accepted technical reference for monitoring and evaluation. The section on ‘Information Management’ includes sub-sections on ‘Regional Information System’ and ‘Transboundary Reporting’. The sub-section on ‘Regional Information System’ presents an overview of the NWSAS regional cooperation mechanisms and efforts on information storage and dissemination through a regional information system, emphasizing the important role of information management for transboundary cooperation. The sub-section on ‘Transboundary Reporting’ describes the status of NWSAS regional reporting procedures including the role of the national institutions and the support of regional and international organizations. The section on ‘SWOT Analysis’ provides a diagnostic analysis to evaluate negative and positive factors involved in the transboundary management of the NWSAS and the relevant aquifer management organization.

3. IWRM: Transboundary Aquifers

Integrated water resources management (IWRM) seeks to manage the water resources in a comprehensive and holistic way. It therefore has to consider the water resources from a number of different perspectives or dimensions (water resources, water users, spatial scales, time dimensions) and pays attention to a large number of often-related issues and principles. Some of these principles are efficient and equitable water allocation, public health and environmental sustainability, institutional arrangements, and international water rights (GWP-TAC4 2000). IWRM decision-making would involve the integration of the different objectives where possible, according to societal objectives and constraints.

Integrated management of aquifer systems essentially aims at achieving certain goals through a set of decisions related to the operation of the system. Goals can be achieved by different operation policies. Such policies are generally based on the driving forces related to socio-economic development. Within a national context, most management issues can be addressed under the single national constitution. Obviously, this is not the case regarding the management of shared transboundary aquifers, extending across two or more national constitutions, where water national policies may have to be adjusted to achieve mutual satisfaction among countries sharing the aquifer system (Khater 2005).

3.1 Governance

There is a general agreement in the water community that IWRM provides the only viable way forward for sustainable water use and management. Governance provides the context within which IWRM can be applied. Water governance relates to the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services at different levels of society (Rogers & Hall 2003). Thus, governance is the process of decision-making and decisions implementation. It is concerned mainly with the institutional setups that are necessary for water development and management.

Institutional frameworks should specify, the exact responsibilities and authority granted to perform tasks related to water planning, coordination among various water users, the regulations and enforcement mechanism designed to protect and reconcile the interests of all groups and the management of physical operations. The existing institutions determine, to a large extent, whether objectives and strategies can be achieved in practice. In shared aquifer systems, an understanding of the national institutional arrangements for groundwater management influences the developing of transboundary groundwater management setups. On the national scale groundwater-related issues are generally governed through the respective water authorities. This holds true for all three riparian states. In Algeria it is the Agence Nationale des Ressources Hydrauliques (ANRH), in Tunisia groundwater is governed by the Direction Générale des Ressources en Eau (DGRE) and in Libya the General Water Authority (GWA) takes charge (Schmidt 2008). The following is an overview of national and transboundary NWSAS related institutional arrangements for groundwater management in Algeria, Libya and Tunisia.

Institutions in Algeria:

The country is divided into 17 major hydrographical basins, of which 5 are transboundary: the Medjerda basin is shared with Tunisia, and the Tafna, Draa, Guir and Daoura basins are shared with Morocco. In terms of administration, the country is divided into 48 Wilayas (provinces), 567 Dairas (counties) and 1540 municipalities. The Ministry of Water Resources is the government's department in charge of water resource planning and management in Algeria. It is also responsible for allocating surface water and groundwater among the different uses, and for controlling all water-related infrastructures (AWC 2011). Additional tasks include monitoring of water resources, in terms of both quantity and quality. Following its central role in water management, the Ministry also has control over five national public service agencies and five regional hydrographical basin agencies (AWC 2011).

The Water Law of 1983 set the framework for water management in Algeria, defining the public ownership of water resources (surface and groundwater) of the country, and the priorities for water allocation. The National Agency of Hydraulic Resources and the hydrographical basin agencies monitor both surface and groundwater through a network of measuring points (INECO 2009a). A large number of wells and boreholes are being drilled, in many cases without prior authorization or permit. In 2006, authorities decided to develop an inventory of water extraction points; however, this is considered a difficult task as the number of illegal wells or boreholes is at present estimated at several thousands (INECO 2009a).

Institutions in Libya:

At present, the Ministry of Water Resources, and previously the Secretariat of Agriculture and Animal Wealth, is responsible for the development of irrigated agriculture and the implementation of major irrigation projects. The General Water Authority (GWA) has been appointed as the water resources focal institution. Groundwater in Libya is owned by the state and has been managed by GWA. The General Water Authority (GWA) was established in 1972 as a central body with the head office in Tripoli and five branch offices. GWA is responsible for assessment, monitoring, development, planning and management of water resources. GWA also Investigates, designs, licensing, and supervises implementation of all water resources projects in Libya. The Authority is entrusted to control and regulate groundwater extractions and groundwater use, including legislative aspects and enforcement of laws. The Authority is organized into six General Directorates: Planning; Follow-up and Statistics; Water Resources; Dams, Irrigation and Drainage; Soils; and Finance and Administration (FAO 2006).

For the Man-Made River Project, a special authority, the "The Man-Made River Water Utilization Authority" (MmRA), was established in 1983. MmRA is supervising the whole project and mainly concerned with drilling and construction of the well fields, pipelines, reservoirs, pumping stations and other related works to transport water to the coastal areas for irrigation and domestic uses. MmRA is also responsible for operation and maintenance of the water conveyance system (Bakhbakhi 2009). Eventually, the MmRA was divided into three independent authorities (Sahl Benghazi, Central Region and Jefara-Hasawna System).

Institutions in Tunisia:

The country is divided in 7 River Basin Districts extending from the north-most part of the country to the south-most part of the country, up to the Algerian and Libyan borderlines. The most important water use sector is irrigation, using 80% of the country's available resources. Inter-basin transfer is performed among northern regions, towards the coast and from the western to the eastern part of the country. Transferred water is primarily used for domestic and irrigation purposes. At the national level, most water resources management tasks fall under the Ministry of Agriculture and Hydraulic Resources and the 12 directions/institutions under its authority (INECO 2009b). The ministry has also control over four national public service agencies (SONEDE, SECADENORD, RSH, RTMA); two inventory and planning water resources bureaus (BPEH,BIRH) and an institution of research and higher education in agriculture sector (IRESA). At the regional level, the Regional Departments for Agriculture Development (CRDAs), established in each of the 24 Governorates of the country, undertake tasks relevant to the assessment of water resources, the monitoring of water resource use and implementation of irrigation and potable water supply projects, and to the maintenance and updating of the respective regional databases, in line with the requirements of the National Information System of Tunisia. In addition, and in order to assess and monitor water availability and quality, a monitoring network has been established all over the country.

Under the Ministry of Agriculture and Hydraulic Resources, the governmental institutions mostly involved in groundwater resource management and exploitation, including all tasks related to monitoring and assessment, are the General Direction of Water Resources, the General Direction of Rural Engineering and Water Exploitation, and the National Company for Water Exploitation and Distribution. Given the inherently uncontrollable nature of groundwater abstractions, the number of pumping shallow wells escalated from 23,061 in 1980 to 86,965 in 2000, in the whole Tunisia (growth of about 19% per year). However, all these abstractions have been authorized by the responsible Ministry. Due to the existence of numerous private boreholes, the emphasis is placed on creating an appropriate institutional environment for enabling the shared management of groundwater at the user level (INECO 2009b).

Transboundary Organization:

Scientific characterization studies of the NWSAS had started in the 1960s, and developed in 1980 mainly between Algeria and Tunisia. Libya joined later. Bilateral commissions were established such as the technical committee on water and environment between Algeria and Tunisia (in the 1980s), the technical committee on water resources between Algeria and Libya in the 1990s, and the sectoral commission between Tunisia and Libya on agriculture in the 1990s (OSS, 2008). Authorities in the three countries, well aware of the risks facing the Saharan Basin, have begun joint studies under the supervision of the Observatory of the Sahara and the Sahel (OSS). In 1998 the OSS obtained support from the Swiss Agency for Development and Cooperation, the International Fund for Agricultural Development (IFAD) and the UN Food and Agricultural Organization (FAO) for a three-year study (Mamou et al. 2006). The OSS was selected as an executing agency, and Tunis was chosen for hosting the project management team, which consists of representatives of the three countries, assisted by technical working teams in each country for data collection and transfer to the project headquarters (Mamou et al. 2006). While no formal treaty has been signed, the Member States reached an agreement in 2002 to establish a "Consultation Mechanism" for the NWSAS. The consultation mechanism has been implemented in the form of a steering committee composed of representatives of the national agencies in charge of water resources. This mechanism evolved towards a permanent structure in the second phase of the project during the period 2003-2006 (Puyoô, 2007).

3.1.1 NWSAS Consultation Mechanism Organogram

The Declaration of establishment of the permanent consultation mechanism was endorsed by the ministers of water in the three countries in 2006 (Annex I). It creates a permanent Consultation Mechanism ("Mécanisme de concertation") for the NWSAS, defining the role and missions, and requesting support from OSS to put in place a secretariat (Puyoô, 2007). The mechanism is composed of: a Council of Ministers in charge of water resources in the three countries; a Steering Committee consist of the national institutions in charge of water resources in the three countries; National Committees including other institutions concerned with water resources, users associations, and non-governmental organizations (NGOs); National and regional technical working groups; and a coordination unit led by a coordinator at the Tunis-based Sahara and Sahel Observatory (OSS). The NWSAS permanent Consultation Mechanism organogram is illustrated in Figure 4.

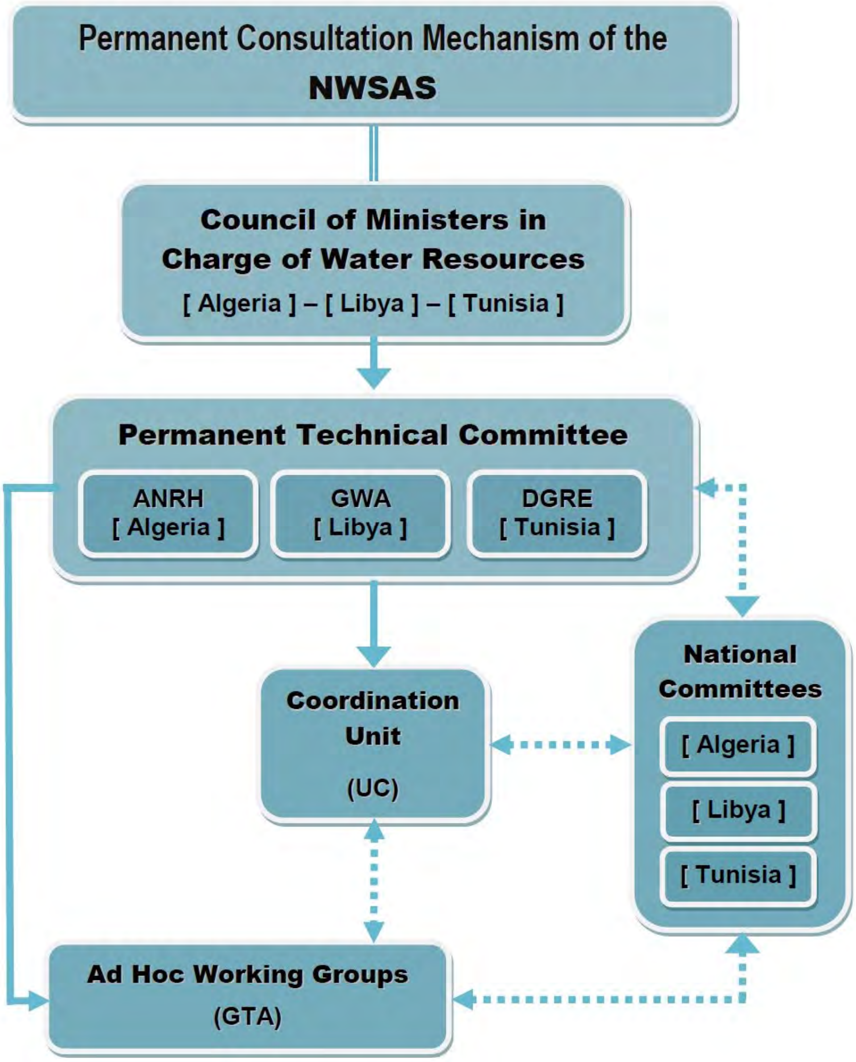

Figure 4. NWSAS Organogram

ANRH	Agence Nationale des Ressources Hydrauliques (Algeria)
GWA	General Water Authority (Libya)
DGRE	Direction Générale des Ressources en Eau (Tunisia)
GTA	Groupes de Travail ad hoc
UC	Unité de Coordination

3.1.2 Mission and Mandate

From the standpoint of governance, the mission of the NWSAS permanent Consultation Mechanism is to provide a regional institutional framework necessary to formalize regional cooperation for the management of the shared NWSAS water resources among the three countries. Therefore, the Consultation Mechanism mandate is to collaborate and develop co-operative activities for the sustainable mutual development of the NWSAS, including monitoring the status of utilization of the Aquifer, and evaluation of the progress and activities enacted on the regional and national levels (Diallo and Dorsouma, 2008). Accordingly, the Consultation Mechanism is responsible to: i) Support the countries in implementing the main technical activities aimed at facilitating consultation, especially data collection by establishing joint networks and updating common databases and models; ii) Simplify the institutional process by identifying transboundary water resources challenges, formulating proposals for solution, and formalizing consents; and iii) Ensure information dissemination and organizing discussion at the level of decision-makers on programmes and development options in the basins, and promote participatory management through real communication work (Puyoô, 2007).

3.1.3 Departments and Management

The NWSAS permanent Consultation Mechanism is managed through a Steering Committee consisting of the three General Managers of Water Resources in the three countries, assisted by their National Steering Committee, the OSS Executive Secretary, the potential cooperating partners, and any institutional or legal entity whose contribution deem useful in their work. The Steering Committee is tasked with reviewing the validity and quality of the scientific research; approving or modifying the proposals and plans submitted by regional coordinators and the OSS; and resolving problems that arise during the execution of the program (UNDP-GEF, 2011). The Steering Committee meets for one ordinary session each year, and extraordinary sessions may be convened at the request of one of the Member States. The sessions are held on a rotating basis in each of the three Member States, and the Steering Committee's chairmanship is held by the representative of the host country (Schmidt, 2008).

The OSS, as the Executive Agency, presides over a Steering Committee that is responsible for the execution of projects. The OSS is in charge of managing funds, recruiting experts and consultants, obtaining equipment, providing logistical assistance, and auditing scientific reports. In addition to the Steering Committee, the NWSAS Project's organizational structure includes a Coordination Unit, led by a coordinator designated by the OSS in consultation with the Steering Committee, and an ad hoc scientific committee that provides technical advice and knowledge as needed (UNDP-GEF, 2011). At the setup of the consultation mechanism the following schedule has been established (by the end of 2007):

- Step one: choice of the country that will appoint the first coordinator. Tunisia proposed to ensure the first mandate. Given that the consultation mechanism is hosted by OSS Tunis premises; choosing Tunisia as the first coordinator would facilitate the start of the mechanism.

- Step two: the selected country appoints a coordinator for a two-year mandate on the basis of an alphabetical rotation between the three countries.

- Step three: Kick-start of the coordination unit: December 1st 2007.

3.2 Key Players

The first study on the NWSAS was undertaken by UNESCO in 1968-1971 with the participation of Algeria and Tunisia. In 1982-1983, with assistance from UNDP, the project work was updated to support agricultural development plans in Algeria and Tunisia. Libya joined later, the technical committee on water resources between Algeria and Libya in the 1990s, and the sectoral commission between Tunisia and Libya on agriculture in the 1990s. Established in 1992, the Sahara and Sahel Observatory (OSS) is an international organization composed of 22 African countries, 5 countries in Europe and North America (Germany, Canada, France, Italy and Switzerland), four sub-regional African organizations (representing West, East and North Africa), as well as United Nations specialized organizations, and NGO's. As of 1992, the Sahara and Sahel Observatory (OSS) started working with national experts on NWSAS and were able to bring together interested national and international partners. Authorities in the three countries have begun a multi-phased project under the supervision of the OSS (UNDP-GEF, 2011). Partnership relations throughout the NWSAS project, forged mutual confidence among the technical teams and conviction that joint actions increase the effectiveness of solutions. A formalized agreement was signed to establish a permanent Consultation Mechanism requesting support from OSS to put in place a secretariat.

The NWSAS permanent Consultation Mechanism is managed through a Steering Committee composed of the General Directors of the national institutions responsible for water resources in the Member States (the Algerian Agence Nationale des Ressources Hydrauliques ("ANRH"); the Libyan General Water Authority ("GWA"); and the Tunisian Direction Générale des Ressources en Eau ("DGRE"); international scientific partners (such as the United Nations Educational, Scientific and Cultural Organization ("UNESCO"); the Arab Center for the Studies of Arid Zones and Dry Lands ("ACSAD"); and German Federal Institute for Geosciences and Natural Resources ("BGR"); and cooperation partners (including the FAO; the United Nation's International Fund for Agricultural Development ("IFAD"); and Switzerland's Direction du Développement et de la Coopération ("DDC-Suisse") (Puyoô, 2007).

The support provided from regional and international organizations plays a major role in sustaining mechanisms of regional cooperation for the joint management of the NWSAS. This is manifested by the support obtained from Swiss, German and French development cooperation agencies, as well as from the International Fund for Agricultural Development (IFAD), FAO, African Water facility (AWF), French Global Environment Facility (FFEM) and the Global Environment Facility (GEF). In this respect, the OSS with the help of the three countries worked on developing a strategic partnership with the regional and international organizations in terms of the NWSAS multi-phased project characterized by: Phase 1: (1999–2002) Knowledge improvement; Phase 2: (2003–2007) Consultation mechanism; and Phase 3: (2009–2014) Strategy for a sustainable management (Latrech et al. 2012).

