THE NORTH-WESTERN SAHARA AQUIFER SYSTEM

BASIN AWARENESS

HYDROGEOLOGY

VOLUME II

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OBSERVATOIRE DU SAHARA ET DU SAHEL

THE NORTH-WESTERN SAHARA AQUIFER SYSTEM

A Basin Awareness

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Observatoire du Sahara et du Sahel
Boulevard de l'Environnement – BP 31 Tunis Cedex, Tunisie
Tel. + 216 71 806 522 – Fax. + 216 71 807 310
E-mail : boc@oss.org.tn - URL : www.unesco.org/oss

PREFACE

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

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

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

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

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

Upon request by the three countries, OSS sought out and obtained financial support from the Swiss Cooperation Agency, IFAD and FAO for a first three-year phase which was officially initiated in May 1999 in Rome and whose main objective was to update the evaluation of the resources exploitable, as well as to set up a consultation mechanism between the three countries.

Compared with its predecessor, i.e. ERESS, the SASS project was to avail itself of a major asset: participation by Libya and use of the data compiled over the last thirty years. These data were to allow:

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

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

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

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

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

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

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

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

Dr. Chedli FEZZANI

Executive Secretary

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

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

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- ABIDI Brahim
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Scientific assessment committee :
- DE MARSILY Ghislain
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Project Team
- LATRECH Djamel, Regional Coordinator
- MAMOU Ahmed, Scientific Advisor
- KADRI Sadek, Advisor for the Consultation Mechanism
- BESBES Mustapha, Chief Consultant for the Model
- ABDOUS Belcacem, Chief Consultant for the Data Base
- BABASY Mohamadou Lamine, PhD Student
- JOUINI Wafa, Assistant
- OTHMAN Olfa, Documentalist

CONTENTS

LIST OF ANNEXES

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES (OFF TEXT)1

1 These plates are included in the text for the sake of information only. To consult them, please refer to the prints (maps at scale 1/2 000 000).

GLOSSARY

ANRH	Agence Nationale des Ressources Hydrauliques (National Agency for Water Resources))
SASS	Système Aquifère du Sahara Septentrional (North-Western Sahara Aquifer System)
DGRE	Direction Générale des Ressources en Eau (General Directorate of Water Resources)
GWA	General Water Authority
ERESS	Etude des Ressources en Eau du Sahara Septentrional (Study of North-Western Sahara Water Resources)
BRL	
DJ	Djebel or Jabal
SYRTE or SIRT	
CI	Continental Intercalaire
CT	Complexe Terminal

SPELLING OF PLACE NAMES

W. Wadi, equivalent of Oued for the Algerian – Tunisian part

Place names in Tunisia and Algeria have been retranscribed in the document based on French spelling which is commonly used in cartography. As for Libya, the common rules of phonetic transcription of place names have been applied. For certain place names, or for common topographic terms to Tunisia and Algeria, on the one hand, and to Libya, on the other hand, the spelling relevant to the zone concerned has been kept; thus, the spelling will go as follows:

- Oued, in Algeria and in Tunisia (e.g. : Oued Rhir) and Wadi, in Libya (e.g.: Wadi Zamzam)

- Djebel, in Algeria and in Tunisia (e.g. : Djebel Tebaga) and Jabal, in Libya (e.g. : Jabal Nafusah)

- Djeffara, for the Tunisian coastal plain, and Jifarah, for the Libyan coastal plain

- Sirt, for the Libyan town, although, in certain French Atlases, this town is known as Syrte

- Kikla or Kiklah, or the continental geological formation between the Cambro - Ordovician and the marine Cenomanian.

1- PREAMBLE

The present volume, entitled “Volume 2: Hydrogeological Synthesis”, is part of a set of three volumes which sum up the scientific activity of the project “North-Western Sahara Aquifer System” (SASS/OSS). Its objective is to present the physiographic and hydrogeological data which have been taken into consideration in developing the digital model that simulates the hydrodynamic behaviour of the Saharan aquifers.

Following an overview of the previous studies on the hydrogeology of the Saharan basin, the present report presents respectively:

- the aquifer formations of the North-Western Sahara and their schematisation with a view to their hydrogeological modelling;
- the various hydrogeological characteristics of the aquifers of this system through an analysis that is focused on hydraulic exchanges and the impact of the exploitation on piezometry and on water salinity;
- the chemical quality of the water and its isotopic characteristics allowing a better understanding of the hydrodynamic operating of the system.

It is designed as a basic document for a better appreciation of the options adopted during the modelling process and of the basic data used.

INTRODUCTION

1.1- Contribution of the previous studies and definition of the reservoirs adopted

The North-Western Sahara Aquifer System “SASS” extends over a large zone whose boundaries are located in Algeria, Tunisia and Libya. This basin comprises a series of aquifer layers which have been grouped into two reservoirs called the Continental Intercalaire (CI) and the Complexe Terminal (CT).

The term “CI” designates, according to its author (C. Kilian, 1932), a continental episode located between two marine sedimentary cycles, with:

- at the base, the Palaeozoic cycle which completes the Hercynian orogenesis;
- on top, the Upper Cretaceous cycle.

As for the TC, it consists of a fairly little homogeneous set including carbonated formations of the Upper Cretaceous and detritic episodes of the Tertiary and, mainly, the Miocene. These definitions were adopted, at the beginning, in order to analyse and schematise, for purposes of modelling the hydrodynamic operation of the Algerian aquifers and, by extension, the Tunisian aquifers. With the advent of the SASS project, the adding to the study of the Libyan Saharan basin has required a new analysis of the geological, geophysical and hydrogeological data, based at the same time on the previous studies and on the collection of new data.

The state of knowledge relating to the North-Western Sahara Aquifer System “SASS” is the outcome of over a century of geological and hydrogeological surveys and studies. The first water wells were sunk in this basin in the Oued Rhir region toward the middle of the XIXth century. They had made it possible to survey the first artesian levels of the CT. Those executed in the Tunisian south date back to the early XXth century (R. Bousquet, 1947).

With the advent of petroleum exploration in the Sahara in the 1950s, the geological structure of the Saharan basin was to become clearer (J. Fabre, 1976; and G. Busson, 1970). The intensification of the construction of water wells since then has allowed a refining of the knowledge gathered on the hydrodynamic operation of the aquifer tables and their hydrogeological characteristics.

The major studies used for the analysis and processing of the data available, as well as for the execution of the mathematical model, are as follows:

1.1.1. Regional studies

These consist mainly in two studies which have benefited from UN assistance: UNESCO/Special Fund, for the first study, and UNDP/OPS, for the second study:

Study of the North-Western Sahara Water Resources (ERESS, 1972): This study has allowed, for the first time, a synthesis of the hydrogeological data on Saharan aquifers, as well as a presentation of their balance through the use of digital models. It has established the bases for monitoring the evolution of the resource by adopting exploitation scenarios for the period 1970 - 2000 and by simulating the behaviour of the aquifers with respect to this exploitation.

Updating the Study of the North-Western Sahara Water Resources (RAB 80, 1983): This study, which adopted the same approach as that of ERESS, has examined the behaviour of the Saharan aquifers for the period 1971 - 1981 and extended the forecast simulations up to the time frame 2010.

These two studies were, however, limited to Algeria and Tunisia and did not include the Libyan part of the basin.

1.1.2. Algerian studies

Detailed model study of the CT in the Oued (Wadi) Rhir zone (Ecole des Mines de Paris (Paris Mines School), 1973): This study has set to refine the results of the ERESS study in a particular zone of Algeria, namely Oued Rhir, where the ERESS model could not take into consideration the complexity of the multi-layer aquifers of the CT.

Study of the Master Plan for the Development of Saharan Regions (BRL, 1998): This study has analysed and revised critically the results of the previous two studies; it has reworked the two CI and CT models on new bases, but without the availability of the total updated Algerian data nor the Tunisian data.

This recent study which constitutes the first attempt to look beyond the scope of the ERESS approach could not, however, be carried on to the desired refinement stage, and this for the following reasons (BRL, 1998):

- **For the CT:**
  - absence of recent hydrogeological synthesis,
  - absence of a permanent observation system of the aquifers and of control of their exploitation,
  - great disparity of the knowledge available with a concentration of data on the oases and lack of information about the new development zones . . .
- **For the CI:**
  - schematised design of the geometry which influences its hydrodynamic operation,
  - scarcity of updated information on the piezometry and abstractions from the water table.

1.1.3. Tunisian studies

Mathematical Model of the CT: Nefzaoua – Djerid (ARMINES, 1985): The ERESS and RAB 80 studies had constituted, for the Algerian-Tunisian part of the Saharan basin, the basis for the information previous to 1980. The approach adopted at the time for the evaluation of the water resources exploitable is that of mathematical simulation. Since then, digital modelling has witnessed a substantial progress that allows a refining of the simulation of the hydrodynamic behaviour of aquifer tables and helps provide a set of digital tools likely to ensure a more rigorous and a more optimised aquifer management. The ARMINES study (1985), which followed the RAB 80 study, has allowed a revision of the sub-model Nefzaoua-Djerid based on a new approach (variable sizes in the grid cells/ net mesh cells) and has benefited from an additional body of data collected in 1971, based on the monitoring of water points and of the data relating to new wells. This study has made it possible to forecast the reaction of the water table with respect to exploitation up to 2040. These results were taken into consideration for the development of new irrigated zones in Djerid and Nefzaoua.

Characteristics and Evaluation of the Water Resources of the Tunisian South (MAMOU, 1990): This hydrogeological synthesis reviews the data available until 1988 with an analysis of the various evaluations of the water resources of the Tunisian South and proposes new data with regard to the geometry of the aquifer reservoirs, their piezometry and the abstractions made from them.

Yearbooks of the Exploitation of Tunisia’s Deep Aquifers (1971-1999) and Yearbooks of the Piezometry of Tunisia’s aquifers (1991-1999): The Yearbooks of the exploitation of the deep aquifers collect the data related to abstractions from the CI and the CT tables which result from the measurements made once or twice a year. The piezometric yearbooks of Tunisia’s aquifers provide the piezometric measurements made on the surface and deep aquifers observation network.

1.1.4. Libyan studies

Regional Report on Hydrogeological Study in Ghadames-Derj-Sinawan Area (M. L. Srivastava, 1981): This hydrogeological study, with aquifer modelling, covers the western part of the Basin, particularly the Ghadames – Sinawan - Derj zone.

North-Western Part of Libya: Ghadames-Hamada Basin (Sinha, 1980): This study has consisted in an interpretation of the loggings performed in petroleum wells and in deep water wells in order to identify permeable and aquifer formations, as well as to estimate water salinity for the whole north-western quarter of Libya, except for the Jifara.

Hydrological Study of Wadi ash-Shati, Al Jufra and Jabal Fazzan Area (Idrotecneco, 1982): This study covers, first, the South-Eastern part (Wadi ash-Shati & Jabal Hassawunah); then, it extends to the entire natural boundaries of the basin, with the first model developed by Pizzi *et al*.

Survey for the Development of the Central Wadi Zone & Gulf of Sirt: Groundwater Resources (GEFLI, 1978): This study covers the entire North-Eastern part of the basin. It allows a better appreciation of the Hun graben, as well as the Libyan outlet of the CI water table (Ain Tawargha & Ain Kaam).

Western Jamahiryya Hydrological Modelling of the Aquifers and Well Fields System (GEOMATH, 1994): This study is an updating of the regional model developed by Idrotecneco (1982).

Ghadames Project: Water Resources (BRL, 1998): This study constitutes the first attempt at a presentation of data on the whole Basin of Hamada El Hamra with reference to Tunisian data (MAMOU, 1990) and Algerian data (RAB 80, 1983). It draws upon the syntheses made by Ph. Pallas (1978) and O. Salem & S. al Baruni (1990).

On the other hand, during the period 1970 - 2000, the Algerian-Tunisian Sahara has formed the subject of several academic studies relating to hydrogeology (Ben Dhia, 1985; and A. Mamou, 1990) and to isotopic hydrochemistry (Gonfiantini et al, 1974 & 1976; and Yousfi, 1984; Guendouz, 1985; and Zouari, 1988). Several other studies, of a local nature, have also been used. The whole set of these studies (see full list in bibliography attached) has provided clarifications with regard to the climate system of the region, the geology of the Saharan sub-spetroleum and the operation of the aquifers.

1.2- Collection and synthesis of geological and hydrogeological data in the framework of the SASS project

The SASS project is a phase of synthesis and updating of the information collected on the hydrogeology of the Saharan basin. This phase has led to an improvement of the geological knowledge of the basin as a whole and, more precisely, at the level of the sub-basin of the Grand Erg Occidental, the Tunisian outlet and of Hamada El Hamra. This improvement results from the data obtaining from the new wells drilled in these zones, as well as from the recently made geological syntheses.

From a hydrogeological point of view, the new information has come for the first time to cover a period of 50 years (1950-2000), with a record of the piezometry, water salinity and exploitation. This has been complemented by several pumping tests and chemical and isotopic analyses of the water of the various aquifers of the Saharan basin.

This body of geological and hydrogeological data is the fullest and most reliable possible. It represents an asset that has never been available before to cover such a large geographic space and extend over such a long monitoring period.

The new hydrogeological data, with respect to those that were available at the time of the major syntheses of the 1970s and 1980s, are obtained from the three countries **concerned.**

They have been collected by the administrations in charge of water resources in these countries which have made them available to the project.

The hydrogeological data thus collected involve the geological structure, particularly in Libya, the piezometry, the abstractions, the water geo-chemistry and the hydrodynamic characteristics of the aquifers. These data have required preliminary processing (checking and ACCESS tabulation) for purposes of their integration within the data base and their homogenisation. They have, afterwards, been processed by the national and project teams, for purposes of their validation, the reconstruction of their records and their time and space classification according to the model requirements.

Following the collection and arrangement under the data base format, the hydrogeological data collected in the three countries were exchanged several times between the project team and the national teams in order to be checked, validated and corrected, if need be, as well as to be complemented by new data. These data were also revised during the development of the model.

After they had been processed, validated and entered in the data base, these data were directly used by the model via the classification and inquiry (interrogation) interfaces implemented by the project. The structure of the data base called "SAGESSE" (Système d'Aide à la Gestion des Eaux du Sahara Septentrional) is described in detail in the document entitled "Volume 3: Data Base and GIS". In brief, the latter includes the following tables:

- a **"Points"** table comprising the data relating to the identification and location of the water points, as well as their hydrogeological characteristics at the time of construction of the water point;
- an **"Exploitation"** table comprising the exploitation data generated by the previous studies and the inventories, after their verification, validation and interpolation from 1950 to 2000;
- a **"Piezometry"** table comprising piezometric data deriving from the previous studies and the inventories, after their verification;
- a **"Quality"** table comprising the data relating to dry residue and to chemical contents, as deriving from the previous studies and the inventories, after their verification and validation;
- a "Geology" table comprising the lithological description, the thickness and the height of the top of the formations encountered in the water wells and petroleum wells;
- **a "Hydrodynamics"** table comprising the data relating to transmissivity and to storage coefficient, as deriving from the flow tests.

Table 1 below shows the current contents of the data base as per table and as per country.

Table 1 – Contents of the data base

	Number of water points			
	Algeria	**Tunisia**	**Libya**	**Total**
Points	6108	1159	847	8114
Exploitation	2905	894	36	3835
Piezometry	2135	452	297	2884
Quality	1091	365	236	1692
Geology	82	7	43	132
Hydrodynamics	4176	240	353	4769

1.3- Spatial distribution of data

The number of water wells tapping the two major aquifers of the Saharan basin was fairly small before 1950, and most of these wells were located in the Algerian Sahara and, to a lesser extent, in Tunisia (Nefzaoua and Djerid). In the early 1970s, this number was about 1646 wells, most of which tapping the TC aquifer (1398 wells). Since the mid-70s, the number of new wells has constantly been on the increase so that, by the year 2000, there were over 8000 water points.

Thus, we can notice the increase in the number of water points taken into consideration in this study by comparison with the previous situations. Besides, it is worth pointing out that the data used is more exhaustive, updated and covers the whole period of monitoring the aquifer system which extends from 1950 to 2000. This new situation was, as it turned out, the reason for the decision to establish a hydrogeological data base.

1.3.1. Algerian data

The summary statement of the water points of the Saharan basin located in Algerian territory indicates, in 2001, a total 6108 water points (Figure N° 1), distributed as follows:

Table 2 – Algerian data

Aquifer	Foggaras	Groups of foggaras	Pumped wells	Artesian wells	Petroleum wells	Springs	Piezometers ([1])	Total water points
Continental Intercalaire	701	176	1257	214	33		2	2383
Complexe Terminal			3415	156	87	66	1	3725
Total	701	176	4672	370	120	66	3	6108

Considerable effort has been made by the team of the National Agency for Water Resources (ANRH) in order to better identify the water points and complement their data with the updating of the inventory of the foggaras, the revision of the situation of the water wells and the petroleum wells, and the increase of the data relevant to the various fields of the data base.

The development of the records of the abstractions from the aquifer resources, for the period 1950-2000, has been conducted in collaboration between the SASS/OSS team (for the period 1950-1981) and the ANRH team (for the period 1982-2000). The record of the abstractions during the period 1950-1981 has consisted in revising the ERESS data (1972) and the RAB 80/011 data (1983) from a perspective of verification and filling of gaps (especially for the RAB data). The ANRH team has mainly carried out an analysis of the various inventories with a view to bringing out the evolution of the exploitation of the old water wells and complementing it with that of the newly drilled wells.

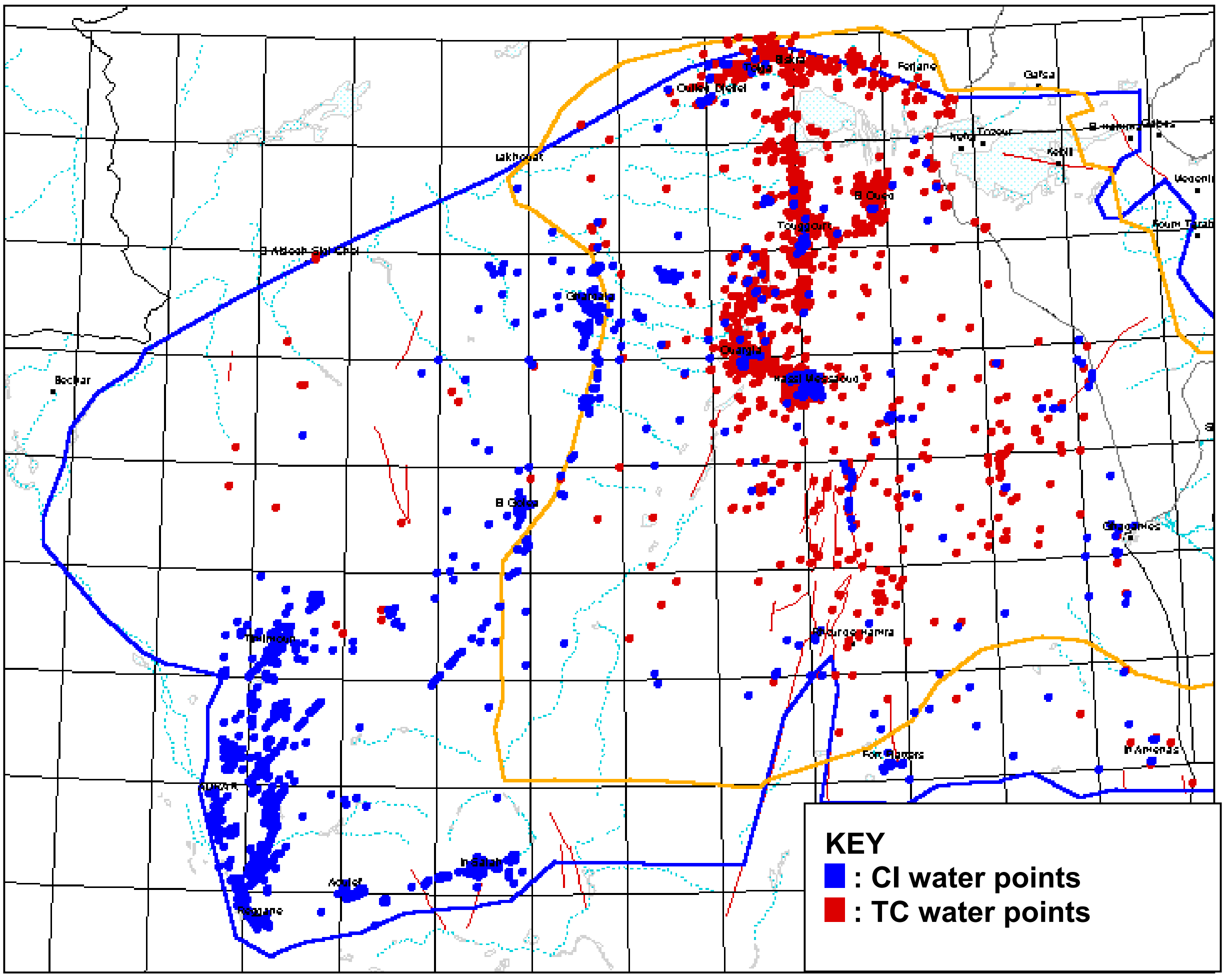
In view of the discontinuous nature of the measurements over time, moving from the located flow values to the volumes exploited at year level has required hypotheses on the duration of daily pumping, the duration of exploitation per year, the decrease in artesianism and the evolution of the flow of the foggaras. These hypotheses (which are detailed in Annexes 4 and 5, relating to the water abstractions from the aquifers of the Saharan system) have been adopted with reference to the results of the surveys conducted at the time of making the inventories.

The validation of the volumes abstracted from the two aquifers has required several exchanges of points of view between the SASS/OSS teams and ANRH teams, together with a comparison with the analysis carried out on these data by BRL (1997), before reaching the

[1] *(*) Several wells are actually used for the monitoring though not declared as piezometers.*

final situation which has been adopted for the simulation of the transitory system (1950-2000 period) on the model.

Figure N° 1: Map of the CI and TC water points in Algeria



Key :

: **Boundary of the Continental Intercalaire**

: **Boundary of the Complexe Terminal**

1.3.2. Tunisian data

The number of water points collected at the level of the Tunisian part of the Saharan basin amounts to 1159, distributed as indicated in Table 3 below.

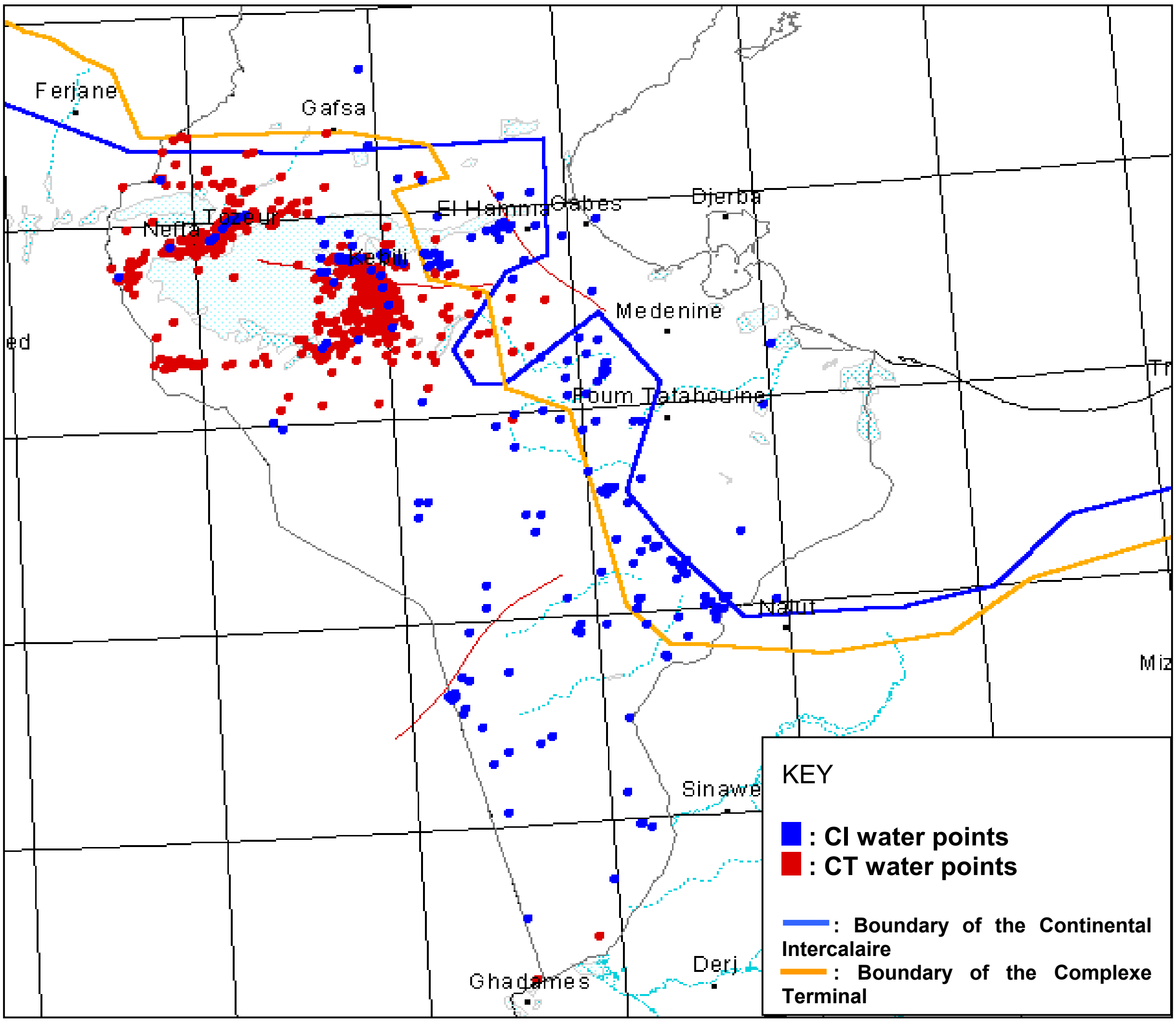
Table 3 – Tunisian data

Aquifer	Pumped wells	Artesian wells	Petroleum wells	Springs	Piezometers (*)	Total water points
Continental Intercalaire	**138**	**98**	**4**	**10**	**6**	256
Complexe Terminal	**512**	**312**		**62**	**17**	903
Total	650	410	4	72	23	1159

(*) Several wells are actually used for the monitoring though not declared as piezometers.

The inventory of the water points of the Tunisian part is almost complete and reveals efficient monitoring and controlled management of the water points files. (Figure N° 2)

Figure n° 2 : Map of the CI and CT water points in Tunisia



1.3.3. Libyan data

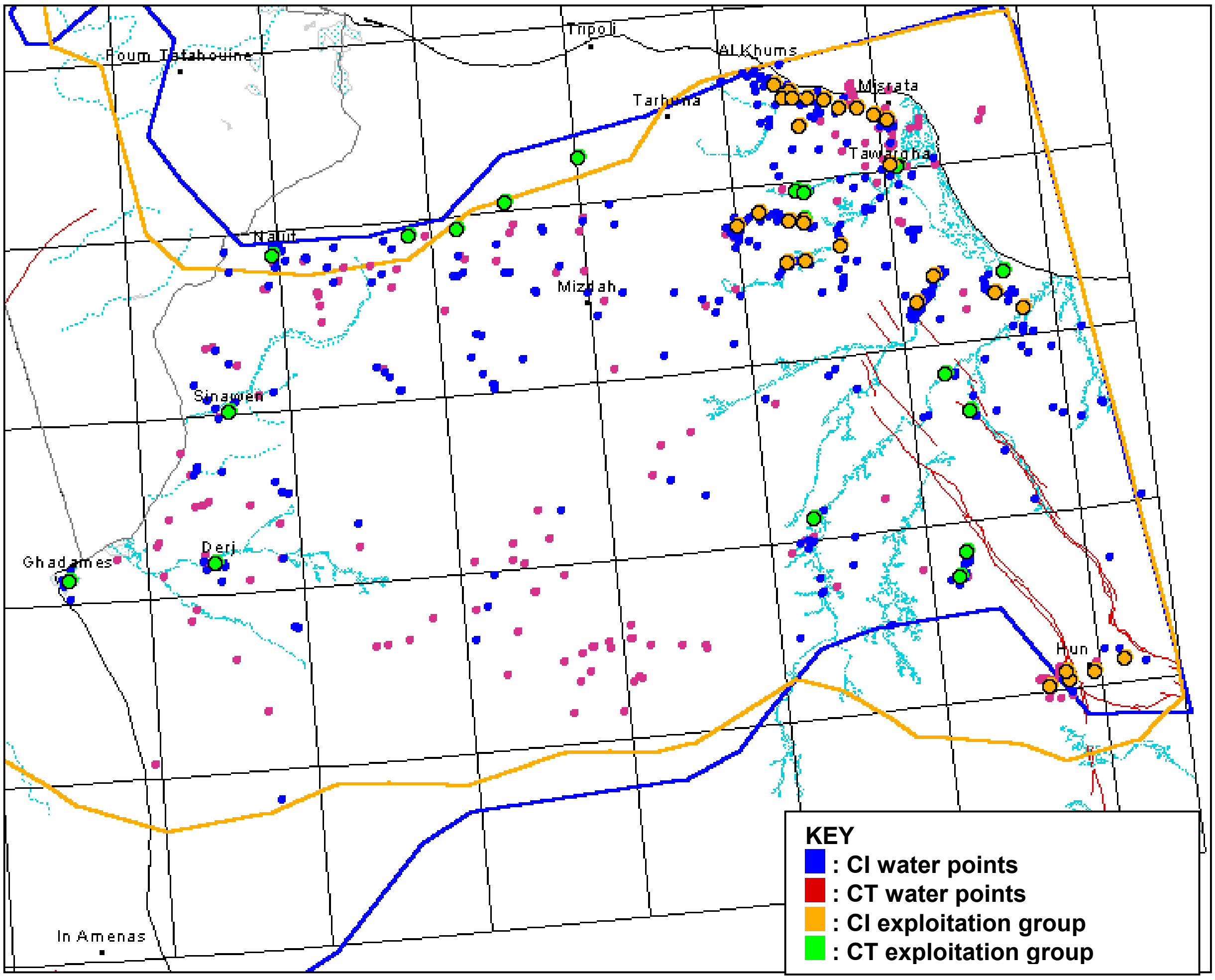
The water points files provided by GWA (General Water Authority) did not include, at the beginning, any specification of the aquifer, nor of the geographical region. They all appeared under the form of artesian wells and pumped wells. The Libyan team largely contributed, afterwards, in improving the quality of the information. However, this still did not make it possible to distinguish, for example, whether the water points served for drinking water supply to a town, or for the irrigation of a farming project. In such a case, the exploitation system has been entered in the base under "group" form. This method has in particular been applied for establishing the record of the abstractions. For the reconstruction of the piezometric, exploitation and salinity records, as well as for making up the "Geology" table of the data base, the project team has undertaken an analysis of the previous studies in order to obtain the relevant data; it has also drawn upon recent surveys conducted by the Libyan technicians of GWA.

The number of Libyan water points entered in the data base is 847 (Figure N° 3), distributed as indicated in Table 4 below.

Table 4 – Libyan data

Aquifer	Pumped wells	Artesian wells	Springs	Groups	Piezometers	Total water points
Continental Intercalaire	421	56	1	22		500
Complexe Terminal	307	3	1	19	1	331
Turonian (Nalut)	16					16
Total	744	59	2	41	1	847

Figure n° 3 : Map of CI and CT water points in Libya



The whole set of these studies shows that the Saharan basin stands out by its large expanse, its geological structure and its current climate, apart from classical hydrogeographic entities. It thus constitutes an aquifer system whose hydrogeological balance should be considered in terms of its natural boundaries and over a fairly extended time period in order to account for all the effects that take place in it.

From a structural point of view, the three sub-basins of the Grand Erg Occidental, of the Grand Erg Oriental and of Hamada El Hamra correspond to hydrographic entities which do not always reflect the structural configuration of the aquifers. Horizontal and vertical discontinuities are complex in the three sub-basins and are the outcome of a long geological evolution characterized by notable changes in sedimentation conditions, an orogenic evolution that is highly influenced by the closeness of the Saharan cratons (Hoggar, Hassawna, Dahar) and the southern Atlas fault.

From a hydrogeological point of view, this basin is a multi-layer system whose hydrodynamic operation is highly influenced by the state of the aquifers (confined, semi-confined and unconfined), the size of the outcrops (recharge) and the extent of the outlets (flow of natural outlets and abstractions). The constitution of the water reserves of this system has taken place over a long period of time during which the climatic conditions were more favourable than those prevailing at present. The exploitation of this system has recently experienced a marked acceleration. Its reactions are those of a system that is under considerable demand, a pressure that induces a discharge and a storage of geological reserves.

Information about the North-Western Sahara aquifers has improved considerably throughout the duration of the project. The body of information collected for the development of the models is currently available in the three countries. It is, however, in need of being constantly maintained by the addition of new data and can, thus, constitute a solid base for support to decision-making within the framework of "consultation" between the three countries for purposes of the management of the basin's water resources.

This body of information relates to the various aspects leading to a better evaluation, by means of modelling, of the behaviour of the aquifers in reaction to the intensification of exploitation. A substantial contribution relates to the geometry of the aquifers under the form of geological data on petroleum wells and hydrogeological data. The records of the exploitation of piezometry and of water salinity cover the period from 1950 to 2000, which was not available before.

2- THE NORTH-WESTERN SAHARA AQUIFER FORMATIONS

2.1- Lithostratigraphic columns in the three countries (identification of aquifer formations)

The North-Western Sahara basin is a fairly extended geographical entity (with an area of about 1000.000 km2). From an orographic point of view, this entity is flanked along its boundaries by reliefs which consist mainly in mountain chains (Saharan Atlas) and plateaux (Dahar, Tademaït, Tnirhert, etc . . .). With a relatively little dense and half fossilized hydrographic network, this basin stands out as a structure made up of three sub-sets which are the Grand Erg Occidental, the Grand Erg Oriental and the plateau of Hamada El Hamra. The first two sub-sets are depressions with endoreic flow into closed depressions which are “sebkhas and chotts”. The plateau of Hamada El Hamra is a slightly sloping reg.

It has proved necessary to add, in the context of the present study, a geological description which did not exist in the previous studies. In fact, this aspect results from the compilation of a significant number of specific studies and of data relating to petroleum wells. The body of knowledge which has thus been generated on the geology of Saharan zones makes it possible to attempt a synthesis with a view to schematising the structure of the North-Western Sahara basin.

In this synthesis analysis of the stratigraphy of the layers of the Saharan basin, we have deliberately chosen to limit our consideration to the horizons described in the petroleum wells that have crossed them and which are likely to belong in the aquifer layers or in those which border such layers.

2.1.1. Algeria

In Algerian Sahara, the works of G. Busson (1963, 1967 and 1970) and of J. Fabre (1976) constitute basic references for a proper understanding of the geology of the Algerian Sahara. However, complementary information needs to be sought in the various geological maps which have covered this region. The stratigraphic description of the formations influencing the aquifers of this zone is limited at the Trias base.

- **The Trias** presents a large variation of facies and thicknesses (Busson, G., 1970). The Trias is divided into major distinct lithological units which, from bottom to top, are as follows:
    - The clayey-sandy lower Trias (Nezla sandstone);
    - The carbonated Trias;
    - The clayey-sandy upper Trias (Tartrat sandstone);
    - The clayey Trias;
    - The saline Trias.

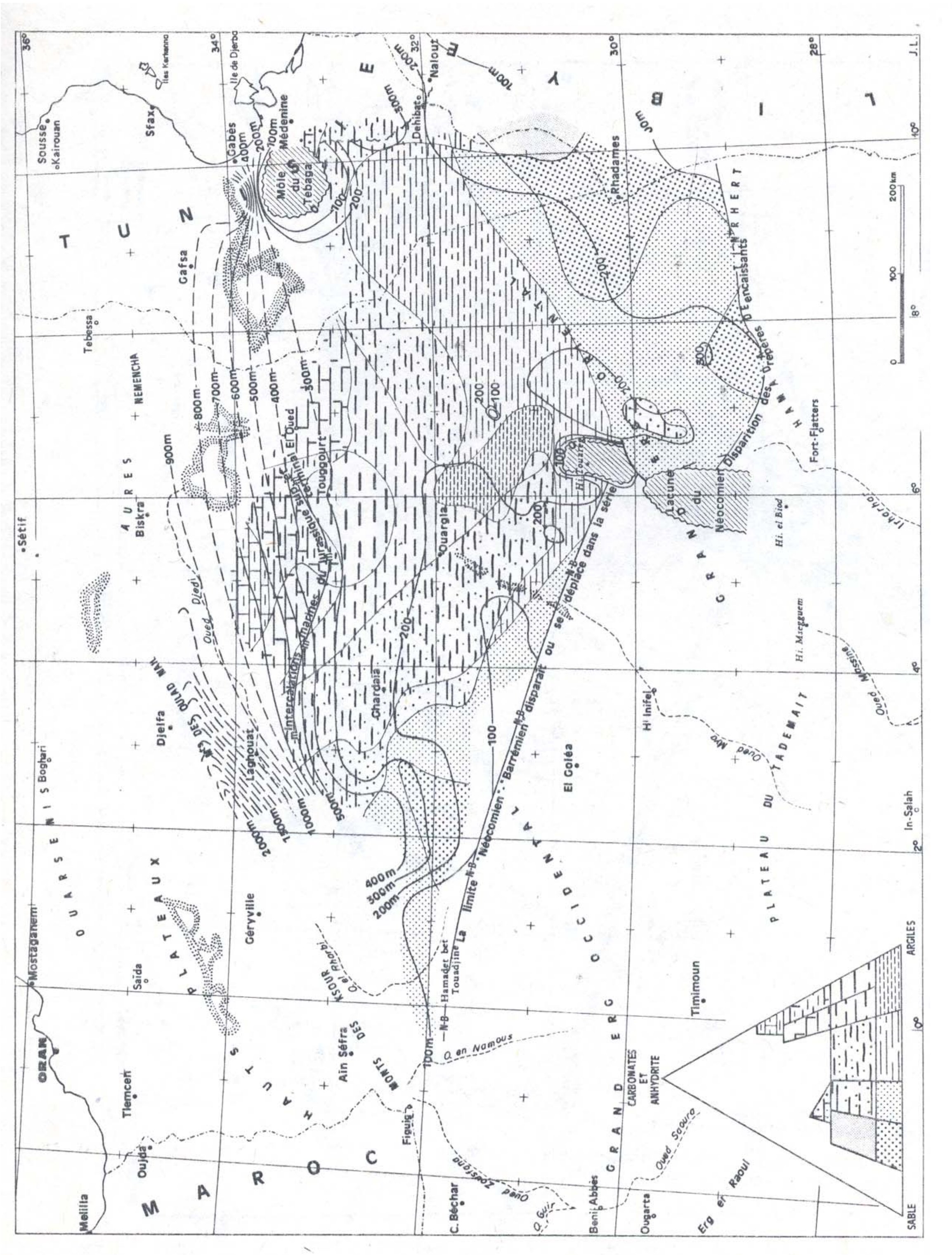
The thickness of these various formations is quite variable, mainly in zones where diapiric salty banks are interbedded (Rhourde El Baguel). The thickness of the clayey-sandy lower Trias increases in a north-eastern direction (150-180 m). It decreases in the shallows (Hassi Messaoud, G. El Baguel). The saline Trias presents a large thickness (to the North-East of Ghadames: 700 m and H. Messaoud: 1300 m). The Trias does not play any part in the hydrogeology of the Algerian Saharan basin.

- **The Lower and Middle Jurassic** (Lias-Dogger) comprises for the major part lagoon layers consisting of salt, anhydrite and clays which, subsequently, become of a marine nature and appear under the form of limestone and clays with anhydrite banks. The Jurassic encroachment covers the whole basin of the Eastern Grand Erg and the Jurassic series are thick in this location.

The Jurassic is characterized by a relative permanence of the marine sedimentation with confined environment sediments. In the western part of the basin, the marine deposits show a certain recession similar to what takes place further east and south (Figure N° 4).

The transition from the Jurassic to the Lower Cretaceous is characterized by earth deposits whose origin is generated by the feeder reliefs (recharge outcrops) situated south of the Saharan basin (Hoggar).

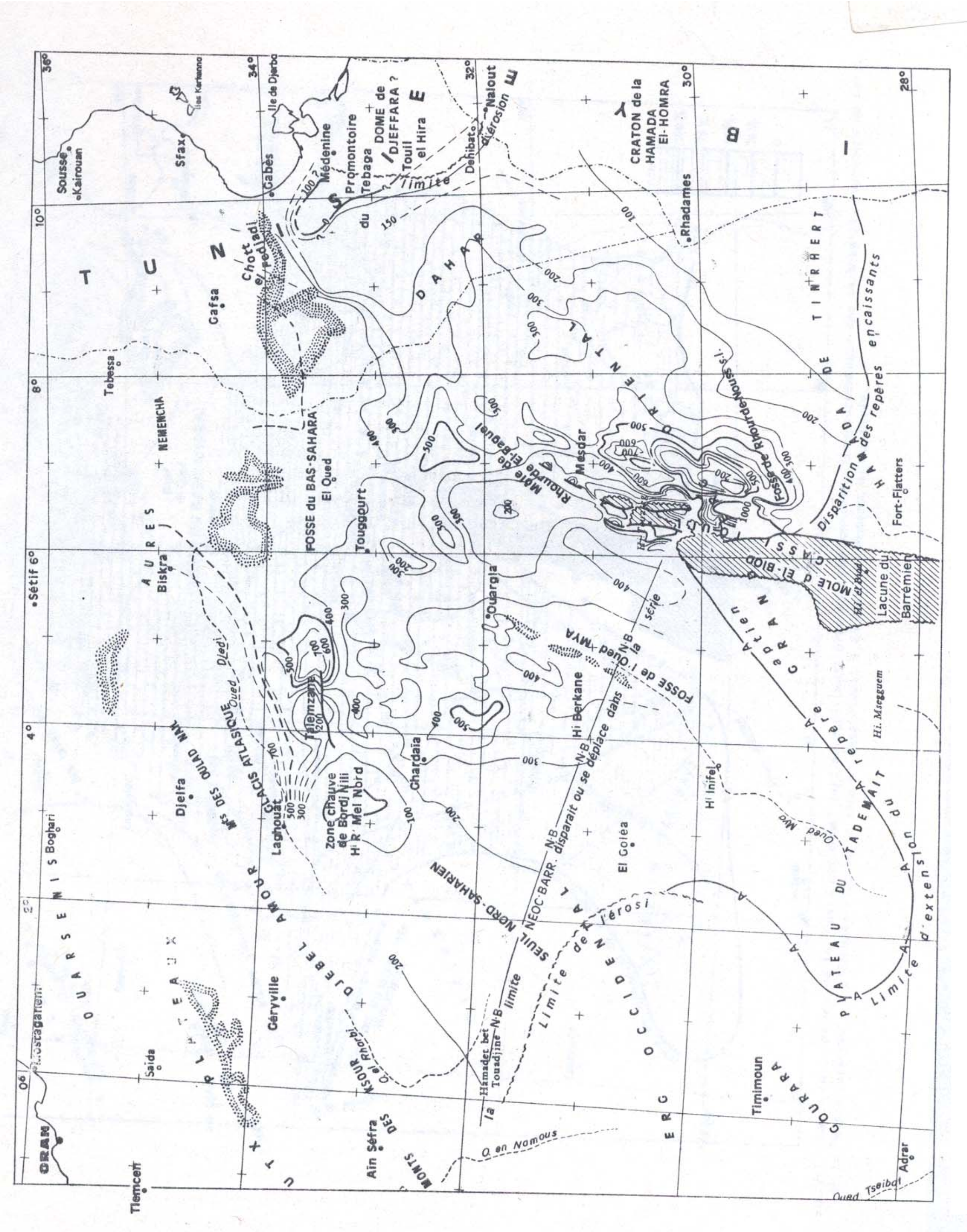
Figure N° 4: Map of the Upper Jurassic – Neocomian of the Saharan platform (Algerian-Tunisian basin) with 100 m equidistance isopaques and sketchy and simplified representation of the facies (G. Busson, 1970)



- **The Lower Cretaceous** consists of azoic earth continental layers which contrast both in lithological and sedimentary aspects with the marine formations of the Upper Jurassic. The Lower Cretaceous comprises, starting from the most ancient formations:

- *The Neocomian*, which comprises, in the Lower-Sahara, green and red clays with sizeable anhydrite banks deposited at base. They are overlaid by an alternation of dolomites and clays. In the Hassi Rmel region, we find mainly clays and sands with a few layers of lignite and few carbonated banks. This lateral facies evolution becomes more marked in an eastern direction in Mzab and in the north east of the Grand Erg Occidental, as well as towards the centre and the south of the basin where the equivalent of the Neocomian merges into a clayey-sandy transition set between the Jurassic and the Lower Cretaceous.
- *The Barremian* is the era that witnessed a generalised spreading of the detritic formations of the Lower Cretaceous down to the Lower-Sahara. These formations appear under the form of fine or coarse sandstones and of clays apparently originating in the South (Hoggar). In the region of Touggourt, the wells have crossed arkostic sandstones. The carbonated banks are very few and concentrated to the north east of the Algerian Sahara, in the region of the daïas and north of Mzab. On the whole, the Barremian corresponds to a sedimentation in river and lacustrine continental environment over most of the Lower-Sahara. On the north-eastern side, this sedimentation is mixed, deltaic, with a few marine influences. The thickness of the sediments varied notably from one location to another. It is considerable in the subsidence zones of the Lower-Sahara (Laghoua: 800-1100 m), while it is small on the uplifts (El Abiod, Gassi Touil, Rh. El Baguel: 100-300 m) and in the eastern and south-eastern border zones (Figure N° 5).
- *The Aptian* is a good lithological marker in the wells. It is represented in the larger part of the Lower-Sahara, at a thickness of 20 to 30 m on overage, by dolomites alternating with anhydrite, clay and lignite beds (lagoon sediments). This Aptian dolomitic bar shifts laterally towards the south into red and sandy clays, and towards the north into grey, green and beige clays. The sandstone formations of the Aptian are located along the boundaries of the basin. At the Atlas outskirts and towards the Tunisian south, Aptian dolomites shift, laterally over a short distance, into orbitoline and algae laden limestone. On the whole, the Aptian is characterised, in the Algerian Sahara, by a very high homogeneity of facies and thickness. It seems to coincide with a slackening of earth deposits and of subsidence. This is an era of stability of the platform.
- *The Albian* is characterized by a massive resumption of earth sedimentation. This stage groups the mass of sands and clays comprised between the Aptian bar and the underlying clayey horizon ascribed to the Cenomanian. The sandstone Albian is composed of very fine sandstone with a few carbonated intercalations. Towards the borders of the basin (Tinrhert and Tademaït), the sediments become more coarse in structure.

Figure n° 5 : Isopaque map of the Barremian of the Saharan platform (Algerian-Tunisian basin). Equidistance 100 m. (G. Busson, 1970)



- **The Upper Cretaceous** consists mainly in limestone and dolomitic marine layers. It is, for the major part, composed of:

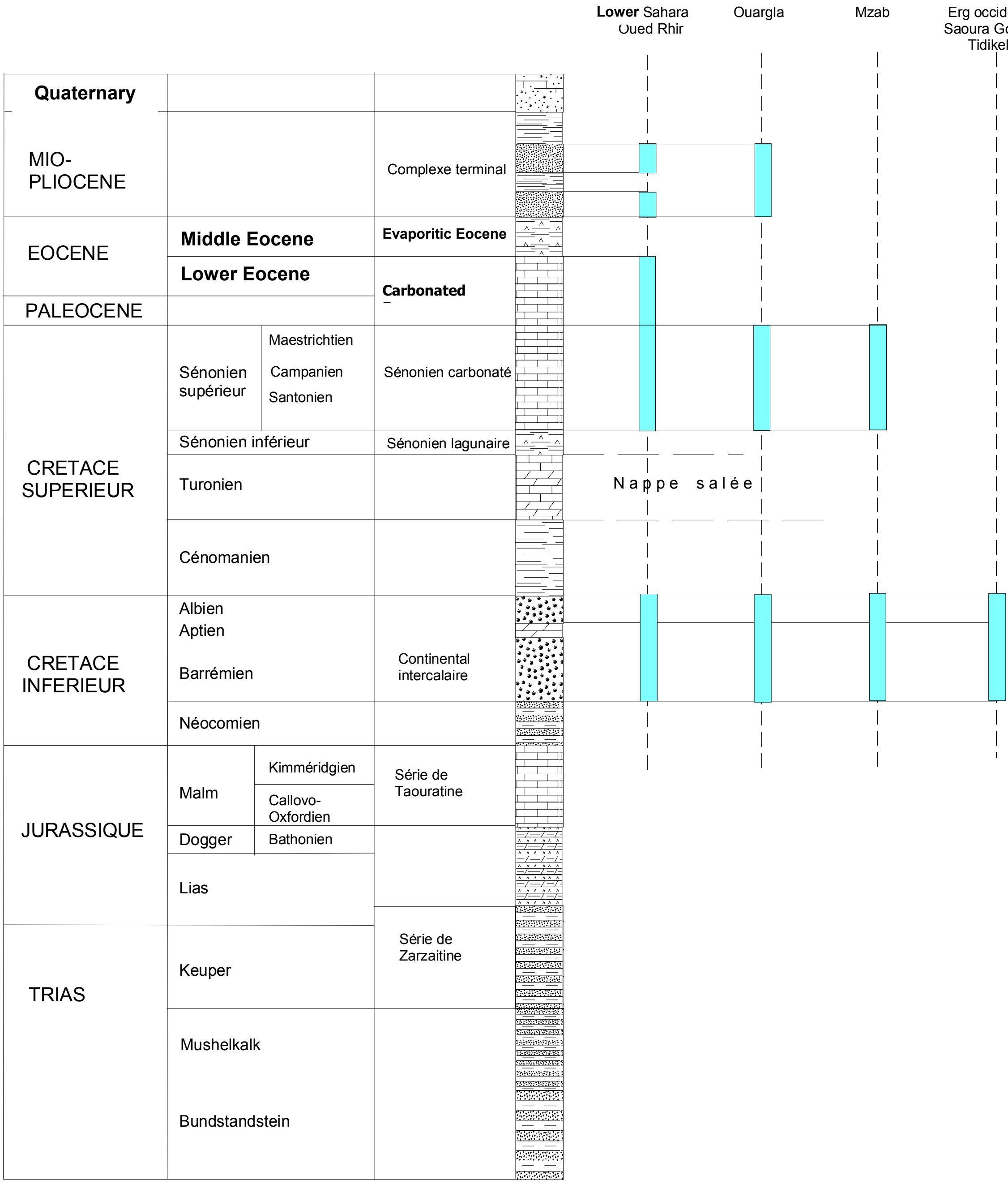
➢ The clayey *Cenomanian* in the Tinrhert and Lower-Sahara. The Upper Cenomanian and the Turonian are of a sandstone structure. These formations contain, for the major part, saline water;

- The *Lower Senonian* with lagoon sedimentation is characterized by clayey and salty formations with anhydrite and rock salt;
- The *Carbonated Senonian* composed of sandstones and dolomites, with a few clayey alternations. This formation terminates with the sandstone sedimentation of the Maestrichtian which continues into the Eocene that constitutes the last marine episode of the Algerian Sahara.

- **The Tertiary Continental** of the Sahara may be fairly thick (150 m). it appears under the form of a sandy and clayey facies with gypsum. In the Lower-Sahara, lacustrine sedimentation appears under the form of sandy and clayey series known as the Continental Terminal whose thickness may be found to reach, in the region of the Tunisian-Algerian chotts, a few hundred metres. One distinguishes here, in the region of Oued Rhir, two aquifer levels within the sands which are separated by a clayey layer in the middle (first and second aquifers of Oued Rhir). The whole set is overlaid by the clayey-sandy and gypseous Plio-Quaternary which originates from sedimentation in lacustrine environment during the phase of drying up of the Chotts lagoons.

Summary: The sketch proposed in Figure 6 sums up and illustrates the description of the geological formations and their hydrogeological significance.

Figure n° 6 – Geological formations and aquifers of the Algerian Saharan basin



In the Algerian Sahara, the Secondary, Tertiary and Quaternary layers present an increase in thickness in the depression of the sub-basin of the Grand Erg Oriental and a more reduced or zero thickness (for the Complexe Terminal) in the sub-basin of the Grand Erg Occidental. These outcropping formations along the southern boundaries of the basin (Tadmaït and Tinrhert plateaux) are of considerable depth in the vicinity of the south Atlas flexure.

This structure is favourable for the presence of multi-layer, and often confined, aquifers in the major sedimentation troughs.

2.1.2. Tunisia

In Tunisia, the most ancient formations of interest from a hydrogeological point of view originate at the Upper Jurassic. The Upper Triassic and the Lower Jurassic are evaporitic and salty and form a strong impervious screen between the Upper Jurassic and the Lower Triassic. The considerable depths which it would be necessary to reach in order to collect the sandstone Triassic do not make of it, in any case, a very attractive objective.

- **The Upper Jurassic – Lower Cretaceous** is characterized by a long episode of continental sedimentation, incepted in certain zones at the end of the Upper Jurassic and cut across by rapid marine incursions of which the dolomitic bar which we encounter almost everywhere in the Saharan domain. Above the Aptian bar, the Albian does not present any detritic facies, except in the south. Closer to the north-eastern border and the depression of the chotts, the Albian is the seat of a marine sedimentation with a predominance of clays and carbonates. The detritic series constitutes an aquifer set corresponding to the Algerian Continental Intercalaire.
- **The Upper Cretaceous** corresponds to a marine sedimentary cycle which is characterized by the alternation of dolomitic, sandstone and clayey-marly formations with, at times, gypsum and anhydrite.
    - ➢ In the Cenomanian, the sea covered a large part of the Tunisian south. The Dahar uplift, which had emerged since the Upper Jurassic, was again covered by the sea. Cenomanian vegetation comprises mainly a limestone and dolomitic episode at base, marl and marly alternations in the middle, and then again limestone and dolomites on top;
    - ➢ The Turonian of the Tunisian south is quite homogeneous with its dolomitic facies which keeps, over the whole far southern region, a thickness in the range of 80 to 100 m. This formation is of a hydrogeological interest as an aquifer in the Nefzaoua zone;
    - ➢ The Senonian stands out in two facies:

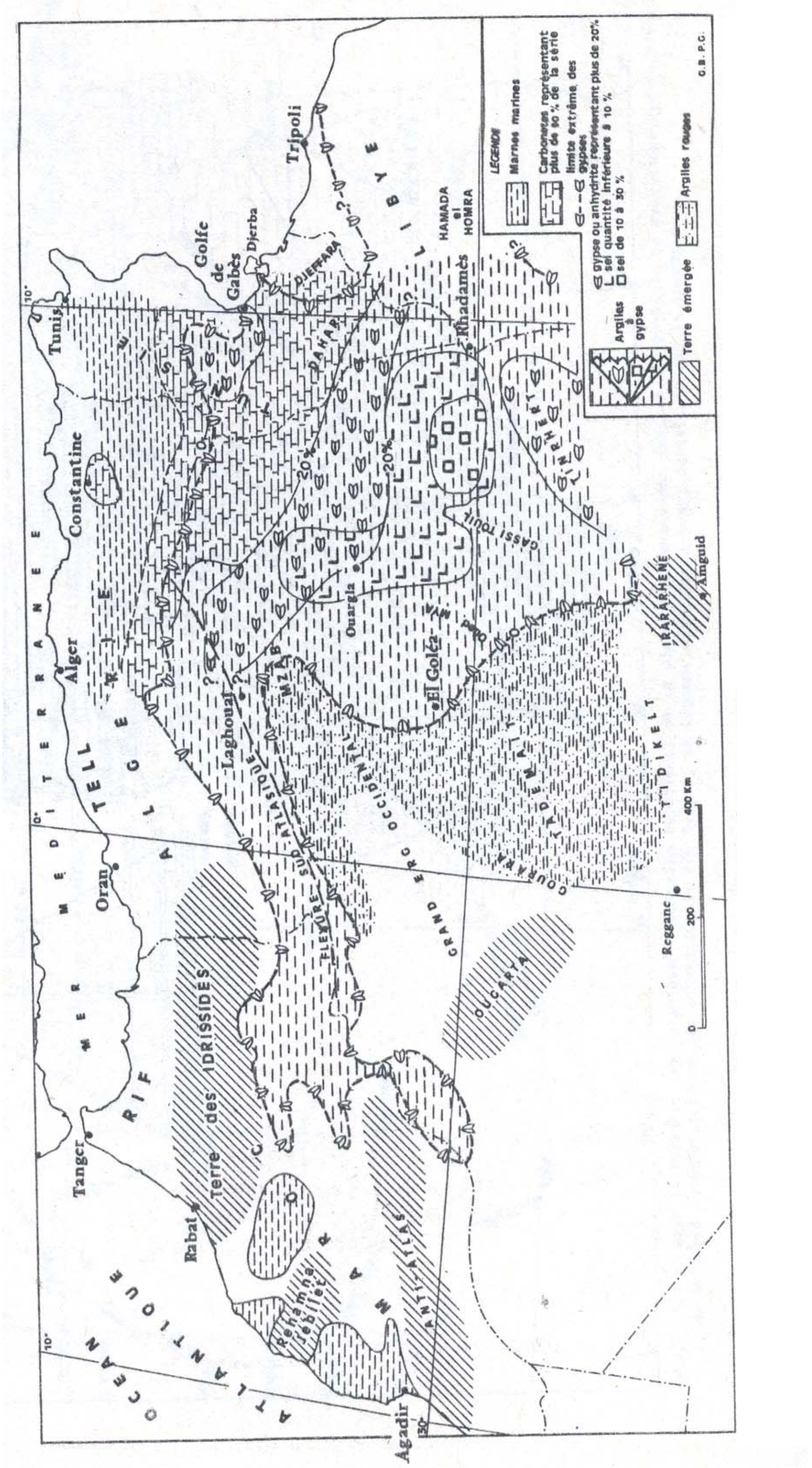
- a lagoon Senonian at the base, which is hardly permeable, if at all;
- a carbonated Senonian at the top, which is aquiferous in the Nefzaoua and Djerid.

Evaporitic sedimentation (anhydrite and gypsum) is fairly developed during the Cenomanian and the lagoon Senonian (Figure N° 7). It corresponds to that of the evaporitic Triassic and the Lower Jurassic, and is indicative of changes in the climatic conditions which are, subsequently, reflected in the passage from the marine environment to the continental environment.

- **The Palaeocene – Eocene** plays a small part in the hydrogeology of the Tunisian Saharan basin. It outcrops between the Gafsa chain and the chain of the Chotts, and comprises mainly:

- ➢ A clayey-marly series at the base, known as the El Haria formation;
- ➢ A sandstone series at the top of the Metlaoui formation which equally appears under an evaporitic facies on the southern flank of the chain of the chotts, with massive gypsum banks.

Figure N° 7: Schematic map of the Cenomanian facies (Cenomanian p.p. max. in part of Saharan regions) of the north east of the Saharan platform and of Berberland (G. Busson, 1970)



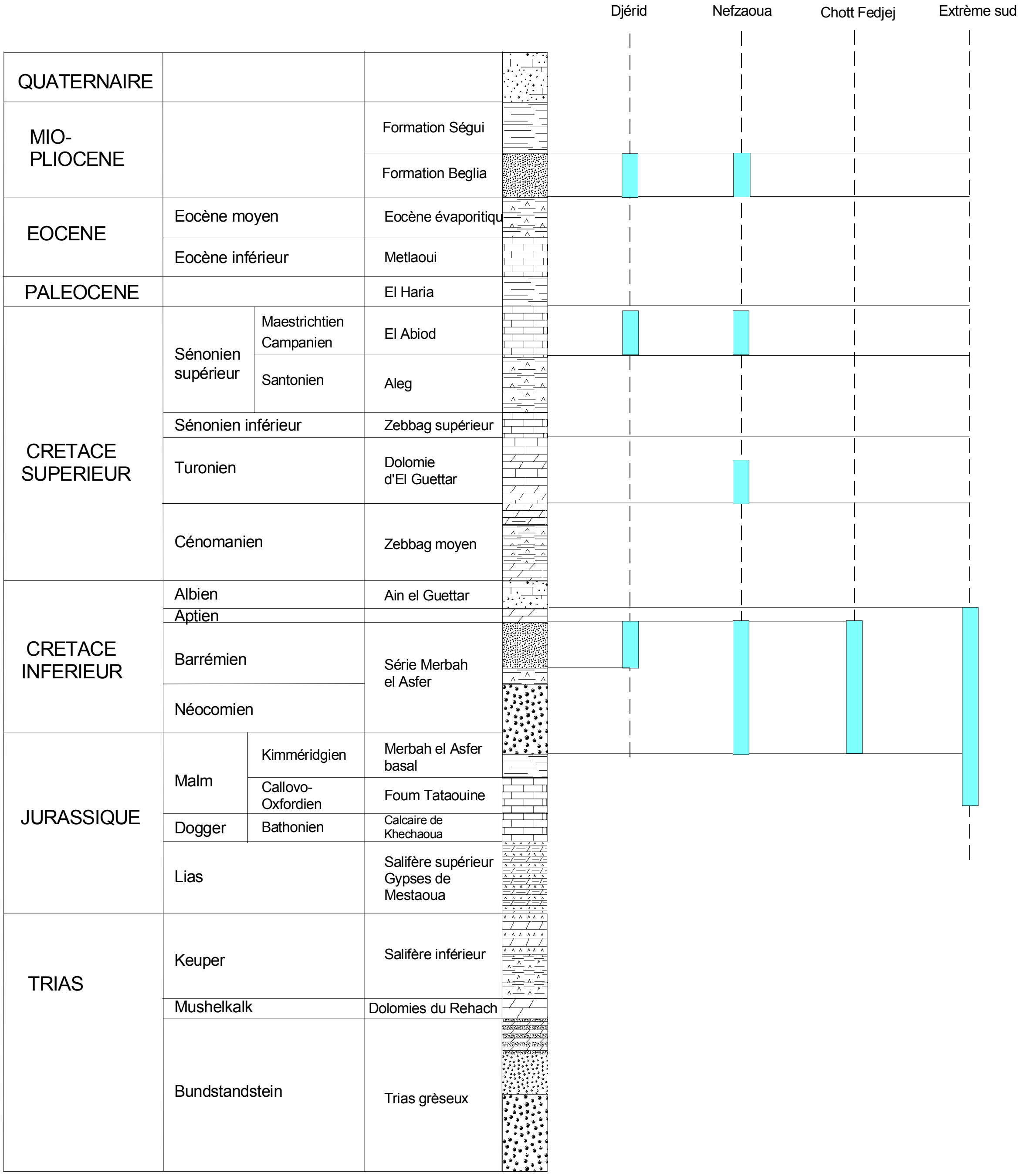
- **The** Miocene is present in the Nefzaoua and the Djerid and presents mainly two facies:
  - The Beglia formation ascribed to the Pontian and composed of sands with clayey transitions. It forms an aquifer that is largely exploited in the whole north of the Tunisian Saharan basin;
  - The Ségui formation which is composed of sandy clays, with conglomeratic levels in the upper part.
- **The Quaternary** of the region of the Chotts corresponds to a terminal episode of the Ségui formation. This is a lagoon and conglomeratic facies that is largely dominated by clays.

In the Tunisian South, the depression of the Chotts has been, since the beginning of the Secondary, a subsidence zone with thick sedimentary series. The Dahar and the far Tunisian south are, on the other hand, zones with a positive tendency presenting less thick series. The sedimentation gaps for the transition from the Lower Cretaceous (sands, sandstone and clays) to the Upper Cretaceous (carbonates, marls and clays), and from the Senonian-Eocene to the Miocene (detritic continental series), account for the subdivision of this sedimentary set into continental cycles and marine cycles.

This structure which appears under the form of a depression largely shaped by tectonic evolution has favoured the presence of a multi-layer aquifer system within which it becomes difficult at times to distinguish the various aquifer levels.

- **Summary:** The sketch proposed in Figure 8 illustrates the description of the geological formations and their hydrogeological significance.

Figure n° 8 – Geological formations and aquifers of the Tunisian south



2.1.3. Libya

Beginning with the most ancient, the formations present in the sub-soil of the Libyan Saharan basin and playing a role in the hydrogeology of the Saharan basin are as follows:

- **The Palaeozoic** only outcrops alongside the southern boundary and is an extension of the Algerian outcrops. The Palaeozoic formations constitute a synclinal depression with over 3500 m in depth under Hamada El Hamra. Only the Cambro-Ordovician composed of sandstone and of quartzites has a role in the hydrogeology of the basin as an unconfined aquifer in direct contact with the formation of the Lower Cretaceous in Jabal Hassawna and immediately to the north of the latter. This sandstone

Cambro-Ordovician re-emerges at the location of the horst of Tawurgha where it is collected by a series of deep wells supplying a fairly soft water. Under the Hamada, the Palaeozoic composed of Silurian, Devonian and carboniferous formations, which are generally impervious or containing salty water, constitutes the bedrock of the Mesozoic layers.

- **The Triassic** presents several facies which vary from one sector to the other:

❑ *To the north and in the southern part of the Jifarah*

The Triassic is divided into several formations some of which having a particular importance in the hydrogeology of the northern part of the basin.

The less impervious permeable red sandstones Ouled Chebbi;

➢ The sandstones of Ras Hamia which are often clayey and which alternate frequently with red or green clay layers. The Ras Hamia formation is generally considered as an aquifer of medium to poor quality whose thickness ranges from a few ten metres to a few hundred metres;

➢ The dolomitic limestone of Aziziya formation which is quite fractured in the south of the Jifarah where it constitutes a good aquifer. In the north-west of the Saharan basin, the dolomitic limestone of Aziziyah are still present before they disappear under the Hamada where they are eroded;

➢ The clayey sandstones and clays of Abu Shaybah formation which are generally little permeable in the Saharan basin.

❑ *In the centre and in the south-west*

The Triassic presents a continental facies (Zarzaïtine) and merges with the similar formations of the Jurassic where they exist. This is, on the whole, a soft water aquifer. To the South-West, the continental Triassic outcrops and rests directly on the Palaeozoic formations.

❑ *In the south-east*

The Triassic is eroded and the Cretaceous rests directly on the Palaeozoic.

- **The Jurassic** comprises, at the base, a strong evaporitic series (gypsum, anhydrite) presenting dolomitic intercalations. This series, corresponding to the Bu Ghaylan and Abreghs formations is quite developed in the north west, in the zone of Sinawan-Nalut, where it reaches 500 to 600 m in thickness and thus constitutes an impermeable formation which isolates completely the Cretaceous aquifers from the Triassic aquifers. This series is almost totally absent in the remaining part of the basin where the Jurassic is represented:

➢ by the marly limestone of the Tiji Group to the North-West between Jabal Nefusah and the scarps which constitute the northern boundary of the Hamada. This series is little permeable and complements the hydraulic isolation of the Lower Cretaceous (Kiklah) with respect to the Triassic aquifers;

➢ a continental series which, at times, merges with the Lower Cretaceous but remains still isolated from the sandstone Triassic in the north-eastern and western part of the Hamada and to the south of Ghadames. Throughout a zone which runs across the Hamada from south west to north east, this continental series merges into a sand – sandstone unit of indifferenciated age ranging from Triassic to Lower Cretaceous, which may be assimilated to the Nubian sandstones of the south-east of Libya and to the post-Tassilian continental series of the Murzuq basin.

- **The Lower Cretaceous** presents a notably constant facies throughout the whole Libyan Saharan basin of continental sandstone which, in Libya, bears the name of

"Kiklah formation" and which constitutes the best freshwater aquifer of the basin, joining the same aquifer formations of the same age in Tunisia and Algeria, and even in Egypt. In fact, the Cenomanian encroachment from the North had gradually invaded the whole basin up to the 29th parallel in such a way that, to the south, continental sedimentation had prevailed for a large part of the Lower Cenomanian. Accordingly, the top of the Kiklah formation, which is generally ascribed to the Albian, dates back in the stratigraphic scale up to the wall of the Upper Cenomanian in the southern part of the domain. In the north, in the Misratah-Tawurgha zone, the Lower Cretaceous takes up a dolomitic and marly-dolomitic facies in continuity with the carbonated facies of the Upper Cretaceous.

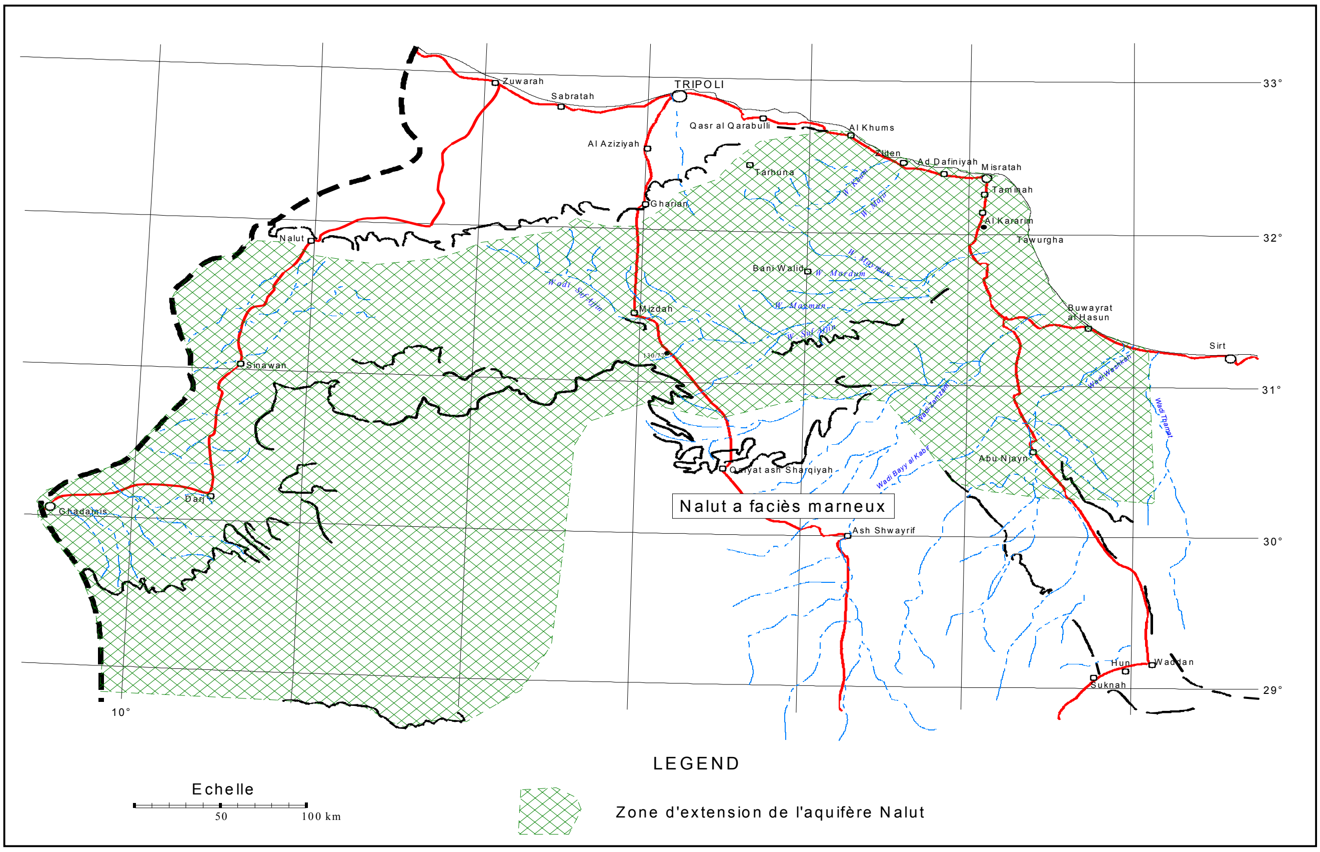
- **The Upper Cretaceous** comprises mainly carbonated formations alternating with little permeable marly formations. The following formations have been encountered in wells, starting from the most ancient up to the Kiklah top:

➢ the limestone and dolomitic limestone of Ain Tobi formation of the middle Cenomanian which shift gradually into detritic facies assimilated with the Kiklah towards the south. In a northward direction, the dolomitic sandstones of Ain Tobi are in continuity with the dolomitic facies of the Kiklah. On the whole, this series, under its carbonated facies, constitutes a mediocre quality aquifer;

➢ the marls and clays of the Yafrin formation of the middle Cenomanian generally constitute a good water insulator between the aquifers of the Lower Cretaceous and the carbonated aquifers of the Upper Cretaceous. The little permeable marly series presents a thickness in the range of 100 to 150 m over the whole domain; however, east of the meridian 15°E, and particularly in the Hun graben and east of the graben, the thickness of the marls decreases to a few ten metres only, thus probably facilitating exchanges between the sandy-sandstone aquifers of the Lower Cretaceous and the carbonated aquifers of the Upper Cretaceous;

➢ the dolomitic limestone and dolomites of the Nalut formation ascribed to the Upper Cenomanian and the Lower Turonian constitute a fair to good aquifer in the northern part of the Libyan Saharan basin only. South of the 31st parallel (Figure N° 9), the Nalut formation acquires an increasingly marly facies and comes to constitute only a mediocre aquifer where the water is frequently brackish.

Figure n° 9 - Extension of the Nalut aquifer (Cenomano-Turonian) in Libya



- **the marly and marly-limestone series, with evaporitic intercalations (gypsum) of** the Tigrinna formation of the Upper Turonian, partly isoles the aquifer from the Nalut formation of the carbonated aquifer of the Senonian. The marls of Tigrinna have a thickness in the range of 100 to 200 m, with a marked thinning towards the East in the Misratah-Tawurgha zone;
- the carbonated series of the Mizdah formation of the Senonian outcrops significantly in the upper basin of Wadi Sufajjin. In these zones where the Mizdah sandstones are outcropping or sub-outcropping, they constitute a good quality aquifer that has been largely exploited for a few years now by private farming. The Mizdah limestone also play a major role in the hydrogeology of the zone of al Jufrah to the west of the Hun graben where they are supplied by the Cambro-Ordivician aquifer favoured by the system of faults which border the graben to the west;
- the marls and marly-limestone of the Soknah formation of the Maestrichtian constitute the transition between the Upper cretaceous and the Palaeocene.

- **The Palaeocene**
  The Palaeocene appears normally under the form of marls and marly-limestone that are well developed on the plateau of Hamada al Hamra and in the Sirt basin. The Palaeocene formations do not seem to play a major role in the hydrogeology of the Libyan Saharan basin.
- **The Eocene** is quite developed only in the graben and east of the Hun graben where two horizons belonging, respectively, in the Lower Eocene (limestone) and the Upper Eocene (chalky limestone and oolithic limestone) are sometimes exploited by wells**.**

An agricultural project has been implemented in Abu Njaym based on the wells collecting the Eocene aquifers. In the zones of Wadi Zamzam and Wadi Wishkah, the farmers have started to exploit the Upper Eocene water table by wells of little depth supplying a water of a poor quality. On the whole, these are poor aquifers of little importance at regional level.

- **The Oligocene and the Oligo-Miocene** are little represented in the Libyan Saharan basin, except to the south of the graben where the Oligocene limestone contains a small shallow aquifer exploited by the people of Hun and Waddan to irrigate their palm-tree groves;
- **The Mio-Plio-Quaternary** is quite developed along the northern coast between Tawurgha and Zliten. This series is transgressive on the Upper Cretaceous and comprises mainly two aquifers:
  - The upper level, being of the Plio-Quaternary and Upper Miocene, composed of limestone with alternations of marls and, sometimes, of gypsum, is the aquifer traditionally exploited, at first by means of dug wells and, since the 1970s, by means of drilled wells. The aquifer rests on the marly levels of the middle Miocene;
  - The lower level of the Aquitanian, at the base of the Miocene, which consists of quite fissured limestone, is generally more productive and supplied by direct connection to the aquifer formations of the Upper Cretaceous.

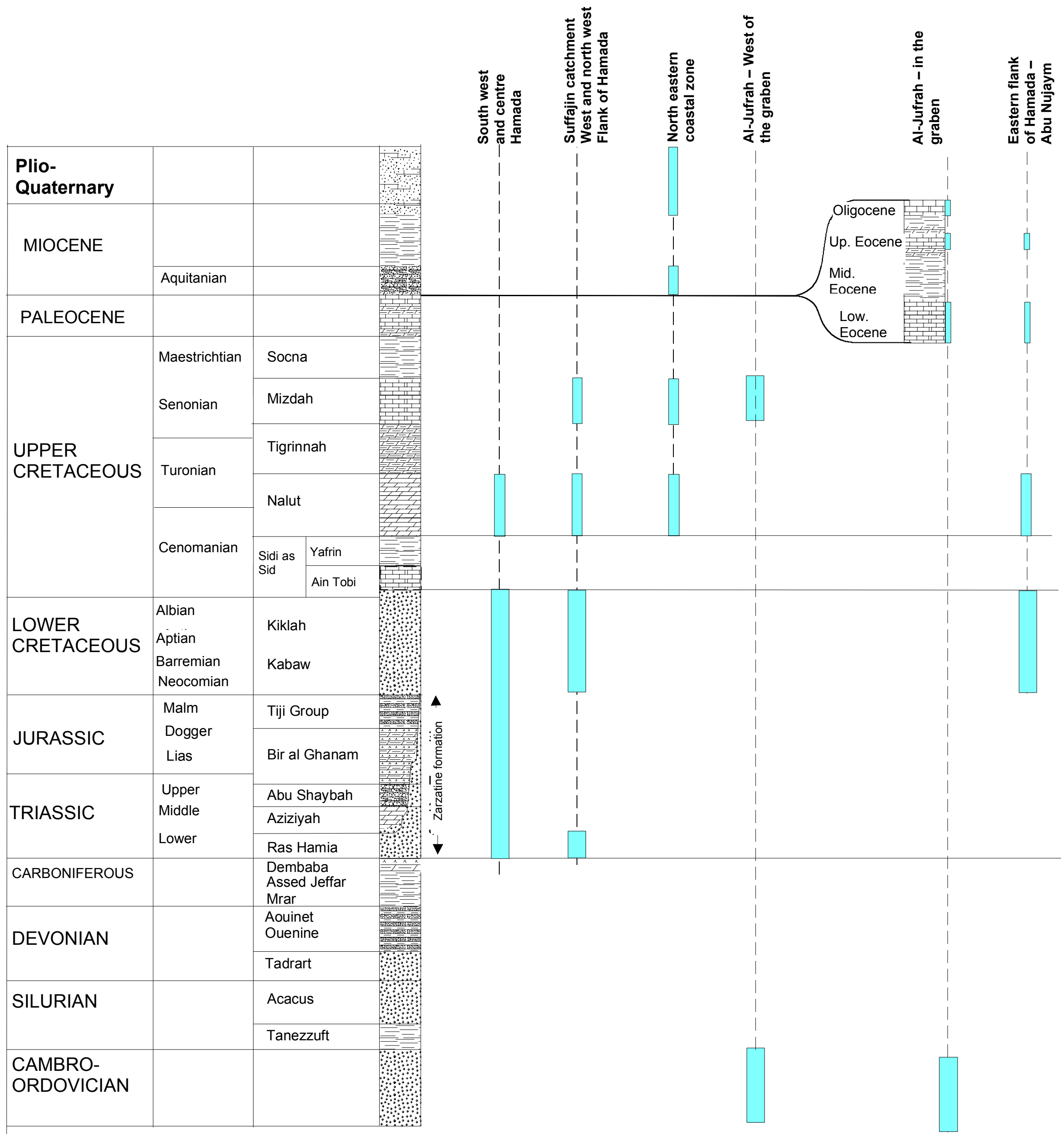
- **Summary:**

  The sketch of Figure N° 10 illustrates the description of the geological formations and their hydrogeological signification. The aquifers are indicated under the form of clear blue columns in correspondence with the formations that contain them. The width of the column indicates the size of the aquifer.

The Hamada al Hamra region belongs in the zone of the Saharan platform where the succession between the marine and continental sedimentation cycles since the Cambro-Ordovicien is the reason for the predominance of earth sedimentation starting from the basement outcrops located south of the basin (Jabal Hasswnah). The role of the carbonated marine formations is reduced on the southern flank of Jabal Hassawna and in the basin of the gulf of Sirt (eastern flank of the Hamada).

This structure gives rise to an aquifer system whose various levels present similarities with those of the sub-basin of the Grand Erg Oriental.

Figure n° 10 – Geological formations and aquifers of the Libyan Saharan basin



2.2- Map of the outcrops of the main aquifer formations

The data on the geometry of the aquifer reservoirs of the Saharan basin originates from the set of geological and structural data available on this region. This information may be distinguished into the following sources:

- geological maps of the outcropping layers, made at various scales and for specific regions;
- geophysical surveys having generated thickness maps or maps relating to the top and bottom position of one or several formations;
- descriptions of the layers crossed by oil or water wells.

The body of these data had formed the subject of developed syntheses in the context of previous studies that addressed the geometry of the aquifers of the Saharan basin. A synthesis effort involving the whole basin has been undertaken and has resulted in:

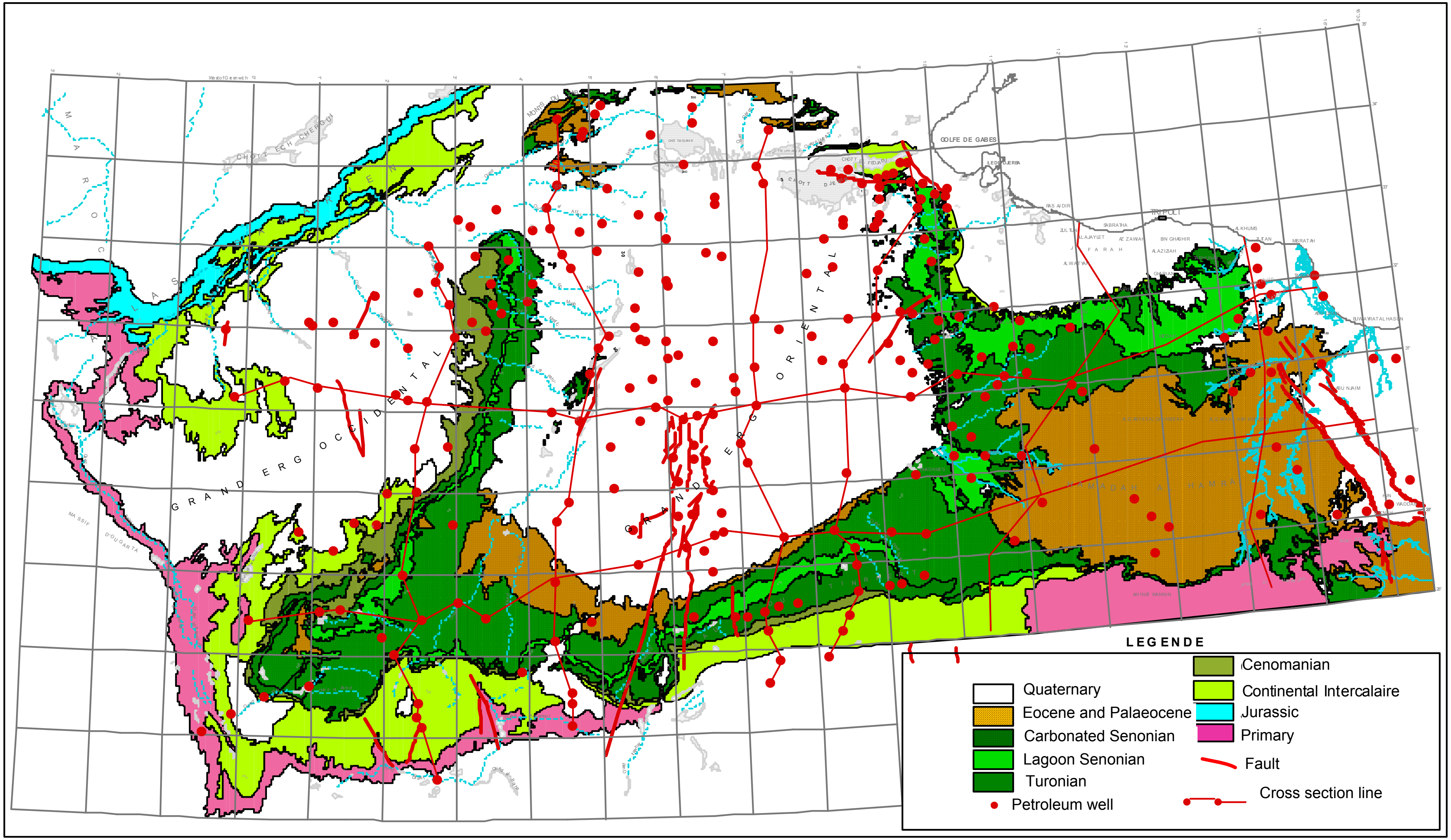
- a digitised geological map of the outcrops over the whole Saharan basin;
- litho-stratigraphic cross-sections which present, under a schematic form, the geological structure of the three sub-basins;
- top, wall and thickness maps of the aquifer formations of the Intercalary Continental.

A geological map of the outcrops of the whole Saharan basin has been developed at scale 1/ 2 000 000 (Plate N° 1) based on the national geological maps at 1/ 500 000 and at 1/1 000 000. This map has drawn, for the two sub-basins of the Eastern and Western Grand Erg, upon the cartographic synthesis at scale 1/ 2 000 000 developed by G. Busson (G. Busson, 1970). For the Libyan part of the basin, the geological map of Libya at scale 1/ 1 000 000 and various sheets at 1/ 250 000 of the geological map of Libya have been used.

Formation groups or stages have proved necessary to produce the adopted hydrogeological nomenclature generalised to the whole Saharan basin.

Plate n°1

GEOLOGICAL MAP OF SASS



2.3- NS and EW cross sections : Geological structure, horizontal and vertical extension of the aquifers

In order to illustrate the geometry of the Saharan aquifer system and its evolution in each of the sub-basins, a certain number of litho-stratigraphic cross sections have been developed and are proposed outside of the text (Plates N° 5 to N° 9). These cross sections have been made by reference to the data obtaining from 150 oil wells. The Tunisian south has been part of a special detailed study based on the data of 186 wells specific to this zone. The examination of these cross sections reveals:

- the continuity of the division adopted from one end of the basin to the other;
- the variations in thickness of the continental series (Lower Cretaceous and Continental Terminal) and the marine series (Jurassic, Upper Cretaceous, Tertiary) in conformity with the paleo-geographic sedimentation conditions. Thus, the zones having developed into subsiding depressions (Eastern Gran Erg and the Eastern flank of El Hamada) are characterized by thick formations reflecting a certain subsidence. This is particularly the case of the Lower-Saharan zone which had accumulated, since the beginning of the Secondary, increasingly thicker sedimentary series regardless of whether the sedimentation conditions are marine or continental. The regions of the basin of the Grand Erg Occidental, of the Far Tunisian South and of Hamada al Hamra have developed into plateaux, with a platform sedimentation which often presents a reduced thickness with a facies indicating the passage from a sedimentation environment to another;
- the major tectonic axes are influenced by the closeness of the southern Atlas flexure (line of the Chotts, Gafsa faults), the Gulf of Syrte (Hun graben) and the outcropping of the basement (Amguid dorsal). They indicate a zone of passage from the Hoggar craton, in the south, to the Atlas domain, in the north, with a narrowing of the folds and abrupt fault with a more marked displacement.

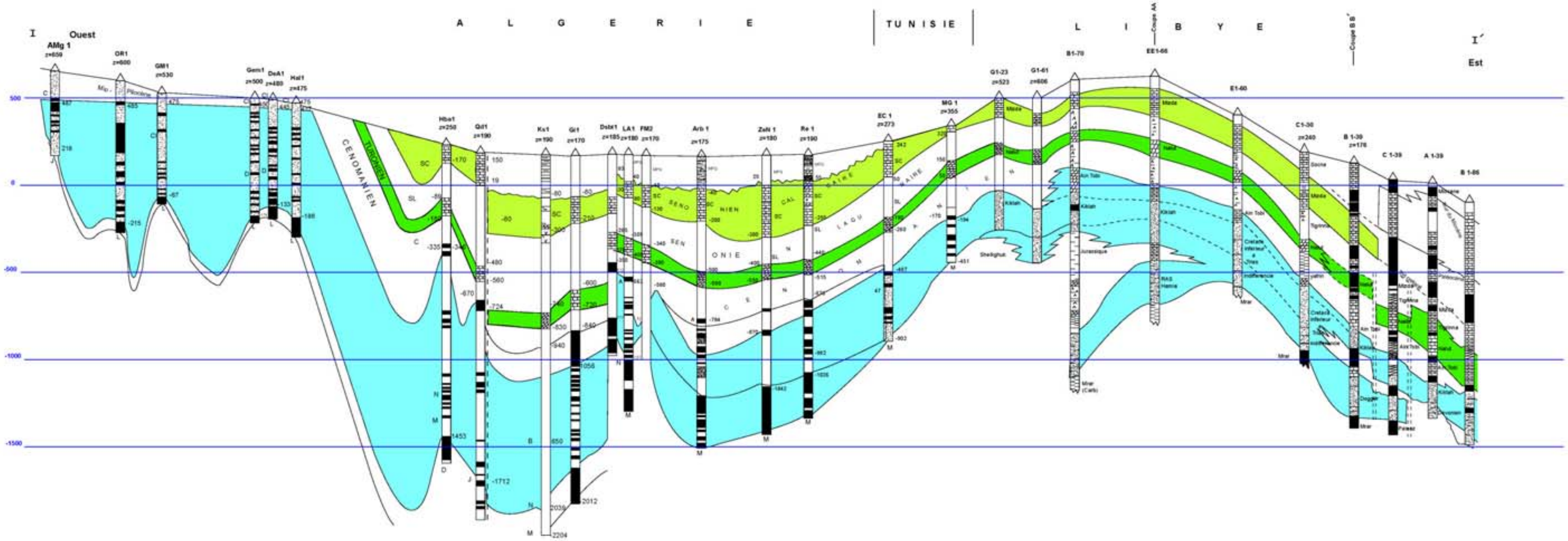
2.3.1. West-East cross sections

The longitudinal structure of the basin has been analysed based two litho-stratigraphic correlations which extend from the West to the East of the basin. These two cross sections reveal clearly the distinctness of the sub-basins, particularly that of the Grand Erg Oriental within which the secondary layers undergo a subsidence accompanied by a thickening.

- The **cross-section I-I'** (Plate N° 5), located near the south Atlas flexure, indicates the passage from the sub-basin of the Grand Erg Occidental towards the Lower-Sahara. It reveals the extent of sedimentation of the continental cycle of the of the Lower Cretaceous and highlights the role of the Lower-Sahara in the subsiding evolution of the sub-basin of the Grand Erg Oriental (thickening of the Cenomanian, of the Lower Senonian, of the Upper Senonian and of the Continental Terminal: Mio-Plio-Quaternary). In Libya, this cross section crosses the Libyan Saharan basin and its centre and reaches into the sea, in the gulf of Syrte. This cross section reveals:
  - ➢ The disappearance, at 200 – 250 km of the Algerian border, of the marly and evaporitic formations of the Lower and Middle Jurassic which used to isolate the Triassic aquifer from the aquifers contained in the Upper Jurassic – Lower Cretaceous formations;
  - ➢ The presence of a paleozoic mole at the centre of the basin, then a dip of Palaezoic top towards the Syrte basin where the Tertiary formations are developed;
  - ➢ The minimal role of the Hun graben in its northern part where the heave does not exceed a few ten metres and does not seem to affect the horizontal hydraulic continuity of the aquifer layers.

Plate n° 5

CROSS SECTION I I' : EAST-WEST CORRELATION BETWEEN THE GRAND ERG OCCIDENTAL AND TAWARGHA (LIBYA)



- The **cross-section II-II'** (Plate N° 6), located near the Hoggar craton, reveals the sands substratum of the Continental Intercalaire composed of old detritic series (Cambro-Ordovician). This underscores the part played by these formations in supplying the Saharan basin with detritic materials during the eras when the sea, coming from the north, could not reach these regions. Starting from the Algerian border, the cross-section shows, at the beginning, the relative isolation of these aquifer formations of the Trias with respect to those of the continental deposits of the whole Lower Cretaceous – Jurassic. In Libya, this cross-section also runs along the southern border of the Mesozoic sandstone aquifer formations. Further East, the Paleozoic dome interrupts the Jurassic and Triassic deposits, leaving only about a hundred metres of sandy-sandstone formations ascribed to the Lower Cretaceous (Kikla). At about fifty kilometres of Hun graben and up to the graben, the Kikla aquifer is merged in the Cambro-Ordovician. In the graben, the whole Tertiary and Upper Cretaceous series has been preserved from erosion, but, at the level of the cross section, the aquifer formations are small in number and limited to a few horizons of the Eocene and to the deep Lower Cretaceous – Trias system in continuity with the Cambro-Ordovician.

2.3.2. North-South cross sections

These litho-stratigraphic cross sections, established across the Saharan basin, lead to highlighting the evolution of the Secondary, Tertiary and Quaternary sedimentation between the southern boundary of the basin and south Atlas flexure. To the West, the Cretaceous series dip from the north to the south (Plate N° 7), across the sub-basin of the Grand Erg Occidental under the dunes of the Erg and the Hamadan slab. They give thus the shape of a depression which is soon dimmed by the outcropping to the South of the series of the Intercalary Continental. This depression structure is of markedly smaller size than the depression of the Grand Erg Oriental located farther East.

In the depression of the Grand Erg Oriental, the transition from the South to the North starting from the outcroppings of the Continental Intercalaire towards the south Atlas flexure is accompanied by an in-depth burying of all the Cretaceous layers under the effect of the thick Tertiary and Quaternary sediment series (Plate N° 8). This burying peaks just south the south Atlas accident. The role of the Amguid dorsal is highlighted by the thinning of the layers and their rising to the ground surface with lateral discontinuities alongside the major accidents.

In Libya, two North-South cross sections are presented:

- The cross-section E-E' (Plate N° 9) of the carboniferous outcroppings of the south, in the vicinity of the Algerian border, up to the sea to the East of Tripoli, shows the deepening of the basin under Hamada al Hamra and the complex connection of the Saharan system with the Jifarah plain through the horst of Jabal Nefusa. The southern part of the cross-section shows the ending of the various aquifer formations probably due to erosion. The oldest Triassic formations are those which extend further to the south. The aquiferous Senonian (Mizdah), which is the most recent aquifer formation, ends with the boorder of the Hamadan plateau. This cross section also shows a development towards the south of the detritic facies of the Lower Cretaceous at the base of the Trias, which leads to the assumption of a practically continuous aquifer system from the Cenomanian to the base of the Trias under the Hamadah.