3.3 Finance

The secretariat of the permanent Consultation Mechanism, being placed under the OSS, secures the stability of the secretariat; with OSS being a multi-country, well-established organization with an adequate funding structure. The direct financing of the secretariat by countries was agreed upon. However, explicit information on the level of contribution, regularity and details of operation could not be detected in this assessment. The planned budget of this secretariat for the year 2006 was estimated Euro 100,000 (Puyoô, 2007). The NWSAS permanent Consultation Mechanism is managed through a Steering Committee. The Steering Committee is responsible for approving the expenditure plans of the regional coordinators of the program and the OSS. The OSS, in turn, has to manage the allocated funds for a project. There is also an external financial audit concerning the management of program funds (UNDP-GEF, 2011). The Coordination Unit is managed and hosted by the OSS. Each country finances the operating costs of its focal point. The operating of the Coordination Unit is funded by subsidies and donations granted to the OSS by the countries concerned and the cooperation partners (Puyoô, 2007).

Appropriate financial resources are crucial to reinforce long term support for the existing initiatives on groundwater joint management and to develop new initiatives. International agencies have taken a significant role in financing and implementing the NWSAS multi-phased project. In addition to funding received from the main partner organizations, the NWSAS also receives funding support from national development agencies (such as France's Fonds Français pour l'Environnement Mondial ("FFEM") and DDC-Suisse).

The first phase of the project was initiated in 1998 by OSS for a three-year study with funding grants from donors totaled approximately US $1.7 million (IFAD: US$1,065,000, DDC-Switzerland: US$380,000, and FAO: US$293,000). The second phase of the project was initiated by GEF-UNEP in December 2002 with approved grant funds to the value of US$600,000, and this GEF funding is matched with the funding from the Fond Français pour l'Environnement Mondial (FFEM) (Euro 300,000) and SDC-Switzerland (Euro 400,000) together with in-kind contributions from the participating governments (US$116,000) (Puyoô, 2007).

In 2008, OSS together with the beneficiary countries and development cooperation partners (FFEM, GEF and AWF) prepared the first Part of phase III of the NWSAS project, incorporating socio-economic and environmental dimensions. Funding was obtained from the AWF (Euro 487,800) in 2008 and from FFEM (Euro 500,000) and GEF/UNEP (US$960,000) in June 2009 (OSS, 2010). By the end of 2009, the Executive Secretariat of the OSS has announced the launch of the second Part of Phase III of the NWSAS project with funding from AWF, GEF and FFEM. Phase III of the project is planned to be terminated reaching a strategy for sustainable management in 2014 (Latrech et al. 2012).

4. Monitoring and Evaluation

Monitoring is comprehended as the process of repetitive observing, for defined purposes of one or more elements of the environment in space and time, using comparable methodologies for data collection. Evaluation can be defined as the assessment of the state variables of groundwaters in relation to the background conditions, human effects, and the actual or intended uses. One major purpose of monitoring is to enable evaluation of the current state of water quantity and quality and their variability in space and time. The process for monitoring and evaluation in transboundary aquifers is a cycle of dependent activities that countries will have to study jointly to determine the specific long-term evolution of aquifers characteristics and behavior (UN/ECE 2000).

4.1 Parameters and Indicators

NWSAS basin-scale monitoring and evaluation has been only considered in the framework of the multi-phased project under supervision of the OSS. The multi-phased NWSAS project has been developed by the OSS with partnership from international and regional organizations (UNDP-GEF, 2011), comprising: Phase 1: (1999–2002) Knowledge Improvement; Phase 2: (2003–2007) Permanent Consultation Mechanism; and Phase 3: (2009–2014) Strategy for Sustainable Management (Latrech et al. 2012). The first phase of the project, through mathematical modeling, led to identification of risks associated with major future abstractions. The identified risks related to over exploitation of the NWSAS include interference piezometric depressions; loss of artesian pressure; saltwater intrusion from salt lakes (Chotts) or sea waters; and drying up of springs and natural oasis (Mamou et al., 2006). These risks define high priority transboundary problems and relevant parameters and indicators for monitoring and evaluation. Accordingly, emphasis has been placed on the need for monitoring and evaluation. While no formal agreement concerning transboundary monitoring and evaluation of the NWSAS has been signed; the three countries reached an agreement in 2002 to establish a “Consultation Mechanism” for the NWSAS. Functions of the consultation mechanism recognize identification of monitoring indicators and establishing monitoring network.

The second phase of the project aimed at enhancing joint integrated management of the NWSAS, based on the development of more precise data, with a particular focus on the risk zones identified during the first phase. Monitoring and evaluation have been explicitly addressed in phase 2 of the project. This is manifested by the activities of the project sub-component: “WP13000 – NWSAS monitoring indicators”, setting up common monitoring networks and defining a set of monitoring indicators (Puyoô, 2007). The objective of the sub-component is: i) validation of the selection of the existing water points to be used for monitoring; and ii) identification of the sectors to be provided with new monitoring points. The main functions of the piezometry network are to: monitor generalized drawdowns and abstraction flows; control of the risk zones identified in phase 1; and control of the simulation modeling predicted (2000–2050) drawdowns. The NWSAS networks constitute the first large-scale action of consultation (concerted action) insofar as their setting up and the data collected and exchanged represent the basis of monitoring the Basin and of the likely modes to be implemented by the three countries within the framework of shared management (Puyoô, 2007).

Observation well networks specifically dedicated to monitoring are not yet well developed within the NWSAS. A tri-partite working group was set up with the objective of identifying a reference network from the 8,825 existing withdrawal water points, of which 7,600 points may provide an indication of piezometric level (Figure 5). The development of a monitoring network on NWSAS level requires preliminary management on the national level of a network validated by the 3 countries, then implementing a mechanism of data exchange via the NWSAS Information System. A certain number of indicators for characterizing and evaluating the quality of that reference network are then proposed: space cover, monitoring of the extraction, control of drawdown and sustainability of the network wells. These indicators with other many clues have been taken into consideration for a knowledgeable consolidation of the network wells. The identification has been achieved by analyzing, regrouping and filtering data; the final result produced a 73 water point monitoring network (Figure 6). The distribution of the rationalized monitoring water points by aquifer is 46 points in the CT and 27 points in the CI, resulting in a by country distribution of 20 points in Algeria, 31 points in Libya, and 22 points in Tunisia (Besbes and Horriche 2007).

The following transboundary parameters and indicators are recommended and could be presented in map format

1. Water abstractions.
2. Groundwater levels.
3. Drawdown.
4. Depth to groundwater.
5. Depth to basement aquifer thickness.
6. Water quality

The following transboundary parameters and indicators which focus on to the non-renewable nature of NWSAS are recommended

1. Safe Yield
2. Sustainability period
3. Maximum allowable drawdown

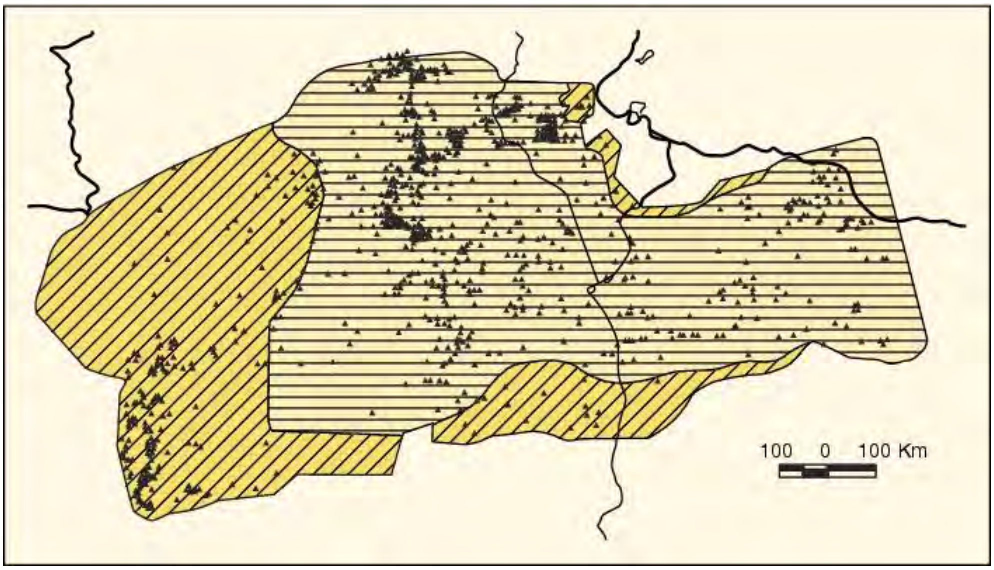

Figure 5. NWSAS Withdrawal Water Points
(Source: Besbès and Horriche, 2007)

National teams have conducted site visits in order to identify the rationalized water point's network. A workshop was also organized in order to finalize agreement of the authorities in the three countries on the selection of the network points. The network proposed so far, after validation by the national teams, has reached 100 water points. However, new water points must be integrated or constructed, particularly in the Western Basin (Bassin Occidental) where the list of 100 water points leaves certain gaps. National willingness is clearly expressed in this regard (Puyoô, 2007).

According to the project report, despite completion of the piezometric network study and integration of national monitoring points in the NWSAS monitoring network, certain technical and operational difficulties have been noted. Recommendations put forward in the project report on setting up the NWSAS piezometric network suggest: having a data acquisition protocol providing for necessary annual measurement sufficient for the natural slow evolution in the states of the aquifers, formalization of the data exchange modes (a centralized system is envisioned), dissemination of the annual status reports every 3 years, and having a task force within the Consultation Mechanism. With regard to the quality monitoring network, the project report pointed out that "the establishment of such a network is necessary and urgent; it will be done based on the analysis of the Tunisian network and the possibilities of its extension to the rest of the basin". However, the water quality monitoring network has not yet been put in place (Puyoô, 2007).

There is a direct link between the development of a transboundary monitoring network to meet the objective of global management of the NWSAS and national monitoring of water resources, in terms of standards; procedures and equipment. This component of the project has led to a real mobilization of the national teams that have benefited from the study conducted under the project, insofar as the network will, on the one hand, meet the national needs and, on the other hand, supply the data base common to the three countries. Substantial progress in the rationalization of the networks on national level has been noted, and some harmonization has begun between the three countries. However, there remains the task of carrying out the whole set of activities which will make the network operational (Puyoô, 2007). Apparently, the NWSAS countries and the Permanent Consultation Mechanism adapt comfortably to monitoring and evaluation in a regional context only when it is carried out within a regional cooperation program facilitated with the involvement of regional and international organizations.

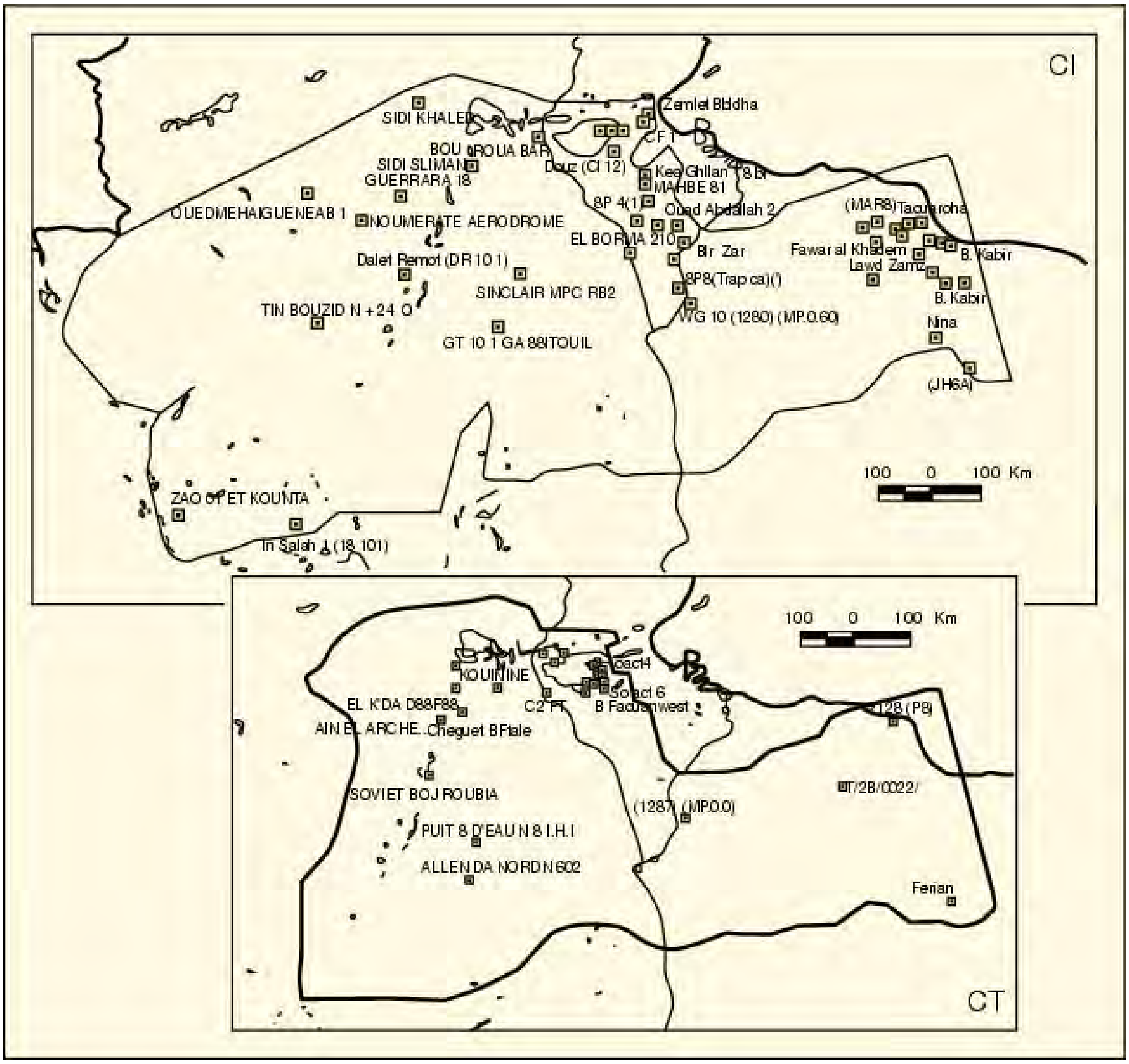

Figure 6. NWSAS Identified Water Points Monitoring Network
(Source: Besbes and Horriche 2007)

4.2 Regional Modeling

Models are useful tools for monitoring and evaluation because they allow probing the potential impacts of pumping variations on the overall groundwater-flow system. Within this function, groundwater-flow modeling in transboundary aquifers plays an integrative role; when model predictions are tested, the results frequently lead to re-evaluation, reconsideration, and quantitative adjustments of the understanding of the hydrogeological regime. Groundwater models have benefits that extend beyond simply predicting groundwater movement and contaminant transport. Properly calibrated models help to prioritize data-collection activities and provide a method for forecasting future conditions under alternative development scenarios. They provide mutually accepted sophisticated method to evaluate the cumulative impacts that arise from the many pumping sites and groundwater-dependent development areas.

Scientific characterization studies of the NWSAS had started in the 1960s. The NWSAS was extensively studied with numerical models, starting from the survey conducted in 1972 within the UNESCO "ERESS" (Etude des Ressources en Eau du Sahara Septentrional) project (Sappa and Rossi, 2012). This first numerical model was used to develop a sub-model for Nefazoua-Djerid, developed by the Engineering School of the Tunis University, in 1984 (Armines-ENIT, 1984). This sub-model was used to implement the agricultural development scenarios of the whole South Tunisian area. The simulations conducted showed a 2010 scenario with residual artesian conditions in the whole Rjim Maatoug area, without any risk of groundwater contamination from shallow brackish water (Sappa and Rossi, 2012). By the support of the General Directorate of Water Resources of the Ministry of Agriculture (DGRE), new simulations were conducted in 1997 to analyze the local impact of stage II withdrawals in the Rjim Maatoug area, calibrated using historical data of withdrawals and of the piezometric levels measured through the available monitoring networks (Sappa and Rossi, 2012).

The ODRM (Office de Développement de Rjim Maatoug) was responsible for carrying out 2,000 ha of irrigated areas which will be implemented in two phases in Rejim Maatoug region: (i) First phase: 1152 ha irrigated from 13 drilling wells and performed from 1992 to 1997; (ii) Second phase: 1008 hectares to be irrigated from 11 new drilling wells and 3 regenerated drilling wells. In 1997, the DGRE conducted an updated study of TC aquifer based on: (i) Modeling of the aquifer, taking into account new data and changes that have occurred relating to withdrawals and piezometry; (ii) Exploratory simulations to determine the effect of the completion of the second phase on the artesian groundwater and the impact of withdrawals on areas bordering Djerid and Nefzaoua. RESULTS: 1 - In case of conservation of the first phase irrigated areas and maintain withdrawals at 850 l / s, the drawdown of the groundwater level will be at around 11 to 12 meters by 2010 with an average drawdown of 0.7 to 0.8 m / year; 2 - In case of implementation of the second phase of the RM project and began operating from the year 2001 the entire project at a rate of 2000 l /s, the recorded drawdown of groundwater level will be between 12 and 14 m by 2010, i.e. an average drawdown of 0.8 to 0.9 m /year).

A comprehensive NWSAS regional modeling effort was undertaken in the framework of the multi-phased project under supervision of the OSS. This effort aimed to develop a model that could be used as a mutually accepted technical reference for discussions of transboundary issues among the three NWSAS countries.

In the first phase of the project in 2002, under the aegis of the OSS, a numerical model of the whole North Western Sahara Aquifer System was developed including the whole CT and CI aquifers in the region across Tunisia, Algeria and Libya (OSS, 2004b). Management with full factual knowledge of the Aquifer System is facilitated by the availability of such mathematical simulation model. This model provided predictions given various management scenarios. Data for the reference period 1950-2000 has been used for the calibration and validation of the model. Alternative policies in each country have been simulated to predict their combined effects on the aquifer. A reference pattern, named scenario zero, was also defined by maintaining the withdrawals from drilled wells carried out in the year 2000, and calculating the system's corresponding evolution over 50 years (OSS, 2004a).

At the completion of the exploratory simulations, the adopted principle has been to seek the building of extraction patterns founded upon NWSAS output capacities while minimizing the identified risks of harmful effects at the sites close to the places where present or future demand might be expressed. At the same time sites that would be favorable for exploitation in the future are being identified. The model has been instrumental in identifying new withdrawal potential and risks associated with major future abstractions with future prediction scenarios up to 2050. The study confirmed the results of the DGRE simulations of 1997 and allowed for implementing the numerical model on more powerful and updated IT platforms, with the aim to refine the official tool for the regional and local development scenarios to manage this transboundary water resource (Sappa and Rossi, 2012)

The second phase of the project aimed at enhancing joint integrated management of the NWSAS based on modeling efforts achieved in the first phase of the project (Puyoô, 2007). This is manifested by the activities of the project sub-components: "WP11000 – Development of Regional Models" comprising:

- Model of the groundwater aquifer of the Djeffara (WP11100): The aquifer of the Djeffara is shared by Tunisia and Libya. The Djeffara Model aimed at informing on the potential available, the impacts of the abstractions, the likely interferences between Tunisian and Libyan abstractions and better understanding of the salinity variations of the aquifer horizons and seawater intrusion. Meanwhile, the development of the Djeffara Model should improve knowledge about the boundary conditions in the upstream part of the NWSAS Model. The Djeffara model main conclusion is that the current abstraction level in the Djeffara is not sustainable in the Djeffara Plain, in particular in the Libyan part, and would entail a dramatic increase of water salinity in the near future if efforts are not made to reduce it (Puyoô, 2007).
- Model of the Western Basin (Bassin Occidental) (WP 11200): The NWSAS Western Basin relates mainly to the unconfined part of the Intercalary Continental (CI) aquifer. The zone has been identified, in Phase 1 of the NWSAS project, as a target zone for additional studies. New exploitation zones could be created allowing a transfer of abstractions from the region of the Chotts, thus reducing the exploitation pressure in the risk zones. The model aimed to provide a decision-making support for the exploitation of the aquifer. The model results showed that new well fields will generate a new resource for export northwards, but with reduction impact on the foggaras flow (from 2.08 m^3/s under current withdrawal conditions to 1.35 in 2050). In this modeling process, the hydro-geological parameters and the hydraulic conditions of the foggaras have been made much more precise, compared to the phase I modeling of the whole NWSAS. The results of this modeling component should serve reactivating and updating the full NWSAS model (Puyoô, 2007).
- Model of North of the Chotts (Biskra) (WP11300): The region of Biskra constitutes the northern boundary of the NWSAS model. It is a zone where abstractions are quite considerable, while the complexity of the aquifer systems remains little known. The objective of the model study was to better assess the relations between the overlapping aquifers, thus making it possible to plan the use of the resources. The model helped to provide more precise information on the region of Biskra, where the current exploitation, at least of the Mio-Pliocene, cannot be pursued in the same way for any considerable time in the future. The model offered the opportunity to suggest management actions while seeking to promote a more conservative management of the resources. The fairly long term impact of the current overexploitation remains to be evaluated, though it is considered that, on the whole, the zone of Biskra is partially isolated from the main SASS zone by the region of the Chotts (Puyoô, 2007).

Updating the NWSAS mathematical model was started by the Consultation Mechanism in October 2009 and was continued until the end of March 2010. New transmissivity figures and storage coefficients obtained from the pumping tests carried out in the Ghadames region of Libya were incorporated in the NWSAS model (1999-2002), and the model was updated by integrating new data collected during the 2001-2008 period. This activity was validated by the water resources directors in the three countries in May 2010. The results of the model were returned to the countries in July 2010 in Tripoli. This made it possible for the country representatives to learn about the new tendencies in groundwater exploitation (OSS, 2010). Modeling results can help to assess the regional monitoring network coverage and technical basis for cooperation between the sharing countries. Successful modeling is possible only if the methodology is properly integrated with data collection, data processing and other techniques/approaches for the evaluation of the groundwater system characteristics.

It is recommended that regional monitoring and evaluation activities should be considered in the longer term. There are many reasons for this; mainly, that seeking sustainable finances and stakeholder support is generally a time consuming process. Apart from this, a fundamental reason for extending activities to the long term is that aquifer systems respond more slowly compared to surface water systems. Consequently, the management and monitoring of transboundary aquifers are closely linked and have to be viewed in that perspective.

From all of the above studies and the planned future withdrawals till 2050 indicated in table 1, it could be concluded that future safe yields are based on a sustainability period of 50 years and a maximum allowable drawdown of 50 meters at the end of the sustainability period.

5. Information Management

Groundwater management either within the national or in the shared transboundary context is very much about making informed decisions. Informed decisions can only be made by using relevant and up to date information based on collected and analyzed groundwater data. Transboundary Aquifer resources management should put priority in generating this information based on mutually accepted standards and make it accessible in a uniform and transparent way. Special effort should be placed in delivering information symmetrically to all stakeholders via various channels and at various platforms. One of the most complicating aspects is the large number of factors that determines the status of a groundwater system, making monitoring of groundwater use complicated and costly. However, sound monitoring data is therefore an essential prerequisite to implementing any form of transboundary governance. Data harmonization and information management are important in the shared transboundary context. They are difficult to carry out without establishment of regional agreements and frameworks providing for institutional mechanisms (Khater 2003). The three NWSAS countries have already embarked on an institutional mechanism to cooperate on information management by establishing the Consultation Mechanism. On the other hand, the activities undertaken in the framework of the joint regional cooperation multi-phased project under supervision of the OSS bear also evidence of acceptance of the obligation to exchange available data and information on the shared water resource.

5.1 Regional Information System

In the first phase of the NWSAS multi-phased project, activities comprised development of the database "SAGESSE" allowing standardizing of the hydro geological data collected in the three countries, so as to meet the needs for the hydro geological modeling of the NWSAS (Annex II). It was initially intended to store data on NWSAS water resources and organize it according to suitable formats, with the objective of having a common database for integrating and streamlining all the surveyed information, in addition to new data collection, integration and updating. The development of the NWSAS project, however, revealed the need to transform this database into an integrated information system including the database itself, a suit of mapping tools and the model (OSS, 2004a). Fulfilling such an objective required that the national databases be adapted and homogenized. This implied homogenized data structures and codifications, a GIS interface and the developing of an access module for the digital model. The Information System (IS) design included the diagnosis, and realization of a common database, with the objective of making IS accessible simultaneously in the project's headquarters and by each water administration in the three partner countries (Diallo and Dorsouma, 2008).

The developed information system allows updating of data in addition to performing statistical tests, graphically depicting the information and checking model connections. The system contains all the basic elements to establish the monitoring control panel and basin water exploitation. With the introduction of the Consultation Mechanism, this system has been oriented towards the monitoring of the concerted management, both on the technical and political levels. The OSS claims that, currently, there is a very good quality management tool operating in each of the three country administrations (OSS, 2008). At the same time, a map server has been developed to ensure a geo-referenced representation of the available information (Diallo and Dorsouma, 2008). This multilayer, thematic representation acts as a decision support tool for planners and makes it possible to go beyond the national framework to improved assessment of the impacts of exploitation. The NWSAS IS architecture is made of three main components:

the DB, the GIS and the digital pattern (OSS, 2004b). The meshing of the pattern, which is at the same time a table of the DB and a layer of the GIS, allows securing these links, as shown by the scheme in Figure 7. Detailed description of the information system is given in the Synthesis (OSS, 2004a).

The project's second phase (2002–2006) focused on advancing the fruitful cooperation and identifying those technical tools that would lead to a permanent consultation mechanism. In addition to continuing the work on hydrology, information systems and consultation mechanism, the project also stated to address the socio-economic issues of the environment and their relation to resource mobilization in the NWSAS (Puyoô, 2007). The third phase of project is about to start with the aim of further improving the management tools and advancing the socio-economic and environmental aspects by use of remote sensing technology to estimate irrigation water consumptions as well as sustaining the consultation mechanism (OSS, 2012). Information pertaining to environmental and socio-economic aspects was incorporated, thus allowing to validate the afore-mentioned tools and to launch GEOSASS, a key tool developed as part of the project. GEOSASS went on line in 2005 in order to ensure a broad dissemination of NWSAS project achievements.

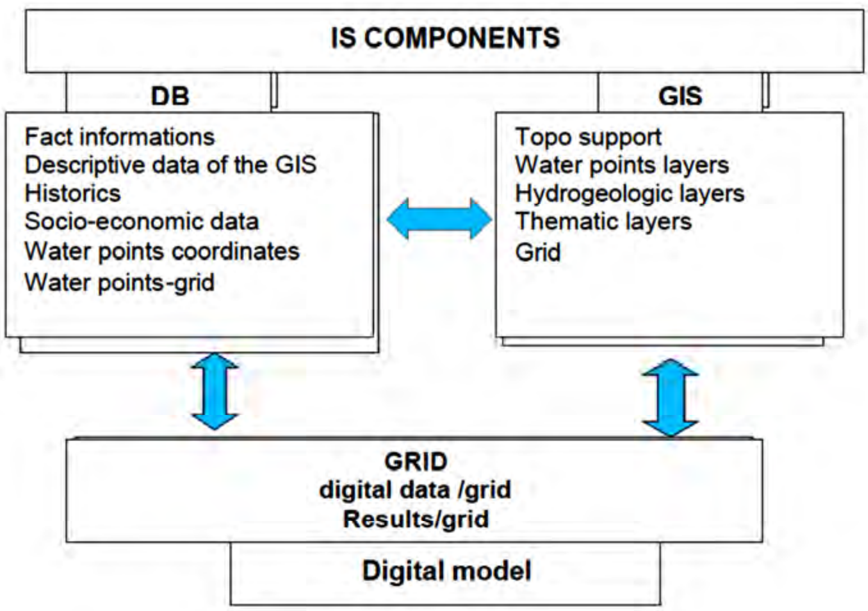

Figure 7. NWSAS Information System Architecture

(Source: OSS, 2004a)

The management of the data is performed by the database administrator based at OSS. Experts from the three countries are responsible for the collection, processing and editing of data supplied by the NWSAS common monitoring network, in compliance with the required formats. They are also requested to send new data to the "SAGESSE" database administrator who gathers and harmonizes them. The data sets are subsequently validated through an exchange between the national experts and the central administrator. It is finally up to the OSS scientific managers to analyze the information and to draw the relevant elements, which will then be submitted to the decision makers in the three countries (OSS, 2010).

The comprehensive inventories carried out in Algeria and Tunisia between 2005 and 2008 helped integrate 9,360 new water points. At present, the database has become more representative and encompasses the characteristics of 18,160 water points and 78,422 pieces of information pertaining to the use of the aquifer *system, piezometry and water quality.* Table2 shows the evolution of NWSAS water extraction points number and withdrawal trend (2000-2008).

Table 2.The evolution of NWSAS water extraction points number and withdrawal trend (2000-2008)

	State 2000				State 2008			
	NWSAS	Algeria	Tunisia	Libya	NWSAS	Algeria	Tunisia	Libya
Area in 10^3 km^2	1 000	670 (67%)	80 (8%)	250 (25%)	1 000	670 (67%)	80 (8%)	250 (25%)
Water extraction points number	8 800	6 500 (73, 8%)	1 200 (13, 6%)	1 100 (12, 6%)	18 160	11 410 (62, 8%)	5 600 (30, 8%)	1 150 (6, 4%)
Withdrawal in 10^9 m^3/year	2,18	1, 3 (59, 1%)	0, 55 (25%)	0, 33 (15, 9%)	2,5	1, 74 (69, 6%)	0, 54 (21, 6%)	0, 22 (8, 8%)

Source: Chaieb H. & Hamza M. (2013)

The first efforts to update the NWSAS IS were started in 2008. They were continued in 2009-2010. During the period between 2001 and 2008, ANRH (Algeria) and DGRE (Tunisia) made considerable efforts to inventory all the NWSAS water points. The database is being used by the three technical departments of the three countries concerned and also to update the mathematical model of the aquifer system (OSS, 2010). Recently, in the framework of third phase of the NWSAS project, in early 2012, a call for tender has been announced by OSS for updating the database of NWSAS (OSS, 2012).

5.2 Transboundary Reporting

The support provided from regional and international organizations plays a major role in sustaining regional cooperation for the joint management of the NWSAS including data sharing, transboundary monitoring, regional modeling, and production of regional transboundary technical reports. This is established through the multi-phased NWSAS project undertaken by the NWSAS countries and the Consultation Mechanism under the coordination of the OSS (Mamou et al., 2006). In this respect, for the past fifteen years, the multi-phased NWSAS project has produced series of NWSAS activity reports (Basin Awareness and Synthesis Collection reports). These reports, produced through the OSS, provide technical documentation of the NWSAS project activities and the obtained results. The NWSAS project is monitored by the OSS as the Executive Agency in charge of the project, where data is being exchanged regularly and the Consultation Mechanism has evolved in the course of the project (Puyoô, 2007).
The Consultation Mechanism mandate is to collaborate and develop co-operative activities for the sustainable mutual development of the NWSAS, including monitoring the status of utilization of the Aquifer, and evaluation of the progress and activities enacted on the regional and national levels (Diallo and Dorsouma, 2008). Technical responsibilities of the Consultation Mechanism national committees

comprise monitoring, collection and interpretation of data, and periodical reporting. Reporting information is the final step in the data management programme and links the gathering of information to the information users. To distribute the information, reports should be prepared on a regular basis. According to Mid-term Review of the Consultation Mechanism component of the NWSAS project (Halle, 2005), recommended tasks to be undertaken by the Consultation Mechanism include: exchange of information among the three countries; collating reports from the authorities in the three countries; preparation of briefing documents and publication of regular updates; and publication of periodic reports on the state of the aquifer. However, uniform reporting procedures require comparable information and compatible assessment methods and data management systems.

6. SWOT Analysis

The following section includes SWOT analysis of the North-West Sahara Aquifer System (NWSAS) and the Consultation Mechanism, being the regional management organization of the aquifer system:

Strengths	Weaknesses
Authorities in the three NWSAS countries are well aware of the risks facing the Saharan Basin. The technical cooperation has gradually led to mutual confidence and recognition of the problems and risks affecting the aquifer system. Cooperation concerning exploitation of the NWSAS is a strategic choice for the riparian countries that have created a promising environment for mutual cooperation supported by political will, and participation in decision making structures. The NWSAS riparian countries have institutionalized their cooperation through activities undertaken by national bodies in the framework of a joint cooperation program of a multi-phased project under supervision of the OSS. While no formal treaty has been signed, the three NWSAS countries reached an agreement to establish a permanent "Consultation Mechanism" acknowledging the significant role of having a regional joint management structure. The NWSAS Consultation Mechanism is managed through a Steering Committee comprised of the three General Managers of Water Resources in the three countries, assisted by National Steering Committee. Analysis shows that the study topics considered by the riparian countries and reflected in the NWSAS project phases go beyond hydrogeological and technical issues to include the socio-economic, environmental, legal and institutional dimensions of groundwater use in the region. Government services in charge of water resources have a common updated data base "SAGESSE" developed through the NWSAS project with full information that gradually led to mutual confidence on monitoring and exchange of information within each country. The secretariat of the permanent Consultation Mechanism, being placed under the OSS, secures the stability of the secretariat; with the OSS being well-established with an agreed upon adequate funding structure. The support provided from regional and international organizations plays a major role in sustaining mechanisms of regional cooperation for the joint management of the NWSAS. The Consultation Mechanism is an important part of	Observation well networks specifically dedicated to monitoring are not yet well developed within the NWSAS countries, where technical and operational difficulties have been noted. NWSAS basin-scale monitoring and evaluation has been only considered in the multi-phased project framework. The Consultation Mechanism is perceived as a structure serving technically-based project, however, the challenge ahead is the transition to an action-based approach focused on shaping decisions for joint management of the NWSAS. The major challenge appears to lie in improving the interface between monitoring and decision-making in order to react to changes within the system and to arrive at decisions based on reliable monitoring results. Harmonizing monitoring, observation and information systems for the NWSAS are difficult, lengthy and expensive operations, which however are necessary for the adoption of common standards for transboundary reporting. The OSS is mainly responsible for mobilizing financial resources needed to implement the NWSAS development and management programs, and implementation of the Consultation Mechanism. The results derived from multi-phased project needs to be strengthened and developed so that the impact of the project would actually extend beyond the offices of the relevant institutions in order to reach the water users and so that the actions should have measurable effects on the ground. The extent to which joint management issues are actually reflected in national policy making cannot be fully assessed. Growing pressure on the NWSAS and lack of joint management of shared groundwater and related land resources in the Sahara region can result in loss of water resources, productive land and life-supporting eco-systems.

Africa's institutional architecture for transboundary water management. While it may not yet have the authority to implement management decisions, it remains a successful forum for information collection and exchange.	
Opportunities	**Threats**
The support of regional and international organizations and the associated successful regional multi-phased project provide evidence to possible direction of further regional and international assistance towards enhancement and strengthening of the NWSAS and the Consultation Mechanism institutional framework to achieve a joint management of the NWSAS. Since the NWSAS is one of ten transboundary water basins selected by African Ministers' Council on Water (AMCOW) within the framework of New Partnership for Africa's Development (NEPAD) to receive support from the African Water Facility, further activities in joint monitoring and evaluation as well as strategic development can be expected. Joint management should lead to identification of mutual opportunities for development and investments for socio-economic development with poverty alleviation, based on efficient and equitable utilization of shared aquifer resources.	Given the arid to Saharan climate conditions, development of the NWSAS is a matter of national security, especially for Algeria and Libya; therefore, decisions concerning groundwater development projects are politically highly sensitive. Major threats are concerned with the political vulnerabilities and volatility of the NWSAS region as well as the past and present conflicts in the region. While the incentives for cooperation are similar, they are not equally strong for each riparian state: in each case, the capacity to pursue national interests differs substantially in practice depending on economic disparities and political power and stability. Functions of the Consultation Mechanism can be hindered by the lack of clear definition of institutional responsibilities, functions and jurisdictions at the national level in the concerned water institutions in NWSAS countries. In the absence of joint management there is risk to impose high social and economic cost and incur loss of resources and benefits.