Plate n° 6

CROSS SECTION II II' : WEST-EAST CORRELATION BETWEEN REGGANE (ALGERIA) AND THE HUN GRABEN (LIBYA)

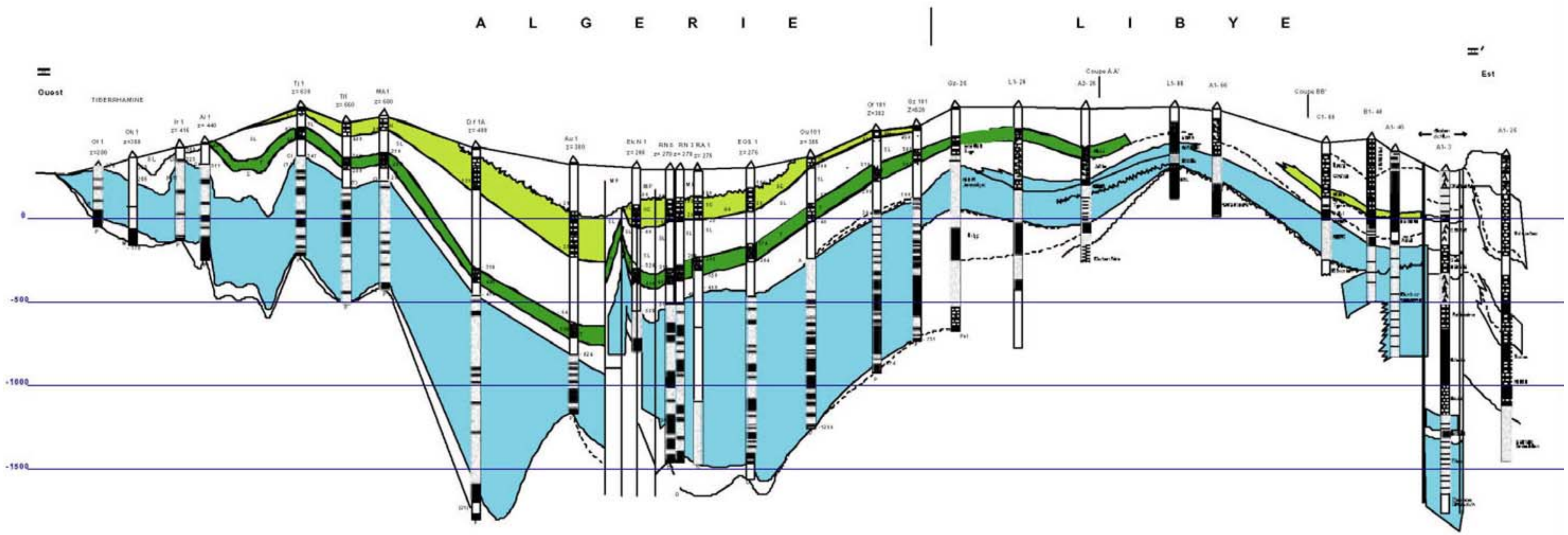


Plate n° 7

CROSS SECTION A A' : NORTH-SOUTH CORRELATION ACROSS THE BASIN OF THE GRAND ERG OCCIDENTAL

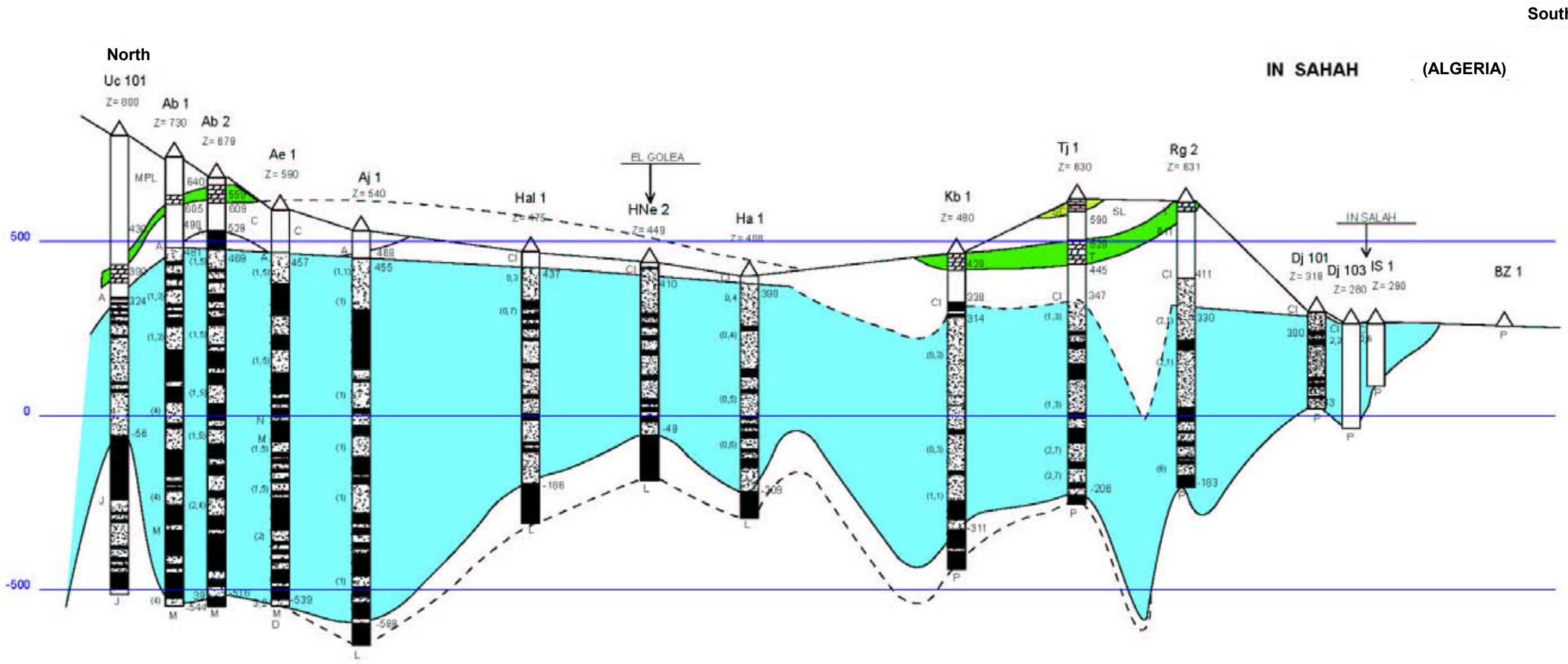
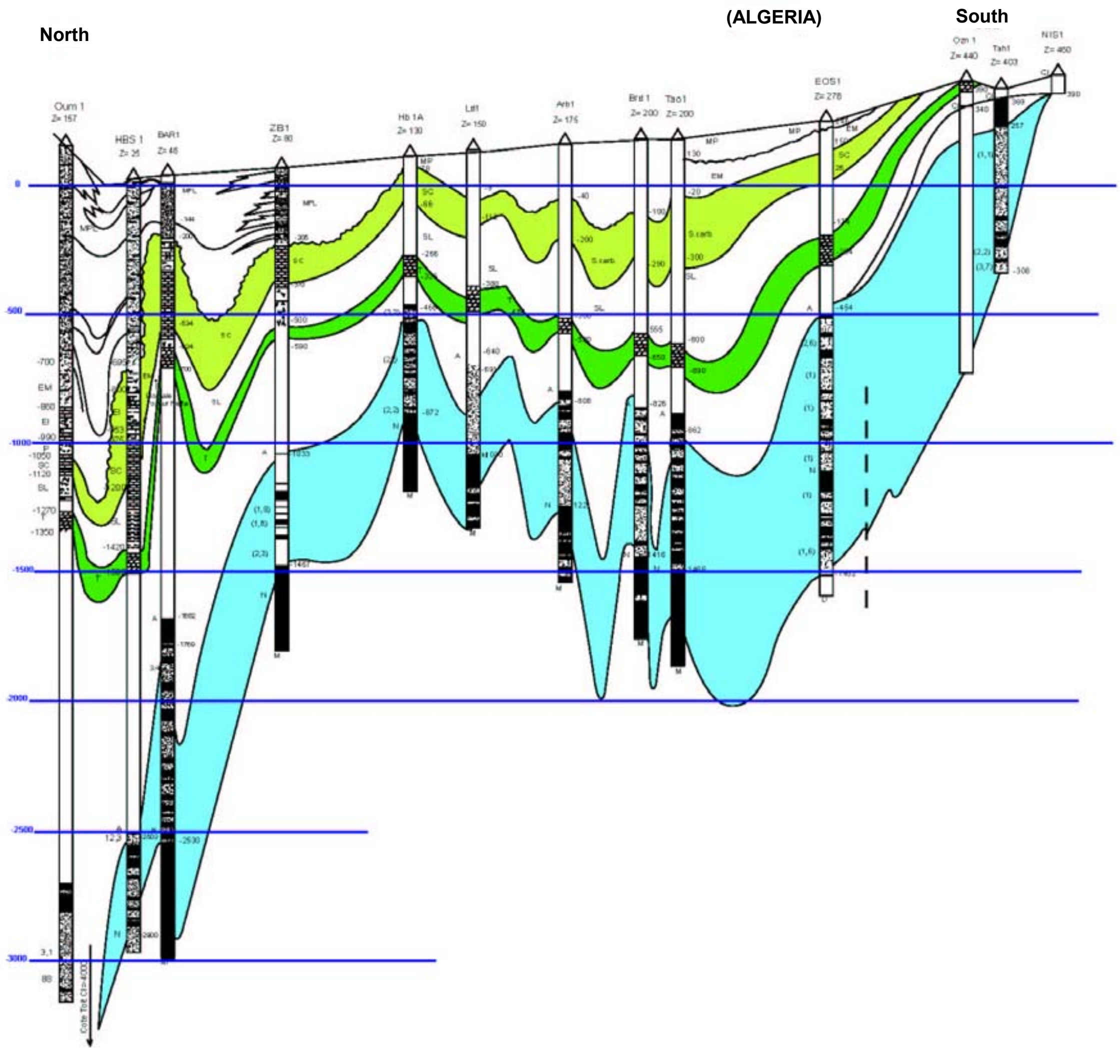


Plate n° 8

CROSS SECTION C C' : NORTH – SOUTH CORRELATION BETWEEN THE ALGERIAN LOWER SAHARA AND THE TADEMAIT PLATEAU



- The cross-section F-F' (Plate N° 9), extending from the Cambro-Ordovician outcrops of Jabal Hassawnah in the south up to the sea at the level of Zliten, equally shows a deepening of the basin at the centre and a merging, south of parallel 31°30', of the various aquifer levels from the Triassic to Lower Cretaceous into a single system that is equivalent to the Continental Intercalaire in Algeria and Tunisia. This cross section also shows a change of facies towards the north which shifts to a carbonated dolomitic marine facies at the level of the Tawurgha spring. This change of facies, which is accompanied by a substantial reduction in transmissivity of the Continental Intercalaire is probably one of the causes for the emergence of the Ayn Tawurgha spring in this zone.

2.3.3. Horizontal and vertical extension of the Continental Intercalaire aquifers

2.3.3.1. Horizontal extension to the West: The basin of the Grand Erg Occidental

This part of the Saharan basin has not been considered in its entirety up to its western boundaries in the previous models, but only in the part where the Continental Intercalaire is outcropping. The remaining part of the basin where the Continental Intercalaire is directly under the dune cover of the Western Erg is in fact an area of aquifer recharge. Its integration, within the domain taken into consideration by the model, has made it possible to take into consideration the basin as a whole.

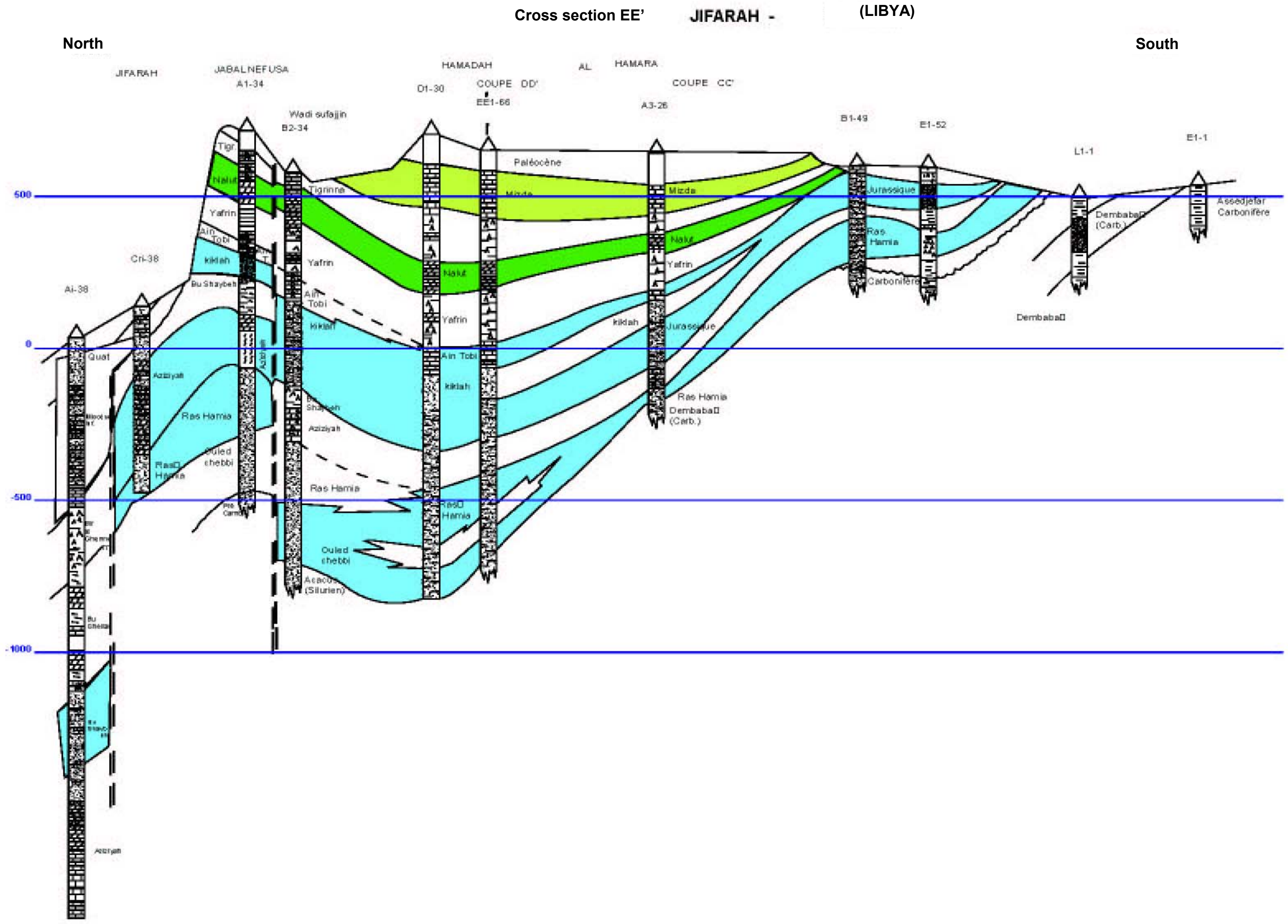
In this part of the basin, where no new water points allowing a detailing of the geometry of the aquifer reservoirs are available, we shall stick to the hypothesis that has already been accepted and which indicates that the water table of the CI receives a certain recharge through the dune cover of the Grand Erg Occidental.

In reality, the sub-basin of the Grand Erg Occidental is a geographical entity where the Continental Intercalaire aquifer is, for the major part, unconfined and thus constitutes a ground water reserve that is easily accessible by means of equipments (foggaras, dug wells and drilled wells) of little depth (a few ten metres).

The geology of this part of the basin shows that the passage from the Saharan Atlas, in the north, to the valley of Saoura, in the south, is accompanied by the deepening of the series of the Complexe Terminal under the Hamadan slab which is, itself, covered at certain spots by the dunes of the Grand Erg Occidental. This slab follows, at times, directly from the sands of the Continental Intercalaire.

Plate n° 9

CROSS SECTION E E' : NORTH-SOUTH CORRELATION BETWEEN JABAL NEFUSA (LIBYA) AND GHADAMES (LIBYA)



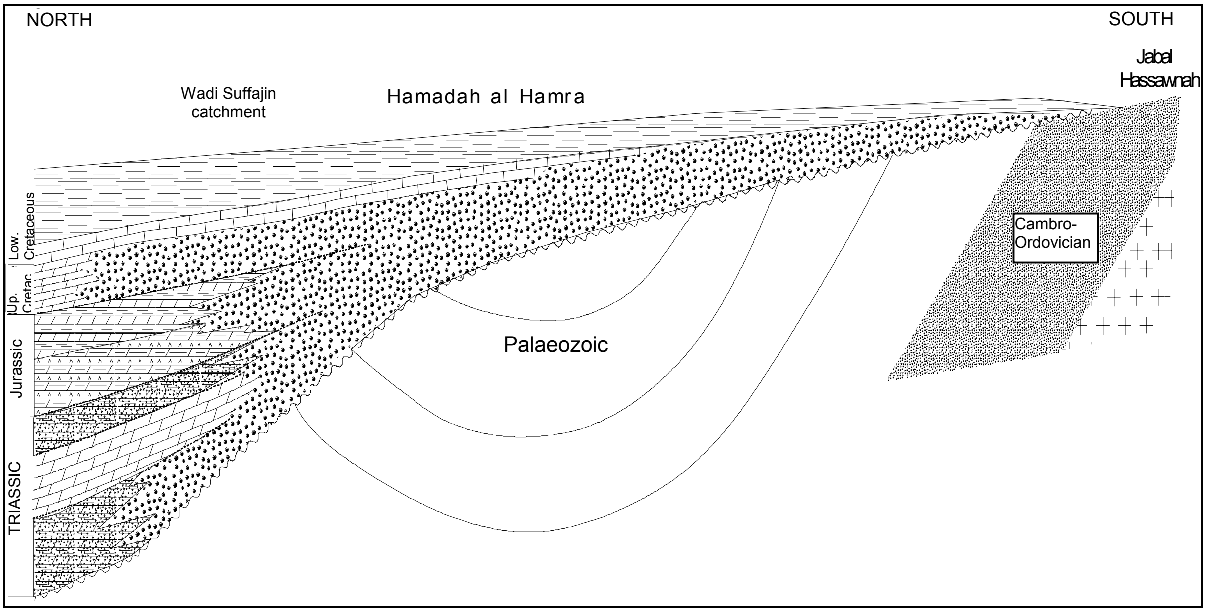
2.3.3.2. Horizontal eastward and south-eastward extension in Libya

The immersion of the zone located to the north of the Palaeozoic uplift of Gargaf (Jabal Fazzan, Jabal Hassawnah) up to the level of a line Bani Walid – Mizdah - Derj has persisted throughout the era extending from the Triassic to the end of the Lower Cretaceous and had been characterized by a predominance of the detritic sedimentation of a continental origin. Farther north, marine or lagoon episodes, favoured by the subsidence of the basin, had alternated with emergence eras of little deep continental or marine sedimentation as illustrated quite sketchily by the North-South cross-section of Figure N° 11.

Marine incursion had not invaded the Libyan Saharan basin until the Cenomanian. The pre-Cenomanian Mesozoic aquifers appear, therefore, under the following facies and associations:

- To the North-East, in the Tawurgha – Zliten – Al Khums zone, all the Mesozoic formations, including Kikla, have a marine origin and present a dolomitic carbonated facies;

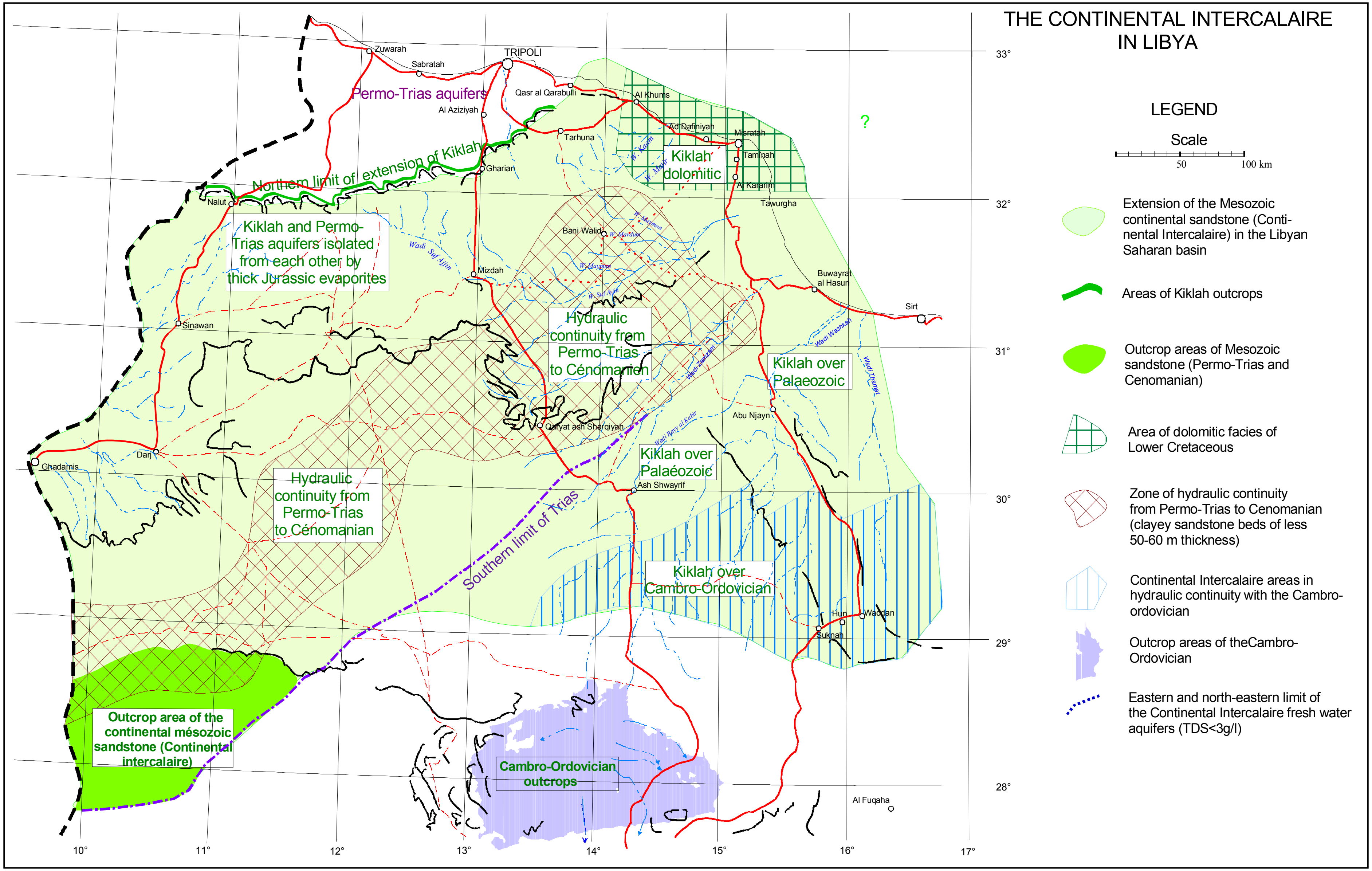
Figure N° 11: Schematic North-South cross section in the Libyan Saharan basin



- To the North of a line Bani Walid – Mizdah – Serj, the sandy-sandstone Kikla aquifer, often associated with the Upper Jurassic, is isolated from the Triassic aquifers by the marly and evaporitic carbonated marine deposits of the Lower Jurassic;
- In a zone which cuts across the Hamadah al Hamra from the far south-west to the Bani Walid – Wadi Zamzam zone, the pre-Cenomanian Mesozoic formations present a continental facies and constitute an aquifer reservoir whose thickness exceeds 500 m at certain locations;
- To the South of the preceding zone and up to the southern boundary of the extension of the pre-Cenomanian Mesozoic formations, the Jurassic and Triassic deposits had been eroded and there remains only the Lower Cretaceous up to the 29th parallel where it is in direct contact with the Cambro-Ordovician over a vast zone comprised between the 29th and the 30th parallel. To the South-West, on the contrary, it is the Triassic deposits which had been preserved and which extend towards the south up to the 28th parallel where they are in contact with the Carboniferous.

The map of Figure N° 12 shows the extension and the position of the various zones described above.

Figure n° 12 - Composition of the Continental Intercalaire in Libya



2.4- Geometry of the main aquifers :

2.4.1. Isohypse map of the top of the Continental Intercalaire (CI)/ Kikla

The CI/ Kikla top is defined as being the first formation overlying the sandy series of the Lower Cretaceous. This top varies, from one location of the basin to the other, from the dolomites of the Aptian to the clays and marls of the Vraconian.

At the level of the Saharan basin (Plate N° 2), the Continental Intercalaire/ Kikla outcrops over the boundaries of the basin at the following locations:

- to the north, along the Saharan flexure and at the very middle of the anti-cline of Chott Fedjej;
- to the east, along the eastern flank of Dahar and of Jabal Nafusa;
- to the south, on the plateaux of Tinghert and of Tadmaït;
- to the west, under the dunes of the Grand Erg Occidental and between Reggane and al Goléa.

This top is at its least deep under Hamada al Hamra (+ 400 to – 250 m /NGM). It grows slightly deeper in the eastern part of the Hamada between Mizda and Tawurgha (-200 to 1000 m) and grows deeper in the Hun graben (- 750 to - 1300 m).
In the basin of the Grand Erg Oriental, the top of the Continental Intercalaire gradually deepens from South to North. It is the least deep along the western border of Dahar and near the Tadmaït plateau (0 to – 500 m) and exceeds the depth of 1000 m only in the depression of the Algerian-Tunisian Chotts (- 1500 to 6 3500 m).
This configuration of the position of the CI/ Kikla top is closely connected with the thickness of its geological formations and with the evolution of the facies from that of the platform to those of the fluvial-lacustrine depression of the Chotts.

2.4.2. Isohypse map of the bottom of the Continental Intercalaire/ Kikla

The Continental Intercalaire/ Kikla series, which indicate the beginning of a largely extended continental cycle, have been deposited over various geological formations that are often rubbed down by erosion and which are non conform. The geological section of the CI/ Kikla bottom is composed, according to the locations, of the Primary, Triassic, Jurassic (Lias, Dogger and Malm). The main detritic aquifer formations vary in position and range from the Neocomian to the Albian (Plate N° 3).

The CI/ Kikla bottom of the Saharan basin is the least deep in the vicinity of the outcrops (from – 250 m on the Dahar to – 500 m in Jabal Hassawnah). It becomes particularly deep in two major grooves which correspond to the depression of the Algerian-Tunisian Chotts (– 1570 to – 3500 m) and the Hun graben (– 1200 to – 1900 m). It presents localised deepening in the Amguid Ridge and its northward extension (- 1000 to – 1500 m).

PLATE N° 2: MAP OF THE TOP OF THE CONTINENTAL INTERCALAIRE/ KIKLAH EFFICIENT RESERVOIR

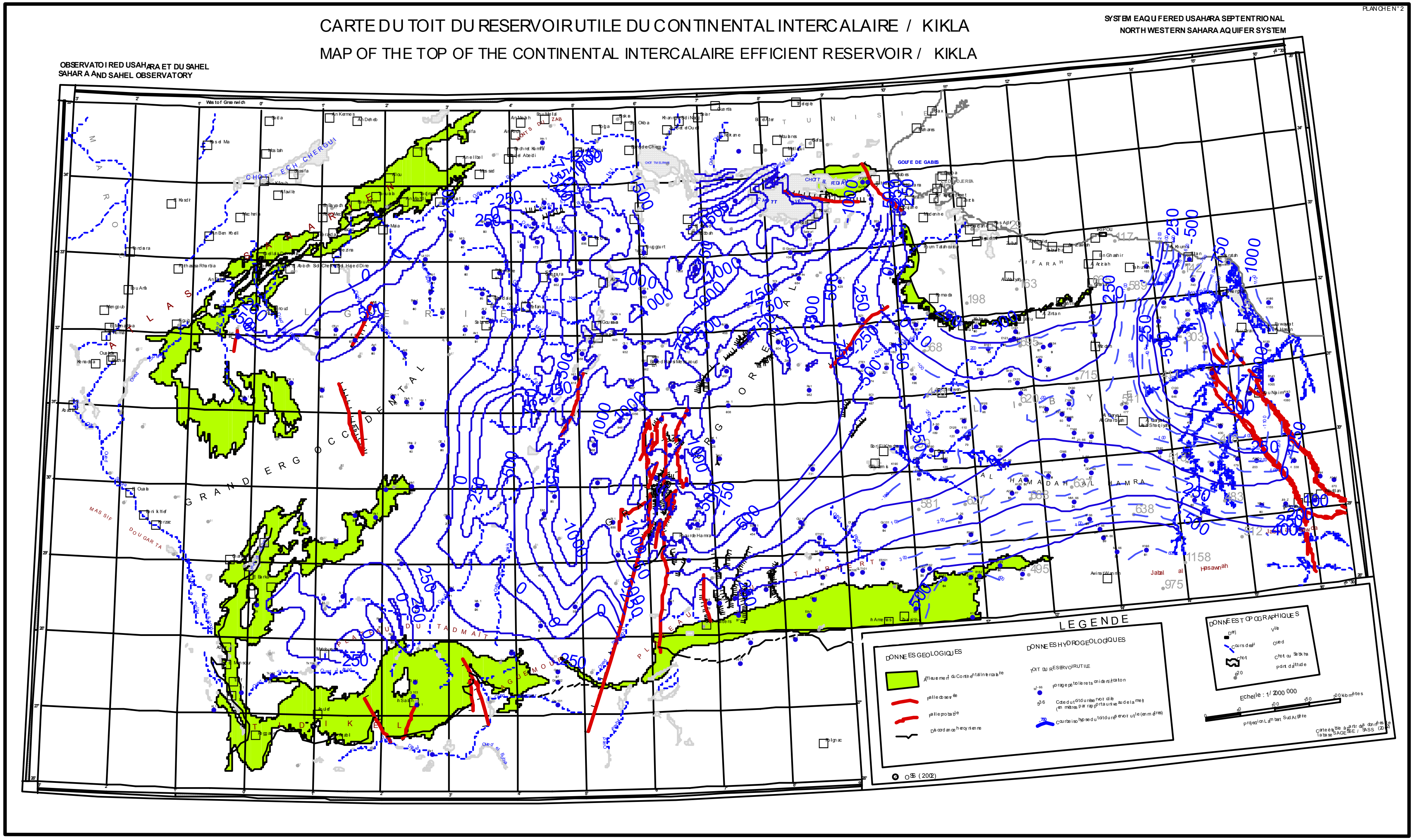
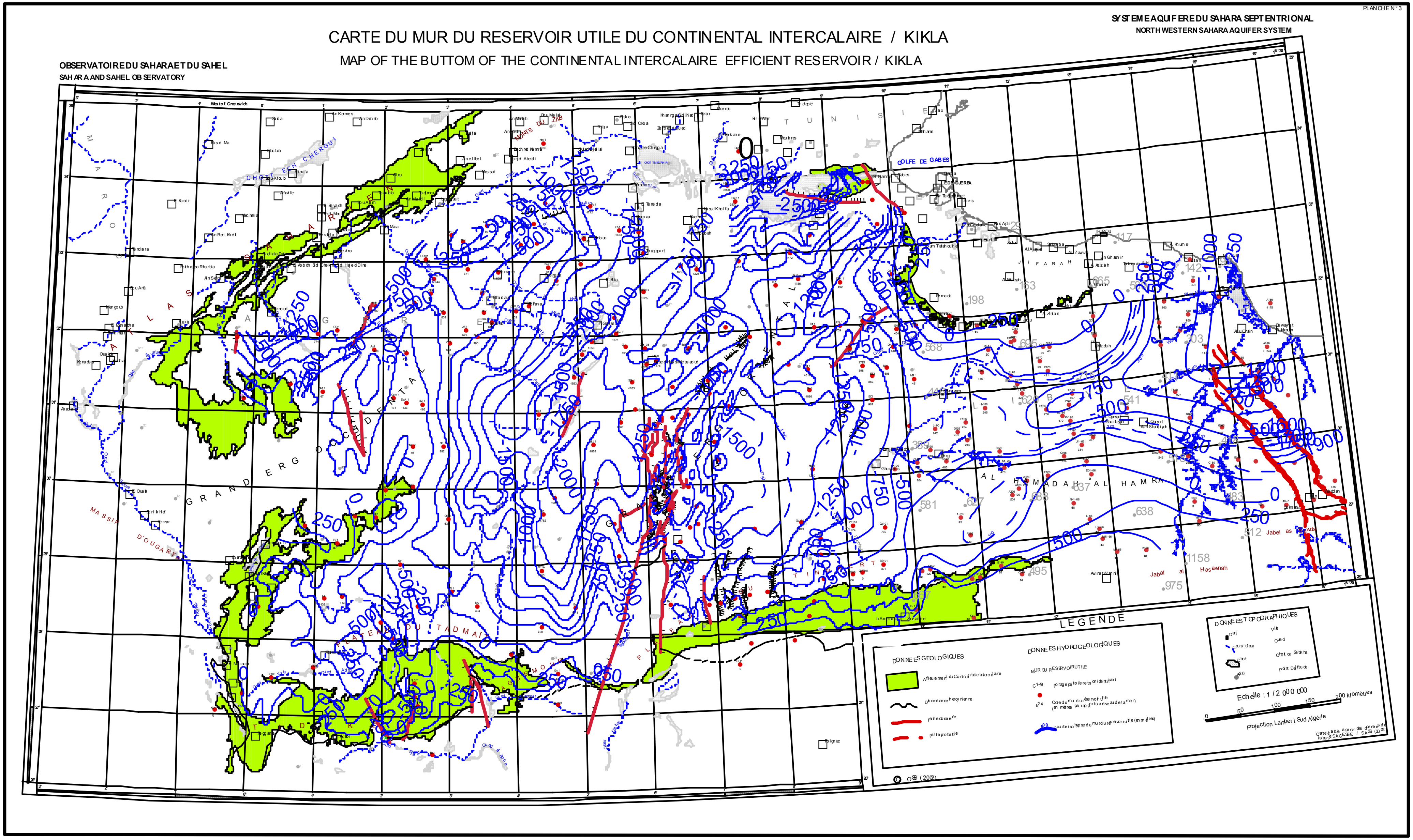


PLATE 3: MAP OF THE BUTTOM OF THE CONTINENTAL INTERCALAIRE EFFICIENT RESERVOIR / KIKLA



2.4.3. Isobathe map of the thickness of the Continental Intercalaire

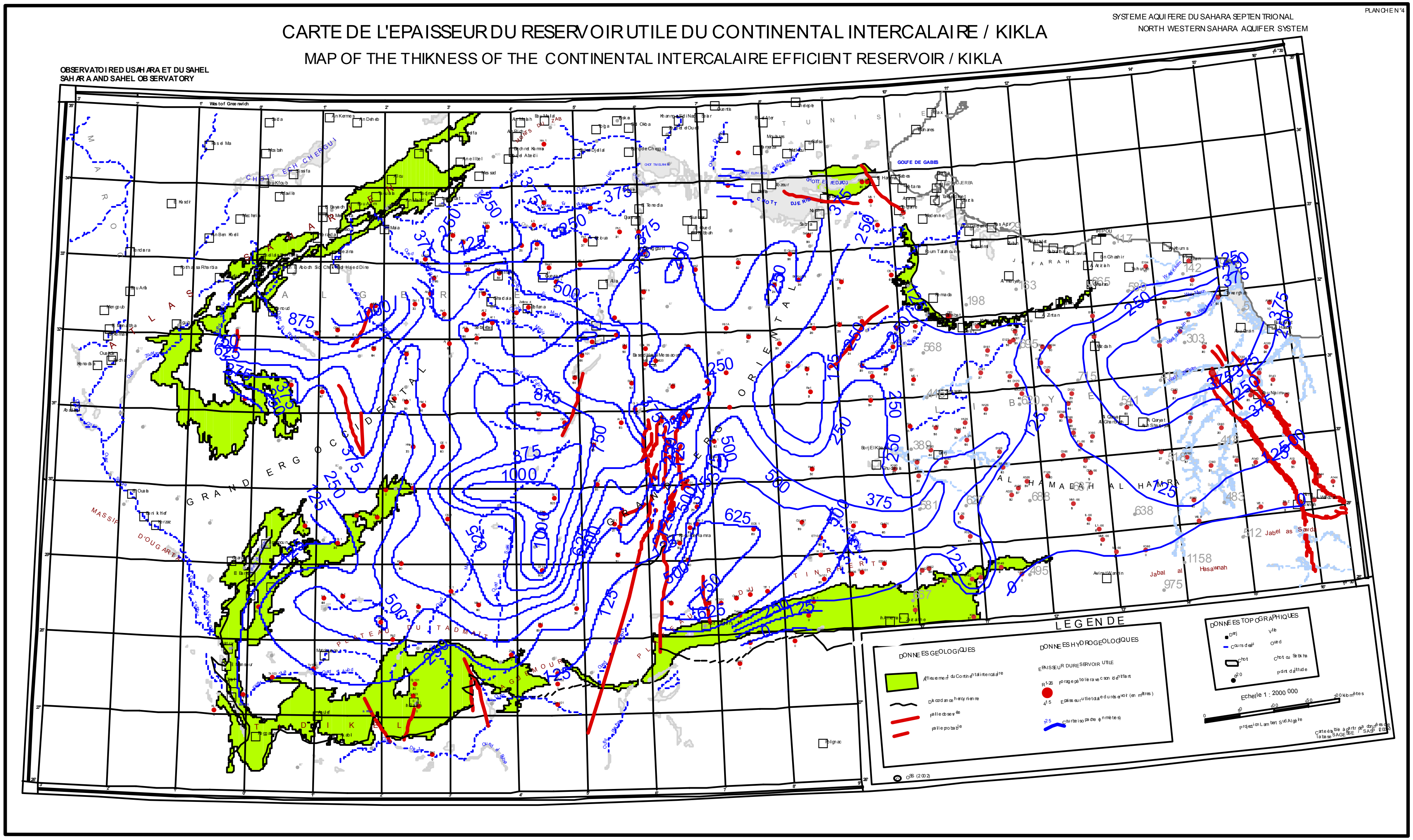
The average thickness of the CI/ Kikla is in the range of 125 to 150 m under the Western part of Hamada al Hamra and the far Tunisian south. It becomes more significant (125 to 375 m) in the eastern part of the Hamada (Plate N° 4). A notable thickening of these formations is noticed alongside the valley of Wadi Maya and under the Grand Erg Occidental in the vicinity of the south Atlas flexure (500 to 1000 m). The tectonics seems to play a certain role in the thickening of these series only alongside the Amguid Ridge and the Hun graben. Besides, in the vicinity of the south Atlas flexure, the series become thicker.

2.4.4. Geometry of the semi-permeable intercalary layers

With a basin as vast as that of the Northern Sahara, changes of facies throughout the secondary and tertiary series are often numerous. The sedimentation conditions off the Hoggar craton have favoured considerably these changes of facies and thickness. Accordingly, the semi-permeable layers separating the aquifer levels also present variations in thickness ranging from a few metres to a few hundred metres. There results an overall arrangement that causes these series to be thick in the subsiding zones and thin on the borders of the sedimentary depressions and near the shallows. Only through a detailed geographical analysis based on the lithological cross sections of the wells and the geophysical surveys would it be possible to establish thickness maps of the “aquitards” separating the various aquifer levels of the Saharan basin. It is, nevertheless, possible to consider, in a quite sketchy way, five major “aquitards”:

- the layers separating the Continental Intercalaire from the underlying aquifer formations: these layers are thick everywhere (a few hundred to a few thousand metres), except for the zone located immediately north of the shallow of Jabal Hassawnah separating the Murzuq basin from the Hamadah. The passage towards the gulf of Sirt is again accompanied by a thickening of these formations which, however, thin out in the vicinity of the spring of Tawurgha;
- the layers separating the Continental Intercalaire from the Turonian: these clayey-marly formations, of a usual thickness of a few hundred metres, present a significant thickening (over 500 m) in the basin of the Grand Erg Oriental and in the vicinity of the depression of the Chotts (G. Busson, 1970). There, one can identify a saline series composed of gypsum and anhydrite which is perhaps the cause of the relatively high salinity of the water (4 to 6 g/l) contained in the Aptian dolomite between El Borma and Hassi Messaoud;
- the series separating the Turonian from the Carbonated Senonian. These marly-clayey and carbonated, and at times saline, formations are similar to those of the Albo-Cenomanian. They are likely to induce a salinisation of the water of the Complexe Terminal under the Grand Erg Oriental and the depression of the Chotts;
- the layers separating the Senonian limestone from the Miocene sands: these series correspond to the Palaeocene and to the Eocene. They are developed over the whole basin in its western part, underneath the depression of the Chotts and underneath Hamada al Hamra. They are often carbonated and little permeable;

PLATE N° 4: MAP OF THE THICKNESS OF THE CONTINENTAL INTERCALAIRE/ KIKLAH EFFICIENT RESERVOIR



- the layers overlaying the Miocene sands and constituting the top of the aquifer of the Complexe Terminal. They are relatively developed in the depression of the Chotts and the Gulf of Sirt. It is through these formations that the water of the Complexe Terminal rises to the natural outlets constituted by the Chotts and the Sebkhas.

2.5- Effect of geological structure on the aquifers

The new data relating to the Saharan basin in the Algerian -Tunisian part derive from the new boreholes, which had provided additional information that was not available before or which relates to zones that had not been taken into consideration in the previous modelling of the aquifers of the basin. This is particularly the case of the ERESS model of the Continental Intercalaire which did not cover in the past the entirety of the sub-basin of the Grand Erg Occidental and of that of the Complexe Terminal which had focused only on the region of the Algerian – Tunisian Lower Sahara. To this, there must be added the part located in Libya and which had not been considered before in its complete framework.

The whole of this depression and plateaux structure presents formations with considerable variations in thickness resulting from a long evolution in marine and continental environments and which have undergone the alpine fold phase, though relatively mitigated. Within this synclinal mega-structure, the tectonic barriers are fairly limited (Amguid ridge, Tozeur ridge and Hun graben). These barriers are rather found along the northern boundary of the basin in the passage zone to the Saharan Atlas. It is towards the borders that the main secondary and tertiary geological formations outcrop. For this reason, the borderline plateaux constitute the recharge areas of the new aquifers.

2.5.1. In Algeria

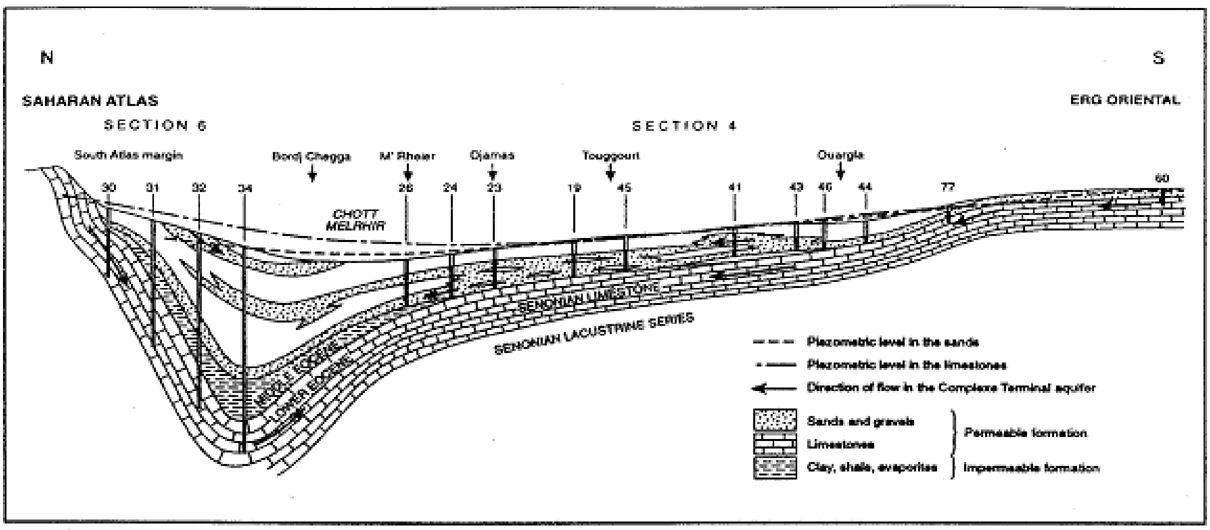
2.5.1.1. Basin of the Grand Erg Oriental

Several oil wells (120 wells) have been constructed since the early 1980s in this zone. These wells are distributed among the Wilayas (regional administrative departments) of Ouargla and Ghardaïa. Those which tap the CI are 33 in number, while the others are limited to the Complexe Terminal. The water wells, drilled after 1981 in this part of the basin, count **4600 wells** of which 28% tap the CI, while the others tap the CT.

These wells have been drilled mainly in the Wilayas of Adrar, Ghardaïa and Ouargla for the CI and in those of Ouargla, El Oued and Biskra for the CT. (See Vol. 3: Data Base & GIS).

These wells supply information on the hydraulic characteristics of the aquifers of the basin, from a geological perspective. However, they only confirm the structure already known. This is particularly the case of the wells drilled in northern Oued Rhir and tapping the CI aquifer, as well as that of the wells tapping the CT in Biskra and in Adrar. Among the latter, several hundred wells are limited to the surface formations (Miocene and Plenipotentiary). The data make it possible to envisage, during the establishment of the sub-models, a differentiation, within the CT, of the limestone aquifer (Senonian and Eocene limestone) from that of the Tertiary sands **(Figure N° 13)**.

Figure n° 13 : North-South geological correlation across the Complexe Terminal between the Grand Erg Oriental – Ouargla and the Saharan Atlas (M. Edmunds et al, 1997)



2.5.1.2. South Atlas flexure and CT aquifer in Biskra

The Algerian Lower Sahara appears as a synclinal depression whose structural evolution dates back to the early Mesozoic. This depression which houses the major Chotts in Algeria and Tunisia is bordered, to the West, by the Mzab ridge, to the South, by the southern Tinrhert cliff, to the East, by the Cretaceous outcrops of the Tunisian-Libyan Dahar, and to the north, by the south Atlas chain. Along the boundaries of this depression, the limestone of the Senonian or of the Eocene are regularly inclined to the inside, except for the northern side which is abruptly cut by the south Atlas accident. This accident takes the form of a flexure causing he Cretaceous layers to rise almost vertically.

To the west of Biskra, large Eocene outcrops are found in contact with the Saharan flexure and indicate that their displacement (strike-slip) is not quite considerable. Nearing Biskra, the south-Atlas flexure becomes considerable and it causes, at the level of Bou Rhézel, a reversing of the southern flank of this anti-cline. In this location, the Turonian limestone oscillate on both sides of the vertical and disappear to the south under the deposits. A similar phenomenon may be noted at the level of Gafsa, in Tunisia, where the south Atlas accident is materialised by the Gafsa fault. The wells of the Tolga zone, to the east of Biskra, exploit the Senonian and Eocene limestone at variable depths which increase rapidly to the south and exceed 500 m.

To the East of Biskra, the displacement of the south Atlas flexure increases rapidly and all the Cretaceous and Tertiary layers are raised vertically. We are thus on the border of the south Aurasian trough which constitutes the deepest part of the Lower-Sahara depression.

Further East, in the Tunisian south, the south Atlas accident is further divided into several branches with variable displacements according to the locations. On the Saharan platform, the Cretaceous substratum reappears due to a vast anti-cline whose eroded core, which serves as the seat for Chott Fedjej, causes an outcrop of the Lower Cretaceous. The Lower-Sahara thus appears as a quite dissymmetrical depression whose centre is located between Chott Melrhir and the Aurès chain. Its northern flank, extending eastward up to the region of Gafsa, is quiet abrupt while its southern, western and eastern borders are steadily widened. The bottom of this depression had steadily subsided until a recent period according to the accumulation of Tertiary and Quaternary continental sedimentation. This subsidence is the reason for the configuration of the outlet of the aquifer of the Complexe Terminal centred on the depression of the Tunisian Chotts (El Gharsa and Djerid) in its current configuration. The

Tertiary sedimentation constitutes the reservoirs of the first and second aquifers of Oued Rhir which extends in Tunisia in the Pontian sands of Djerid.

The wells drilled to the north of El Oued (Hamaïra, El Feidh and Aïn Naga) reveal clearly the subdivision of the Pontian into a lower clayey-sandstone part and an upper clayey-gypseous part. The substratum of Pontian sands deepens in the vicinity of the south Atlas accident down to 1000 m (Aïn Naga well: 1300 m).

At the Aurès base, the Turonian and Senonian limestone gives rise to a series of springs of a more or less significant flow, such as may be found along the mountain chain of Gafsa in Tunisia, between Tamerza and Métlaoui. The Eocene limestone outcrops in this zone, where it is of little depth, and gives rise to a series of springs (Tolga, Foughala) which spring at times directly from the limestone, while at other times they transit through the sands and the Plio-Quaternary alluvial cover.

In a southward direction from the Atlas outcrops, the Pontian sands become increasingly thicker and water inflows occur with losses of head which reduce the flow of the springs. The major part of the water circulating from the confined aquifer into the limestone and the sands rises towards the surface as it runs against the south Atlas chain, and flows into the aquifer.

The hydrostatic levels reveal that the set of the Tolga wells is supplied by the North via infiltration of the water that runs into the Senonian and Eocene limestone. In Ouled Djellel, the wells tapping the Eocene limestone present a piezometry that links up to that of North of Mzab which taps the sands aquifer. It thus becomes quite difficult to distinguish, in this multi-layer set, whether the aquifers belong to the north Atlas domain or to the Saharan domain and to identify with precision the role of the south Atlas accident in supplying the aquifer of the Complexe Terminal from the north.

The south Atlas flexure presents the same structural configuration between Biskra (Algeria), to the West, and Gafsa (Tunisia), to the East: gradual downdisplacement (depression) of the surface layers down to depths of several hundred metres, thus bringing in contact, along a series of relaying tectonic accidents, layers of different ages. This settling phenomenon had been accompanied by a subsidence having led to the accumulation in the south Atlas trough (Lower-Sahara and depressions of the Chotts) of a thick sedimentary layer of the Tertiary and the Quaternary.

2.5.1.3. Amguid faults

The faults of the Amguid ridge are connected with a network of a North-South direction which crosses the Precambrian massif of the Hoggar and extends in a northward direction while affecting the primary and secondary sedimentary cover. The tertiary and quaternary sediments conceal the continuity, towards the north, of this network of faults which seem to extend in depth up to the south Atlas trough.

At the location of the network of faults of the Amguid ridge, the Mesozoic (Cretaceous) geological series display in the wells (Plate N° 6) vertical displacements in the order of 300 to 400 m (wells Au 1 and EkN 1). In the depression of Oued Mya, located to the west of these faults, the Permian sub-stratum is located, at the level of well Au 1, at – 1170 m in depth and appears as an ancient shallow where the deposits of the Trias and of the Jurassic are absent (a case similar to the Malaab dome in Tunisia). On this dome, the continental series of the CI present a marked reduction in thickness (352 m instead of over 1000 m at Df1A). The thickness of the Lower Cretaceous seems to be affected by the ejection of these faults, particularly the detritic part of the series.

The vertical play of these faults is felt in the upper series of the Cretaceous and affects even the thickness of the Senonian limestone. These are, therefore, ancient regional tectonic accidents which had continued to operate again until recent times. Their belated activity is attested by the subsidence which has accompanied the Plio-Quaternary sedimentation in the

Oued Maya – Oued Rhir groove. These accidents probably also have a role in underground flows by facilitating vertical exchanges between the Continental Intercalaire and the formations of the Upper Cretaceous.

The hydrogeological role of the Amguid ridge in the communication between the aquifers of the Continental Intercalaire and the Complexe Terminal is one of the hypotheses to be checked by the models. It is assumed, in the previous studies, that the faults, with a vertical play affecting, in this zone, the Secondary and Tertiary series, are the reasons for the leakage whose flow remains to be quantified.

2.5.2. In Tunisia

2.5.2.1. Tunisian outlet and Dahar dome

The notion of outlet of the IC aquifer in the Tunisian south had emerged at the inception of the synthesis studies having involved this aquifer (Cornet, 1961). This notion has been one of the major orientations adopted in the ERESS study at the time of establishing the balance of the aquifer. This outlet is demarcated as being “the zone, extending from the Malaab, in the south, up to the most folded zone made up of the Djebels Hadifa, Haïdoudi and Zemlet Beïda, in the south (the chain north of the Chotts), forms, in our opinion, the only outlet in Tunisia of the Continental Intercalaire aquifer” (R. Rouatbi, 1970).

Based on a deep interpretation of the geology, the piezometry and the chemistry of the water, this demarcation subsequently ended up being questioned at the time of establishing the balance of the CI aquifer (ERESS, 1972). The chain north of the Chotts, with its coffered folds does, indeed, constitute the northern boundary of the aquifer; however, towards the south, the outlet of this aquifer was extended further to the Dahar of Tataouine (with a double width reaching 80 km) in spite of the absence of the detritic series of the Lower Cretaceous, and this in order to be able to simulate over this area a recharge of the aquifer of 1.99 m3/s and to allow the passage via this outlet of a flow into the Djeffara of 3.5 m3/s. It has been assumed that, in the absence of the sandy series of the Lower Cretaceous, the limestone and dolomitic formations of the Albo-Aptian at the top, and of the Jurassic at the base, could constitute a relay of the aquifer of the Continental Intercalaire.

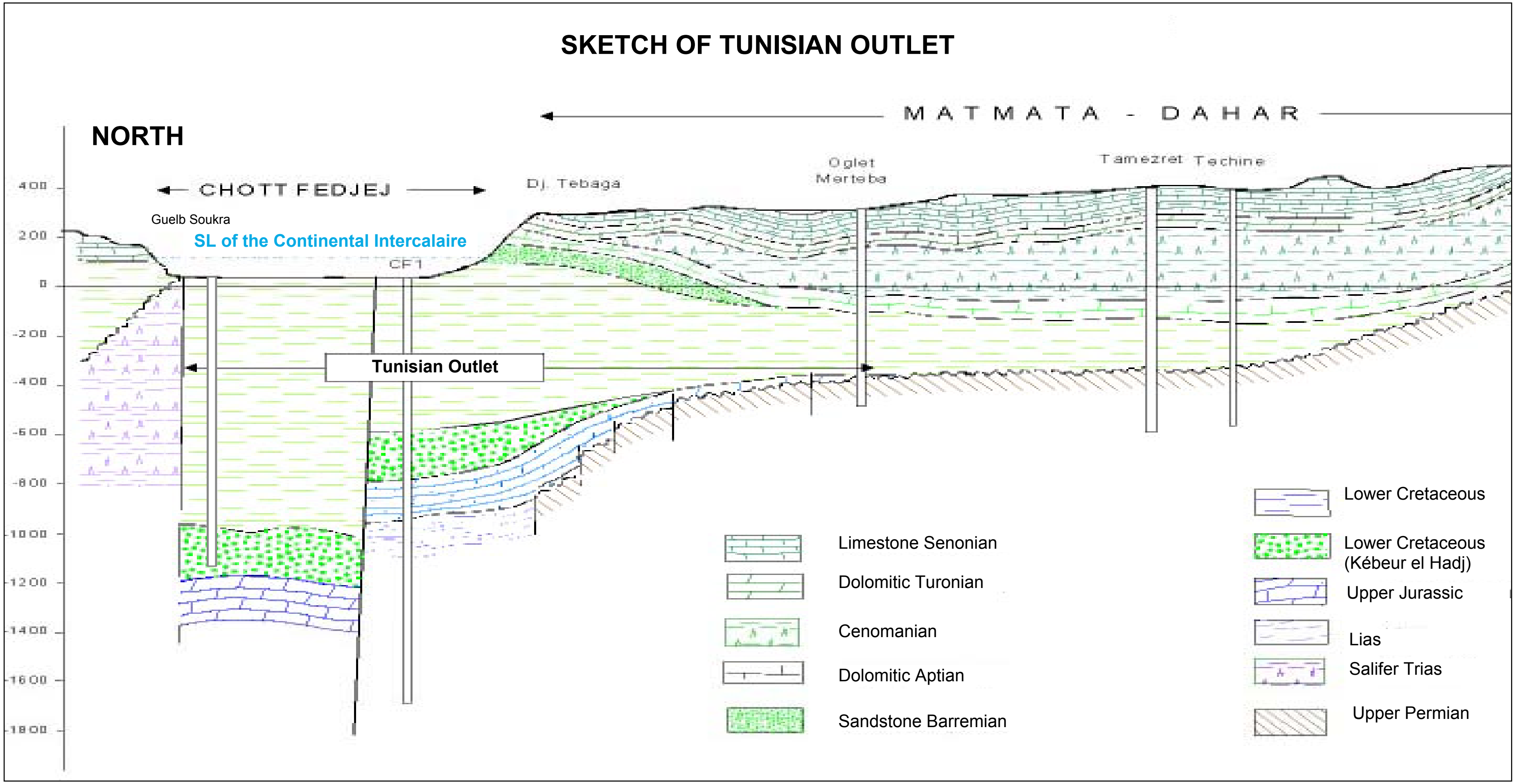
In the light of the new wells drilled in this zone in Tamezret, Matmata, Zmerten and Techine during the 1980s (B. Ben Baccar, 1985), it has been found that the detritic formations of the Lower Cretaceous or of the Jurassic were absent under the Matmatas. Only the Tamezret well has crossed, between the Permian and the Albo-Aptian, a clayey facies ascribed to the Lower Cretaceous or to the Upper Jurassic. The Albo-Aptian formations tend to be less dolomitised and more holed and marly.

The Albo-Aptian of Dj. Malaab contains a aquifer of little water potential whose salinity is of 10 g/l. Similarly, the two wells Matmata and Zmerten have yielded, at a low specific flow within the Albo-Aptian, water whose salinity is in the range of 5 to 10 g/l, which indicates the isolation of the compartment of the Matmatas from the CI outlet to Chott Fedjej.

The only aquifer identified in the Matmatas mountains is that connected with the limestone of the Upper Cretaceous (Turonian and Senonian). The Malaab dome and the Matmatas correspond to a zone where the CI aquifer is absent over an area which extends up to the Tébaga of Médenine.

A detailed analysis of the data on the wells of the Tunisian south, which has recently been conducted in the framework of the SASS/OSS project (Abidi B., 2002 ; Ben Baccar B., 2002 and Moumni L., 2002), has allowed the presentation of a new conception of the Tunisian outlet which takes into consideration the geological structure of the region and the hydrogeological characteristics of the aquifer throughout the Tunisian south (**Figure n° 14**).

Figure n° 14 – Sketch of the Tunisian outlet



2.5.2.2. Structural configuration

The Tunisian outlet corresponds to a structural configuration that has caused the aquifer formations of the Lower Cretaceous (Neocomian and Barremian), which are known in the whole Saharan basin under their sandy-sandstone facies, to undergo a considerable reduction in thickness as they get closer to the Gulf of Gabes before presenting a deep lithological change (clays and marls).

Indeed, the continental series of the Neocomian and of the Barremian, deposited in a fluvial-lacustrine and deltaic sedimentary environment undergo, in the location of the passage of the Saharan platform towards central Tunisia and the platform of eastern Tunisia, a distinct change in their sedimentary environment. The tectonic evolution of the region during the Tertiary and the Quaternary has largely favoured the individual characterisation of the major structural units of which, in particular, the dome of Chott Fedjej and the anti-cdepression of the Djeffara (the present Dahar is but the western flank of this Djeffara anti-cline). Over the area of the Algerian-Tunisian Chotts, there has been confirmed the subsidence started since the early Mesozoic and which had continued until the Quaternary by the depression of the Chotts. The south Atlas flexure has ended up bordering the Saharan domain to the north, by a string of lined folds, represented mainly by the two mountain chains to the north of the Chotts and of Gafsa.

This paleogeographic evolution of the sedimentary conditions and of the lithological facies during the Atlasic orogenesis was completed with the establishment of the major structural units of which the dome of the Dahar-Djeffara to the East and the south Atlas mountain chain which constitute the boundary, to the East and the North, of the extension of the Saharan platform. The breaking tectonics that had followed upon this orogenic evolution has ended up finalising the structural configuration of the region with the introduction of the major tectonic accidents such as the two faults of Gafsa- El Hamma and of Médenine.

It was subsequent to this structural evolution that the Tunisian outlet of the Continental Intercalaire aquifer had ended up being confined to a small corridor located between the Dahar dome, to the south, and the mountain chain north of the Chotts, to the north, with the Gafsa – El Hamma fault constituting the eastern boundary of this aquifer. This outlet is the play of a series of sedimentary and tectonic conditions. It results from a paleogeographic evolution of the facies, while it is at the same time the outcome of a tectonics that has favoured the creation of a hydraulic threshold (bottom line) at the location of the transition from the dome of Fedjej to the the Djeffara plain.

The new configuration of the Tunisian outlet allows the demarcation of the recharge zone of the Djeffara aquifer from the Continental Intercalaire to the Chott Fedjej sector. This is likely to better explain the leakage losses in the upper series of the Lower Cretaceous of the Chott, and assigns to the west-east flow within the CI aquifer much more importance in the underground drainage in the Djeffara.

2.5.2.3. Hydraulic continuity with the Djeffara

The hydraulic continuity of the Continental Intercalaire aquifer with that of the Djeffara is evidenced between El Hamma and the coastal plain by means of a series of survey boreholes which have provided several consistent hydrogeological parameters. One notices more particularly the following aspects:

- **Evolution of the lithological facies** : the Kébeur el Hadj (sandy-sandstone Neocomian), known in the depression of the Chotts (Nefzaoua and Chott Fedjej) by its coarse sands facies, presents under the Djeffara (to the east and south-east of the Saharan platform) a marked degradation of its permeability at the same time that its thickness is reduced and that it ends up disappearing completely. This is equally the case of the sandstone series of the Barremian which constitute a non negligible part of the aquifer formations of the Saharan Continental Intercalaire. The sandy-sandstone facies of the Barrimean remain with a reduced thickness and a lower permeability only to the north of Chott Fedjej, underneath the Ségui, but their hydrogeological role in the aquifer flow is markedly more reduced than in the Saharan part.

- **Hydrogeological parameters** : or, more particularly, the piezometry, the water temperature and its chemical and isotopic composition which reveal the continuity of the «range » of the water of the Continental Intercalaire into that of the Djeffara aquifer. In fact, temperature anomalies (of 25 to 30°C above the average temperature of the aquifer water) have been reported for the water of wells of El Hamma and Chenchou. They cannot be explained except by hydraulic connections, via the faults, between the two aquifers of the CI and of the Djeffara. These thermal anomalies are accompanied by a « chemical kinship » between the waters of the CI and of the Djeffara which takes up the form of the same chemical facies. The values of age of the waters and of their stable isotopes contents also highlight a "rejuvenation" of these waters during their passage into the the Djeffara aquifer.
- **The configuration of the piezometry of the Continental Intercalaire and that of the Djeffara** indicates clearly a west-east flow which runs across the El Hamma threshold (tectonic threshold) revealing a piezometric decrease of over 50 m. This piezometric drawdown is justified by the geological configuration forcing the water of the CI to rise along the tectonic accidents of Gafsa – El Hamma in order to flow into the various aquifer formations of the Djeffara.

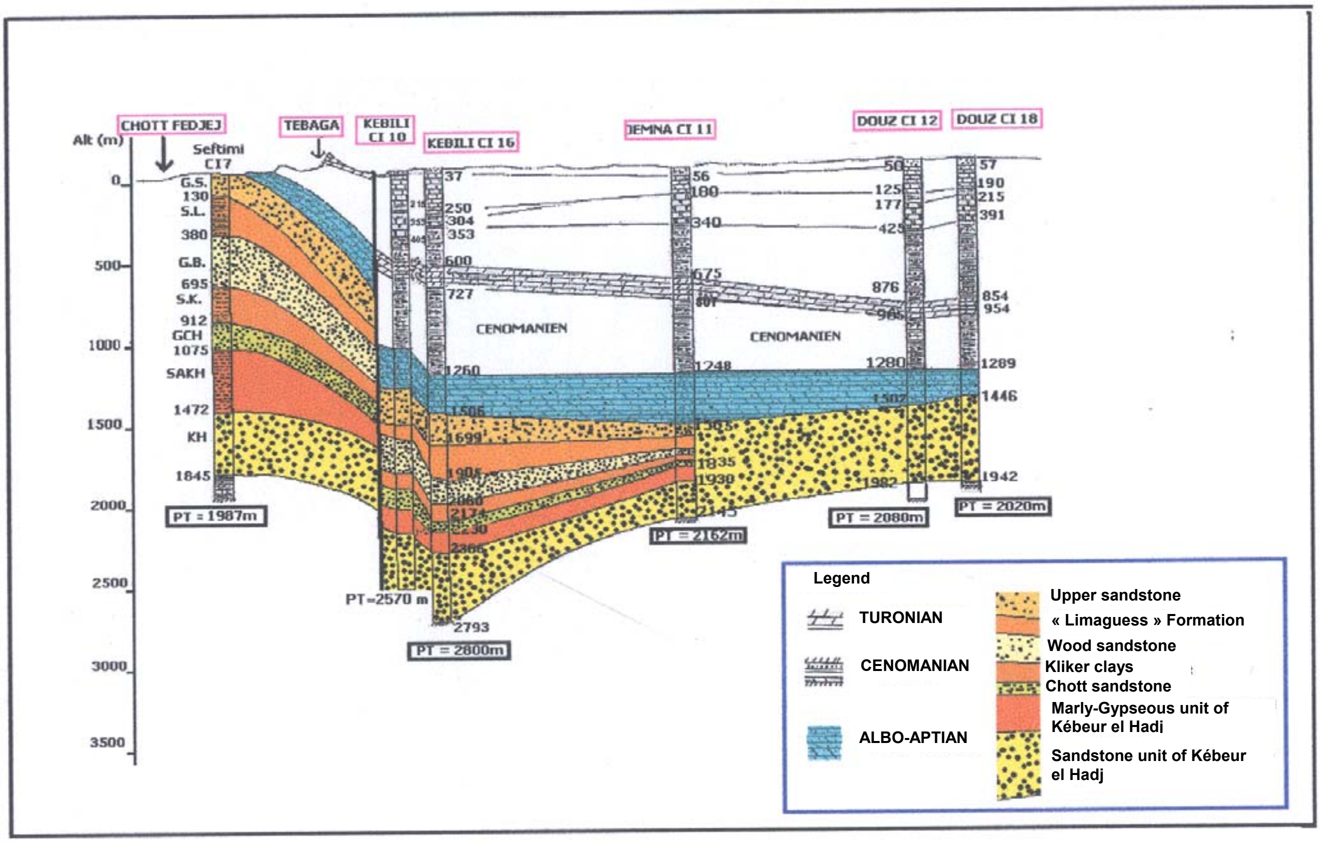
2.5.2.4. Effects on model design

The impact of the Tunisian outlet on the design of the model occurs under the form of two phenomena :

- A reduction of the runoff section of the outlet which is thus brought down to about 40 km in width. This reduction affects in a significant way the flow which crosses this section and causes it to be the reason for the lateral input in the Djeffara aquifer. The geological configuration of the dome of Dj Melaab, together with the geological findings of the recent wells of Oglet El Marteba, Tamezret, Matmata, Techine and Zemertene, does not leave any doubt as to the boundary of the real extension of the series of the Continental Intercalaire under the Dahar. In such conditions, the weighting of the transmissivities across the section of this outlet is the only resort for weighting its outflow.
- The revision of the geological and hydrogeological study of the CI aquifer in the Tunisian south in the light of the recent data as updated for the year 2000 (L. Moumni, B. Ben Baccar, 2002 and B. Abidi, 2002) has led to distinguishing, at the level of the Tunisian south, a doubling up of the sandy series within the CI which, thus, emerges as a "multilayer" structure that is unusually thick compared with the Saharan platform domain (**Figure n° 15**). This structure, which is analysed in detail with the lateral connections of the aquifer levels on both sides of the Tunisian south borders, has led to distinguishing, within the CI, of two major aquifer levels of which the thickest is the connection between the Saharan part and the outlet. This new configuration has made it possible to better relate the wells to their hydrogeological environment and to choose the hydrodynamic characteristics which are in perfect consistency with the hydrodynamic behaviour of the system.

During the design of the hydrodynamic operating of the CI aquifer, the new structural configuration of the Tunisian outlet has emerged as characterized by two new elements :
- the distinction, within the CI, of two aquifer levels (upper sandstone and CI proper) ;
- the demarcation of the CI outlet towards the Djeffara, at the level of the zone located between the chain north of the Chotts and the Matmata mountains.
This situation reduces the recharge to the Djeffara aquifer from the current infiltrations and assigns the Tunisian outlet of the CI a key role in this input.

Figure n° 15 : North-South correlation across the Nefzaoua between Seftimi (Chott Fedjej) and Douz (Nefzaoua)



2.5.3 – In Libya

2.5.3.1.Connections of the Libyan Saharan basin with the Jifarah

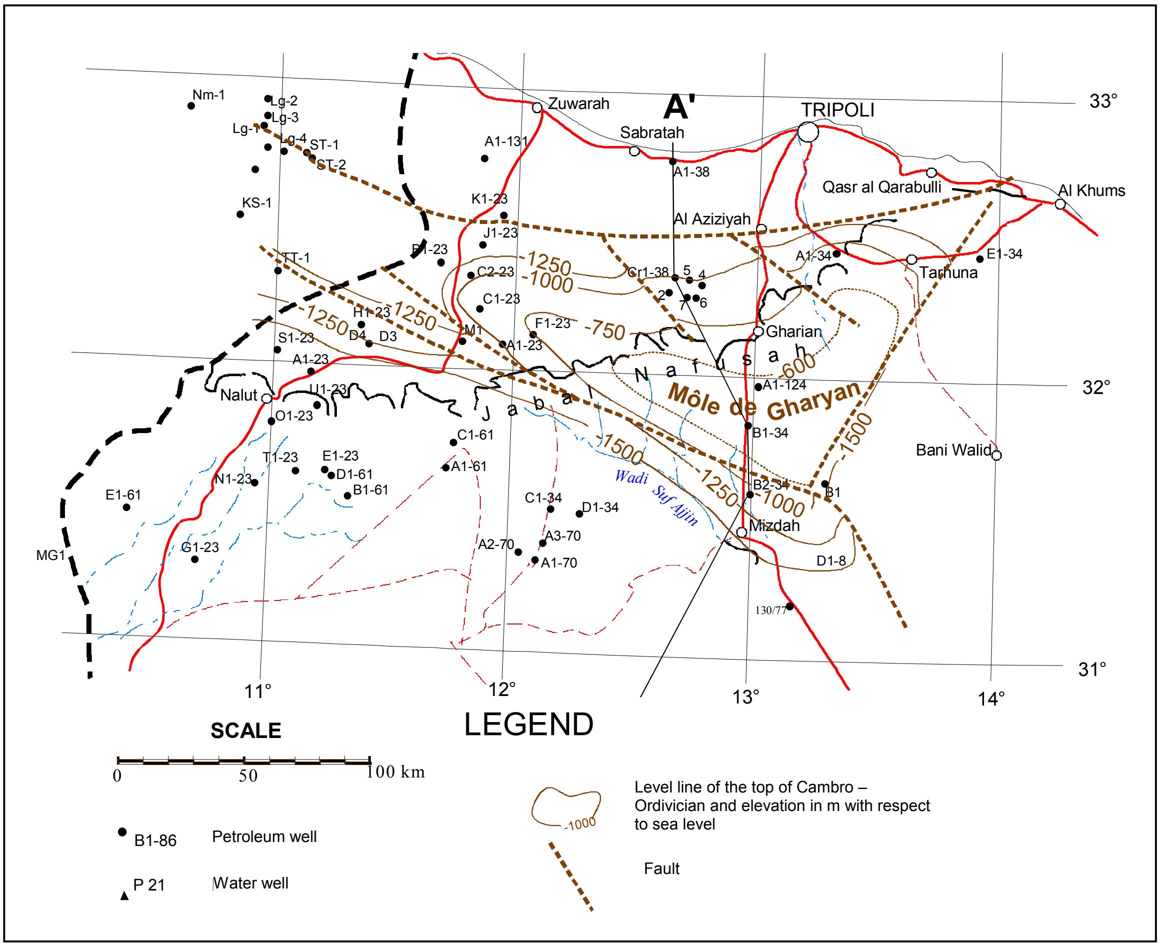
If there is any hydraulic connection between the Saharan basin and the Jifarah, this can only be at the level of the Triassic, the aquifer of the Lower Cretaceous (Kiklah) being interrupted at the level of the cliff of Jabal Nafusah and the Jurassic being for the major part impermeable, at least in the plain. Exchanges with the Djeffarah aquifer in Tunisia are conditioned by several phenomena of a structural and a lithological nature:

- Jabal Nafusah corresponds, in its central part, to a horst which has even caused the Precambrian to rise to an elevation in the order of – 500 m with respect to sea level at the location of well B1-34, some thirty kilometers to the south of the town of Gharyan, while a few kilometres further south, at the location of well B2-34, the Precambrian is at an elevation less than – 1500 m with respect to sea level. The upper structural zone, called Mole of Gharyan (uplift), is indicated on the map of figure 16 representing the top of the Cambro-Ordovician.
- Although the faults have not affected the post-Palaeozoïc formations as deeply, they have caused vertical drifts which are likely to make the communications between upstream and downstream rather difficult, or to facilitate them, at times, by bringing the Kikla – Upper Continental Jurassic to the south in contact with the Triassic formations (Al Aziziyah) north of the fault, such as suggested in the cross section AA'. The phenomenon is much more mitigated to the west, where the faults have a more reduced displacement and to the east, in the zone of Qasr al Qarabulli where the Kiklah formation seems to exist in the plain associated with the lower part of Abu Shaybah.

- The Triassic formations, which are considered as aquifers, undergo considerable changes of facies which alter their hydrodynamic properties. Thus, the sandstone formation of Abu Shaybah of the Upper Trias, which is largely exploited in the plain, becomes more and more clayey to the south, beyond Jabal Nafusah, and includes even evaporitic episodes. The dolomites and dolomitic limestone of Al Aziziyah of the Middle Triassic, which are excellent aquifers in the zone, turn gradually into marly limestone in the south and lose their aquifer nature. By contrast, the Upper Jurassic, which is impermeable in the plain, takes on a sandy-sandstone facies in the south and is frequently associated with the Kikla in the formation of a continuous aquifer over a large part of the Libyan Saharan basin.

In conclusion, there may possibly be underground flows from the Saharan basin to the Jifarah plain ; however, the data available do not allow an indication of their volume. In case a new model of the Jifarah plain is developed, this question of the underground outlets of the Saharan basin becoming inputs in the aquifers of the plain would need to be studied in detail.

Figure n° 16 : Connection with the Jifarah plain



2.5.3.2. Continuity of the aquifers to the South with the Palaeozoic

The Cambro-Ordovician of Jabal Hassawnah appears as a large, quite fractured sandstone and quartzitic massif, outcropping and sub-outcropping to the north under a thin Palaeocene or Upper Cretaceous cover, over an area of more than 20 000 km^2. Over a whole zone comprised between the 29th and the 30th parallel, the Lower Cretaceous aquifer (Kikla) is in direct contact with the Cambro-Ordovician, thus ensuring a perfect hydraulic continuity between the two aquifer systems. This coupling of two systems presents two major and contradictory consequences:

- As the Cambro-Ordovician constitutes a large reservoir of unconfined aquifer, the Kiklah aquifer associated with it will benefit, even at a distance, from this considerable reserve ;
- By contrast, as the zone of Jabal Hassawnah is the centre of a vast well field collecting the aquifer of the Cambro-Ordovician, intended to supply the western tributary of the Great (Manmade) River, the Kiklah aquifer will undergo directly the repercussions of the considerable abstractions (2.5 million m^3 day) envisaged for the Cambro-Ordovician.

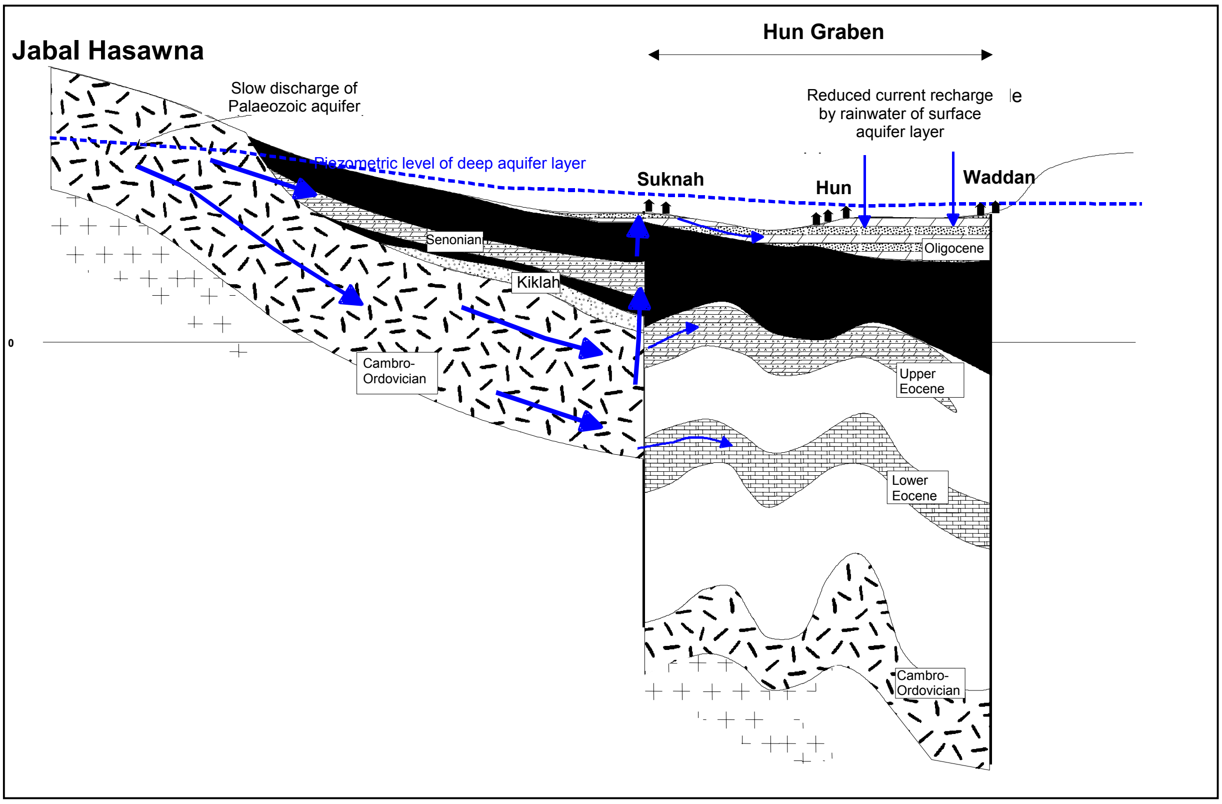
To the south-west, near the Algerian border, it is the Triassic detritic formations which advance further south. These formations are in contact with the impermeable aquifer and, therefore, there is in this zone no hydraulic connection with the Palaeozoic.

> In the eastern part of Hamada El Hamra, the aquifer reservoir of the Continental Intercalaire is not limited to the Kiklah series, but is in continuity with the aquifer formations of the Triassic and the Jurassic.
>
> Further south (Jabal Hassawna), the hydraulic continuity between these formations and the Cambro-Ordovician is assumed to be the origin of supply of this aquifer.

2.5.3.3. Role of the Hun graben

The Hun graben appears like a piano key whose axis would be located to the north where the throw is minimal, while to the south, in the zone of Al Jufrah, the deepening into the graben reaches 1000 m. The first consequence of this structure, which probably occurred in the Miocene, is the preservation of the Tertiary, pre-Miocene formations over a large part of the graben and the burying of the aquifer formations of the Pre-Cenomanian Mesozoic. The hydrogeological role of the graben may be summed up as follows :

Figure n° 17 - Role of the Hun graben in Al Jufrah zone



- The impacts of the structure are little sensitive to the north where the aquifer formations of Wadi Zamzam (Eocene, Nalut, Kikla) remain in continuity on both parts of the graben faults;
- At the centre, in the Abu Njaym zone, and to the south, in the Al Jufrah zone, the aquifer layers (Cambro-Ordovician, Kikla, Nalut, Mizdah) are completely disconnected on both parts of the western fault which interrupts the horizontal flow. By contrast, the western fault is the seat of vertical flow which allow recharge of the Eocene aquifers in the graben and, particularly, that of the Senonian aquifer (Mizdah) to the west of Suknah, as illustrated by the sketch of Figure 17.

2.5.3.4. The Tawurgha spring

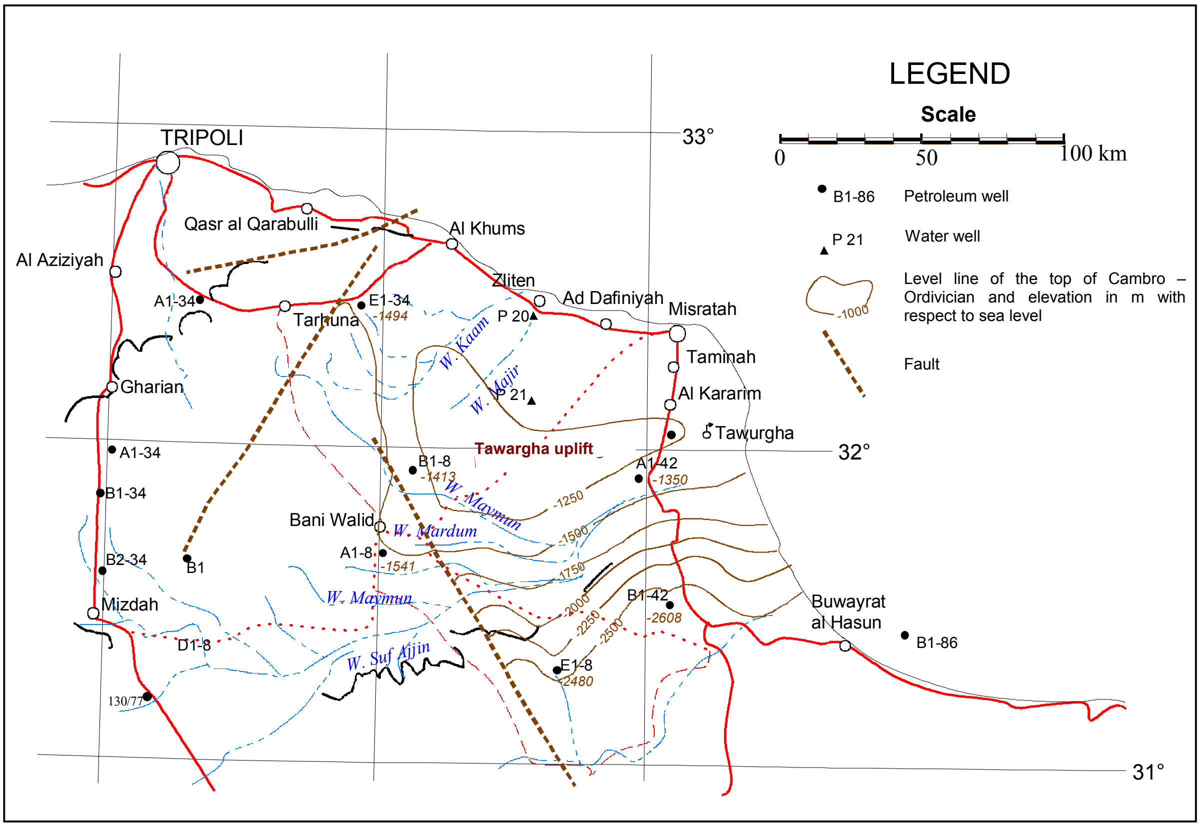
The Tawurgha spring (Figure n° 18) is one of the two most important springs of Libya, the other being the Ayn Zayanah spring north of Binghazi. The Tawurgha spring supplies a flow in the order of $2m^3/s$ via a link of several ten metres in depth which supplies a vast basin whose outlets used to flow over the sabkhah but which are currently conveyed to a pumping station that transfers the water to a farming project.

The outlet is located in an extremely flat zone and the topography provides no indication as to the possible origin of the spring and its location. Based on the many geophysical boreholes profiles carried out in the zone, as well as on the water chemical and isotopic analyses (Pallas and Bufila, 1978), it is possible to draw the following conclusions :

Figure n° 18 – The Tawurgha spring

- The Tawurgha zone is located at the edge of a high zone of the basement which is under the form of a Cambro-ordovician uplift illustrated by the map of Figure 19. In fact, the rise in the basement is even more abrupt since, at the level of well A1-42 located near the spring, the Precambrian basement is at elevation – 1500 m with respect to sea level, while at the level of well B1-42, located some 50 km further south, the substratum is at an elevation less than – 2700 m. This rise of the substratum esults in a reduction of the thickness of the sediments and, more particularly, of the aquifers, mainly in the Palaeozoic, thus forming some sort of an underground barrier perpendicular to the direction of the flows.

Figure n° 19: Cambro-Ordovician top around the Tawurgha spring



➢ The major aquifer of the zone, the Kiklah formation, loses its usual detritic facies over the whole basin to become carbonated dolomitic to the north of the Tawurgha parallel. The wells tapping the dolomitic Kiklah indicate a high reduction in transmissivity which comes to further reinforce the barrier effect due to the reduction in the thickness of the sediments.

➢ The isotopic analyses performed on the waters of the spring and on those of neighbouring wells clearly indicate that the water of the spring results from a mixture of old waters originating from the Kiklah and the Cambro-Ordovician and of more recent waters originating from the aquifers of the Upper Cretaceous supplied in the basin of Wadi Sufajjin.

The zone located between Zliten and Ain Tawurgha constitutes the main natural outlet, in Libya, of the Saharan system. The two springs of Ain Tawaurgha and Wadi Kaam as well as the sebkhas associated with them are the materialisation, on the surface, of this outlet.

3- SCHEMATIZATION OF THE AQUIFERS WITH A VIEW TO CONSTRUCTING THE MODEL

3.1- Choice of the aquifers and “aquitards” to be represented

The cross-sections described in paragraph 2.3 suggest a schematization of the aquifer over the entire territory studied. The permeable layers, which apparently have hydraulic interconnections between them, merge into an aquifer reservoir whose thickness varies according to the local conditions of their sedimentation. The other layers, approached as “aquitards”, ensure the horizontal continuity of the aquifers over the whole basin.

The structure of the Saharan basin as a large sedimentary entity favours its design as a multilayer aquifer system.

The adoption of a representation of the entire aquifer layers of the Saharan basin into a single multilayer system makes it possible to realise the lateral and vertical connections which govern the hydraulic and chemical exchanges. As the objective of this study is to analyse the behaviour of the system in the middle and long term, taking into consideration the various layers and of their relation has been deemed as a credibility requirement for the study.

The litho-stratigraphic sequence common to the three countries and making it possible to schematise the aquifer system of the north-western Sahara on the models is, from bottom to top, as follows:

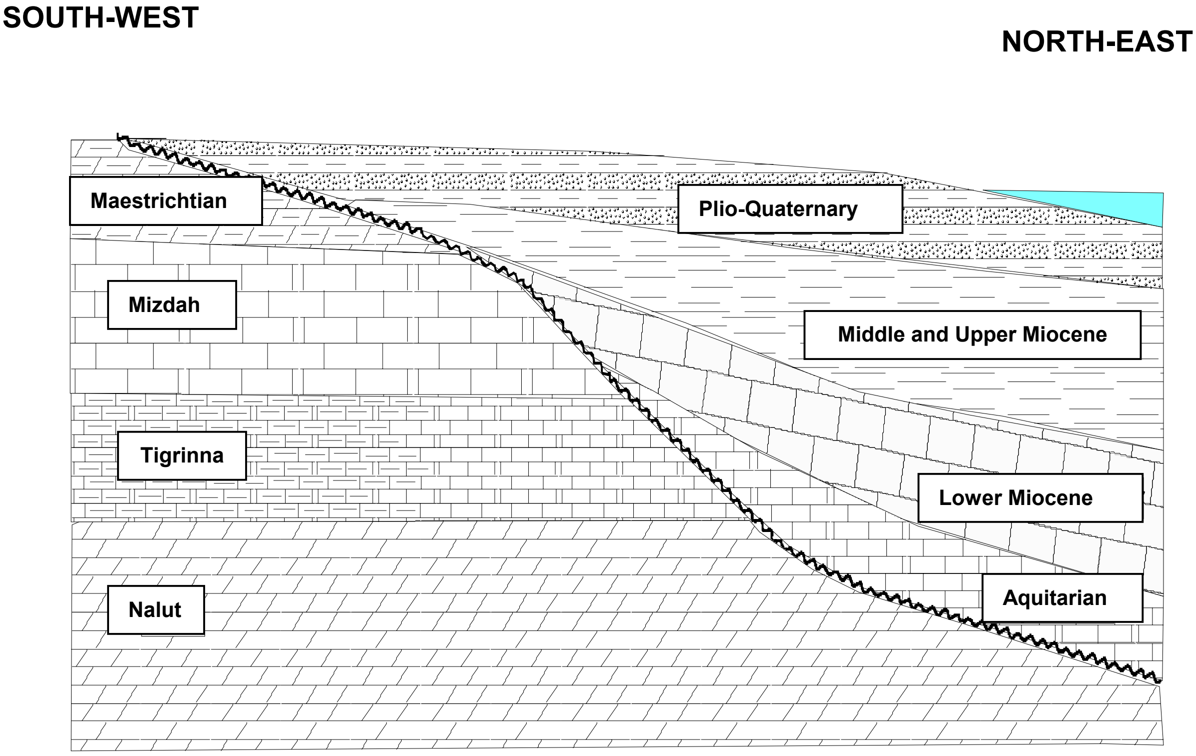
- The **overall impermeable substratum of the system** is composed, according to the zones, by the clayey-marly and evaporitic Trias or Jurassic, or more commonly by the clayey or clayey-sandy formations of the Palaeozoic. However, in the eastern part of the Libyan Saharan basin, the substratum of the system between the 29th and 30th parallels and at the location of the Tawurgha source, is composed of the sandstone of the Cambro-Ordovician forming a huge freshwater reservoir occupying the eastern half of Libya. This Palaeozoic reservoir is in direct contact with the Continental Intercalaire favoured by the faulted anticline structures : the horst of Gargaf (in which Jabal Hassawnah belongs) and the horst of Tawurgha. The communication of the Cambro-Ordovician reservoir with the aquifer system of the northern Sahara, at the location of Jabal Hassawnah, is the reason for the south-north flow into the eastern part of the basin, resulting from the slow discharge of the Palaeozoic reservoir.
- the **aquifer reservoir of the Continental Intercalaire** is associated with the detritic series of the top of the Palaeozoic up to the Upper Cenomanian. However, in the eastern part of the basin of the Eastern Grand Erg in Algeria, over a large part of the Tunisian territory and in the north-western part of the basin in Libya, the Jurassic and Triassic sedimentation stands out clearly in distinct, successive marine cycles. It then constitutes the Continental Intercalaire substratum composed exclusively of the Lower Cretaceous which is, at times, associated (in Tunisia and in Libya) with the detritic Upper Jurassic.

This configuration implies that the sandstone Lower Jurassic, though of a water bearing character, is not taken into consideration in the North-Western Sahara Aquifer System except when it is in hydraulic continuity with the aquifer of the Lower Cretaceous, that is when the thickness of the impermeable formations of the Jurassic or of the Triassic is less than 80 – 100 m, and when the formations consist of semi-permeable sediments without salty horizons.

- The **impermeable formation overlaying the Continental Intercalaire aquifer** corresponds to the marine transgression that had succeeded the long continental episode of the Lower and middle Mesozoic and which had covered the whole Saharan basin. This impermeable formation is composed of a clayey-marly series with, at certain locations, evaporitic passages, of Cenomanian age, whose thickness may be of several hundred metres in the central part of the basin, located in Algeria. It goes on thinning to the east in Libya where it is of only a few ten metres in the zones of Buwayrat al Hasun and Tawurgha.

- The **carbonated dolomitic aquifer** extending from the Upper Cenomanian to the Turonian, whose thickness is fairly constant over the whole Saharan basin and hardly exceeds 50 m, is present throughout the Saharan basin. The formation known as Nalut in Libya presents a more marly facies in the south-east of the Libyan Saharan basin. This aquifer is exploited in Libya (region of Misratah) and in Tunisia (Dahar and Nefzaoua) where its water is of acceptable quality (with a salinity less than 3 g/l). Elsewhere, and especially in Algeria, its water is excessively saline (50 to 80 g/l) and constitutes a contamination risk for the aquifers located above.
- The **marly-gypseous series** of the Lower Senonian, which grow fairly thick within the basin of the Grand Erg Oriental, isolate the aquifer of the Cenomano-Turonian from the underlying Complexe Terminal. In Algeria, this impermeable formation is composed of the lagoon Cenomanian whose overriding facies consists of limestone-marls, marls and anhydrite. The “saline” level of the Lower Senonian is vastly extended in the basin of the Grand Erg Oriental. In Tunisia, this level becomes semi-permeable and is made up of the marly-gypseous unit of the Lower Senonian (Upper Zebbag formation). In Libya, the semi-permeable series corresponds to the clays, marls and gypsum of the Tigrinna formation whose thickness may reach a few hundred metres.
- The **aquifer series**, which overlays the Lower Senonian, constitutes a hardly homogeneous set, known in Algeria and Tunisia as the « Complexe Terminal » which encompasses the carbonated series of the Senonian and the Tertiary sands.
- The **Senonian and Palaeocene limestone aquifer** gains in importance in the zones where the Tertiary sands are absent or of a small thickness (Biskra, Nefzaoua, J. Nafusa). Their thickness and their permeability vary according to the conditions of sedimentation and of surface alteration (fracturing and fissuring). In Algeria, the aquifer level of the limestone of the Complexe Terminal is made up of the Carbonated Senonian (Santonian, Campanian and Maestrichtian) and of the Carbonated Eocene which includes the limestone of the Palaeocene and the Lower Eocene. In Libya, the Upper Senonian (Mizda formation) appears under the form of limestone that is extensively scattered over the southern flank of Jabal Nafusa and in the south-eastern part of the basin, where it constitutes a fair aquifer (basin of wadi Sufajjin) to excellent aquifer (Al Jufrah).

Figure n° 20 – Sketchy cross-section showing the relations between the Upper Cretaceous and the Miocene in the zone of Misratah



- The **semi-permeable formation overlaying the aquifer of the Senonian limestone** is composed of the formations of the evaporitic Middle Eocene (Algeria) or of the Eocene and the Palaeocene (Tunisia) of a marly-clayey to marly-limestone nature. In Libya, this semi permeable formation gains in importance to the east (Hun graben and Sirt basin).
- The **Tertiary sands aquifer** is of paramount importance for the Algerian-Tunisian Lower-Sahara region (Oued Rhir and Djérid). In Libya, the sands and limestone of the Lower Miocene are represented only in the north-eastern part of the basin where they are in connection with the carbonated aquifers of the Upper Cretaceous as indicated on the sketch of Figure 20.
- An **impermeable top** overlays the Tertiary sands aquifer and is composed of little permeable clayey series. In certain locations in the basin of the Western Grand Erg, this top is made up of the Mio-Pliocene series and overlays immediately the formations of the Lower Cretaceous. In Libya, in the zone of Misratah, it is the clays and marls of the Middle and Upper Miocene which constitute the top of the underlying aquifer sands.
- **Other aquifers** are found in the Libyan Saharan basin, and their strictly local importance makes difficult their integration within a regional context. These are in particular:
  - the Oligocene aquifer present exclusively in the southern half of the Hun graben ;
  - the Upper Eocene aquifer present in the northern half of the graben and towards the gulf of Sirt. This aquifer is exploited in particular by private farming in the wadis of Zamzam, Wishkah and Mrah ;
  - the Plio-Quaternary shallow aquifer composed of sands and limestone-like materials which, in fact, constitutes a unit limited to the coastal zone of the north-east without any real link with the other aquifers.

It does not seem useful, in the context of the present study, to represent these aquifers in the Model.

3.2- Schematisation with a view to the construction of the Model

Based on reference to geological structure of the Saharan basin and to the bahaviour of these various aquifer levels, after about a century of steadily increasing exploitation, the Model has been designed as a multilayer whose vertical exchanges are duly taken into consideration in the calculation of its water balance. This option adopted by the current SASS study stands out from all the previous modelling conceptions, particularly the ERESS study. It allows for the first time to be closer to the natural operating of the system and provides many indications as to the water exchanges between the various aquifer levels of this system.
Figure 21 shows the schematisation adopted with a view to modelling the system.

Figure 21 – Aquifers - "aquitards" schematisation with a view to constructing the Model

ALGERIA	TUNSIA	LIBYA
Impermeable top	Impermeable top	Impermeable top
Sands aquifer	Sands aquifer (Djérid)	Lower Miocene sands and limestone aquifer (coastal zone)
	Complexe Terminal aquifers	
Limestone aquifer	Limestone aquifer (Nefzaoua)	Limestone aquifer (Mizdah
Semi-permeable	Semi-permeable	Semi-permeable
Turonian aquifer	Turonian aquifer	Turonian aquifer
Semi-permeable	Semi-permeable	Semi-permeable
	Continental Intercalaire Aquifer	
Lower Cretaceous Jurassic - Trias	Lower Cretaceous Upper Jurassic / Lower Cretaceous Upper Jurassic	L. Cretaceous (Kiklah) – Upper Jurassic -Trias
	Impermeable Substratum	
Palaeozoic / Lower Jurassic – Trias	L. Jurassic - Trias	Carbonif. / Cambro-Ordovician aquifer

3.3- Recommended boundaries for the model

3.3.1- Horizontal extension of the Complexe Terminal and recommended boundary for the layer representing the Complexe Terminal

The western and northern TC boundaries are natural boundaries. They are approximately the same as those adopted by ERESS. To the South, the TC has been extended up to the southern confines of the outcrops, thus allowing a better consideration of the aquifer reserves which had not been taken into consideration by ERESS. Problems relating to the boundaries to be taken into consideration exist, however, in Libya in the eastern part of the basin which runs, due to the Hun graben, into the Sirt basin where the Tertiary sedimentation is highly developed and substitutes for the Upper Cretaceous which subsides deeply and becomes very little transmissive and saline.

The map of Figure 22 represents the natural boundaries of the two aquifers of the Cenomanian Turonian (Nalut) and the Senonian (Mizdah), corresponding, to the north and to the south, to the extension boundary of these formations. To the east, on the other hand, the formations are still found under the Tertiary cover, but it is assumed that, east of the meridians 16°30' - 17°, the two aquifers become very little transmissive and water salinity exceeds **5 to 6 g/l**.

3.3.2- Horizontal extension of the Continental Intercalaire and recommended boundary for the layer representing the Continental Intercalaire in the Model

The boundaries of the Continental Intercalaire in Algeria and in Tunisia are almost the same as those adopted by ERESS. In Algeria, however, the Model is extended to the north east so as to include the Western Grand Erg up to the Saoura. This adjustment is justified by the fact that the Continental Intercalaire is relayed by the sandy formations of the Mio-Pliocene and by the dunes of the Grand Erg.