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Annexes

Annex A: Declaration of the Establishment of the Permanent Consultation Mechanism Endorsed by the Ministers of Water Resources in the three NWSAS Countries

OSS

OBSERVATOIRE DU SAHARA ET DU SAHEL

SAHARA AND SAHEL OBSERVATORY

DECLARATION DES MINISTRES DES RESSOURCES EN EAU DES PAYS PARTAGEANT LE SYSTEME AQUIFERE DU SAHARA SEPTENTRIONAL

L'Algérie, la Libye, la Tunisie

- Conscient du fait que nos trois pays partagent le bassin du Système Aquifère du Sahara Septentrional (SASS), et que le progrès économique et social de la région passe par une coopération fondée sur la concertation pour une gestion équitable des ressources de ce bassin ;
- Considérant le niveau important atteint dans l'exploitation des ressources du système aquifère durant les trois dernières décennies ;
- Reconnaissant la vulnérabilité de cette ressource et la nécessité de mettre en place des protocoles communs d'exploitation rationnelle et de protection de ce système aquifère ;
- Convaincus de la nécessité de préserver et de protéger cette précieuse ressource dans l'objectif d'un développement durable ;
- Désireux de renforcer nos liens de coopération scientifique et technique pour une mise en valeur rationnelle des ressources en eau du Système Aquifère du Sahara Septentrional ;
- Résolus à assurer la continuité et la coordination des activités d'observation du Système du Sahara Septentrional ;

Déclarons la création d'un organe de coordination autonome dénommé **« mécanisme de concertation permanent pour le Système Aquifère du Sahara Septentrional »** et

Convenons de solliciter l'Observatoire du Sahara et du Sahel pour apporter son concours à la mise en œuvre du Mécanisme de Concertation du Système Aquifère du Sahara Septentrional et son appui à la mise en place de son secrétariat.

Ce mécanisme de concertation est fondé sur :

- Le renforcement des moyens de nos pays et la capacité à produire les éléments d'aide à la décision visant à assurer en commun, dans un esprit d'équité, la gestion durable des ressources en eau partagées du SASS
- La capitalisation des acquis du projet SASS notamment en terme de coopération ;

Ce mécanisme de concertation aura pour principale mission d'assurer un cadre d'échange et de coopération entre nos trois pays par

- la production d'indicateurs sur la ressource et la demande en eau
- l'élaboration de scénarios de gestion des ressources en eau pour le développement dans le bassin
- le renforcement et l'actualisation des bases de données communes par l'échange de données et d'informations
- le développement et la gestion de réseaux communs d'observation du système aquifère

Pour atteindre ces objectifs, le mécanisme aura notamment à :

1. Réaliser des études et recherches en commun
2. Définir des protocoles d'échanges de données
3. Procéder à la mise à jour des modèles et à leur exploitation
4. Assurer la diffusion des indicateurs de suivi des ressources et des usages
5. Identifier les zones à risques et les zones vulnérables
6. Proposer des plans d'action pour les zones identifiées comme étant les plus critiques
7. Assurer des actions de formation, d'information et de sensibilisation
8. Publier un Rapport Annuel sur l'état du Système Aquifère du Sahara Septentrional

Pour l'Algérie	Pour la Libye	Pour la Tunisie

مرصد الصحـــــراء والسّـــــاحل
OBSERVATOIRE DU SAHARA ET DU SAHEL
SAHARA AND SAHEL OBSERVATORY

OSS

إعلان وزراء الموارد المائيّة
للبلدان التي تتقاسم منظومة الحوض الجوفي للصحراء الشمالية

نحن وزراء الموارد المائية في كلّ من تونس والجزائر وليبيا

- **وعيا** منا بأنّ بلداننا الثلاثة تتقاسم منظومة الحوض الجوفي للصحراء الشمالية (SASS) وبأنّ نموّ المنطقة الاقتصادي وتطوّرها الاجتماعي يرتكز على تعاون أساسه التشاور لتحقيق إدارة متكافئة لموارد هذا الحوض المشترك،
- **واعتبارا** لمستوى الاستغلال المرتفع لمنظومة المياه الجوفية خلال السنوات الثلاث الأخيرة،
- **واعترافا** بهشاشة هذا المورد المائي وضرورة وضع اتفاقيات مشتركة لاستغلالها بشكل رشيد وضمان حمايتها،
- **وإيمانا** بضرورة الحفاظ على هذا المورد الثمين وتأمين توظيفه في سبيل تحقيق التنمية المستديمة،
- **وسعيا** إلى توثيق صلات التعاون العلمي والفنّي في سبيل تحقيق استخدام رشيد للموارد المائية لمنظومة الحوض المائي للصحراء الشمالية،
- **وعزما** على ضمان استمرارية تنسيق أنشطة متابعة ورصد منظومة الحوض المائي للصحراء الشمالية وتنسيقها،

نعلن إنشـــاء جهاز تنسيق مستقلّ يسمّى **"آلية التشاور الدائمة للحوض الجوفي للصحراء الشمالية"**

ونـتّـفق على طلب مساهمة مرصد الصحراء والساحل في تنفيذ آليّة التشاور الدائمة للحوض المائي للصحراء الشمالية ودعمه قصد وضع أمانة هذا الجهاز.

وتقـوم آليّـة التشاور هذه على المبادئ التالية:

- تعزيز قدرات بلداننا على إنتاج أدوات مساعدة على صنع القرار بما يمكن من تحقيق إدارة مستديمة للموارد المائية المشتركة للحوض الجوفي للصحراء الشمالية تسودها روح التكافؤ،
- الاستفادة المثلى من إنجازات ومكاسب مشروع الحوض الجوفي للصحراء الشمالية (SASS)، خاصّة فيما يتعلق بالتعاون.

وستكون **مهمّة آلية التشاور الرئيسية هذه تحقيق إطار تشاور وتعاون بين بلداننا الثلاث قِوامُه:**

- إنتاج مؤشّرات حول المورد المائي والطلب على المياه،
- وضع خيارات إدارة الموارد المائية بهدف التنمية في منطقة الحوض الجوفي،
- دعم قواعد البيانات المشتركة وتحيينها قصد تبادل المعلومات والمعطيات،
- تطوير شبكات مشتركة لرصد منظومة المياه الجوفية وإدارتها.

ولتحقيق هذه الغايات، فقد وُضِعت لآلية التشاور هذه مهمّة تحقيق الأهداف التالية على وجه التحديد:

1. إنجاز دراسات وبحوث إيلافية (أي مشتركة)،
2. وضع بروتوكولات لتبادل المعلومات،
3. تحيين النماذج والاستفادة منها،
4. ضمان نشر مؤشرات متابعة الموارد واستخداماتها،
5. تحديد المناطق المهدّدة والمناطق الهشّة،
6. اقتراح خطط عمل للمناطق المهدّدة أكثر من غيرها،
7. تأمين أنشطة تدريب وإعلام وتوعية،
8. نشر تقرير سنوي عن حالة منظومة الحوض الجوفي للصحراء الشمالية (SASS).

عن الجمهورية الجزائرية	عن الجمهورية التونسية	عن الجماهيرية الليبية
وزير الموارد المائية عبد المالك سلال	وزير الفلاحة والموارد المائية محمد الحبيب الحداد	

Annex B: SAGESSE User Instructions

SAGESSE:

"**S**ystème d'**A**ide à la **G**estion des **E**aux du **S**ahara **SE**ptentrional"

"System of help to the Management of the Septentrional Sahara Waters"

Source: *OSS (Observatoire du Sahara et du Sahel) (2004a), North-Western Sahara Aquifer System. Basin Awareness. Data Base and GIS, volume III.*

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 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:

Files	Content
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	***CT 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***»

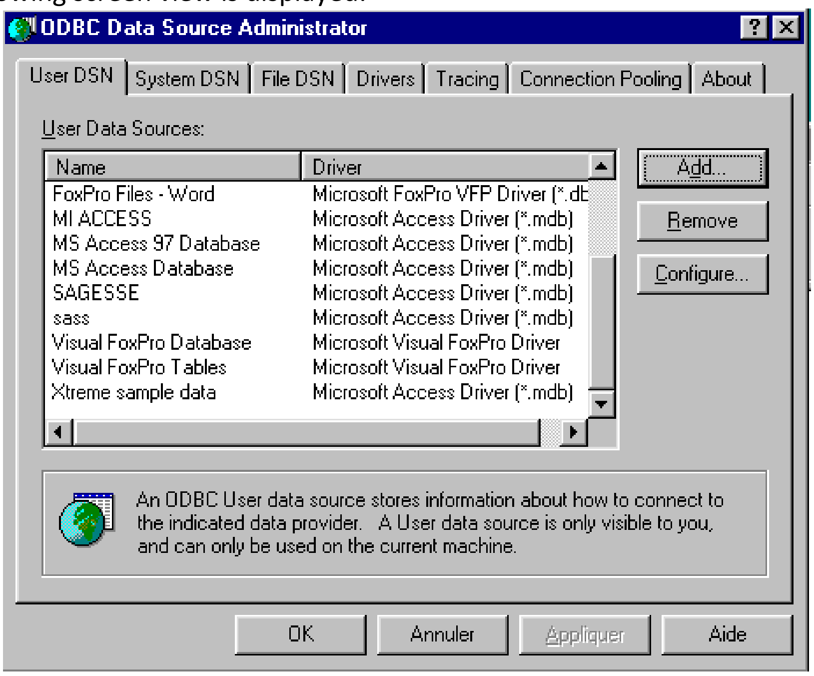
With U designating the drive where the ARCVIEW software is installed:

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

Step 3: ODBC configuration

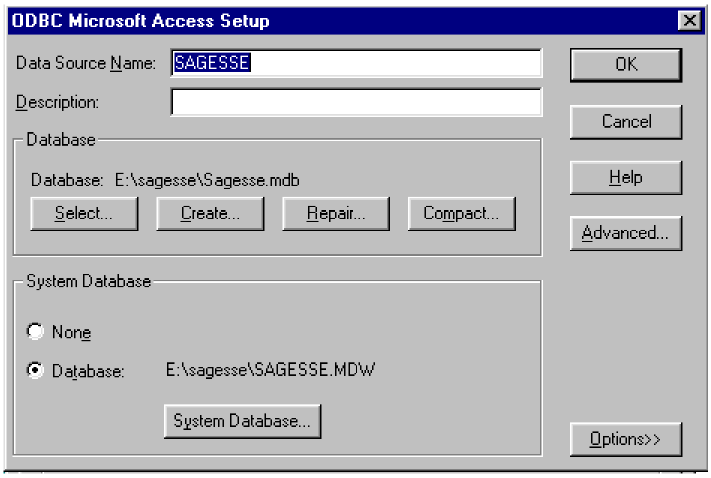
For this purpose, initiate the module «*Odbc 32* » from the configuration panel:

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.

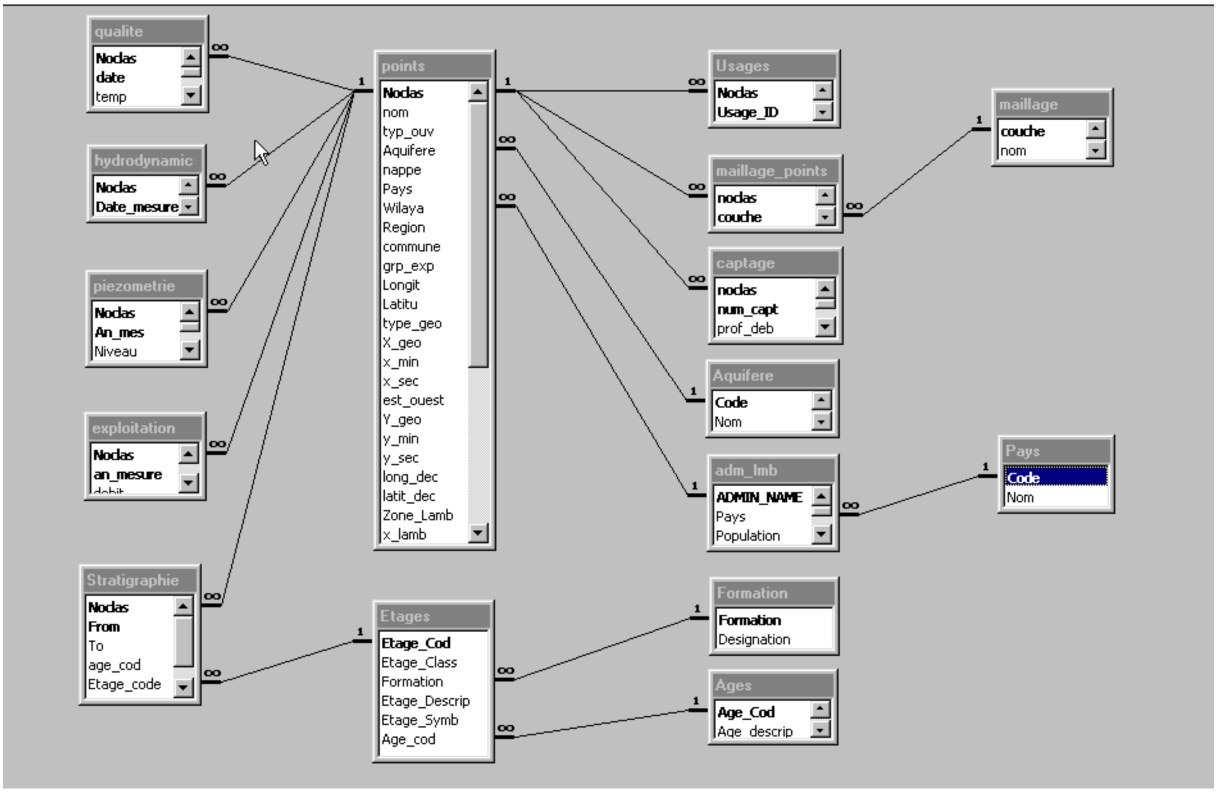
Presentation of the data base

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;
- The 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_lmb*** 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 m^3/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 Salts (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 origin
	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

Group	Name
	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	Abstractions records
	Abstractions from CI as per Administrative Unit and per year
	Abstractions compared in 2000
	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

[*] Cf. Annex 3

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
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 and performing operations in ACCESS in 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 

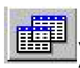
«***grades ou degrés***»: (Grades or degrees) displays the text «*Degré*» or «*Grad*» according to the choice made by the user for controlling the «*unité geog.* » (geographical unit).

«***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

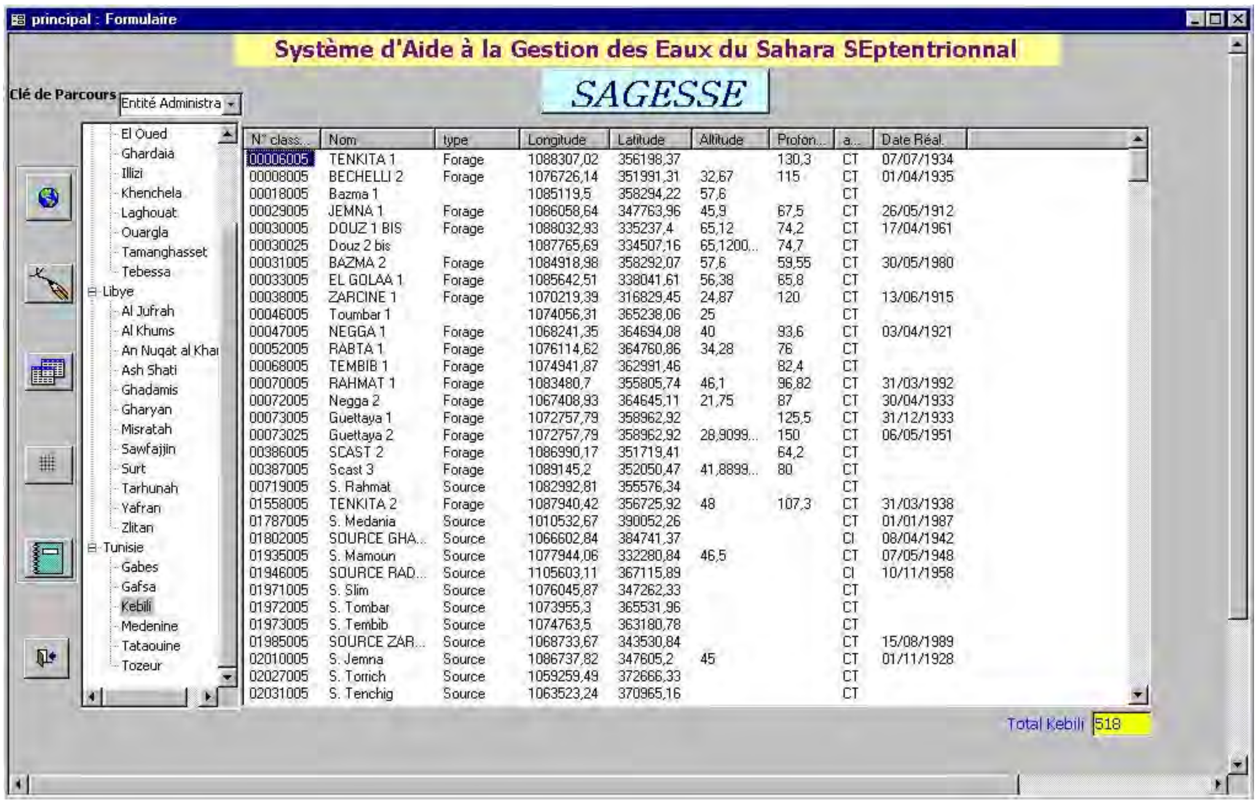
«**Importations**» **Module:** Procedures and functions used for automatic transfer of old DGRE data

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

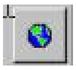
The explorer is the key component of the software based on which all the other functions are activated. It is automatically initiated upon loading of the data base and makes it possible to visualise and scroll down the whole set of data available under various forms and according to multiple entry points.
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.



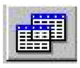
Two representation modes are offered: the digital mode (main attributes) and the cartographic mode (geographic location).

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

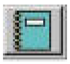
Allows to choose a sorting criterion of water points by country and administrative unit, or else by aquifer and type of water point.

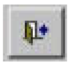
 Used for toggling between the digital mode and the cartographic mode.

 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.

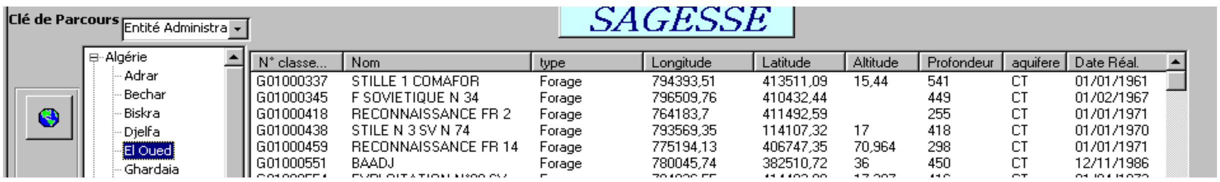
 Initiates the module which allows the transfer of the data to ***PM5***: flows by cell, piezometry.

 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.

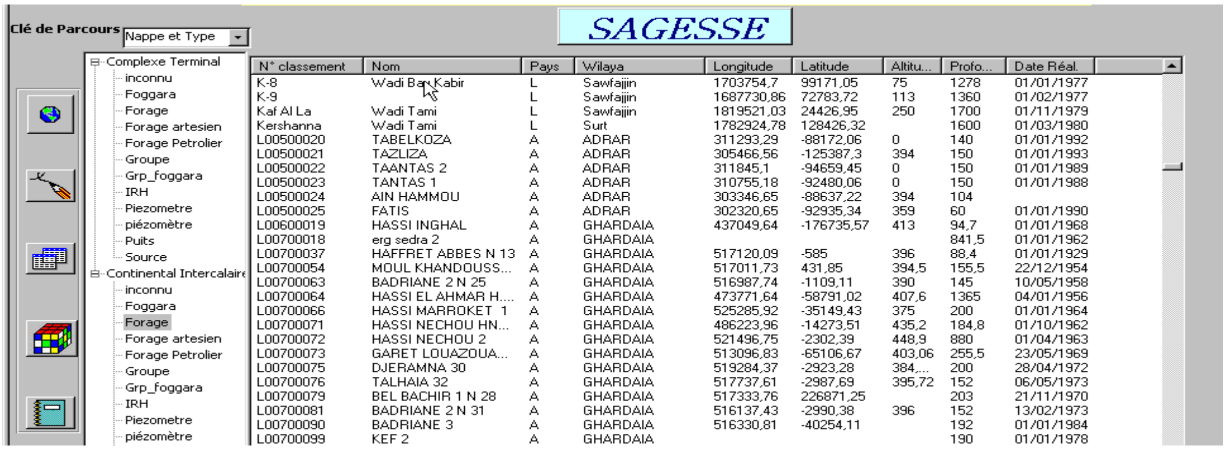
In the case of a digital table, the characteristics displayed differ according as to whether we choose the «*entité administrative*» (administrative unit) key or the «*par aquifère et type*» (by aquifer and type) key. In the first case, the following data are displayed:


Clé de Parcours Entité Administra
SAGESSE
Algérie
Adrar
Bechar
Biskra
Djelfa
El Oued
Ghardaia

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.

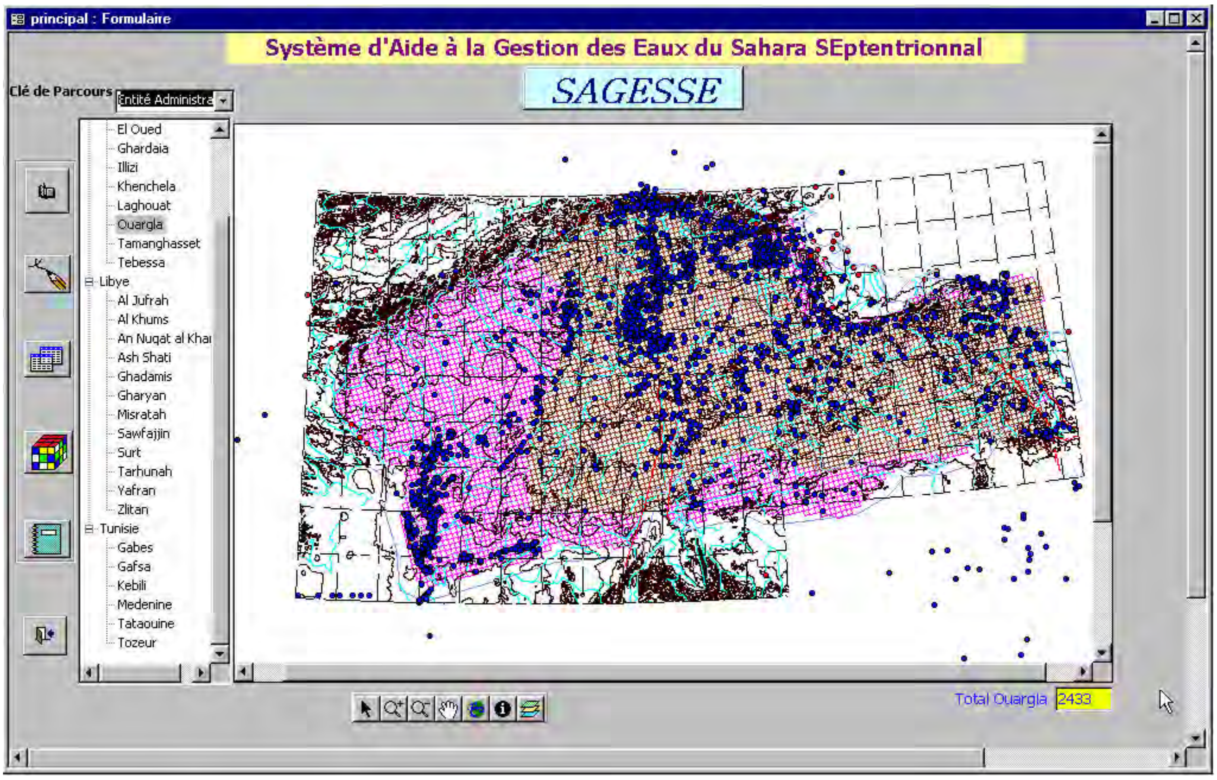
On the other hand, if the entry criterion is the “aquifer” and “water point”, the table is modified:



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

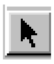
As per default, the data are sorted out by “classification n°”. However, by clicking on a column heading, the data are sorted out according to the heading under consideration.

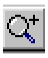
A click on the toggle button makes it possible to display the most important GIS layers figuring in the file «*CARTE_SASS*» (SASS maps).

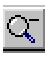


The ARCVIEW coverages cannot be modified except by means of the GIS software; however, these updates are automatically reflected on the contents of this window.

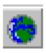
A set of buttons have been created so that each could perform the main GIS functions, namely:

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

 Zoom in: factor 2.

 Zoom out: factor 0.5.

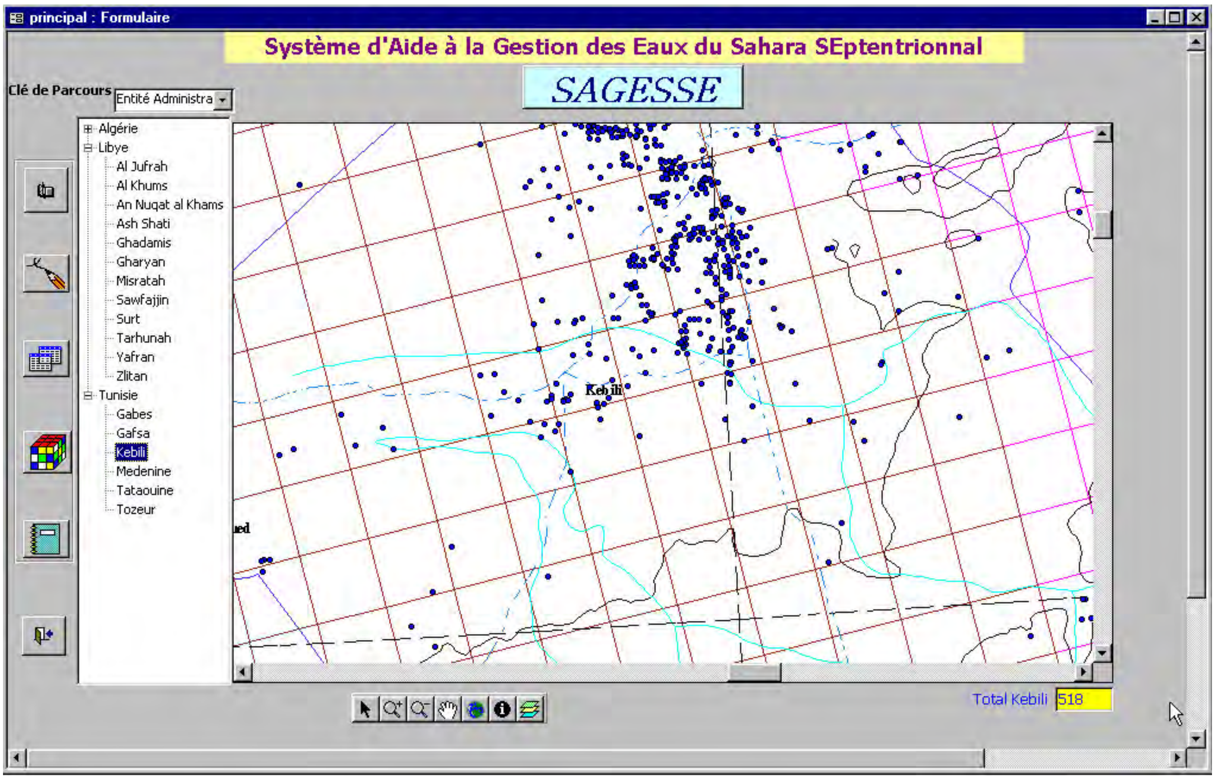
 Pan: does not operate in full extent.

 Full extent: Total view.

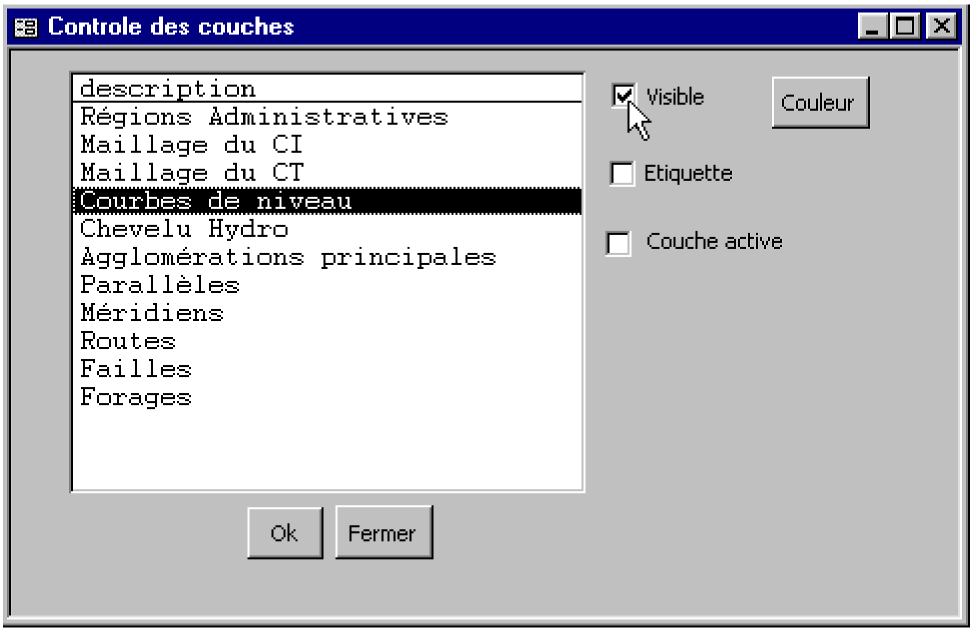
 *Identify*: button: a button that serves to display the «***Données générales***» form (« General data » form) which contains the detailed data about the water point.

 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:



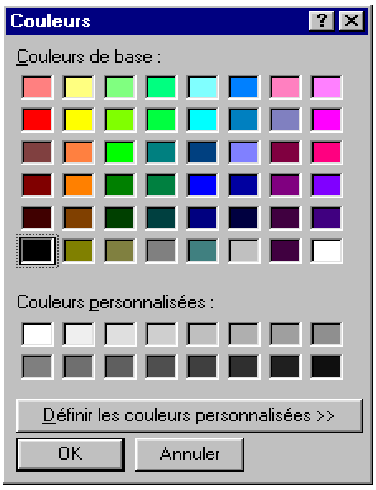
The list of the various layers is displayed, and opposite them the boxes to be ticked for the properties:

- 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:



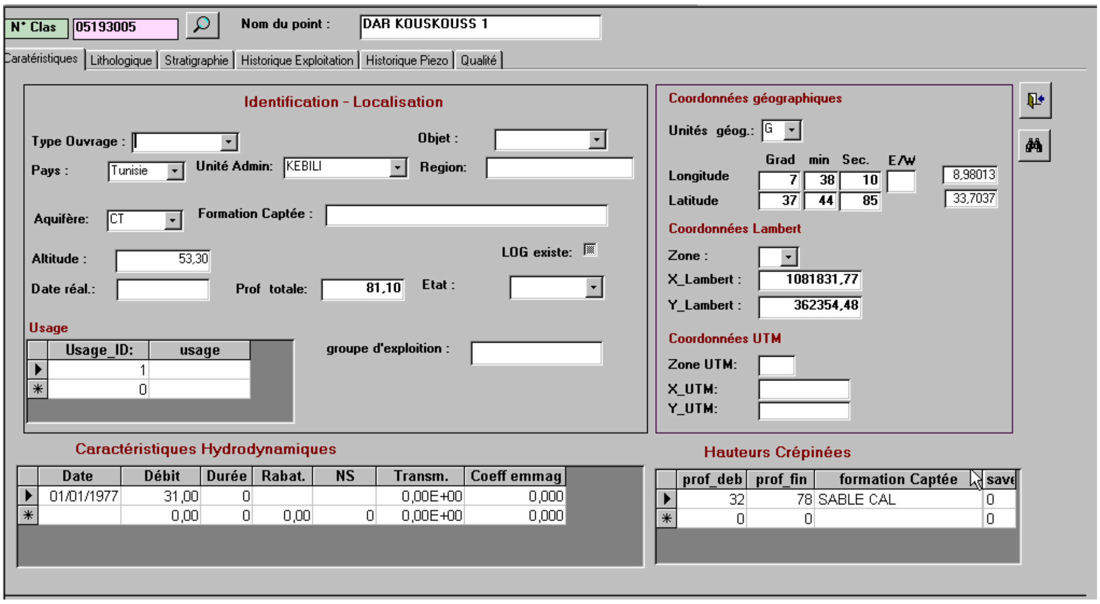
Use of the software

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 brushing (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 (▶*).

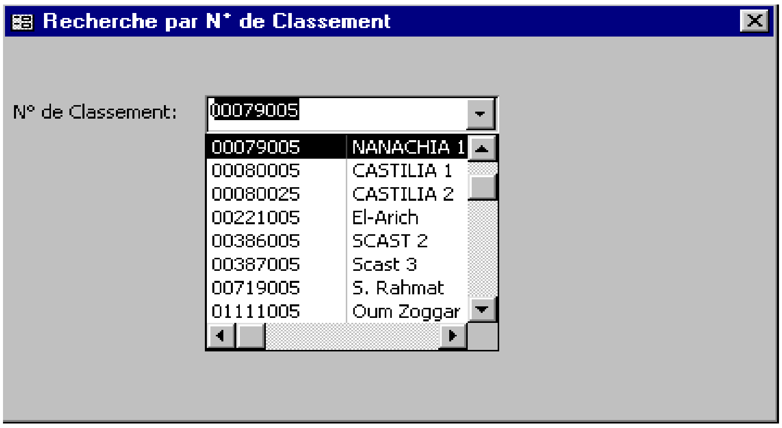
General characteristics:

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).

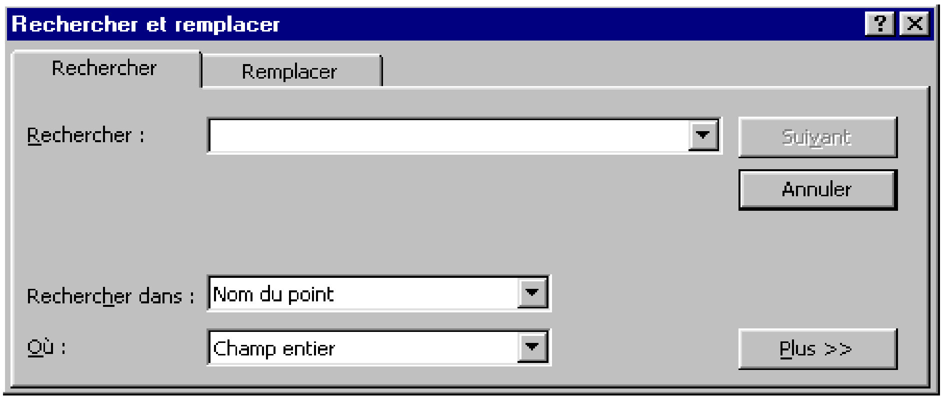
In the SAGESSE software, an additional button has been added in order to search (i.e., retrieve) a water point by recognising its classification number: this is the button .