The inclusion of this additional aquifer volume allows a consideration of the reserves contained therein. The eastern boundaries to be adopted in the Model in Libya give rise to a certain number of problems, of which in particular:

- **The south-eastern boundary does correspond to a natural boundary** of extension of the Lower Cretaceous formations, but it is in continuity with the Cambro-ordovician aquifer with which the Continental Intercalaire is in direct contact over an area of more than 20 000 km^2;
- The north-eastern boundary is not a natural boundary, as the formations of the Cretaceous or of the Jurassic extend into the sea. However, the sandstone formations of the Lower Cretaceous which constitute the active body of the aquifer system of the Continental Intercalaire pass rapidly into carbonated dolomitic formations at the level of the parallel of the Tawurgha spring (**Figure n° 23**). This change of facies, which is partially at the origin of the spring, translates into a **major reduction in transmissivity whose values obtained by flow tests are less than 10^{-3} m^2/s along the cost.**
- **The eastern boundary is not a natural limit either** since the aquifer formation of the Lower Cretaceous extends substantially beyond the graben. Beyond meridian 16°E, the aquifer of the Continental Intercalaire presents a low transmissivity (in tests) and a water salinity which soon exceeds 3 - 4 g/l towards the Sirt basin and obviously loses any significance for any possible exploitation. However, given the presence of farming projects (Wadi Wishkah, Wadi Zamzam, Wadi Bayy al Kabir) located in the immediate vicinity of this boundary, it is essential that the model should estimate the impacts of an increase in abstractions in this neighbouring zone on the chemical quality of the water which would undergo considerable degradation if the direction of the flow were to be inverted. **It is, therefore, important to plot, on this Model, the boundary of the layer representing the Continental Intercalaire as further East as possible, at least, along meridian 16°30' and, at most, along meridian 17°.**

Figure n° 22 – Recommended boundary for the layer representing the Complexe Terminal

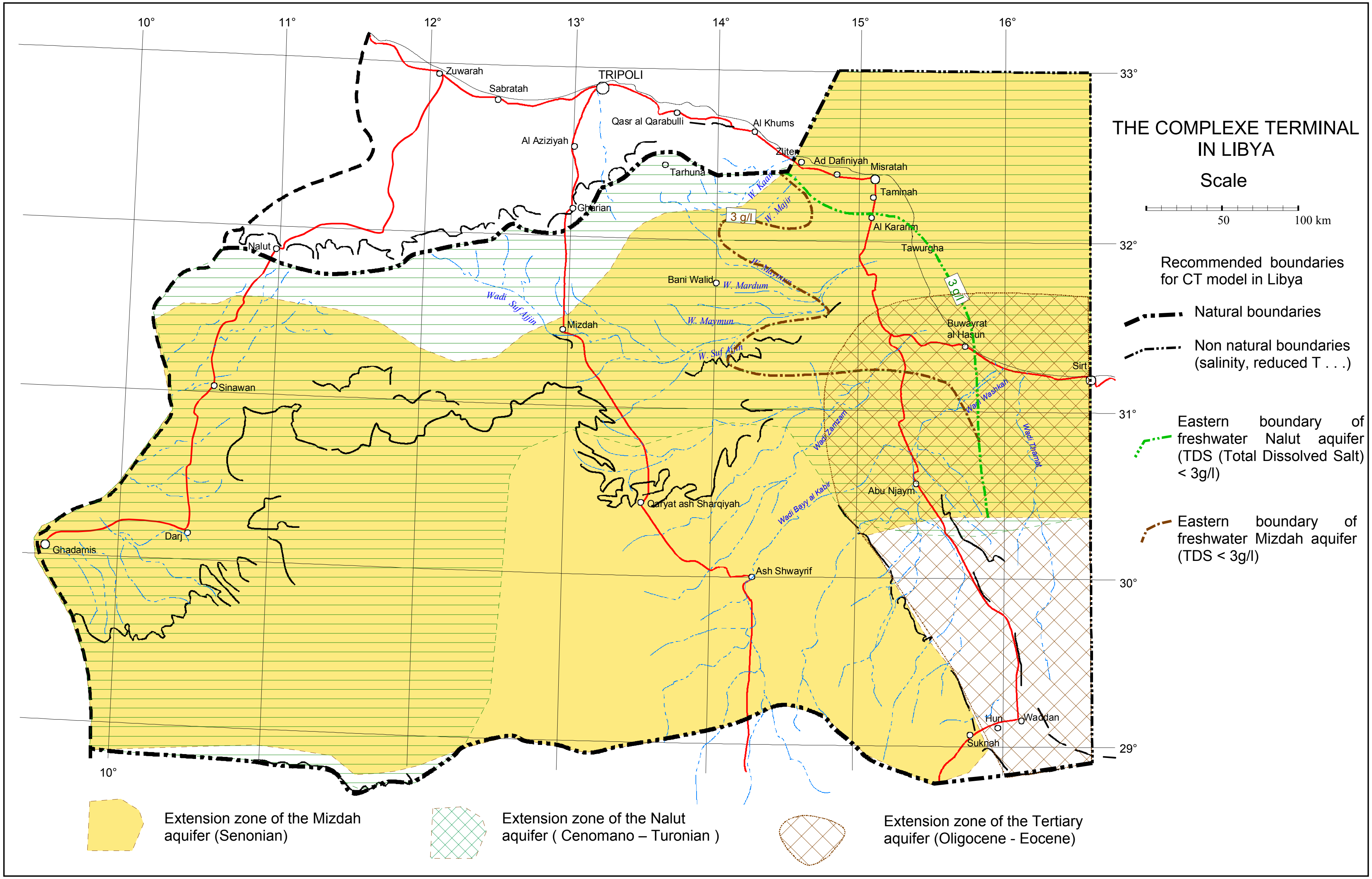
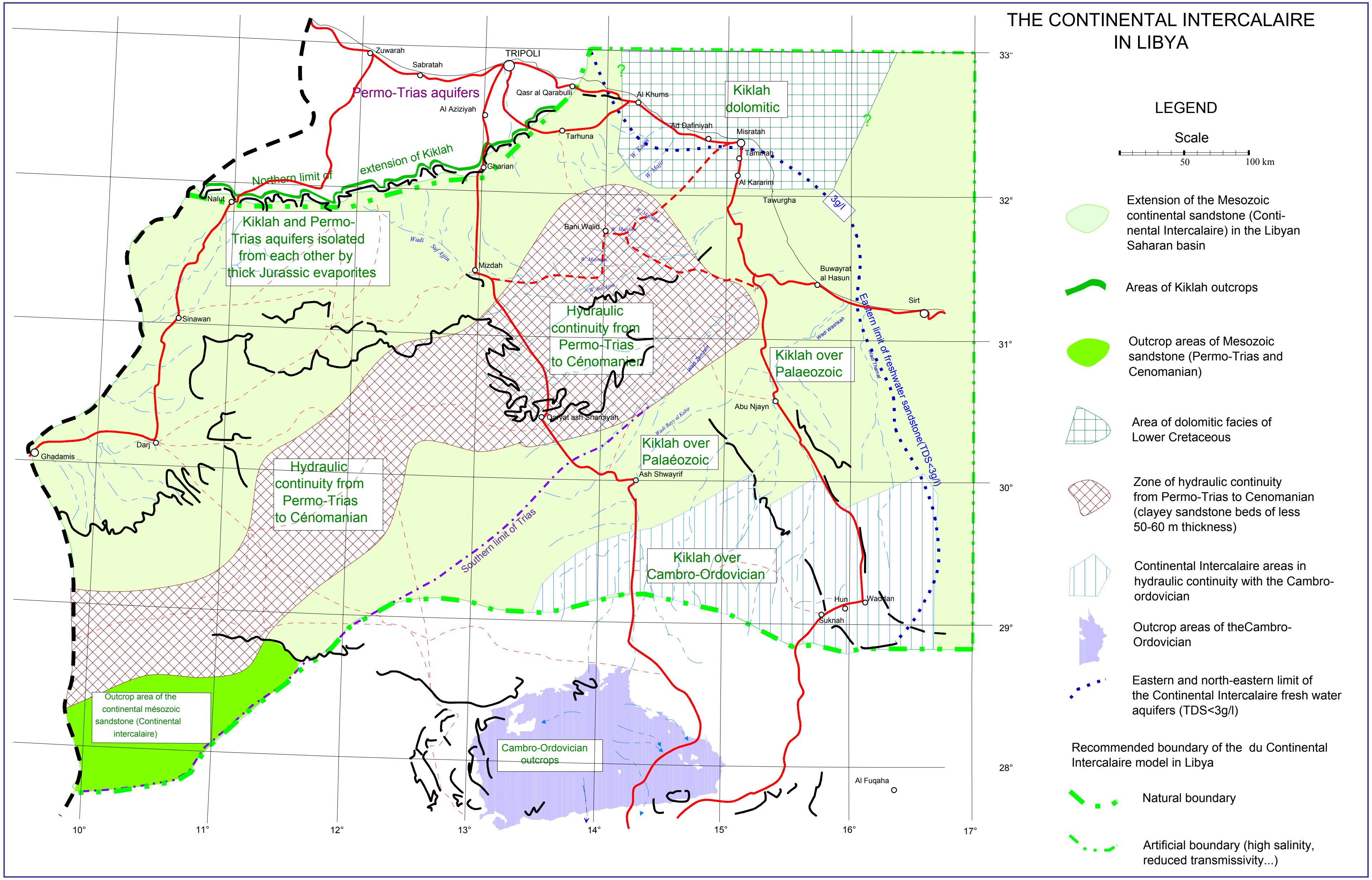


Figure n° 23 – Recommended boundary for the layer representing the Continental Intercalaire



4- HYDRODYNAMICS OF THE AQUIFER SYSTEM

4.1- Dynamics of the system

The depression-like structure of the Saharan basin causes the ancient geological layers to outcrop only on the borderlines. On the whole, the major part of these aquifer formations, other than the quaternary levels, are under a more or less thick sedimentary cover. This results in the fact that, over a large part of this basin, the aquifers are confined; however, unconfined aquifer zones exist also on the periphery and fairly often correspond to the recharge areas.

This complex configuration causes the hydrodynamics of the whole basin to be largely dependent, in the middle and long term, on the impact of the vertical exchanges between the various aquifer levels. The influence of the exploitation fields on the neighbouring zones will be different in the confined part of the aquifer (large action radius) from the part where it is unconfined (case of the sub-basin of the Grand Erg Occidental). These phenomena also affect the water circulation speed within the aquifer, the vertical chemical exchanges and the losses at the outlets.

Throughout the part of the basin where the Plio-Quaternary sedimentation is sufficiently thick and detritic, an unconfined shallow aquifer constitutes the most superficial aquifer level. This aquifer has a significant role in the exchanges of the groundwater system with the surface. This role is expected to become all the more crucial as the pressure of the underlying confined levels diminishes.

4.1.1- Reference piezometric map

4.1.1.1- Definition and significance in the three countries

Reference piezometry is a notion required by the drilling of the aquifer simulation model. The calibrating of the model, which allows to ensure the consistency of the various parameters involved in the execution of the model (transmissivities, boundary conditions, recharge, outlet flows, exploitation flows . . .), consists in checking that the piezometry calculated by the model is consistent with that which has been measured. In order to avoid having also to calibrate the parameter governing the storage, it is common practice to refer, for the calibrating of the model, to the piezometry that corresponds to a date during which the system is supposed to be in steady state (equilibrium)[(1)], which corresponds to a system that is not influenced by human activities. We have, accordingly, chosen a date during which the exploitations by wells were quite reduced.

In reality, the exploitation of the Continental Intercalaire did not start in the same period in the three countries. The drilling of the first wells tapping this aquifer dates back to the early 20th century, for Algeria, to the 1950s, for Tunisia, and to the 1970s, for Libya. In spite of this time difference with regard to the exploitation of this aquifer, the exploitation had remained fairly small until the 1960s. There are hardly any piezometric measurements relating to the old wells prior to 1956. We have, therefore, chosen to consider the year 1950 as a reference date for the initial piezometry of the non influence system, and this despite the fact that the data used for plotting the initial piezometric map only rarely correspond to this date. In fact :

- **In Algeria**, it was in 1956 that exploitations by deep boreholes started in the zone of the Algerian Lower Sahara where the abstractions were the most developed. Prior to this date, the only major exploitations of the CI aquifer had consisted in :
    - the foggaras of Touat-Gourar and Tidikelt whose flow did not vary for several ten years ;

([1]) the inlets are equal to the outlets and the reserves do not apply.

- the El Golea exploitation set, located on the confines of the confined/ unconfined aquifer, does not seem to influence the piezometric forms of the neighbouring zones.

In the other exploitation zones (Ghardaïa, El Oued and Ain Salah), the abstractions were little and could not modify in any significant way the aquifer's water system.

- **In Tunisia**, the first borehole tapping the CI aquifer in Tunisia (Borj Bourguiba) was drilled in 1950. It was followed upon closely by that of Ksar Ghilane. The two wells of Chott Fedjej (CF1 and CF2), drilled almost in the same period, were not to come into exploitation until the late 1960s. Prior to this date, the exploitation of the aquifer of the Continental Intercalaire was taking place in the Tunisian south by means of springs located in the regions of Chott Fedjej and whose flow did not exceed 50 l/s.
- **In Libya**, the early boreholes tapping the Kiklah aquifer were drilled in the early 1970s. In reality, however, this exploitation had remained fairly small throughout the decade 1970-1980. Only in the late 1970s were the farming projects of the eastern flank of Hamadah El Hamra set up which intensified the exploitation of the deep aquifer.

4.1.1.2. Existing data

The reference piezometry adopted has been established based on the following items :

- the topographic level elevations of the water points as determined by measurements made by the countries or by interpolation onto the topographic maps in case of absence of such measurements,
- the head measurements made in wells both at surface and in depth of the water.

As a general rule, only the altitudes determined by leveling survey are considered precise in the establishment of the initial piezometry. The altitudes determined based on maps may contain errors in the range of up ±20m.

As regards the Complexe Terminal, its exploitation had started in Algeria and in Tunisia long before the drilling of boreholes of which the early ones in Algeria date back to the second half of the 19th century and in Tunisia to the early 20th century. In Libya, this exploitation is much more recent, though a certain number of wells were drilled, in the Upper Cretaceous, as early as the 1930s in the agricultural projects zones of Dafniyah, Tumina an Kararim.

The data used to represent the initial piezometry of the aquifers of the Complexe Terminal and of the Continental Intercalaire are provided in Annexe 2.

4.1.1.3. Description of the reference piezometric maps

Two reference piezometric maps are proposed off text under the form of plates.

- ***Complexe Terminal***

The reference piezometric map of the CT (Pl. n°10) was established based on measurements made in 1950 – 56, for the Tunisian-Algerian part, and in the period 1950 – 70, for the Libyan part. The wells of the oilfield projects of Hamada El Hamra have made it possible to fill in a major gap in the establishment of the piezometry of this aquifer in Libya.

This piezometry has involved, in Algeria and in Tunisia, the wells that tap the Senonian and Eocene limestone, as well as the Pontian sands (Oued Rhir and Djérid). The piezometry of these formations, which are often under the form of hydrogeological relays, matches perfectly and allows for the obtaining of a continuity of underground flow as one passes from one zone to the other. In Libya, it rather relates to the wells tapping the limestone and dolomites of the Nalut formation (Turonian) and, at times, the Mizdah formation (Senonian). In Tunisia, the piezometry of the Turonian limestone merges in the region of the Kebili peninsula with that of the Senonian limestone. In Algeria, apart from the region of Hassi

Messaoud, the Turonian is not a good aquifer and, in this zone, **salinity often exceeds 50 g/l**.

This piezometry reveals :

- the division of the saharan domain into two main hydrogeological sub-basins which are those of the Grand Erg Oriental and of Hamada el Hamra;
- the same major recharge zones as those of the IC/ Kiklah aquifer (Saharan Atlas, Dahar - J. Nafusa and J. Hassawnah);
- the outlet zones mainly concentrated in the Algerian-Tunisian Chotts and the Gulf of Sirt between Misratah and Buwayrat Al Hasun.

The piezometry of the CT/ SC aquifer reveals, in the sub-basin of the Grand Erg Oriental, the role of the Algerian-Tunisian Lower Sahara in centering the underground flow, thus forming an endoreic basin. The Marouan - Melrhir Chotts in Algeria and Gharsa – Djérid in Tunisia constitute the outlet of the aquifer and, at the same time, the region where the abstractions via springs and wells are concentrated.

In Libya, the recharge from the south seems to override that from J. Nafusa. The Hamada El Hamra zone is a « shelf » zone where the piezometric gradient is relatively smooth but where the runoff directions seem to assign the Hamada the role of a recharge zone. This is more probably a large ground reservoir that is currently not recharged and whose slow discharge maintains a flow to the outside of the zone. In the north-eastern part of the Libyan basin, the Tertiary and Quaternary sedimentary layers seem to play a major role in the recharge of the CT/ SC aquifer and in its losses by vertical leakage, in the outlet zones.

- ***Continental Intercalaire and link with the Palaeozoic***

The reference piezometry map of the CI (Pl. n° 11) reveals:

- a **division of the Saharan domain** into several hydrogeological provinces which are :
  - the Lower Sahara with a west-east flow,
  - the Tinrhert and the Eastern Grand Erg, with a south-north flow,
  - the Grand Erg Occidental, the Touat - Gourara and the Tidkelt, with a north-south and a south-west flow,
  - the Dahar and J. Nafusa, with a east-west and north-south flow ,
  - J. Hassawna, with south-north and north-east flow,
  - the **recharge zones,** with the boundaries suggested by the aquifer, and which are :

Plate 10 : Initial piezometric map of the Complexe Terminal

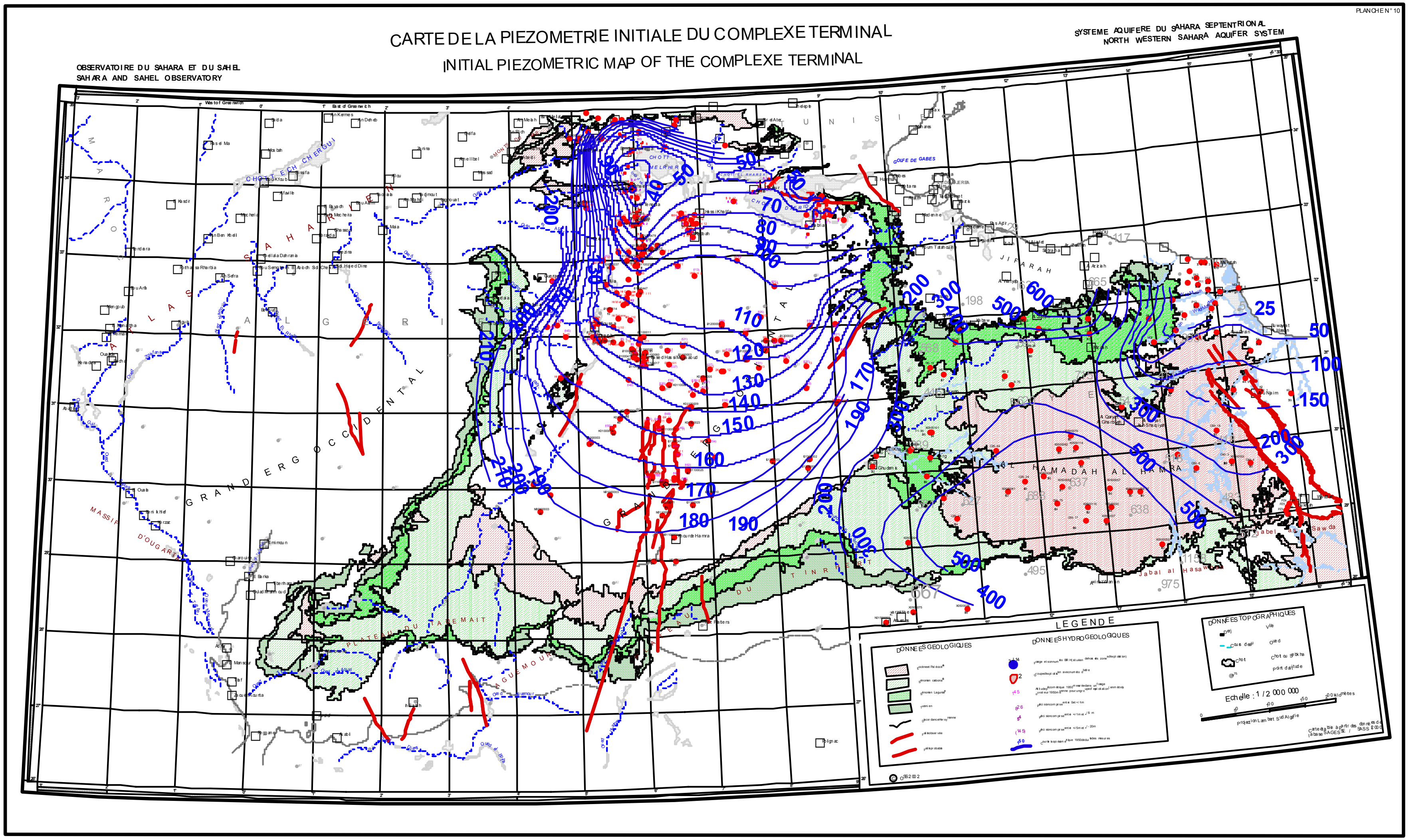
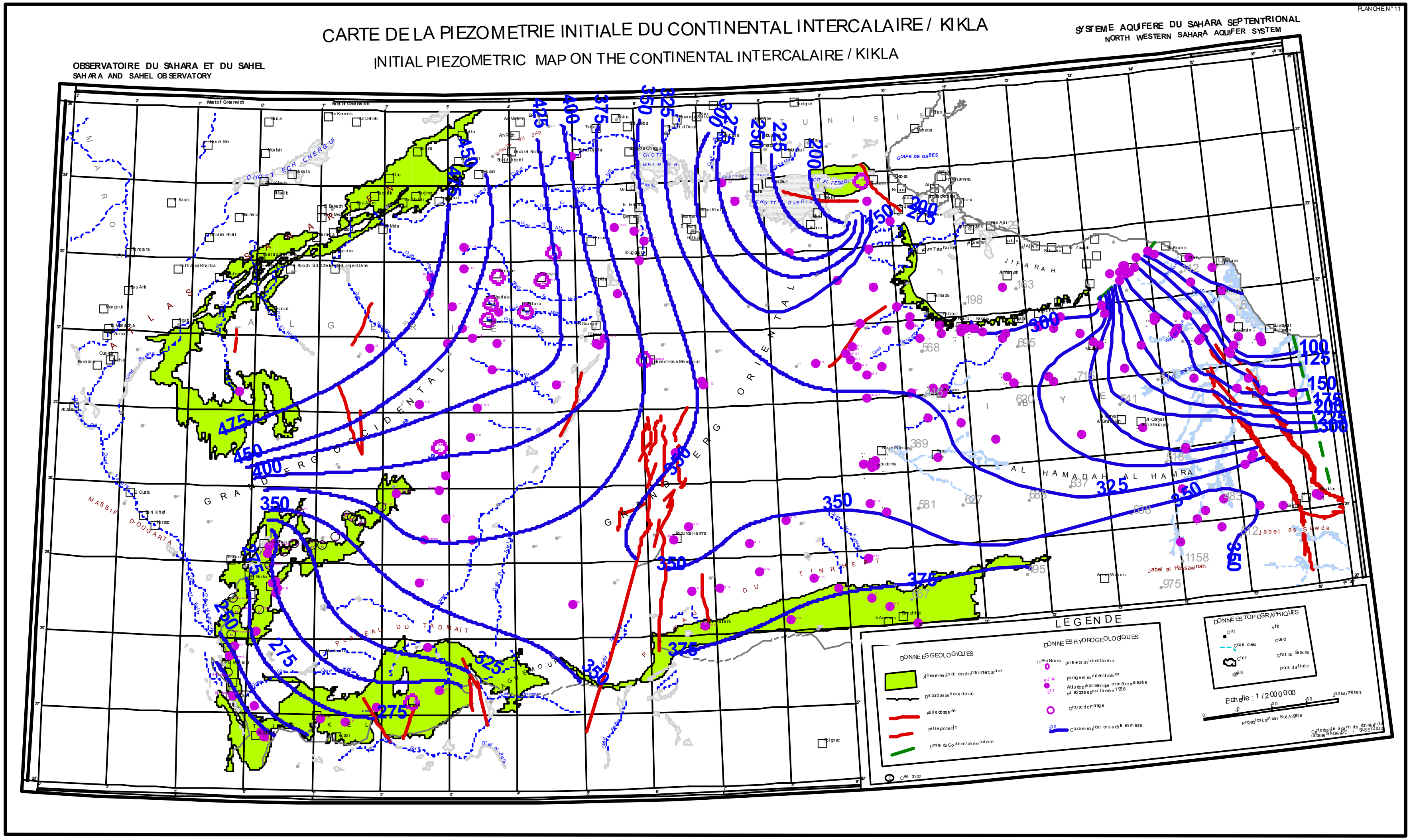


Plate 11 : Initial piezometric map of the Continental Intercalaire/ Kiklah



- the south Atlas piedmont of the north-west,
- the Tinrhert, where the recharge is probably more an effect of slow discharge of the reservoir than an actual recharge of the aquifer from a rather very scarce rainfall,
- the Dahar (Tunisia) and J. Nafusa (Libya),
- J. Hassawnah, where the piezometry of the Kiklah matches perfectly the piezometry of the Cambro-Ordovician aquifer which presents, on Jabal Hassawnah, a dome at an elevation of 350 m that is drained to the south by wadi ash-Shati and to the north by the Continental Intercalaire aquifer. The only possible explanation for these flow directions is, here again, a slow discharge of the Palaeozoic reservoir which gives rise to south-north flows in the Continental Intercalaire.

➢ the **outlet zones**, suggested by the end points of the current contours drawn by the piezometric map, which are :
  - the Touat - Gourara and the Tidkelt,
  - the Tunisian outlet, marked by El Hamma fault,
  - the Libyan outlet at the level of Ain Tawargha.

The piezometry of the CI aquifer reveals, in the sub-basin of the Grand Erg Occidental, a quasi total dependence on the remainder of the aquifer with a flow from the saharan Atlas towards the south, then the south-west. A dividing line of the groundwater separates the flow taking place in a westward direction from that which relates to the eastern part of the basin. The aquifer outlet was initially presented under the form of springs that were transformed by man into foggaras, following a drawdown of the piezometric area.

The piezometric dome centered on the Dahar - Jabal Nafusa reveals a local recharge area in the zone where the aquifer is not spouting. This present recharge is reflected in the chemical composition of the water and its isotopic characteristics.

The piezometric anomaly on the Amguid ridge can only be explained by a vertical leakage towards the Complexe Terminal, through the faults of this zone.

4.1.2- Current recharge : Data and hypotheses

The current recharge of the aquifers obtains on the boundaries when three conditions are met :

- sufficient rainfall and a relatively marked relief such as to induce a streaming into the wadis,
- the outcrop of permeable formations, belonging in one of the aquifer systems, or in direct relation with one of the Saharan aquifers.

The value of recharge in the model is not a fundamental parameter in the simulation of the future behaviour of the aquifers, since the abstractions are generally located far from potential recharge zones. However, in the steady-state calibrating phase which allows the definition of the distribution of transmissivities, the recharge is the result of the calculation obtained by setting the boundary potentials and by varying the transmissivities: when the recharge value is set and considered as a datum for the model, the transmissivity is gradually varied until obtaining the calibrating of the piezometry which is reproduced on that which is measured. This approach allows the achievement of a distribution that is different from the transmissivities and, therefore, a different behaviour of the aquifer when it is prompted by the abstractions.

In any case, the current recharge of these aquifers is low with respect to the current and expected future abstractions ; whatever the result of more precise hydrological studies may be, the latter will not change the non-renewable character of the water resources of the Sahara.

4.1.2.1. In Algeria

In Algeria, these conditions do obtain along the north-western boundary, at the base of the Saharan Atlas. The runoffs originating from the Atlas will infiltrate into the dune sands of the Grand Erg Occidental to ultimately join the Continental Intercalaire. Unfortunately, no hydrological study has been conducted in this zone which would have provided estimates, albeit approximative ones, of the annual volumes streaming and infiltrated. Synthesis studies need to be promoted in this respect in future.
The Mzab ridge, though receiving little rainfall, is nonetheless the seat of runoffs into the wadis which flow in an eastward direction and contribute in the recharge of Upper Cretaceous and Eocene limestone belonging to the Complexe Terminal. Here again, no study has come to provide estimates of the quantities that stream in this location. **This hydrological aspect of the Algerian Sahara needs to be enhanced by specific studies to be conducted subsequently even in the framework of research works.**

4.1.2.2. In Tunisia

In Tunisia, the recharge of the aquifers of the Complexe Terminal and, indirectly, of the Continental Intercalaire depends mainly on the rainfalls and runoffs on the massif of Dahar. The inflows from the northern hydrological basins, originating in the Atlas, will either feed the surface aquifers of the zone of the Chotts, or accumulate in the Chotts where they are reclaimed by evaporation. In the ERESS study, the current recharge of the Continental Intercalaire from the Dahar had been estimated as **2 m^3/s**. Since then, hydrological studies (M. Fersi, 1979) relating to the wadis of the western flank of the Dahar, have led to a more reliable estimate of the recharge. Table 5 gives the results of these studies.

Table 5 – Hydrological characteristics of the wadis of the western flank of the Dahar (M. Fersi, 1979)

Catchment	Area S (Km²)	Rainfall P (mm/year)	Flow Q (m^3/s)	Specific flow Qs ($m^3/s/km^2$)	Runoff coefficient Kr (%)
Oued Tarfa					
- Oued Léguine	206	90	131	0.630	21.6
- Oued. Oum Labbes	86	100	160	1.860	26.8
- Oued. Zmertene	44	140	340	0.821	8.4
- Oued. Hallouf	1800	95	1140	0.633	7.2
Garaet Bou Flidja	1540	140	1940	1.260	12.9
- Oued. Bel Khacheb	670	125	550	0.821	9.8
- Oued. . Laraj	108	100	33	0.306	4.4
- Oued. rechada	576	100	150	0.260	3.8
- Oued. Mahabès					
	Total:5030	**P :120mm**		**Av. Qs: 0.85**	**Av. Kr: 12%**

Considering that the total area of these two basins is filtrating (Senonian limestone formations), and considering an average annual rainfall of 120 mm and a runoff coefficient of 12%, the streamed volume would be in the order of 72.4 10^6 m^3/year. Infiltration down to the aquifer involves only about 10% of this volume, which yields an infiltrated volume in the order of 7.2. 10^6 m^3/year (Q :229 l/s).

This recharge has also been evaluated based on the speed of underground flow as deduced from the carbon-14 activities, and this by means of the following formula (Aranyossi & Mamou, 1985):

$$Q = Ve.S.ne$$

where : Q : Recharge flow from the Dahar,
Ve: Underground flow speed determined based on the Carbon 14 contents (Ve = 2m/year)
S : Total aquifer flow section (length of outcrop : 200 km and thickness of the aquifer formation : 150 m).
ne : Cinematic porosity of the aquifer formation (ne = 0,05 to 0,1).

The application of the formula based on the speed measurements yields a recharge flow which is, at best, equal to 190 l/s, corresponding to 10% only of the value adopted by ERESS. This value, even if it is only a range of magnitude, seems more consistent with the piezometric evolution of the aquifer which presents, in the Tunisian far south, a decreasing trend (annual drop in the range of 1 to 2,5 m/year), thus implying lower transmissivity values than those adopted by ERESS.

The whole body of geological data (wells), hydrogeological data (piezometry) and geochemical data (isotopes) reveals that the ERESS evaluation of the recharge of the Saharan aquifers by current infiltration on the Dahar (Q :2 m^3/s) is overestimated and does not exceed, at best, 250 l/s. It is worth pointing out that hypotheses relating to the current recharge of the Saharan aquifers are subject to considerable uncertainties under the overall aridity conditions of the region.
In addition, the inter-annual variability of such supplies is quite considerable and significantly reduces the precision of the mean values. The approach focused on hydrometric observations based on which « empirical formulas » or hydrological models are established (as is the case in Tunisia), allows the achievement of mean recharge estimates that are consistent with the other data. All the hydrological estimates remain approximate as long as they do not correlate with attempts to develop a water balance of the system.

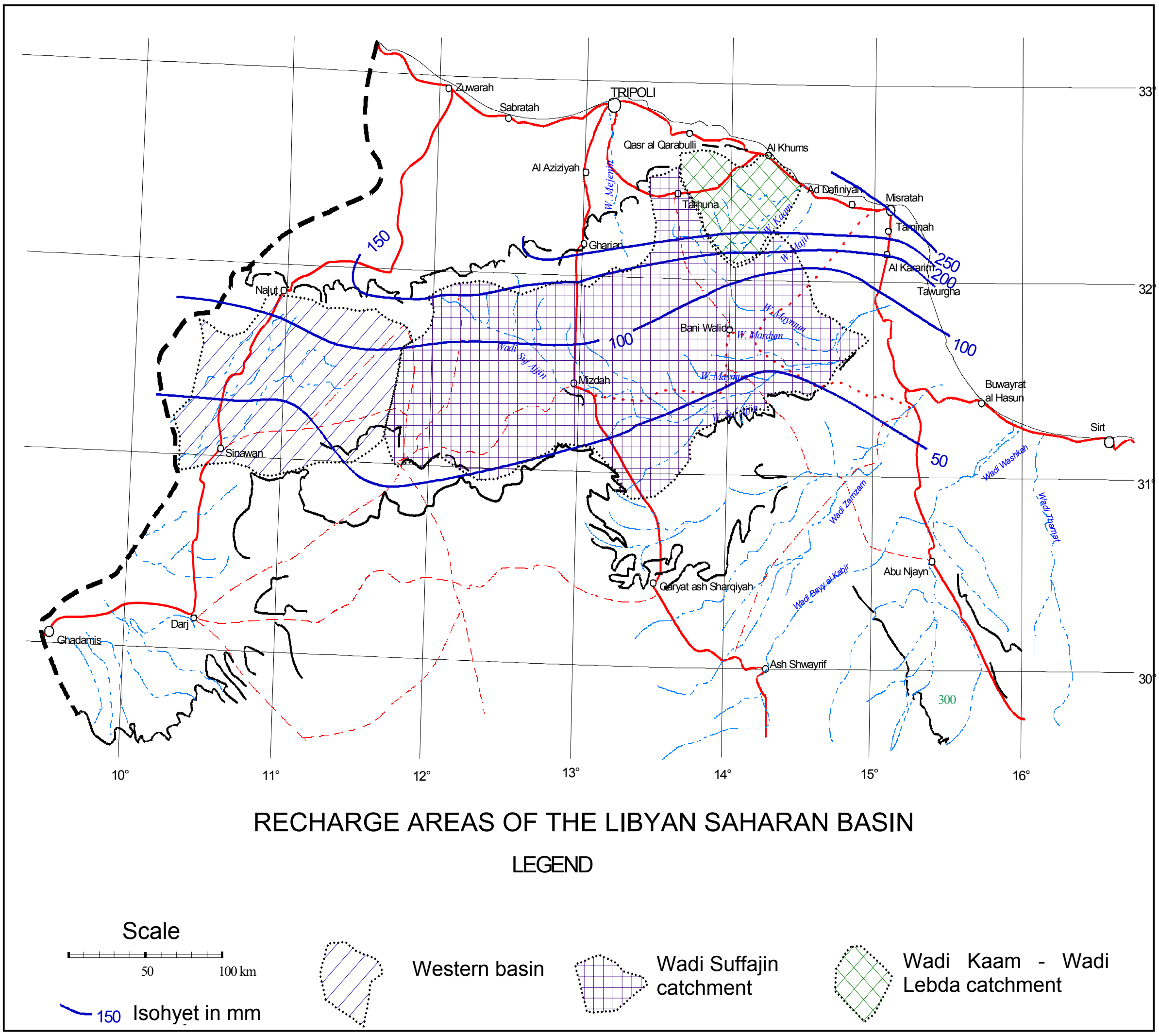
4.1.2.3. In Libya

In Libya, the recharge of the carbonated aquifers of the Upper Cretaceous prevails on all the southern and eastern flanks of Jabal Nafusa. Two major catchments drain the runoff water towards the Mediterranean : Wadi Sufajjin and Wadi Kaam (**Figure 24**). To these two major catchments, there should be added the minor hydrographic systems, Wadi Lebda and Wadi Majir to the north east, and other small endoreic catchments on the north-western part of Jabal Nefusa which disappear and evaporate into depressions to the south.

As estimate of the runoff of Wadi Sufajjin basin has been conducted by GEFLI (GEFLI, 1976, 1978). The preferential recharge zones, in the beds of the wadis, were surveyed and confirmed by isotopic analyses (presence of Tritium) and the recharge of the aquifers was estimated as follows :

- Upstream catchment (upstream of Bani Walid up to the meridian of Mizdah) : recharge estimated by calculation based on the hydraulic gradient in the aquifers of the Upper Cretaceous and a mean transmissivity value of 10^{-3} m^2/s : (12 million m^3/ year).
- Downstream catchment (downstream of Bani Walid to the impermeable outcrops of the Palaeocene and of the Miocene : 8 million m^3/ year.
- The part of the catchment upstream the meridian of Mizdah was not studied by GEFLI. Its contribution is estimated as 20 Mm^3/year. This zone belongs in the hydrogeological basin of Ghadamis.

Figure 24 – Recharge zones of the Upper Cretaceous aquifers in Libya



The Wadi Kaam - Wadi Lebda catchments extend over an area of about 2000 km^2 in a zone of carbonated outcrops and with a more ample rainfall in the range of 200 to 250 mm per year. Favoured by the losses into Wadi Kaam dam and by several small traditional structures drilled on the catchment, infiltration is estimated as ranging between 25 and 30 Million m^3/year. It is located, for the major part, in the flow of the Wadi Kaam spring.

The endoreic western catchment, including the wadis that flow towards the north east, equally participates in the recharge of the Upper Cretaceous aquifers. The area of the catchment is about 12 000 km^2 and the infiltration into the aquifers, from the runoff of the wadis, is estimated as some twenty Mm^3/year.

As regards the Lower Cretaceous aquifer, the piezometry indicates a recharge in the zone of Jabal Nefusa; however, in view of the very small size of the outcrops located in the cliff north of the Jabal, this can only take place by vertical transfer from the Upper Cretaceous aquifers.

4.1.3. Natural outlets

The springs originating from the Complexe Terminal of the Algerian Sahara were known in the region of Oued Rhir up to the early XXth century. Their flow had been estimated, prior to this date, as about 2.85 m3/s. The intensification of the drilling of the boreholes that were artesian during that period was the reason for their definitive drying up. As for the springs originating from the Continental Intercalaire, they were confined to the sub-basin of the Grand Erg Occidental (Adrar, Tidikelt and Gourara). They were substituted by foggaras.

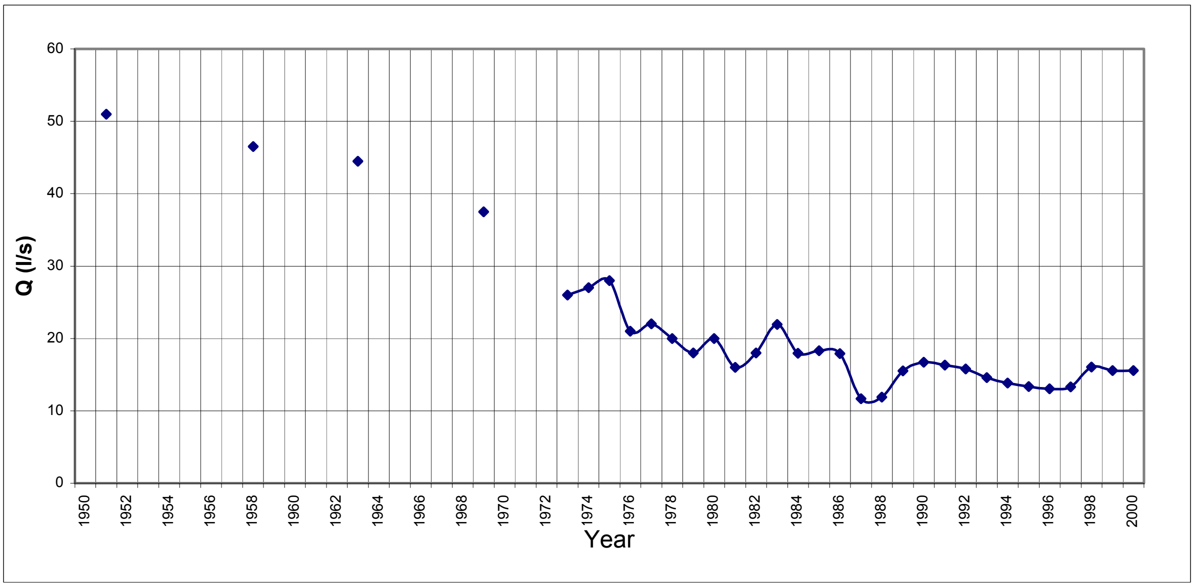
4.1.3.1. Springs

- ***In Tunisia***

The springs originating in the aquifers of the Continental Intercalaire and of the Complexe Terminal in the Tunisian south have always formed the subject of a more or less regular monitoring over time. Those which were connected with the Complexe Terminal are by far the most important ones.

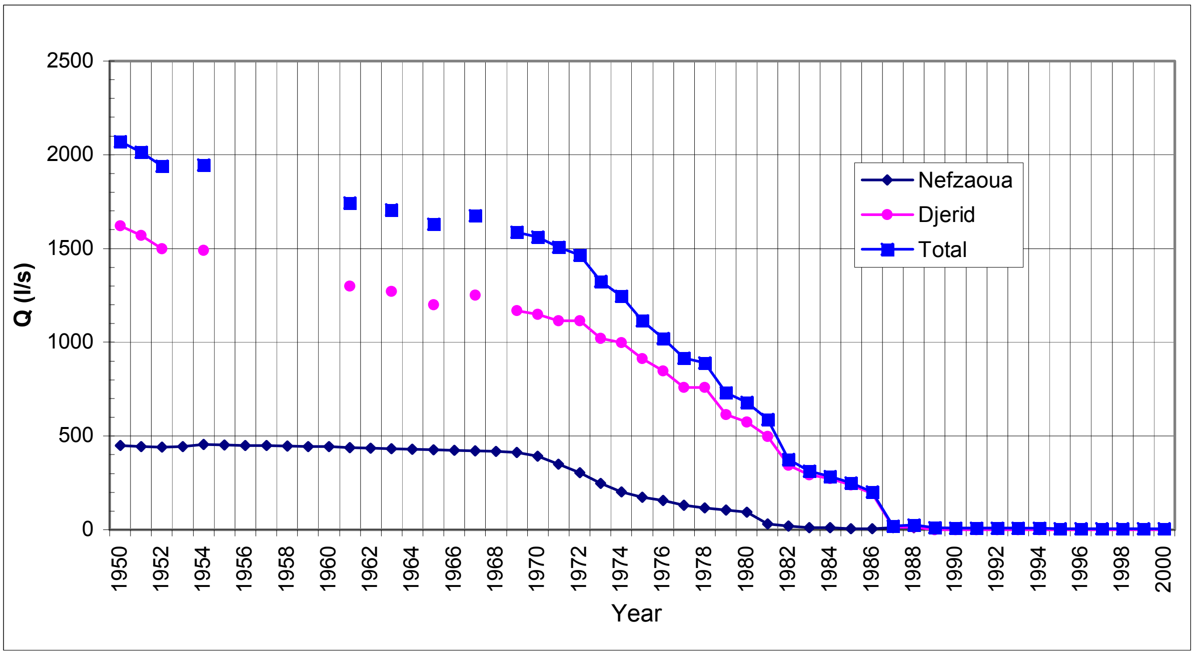
➢ **The Continental Intercalaire springs** of the Tunisian south are located in the region of Chott Fedjej. They involve more particularly the two levels of "Grès Supérieurs" (upper sandstone) and "Grès à bois" (woody sandstone) and correspond to overflow springs whose flow is often no more than a few litres per second (Figure n°25). The monitoring of the flows of these springs was irregular until 1974. Since then, the major ones have formed the subject of an annual monitoring and the yearbooks of exploitation of the deep aquifers of Tunisia reports the water volumes which come to the surface from those outlets. The flow of these springs has never exceeded 50 l/s. It has been steadily on the decrease since 1950 and was, as of the year 2000, of about 15 l/s. This situation reflects the discharge experienced by the upper sandstone aquifer within the multilayer system of Chott Fedjej (drop by 70% of the initial flow).

Figure 25 – Record of the flow of the Continental Intercalaire springs in Tunisia (Chott Fedjej)



➢ **The Complexe Terminal springs** in Tunisia are located in the two regions of Djérid and Nefzaoua. These springs correspond to emerging waters which operate under the effect of the aquifer artesian pressure. Their flow lowers with the increase in exploitation of the aquifer under the effect of multiplication of the boreholes (Figure n° 26).

Figure n° 26 – Record of the flow of the Complexe Terminal springs (Tunisia) from 1950 to 1985



- *The springs of Djérid* appear under the form of an over-deepening of the aquifer formation which outcrops along the Draa of Djérid up to the intersecting of the piezometric area of the aquifer. This situation allows for a gravity runoff of the water at ground surface to the lower lying zones (Mamou, 1990). The Djérid springs are those of Nefta, Tozeur, El Hamma and El Oudiane. The springs of Nefta and Tozeur are found at the bottom of topographic craters, while those of El Oudiane were sunk along the mountain flank. The springs of El Oudiane used to be more numerous, of low flow and were the first to dry up between 1968 and 1974. This was also the case of the springs of el Hamma (1987). Those of Tozeur and Nefta had continued to flow until 1988-89. These two sets used to account for the major part of the flow of the springs of Djerid (over 85% in 1950). The evolution of the flow of the springs of Djérid, which used to be of about 1600 l/s in 1950, was to experience a marked trend towards decreasing which has accelerated since the early 1970s (1100 l /s). This decrease, which was to be further accelerated starting from 1982 (350 l/s), indicated a marked dry up regime. By 1988, these springs had completely dried up.
- *The springs of Nefzaoua (Kébili)* are emergences from the limestone of the Turonian and the Senonian. The Turonian springs, located at the level of the Kébili peninsula, are quite similar, in their hydrodynamic operating, to the springs of El Ouediane (of the Djérid region). The most important one of these springs was that of Oued Zira, which had been exploited until 1974. The other springs of Nefzaoua emerge at the bottom of small depressions (« guelta »). Scattered throughout the region of Nefzaoua, they had given rise to the oases in this region before the construction of the first water boreholes at the beginning of the past century (1907). The major one of these springs is that of Mansoura which had continued to flow until 1978. With a total flow of about 450 l/s in 1950, these springs had experienced a dry up regime which was accelerated in the early 1970s, to further drop to less than 100 l/s in the early 1980s. At present, most of these springs have dried up, and those which have not only present a flow of a mere few l/s.

- ***In Libya***

  - **The Tawurgha spring**, located at the middle of a swampy (marshy) zone of which it is undoubtedly the origin, continues to supply a significant flow which has not varied much in the course of the past fifty years in spite of the increasing abstractions from the aquifers connected with this spring. Several flow measurements were made between 1972 and 1977 yielding a mean flow of 1.966 m3/s (62 Mm³/year). In February 2001, a flow measurement yielded a mean value of 55.9 Mm³/year. A report drafted by GWA in 1988 (Pallas and Bufila, 1978) indicated that, out of the 62 Mm³/year measured, 22 would originate from the Upper Cretaceous aquifer of the catchment of wadi Sufajjin while 40 would originate from the deep aquifers of the Kiklah and of the Palaeozoic. Keeping the same distribution of the origin of the water, the 56 Mm^3/year measured in 2001 would originate at 18 Mm^3/year from the Upper Cretaceous and 38 Mm³/year from the Kiklah/ Palaeozoic.

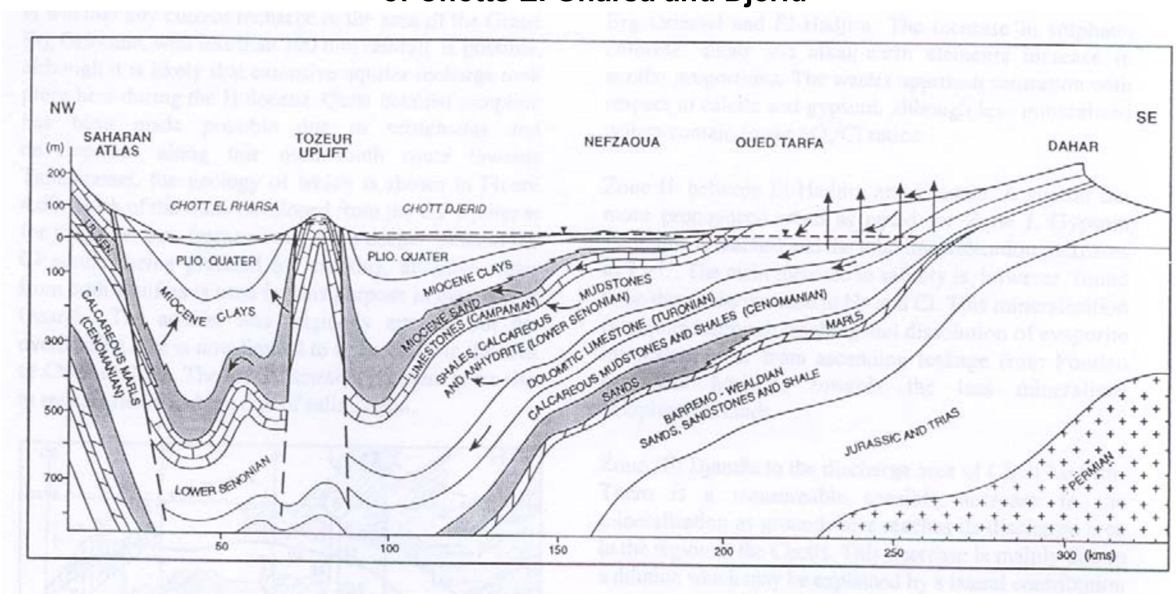
- **The Wadi Kaam spring** emerges in the bed of the wadi whose name it bears. It originated in the limestone and dolomitic limestone of the Upper Cretaceous. Its flow was in the order of 450 l/s in the early 1970s, but it has started to drop with the construction of the farming projects of Wadi Kaam supplied by a whole set of wells tapping the formations which used to give rise to the spring. A few years ago, four pumps of 300 m^3/h were installed in the spring outlet. The source now consequently operates as a well. Its natural flow is zero and its exploitation flow is considered as an abstraction from the Upper Cretaceous.

4.1.3.2. The Chotts and sabkhas

A study of the piezometric maps clearly indicates that the Algerian and Tunisian Chotts play the role of a natural outlet for the two aquifers, though mainly for that of the Complexe Terminal. No exhaustive study has been conducted as yet which would seek to determine the volumes evaporated in each of the Chotts. Only a few estimates have been done.

In Tunisia, the water from the Complexe Terminal which passes by vertical leakage into the surface aquifer of Chotts Djérid and Gharsa is subjected to evaporation throughout the area of the Chott which it covers (Figure n° 27). This evaporation also applies to the water that reaches the Chott by runoff. The evaporated flow has been indirectly estimated, by application of the Darcy law based on hypotheses on the vertical permeabilities of the semi-permeable formations, as 1.57 m^3/s (approximately 50 Mm^3/year). This flow is, however, expected to decrease with the aquifer drawdown which will reduce the vertical hydraulic gradient. This method is the same as that applied for the model, though it involves considerable estimates of the parameters governing the vertical leakage.

Figure n° 27 : Schematic cross-section across the region of Chotts El Gharsa and Djérid



An estimate of the water balance of the depression of Chott Djérid was proposed in 1983 (Hezzi, 1983). It estimates the area of the catchment of the Chotts as 10 500 Km² and that of Chott Djérid as 4 750 Km². The supplies due to runoff, estimated as about 16 Mm^3/year, only represent a small fraction of potential evaporation on the surface of the Chott, which is estimated as 810 Mm^3/year. This calculation indicates that all the water originating from the underlying aquifers is completely evaporated. More precise estimates based on the energy balance relating to solar radiance and to evaporation have not been made.

4.1.3.3. Underground outlets

The structural configuration of the aquifers of the Saharan basin causes certain major faults (fault of Gafsa in Tunisia, faults of the Hun graben in Libya, . . .), following a breaking tectonics, to give rise to a vertical shift of the aquifer layers on both sides of these faults. This results, at the level of the aquifer formations, in a « connection » of one aquifer with the other. This is particularly the case of :

- ***The Tunisian outlet of the CI***

  Upon occurrence of the fault Gafsa - El Hamma, the Lower Cretaceous formations are caused, in the region of Chott Fedjej, to meet face to face with those containing the aquifer of Djeffara aquifer.

  The outcome is an underground flow of the Continental Intercalaire aquifer towards the coastal plain, thus feeding the Djeffara aquifer (*cf* 2.5.2.1.). This underground recharge is an aspect whose qualification is of paramount importance for the exploitation of the aquifer downstream.

  In fact, the evolution of the flow passing via this outlet according to the intensification of the exploitation of the Continental Intercalaire upstream of this outlet influences significantly the recharge of the Djeffara aquifer in Tunisia.

  It is highly recommended that the model should simulate the behaviour of this outlet in such a way as to allow a monitoring of its flow over time.

- ***The Libyan outlet of the CI***

  The Libyan outlet of the Kikla aquifer is marked by a certain flow which is assumed to pass under Jabal Nafusa through the Triassic aquifer formations into those which contain the aquifer of the Libyan Djeffara.

  In fact, this outlet is inadequately defined due to the fact that it does not correspond to a quite clear structural configuration (PL. n° 9). Similarly to the case of the Tunisian outlet, it is highly recommended that the model should take into account this ground flow and evaluate the recharge passing into the Libyan Djeffara aquifer.

Table n° 6 sums up the various natural outflows. Apart from the springs for which the monitoring of their flow has constituted, for about a century, an indicator of the hydrodynamic operating of the Saharan system, the other outflows form the subject of little precise estimates which can only by further refined through modelling.

It should be pointed out that the total flow of emergences, including the foggaras that are comparable to springs, of a non influenced state in the early XXth century, hardly exceeded 10 m^3/s. This flow indicated the range of magnitude of the total recharge of the system, and this for two reasons :

- a notable part of the outflows is invisible and is lost to the emergences : real evaporation of the Chotts and Sebkhas and underground outlets towards the Djeffara aquifer ;

- it is not at all certain that the system was in equilibrium (inputs = outputs) ; rather, the contrary is more probable in view of the fact that the system is in a state of slow discharge of the reserves.

Tableau n° 6 : Natural outflows from the Saharan basin

Outlet	Continental Intercalaire	Complexe Terminal
1- Springs (or foggaras)		
-Tunisia	Springs of Chott Fedjej	Springs of Djerid and of Nefzeoua
- Algeria	Foggara of Tauar, Tidikilt – Gourara	_
- Libya	Ain Tawurgha	Ayn of Wadi Kaam
2- Chotts and Sebkhas	(Evaporation)	
- Algeria	Sabkhet Timimou	Chotts Melghir Merouan
- Tunisia	Chott Fedjej	Chotts Djerid and El Gharsa
- Libya	Sabkhet Mzezeur (Ghadamis)	Sabkhet Tawurgha
3- Underground outlets	Groung recharge	
-Tunisia	Outlet of Chott Fedjej	_
- Libya	Outlet of Jabal Nafusa	_

4.1.4- Hydrodynamic parameters

The hydraulic parameters originate in part from the data collected during the previous studies and in part from the data obtaining from the tests performed on the new wells. The data collected in the data base are transferred to the tables of Annex 3.

4.1.4.1. Transmissivity

- ***The Complexe Terminal***

The geological configuration of the Complexe Terminal in Algeria and in Tunisia causes the wells which tap this aquifer set not to reach in fact except one level out of two or three. During the tests, these wells do not reveal the effect of leakage from the non collected layers. In fact, leakage operates on a long term basis and is indicated by transmissivities that are higher by far than those obtaining from flow tests of a few hours or of a few days.

The variation of the lithological nature of the aquifer from one zone to another (Turonian dolomites, Senonian limestone and Mio-pliocene sands) is the reason for the variations observed with regard to the transmissivity values obtained from hydrodynamic tests. The variation in permeability (primary permeability and secondary permeability) within these formations, added to the imperfect collection and the short duration of pumping during the acceptance tests, causes the values obtained to be indeed no more than an order of magnitude. It was not deemed useful to proceed to spatial interpolations between the data. The latter were merely gathered into groups corresponding to transmissivity ranges within a same order of magnitude. These groups are represented on the map of Figure 28.

- **Algeria**

  - *Region of Souf*

  The transmissivity values obtained from the pumping tests only correspond, in general, to one part of the aquifer. They are in the range of 5 to 25.10^{-3}m²/s.

  - *South Atlas boundary*

  Pumping tests have been conducted in the region of Biskra (Tolga aquifer) on wells tapping the aquifer levels of the Complexe Terminal located in the Mio-pliocene sands and in the Eocene or Senonian limestone. They supply (SCET, 1972) transmissivity values which represent two ranges :

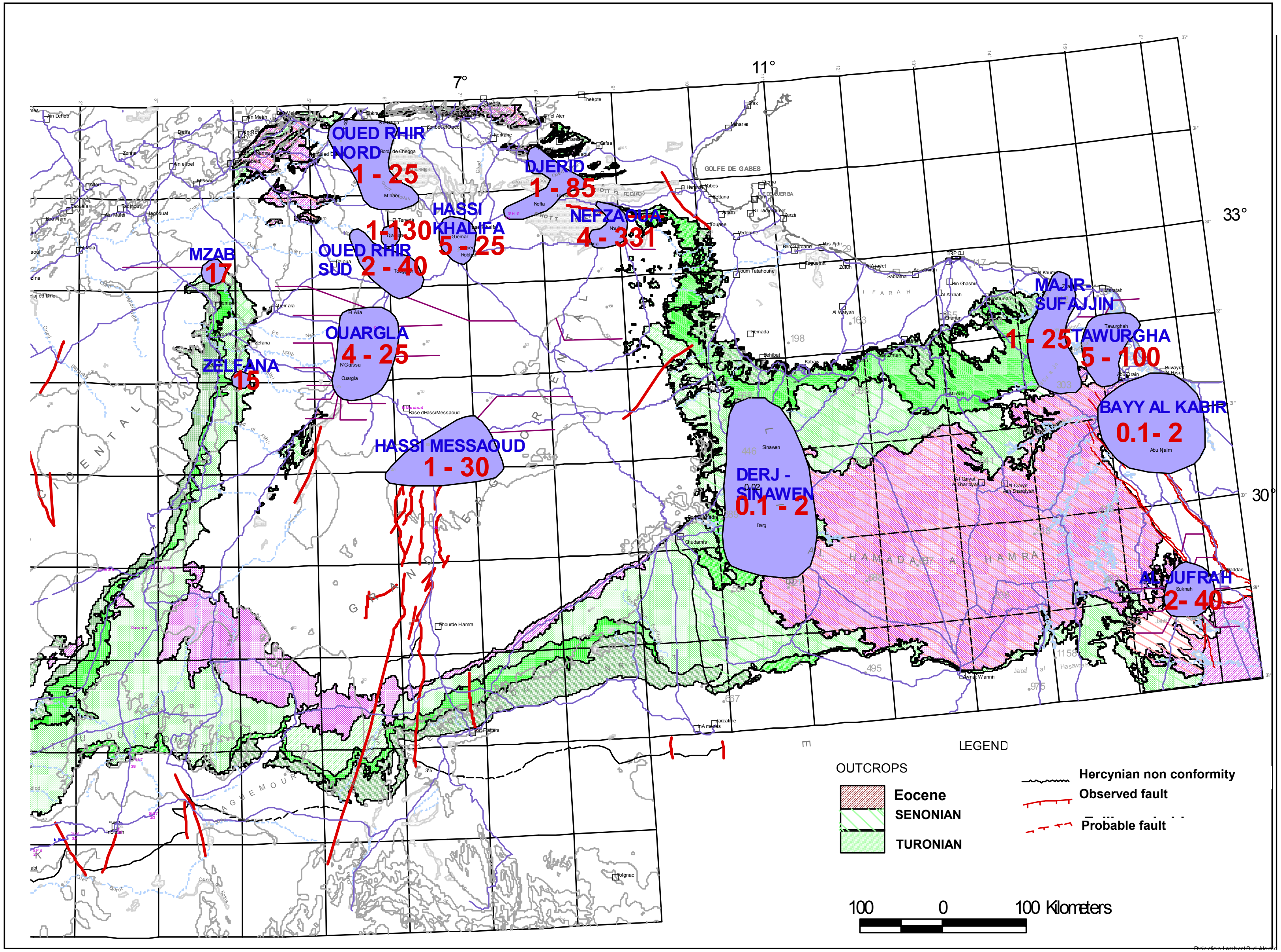
  - 1 to 10 . 10^{-3} m²/s (sandy aquifers),
  - 10 to 50 . 10^{-3} m²/s (limestone aquifers).

  Other tests conducted on the wells of Oued Rhir-Nord (northern) have yielded transmissivity values which range between 1 and 25. 10^{-3}m²/s. The highest transmissivity values are obtained in the regions of Oued Rhir-Sud (southern) where the wells collect preferentially the sandy levels. They range between 1 and 130. 10^{-3}m²/s.

The transmissivity values deduced from the pump tests performed on the wells and grouped by zone (**Figure n°28**) are to be taken as a range of magnitude, and this for various reasons, among which in particular :

- ✓ the tests were performed and interpreted by teams that were not the same at various times,
- ✓ the quasi entirety of these wells are imperfect wells with a partial tapping in varied lithological formations (sandy or limestone),
- ✓ the duration of the tests is often limited to a few hours which would not allow a stabilization of the system and its extension to the whole aquifer. Under such conditions, it is illusory to seek to deduce an iso-transmissivities map.

Figure n° 28 : Transmissivities map of the Complexe Terminal



The transmissivity values deduced from these tests do not make it possible to distinguish a specific variation of the lithological nature of the aquifer formation (sands or limestone); the thickness of the collected formation seems to play a more important role.

The ERESS study, faced with a shortage of values deduced from pump stations in Algeria, has resorted to adopting ranges of magnitude (Franlab, 1972). The new boreholes drilled in this zone have not formed the subject of tests allowing to deduce their hydrodynamic characteristics. In the light of the existing values, the ranges of magnitude adopted are as follows:

- Region of Souf : 5 to 25 x 10^{-3}m²/s
- South-Atlas boundary (Oued Rhir-Nord) : 1 to 25 x 10^{-3} m²/s,
- Oued Rhir-Sud (southern): 1 to 130 x 10^{-3} m²/s,
- Ouargla : 4 to 25 x 10^{-3} m²/s,
- Hassi Messaoud : 1 to 30 x 10^{-3} m²/s,
- Eastern Grand Erg : 100 x 10^{-3} m²/s,
- El Borma: 40 x 10^{-3} m²/s.

In the absence of new data, the values above have been taken into consideration in the calibrating of the SASS model.

- **Tunisia**

In Tunisia, most of the boreholes drilled after 1970 have formed the subject of acceptance tests which allowed an evaluation of transmissivity and, in certain cases, of the storage coefficient. It is convenient to distinguish two major zones:

- **The Nefzaoua** zone, where the aquifer reservoir is dolomitic (Turonian dolomites in the peninsula of Kébili) or limestone (Upper Senonian limestone in the rest of the Nefzaoua, except for the region of Redjim Maatoug, located SW of Chott Djérid). In this region, artesianism had prevailed until the early 1980s. Most of the time, the wells tap only the upper part of the aquifer formation which is often highly fissured. The transmissivities obtained have been distributed into two major ranges which are as follows :
  - **The Kébili peninsula**, where the aquifer reservoir consists of Turonian dolomites. T= 150 to 300 x 10^{-3} m²/s. These dolomites are quite fissured, with large permeability being developed on the southern boundary of the Tébaga chain.
  - **The Nefzaoua proper**, where the aquifer reservoir is made up of Senonian limestone. T= 50 - 150 x 10^{-3} m²/s. The Senonian limestone are more fissured and more permeable along the line of the tectonic accidents and in the zones where the semi-permeable top is little thick.
  - **The eastern piedmont of the Dahar**, where the aquifer is lodged in the Senonian limestone with an unconfined piezometric area, or one which is little confined. T= 20.10^{-3}m²/s.
- **The Djérid and Redjim Maatoug**, where the aquifer reservoir consists of Miocene and Pliocene sands. T= 1-100. 10^{-3}m²/s.

  Under the Chotts Djérid and El Gharsa, the underground flow of the Complexe Terminal water takes place across the semi-permeable Mio-Plio-Quaternary cover : T = 50 to 70. 10-^{3} m²/s.

- ***Libya***

In Libya, the Complexe Terminal aquifers taken into consideration in the framework of the study involve only the aquifers of the Upper Cretaceous (Nalut and Mizdah). The transmissivities, determined based on tests performed either on equipped wells or on parts of wells by means of a packer, are generally low and less than 5 x 10^{-3} m^2/s. The only exceptions relate to:

- the zone of Al Jufrah, on the western side of the graben, where the highly fractured limestone of the Upper Cretaceous aquifer present a transmissivity that is higher than 5 x 10^{-2} m^2/s ;
- the Tawurgha, where the Cretaceous aquifers, which communicate almost throughout the zone, present a transmissivity in the range of 1 to 4 x 10^{-2} m^2/s ;
- to the north of Wadi Zamzam, in the vicinity of the eastern fault of the graben, where transmissivities in the order of 1 to 5 x 10^{-2} m^2/s have been recorded during pump tests ;
- in the downstream basin of Wadi Sufajjin (w. Maymun, w. Mardum, w. Sufajjin), where the transmissivity of the Cenomanian – Turonian aquifer reaches 1 x 10^{-2} m^2/s.

- ***The Continental Intercalaire***

The wells tapping the Continental Intercalaire penetrate only partially the reservoir whose thickness exceeds at times 500 m. As a consequence, the transmissivity values deduced from the hydrodynamic tests vary in accordance with the thickness of the formation collected and are rarely representative of the overall transmissivity of the reservoir. In the course of the ERESS study, the oil wells loggings have been analysed and have led to extrapolating the transmissivity values deduced from the tests applying to the whole reservoir.

- **Algeria**

The Continental Intercalaire aquifer covers the two major Saharan basins : the western unconfined aquifer basin and the Lower Sahara where the aquifer is confined. It has not been deemed useful to proceed to spatial interpolations between the data. The latter have simply been assembled in groups corresponding to transmissivity intervals within a same order of magnitude. These groups are represented on the map of Figure 29.

- **Basin of the Grand Erg Occidental** : in this region, the transmissivity values determined by pump tests on the forages are generally comprised between 10 and 30 x $10^{-3}m^2/s$. Some lower values have, nevertheless, been recorded on the southern boundary of the basin (Tidikelt) ;
- **Lower Sahara and basin of the Grand Erg Oriental :** in this region, too, the transmissivities are generally comprised between 10 and 40 x $10^{-3}m^2/s$. the highest values are located in the western part of the basin (El Goléa - Zelfana) where the aquifer formations are thicker and more permeable. Lower values that are less than 5 x $10^{-3}m^2/s$ have been recorded in the central (Ouargla - Hassi Messaoud) and southern (Tinrhert) part of the basin.

- ***Tunisia***

The transmissivity values deduced from the hydrodynamic tests on the boreholes tapping the Continental Intercalaire aquifer are reproduced by group on the map of Figure 20. on the whole, the transmissivities deduced from the tests range between 10 and 50 x $10^{-3}m^2/s$. The highest values are observed in the Nefzaoua, Chott Fedjej and the far South. The sands collected in Djérid are finer and less permeable. They belong in a fairly isolated system with respect to the other aquifer layers of the Continental Intercalaire. The transmissivities recorded in Djérid are, consequently, less high.

- ***Libya***

The examination of the map of Figure 26 reveals a relative homogeneity of the transmissivity values whose major part is comprised between 10 and 30 x 10^{-3} m^2/s. Some higher values, of up to 100 x 10^{-3} m^2/s, have been observed in the zones of Derj - Ghadamès and Al Jufrah. In Al Jufrah zone, west of the Hun graben, as well as in the wadi Zmam and wadi Ninah zone, the deep wells collect in fact the Continental Intercalaire aquifers, which are very little thick in the zone but associated with the Cambro-Ordovician aquifer. Lower values that are less than 5 x 10^{-3} m^2/s are recorded in the North-East where the detritic formations of the Lower Cretaceous – Upper Jurassic are substituted by less permeable marine formations.

4.1.4.2. Storage coefficient

- ***The Complexe Terminal***

- ***Algeria***

In Algeria, the storage coefficients have hardly been determined from flow tests. The indications given further down originate from ERESS estimates based on a methodology that differs according as to whether we have unconfined aquifers or confined ones.

In the zones of unconfined aquifers, the lithological nature of the aquifer reservoir has led, in the previous studies, to distinguishing two cases :

- the rocks with an inter-granular porosity, for which a mean value of 150.10^{-3} has been adopted,
- the fissured rocks, for which a slightly lower value has been adopted : 100 -150.10^{-3}.

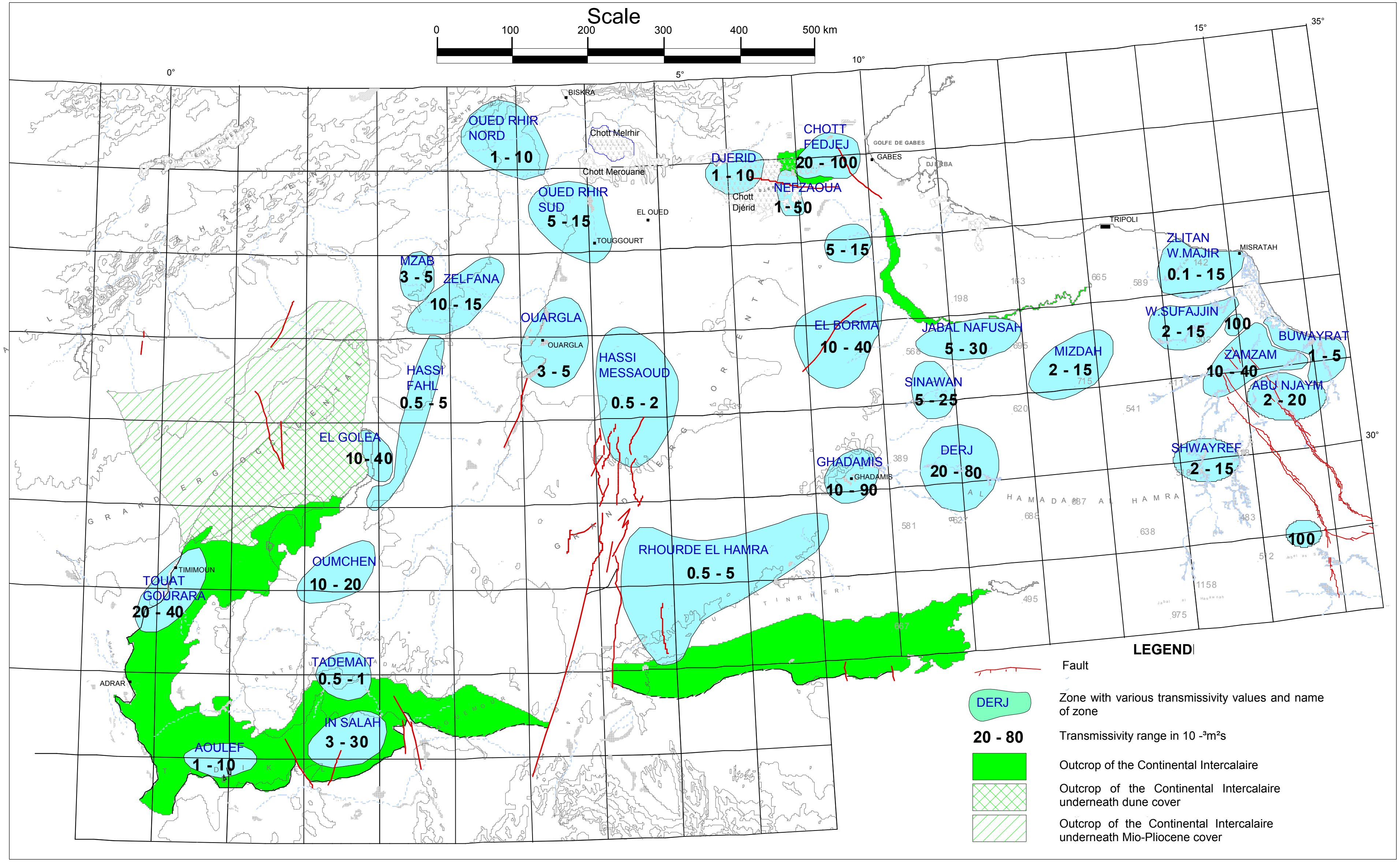
With this schematisation, it has been possible to ensure a calibration of the various models and their proper representativeness during the simulation of the transitory system. In the absence of new data, a similar procedure has been adopted for the schematisation of the storage coefficient in this part of the basin.

In the zones of confined aquifers, the estimate of the values of the storage coefficient has been made on a certain number of wells by ERESS, based on the analysis of their lithological cross-sections. The results obtained are given in the following table.

Table 7 – Storage coefficients of the CT estimated based on the lithology of the wells (Algeria)

Region	Well	Storage coefficient (10^{-3})	Region	Well	Storage coefficient (10^{-3})
El Hadjira	R11 J 10	5.4	Touggourt	439 I 11	11.1
	9 I 10	11.4		474 I 11	8.4
	11 I 10	10.4		275 J 11	10.6
	7 I 10	11.6	Djemaa	439 J 11	4.4
	407 I 11	11.3		484 H 11	5.4
	449 I 11	12.4		502 H 11	5.4
				402 H 11	5.0

Figure n° 29 – Transmissivities map of the Continental Intercalaire (Tunisia)



- ***Tunisia***

The configuration of the Complexe Terminal aquifer in the Tunisian south reveals that it is :

- Unconfined near the Turnonian-Senonian outcrops of Dahar, and that it is a sandy aquifer reservoir in Draa Djérid. These zones also constitute the aquifer recharge areas ;
- Confined or semi confined under the Nefzaoua and the dunes of the Grand Erg Oriental, as well as under the Chotts of Djérid and El Gharsa.

The pump tests, which have allowed an evaluation of this aquifer's storage coefficient value, have been performed on structures located in confined zone. Accordingly, the values determined based on the tests do not involve the unconfined part of the aquifer.

Zones of confined or semi confined aquifer

In view of the small number of piezometers likely to be used for test monitoring in this zone, the number of tests allowing a determination of the storage coefficient value is equally small.

For the Nefzaoua limestone, the two extreme values of the storage coefficient as deduced from the pumping tests are as follows :

- Oum Soumaa well n°1 (NIRH : 9347/5) : storage coefficient = 1.3×10^{-5},
- Rahmat 2 well (NIRH :9692/5) : storage coefficient = 7.6×10^{-5}.

The estimate of the storage coefficient based on the thickness of the aquifer and a certain porosity of the formation has allowed an estimate, for the wells of the Nefzaoua, of the storage coefficient values as being in the range of 1.7 to $6.8 \times 10^{-5.}$

ERESS has adopted, for the confined zone, storage coefficient values in the range of 1 to 26 $\times 10^{-4}$.

The wells tapping the sandy formations (Djérid and Redjim Maatoug) have yielded storage coefficient values ranging between 1 and 20×10^{-4} .

Zones of unconfined aquifer

In the unconfined zone of the Complexe Terminal aquifer, the porosity has been determined based on the Archie formula applied to a water saturated porous medium

$$F = R_t/R_w = 1/\Phi^m$$

Where F is the formation factor,

R_t is the resistivity of the saturated formation as determined based on the loggings
R_w is the water resistivity
Φ is the porosity
m is the cementing factor ranging normally between 1.2 and 1.8

Some values of the actual porosity (P) have been obtained by this method for the Complexe Terminal wells of Djérid :

Table 8 – Actual porosity values in the wells of Djerid

Well	N°IRH	F	m	Φ (%)	m	Φ (%)	M	Φ (%)
Seddada	10197	4.85	1.2	30	1.5	35	1.7	38
Degache Nord 1	10453	4.1	1.2	34	1.5	39	1.7	41
Zaouiet el Arab	9455	4.3	1.2	38	1.5	38	1.7	42
Ain Torba 1	8981	7.25	1.2	22	1.5	26	1.7	30
Nefta 1	8262	4.0	1.2	34	1.5	40	1.7	44
Tozeur gare 2	8405	5.85	1.2	26	1.5	31	1.7	34

- ***Libya***

No reliable storage coefficient value for the Upper Cretaceous aquifers is available in Libya.

❑ ***The Continental Intercalaire***

- ***Algeria***

In the unconfined aquifer zones, the estimate of porosity, based on an analysis of the loggings, yields values in the range of 16.8 x 10^{-2} (Well Af1) and 18 x 10^{-2} (Well AH 1). ERESS has adopted throughout an effective porosity value of 20%.

In the confined aquifer zone, the value of the storage coefficient (CE) has been estimated based on the volumic porosity, the total thickness of the aquifer layer and water density. It is yielded by the empirical formula :

$$CE = 10^{-3}. Hu \times \Phi \times \beta$$

With :
Hu : Total efficient thickness of the aquifer participating in the flow in cm
Φ : Volumic porosity
β : Coefficient depending on the depth, and determined empirically based on the loggings, and ranging between 5 and 100 x 10^{-5}.

The storage coefficient values obtained range between 4 x 10^{-4} (Well Aa N1) and 30.3 x 10^{-4} (Well Bel 1).
In the absence of new values in this part of the basin, these magnitude ranges, which have proved to be adequate for the calibrating of the ERESS model, are to be selected.

- ***Tunisia***

New storage coefficient estimates made in the confined part of the CI aquifer in Tunisia, by reference to the efficient height of the aquifer layer and to the volumic porosity of the formation, and this in accordance with the empirical formula adopted in the interpretation of the pumping tests.

The values thus determined are distributed as follows (CE = Storage coefficient):
Chott Fedjej : CE= 20 to 45 x 10^{-5}
Djérid : CE= 1 to 10 x 10^{-5}
Nefzaoua : CE= 10 to 55 x 10^{-5}
Far south : CE= 1 to 10 x 10^{-5}

- ***Libya***

An only one storage coefficient value has been determined based on a test performed on Well ZZ4 in Wadi Zamzam while using the neighbouring wells as piezometers. The value obtained is equal to 2 x 10^{-4}.

4.2- Abstractions and their influences

4.2.1. Abstractions

4.2.1.1. Problems related to the collection of data on abstractions

Abstractions from the aquifer constitute an important component of the management of the resources, as well as an indispensable parameters for the calibration of the models. Unfortunately, however, the collection of data on these abstractions raises a number of problems due to:

- **the sometimes considerable number of structures** (equipment) making any monitoring operation rather costly in view of the means required ;
- **the difficulty of measurement** particularly in the artesian wells presenting high-temperature water or obstacles to a systematic monitoring of abstractions. In the case of

the foggaras, the measurement of the flow at the outlet of the draining tunnel is often difficult to be made due to the traditional water distribution system. Measuring the flow at a certain distance downstream may have been the reason for its underestimation due to lateral losses or those caused by infiltration. In the case of pump operated wells, the flow measurement must be accompanied by an estimate of the daily and seasonal pumping times, which often proves to be a reason for errors that are, at times, greater than those made by mere estimate of the flow.

These problems translate, with regard to monitoring the abstractions made from the Saharan aquifers, into measurement gaps whose reconstruction is, at times, difficult. For that reason, we find ourselves obliged to adopt methods of evaluation of these abstractions which resort to hypotheses on the drop in artesianism and the duration of the pumping.

4.2.1.2. Methods of estimate of the abstractions by well and foggara in Algeria, in Tunisia and in Libya – Reliability of the data

The estimate of abstractions from the water resources of the saharan aquifers is conducted differently in each of the three countries of the northern Sahara. This situation results from the structural organization of the administrations entrusted with monitoring the state of the aquifers, as well as the means available to them.

- ***The " annual monitoring" method (Tunisia)***

In Tunisia, the monitoring of the country's deep aquifers is carried out by regional bodies ("Arrondissement des Ressources en Eau" (Water Resources District)). The measurements made constitute the subject of an annual publication (Annuaire d'exploitation des nappes profondes (deep aquifers exploitation yearbook)), which reports the synthesis, according to administrative division, of the exploitation of all deep aquifers. The major two aquifers of the Continental Intercalaire and of the Complexe Terminal are monitored in the Governorates of Gabès, Kébili, Tozeur and Tataouine.

Thus, the values of the abstractions proposed in the deep aquifers exploitation yearbook of Tunisia constitute a source of analysed and criticized data, and only require elementary processing prior to their integration in the total evaluation.

- ***The " inventories method" (Algeria)***

In Algeria, the monitoring of the exploitation of the Saharan aquifers is carried out during the inventory campaigns of the whole water points. These operations, which depend on the means made available to the field teams, are staggered in time from one zone to the other. Table 8 below gives the various inventories carried out in the 1990s :

Table 9 – Inventory of the water points exploiting the CI and CT aquifers in Algeria (inventories made from 1991 to 2001)

Wilaya or Commune	Inventory year	Number of CI wells	Number of CT wells
Adrar	1996	393	1
Ghardaïa	1994	103	0
El Oued	1991	5	222
Oued Rhir & Souf	1997	0	113
Ouargla	1991	56	916
Ouargla-Hassi Messaoud-Gassi Touil	1997	57	406
Biskra	1994	19	0
Toggourt- Ain Salah	1997	10	475
Illizi (DHW Survey)	1997	58	0
Total		**701**	**2133**

The latest inventory campaign, conducted in 1997-99 in the region, has led to numbering 2834 exploited wells, of which over a half have been constructed after 1980.

- ***The "estimate of utilizations" method (Libya)***

In Libya, only the wells supplying the Great (Manmade) River are equipped with meters and are regularly monitored. The many wells constructed in the eastern part of the Saharan basin for Drinking Water Supply and, mainly, for irrigation do not form the subject of a monitoring of abstractions. Only on the occasion of major synthesis studies is an exhaustive inventory carried out, allowing an estimate with reasonable approximation of the flows abstracted. The studies conducted by GEFLI in the 1970s (GEFLI, 1976, GEFLI, 1978) in fact constitute the only serious reference elements for establishing the record of abstractions. Unfortunately, these studies date back to a period corresponding to the very inception of the exploitation of the deep aquifers and much earlier than the advent of private irrigation which was to effectively start in the Saharan basin only in the 1990s.

The estimates provided in the present report result from a combination of information and data elicited from various sources, of which in particular :

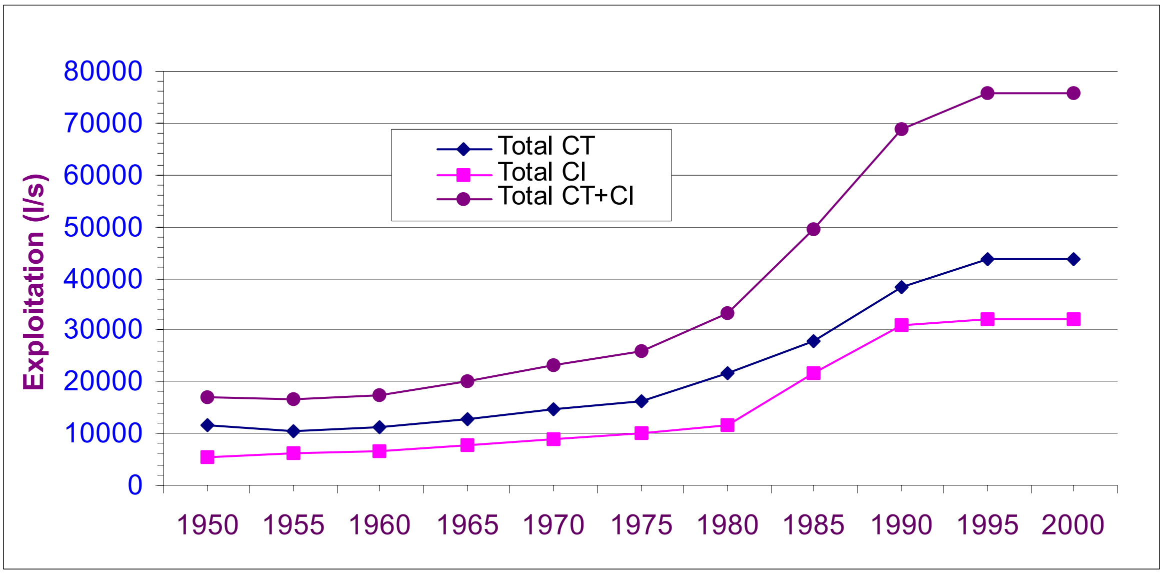
- Sketchy inventories by GWA technicians which are, unfortunately, lacking in direct flow measurements,
- Irrigated area and estimate of water needs according to the crops,
- Number of power supply contracts and rapid surveys in order to evaluate the average area of the farms and the type of crop rotation practiced.

The uncertainties which affect each of the parameters used to establish the abstractions records justify the changes introduced in the successive estimates, according to the newly acquired information.

4.2.1.3. Abstractions by aquifer and by country

Since 1950, the exploitation of the two aquifers of the North-Western Sahara Aquifer System (CI and CT) has been steadily increasing. The total abstractions from the system (including the flow of the springs), which were in the order of 14 m^3/s in 1950, amounted to 20 m^3/s in 1970, 29 m^3/s in 1980 and 75 m^3/s in 2000. This situation indicates a trend, in the three countries, towards intensification of the mobilisation of the water resources of these aquifers, and this through stepping up the exploitation structures (wells, in particular), as well as an increasingly marked resort to pumping in the zones where artesianism has slackened (Tunisia and Algeria). This evolution is illustrated by Figure 30. The drop in the flow of springs is an indicator of the impact of the intensification of abstractions by means of wells.

Figure n° 30 – Total abstractions from the CI and CT in the three countries in l/s (1950 - 2000)



In truth, this general situation conceals a large number of nuances on the level of each of these two aquifers, as well as of the zones where their water resources are mobilised.

- ***Exploitation of the Complexe Terminal as per country***

The Complexe Terminal aquifer is largely exploited in Tunisia and in Algeria in the region of the Lower Sahara or the region of the Chotts. In Libya, the exploitation of the Complexe Terminal is limited to the north-eastern part of the basin. The total exploitation of this aquifer was, for the year 2000, in the order of 50.3 m^3/s. The prevailing exploitation of this aquifer in Algeria and in Tunisia may be explained by the fact that it is accessible at depths that are often less than 500 m and with easily manageable mobilisation conditions (low artesianism and water temperature). More detailed information on the abstractions is given in Annex 4, for Algeria and Tunisia, and in Annex 5, for Libya.

➢ **In Algeria**, the exploitation of the Complexe Terminal aquifer was, for the year 2000, in the order of 21.2 m^3/s. It has thus experienced a marked evolution since 1950 when this exploitation did not exceed 5.77 m^3/s. This evolution was further quite accelerated in the early 1980s. In fact, the abstractions had remained less than 8.5 m^3/s until 1970 to rise to 11.5 m^3/s in 1980 and reach 17.4 m^3/s in 1990. The exploitation of the Complexe Terminal aquifer is made, in Algeria, mainly by pumping (19.4 m^3/s, that is 91% of its total exploitation in Algeria). Exploitation by artesianism has always been fairly low. It does not exceed currently 1.8 m^3/s. This aquifer is mainly exploited in the regions of El Oued, Ouargla and Biskra, and to a lesser extent in the wilayas of Khenchela and Tébessa.

Table 10 – Record of abstractions from the Complexe Terminal in Algeria as per Wilaya (l/s) (PW: Pumped wells; AW : Artesian wells)

Year	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000
Total PW Biskra	112.0	170.0	293.0	238.0	388.0	262.0	305.0	324.0	324.0	324.0	324.0
Total AW Biskra	7.0	26.0	25.0	27.0	27.0	22.0	30.0	34.0	34.0	34.0	34.0
Total PW + AW Biskra	119.0	196.0	318.0	265.0	415.0	284.0	335.0	358.0	358.0	358.0	358.0
Total PW El Oued	3011.0	2917.0	2941.0	3238.0	4195.0	3729.5	3698.3	4274.2	6383.3	8082.1	8934.5
Total AW El Oued	0.0	104.0	93.0	91.0	85.0	389.4	362.3	1382.3	1600.2	1733.2	1733.2
Total PW + AW El Oued	3011.0	3021.0	3034.0	3329.0	4280.0	4118.9	4060.7	5656.5	7983.5	9815.2	10667.7
Total PW Khenchela	0.0	0.0	0.0	0.0	0.0	0.0	0.0	144.0	465.3	485.3	460.3
Total PW Ouargla	2640.0	2902.0	2982.0	3109.0	3510.0	3201.1	3666.0	4989.2	8091.3	9906.3	9213.0
Total AW Ouargla	0.0	0.0	0.0	0.0	0.0	171.5	189.0	43.8	70.1	70.1	70.1
Total PW + AW Ouargla	2640.0	2902.0	2982.0	3109.0	3510.0	3372.6	3855.0	5063.8	8192.2	10007.2	9313.9
Total PW Tebessa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	162.4	255.8	255.8	228.8
Total PW Illizi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.2	141.8	183.3	183.3
Total TC Algeria	**5770**	**6119**	**6334**	**6703**	**8205**	**7776**	**8251**	**11510**	**17397**	**21105**	**21212**

➢ **In Tunisia,** the exploitation of the Complexe Terminal aquifer is made mainly in the regions of Djérid and of Kébili (99%) and, to a lesser extent, in those of Gafsa and Tataouine. This exploitation, which had started by means of springs, was to witness at the beginning of the 20th century (1907, for Kébili, and 1911, for Djérid) the construction of artesian wells which have largely contributed in increasing the volumes exploited and in allowing the development of new irrigated zones. The multiplication of the number of wells was soon to impact artesianism, as well as the flow of the springs, and, since the 1960s, resorting to pumping has become dominant. By the year 2000, the major part of the flow exploited originated from pumped wells following the establishment of artesianism and the drying up of the springs of Kébili and of Tozeur.

Table 11 - Exploitation of the Complexe Terminal in Tunisia (wells and springs) in l/s (W : Wells ; Spr. : Springs)

Year	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000
Total W Gafsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0	150.9	54.9	88.2
Total W Kébili	959.7	1369.1	1599.2	1551.4	1784.6	2523.0	3506.0	5093.0	7616.3	10435.6	10099.5
Total Spr. Kébili	468.0	454.0	444.0	430.0	412.0	201.5	106.0	11.7	8.8	6.7	6.0
Total W+Spr. Kébili	1427.7	1823.1	2043.2	1981.4	2196.6	2724.5	3612.0	5104.7	7625.1	10442.3	10105.5
Total W Tataouine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	48.3	48.0	48.0
Total W Tozeur	321.7	554.6	495.2	560.3	857.6	1820.0	2549.0	3533.9	5051.8	4134.1	4190.6
Total Spr. Tozeur	1620.0			1200.0	1150.0	914.0	574.0	238.2	0.0	0.0	0.0
Total W+Spr. Tozeur	1941.7	554.6	495.2	1760.3	2007.6	2734.0	3123.0	3772.1	5051.8	4134.1	4190.6
Total CT-Wells-Tunisia	1281.4	1923.7	2094.4	2111.7	2642.2	4343.0	6055.0	8696.0	12867.3	14672.5	14426.4
Total CT-Tunisia	**3369**	**2378**	**2538**	**3742**	**4204**	**5459**	**6735**	**8946**	**12876**	**14679**	**14432**

- **In Libya**, the exploitation of the Complexe Terminal aquifer, limited to the Upper Cretaceous, is made mainly in the coastal zone in the old farming projects of Dafniyah, Tumina and Kararim, as well as in the zone of Al Jufrah, for the farming projects of Ferjan and Hammam. For a few years now, wells collecting the Mizdah aquifer have multiplied in the valleys of the catchment of Wadi Sufajjin. Table 12 below shows the evolution of the abstractions since 1950. Details on the exploitation zones and the quantities abstracted are given Annex 5.

The flows of the two major zones of the Libyan Saharan basin, which originate in the Upper Cretaceous aquifer are also given in Table 12 ; the total proposed in the last line of the Table represents the sum of the abstractions as per wells and per spring flows. For the Tawurgha spring, only the flow that is assumed to originate from the Upper Cretaceous has been given.

Table 12 – Exploitation of the Complexe Terminal (Upper Cretaceous -Tertiary) in Libya in l/s (1950 - 2000)

Year	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000
Total Jufrah	63	63	95	127	317	539	2981	3805	4122	3805	3422
Total Wells Khums	996	723	897	821	713	1262	2409	2873	2857	2857	3095
Total Springs Khums	1237	1237	1205	1205	1173	1142	1078	761	698	602	571
Total W+Spr. Khums	2232	1960	2102	2026	1887	2404	3487	3634	3555	3460	3666
Total Sufajjin	0	0	0	0	0	32	32	63	222	507	856
Total Springs	1236.7	1236.7	1205.0	1205.0	1173.3	1141.6	1078.1	761.0	697.6	602.5	570.8
Total Wells	1059.1	786.4	992.5	948.1	1030.6	1832.8	5421.7	6741.5	7201.3	7169.6	7373.0
Total CT Libya	**2295.8**	**2023.1**	**2197.5**	**2153.1**	**2203.8**	**2974.4**	**6499.9**	**7502.5**	**7898.9**	**7772.1**	**7943.8**

- ***Exploitation of the Continental Intercalaire as per country***

The Continental Intercalaire aquifer is mainly exploited in Algeria where abstractions from these resources amounted, for the year 2000, to the equivalent of 24.9 m^3/s, which represents 78 % of the total of its exploitation in the Saharan basin. In Libya, the exploitation of this table amounts to 4.6 m^3/s, which is 14.4 % of its total exploitation, while in Tunisia it is of 2,5 m^3/s, which is 7.8% of the total.

- **In Algeria**, the CI aquifer, which is traditionally exploited in the wilayas of Adrar, Ghardaïa, El Oued and Ouargla, has extended in a marked way, since the early 1980s, to the wilayas of Biskra, Tamanrasset and Illizi. This exploitation—which, at the beginning, used to be made by Foggaras (Adrar) and artesian wells (Ghardaïa, Ouargla and El Oued)—extended considerably thanks to the generalization of pumping. Thus, pump abstractions, which in 1950 were in the order of 0.36 m^3/s (that is 6.4% of the abstractions at the time), reached in the year 2000 the value of 18.1 m^3/s (that is 56.6%

of the abstractions in 2000). The generalization of pumping is particularly spectacular in the wilaya of Adrar, where the volumes pumped passed from 0.5 m^3/s, in 1982, to 6.1 m^3/s in the year 2000. A similar situation may be observed in the Wilaya of Ghardaïa. This situation is largely dictated by the arrangement of the aquifer to be collected at small depth and with a piezometry close to the ground surface.

The foggaras[1] of Gourara, of Touat and of Tidikelt constitute the main manmade outlet with a natural hydrodynamic operating of the Continental Intercalaire aquifer in the south-western part of the basin. Since the 1950s, the drilling of wells for the exploitation of the Continental Intercalaire groundwater bearing has been steadily on the increase, without however marginalizing the exploitation of the foggaras.

Three foggaras gauges, which were made in 1932, 1950 and 1960, have served for the ERESS study (1972) to present a first evaluation of the abstractions from these structures and the record of the abstractions between 1950 and 1970. These three measurement campaigns have revealed that, while the unit flows of each foggara may vary, the total flows as per palm-tree grove remained more or less constant. The total flow abstracted from the foggaras is estimated, for 1960, as 3.6m^3/s. This flow represented 51% of the total flow abstracted from the aquifer of the Continental Intercalaire in Algeria and in Tunisia. The flow of these foggaras was distributed, in 1970, into three major sets, as indicated in Table 13 :

Table 13 – Flow of the foggaras in 1970 (l/s)

Zone	Gourara	Touat	Tidikelt	Total flow
Flow in l/s	887	2085	693	3665

The updating of the ERESS study, which was carried out in 1981 (RAB 80, 1983), has considered the same situation, in the absence of new measurements. The BRL study (1998) only availed itself of part of a new inventory involving 318 foggaras out the thousand foggaras which were presented in 1960. This study only considered the foggaras of the regions of Touat and Tidikelt. Out of the 318 foggaras considered, 36 had dried up and 282 foggaras were being exploited with a total flow of 1037 l/s. By comparison with the situation of the same foggaras in 1960, BRL has estimated the drop in flow as 23%, corresponding to the various flows indicated in Table 14:

Table 14 – Flow of the foggaras in 1998 (BRL, 1998)

Zone	Gourara	Touat	Tidikelt	Total flow
Flow in l/s	707	1088	693	2488

An exhaustive inventory of the foggaras by the ANRH team (DRSO Adrar) in 1999[2] has led to defining their situation as given in Table 14 :

Table 15 - Situation of the foggaras in 1999 according to ANRH inventory

Region	Active Foggaras	Dried up Foggaras	« Old » flow (m3/s)	Current flow (m3/s)
Gourara	318	54	0.448	0.766
Touat	448	186	1.586	1.586
Tidikelt	41		0.353	0.345
Total	**807**	**240**	**2.387**	**2.697**

[1] *Manmade draining tunnels to exploit the aquifer whose piezometric area is of little depth.*

[2] *DRSO-Adrar (1999) : Etude d'approche sur le captage traditionnel (Foggara) (« Study of Approach to Foggaras ») . Ministère de l'Equipement et de l'Aménagement du Territoire. ANRH, Dir. Rég. du Sud-ouest-Adrar, Avril 1999, (Document not numbered, 120 pp.)*

The drop in flow between 1960 and 1999 is of 968 l/s (29% of the initial flow).

In the wilaya of Ghardaîa where artenianism was, until the early 1970s, more predominant than pumping, the pumped volumes have steadily increased to exceed, from 1971 onwards, artesian abstractions, thus reaching by the year 2000 about 4.0 m^3/s, that is 1.5 times the volume abstracted by artesianism (2.650m^3/s) .

In the wilaya of Ouargla, the situation is similar. Pumping started back in the 1960s, but it has become in recent years far more common than artesianism (3.15 m^3/s, as against 0.76 m^3/s in the year 2000). In this region, the exploitation of oil wells is a characteristic feature which is not common in the other wilayas, although it remains quantitatively marginal with respect to other usages of the water of this aquifer (20 l/s) and has not been accounted for in Table 16.

Table 16 – Record of the exploitation of the Continental Intercalaire in Algeria as per Wilaya (l/s) (PW : Pumped wells; AW : Artesian wells ; Fogg. : Foggara)

Country	Wilaya	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000
ALGERIA	Adrar – PW	0.0	0.0	0.0	0.0	0.0	1.0	1.0	697.2	5035.7	6113.1	6102.2
	Adrar – AW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.0	57.0	57.0
	Adrar Foggaras	3665.0	3665.0	3665.0	3665.0	3665.0	3505.0	3340.0	3175.0	3010.0	2840.0	2697.0
	Total Adrar	3665.0	3665.0	3665.0	3665.0	3665.0	3506.0	3341.0	3872.2	8102.7	9010.1	8856.2
	Biskra – PW	0.0	0.0	100.0	100.0	100.0	181.0	464.0	1565.0	2175.0	2155.0	2248.0
	El Oued - PW	174.0	139.0	216.0	240.0	442.0	547.0	490.0	340.0	760.0	590.0	460.0
	El Oued - AW	0	0	0	0	0	200	200	655	1285	780	680
	Total El Oued	174.0	139.0	216.0	240.0	442.0	747.0	690.0	995.0	2045.0	1370.0	1140.0
	Ghardaïa - PW	24	197	300	368	404	618	705	1928	2511	3358	4066
	Ghardaïa - AW	130.0	404.1	400.0	503.4	457.6	462.6	545.1	1244.8	2288.5	2911.4	2650.6
	Total Ghardaia	154	601	700	872	861	1081	1250	3173	4799	6269	6717
	Illizi - PW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	434.5	439.5	495.0	1020.0
	Ouargla - PW	0.0	0.0	10.0	395.0	986.0	1158.0	1173.0	1841.3	2814.6	3005.9	2747.2
	Ouargla - AW	0.0	0.0	0.0	0.0	117.0	442.0	554.0	764.6	764.6	764.6	764.6
	Total Ouargla	0.0	0.0	10.0	395.0	1103.0	1600.0	1727.0	2605.9	3579.2	3770.5	3511.8
	Tamanrasset - PW	157.3	158.8	220.0	310.4	400.0	380.0	380.0	588.5	1209.4	1337.7	1427.7
	Total Pumped Wells	355	494	846	1414	2332	2885	3213	7395	14945	17055	18071
	Total Artesian Wells	130	404	400	503	575	1105	1299	2664	4395	4513	4152
	Total Foggaras	3665	3665	3665	3665	3665	3505	3340	3175	3010	2840	2697
	Total PW + AW	485	899	1246	1917	2906	3990	4512	10059	19340	21568	22224
Total CI Algeria (Wells + Fogg)		4150	4564	4911	5582	6571	7495	7852	13234	22350	24408	24921

In the Wilaya of El Oued, the IC aquifer is fairly deep and under high pressure. Its exploitation by artesianism is the rule, though pumping has been steadily on the increase since the 1970s. By the year 2000, it had reached the equivalent of 0.46 m^3/s. The more developed exploitation by artesianism has steadily been on the decrease in this zone (0.68 m^3/s in the year 2000, as against 1.28 m^3/s in 1990).

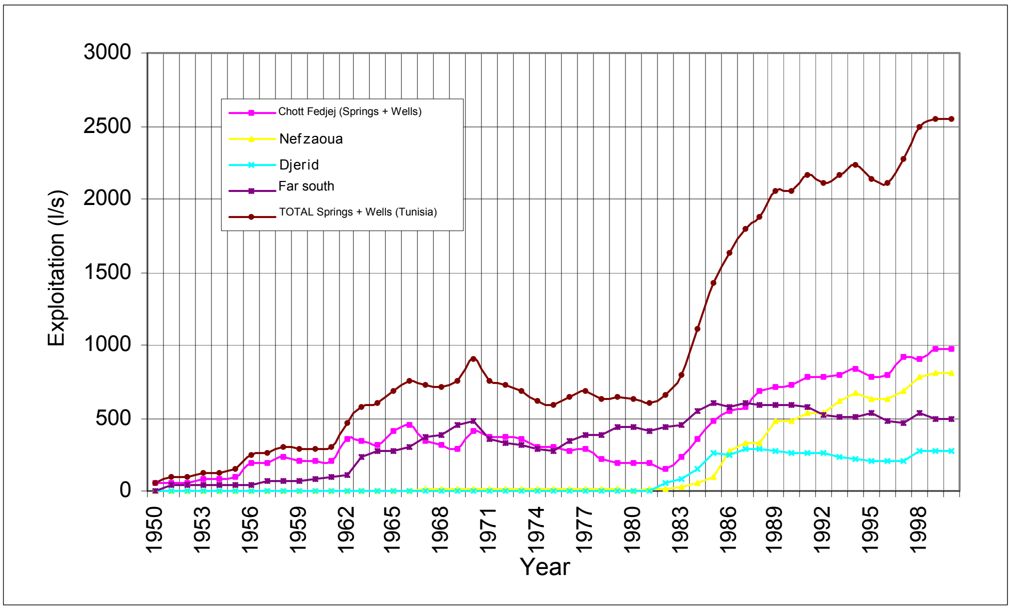
- **In Tunisia**, the exploitation of the aquifer of the Continental Intercalaire had proceeded by artesianism and springs until the early 1980s, in both Chott Fedjej and the far south. The drilling of deep boreholes in Djérid and in Nefzaoua has contributed in extending its exploitation to these regions. The exploitation by wells, which was of 52 l/s in 1950, was to rise to 865 l/s l/s in 1970 to then markedly increase afterwards, thus amounting to as much as 2.54 m^3/s in the year 2000. This increase has gradually taken place in the various regions and, particularly, in (0.8 m^3/s) and in Chott Fedjej (0.97 m^3/s) where this aquifer is exploited for its high artesianism. The wells of Djérid, constructed in the early 1980s, have thenceforward been exploited at a flow nearing 0.27 m^3/s. Those of Tozeur and of Nefta have experienced a marked drop in their artesianism to such an extent that two wells in Tozeur are currently exploited by pumping. These wells, like the springs of Chott Fedjej, are connected with the “Grès Supérieurs” (Upper Sandstone) aquifers ; they present a marked drop in spouting pressure.