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:

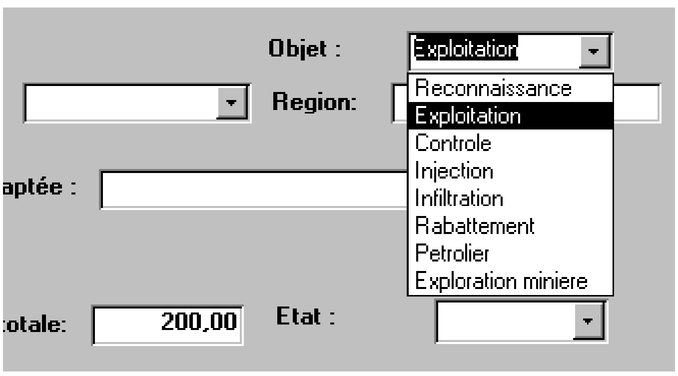
The fields represented in Combo boxes are of two types:

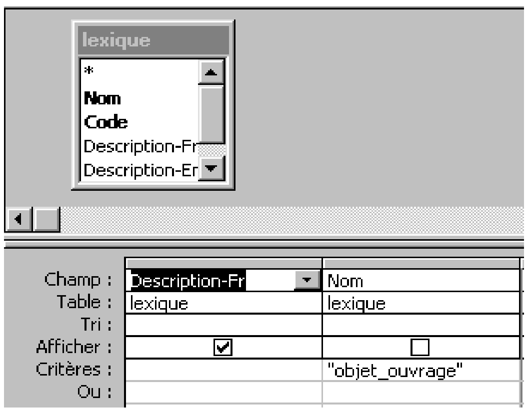
- Data originating from the lexis;
- Data originating from another table that is in relation with the «***Points***» table.

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:

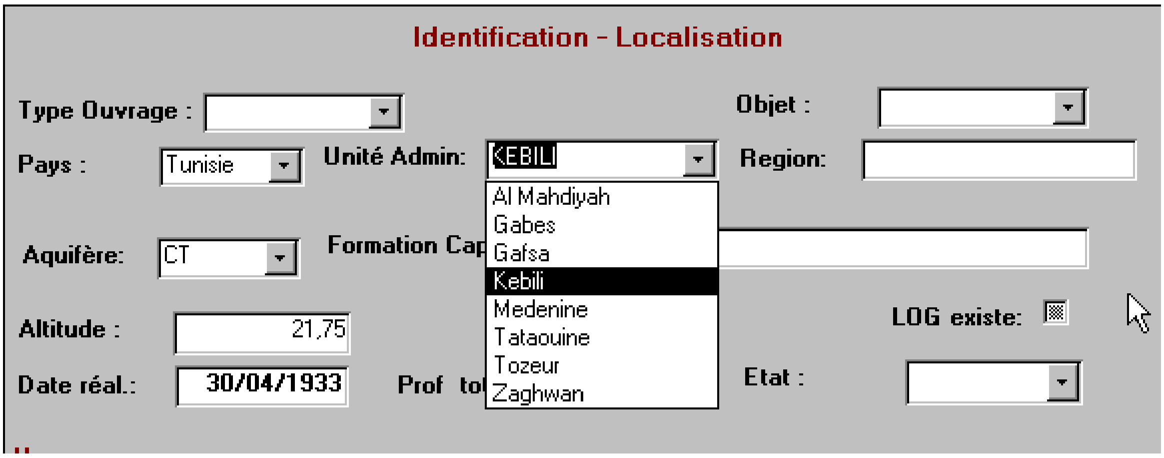
- Based on the lexis:



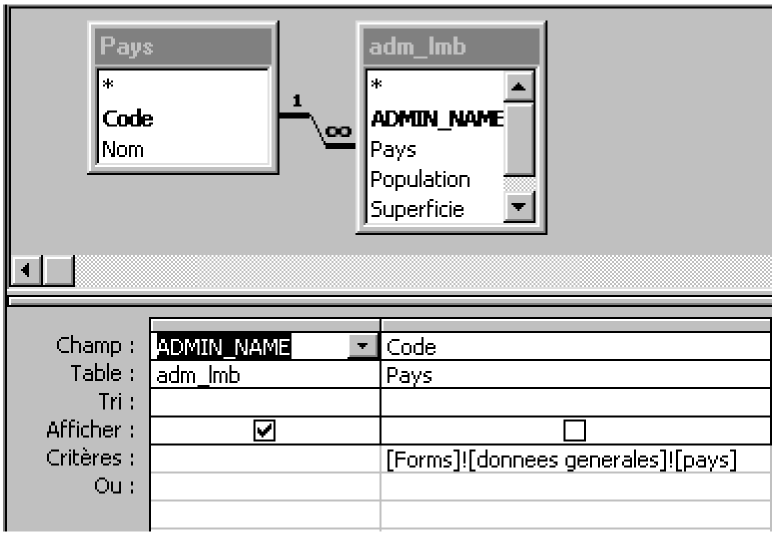


In order to obtain this output, it was necessary to input to the property «***contenu***» (content) of the combo box the query proposed on the right hand site.

- 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:

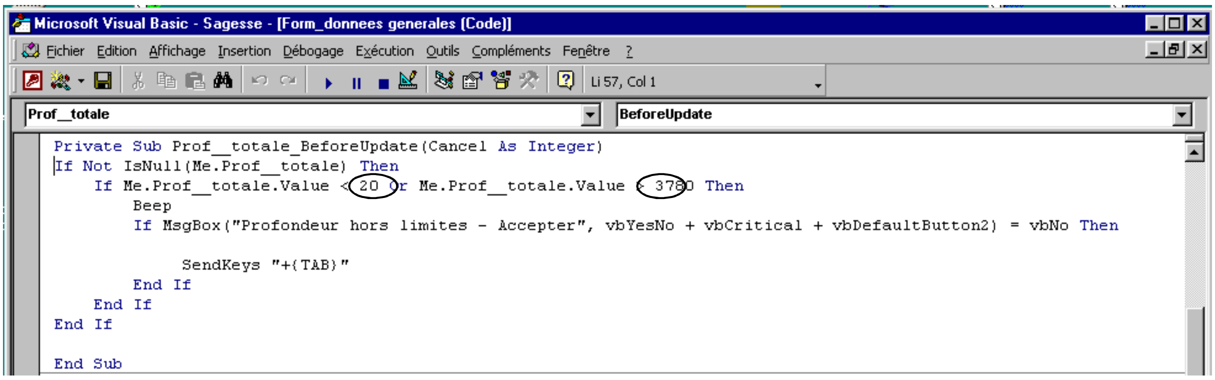
The controls conducted in process of entry of major fields, such as dates, coordinates, altitudes and depths, have been comprised. Upper and lower delimiters for these fields have been calculated based on statistics relating to the values collected for each country.

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

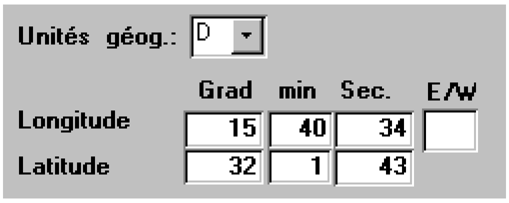
These may be modified by opening the form in design mode, then acting on the events « *Before_Update* » of the controls concerned, as shown by the following example:



Invisible calculated fields:

Certain items need to be calculated automatically and, hence, cannot be handled by the user. These are mainly:

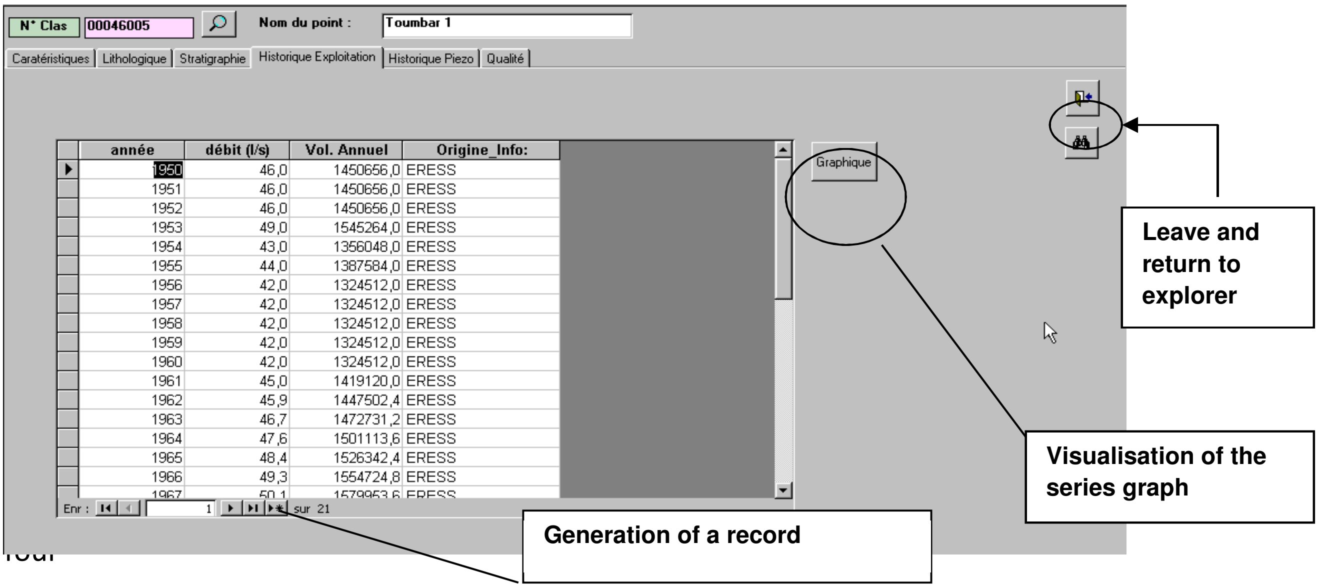
- The date on which the data has been updated: this is necessary for updating the SASS data base based on the national data bases;
- The longitude and latitude fields in «decimal degrees»: the calculation of these fields is made upon each change in coordinates.



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°...

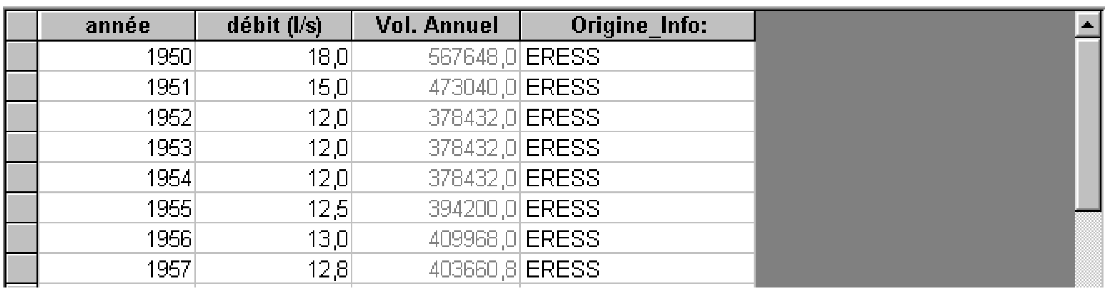


année	débit (l/s)	Vol. Annuel	Origine_Info:
1950	46,0	1450656,0	ERESS
1951	46,0	1450656,0	ERESS
1952	46,0	1450656,0	ERESS
1953	49,0	1545264,0	ERESS
1954	43,0	1356048,0	ERESS
1955	44,0	1387584,0	ERESS
1956	42,0	1324512,0	ERESS
1957	42,0	1324512,0	ERESS
1958	42,0	1324512,0	ERESS
1959	42,0	1324512,0	ERESS
1960	42,0	1324512,0	ERESS
1961	45,0	1419120,0	ERESS
1962	45,9	1447502,4	ERESS
1963	46,7	1472731,2	ERESS
1964	47,6	1501113,6	ERESS
1965	48,4	1526342,4	ERESS
1966	49,3	1554724,8	ERESS
1967	50,1	1579953,6	ERESS

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 m^3/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

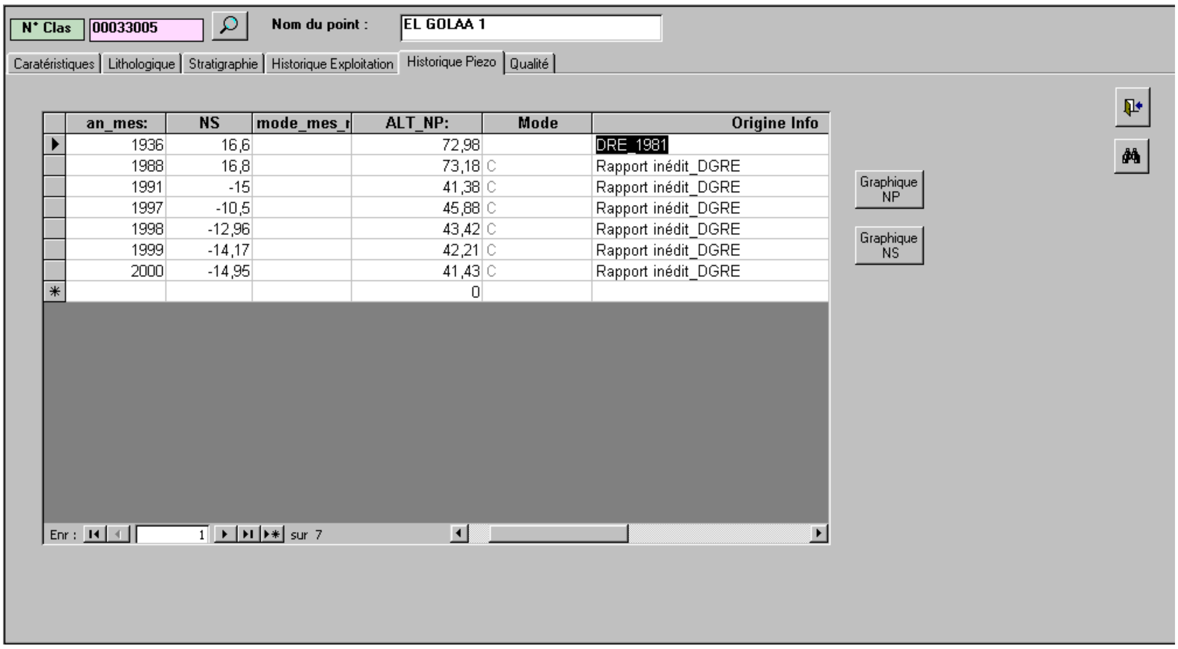
As shown by the example above, if the field «***débit***» (flow) is entered by the user, the field «***Vol.Annuel***» (annual volume) is calculated by the programme (the cursor does not stop at the level of entry to this field). The opposite situation is equally provided.

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:


N° Clas 00033005 Nom du point : EL GOLAA 1

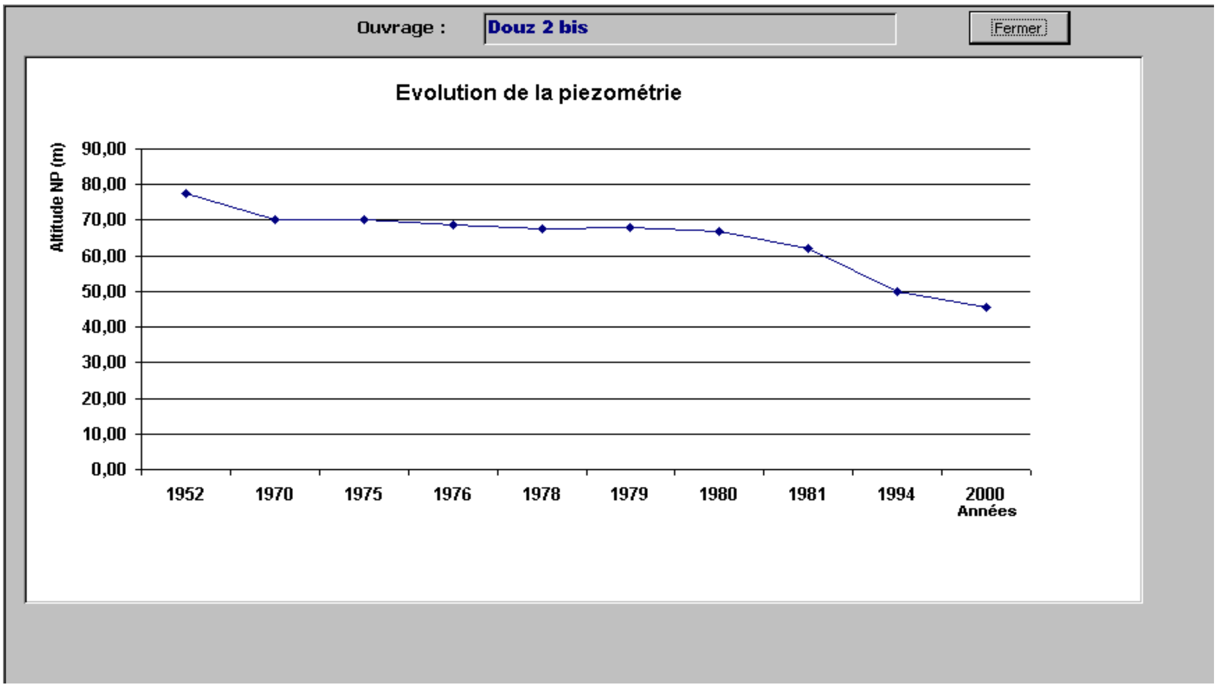
Caratéristiques | Lithologique | Stratigraphie | Historique Exploitation | Historique Piezo | Qualité

an_mes:	NS	mode_mes_	ALT_NP:	Mode	Origine Info
1936	16,6		72,98		DRE_1981
1988	16,8		73,18	C	Rapport inédit_DGRE
1991	-15		41,38	C	Rapport inédit_DGRE
1997	-10,5		45,88	C	Rapport inédit_DGRE
1998	-12,96		43,42	C	Rapport inédit_DGRE
1999	-14,17		42,21	C	Rapport inédit_DGRE
2000	-14,95		41,43	C	Rapport inédit_DGRE
			0		

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).