In the far south of Tunisia, the exploitation of the CI used to be done, up to the early 1980s, mainly on the western flank of Dahar and in the Grand Erg Oriental iis mainly at the level of the field of EL Borma that the major part of this exploitation is done (0. 4 to 0.5 m^3/s on average since 1980). Figure 31 presents the evolution of the abstractions from the Continental Intercalaire aquifer in Tunisia from 1950 to 2000.

Table 17 – Record of the exploitation of the Continental Intercalaire in Tunisia in l/s (1950 - 2000)

	Region	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000
TUNISIA	Total Wells Ch. Fedjej	0	52	160	365	372	271	169	459	704	763	955
	Springs Ch. Fedjej	51	49	44	43	38	28	20	18	16	12	15
	Tot. Ch. Fedj	51	101	204	408	409	299	189	477	720	775	970
	Nefzaoua	0	0	0	0	20	18	5	95	486	626	806
	Djerid	0	0	0	0	0	0	0	263	265	207	275
	Far South	2	44	48	249	444	278	432	597	587	529	496
	Total Wells	2	96	238	644	865	567	606	1413	2041	2125	2533
Total CI Tunisia (W + Spr.)		**53**	**145**	**282**	**687**	**903**	**595**	**626**	**1431**	**2058**	**2137**	**2548**

Figure n° 31 - Exploitation of the Continental Intercalaire in Tunisia as per wells and as per springs in l/s



- **In Libya**, the Continental Intercalaire aquifer is exploited in the zone of Tawurgha, in the valleys of wadi Sufajjin, in the valleys originating from the eastern flank of Hamada al Hamra and Al Jufrah.
  - In the 1980s, nine artesian wells, collecting the Kiklah and Cambro-Ordovician aquifer, were constructed in the vicinity of the **Tawurgha spring. Eight of the nine wells** are used for water supply to the city of Misratah. However, since 1998, the major drinking water supply to Misratah has been provided by the Great (Manmade) River, while the wells of Tawurgha have become reduced to a regulation role.

- In the **affluent valleys of wadi Sufajjin**, 46 deep wells collecting the Kiklah aquifer were constructed in the late 1970s and in the early 1980s, and have led to the development of irrigated crop zones totaling about 3500 ha. However, following the drop in artesianism, problems of corrosion of spring well heads and difficulties in the maintenance of pumps, exploitation flows have constantly been on the decrease since the commissioning of the wells. So as to remedy the insufficiency of the flows of the deep wells, farmers have gradually drilled wells in the range of 100 to 150 m depth, collecting the Upper Cretaceous (Mizdah);

- The bottom of the valleys issuing from the Hamada has been the seat for an agricultural development based on the deep wells collecting the Lower Cretaceous and, sometimes even, the Palaeozoic, which were constructed in the late 1970s and in the early 1980s. These wells, whose depth exceeds at times 2000 m, supply hot water whose use for irrigation is not altogether easy. Problems of corrosion of well heads, together with the difficulties related to the water temperature, have combined to lead to abandoning several wells which now flow into the wild.

Table 18 - Exploitation of the Continental Intercalaire in Libya (l/s)

	Region	1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000
LIBYA	Sufajin	0	0	0	0	0	0	0	2061	1807	1364	824
	Eastern flank of El Jufra	0	0	0	0	0	476	1161	1712	1592	1237	920
	Southern flank of J. Nafusa	0	0	0	0	0	38	295	414	470	473	498
	Ghadamis	0	0	0	0	4	4	166	180	180	180	180
	Al Khums - Tawargha	0	0	0	0	0	0	0	793	634	381	190
	Al Jufra	0	0	0	0	0	0	0	0	159	317	444
	Eastern flank of HH -W. Nina	0	0	0	0	0	0	317	476	381	349	308
	Total CI – Palaeozic	0	0	0	0	0	0	317	1268	1173	1046	942
	Total CI Wells	0	0	0	0	4	518	1938	5635	5222	4299	3364
	Tawargha spring	1350	1300	1300	1268	1268	1268	1268	1173	1173	1173	1205
Total CI Libya (Wells + Spr.		**1350**	**1300**	**1300**	**1268**	**1272**	**1786**	**3206**	**6808**	**6395**	**5472**	**4569**

- Three oases are found in the western part of the Libyan territory, along the Tunisian border. Ghadamis is by far the most important one, and the palm-tree groves used to be supplied by a spring that dried up several years ago. The exploitation of groundwater by wells has started with the construction of structures (equipment) tapping the Nalut formation of the Upper Cretaceous. The water, of a rather mediocre quality, has rapidly led to the construction of wells collecting the Lower Cretaceous (Kiklah) which are currently the main drinking water supply and irrigation water for the palm-tree groves.

- A few deep wells (1500 to 2000 m), reaching into the Kiklah aquifer and the Palaeozoic horizons, have been constructed in the zone of Waddan in order the complement water supply to the palm-tree groves.

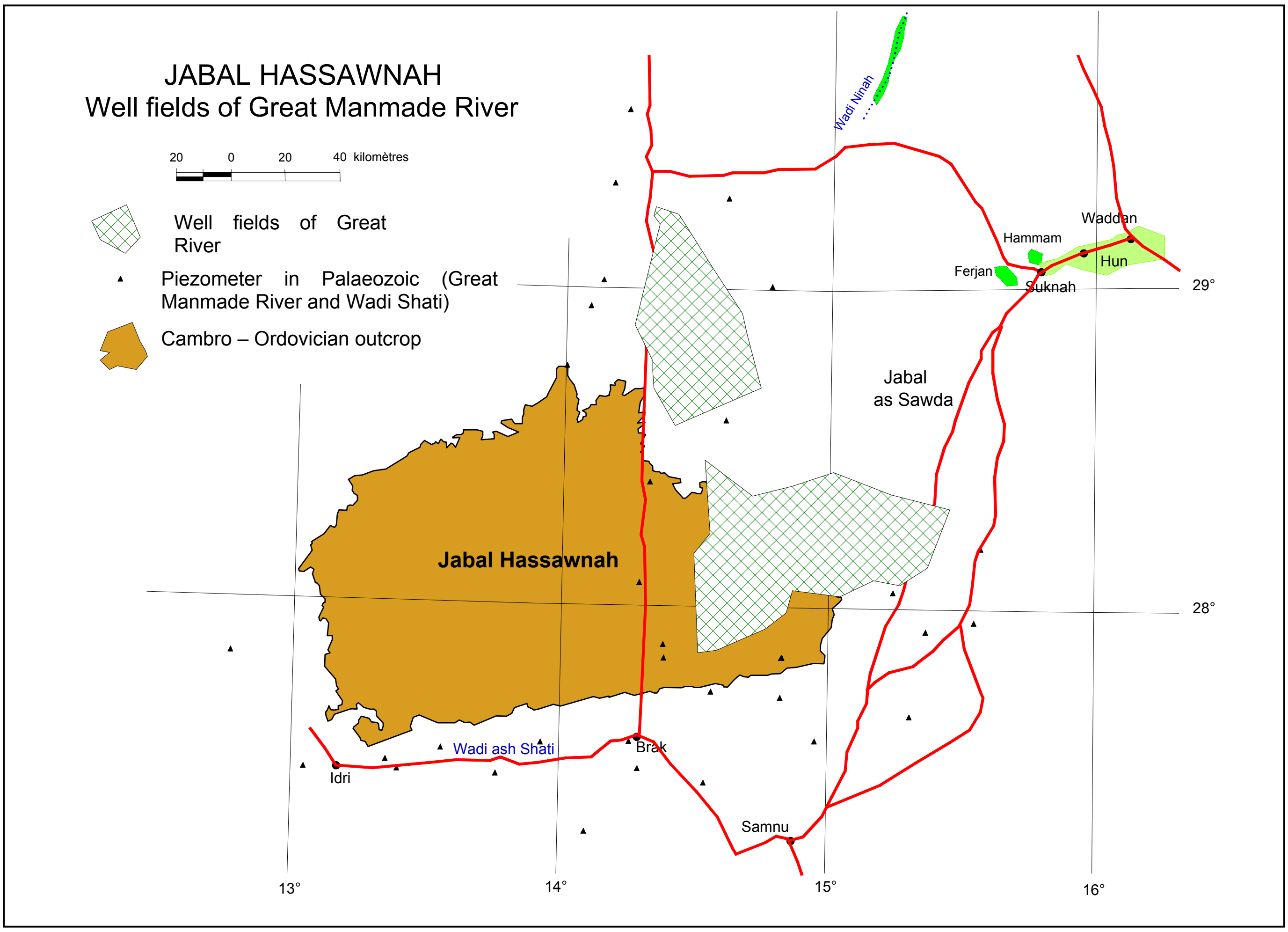
- The southern flank of Jabal Nafusa is populated with small towns which have gradually been equipped with water piping supplied by wells that generally tap the Kiklah.

At present, a new programme for the exploitation of the aquifer of the Continental Intercalaire is under study for the zone between Derj and Ghadamis. The objective set for this programme is drinking water supply to those towns of the western part of Jifarah which are not included in the objectives of Phase II of the Great (Manmade) River issuing from Jabal Hassawnah. The flow that will be abstracted from this new wells field has not been set yet in any definite manner, but it is likely to be in the range of 50 and 90 million m^3/year.

4.2.1.4. External abstractions with consequences on the behaviour of the Saharan aquifers

A major exploitation programme of the Cambro-Ordovician aquifer has been set to the south-east of the Libyan Saharan basin, in Jabal Hassawnah. This programme consists in a set of over 500 wells whose forecast total flow is of 912 Mm^3/year (29 m^3/s). The water pumped is intended to provide supply to the Great Manmade River conveying water to the plain of Jifarah. The location of the two well fields is given in Figure 32. The exploitation of the field located furthest to the north has started in September 1996 for water supply to the city of Tripoli. As of the year 2000, the average flow abstracted was of 4 m^3/s. Given the hydraulic continuity existing between the aquifer of the Cambro-Ordovician and that of the Continental Intercalaire, these new abstractions will have an impact in future on the behaviour of the Continental Intercalaire aquifer.

Figure n° 32 – Well fields of the Great Manmade River



4.2.1.5. Conclusions

The exploitation of the Saharan basin aquifers has experienced in the past thirty years a phase of intensive mobilisation of the resources, which has translated into an increase in exploitation wells. These wells, in turn, have impacted negatively the spouting of springs and artesian flows. This situation has induced a drop in the flow of the foggaras in Algeria (23%) which collect the CI aquifer and the springs of Chott Fedjej which equally collect this same aquifer. On the other hand, it has induced the drying up of the Tunisian springs which tap the Complexe Terminal aquifer in Djérid and in Kébili.

> The increase in pumped volumes and the development of Saharan farming have repercussions on these Saharan aquifers under the form of drying up of springs and a drop in artesianism. This increasing exploitation is likely to induce, in the vulnerable zones, changes in water quality.

4.2.2. Piezometric record

4.2.2.1. Problems related to level and pressure measurements (for artesian wells in particular)

Measurements of piezometric level in the Saharan wells are hampered by several problems :

- The first problem is the **absence**, or very small number, of true piezometers specifically intended for measurements. This is due to the advent of great depths (case of the Continental Intercalaire, for instance), which would make piezometers prohibitively costly. The piezometric measurements are, accordingly, made for operating wells, which requires either a stoppage of pumping or a closing of the well. Such an operation is hampered by a reluctance on the part of the users who would thus find themselves deprived of water for a certain period of time.
- The second problem is related to the measurement difficulties with regard to **artesian wells** whose closing is not always possible and which are not always equipped with an outlet upstream of the valve for placing a manometer. As a general rule, a measurement is made at the moment of construction of the well, but measurement becomes increasingly difficult over time if no arrangement has been provided for the maintenance of the main valve.
- It is also worth pointing out the difficulty related to the **high temperature** of the water in certain deep wells ; a major adjustment of the measurement is, therefore, necessary to take into account the reduction in the specific weight of the water due to the temperature.

4.2.2.2. Piezometric record of the Complexe Terminal

The main drawdown values recorded in the three countries are given in Annex 6.

- ***Algeria***

The drop in the piezometry of the Complexe Terminal aquifer is monitored in Algeria between 1950 and 2000 in several zones or oases groups, of which in particular Mrhaïer, Djemaa, El Oued, Touggourt, Hassi Khalifa, Ouargla and Gassi Touil. This monitoring is discontinuous over time and only takes place on the occasion of specific measurement campaigns.

In the region of northern Oued Rhir, the Sidi Ahmed Tidjani well shows, between 1952 and 1995, a total piezometric drop by 32 m. Similarly, that of Chemora indicates a drop by 25.7m between 1955 and 1991. In general, the piezometric drop of the CT is, in this zone (Mghaïer and Djemaa) where exploitation has been fairly intensive in recent years, linear and ranges between 0.6 and 1.0 m/year.

At the level of Touggourt – El Oued, this piezometric drop is in the order of 0.9 m/year. It seems to have become more accelerated since the middle 1970s.

This drop becomes less marked at the level of Ouargla where it has been is in the range of 3.8 to 8.5 m in 27 years, but further reduced in Gassi Touil and in Hassi Messaoud (0.5 to 5.5 m in 25-30 years).

Over the whole Algerian Lower Sahara, the piezometric drop of the Complexe Terminal ranges between 32 m in 43 years, in northern Oued Rhir, and to about 5 m in 30 years, in Ouargla. It becomes more mitigated towards the bordering zones where the density of the wells collecting this aquifer is low.

- ***Tunisia***

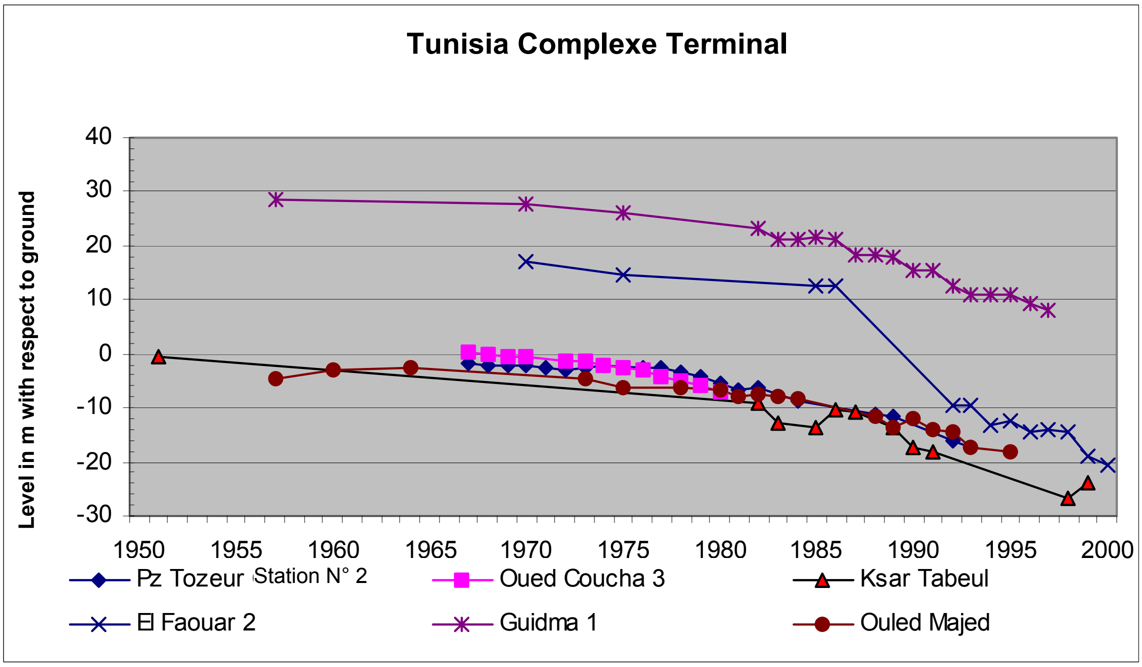
In Tunisia, the Complexe Terminal aquifer has started to be intensively exploited in Nefzaoua and Djérid since the mid-1970s. This exploitation is twice higher in Nefzaoua than in Djérid. The evolution of the piezometry of the Complexe Terminal, between 1950 and 2000, has been experiencing a continuous drop whose downward line has become more marked since the 1990s. This drop is more marked in the part located between Kébili (22.8 m in 25 years) and Bou Abdellah (23 m in 27 years) where abstractions are intensive and where the wells are very close to each other. Elsewhere in Nefzaoua, the drawdowns between 1950 and 2000 are less marked : Messaïd - Djemna : 20 - 30 m in 40 years, Douz - Galaa : 25 - 30 m in 50 - 60 years, Nouaiel - Zarcine : 5 - 10 m in 20 years. This piezometric drop is of 10 -15 m in 10 years in the region of Redjim Maatoug where the exploitation of the CT was started in 1980.

In Djérid, the longest piezometric chronicles report drops of 14 m in 66 years (Castilia), of 13.5 m in 27 years (Sebaa Biar) and of 2.1 m in 33 years (Ghardgaïa). In Nefta, this drop has amounted to 3.7 m in 15 years.

Artesianism has almost disappeared from the Complexe Terminal of Djérid. It is steadily decreasing in Nefzaoua. It has thus disappeared in the Kébili peninsula where the wells are exploited by pumping. Towards the least elevated zones (adjacent to Chott Djérid), the highest artesian heads are in the range of 20 to 35 m above ground.

The overall trend of the piezometric drop of the CT reveals, in Djérid and Nefzaoua (Figure n° 33), an acceleration during the last decade which is due to the intensification of abstractions.

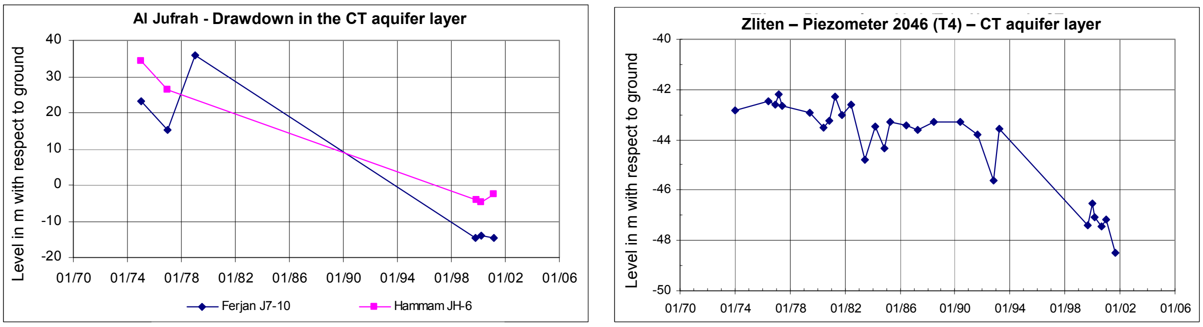
Figure n° 33 - Complexe Terminal – Examples of drawdowns in Tunisia



- ***Libya***

In Libya, the wells with several piezometric level measurements are very small in number and are concentrated in two zones :

Figure n° 34 - Complexe Terminal - Examples of drawdowns in Libya



- the Al Jufrah zone where the exploitation of the Senonian limestone, mainly by the farming projects of Ferjan and Hammam, has induced a drawdown in the range of 35 to 40 m since the inception of the operations in the late 1970s ;
- the coastal zone, between Zliten and Tawurgha, where several farming projects have exploited the Upper Cretaceous aquifers since the late 1930s. During the 1970s, new wells were constructed, but they have been gradually abandoned following an increase in water salinity. The resulting drawdowns, measured only in a few wells located outside of the exploitation zones, have been in the range of 4 to 6 m since 1974 - 1975.

4.2.2.3. Piezometric record of the Continental Intercalaire

The Continental Intercalaire aquifer is the one whose piezometric record is the most difficult to establish due to the fact that the wells which collect it are not as accessible to measurement as those of the Complexe Terminal. A preliminary work of analysis of the content of the data base has been done with a view to bringing out those wells which present two, three or more piezometric measurements. In this list, there have been selected a few wells whose piezometric record covers a longer period extending, preferentially, from the 1980s to 2000. Based on this, there has been developed a list of the wells adopted in each country for obtaining a piezometric record of this aquifer.

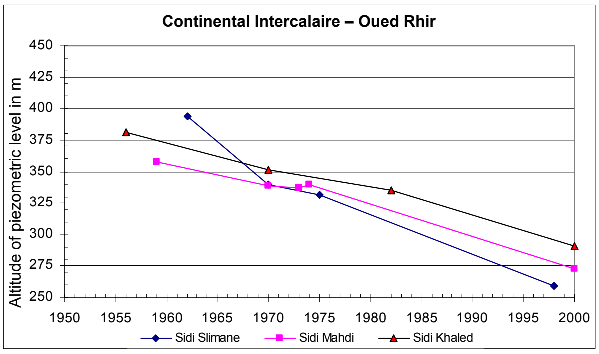
- ***Algeria***

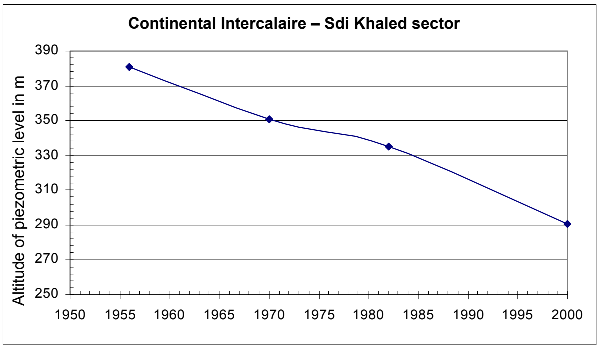
The water points presenting a piezometric record have been grouped as per homogeneous geographic sector in order to deduce from it the piezometric drop by zone (cf. Table of Annex 6).

In the region of Oued Rhir where the piezometric drop is the highest, most wells have been experiencing, since the 1960s, an acceleration of that drop due to the increase in abstractions in this zone since that date (**Figure n° 35**).

In Ouargla (El Hadeb), too, the piezometric drop has accelerated between 1956 and 2000. It has amounted to 66 m in 44 years.

Figure n° 35 - Continental Intercalaire - Examples of drawdowns in Algeria





In Gassi Touil, the piezometric drop, which was fairly low before 1970, was to accelerate afterwards until 1987 before stabilising. It amounted to 15 m in 25 years.

In Hassi Messaoud, the piezometric drop of the Continental Intercalaire, which had been low until 1978, has accelerated since then. It amounted to 46 m in 43 years.

In Ghardaïa, the piezometric drop ranges between 88 m (Sinclair), from 1966 to 1991, and 15.6 m (Nezla), in 12 years (1988 - 2000). It becomes mitigated in El Goléa (10.4 m in 50 years).

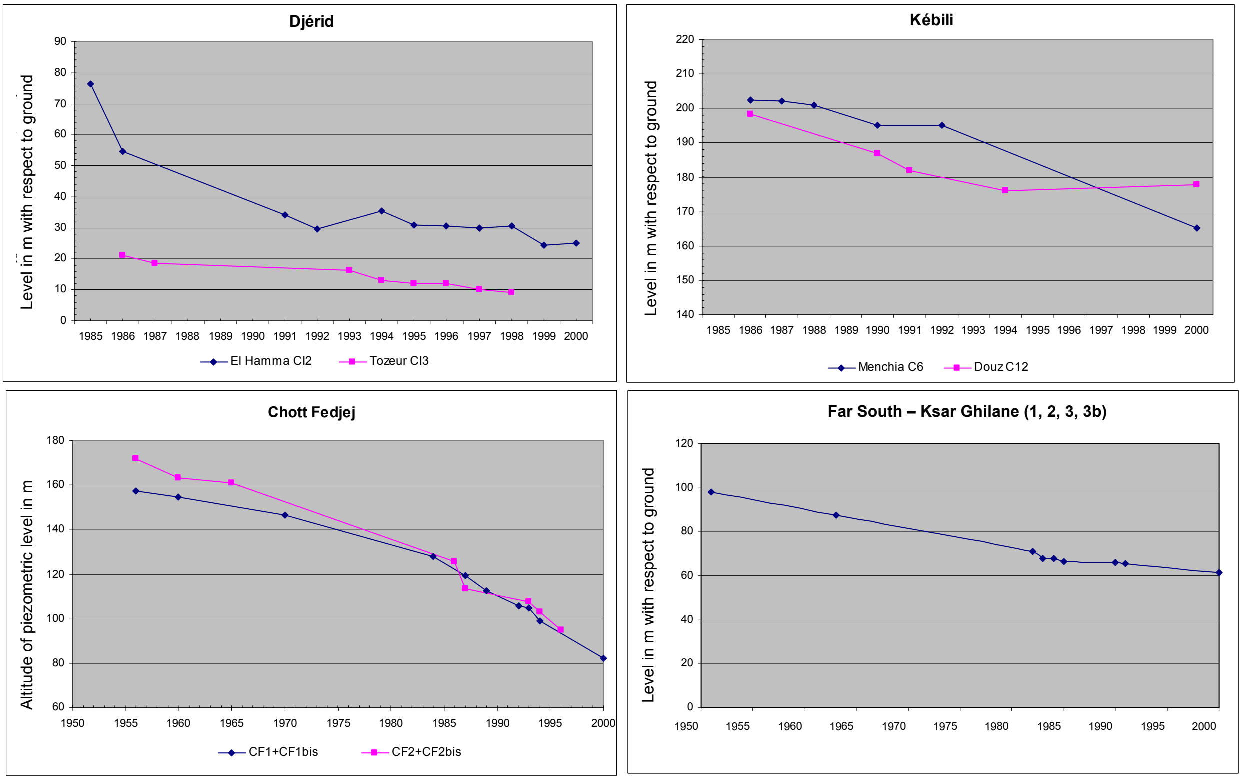
In Adrar, where the Continental Intercalaire aquifer is unconfined over a large area, the piezometric drop observed between 1950 and 2000 is often of a few metres: 5 to 20 m in 20 years, in Gourara, 3 to 28 m in 30 - 35 years, in Touat and 5 to 10 m in 30 - 35 years in Tidikelt.

On the whole, the Continental Intercalaire aquifer had experienced, between 1950 and 2000, a marked drop in Algeria in the zones where it is under high pressure and where its exploitation has been significantly increased since the early 1980s by the construction of new wells. This is the case of Oued Rhir, Ouargla, El Oued and Hassi Messaoud. In these zones, the piezometric drop recorded often exceeds 2 m/year for the past two decades.

- ***Tunisia***

The exploitation of the Continental Intercalaire aquifer used to take place before 1950 in the region of Chott Fedjej by means of springs that rise from the “Grès spérieurs” (Upper Sandstone) and “Grès à bois” (Woody sandstone) (Barremian - Aptian). This exploitation was low and only involved the upper levels of this aquifer. With the construction of the early wells in the Tunisian far south in the early 1950s (Bordj Bourguiba and Ksar Ghilane), this exploitation has started to gain in importance. It was not until the early 1960s that the wells of Chott Fedjej (CF1 and CF2), as well as those of El Borma (EB A1 and EB A4), were to be brought on stream. This exploitation was not to become really significant until the mid-1970s with the commissioning of the wells of El Borma and the construction of the well CF 3. The 1980s were marked by the construction of wells collecting the CI in the regions of Djérid and of Kébili (Nefzaoua).

Figure n° 36 - Continental Intercalaire - Examples of drawdowns in Tunisia



➢ *Chott Fedjej*

The region of Chott Fedjej - El Bahaîer is the closest zone to the outlet of the Continental Intercalaire in Tunisia. In this zone, the wells of Seftimi, El Bahaîer and CF follow a line from upstream to downstream. The record of the piezometry of the aquifer has been monitored there in a continuous manner since the mid-1980s. Here, the average drop is about 2 to 2.5 m/year. It tends to be more marked with the intensification of exploitation.

The wells CF1 and CF2, with their substitutes (CF1bis and CF2bis) have caused, from 1956 to 2000, a total drop of 71 to 76 m. This drop is more marked at the level of the wells exploited under the form of groups (CF F1, CF F3, CF8, CF9 and CF 10). Some of these wells (CF9 and CF 10) had experienced, between 1982 et 1993, an average annual drop in the order of 3.0 m. Thus, the drop in the piezometry of well CF 3b had come to take on, between 1993 and 2000, an exponential trend which is induced by the impact of the other adjacent wells.

The piezometry of the wells of Siftimi and El Bahaïer, recorded since 1986, has presented a regular drop in the range of 32 to 53 m in 14 ans.

➢ *Nefzaoua (Kébili)*

Most of the wells exploiting the Continental Intercalaire aquifer in Nefzaoua were brought into stream between 1985 and 1987. Since then, their piezometry has presented a drop which was rather little marked at the beginning, but which has intensified since the early 1990s. The drop reached 19 m in 14 years for the well of Kébili CI 10, and 32 m in El Faouar CI 19. It is fairly marked in the Kébili peninsula (Débabcha: 3.6 m/year; Zaouiet el Aness: 3.6 m/year; and Menchia: 2.6 m/year).

The drop by 4.4 m/year recorded at the level of the well of El Faouar for the period 1993 – 2000, seems to be fairly high in a zone where interference is absent.

➢ ***Djérid***

The exploitation of the Continental Intercalaire aquifer started in Djérid between 1981 and 1983. Since the beginning of exploitation, the piezometric drop had been substantial (35 to 80 m) in the wells of Tozeur, Nefta and El Hamma, between 1983 and 1987. Only the well of Tozeur CI 2 has had a belated reaction which translated into a drop of about 30 m between 1993 and 1995. This phenomenon has taken place following the exploitation of the wells by pumping. During the 1990s, all the wells of Djérid exploiting the CI have presented a stabilisation of their piezometry which is in total contrast with what had happened in the preceding decade.

The piezometric drop has been accompanied in these wells by a consistent drop of their spouting flow which has brought down their exploitation to a half of its volume of 1986 (550 l/s). This fairly considerable drop in the exploitation of the wells of Djérid is revelatory of the case of an aquifer level with low reserves and experiencing an accelerated discharge. In fact, these wells collect an aquifer formation that is not in perfect continuity with the CI aquifer of the Saharan basin. This aquifer is lodged in the Aptian sands connected to the upper sandstone aquifer level whose extension is limited to the line of the Chotts. The piezometric drop recorded in these wells actually corresponds to that of the springs of Chott Fedjej which has become more marked since 1970.

➢ ***Far south***

In the Tunisian far south, the exploitation of the Continental Intercalaire aquifer has remained fairly low, except for the Field of El Borma where, since 1974, about 300 l/s have been abstracted on average. This situation has translated, at the level of the piezometry of the aquifer, by a drop that was only to become felt in Bordj Bourguiba, Lorzot and SP 4N between 1978 and 1981, and some time later in Oued Abdellah (1985). Further north, in Ksar Ghilane, the piezometric drop recorded at the level of the four wells which have inter-relayed in this zone, is both regular and low, being of 0.74 m/year.

In the region of El Borma, the measurements available allow the obtaining of an average drop for the group of wells in the range of 1.25 m/year (El Borma 4) to 1.5 m/year (El Borma A 10).

Conclusion

The piezometric drop of the Continental Intercalaire aquifer, which had been both regular and little accelerated from the 1950s to the 1970s, has become more marked in the course of the past twenty years. It is in the order of 50 m, in the region of Chott Fedjej, 30 to 40 m, in Nefzaoua, and 25 to 35 m, in the Tunisian far south.

The case of the wells of Djérid (Nefta, Tozeur and El Hamma), which present drop values exceeding, in certain locations, 50 m in 20 years, has to be considered as a local anomaly due to the fact that the aquifer level to which these wells are connected does not correspond to the main part of the CI Saharan aquifer. Within the same groups, other wells only present, for the same period, a piezometric drop of 15 to 30 m (Dégache CI 3, Tozeur CI 2 and Tozeur CI 3). This variation in the piezometric drop of Djérid is interpreted as being the outcome of the variation in permeability from one compartment to the other. The Tozeur-Nefta compartment, which is bordered by the two faults of Draa of Djérid, seems to present poor permeability and to be in lateral discontinuity with the Saharan part of the aquifer.

- ***Libya***

Only a few wells collecting the Continental Intercalaire have been recorded several times since their construction. The data available make it possible, however, to elicit a framework of behaviour of the Mesozoic sandstone aquifer from the inception of its exploitation up to the year 2000.

- In the Wadi Sufajjin catchment, the piezometric level ranges between 30 to 45 m. One well, the SOF5, reveals, however, a higher drawdown reaching 60 m ;
- In Zamzam, an only one well, the ZZ9, has been recorded recently, indicating a piezometric drop of 41 m since it was brought into stream. Another well, constructed at a later period, indicates a drop of 21m from 1987 to 2000 ;
- A few kilometres further south, in Wadi Bayy al Kabir, the well K7 presents a drop of 46 m from 1976 to 2000 ;
- Near the Tawurgha spring, one of the 9 wells collecting the whole Kiklah – Palaeozoic has been observed recently, indicating a drop of 24 m in the course of the period 1985 - 2000 ;
- In the western part of the Libyan Saharan basin, several wells have been recorded and reveal a fairly homogeneous behaviour, with piezometric drops in the range of 2 to 65 m. It is likely, however, that some of the values recorded were erroneous or corresponding to particular situations.

4.2.3. Piezometric situation in 2000

For the whole Saharan basin, the configuration of the piezometry of the two major aquifers of the Continental Intercalaire and the Complexe Terminal has experienced little variation between 1950 and 2000. This configuration has virtually remained unchanged with, locally, at the level of high exploitation zones, a marked drop effect. It has proved difficult to obtain, for the year 2000, an updated situation of the overall piezometry for the whole basin, the piezometric measurements relating to this year being too scanty to establish a precise map. It is, indeed, difficult to determine, without a mathematical model, the extension of the depression cones induced by the exploitation of the wells groups, even when recent piezometric measurements for these wells are available.

A piezometric map corresponding to the year 2000 has, nevertheless, been developed for the Complexe Terminal and the Continental Intercalaire by extrapolation of the measurements made during the past ten years, by assuming mean values of annual piezometric drops at the level of the main zones considered. In fact, these maps have not been used for the calibration of the models. This calibration rests, basically, on the drawdowns recorded at the level of a certain number of control points.

4.2.3.1. Complexe Terminal

The piezometry of the Complexe Terminal aquifer for the year 2000 (Pl. n°12) presents a trend similar to that of 1950 with, however, a generalised drawdown of the piezometric area that is marked at the level of high exploitation zones. This drop is particularly noted in the following three zones :

- the Lower Sahara between Touggourt, in the south, and Biskra, in the north, where the main oases and towns exploiting this aquifer are concentrated ;
- the region of the Chotts in Tunisia (Nefzaoua and Djérid), where the main Tunisian oases are found ;
- the eastern flank of Hamada El Hamra in Libya (Wadi Zemzem – Ain Tawargha), where the main water collection fields were constructed between 1972 and 1985, for purposes of agricultural development, based on the water of the Upper Cretaceous and Tertiary aquifers.

In view of the configuration of this piezometry, the Algerian chotts (Chotts Marouen and Melghir) and Tunisian chotts (Chotts Djérid and Fedjej) continue to be the outlets of this aquifer with, however, a low head, they having recorded values in the range of 30 to 70 m of drawdown with respect to 1950.

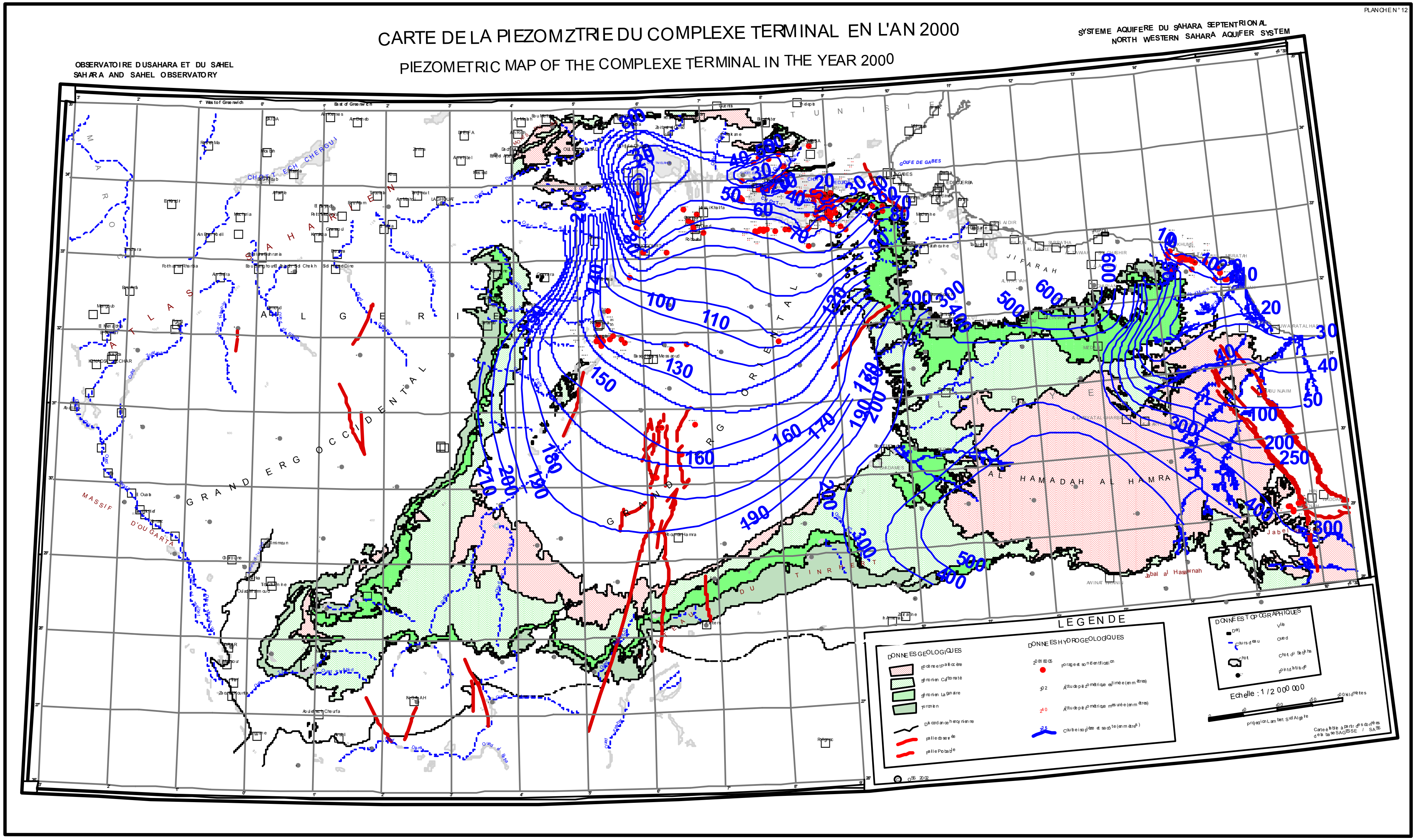
4.2.3.2. Continental Intercalaire

The map of the piezometry of the CI in the year 2000 (Pl. n° 13) reveals, in the sub-basin of the Grand Erg Occidental, the same runoff directions which run towards the outlet of the aquifer consisting of the outcrop zone of the foggaras (Ain Salah - Reggane).

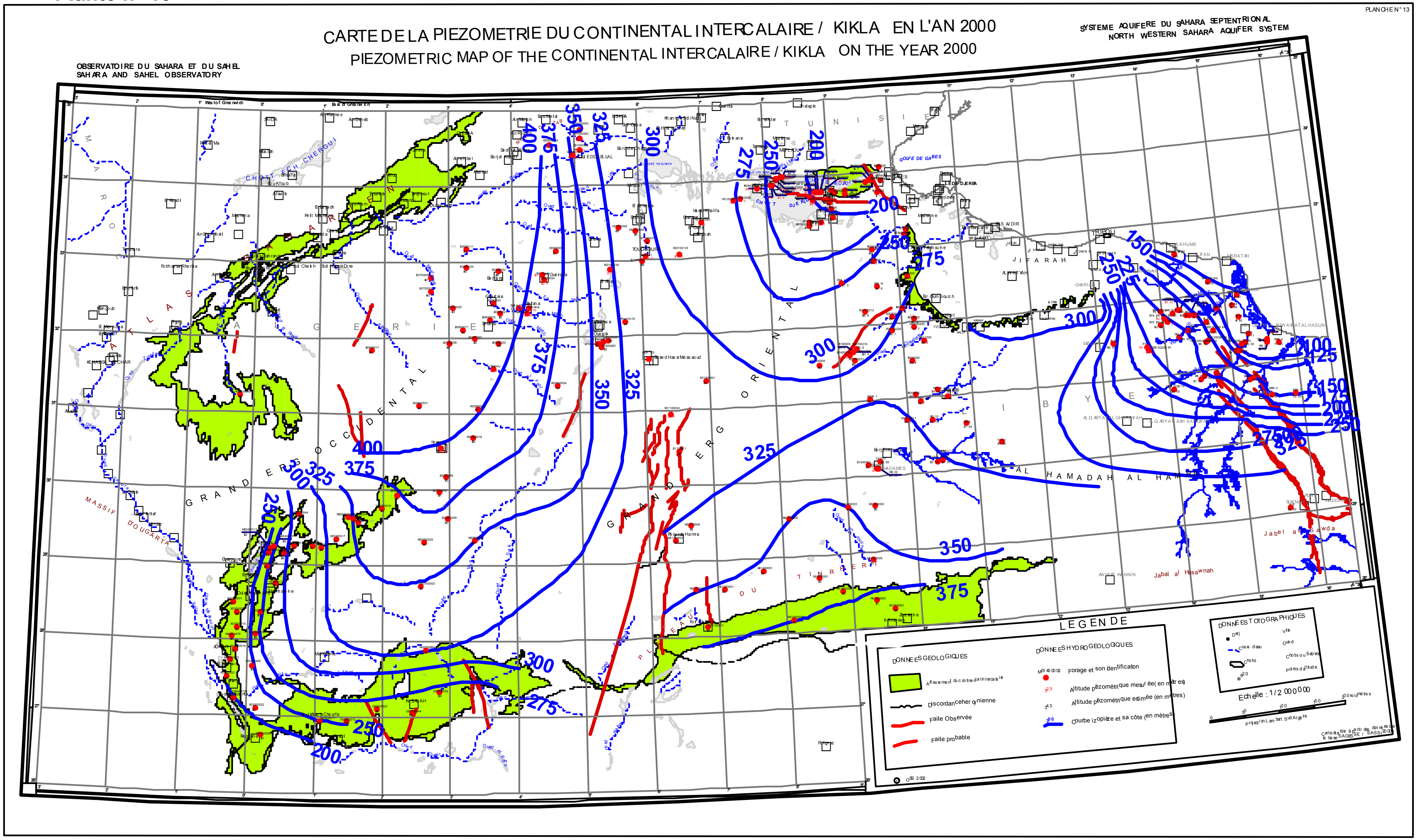
In the central part of the aquifer (sub-basin of the Grand Erg Oriental), the runoff, from the plateau of Tinrhert, south of the Grand Erg Oriental, remains the same and presents the same outlook as in 1950, heading from the south to the north across the Tunisian far south. The region of the Chotts, where the aquifer outlet to the Djeffara is found, is the zone towards which this runoff, as well as that of the Atlas, converge.

In the eastern part of the Libyan Saharan basin, the recharge zone located to the south (Jabal Hasawnah) is the origin of the runoff towards the eastern flank of the Hamada whose outlet consists in Ain Tawurgha and the sea, that is without change with respect to the initial situation, except locally around the exploitation zones. The flow of the aquifer towards Ghadames and the Tunisian south seems to override the runoff from Jabal Nafusah towards the south without any change with respect to the initial situation.

Plate n° 12


CARTE DE LA PIEZOMZTRIE DU COMPLEXE TERMINAL EN L'AN 2000
PIEZOMETRIC MAP OF THE COMPLEXE TERMINAL IN THE YEAR 2000
OBSERVATOIRE DU SAHARA ET DU SAHEL
SAHARA AND SAHEL OBSERVATORY
SYSTEME AQUIFERE DU SAHARA SEPTENTRIONAL
NORTH WESTERN SAHARA AQUIFER SYSTEM
PLANCHE N° 12
ALGERIE
TUNISIE
GRAND ERG OCCIDENTAL
GRAND ERG ORIENTAL
HAMADAH AL HAMRA
JIFARAH
TINRHERT
LEGENDE
DONNEES GEOLOGIQUES
DONNEES HYDROGEOLOGIQUES
DONNEES TOPOGRAPHIQUES
Echelle : 1 / 2 000 000

Plante n° 13


CARTE DE LA PIEZOMETRIE DU CONTINENTAL INTERCALAIRE / KIKLA EN L'AN 2000
PIEZOMETRIC MAP OF THE CONTINENTAL INTERCALAIRE / KIKLA ON THE YEAR 2000
OBSERVATOIRE DU SAHARA ET DU SAHEL
SAHARA AND SAHEL OBSERVATORY
SYSTEME AQUIFERE DU SAHARA SEPTENTRIONAL
NORTH WESTERN SAHARA AQUIFER SYSTEM
PLANCHE N° 13
LEGENDE
DONNEES GEOLOGIQUES
Discordance hercynienne
Faille Observée
Faille probable
DONNEES HYDROGEOLOGIQUES
Forage et son identification
Altitude piézométrique mesurée (en mètres)
Altitude piézométrique estimée (en mètres)
Courbe izopièze et sa côte (en mètres)
DONNEES TOPOGRAPHIQUES
Echelle : 1/2 000 000
GRAND ERG OCCIDENTAL
GRAND ERG ORIENTAL
HAMADAH AL HAMRA
PLATEAU DU TINRHERT
GOLFE DE GABES

5- CHEMICAL QUALITY OF WATER

Water salinity is a hydrogeological parameter which has increasingly been gaining in importance in the operating of the SASS aquifers due to the changes that the rise in abstractions has brought to bear on the balance of the piezometry and the conditions of underground flow. The chemical composition of these waters and their classification into groups is likely to contribute in better assigning chemical relationships between the various aquifer levels of the system, as well as to appreciate qualitatively the phenomena of recharge of the aquifers and of inter-aquifer exchanges.

Water quality is an aspect that determines the use of water in arid regions. With regard to the SASS aquifers, this aspect has become, with the intensification of exploitation, a likely factor of far-reaching changes resulting from hyper-saline water prompting from potential pollution sources (Chotts, drainage water and saline water aquifers such as the Aptian or the Neocomian, seawater).

5.1- Data used

The data on salinity and the chemical composition of water are unevenly distributed over time, both between the aquifers and between the three countries. Those relating to water salinity are by far the more numerous. They result from sampling operations made upon the construction of the structure or on the occasion of inventories or periodical measurement campaigns. Those relating to the chemical composition of water are less numerous and hardly periodical.

The data are dense and substantial in certain exploitation zones, and often discontinuous or non existent elsewhere. Their space/time density attests to the importance that the three countries grant to the monitoring of the aquifers ; this monitoring remains, however, insufficient for an exhaustive analysis of the water in the whole Saharan basin. The collection of data on the chemical composition and salinities of the water of the two major aquifers of the Saharan basin has been part of the activities conducted by the SASS project. Only the Libyan party has undertaken, during the project, to conduct water sampling campaigns for chemical analyses. The other geo-chemical data obtaining from Algeria and from Tunisia are data prior to the project which the latter has undertaken to examine and to analyse. A "**quality** » Table, set up within the data base, groups the data relating to the salinities and the chemical analyses available in the three countries.

The data available in the SASS data base on the salinities of the CI and CT waters in the three countries may be distributed as follows :

Table 19 – Salinity data available in the three countries

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

For all this set, practically all the salinity values are assigned by aquifer. The major part of these data has been related to the water points that collect any of these two main aquifers of the Saharan basin.

5.2- Quality of the chemical analyses

The quality of the chemical data thus collected is quite uneven due to the fact that they obtain from chemical analyses conducted by several laboratories and at different periods. In fact, these data which are distributed among the three countries extend over a period of a half century (1950 - 2000). They result from samples taken and analysed under very heterogeneous conditions. As the analysis methods have developed over time, it is sometimes difficult to compare the chemical quality of the water of the same well at different times. Moreover, certain samples were taken upon acceptance of the wells before the water collected could become representative of the aquifer. The ionic balance of the measurements for the same water point is not always well balanced.

5.3- Evolution of salinities

5.3.1. Complexe Terminal aquifer

The Complexe Terminal water mineralisation map (Pl. n° 14) seeks to highlight a certain differentiation between the sands water and the limestone water. On this map, water salinity makes it possible to locate the recharge areas and the outlet zones. Fairly often, anomalies due to the heterogeneous nature of the aquifer and, at times, due to the fact that the analyses do not correspond to the same date make it difficult to establish a spatial correlation.

A certain differentiation in the evolution of the total water mineralisation is possible between the sands aquifer and the limestone aquifer. This is due to the fact that the Senonian and Eocene sandstone formations are more accessible to recharge on the boundaries of the basin than the Mio-Pliocene sands.

It is important not to look upon this map as presenting an updated situation of the salinity of the aquifer system lodged in the various levels of the Senonian, Palaeocene and Miocene, but rather as a sketch of the hydrodynamic operating which indicates the origin of salinity. Accordingly, it would be illusory to attempt a correlation of the salinities when passing from the limestone to the sands because the local salinity effect may be prevalent.

This map has been developed based on non homogeneous data over time owing to the fact that we have not been able to obtain updated information for the whole basin. The situation thus represented is that which is closest to the initial state of the system. It makes it possible to put forward certain hypotheses on the recharge of the aquifers, the impact of high exploitation and the lateral continuity of the flow.

5.3.1.1. The Mio-Pliocene sands aquifers

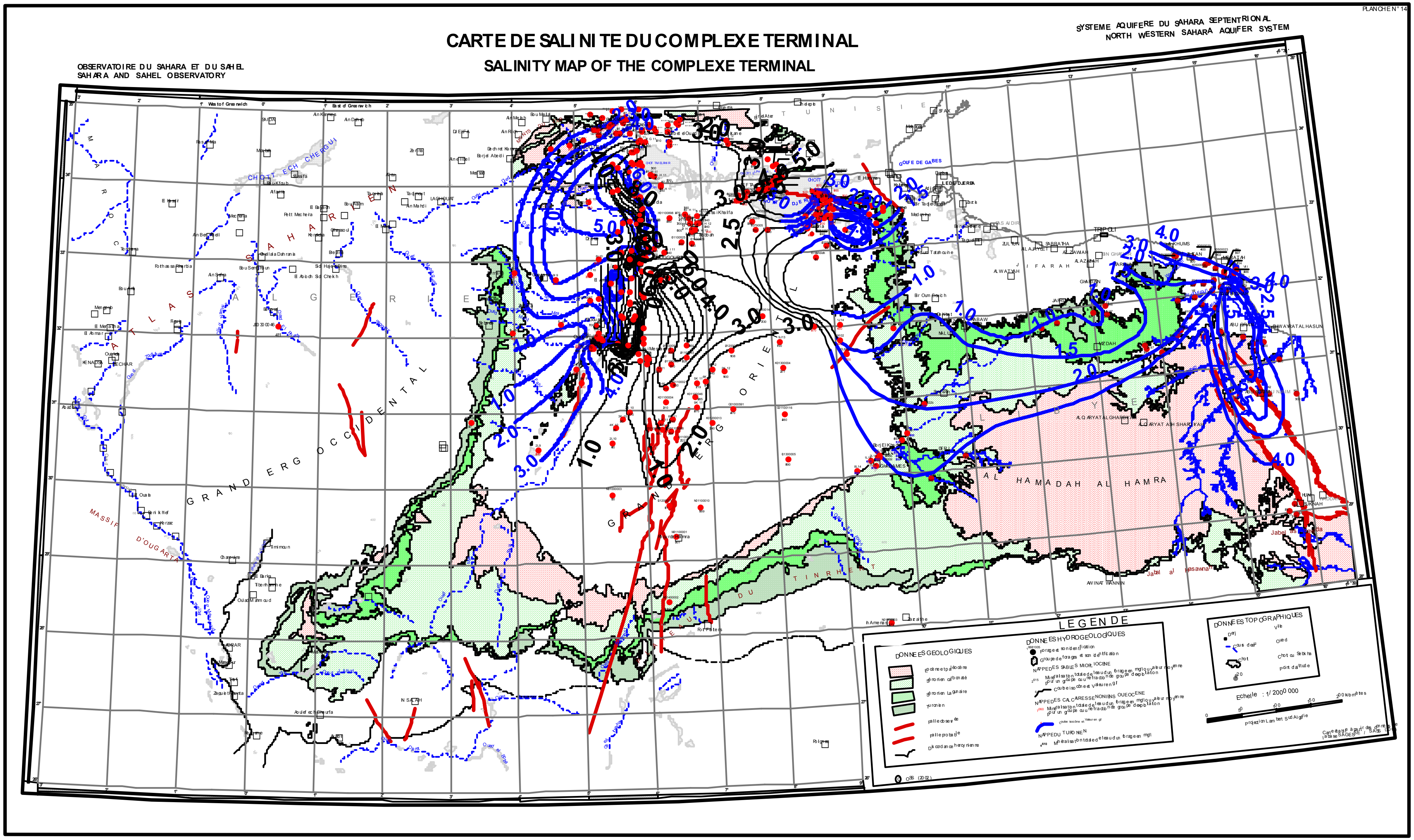
The total mineralisation map of the waters of the sands aquifer has been plotted based on the results of the analyses whose geographical distribution is quite heterogeneous. The measurements points are fairly often concentrated in exploitation zones with very few data outside of these groups. Particular phenomena, such as the effect of concentrated intensive exploitation and return of irrigation water, are the reason for certain localised chemical anomalies.

The isoconical contours (equal to salt concentration) reveal, between Ouargla and Oued Rhir, which is the area concerned by the presence of the sands aquifer, the following phenomena :

- a zone of less than 2 g/l which covers the southern half of the Grand Erg Oriental, to the south of latitude 32°. This zone corresponds to the current area of recharge from the exceptional rainfalls in the Erg,
- another zone of less than 2 g/l concentrated on the slopes of Mzab and on the western part of the aquifer, north of Ouargla,

a zone of less than 2.5 g/l concentrated on Draa Djérid in Tunisia, corresponding to the outcrop of these aquifer sands.

Plate n° 14


CARTE DE SALINITE DU COMPLEXE TERMINAL
SALINITY MAP OF THE COMPLEXE TERMINAL
OBSERVATOIRE DU SAHARA ET DU SAHEL
SAHARA AND SAHEL OBSERVATORY
SYSTEME AQUIFERE DU SAHARA SEPTENTRIONAL
NORTH WESTERN SAHARA AQUIFER SYSTEM
PLANCHE N° 14
GRAND ERG OCCIDENTAL
GRAND ERG ORIENTAL
HAMADAH AL HAMRA
GOLFE DE GABES
TRIPOLI
LEGENDE
DONNEES GEOLOGIQUES
DONNEES HYDROGEOLOGIQUES
DONNEES TOPOGRAPHIQUES
Echelle : 1/ 2000 000
OSS (2002)

Outside of these zones, mineralisation is generally high. This is particularly the case in :

- Ouargla, where a saline water zone of over 5 g/l is concentrated in Oued Mya,
- Along the Hassi Messaoud axis to the south, up to the north of Chott Melrhir, where salinity is above 5 g/l and can even reach 10 g/l.

The fairly saline water zone (of over 5g/l), along the axis connecting Hassi Méssaoud, in the south, to Oued Rhir, in the north, seems to indicate the double effect of high exploitation and irrigation water return in the poorly drained upper levels of the aquifer. In these zones, where the unconfined aquifer is located at little depth, even outcropping in certain recent eras, evaporation has induced, at surface level, salt concentrations. Under the effect of piezometric drop, these zones operate as saline water recharge areas.

The Mio-Pliocene sands aquifer is fairly often found in the closed depressions (Chotts and sebkhets) which constitute its natural outlets. It is towards these zones that the underground flows of the aquifer converge and join its waters both by their horizontal flow as by the percolation that fetches them to the surface from the deep limestone formations. This phenomenon is all the more marked as exploitation has intensified within close and high flow groups.

Figure n° 37 : View of the drainage-canal of Oued Rhir

5.3.1.2. Limestone aquifer

In Algeria, lthe Senonian and Eocene limestone aquifer is exploited in the zone that extends from Biskra, in the north, up to Ouargla, in the south. In Tunisia, it is concentrated in the region of Nefzaoua and in the basin of Ghadames. In Libya, it is found in the major part of El Hamada El Hamra, along Jabal Nafusa and in the coastal zone of Al Khums to Tawurgha.
The data relating to the mineralisation of the waters of this aquifer are more fragmentary than for the sands aquifer. The map presenting the iso-cones of the Senonian and Eocene limestone reveals :

- A little mineralised zone over all the western Algerian boundary of the basin, corresponding to the recharge zones in the reliefs of Mzab ;
- A little mineralised zone, concentrated on the eastern part of the Grand Erg Oriental and corresponding to the direct infiltration zones of rain water in the dune sands. This aspect is particularly highlighted over the western flank of Dahar ;
- A fairly mineralised zone on the southern flank of Jabal Nafusah, corresponding to a recharge zone of the aquifer ;
- A high mineralisation zone (over 5 g/l), focused on the northern part of Oued Rhir (El Meghair - Djamaa) ;
- A high mineralisation zone (over 5 g/l) between Ouargla and Touggourt, focused on El Hadjira.

The mineralisation of the water of the limestone aquifer reveals an increase towards the Algerian-Tunisian Lower Sahara zone which is its outlet area. This zone is also the location of deepening of the aquifer formation (over 1000 m).

The water of the Complexe Terminal presents in Tunisia, in the zone located in the vicinity of the Chotts, a slight increase in its mineralisation. This is particularly noticeable in the two regions of El Ouediane (Djérid) and of the Kébili peninsula (Nefzaoua).

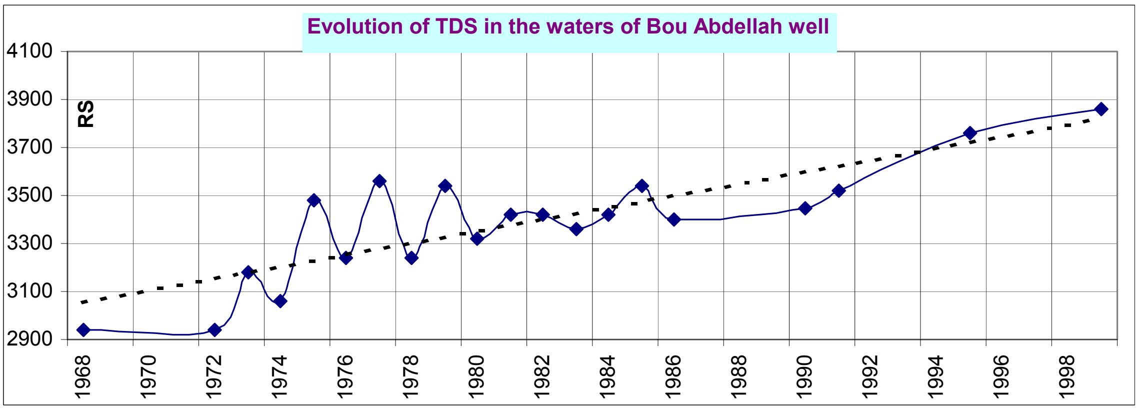
The increase in water salinity results, in these two regions, from the fact that the thickness of the top separating the aquifer from the Chotts water is only in the range of 30 to 90 m, which reduces the imperviousness of this top. This is the case in the Kébili peninsula, in Tawurgha, Oum Souma and Bou Abdellah (Figure n° 38).

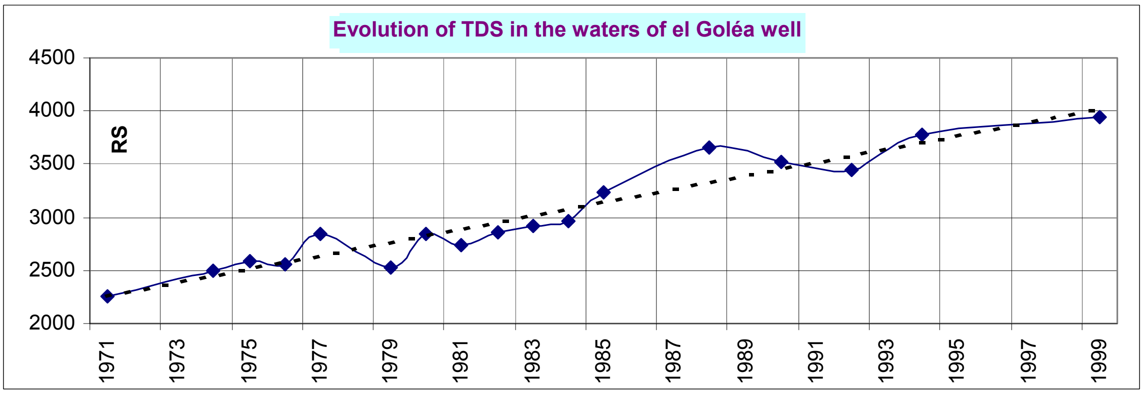
Elsewhere, in the oases adjacent to the Chott, this salinisation phenomenon is all the more sensitive as the collection fields are highly exploited and that the piezometric area of the aquifer is less than that of the Chotts. This is the case in Kébili and in Douz - El Golaa.

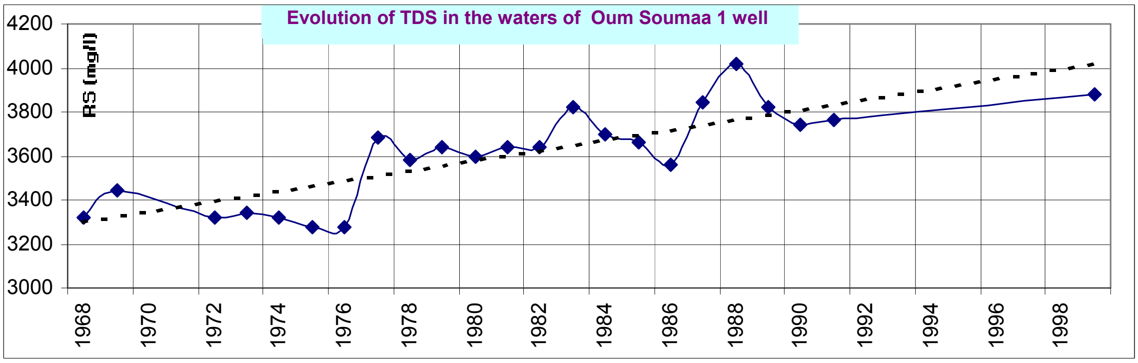
This salinisation phenomenon, which was relatively little sensible not long ago, has become more sensitive with the rise in abstractions. It is expected to become more marked in view of the risks attendant upon the nearness of the hyper-salinated waters of the Chotts and the return of drainage water to the aquifer.

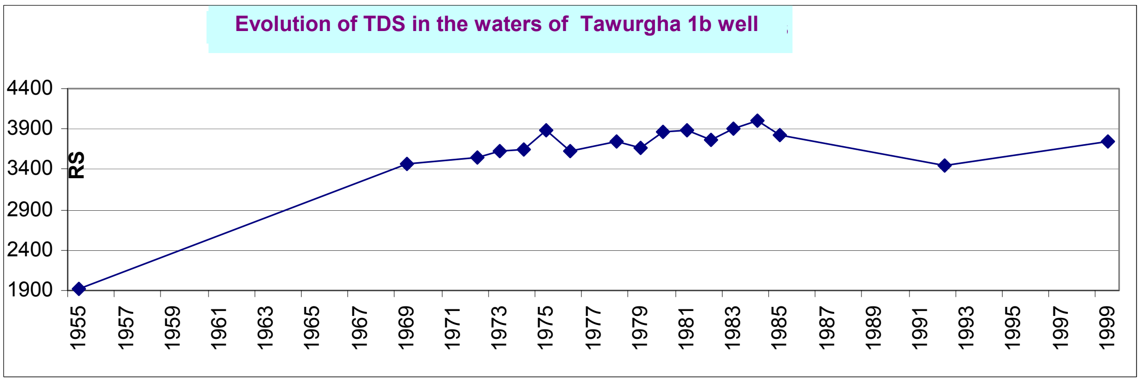
The water salinity of the Complexe Terminal is highly influenced by the relations between this aquifer and its surrounding formations. With the increase in exploitation, this salinity has experienced a certain increase. The two major potential sources for the increase in this salinity are the waters of the Chotts and the return to the aquifer of drainage water in the zones where the top is little thick. Any potential contamination from the more saline Turonian waters remains dependent on the load differences between the piezometry of the two aquifers.

Figure n° 38 : Evolution of water salinity of the Complexe Terminal in the Kébili peninsula (Nefzaoua -Tunisia)









It is highly recommended to ensure the monitoring of the salinity of the Complexe Terminal water in the zones of Oued Rhir (Algeria) and of Nefzaoua - Djérid (Tunisia) which are the locations where the exploitation of the aquifers is intensive and is done by means of wells that are grouped in several exploitation fields. This monitoring needs to be done in parallel with that of the exploitation and of the piezometry.

In these regions, the top of the aquifer is often of little depth and the drainage waters are of a large quantity there.

This monitoring should also involve the chemical contents of the water. Studies which allow a better understanding of the origin of salinisation are also necessary.

5.3.2. The Continental Intercalaire aquifer

5.3.2.1. Algeria

The Algerian data relating to the salinity of the water of the Continental Intercalaire reveal, for the period between 1945 and 2000, the following distribution :

Table 20 – Salinity classes of the waters of the Continental Intercalaire in Algeria

Number of samples	Chemical classes (g/l)						
	0 - 1	1 – 2	2 – 3	3 – 4	4 – 5	5 - 10	TDS > 10
286	131(45.8%)	97(33.9%)	36(12.6%)	8 (2.8%)	6 (2.1%)	8 (2.8 %)	

Most of the water points (79.7 %) have salinity values less than 2 g/l, while 92% of the water points have a salinity less than 3 g/l. The salinity values above 5 g/l do not exceed 2.8% of the analyses available.

The waters of the basin of the Grand Erg Occidental present salinity values that are, for most of them, less than 1 g/l. This is not the case in the basin of the Grand Erg Oriental where the aquifer is confined at several hundred metres and where the salinity values range between 1 and 3 g/l. The highest values are recorded in the region of Oued Rhir-nord (northern) where the aquifer is the most confined.

5.3.2.2. Tunisia

In Tunisia, the values of total dissolved salt of the waters of the Continental Intercalaire range between 1500 and 7020 mg/l. Most of the water points collecting the Continental Intercalaire in Tunisia present salinity values ranging between 1.5 and 3.5 g/l (56%). The lowest values are those of the least deep formations (Kébeur el Hadj series).

The waters of the springs of Chott Fedjej present higher values (4.5 to 5.5 g/l). The distribution of these salinity values are as follows :

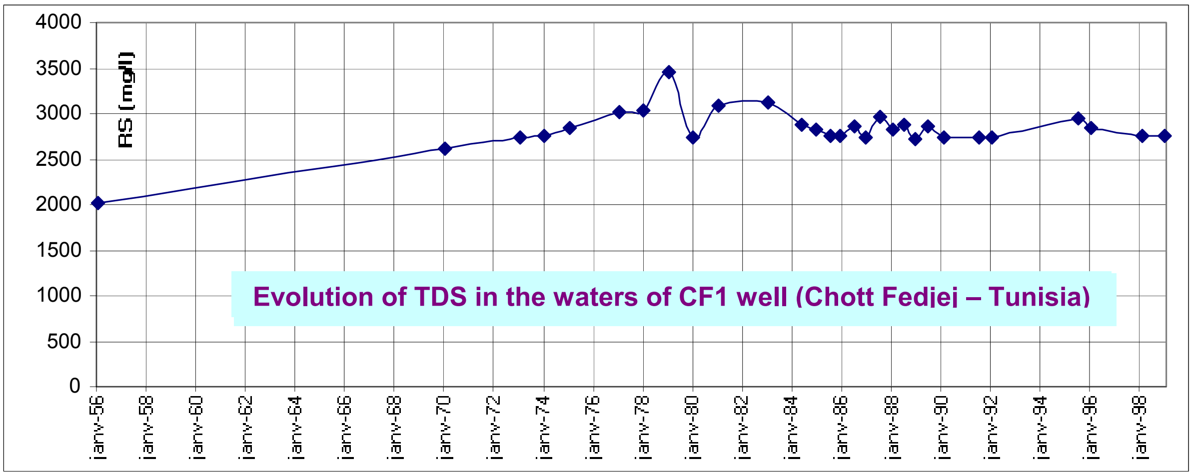
Table 21 – Salinity classes of the water of the Continental Intercalaire in Tunisia

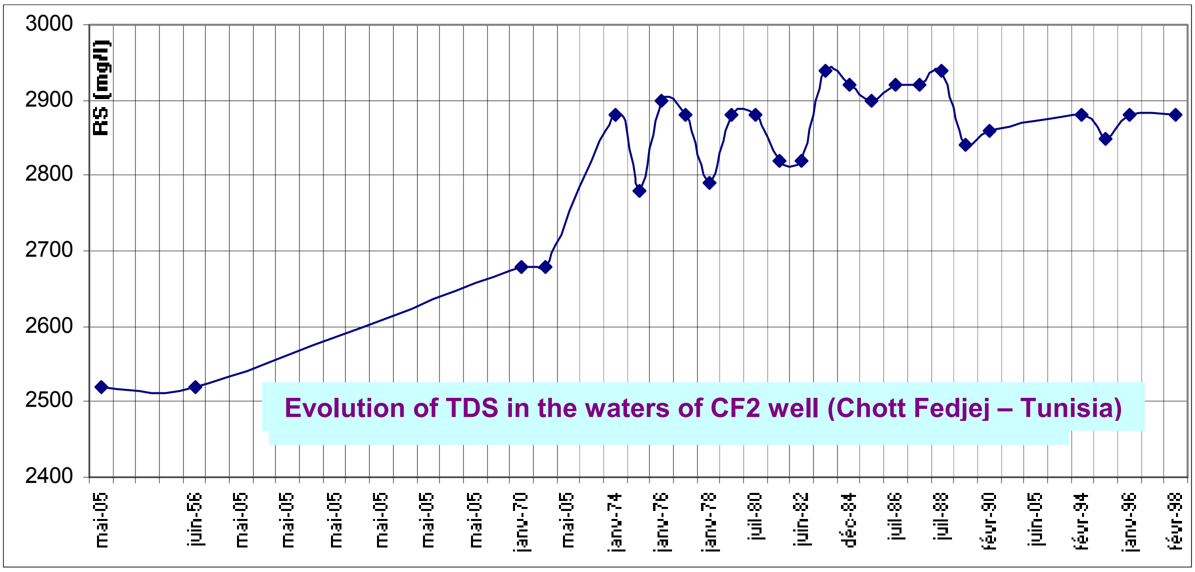
Number of samples	Classes of the values of water Total Dissolved Salt (TDS) (g/l)						
	0 - 1	1 – 2	2 – 3	3 - 4	4 – 5	5 – 10	TDS > 10
226	0	7	87	68	50	13	0
%		(3.1%)	(38.5%)	(30.1%)	(22.1%)	(5.8%)	

On the whole, the waters of the Continental Intercalaire in Tunisia have a fairly high salinity (TDS > 2g/l), which limits their use for drinking water supply. This situation is due to the fact that these waters are fairly often located in the confined part of the aquifer where they have had a long stay (low speed of ground circulation) in contact with enclosing formations containing clayey and gypseous impurities (soiled marks).

The salinity values of the waters of the Continental Intercalaire are relatively high in Tunisia by comparison with the other regions of the Saharan basin. This seems to result mainly from the lithological nature of the aquiferous formations containing more clays and gypsum. The evolution of this salinity over time is little perceptible (Figure n° 39). It attests, most often, to the influence effects within the multi-layer system. This salinity is expected to increase with the intensification of exploitation to mean values indicating homogeneisation within the system.

Figure n° 39 : Evolution water salinity of the Continental Intercalaire in Tunisia





5.3.2.3. Libya

The waters of the Kiklah El Hamada El Hamra formation present total dissolved salts which are often less than 2.0 g/l. This is due to the fact that the aquifer formation is clean and that it does not allow clayey inclusions.

Table n° 22 – Salinity classes of the Continental Intercalaire in Libya

Number of samples	Classes of the values of water Total Dissolved Salt (TDS) (g/l)						
	0 - 1	1 – 2	2 - 3	3 - 4	4 – 5	5 - 10	TDS > 10
124	1	95	10	8	6	3	0
%	(0.9%)	(76.7%)	(8.2%)	(6.5%)	(4.9%)	(2.5%)	

5.3.2.4. Iso-salinities map

The iso-cone contours (Pl. n° 15) correspond to the efficient aquifer of the Continental Intercalaire (that is, containing less than 6g/l of dissolved salts). However, certain sandstone horizons included in the CI contain water with a higher load and have not been included in the efficient aquifer. These salty horizons salés are generally located in Algeria, underneath the efficient aquifer (Neocomien and, possibly, Barremian). In Tunisia, on the contrary, they are in the upper part of the CI (Barremian : Upper sandstone and Aptian – Albian). The values used for the plotting of the card are given in Annex 6.

The map of the iso-cones of the CI reveals an increase in mineralisation starting from the recharge zones which are :

- In the north-west : the valley of Saoura and the south Atlas chain ;
- In the south : the plateaux of Tademaït, Agemour, Tinrhert and Jabal Hassawnah, it being understood that the recharge originating from these zones is probably not a current recharge but the continuation of a flow in the Palaeozoic formations which outcrop in the south ;
- In the east : plateau of Dahar and Jabal Nafusah.

For the whole of these recharge zones, the total mineralisation of the water of the Continental Intercalaire is fairly often less than 1 g/l, probably because of its origin in sandstone formations with a little soluble matrix.

The zones where this water is at its highest concentration correspond to the confined part of the aquifer where the aquifer formation is deepest. This is in particular the case of the regions of :

- the Algerian – Tunisian Lower Sahara, where the aquifer formation is often at over 1000 m in depth ;
- underneath the Grand Erg Oriental, where the Continental Intercalaire is a multi-layer formation with particularly saline levels (Upper Barremian sands and Aptian dolomites) ;
- on the eastern flank of El Hamada el Hamra, where the underground flow into the Kiklah sandstone levels is at the end of its course ;
- in the north-west, where the sandstone formations of the Mesozoic turn gradually into little permeable, carbonated – dolomitic facies, slowing the flow speeds and allowing a prolonged contact between water and rock within the aquifer.

Plate n° 15

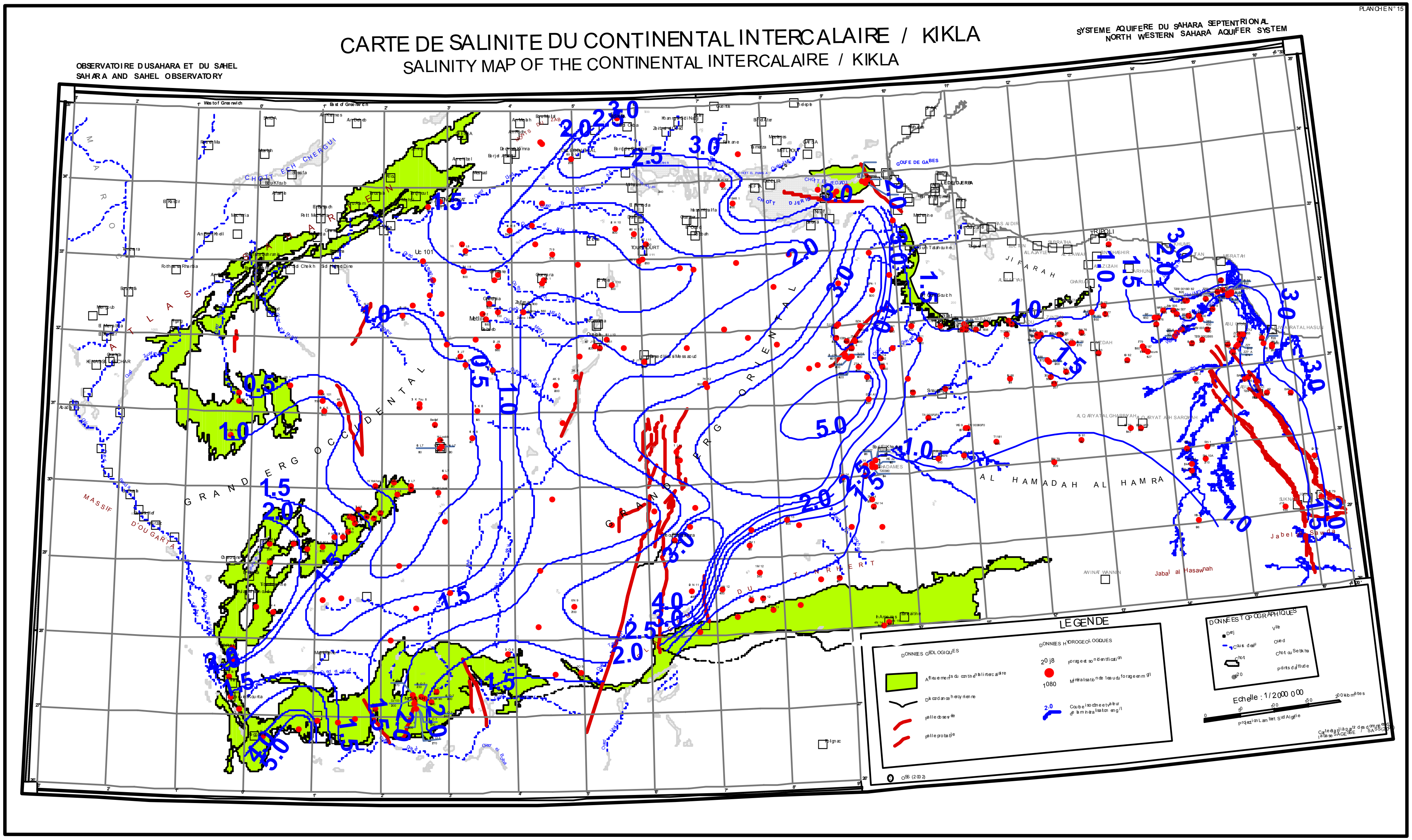


PLANCHE N° 15
CARTE DE SALINITE DU CONTINENTAL INTERCALAIRE / KIKLA
SALINITY MAP OF THE CONTINENTAL INTERCALAIRE / KIKLA
OBSERVATOIRE DU SAHARA ET DU SAHEL
SAHARA AND SAHEL OBSERVATORY
SYSTEME AQUIFERE DU SAHARA SEPTENTRIONAL
NORTH WESTERN SAHARA AQUIFER SYSTEM
GRAND ERG OCCIDENTAL
GRAND ERG ORIENTAL
AL HAMADAH AL HAMRA
TRIPOLI
GHADAMES
GOLFE DE GABES
MASSIF D'OUGARTA
LEGENDE
Echelle : 1/2 000 000

5.3.2.5. Vertical variation of mineralisation

The vertical variation of mineralisation does not seem to be gradual within the aquifer, but arises with the lithological changes. The horizons of different mineralisation are separated by more or less clayey layers which generally present a thickness of a few ten metres.

As long as the exploitation of the CI aquifer is fairly low, this vertical heterogeneity of water mineralisation will not have a major influence on the overall salinity of the water of the CI. With the rise in exploitation, the piezometric misbalance, induced by the abstractions made in the more permeable layers, has led to vertical exchanges by leakage between the various superimposed layers. This gives rise to a certain homogenisation of water salinity with an increasing trend.

On the whole, the high mineralisations observed in certain horizons are due to the fact that the aquifer levels where they are lodged are relatively isolated from the main aquifer. These levels with a lower permeability represent a lower runoff speed. The load concentration contributes in making the time of contact between the water and the bedrock longer.

Table 22 gives a few examples of wells in Algeria, with a vertical variation of the mineralisation of the water of the Continental Intercalaire in Algeria.

Table 23 – Examples of drillings showing a vertical variation of the mineralisation of the water of the Continental Intercalaire (Algeria)

Name of well		**N1 3**	**Li 3**	**Li 4**	**Btr 1**	**Qd 1**	**Df 1A**	**Rg é**	**Ab 1**	**GE 1**
Group :		**Group I : Saline h**orizons outside of the useful aquifer (TDS of the saline water >6 g/l)						**Group II** : Saline horizons in the useful aquifer (TDS of the saline water < 6g/l)		
Geographical location		North - west (ALG)	North - NW (ALG)	North - NW (ALG)	Eastern Gr. Erg (ALG)	Centre (ALG)	Centre-south (ALG)	South - West (ALG)	North - West (ALG)	Centre - West (ALG)
Characteristics of the freshwater horizons	**Mineralisation (g/l)**	1.6	1.5	1.9	4.2	2.2	2.0	2.1	1.3	0.24 - 0.4
	Depth (m)	335 - 426	805 - 1210	675 - 1209	1136 - 1211	1325 - 1825	874 - 1983	301 - 580	260 - 780	57 - 287
Characteristics of the saline water horizons	**Mineralisation (g/l)**	8.8	22	13	20	6.6	21	6	4	4.9
	Depth (m)	590	1650	1510	1070	1980	2100	750	930	510
Saline water/ Freshwater					+					
Freshwater/ saline water		+	+	+		+	+	+	+	+
Total thickness of the layers separating the two horizons		160	440	300	60	70	120	70	140	40
Thickness of the thickest clayey layer		160	440	300	50	40	120	40	140	15

In the Algerian Sahara, the lower layers of the Continental Intercalaire are the most saline and it is only in the upper part that the good quality aquifer levels (Barremian and Ablian) are located.

In Tunisia, the situation is the opposite one in the line of the Chotts (Chott Fedjej – Nefzaoua - Djérid), where the Continental Intercalaire is doubled up in several aquifer levels. The lower part connected with the Neocomian (Kébeur el Hadj series) constitutes there the main aquifer whose water presents the best chemical quality in the region. The other aquifers which overlay this series (Barremian and Aptian) contain the poorest water quality. In the far south, on the Saharan platform, the Continental Intercalaire is mainly represented by the sandstone Barremian whose water is of better quality than that of the dolomitic Aptian which overlays it.

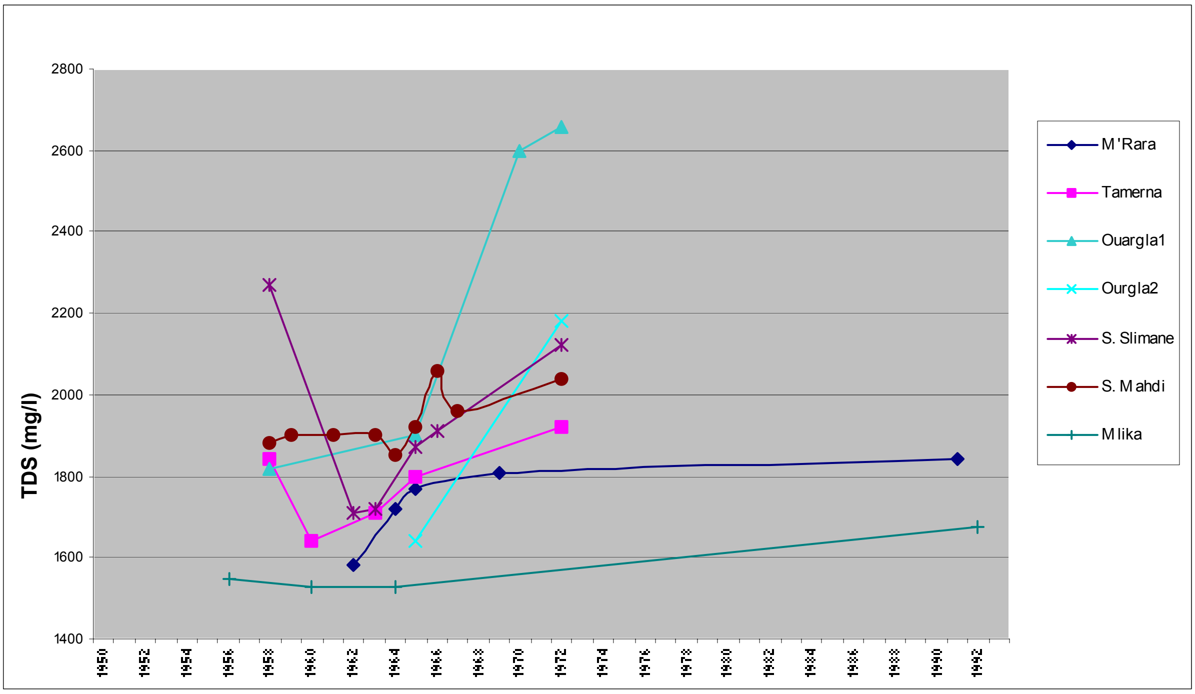
Table n° 24 : Examples of drillings showing a vertical mineralisation of the water of the Continental Intercalaire (Tunisia)

Group		El Bahaïer			Limaguess		Taourgha		saïdane	
Name of well		**El Bahaïer 19484/5**	**Oum El Ferth 1 5918/5**	**Oum El Ferth 2 6480/5**	**Limaguess Cl8 19394/5**	**Limaguess 16729/5**	**Taourgha Cl2 19199/5**	**Débabcha 19916/5**	**Saidane 19272/5**	**Mazraa Naji 5821T/5**
Geographical location		CF (Tunisia)	CF (Tunisia)	CF (Tunisia)	**CF (Tunisia)**	**CF (Tunisia)**	**Kébili (Tunisia)**	**Kébili (Tunisia)**	**CF (Tunisia)**	**CF (Tunisia)**
Characteristics of the freshwater horizons	**Mineralisation (g/l)**	2.68			2.3			2.3	3.0	
	Depth (m)	1268-1400			1568-1730			2119- 2290	715-745	
Characteristics of the saline water horizons	**Mineralisation (g/l)**		5.24	3.35		3.8	2.68			4.0
	Depth (m)		480-660	302-354		540-583	900-1098			387-451
Saline water/ Freshwater		+			+		+		+	
Freshwater/ Saline water										
Total thickness of the layers separating the two horizons		608			985		1021		264	
Thickness of the thickest clayey layer		311			505		246		279	

5.3.2.6. Evolution of salinity and chemical contents according to exploitation

The variations of the total mineralisation of the waters in the wells for which there is a series of chemical analyses present, fairly often, fluctuations which remain within the limit analysis errors. Certain of these wells reveal, however, a slight trend towards a rise in salinity over time. This is particularly the case, in Algeria, for certain wells of Oued Rhir and of Ouargla as illustrated in Figure 40.

Figure n° 40: Examples of the trend towards a rise in salinity of the CI in Algeria



This phenomenon should, however, be interpreted with caution, and one should not deduce from it a marked trend towards a rise in salinity accompanying increased exploitation. In reality, the evolution noted could only be the result of a homogenisation of salinity within the various aquifer layers that is likely to stabilise over time.

The wells of Oued Rhir, which experience a certain increase in total mineralisation over time, also reveal an increase over time in their sulphates content, which indicates the mobilisation of a more confined water within the aquifer. It is, therefore, the leaching of the clayey and semi-clayey layers which could be the cause for the salinity changes recorded.

5.3.2.7. Evolution of chemical contents according to distance from recharge zones

- ***Tunisia***

In the Tunisian far south, the role of Dahar as a current recharge zone is highlighted by the evolution of the total mineralisation of the water and its chemical contents when passing from the zones where the formations of the Lower Cretaceous are outcropping towards the part where the aquifer is confined. Radials starting from the wells adjacent to Dahar, where the CI aquifer is either unconfined or slightly ascending, towards the zone of the Grand Erg Oriental, where the water is highly confined, reveal a rise in salinity values, as well as a rise in the chemical contents mainly of Na^{+} and Cl^{-} and, to a lesser extent, of Ca^{++} and SO_4^{--} (A. Mamou, 1990). Passing from the unconfined part of the aquifer to its confined part is accompanied by :

- An impoverishment in bicarbonate whose concentration is already low ;
- An increase in Ca^{++} and SO_4^{--}concentration, with almost always rSO_4^{--}= 2 rCa^{++}([1]). This probably indicates gypsum leaching within the formation ;
- An increase in rNa^{+} and rCl^{-} concentration, with an excess in rCl^{-}, which indicates the dissolving of the NaCl contained in the underlying evaporitic formations (Cenomanian and Lagoon Senonian).

The increase in pressure and temperature which accompany the confinement of the aquifer could be the reason for these leachings.

In the region of the line of the Chotts (Djérid, Nefzaoua and Chott Fedjej), the chemical facies of the water of the main formation where the CI aquifer is lodged is of the calcium-sulphated and sodic type. In the Tunisian far south, it is on the contrary sodium-chlorinated and calcic. Along the line of the Chotts, the CI water is less concentrated in dissolved salts (TDS (Total Dissolved Salt) : 2 to 3 g/l) than that of the far south (being likely to reach 5.5 g/l) and it does not undergo any notable variation in passing from Djérid to Chott Fedjej.

These phenomena are illustrated in Figures 41 and 42.

On a vertical level, the salinity of the water and its chemical contents present notable variations within the various aquifer formations connected with the Continental Intercalaire. This phenomenon seems to result from the differential confinement and from the lithological nature of the enclosing rock. The sands series of Kébeur el Hadj is the one which presents the least saline water. The Aptian dolomite contains a highly saline water (over 5 g/l).

[1] Concentration in chemical equivalent

Figure n° 41 - Evolution of the chemical contents of the CI waters according to distance from recharge zone (Tunisia)

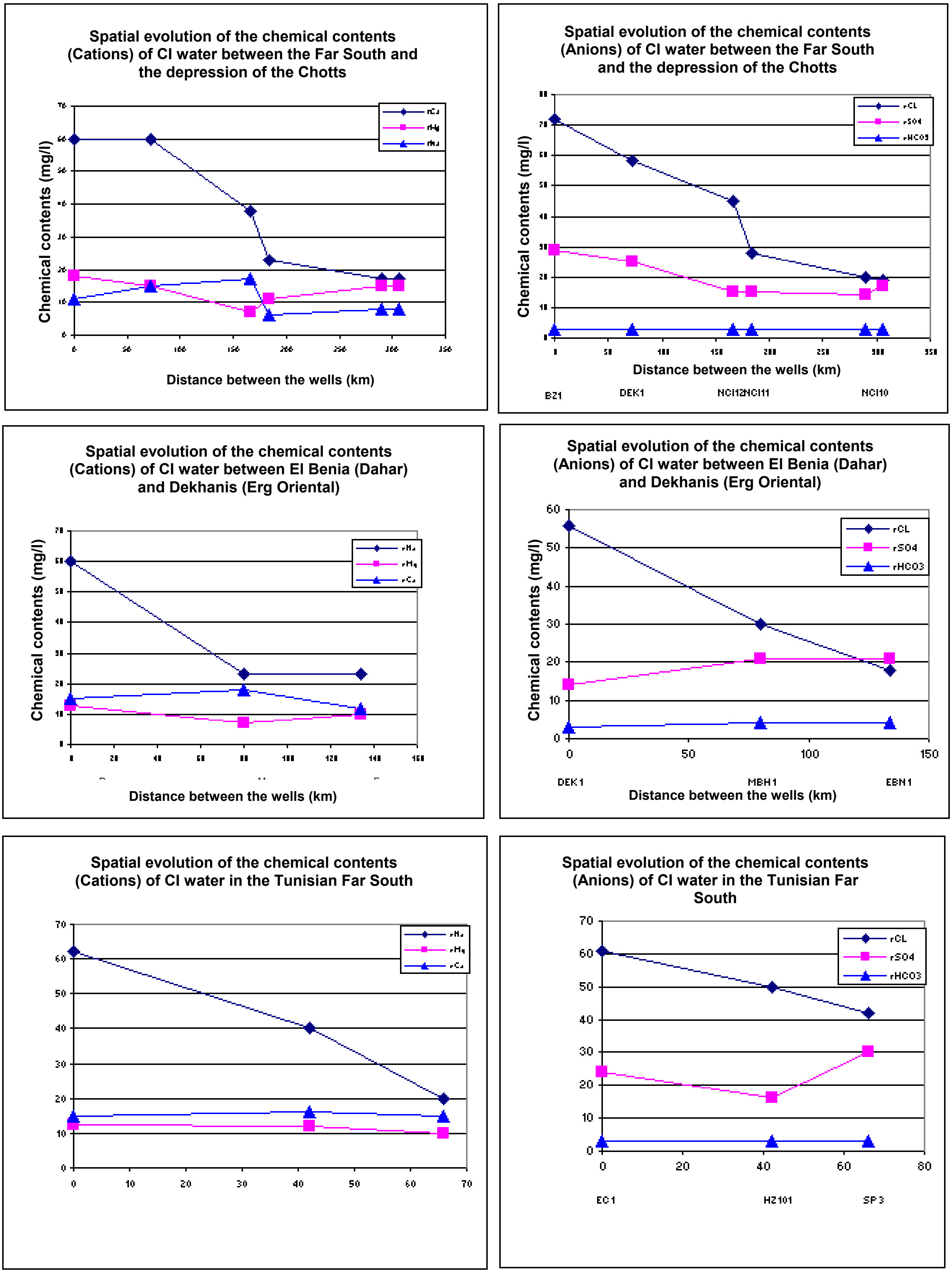
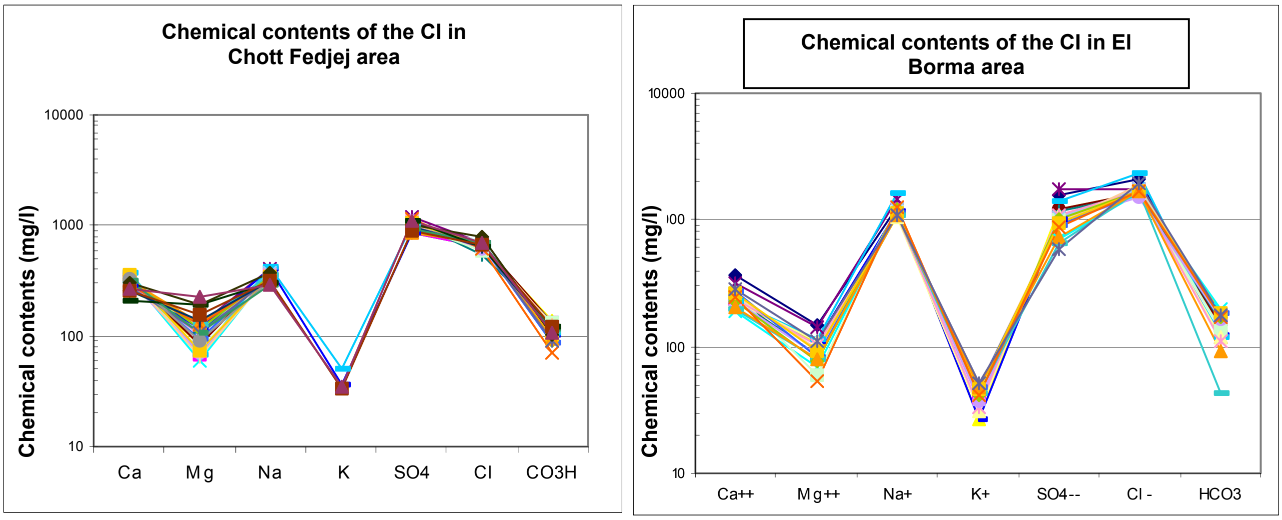


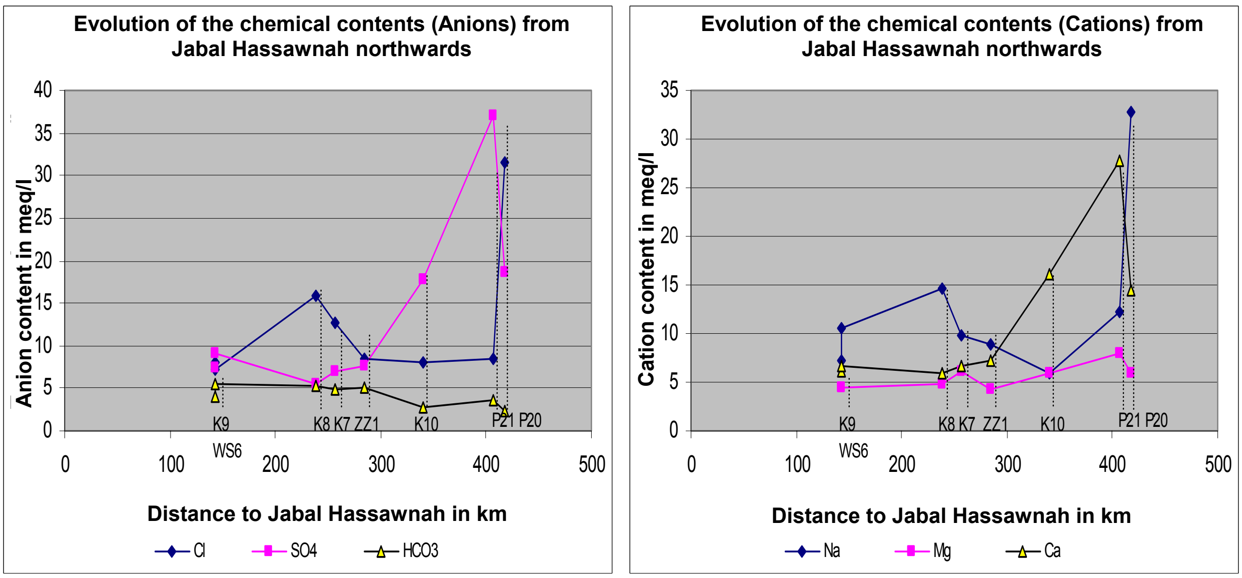
Figure n° 42 – Chemical contents of the waters of the Continental Intercalaire in Tunisia



- ***Libya***

Figure 43 shows the chemical evolution of the Kiklah waters starting from the south-east, where the Kiklah is in continuity with the Palaeozoic, up to the level of Tawurgha and to the sea at the level of Zliten. The water passes from a fairly homogeneous chemical facies, in the south, to calcic-sulphated facies at the level of Tawurgha, then to a sodium-chlorinated facies near the sea in Zliten.

Figure n° 43 – Evolution of the chemical contents of the waters of the Continental Intercalaire in Libya from Jabal Hassawna to the North



6- ISOTOPIC CHARACTERISTICS

The aspects with regard to which the study of isotopic characteristics is likely to bring a certain contribution in the knowledge about the hydrodynamic operating of the Continental Intercalaire aquifer, are as follows :

- a differentiation of the water volumes and their origins, based on the stable isotopes contents ;
- an estimate of the duration of water stay in the aquifer formations, based on the radioactive isotopes content and the carbon-14 activity of the carbonates dissolved into the water, as well as an estimate of the speed of underground flow ;
- a qualitative evaluation of current recharge from the outcrops ;
- highlighting the isolation and intercommunications between the various aquifer levels of the Continental Intercalaire, on the one hand, and the other aquifers superimposed on them, on the other hand.