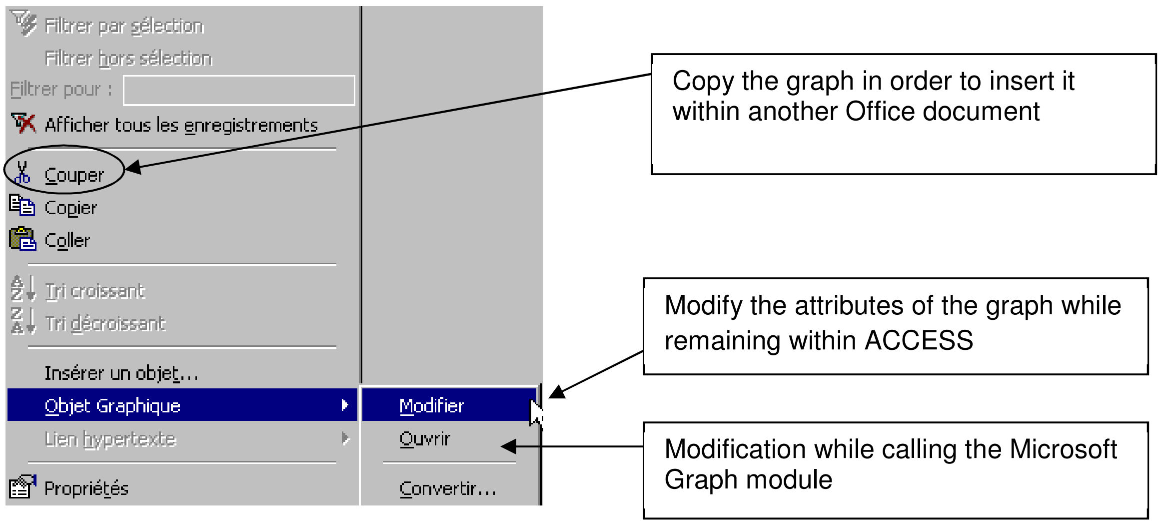
The updating of a field based on knowing the other is ensured by the programme, with, in addition, the assignment of value «***C***» to the columns «***Mode_mes_NS***» (static level measurements mode) or «***Mode_mes_NP***» (piezometric levels measurements mode), according to the case under consideration (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:



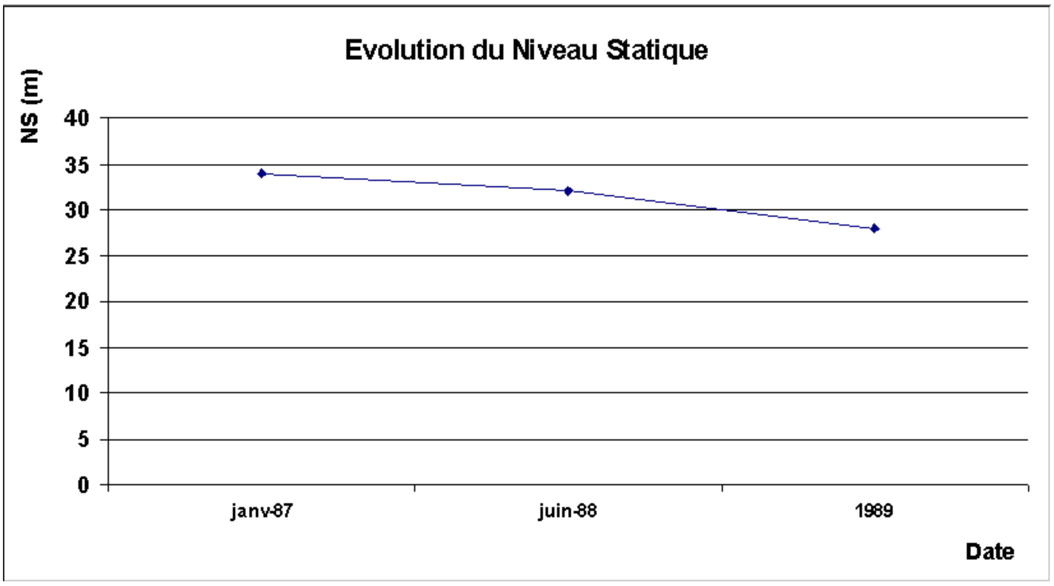
In the context of the project, an only one annual piezometric record has been collected for each water point. However, in order to meet the needs of the countries concerned, we have added an option that allows for the storage of several values per year, and by modifying certain features as follows:

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;

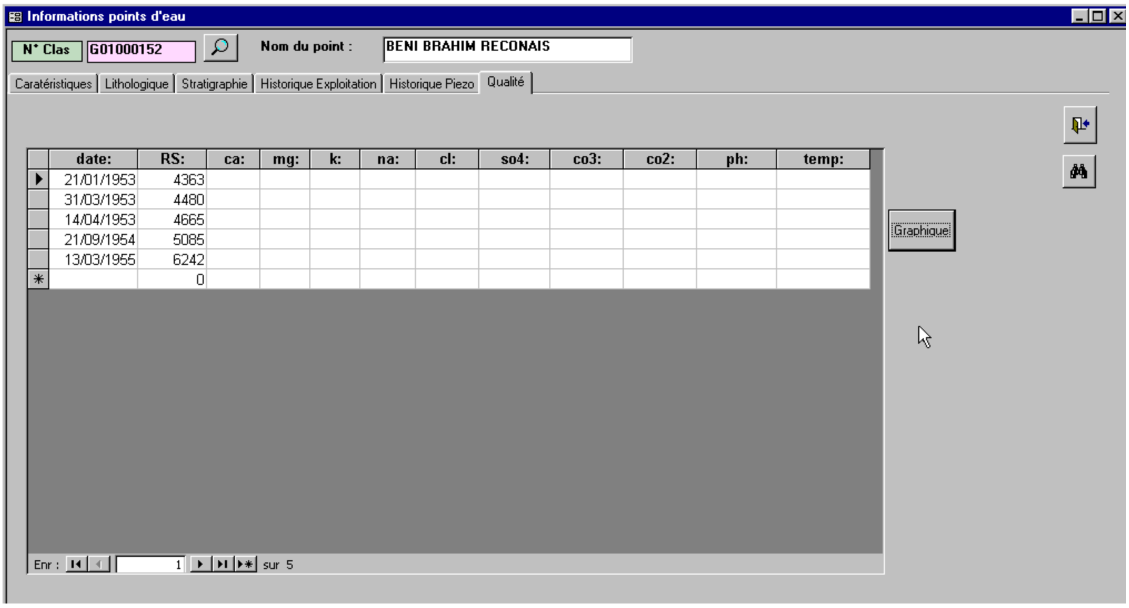
c) The two related graphs which display, in case the field has been filled out, the month when the piezometric measurement was carried out, as shown by the following example:



If the month is entered (filled out), it figures in the abscissa label.

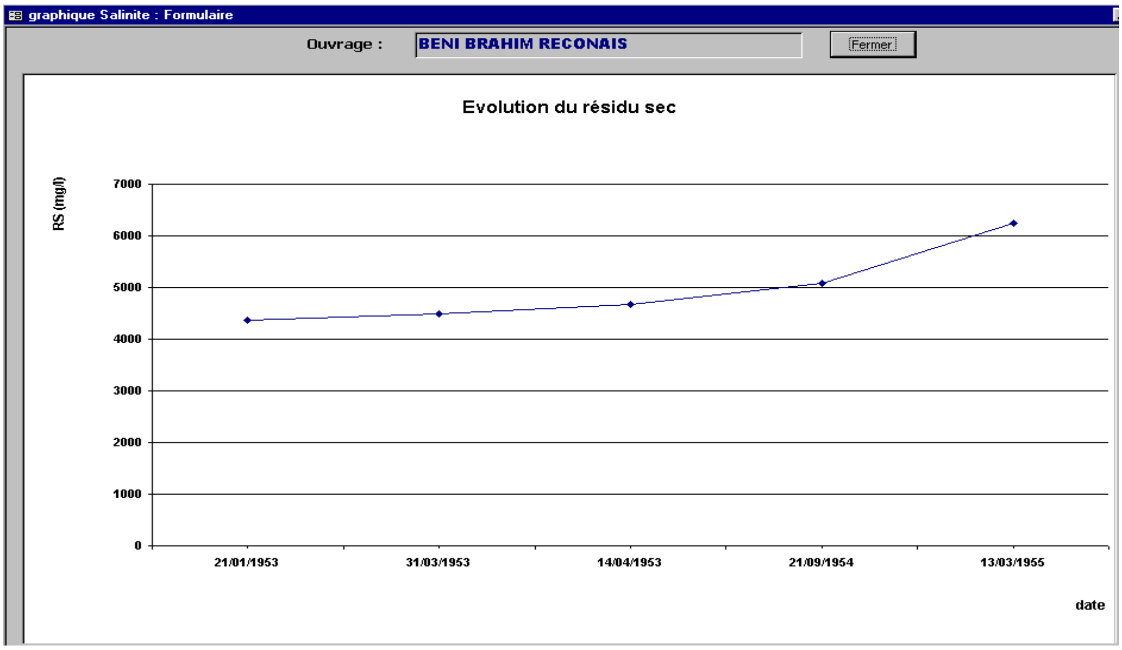
Quality record:

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.

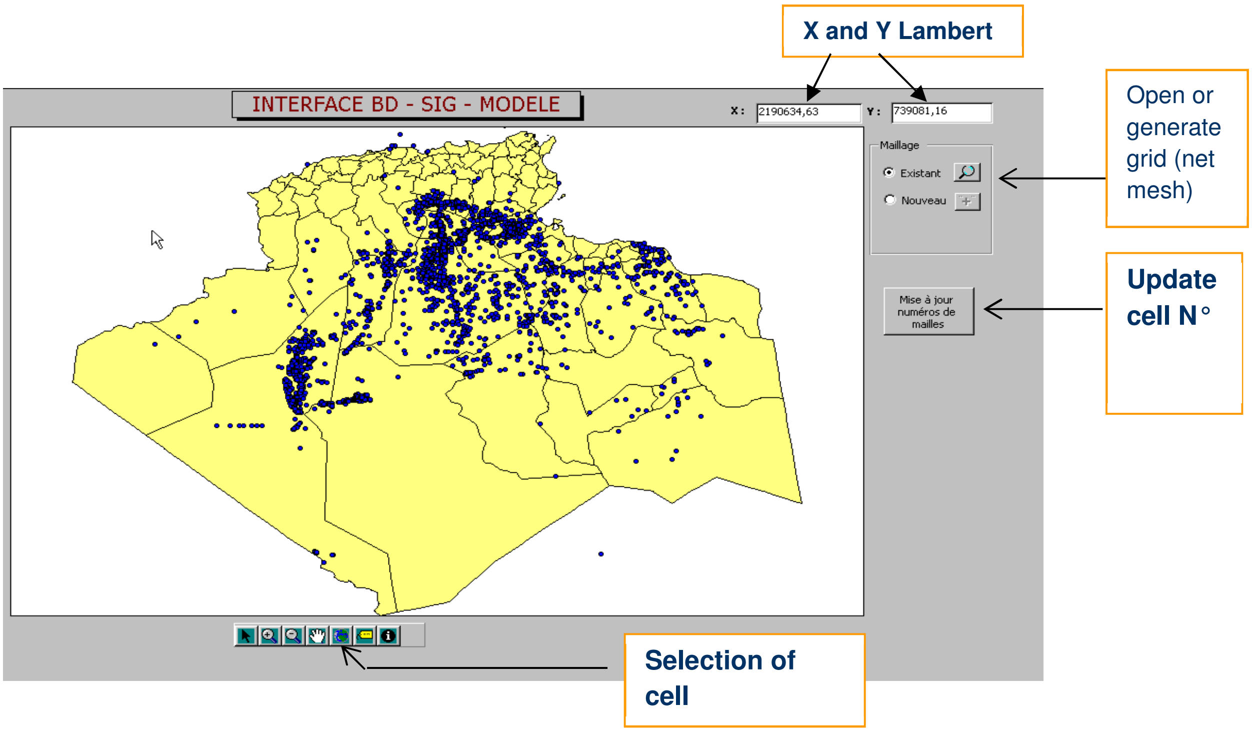
An interactive graphic interface has been generated in order to allow the user to perform those tasks: form « ***BD-SIG-Modele*** » (DB – GIS – Model form).

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).

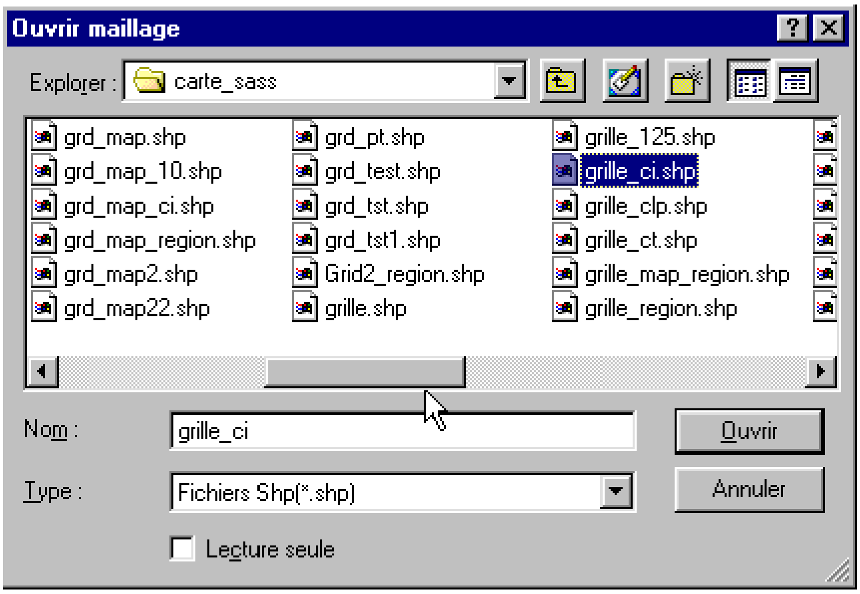
Then, the «*Points*» table may be scrolled down and each water point provided with Lambert coordinates is projected on this window. Two fields X and Y have been added in order to permanently display the coordinates corresponding to the position of the mouse on the map.

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).



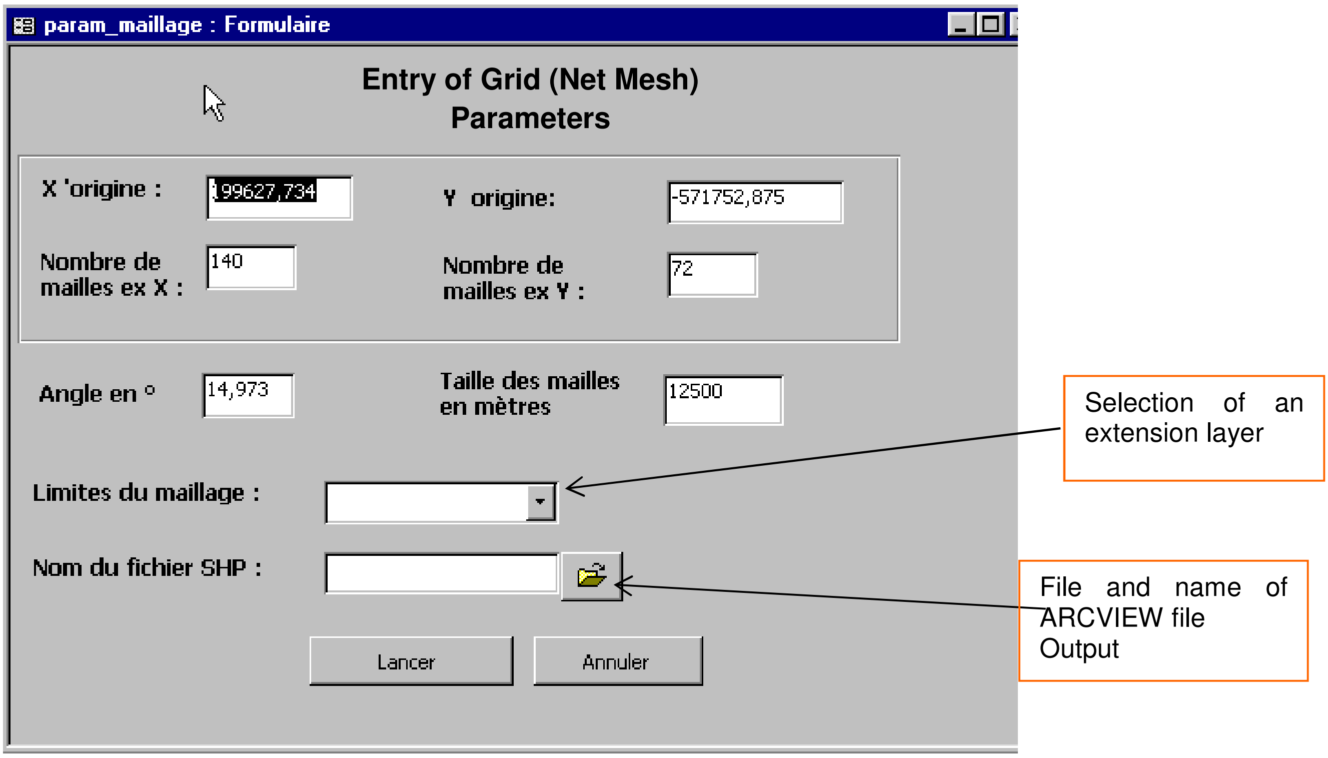
Two types of files may be selected: «*shp*» (SHP) and «*dxf*» (DXF).

After selecting the file, click on «*Ouvrir*» (Open)...