Isotopic techniques have been used in the framework of the ERESS study in order to "specify the possible inputs between the aquifers and to check the hydrogeological hypotheses on the origin and the itinerary of the water" (ERESS, 1972). In its concern for the homogeneity of the isotopic contents obtained in the spouting part of the aquifer, this study has examined in detail only the hydraulic exchange relations of the Continental Intercalaire aquifer with the other aquifers of the North-Western Sahara (Gonfiantini R., & al, 1974).

In Tunisia, particular attention has been granted to current recharge and to the vertical communications of the Continental Intercalaire aquifer (Aranyossi & Mamou, 1985). The use of radio-active elements other than ^{14}C, such as ^{36}Cl and ^{238}U (Fontes & al 1984 ; Zouari, 1986), has allowed a better understanding of the passage from the unconfined zone of the aquifer to the zone where it is confined, as well as a better appreciation of the Palaeo-climatic conditions of the constitution of the water reserves of this aquifer.

The extension of the isotopic studies to the trace elements in the water has led to a better understanding of the hydrodynamic operating of the Continental Intercalaire aquifer (BGS, 1997).

In Algeria, the effort in the isotopic studies conducted after 1972 has been devoted mainly to the localisation of the exchange mechanisms between the various superimposed aquifer levels and to recent recharge from the domains of the Ergs (Guendouz, 1985 and BGS, 1997).

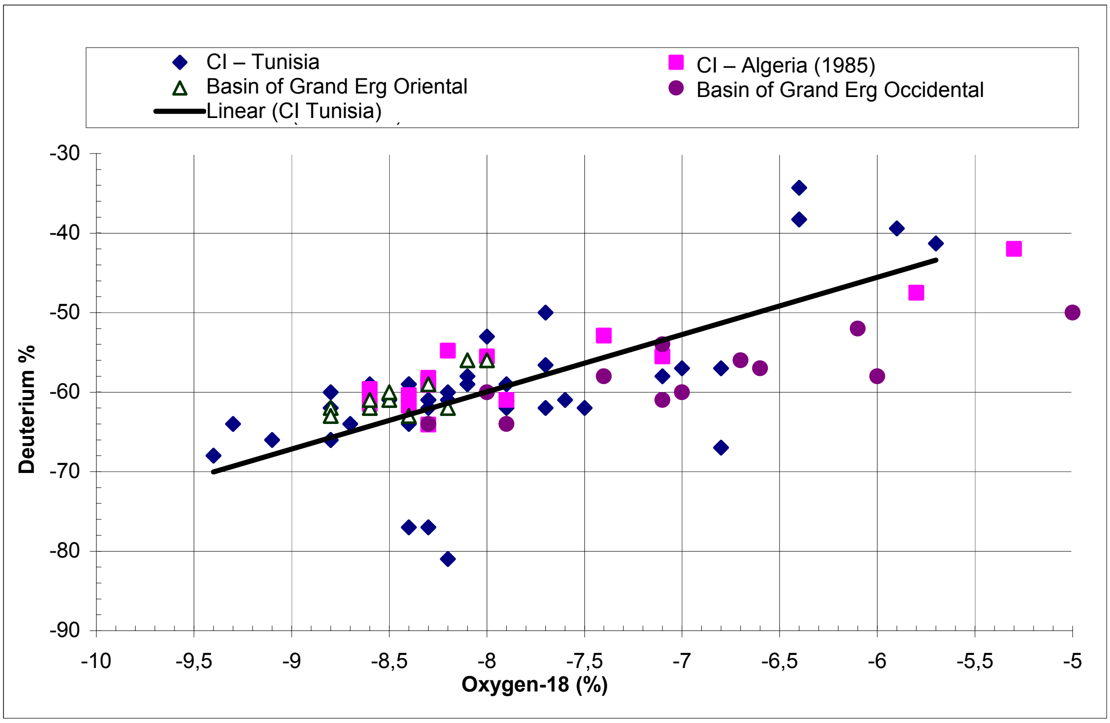
The whole body of these studies has led to a better understanding of the hydrodynamic operating of the aquifers of the Saharan system and to an evaluation of both the speed of underground circulation and the transit times.

6.1- The Continental Intercalaire aquifer

6.1.1. Central zone (Basin of the Grand Erg Oriental)

In this zone, water flows towards the Tunisian outlet. The values for $\delta^{18}O$ and $\delta^{2}H$ are quite homogeneous and the variation interval ranges from –7.6%◦ to –9.1%◦, for $\delta^{18}O$, and from –56%◦ to – 66%◦, for $\delta^{2}H$. The most evaporated waters (high $\delta^{18}O$ and $\delta^{2}H$ values) are closer to the recharge zones which are, mainly, the Saharan Atlas and Dahar (Figure n° 44).

Figure n° 44: Isotopic composition of the waters of the Continental Intercalaire in Algeria and in Tunisia



The Palaeo-climatic effect is of paramount importance in the istopic composition of the water of the Continental Intercalaire due to the fact that the water reserves of this aquifer are supposed to have been stored at various eras when the climate was less arid and colder. This effect translates into a lower content in stable isotopes in the recharge zones underneath the Eastern Erg and the Lower Sahara where the effect of the current recharge is less perceptible. It is thus expected that the water of the Continental Intercalaire should be more enriched in heavy isotopes in the zones adjacent to the current recharge area. This is clearly reflected in the distribution of $\delta^{18}O$ contents which make it possible to distinguish the various zones cited below.

6.1.2. Dahar zone

In the Dahar zone, $\delta^{18}O$ and $\delta^{2}H$ contents range between -5,4 %◦ and -6,79 %◦. In this area, the aquifer lies at little depth and is either slightly confined, or unconfined. Rainfall is fairly high (150 – 250 mm/year) and the runoff and infiltration conditions are favourable for aquifer recharge.
This zone is among the most exposed to current recharge, since the outcrops of the aquifer formations are largely lined by oueds that collect the runoff.

6.1.3. The Saharan confined aquifer zone (Tunisia and Algeria)

The zone where the aquifer is confined presents Oxygen-18 contents ranging between -9,3%◦ and 7,7%◦. The lowest contents correspond to the most confined part of the aquifer (Lower Sahara). In this zone, these contents are fairly low in the basic sandstone formations of the Continental Intercalaire.

Thus, in **the Tunisian south**, the « woody sandstone » and « upper sandstone » series of Chott Fedjej – Nefzaoua, overlaying the Barremian and Neocomian formations (-7,6%◦. to -7,9%◦), present higher $\delta^{18}O$ contents than the latter. In the Tunisian far south, in spite of an overall trend towards low $\delta^{18}O$ contents, the little depth of the aquifer formation (Barremian sands) and the nearness of the recharge area induce a “rejuvenation” of these waters.

Underneath the **Algerian Sahara**, the $\delta^{18}O$ contents range from - 8%◦ to -9,0%◦. These values are characteristic of the least evaporated water of the Saharan aquifers (Gandouz, 1985). Contents in the same range of magnitude appear in the Tunisian south and underneath Hamada EL Hamra where the Continental Intercalaire aquifer is deeply buried and confined. The waters of the Continental Intercalaire are all the more influenced by the aridity of the current climate as the aquifer formation is deeper and quite confined.

In Algeria, it is possible to distinguish the two sub-basins : the Grand Erg Oriental and the Grand Erg Occidental. In the basin of the Grand Erg Oriental, the Continental Intercalaire aquifer is often loaded. It is highly confined (at over 1000 m depth), particularly in the region of the Lower Sahara. In the basin of the Grand Erg Occidental, this aquifer is often unconfined or of little pressure, with a large zone where the aquifer formation is outcropping. It is in this zone in particular that the oueds streaming down the Saharan Atlas end up.

In the basin of the Grand Erg Oriental, the Oxygen-18 contents range between -7.1%◦ and - 8.6%◦. The lowest values characterise the water of the fossil aquifers of the Sahara which are well protected from any recent inflow (Gonfiantini et al., 1974 & Gandouz, 1985). These contents are also found in the Tunisian south where the Continental Intercalaire aquifer is confined. They are all the lower as the aquifer formation is older. The **$\delta^{18}O$=-8.4±0.4**%◦ **and $\delta^{2}H$=61±3**%◦ values, around which the contents of the CI waters are concentrated, are considered as the most characteristic of the geological reserves of the aquifer.

Nearing the bordering zones (Plateaux of Tinrhert and of Dahar), the $\delta^{18}O$ and $\delta^{2}H$ contents are higher. These waters are, on the whole, of a low ^{14}C activity. Only in the recharge areas or in the vicinity of the latter will the ^{14}C values become fairly high. This is the case for the values of 54.7% and ^{14}C in Laghouat, towards the southern fold of the Saharan Atlas, of 44.9 to 53.3% on the Dahar, of 22.8% in Fort Flatters and of 17.3% in Tabankort in Tinrhert. These ^{14}C contents decrease starting from the recharge zones underneath the Hamada of Tinrhert and the dunes of the Grand Erg Oriental and account for the duration of the underground journey.

Certain springs of Chott Fedjej or a few surface wells collecting the formations near the outcrops of the Lower Cretaceous of Dahar, which have revealed the presence of tritium in their waters, have never presented contents exceeding 16 T.U. (case of Aïn el Guettar in Chott Fedjej). It is quite likely that the detected tritium traces originate in a local recharge or in an open air contamination.

On the whole, outside of the recharge zones, the water of the Continental Intercalaire is ^{3}H free (less than 30 years of age). It is, therefore, mainly old waters which have stayed in the aquifer for a long time. The confinement of the aquifer has caused the oldest waters to lie in its confined part. Those having undergone a mix with the most recent waters are located in the vicinity of the recharge areas where the aquifer ranges from unconfined to ascending.

The lowest and least homogeneous ages are found all around the recharge zones, such as Dahar (1000 to 24 000 years). Compared to those of the Kiklah waters in Libya, these ages are found to be of the same range of magnitude and present the same dispersion (Salem & al, 1980, SRDOC & al, 1980), which reveals a similar recharge effect.

The underground circulation speed of the aquifer is evaluated in the confined zone of the aquifer between Oum Zab (14C = 2,9±0,4%), El Borma 203 (^{14}C = 1,4±0,3%) and Bir Zobbas (^{14}C = 0,4±0,6%). It is estimated as ranging between 3 and 6 m/year. This speed, estimated between the infiltration zone (Nekrif) and the confined part of the aquifer (Bordj Bourguiba), yields a value of 1 to 2 m/ year, which brings to 25 000 years the period necessary for the water infiltrating on the eastern boundary of the Dahar to cover a distance of 35 km. Based on this observation, it has been assumed, for the Algerian part (DRAY & al, 1983), that the waters of the Continental Intercalaire aquifer correspond to a colder and more humid climatic period than the current one.

Certain estimates of the age of the water (Gonfiantini et al., 1974), as made after correction and with reference to the $\delta^{13}C$ and pH contents, give values ranging between 46 000 (Oued Nekhla - Tunisia) and 18 000 years (Ech Chouech -Tunisia). The highest age values (>35 000 years) are close to the limit of the ^{14}C method. On the level of the basin of the Grand Erg Oriental, the Oxygen-18 contents, in the confined part of the aquifer, are more homogeneous and generally low. The homogeneous nature of these contents starting from the Algerian Sahara up to the basin of Hamada el Hamra in Libya (Gandouz, 1985 ; Salem & al, 1980), through the Tunisian south, leads to the assumption that these waters belong in a climatic era that is fairly homogeneous and less arid than the current one.

The estimate of the ages of the CI waters (ERESS, 1972, Aranyossy & Mamou, 1986), as corrected by means of the carbon-13 contents, yields values in the range of 9 950 ± 330 years and 46 000 ± 12 000 years. The geographical distribution of these ages reveals that the highest values correspond to the confined part of the aquifer whose Oxygen-18 contents are low. The dispersion of the other values indicates a certain distribution over the aquifer recharge area. The more the infiltration conditions of “modern water” are favourable, the lower is the water age value.

The highest ages (25 000 to 46 000 years) are noted in the confined part of the aquifer, which is the case of a large part of the Continental Intercalaire of the basin of the Grand Erg Oriental in Algeria (Gandouz, 1985). The carbon-14 contents are in the order of the detection limit of this dating method, which suggests that these waters may be much more ancient than the method’s theoretical scope (40 000 years).

On the whole, the oldest ages of the Saharan waters are in the range of 50 000 to 20 000 years, with higher values in the part where the aquifer is confined and spouting. The estimate of the Palaeo-temperatures by means of rare gases (Rudolph & al, 1984) has revealed that, to this period, there corresponded lower temperatures than the current 2°C at least. The value of 18°C has been estimated for the waters of El Golea on the Western Erg in Algeria, as well as for those of Ksar Ghilane in the Tunisian south (Fontes J. Ch. & al, 1984).

The corrected ages range between 20 and 40 000 years. The waters of the Continental Intercalaire have taken place in the aquifer during the major humid phase of the Lower Pleistocene, as noted in several worldwide aquifer sets. This era is the main period of constitution of the geological reserves of the Saharan aquifers.

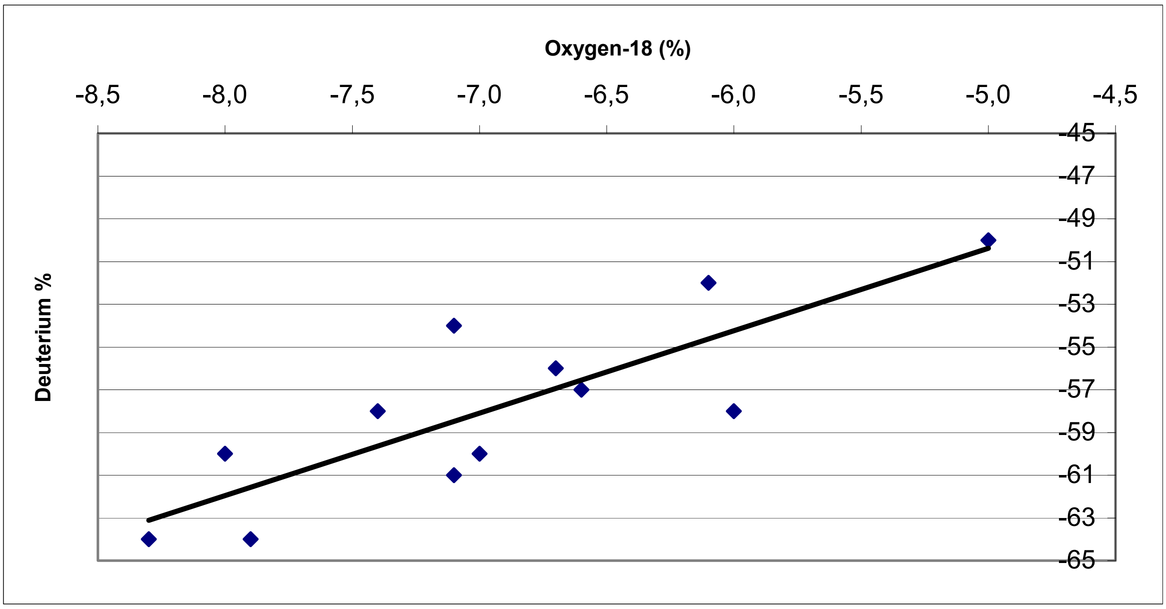
6.1.4. Western zone (Basin of the Grand Erg Occidental)

Except for the plateau of Tademaït, the CI aquifer is either unconfined or covered by the dunes of the Grand Erg Occidental. The Lower Cretaceous outcrop zones constitute the natural outlets of the aquifer. The stable isotopes contents are quite varied there ($\delta^{18}O$ = -9.6‰ to –4.1‰). The zone of Tidikelt presents values that are very close to those of the basin of the Grand Erg Oriental, but are more active in ^{14}C (4 to 40%), which attests to a local inflow into the aquifer recharge.

These local inflows are the reason for the water mixes within the aquifer which give apparent ages extending over several thousand years. In Touat and Gourara, where the CI waters present high ^{14}C activities (of up to 60%), the stable isotopes contents are variable but higher than those found in Tidikelt. To the east and the south of the Grand Erg Occidental, the CI waters present isotopic compositions that are identical to those of the waters of the aquifer of the Erg. This region corresponds to a vast zone of water overflowing from the Grand Erg into the CI aquifer.

Underneath the Tademaït plateau, the heavy isotopes contents decrease from north to south, which suggests a decreasing inflow of the Grand Erg waters. This inflow is particularly sensitive at the level of Gourara. The waters arriving from the Grand Erg are then mixed with those of the aquifers and circulate in direction of the outlet of the aquifer into Touat.

Figure n° 45: Oxygen-18/deuterium correlation for the CI waters of the basin of the Grand Erg Occidental (Algeria)



6.1.5. Libyan Saharan basin

Underneath Hamada al Hamra in Libya, the stable isotopes contents range between –8.2%◦ and – 9.3%°, for ^{18}O, and between –56 to -70%◦, for ^{2}H, with respect to SMOW. These values are among the highest in the region and thus correspond to those found for the Continental Intercalaire water of the confined part of the aquifer (Salem et al., 1996). In the zones where the Kiklah formation is in continuity with the Cambro-Ordovician, these contents are lower and even amount even to ^{18}O= - 10.9%◦ and ^{2}H= -80.7%◦.

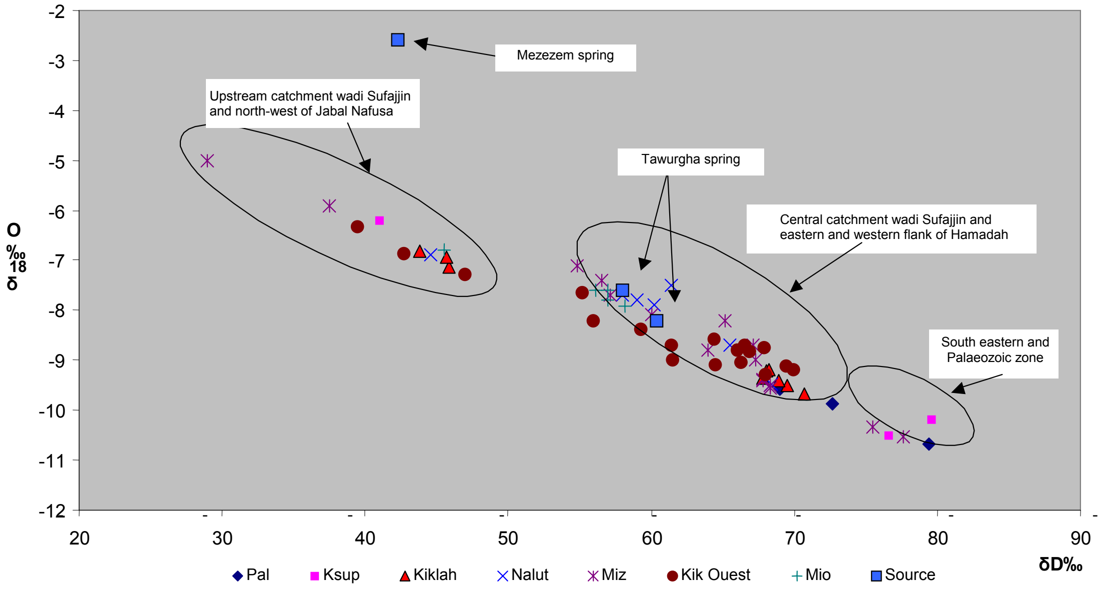
In the eastern part of the Libyan Saharan basin (W. Zamzam, Ayn Tawurgha…), the stable isotopes contents of the water of the Kiklah formation are in the same range of magnitude for similar collection depths (Salem et al., 1985). They indicate similar climatic conditions of establishment of the aquifer reserves.

The ^{3}H contents are low (<2 TU) and the ^{14}C activities are often low (ranging from 1 to 5 %), thus yielding water ages in the range of 16 800 to 31 500 years for collection depths of 600 to 1200 m. These isotopic characteristics are those of the confined aquifer. The high values of excess ^{2}H (+2 to +12) are the indicator of a meteoric water infiltration under highly varied climatic conditions (different eras). This ^{2}H enrichment is higher in the wells that are close to the reliefs of Jabal Nafusa (Nalut, Zintan) whose waters seem to be much influenced by « modern water » inflows.

The $\delta^{18}O$‰/ δD‰ relation (Figure 46) for all the waters of Hamada Al Hamra with groups per zone, all origins considered, reveals that the zone most enriched in stable isotopes ($\delta^{18}O$ comprised between –7 and -5 ‰, and δD‰ comprised between –45 and –30 ‰) corresponds to the upstream basin of Wadi Sufajjin and to the western part of Jabal Nafusah in the outcrop zones of the Upper Cretaceous. This zone is the seat of an annual recharge of the aquifers, mainly those contained in the Upper Cretaceous formations. The recharge of the aquifers takes place mainly in the oueds during the winter floods. The high values of the stable isotopes are an indicator of current recharge, though the Tritium contents remain quite low. This apparent anomaly is due to the fact that the enrichment in meteoric water, and hence, in Tritium, occurs only in the zones where the water level is fairly close to the surface, that is in the bottom of the oueds.

The wells for which the isotopic analyses have been made collect the aquifers located at several hundred metres of depth which undergo the effect of recharge but in a delayed manner. The isotopic compositions thus result from a mix of recent meteoric waters with ancient waters stored in the aquifers.

Figure n°46 : Stable isotopes composition of the waters of El Hamada El Hamra in Libya



The waters with a very low stable isotopes content correspond to the waters of the Palaeozoic aquifers of the south of the Saharan basin and to those of the Upper Cretaceous (Mizdah) in direct relation with the Cambro-Ordovician aquifer. Carbon 14 yields, for these waters, ages of more than 25 000 years.

The intermediate waters group comprises almost all the waters of the Cretaceous aquifers (Kikla, Nalut, Mizdah), originating from the central zone, between parallels 30° and 31°30', on both sides of Hamadah al Hamra. It is worth noting, however, that the Kiklah waters originating from the eastern flank of the Hamadah have a stable isotopes composition that is very close to that of the Palaeozoic waters.

This group also comprises the waters of the Tawurgha spring whose position with respect to the other waters of the basin suggests a mix of ancient waters (Kikla -Palaeozoic) and more recent waters arriving from the upstream basin of Wadi Sufajjin. This hypothesis is confirmed by the outlook of the isopieze contours which indicate the double origin of the waters of the spring.

The Mezezzem spring, located near Ghadamis, constitutes a particular case of a mix of ancient waters originating from the deep horizons and « modern » waters that are highly enriched waters originating from the surface horizons of the sabkha.

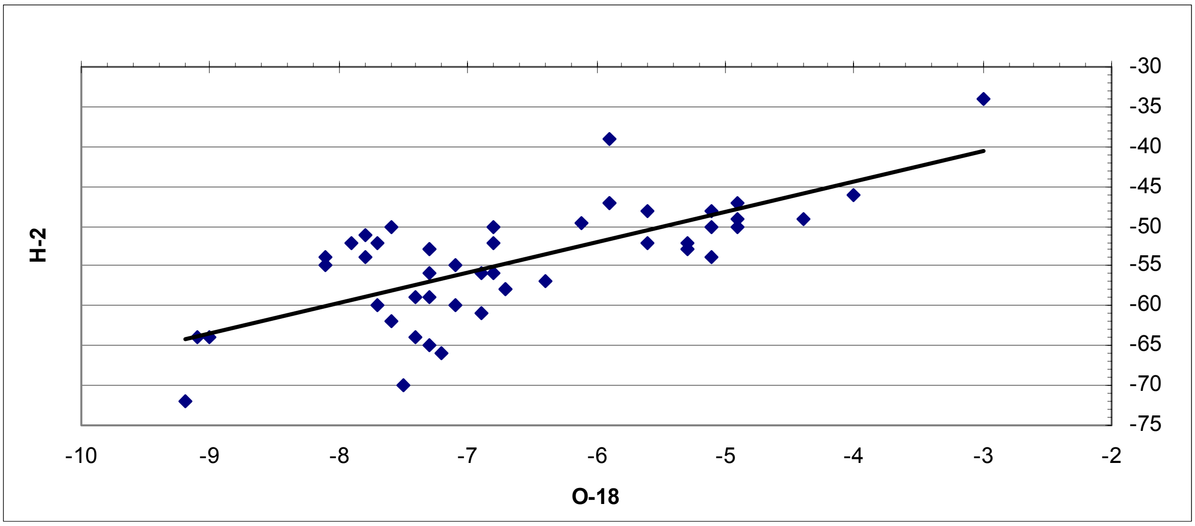
Comparing several aquifers of major basins like those of the Sahara and of the Nubian Sandstone, C. Sontag (Sontag & al, 1978) notes that these aquifers present waters whose isotopic characters are homogeneous. They contain waters that are quite poor in Oxygen-18 and with little carbon-14. This has been explained as being the result of similar climatic conditions at the time of the establishment of the aquifer reserves of these aquifers. The climate of this era was characterised by temperatures that were lower by a few degrees than those of the current era. It is also assumed that the origin of the rainfalls was oceanic with a higher humidity rate than that observed nowadays in these arid regions.

The domain of the Tunisian – Libyan Dahar corresponds to the era when the aquifer of the Continental Intercalaire was the most exposed to recharge from the infiltration waters. Correlated with the collection depth, the ages of the waters of these zones reveal a dispersion which is more marked on the Libyan Dahar. In Tunisia, a certain correlation appears between the age of the water and the depth at which it is collected, which indicates, in this zone, a vertical flow that is predominant with respect to the horizontal flow. Compared to the stable isotopes composition of the waters of the Kufra basin in Libya, that of the Continental Intercalaire of Dahar presents similar contents, which indicates a certain climatic zoneness at the time of constitution of the reserves of these Saharan aquifers.

6.2- The Complexe Terminal aquifer

The isotopic composition of the waters of the Complexe Terminal reflects the heterogeneity of the aquifer reservoir, as well as a greater accessibility of its various aquifer levels at the location of the current recharge. The domain of variation of the stable isotopes contents is larger in the case of the CT than for the Continental Intercalaire, with values in the range of – 9.3 and – 3.9%◦ (Figure 47). The zones located underneath the dunes of the two Grand Ergs are characterised by an enrichment in heavy isotopes which reflects the effect of the current arid climate.

Figure n° 47: Isotopic composition of the CT waters in Algeria



The waters of the Complexe Terminal present everywhere the outlook of a water marked by evaporation. This enrichment in heavy isotopes is equally marked in the current rain water which reflects the effect of the aridity of the climate. The recharge of the CT aquifer seems to have varied over time in parallel with the evolution of the climate during the last millennia. The enrichment in heavy isotopes, which may be observed even in the most confined waters of this aquifer (El Oued in Algeria), is due to a Palaeo-climatic recharge which has undergone changes in the isotopic composition of the waters during the evolution of the aridity. In this process, which still continues, two recharge zones need to be distinguished :

- the zones where the aquifer formations of the CT are outcropping. Infiltration here is more rapid and evaporation does not apply ;
- the dune zones of the Ergs where direct infiltration is only partial due to the reclaiming of water by evaporation in the non saturated zone, which gives rise to an isotopic enrichment until heavy rain comes to leach the whole lot and contributes in the effective recharge of the aquifer.

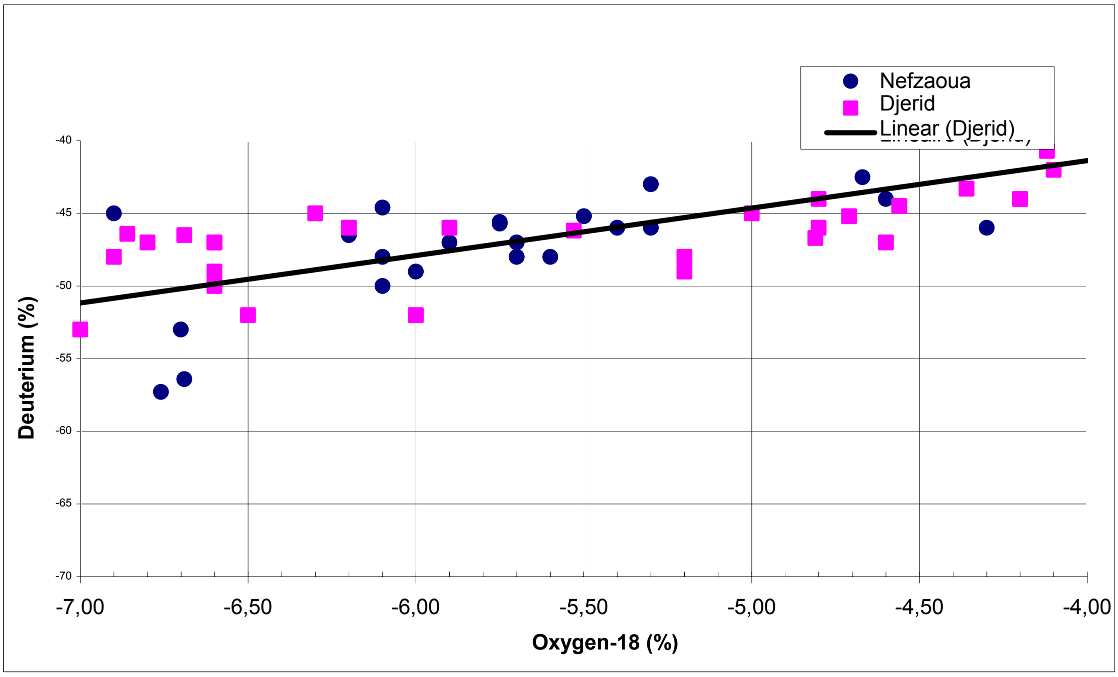
6.2.1. The Mio-Pliocene sands aquifer

In the valley of Oued Rhir in Algeria, the heavy isotopes contents are fairly heterogeneous ($\delta^{18}O$= -5 to –7.2%◦ and $\delta^{2}H$=-48 to -56%◦) and lower than those of the current meteoric waters, which leads to the conclusion that these waters have undergone evaporation before reaching the aquifer (Gandouz, 1985). Between Ouargla and the zone of the Algerian Chotts (aquifer outlet), the heavy isotopes contents are close to those of the aquifer of the Grand Erg Oriental.

This evaporated character of the waters of the sands aquifer is linked to its recharge mechanism. In fact, this aquifer is confined underneath the Lower Sahara, except on its west and south boundaries where its current recharge is made from the surface waters.

The western boundary (extension limit of the aquifer sands) used to correspond to an evaporation zone since the aquifer was a spouting one. Currently, the rain waters and those that stream into the oueds of the Saharan Atlas undergo evaporation prior to reaching the aquifer.

Figure n° 48: Isotopic composition of the CT water in the Tunisian south



The aquifer lodged in the Mio-Pliocene sands of the Tunisian south (south-west of Chott Djérid and Djérid) contains waters that reflect the same heavy isotopes features as those of the Grand Erg Oriental in Algeria, with contents ranging between $\delta^{18}O$=-4.8 and –4.6%◦. In Draa Djérid, where these sands are outcropping, the $\delta^{18}O$= -4.36 to – 3.9%◦ contents thus indicate a non negligible evaporated water percentage.

Outside of the region of Deghoumes, the ^{14}C contents of the CT waters are low throughout the region, thus indicating fairly high ages. The speed of the ground water flow is estimated, there, based on ages corrected at 2- 4 m/year.

6.2.2. The limestone aquifer

The heavy isotopes composition of the water of the limestone aquifer reveals, in Algeria too, fairly dispersed contents, with a mean value of $\delta^{18}O$= - 7.42 to ± 0.47%◦ and $\delta^{2}H$ = -49.3±3.6%◦ (+10 excess on average).

In Nefzaoua in Tunisia, the heavy isotopes contents are higher than those of the sands waters, though presenting a dispersion that results from the closeness of the recharge area of Dahar.

The ^{14}C contents of the water points located in the vicinity of the aquifer outcrop area indicate fairly significant activities of a certain modern recharge contribution to the aquifer. A decreasing ^{14}C concentration gradient is found in Nefzaoua between Douz and Kébili according to the aquifer flow direction. This gradient allows an evaluation of the ground flow speed as being in the range of 1 to 2m/year (Mamou, 1990).

The gross water ages of the CT water of Nefzaoua range between 3500 (Douz) and 27 000 years (Aïn Tawurgha). The lowest values (<10 000 years) are closer to the recharge zones, and the highest (18 000 to 27 000 years) correspond to the waters that are more confined and closer to the outlet.

Along the valley of Oued Rhir, between Djemaa and Mghaier, the sandy aquifer levels of the Mio-Pliocene happen to be separated from the Senonian and Eocene limestone by the marine-evaporitic Middle Eocene. The heavy isotopes contents of the waters of this zone are distributed over a mix line whose poles would consist of:

- the non evaporated waters of a leakage origin from the underlying Senonian and Eocene limestone. This leakage is due to the difference in piezometric levels between the limestone aquifer and the sands aquifer.
- the evaporated waters arriving from El Oued (Grand Erg Oriental), as well as from the recharge on the western boundary of the aquifer.

6.2.3. The Grand Ergs aquifers

The aquifer of the Grand Erg Occidental circulates in the dolomitic limestone slab of the Hamada on which the dunes of the Erg rest. This aquifer is accessible at a small depth. Its resources originate mainly from the current recharge based on rain water (after streaming). The heavy isotopes contents of these waters attest to an enrichment due to evaporation.

Through the correlation of the ^{18}O and ^{2}H contents, it has been possible to distinguish two water groups :

- A group of non evaporated waters which fall on the line of the current precipitations waters. The intersection of this contour with the line of the meteoric waters is located at the ^{18}O= - 8‰ and ^{2}H= - 60‰ point ;
- A group of evaporated waters which fall on a sloping line lower than that of the meteoric waters.

These two groups reveal the mechanism of recent recharge of the aquifer from rain water. The first group corresponds to water that infiltrates directly from the dunes without streaming, while the second group corresponds to that of flood water which streams into the oueds while evaporating.

6.2.4. The Turonian aquifer

The Turonian aquifer is collected in the Tunisian far south on the western piedmont of Dahar and between Jabal Nafusa and Ghadamès. The isotopic outlook of the waters of this aquifer is close to that of the waters of the Continental Intercalaire. These waters are characterised by low stable isotopes contents (^{18}O= - 8 to – 9.5‰ and ^{2}H= - 60 to – 65‰).
In view of the fairly considerable depth of this aquifer (over 600 m), its small outcrop area and its confinement, it is expected that its recent and modern recharge should be limited. Where it is present, it presents stable isotopes contents that are very low and almost identical to those of the lowest values of the CI (Tunisian – Libyan Dahar). The age of the waters lodged in this aquifer level is often above 20 000 years.

6.3- Conclusion

The waters of the North-Western Sahara Aquifer System result from a long process of establishment of the reserves which extends over several ten thousand years. The major part of the geological reserves located in the confined part of the aquifer has been established in an era when the climate of the region was more rainy (Pluvial Quternary of 150 000 to – 20 000). This phase reached its peak with the transformation of the depressions of Tunisian-Algerian Chotts into major lagoons (Cardium lakes) whose extension was two to three times their current area. This phase also corresponds to the loading of the confined levels of the system and to the emergence of the main springs of the region both at the level of the CI and of the CT.

With the gradual aridification of the climate, there has started a slow and continuous discharge of the aquifer system. The spouting of the sources was the indicator of the overflow of these aquifers, but the loading of the aquifer levels has only decreased in view of a reduction in recharge on the boundaries. Afterwards, the aquifer system has experienced an increasingly greater decompression since the end of the 19th century at the time of the construction of the early water wells in the Tunisian-Algerian part. In the 20th century, this phenomenon has greatly intensified particularly since the 1980s, following the construction of wells whose impact was soon to translate into a drying up of the main springs of the region and a drop in the artesian flows of the wells.

The outcrop zones of the aquifer formations have continued to play the role of recharge areas, but with low contributions to the aquifers in view of the fairly low, irregular and occasional rain quantities. With arid climatic conditions, the waters reaching the aquifer constitute « mixes » of a water that infiltrates directly, and water reserves of the soil that are subjected to evaporation prior to their being carried to the saturated part of the aquifer on the occasion of major rainfall events.

This situation is attested by the presence of water of an evaporated outlook and under the form of a « mix » in the vicinity of the system's recharge areas. In the confined part of the system, the water is more ancient and with more homogeneous isotopic characteristics. Its confinement causes its ground circulation to be slower and allows it a longer time of contact with the bedrock.

Thus, under the effect of high pressure and of temperature, this water undergoes chemical exchanges with the enclosing formations. Part of the chemical outlook of the water is equally acquired in certain zones, on the occasion of lateral and vertical communications between various aquifer levels. This is particularly the case during major tectonic accidents (Amguid Ridge, Hun Faults, Kébili Fault, etc…) and lateral facies passages (passage from limestone to sands).

7- CONCLUSIONS AND RECOMMENDATIONS

7.1- Conclusions on the hydrodynamic operating of the system and the quality of the data

In the light of the body of geological and hydrogeological data collected on the Saharan basin, its hydrodynamic operating emerges as being characterised by :

- a complex multi-layer structure, though not comprising any inner barriers preventing a propagation of the flow or the influence of the exploitation fields, between the aquifer layers ;
- the mobilisable aquifer reserves are mainly located in peripheral unconfined aquifer zones and partly in the « aquitards » (semi-permeable layers) ;
- confinement prevails and renewal is minimal ;
- artesianism, which was quite considerable at the beginning, had favoured the early exploitations, but has already markedly diminished, thus inducing more marked interferences with the enclosing layers ;
- the « most transmissive » confined aquifer layers offer the highest well productivities, but they are above all conveyors, while the « collector functions » are ensured by the « aquitards » and the unconfined groundwater aquifers ;
- a resource that is, for the major part, non renewable, and which needs to be evaluated and managed from a mining perspective and not as a balance system, with respect to the current minor recharge flows. The latter need to be better known for a correct modelling of the dynamics of the system, but not for a definition of the resource.

The North-Western Sahara Aquifer System, whose extension reaches beyond the framework of the national borders of the three countries that host it, is the quasi exclusive origin of the water resources available in this territory. These resources, which play a paramount role in the economic and social development of the region, have a strategic dimension insofar as they are, for the major part, non renewable and that they have actually entered a phase of intensive exploitation having already entailed notable changes in the behaviour of the aquifers. A controlled and concerted management of these resources is now a necessity to extend as much as possible the sustainability of the economic system dependent thereon.

7.1.1. Hydraulic operating of the aquifer system

After a phase during which the exploitation of this system was mainly based on artesianism (before 1970), these aquifers have increasingly been pump operated. Concurrent with this situation, the exploitation, which used to take place within certain groups of oases that were fairly limited in space, has become more intensive and more widely distributed into several new development poles.

Such a new arrangement has ended not only in more marked piezometric drawdowns at the level of the groups of old oases, but also in a higher general drawdown than that observed previously. This has led to a quasi total drying up of the main springs (Nefzaoua, Djérid and Kaam), as well as to a marked reduction of artesianism in the basins of the Grand Erg Oriental and in the Libyan Saharan basin.

The increasingly frequent and intensive resort to pumping has translated, at the level of the whole aquifer system, into larger abstractions from the geological reserves, as well as in interactions between the various interconnected levels, either directly or by leakage through the semi-permeable horizons. This hydrodynamic situation is reflected on the hydrochemical level under the form of salt exchanges between :

- the aquifer levels connected to the same aquifer, which leads to a homogeneisation of the salinity of its water around a certain mean value ;
- the potential sources of salinisation (Chotts, Turonian, Aptian, etc…) and the adjacent aquifers, thus increasingly giving rise to localised zones of chemical anomalies.

7.1.2. Data archiving and management system

The information available on the hydrogeology of the SASS aquifers is increasingly voluminous, but it is discontinuous over time and unevenly distributed in space. Thus, it does not cover in a homogeneous way all parts of the basin and does not allow records that are complete enough for a representative monitoring of the evolution of the various parameters. To this, there should be added the fact that such monitoring does not involve the whole set of variables necessary for monitoring (chemical quality).

The set up of the package entitled SAGESSE (**S**ystème d'**A**ide à la **G**estion des **E**aux du **S**ahara **Se**ptentrional) in the context of this study constitutes a fairly sound basis for data collection and rapid processing for assistance in decision-making. This computer system structured around a data base that is specific to the SASS aquifers is set to allow a formatting of the data collected, its interpretation and its graphic representation. The connections established between this information system and the SASS models also allow the making of periodical simulations whenever needed for decision-making purposes.

7.1.3. Knowledge of abstractions

The exploitation of the two major SASS aquifers is a monitoring aspect that presents several deficiencies and considerably distorts the representativeness of its evolution over time. With the increase in the number of exploitation points, it becomes illusory to ensure monitoring under the form of systematic inventories covering all water points.

The estimate of abstractions requires knowledge of the location of the exploitation wells, their flow and the operating duration of the water pumping system or of the duration of opening the valves in the case of artesian wells. While the first two parameters may be determined fairly easily—which requires, however, the use of non negligible means—, the duration of pumping remains difficult to establish over a year since it varies according to the seasons and according to water use. The volumes exploited annually will, therefore, remain always marked by errors and continue to constitute the weak link in the chain of knowledge about the aquifers for purposes of establishing the models.

The approach adopted by Algeria for the evaluation of exploitation, based on systematic ten-year inventories, has revealed, with the latest inventories of 1997 - 2000, their limitations as being cumbersome and too much extended over time. **The approach of Tunisia**, based on conducting annual monitoring with the issuing of a specific yearbook, is desirable as long as it is still feasible, but needs to be complemented with analyses that resort to other crosscheck methods in order to ascertain the validity of the information collected.

For the moment, **in Libya**, only the well fields supplying the Great (Manmade) River are regularly monitored (level, flows and salinity). The other abstractions in Libya have been estimated on the occasion of major studies which have no periodical character. For a few years now, the development of private farming has added to the uncertain nature of the estimate of abstractions and requires a more careful monitoring.

7.1.4. Knowledge of piezometry

7.1.4.1. Reference piezometry

The initial piezometry considered is that of 1950. It has been extrapolated from the sum of the old piezometric measurements and represented under the form of a map of initial piezometry used for calibrating the model. Certain measurements, however, do not correspond exactly to the 1950 situation, but their adopting as a reference piezometry is justified by the fact that exploitation in the whole zone of the new well was, at the time of measurement, fairly low or nil, and that the piezometric drop, with respect to an ideal situation in 1950, could be considered as negligible. **The greatest problem encountered and the greatest source of error arise in fact from uncertainties about the altitude of the water points on which the approximation, made by using the topographic maps, may exceed ±20m.**

7.1.4.2. Piezometric monitoring

Piezometry is more or less well monitored in the three countries, and the measurements available, while being discontinuous and unevenly distributed over time, lead nevertheless to deducing the drawdowns occurring in the two major SASS aquifers in the major exploitation zones. A marked improvement in the spatial and temporal distribution of the observations remains, however, much desired.

7.1.5. Chemical quality of the waters

No monitoring of the chemical quality of the water is made, in the whole Saharan basin, except in the **Tunisian part**. In this part, the monitoring is only fairly well done with regard to salinity. The chemical quality of the water, which is controlled in a quite irregular manner, deserves particular attention in the zones where salinisation risks are considerable (Oued Rhir, Nefzaoua and Djerid).

In Algeria, no monitoring of the chemical quality of the water is ensured. The few measurements of total dissolved salt or of conductivity often correspond to the date of construction of the well. These measurements only cover a small percentage of existing water points and do not help distinguish the evolution over time of the salinity of their water.

In Libya, no systematic monitoring of the salinity of the waters is operational over the whole Saharan basin. All the wells have, however, formed the subject of a chemical analysis at the time of their construction. A few water points, particularly those collecting the deep Kiklah aquifer in the western part of the basin have formed the subject of measurements in the course of the last decade, but the coastal zone, which is the most exposed to a deterioration of the chemical quality of the water, does not have yet an operational salinity monitoring network.

7.2- Recommendations on the monitoring and improvement of certain data

The monitoring of the SASS aquifer system is at the same time a source of additional information to be acquired and of new measurements to be collected. The current monitoring of the exploitation of the water resources of the system in the three countries concerned is done in a manner that is not sufficient enough to allow a periodical updating of the aquifers management models and to informedly select the management options to take in the context of an optimised management of these resources. This monitoring presents glaring deficiencies in matter of evaluation of abstractions and of evolution of the chemical quality of the water. Certain zones (underneath the ergs in particular), which have not yet been covered by the surveys or the evaluation of certain hydrogeological parameters require the collection of additional data in order to refine the calibrating of the model.

7.2.1. Improvement of knowledge of certain data

7.2.1.1. Basic piezometric data

A marked improvement of the knowledge of the piezometry could certainly be achieved by improving the precision of the altitude of the water points through proper measurement by levelling or by the use of GPS. Certain zones also present particular features which rest only on a few points whose characteristic details (for confined aquifer in particular) are not always a 100% reliable. This is the case, for instance, of the Kiklah piezometric dome on Jabal

Nafusah in Libya: it would be useful to check the water points (altitude and level depth) on which this dome rests and whose existence is questioned by certain authors and, at times, in contradiction with the spatial evolution of salinity towards the south-west.

The data resulting from the construction of new wells in the zones where exploitation is still low may be used in a profitable way for purposes of improving knowledge about the piezometry.

7.2.1.2. Geometry of the reservoirs

The knowledge about the geometry of the aquifer reservoirs and their communications remains as yet to be made more precise and to be analysed in the light of the new geophysical data and those obtaining from the deep wells constructed in the context of water and oil exploration works. This is in particular the case in the basin of the Grand Erg Occidental in Algeria where exploitation used to be made for the major part and until recent years by means of Foggaras. The need to extend the exploitation to new zones, as well as the piezometric drop in this basin, make the generalisation of drilled wells over the whole basin only a matter of time, hence the need to better know the thickness and depth of the CI throughout this basin.

The relations existing between the pre-Cenomanian formations of the Saharan basin and the Triassic formations of the Libyan Jifarah also deserve a detailed study based on the wells and the geophysical studies.

The multi-layer nature of the Complexe Terminal aquifer causes the geometry of its aquifer reservoir (sands and limestone) to be still insufficiently known in several zones, of which in particular the Tolga aquifer (at the level of Biskra) and, more generally, outside of the exploitation zones. The refining of the geometry of this reservoir allows a better conception of the management models and of the exchanges of water and solutions between the various aquifer levels.

The role of the Turonian dolomites in the flow of the CT waters is only partially well-known on the boundaries of the basin (Kébili peninsula and Tunisian-Libyan Dahar). **Its role as high salinity aquifer level underneath the Grand Erg Oriental (Hassi Messaoud and Tunisian far south) needs to be analysed with much attention, given the potential risk of salinisation attendant upon this aquifer.**

7.2.1.3. Current recharge of the system

The current sporadic recharge is mainly located in the basin's bordering zones. It originates mainly from direct infiltration of exceptional rains and, more generally, from runoff waters. The estimate of this infiltration should be based on hydrological measurements helping to define the surface runoff system and to specify the occurrence of hydrological phenomena and their magnitude. The geochemical approach referring to infiltration speed and to water dating may, in certain cases, allow a better evaluation of global infiltration. It seems, however, that for reasons of remoteness and difficulty of access to the aquifers potential recharge zones, any reliable measurements—i.e., made over several years—are difficult to consider. **It is strongly recommended**, before envisaging such measurements, to perform sensitivity tests on the model in order to determine whether appreciation errors of the current recharge could translate into very different behaviours of the aquifer in the present and future exploitation zones.

7.2.1.4. Flow of natural outlets and evaporation losses

Evaporation losses are also estimated and, often, evaluated as quantity allowing to complement the balance. The drop in piezometric level resulting from the impact of exploitation in neighbouring zones reduces the water rise in the surface layers exposed to evaporation or to evapo-transpiration, but vertical flow has always been calculated by applying theoretical formulas (Darcy law) and using non verifiable vertical permeability values. Here again, academic research may be encouraged so as to seek to determine evaporatory flows through an analysis of the ground level energy balances.

7.2.1.5. Hydrochemistry

The chemical analyses carried out at the time of acceptance of the wells are fairly numerous in Libya and in Tunisia, but they are, on the contrary, rare in Algeria. A first recommendation in this regard would be to increase the number of full-fledged chemical analyses in Algeria. As for Libya, an exhaustive interpretation of the various analyses available is highly recommended in order to account for the spatial evolution of contents in matter of various ions with regard to geology, on the one hand, and with the flow characteristics, on the other hand.

7.2.1.6. Data relating to water use and cost

The data relating to water use (irrigation, drinking water supply, industry, etc…), to water drawing means (artesianism, pumping, foggaras, etc…) and to the costs related to groundwater exploitation allow a better evaluation of water-related socio-economic aspects, as well as tailoring management to optimised uses.

Since pumping became predominant in the exploitation of the water of the Saharan basin (in the 1980s), exploitation costs have gained major importance. This increase in importance remains, nevertheless, undocumented with precise data. The monitoring of the economic aspect is felt on each occasion of updating the SASS models as a gap that needs to be bridged by the collection of certain soci-economic data in order to better evaluate the stakes and to set out the future development scenarios for this aquifer system's water resources not only on hydrodynamic and hydrochemical bases, but also based on soci-economic criteria.

7.2.2. Improvement of monitoring

7.2.2.1. Monitoring of abstractions

Over the whole Saharan basin, the knowledge of the abstractions and a periodical monitoring of them are necessary in order to allow an appreciation of the reliability of the models. It is important, in this regard, to urge the users to install meters which would allow a monitoring of the volumes exploited.

The difficulties related to a direct approach of survey-based estimates of abstractions are considerable and reduce the possibilities of a serious and reliable monitoring of the whole basin. The adoption of statistical methods (sampling and representative zones) that are crosschecked by other evaluation means (irrigated zones by interpretation of satellite images, power consumption, etc…) would make it possible to ensure exploitation monitoring and to provide a more or less regular information on the abstractions, without, however, requiring the deployment of considerable means.

The design of a methodology that makes it possible to move from power meter readings or the study of irrigated areas based on satellite images, to water volumes abstracted from the underground, could form the subject of academic research works targeted by zone, up to doctoral dissertations. Such an approach would contribute in facilitating the task of administration technical staff who would thus be provided with a rapid tool for determining abstractions as per zone.

Periodical publication of the measurements results, under the form of yearbooks accompanied by critical analyses, would help ensure in an efficient way an updated acquaintance with this information. This approach is, for the time being, implemented only in Tunisia. It may constitute an option to be implemented within the framework of a concerted management of the Saharan basin.

7.2.2.2. Piezometric monitoring

Piezometric monitoring should be conducted in the three countries with a greater regularity in order to avoid resorting to an extrapolation of measurements which do not correspond all of them to the same date. A minimum network needs to be set up in each country for purposes of monitoring the Continental Intercalaire and the Complexe Terminal. This network should meet the following major criteria :

- a good representativeness of the variations of piezometry in the various parts of the basin, and more particularly on the borderlines of the zones of high exploitation and of major density in water points ;
- a regular data collection over time such as to allow deductions about the response of the aquifer to phenomena that disturb its hydrodynamic character, such as exceptional exploitation or recharge ;
- a time pace adapted to the piezometric variations of each aquifer.

It is highly recommended that the three countries seek to obtain the longest observations series possible (connections with substitution wells). Acquiring information on the altitude of measurement points is complementary to piezometric information and allows for extrapolation between points located within the same influence zone.

Piezometric monitoring is fairly often doubled by the need to properly position the structure and to obtaining its altitude. With the development of GPS based levelling techniques, it has become easier to determine the exact location of a water point as well as its altitude. This operation needs to accompany each new well.

7.2.2.3. Monitoring salinity and chemical contents

Water quality and its future evolution constitute the most troublesome aspect in achieving control over the management of the SASS water resources ; unfortunately, the chemical monitoring of the SASS aquifers is far from being secured everywhere and, when it is more or less secured, it only relates to water salinity.

With the rise in exploitation and the drop in piezometric levels below natural ground, the risks of inversion of the flow within the aquifer formations have become even greater. This is particularly the case of the Complexe Terminal aquifer at the locations where its semi-impermeable top is very little thick. Risks of contamination of this aquifer by irrigation water and the water of the Chotts are considerable. This phenomenon, which is noted in the oases of El Oued and of Nefzaoua – Djérid, needs to be accordingly better recorded and analysed. Risks of marine intrusion in the aquifers located in the vicinity of the sea in Libya also require surveillance, which is still lacking.

The management of the water resources of this system is not only a management of exploitable volumes ; it is also a management of the quality of the water that will be abstracted and whose deterioration would be liable to seriously jeopardize its use in certain sectors, such as drinking water supply and industry, both of which require good chemical quality. This chemical monitoring needs to be gradually directed to the chemical contents of the water, in addition to its overall salinity. It is, indeed, through the analysis of this composition that the origins of contamination, and the measures to be taken in order to remedy it, can be better highlighted.

7.2.3. Acquisition of new data and updating of the data base

The data relating to new wells and contributing in improving the knowledge of the geometry of the aquifer reservoirs (geological logging) and in updating the hydrogeological information (piezometry, exploitation flow, transmissivity, total dissolved salt, chemistry, isotopic analysis, etc…) should systematically be archived in the data base, according to the formats defined in the framework of the SASS project. The entering of this information within the data base will, in addition, facilitate its interpretation and its integration in the models.

7.3- Recommendations for the establishment of a monitoring network at the basin level

The periodical measurements of flows, piezometric level, and water salinity and chemical contents should be acquired within the framework of national monitoring networks that are well-structured and that meet the various national objectives of surveillance and management. It is equally important to ensure, at basin level, a sustainable development which is based on a monitoring that ensures minimal interference between the countries. Such a regional vision will better obtain on the ground through consultation and a basin awareness. The structuring of these networks is integrated within the policy of each of the countries with a view to ensuring the management of these water resources.

However, the setting up of a minimal network for surveillance of the levels and a monitoring of the abstractions and of water quality, such as to allow for collecting the information necessary on the level of the whole basin, constitutes a course of action which meets the objective of setting up a "monitoring and consultation mechanism" that allows for coordinating the management of these resources.

The definition of this minimal network will result from a model simulation of the various development scenarios allowing to locate the sensitive zones that require particular surveillance and which are necessary for calibrating the models.

The monitoring of the North-Western Sahara Aquifer System needs to take into consideration the following three aspects :

- exploitation
- piezometry
- water salinity and its chemical contents.

7.3.1. Monitoring of exploitation

The monitoring of the exploitation of the Saharan basin aquifers needs to be reinforced in the three countries through the use of various approaches that allow an evaluation of the water quantities abstracted from the system and the evolution of spouting flows (springs, foggaras and artesian wells). This monitoring needs to cover almost all water points whether exploited or of natural flow. Particular attention needs to be granted to the measurement of pumped flows and to the duration of pumping.

The publication of exploitation yearbooks remains the best approach for obtaining information that is regularly updated, analysed and representative.

7.3.2. Monitoring of piezometry

The monitoring of piezometry is an operation that starts at the time of construction of the wells. It has proved difficult to maintain a certain regularity of piezometric measurements over time and that the record of the piezometric measurements made is marred with errors, with often a substitution of certain points by others.

The evolution of the piezometry of the two Saharan aquifers has revealed, between 1950 and 2000, that this piezometry had not undergone any major changes, except in the zones where exploitation is high. It is, therefore, proper to recommend a monitoring that is more focused on the establishment of a record of piezometric drops than on the making of general maps.

7.3.2.1. The Continental Intercalaire aquifer

In Algeria, the drop in the piezometry of the Continental Intercalaire is more sensitive in the basin of the Grand Erg Oriental than in that of the Grand Erg Occidental. The highest drawdowns are located in the regions of Oued Rhir, Ourghla, Hassi Messaoud, El Borma and

Ghardaïa. The monitoring of piezometry in these regions helps to highlight the response of the aquifer to an intensification of its exploitation in this confined part.

In Tunisia, the monitoring of the piezometry of the Continental Intercalaire needs to be made in Chott Fedjej, Nefzaoua, Djerid, El Borma and the far south. Particular attention should be granted to this piezometry in the vicinity of the Tunisian outlet (Chott Fedjej). Transborder influences on the Algerian side need to be monitored in Hazoua (Bjeid), El Borma and El Chouech. On the Libyan side, these influences need to be monitored in Tiaret – TEI, Borj Bourguiba and Bir Zaar.

In Libya, the monitoring of the Continental Intercalaire needs to be made alongside the cliff of J. Nafusa, in Ghadamis, Derj, Suffajin, Al Khums, Al Jifra. Particular attention needs to be granted to this monitoring in future in the exploitation field of Ghadamis – Derj, downstream J. Hassawna and in the region of A. Tawargha.

7.3.2.2. The Complexe Terminal aquifer

The inception of artesianism in this aquifer in the three countries gives rise to a new situation of inversion of the flows within and across the formations overlaying the various aquifer levels that collect the Complexe Terminal. It is, therefore, highly recommended to ensure piezometric monitoring of this aquifer in the zones that are the most influenced by the disappearance of artesianism.

In Algeria, the piezometric monitoring of the CT needs to grant priority order to the zones of Souf, Oued Rhir and Ouergha.

In Tunisia, the piezometric monitoring of the CT is secured in Nefzaoua (Kébili peninsula, Douz, Redjim Maatoug), Djerid and in Borj El Khadra.

In Libya, the piezometric monitoring of the CT is secured in the eastern part of Hamada El Hamra (Al Khums, Suffajin, Al Jufra).

7.3.3. Monitoring of water salinity and chemical contents

The aquifer of the Continental Intercalaire is less sensitive to the evolution of water salinity than that of the Complexe Terminal, due to the fact that it is fairly often protected against leakage and contamination by surface water.

Nevertheless, it is recommended to ensure a monitoring of the salinity of its water in the zones where it is exploited.

The Complexe Terminal presents in the three countries signs of vulnerability to contamination by the saline waters of the phreatic aquifers and closed depressions (Chotts and Sebkhas). This is particularly the case in the Algerian-Tunisian Lower Sahara and in the eastern part of Hamada El Hamra.

In Algeria, the chemical monitoring of the Complexe Terminal needs to be secured in the zones close to the Chotts (Suf, Oued Rhir, Ouergla). The monitoring of chemical contents makes it possible to better explain the origin of salinisation.

In Tunisia, the chemical monitoring of the Complexe Terminal needs to be secured, like in Algeria, in the zones close to the Chotts (Djerid and Nefzaoua), similarly to piezometric monitoring.

In Libya, the chemical monitoring of the Complexe Terminal needs to be secured in the zones of Al Khums (W. Kaam and A. Tawagha) and in Al Jufra.

ANNEXES

ANNEX 1

BIBLIOGRAPHY

ANNEX 1

BIBLIOGRAPHY

General

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ANNEX 2

PIEZOMETRY

ANNEX 2

1. Reference piezometry in the Complexe Terminal aquifer

Annex 2 Table 1 – Reference piezometry in the CT aquifer in Algeria

Zone	Type of equipment	Data base class number	Well denomination	Altitude in m	Measurement year	SL/GL	Altitude piezo.level	Origin of data
Debdeb	Artes. Well	L01500002	F.De Fort Saint 2	300	1955	47	347	ANRH
Debdeb	Well	L01300001	Haiad 601 Et 602	225	1964	-88	137	ANRH
Debdeb	Well	L01300002	Bir Morel Rap	243	1969	-63	180	ANRH
Debdeb	Well	L01300003	Bir Rogers 1et 2 Rap	230	1969	-60	170	ANRH
El Borma	Well	J01300001	Zemlet El Khalef Z K	140	1961	-35	105	ANRH
El Borma	Well	J01300002	Bir Dolmane1 Zemoul	149	1960	-40	109	ANRH
El Borma	Well	J01100003	Hassi Messaoud Md 1	167	1956	-40	127	ANRH
El Borma	Well	J01200007	El Arich Ettahtania	150	1968	-31	119	ANRH
El Borma	Well	K01100009	Fes 1-H1	171	1967	-33	138	ANRH
El Borma	Well	K01200005	Rhourd El Baguel 101	151	1961	-24	127	ANRH
El Borma	Well	K01400006	Camp Sismique	230	1963	-80	150	ANRH
El Borma	Well	J01200003	Rhourd Sefar (Rs 1)	145	1962	-28.9	116.1	ERESS
El Borma	Well	J01300003	Bir Delmane 2 (Brd 2)	150	1960	-41	109	ERESS
El Borma	Well	J01300009	Zemlet Eel Kalef	140	1961	-35.45	104.55	ERESS
El Borma	Well	J01300009	Zemlet Eel Kalef (Zk1)	140	1970	-35.72	104.28	ERESS
El Borma	Well	J01300013	Bir Retma (Brt 101)	172	1967	-68	104	ERESS
El Borma	Well	J01400001	El Guelta	268	1966	-130	138	ERESS
El Borma	Oil Well	RE 1	Rebaa	190	1964	-60	130	ERESS
El Borma	Oil Well	REL 101	Rhourd El Lia	135	1970	-19.86	115.14	ERESS
El Borma	Oil Well	Arb 1	El Arbi	177.26	1963	-41	136.26	ERESS
El Borma	Oil Well	BRD 1	Brides	204.5	1963	-49.9	154.6	ERESS
El Borma	Oil Well	EAT 101	El Arich Et Tahtania	150	1970	-30.3	119.7	ERESS
El Borma	Well	J01100019	Dorbane Sd 1	140.4	1959	-19.5	120.9	ERESS
El Borma	Well	J01200006	Rhourd El Baguel Nord	152	1967	-25	127	ERESS
El Borma	Well	J01300011	Guenafide (Gef 1)	150	1963	-39	111	ERESS
El Borma	Well	J01400005	El Borma 103 (Elb 103)	221	1969	-64.46	156.54	ERESS
El Borma	Well	J01400006	Keskessa 101 (Ka 101)	187	1968	-66	121	ERESS
El Borma	Well	K01100011	Rhourd El Baguel West	155	1966	-29	126	ERESS
El Borma	Well	K01200002	Loudje (Ld 1)	148.1	1964	-24.5	123.5	ERESS
El Borma	Well	K01200003	Sinclair Akr 101	157	1964	-29	128	ERESS
El Borma	Well	K01200004	Rhourd El Baguel (Rb 101)	151	1961	-24	127	ERESS
El Borma	Well	K01200006	Rhourd El Baguel 102 (Rb 102)	154	1967	-26	128	ERESS
El Borma	Well	K01200008	(Pk 40)	155	1970	-22	133	ERESS
El Borma	Artes. Well	K01200010	Massdar 101	166.5	1964	-28.4	138.1	ERESS
El Borma	Well	K01300003	Bir Tangueur (Btr 1)	190	1970	-57.68	132.32	ERESS
El Borma	Well	K01300004	Pk 92	160	1970	-28.5	131.5	ERESS
El Borma	Well	L01200002	Touil (Tao 601)	202	1966	-50	152	ERESS
El Borma	Oil Well	Zar 1	Zemlet El Arbi	167	1964	-40	127	ERESS
El Borma	Well	J01400004	El Borma 102 (Elb 102)	223.7	1968	-68	155.7	ERESS
El Borma	Well	X03000030	Bir Atchane	230	1963	-80	150	ERESS
El Borma	Group	4					156	ERESS
El Oued	Well	J01200004	Hassi Bedda 1h B1 N1	130	1960	-20	110	ANRH
El Oued	Well	I01100242	A.Tarfaia Djedida D2	55	1954	3	58	ANRH
El Oued	Oil Well	EHT 101	El Hamamit	128	1970	-23.5	104.5	ERESS
El Oued	Well	I01200009	Zemlet El Bazima	80	1961	20	100	ERESS
El Oued	Well	I01300002	T 01 De La Ste Esso	120	1962	-19	101	ERESS
El Oued	Oil Well	HB 1	Hassi Bedda	129.5	1960	-20.5	109	ERESS
Hassi Messaoud	Well	J01000468	Well H1 Hm Omn 53	168	1958	-41	127	ANRH
Hassi Messaoud	Well	J01000474	Mdw1bh1(Snrepal)	174	1954	-46	128	ANRH
Hassi Messaoud	Well	J01100011	Haoud Tarfa N1 Omy57	164	1958	-46	118	ANRH

Zone	Type of equipment	Data base class number	Well denomination	Altitude in m	Measurement year	SL/GL	Altitude piezo.level	Origin of data
Hassi Messaoud	Well	J01100014	Mdw1 A H1	173	1959	-45	128	ANRH
Hassi Messaoud	Well	J01100016	Mds Bh Sn Repal S1b	142	1959	-10	132	ANRH
Hassi Messaoud	Well	J01100017	Snrepal Hi M Mde 2bh	146	1959	-16	130	ANRH
Hassi Messaoud	Well	J01100020	H 6 Om 1	169	1959	-44	125	ANRH
Hassi Messaoud	Well	J01100060	Hassi Messaoud F5 Ae	168	1965	-42	126	ANRH
Hassi Messaoud	Well	K01000001	Hassi El Gassi N1	185	1958	-40	145	ANRH
Hassi Messaoud	Well	K01000003	Pour Snpa Ar 1	192	1959	-43	149	ANRH
Hassi Messaoud	Well	K01000004	El Agreb H Ar6	200	1960	-45	155	ANRH
Hassi Messaoud	Well	K01100021	F.L.D.I-Hi Sn Repal	160	1966	-25	135	ANRH
Hassi Messaoud	Well	K01100022	Puits D'eau Ns I.H.I	188	1960	-43	145	ANRH
Hassi Messaoud	Well	K01100023	Gassi El Adam 101	188	1967	-41	147	ANRH
Hassi Messaoud	Well	L00900001	Es Settar St 1 Cpa	261	1969	-83	178	ANRH
Hassi Messaoud	Well	L00900005	Saf Saf 101	258	1900	-78	180	ANRH
Hassi Messaoud	Well	L01000003	Hll1 N°2	207	1960	-46	161	ANRH
Hassi Messaoud	Well	L01100008	Azel Nord Aln 1	233	1961	-65	168	ANRH
Hassi Messaoud	Well	L01100025	Toual 101	223	1962	-61	162	ANRH
Hassi Messaoud	Well	L01100028	Allenda Nord N 1	229	1962	-61	168	ANRH
Hassi Messaoud	Well	L01100047	Ht-01	202	1900	-45	157	ANRH
Hassi Messaoud	Well	M00900003	Ea Iww Phillips	290	1960	-110	180	ANRH
Hassi Messaoud	Well	M01000003	Baguel 1 Rl1 Cpa	268	1969	-90	178	ANRH
Hassi Messaoud	Well	G01000438	Stile (N° 3)	17.87	1970	4.47	22.34	ERESS
Hassi Messaoud	Oil Well	Aa N 601	Allenda Nord N 601	229	1962	-60.5	168.5	ERESS
Hassi Messaoud	Oil Well	BSE 101	Bou Settach	155	1968	-17.5	137.5	ERESS
Hassi Messaoud	Oil Well	Fld 1	Fort Lallemand H1	160	1966	-25	135	ERESS
Hassi Messaoud	Oil Well	GTM 1	Gassi Touil	209	1969	-51.5	157.5	ERESS
Hassi Messaoud	Oil Well	Hll 1	Hassi Leila	207	1960	-45.52	161.48	ERESS
Hassi Messaoud	Well	J01100005	Hassi Messaoud Sud (Mds1 Ah)	140	1959	-11.8	128.2	ERESS
Hassi Messaoud	Well	J01100012	Haouad Tarfa 2 (Omg 57)	164	1958	-46.75	-117.25	ERESS
Hassi Messaoud	Well	J01100018	Hassi Messaoud Nord ((Om 1))	169	1959	-43.5	125.5	ERESS
Hassi Messaoud	Well	J01100056	Hassi On 1	140	1961	-15	125	ERESS
Hassi Messaoud	Well	K01100004	Fort Lallemand	150	1958	-16.42	133.58	ERESS
Hassi Messaoud	Well	K01100006	Hassi Laroque	185	1959	-36.65	148.35	ERESS
Hassi Messaoud	Well	K01100007	Nezla	190	1960	-43.5	146.5	ERESS
Hassi Messaoud	Well	K01100012	Rhourd El Guemra	180	1968	-38	142	ERESS
Hassi Messaoud	Well	K01100013	Draa Sbeit	190	1968	-43.5	146.5	ERESS
Hassi Messaoud	Well	L01000002	El Agreb (Ar 6)	200	1960	-45.2	154.8	ERESS

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Hassi Messaoud	Well	L01100004	Azel Nord	232	1961	-65	167	ERESS
Hassi Messaoud	Well	L01100005	Hassi Touareg	202	1959	-47.5	154.5	ERESS
Hassi Messaoud	Well	L01100012	Allenda Nord N 602	223	1968	-54	169	ERESS
Hassi Messaoud	Oil Well	NS1H1	Oulad N'sir	188	1969	-42.59	145.41	ERESS
Hassi Messaoud	Oil Well	SG 1	Slassed Guerba	168	1960	-27.7	140.3	ERESS
Hassi Messaoud	Oil Well	Tou 1	Touat	222	1962	-60.5	161.5	ERESS
Hassi Messaoud	Group	1					155	ERESS
Hassi Messaoud	Group	2					127	ERESS
Ouargla	Well	J01000338	Ain Briss	132	1954	-1	131	ANRH
Ouargla	Well	J01000428	A.Tafessaouine D4 F	130	1954	1	131	ANRH
Ouargla	Well	I01100447	Gueddich Gd1 Pts Eau	110	1964	-5	105	ANRH
Ouargla	Well	J01000514	Oulougga 2 Oa2	145	1966	-26	119	ANRH
Ouargla	Well	J01000411	Sar Mekhadma Ouargla	132	1954	5	137	ANRH
Ouargla	Well	J01000426	Sidi El Maghraoui	130	1954	1	131	ANRH
Ouargla	Well	J01000521	Banounou D2 F54	131	1966	-2	129	ANRH
Ouargla	Well	J01000202	Bentadjine Rouissat	132	1954	1	133	ANRH
Ouargla	Well	J01000402	S.N.Repal	144	1956	-5	139	ANRH
Ouargla	Well	J01000464	Hassi Rhenani 1	133.94	1970	-8.9	125.04	ERESS
Ouargla	Well	J01000465	Hassi Rhenani 2	136.12	1957	-11.2	124.92	ERESS
Ouargla	Well	J00900015	Daïa Ghemta	233	1958	-87.75	145.25	ERESS
Ouargla	Well	J01000001	Kechem Er Rihr (Puits)	148.89	1970	-31.29	117.6	ERESS
Ouargla	Well	J01000007	Square Bresson	120.25	1957	-9.5	111.75	ERESS
Ouargla	Well	J01000469	Carrière	139	1958	-26.71	112.29	ERESS
Ouargla	Well	J01000475	Garet Chennter	163.13	1959	-37.85	125.28	ERESS
Ouargla	Well	J01100013	Rhourd El Hamra	149.5	1968	-28.5	121.00	ERESS
Ouargla	Well	J00900017	Bordj Houbrat	251	1966	-106	145	ERESS
Ouargla	Well	J010 00529	Ali Rached	128.96	1967	-0.95	128.01	ERESS
Ouargla	Well	J01000518	Bou Roubia (Sov. 14) (D 2 F 59)	130.48	1966	-1.22	129.26	ERESS
Ouargla	Well	J01000522	Bamendil Cofor	135.5	1969	-6.6	128.9	ERESS
Ouargla	Well	J01000527	N'goussa (Cofor) A. Gallousch (D 6 F 44)	120.3	1966	-0.96	119.34	ERESS
Ouargla	Well	J00900016	Hofra Trajma	273	1957	-122.63	150.37	ERESS
Ouargla	Well	K00900008	Erg Djouad	182.86	1969	-32.81	150.05	ERESS
Ouargla	Well	X03000023	Hassi El Bakret (Puits)	156.62	1970	-29.14	127.48	ERESS
Ouargla	Well	X03000024	Hassi Sayah (Puits)	143.28	1970	-17.66	125.62	ERESS
Ouargla	Well	X03000025	Frana	134.5	1969	-18.5	116.00	ERESS
Ouargla	Well	X03000026	Hassi Sahane (Puits)	122.94	1970	-9.68	113.26	ERESS
Ouargla	Well	X03000027	Aïn Ali Ben Salah (Puits)	109.58	1970	-0.78	108.8	ERESS
Ouargla	Well	X03000028	Hassi Mellah (Puits)	118.74	1970	-8.4	110.34	ERESS
Ouargla	Well	X03000029	Hassi Chouara (Puits)	122.4	1970	-16.19	106.21	ERESS
Ouargla	Well	X03000031	Hassi El Hadjar (Puits)	280	1969	-128.92	151.08	ERESS
Ouargla	Group	6					130.7	ERESS
Ouargla	Well	D 16 F 11	Propriété Saïssa		1949		53.85	ERESS
Ouargla	Well	D 1 F 103	B El Guetaïf	132.39	1956	-0.64	131.74	ERESS
Ouargla	Well	D 1 F 94	Aïn Ramel	131.61	1957	-0.74	130.87	ERESS
Oued Rhir Nord	Well	G01100061	Ain Naga 3 Aep	13	1958	55	68	ANRH

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Oued Rhir Nord	Artes. Well	G01000240	Hammam Salihine	125	1959	5	130	ANRH
Oued Rhir Nord	Well	G01000225	Bouchagroune Ouest	153	1951	-1	152	ANRH
Oued Rhir Nord	Artes. Well	G01000279	Bir Bou Soudane N°3c	120	1954	5	125	ANRH
Oued Rhir Nord	Well	G00900111	F.Reconnaissance Ber	236	1953	-51	185	ANRH
Oued Rhir Nord	Well	G01000378	Puits Khafoura Douce	180	1951	-8	172	ANRH
Oued Rhir Nord	Well	G01000416	Doucen N°79 Miss Sov	180	1969	-2	178	ANRH
Oued Rhir Nord	Well	G01000278	El Ghrouz N°2	156	1953	3	159	ANRH
Oued Rhir Nord	Artes. Well	G01000164	Puits Berland N 2	100	1947	8	108	ANRH
Oued Rhir Nord	Well	G01000295	Sidi Haddoud A Kerma	141	1955	6	147	ANRH
Oued Rhir Nord	Well	G01000299	Puits Du Cafe Maure	150	1951	-7	143	ANRH
Oued Rhir Nord	Artes. Well	H01100027	Tarfait Salah Meghai	-1	1949	25	24	ANRH
Oued Rhir Nord	Artes. Well	H01100249	Ain Bertin	1	1949	29	30	ANRH
Oued Rhir Nord	Well	G01000316	Mebdoua Gharbia	151	1956	4	155	ANRH
Oued Rhir Nord	Well	G01000344	Mekhadna N°3	107	1966	44	151	ANRH
Oued Rhir Nord	Well	G01000359	Ain Laborde Lioua	120	1949	34	154	ANRH
Oued Rhir Nord	Well	G01000380	El-Beida Djedjdàbent	88	1912	1	89	ANRH
Oued Rhir Nord	Well	I01100013	Ain Thomas A Moggard	54	1950	5	59	ANRH
Oued Rhir Nord	Well	I01100225	Ain Aouf Temacine D3	76	1954	-4	72	ANRH
Oued Rhir Nord	Well	H01100244	Ain Brusalin Srouna	44	1949	4	48	ANRH
Oued Rhir Nord	Well	H01100372	Ain Tamzalit 2	50	1954	-1	49	ANRH
Oued Rhir Nord	Well	I01100478	A.Zaouali A Moggard2	55	1956	4	59	ANRH
Oued Rhir Nord	Well	G01000003	El Mazoucchia	230	1954	-60	170	ANRH
Oued Rhir Nord	Well	G01000350	Bir Labrache N°2	180	1963	-17	163	ANRH
Oued Rhir Nord	Well	G01100060	Ziribet El Oued	47	1958	50	97	ANRH
Oued Rhir Nord	Well	G01100076	Reconnaissance A Lia	190	1950	-56	134	ANRH
Oued Rhir Nord	Well	G01100067	Aïn Naga	4.65	1962	54	59.65	ERESS
Oued Rhir Nord	Well	H01000041	El Amria (Ph 1)	147	1958	-74.5	72.5	ERESS
Oued Rhir Nord	Well	G01100056	El Feidh	1.325	1956	58.98	60.3	ERESS
Oued Rhir Nord	Well	H01000001	Aïn Steeg	-10.5	1950		30	ERESS
Oued Rhir Nord	Well	H01000047	Hassi Gouira	31	1963	-11	20	ERESS
Oued Rhir Nord	Well	H01100001	Zaouiet Riab A. Sif	30.5	1949		47.2	ERESS
Oued Rhir Nord	Well	F 54	Aïn Dusquenay	-0.01	1960	20	20.00	ERESS
Oued Rhir Nord	Well	F 74	Tebesbest Aïn Nacent	63.68	1970	-1.56	62.12	ERESS
Oued Rhir Nord	Well	F 74	Aïn Kebira	-19.22	1970	31.51	12.29	ERESS
Oued Rhir Nord	Oil Well	F10	Aïn Saïba	1.43	1970	7.55	8.98	ERESS
Oued Rhir Nord	Artes. Well	H01100401	El Hamraïa 1	-19.95	1955	65	45.05	ERESS

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Oued Rhir Nord	Artes. Well	G01100068	Khanga Sidi Nadji	176.78	1967	1.25	178.03	ERESS
Oued Rhir Nord	Well	H01200022	Kouinine	74.47	1961	3.5	77.97	ERESS
Oued Rhir Nord	Well	G01000341	Benthious	94.15	1965	-13	81.15	ERESS
Oued Rhir Nord	Well	H01100522	Recon S.E.S Fr 13	22	1971	4.5	26.5	ERESS
Oued Rhir Nord	Oil Well	F21	Zaouiet Riab	28.4	1970	6.44	34.84	ERESS
Oued Rhir Nord	Well	I01100502	Sidi Bou Hanra (Reconn. Fr 3)	100	1971	-6.81	93.19	ERESS
Oued Rhir Nord	Well	H01000044	Chaab El Megalem (Sp I Bis)	94	1960	-34.6	57.4	ERESS
Oued Rhir Nord	Well	H01200015	El Khobna	48.13	1954	17.63	65.76	ERESS
Oued Rhir Nord	Well	G01000346	Chegga Soviétique	15.86	1967	17.8	36.14	ERESS
Oued Rhir Nord	Well	H01100484	Tamerna Guedima A. Chemorah (F 34)	53.55	1970	-3.58	50.17	ERESS
Oued Rhir Nord	Well	H01100505	Aïn Bedjadi	53.15	1957	-2.5	50.65	ERESS
Oued Rhir Nord	Oil Well	F17	Tiguechdine Aïn Paul Cassoute	33.48	1970	7.23	40.71	ERESS
Oued Rhir Nord	Well	H01200035	Magrane	52.82	1961	15.5	68.32	ERESS
Oued Rhir Nord	Artes. Well	H01100356	Sidi Ahmed Tidjani	7.37	1952	24.57	31.94	ERESS
Oued Rhir Nord	Oil Well	F5	Sidi Slimane A. Compagne	55.5	1970	-0.47	55.03	ERESS
Oued Rhir Nord	Well	X00101038	Sidi Slimane A. Tarfaïa Djedida	55.14	1954	3.26	58.4	ERESS
Oued Rhir Nord	Well	F 7	Aïn Deguel	11.8	1970	5.73	17.53	ERESS
Oued Rhir Nord	Well	H01100490	Caper	25.03	1970	7.6	32.63	ERESS
Oued Rhir Nord	Oil Well	F15	Tinedla	13.06	1970	12.47	25.53	ERESS
Oued Rhir Nord	Well	H01100347	Gd Puits Ourir N'sigha 5(D2 F 14)	-5.6	1950		32.4	ERESS
Oued Rhir Nord	Well	FR 10	Chouchet Dentsa	55	1971	-12.19	42.81	ERESS
Oued Rhir Nord	Well	FR 8	Ahanet Tamerna	100	1971	-29.5	70.5	ERESS
Oued Rhir Nord	Group	20					54	ERESS
Oued Rhir Nord	Group	21					46	ERESS
Oued Rhir Nord	Group	22					46.2	ERESS
Oued Rhir Nord	Group	23					53.2	ERESS
Oued Rhir Nord	Group	24					42	ERESS
Oued Rhir Nord	Group	26					32	ERESS
Oued Rhir Nord	Group	27					30	ERESS
Oued Rhir Nord	Group	28					44	ERESS
Oued Rhir Nord	Group	29					32.4	ERESS
Oued Rhir Nord	Group	30					40	ERESS
Oued Rhir Nord	Group	31					36	ERESS
Oued Rhir Nord	Group	36					60	ERESS
Oued Rhir Nord	Group	38					60	ERESS

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Oued Rhir Nord	Well	H01100278	Guedima Porte Ranfaine (D 20 F 30)		1949		51.37	ERESS
Oued Rhir Nord	Well	H01100057	El Serd A. Pionnier ((D 9 F 5))		1952		40	ERESS
Oued Rhir Nord	Well	H01000029	Aïn Aïssa 5(D 1 F 5)		1942		42.3	ERESS
Oued Rhir Sud	Well	I01100238	Ain Ahiba D46f62	84	1953	2	86	ANRH
Oued Rhir Sud	Well	I01100578	A.Cheraga Djedida D4	87	1969	0	87	ANRH
Oued Rhir Sud	Well	H01100369	Ain Nazika	37	1954	7	44	ANRH
Oued Rhir Sud	Well	I01000037	Chegguet El Ftaiet	91	1970	6	97	ANRH
Oued Rhir Sud	Well	I01100038	Ain Merouane D29f73	59	1952	8	67	ANRH
Oued Rhir Sud	Well	I01100080	Ain Chotte Touggourt	69	1953	3	72	ANRH
Oued Rhir Sud	Well	H01000078	Djouf Msellem Pa 1	259	1960	-101	158	ANRH
Oued Rhir Sud	Well	I01100053	A.Danoun Djedida D40	75	1952	3	78	ANRH
Oued Rhir Sud	Well	I01100575	Ain Khadra Tamelht	79	1969	-1	78	ANRH
Oued Rhir Sud	Well	I01100227	Ain Chaouche 2 D32f1	63	1954	3	66	ANRH
Oued Rhir Sud	Oil Well	D45F41	Blidet Amor Ouest Cheih Tahar	82.66	1970	-1.08	81.58	ERESS
Oued Rhir Sud	Oil Well	D46F49	Blidet Amor Est Alegouigui	84.21	1970	-1.98	82.23	ERESS
Oued Rhir Sud	Well	D47 F 16	Aïn Larbi	86.39	1970	2.2	88.59	ERESS
Oued Rhir Sud	Well	H01100364	Aïn Djenane	40.96	1953	1.35	42.31	ERESS
Oued Rhir Sud	Artes. Well	H01100474	Mazer Aïn Kemgassem	28.22	1970	7.48	35.7	ERESS
Oued Rhir Sud	Well	H01100704	Teguedine Aïn Cheitch Saad	36	1953	6.7	42.7	ERESS
Oued Rhir Sud	Well	H01100777	Aïn Bel Kassem Oubira		1950		44.9	ERESS
Oued Rhir Sud	Well	H01000056	Chott Amar	72	1971	-27.00	45.00	ERESS
Oued Rhir Sud	Well	I01000008	Bled Haouad El Maïa	165	1959	-62.02	102.98	ERESS
Oued Rhir Sud	Well	I01000009	El Hadjira 2	101.4	1958	-7	94.4	ERESS
Oued Rhir Sud	Well	D34FR7	El Haïcha	89.16	1971	-14.67	74.49	ERESS
Oued Rhir Sud	Oil Well	FR 1	Melah Ben Taïeb	103	1971	-7.38	95.62	ERESS
Oued Rhir Sud	Oil Well	F65	Meggarine Guedima Aïn Bassoud	59.15	1969	-0.09	59.06	ERESS
Oued Rhir Sud	Well	X00101230	Meggarine Guedima Aïn Merouane		1952		67.5	ERESS
Oued Rhir Sud	Well	X00101247	Puits Du Sar	61.3	1953	4.98	66.28	ERESS
Oued Rhir Sud	Oil Well	D36F48	Taggourt S. Ranou	71.51	1970	-0.37	71.14	ERESS
Oued Rhir Sud	Well	X00101241	Aïn Sahara		1954		71.5	ERESS
Oued Rhir Sud	Well	H01000046		259	1960	-101.4	157.6	ERESS
Oued Rhir Sud	Well	H01000046		259	1960	-101.4	157.6	ERESS
Oued Rhir Sud	Well	I01200019	Hassi Amrane Hnb 2	123	1960	-10	113	ERESS
Oued Rhir Sud	Well	I00900009	Guerrara	328.14	1957	-130.2	197.94	ERESS
Oued Rhir Sud	Well	I01100448	Taïbet	102	1967	-12.8	89.2	ERESS
Oued Rhir Sud	Oil Well	D38F17	Temacine W Ben Dadi	78.27	1970	-3.93	74.34	ERESS
Oued Rhir Sud	Oil Well	D39F15	Temacine Se Alchaoubi	79.27	1970	-2.2	77.07	ERESS
Oued Rhir Sud	Oil Well	D41F70	Madjoub Bouhabache	74.19	1970	-1.68	72.51	ERESS
Oued Rhir Sud	Oil Well	D43F13	Kardache Aïn Delion	81.14	1970	-1.41	79.73	ERESS
Oued Rhir Sud	Well	X00101225	Temelhat (Ain Bourouba D41 F63)		1950		82	ERESS
Oued Rhir Sud	Well	D34 F100	Taggourt A. Messaoud	69.53	1970	-1.67	67.86	ERESS
Oued Rhir Sud	Oil Well	D35F43	Nezla Aïn Sahara	70.19	1969	-1.9	68.29	ERESS
Oued Rhir Sud	Oil Well	F130	Zaouia Sidi Labed A. Sovalga	60.32	1969	3.49	63.81	ERESS
Oued Rhir Sud	Oil Well	F46	Zaouia Sidi Labed Ladgar Riri	60.56	1970	-1.15	59.41	ERESS
Oued Rhir Sud	Well	FR 5	Daoula	114.9	1971	-23.86	91.04	ERESS
Oued Rhir Sud	Well	FR 6	Mouïer Rebah	92.84	1971	-14	78.84	ERESS
Oued Rhir Sud	Group	11					82	ERESS
Oued Rhir Sud	Group	13					73	ERESS
Oued Rhir Sud	Group	16					66.9	ERESS
Oued Rhir Sud	Group	18					60	ERESS
Oued Rhir Sud	Well	I01100439	Hassi Amrane	121.1	1959	-16.1	105	ERESS
Souf	Artes. Well	H01100466	Reguiba 1	70	1962	15	85	ANRH
Souf	Well	H01200016	El Oued	80.35	1956	2.4	82.75	ERESS

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Souf	Well	H01200032	Tiksebt	76.14	1967	1.68	77.82	ERESS
Souf	Artes. Well	H01100004	Ghamra Tala Soviétique	60.77	1970	1.4	62.17	ERESS
Souf	Well	H01100465	Rhamra	57.03	1962	12.5	69.53	ERESS
Souf	Well	H01200034	Zgoum Behima	64.54	1967	7.68	68.84	ERESS
Souf	Artes. Well	H01100104	Sif El Menadi	-21.97	1953	66	40.03	ERESS
Souf	Well	H01100166	Reguiba	54.68	1962	15	69.68	ERESS
Souf	Well	H01200023	Amiche	92.65	1961	-10	82.65	ERESS
Souf	Well	H01100413	Guemar	65.38	1957	7	72.38	ERESS
Souf	Well	H01200021	Debila	61.16	1960	11	72.16	ERESS
Souf	Well	H01200038	Sidi Aoun	54.7	1970	12.05	66.75	ERESS
Tidikelt	Well	L01200011	Azel Cpa 1	246	1959	-78	168	ANRH
Tidikelt	Well	L01100009	Rhourd Nous Pazo Rw	251	1967	-77	174	ANRH
Tidikelt	Well	L01200010	Rhourd Chouf 1	236	1962	-68	168	ANRH
Tidikelt	Well	M01100001	Hamra Hri Cpa	284	1956	-100	184	ANRH
Tidikelt	Well	M01100004	Hassi Ramdane Ht2	310	1958	-111	199	ANRH
Tidikelt	Well	M01100008	Azel Sud 101	262	1968	-88	174	ANRH
Tidikelt	Well	M01100021	Mkratta Mk 1 Cpa	310	1957	-106	204	ANRH
Tidikelt	Well	N01500002	Terminal Creps 102	550	1958	-160	390	ANRH
Tidikelt	Well	L01100001	Tartrat	230.73	1958	-69	161.73	ERESS
Tidikelt	Well	L01100003	Hassi Tartrat	228	1958	-64.6	163.4	ERESS
Tidikelt	Oil Well	MF 101	El Mourfag	232.6	1963	-73	159.6	ERESS

Annex 2 Table 2 – Reference piezometry in the CT aquifer n Tunisia

Zone	Type of equipment	Data base class number	Well denomination	Altitude in m	Measure ment year	SL/GL	Altitude piezo.level	Origin of data
KEBILI	Well	02051035	Ain Taouergha 2	27.22	1955	9.7	36.92	ERESS
KEBILI	Well	P6	Bazma Est	57.7	1970	2.98	60.68	ERESS
KEBILI	Well	05716005	Ben Zitoun	31.4	1951	38.59	69.99	ERESS
KEBILI	Well	P2	Djemna Est	64.00	1971	1.4	65.40	ERESS
KEBILI	Well	00030025	Douz 2b	65.12	1952	12.57	77.69	ERESS
KEBILI	Well	05484005	El Faouar 2	49.6	1949	19.43	69.03	ERESS
KEBILI	Well	05754005	Grad	51.00	1951	20.9	71.90	ERESS
KEBILI	Well	P5	Kebili N.	48.35	1970	-2.81	45.54	ERESS
KEBILI	Well	06070005	Oued Tarfa	92.00	1953	-17.3	74.70	ERESS
KEBILI	Well	09347005	Oum Soumaa 1	36.32	1968	0.04	36.36	ERESS
KEBILI	Well	P3	Piézomètre Darjine 1	19.2	1971	43.12	62.32	ERESS
KEBILI	Well	P1	Pz Damrana (Douz Est)	74.95	1970	-6.00	68.95	ERESS
KEBILI	Well	06756005	Ras El Aïn 1	41.94	1958	8.46	50.40	ERESS
KEBILI	Well	05713005	Scast 4	41.00	1949	26.00	67.00	ERESS
KEBILI	Well	12320005	Stil 1	45.46	1969	20.58	66.04	ERESS
KEBILI	Well	10199005	Zaafrane 2	39.5	1969	30.8	70.30	ERESS
KEBILI	Well	09632005	BOU ABDALLAH 1	39.67	1968	-2.58	37.09	ARMINES-ENIT
KEBILI	Well	09653005	Bou Abdallah 2	45.90	1968	-8.20	37.70	ARMINES-ENIT
KEBILI	Well	12300005	Chott Salhia 1(Stil 1)	45.46	1969	19.84	65.30	ARMINES-ENIT
KEBILI	Well	05193005	DAR KOUSKOUSS 1	53.3	1950	-10.00	43.30	ARMINES-ENIT
KEBILI	Well	05263005	DOUZ 2	68.09	1950	12.51	80.60	ARMINES-ENIT
KEBILI	Well	06999005	DOUZE SONEDE		1959		68.60	ARMINES-ENIT
KEBILI	Well	05755005	Ksar Tabeul	50.56	1951	-6.16	44.40	ARMINES-ENIT
KEBILI	Well	09631005	MANSOURA	35.5	1969	11	46.5	ARMINES-ENIT
KEBILI	Well	09617005	Negga 4	24.67	1969	29.03	53.70	ARMINES-ENIT
KEBILI	Well	09616005	OUM SOMAA 2	32.37	1968	-0.74	31.63	DRE-1981
KEBILI	Well	09964005	Oum Soumaa 3	35.8	1969	0.48	36.28	DRE-1981
KEBILI	Well	09654005	RABTA 2	32.27	1968	14.20	46.47	DRE-1981
KEBILI	Well	10226005	Rahmat 3	46.70	1969	11.5	58.20	DRE-1981
KEBILI	Well	05585005	Telmine 2	26.54	1948	23.70	50.24	DRE-1981
KEBILI	Well	01558005	TENKITA 2	48	1937	**-9**	**39**	DRE-1981
KEBILI	Artes. Well	00008005	Bechelli	32.67	1935	38.00	70.67	ERESS
KEBILI	Artes. Well	07630005	Chott Tibni (Sabria)	47.59	1970	26.42	74.01	ERESS
KEBILI	Artes. Well	05571005	El Faouar 1	50.14	1949	19.13	69.27	ERESS
KEBILI	Artes. Well	00073025	Guettaia 2	28.91	1951	33.34	62.25	ERESS
KEBILI	Artes. Well	05894005	Klebia	36.83	1952	33.25	70.08	ERESS
KEBILI	Artes. Well	06470005	Methouria 1	54.00	1955	15.2	69.20	ERESS
KEBILI	Artes. Well	05570005	Negga 3	21.00	1950	34.3	55.30	ERESS
KEBILI	Artes. Well	05692005	Rahmat 2	46.73	1951	15.62	62.35	ERESS
KEBILI	Artes. Well	05840005	Rhelissia 1	62.93	1952	10.28	73.21	ERESS
KEBILI	Artes. Well	06689005	Rhidma 1	42.08	1957	28.6	70.68	ERESS
KEBILI	Artes. Well	05956005	Sidi Messaid 2	45.89	1952	16.6	62.49	ERESS
KEBILI	Artes. Well	05650005	Tembib 2	24.07	1950	23.4	47.47	ERESS
KEBILI	Artes. Well	10195005	Tembib 3	23.78	1969	21.8	45.58	ERESS
KEBILI	Artes. Well	05356005	Zaafrane 1	41.7	1948	31.7	73.40	ERESS
KEBILI	Artes. Well	06906005	Zarsine 2	27.54	1959	42.7	70.24	ERESS
KEBILI	Artes. Well	00031005	BAZMA 2	57.6	1912	1.30	53.61	DRE-1981
KEBILI	Artes. Well	05941005	BAZMA 3	44.17	1952	13.33	57.5	ARMINES-ENIT
KEBILI	Artes. Well	11334005	EL FAOUAR 3	48.57	1969	21.92	70.49	DRE-1981

Zone	Type of equipment	Data base class number	Well denomination	Altitude in m	Measure ment year	SL/GL	Altitude piezo.level	Origin of data
KEBILI	Artes. Well	00033005	EL GOLAA 1	56.38	1936	16.60	72.98	DRE-1981
KEBILI	Artes. Well	06481005	GUELIADA 1	32	1954	35.5	75.60	ARMINES-ENIT
KEBILI	Artes. Well	00073005	Guettaya 1		1934	33.34	62.25	DRE-1981
KEBILI	Artes. Well	00073025	Guettaya 2	28.91	1951	33.34	62.25	DRE-1981
KEBILI	Artes. Well	05894005	Klebia 1	36.83	1952	33.25	70.08	ARMINES-ENIT
KEBILI	Artes. Well	05956005	MESSAID 2	45.89	1952	16.60	62.49	ARMINES-ENIT
KEBILI	Artes. Well	06690005	Nouaiel 1	43.40	1957	29.15	72.55	ARMINES-ENIT
KEBILI	Artes. Well	00052005	RABTA 1	34.28	1923	0.80	35.77	DRE-1981
KEBILI	Artes. Well	10195005	TEMBIB 3	23.78	1969	21.8	45.58	ERESS
KEBILI	Artes. Well	00006005	TENKITA 1		1933	18.5	63.5	DRE-1981
KEBILI	Artes. Well	00038005	ZARCINE 1	24.87	1915	28	52.87	DRE-1981
KEBILI	Group	1					75	ERESS
KEBILI	Group	10					72	ERESS
KEBILI	Group	11					70	ERESS
KEBILI	Group	12					67	ERESS
KEBILI	Group	14					62	ERESS
KEBILI	Group	15					55.3	ERESS
KEBILI	Group	16					47.5	ERESS
KEBILI	Group	17					62.7	ERESS
KEBILI	Group	18					62.5	ERESS
KEBILI	Group	19					50	ERESS
KEBILI	Group	2					69	ERESS
KEBILI	Group	22					37.2	ERESS
KEBILI	Group	3					72	ERESS
KEBILI	Group	4					73	ERESS
KEBILI	Group	5					73.5	ERESS
KEBILI	Group	7					70.3	ERESS
KEBILI	Group	9					68	ERESS
TOZEUR	Well	10453005	Degache Nord 1	53.45	1969	-1.00	52.45	ERESS
TOZEUR	Well	05222005	El Hamma 3	37.76	1951	12.54	50.30	ERESS
TOZEUR	Well	08564005	El Hamma 6	31.27	1966	18.2	49.47	ERESS
TOZEUR	Well	06267005	El Louah (Chemsa 1)	34.8	1954	18.5	53.30	ERESS
TOZEUR	Well	06103005	Gouifla	41.2	1953	14.6	55.80	ERESS
TOZEUR	Well	06090005	Hazoua 1	40.57	1953	24.2	64.77	ERESS
TOZEUR	Well	05262005	Hebla 2	48.76	1947	8.9	57.66	ERESS
TOZEUR	Well	08262005	Nefta 1	49.51	1965	4.2	53.71	ERESS
TOZEUR	Well	05436005	Neftlaiet	45.79	1948	6.9	52.69	ERESS
TOZEUR	Well	05776005	O. Chakmou	30.05	1952	24.03	54.08	ERESS
TOZEUR	Well	08729005	Oued Koucha 1	44.21	1966	12.3	56.51	ERESS
TOZEUR	Well	00078005	Ouled Maged	51.5	1932	-0.2	51.30	ERESS
TOZEUR	Well	05487005	Rhergdaïa 1	50.74	1950	12.84	63.58	ERESS
TOZEUR	Well	12325005	Rhergdaïa 3	63.03	1970	-2.19	60.84	ERESS
TOZEUR	Well	09456005	Sebaa Biar 1	58.53	1970	-12.35	46.18	ERESS
TOZEUR	Well	05893005	Seddada 1	53.3	1952	3.95	57.25	ERESS
TOZEUR	Well	09342005	Seddada 2	64.19	1970	-16.04	48.15	ERESS
TOZEUR	Well	05289005	Tozeur Gare 1	49.19	1948	6.4	55.59	ERESS
TOZEUR	Well	08405005	Tozeur Gare 2	57.29	1967	-3.8	53.49	ERESS
TOZEUR	Well	08981005	AIN TORBA 1	54	1967		53.70	ARMINES-ENIT
TOZEUR	Well	00080005	CASTILIA 1	47	1941	10.10	57.10	ARMINES-ENIT
TOZEUR	Well	10453025	Degache Nord 2		1969		51.20	ARMINES-ENIT
TOZEUR	Well	00076005	EL HAMMA 2	36.7	1932	15.1	51.80	ARMINES-ENIT
TOZEUR	Well	06922005	El Hamma 4		1959		48.20	ARMINES-ENIT
TOZEUR	Well	08563005	EL HAMMA 5	36.6	1965	14.50	51.10	ARMINES-ENIT
TOZEUR	Well	08837005	El Hamma 7		1967		48.60	ARMINES-ENIT
TOZEUR	Well	08838005	El Hamma 8		1967		47.90	ARMINES-ENIT
TOZEUR	Well	08982005	El Manachi 2		1967		54.80	ARMINES-ENIT
TOZEUR	Well	05487005	Ghardgaya 1	50.74	1950	12.84	63.58	ARMINES-ENIT

Zone	Type of equipment	Data base class number	Well denomination	Altitude in m	Measure ment year	SL/GL	Altitude piezo.level	Origin of data
TOZEUR	Well	05660005	Ghardgaya2	84.79	1950	-20.80	64	ARMINES-ENIT
TOZEUR	Well	05262025	HELBA 3bis	54	1947	3.70	57.70	ARMINES-ENIT
TOZEUR	Well	09340005	Kriz 1		1967		46.80	ARMINES-ENIT
TOZEUR	Well	09627005	Kriz 2	70	1968	-29.80	40.20	ARMINES-ENIT
TOZEUR	Well	10452005	Kriz 3		1969		46.70	ARMINES-ENIT
TOZEUR	Well	00079005	NANACHIA 1	47	1932	9.3	56.30	ARMINES-ENIT
TOZEUR	Well	08262025	Nefta 2		1965		52	ARMINES-ENIT
TOZEUR	Well	08262035	Nefta 3		1966		53	ARMINES-ENIT
TOZEUR	Well	08729035	Oued Coucha 3	53.96	1967	0.14	54.10	ARMINES-ENIT
TOZEUR	Well	06103005	OUED Shili 1	41.2	1953	14.6	55.80	ARMINES-ENIT
TOZEUR	Well	08985005	PZ Tozeur gare 2	55.1	1967	-2.30	52.80	ARMINES-ENIT
TOZEUR	Well	12325005	Rherdgaya 3	63.03	1969	-1.63	61.40	ARMINES-ENIT
TOZEUR	Well	09456025	Sebaa Biar 2	58.46	1968	-10.46	48	ARMINES-ENIT
TOZEUR	Well	10192005	Sedada 3		1969		48.80	ARMINES-ENIT
TOZEUR	Well	12319005	Tozeur Ouest 1	91.56	1969	-39.36	52.20	Rapport inédit-DGRE
TOZEUR	Well	09959005	Zaafrana		1968		61.80	ARMINES-ENIT
TOZEUR	Artes. Well	13351005	Hazoua 2	39.7	1970	22.2	61.90	ERESS
TOZEUR	Group	13					65	ERESS
TOZEUR	Group	20					55.5	ERESS
TOZEUR	Group	21					63.6	ERESS
TOZEUR	Group	24					55.5	ERESS
TOZEUR	Group	25					54	ERESS
TOZEUR	Group	26					52.5	ERESS
TOZEUR	Group	27					57.3	ERESS
TOZEUR	Group	30					50.2	ERESS
TOZEUR	Group	31					49	ERESS
TOZEUR	Group	33					54.5	ERESS
TOZEUR	Group	34					56	ERESS

Annex 2 Table 3 – Reference piezometry of the Complexe Terminal aquifer in Libya

Zone	Data base class number	Altitude in m	Measurement year	SL/GL	Altitude piezo.level	Origin of data
Al Jufrah	J3	320	1970	8	328	Geomath-1994
Al Jufrah	PZ3	320	1970	9	329	Geomath-1994
Al Jufrah	PZ4	298	1970	31	329	Geomath-1994
Al Jufrah	PZ5	300	1970	28	328	Geomath-1994
Bou Njaïm	C 40-3	426	1959	-146	280	Geomath-1994
Jabal Nafusah	1788/3/1	600		-232	368	Geomath-1994
Jabal Nafusah	1788/3/4	580		-79	501	Geomath-1994
Jabal Nafusah	NN 1	600		-90	510	Geomath-1994
Jabal Nafusah	X0500106	600	1960	-130	470	GWA
Jabal Nafusah	1/60	670		-18	652	Geomath-1994
Flanc Oriental	9-70	605		-300	305	Geomath-1994
Flanc Oriental	NN 2	580		-263	317	Geomath-1994
Flanc Oriental	X0500099	413.61	1964	-27.43	386.18	GWA
Ghadamis	X0500101	451.10	1964	-137.16	313.94	GWA
Ghadamis	X0500098	347.90	1964	-28.10	319.80	GWA
Ghadamis	C 1-40	347		-32	315	Geomath-1994
Ghadamis	C 26-47	604	1964	-107	497	Geomath-1994
Ghadamis	C 26-64	597	1965	-123	474	Geomath-1994
Ghadamis	F 1-90	450		-145	305	Geomath-1994
Ghadamis	WG 12	412.12		-43.12	369	Geomath-1994
Ghadamis	WG 18	479.07		-192.07	287	Geomath-1994
Ghadamis	WG 19	461.08		-120.08	341	Geomath-1994
Ghadamis	WG 20	542.27		-135.27	407	Geomath-1994
Gharyan	1888/1/2	800		-170	630	Geomath-1994
Gharyan	C 34-9	627	1960	-244	383	Geomath-1994
Gharyan	C 60-14	436	1963	-214	222	Geomath-1994
Gharyan	C 60-17	417	1964	-68	349	Geomath-1994
Gharyan	C 60-8	420	1961	-66	354	Geomath-1994
H. El Hamra	C 26-24	633	1960	-88	545	Geomath-1994
H. El Hamra	C 26-43	661	1963	-107	554	Geomath-1994
H. El Hamra	C 26-5	632	1958	-82	550	Geomath-1994
H. El Hamra	C 60-18	331	1964	-146	185	Geomath-1994
H. El Hamra	C 66-17	644	1961	-138	506	Geomath-1994
H. El Hamra	C 66-47	580	1961	-90	490	Geomath-1994
H. El Hamra	C 66-75	636	1962	-112	524	Geomath-1994
H. El Hamra	X0500030	616.30	1959	-62.48	553.82	GWA
H. El Hamra	X0500037	624.10	1959	-26.00	598.10	GWA
H. El Hamra	X0500048	623.00	1960	-58.00	565.00	GWA
H. El Hamra	X0500050	590.00	1960	-27.40	562.60	GWA
H. El Hamra	X0500052	631.80	1961	-61.00	570.80	GWA
H. El Hamra	X0500057	612.50	1961	-56.30	556.20	GWA
H. El Hamra	X0500062	623.10	1961	-54.90	568.20	GWA
H. El Hamra	X0500064	588.00	1961	-57.90	530.10	GWA
H. El Hamra	X0500070	623.60	1961	-117.40	506.20	GWA
H. El Hamra	X0500081	632.16	1958	-81.90	550.26	GWA
H. El Hamra	X0500088	636.12	1961	-60.65	575.47	GWA
H. El Hamra	X0500115	641.00	1962	-78.70	562.30	GWA
Sawfajjin	C 30-5	226	1960	-61	165	Geomath-1994
Sawfajjin	C 40-4	370	1960	-80	290	Geomath-1994
Sawfajjin	M 6-2	200		-170	30	Geomath-1994
SW Hamada	X0500075	550.00	1959	-170.68	379.32	GWA
SW Hamada	X0500076	568.90	1959	-171.00	397.90	GWA
SW Hamada	X0500091	642.21	1961	-160.20	482.01	GWA

2. Reference piezometry in the Continental Intercalaire aquifer

Annex 2 Table 4 – Reference piezometry of the Continental Intercalaire aquifer in Algeria

Zone	Data base class number	Well denomination	Altitude in m	Measurement year	SL/GL	Altitude piezo.level	Origin of data
Béchar	K00400005	Oued Namous	695	1955	-200	495	ERESS
El Borma	J01400002	El Guelta (Eg 102)	269.24	1966	34	303.24	ERESS
El Borma	J01400009	El Borma S 4	191.25	1971	120	311.25	ERESS
El Borma	J01400013	Hassi Keskessa 102	225	1968	90	315	ANRH
Ghardaia	I00900007	Guettara	366.16	1954	62	428.16	ERESS
Ghardaia	I00700009	Erg El Anngueur	738.5	1955	-257.5	481	ERESS
Ghardaia	I00700019	Erg El Anngueur	682	1957	-205	477	ERESS
Ghardaia	I00700020	Erg El Anngueur	707	1957	-247	460	ERESS
Ghardaia	J00800021	Noumerate Aerodrome	439.71	1957	1	440.71	ERESS
Ghardaia	J00800071	Erg El Anngueur Af 3	653	1958	-212	441	ERESS
Ghardaia	J00800067	Erg El Anngueur Ak 1	491.5	1958	-50	441.5	ERESS
Ghardaia	J00800020	Hassi Touil	389.58	1956	42.5	432.08	ERESS
Ghardaia	J00700008	Erg El Anngueur	550	1955	-95	455	ERESS
Ghardaia	J00600017	Erg El Anngueur	590	1955	-100	490	ERESS
Ghardaia	J00800001	Albien Hassi Fahl 1	375.53	1970	45.54	421.07	ERESS
Ghardaia	I00700003	Dakrlet El Ardjam	620	1954	-42.56	577.44	ANRH
Ghardaia	I00700018	Bel 1 H 1	630	1962	-158	472	ANRH
Ghardaia	I00800015	Ain Lebeau	499.27	1937	-55.27	444	ANRH
Ghardaia	I00800019	Del Ateuf 1 Ghardaia	452.72	1948	-11.10	441.62	ANRH
Ghardaia	I00800020	Beni Isguene	497	1949	-53	444	ANRH
Ghardaia	I00800021	F De Melika Ain Lehu	494.25	1948	-48	446.25	ANRH
Ghardaia	I00800022	Berriane Sn Repal	520	1952	-75	445	ANRH
Ghardaia	I00800024	Albien De Ben Ghanem	512.1	1956	-67.80	444.30	ANRH
Ghardaia	I00800025	Berriane 1	520	1952	-78.53	441.47	ANRH
Ghardaia	I00800027	Touzouz 1 Ghardaia	522.3	1957	-78.86	443.44	ANRH
Ghardaia	I00800030	N 7 Dit Bounoura 1	489.21	1957	-59.15	430.06	ANRH
Ghardaia	I00800031	Beni Isguene N 8	515	1958	-66.68	448.32	ANRH
Ghardaia	I00800034	Bou Haraoua	498.48	1959	-54	444.48	ANRH
Ghardaia	I00800101	Ain Lebeau Gharda N	501	1958	-57	444	ANRH
Ghardaia	I00800104	Beni Isguene 2	495.7	1960	-51.70	444.00	ANRH
Ghardaia	I00800112	Melika 3 Ghardaia	494	1969	-56.39	437.61	ANRH
Ghardaia	I00800114	El Ateuf 2 Ghardaia	464.33	1963	-25.40	438.93	ANRH
Ghardaia	I00800118	Daya Ben Dahoua 1	533.15	1965	-86.80	446.35	ANRH
Ghardaia	I00800119	Bellouh	535	1966	-91.80	443.20	ANRH
Ghardaia	I00800120	F Sovietique 20 Bouc	515.7	1966	-74.5	441.2	ANRH
Ghardaia	I00800121	Sonatrach Sp 3	492	1969	-55.58	436.42	ANRH
Ghardaia	I00900005	Guerrara	315	1950	107.5	422.5	ANRH
Ghardaia	I00900017	Guerrara 2	315	1960	114.5	429.5	ANRH
Ghardaia	I00900050	Guerrara 2 Foussaha	293	1965	108	401	ANRH
Ghardaia	J00800015	Metlili 1	490	1949	-46.5	443.5	ANRH
Ghardaia	J00800019	Oued Seb-Seb	600	1956	-126	474	ANRH
Ghardaia	J00800023	Hf Erg El Anngueur	496	1956	245	741	ANRH
Ghardaia	J00800070	Guemgouma 4	515	1966	-72.90	442.10	ANRH
Ghardaia	J00800092	Ait El Cheir 13	424	1900	6	430	ANRH
Ghardaia	J00900011	Zelfana N°3	355.09	1954	70	425.095	ANRH
Goléa	K00800031	Hassi Allal	477	1961	-42.2	434.8	ERESS
Goléa	K00800015	Gouiret Moussa	380.96	1958	33	413.96	ERESS
Goléa	K00800016	Daïet Khanem	361.12	1957	46	407.12	ERESS
Goléa	L00700066	Hassi Maroket	341.33	1964	48.5	389.83	ERESS
Goléa	L00600019	Hassi Inkhal	412.63	1969	-27.2	385.43	ERESS
Goléa	X00300019	Puits N°8 De La Rn 51	405.11	1969	-28.15	376.96	ERESS
Goléa	X00300009	Oued Saret (Os 1)	463.7	1964	-82.55	381.15	ERESS
Goléa	M00700020	Oumchen	543.37	1970	-170.62	372.75	ERESS
Goléa	L00700073	Gouret Louazoua 1	403.06	1969	-14.85	388.21	ERESS
Goléa	J00600021	H1 H1	540	1963	-80	460	ANRH
Goléa	K00700030	Puits De Foucault 19	397.03	1953	-6.41	390.625	ANRH
Goléa	K00700056	Hadjaj 01	415	1900	-12	403	ANRH
Goléa	K00700057	Hadjaj 02	415	1900	-8	407	ANRH
Goléa	K00700058	Hadjajo 03	415	1900	-14	401	ANRH
Goléa	L00700003	Hadj Halima N 16	396.32	1948	4.33	400.65	ANRH
Goléa	L00700038	Belaid Nouveau N 17	396.43	1950	2.96	399.39	ANRH
Goléa	L00700041	Hassi El Gara	381	1950	23	404	ANRH
Goléa	L00700052	Douar El Kcheb N 20	386.5	1954	14.80	401.3	ANRH
Goléa	L00700054	Moul Khandouss N 21	394.5	1954	8.10	402.6	ANRH
Goléa	L00700055	Aviation N 22	391.054	1955	10.5	401.554	ANRH
Goléa	L00700056	Taghit 2	398.1	1968	1.95	400.05	RAB
Goléa	L00700060	Ben Eddin N 26	399.7	1962	7.65	407.35	ANRH

Zone	Data base class number	Well denomination	Altitude in m	Measurement year	SL/GL	Altitude piezo.level	Origin of data
Goléa	L00700062	Tin Bouzid N°24 Nouv	395	1958	6	401	ANRH
Goléa	L00700063	Badriane 2 N 25	390	1958	2	392	ANRH
Goléa	L00700068	Kef N 27	419.5	1962	-16.20	403.30	ANRH
Gourrara	M00500044	Puits Du Bordj	379	1969	-23.3	355.7	ERESS
Gourrara	M00600001	Hassi Tissemt	369	1969	-7.1	361.9	ERESS
Gourrara	M00600004	Kerboub 1	377.94	1970	-14.2	363.74	ERESS
Gourrara	X00300018	Puits N°6 De La Rn 51	385.88	1969	-23.68	362.2	ERESS
Gourrara	X00300017	Hassi Houf	350.57	1969	-6.86	343.71	ERESS
Gourrara	M00400297	Timimoun 4	321.46	1970	-35	286.46	ERESS
Gourrara	X00300014	Puits N°1 De La Rn 51	323.55	1969	-5.86	317.69	ERESS
Gourrara	X00300016	Hassi Debout	328.51	1969	-1.45	327.06	ERESS
Gourrara	X00300015	Hassi Taragat	336.59	1969	-2.15	334.44	ERESS
Gourrara	M00400112	Timimoun 2	313.5	1970	-34	279.5	ERESS
Gourrara	X00300012	Hassi Cross	324.91	1969	-17.48	307.43	ERESS
Gourrara	M00500045	Hassi Moussa	318.27	1970	-16	302.27	ERESS
Gourrara	X00300011	Timimoun 6	311.33	1970	-30.7	280.63	ERESS
Gourrara	X00300008	Hassi Rhaba	300	1969	-4.9	295.1	ERESS
Gourrara	N00400175	Tiberrhamine 4	310.4	1970	-10.01	300.39	ERESS
Gourrara	X00300002	Tiberrhamine 1	308.5	1970	-11.56	296.94	ERESS
Gourrara	X00300004	Tiberrahamine 5b (Th 5b)	327.2	1970	-26.92	300.28	ERESS
Gourrara	X00300005	Tiberrahamine 6 (Th 6)	325.03	1970	-25.7	299.33	ERESS
Gourrara	X03000017	Hassi Système	264.9	1969	-6.8	258.1	ERESS
Gourrara	X03000016	Oufrane	290	1970	-10.54	279.46	ERESS
Hassi Messaoud	K01200001	Rhourde El Baguel	151	1969	182	333	ERESS
Hassi Messaoud	L01100011	Gassi Touil (Gt 101)	200	1962	150	350	ANRH
Hassi Messaoud	M01100006	Rhourde Nouss Rn 5	269.64	1963	70	339.64	ERESS
Hassi Messaoud	J01100008	Hassi.M Snrepal Mdh1	165	1957	210	375	ANRH
Hassi Messaoud	J01100037	Mdh 102 Md8	140	1958	208	348	ANRH
Hassi Messaoud	J01100093	H.I Up.I Hassi-Messa	167.5	1963	198	365.5	ANRH
Hassi Messaoud	J01100094	Hassi Messaoud Mdh 1	144	1963	223	367	ANRH
Hassi Messaoud	J01100116	Omph 732	138	1900	80		ANRH
Hassi Messaoud	J01100136	Mdh 113	150	1900	200	350	ANRH
Hassi Messaoud	K01200007	Sinclair Rb 7	151	1966	200	351	ANRH
Hassi Messaoud	K01200010	Brides 2	186	1964	28.40	214.4	ERESS
Laghouat	I00800111	Tilrempt	766.8	1958	-308	458.8	ERESS
Laghouat	I00800124	Hassi R'mel Hr 102	764.25	1958	-315	449.25	ERESS
Ouargla	J01000551	Ouargla 3	130	1956	269.5	399.5	ERESS
Ouargla	J01000447	Ouargla 1	138.3	1956	266.7	405	ERESS
Ouargla	J01000480	Ouargla 2	158	1956	245	403	ERESS
Ouargla	K00900004	Daïet Remt (Dr 101)	237.65	1960	186.9	424.55	ERESS
Ouargla	K00900007	Hassi Berkane Hba 10	240	1961	180	420	ANRH
Ouargla	K01500001	Mg 1	360	1958	48	408	ANRH
Oued Rhir nord	H01000042	M'rara	113.95	1956		362	ERESS
Oued Rhir sud	H01100408	Tamerna	68.93	1956	289	357.93	ERESS
Oued Rhir Sud	I01100437	Sidi Slimane	64.15	1962	330	394.15	ERESS
Oued Rhir Sud	I01100228	Tamelhat	85	1956		362	ERESS
Oued Rhir sud	I01100436	Sidi Mahdi	92.97	1959	265	357.97	ERESS
Ouled Djellal	G00900109	Sidi Khaled	221	1956	160	381	ERESS
Souf	H01200036	Hassi Bouras	25	1971	212	237	ERESS
Souf	H01200037	Bou Aroua	45.9	1970	222	267.9	ERESS
Tidikelt	P00500011	Aoulef Ocrs	290.75	1961	-24.4	266.35	ERESS
Tidikelt	P00600013	Tit 3	272.8	1959	4.2	277	ERESS
Tidikelt	P00400090	Reggane 5	278.72	1971	-23.52	255.2	ERESS
Tidikelt	P00400012	Reggane N°3	282	1958	-64	218	ANRH
Tidikelt	O00700044	In Salah 1 (Is 101)	289.3	1956	-8	281.3	ERESS
Tidikelt	O00500053	Aoulef Larbi	290	1952	-19	271	ANRH
Tidikelt	P00400009	Reggane 1	283	1958	-54.5	228.5	ANRH
Tidikelt	P00400010	Reggane N°2	221	1958	-19.75	201.25	ANRH
Tidikelt	P00400013	Reggane N°4	281	1958	-67	214	ANRH
Tidikelt	P00400018	Reggane N°6	222	1959	-28	194	ANRH
Tidikelt	P00400021	Hammoudia 1	220	1959	-22	198	ANRH
Tidikelt	P00400022	Azrafil	230.5	1957	-7.5	223	ANRH
Tidikelt	P00400068	Taourirt 1	230	1959	-18.5	211.5	ANRH
Tidikelt	P00400091	Reggane N°7	281	1960	-72.05	208.95	ANRH
Tidikelt	P00400092	Reggane N°8	281	1959	-66.65	214.35	ANRH
Tidikelt	P00400093	Reggane N°9	282	1960	-73.60	208.40	ANRH
Tidikelt	P00400094	Reggane N°10	280	1960	-71.20	208.80	ANRH
Tidikelt	P00400095	Hamoudia 2	220	1960	-24.40	195.6	ANRH
Tidikelt	P00600012	Tit Tadoura N°2	300	1958	-24.64	275.36	ANRH
Tidikelt	L01400001	Messouda	310	1959	25	335	ERESS
Tidikelt	M01400002	Station 2 Cep	475	1959	-130	345	ERESS
Tidikelt	M01300002	Odoumé 1b	292.95	1958	60	352.95	ERESS
Tidikelt	M01100003	Hamra	284.25	1959	45	329.25	ERESS

Zone	Data base class number	Well denomination	Altitude in m	Measurement year	SL/GL	Altitude piezo.level	Origin of data
Tidikelt	M01400005	Tamadanet	626.28	1959	-273.75	352.53	ERESS
Tidikelt	M01200001	Tamendjelt	341.8	1958	16	357.8	ERESS
Tidikelt	N01300001	Tesselit	508.9	1957	-155	353.9	ERESS
Tidikelt	N01200001	Hassi Tabankort	350.4	1958	24	374.4	ERESS
Tidikelt	N01400002	Ohanet 101	454	1955	-100	354	ERESS
Tidikelt	N01100020	Oued Ameskiki	305	1958	37	342	ERESS
Tidikelt	N01400003	Edjelé	555	1957	-182	373	ERESS
Tidikelt	N01500001	Alrar Creps 101	640	1956	-230	410	ERESS
Tidikelt	N01300002	Isn 101 Creps	480	1959	-101.7	378.3	ERESS
Tidikelt	N01100021	Zaouia El Khala (Fort Flatters)	253	1958	16	269	ERESS
Tidikelt	M01400003	Station De Pompage 2	475	1959	-130	345	ERESS
Tidikelt	M01400004	Lassallette 130	575	1964	-222	353	ANRH
Tidikelt	N01100018	Zaouia De F.Flatters	165	1957	-12.60	152.4	ANRH
Tidikelt	N01200004	Daiet Ouan Tibokati	489.95	1960	-119.5	370.45	ANRH
Tidikelt	N01200012	Tin Fouye Tab.Tft 60	430	1968	-72.5	357.5	ANRH
Tidikelt	N01400026	Edjel Tp 2	555	1958	-182.97	372.03	ANRH
Tidikelt	M00800002	Miribel	405	1969	-38	367	ERESS
Tidikelt	N00900006	Beguira 1	425.03	1955	-46.57	378.46	ANRH
Tidikelt	N00700003	Timeldjane	586.86	1965	-228.79	358.07	ERESS
Tidikelt	N00700004	El Hassene	467.88	1964	-121.5	346.38	ERESS
Tidikelt	O00700055	Foggaret Ezzoua 6	270	1959	2.7	272.7	ERESS
Tidikelt	O00600022	In Rhar 2	287	1960	-18.2	268.8	ERESS
Touat	X00300001	Hi En Nouss	254.85	1970	-4.13	250.72	ERESS
Touat	X03000018	Bh 2	297	1969	-15.95	281.05	ERESS
Touat	N00400478	Hi Meraguene	262	1969	-3.3	258.7	ERESS
Touat	X03000019	Adrar 2	270.25	1970	-5.57	264.68	ERESS
Touat	X03000020	Hassi Tamentit	243.95	1970	-11.1	232.85	ERESS
Touat	X03000021	Hassi Borj Si Youcef	247.6	1970	-9.73	237.87	ERESS
Touat	O00400139	Zaouiet Kounta	234.87	1960	-16.4	218.47	ANRH
Touat	X03000022	Tidikelt (Tk 105)	295	1970	-28.7	266.3	ERESS
Touat	X03000015	Hassi Sbaa	261.4	1969	-3.3	258	ERESS

Annex 2 Table 5 – Reference piezometry of the Continental Intercalaire aquifer in Tunisia

Zone	Data base class number	Well denomination	Altitude in m	Measurement year	SL/GL	Altitude piezo.level	Origin of data
Chott Fedjej	05664005	Chott Fedjej 1	33.55	1956	123.84	157.30	ERESS
Chott Fedjej	05950005	Chott Fedjej 2	30.95	1956	140.84	171.79	ERESS
Chott Fedjej	05918005	Om El Fareth 1	48.25	1953	66.21	114.46	DRE-1981
Chott Fedjej	07305005	SEFTIMI 1	54	1962	84.33	133.09	DRE-1981
Chott Fedjej	08429005	Chott Fedjej 3	31.02	1966	109	140.02	RAB
Extrème Sud	06937005	Djebel Melab 1 (MA1)	245.00	1959	-45.1	199.90	ERESS
Extrème Sud	08928005	El Benia	425.00	1968	-90.00	335.00	ERESS
Extrème Sud	EG 1	Aco El Gouna 1	80.9	1962	161.00	241.90	ERESS
Extrème Sud	05654005	Borj Bourguiba 1	333	1950	-20.8	312.20	ERESS
Extrème Sud	06368005	Oued Abdallah 2	386.00	1964	-79.80	306.20	ERESS
Extrème Sud	X00700226	Djebel Sanghar a (Sna)	355	1957	-40.00	315.00	DGRE
Extrème Sud	06511005	Lorzot	350	1955	-33.40	316.80	DGRE
Extrème Sud	EBA 4	El Borma A4	257.31	1964	60.89	318.20	MAMOU, 1999
Extrème Sud	EBA 7	El Borma A7	232.28	1969	87.22	319.50	MAMOU, 1999
Extrème Sud	ZTA 1	Zemlet Tarfara	258	1970	58.00	316.00	ERESS
Extrème Sud	Sba 1	Garaet Ben Sabeur	282	1956	30.00	312.00	DGRE
Extrème Sud	EZA 1	Em Zab	254	1970	63.00	317.00	ERESS
Extrème Sud	07000005	SP3(Trapsa)	368.00	1956	-45.00	322.00	ERESS
Extrème Sud	ECH A 1	Ech Chouech	267	1970	65.00	332.00	Geomath, 1994
Extrème Sud	BZA 1	Bir Zobbas	268.3	1966	38.5	306.80	DGRE
Extrème Sud	X00700211	Garaet Tibourt T.E.1	354	1964	37	391	DGRE
Extrème Sud	X00700217	El Borma A6	242.04	1967	60.26	302.30	MAMOU, 1999
Extrème Sud	X00700221	El Borma A2	270.06	1965	37.94	308	MAMOU, 1999
Extrème Sud	X00700223	El Borma A1	254.45	1963	56.85	311.30	MAMOU, 1999
Extrème Sud	X00700229	Makhrouga	410	1961	-95	315	DGRE
Extrème Sud	EB A-5	El Borma A5	230.95	1966	80.65	311.60	MAMOU, 1999
Kébili	09346005	MENCHIA	33.21	1967	62	95.21	DRE-1981
Ksar Ghilane	DKA 1	Dekhanis	195.95	1969	105	300.95	ERESS
Ksar Ghilane	SP 4 N	Station de pompage Trapsa	295	1963	12.15	307.15	ERESS
Ksar Ghilane	05717005	Ksar Ghilane	220.00	1951	90.00	310.00	ERESS

Annex 2 Table 6 – Reference piezometry of the Continental Intercalaire aquifer in Libya

Zone	Data base class number	Well denomination	Altitude in m	Measurement year	SL/GL	Altitude piezo.level	Origin of data
Abu Njaim	K-1		165		-13.4	151.60	GEFLI
Abu Njaim	K-2		145.44		-0.5	144.94	GEFLI
Abu Njaim	K-7		75.03	1975	71.59	146.62	GEFLI
Abu Njaim	K-8		112.67	1975	49.33	162	GEFLI
Al Jufrah (Waddan)	19/79		295		42	337.00	GWA
Al Jufrah (Waddan)	20/79		295		37	332.00	GWA
Al Jufrah	J-18		373	1976	34.15	339	SASS
Al Khums	C 23-5		98	1970	-20	78.00	GEOMATH
Al Khums	T22-76		401.75	1976	-90.00	311.75	BRL 1997
Al Khums	T95-82		631.75	1982	-280.00	351.75	BRL 1997
Buwayrat al Hasun	K4		13.81	1977	82.40	96.21	GEFLI
Buwayrat al Hasun	WH I		34.83	1976	63.40	98.23	GEFLI
Buwayrat al Hasun	WH2		24	1977	58.35	82.00	SASS
Derj	T11-81		597.74	1978	-282.78	314.96	BRL 1997
Derj	WG 16		425.42	1981	-104.80	320.62	BRL 1997
Derj	WG9	(1232) (MP.0.57)	539.04	1981	-220.50	318.54	BRL, 1997
Jabal Nafusah	Cabao3		651.69	1978	-289.70	361.99	BRL 1997
Jabal Nafusah	T125-81		604.66	1981	-300.50	304.16	BRL 1997
Jabal Nafusah	T126-81		618.00	1981	-314.00	304.00	BRL 1997
Jabal Nafusah	T39-78		622.00	1978	-323.20	298.80	BRL 1997
Jabal Nafusah	T5-78		698.00	1978	-342.80	355.20	BRL 1997
Jabal Nafusah	5/78		698.00	1970	-393	305.00	GEOMATH
Jabal Nafusah	183/80		605	1970	-315	290	GEOMATH
Jabal Nafusah	46/77		650	1970	-330	320	GEOMATH
Jabal Nafusah	47/77		630	1970	-304	326	GEOMATH
Jabal Nafusah	48/77		620	1970	-326	294	GEOMATH
J. Nafusah (Tarhuna)	104/76	Tariq al Abid	385	1977	-308	77	SASS
J. Nafusah (Tarhuna)	3/75	Sidi as Sid	390	1976	-321	69	SASS
J. Nafusah (Tarhuna)	164/76	Awlad Ali	250	1978	-188	62	SASS
J. Nafusah (Tarhuna)	106/76	Al Khadra	380	1977	-314	66	SASS
J. Nafusah (Tarhuna)	99/76	Mesellata (Qusbat)	280	1978	-214	66	SASS
J. Nafusah (Tarhuna)	67/76	Ababsa	170	1905	-110	60	SASS
J. Nafusah (Tarhuna)	79/76	Maatig	330	1976	-259	71	SASS
J. Nafusah (Tarhuna)	102/76	Shershariyah	348	1976	-275	73	SASS
J. Nafusah (Tarhuna)	105/76	Twil Suq	380	1977	-300	80	SASS
J. Nafusah (Tarhuna)	98/76	Qarim	180	1977	-123	57	SASS
J. Nafusah (Tarhuna)	302/76	Gararat	180	1978	-128	52	SASS
J. Nafusah (Tarhuna)	165/76	Awlad Youssef	400	1978	-314	86	SASS
Flanc Oriental	9 - 70		615	1970	-310	305.00	GEOMATH
Flanc Oriental	C 70-5		601	1970	-297	304.00	GEOMATH
Flanc Oriental	C 70-8		615	1970	-307	308.00	GEOMATH
Ghadamis	T110-76		490	1905	-100.20	389.80	BRL 1997
Ghadamis	T175-78		573.09	1978	-369.90	203.19	BRL 1997
Ghadamis	T203-80		331.57	1981	12.90	344.47	BRL 1997
Ghadamis	T276-77		324.99	1977	31.00	355.99	BRL 1997
Ghadamis	T277-77		341.49	1977	6.90	348.39	BRL 1997
Ghadamis	T35-75		573.22	1976	-260.60	312.62	BRL 1997
Ghadamis	T41-81		579.60	1981	-266.90	312.70	BRL 1997
Ghadamis	T96-76		430.94	1978	-100.20	330.74	BRL 1997
Ghadamis	WG 13		432.73	1970	-110	322.73	GEOMATH
Ghadamis	WG 22		325.48	1978	12.00	337.48	BRL 1997
Ghadamis	WG10		397.18	1975	-127.27	269.91	BRL 1997
Gharyan	51/77		750	1970	-353	397	GEOMATH
Hamadah	10/81		624	1970	-343	281	GWA
Hamadah	18 Z		465	1996	-113.64	351	SASS
Hamadah	19 Z		450	1996	-92.03	358	SASS
Hamadah	20 Z		470	1996	-150.46	320	SASS
Hamadah	3 Z		543	1996	-206.47	337	SASS
Hamadah	5 Z		470	1996	-124.21	346	SASS
Hamadah (Ash Shwayrif)	Shwarif		420		-150	270	SASS
Hamadah	WS-4		495		-236	259	SASS
Hamadah (Ash Shwayrif)	WS-6		420		-139	281	GWA
Hamadah (Ash Shwayrif)	WS-8		477.5	*	-200	278	GWA
Mizdah	219/76		590	1970	-304	286	GEOMATH
Mizdah	29/83		520	1970	-266	254	GEOMATH
Mizdah	WS-14		550	1970	-285	265	GEOMATH
Mizdah	130/77		610	1970	-313	297	GEOMATH
Mizdah	131/77		610	1970	-319	291	GEOMATH
Ninah	5/81		400		-73	327	GWA
Ninah	N9 (47/81		293.78	1983	42.00	335.78	SASS
Sufajjin	23/82		90	1978	-62.78	153	SASS
Sufajjin	3/83		51	1978	-89.45	140	SASS

Zone	Data base class number	Well denomination	Altitude in m	Measurement year	SL/GL	Altitude piezo.level	Origin of data
Sufajjin	35/85		210	1970	-35	175	GEOMATH
Sufajjin	5/82		186	1970	4	190	GEOMATH
Sufajjin	66/82		395	1982	-159	236	GWA
Sufajjin	7/79		229	1970	-14	215	GEOMATH
Sufajjin	B 2		204.51		-23.88	180.63	GEFLI
Sufajjin	B-3		188.55		-11.4	177.15	GEFLI
Sufajjin	K 12		104.44	1978	73.60	178.04	GEFLI
Sufajjin	K-10		86.05	1978	44.55	130.60	GEFLI
Sufajjin		MW-1284		1978		146	GWA
Sufajjin	NI (K-9)		295.78	1976	27.1	322.88	SASS
Sufajjin	NOR1		231.09		-42.76	188.33	GEFLI
Sufajjin	SIQ2		133	1978	65.86	199	SASS
Sufajjin	SIQM		125	1978	68.23	193	SASS
Sufajjin	SOF5		107.2	1978	73.60	180.80	GEFLI
Sufajjin		T/2B/0002	192	1987	-10.61	181	SASS
Sufajjin		T/2B/0003	187	1987	-26.48	161	SASS
Sufajjin		T/2B/0031	125	1985	36.64	162	SASS
Sufajjin	WS 2		209.4	1987	-30.40	179	SASS
Sufajjin - Mardum	41/84		11	1987	61.03	72.00	SASS
Sinawen	T64-78		434.76	1980	-117.90	316.86	BRL 1997
Suknah	W-1		410		-68	342	SASS
Zam Zam		T/2B/0010	87	1987	29.26	116	SASS
Zam Zam	WS 10		87	1977	32.51	120	SASS
Zam Zam	WS 21		46	1976	51.00	97	SASS
Zam Zam	ZZ 1		64.48	1972	70.00	134.48	GEFLI
Zam Zam	ZZ 2		30.85	1973	67.10	97.95	GEFLI
Zone Cotière	27/80		50	1980	16	65.90	GWA
Zone Cotière	P20		16.04		-1.04	15.00	GEFLI
Zone Cotière	P21		127.67		-60	67.67	GEFLI
Zone Cotière	T2-A		74.42		-54.16	20.26	GEFLI

ANNEX 3

TRANSMISSIVITY

ANNEX 3

1. Transmissivity of the Complexe Terminal aquifer

Annex 3 Table 1 - Transmissivity of the Complexe Terminal aquifer in Algeria

Zone	Data base class. number	Well denomination	Transmissivity in 10^{-3} m^2/s	Data origin
El Oued	I01300002	T 01 De La Société Esso	6	ERESS
Hassi Messaoud	K01100009	Fes 1-H1	3	ERESS
Hassi Messaoud	K01200002	Loudje 1 Cpa Ld1	15	ERESS
Hassi Messaoud	K01200004	Arb 1- El Arbi Du Cp	15	ERESS
Hassi Messaoud	K01200006	Rhourde Baguel Rb 10	1	ERESS
Ouargla	F01100576	Ain Cheikh D 41 F 69	15	ERESS
Ouargla	FR 1	Melah Ben Taïeb	10	ERESS
Ouargla	I01000007	Square Bresson 2	7	ERESS
Ouargla	I01100025	Baba Youcef D1 F111	15	ERESS
Ouargla	I01100447	Gueddich Gd1 Pts Eau	5	ERESS
Ouargla	J01000469	Carrière P80	20	ERESS
Ouargla	J01000475	Ol1	25	ERESS
Ouargla	J01000518	F Soviet Bouroubia	6	ERESS
Ouargla	J01000519	F Soviet A.Louise D4	4	ERESS
Ouargla	J01000522	Bamendil Ii Cofor	12	ERESS
Ouargla	J01000533	Garet Chemia D1 F113	4	ERESS
Ouargla	J01000625	Ain El Bour Di F 118	9	ERESS
Ouargla	J01000631	Sodexur Bahmid I D1	10	ERESS
Ouargla	J01000792	Outaja D1f116	10	ERESS
Ouargla	K01000012	Slassel Yaich Sly1	30	ERESS
Ouargla	D11F11	F.Périm. Bendabane Allia D11f11	25	ERESS
Oued Rhir Nord	G01100036	Ain Naga	0.50	ERESS
Oued Rhir Nord	G01100043	P. Berland Ghegga	3	ERESS
Oued Rhir Nord	G01100067	Ain Naga 4	0.2	ERESS
Oued Rhir Nord	H01000030		20	ERESS
Oued Rhir Nord	H01000043	Duquenoy N°5 A M'ra	20	ERESS
Oued Rhir Nord	H01000044	Chaab El Meguedem Sp	1.5	ERESS
Oued Rhir Nord	H01000047	Hassi Gouira	15	ERESS
Oued Rhir Nord	H01000077	Ain Draa El Bar F 9	25	ERESS
Oued Rhir Nord	H01100027	Tarfait Salah Meghai	24	ERESS
Oued Rhir Nord	H01100104	Sif El Menadi	4.8	ERESS
Oued Rhir Nord	H01100249	Ain Bertin	5	ERESS
Oued Rhir Nord	H01100373	Sebela Metay 1	2	ERESS
Oued Rhir Nord	H01100411	Bouhour	1.9	ERESS
Oued Rhir Nord	H01100472	Ain Sousou	3.9	ERESS
Oued Rhir Nord	X03000007	Tolga N°Demrh 162	1.5	SCET, 1972
Oued Rhir Nord	X03000008	Tolga N°Demrh 283	2	SCET, 1972
Oued Rhir Nord	X03000009	Tolga N°Demrh 295	5.6	SCET, 1972
Oued Rhir Nord	X03000010	Tolga N°Demrh 334	7.4	SCET, 1972
Oued Rhir Nord	X03000011	Tolga N°Demrh 339	4.8	SCET, 1972
Oued Rhir Nord	X03000012	Tolga N°Demrh 341	4	SCET, 1972
Oued Rhir Nord	X03000013	Tolga N°Demrh 342	4.3	SCET, 1972
Oued Rhir Nord	X03000014	Tolga N°Demrh 344	1.7	SCET, 1972
Oued Rhir Sud	H01100178	Jardin Cmmunal	1.2	ERESS
Oued Rhir Sud	H01100340	Ain Debdaba	10	ERESS

Zone	Data base class. number	Well denomination	Transmissivity in 10-3 m2/s	Data origin
Oued Rhir Sud	H01100413	Guemar 1	1.3	ERESS
Oued Rhir Sud	H01100502	Ain Zaoualia	130	ERESS
Oued Rhir Sud	H01100575	Ain El Khadra D 41 F 68	5	ERESS
Oued Rhir Sud	H01200015	El Khobna	1.1	ERESS
Oued Rhir Sud	H01200021	Debila N1	1.4	ERESS
Oued Rhir Sud	H01200023	Amiche Robah 1	2	ERESS
Oued Rhir Sud	H01200032	Tiksebt El Oued Aep	9.6	ERESS
Oued Rhir Sud	H01200035	Magrane Souf	10	ERESS
Oued Rhir Sud	H01200038	Sahane Berry N 1	25	ERESS
Oued Rhir Sud	I01100011	Puits Rannou D36f61	40	ERESS
Oued Rhir Sud	I01100012	Zaouia Si Labed	7	ERESS
Oued Rhir Sud	I01100014	A.Lamari A Toug D36f	10	ERESS
Oued Rhir Sud	I01100021	Ain Naeglen	17	ERESS
Oued Rhir Sud	I01100080	Ain Chotte Touggourt	7	ERESS
Oued Rhir Sud	I01100206	Puits Devicq 2 D24f2	1.6	ERESS
Oued Rhir Sud	I01100207	Ain Guemmou D33f77	6	ERESS
Oued Rhir Sud	I01100223	Gonord Touggourt D36	7.3	ERESS
Oued Rhir Sud	I01100225	Ain Aouf Temacine D3	10	ERESS
Oued Rhir Sud	I01100226	Ain Midouna D28f10	10	ERESS
Oued Rhir Sud	I01100227	Ain Chaouche 2 D32f1	8	ERESS
Oued Rhir Sud	I01100448	Taibet	4.5	ERESS
Oued Rhir Sud	X00101188	Ain Madjoudja Ahmed D33 F94	4	ERESS
Oued Rhir Sud	D39 F44	Ain Ourirh D39 F44	15	ERESS
Oued Rhir Sud	FR 5	Daoula	3.4	ERESS
Oued Rhir Sud	D34 F117	A.Trabelssi El Arbi D34 F117	10	ERESS
Oued Rhir Sud	D33 F93	Ain Chaouche El Meki D33 F93	7	ERESS
Oued Rhir Sud	D33 F92	Ain Benhmida Ali D33 F92	7	ERESS
Oued Rhir Sud	D33 F94	Ain Madjoudja Ahmed D33 F94	6	ERESS
Oued Rhir Sud	D33 90	Ain Bourass D33 90	15	ERESS
Oued Rhir Sud	D32 F140	Ain Hadri Sayah D32 F140	7	ERESS
Oued Rhir Sud	H01100484	Tamerna Guedima A. Chemorah	1.3	ERESS
Oued Rhir Sud	H01100166	Reguiba	15	ERESS
Oued Rhir Sud	H01100465	Ghamra	10	ERESS

Annex 3 Table 2 - Transmissivity of the Complexe Terminal aquifer in Tunisia

Zone	Data base class. number	Well denomination	Transmissivity in 10^{-3} m^2/s	Data origin
Djerid	06090005	Hezoua 1	6	ERESS
Djerid	06922005	El Hamma 4	10	ERESS
Djerid	08262025	Nefta 2	34	ERESS
Djerid	08262035	Nefta 3	10	ERESS
Djerid	08564005	El Hamma 6	50	ERESS
Djerid	08838005	El Hamma 8	30	ERESS
Djerid	12668005	Jhim 1	4	ERESS
Djerid	13351005	Hezoua 2	8	ERESS
Djerid	13443005	Nefta 4	40	ERESS
Djerid	05660005	Ghardgaya2	1	ERESS
Djerid	00080025	CASTILIA 2	8	ERESS
Djerid	00078005	Ouled Majed	6	ERESS
Djerid	00076005	EL HAMMA 2	10	ERESS
Djerid	09455035	ZAOUIT LARAB 3	15	ERESS
Djerid	09456005	Sebaa Biar 1	4	ERESS
Djerid	09341005	Kriz 1	50	ERESS
Djerid	06103005	OUED Shili 1	5	ERESS
Djerid	00800005	Kastilia 2	8	SASS
Djerid	05262005	Helba 2	10	SASS
Djerid	05436005	Neflayett 1	1.4	SASS
Djerid	05487005	Ghardgaya 1	2.1	SASS
Djerid	05776005	Chakmou	7	SASS
Djerid	05893005	Cedada 1	2	SASS
Djerid	06267005	Chemsa 1	15	SASS
Djerid	08262005	Nefta	6	SASS
Djerid	08405005	Tozeur Gare 2	15	SASS
Djerid	08729005	Oued Koucha 1	10	SASS
Djerid	08982005	El Manachi 2	8	SASS
Djerid	09340005	Kriz 1	50	SASS
Djerid	09495035	Zaouiet El Arab		SASS
Djerid	09627005	Kriz 2	5	SASS
Djerid	09959005	Zaafrana	10	SASS
Djerid	10192005	Sedada 3	8	SASS
Djerid	10193005	El Hamma 9	23	SASS
Djerid	10452005	Kriz 3	20	SASS
Djerid	10453005	Degache Nord 1	6	SASS
Djerid	10453025	Degache Nord 2	12	SASS
Djerid	12330005	El Hamma 10	30	SASS
Djerid	13119005	Nefta 5	3.2	SASS
Djerid	13346005	herdgaya 4	9	SASS
Djerid	13991005	Oued Dghouumes 2	7.35	SASS
Djerid	13992005	Neflaiet 2	3	SASS
Djerid	14000005	Degache Sonede	0.90	SASS
Djerid	14001005	Tozeur Sonede	4	SASS
Djerid	14621005	Oued Kebir	2.8	SASS
Djerid	14628005	Sif El Akhdar	3	SASS
Djerid	14630005	Aîn Djedida	1.5	SASS
Djerid	16558005	Ben Chaouch	3	SASS
Djerid	16639005	Nefta 6	28	SASS
Djerid	16695005	Chouchet Zerga	2.7	SASS
Djerid	16732005	El Mekmen	8	SASS
Djerid	16749005	Hamma12	1.4	SASS
Djerid	17656005	Essouni	22	SASS
Djerid	17679005	Oued Tozeur 8	31	SASS

Zone	Data base class. Number	Well denomination	Transmissivity in 10^{-3} m^2/s	Data origin
Djerid	18650005	Oued Tozeur 5	18	SASS
Djerid	18651005	Hazoua 1bis	40	SASS
Djerid	18660005	Oued Shili 2	8	SASS
Djerid	18728005	Nefta 1bis	0.36	SASS
Djerid	18758005	Errached 1	9	SASS
Djerid	18765005	Nefta 7	10	SASS
Djerid	18766005	Nefta 2bis	9	SASS
Djerid	18791005	Oued Touzeur 4	2.1	SASS
Djerid	18800005	Hamma 11 bis	7	SASS
Djerid	18801005	Drâa Nord 2	5.2	SASS
Djerid	18802005	El Melah	5	SASS
Djerid	18844005	Aïn Torba 3	9	SASS
Djerid	18852005	Oued Kebir 2	18	SASS
Djerid	18927005	Nefta 3 bis	1.43	SASS
Djerid	18928005	Kriz 3 bis	2	SASS
Djerid	18996005	Zaouiet Larab 1 bis	8	SASS
Djerid	18999005	Tozeur Gare 2 bis	15	SASS
Djerid	19029005	IBN Chabbat 13	7	SASS
Djerid	19031005	IBN Chabbat 10	5	SASS
Djerid	19113005	Chakmou 4	35	SASS
Djerid	19121005	El Faouz	24	SASS
Djerid	19137005	Ouled Ghrissi	27	SASS
Djerid	19166005	Hazoua 4	20	SASS
Djerid	19176005	Hazoua BM 2	20	SASS
Djerid	19203005	Hazoua BM 1	16	SASS
Djerid	19250005	Neflaiet 3 bis	6.7	SASS
Djerid	19269005	Segdoud Ct1	9.1	SASS
Djerid	19284005	Nefta 5 bis	13	SASS
Djerid	19324005	Mides	0.36	SASS
Djerid	19329005	Manachi 2 bis	24	SASS
Djerid	19335005	Nefta 6 bis	29	SASS
Djerid	19342005	Oued El Kebir 1 bis	13	SASS
Djerid	19357005	Dgoumes 2 bis	5.4	SASS
Djerid	19358005	Hamma 8 bis	8	SASS
Djerid	19359005	Hamma 9 bis	22	SASS
Djerid	19419005	PK 14 bis	15	SASS
Djerid	19420005	PK 13 bis	30	SASS
Djerid	19447005	Nefta 8	30	SASS
Djerid	19448005	Nefta 9	2	SASS
Djerid	19477005	Helba 4bis	21	SASS
Djerid	19493005	Helba 1 bis	23	SASS
Djerid	19496005	Kriz 3 ter	9.4	SASS
Djerid	19502005	Gardgaya 4 bis	38	SASS
Djerid	19503005	El Hamma 4 bis	85.5	SASS
Djerid	19525005	Chemsa 1 bis	40	SASS
Djerid	19549005	Cedada 6 bis	4	SASS
Djerid	19550005	IBN Chabbat 11 bis	30	SASS
Djerid	19575005	Mrah lahouar 1 bis	13	SASS
Djerid	19598005	Boulifa 1 (Tozeur 11)	15	SASS
Djerid	19761005	Oued Naguess	8.5	SASS
Djerid	19778005	Nefta 11	5	SASS
Djerid	19784005	Dghoumes 3 bis	10	SASS
Djerid	19881005	El Hamma 16	10	SASS
Djerid	19882005	Tozeur 7 ter	22	SASS
Djerid	19883005	Tozeur 12	7	SASS
Djerid	20026005	Aïn Torba 3 ter	25	SASS

Zone	Data base class. number	Well denomination	Transmissivity in 10^{-3} m^2/s	Data origin
Djerid	20040005	El Moncef 4 bis	13	SASS
Djerid	20073005	Zaouit El Arab 1 ter	27	SASS
Djerid	20281005	Nefta 7 bis	14	SASS
Djerid	20282005	Nefta 3Ter	12	SASS
Djerid	20290005	Sif Lakhder 1 bis	32	SASS
Djerid	20371005	Tozeur Sonede 3	35	SASS
Djerid	20373005	IBN Chabbat 3 ter	10.9	SASS
Djerid	20377005	Sedada 3 ter	3.6	SASS
Djerid	20446005	Horchani 2 bis	1.8	SASS
Djerid	20448005	Hamma 17	12	SASS
Djerid	20482005	Hezoua 4 bis	20	SASS
Djerid	20487005	Mrah Lahouar 2 bis	23	SASS
Djerid	20488005	Tozeur Ras El Aïn	19	SASS
Djerid	20489005	Serra Hotel	1.5	SASS
Djerid	20492005	Moncef 3 bis	29	SASS
Djerid	20515005	IBN Chabbat 13 bis	6.5	SASS
Djerid	20972005	Manachi CRFA	15	SASS
Nefzaoua	05941005	BAZMA 3	10	ERESS
Nefzaoua	06481005	GUELIADA 1	5	ERESS
Nefzaoua	06690005	Nouaiel 1	20	ERESS
Nefzaoua	06756005	Ras El Aïn 1	46	ERESS
Nefzaoua	09654005	RABTA 2	14	ERESS
Nefzaoua	05484005	El Faouar 2	5	ERESS
Nefzaoua	05571005	El Faouar 1	4	ERESS
Nefzaoua	11334005	EL FAOUAR 3	4	ERESS
Nefzaoua	06689005	Guidma 1	7	ERESS
Nefzaoua	05840005	EL HSAY 1	20	ERESS
Nefzaoua	06522005	Tarfaïet El Kroub	9	ERESS
Nefzaoua	00030025	Douz 2 bis	30	ERESS
Nefzaoua	06906005	Zarcine 2	12	ERESS
Nefzaoua	05754005	Grad 1	120	ERESS
Nefzaoua	06470005	EL METOURIA 1	8	ERESS
Nefzaoua	12320005	Chott Salhia 1	10	ERESS
Nefzaoua	00073025	Guettaya 2	6	ERESS
Nefzaoua	05570005	Negga 3	4	ERESS
Nefzaoua	16703005	Negga 5	10	ERESS
Nefzaoua	00046035	Toumbar	26	ERESS
Nefzaoua	05585005	Telmine 2	10	ERESS
Nefzaoua	19246005	MANSOURA 2bis	15	ERESS
Nefzaoua	05956005	MESSAID 2	8	ERESS
Nefzaoua	05692005	RAHMAT 2	20	ERESS
Nefzaoua	10226005	Rahmat 3	6	ERESS
Nefzaoua	05755005	Ksar Tabeul	15	ERESS
Nefzaoua	02051035	Taourgha 3	8	ERESS
Nefzaoua	09347005	Om Somâa 1	15	ERESS
Nefzaoua	09632005	BOU ABDALLAH 1	20	ERESS
Nefzaoua	09653005	Bou Abdallah 2	30	ERESS
Nefzaoua	16702005	Bazma 5	9.3	MAMOU, 1990
Nefzaoua	17611005	PZ.CHOTT Nefzaoua	2.2	MAMOU, 1990
Nefzaoua	18681005	Bechni	59.8	MAMOU, 1990
Nefzaoua	18746005	Blidette 3	12.9	MAMOU, 1990
Nefzaoua	18755005	Dergine El Ameur	8.5	MAMOU, 1990
Nefzaoua	19003005	Ras El Aïn 4	7.1	MAMOU, 1990
Nefzaoua	19106005	Rabta 2 bis	10.4	MAMOU, 1990
Nefzaoua	19141005	Klebia 2	57	MAMOU, 1990
Nefzaoua	19209005	Nefzaoua MILITAIRE	112	MAMOU, 1990

Zone	Data base class. number	Well denomination	Transmissivity in 10^{-3} m^2/s	Data origin
Nefzaoua	19278005	Zarcine 4	5.4	MAMOU, 1990
Nefzaoua	19316005	El Golâa 2	47.6	MAMOU, 1990
Nefzaoua	19317005	Kelwamen	5.5	MAMOU, 1990
Nefzaoua	19340005	Rahmat 5	31.9	MAMOU, 1990
Nefzaoua	19345005	Nefzaoua VILLAGE	19.02	MAMOU, 1990
Nefzaoua	18826005	GUETTAYA 4 bis	6.9	MAMOU, 1990
Nefzaoua	19375005	NEGGA SONEDE 2	3.7	MAMOU, 1990
Nefzaoua	19375005	NEGGA SONEDE 2	26.1	MAMOU, 1990
Nefzaoua	18851005	Guettaya 7 bis	26.1	MAMOU, 1990
Nefzaoua	18747005	Guettaya 8	30.3	MAMOU, 1990
Nefzaoua	16733005	Guettaya 6	45.8	MAMOU, 1990
Nefzaoua	16731005	Oued Zira 2	17	MAMOU, 1990
Nefzaoua	19408005	NOUIEL 2	23.5	MAMOU, 1990
Nefzaoua	19102005	Chott yane	6.4	MAMOU, 1990
Nefzaoua	19104005	Brika Jemna	6.4	MAMOU, 1990
Nefzaoua	19103005	Aïn Salah 1	15.4	MAMOU, 1990
Nefzaoua	19343005	El Faouar 4	71	MAMOU, 1990
Nefzaoua	19351005	Sabria 3	13.7	MAMOU, 1990
Nefzaoua	19376005	JEMNA SONEDE	2.6	MAMOU, 1990
Nefzaoua	18774005	Negga 6	2.1	MAMOU, 1990
Nefzaoua	17608005	Sidi Hamed	186	MAMOU, 1990
Nefzaoua	19149005	RAHMAT SONEDE	62.7	MAMOU, 1990
Nefzaoua	16735005	El Ghoula	11.2	MAMOU, 1990
Nefzaoua	18790005	DOUZ 6	15.2	MAMOU, 1990
Nefzaoua	19092005	Smida	331	MAMOU, 1990

Annex 3 Table 3 - Transmissivities of the Complexe Terminal aquifer in Libya

Zone	Well denomination	Aquifer	Transmissivity in 10^{-3} m^2/s	Data origin
Abu Njaym	K1	Nalut	1	GEFLI 1978
Abu Njaym	K2	Nalut	2	GEFLI 1978
Al Jufrah	J18	Mizdah-Tigrinna	40	GEFLI 1978
Derj	Wg-6		1.76	Srivastava, 1981
Derj	Wg-8		0.19	Srivastava, 1981
Derj	Wg-12		1.97	Srivastava, 1981
Derj	Wg-1		0.255	Srivastava, 1981
Derj	Wg-5		0.00289	Srivastava, 1981
Derj	Wg-7		0.0271	Srivastava, 1981
Derj	Wg-11		0.0153	Srivastava, 1981
Fl. oriental Hamada	MG1	Nalut	2	GEFLI 1978
Fl. oriental Hamada	K5	Nalut	50	GEFLI 1978
Fl. oriental Hamada (W. Bayy al Kabir)	K7	Nalut	0.6	GEFLI 1978
Fl. oriental Hamada (W. Ninah)	K9	Mizdah-Tigrinna	0.05	GEFLI 1978
Fl. oriental Hamada (W. Washkah)	K3	Mizdah-Tigrinna	0.1	GEFLI 1978
Fl. oriental Hamada (W. Washkah)	K4	Mizdah-Tigrinna	0.05	GEFLI 1978
Fl. Oriental Hamada (W. Zamzam)	ZZ1	Mizdah-Tigrinna	0.1	GEFLI 1978
Flanc sud J Nefusa	Wg-14		0.021	Srivastava, 1981
Flanc sud J Nefusa	Wg-15		0.0996	Srivastava, 1981
Flanc sud J Nefusa	WG 17		0.00915	Srivastava, 1981
Flanc sud J Nefusa	WG 19		0.0234	Srivastava, 1981
Tawurgha	MG3	Nalut	40	GEFLI 1978
Tawurgha	P22	Mizdah-Tigrinna	10	GEFLI 1978
Tawurgha	P22	Mizdah-Tigrinna-Miocène	100	GEFLI 1978
Tawurgha	P18	Mizdah-Tigrinna	50	GEFLI 1978
Wadi Sufajjin	MG2	Nalut	0.2	GEFLI 1978
Wadi Sufajjin	K6	Nalut	5	GEFLI 1978
Wadi Sufajjin	K10	Nalut	1	GEFLI 1978
Wadi Sufajjin	K12	Nalut	10	GEFLI 1978
Wadi Sufajjin	SOF2	Nalut	3	GEFLI 1978
Wadi Sufajjin	SOF5	Nalut		GEFLI 1978
Wadi Sufajjin	P9	Nalut	25	GEFLI 1978
Zone cotière	P21	Nalut	6	GEFLI 1978
	WS9	Nalut	3	GEFLI 1978

2. Transmissivity of the Continental Intercalaire aquifer

Annex 3 Table 4 – Transmissivities of the Continental Intercalaire aquifer in Algeria

Zone	Data base class. Number	Well denomination	Transmissivity in 10^{-3} m^2/s	Data origin
Aoulef	P00500011	Aoulef 2	5.80	ERESS
Aoulef	P00600013	Tit 3	8.00	ERESS
El Golea	L00700003	Hadj Halima	35.00	ERESS
El Golea	L00700041	Hassi El Gara	14.10	ERESS
El Golea	K00700030	Foucault	17.00	ERESS
El Golea	L00700056	Taghit nouveau	9.50	ERESS
El Golea	K00700021	Bel Bechir	10.00	ERESS
Gourara	M00400284	Timimoun	36.00	ERESS
Gourara	N00400302	Igostene	22.60	ERESS
Hassi Fahl	J00800001	Hassi Fahl	0.50	ERESS
Hassi Fahl	J00800020	Hassi Touil	3.50	ERESS
Hassi Fahl	L00700066	Hassi Maroket	0.50	ERESS
Hassi Fahl	K00800016	Dayet Ghanem	5.00	ERESS
Hassi Fahl	K00800015	Gouiret Moussa	1.50	ERESS
Hassi Messaoud	K01200001	Rhourd El Baguel	0.60	ERESS
Hassi Messaoud	J01100094	Hassi Mesaoud	2.00	ERESS
Hassi Messaoud	L01100011	Gassi Touil	2.00	ERESS
In Salah	In Salah 18	In Salah 18	16.00	ERESS
In Salah	In Salah 19	In Salah 19	16.00	ERESS
In Salah	In Salah 20	In Salah 20	27.00	ERESS
In Salah	In Salah 21	In Salah 21	3.60	ERESS
Ouargla	J01000447	Ouargla 1	3.20	ERESS
Ouargla	J01000480	Ouargla 2	5.10	ERESS
Ouargla	J01000511	Ouargla 3	5.10	ERESS
Oued Rhir Nord	G00900109	Sidi Khaled	2.30	ERESS
Oued Rhir Sud	H01000042	M'rara	6.00	ERESS
Oued Rhir Sud	H01100408	Tamerna	6.00	ERESS
Oued Rhir Sud	I01100436	Sidi Mahdi	7.00	ERESS
Oued Rhir Sud	I01100437	Sidi Slimane	5.00	ERESS
Oued Rhir Sud	X00700035	Guettara	12.00	ERESS
Oumchen	L00600019	Hassi Inkhal	17.00	ERESS
Oumchen	M00700020	Oumchen	15.00	ERESS
Rhourde El Hamra	6 M 11		0.39	GEOMATH
Rhourde El Hamra	M01100006	Rhourd Nouss	0.40	ERESS
Rhourde El Hamra	M01200001	Tamendjelt	0.30	ERESS
Rhourde El Hamra	SP 2	SP 2	2.00	ERESS
Rhourde El Hamra	N01100021	Fort Flatters	3.70	ERESS
Rhourde El Hamra	N01100020	O. Ameskiki	2.20	ERESS
Tadmait	N00700003	Tineldjane	0.80	ERESS
Tadmait	N00700004	El Hassene	0.60	ERESS
Tidikelt	O00700055	Fog. Ez Zoug	7.00	ERESS
Zelfana	J00800070	Metlili 5	15.00	ERESS
Zelfana	J00900011	Zelfana 2	23.80	ERESS
Zelfana	J00900011	ZELFANA N°3	13.60	ERESS
Zelfana	I00800112	Melika 3	12.20	ERESS
Zelfana	I00900050	Guerrara 3	10.00	ERESS

Annex 3 Table 5 - Transmissivities of the Continental Intercalaire aquifer in Tunisia

Zone	Data base class. number	Well denomination	Transmissivity in 10^{-3} m^2/s	Data origin
Chott Fedjej	05664005	Ch Fedjej 1	27.70	MAMOU, 1990
Chott Fedjej	05950005	Ch Fedjej 2	83.00	MAMOU, 1990
Chott Fedjej	08429005	Ch Fedjej 3	88.50	MAMOU, 1990
Chott Fedjej	ZTA 1	Zemlet Taiara	6.00	ERESS
Chott Fedjej	19394005	Limagues (CI 8)	56.60	MAMOU, 1990
Chott Fedjej	19190005	CF 1 bis	25.40	MAMOU, 1990
Chott Fedjej	18700005	CF F10	323.00	MAMOU, 1990
Chott Fedjej	19175005	CF 3bis	23.40	MAMOU, 1990
Chott Fedjej	18697005	CF F3	88.50	MAMOU, 1990
Chott Fedjej	18698005	CF F8	6.30	MAMOU, 1990
Chott Fedjej	18699005	CF 9	100.00	MAMOU, 1990
Chott Fedjej	19452005	Steftimi (CI 7)	3.40	MAMOU, 1990
Chott Fedjej	19484005	Behaier (CI 9)	87.00	MAMOU, 1990
Djerid	19230005	Degache CI2	1.10	MAMOU, 1990
Djerid	19084005	Nefta CI	0.80	MAMOU, 1990
Far South	BZA 1		2.00	Geomath
Far South	ZTA 1		5.99	Geomath
Far South	ZN A1	Zemlet En Nous	10.00	ERESS
Far South	05654005	Bordj Bourguiba	30.00	ERESS
Far South	X00700223	El Borma A1	0.40	MAMOU, 1990
Far South	X00700217	El Borma A6	43.00	MAMOU, 1990
Far South	16726005	El-Borma 202(*)	3.10	MAMOU, 1990
Far South	18684005	El-Borma 203(*)	2.50	MAMOU, 1990
Far South	18643005	El-Borma 207(*)	1.50	MAMOU, 1990
Far South	18644005	El-Borma 208(*)	11.00	MAMOU, 1990
Ksar Ghilane	05717005	Ksar Ghilane	6.00	ERESS
Ksar Ghilane	19009005	Ksar Ghilane 3 bis	12.70	MAMOU, 1990
Nefzaoua	19157005	Bou Abdallah (CI 1)	4.50	MAMOU, 1990
Nefzaoua	19199005	Taourgha (CI 2)	55.10	MAMOU, 1990
Nefzaoua	19140005	Mansoura (CI 3)	2.70	MAMOU, 1990
Nefzaoua	19348005	Zaoueïet Anes (CI 5)	13.80	MAMOU, 1990
Nefzaoua	19412005	Menchia CI 6	39.70	MAMOU, 1990
Nefzaoua	19400005	Kébili (CI 10)	9.40	MAMOU, 1990
Nefzaoua	19468005	Jemna (CI 11)	3.10	MAMOU, 1990
Nefzaoua	20051005	Kébili (CI 16)	1.96	MAMOU, 1990
Nefzaoua	19304005	Zaoueiet Chorfa (CI 4)	69.00	MAMOU, 1990
Nefzaoua	20663005	Zouaia CI 22	41.23	MAMOU, 1990
Nefzaoua	19916005	DEBEBCHA CI 14	9.90	MAMOU, 1990
Nefzaoua	20109005	S.Lahad (CI 17)	23.00	MAMOU, 1990
Nefzaoua	20662005	Bou Abdallah CI 21	3.80	MAMOU, 1990
Nefzaoua	20018005	Douz (CI 18)	45.20	MAMOU, 1990
Nefzaoua	19450005	Douz (CI 12)	13.70	MAMOU, 1990

Annex 3 Table 6 - Transmissivities of the Continental Intercalaire aquifer in Libya

Zone	Well denomination	Transmissivity in 10^{-3} m^2/s	Data origin
Abu Njaym	K-1	13.99	GEFLI
Abu Njaym	K-2	3.50	GEFLI
Abu Njaym	K-7	2.70	GEFLI
Abu Njaym	K-8	2.00	GEFLI
Abu Njaym	K-9	17.00	GEFLI
Buwayrat al Hasun	K4	1.30	GEFLI
Buwayrat al Hasun	K-11	0.69	GEFLI
Buwayrat al Hasun	WH-1	2.60	GEFLI
Shwayref	WS-6	12.00	GEOMATH
Shwayref	SH-1	1.50	GEFLI
Derj	T11-81	25.50	BRL 1997
Derj	T96-76	18.00	BRL 1997
Derj	T159-89	74.00	BRL 1997
Derj	WG9	17.00	BRL 1997
Derj	WG 16	1.70	BRL 1997
Ghadamis	T203-80	75.00	BRL 1997
Ghadamis	T276-77	85.00	BRL 1997
Ghadamis	T277-77	60.00	BRL 1997
Ghadamis	WG 22	8.30	BRL 1997
Jabal Nafusah	T5-78	2.70	BRL 1997
Jabal Nafusah	T35-75	7.90	BRL 1997
Jabal Nafusah	T110-76	2.70	BRL 1997
Jabal Nafusah	T125-81	9.20	BRL 1997
Jabal Nafusah	T126-81	28.00	BRL 1997
Jabal Nafusah	T39-78	7.90	BRL 1997
Jabal Nafusah	T175-78	11.00	BRL 1997
Wadi Majir	P20	15.00	GEFLI
Wadi Majir	P21	0.10	GEFLI
Wadi Majir	T-2A	10.00	GEFLI
Mizdah	T313-76	1.60	BRL 1997
Mizdah	131/77	13.00	BRL 1997
Mizdah	WS 14	5.99	GEOMATH
Sinawen	T64-78	24.00	BRL 1997
Sinawen	T158-89	19.00	BRL 1997
Sinawen	Wg-13	4.50	BRL 1997
Wadi Sufajjin Mardum	K 12	15.00	Geomath
Wadi Sufajjin Mardum	B 2	15.00	Geomath
Wadi Sufajjin Mardum	K5	100.00	GEFLI
Wadi Sufajjin Mardum	K6	3.50	GEFLI
Wadi Sufajjin Mardum	K-10	2.40	GEFLI
Wadi Sufajjin Mardum	SOF5	0.00	GEFLI
Wadi Sufajjin Mardum	NOR1	15.00	GEFLI
Suknah	J-18	100.00	GEFLI
Wadi Zam Zam	WS-2	8.59	GEOMATH
Wadi Zam Zam	ZZ 1	10.00	GEOMATH
Wadi Zam Zam	ZZ 2	8.99	GEOMATH
Wadi Zam Zam	ZZ 3	20.00	GEOMATH
Wadi Zam Zam	ZZ 4	21.00	GEOMATH
Wadi Zam Zam	ZZ 5	14.00	GEOMATH
Wadi Zam Zam	ZZ 6	12.00	GEOMATH
Wadi Zam Zam	K3	39.00	GEFLI

ANNEX 4

RECORD OF ABSTRACTIONS FROM THE CI AND THE CT IN ALGERIA AND IN TUNISIA (1950 – 2000)

ANNEX 4

Record of abstractions from the Continental Intercalaire and the Complexe Terminal in Algeria and in Tunisia (1950 – 2000)

1 – Introduction

At the time of establishing the records of abstractions between 1950 and 2000 from the aquifers of the Continental Intercalaire (CI) and the Complexe Terminal (CT) of Algeria (Al) and Tunisia (Tu), it was noted that the information available had changed considerably with respect to that of 1972 (ERESS) or that of 1982 (RAB 80/011). This new situation is characterised by an increase in the number of new water wells (boreholes and dug wells) outside of the ancient oases. The monitoring of the exploitation of these water points is far from being under control due to their large number. Inventory operations, including an estimate of abstractions, have taken place on the occasion of updating the models.

In Tunisia, the rise in the number of water points is fairly more under control than in Algeria. The exploitation of water points is controlled annually on the occasion of one or two campaign(s) of measurement of the flow of each exploited water point. The estimate of abstractions is made based on an estimate of the Total number of hours of pumping operation, for non artesian wells.

The present note aims at analysing the evolution of this exploitation in order to develop data for the calibration of the model. It has made it possible to check the old estimates made in the context of the ERESS studies: AB 80/011 and BRL, 1997 (in Algeria), as well as to have a closer focus on the evaluation of these abstractions by resorting to comparisons between the various estimates.

2 – Abstractions in Algeria

The source of the data proposed further down consists in the SASS data base in its final version of 2002 which comprises the results of all the inventories made, including those for El Oued and Illizi, made in 1999. The spatial distribution of these abstractions between the various zones of the Algerian Sahara reveals that the major part of the water points is located in the zones of the Grand Erg Occidental, the Lower Sahara and Ouargla.

The data relating to these abstractions have formed the subject, during recent years, of several analyses with a view to evaluating the evolution of exploitation over time since the early 1980s (BRL, 1997 ; Biout and Larbes, 2000). Only the analysis of these data made by the SASS team (SASS, May 2001) has covered the whole body of data collected between 1991 and 2000. It has allowed the collation of the data available, as well as a comparison between the various ways in which the were processed, in order to develop a record (history) of exploitation of the two major aquifers of the Saharan system between 1950 and 2000.

2.1. Record of exploitation of the Continental Intercalaire in Algeria

The record of exploitation of the aquifer of the CI in Algeria was established between 1950 and 2000, based on the information available at the level of the Wilayas (regional administrative departments), with reference to the local data pertinent to the water points and which indicate the characteristics and conditions of their exploitation.

This record (tables n°1-1 to 1-3) groups the water points collecting this aquifer in the Wilayas of Adrar, Ghardaïa, El Oued, Ouargla, Biskra, Illizi and Tamanghasset. The major part of this exploitation is done in the Wilayas of Adrar, Ghardaïa, Ouargla and El Oued. The foggaras are all concentrated in the Wilaya of Adrar. Elsewhere than in the Wilaya of Adrar, where the flow of the foggaras and the artesian wells presents a certain decrease, in the other regions of the Algerian Sahara, the exploitation of the aquifer of the Continental Intercalaire presents a marked increase from the 1980s onwards (Figures n°1 and 2). This situation results from the proliferation of the number of water points and it translates into Total abstractions, for 2000, which are four times higher than in 1980.

2.2. Record of the exploitation of the Complexe Terminal in Algeria

The exploitation of the aquifer of the Complexe Terminal is done in Algeria, in the Wilayas of Ouargla, El Oued, Biskra, Khenchela and Tebessa (Table n°2-1). Most of the water points tapping this aquifer are located in the Wilayas of Ouargla, El Oued and Biskra.

Similarly to the case of the Continental Intercalaire aquifer, the exploitation of the Complexe Terminal aquifer has experienced in Algeria, since the mid-A980s, a marked rise. Thus, the exploited flow has doubled up between 1982 and 2000 (Figures n° 3 and 4). The major part of this exploitation is done by means of Pumped Wells which abstract about 93%. Artesian wells are fairly numerous only in the Wilayas of El Oued and of Ouargla.

Exploitation by artesianism contribute about 18% in the abstractions from the CT aquifer in the Wilaya of El Oued. In the Wilaya of Ouargla, the share of artesianism in the volumes abstracted is lower by far.

3 – Abstractions in Tunisia

The exploitation of the aquifers of the Saharan basin has always been, in Tunisia, mainly concentrated on the Complexe Terminal aquifer which is more accessible in view of the little depth at which it lies in the Djérid and Nefzaoua regions. Since the early 1980s, a shift has taken place towards the exploitation of the Continental Intercalaire aquifer in the zones of Chott Fedjej, Nefzaoua and Djérid. Being fairly deep in these zones (over 1000 m), this aquifer is considered as a supplement to that of the Complexe Terminal. At the same time, the Complexe Terminal aquifer has experienced a considerable increase in its exploitation outside of the traditional oases. The establishment of the record of exploitation of the aquifers of the Saharan basin of the Tunisian south is made fairly easy by the regular monitoring that is made on a yearly basis.

3.1. Record of exploitation of the Continental Intercalaire in Tunisia

The record of exploitation of the Continental Intercalaire aquifer in the Tunisian south, between 1950 and 2000, is closely connected with that of the development of wells in Chott Fedjej, in Nefzaoua and in Djérid. Prior to 1983, the exploitation of this aquifer used to be done by means of springs and wells, as well as by the boreholes of the Far South (El Borma and Ksar Ghilane). With the development of the exploitation of this aquifer at the level of Chott Fedjej, of Nefzaoua and of Djérid, the volumes exploited had passed, in the mid-1980s, from less than 800 l/s to more than 2500 l/s in the year 2000 (Table n° 3). The major part of this exploitation takes place in Chott Fedjej, in the Tunisian Far South, and in Nefzaoua (Figure n° 5). Most of this exploitation is done by artesian wells.

3.2. Record of exploitation of the Complexe Terminal in Tunisia

The exploitation of the Complexe Terminal aquifer takes place in the Tunisian south, mainly in the Governorates (regional administrative departments) of Kébili (Nefzaoua) and of Tozeur (Djérid), and to a lesser extent in those of Gafsa and of Tataouine. The monitoring of this exploitation is made on an annual bases by means of measurement campaigns that involve most of the exploited water points. This monitoring reveals that most of the exploitation occurs in the regions of Djérid and of Nefzaoua.

This exploitation which used to take place, until the mid-1970s, by means of springs and artesian wells has come to increasingly require the use of pumping (Table n°4). Thus, the flow of the springs of Djérid and of Nefzaoua, which used to account in the early 1950s for about 62% of the abstractions in the Tunisian south from the reserves of this aquifer, had ended up drying out completely by the early 1080s. The case of the springs of Djérid is highly significant (Figure n° 6). At the same time, the flow of Pumped Wells has been on the increase. The case of the exploitation of this aquifer in the region of Kébili is eloquently significant in this regard (Figure n° 7).

4- Conclusion

The exploitation of the two major Saharan aquifers of the CI and the CT has experienced, in the past twenty years, a marked rise following the multiplication of the number of wells and the increase in abstractions. This situation is characteristic of the Continental Intercalaire aquifer in Algeria and that of the Complexe Terminal in Tunisia.

The monitoring of this exploitation calls for a more regular and more precise monitoring in order to better highlight the expected changes in the hydrodynamic operating of the aquifer system and of the quality of its water.

Table 1 – Record of exploitation of the Continental Intercalaire in Algeria as per Wilaya

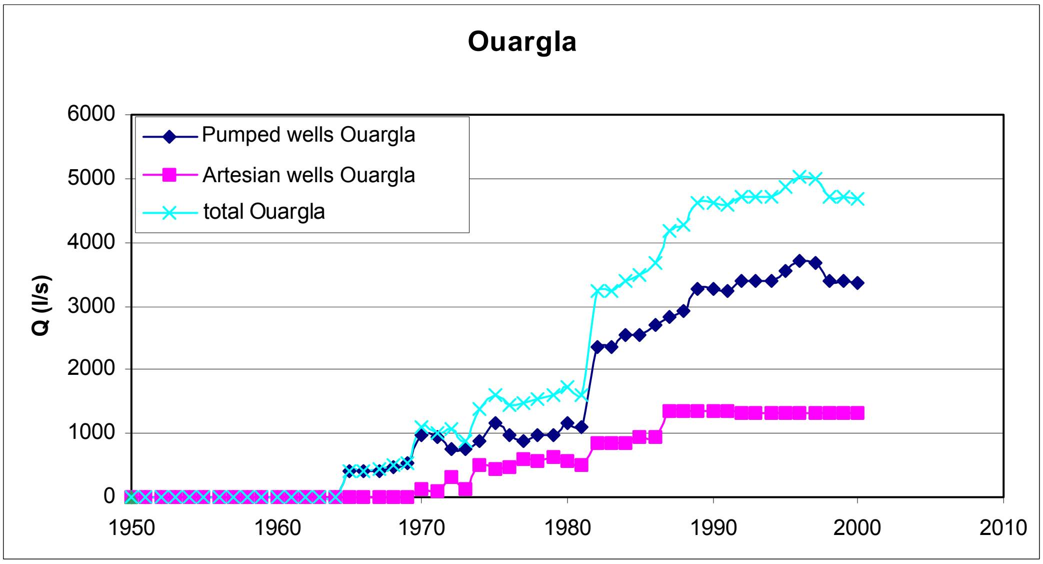
	Adrar				Biskra	El Oued			Ghardaia			Illizi	Ouargla			Tamanrasset
Date	Pumped Wells	Artesian Wells	Foggaras	Total Adrar	Pumped Wells	Pumped Wells	Artesian Wells	Total El Oued	Pumped Wells	Artesian Wells	Total Ghardaia	Wells in Illizi	Pumped Wells	Artesian Wells	Total Ouargla	Forages Tamanrasset
1950	0		3665.0	3665.0	100	206	0	206	300.0	420.0	720.0	0	10	0.0	10.0	250.0
1951	0		3665.0	3665.0	100	210	0	210	320.0	420.0	740.0	0	10	0.0	10.0	250.0
1952	0		3665.0	3665.0	100	220	0	220	330.0	450.0	780.0	0	10	0.0	10.0	280.0
1953	0		3665.0	3665.0	100	230	0	230	350.0	450.0	800.0	0	10	0.0	10.0	300.0
1954	0		3665.0	3665.0	100	240	0	240	368.3	503.4	871.7	0	395	0.0	395.0	310.4
1955	0		3665.0	3665.0	100	250	0	250	363.3	468.5	831.8	0	395	7.0	402.0	340.4
1956	0		3665.0	3665.0	100	258	0	258	363.1	439.1	802.2	0	420	7.0	427.0	370.4
1957	0		3665.0	3665.0	100	296	0	296	367.9	422.0	789.8	0	480	7.0	487.0	400.4
1958	0		3665.0	3665.0	100	290	0	290	353.9	427.2	781.1	0	530	7.0	537.0	400.0
1959	0		3665.0	3665.0	100	442	0	442	403.7	457.6	861.3	0	986	117.0	1103.0	400.0
1960	0		3665.0	3665.0	100	445	0	445	436.0	507.0	943.0	0	930	88.0	1018.0	390.0
1961	0		3665.0	3665.0	94	455	0	455	555.1	493.9	1049.0	0	759	302.0	1061.0	390.0
1962	0		3665.0	3665.0	88	455	0	455	596.2	482.8	1079.0	0	760	120.0	880.0	390.0
1963	0		3665.0	3665.0	189	532	0	532	576.3	469.7	1046.0	0	879	505.0	1384.0	380.0
1964	0		3665.0	3665.0	181	547	200	747	618.4	462.6	1081.0	0	1158	442.0	1600.0	380.0
1965	0		3665.0	3665.0	175	563	200	763	611.5	441.5	1053.0	0	979	462.0	1441.0	380.0
1966	0		3665.0	3665.0	171	560	200	760	603.6	456.4	1060.0	0	875	602.0	1477.0	380.0
1967	0		3665.0	3665.0	162	537	200	737	1001.7	434.3	1436.0	0	977	554.0	1531.0	380.0
1968	0		3665.0	3665.0	398	513	200	713	704.8	556.2	1261.0	0	988	617.0	1605.0	380.0
1969	0		3665.0	3665.0	464	490	200	690	704.9	545.1	1250.0	0	1173	554.0	1727.0	380.0
1970	0		3665.0	3665.0	490	654	200	854	978.0	584.0	1562.0	0	1098	495.0	1593.0	380.0
1971	1		3635.0	3636.0	100	206	0	206	300.0	420.0	720.0	0	10	0.0	10.0	250.0
1972	1		3600.0	3601.0	100	210	0	210	320.0	420.0	740.0	0	10	0.0	10.0	250.0
1973	1		3570.0	3571.0	100	220	0	220	330.0	450.0	780.0	0	10	0.0	10.0	280.0
1974	1		3535.0	3536.0	100	230	0	230	350.0	450.0	800.0	0	10	0.0	10.0	300.0
1975	1		3505.0	3506.0	100	240	0	240	368.3	503.4	871.7	0	395	0.0	395.0	310.4
1976	1		3475.0	3476.0	100	250	0	250	363.3	468.5	831.8	0	395	7.0	402.0	340.4
1977	1		3440.0	3441.0	100	258	0	258	363.1	439.1	802.2	0	420	7.0	427.0	370.4
1978	1		3410.0	3411.0	100	296	0	296	367.9	422.0	789.8	0	480	7.0	487.0	400.4
1979	1		3375.0	3376.0	100	290	0	290	353.9	427.2	781.1	0	530	7.0	537.0	400.0
1980	1		3340.0	3341.0	100	442	0	442	403.7	457.6	861.3	0	986	117.0	1103.0	400.0
1981	56		3310.0	3366.0	100	445	0	445	436.0	507.0	943.0	0	930	88.0	1018.0	390.0

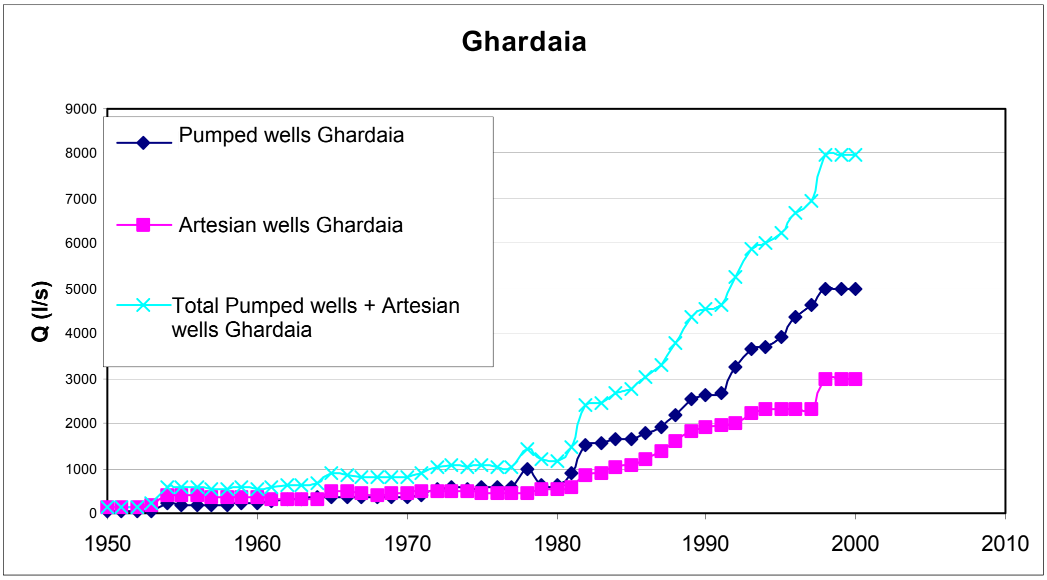
	Adrar				Biskra	El Oued			Ghardaia			Illizi	Ouargla			Tamanrasset
Date	Pumped Wells	Artesian Wells	Foggaras	Total Adrar	Pumped Wells	Pumped Wells	Artesian Wells	Total El Oued	Pumped Wells	Artesian Wells	Total Ghardaia	Wells in Illizi	Pumped Wells	Artesian Wells	Total Ouargla	Forages Tamanrasset
1982	402.2		3275.0	3677.2	1105	340	655	995	1832.8	970.5	2803.3	435	1741.3	764.6	2505.9	373.8
1983	503.0		3240.0	3743.0	1325	340	655	995	1844.8	1003.5	2848.3	435	1741.3	764.6	2505.9	463.8
1984	654.6		3210.0	3864.6	1565	340	655	995	1911.1	1072.3	2983.4	435	1841.3	764.6	2605.9	478.8
1985	697.2		3175.0	3872.2	1565	340	655	995	1928.1	1244.8	3172.9	435	1841.3	764.6	2605.9	588.5
1986	1534.6		3140.0	4674.6	1685	340	1055	1395	2045.2	1597.3	3642.4	435	1991.3	764.6	2755.9	663.5
1987	2224.5		3110.0	5334.5	1770	340	1535	1875	2141.5	1779.1	3920.7	435	2321.3	764.6	3085.9	1161.4
1988	3121.8		3075.0	6196.8	1975	760	1535	2295	2312.5	2015.7	4328.2	435	2474.64	764.6	3239.2	1161.4
1989	4139.2	57	3040.0	7236.2	2175	760	1535	2295	2494.4	2252.4	4746.8	440	2824.64	764.6	3589.2	1209.4
1990	5035.7	57	3010.0	8102.7	2175	760	1535	2295	2510.6	2288.5	4799.1	440	2814.64	764.6	3579.2	1209.4
1991	5802.3	57	2975.0	8834.3	2175	590	980	1570	2553.6	2432.6	4986.2	456	2814.64	764.6	3579.2	1279.4
1992	6857.4	57	2940.0	9854.4	2175	590	980	1570	2689.9	2595.5	5285.4	456	2934.64	764.6	3699.2	1307.7
1993	7780.9	57	2910.0	10747.9	2175	590	980	1570	2906.9	2886.4	5793.3	464	2934.64	764.6	3699.2	1337.7
1994	6116.1	57	2875.0	9048.1	2125	590	780	1370	3062.2	2911.4	5973.6	464	2834.64	764.6	3599.2	1337.7
1995	6113.1	57	2840.0	9010.1	2155	590	780	1370	3357.8	2911.4	6269.2	495	3005.89	764.6	3770.5	1337.7
1996	6113.1	57	2810.0	8980.1	2155	590	780	1370	3827.3	2911.4	6738.7	505	3127.21	764.6	3891.8	1337.7
1997	6113.1	57	2775.0	8945.1	2155	590	780	1370	4089.3	2911.4	7000.7	564	3077.21	764.6	3841.8	1427.7
1998	6113.1	57	2740.0	8910.1	2155	590	780	1370	4079.6	2650.6	6730.2	564	2777.21	764.6	3541.8	1427.7
1999	6113.1	57	2710.0	8880.1	2155	590	780	1370	4067.5	2650.6	6718.1	564	2747.21	764.6	3511.8	1427.7
2000	6102.2	57	2697.0	8856.2	2248	460	680	1140	4066.3	2650.6	6716.9	404	2747.21	764.6	3511.8	1427.7

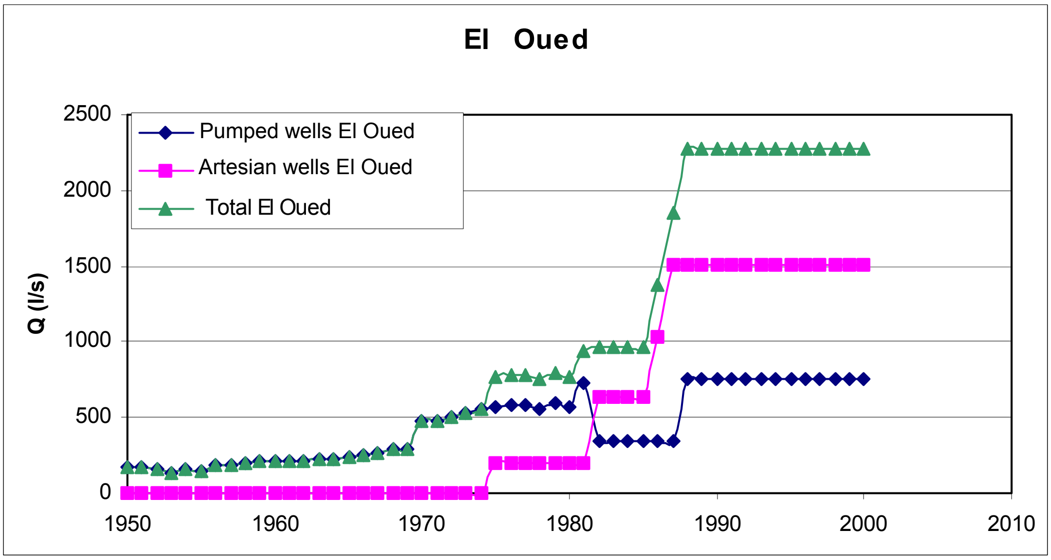
Annex 4 Table 2 – Record of exploitation of the Continental Intercalaire in Algeria (summary)

Date	Total Pumped Wells	Total artesian wells	Total Pumped Wells + Foggaras	Total Pumped Wells + Artesian wells	Total exploitation
1950	355	130.0	4020.3	485.3	4150
1951	360	127.1	4024.6	486.7	4152
1952	338	124.2	4002.9	462.1	4127
1953	341	182.8	4006.2	524.0	4189
1954	525	380.1	4190.3	905.4	4570
1955	494	404.1	4159.5	898.6	4564
1956	633	383.8	4297.7	1016.5	4682
1957	626	363.6	4290.9	989.5	4654
1958	660	380.0	4325.0	1040.0	4705
1959	760	400.0	4425.0	1160.0	4825
1960	846	400.0	4511.0	1246.0	4911
1961	866	420.0	4531.0	1286.0	4951
1962	890	420.0	4555.0	1310.0	4975
1963	940	450.0	4605.0	1390.0	5055
1964	990	450.0	4655.0	1440.0	5105
1965	1414	503.4	5078.7	1917.1	5582
1966	1449	475.5	5113.7	1924.2	5589
1967	1512	446.1	5176.5	1957.6	5623
1968	1644	429.0	5309.3	2073.2	5738
1969	1674	434.2	5338.9	2108.1	5773
1970	2332	574.6	5996.7	2906.3	6571
1971	2302	595.0	5937.0	2897.0	6532
1972	2254	795.9	5854.1	3050.0	6650
1973	2290	602.8	5860.2	2893.0	6463
1974	2557	974.7	6092.3	3532.0	7067
1975	2885	1104.6	6390.4	3990.0	7495
1976	2709	1103.5	6184.5	3813.0	7288
1977	2591	1258.4	6030.6	3849.0	7289
1978	3059	1188.3	6468.7	4247.0	7657
1979	2985	1373.2	6359.8	4358.0	7733
1980	3213	1299.1	6552.9	4512.0	7852
1981	3656	1279.0	6966.0	4935.0	8245
1982	6230	2390.1	9504.6	8619.6	11895
1983	6652	2423.1	9892.4	9075.4	12315
1984	7225	2491.8	10435.3	9717.1	12927
1985	7395	2664.3	10569.7	10059.0	13234
1986	8694	3416.8	11834.1	12111.0	15251
1987	10393	4078.7	13503.2	14471.9	17582
1988	12240	4315.3	15314.9	16555.1	19630
1989	14042	4609.0	17082.2	18651.1	21691
1990	14945	4645.0	17954.9	19589.9	22600
1991	15670	4234.2	18645.4	19904.7	22880
1992	17010	4397.0	19950.2	21407.2	24347
1993	18189	4688.0	21098.8	22876.7	25787
1994	16529	4513.0	19404.1	21042.1	23917
1995	17055	4513.0	19894.5	21567.5	24408
1996	17655	4513.0	20465.4	22168.3	24978
1997	18016	4513.0	20791.2	22529.1	25304
1998	17706	4252.2	20446.4	21958.6	24699
1999	17664	4252.2	20374.3	21916.5	24626
2000	17455	4152.2	20152.4	21607.6	24305

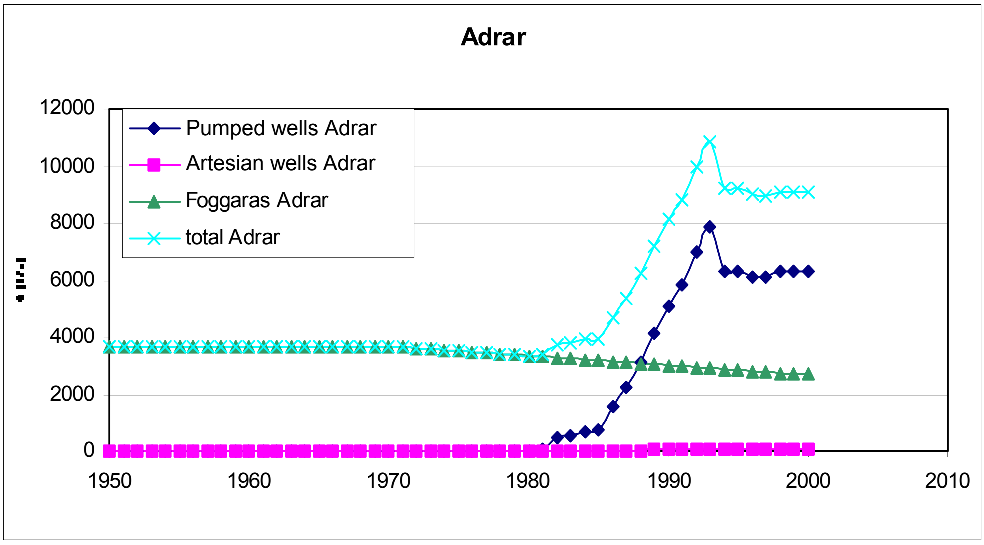
Annex 4 Figure 1 – Record of exploitation of the CI in Algeria

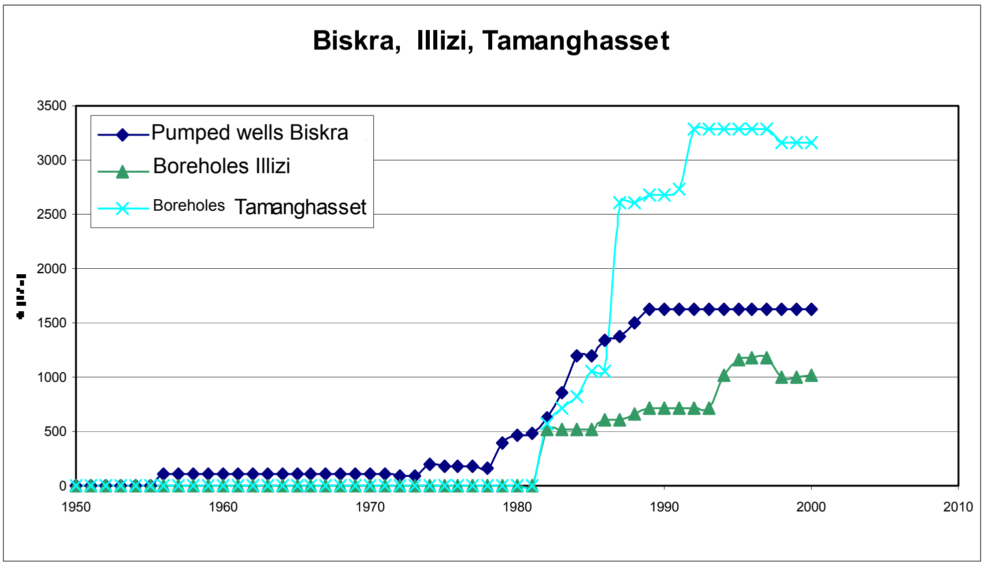


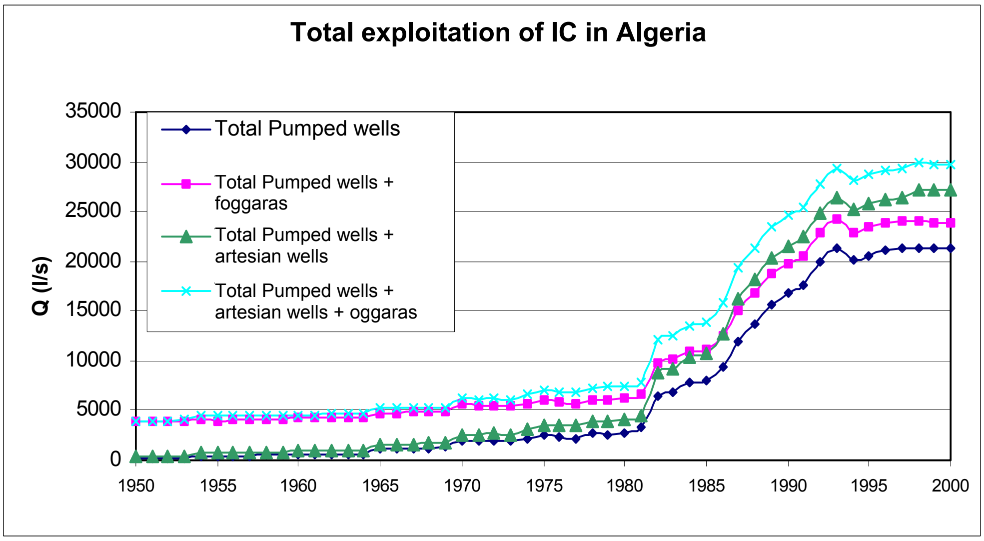




Annex 4 Figure 2 – Record of exploitation of the CI in Algeria (continued)