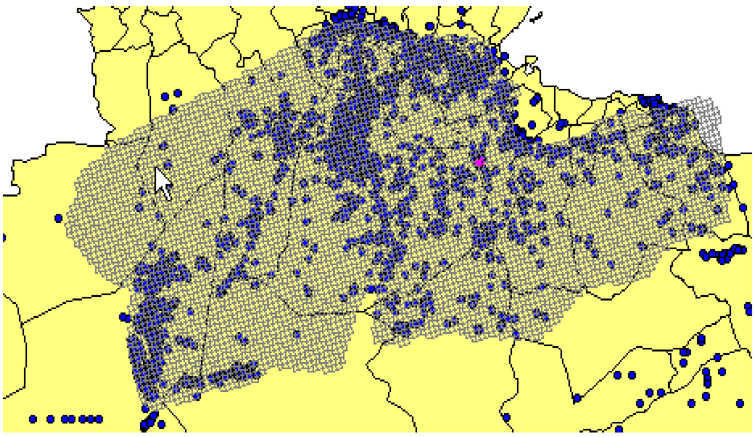
A control operation is performed before loading the file in order to check whether it is conform to a grid (net mesh) file. In case it is not, the file is not opened.

Generation of a new grid (net mesh)

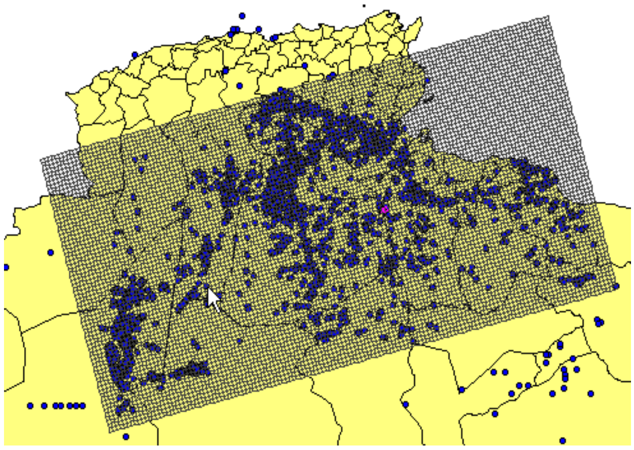
The button initiates the form «Param_maillage» (grid (net mesh) parameter) which makes it possible to introduce the grid (net mesh) parameters and to generate it, then display it on the map window.



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;

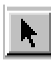
addition of new points.

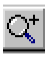
Handling of the tool bar:

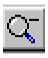
Once the net mesh is displayed, the user may proceed to the following operations:

- 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).

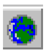
The tool bar, located below the map window, makes it possible to perform the more extended operations: Zoom, Pan, selection,

 Zoom rectangle performed by means of the mouse;

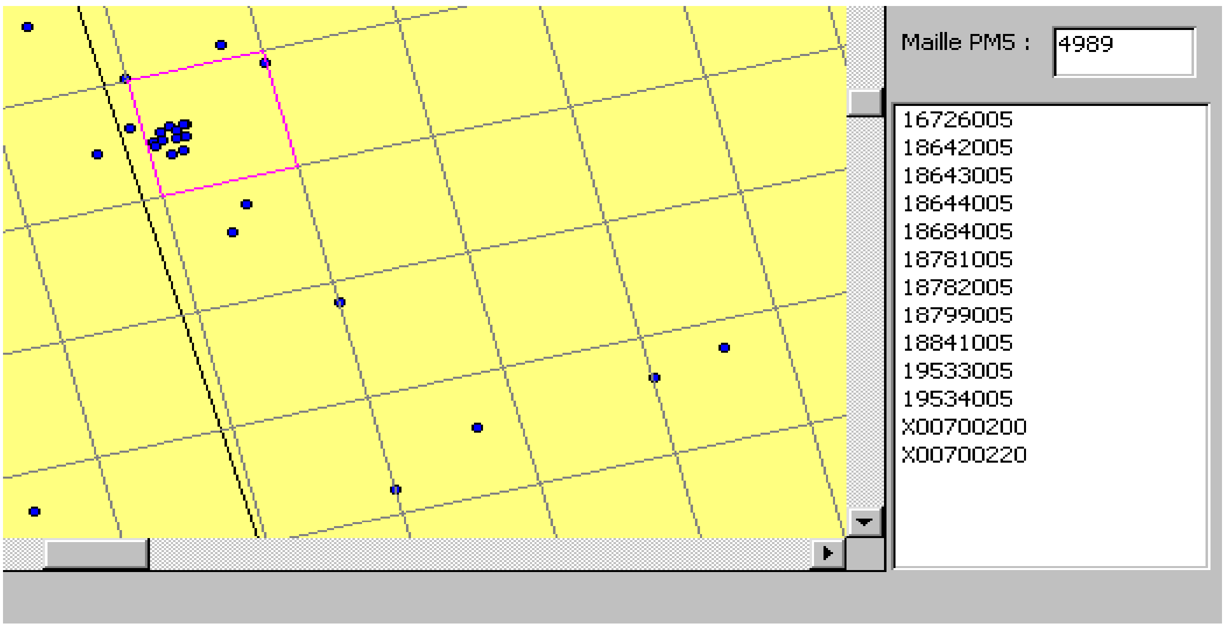
 Zoom In factor 2

 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:

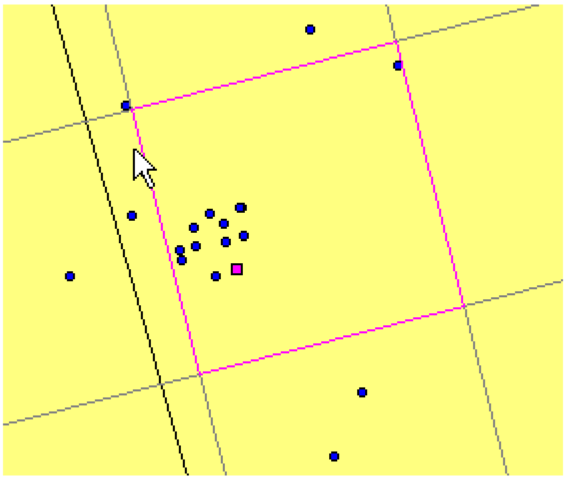


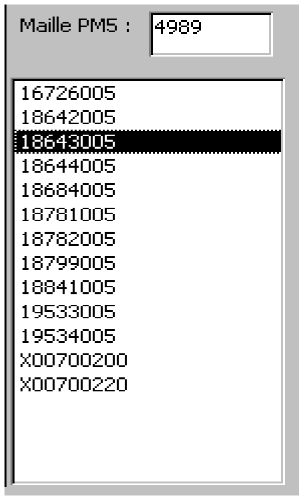
The selected cell is highlighted, and a list of the water points it contains is displayed.

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.

Example:





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).

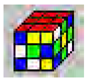
Stage 3: Initiating the procedure of transfer of data to PM5

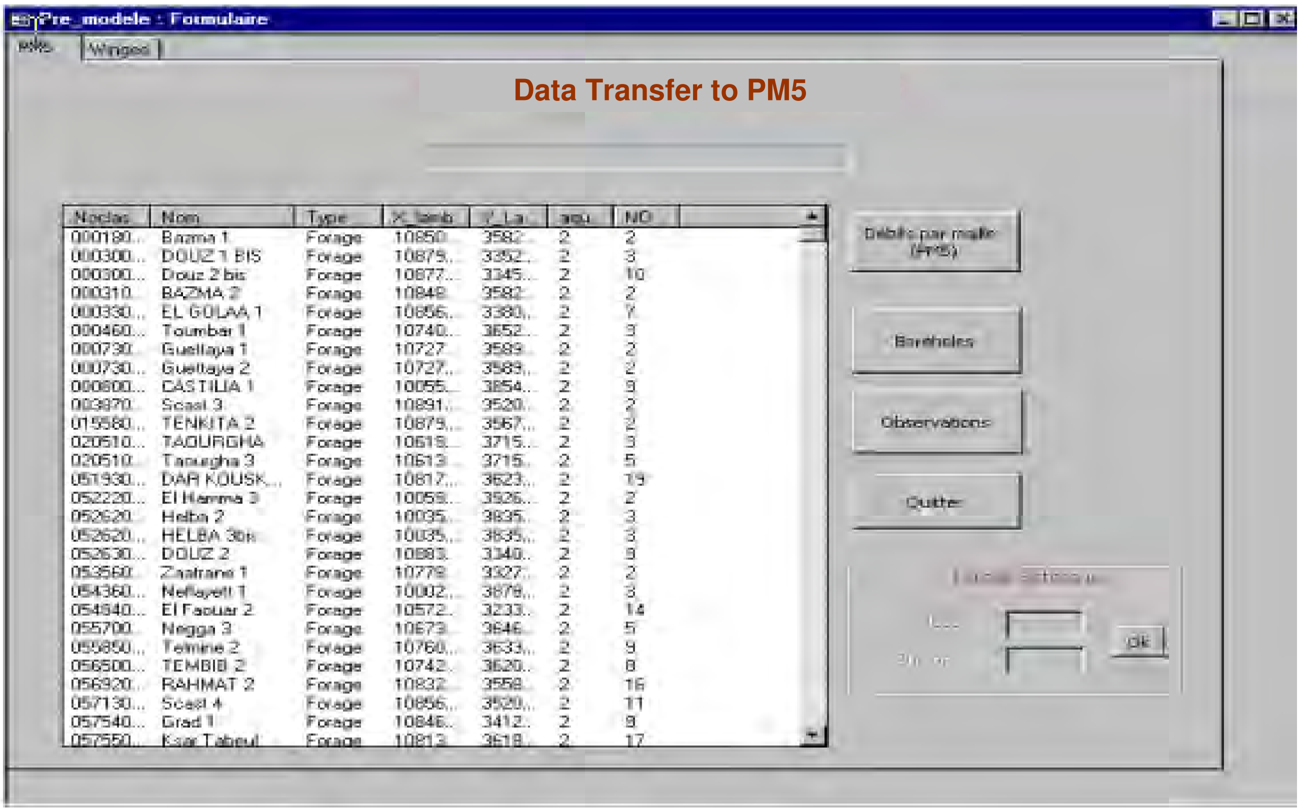
The preparation of the data is the operation that is most difficult to conduct manually. The development of the automatic transfer procedure allows not only to facilitate the task of the model designer, but also to ensure consistency between the data and to reduce errors.

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.

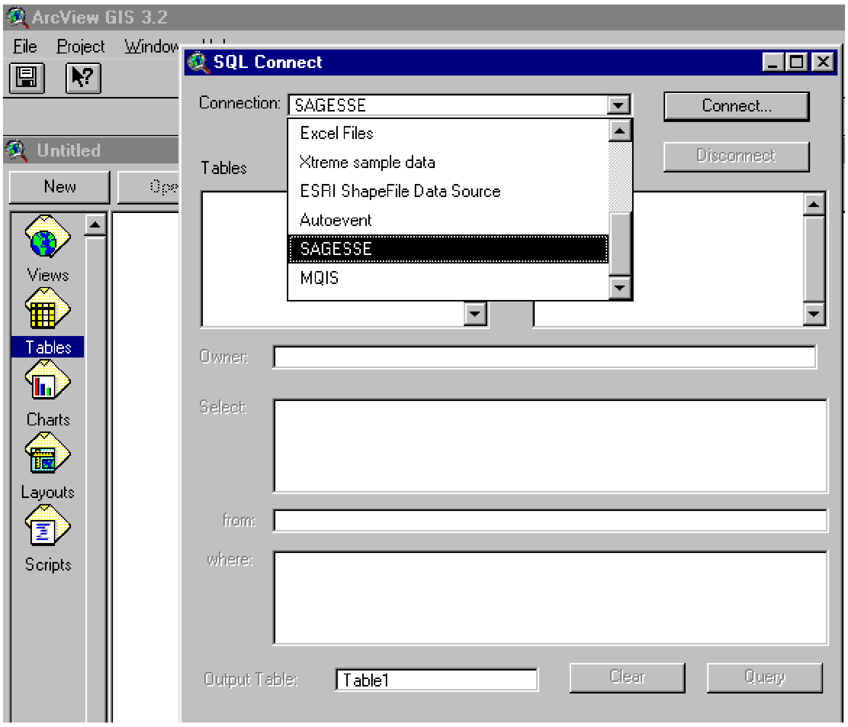
In process of entry, a conversion into decimal degrees is ensured by the entry programme and updating is automatic.

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.

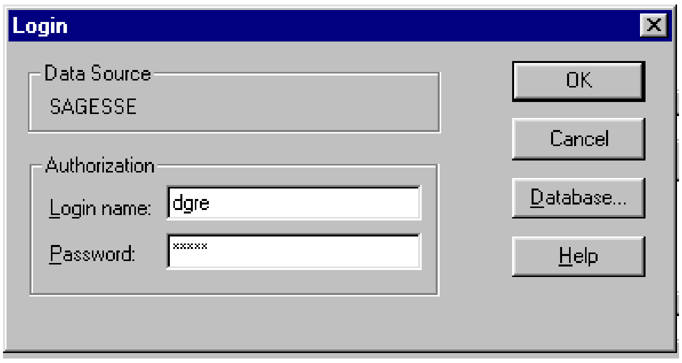
Procedure

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:



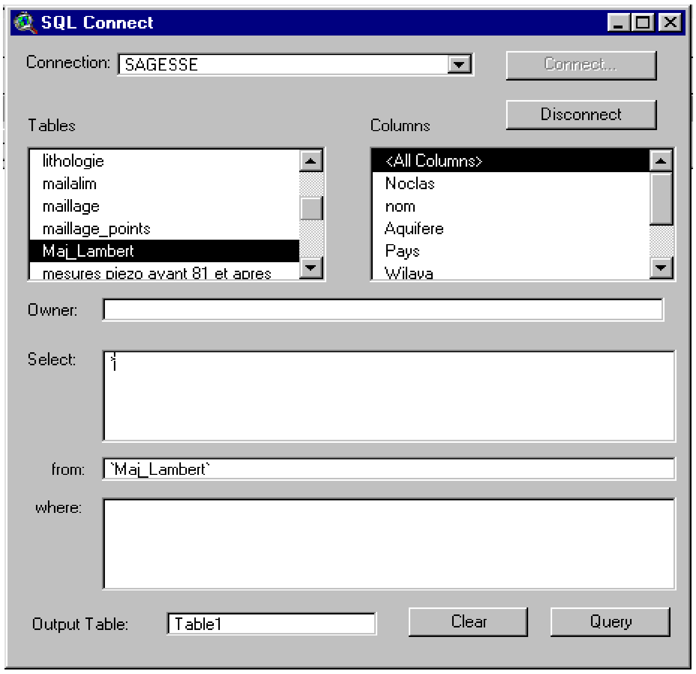
Enter account and password.

2. Stage of conversion of coordinates and updating the «points» table:

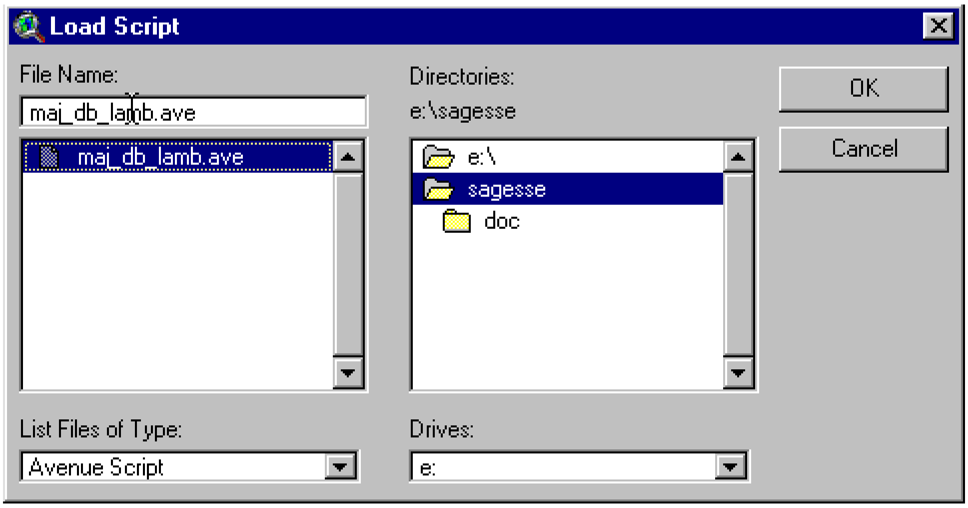
- Open the query «***Maj_Lambert***» by a double click;
- Also double click on «***all columns***»

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.

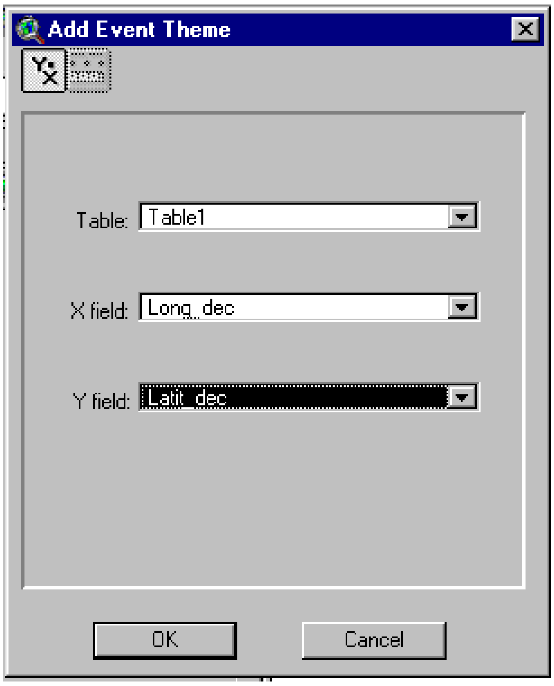


This query contains all the points that require an update: that is, all those that contain valid decimal degrees and whose field «Type_geo» is different from «**L**»:

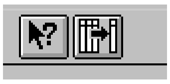


- Generate a view comprising these points:

  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.

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