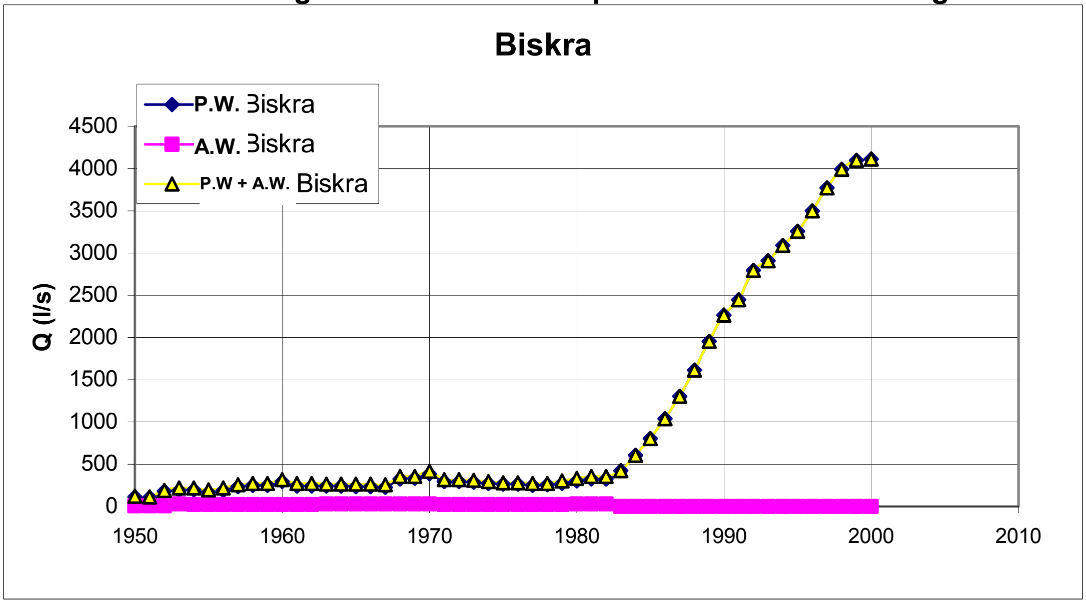


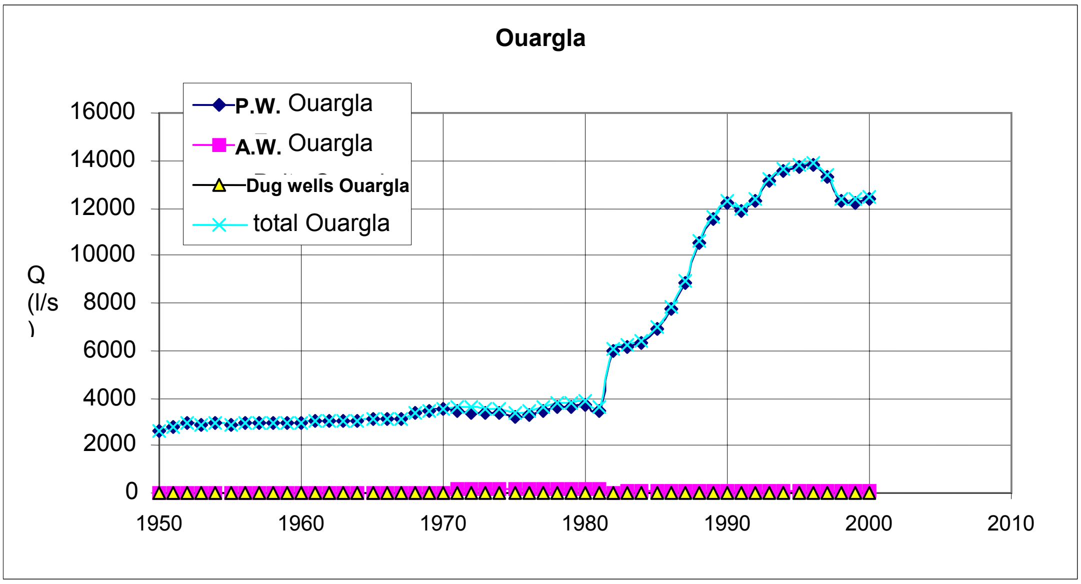
Annex 4 Table 3 – Record of exploitation of the CT in Algeria

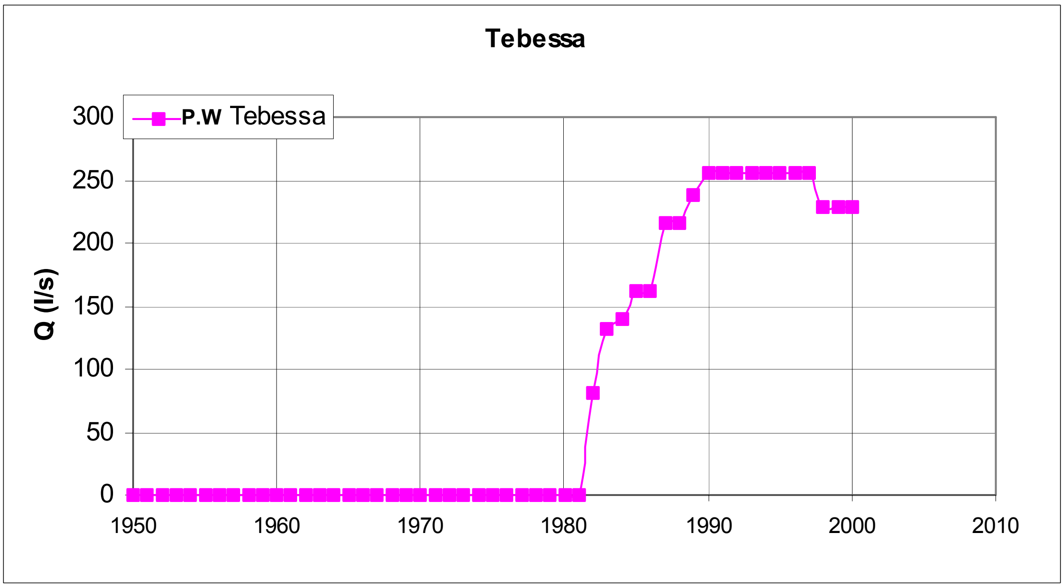
DATE	Pumped Wells	Artesian wells	Total Biskra	Pumped Wells	Artesian wells	Total El Oued	Pumped Wells	Pumped Wells	Artesian wells	Dug wells	Total Ouargla	Pumped Wells	Pumped Wells	Pumped Wells	Artesian wells	Total
1950	112	7	119	3011	0	3011	0.0	2640	0		2640.0	0.0	0.0	5763.0	7.0	5770.0
1951	106	7	113	2912	0	2912	0.0	2801	0		2801.0	0.0	0.0	5819.0	7.0	5826.0
1952	181	7	188	2876	1	2877	0.0	2935	0		2935.0	0.0	0.0	5992.0	8.0	6000.0
1953	190	28	218	2888	26	2914	0.0	2846	0		2846.0	0.0	0.0	5924.0	54.0	5978.0
1954	194	26	220	2948	25	2973	0.0	2965	0		2965.0	0.0	0.0	6107.0	51.0	6158.0
1955	170	26	196	2917	104	3021	0.0	2902	0		2902.0	0.0	0.0	5989.0	130.0	6119.0
1956	192	26	218	3077	104	3181	0.0	2973	0		2973.0	0.0	0.0	6242.0	130.0	6372.0
1957	236	25	261	2930	101	3031	0.0	2965	0		2965.0	0.0	0.0	6131.0	126.0	6257.0
1958	249	25	274	3009	98	3107	0.0	2962	0		2962.0	0.0	0.0	6220.0	123.0	6343.0
1959	249	25	274	2982	96	3078	0.0	2953	0		2953.0	0.0	0.0	6184.0	121.0	6305.0
1960	239	25	264	2941	93	3034	0.0	2982	0		2982.0	0.0	0.0	6162.0	118.0	6280.0
1961	246	24	270	3056	96	3152	0.0	3047	0		3047.0	0.0	0.0	6349.0	120.0	6469.0
1962	243	26	269	3147	95	3242	0.0	3014	0		3014.0	0.0	0.0	6404.0	121.0	6525.0
1963	241	27	268	3154	94	3248	0.0	3042	0		3042.0	0.0	0.0	6437.0	121.0	6558.0
1964	240	27	267	3142	92	3234	0.0	3055	0		3055.0	0.0	0.0	6437.0	119.0	6556.0
1965	238	27	265	3238	91	3329	0.0	3109	0		3109.0	0.0	0.0	6585.0	118.0	6703.0
1966	236	27	263	3233	89	3322	0.0	3133	0		3133.0	0.0	0.0	6602.0	116.0	6718.0
1967	228	27	255	3362	87	3449	0.0	3151	0		3151.0	0.0	0.0	6741.0	114.0	6855.0
1968	329	27	356	3389	87	3476	0.0	3379	0		3379.0	0.0	0.0	7097.0	114.0	7211.0
1969	331	27	358	3549	87	3636	0.0	3449	0		3449.0	0.0	0.0	7329.0	114.0	7443.0
1970	388	27	415	4195	85	4280	0.0	3510	0		3510.0	0.0	0.0	8093.0	112.0	8205.0
1971	294	26	320	3216	299	3515	0.0	3442	208		3650.0	0.0	0.0	6952.0	533.0	7485.0
1972	293	25	318	3329	320	3649	0.0	3384	208		3592.0	0.0	0.0	7006.0	553.0	7559.0
1973	285	24	309	3466	341.1	3807.1	0.0	3367.9	189.5		3557.4	0.0	0.0	7118.9	554.6	7673.5
1974	272	23	295	3716	383.3	4099.3	0.0	3352.2	171		3523.2	0.0	0.0	7340.2	577.3	7917.5
1975	262	22	284	3729.5	389.4	4118.9	0.0	3201.1	171.5		3372.6	0.0	0.0	7192.6	582.9	7775.5
1976	262	21	283	3717.0	378.9	4095.9	0.0	3310.9	172		3482.9	0.0	0.0	7289.9	571.9	7861.8
1977	250	20	270	3692.5	405.4	4097.9	0.0	3470.8	172.5		3643.3	0.0	0.0	7413.3	597.9	8011.2
1978	254	21	275	3756.0	392.9	4148.9	0.0	3632.1	173		3805.1	0.0	0.0	7642.1	586.9	8229.0

DATE	Pumped Wells	Artesian wells	Total Biskra	Pumped Wells	Artesian wells	Total El Oued	Pumped Wells	Pumped Wells	Artesian wells	Dug wells	Total Ouargla	Pumped Wells	Pumped Wells	Pumped Wells	Artesian wells	Total
1979	275	25	300	3705.7	376.7	4082.3	0.0	3627.0	181		3808.0	0.0	0.0	7607.7	582.7	8190.3
1980	305	30	335	3698.3	362.3	4060.7	0.0	3666.0	189		3855.0	0.0	0.0	7669.3	581.3	8250.7
1981	324	34	358	3742.0	408.0	4150.0	0.0	3416.0	197		3613.0	0.0	0.0	7482.0	639.0	8121.0
1982	324	34	358	3913.2	1233.2	5146.4	25.0	4299.7	33.5	30.8	4364.0	81.4	125.2	8799.3	1300.6	10099.9
1983	324	34	358	4005.1	1279.0	5284.1	88.0	4446.3	42.8	30.8	4520.0	131.4	125.2	9150.9	1355.8	10506.7
1984	324	34	358	4098.4	1315.7	5414.1	123.0	4557.0	42.8	30.8	4630.7	140.4	125.2	9398.9	1392.5	10791.4
1985	324	34	358	4274.2	1382.3	5656.5	144.0	4989.2	43.8	30.8	5063.8	162.4	125.2	10049.8	1460.2	11509.9
1986	324	34	358	4660.0	1530.0	6190.0	174.5	5632.4	43.8	30.8	5707.1	162.4	125.2	11109.4	1607.8	12717.2
1987	324	34	358	4827.0	1599.2	6426.2	174.5	6094.4	48.8	30.8	6174.1	216.4	125.2	11792.4	1682.0	13474.4
1988	324	34	358	5355.0	1600.2	6955.2	174.5	6901.4	48.8	30.8	6981.1	216.4	141.8	13144.0	1683.0	14827.0
1989	324	34	358	5871.3	1600.2	7471.5	115.3	7635.3	60.1	30.8	7726.2	237.8	141.8	14356.3	1694.3	16050.6
1990	324	34	358	6383.3	1600.2	7983.5	465.3	8091.3	70.1	30.8	8192.2	255.8	141.8	15692.4	1704.3	17396.7
1991	324	34	358	6637.6	1676.2	8313.8	485.3	8265.0	70.1	30.8	8366.0	255.8	141.8	16140.4	1780.3	17920.6
1992	324	34	358	7022.5	1726.2	8748.6	485.3	8845.3	70.1	30.8	8946.3	255.8	166.7	17130.4	1830.3	18960.7
1993	324	34	358	7320.1	1733.2	9053.2	485.3	9451.0	70.1	30.8	9552.0	255.8	166.7	18033.8	1837.3	19871.0
1994	324	34	358	7524.9	1733.2	9258.0	485.3	9760.1	70.1	30.8	9861.0	255.8	179.1	18560.1	1837.3	20397.3
1995	324	34	358	8082.1	1733.2	9815.2	485.3	9906.3	70.1	30.8	10007.2	255.8	183.3	19267.6	1837.3	21104.8
1996	324	34	358	8579.8	1733.2	10313.0	485.3	9971.0	70.1	30.8	10072.0	255.8	183.3	19830.1	1837.3	21667.4
1997	324	34	358	8838.6	1733.2	10571.7	481.3	10151.5	70.1	30.8	10252.4	255.8	183.3	20265.3	1837.3	22102.6
1998	324	34	358	8934.5	1733.2	10667.7	460.3	9213.0	70.1	30.8	9313.9	228.8	183.3	19374.7	1837.3	21212.0
1999	324	34	358	8934.5	1733.2	10667.7	460.3	9213.0	70.1	30.8	9313.9	228.8	183.3	19374.7	1837.3	21212.0
2000	324	34	358	8934.5	1733.2	10667.7	460.3	9212.98	70.1	30.8	9313.9	228.8	183.3	19374.7	1837.3	21212.0

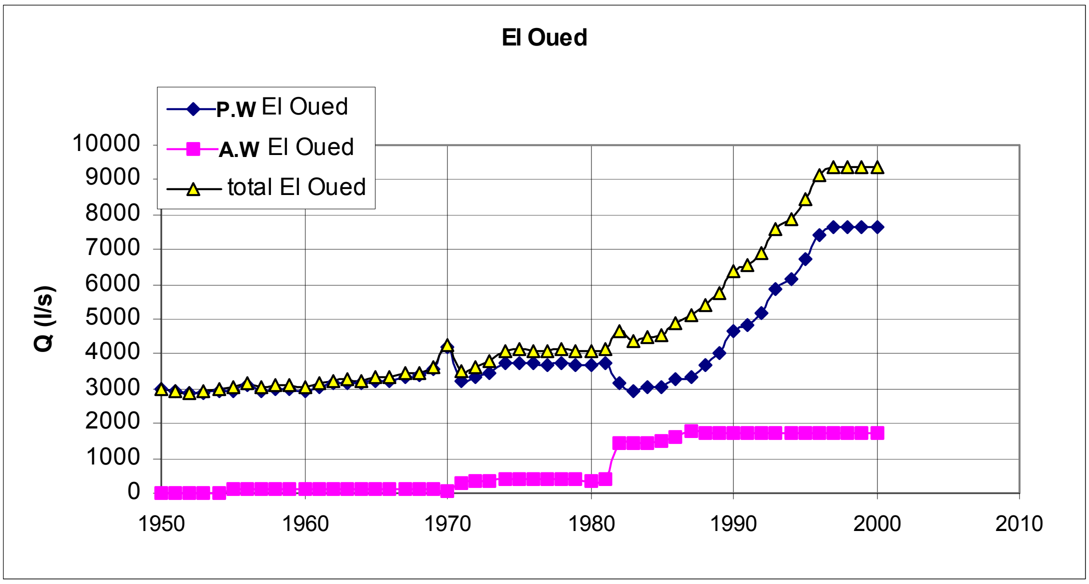
Annex 4 Figure 3 – Record of exploitation of the CT in Algeria

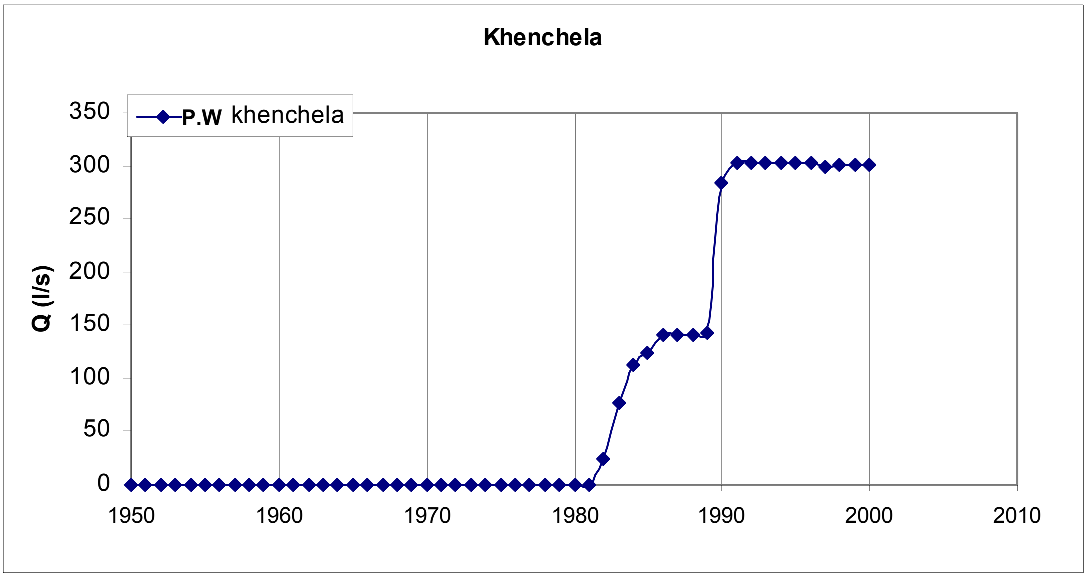


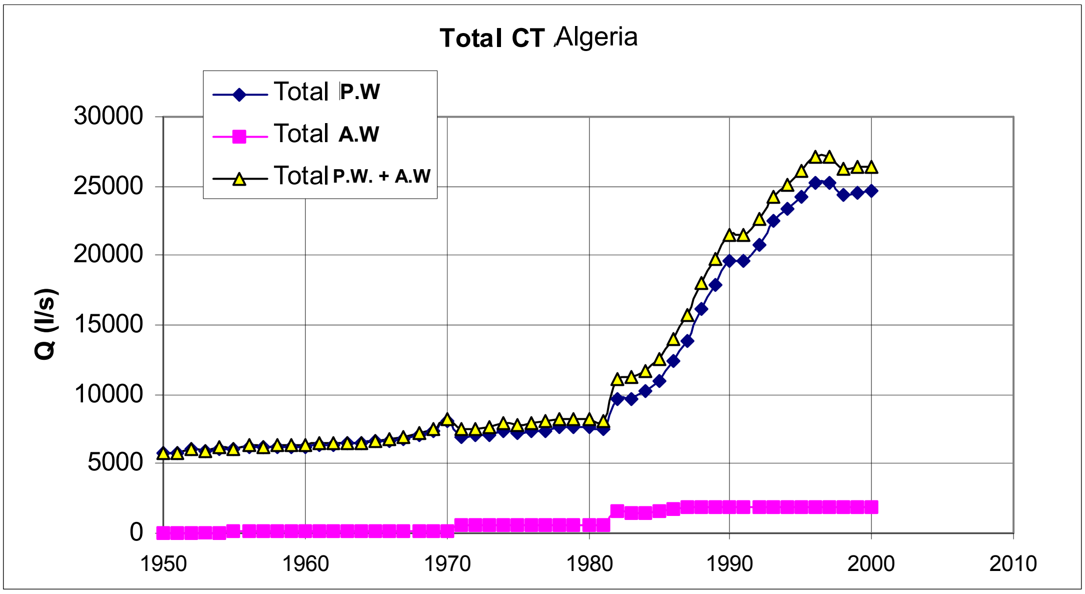




Annex 4 Figure 4 – Record of exploitation of the CT in Algeria (continued)



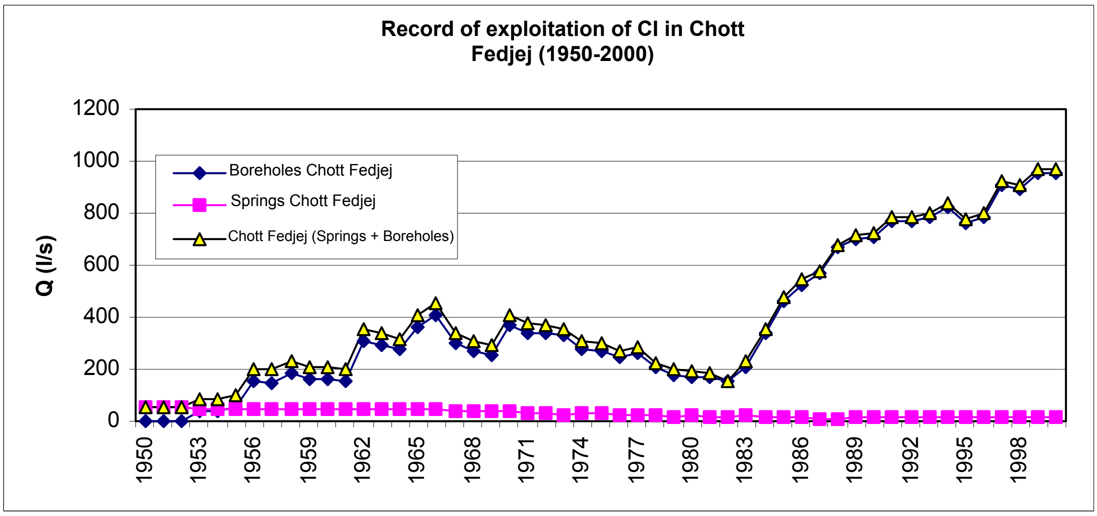


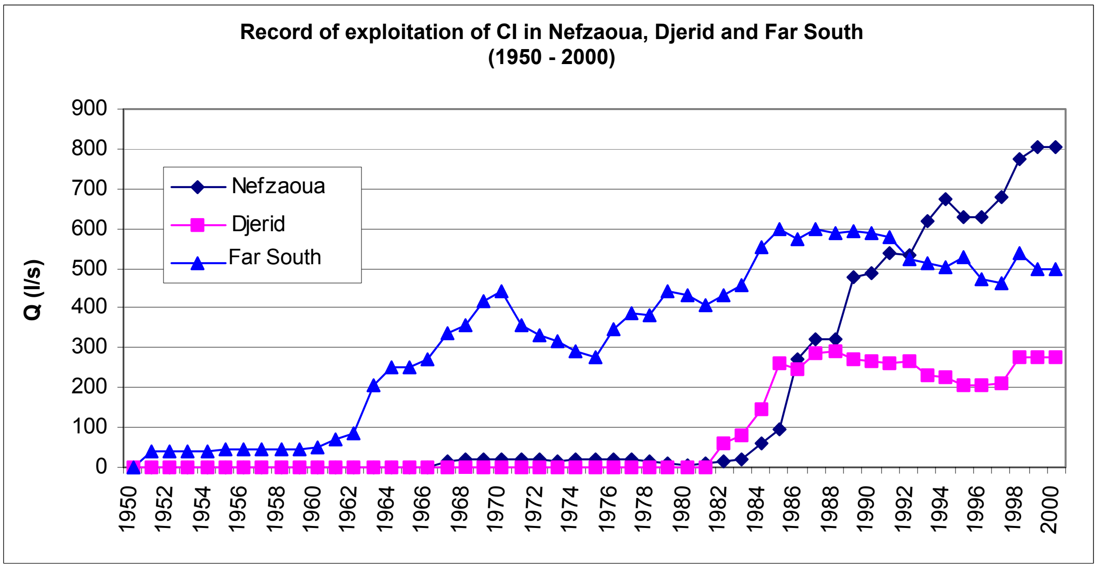


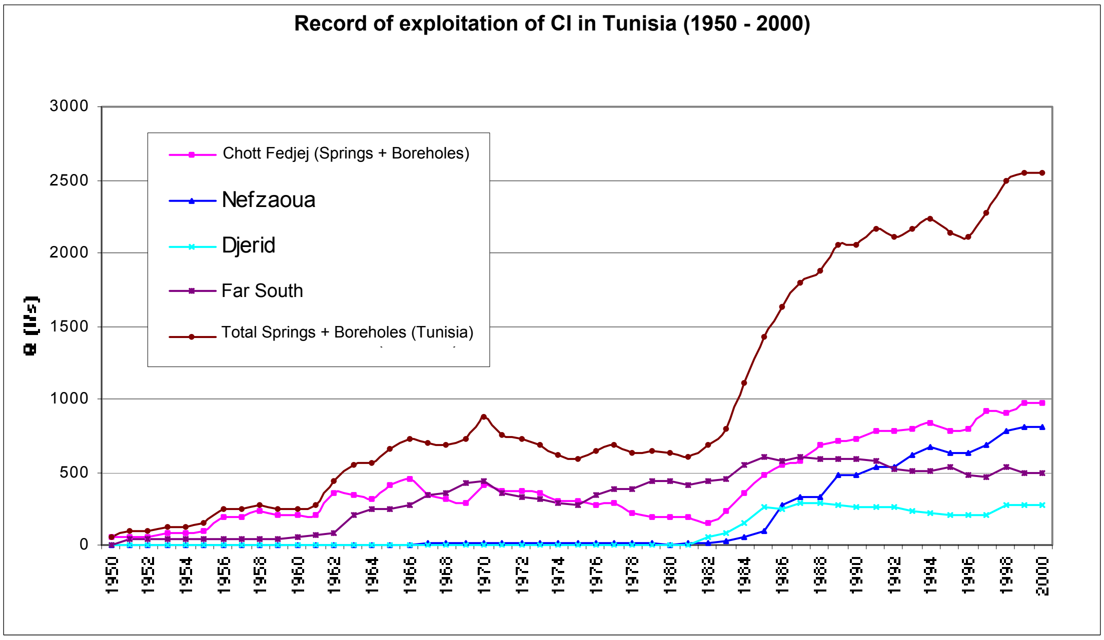
Annex 4 Table 4 – Record of exploitation of the CI in Tunisia

	Chott Fedjej						Total Tunisia	
Date	Wells	Springs	Total	Nefzaoua	Djerid	Far South	Wells	Springs + Forages
1950	0.0	51.0	51.0	0.0	0.0	2.0	2.0	53.0
1951	0.0	51.0	51.0	0.0	0.0	42.0	42.0	93.0
1952	0.0	51.0	51.0	0.0	0.0	42.0	42.0	93.0
1953	37.5	49.5	87.0	0.0	0.0	42.0	79.5	129.0
1954	36.0	49.5	85.5	0.0	0.0	42.0	78.0	127.5
1955	52.0	48.5	100.5	0.0	0.0	44.0	96.0	144.5
1956	152.0	46.5	198.5	0.0	0.0	44.0	196.0	242.5
1957	150.0	46.5	196.5	0.0	0.0	44.0	194.0	240.5
1958	184.6	46.5	231.1	0.0	0.0	44.0	228.6	275.1
1959	162.0	45.5	207.5	0.0	0.0	44.0	206.0	251.5
1960	160.0	44.0	204.0	0.0	0.0	48.0	208.0	252.0
1961	156.0	44.0	200.0	0.0	0.0	68.0	224.0	268.0
1962	310.2	43.5	353.7	0.0	0.0	83.0	393.2	436.7
1963	294.0	44.5	338.5	0.0	0.0	206.9	500.9	545.4
1964	275.0	43.0	318.0	0.0	0.0	248.9	523.9	566.9
1965	365.0	43.0	408.0	0.0	0.0	248.9	613.9	656.9
1966	409.5	43.0	452.5	0.0	0.0	273.9	683.4	726.4
1967	298.0	39.5	337.5	16.0	0.0	338.4	652.4	691.9
1968	273.0	37.5	310.5	18.0	0.0	357.5	648.5	686.0
1969	253.5	37.5	291.0	18.0	0.0	419.0	690.5	728.0
1970	371.5	37.5	409.0	20.0	0.0	443.6	835.1	872.6
1971	342.0	34.0	376.0	20.0	0.0	356.6	718.6	752.6
1972	339.0	31.0	370.0	18.0	0.0	331.6	688.6	719.6
1973	328.0	26.0	354.0	16.0	0.0	316.6	660.6	686.6
1974	280.0	27.0	307.0	18.0	0.0	291.6	589.6	616.6
1975	271.0	28.0	299.0	18.0	0.0	277.6	566.6	594.6
1976	249.0	21.0	270.0	20.0	0.0	348.6	617.6	638.6
1977	260.0	22.0	282.0	20.0	0.0	388.6	668.6	690.6
1978	205.0	20.0	225.0	15.0	0.0	383.7	603.7	623.7
1979	179.0	18.0	197.0	9.0	0.0	443.7	631.7	649.7
1980	169.0	20.0	189.0	5.0	0.0	431.6	605.6	625.6
1981	170.0	16.0	186.0	10.0	0.0	409.6	589.6	605.6
1982	157.2	18.0	157.2	12.9	58.1	432.7	660.9	678.9
1983	206.8	21.0	227.9	22.3	81.9	455.9	766.9	788.0
1984	337.5	17.4	354.9	59.4	145.3	551.5	1093.7	1111.0
1985	459.4	18.1	477.5	94.6	262.7	596.7	1413.4	1431.5
1986	526.9	17.7	544.6	269.6	248.8	573.5	1618.8	1636.5
1987	567.9	11.5	579.4	322.8	288.0	598.3	1777.0	1788.4
1988	668.8	11.4	680.2	323.1	291.1	586.8	1869.7	1881.1
1989	700.6	15.3	715.8	478.4	272.3	591.9	2043.2	2058.5
1990	703.9	16.3	720.2	485.7	265.3	586.6	2041.4	2057.8
1991	769.0	15.5	784.5	539.1	262.0	578.6	2148.7	2164.2
1992	767.6	15.0	782.6	535.4	265.3	522.4	2090.8	2105.8
1993	787.3	13.1	800.4	617.4	230.3	510.7	2145.8	2158.9
1994	825.2	12.3	837.6	672.0	223.9	502.7	2223.8	2236.1
1995	763.3	11.8	775.1	626.1	206.8	528.7	2124.9	2136.7
1996	786.6	11.6	798.1	627.3	205.8	474.8	2094.5	2106.0
1997	910.8	12.2	922.9	680.0	210.3	461.1	2262.1	2274.3
1998	889.3	15.1	904.4	776.6	277.1	539.8	2482.8	2497.8
1999	954.6	15.4	970.0	805.5	275.1	496.1	2531.4	2546.7
2000	**954.6**	**15.4**	**970.0**	**805.5**	**275.1**	**496.4**	**2531.7**	**2547.1**

Annexe 4 Figure 5 – Record of exploitation of the CI in Tunisia



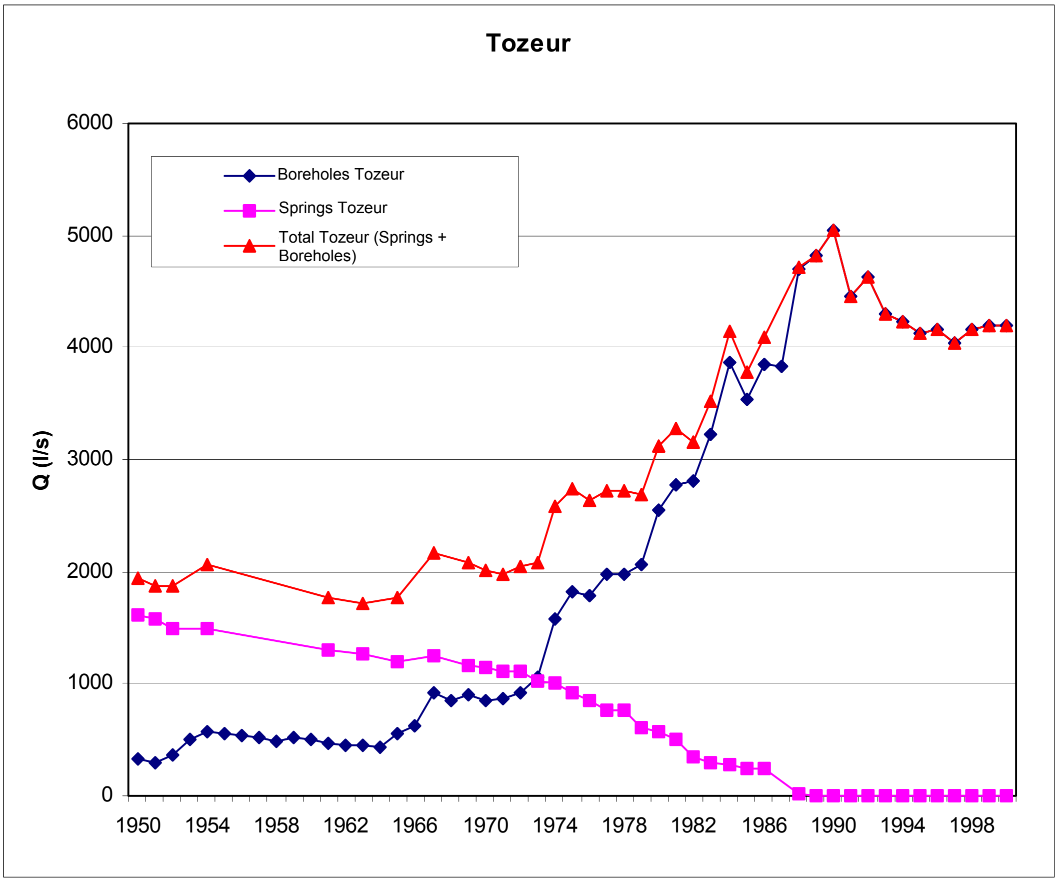


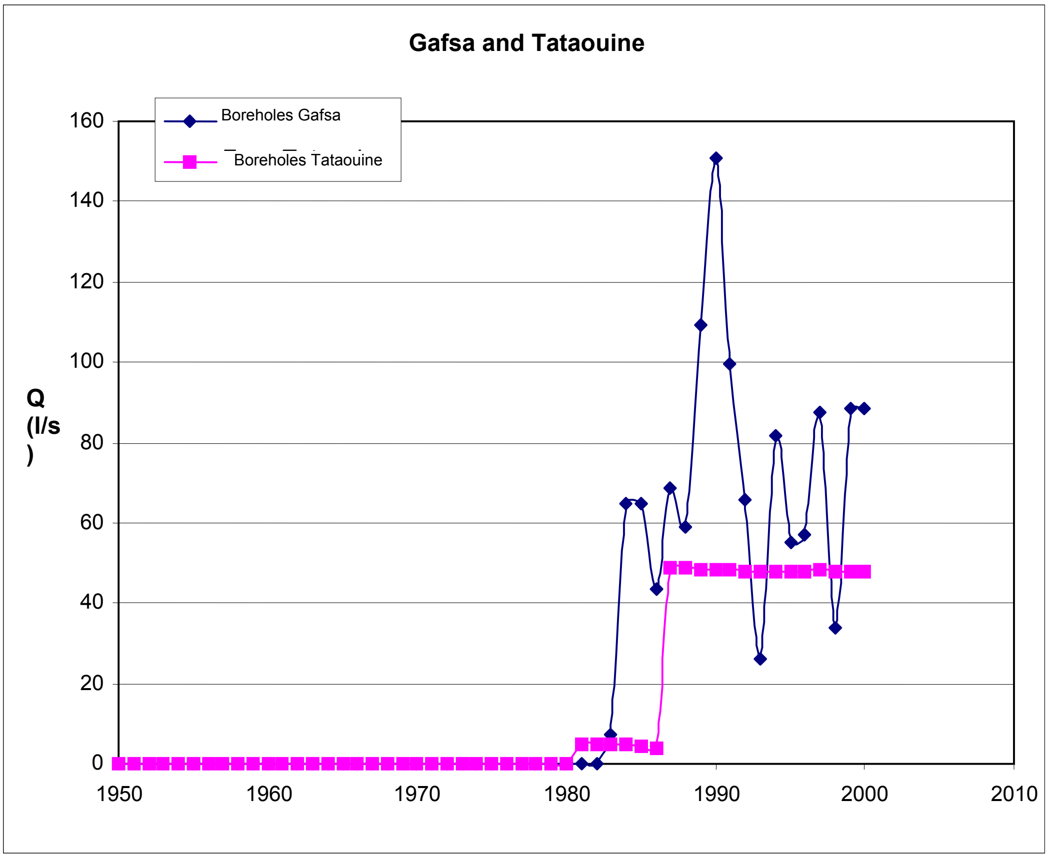


Annex 4 Table 5 – Record of exploitation of the CT aquifer in Tunisia

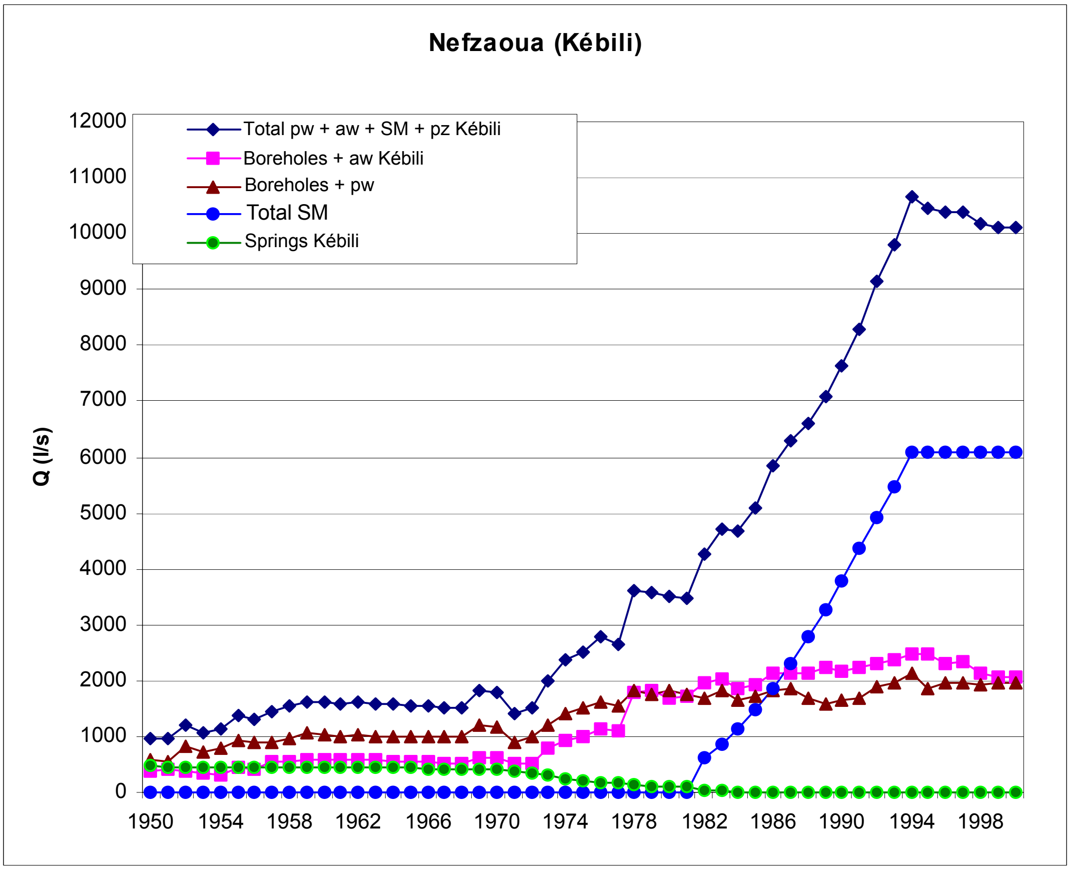
Date	Gafsa	Kebili			Tataouine	Tozeur			Tunisia	
	Boreholes	Boreholes	Springs	Total	Boreholes	Boreholes	Springs	Total	Boreholes	Total Springs + Boreholes
1950	0.0	959.7	468.0	1427.7	0.0	321.7	1620.0	1941.7	1281.4	3369.4
1951	0.0	978.6	450.0	1428.6	0.0	298.0	1570.0	1868.0	1276.6	3296.6
1952	0.0	1198.3	445.0	1643.3	0.0	370.2	1500.0	1870.2	1568.5	3513.5
1953	0.0	1073.3	440.2	1513.5	0.0	510.7			1584.0	2024.2
1954	0.0	1125.2	445.0	1570.2	0.0	569.6	1490.0	2059.6	1694.8	3629.8
1955	0.0	1369.1	454.0	1823.1	0.0	554.6			1923.7	2377.7
1956	0.0	1307.5	452.0	1759.5	0.0	534.0			1841.5	2293.5
1957	0.0	1444.1	450.0	1894.1	0.0	512.8			1956.9	2406.9
1958	0.0	1543.5	448.0	1991.5	0.0	491.6			2035.1	2483.1
1959	0.0	1628.9	446.0	2074.9	0.0	517.7			2146.6	2592.6
1960	0.0	1599.2	444.0	2043.2	0.0	495.2			2094.4	2538.4
1961	0.0	1580.8	442.5	2023.3	0.0	474.2	1300.0	1774.2	2055.0	3797.5
1962	0.0	1602.9	439.0	2041.9	0.0	452.8			2055.7	2494.7
1963	0.0	1584.4	436.0	2020.4	0.0	448.8	1270.0	1718.8	2033.2	3739.2
1964	0.0	1566.6	433.0	1999.6	0.0	431.0			1997.6	2430.6
1965	0.0	1551.4	430.0	1981.4	0.0	560.3	1200.0	1760.3	2111.7	3741.7
1966	0.0	1535.4	427.0	1962.4	0.0	618.5			2153.9	2580.9
1967	0.0	1516.2	424.0	1940.2	0.0	917.5	1250.0	2167.5	2433.7	4107.7
1968	0.0	1521.8	421.0	1942.8	0.0	844.1			2365.9	2786.9
1969	0.0	1809.7	417.0	2226.7	0.0	909.8	1170.0	2079.8	2719.5	4306.5
1970	0.0	1784.6	412.0	2196.6	0.0	857.6	1150.0	2007.6	2642.2	4204.2
1971	0.0	1419.0	393.0	1812.0	0.0	865.0	1115.0	1980.0	2284.0	3792.0
1972	0.0	1519.0	350.0	1869.0	0.0	925.0	1115.0	2040.0	2444.0	3909.0
1973	0.0	1994.0	304.5	2298.5	0.0	1054.0	1021.0	2075.0	3048.0	4373.5
1974	0.0	2366.0	247.5	2613.5	0.0	1586.0	999.0	2585.0	3952.0	5198.5
1975	0.0	2523.0	201.5	2724.5	0.0	1820.0	914.0	2734.0	4343.0	5458.5
1976	0.0	2768.0	174.5	2942.5	0.0	1788.0	847.0	2635.0	4556.0	5577.5
1977	0.0	2644.0	156.0	2800.0	0.0	1972.0	759.0	2731.0	4616.0	5531.0
1978	0.0	3598.0	131.0	3729.0	0.0	1969.0	758.0	2727.0	5567.0	6456.0
1979	0.0	3573.0	117.0	3690.0	0.0	2072.0	615.0	2687.0	5645.0	6377.0
1980	0.0	3506.0	106.0	3612.0	0.0	2549.0	574.0	3123.0	6055.0	6735.0
1981	0.0	3466.0	93.0	3559.0	5.1	2776.0	497.0	3273.0	6247.1	6837.1
1982	0.0	4262.3	30.6	4292.9	4.8	2811.2	345.1	3156.4	7078.3	7454.0
1983	7.3	4715.3	20.2	4735.5	4.8	3227.9	293.7	3521.6	7955.3	8269.2
1984	64.8	4669.1	11.3	4680.4	4.8	3872.6	273.4	4146.0	8611.4	8896.0
1985	65.0	5093.0	11.7	5104.7	4.1	3533.9	237.9	3771.8	8696.0	8945.6
1986	43.4	5835.2	6.6	5841.8	3.8	3847.0	238.8	4085.8	9729.4	9974.8
1987	68.8	6296.3	5.6	6301.9	48.8	3832.3			10246.2	10251.8
1988	59.1	6605.4	11.8	6617.2	48.6	4699.9	23.0	4722.9	11413.0	11447.9
1989	109.2	7085.2	10.0	7095.2	48.3	4825.8	0.0	4825.8	12068.6	12078.6
1990	150.9	7616.3	8.8	7625.1	48.3	5051.8	0.0	5051.8	12867.3	12876.1
1991	99.6	8283.7	8.5	8292.3	48.2	4455.9	0.0	4455.9	12887.4	12895.9
1992	65.8	9129.6	7.5	9137.1	47.8	4637.8	0.0	4637.8	13881.0	13888.6
1993	25.9	9800.5	7.5	9808.1	47.8	4293.9	0.0	4293.9	14168.3	14175.8
1994	81.5	10666.3	7.5	10673.9	48.0	4233.4	0.0	4233.4	15029.2	15036.7
1995	54.9	10435.6	6.7	10442.3	48.0	4134.1	0.0	4134.1	14672.5	14679.2
1996	57.1	10377.2	6.0	10383.2	48.0	4163.4	0.0	4163.4	14645.7	14651.7
1997	87.3	10384.3	5.2	10389.5	48.1	4037.9	0.0	4037.9	14557.7	14562.8
1998	33.8	10168.3	4.3	10172.6	48.0	4160.9	0.0	4160.9	14411.0	14415.4
1999	88.2	10099.5	6.0	10105.5	48.0	4190.6	0.0	4190.6	14426.4	14432.4
2000	88.2	10099.5	6.0	10105.5	48.0	4190.6	0.0	4190.6	14426.4	14432.4

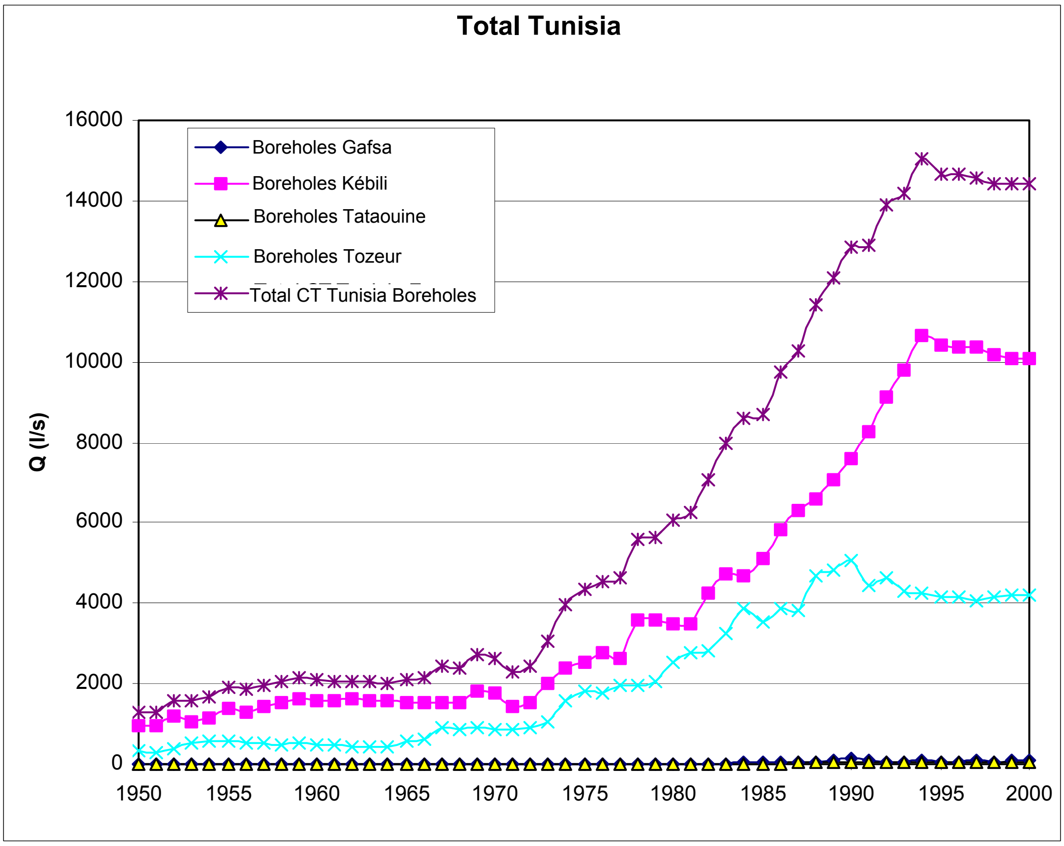
Annex 4 Table 6 – Record of exploitation du CT in Tunisia (graphs





Annex 4 Table 7 – Record of exploitation of the CT in Tunisia (graphs)





ANNEXE 5

RECORD OF ABSTRACTIONS FROM THE LIBYAN SAHARAN BASIN

ANNEX 5

Record of abstractions from the Libyan Saharan basin

Only the wells supplying the pipelines of the Great Manmade River are equipped with recorders and are regularly monitored. The many wells drilled in the eastern Saharan basin in Libya for drinking water supply and, mainly, for irrigation do not form the subject of a monitoring of abstractions. Only on the occasion of major synthesis studies is an exhaustive inventory carried out, allowing an estimate with reasonable approximation of the flows abstracted. The studies conducted by GEFLI in the 1970s (GEFLI, 1976, GEFLI, 1978) in fact constitute the only serious reference elements for establishing the record of abstractions. Unfortunately, these studies date back to a period corresponding to the very inception of the exploitation of the deep aquifers and much earlier than the advent of private irrigation which was to effectively start in the Saharan basin only in the 1990s.

The estimates provided in the present report result from a combination of information and data elicited from various sources, of which in particular :

- Sketchy inventories by GWA technicians which are, unfortunately, lacking in direct flow measurements ;
- Irrigated area and estimate of water needs according to the crops ;
- Number of power supply contracts and rapid surveys in order to evaluate the average area of the farms and the type of crop rotation practiced.

The uncertainties which affect each of the parameters used to establish the abstractions records justify the changes introduced in the successive estimates, according to newly acquired information.

In view of the impossibility to assign a flow to each exploitation well, it has been deemed preferable to assign the estimated abstraction flows to abstraction groups located approximately at the gravity groups of the abstraction zones determined by GPS. The distribution of the abstraction groups has been selected by taking into account the measurements of the model grids (12.5 x 12.5 km). The record (histories) tables provided as per zone in the present report indicate the exploitation flows to be assigned to each abstraction group. The coordinates of the abstraction groups are given in Annex.

The abstraction records have been established separately by major zones with homogeneous geological and geomorphological characteristics :

- The coastal zone from Al Khums to Tawurgha, dominated by a major spring, Ayn Tawurgha, and the oresence of a Mio-Plio-Quaternary aquifer used by private farming and of a Cretaceous aquifer exploited for the irrigation of agricultural projects ;
- The catchment of Wadi Sufajjin whose valleys, which are regularly watered by floods, have been equipped with deep wells allowing the irrigation of several crop zones ;
- The southern flank of Jabal Nefusa where the wells which often reach the Lower Cretaceous serve to supply a series of small towns ;
- The eastern flank of Hamadah al Hamra where very deep wells, some of which reach 2000 m, have been drilled for the irrigation of crop zones located in valleys lying in the Hamadah ;
- The western flank of Hamadah al Hamra, characterized by the presence of a few traditional oases, of which Ghadamis ;

- The zone of Al Jufrah which has a little deep artesian aquifer west of the Hun graben on which the exploitation of groundwater has been concentrated for both irrigation and drinking water supply.

1. Coastal zone from Al Khums to Tawurgha

In this zone, several agricultural projects were established in the late 1970s, at the location of old projects (Dafniyah, Tuminah, Kararim). Initially, the water used for agriculture used to originate from artesian wells tapping the deep aquifer of the Upper Cretaceous. Artesianism almost disappeared in Dafniyah and Tuminah in the 1860s and 1970s. Afterwards, 25 new deep wells (450 to 500 m), also tapping the aquifer formations of the Upper Cretaceous, were drilled in Dafniyah, 31 wells in Tuminah and 9 wells in Kararim, within the framework of rehabilitation of these projects. Since then, most of the wells have been abandoned, either following pump failure, or due to excess water salinity (1700 to 5000 mg/l, approx. 3000 mg/l on average). At present, only 29 wells are still in operating order out of the 65 that were drilled back in the 1970s.

In the valley of Wadi Kaam, the water arriving from the spring of Kaam, added to the water supplied by the 15 wells drilled upstream of the spring, has been used for the irrigation of two farming projects of 1362 ha. Actually, the water of the spring is at present obtained by 4 pumps introduced in the spring and supplying about 8 Mm3/year, while the natural flow of the spring is considered as nil.

The Tawurgha spring, on the contrary, continues to supply a high flow which has varied fairly little during the past 50 years in spite of the abstractions made from all the aquifers present in the zone and being probably connected with the spring. During the 1980s, 9 artesian wells tapping the aquifer of the Cambro-Ordovician were drilled in the vicinity of the spring, of which 8 are used to supply the town of Misratah. Since 1998, however, the major part of the drinking water supply to Misratah has been supplied by the Great Manmade River, while the wells of Tawurgha are assigned a regulation role.

Alongside with agricultural development in the context of projects financed by the State, private farming using, at the beginning, sunk wells water, then, gradually, the water of drilled wells tapping the Moi-Pliocene upper aquifer has developed at an accelerated pace in the course of the past decade. Private farming has mainly extended in the valleys located south of Zliten and in the whole zone of As Sikt, to the south-west of Misratah

RECORD OF ABSTRACTIONS FROM THE COASTAL ZONE FROM AL KHUMS TO TAWURGHA

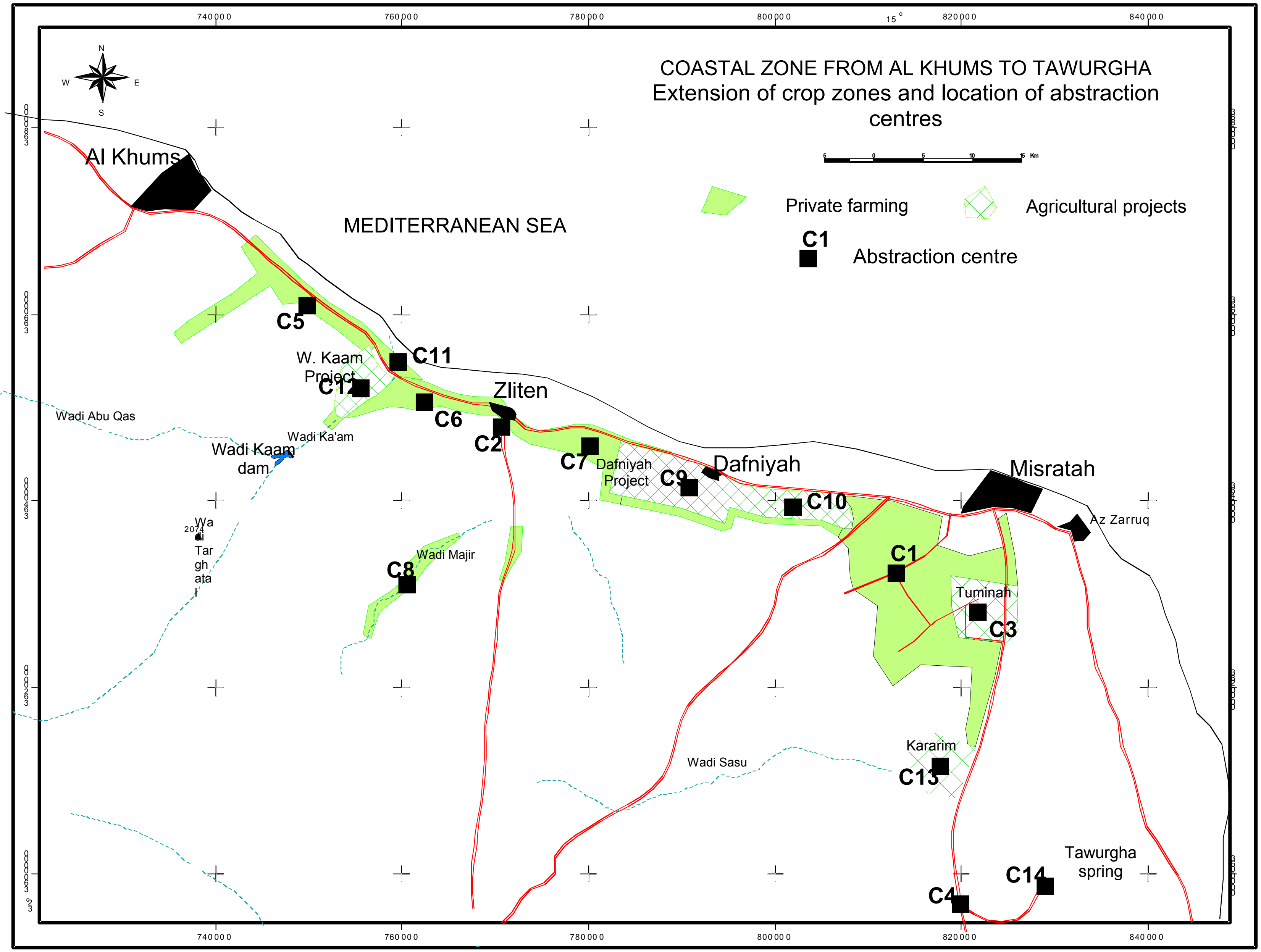
Aquifer and abstraction zone		Number of abstr. group on map	Abstractions in million m3/an										
			1950	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000
Mio-Plio-Quaternary													
DWS	Sikt Misratah	C1	0.0	0.0	0.0	0.0	0.0	5.0	8.0	8.0	4.0	1.0	0.0
	Zliten	C2	0.5	0.5	0.5	0.5	0.8	0.8	1.0	1.0	2.0	2.0	1.0
	Tuminah	C3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	1.0	1.0	1.0
Sub-total MPQ DWS			*0.5*	*0.5*	*0.5*	*0.5*	*0.8*	*5.8*	*9.5*	*9.5*	*7.0*	*4.0*	*2.0*
Private farming	Kaam	C5	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.0	2.0	2.0	3.0
	Zliten	C6	0.5	0.5	1.0	1.0	1.5	2.0	2.0	3.0	4.0	5.0	5.0
	Zliten	C7	0.5	0.5	1.0	1.0	1.5	2.0	2.0	3.0	3.0	4.0	4.0
	Wadi Majir	C8	0	0	0	0	0	0.0	0.0	0.0	2.0	3.0	5.0
	Dafniyah	C9	2.5	2.5	4.5	4.5	4.5	8.0	8.0	9.0	9.0	10.0	12.0
	Dafniyah	C10	2.6	2.6	4.6	4.6	4.6	7.0	7.0	8.0	8.0	10.0	11.0
	Sikt	C1	0.0	0.0	0.0	0.0	1.0	1.5	2.0	3.0	3.0	4.0	10.0
	Tuminah	C3	1.1	1.1	2.4	2.4	2.4	3.2	3.0	3.0	4.0	4.0	5.0
Sub-total MPQ agriculture privée			*7.7*	*7.7*	*14.0*	*14.5*	*16.5*	*24.7*	*25.0*	*30.0*	*35.0*	*42.0*	*55.0*
Total MioPlioQuaternary			**8.2**	**8.2**	**14.5**	**15.0**	**17.3**	**30.5**	**34.5**	**39.5**	**42.0**	**46.0**	**57.0**
Upper Cretaceous													
Agricultural projects	Source wadi Kaam	C11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	8.2	8.2	8.2
	Wadi Kaam project	C12	0.0	0.0	0.0	0.0	0.0	0.0	11.0	11.0	11.0	11.0	11.0
	Dafniyah	C9	1.3	0.9	0.5	0.3	0.0	0.0	5.0	5.0	4.0	2.0	0.5
	Dafniyah	C10	1.3	0.9	0.5	0.3	0.0	0.0	5.0	5.0	4.0	2.0	0.5
	Tummina	C3	17.0	10.0	9.9	8.2	2.7	4.4	12.6	13.0	13.0	12.0	11.5
	Kararim	C13	2.1	1.3	1.2	0.4	0.1	0.0	2.9	2.9	2.9	2.9	2.9
Sub-total Projets			*21.7*	*13.1*	*12.1*	*9.2*	*2.8*	*4.4*	*36.5*	*45.1*	*43.1*	*38.1*	*34.6*
DWS	Tawurgha pour DWS Misratah	C4	0.0	0.0	0.0	0.0	0.0	2.0	2.0	2.0	1.0	0.0	0.0
	Zliten	C2	0.5	0.5	0.6	0.6	0.8	1.0	1.0	2.0	2.0	3.0	3.0
	Tuminah	C3	0.5	0.5	0.6	0.6	0.8	1.0	1.0	1.0	1.0	2.0	2.0
	Kararim	C13	0.5	0.5	0.5	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0
Sub-total DWS Ks			*1.5*	*1.5*	*1.7*	*1.7*	*2.4*	*4.9*	*5.0*	*6.0*	*5.0*	*6.0*	*6.0*
Total Upper Cretaceous			**23.2**	**14.6**	**13.8**	**10.9**	**5.2**	**9.3**	**41.5**	**51.1**	**48.1**	**44.1**	**40.6**
Lower Cretaceous – Palaeozoic													
Tawurgha wells forr DWS Misratah		C14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	20.0	12.0	6.0
Total Lower Cretaceous-Palaezoic			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**25.0**	**20.0**	**12.0**	**6.0**
TOTAL zone			**31.4**	**22.8**	**28.3**	**25.9**	**22.5**	**39.8**	**76.0**	**115.6**	**110.1**	**102.1**	**103.6**

Kaam spring													
	Upper Cretaceous		16	16	15	15	14	14	12	4	2	0	0
Total flow of spring			16	16	15	15	14	14	12	4	2	0	0

Note on Kaam spring : For a few years now, 4 pumps of 300 m3/hr have been installed into the spring. The spring operates, therefore now, as a well and is computed as an abstraction from the Upper Cretaceous. Currently, the natural flow of the spring is nil.

Source Tawurgha													
	Upper Cretaceous	C14	23	23	23	23	23	22	22	20	20	19	18
	Crétacé Inf. - Paléozoique	C14	43	41	41	40	40	40	40	37	37	37	38
Total flow of spring			66	64	64	63	63	62	62	57	57	56	56

Note on the flow of the Tawurgha spring: Several flow measurements were conducted between 1972 and 1977. The mean value of the measured flows was of 1,966 m3/s (62 Mm3/year). In February 2001, a flow measurement yielded a mean value, over several days, of 55.9 Mm3/year. A report for 1977 by GWA (authors: Pallas and Bufila) proposed that out of the 62 Mm3/year measured at the time, 22 would be originating from current recharge in the catchment of Wadi Sufajjin, especially in the Upper Cretaceous formations, while 40 would be originating from the Kiklah and Palaeozoic deep aquifers. This distribution of water origin has been maintained in the record. Previous values to 1970 have been extrapolated.


COASTAL ZONE FROM AL KHUMS TO TAWURGHA
Extension of crop zones and location of abstraction centres
Private farming
Agricultural projects
C1
Abstraction centre
MEDITERRANEAN SEA
Al Khums
Zliten
Dafniyah
Misratah
Az Zarruq
W. Kaam Project
Dafniyah Project
Tuminah
Kararim
Tawurgha spring
Wadi Abu Qas
Wadi Ka'am
Wadi Kaam dam
Wadi Majir
Wadi Sasu
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
740000
760000
780000
800000
820000
840000

2. Basin of Wadi Sufajjin

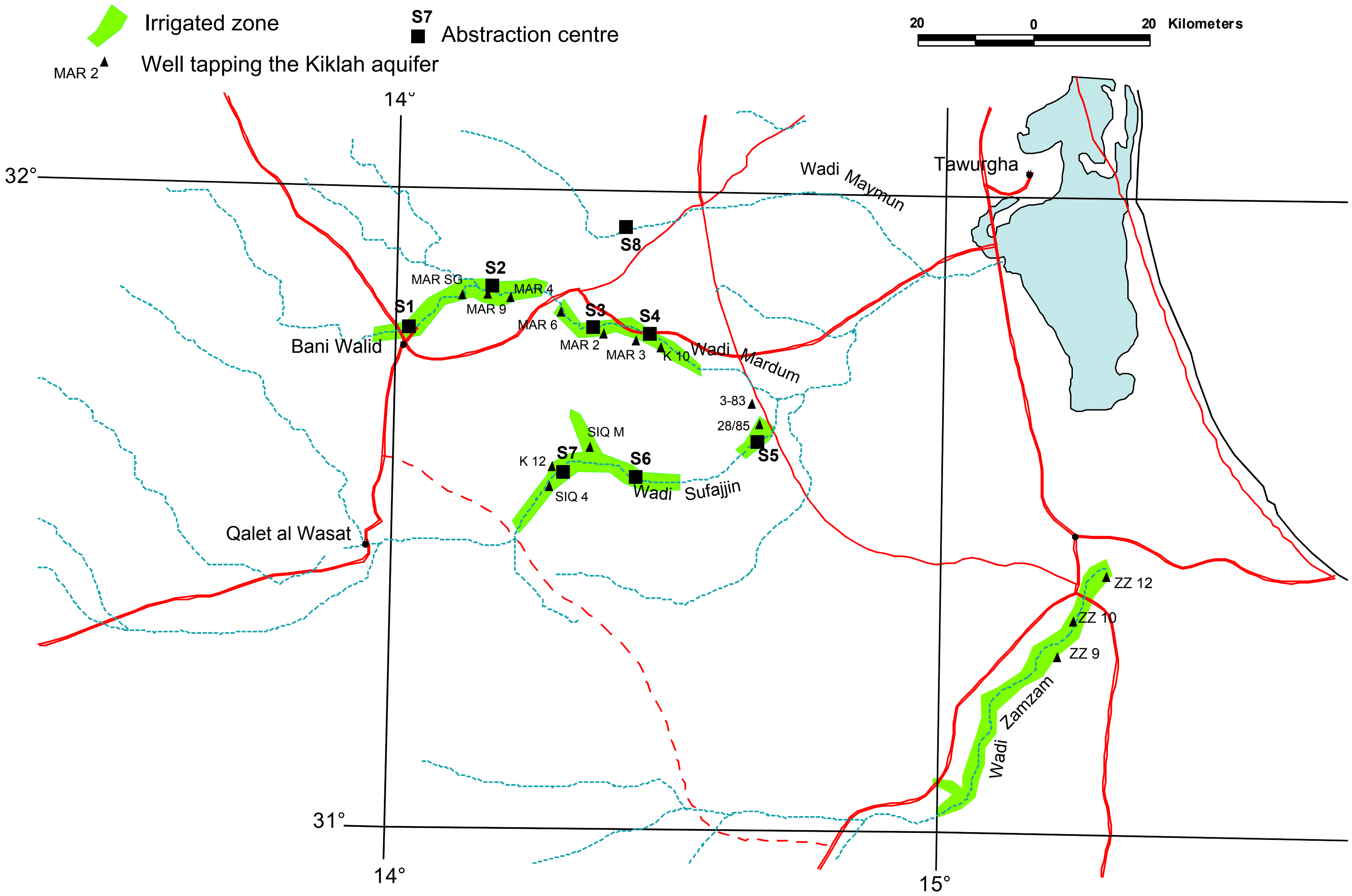
In the affluent valleys of wadi Sufajjin, 46 deep wells tapping the Kiklah aquifer were drilled in the late 1970s and the beginning of the 1980s, and gave rise to irrigated crop zones representing about 3500 ha. However, following the drop in artesianism, corrosion problems at well head in the case of flowing wells, and difficulties to ensure maintenance of the pumps, exploitation flows have steadily decreased since the wells were brought on stream. In order to compensate the insufficiency of the deep flows, the farmers have gradually drilled wells of 100 to 150 m depth, tapping the Upper Cretaceous (Mizdah).

Alongside with the agricultural use of water, two towns of the zone (Mizdah and Bani Walid) were equipped with pipelines supplied by Kiklah wells.

RECORD OF ABSTRACTIONS FROM THE CATCHMENT OF WADI SUFAJJIN

Aquifer and abstraction zone		Number of abstr. group on map	Abstractions in million m3/an										
			1950	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**
Upper Cretaceous													
Private farming	Wadi Mardum	S3	0	0	0	0	0	0	0	1	1	2	2
		S4	0	0	0	0	0	0	0	0	1	1	2
	Wadi Mardum - Bani Walid	S1	0	0	0	0	0	0	0	0	1	2	3
		S2	0	0	0	0	0	1	1	1	1	2	3
	Wadi Sufajjin	S5	0	0	0	0	0	0	0	0	0	1	1
		S6	0	0	0	0	0	0	0	0	1	1	2
		S7	0	0	0	0	0	0	0	0	0	1	2
Total abstractions from Upper Cretaceous			*0*	*0*	*0*	*0*	*0*	*1*	*1*	*2*	*5*	*10*	*15*
Lower Cretaceous (Kiklah)													
DWS Bani Walid		S1	0	0	0	0	0	0	0	2	2	3	3
DWS Mizda		S9	0	0	0	0	0	0	0	2	2	3	3
Agricultural projects	Wadi Maymun	S8	0	0	0	0	0	0	0	10	9	5	0
	Wadi Mardum	S3	0	0	0	0	0	0	0	6	5	4	2
		S4	0	0	0	0	0	0	0	6	5	4	2
	Wadi Suffajin	S5	0	0	0	0	0	0	0	0	3	2	2
		S6	0	0	0	0	0	0	0	11	8	5	2
		S7	0	0	0	0	0	0	0	12	9	5	3
	Wadi Mardum-Bani Walid	S1	0	0	0	0	0	0	0	8	7	6	5
		S2	0	0	0	0	0	0	0	8	7	6	4
Total abstractions from Lower Cretaceous			*0*	*0*	*0*	*0*	*0*	*0*	*0*	*65*	*57*	*43*	*26*
Total abstractions for zone			**0**	**0**	**0**	**0**	**0**	**1**	**1**	**67**	**62**	**53**	**41**

Wadi Suffajin – Wadi Mardum
Crop Zones



3. Southern flank of Jabal Nefusa

The southern flank of Jabal Nafusa is populated with small towns which have gradually been equipped with pipelines supplied by wells tapping for the major part the Kiklah. The following table shows the estimated flows of drinking water wells supplying the main towns of the zones.

RECORD OF ABSTRACTIONS ON THE SOUTHERN FLANK OF JABAL NEFUSA

Aquifer and abstraction zone		Number of abstr. group on map	Abstractions in million m3/an										
			1950	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**
Lower Cretaceous (Kiklah)													
	Nalut		0.0	0.0	0.0	0.0		0.9	6.4	8.3	9.2	9.2	10.0
	Gharyan		0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.0	1.1	1.2	1.2
	Yafrin		0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.5	0.5
	Zintan		0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.5	2.5	2.5	2.5
	Jadu		0.0	0.0	0.0	0.0	0.0	0.3	0.8	0.9	1.5	1.5	1.5
Total abstractions from Kiklah			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.2**	**9.3**	**13.0**	**14.8**	**14.9**	**15.7**

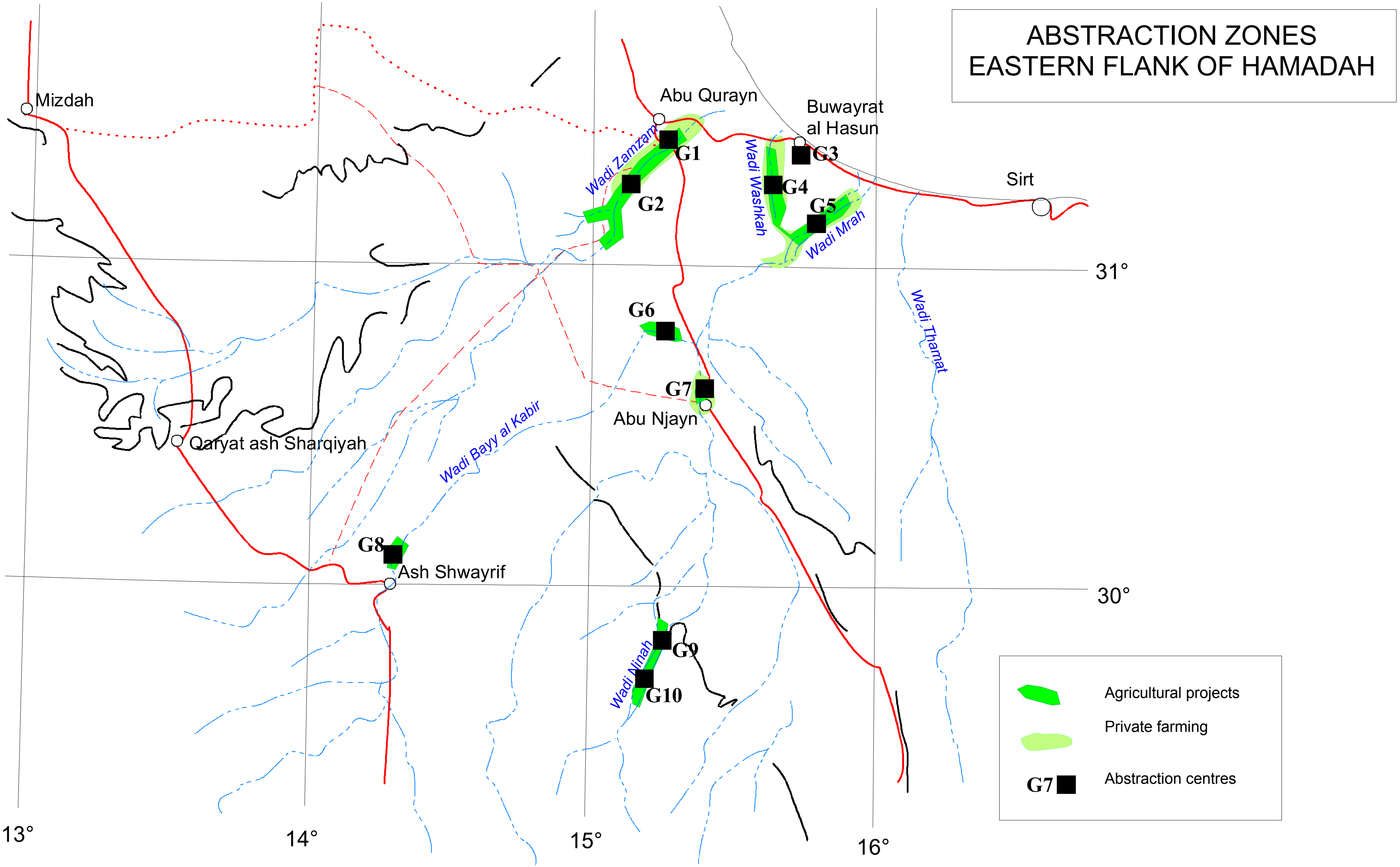
4. Eastern flank of Hamadah al Hamra

The eastern flank of Hamadah al Hamra is lined by a hydrographic network which now operated only exceptionally. The bottom of these valleys, full of alluvia, has been the location for an agricultural development based on deep wells tapping the Lower Cretaceous and, at times even, the Palaeozoic which were drilled in the late 1970s and the early 1980s. These wells, whose depth sometimes exceeds 2000 m, supply a hot water whose agricultural use is not always easy. Problems of corrosion at well head, combined with constraints related to water temperature, have led to abandoning several wells which now flow into the wild.

Similarly to the situation in the catchment of wadi Sufajjin, the farmers have gradually undertaken to collect the shallow aquifer of the Upper Eocene by wells of 100 to 120 m depth equipped with pumps. The data relevant to private wells are very sketchy and abstraction estimates rest exclusively on a number of farms (about 400 in Wadi Zamzam and about one hundred in Wadi Wishkah - Wadi Mrah), as well as on an estimate of unit areas and water needs. The only unquestionable information relates to the highly speedy increase in the number of private farms, mainly in Wadi Zamzam and Wadi Wishkah.

RECORD OF ABSTRACTIONS ON THE EASTERN FLANK OF HAMADAH AL HAMRA

Aquifer and abstraction zone	Number of abstr. group on map	Abstractions in million m3/an										
		1950	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**
Upper Eocene												
Wadi Zamzam	G1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	4.0
	G2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	4.0
Wadi Mrah-Wadi Whishkah	G4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0
	G5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0
Total abstractions from Upper Eocene		*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*1.0*	*6.0*	*12.0*
Lower Cretaceous (Kiklah)												
Abu Qurayn	G1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.5	0.5
Buwayrat al Hasun	G3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.5	0.5
Wadi Zamzam	G1	0.0	0.0	0.0	0.0	0.0	7.5	6.0	12.5	12.5	10.0	7.5
	G2	0.0	0.0	0.0	0.0	0.0	7.5	6.0	12.5	12.5	10.0	7.5
Wadi Mrah - Washkah	G4	0.0	0.0	0.0	0.0	0.0	0.0	7.5	9.0	7.5	5.0	3.0
	G5	0.0	0.0	0.0	0.0	0.0		7.5	9.0	7.5	5.0	3.0
Wadi Bayy el Kebir	G6	0.0	0.0	0.0	0.0	0.0	0.0	8.0	6.0	5.0	5.0	5.0
Ash Shwayrif	G8	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.6	1.6	1.0	0.0
Abu Njaym	G7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	3.0	2.0	2.0
Total abstractions from Lower Cretaceous		*0*	*0*	*0*	*0*	*0*	*15*	*36.6*	*54*	*50.2*	*39*	*29*
Lower Cretaceous (Kiklah) – Palaeozoic												
Wadi Ninah	G9	0.0	0.0	0.0	0.0	0.0	0.0	5.0	7.5	6.0	5.5	4.5
	G10	0.0	0.0	0.0	0.0	0.0	0.0	**5.0**	**7.5**	**6.0**	**5.5**	**5.2**
Total abstractions from Lower Cretaceous – Palaeozoic		*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*10.0*	*15.0*	*12.0*	*11.0*	*9.7*
Total abstractions from zone		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**15.0**	**46.6**	**69.0**	**63.2**	**56.0**	**50.7**


ABSTRACTION ZONES
EASTERN FLANK OF HAMADAH
Mizdah
Abu Qurayn
Buwayrat
al Hasun
Sirt
Wadi Zamzam
Wadi Washkah
Wadi Mrah
Wadi Thamat
G1
G2
G3
G4
G5
G6
G7
G8
G9
G10
Abu Njayn
Qaryat ash Sharqiyah
Wadi Bayy al Kabir
Ash Shwayrif
Wadi Ninah
31°
30°
13°
14°
15°
16°
Agricultural projects
Private farming
G7 Abstraction centres

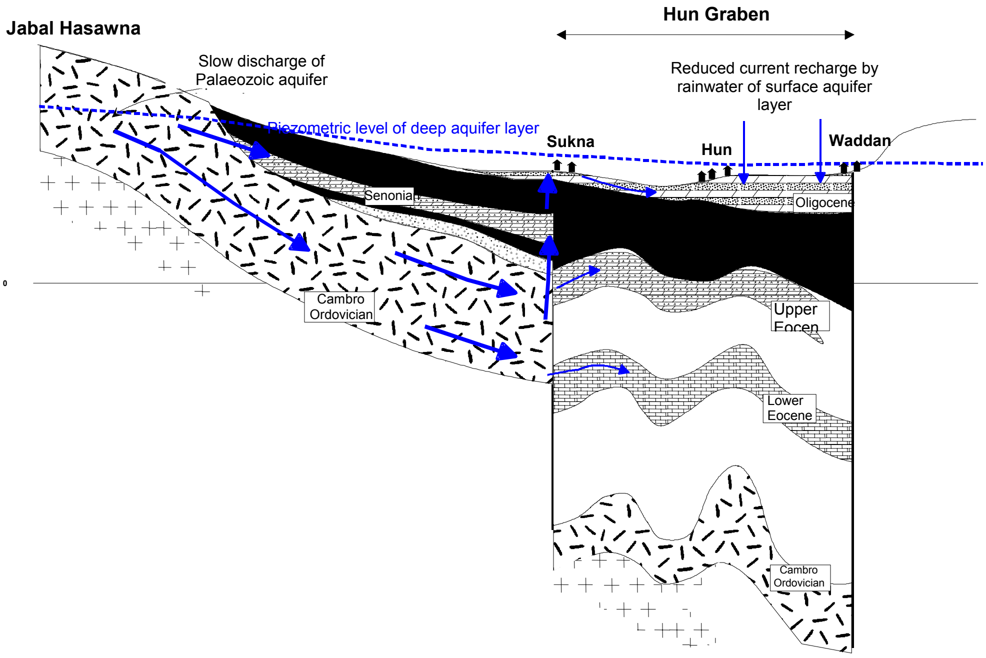
5. Western flank of Hamadah al Hamra

Three oases are found in the far western part of the Libyan territory, along the Tunisian border. Ghadamis is by far the major oasis and the pal-tree groves there used to be supplied by a spring that dried up several years ago. The exploitation of groundwater by wells started with structures tapping the Nalut formation of the Upper Cretaceous. The waters, of mediocre quality, have soon led to the construction of wells tapping the Lower Cretaceous (Kiklah) which currently represent the main source of drinking water and irrigation water supply for the oasis zone.

RECORD OF ABSTRACTIONS ON THE WESTERN FLANK OF HAMADAH AL HAMRA													
Aquifer and abstraction zone		Number of abstr. group on map	Abstractions in million m3/an										
			1950	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**
Upper Cretaceous													
	Ghadamis												
Lower Cretaceous (Kiklah)													
	Ghadamis		0.0	0.0	0.0	0.0	0.1	0.1	4.3	4.3	4.3	4.3	4.3
	Sinawan		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4
	Derj		0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0
Total abstractions from Kiklah			**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**5.2**	**5.7**	**5.7**	**5.7**	**5.7**

6. Zone of Al Jufrah

To the west of the Hun graben, a carbonated horizon probably belonging in the Upper Cretaceous contains a highly productive aquifer which has given rise to two irrigated crop areas, Ferjan and Hammam, and which has subsequently been collected to meet the needs of the zone located inside the graben which is a zone lacking in good water quality.



The table above shows the recharge mechanism of the aquifers of Al Jufrah zone based on the Palaeozoic reservoir and due to the western fault of the Hun graben.

The artesian flows of the two projects have considerably decreased since the inception of the projects due to a drop in piezometric level. In addition, insufficient drainage has induced phenomena of waterlogging, salinisation of the soil in certain zones and abandoning several farms.

A few very deep wells reaching the Palaeozoic horizons have been drilled in the zone of Waddan to supplement water supply to the palm tree groves. Private farms have developed considerably during the past decade around the three towns of Suknah, Hun and Waddan, but more particularly around Waddan. These private farms, mainly dedicated to Phoenician crop growing are irrigated from little deep wells tapping the Oligocene aquifer which is recharged by the rare rainfalls and by surface runoffs arriving from the neighbouring mountain ranges.

RECORD OF ABSTRACTIONS IN AL JUFRAH ZONE

Aquifer and abstraction zone	Number of abstr. group on map	Abstractions in million m3/an										
		1950	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**
Oligocene												
Private farms Suknah	J1	1	1	1	1	1	1	1	1	2	2	3
Private farms Hun	J2	1	1	1	1	1	1	1	2	3	4	5
Private farms Waddan	J3	1	1	2	2	2	2	2	5	10	15	25
Total Oligocene		*2*	*2*	*3*	*4*	*4*	*4*	*4*	*8*	*15*	*21*	*32*
Eocene												
Palm-tree groves support (Minagri)-Hun	J2	0	0	0	0	0	0	0	1	1	2	2
Date processing factory	J2	0	0	0	0	0	0	0	0	0	0	0
Total Eocene		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*1*	*2*	*2*
Upper Cretaceous (Senonien)												
Palm-tree groves support (Minagri)-Socna	J1	0	0	0	0	0	0	0	1	2	4	4
Ferjan project	J4	0	0	0	0	0	2	50	50	50	30	14
Hammam project	J5	0	0	0	0	5	10	35	50	45	40	32
Private farms – Socna	J1	0	0	0	0	0	0	0	1	2	3	3
DWS - Socna-Hun	J1	0	0	0	0	1	1	2	5	8	12	12
DWS – Ferjan	J4	0	0	0	0	0	0	2	2	2	1	1
Military camp	J1	0	0	0	0	0	0	1	2	4	6	6
Institute	J1	0	0	0	0	0	0	0	0	0	0	*0*
Power plant	J1	0	0	0	0	0	0	0	0	0	0	*0*
Building company	J1	0	0	0	0	0	0	0	0	0	0	*0*
El Fatah farm	J1	0	0	0	0	0	0	0	0	1	1	*1*
Tourist village (projected)	J1	0	0	0	0	0	0	0	0	0	0	*0*
Total Upper Cretaceous		*0*	*0*	*0*	*0*	*6*	*13*	*90*	*111*	*114*	*97*	*73*
Palaeozoic												
Palm-tree groves support (Minagri)-Waddan	J3	0	0	0	0	0	0	0	0	5	10	14
Total Palaeozoic		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*5*	*10*	*14*
Total abstractions for zone		**2**	**2**	**3**	**4**	**10**	**17**	**94**	**120**	**135**	**130**	**122**

7. Summary

The following table sums up the records of abstractions as per zone and per aquifer over the whole eastern Saharan basin.

RECORD OF ABSTRACTIONS IN THE LIBYAN SAHARAN BASIN

Aquifer and abstraction zone		Abstractions in million m3/an										
		1950	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**
Upper aquifer (Mio-Pliocene, Oligocene, Upper Eocene)												
	Coastal zone (Al Khums - Tawurgha)	8	8	15	15	17	31	35	40	42	46	57
	Eastern flank of Hamadah al Hamra	0	0	0	0	0	0	0	0	1	6	12
	Al Jufrah	2	2	3	4	4	4	4	9	16	23	34
Total upper aquifer		*10*	*10*	*18*	*19*	*21*	*35*	*39*	*49*	*59*	*75*	*103*
Upper Cretaceous (Mizdah - Nalut)												
	Coastal zone (Al Khums - Tawurgha)	23.2	14.6	13.8	10.9	5.2	9.3	41.48	51.1	48.1	44.1	40.6
	Sufajjin catchment	0	0	0	0	0	1	1	2	5	10	15
	Al Jufrah	0	0	0	0	6	13	90	111	114	97	73
	Ghadamis											
Total Upper Cretaceous		*23*	*15*	*14*	*11*	*11*	*23*	*132*	*164*	*167*	*151*	*129*
Lower Cretaceous (Kiklah)												
	Sufajjin catchment	0	0	0	0	0	0	0	65	57	43	26
	Eastern flank of Hamadah al Hamra	0	0	0	0	0	15	37	54	50	39	29
	Southern flank of Jabal Nefusa	0	0	0	0	0	1	9	13	15	15	16
	Ghadamis	0	0	0	0	0	0	5	6	6	6	6
Total Lower Cretaceous		*0*	*0*	*0*	*0*	*0*	*16*	*51*	*138*	*128*	*103*	*76*
Lower Cretaceous (Kiklah) – Palaeozoic												
	Coastal zone (Al Khums - Tawurgha)	0	0	0	0	0	0	0	25	20	12	6
	Al Jufrah	0	0	0	0	0	0	0	0	5	10	14
	Eastern flank of Hamadah al Hamra (W. Ninah)	0	0	0	0	0	0	10	15	12	11	10
Total Lower Cretaceous - Palaeozoic		*0*	*0*	*0*	*0*	*0*	*0*	*10*	*40*	*37*	*33*	*30*
Total abstraction from Libyan Saharan basin		**33**	**25**	**31**	**30**	**33**	**74**	**232**	**390**	**392**	**362**	**339**
Kaam spring												
	Upper Cretaceous	16	16	15	15	14	14	12	4	2	0	0
Total flow of spring		**16**	**16**	**15**	**15**	**14**	**14**	**12**	**4**	**2**	**0**	**0**
Tawurgha spring												
	Upper Cretaceous	23	23	23	23	23	22	22	20	20	19	18
	Lower Cretaceous – Palaeozoic	43	41	41	40	40	40	40	37	37	37	38
Total flow of spring		**66**	**64**	**64**	**63**	**63**	**62**	**62**	**57**	**57**	**56**	**56**

Appendice
Coordinates of abstraction groups

Locality	Group	X	Y
As Sikt - Misratah	C1	14°59'	32°19'
Zliten	C2	14°34'	32°27'
Tuminah	C3	15°04'	32°17'
Tawurgha village	C4	15°03'	32°02'
Kaam - Al Khums	C5	14°21'	32°33'
Zliten	C6	14°28'	32°28'
Zliten	C7	14°40'	32°26'
Wadi Majir	C8	14°29'	32°18'
Dafniyah	C9	14°46'	32°23'
Dafniyah	C10	14°53'	32°22'
Ayn Kaam	C11	14°27'	32°30'
Projet Wadi Kaam	C12	14°24'	32°28'
Kararim	C13	15°03'	32°08'
Ayn Tawurgha	C14	15°06	32°01'
Bani Walid	S1	14°01'	31°47'
Wadi Mardum	S2	14°10'	31°51'
Wadi Mardum	S3	14°21'	31°47'
Wadi Mardum	S4	14°27'	31°46'
Wadi Sufajjin	S5	14°40'	31°37'
Wadi Sufajjin	S6	14°26'	31°33'
Wadi Sufajjin	S7	14°19'	31°33'
Wadi Maymun	S8	14°25'	31°57’
Wadi Zamzam	G1	15°15'	31°23'
Wadi Zamzam	G2	15°07'	31°15'
Buwayrat al Hasun	G3	15°42'	31°22'
Wadi Mrah-Wadi Wishkah	G4	15°38'	31°15'
Wadi Mrah-Wadi Wishkah	G5	15°48'	31°09'
Wadi Bay al Kabir	G6	15°15'	30°50'
Abu Njaym	G7	15°23'	30°37'
Ash Shwayrif	G8	14°18	30°07'
Wadi Ninah	G9	15°15'	29°50'
Wadi Ninah	G10	15°11'	29°42'
Suknah	J1	15°48'	29°03'
Hun	J2	15°58'	29°05'
Waddan	J3	16°10'	29°08'
Ferjan project	J4	15°40'	29°02'
Hammam project	J5	15°47'	29°06'

ANNEX 6

DRAWDOWNS

ANNEX 6

1. Drawdowns in the Complexe Terminal aquifer

Annex 6 Table 1 - Drawdowns in the CT aquifer in Algeria

Wilaya	Zone	Well denomination	Data base class. Number	Period	Drawdown in m
El Oued	Oued Rhir - Nord	Sidi Ahmed Tidjani	H01100356	1952-95	32.14
El Oued	Oued Rhir - Nord	Chemora	H01100412	1955-91	25.70
El Oued	Souf	Guemar 1	H01100413	1957-91	15.40
El Oued	Souf	Ain Cheraga	H01100479	1963-91	10.76
El Oued	Souf	Kouinine	H01100530	1961-95	26.50
El Oued	Souf	Masri	H01100840	1969-91	23.57
El Oued	Souf	Guemar	H01100909	1957-93	12.00
El Oued	Souf	Debila N1	H01200021	1960-77	8.17
El Oued	Oued Rhir - Nord	Sidi Mestour Bis	H01200059	1984-91	25.00
El Oued	Oued Rhir - Sud	Zemlet El Kha.2 K 1	J01300009	1961-70	0.20
Ouargla	Ouargla	Daira De Touggourt F	I01100549	1978-97	8.40
Ouargla	Ouargla	F Soviet Bouroubia	J01000518	1966-97	5.46
Ouargla	Ouargla	A.El Cadi Djedida D4	J01000526	1968-97	4.94
Ouargla	Ouargla	Nouvelle Wilaya D1 F	J01000531	1970-97	3.77
Ouargla	Ouargla	Garet Chemia D1 F113	J01000533	1970-97	4.14
Ouargla	Ouargla	A Cherif D4 F80	J01000536	1970-97	9.06
Ouargla	Ouargla	Ngoussa Recon D6F50	J01000599	1983-97	6.30
Ouargla	Ouargla	Ain-El-Arch Djedida	J01000809	1986-97	5.83
Ouargla	Hassi Messaoud	Puits D'eau Ns I.H.I	K01100022	1960-90	0.40
Ouargla	Hassi Messaoud	Gt M1	L01100026	1969-90	5.50
Ouargla	Hassi Messaoud	Allenda Nord N 1	L01100028	1962-90	0.50

Annex 6 Table 2 - Drawdowns in the CT aquifer in Tunisia

Zone	Name of groups and wells	Data base class. Number	Period	Drawdown in m
DJERID	**Group Gouifla – Ségui**	**CT - T – 50**		
	Gouifla 3	18754005	1980-81	0.58
	Group El Hamma	**CT - T – 54**		
	Hamma 15	18786005	1991-92	0.80
	El Hamma Pz	20374005	1997-99	2.30
	El Hamma 4	06922005	1959-71	17.80
	El Hamma 6	08564005	1966-70	2.40
	El Hamma 9	10193005	1970-98	4.10
	El Hamma 10	12330005	1970-81	1.90
	Hamma12	16749005	1994-98	0.60
	Group Neflaïet - Chamsa - El Louah	**CT - T – 55**		
	Neflayett 1	05436005	1948-65	1.40
	Group Helba – Castilia	**CT - T – 56**		
	Castilia 1	00080005	1933-99	14
	Helba 2	05262005	1933-58	1.54
	Helba 3bis	05262025	1947-62	2.30
	Group Oued Koucha - El Manachi	**CT - T- 57**		
	Oued Koucha 1	08729005	1966-70	1.50
	Oued Coucha 3	08729035	1967-80	7.20
	Group Dégache	CT - T - 58		
	Degache Nord 1	10453005	1968-74	1.10
	Degache Nord 2	10453025	1969-70	0.30
	Group Kriz	CT - T - 60		
	Kriz 1	09340005	1967-76	-0.60
	Group Sabaa Biar	**CT - T - 61**		
	Sebaa Biar 1	09456005	1968-73	-0.80
	Sebaa Biar 2	09456025	1968-95	13.54
	Group Seddada	**CT - T - 62**		
	Sedada 2	09342005	1967-72	-0.90
	Group Deghoumes – Tazrarit	**CT - T- 63**		
	Dgoumes 3	18726005	1991-92	0.55
	Group Tozeur	**CT - T - 64**		
	Tozeur 2	19034005	1995-99	7.50
	Tozeur Gare 2	08405005	1965-80	2.10
	Pz Tozeur Gare 2	08985005	1967-73	0.40
	Tozeur Ouest 1	12319005	1969-75	1.76
	Tozeur 6	15510005	1991-92	0.75
	Group Ghardgaïa	**CT - T - 65**		
	Ghardgaya2	05660005	1950-83	2.10
	Group Mrah Lahouar - Moncef	**CT - T - 66**		
	Group Ibn Chabbat	**CT - T - 67**		
	Ibn Chabbat 4	18847005	1979-80	1.41
	Ibn Chabbat 6 Bis	19018005	1991-92	
	Ibn Chabbat 7	19033005	1991-92	
	Ibn Chabbat Pz2	20364005	1997-99	2.40
	Group Nefta	**CT - T - 68**		
	Nefta	08262005	1965-80	3.70
	Nefta 2	08262025	1965-67	0.60
	Nefta 3	08262035	1966-67	0.60
	Nefta 5	13119005	1994-99	3.00
	Nefta Sonede	17622005	1976-81	2.09
	Nefta 2bis	18766005	1995-98	4.00
	Group Hazoua	**CT - T - 69**		

Zone	Name of groups and wells	Data base class. number	Period	Drawdown in m
	Hazoua Bm 1	19203005	1995-99	9.50
	Group Dhafria	**CT - T - 70**		
	Group Ouled Rhérissi - El Mélah	**CT - T - 71**		
	Pz Oued El Melah	20550005	1998-2000	
NEFZAOUA	**Group Debaébcha - Fatnassa - Bechri - Ain Taourgha**	**CT - T - 1**		
	Taourgha 3	02051035	1955-81	1.90
	Group Oum Soumaa 6 Zaouiet El Aness	**CT - T - 2**		
	Om Somâa 1	09347005	1968-90	8.74
	Oum Somaa 2	09616005	1968-89	6.76
	Oum Soumaa 3	09964005	1969-99	20.79
	Group Bou Abdellah – Menchia	**CT - T - 3**		
	Bou Abdallah 1	09632005	1968-95	23.22
	Bou Abdallah 2	09653005	1968-200	15.70
	El Gléa 1	13529005	1971-2000	15.70
	Bou Abdallah 3	13540005	1970-2000	22.75
	Ouled Touati - Oued Zira	**CT - T - 4**		
	Zt.Oul.Touati	14658005	1973-2000	18.63
	Oued Zira 2	16731005	1974-2000	-0.03
	Oued Zira 3	19812005	1974-2000	7.40
	Pz Ziret Louhichi	19879005	1994-99	4.47
	Group Negga	**CT - T - 5**		
	Negga 3	05570005	1950-82	11.10
	Negga 4	09617005	1969-78	4.40
	Negga 5	16703005	1975-81	8.00
	Negga 6	18774005	1978-80	
	Piez.Negga	18780005	1978-82	7.14
	Chouchet Negga 2	19181005	1983-2000	14.50
	Group Toumbar	**CT - T - 6**		
	Tombar 4	14018005	1972-92	15.60
	Toumbar 1	00046005	1970-75	4
	Group Rabta	**CT - T - 7**		
	Rabta 2	09654005	1968-82	5.75
	Rabta 3	14020005	1972-94	20.34
	Rabta 2 Bis	19106005	1982-85	6.70
	Group Mansoura – Djedida	**CT - T - 8**		
	Djedida	12667005	1970-81	5.10
	Mansoura 2bis	19246005	1984-2000	16.50
	Group Tembib	CT - T - 9		
	Tembib 2	05650005	1950-81	14.57
	Tembib 3	10195005	1969-70	1.59
	Tembib 4	14019005	1973-89	13.12
	Group Telemine	**CT - T - 10**		
	Telmine 2	05585005	1948-88	19.50
	Telmine 3	14172005	1972-94	20.00
	Group Kébili Nord	**CT - T - 11**		
	Dar Kouskouss 1	05193005	1946-89	9.30
	Kebili Sonede	14379005	1972-97	22.81
	Group Guettaia - Ebnes	**CT - T - 12**		
	Guettaya 4	14627005	1973-92	27.75
	Guettaya 5	14659005	1973-80	2.20
	Guettaya 6	16733005	1975-86	6.51
	Guettaya 7	16734005	1975-81	3.40
	Guettaya 4 Bis	18826005	1978-95	21.38
	Guettaya 7 Bis	18851005	1979-89	18.74

Zone	Name of groups and wells	Data base class. number	Period	Drawdown in m
	Guettaya 8	18747005	1977-93	29.56
	Group Kébili	**CT - T - 13**		
	Ksar Tabeul	05755005	1951-99	23.28
	Ras El Aïn 1	06756005	1958-2000	30.76
	Pz.Chott Kebili	17611005	1976-81	-2.20
	Kebili Militaire	19209005	1984-97	52.00
	Dar El Gaied	13993005	1974-77	2.10
	Group Rahmat	**CT - T - 14**		
	Rahmat 2	05692005	1951-2000	37.02
	Rahmat 4	16700005	1975-84	9.85
	Bazma 5	16702005	1975-2000	22.60
	Group Scast - Chott Salhia	**CT - T - 17**		
	30	05713005	1949-2000	35.41999912
	Group Messaïd - Kelwamen	**CT - T - 18**		
	Messaid 2	05956005	1952-93	30.30
	Group Métouria	**CT - T - 24**		
	El Metouria 1	06470005	1955-98	20.50
	Metouria 2	16701005	1976-92	15.03
	Grad 1	05754005	1951-80	7.00
	Group El Golaa	**CT - T - 27**		
	El Golaa 1	00033005	1936-2000	32
	Group Douz	**CT – T – 28**		
	Douz 2 Bis	00030025	1952-2000	32
	Douz 2	05263005	1947-93	25.95
	Douze Sonede	06999005	1959-81	5.40
	Douz 1 Bis	00030005	1978-80	0.50
	Douz 2	05263005	1947-93	25.95
	Douz Sud	14023005	1972-93	18.20
	Group Ghelissia – El Hassay	**CT – T – 32**		
	El Hsay 1	05840005	1952-70	2.07
	El Hsay 2	06800005	1970-86	8.03
	El Hsay 3	06801005	1975-86	6.97
	El Hsay 4	06815005	1976-81	1.70
	El Hsay 5	06821005	1970-86	9.38
	Group Tarfaiet El Kroub – Smida	**CT – T – 33**		
	Tarfaïet El Kroub	06522005	1955-88	16.45
	Group Nouil	**CT – T – 35**		
	Nouaiel 1	06690005	1957-80	5.95
	Group Zarcine	**CT – T – 37**		
	Zarcine 2	06906005	1959-80	9.95
	Zarcine 3	13999005	1973-97	24.12
	Group Darjine – Bechni	**CT – T – 39**		
	Bechni	18681005	1978-2000	21.02
	Group Ghidma	CT – T – 40		
	Guidma 1	06689005	1957-97	20.40
	Group El Faouar	**CT – T – 41**		
	El Faouar 2	05484005	1949-99	
	Group Sabria	**CT – T – 42**		
	Sabria 3	19351005	1976-91	1.10
	Group Chott Tibini	**CT – T – 43**		
	Chott Tbini	07630005	1970-87	7.72
	Redjem Maatoug	CT – T – 44		
	Rejim Maatoug 1	18678005	1977-81	1.37
	Rejim Maatoug 2	18745005	1977-87	4.86
	Rejim Maatoug 3	19101005	1983-86	0.40
	Rejim Maatoug 4	19257005	1985-97	11.38

Zone	Name of groups and wells	Data base class. number	Period	Drawdown in m
	Rejim Maatoug 6	19384005	1986-97	16.90
	Rejim Maatoug 7	19777005	1990-2000	11.50
	Matrouha	**CT – T – 45**		
	Matrouha 2	19781005	1991-2000	6.20
	Group Ferdaous	**CT – T – 46**		
	Ferdaous 1	19380005	1986-97	10.65
	Group Es Salem	**CT – T – 48**		
	Essalem 1	19379005	1985-89	0.78

Annex 6 Table 3 – Drawdowns in the CT aquifer in Libya

Zone	Well denomination	Data base class. number	Period	Drawdown in m
Al Khums-Zliten	T4 – Pz 2046		1974-2000	4.34
Kararim	Kararim VII – Pz 2143		1977-2000	6.26
Kararim	P 17 – Pz 2144		1974-2001	5.56
Al Jufrah (Ferjan)	J 6A		1975-2000	34.19
Al Jufrah (Ferjan)	J 6B		1975-2001	39.18
Al Jufrah (Ferjan)	J 7-10		1975-2001	37.87
Al Jufrah (Ferjan)	J 7-18		1975-2001	36.16
Al Jufrah (Hammam)	JH 11		1975-2001	38.51
Al Jufrah (Hammam)	JH 6		1975-2000	39.07

2. Drawdowns in the Continental Intercalaire aquifer

Annex 6 Table 4 – Drawdowns in the CI aquifer in Algeria

Wilaya	Zone	Well denomination	Data base class. Number	Period	Drawdown in m
Adrar	Gourrara	Aougrout	N00400290	1970-1993	1.1
Adrar	Gourrara	Badriane	M00400290	1984-1994	13.4
Adrar	Gourrara	Bouda	N00400314	1987-1996	3.5
Adrar	Gourrara	Deldoul	N00400301	1983-1991	19.9
Adrar	Gourrara	Guerrara	N00400253	1987-1996	5.2
Adrar	Gourrara	Hassi Moussa	M00500045	1970-1982	5.3
Adrar	Gourrara	Timimoun	M00400284	1960-1996	40.1
Adrar	Gourrara	Zaouiet Sidi Abdella	N00400279	1973-1994	14.1
Adrar	Tidikelt	Aoulef	P00500032	1987-1996	5.2
Adrar	Tidikelt	In Salah (Is 101)	O00700044	1956-1991	9.3
Adrar	Tidikelt	Tit	P00600025	1959-1988	1.7
Adrar	Touat	M'guiden	M00400303	1969-1996	17.8
Adrar	Touat	Reggane 1	P00400009	1958-1988	28.0
Adrar	Touat	Sbaa F21	N00400223	1990-1996	3.0
Adrar	Touat	Zaouiet Kounta	O00400139	1960-1982	4.2
Biskra	Ouled Djelal	Foughaha Ouest	G01000541	1981-2000	66.6
Biskra	Ouled Djelal	Hassi Smara (Ain Smara)	G00900139	1983-2001	131.7
Biskra	Ouled Djelal	Ouled Djelal 3	G01000582	1974-2001	62.7
Biskra	Sidi Khaled	Sidi Khaled 3	G00900137	1956-2000	94.2
El Oued	Oued Rhir – Nord	M'rara	H01000042	1956-2000	88.0
El Oued	Oued Rhir – Nord	Tamerna	H01100408	1956-2000	77.0
Ghardaia	El Goléa	Badriane	L00700062	1950-2000	10.4
Ghardaia	El Goléa	Kef 27	L00700068	1962-1998	9.0
Ghardaia	El Goléa	Taghit Nouv 23	L00700056	1968-1998	5.4
Ghardaia	Ghardaia	Guerrera	I00900005	1950-2000	80.0
Ghardaia	Ghardaia	Oued Mehaiguene + Erg El Am	I00700019	1955-2000	18.9

Wilaya	Zone	Well denomination	Data base class. Number	Period	Drawdown in m
Ghardaia	Ghardaia	Zelfana	J00900011	1954-2000	40.3
Ghardaia	Oued Rhir – Nord	Djermna	L00700075	1972-2000	6.4
Illizi	Ghardaia	Debdeb	L01400014	1959-1992	2.0
Ouargla	Ghardaia	El Borma S4	J01400009	1970-1991	54.2
Ouargla	Ghardaia	Gassi Touil	L01100011	1962-1987	15.0
Ouargla	Ghardaia	Nezla	K01100024	1988-2000	15.6
Ouargla	Ghardaia	Sinclair	K01200001	2966-1991	88.0
Ouargla	Hassi Messaoud	H. Messaoud	MDH 115	1957-2000	46.3
Ouargla	Ouargla	El Hadeb	J01000480	1956-2000	66.1
Ouargla	Oued Rhir – Sud	Sidi Mahdi 2	I01100507	1959-2000	85.8
Ouargla	Oued Rhir – Sud	Sidi Slimane	I01100437	1962-2000	133.9

Annex 6 Table 5 – Drawdowns in the CI aquifer in Tunisia

Zone	Data base class. Number	Well denomination	Period	Drawdown in m
Kebili	19348005	Zaoueïet Anes (Ci 5)	1986-1999	37.20
Kebili	19400005	Kébili (Ci 10)	1986-2000	19.00
Kebili	19893005	Mansoura (Ci 13)	1992-2000	22.25
Kebili	19916005	Debebcha Ci 14	1992-2000	27.45
Kebili	20018005	Douz (Ci 18)	1998-2000	10.30
Kebili	20019005	El Faouar (Ci 19)	1993-2000	31.70
Kebili	20109005	S.Lahad (Ci 17)	1994-2000	31.70
Kebili	19140005	Mansoura (Ci 3)	1986-2000	36.40
Kebili	19412005	Menchia Ci 6	1986-2000	37.00
Kebili	19450005	Douz (Ci 12)	1986-2000	20.50
Kebili	20051005	Kébili (Ci 16)	1994-2000	6.60
Kebili	19304	Zaouiet Echchourfa (Ci	1985-2000	37.05
Kebili	19348	Zaoui Ci 5	1985-2000	45.83
Kebili	19394	Limaguess (Ci 8)	1986-2000	52.75
Djerid	19162005	Tozeur Ci 1	1984-1998	108.50
Djerid	19224005	Tozeur Ci 2	1985-2000	40.90
Djerid	19225005	Tozeur Ci3	1986-2000	20.00
Djerid	19227005	Nefta Ci2	1983-2000	129.50
Djerid	19231005	Degache Ci 3	1985-2000	18.50
Djerid	19233005	El Hamma Ci 2	1985-2000	51.50
Djerid	19260005	El Hamma C.I.1bis	1985-2000	47.50
Djerid	19396005	El Hamma Ci3	1985-2000	26.80
Djerid	19039005	Degache Ci 1	1981-1992	76.00
Djerid	20363005	Hazoua Ci	1997-2000	0.00
Djerid	19084	Nefta Ci 1	1983-2000	132.50
Djerid	19792	El Hamma Ci 4	1993-2000	23.50
Djerid	19791	Ceddada Ci	1993-2000	2.50
Djerid	19793	Tazrarit Ci	1993-2000	14.00
Chott Fedjej	05664005	Cf1	1956-1984	29.34
Chott Fedjej	05950005	Cf2	1956-1986	46.34
Chott Fedjej	18695005	Cf F1	1984-2000	39.85
Chott Fedjej	19190005	Cf 1 Bis	1983-1994	34.80
Chott Fedjej	19482005	Cf 2 Bis	1987-1996	18.30
Chott Fedjej	19175005	Cf 3bis	1983-2000	37.10
Chott Fedjej	18696005	Cf F2	1983-1993	23.45
Chott Fedjej	18697005	Cf F3	1984-1994	18.20
Chott Fedjej	18698005	Cf F8	1982-1993	33.40
Chott Fedjej	18699005	Cf 9	1983-1993	30.65
Chott Fedjej	18700005	Cf F10	1983-1993	20.10
Chott Fedjej	19484005	Behaier (Ci 9)	1986-2000	32.30
Chott Fedjej	19452005	Steftimi (Ci 7)	1986-2000	52.65
Far south	6368005	Oued Abdallah 2	1964-1987	6.20
Far south	5654005	Borj Bourguiba 1	1950-2000	7.20
Far south	SP 4 N	Stat. P Trap Sp 4 (1)	1963-2000	9.55
Far south	6511005	Lorzot	1955-2000	10.30
Far south	16736005	El Benia 2	1975-2000	0.55
Far south	18991005	Ksar Ghilane 3	1982-1991	5.30
Far south	19009005	Ksar Ghilane 3bis	1991-2000	4.24
Far south	X00700223	El Borma A1	1963-2000	41.30
Far south	X00700221	El Borma A2	1965-2000	48.00
Far south	X00700216	El Borma A4	1964-1987	29.00
Far south	EB A-5	El Borma A5	1966-2000	54.60
Far south	X00700217	El Borma A6	1971-2000	75.20
Far south	X00700222	El Borma A7	1969-2000	51.50

Zone	Data base class. number	Denomination du forage	Period	Drawdown in m
Far south	00202005	El Borma A8	1973-2000	43.00
Far south	EB A-9	El Borma A9	1975-2000	40.20
Far south	EB A-10	El Borma A10	1985-2000	27.00
Far south	16726005	El-Borma 202(*)	1975-2000	40.40
Far south	18684005	El-Borma 203(*)	1975-2000	39.60
Far south	19534005	El-Borma 205(*)	1975-2000	27.70
Far south	18643005	El-Borma 207(*)	1976-2000	38.30
Far south	00209005	El Borma 208	1976-2000	40.36
Far south	00211005	El Borma 209	1979-2000	33.20
Far south	00212005	El Borma 211	1978-2000	51.20
Far south	18841005	El-Borma 212(*)	1979-2000	34.90

Annex 6 Table 6 - Drawdowns in the CI aquifer in Libya

Zone	Well denomination	Data base class. number	Period	Drawdown
Al Khums	T22/00/26/80 - Pz 2070		1988-2000	2.5
Tawurgha	40/84 TW6 (*)		1985-2000	24.28
Wadi Sufajjin	SOF5		1978-2000	60.95
Wadi Sufajjin (Wadi Mardum)	MAR6		1979-2001	33.56
Wadi Sufajjin (Wadi Mardum)	MAR8		1982-2000	33.8
Wadi Sufajjin (Wadi Mardum)	MAR9		1982-2001	35.87
Wadi Sufajjin (Wadi Mardum)	MARSG		1979-2001	44.94
Wadi Sufajjin (Wadi Mardum)	K-10		1977-2001	34.75
Wadi Sufajjin	28.85		1991-2001	29.9
Eastern flank	10. 87		1977-1984	16.11
Eastern flank Wadi Zamzam)	T/2B/005/0/87		1987-2000	21.19
Eastern flank Wadi Zamzam)	ZZ 9		1975-2000	40.79
Eastern flank	T/2B/0061/0/77		1976-1982	6.5
Eastern flank (Wadi Bayy Al Kabir)	K-7		1975-2000	45.59
Eastern flank (Al Jufrah)	J-18 (*)		1976-1980	4.45
Ghadames	T203-80		1981-1995	12.4
Ghadames	T276-77		1977-1995	30.1
Ghadames	T277-77		1977-1997	6.47
Ghadames	T11-81		1981-1989	0.5
Ghadames	WG 22		1978-1995	11.17
Ghadames	WG9		1975-1995	1.9
Ghadames	WG10		1976-1995	6.4
Ghadames	MW-1220		1975-1995	64.35
Ghadames	MW-1219		1975-1999	6.1
Jabal Nafusah	96/76		1978-1995	2.4

(*) In fact, the TW6 and J18 wells tap the sandstone of the Cambro - Ordovician in continuity with the Lower Cretaceous which is very thin in the two zones.

ANNEX 7

WATER SALINITY

Annex 7 : Table 1 : Salinity of the Complexe Terminal (CT) waters

1- Algeria

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS* in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
A	BECHAR	Borehole	J00300046	KHERABEH 101 (SONATR	1970		411				Sass
A	BECHAR	Borehole	K00100103	HAMAGUIR 1	1960		927				Sass
A	BISKRA	Borehole	G00900140	GHAIBA	1986		1204				Sass
A	BISKRA	Borehole	G01000163	BLED BELKHOKHE	1953		3440				Sass
A	BISKRA	Borehole	G01000206	EL MAHDER A FOUGHALA	1951		2082				Sass
A	BISKRA	Borehole	G01000342	LIOUA N°10	1970		3018				Sass
A	BISKRA	Borehole	G01000437	DOUCENE MS N 81	1970		3000				Sass
A	BISKRA	Borehole	G01000521	FERME DRISS OMAR	1981		2335				Sass
A	BISKRA	Borehole	G01000530	BRANIS	1983		1124				Sass
A	BISKRA	Borehole	G01000532	FELIACHE	1984		3459				Sass
A	BISKRA	Borehole	G01000591	FERME PILOTE	1980		2470				Sass
A	BISKRA	Borehole	G01000593	GPMV DEBIGHI HAF	1979		2054				Sass
A	BISKRA	Borehole	G01000594	MAZOUCHIA	1981		2248				Sass
A	BISKRA	Borehole	G01100023	A.SIDI BOUNAB à EL H	1949		2939				Sass
A	BISKRA	Borehole	G01100056	EL FEIDH	1970		3723				Sass
A	BISKRA	Borehole	G01100060	ZIRIBET EL OUED	1905		2320				Sass
A	BISKRA	Borehole	G01100064	KHANGA SIDI NADJI KS	1905		3169				Sass
A	BISKRA	Borehole	G01100068	OASIS KHANGA SIDI NA	1905		4000				Sass
A	BISKRA	Borehole	G01100076	RECONNAISSANCE à LIA	1970		2257				Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
A	BISKRA	Borehole	G01100099	LIANA K 3	1978		1742				Sass
A	BISKRA	Borehole	G01100116	OUED MAHANE MH 1	1984		2480				Sass
A	BISKRA	Borehole	G01100117	BENIANE	1984		855				Sass
A	BISKRA	Borehole	G01100118	MANSOURIA	1983		2485				Sass
A	BISKRA	Borehole	G01100126	ZEMOURA	1985		1396				Sass
A	BISKRA	Borehole	G01100129	RECONNAISSANCE N°87	1972		1865				Sass
A	BISKRA	Borehole	G01100132	ZENNOURA N°2	1986		1406				Sass
A	BISKRA	Borehole	G01100135	ZENNOURA N°5	1987		1236				Sass
A	Debdeb	Borehole	L01400008		1970			2560			Eress
A	Debdeb	Borehole	L01500001		1970		4000				Eress
A	Debdeb	Borehole	L01400007		1970			2670			Eress
A	El Borma	Borehole	KA 102		1970		1440				Eress
A	El Borma	Borehole	J01400004	EL BORMA ELB 102	1970		5500				Eress
A	El Borma	Borehole	J01300013	BIR RETMA BRT 101	1970		2670				Eress
A	El Borma	Borehole	J01400001	EL GUELTA GE 101	1970		1480				Eress
A	El Goléa	Borehole	L00900002	EL GOLEA 2	1970		2840				Eress
A	EL OUED	Borehole	I01100525	MIH OUENNSA	1984	5400					Sass
A	EL OUED	Borehole	I01100526	OUED EL ALLENDA	1984	3400					Sass
A	EL OUED	Borehole	J01300014	EL HAMMAMIT 101 HT 1	1970	7330					Sass
A	Gassi Touil	Borehole	L01100008	AZEL NORD ALN 1	1970	1800					Eress
A	Gassi Touil	Borehole	K01100006	HASSI LAROQUE P-C	1970	2740					Eress
A	Gassi Touil	Borehole	K01100013	DRAA SBEIT DSB 601	1970	3530					Eress
A	Gassi Touil	Borehole	L01000002	H1 AR6	1970	640					Eress
A	Gassi Touil	Borehole	K01000004	EL AGREB H AR6	1970	630					Eress
A	Gassi Touil	Borehole	K01000003	POUR SNPA AR 1	1970	800					Eress
A	Gassi Touil	Borehole	K01000002	HASSI EL GASSI N2	1970	1070					Eress
A	Guerrara	Borehole	I00900009	GUERRARA GA 1 SNREPA	1970		4078				Eress
A	Hassi Messaoud	Borehole	K01100004	FORT LALLEMAND	1970	3210					Eress
A	Hassi Messaoud	Borehole	K01100005		1970	2719					Eress

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
A	Hassi Messaoud	Borehole	K01200006	RHOURDE BAGUEL RB 10	1970	2040					Eress
A	Hassi Messaoud	Borehole	K01200002	LOUDJE 1 CPA LD1	1970	1900					Eress
A	Hassi Messaoud	Borehole	J01300009	ZEMLET EL KHA.2 K 1	1970	1790					Eress
A	Hassi Messaoud	Borehole	J01200006	SINCLAIR MPC RBN 101	1970	1940					Eress
A	Hassi Messaoud	Borehole	J01100019	DORBANE SD 1	1970	5950					Eress
A	Hassi Messaoud	Borehole	J01100006	KADDOUR BEN SALEM N1	1970	4250					Eress
A	Hassi Messaoud	Borehole	J01100015	MDS AH REGION H M	1970	1690					Eress
A	Hassi Messaoud	Borehole	J01100023	HASSI MESSAOUD OCRS	1970	2780					Eress
A	Hassi Messaoud	Borehole	J01100060	HASSI MESSAOUD F5 AE	1970	1980					Eress
A	Hassi Messaoud	Borehole	J01100010	HASSI MESSAOUD CAMP	1970	1640					Eress
A	Hassi Messaoud	Borehole	J01100011	HAOUD TARFA N1 OMY57	1970	2100					Eress
A	Hassi Messaoud	Borehole	J01100055		1970	2615					Eress
A	Hassi Messaoud	Borehole	J01000468	BOREHOLE H1 HM OMN 53	1970	1705					Eress
A	Hassi Messaoud	Borehole	J01100014	MDW1 A H1	1970	1700					Eress
A	Hassi Messaoud	Borehole	J01100013	HAOUD EL HAMRA	1970	2600					Eress
A	Illizi	Borehole	L01400001	MESSOUDA	1970			4610			Eress
A	Illizi	Borehole	L01500002	F.DE FORT SAINT 2	1970			2600			Eress
A	Illizi	Borehole	K01100009	FES 1-H1	1970	2870					Eress
A	Illizi	Borehole	L01200011	AZEL CPA 1	1960	761					Sass
A	Illizi	Borehole	N01400002	OHANET OH 101 CREPS	1955	1286					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Illizi	Borehole	N01500003	TERMINAL TL 103	1959	1577					Sass
A	Mzab	Borehole	I00800023	N'KEN EL BOUISSIR	1970		1500				Eress
A	Ouargla	Borehole	K00900008	ERG DJOUAD EDJ 101	1970		2600				Eress
A	Ouargla	Borehole	K00900002		1970		2850				Eress
A	Ouargla	Borehole	J01000903		1970	5990					Eress
A	Ouargla	Borehole	J01000402	S.N.REPAL	1970		4460				Eress
A	Ouargla	Borehole	J01000411	SAR MEKHADMA OUARGLA	1970		2250				Eress
A	Ouargla	Borehole	J01000518	F SOVIET BOUROUBIA	1970	1490					Eress
A	Ouargla	Borehole	J01000519	F SOVIET A.LOUISE D4	1970		1600				Eress
A	Ouargla	Borehole	J01000475	OL1	1970	9335					Eress
A	Ouargla	Borehole	J01000904		1970	3950					Eress
A	Ouargla	Borehole	J01000469	CARRIERE P80	1970	10450					Eress

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
A	Ouargla	Borehole	J01000169		1970	8450					Eress
A	Ouargla	Borehole	J01000902		1970	6230					Eress
A	Ouargla	Borehole	J01000901		1970	5860					Eress
A	Ouargla	Borehole	J01000517	OUARGLA MIS SOVIET D	1970	1700					Eress
A	Ouargla	Borehole	J01000182		1970	2140					Eress
A	Ouargla	Borehole	H01100898	HASSI BESSAOUD 101 B	1993	3860					Sass
A	Ouargla	Borehole	I01000061	PK 100 RECONNAISSANC	1984		5400				Sass
A	Ouargla	Borehole	I01000067	EL HADJIRA EL KHERAR	1986		2750				Sass
A	Ouargla	Borehole	I01000089	EL KHEFIF EL HILI AH	1990		3692				Sass
A	Ouargla	Borehole	I01100502	RECONNAISSANCE FR 3	1971	3492					Sass
A	Ouargla	Borehole	J01100003	HASSI MESSAOUD MD 1	1956	2526					Sass
A	Ouargla	Borehole	J01100056	HI ON 1	1961	4095					Sass
A	Ouargla	Borehole	J01100095	BOU SETTACH BASE 101	1968	2110					Sass
A	Ouargla	Borehole	J01200008	RHOURDE El LIA REL 1	1969	1938					Sass
A	Ouargla	Borehole	K01100004	FORT LALLEMAND	1958	3210					Sass
A	Ouargla	Borehole	K01100008	HASSI TOUAREG TG 4 H	1961	2184					Sass
A	Ouargla	Borehole	K01100021	F.L.D.I-HI SN REPAL	1966	3650					Sass
A	Ouargla	Borehole	K01100022	PUITS D'EAU NS I.H.I	1960	1800					Sass
A	Ouargla	Borehole	K01100046	MESDAR 101	1990	2985					Sass
A	Ouargla	Borehole	K01200013	EL KTIR 601 SOPEFAL	1970	2240					Sass
A	Ouargla	Borehole	K01300004	PK 92	1970	2377					Sass
A	Ouargla	Borehole	L01100039	GASSI-TOUIL F5	1988	2222					Sass
A	Ouargla	Borehole	L01300005	EL MERK 103 EMK 103	1993	1890					Sass
A	Ouargla	Borehole	M01000003	BAGUEL 1 RL1 CPA	1959	550					Sass
A	Ouargla	Borehole	M01100001	HAMRA HRI CPA	1959	3001					Sass
A	Ouargla	Borehole	N01100010	PUITS DU GAID N°6	1954	1589					Sass
A	Oued Rhir Nord	Borehole	H01100405		1905	4300					Eress
A	Oued Rhir Nord	Borehole	H01100401	EL HAMRIA	1905					4600	Eress
A	Oued Rhir Nord	Borehole	G01100001	AIN MESSIF SIDI MED	1905	3300					Eress
A	Oued Rhir Nord	Borehole	G01100015	MGUEBRA 1	1905				5180		Eress

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
A	Oued Rhir Nord	Borehole	G01100026	SIDI MOHAMED MOUSSA	1905	2700					Eress
A	Oued Rhir Nord	Borehole	G01100070	AIN KADRA EL HAOUCH	1905	2510					Eress
A	Oued Rhir Nord	Borehole	G01100040		1970				6200		Eress
A	Oued Rhir Nord	Borehole	G01100066	AIN CHATEAU HER HAOU	1970	3940					Eress
A	Oued Rhir Nord	Borehole	G01100044	SIDI AMAR 2 (EL HAOU	1970				4200		Eress
A	Oued Rhir Nord	Borehole	G01100067	AIN NAGA 4	1970	2020					Eress
A	Oued Rhir Nord	Borehole	G01100036	AIN NAGA	1970	3000					Eress
A	Oued Rhir Nord	Borehole	G01000418	RECONNAISSANCE FR 2	1970	5250					Eress
A	Oued Rhir Nord	Borehole	G01000459	RECONNAISSANCE FR 14	1970					4560	Eress
A	Oued Rhir Nord	Borehole	G01000345	F SOVIETIQUE N 34	1970	3460					Eress
A	Oued Rhir Nord	Borehole	G01000337	STILLE 1 COMAFOR	1970	4230					Eress
A	Oued Rhir Nord	Borehole	G01000273	CHEGGA	1970	3400					Eress
A	Oued Rhir Nord	Borehole	G01000346	OASIS CHEGGA N 35	1970	6350	4600				Eress
A	Oued Rhir Nord	Borehole	G01100043	P. BERLAND GHEGGA	1970	5670					Eress
A	Oued Rhir Nord	Borehole	G01000133	P.DUFOURG N°2 SAADA	1970		4400				Eress
A	Oued Rhir Nord	Borehole	G01000156	AIN KRICHA OUMACHE	1970	15000					Eress
A	Oued Rhir Nord	Borehole	G01000163	BLED BELKHOKHE	1970	10000					Eress
A	Oued Rhir Nord	Borehole	G01000295	SIDI HADDOUD A KERMA	1970		2100				Eress
A	Oued Rhir Nord	Borehole	G01000354	A.KADRA MEGLOUB à ME	1970		2900				Eress
A	Oued Rhir Nord	Borehole	G01000227	AIN BEN CHLILI N°4	1970		2500				Eress
A	Oued Rhir Nord	Borehole	G01000207	AIN GOUSKOV CHETMA	1970		2300				Eress
A	Oued Rhir Nord	Borehole	G01000101	PTS BIR BOU SOUDANE	1970		2000				Eress
A	Oued Rhir Nord	Borehole	Tolga		1970		2100				Eress
A	Oued Rhir Nord	Borehole	G00900113	OULED RAHMA N°67 M S	1970		2500				Eress
A	Oued Rhir Sud	Borehole	I01000901		1970				8750		Eress
A	Oued Rhir Sud	Borehole	I01000901		1970	3040					Eress
A	Oued Rhir Sud	Borehole	I01100447	GUEDDICH GD1 PTS EAU	1970	2960					Eress
A	Oued Rhir Sud	Borehole	I01100920		1970	7720					Eress
A	Oued Rhir Sud	Borehole	I01100921		1970	6080					Eress
A	Oued Rhir Sud	Borehole	I01100502	RECONNAISSANCE FR 3	1970				3450	3350	Eress

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
A	Oued Rhir Sud	Borehole	FR 6	Mouïer Rebah	1970				4400	4200	Eress
A	Oued Rhir Sud	Borehole	I01100448	TAIBET	1970					4040	Eress
A	Oued Rhir Sud	Borehole	H01100522	RECON S.E.S FR 13	1970					3580	Eress
A	Oued Rhir Sud	Borehole	H01100104	SIF EL MENADI	1970					3240	Eress
A	Oued Rhir Sud	Borehole	H01100367	SIF EL MENADI	1970				5150		Eress
A	Oued Rhir Sud	Borehole	J01000007	Square Bresson	1970				7400		Eress
A	Oued Rhir Sud	Borehole	I01000005	SQUARE BRESSON	1970					6250	Eress
A	Oued Rhir Sud	Borehole	I01000012		1970		3700				Eress
A	Oued Rhir Sud	Borehole	I01000009	EL HADJIRA 2	1970	3390	32700				Eress
A	Oued Rhir Sud	Borehole	I01000901		1970				8750		Eress
A	Oued Rhir Sud	Borehole	I01000901		1970	3040					Eress
A	Oued Rhir Sud	Borehole	FR 1	Melah Ben Taïeb	1970				18770	6100	Eress
A	Oued Rhir Sud	Borehole	I01000062	RECONNAISSANCE FR 5	1970					4060	Eress
A	Oued Rhir Sud	Borehole	H01000063	F RECONNAISSANCE FR7	1970		3900		7500	6000	Eress
A	Oued Rhir Sud	Borehole	H01000041	EL HAMRIA PH CFPA	1970		5200				Eress
A	Oued Rhir Sud	Borehole	FR 8	Ahanet Tamerna	1970		4690				Eress
A	Oued Rhir Sud	Borehole	H01000056	Recon S.E.S FR 9	1970		5660		7200	6500	Eress
A	Oued Rhir Sud	Borehole	H01000058	Recon FR 12	1970					8130	Eress
A	Oued Rhir Sud	Borehole	H01000057	RECONNAISSANCE FR 11	1970				4340	7400	Eress
A	Oued Rhir Sud	Borehole	H01000045	DJOUF MSELLEM	1970		5540				Eress
A	Oued Rhir Sud	Borehole	I01000046	ETUDE SES FR 4	1970				16000	15000	Eress
A	Oued Rhir Sud	Borehole	I01000008		1970		3980				Eress
A	Souf	Borehole	H01100413	GUEMAR 1	1970	3700					Eress
A	Souf	Borehole	H01100022		1970	3600					Eress
A	Souf	Borehole	H01200032	TIKSEBT EL OUED AEP	1970	2810					Eress
A	Souf	Borehole	H01200016	EL OUED	1970		2700				Eress
A	Souf	Borehole	H01200021	DEBILA N1	1970	2940					Eress
A	Souf	Borehole	H01200034	Z'GOUM BEHIMA SOUF	1970	3140					Eress
A	Souf	Borehole	H01200015	EL KHOBNA	1970	3060	7060				Eress
A	Souf	Borehole	H01100465	Ghamra	1970	3470					Eress

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
A	Souf	Borehole	H01100410	HOBBA GUEMAR	1970	3180					Eress
A	Souf	Borehole	H01200035	MAGRANE SOUF	1970	3515					Eress
A	Souf - Negrine	Borehole	G01200053		1970	2700					Eress
A	Souf - Negrine	Borehole	G01200052		1970	1860					Eress
A	Zelfana	Borehole	J00900017	BORDJ HOBLAI SP2	1970		1280				Eress
A	Zelfana	Borehole	J00800019	OUED SEB-SEB	1970		1630				Eress
A	Ouargla	Boreholes Grp	6		1970	2600					Eress
A	Ouargla	Boreholes Grp	6		1970	2800					Eress
A	Ouargla	Boreholes Grp	6		1970	3800					Eress
A	Ouargla	Boreholes Grp	7		1970	1700					Eress
A	Oued Rhir Nord	Boreholes Grp	29		1970		4000	4000	3300		Eress
A	Oued Rhir Nord	Boreholes Grp	30		1970			9220			Eress
A	Oued Rhir Nord	Boreholes Grp	31		1970			6000	3600		Eress
A	Oued Rhir Sud	Boreholes Grp	8		1970				3640		Eress
A	Oued Rhir Sud	Boreholes Grp	10		1970	4000					Eress
A	Oued Rhir Sud	Boreholes Grp	10		1970	3600	5200				Eress
A	Oued Rhir Sud	Boreholes Grp	11		1970		4500				Eress
A	Oued Rhir Sud	Boreholes Grp	12		1970		4500				Eress
A	Oued Rhir Sud	Boreholes Grp	13		1970	4800	5000				Eress
A	Oued Rhir Sud	Boreholes Grp	14		1970	5200					Eress
A	Oued Rhir Sud	Boreholes Grp	15		1970	5000					Eress
A	Oued Rhir Sud	Boreholes Grp	16		1970	5000	5400				Eress
A	Oued Rhir Sud	Boreholes Grp	17		1970	5500					Eress
A	Oued Rhir Sud	Boreholes Grp	18		1970	4200	5400				Eress
A	Oued Rhir Sud	Boreholes Grp	18		1970	5400					Eress
A	Oued Rhir Sud	Boreholes Grp	20		1970	5000					Eress
A	Oued Rhir Sud	Boreholes Grp	21		1970	9000	6600				Eress
A	Oued Rhir Sud	Boreholes Grp	21		1970	5000					Eress
A	Oued Rhir Sud	Boreholes Grp	22		1970	7500					Eress
A	Oued Rhir Sud	Boreholes Grp	24		1970	7200					Eress

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
A	Oued Rhir Sud	Boreholes Grp	25		1970	4100					Eress
A	Oued Rhir Sud	Boreholes Grp	25		1970	7400					Eress
A	Oued Rhir Sud	Boreholes Grp	26		1970	4000					Eress
A	Oued Rhir Sud	Boreholes Grp	26		1970	5000					Eress
A	Oued Rhir Sud	Boreholes Grp	27		1970			3300	4300		Eress

TDS = Total Dissolved Salt

2- Tunisia

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Extême Sud	Borehole	06897005	Daklat El Bibane	1970			2120			Eress
T	Extême Sud	Borehole	06521005		1970			2480			Eress
T	Extême Sud	Borehole	06722025		1970			1920			Eress
T	Extême Sud	Borehole	02946005		1970			2580			Eress
T	Extême Sud	Borehole	02946025		1970			2580			Eress
T	Extême Sud	Borehole	13009005	Borj El-Khadra	1970			2580			Eress
T	GAFSA	Borehole	19491005	Segdoud CT 3	1987		2860				Sass
T	KEBILI	Borehole	P2	Djemna Est	1970		1260				Eress
T	KEBILI	Borehole	18745005	Rejim Maatoug 2	1977	2000					Sass
T	KEBILI	Borehole	17675005	El Faouar west	1977		1580				Sass
T	KEBILI	Borehole	19379005	Essalem 1	1986	2700					Sass
T	KEBILI	Borehole	20299005	Bir Hadj Brahim	1983		3400				Sass
T	KEBILI	Borehole	20375005	Djebil	1996		820				Sass
T	KEBILI	Borehole	18681005	Bechni	1978		2040				Sass
T	KEBILI	Borehole	18755005	Dergine El Ameur	1977		1700				Sass
T	KEBILI	Borehole	13996005	Zaafrane 3	1972		1440				Sass
T	KEBILI	Borehole	19089005	Tamezret	1983		2840				Sass
T	KEBILI	Borehole	19418005	Oued Sandoug	1984		1800				Sass
T	KEBILI	Borehole	19823005	Bel Habel	1989		2600				Sass
T	KEBILI	Borehole	20426005	O. Zmertene	1985		1800				Sass
T	KEBILI	Borehole	18845005	Oum Chiah 2	1988		2840				Sass
T	KEBILI	Borehole	El Mahdeth	El Mahdeth	1982		800				Sass
T	Kebili	Borehole	00030025	Douz 2 bis	1994		1680				Sass
T	Kebili	Borehole	01558005	TENKITA 2	1983		1800				Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Kebili	Borehole	02051025	Taourgha 1bis	1992		1920				Sass
T	Kebili	Borehole	03306005	Taourgha (ou Bechri)	1975		1520				Sass
T	Kebili	Borehole	05193005	DAR KOUSKOUSS 1	1985		3000				Sass
T	Kebili	Borehole	05263005	DOUZ 2	1982		1800				Sass
T	Kebili	Borehole	05484005	El Faouar 1	1997		1380				Sass
T	Kebili	Borehole	05585005	Telmine 2	1995		2000				Sass
T	Kebili	Borehole	05713005	Scast 4	1994		1700				Sass
T	Kebili	Borehole	05716005	Ben Zitoun 1	1982		1680				Sass
T	Kebili	Borehole	05754005	Grad 1	1990		1020				Sass
T	Kebili	Borehole	05755005	Ksar Tabeul	1993		2200				Sass
T	Kebili	Borehole	06756005	Ras El Aïn 1	1994		2120				Sass
T	Kebili	Borehole	06821005	EL HSAY 5	1994		1960				Sass
T	Kebili	Borehole	06999005	DOUZE SONEDE	1982		900				Sass
T	Kebili	Borehole	07303005	Chott A. B Ahmed	1975		1050				Sass
T	Kebili	Borehole	09347005	Om Somâa 1	1991		3320				Sass
T	Kebili	Borehole	09616005	OUM SOMAA 2	1977		4080				Sass
T	Kebili	Borehole	09617005	Negga 4	1986		1880				Sass
T	Kebili	Borehole	09631005	MANSOURA	1986		1740				Sass
T	Kebili	Borehole	09632005	BOU ABDALLAH 1	1995		2940				Sass
T	Kebili	Borehole	09653005	Bou Abdallah 2	1982		2940				Sass
T	Kebili	Borehole	09654005	RABTA 2	1982		1820				Sass
T	Kebili	Borehole	09964005	Oum Soumaa 3	1981		3440				Sass
T	Kebili	Borehole	10199005	ZAAFRANE 2	1982		1060				Sass
T	Kebili	Borehole	10226005	Rahmat 3	1982		1760				Sass
T	Kebili	Borehole	12171005	El Hsay STIL 1	1982		2020				Sass
T	Kebili	Borehole	12300005	Chott Salhia 1(Stil 1)	1969		1360				Sass
T	Kebili	Borehole	12320005	Chott Salhia 1	1994		1420				Sass
T	Kebili	Borehole	12667005	Djedida	1982		1620				Sass
T	Kebili	Borehole	13446005	BAZMA 4	1985		1600				Sass
T	Kebili	Borehole	13528005	Ziret Louhichi	1994		2480				Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Kebili	Borehole	13529005	El Gléa 1	1994		2260				Sass
T	Kebili	Borehole	13540005	Bou Abdallah 3	1985		2940				Sass
T	Kebili	Borehole	13541005	Oum Soumaa 4	1975		3600				Sass
T	Kebili	Borehole	13542005	MESSAID STIL 1	1982		1560				Sass
T	Kebili	Borehole	13658005	Ouled Touati	1994		2380				Sass
T	Kebili	Borehole	13993005	DAR EL GAIED	1986		1740				Sass
T	Kebili	Borehole	13995005	Scast 5	1989		1460				Sass
T	Kebili	Borehole	13997005	Chott Salhia 2	1995		1440				Sass
T	Kebili	Borehole	14018005	Tombar 4	1982		1920				Sass
T	Kebili	Borehole	14021005	MESSAID 3	1982		1560				Sass
T	Kebili	Borehole	14023005	Douz Sud	1994		2360				Sass
T	Kebili	Borehole	14172005	Telmine 3	1982		1840				Sass
T	Kebili	Borehole	14377005	Fatnassa 1	1990		4200				Sass
T	Kebili	Borehole	14378005	Fatnassa 2	1990		3660				Sass
T	Kebili	Borehole	14379005	KEBILI SONEDE	1984		2640				Sass
T	Kebili	Borehole	14380005	Scast 6	1990		1440				Sass
T	Kebili	Borehole	14623005	BOURZINE 1	1994		1420				Sass
T	Kebili	Borehole	14658005	Zt.Oul.Touati	1973		2320				Sass
T	Kebili	Borehole	16700005	Rahmat 4	1984		1600				Sass
T	Kebili	Borehole	16701005	Metouria 2	1982		1500				Sass
T	Kebili	Borehole	16702005	Bazma 5	1982		1700				Sass
T	Kebili	Borehole	16703005	Negga 5	1994		2080				Sass
T	Kebili	Borehole	16730005	Draa Essakouma	1994		1240				Sass
T	Kebili	Borehole	16731005	Oued Zira 2	1994		2340				Sass
T	Kebili	Borehole	16734005	GUETTAYA 7	1986		1480				Sass
T	Kebili	Borehole	16735005	El Ghoula	1982		1240				Sass
T	Kebili	Borehole	17612005	PIEZ.HARBAYA	1985		2440				Sass
T	Kebili	Borehole	17615005	Douz Ouest	1975		1520				Sass
T	Kebili	Borehole	17623005	PIK SONEDE	1989		2780				Sass
T	Kebili	Borehole	18475005	Kébili Ouest	1985		1660				Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Kebili	Borehole	18641005	Ben Zitoun 2	1994		1840				Sass
T	Kebili	Borehole	18774005	Negga 6	1982		2000				Sass
T	Kebili	Borehole	18790005	DOUZ 6	1989		2680				Sass
T	Kebili	Borehole	18826005	GUETTAYA 4 bis	1991		1420				Sass
T	Kebili	Borehole	18827005	PIEZ.FATNASSA	1982		2120				Sass
T	Kebili	Borehole	18993005	RAS EL AIN 2	1985		1600				Sass
T	Kebili	Borehole	18997005	RAS EL AIN 3	1982		1700				Sass
T	Kebili	Borehole	19003005	Ras El Aïn 4	1986		2220				Sass
T	Kebili	Borehole	19053005	Ben Zitoun 1 bis	1982		1800				Sass
T	Kebili	Borehole	19102005	Chott yane	1982		1140				Sass
T	Kebili	Borehole	19104005	Brika Jemna	1983		1120				Sass
T	Kebili	Borehole	19106005	Rabta 2 bis	1982		2200				Sass
T	Kebili	Borehole	19141005	Klebia 2	1983		1820				Sass
T	Kebili	Borehole	19277005	Ben Zitoun 3	1985		1900				Sass
T	Kebili	Borehole	19293005	KEBILI SDZ9	1981		1600				Sass
T	Kebili	Borehole	19308005	El Hsay 6	1985		1900				Sass
T	Kebili	Borehole	19309005	Messaïd Still 2	1985		1568				Sass
T	Kebili	Borehole	19310005	Aïn Salah 2	1985		2080				Sass
T	Kebili	Borehole	19315005	Messaïd 5	1985		1580				Sass
T	Kebili	Borehole	19316005	El Golâa 2	1985		1460				Sass
T	Kebili	Borehole	19317005	Kelwamen	1985		1780				Sass
T	Kebili	Borehole	19339005	Tombar 5	1985		2060				Sass
T	Kebili	Borehole	19340005	Rahmat 5	1985		1640				Sass
T	Kebili	Borehole	19344005	Bourzine 2	1985		1480				Sass
T	Kebili	Borehole	19377005	Scast 5 bis	1985		2160				Sass
T	Kebili	Borehole	19811005	El Gléa 2	1991		2640				Sass
T	Kebili	Borehole	19812005	Oued Zira 3	1991		4360				Sass
T	Kebili	Borehole	19837005	Om Somâa 4	1991		3880				Sass
T	Kebili	Borehole	19840005	C2N1	1992		2680				Sass
T	Kebili	Borehole	19923005	Bou Abdallah 1 bis	1992		3500				Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Kebili	Borehole	19988005	Om Somâa 1 bis	1993		3742				Sass
T	Kebili	Borehole	X00800002	Fuite Amoco	1980		1800				Sass
T	Kébili	Boreholes Grp	1		1970		1400				Eress
T	Kébili	Boreholes Grp	2		1970		1400				Eress
T	Kébili	Boreholes Grp	3		1970		1700				Eress
T	Kébili	Boreholes Grp	4		1970		1200				Eress
T	Kébili	Boreholes Grp	5		1970		2070				Eress
T	Kébili	Boreholes Grp	6		1970		1260				Eress
T	Kébili	Boreholes Grp	6		1970		900				Eress
T	Kébili	Boreholes Grp	7		1970		1800				Eress
T	Kébili	Boreholes Grp	8		1970		1800				Eress
T	Kébili	Boreholes Grp	9		1970		1800				Eress
T	Kébili	Boreholes Grp	11		1970		1300				Eress
T	Kébili	Boreholes Grp	12		1970		1400				Eress
T	Kébili	Boreholes Grp	14		1970		1760				Eress
T	Kébili	Boreholes Grp	15		1970		2040				Eress
T	Kébili	Boreholes Grp	16		1970		1900				Eress
T	Kébili	Boreholes Grp	17		1970		1700				Eress
T	Kébili	Boreholes Grp	18		1970		2100				Eress
T	Kébili	Boreholes Grp	18		1970		1600				Eress
T	Kébili	Boreholes Grp	19		1970		2200				Eress
T	Kébili	Boreholes Grp	19		1970		1900				Eress
T	Kébili	Boreholes Grp	22		1970		3300				Eress
T	Kébili	Boreholes Grp	23		1970		2900				Eress
T	Kébili	Boreholes Grp	23		1970		2500				Eress
T	Tozeur	Borehole	013351005		1970	2740					Eress
T	TOZEUR	Borehole	19330005	Dhafria C.T 3	1986	3640					Sass
T	Tozeur	Boreholes Grp	13		1970	2360					Eress
T	Tozeur	Boreholes Grp	20		1970	3200					Eress
T	Tozeur	Boreholes Grp	20		1970	2800					Eress

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Tozeur	Boreholes Grp	21		1970	2300					Eress
T	Tozeur	Boreholes Grp	21		1970	2200					Eress
T	Tozeur	Boreholes Grp	24		1970	2000					Eress
T	Tozeur	Boreholes Grp	25		1970	2960					Eress
T	Tozeur	Boreholes Grp	26		1970	3600					Eress
T	Tozeur	Boreholes Grp	27		1970	2000					Eress
T	Tozeur	Boreholes Grp	28		1970	2200					Eress
T	Tozeur	Boreholes Grp	29		1970	1900					Eress
T	Tozeur	Boreholes Grp	30		1970	4500					Eress
T	Tozeur	Boreholes Grp	31		1970	1800					Eress
T	Tozeur	Boreholes Grp	32		1970	1900					Eress
T	Tozeur	Boreholes Grp	33		1970	6380					Eress
T	Tozeur	Borehole	00011005	TOZEUR 7	1998	8000					Sass
T	Tozeur	Borehole	00039005	TOZEUR 3	2016	4200					Sass
T	Tozeur	Borehole	00051005	TOZEUR 6	2024	3375					Sass
T	Tozeur	Borehole	00076005	EL HAMMA 2	1950	5060					Sass
T	Tozeur	Borehole	00078005	Ouled Majed	1981	1500					Sass
T	Tozeur	Borehole	00079005	NANACHIA 1	1980	1490					Sass
T	Tozeur	Borehole	00080005	CASTILIA 1	1980	1640					Sass
T	Tozeur	Borehole	00080025	CASTILIA 2	1972	1660					Sass
T	Tozeur	Borehole	05222005	El Hamma 3	1951	5160					Sass
T	Tozeur	Borehole	05262005	Helba 2	1979	1780					Sass
T	Tozeur	Borehole	05289005	TOZEUR GARE 1	1950	1700					Sass
T	Tozeur	Borehole	05436005	Neflayett 1	1982	7700					Sass
T	Tozeur	Borehole	05487005	Ghardgaya 1	1966	2180					Sass
T	Tozeur	Borehole	05660005	Ghardgaya2	1966	2220					Sass
T	Tozeur	Borehole	05776005	Chakmou	1981	6138					Sass
T	Tozeur	Borehole	05893005	Cedada 1	1974	3950					Sass
T	Tozeur	Borehole	06090005	Hezoua 1	1982	2760					Sass
T	Tozeur	Borehole	06103005	OUED Shili 1	1953	4220					Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Tozeur	Borehole	06922005	El Hamma 4	1999	6080					Sass
T	Tozeur	Borehole	08262005	Nefta	1970	3040					Sass
T	Tozeur	Borehole	08262025	Nefta 2	1980	2520					Sass
T	Tozeur	Borehole	08262035	Nefta 3	1981	2580					Sass
T	Tozeur	Borehole	08405005	Tozeur Gare 2	1979	1780					Sass
T	Tozeur	Borehole	08563005	EL HAMMA 5	1993	6000					Sass
T	Tozeur	Borehole	08564005	El Hamma 6	1967	5420					Sass
T	Tozeur	Borehole	08729005	Oued Koucha 1	1982	2120					Sass
T	Tozeur	Borehole	08729025	Oued Koucha 2	1974	1940					Sass
T	Tozeur	Borehole	08837005	El Hamma 7	1997	6150					Sass
T	Tozeur	Borehole	08838005	El Hamma 8	1982	3600					Sass
T	Tozeur	Borehole	08981005	AIN TORBA 1	1980	1660					Sass
T	Tozeur	Borehole	08982005	El Manachi 2	1979	1700					Sass
T	Tozeur	Borehole	09341005	Kriz 1	1968	6540					Sass
T	Tozeur	Borehole	09455025	Z. El Areb 1	1969	1500					Sass
T	Tozeur	Borehole	09455035	ZAOUIT LARAB 3	1969	1500					Sass
T	Tozeur	Borehole	09456005	Sebaa Biar 1	1969	2860					Sass
T	Tozeur	Borehole	09456025	Sebaa Biar 2	1969	1600					Sass
T	Tozeur	Borehole	09495035	Zaouiet El Arab	1997	1500					Sass
T	Tozeur	Borehole	09627005	Kriz 2	1969	1040					Sass
T	Tozeur	Borehole	09959005	Zaafrana	1988	2100					Sass
T	Tozeur	Borehole	10192005	Sedada 3	1980	1900					Sass
T	Tozeur	Borehole	10193005	El Hamma 9	1982	6480					Sass
T	Tozeur	Borehole	10452005	Kriz 3	1979	2300					Sass
T	Tozeur	Borehole	10453005	Degache Nord 1	1980	1500					Sass
T	Tozeur	Borehole	10453025	Degache Nord 2	1969	1500					Sass
T	Tozeur	Borehole	12319005	Tozeur Ouest 1	1969	2980					Sass
T	Tozeur	Borehole	12330005	El Hamma 10	1979	2900					Sass
T	Tozeur	Borehole	12668005	Jhim 1	1980	1900					Sass
T	Tozeur	Borehole	13017005	EL HAMMA 11	1979	4840					Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Tozeur	Borehole	13116005	PK 13	1990	2200					Sass
T	Tozeur	Borehole	13119005	Nefta 5	1981	2500					Sass
T	Tozeur	Borehole	13346005	herdgaya 4	1979	2240					Sass
T	Tozeur	Borehole	13443005	Nefta 4	1979	3100					Sass
T	Tozeur	Borehole	13990005	DGHOUMES 1	1972	6000					Sass
T	Tozeur	Borehole	13991005	Oued Dghouumes 2	1994	4000					Sass
T	Tozeur	Borehole	13992005	Neflaiet 2	1977	3540					Sass
T	Tozeur	Borehole	14000005	Degache Sonede	1980	1440					Sass
T	Tozeur	Borehole	14001005	Tozeur Sonede	1974	1980					Sass
T	Tozeur	Borehole	14137005	El Moncef 3	1996	2300					Sass
T	Tozeur	Borehole	14138005	Helba 4	1980	1920					Sass
T	Tozeur	Borehole	14366005	Castilia 3	1972	1920					Sass
T	Tozeur	Borehole	14383005	PK 14	1981	2140					Sass
T	Tozeur	Borehole	14387005	Ouled Majed2	1973	3540					Sass
T	Tozeur	Borehole	14394005	El Moncef 4	1988	2280					Sass
T	Tozeur	Borehole	14395005	Chemsa 2	1972	3020					Sass
T	Tozeur	Borehole	14621005	Oued Kebir	1980	1580					Sass
T	Tozeur	Borehole	14625005	Sedada 5	1982	1900					Sass
T	Tozeur	Borehole	14626005	Sedada 6	1996	1960					Sass
T	Tozeur	Borehole	14630005	Aîn Djedida	1973	1800					Sass
T	Tozeur	Borehole	15510005	Tozeur 6	1988	1960					Sass
T	Tozeur	Borehole	16558005	Ben Chaouch	1973	2020					Sass
T	Tozeur	Borehole	16598005	CASTILIA 4	1988	2020					Sass
T	Tozeur	Borehole	16695005	Chouchet Zerga	1996	3000					Sass
T	Tozeur	Borehole	16707005	C.S.P.S	1974	1840					Sass
T	Tozeur	Borehole	16721005	Oued tozeur 7	1976	1980					Sass
T	Tozeur	Borehole	16732005	El Mekmen	1988	2280					Sass
T	Tozeur	Borehole	16749005	Hamma12	1983	3500					Sass
T	Tozeur	Borehole	17606005	Guifla	1983	6120					Sass
T	Tozeur	Borehole	17622005	Nefta Sonede	1996	3500					Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Tozeur	Borehole	17625005	Chakmou 2	1977	5600					Sass
T	Tozeur	Borehole	17626005	EL HAMMA 13	1988	2100					Sass
T	Tozeur	Borehole	17667005	EL HAMMA 14	1980	2060					Sass
T	Tozeur	Borehole	17679005	Oued Tozeur 8	1980	2100					Sass
T	Tozeur	Borehole	18647005	OUED SHILI 12	1977	3850					Sass
T	Tozeur	Borehole	18650005	Oued Tozeur 5	1996	2020					Sass
T	Tozeur	Borehole	18660005	Oued Shili 2	1977	3800					Sass
T	Tozeur	Borehole	18725005	Aïn Torba 1 bis	1980	1540					Sass
T	Tozeur	Borehole	18726005	Dgoumes 3	1988	2140					Sass
T	Tozeur	Borehole	18728005	Nefta 1bis	1977	2700					Sass
T	Tozeur	Borehole	18753005	Guifla 2	1983	6478					Sass
T	Tozeur	Borehole	18754005	Gouifla 3	1979	6680					Sass
T	Tozeur	Borehole	18757005	IBN CHABBAT 1	1978	3300					Sass
T	Tozeur	Borehole	18765005	Nefta 7	1981	3060					Sass
T	Tozeur	Borehole	18766005	Nefta 2bis	1977	2900					Sass
T	Tozeur	Borehole	18786005	Hamma 15	1996	2140					Sass
T	Tozeur	Borehole	18787005	KOUDIAT LAKHOUA	1996	3120					Sass
T	Tozeur	Borehole	18789005	Ouled Majed 2	1977	1580					Sass
T	Tozeur	Borehole	18791005	Oued Touzeur 4	1980	2060					Sass
T	Tozeur	Borehole	18800005	Hamma 11 bis	1978	3800					Sass
T	Tozeur	Borehole	18801005	Drâa Nord 2	1978	3300					Sass
T	Tozeur	Borehole	18802005	El Melah	1990	2900					Sass
T	Tozeur	Borehole	18807005	Gouifla 4	1979	6500					Sass
T	Tozeur	Borehole	18844005	Aïn Torba 3	1978	1540					Sass
T	Tozeur	Borehole	18846005	Drâa Djerid 3 bis	1979	3140					Sass
T	Tozeur	Borehole	18847005	IBN CHABBAT 4	1979	3080					Sass
T	Tozeur	Borehole	18852005	Oued Kebir 2	1979	1800					Sass
T	Tozeur	Borehole	18857005	Gouifla 4	1981	1500					Sass
T	Tozeur	Borehole	18864005	Tozeur 7 bis	1980	1940					Sass
T	Tozeur	Borehole	18927005	Nefta 3 bis	1980	2600					Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Tozeur	Borehole	18928005	Kriz 3 bis	1980	2300					Sass
T	Tozeur	Borehole	18968005	Neftaiet 2 bis	1980	3520					Sass
T	Tozeur	Borehole	18992005	NEFTA SONEDE 2bis	1980	2360					Sass
T	Tozeur	Borehole	18996005	Zaouiet Larab 1 bis	1980	1700					Sass
T	Tozeur	Borehole	18999005	Tozeur Gare 2 bis	1998	1900					Sass
T	Tozeur	Borehole	19018005	IBN Chabbat 6 bis	1981	3100					Sass
T	Tozeur	Borehole	19019005	IBN Chabbat 8	1996	3100					Sass
T	Tozeur	Borehole	19026005	Menachi 1 bis	1981	1500					Sass
T	Tozeur	Borehole	19027005	IBN Chabbat 11	1982	3000					Sass
T	Tozeur	Borehole	19028005	IBN CHABBAT 12	1983	3020					Sass
T	Tozeur	Borehole	19029005	IBN Chabbat 13	1996	3000					Sass
T	Tozeur	Borehole	19030005	IBN Chabbat 14	1983	2900					Sass
T	Tozeur	Borehole	19031005	IBN Chabbat 10	1981	3080					Sass
T	Tozeur	Borehole	19032005	IBN Chabbat 9	1982	3160					Sass
T	Tozeur	Borehole	19033005	IBN CHABBAT 7	1982	3060					Sass
T	Tozeur	Borehole	19034005	Tozeur 2	1988	2780					Sass
T	Tozeur	Borehole	19035005	Tozeur 3	1982	2700					Sass
T	Tozeur	Borehole	19054005	Nefta 8	1982	2500					Sass
T	Tozeur	Borehole	19083005	OUED SHILI 3	1982	5120					Sass
T	Tozeur	Borehole	19091005	Garaet Jaballah	1995	2800					Sass
T	Tozeur	Borehole	19113005	Chakmou 4	1982	6200					Sass
T	Tozeur	Borehole	19116005	hezoua 4	1984	2660					Sass
T	Tozeur	Borehole	19121005	El Faouz	1982	2900					Sass
T	Tozeur	Borehole	19137005	Ouled Ghrissi	1983	2700					Sass
T	Tozeur	Borehole	19166005	Hazoua 4	1984	2660					Sass
T	Tozeur	Borehole	19167005	HAZOUA BM2	1983	2827					Sass
T	Tozeur	Borehole	19203005	Hazoua BM 1	1984	3080					Sass
T	Tozeur	Borehole	19214005	MRAH LAHOUAR 4	1990	2900					Sass
T	Tozeur	Borehole	19242005	Dafria CT1	1996	3560					Sass
T	Tozeur	Borehole	19250005	Neflaiet 3 bis	1999	7260					Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Tozeur	Borehole	19252005	CEDADA 4bis	1996	2140					Sass
T	Tozeur	Borehole	19284005	Nefta 5 bis	1996	2600					Sass
T	Tozeur	Borehole	19324005	Mides	1985	2500					Sass
T	Tozeur	Borehole	19329005	Manachi 2 bis	1985	1600					Sass
T	Tozeur	Borehole	19331005	DMITHA	1985	950					Sass
T	Tozeur	Borehole	19335005	Nefta 6 bis	1985	3200					Sass
T	Tozeur	Borehole	19342005	Oued El Kebir 1 bis	1985	1900					Sass
T	Tozeur	Borehole	19346005	KRIZ 3TER	1985	2980					Sass
T	Tozeur	Borehole	19357005	Dgoumes 2 bis	1986	2060					Sass
T	Tozeur	Borehole	19358005	Hamma 8 bis	1997	4100					Sass
T	Tozeur	Borehole	19359005	Hamma 9 bis	1985	6000					Sass
T	Tozeur	Borehole	19409005	NEFTA 4BIS	1990	3140					Sass
T	Tozeur	Borehole	19419005	PK 14 bis	1990	2180					Sass
T	Tozeur	Borehole	19420005	PK 13 bis	1987	2180					Sass
T	Tozeur	Borehole	19447005	Nefta 8	1986	3100					Sass
T	Tozeur	Borehole	19448005	Nefta 9	1987	2400					Sass
T	Tozeur	Borehole	19477005	Helba 4bis	1986	1900					Sass
T	Tozeur	Borehole	19492005	IBN CHABBAT 1BIS	1987	3220					Sass
T	Tozeur	Borehole	19493005	Helba 1 bis	1987	2000					Sass
T	Tozeur	Borehole	19502005	Gardgaya 4 bis	1987	3240					Sass
T	Tozeur	Borehole	19503005	El Hamma 4 bis	1987	4200					Sass
T	Tozeur	Borehole	19524005	Margueb Douil 3	1987	7860					Sass
T	Tozeur	Borehole	19525005	Chemsa 1 bis	1987	3020					Sass
T	Tozeur	Borehole	19549005	Cedada 6 bis	1987	1900					Sass
T	Tozeur	Borehole	19550005	IBN Chabbat 11 bis	1987	3000					Sass
T	Tozeur	Borehole	19575005	Mrah lahouar 1 bis	1987	3120					Sass
T	Tozeur	Borehole	19597005	TOUAREGHE	1992	2220					Sass
T	Tozeur	Borehole	19598005	Boulifa 1 (Tozeur 11)	1988	2320					Sass
T	Tozeur	Borehole	19599005	EL BERKA	1978	2360					Sass
T	Tozeur	Borehole	19607005	ZAAFRANA 1BIS	1999	3240					Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Tozeur	Borehole	19644005	TOZEUR 4BIS	1988	2380					Sass
T	Tozeur	Borehole	19717005	Gouifla 8	1990	5800					Sass
T	Tozeur	Borehole	19757005	TOZEUR SONEDE 2BIS	1997	1920					Sass
T	Tozeur	Borehole	19761005	Oued Naguess	1990	3300					Sass
T	Tozeur	Borehole	19778005	Nefta 11	1991	2500					Sass
T	Tozeur	Borehole	19784005	Dghoumes 3 bis	1991	2600					Sass
T	Tozeur	Borehole	19787005	Oudia CT1	1991	2620					Sass
T	Tozeur	Borehole	19881005	El Hamma 16	1992	2100					Sass
T	Tozeur	Borehole	19882005	Tozeur 7 ter	1992	1800					Sass
T	Tozeur	Borehole	19883005	Tozeur 12	1992	1800					Sass
T	Tozeur	Borehole	19927005	Tozeur 2	1988	2500					Sass
T	Tozeur	Borehole	19992005	Nefta Sonede 1	1980	2360					Sass
T	Tozeur	Borehole	20026005	Aïn Torba 3 ter	1994	1800					Sass
T	Tozeur	Borehole	20040005	El Moncef 4 bis	1994	2300					Sass
T	Tozeur	Borehole	20073005	Zaouit El Arab 1 ter	1994	2000					Sass
T	Tozeur	Borehole	20075005	Htam CT1	1995	3140					Sass
T	Tozeur	Borehole	20125005	El Oudia PQ	1992	3160					Sass
T	Tozeur	Borehole	20281005	Nefta 7 bis	1997	3060					Sass
T	Tozeur	Borehole	20282005	Nefta 3Ter	1997	2820					Sass
T	Tozeur	Borehole	20288005	ERRACHED 1bis	1997	2800					Sass
T	Tozeur	Borehole	20289005	MZARAA	1996	2860					Sass
T	Tozeur	Borehole	20290005	Sif Lakhder 1 bis	1996	2260					Sass
T	Tozeur	Borehole	20291005	CHOUCHET ZERGA 1b	1997	3800					Sass
T	Tozeur	Borehole	20364005	IBN Chabbat PZ2	1997	3000					Sass
T	Tozeur	Borehole	20371005	Tozeur Sonede 3	1996	1900					Sass
T	Tozeur	Borehole	20373005	IBN Chabbat 3 ter	1996	3100					Sass
T	Tozeur	Borehole	20377005	Sedada 3 ter	1996	3200					Sass
T	Tozeur	Borehole	20414005	Oued Sebkhat	1999	4800					Sass
T	Tozeur	Borehole	20418005	Bir Roumi	1998	3500					Sass
T	Tozeur	Borehole	20446005	Horchani 2 bis	1997	2000					Sass

Country	Zone	Type of equipment	Identifier	Denomination	Date	TDS in Sand	TDS in Limestone	TDS (MG/L)	Aquifer 1 of Oued Rhir	Aquifer 2 of Oued Rhir	Origin
T	Tozeur	Borehole	20448005	Hamma 17	1999	3160					Sass
T	Tozeur	Borehole	20482005	Hezoua 4 bis	1995	2600					Sass
T	Tozeur	Borehole	20486005	Nefta Ras ELaïn	1997	2450					Sass
T	Tozeur	Borehole	20487005	Mrah Lahouar 2 bis	1992	2800					Sass
T	Tozeur	Borehole	20488005	Tozeur Ras El Aïn	1995	2450					Sass
T	Tozeur	Borehole	20489005	Serra Hotel	1997	2000					Sass
T	Tozeur	Borehole	20492005	Moncef 3 bis	1997	2700					Sass
T	Tozeur	Borehole	20511005	Degache Nord 2 bis	1997	1760					Sass
T	Tozeur	Borehole	20514005	Garet Jaballah 1 bis	1995	2900					Sass
T	Tozeur	Borehole	20515005	IBN Chabbat 13 bis	1997	3220					Sass
T	Tozeur	Borehole	20516005	Tozeur 6 bis	1998	1900					Sass
T	Tozeur	Borehole	20572005	MANACHI CFRA	1997	2500					Sass
T	Tozeur	Borehole	20582005	El Hamma 19	1999	2300					Sass
T	Tozeur	Borehole	20584005	BEN GUECHA	1999	3800					Sass
T	Tozeur	Borehole	20593005	Neflaiet 4	2000	3000					Sass
T	Tozeur	Borehole	20632005	Ibn Chabbat 16	2000	3620					Sass
T	Tozeur	Borehole	20638005	Nefta 12	1999	3280					Sass
T	Tozeur	Borehole	20639005	Tozeur Gare 3	1999	1900					Sass
T	Tozeur	Borehole	20703005	El Hamma 18	1999	4500					Sass
T	Tozeur	Borehole	20831005	EL HAMMA 20	1999	4480					Sass
T	Tozeur	Borehole	20899005	Nefta 13	1995	3440					Sass
T	Tozeur	Borehole	20972005	Manachi CRFA	1997	1640					Sass
T	Tozeur	Borehole	19270005	DHAFRIA CI2	1996	3660					SASS
T	Tozeur	Borehole	X0600010	Seddada 4	1996	3100					Sass

3- Libya

Country	Zone	Identifier	Denomination	Date	TDS* (MG/L)	Origin
L	Abu Njaim	K-7	B. Kabir	1978	1386	GEFLI 1978
L	Abu Njaim	K-8	Wadi Bay Kabir	1978	2028	GEFLI 1978
L	Majir	P21		1978	1999	GEFLI 1978
L	Ninah	K-9	Nina	1978	4024	GEFLI 1978
L	Sufajin - Mardum	K5	Bayy Al Kabir	1978	1882	GEFLI 1978
L	Sufajin - Mardum	K6	Bayy Al Kabir	1978	2024	GEFLI 1978
L	Sufajin - Mardum	K-10	Mardum	1978	2128	GEFLI 1978
L	Sufajin - Mardum	K 12		1978	1996	GEFLI 1978
L	Sufajin - Mardum	WS9		1978	2486	GEFLI 1978
L	Sufajin - Mardum	SOF2		1978	3650	GEFLI 1978
L	Sufajin - Mardum	P9		1978	1820	GEFLI 1978
L	Sufajin - Mardum	TW1		1978	1676	GEFLI 1978
L	Sufajin - Mardum	MG - I		1978	4692	GEFLI 1978
L	Sufajin - Mardum	MG2		1978	9950	GEFLI 1978
L	Tawurgha	P22		1978	1478	GEFLI 1978
L	Tawurgha	MG3		1978	2464	GEFLI 1978
L	Zamzam	ZZ 2		1978	1304	GEFLI 1978
L	Buwayrat	K4		1978	2600	GEFLI 1978
L	Abu Njaim	K-1		1978	3100	GEFLI 1978
L	Zamzam	S1		1978	2000	GEFLI 1978
L	Abu Njaim	K-2		1978	2100	GEFLI 1978
L	Zamzam	K3		1978	3600	GEFLI 1978
L	Sufajin - Mardum	P12		1978	1900	GEFLI 1978
L	Majir	W2		1978	1900	GEFLI 1978
L	Majir	P15		1978	4100	GEFLI 1978
L	Majir	P11		1978	1900	GEFLI 1978
L	Majir	P16		1978	2200	GEFLI 1978
L	Majir	T-2A		1978	4300	GEFLI 1978
L	Majir	P20		1978	3800	GEFLI 1978
L	Zamzam	A1-39		1978	1800	GEFLI 1978
L	Derj	WG8		1994	2972	Sass
L	Derj - Ghadames	WG 12		1994	2542	Sass
L	Flanc sud Dj. Nefusa	47/77		1977	1266	Sass
L	Flanc sud Dj. Nefusa	48/77		1977	1010	Sass
L	Gharian	50/77		1977	1246	Sass
L	Gharian	51/77		1977	1310	Sass
L	Gharian	52/77		1977	932	Sass
L	Jufrah	JF8	Ferjan	1975	1310	Sass
L	Jufrah	JFA	Ferjan	1975	1245	Sass
L	Jufrah	JH4	El Hammam	1972	1312	Sass
L	Majir	I		1974	3340	Sass
L	Majir	MW-2022		2000	3650	Sass
L	Majir	MW-2023		2000	2460	Sass
L	Majir	VIII		1975	4386	Sass
L	Majir	X0500019	Dafina	1974	3556	Sass
L	Majir	X0500020	Dafina	1974	4400	Sass
L	Majir	X0500023	Dafina	1974	3602	Sass
L	Majir	XI		1976	2724	Sass
L	Majir	XIV		1976	3197	Sass

Country	Zone	Identifier	Denomination	Date	TDS* (MG/L)	Origin
L	Majir	XVIII		1975	4450	Sass
L	Sufajin - Mardum	22/87		1987	1741	Sass
L	Sufajin - Mardum	7/79		1979	1580	Sass

TDS = Total Dissolved Salt

Annex 7 – Table 2 : Salinity of the Continental Intercalaire waters

1- Algeria

Country	Zone	Identifier	Denomination	Date	TDS* (mg/l)	Origin
A	Souf	H01200037	BOU AROUA BAR 1	1970	3400	ERESS
A	In Salah	DJ 103		1970	2300	ERESS
A	In Salah	O00700044	In Salah 1	1970	2600	ERESS
A	Reggane	P00400089		1970	4100	ERESS
A	Aoulef	H 69		1970	6030	ERESS
A	Adrar	O00400430	TITTAOUINE CHEURFA	1970	1600	ERESS
A	Adrar	O00400139	Zaouiet Kounta	1970	1600	ERESS
A	Adrar	X03000021	Hassi Borj Sidi Youssef	1970	1200	ERESS
A	Adrar	X03000020	Hassi Tamentit	1970	2430	ERESS
A	In Salah	O00600018		1970	1200	ERESS
A	In Salah	O00700064		1970	2370	ERESS
A	In Salah	O00700058		1970	2230	ERESS
A	In Salah	O00700056		1970	2000	ERESS
A	In Salah	X00100341	Foggaret el Arab	1970	1640	ERESS
A	In Salah	O00700055	FOGGARET EZZOUA 6	1970	1600	ERESS
A	Aoulef	O00800013		1970	1800	ERESS
A	Tademait	O00900003		1970	1700	ERESS
A	Illizi	N01400004		1970	1900	ERESS
A	Illizi	N01500003	TERMINAL TL 103	1970	1580	ERESS
A	Illizi	OT 2		1970	940	ERESS
A	Illizi	N01300004		1970	1500	ERESS
A	Illizi	N01200004	DAIET OUAN TIBOKATI	1970	760	ERESS
A	Illizi	Tfy 1		1970	540	ERESS
A	Illizi	N01200001	HASSI TABANKORT	1970	1480	ERESS
A	Illizi	M01200001	Tamendjelt	1970	1340	ERESS
A	Illizi	N01100020	OUED AMESKIKI	1970	4480	ERESS
A	Illizi	N01100021	FORT FLATTERS DHER 3	1970	1000	ERESS
A	Tademait	N00900006	BEGUIRA 1	1970	2700	ERESS
A	Timimoun	N00400007		1970	3200	ERESS
A	Timimoun	M00400005		1970	2400	ERESS
A	Timimoun	M00400112	TIMIMOUN 2	1970	2200	ERESS
A	Timimoun	P. N°1		1970	2220	ERESS
A	Timimoun	P. N°2		1970	970	ERESS
A	Timimoun	P. N°3		1970	1600	ERESS
A	Timimoun	P. N°4		1970	3800	ERESS
A	Timimoun	M00500039		1970	800	ERESS
A	Timimoun	P. N°5		1970	2140	ERESS
A	Timimoun	M00600004	KERBOUB 1 KE 1 CPA	1970	1400	ERESS
A	Timimoun	P. N°6		1970	1060	ERESS
A	Timimoun	L00600013		1970	1000	ERESS
A	Timimoun	L00600004		1970	400	ERESS
A	Timimoun	P. N°8		1970	600	ERESS
A	El Goléa	L00600011		1970	470	ERESS
A	El Goléa	L00700073	GARET LOUAZOUAZA 1	1970	244	ERESS
A	Illizi	M01100003	HAMRA HR 1 CPA	1970	3700	ERESS
A	Illizi	ZM 1		1970	800	ERESS
A	Illizi	M01300002	Odoumé 1b	1970	1600	ERESS

Country	Zone	Identifier	Denomination	Date	TDS	Origin
A	Illizi	M01400003	STATION DE POMPAGE 2	1970	660	ERESS
A	Illizi	M01400002	STATION 2 CEP	1970	680	ERESS
A	Illizi	L01400001	MESSOUDA	1970	5600	ERESS
A	Gassi Touil	L01100011	GT 101 GASSI TOUIL	1970	3800	ERESS
A	El Goléa	K00800016	HASSI LEGHNEM	1970	340	ERESS
A	El Goléa	Bedjiaf		1970	250	ERESS
A	El Goléa	Hi Laabib		1970	294	ERESS
A	El Goléa	L00700066	HASSI MARROKET 1	1970	325	ERESS
A	El Goléa	L00700012		1970	390	ERESS
A	El Goléa	X00100128	Hi Sebti	1970	420	ERESS
A	El Goléa	Hi Yekhan		1970	470	ERESS
A	Oued Namous	Hi Bel Kacem		1970	920	ERESS
A	Oued Namous	K00400005	Oued Namous	1970	720	ERESS
A	Oued Namous	K00400008	DJORF EL ATFAL AMGH	1970	500	ERESS
A	Oued Namous	GK 101		1970	1750	ERESS
A	Oued Namous	K00500010		1970	1640	ERESS
A	Oued Namous	K00500004		1970	640	ERESS
A	El Goléa	K00700031		1970	275	ERESS
A	Hassi Fahl	J00700013		1970	589	ERESS
A	Hassi Fahl	J00800064		1970	491	ERESS
A	Hassi Fahl	J00800001	ALBIEN HASSI FAHL 1	1970	990	ERESS
A	Hassi Fahl	J00800020	DE HASSI TOUIL	1970	1080	ERESS
A	Hassi Fahl	K00800015	HASSI GOUIRET MOUSSA	1970	545	ERESS
A	Ouargla	K00900004	DR 101	1970	2000	ERESS
A	Ouargla	K00900003		1970	2100	ERESS
A	Ouargla	J01000511	TROIS PITONS OUARGLA	1970	1761	ERESS
A	Ouargla	J01000480	EL HADEB	1970	2150	ERESS
A	Ouargla	J01000447	Ouargla 1	1970	2420	ERESS
A	Hassi Messaoud	K01200007	SINCLAIR RB 7	1970	3080	ERESS
T	El Borma	BZA 1	Bir Zobbas (BZ A1)	1970	5940	ERESS
A	El Borma	J01400003	EL BORMA WEST EBW101	1970	4600	ERESS
A	El Borma	J01400010	EL BORMA 104	1970	4200	ERESS
A	Oued Rhir Sud	I01000011	EL HADJIRA ALBIEN	1970	1300	ERESS
A	Zelfana	j00800021	NOUMERATE AERODROME	1970	1150	ERESS
A	Berriane	i00800124	HASSI R'MEL HR 102	1970	1300	ERESS
A	Oued Seggueur	j00600020		1970	359	ERESS
A	Oued Seggueur	i00600005		1970	1300	ERESS
A	Laghouat	H00700130		1970	500	ERESS
A	Laghouat	H00700193		1970	1640	ERESS
A	Laghouat	L00800111		1970	1650	ERESS
A	Laghouat	H00800049		1970	2148	ERESS
A	Guerrara	I00900007	Guettara	1970	1370	ERESS
A	Oued Rhir Sud	H01000042	M'RARA	1970	1800	ERESS
A	Oued Rhir Sud	H01100408	TAMERNA 1	1970	1910	ERESS
A	Oued Rhir Sud	I01100437	SIDI SLIMANE	1970	2130	ERESS
A	Oued Rhir Sud	I01100228	Tamelhat	1970	1780	ERESS
A	Oued Rhir Sud	I01100236		1970	2050	ERESS
A	Souf	H01200036	HASSI BOURAS HBS 1	1970	2300	ERESS
A	Biskra	G01000252		1970	3300	ERESS

Country	Zone	Identifier	Denomination	Date	TDS	Origin
A	Biskra	G00900109	SIDI KHALED 1	1970	2780	ERESS
A	Guerrara	I00900005	Guerrara	1970	1719	ERESS
A	Ghardaia	I00800019	Ghardaia	1970	1550	ERESS
A	Zelfana	J00900011	ZELFANA N°3	1970	1900	ERESS
A	Zelfana	J00800015	METLILI 1	1970	1580	ERESS
A	Hassi Messaoud	J01100094	Hi Messaoud	1970	1800	ERESS
A	El Goléa	L00700001	EL GOLEA N 9 GENIE	1970	290	ERESS
A	In Salah	O00700046		1970	2340	ERESS
A	In Salah	O00600022	In rhar	1970	1600	ERESS
A	Aoulef	O00500053	AOULEF LARBI	1970	2460	ERESS
A	In Salah	L00700056	TAGHIT NOUVEAU 23	1970	180	ERESS
A	El Goléa	L00700041	HASSI EL GARA	1970	250	ERESS
A	In Salah	O00700039		1970	2590	ERESS
A	In Salah	O00700045		1970	2770	ERESS
A	Zelfana	X00100504	Zelfana II	1970	1380	ERESS
A	Zelfana	J00900027	Zelfana I	1970	1660	ERESS
A	Aoulef	P00600012	TIT TADOURA N°2	1970	1100	ERESS
A	El Borma	J01400009	ELB S 4	1970	1592	ERESS
A	El Borma	J01400002	EL GUELTA GE 102	1970	5766	ERESS
A	El Borma	J01400012	EL BORMA	1970	4691	ERESS
A	El Borma	J01400013	HASSI KESKESSA 102	1970	8830	ERESS
A	Illizi	L01400009	DEBDEB I	1970	900	ERESS
A	Illizi	L01400011	DEBDEB	1970	913	ERESS

TDS = Total Dissolved Salt

2- Tunisia

Country	Zone	Identifier	Denomination	Date	TDS* (mg/l)	Origin
T	Kebili	19832005	Radhouane (CI 23)	1992	5300	SASS
T	Kébili	09346005	MENCHIA	1990	4200	SASS
T	Kébili	19140005	Mansoura (CI 3)	1994	3554	SASS
T	Kébili	19157005	Bou Abdallah (CI 1)	1994	2659	SASS
T	Kébili	19199005	Taourgha (CI 2)	1985	2320	SASS
T	Kébili	19304005	Zaoueiet Chorfa (CI 4)	1994	2400	SASS
T	Kébili	19348005	Zaoueïet Anes (CI 5)	1994	1840	SASS
T	Kébili	19400005	Kébili (CI 10)	1994	2394	SASS
T	Kébili	19412005	Menchia CI 6	1994	2470	SASS
T	Kébili	19450005	Douz (CI 12)	1994	3910	SASS
T	Kébili	19468005	Jemna (CI 11)	1986	2880	SASS
T	Kébili	19893005	Mansoura (CI 13)	1994	1800	SASS
T	Kébili	19916005	DEBERCHA CI 14	1994	1800	SASS
T	Kébili	20051005	Kébili (CI 16)	1994	1500	SASS
T	Tozeur	19039005	DEGACHE CI 1	1985	2200	SASS
T	Tozeur	19084005	Nefta CI	1985	3280	SASS
T	Tozeur	19162005	Tozeur CI 1	1986	3640	SASS
T	Tozeur	19224005	Tozeur CI 2	1994	3540	SASS
T	Tozeur	19225005	Tozeur CI3	1985	2600	SASS
T	Tozeur	19227005	NEFTA CI2	1985	2940	SASS
T	Tozeur	19230005	Degache CI2	1985	2300	SASS
T	Tozeur	19231005	DEGACHE CI 3	1985	3040	SASS
T	Tozeur	19233005	EL HAMMA CI 2	1986	3840	SASS
T	Tozeur	19260005	EL HAMMA C.I.1bis	1986	2670	SASS
T	Tozeur	20363005	HAZOUA CI	1998	1700	SASS
T	Chott Fedjej	05950005	CF2	1970	2680	ERESS
T	Chott Fedjej	08429005	CF3	1970	2740	ERESS
T	Chott Fedjej	05664005	CF1	1983	3120	SASS
T	Chott Fedjej	05821035	MAZRAA NAJI 3	1982	4560	SASS
T	Chott Fedjej	05918005	Om El Fareth 1	1982	3420	SASS
T	Chott Fedjej	05950005	CF2	1983	2720	SASS
T	Chott Fedjej	06480005	Om El Fareth 2	1982	4960	SASS
T	Chott Fedjej	06664005	Oued Nakhla 1	1981	4520	SASS
T	Chott Fedjej	06664025	Oued Nakha 2	1981	4480	SASS
T	Chott Fedjej	06980005	Oued Smed	1981	3340	SASS
T	Chott Fedjej	07283005	SEFTIMI 3	1980	3180	SASS
T	Chott Fedjej	07305005	SEFTIMI 1	1981	4000	SASS
T	Chott Fedjej	07309005	Steftimi 2	1981	2620	SASS
T	Chott Fedjej	08429005	CF3	1983	2840	SASS
T	Chott Fedjej	16729005	LIMAGUESS	1985	2920	SASS
T	Chott Fedjej	18689005	CF F9	1983	3250	SASS
T	Chott Fedjej	18695005	CF F1	1983	3700	SASS
T	Chott Fedjej	18696005	CF F2	1983	2620	SASS
T	Chott Fedjej	18698005	CF F8	1983	2920	SASS
T	Chott Fedjej	18700005	CF F10	1983	3100	SASS
T	Chott Fedjej	19175005	CF 3bis	1983	2730	SASS
T	Chott Fedjej	19272005	Saïdane	1998	2880	SASS
T	Chott Fedjej	19394005	Limagues (CI 8)	1998	2500	SASS
T	Chott Fedjej	19452005	Steftimi (CI 7)	1986	2700	SASS

Country	Zone	Identifier	Denomination	Date	TDS	Origin
T	Chott Fedjej	20217005	Foret limaguess	1996	3820	SASS
T	Chott Fedjej	05664005	CF1	1983	2010	SASS
T	Chott Fedjej	05950005	CF2	1999	2520	SASS
T	Chott Fedjej	08429005	CF3	1983	2840	SASS
T	Chott Fedjej	18689005	CF F9	1999	3250	SASS
T	Chott Fedjej	18695005	CF F1	1999	3700	SASS
T	Chott Fedjej	18696005	CF F2	1999	2620	SASS
T	Chott Fedjej	18697005	CF F3	1984	2840	SASS
T	Chott Fedjej	18698005	CF F8	1999	2920	SASS
T	Chott Fedjej	18700005	CF F10	1999	3100	SASS
T	Chott Fedjej	19090005	Chareb	1999	5080	SASS
T	Chott Fedjej	19175005	CF 3bis	1999	2730	SASS
T	Chott Fedjej	19190005	CF 1 bis	1999	2760	SASS
T	Chott Fedjej	19482005	CF 2 bis	1999	3000	SASS
T	Chott Fedjej	19500005	Guelb Soukra	1987	10320	SASS
T	Chott Fedjej	19529005	Oued Nakhla 1ter	1999	4520	SASS
T	Chott Fedjej	19741005	Oglet Merteba	1992	2920	SASS
T	Chott Fedjej	19884005	Temra	1992	6680	SASS
T	Chott Fedjej	19998005	Zemlet El bidha	1993	7450	SASS
T	Chott Fedjej	20150005	CF 11	1999	2800	SASS
T	Chott Fedjej	20654005	El Hamma Sud CI1	1999	3800	SASS
T	Chott Fedjej	20952005	CF 12	2000	2920	SASS
T	Far South	18684005	El-Borma 203(*)	1970	2780	ERESS
T	Far South	08928005	El Benia	1970	2200	ERESS
T	Far South	05717005	KSAR GHILANE 1	1970	4940	ERESS
T	Far South	08928005	El Benia (EBN A1)	1970	5600	ERESS
T	Far South	X00700220	Zemlet En Nouss (ZN A1)	1970	4680	ERESS
T	Far South	EBA 4	El Borma A4	1970	4520	ERESS
T	Far South	X00700217	El Borma A6	1970	4320	ERESS
T	Far South	ZTA 1	ZEMLET EL TAYARA A1	1970	4600	ERESS
T	Far South	EZA 1	Em ZAB	1970	6200	ERESS
T	Far South	ECH A 1	Ech Chouich	1970	4680	ERESS
T	Far South	Sba 1	Sabria (Sba 1)	1970	3080	ERESS
T	Far South	Sna		1970	2200	ERESS
T	Far South	Mra		1970	1920	ERESS
T	Far South	06511005	Lorzot	1970	2480	ERESS
T	Far South	07000005	SP3(Trapsa)(*)	1970	1080	ERESS
T	Far South	DKA 1	Dekhanis	1970	3280	ERESS
T	Far South	SP 4 N	SP 4 (1)	1970	5500	ERESS
T	Far South	18862005	Nekrif 2(*)	1987	1380	SASS
T	Far South	19192005	Temejine 1(*)	1984	1880	SASS
T	Far South	19255005	O.Abdellah 2(*)	1984	3740	SASS
T	Far South	19323005	Lorzot 2 bis(*)	1987	2360	SASS
T	Far South	19334005	Ouni(Dahar)	1987	1720	SASS
T	Far South	19385005	Nekrif 3(*)	1986	980	SASS
T	Far South	19402005	Beni Guendil(*)	1986	1380	SASS
T	Far South	19405005	Temejine 2(*)	1986	2500	SASS
T	Far South	19413005	Bin el Abreg Bis(*)	1986	4600	SASS
T	Far South	19445005	O Abdellah3(*)	1987	2680	SASS
T	Far South	19504005	Bir Zar	1987	1940	SASS
T	Far South	19560005	Ouni (Jefara) (*)	1990	1700	SASS

Country	Zone	Identifier	Denomination	Date	TDS	Origin
T	Far South	19561005	Mazraa El Hammam	1990	1780	SASS
T	Far South	19634005	Segdel 1(*)	1988	2040	SASS
T	Far South	19635005	Marbah Essafsaf(*)	1988	1200	SASS
T	Far South	19636005	Daghsen 1(*)	1988	3000	SASS
T	Far South	19637005	Daghsen 2(*)	1988	3140	SASS
T	Far South	19638005	Daghsen 3(*)	1988	3780	SASS
T	Far South	19639005	Daghsen 4(*)	1988	2160	SASS
T	Far South	19640005	Mertaba 1	1988	1800	SASS
T	Far South	19641005	Mertaba 2	1989	1820	SASS
T	Far South	19642005	Mertaba 3	1989	2200	SASS
T	Far South	19647005	Oued El Ghar(*)	1988	2700	SASS
T	Far South	19662005	Nekrif 4(*)	1988	1200	SASS
T	Far South	19674005	Marbah El Hamra(*)	1988	2300	SASS
T	Far South	19735005	Kambout 2(*)	1991	2960	SASS
T	Far South	19803005	Nekrif 5(*)	1991	2040	SASS
T	Far South	19895005	Ech-chemel(*)	1993	4800	SASS
T	Far South	19955005	Oued Mijena	1995	4800	SASS
T	Far South	20060005	Ali Bouhala	1994	3150	SASS
T	Far South	20454005	Oued Ennakhla	1998	2900	SASS
T	Far South	20587005	Kohil (Goumrassen)	1998	4000	SASS
T	Far South	05717005	KSAR GHILANE 1	1951	4530	SASS
T	Far South	07810005	Ksar Ghilane 2	1994	4450	SASS
T	Far South	08752005	SP4n°1(Trapsa)(*)	1984	3300	SASS
T	Far South	19009005	Ksar Ghilane 3 bis	1995	4450	SASS
T	Far South	19432005	MAHBES 1	1985	3460	SASS
T	Far South	X00700211	Garaet Tibourt T.E.1	1980	1640	SASS
T	Far South	X00700228	Garet Ben Sbeur	1981	2180	SASS

TDS = Total Dissolved Salt

3- Libya

Country	Zone	Identifier	Denomination	Date	TDS* ml/l)	Origin
L	Suffajin - Mardum	01-85	Seddada	1985	1490	SASS
L	Jufrah	18/79	wadi Tishana	1981	2200	SASS
L	Jufrah	19/79	Waddan	1982	1942	SASS
L	Jufrah	20/79	Waddan	1982	1934	SASS
L	Suffajin - Mardum	22/81	Tininay	1986	1540	SASS
L	Suffajin - Mardum	23.82	Mardum	1982	1846	SASS
L	Zlitan - Majir	27/80	Taouargha	1986	1500	SASS
L	Suffajin - Mardum	3.83	Mardum	1983	1450	SASS
L	Zlitan - Majir	36/84	Taouargha	1986	1790	SASS
L	Suffajin - Mardum	4.83	Mardum	1983	1600	SASS
L	Zlitan - Majir	41/84	Taouargha	1987	1740	SASS
L	Zlitan - Majir	42/84	Taouargha	1987	1630	SASS
L	Zlitan - Majir	43/84	Taouargha	1987	1344	SASS
L	Mizda	Azumi	Wadi Sof	1980	1527	SASS
L	Suffajin - Mardum	B-10 (35/82)	Bani walid	1983	1440	SASS
L	Suffajin - Mardum	B-5 (1/81)	Bani walid	1982	1676	SASS
L	Suffajin - Mardum	B-7 (21/81)	Bani walid	1982	1450	SASS
L	Bou Njaim	BAK-1	B. Kabir	1978	1376	SASS
L	Bou Njaim	BAK-3	B. Kabir	1977	1376	SASS
L	Suffajin - Mardum	BAK-6	B. Kabir	1977	1274	SASS
L	Jufrah	J-18	Socna	1976	1100	SASS
L	Suffajin - Mardum	K-10	Mardum	1976	1983	SASS
L	Bou Njaim	K-2	Bayy Al Kabir	1977	1582	SASS
L	Bou Njaim	K-8	Wadi Bay Kabir	1977	1612	SASS
L	Suffajin - Mardum	Mar S05	Liss Moasker	1978	1410	SASS
L	Suffajin - Mardum	Mar S07	Dafaa Zaouia	1979	1372	SASS
L	Suffajin - Mardum	MAR SG	Chabet Nasar	1979	1528	SASS
L	Suffajin - Mardum	S1Q1	Fawar al Khadem	1978	1374	SASS
L	Suffajin - Mardum	S1Q4	Fawar Asharika	1978	1467	SASS
L	Suffajin - Mardum	S1Q5E	Fawar Machtal	1978	1463	SASS
L	Ash Shwayrif	SH-1	Ash Shwayrif	1976	1209	SASS
L	Ash Shwayrif	SH-10A	Ash Shwayrif	1980	1210	SASS
L	Ash Shwayrif	SH-7A	Ash Shwayrif	1980	1244	SASS
L	Ash Shwayrif	SH-9A	Ash Shwayrif	1981	1252	SASS
L	Derj	T/1/0036/0/70	Derj WG - 9	1975	967	SASS
L	Derj	T/1/0037/0/70	Derj WG - 10	1975	1637	SASS
L	Bou Njaim	T/2A/0012/87	Bu Njim	1988	1749	SASS
L	Suffajin - Mardum	T/2B/0002/085	Seddada	1985	1270	SASS
L	Suffajin - Mardum	T/2B/0008/0/78	Wadi Mayimun	1979	4972	SASS
L	Zlitan - Majir	T/2B/0009/0/78	Wadi Mayimun	1979	2150	SASS
L	Suffajin - Mardum	T/2B/0014/0/82	Wadi Mayimun	1984	2000	SASS
L	Suffajin - Mardum	T/2B/0016/0/82	Wadi Mayimun	1984	1926	SASS
L	Suffajin - Mardum	T/2B/0031/084	Seddada	1985	1190	SASS
L	Derj	T11-81		1983	1056	SASS
L	Ghadames	T203-80		1981	894	SASS
L	Ghadames	T276-77		1995	828	SASS
L	Ghadames	T277-77		1994	935	SASS
L	Sinawen	T64-78		1978	1132	SASS
L	Derj	T96-76		1978	1140	SASS

Country	Zone	Identifier	Denomination	Date	TDS	Origin
L	Zlitan - Majir	VII	(VII)	1975	2370	SASS
L	Ghadames	WG 22		1994	942	SASS
L	Derj	WG 9		1995	3674	SASS
L	Derj	WG8	WG8 (1226)	1994	2972	SASS
L	Buwayrat	WH-1		1976	1646	SASS
L	Buwayrat	WH5	Washkna n░5	1977	1728	SASS
L	Buwayrat	WH8	Washkna n░8	1978	2480	SASS
L	Buwayrat	WH9	Washkna n░9	1978	2360	SASS
L	Zam Zam	WS 20	Jabal Mahidid	1976	1464	SASS
L	Zam Zam	WS-2	Wadi Guarza	1976	1600	SASS
L	Ash Shwayrif	WS-6	Ash Shwayrif	1975	1250	SASS
L	Ash Shwayrif	WS-8	Shayrif	1979	908	SASS
L	Zam Zam	ZZ 10	Fawar chaabya 10	1975	1366	SASS
L	Zam Zam	ZZ 12	Guadahya	1975	1555	SASS
L	Zam Zam	ZZ 15	Fawar Ryadh stat	1976	1414	SASS
L	Zam Zam	ZZ 7	Fawar Um Al Hama	1975	1510	SASS
L	Zam Zam	ZZ 7 A	Fawar Hawach	1976	1474	SASS
L	Zam Zam	ZZ 8	Fawar Dafa Um Al	1975	1544	SASS
L	Jebel Nefusa	T126-81		1981	1114	SASS
L	Jebel Nefusa	50/77		1977	1246	SASS
L	Jebel Nefusa	51/77		1977	1310	SASS
L	Jebel Nefusa	52/77		1977	932	SASS
L	Mizda	130/77		1977	1380	SASS
L	Jebel Nefusa	T22-76		1976	1588	SASS
L	Jebel Nefusa	T39-78		1978	1480	SASS
L	Jebel Nefusa	T5-78		1978	1734	SASS
L	Suffajin - Mardum	22/87		1987	1741	SASS
L	Suffajin - Mardum	7/79		1979	1580	SASS
L	Mizda	18/88		1988	684	GWA
L	Jebel Nefusa	17/76		1976	1698	GWA
L	Jebel Nefusa	19/76		1976	1680	GWA
L	Jebel Nefusa	18/70		1970	1030	GWA
L	Jebel Nefusa	35/78		1978	1525	GWA
L	Jebel Nefusa	35/78		1978	1525	GWA
L	Jebel Nefusa	23/79		1979	1230	GWA
L	Jebel Nefusa	202/79		1979	1320	GWA
L	Mizda	25/87		1987	1257	GWA
L	Mizda	132/77		1977	2097	GWA
L	Mizda	156/80		1980	2000	GWA
L	Mizda	4/88		1988	2172	GWA
L	Mizda	69/75		1975	1270	GWA
L	Mizda	107/75		1975	1568	GWA
L	Jebel Nefusa	108/76		1976	1260	GWA
L	Mizda	190/80		1980	1404	GWA
L	Mizda	107/78		1978	816	GWA
L	Mizda	47/77		1977	1266	GWA
L	Mizda	187/80		1980	700	GWA
L	Mizda	314/76		1976	781	GWA
L	Mizda	316/76		1976	600	GWA
L	Mizda	48/77		1977	1010	GWA
L	Jebel Nefusa	27/83		1983	1050	GWA

Country	Zone	Identifier	Denomination	Date	RS	Origin
L	Hamada Al Hamra	10/81		1981	752	GWA
L	Ash Shwayrif	26/70		1970	1947	GWA
L	Ash Shwayrif	2085/4/10		1985	1868	GWA
L	Hamada Al Hamra	208/79		1979	1209	GWA
L	Hamada Al Hamra	66/82		1982	1350	GWA
L	Mizda	30/83		1983	1300	GWA

TDS = Total Dissolved Salt

ANNEX 8

ISOTOPIC CONTENTS OF THE WATERS

ANNEX 8 : ISOTOPIC CONTENTS OF THE WATERS

Annex 8 Table 1 – Isotopic characteristics of the Continental Intercalaire waters in Algeria

Code	Name of water point	Date	Depth	Aquifer	^{18}O	^{2}H	^{14}C %	^{13}C%.	Gross age	Adjusted age	Excess ^{2}H	Origin
ALG6	Ouled Jellel 463G10		1880-2135	B (Sga)	-7.4	-52.9					6.54	GUANDOUZ A, 1985
ALG15	Djemaa 516H11		1440-1797	AB (ga)	-8.2	-54.8	0,5±0,5	-10.4			10.72	GUANDOUZ A, 1986
ALG19	Aiin Sahra		1545-1796	AB (Sa)	-8.3	-59.1	-	-9.4			8.44	GUANDOUZ A, 1987
ALG23	Sidi Slimane 437I11		1566-1766	AB (Sa)	-8.3	-58.2	0 ± 0,6	-10.1			7.68	GUANDOUZ A, 1988
ALG30	Hadjira 55I10		-	AB (Sa)	-8.3	-58.8	0,8±0,4	-10.4			5.5	GUANDOUZ A, 1989
ALG37	Hassi Bou Abdellah 11J10		1130-1430	AB (ga)	-8.4	-61.7	3,7±1,2	-9.1			8.34	GUANDOUZ A, 1990
ALG42	Zelfana 4 5219		843-938	AB (Sga)	-8.0	-55.5					8.34	GUANDOUZ A, 1991
ALG45	Metlifi 70J8		390-519	AB (Sga)	-71.0	-55.5					6.8	GUANDOUZ A, 1992
ALG53	Bl Ameid-Ghardaia S019		750-938	AB (Sa)	-8.4	-60.4					2.12	GUANDOUZ A, 1993
ALG53	Berraine 3518		443-510	B (ga)	-7.9	-61	0,5±0,4	-8.6			7.3	GUANDOUZ A, 1994
ALG60	Hassi Messaoud MDH 103		1163-1361	-	-8.6	-61.5	0,6±0,3	-11.4			0	GUANDOUZ A, 1995
ALG61	Irrara OMN17		1438-1880	Ni- B	-5.3	-42	3,9±0,3	-6.4			2.62	GUANDOUZ A, 1996
ALG64	Gassi Touil GM01		849-933	AL (ga)	-8.3	-64.1	6±1,4	-10.7			-1.1	GUANDOUZ A, 1997
ALG69	Centre AR6 1R19		1297-1580	J (ag)	-5.8	-47.5	0,8±0,3	-5.6			8.8	GUANDOUZ A, 1998
ALG74	Raguel RB2		800-995	AL (gsa)	-8.6	-59.6						GUANDOUZ A, 1999
Basin of Eastern Grand Erg												
33.0.3	Laghouat 130 H 7	05/03/71		Al (Sg)	-8.0	-56	54.7±1.3	-7.4	moderne	moderne		ERESS, 1972
41.0.10	Tamerna 408 H 11	02/04/71	1482-1730	Al (Sg)	-8.3	-59	1.1 ±0.8	-8.8	32000±3000	29000.0		ERESS, 1972
35.0.5	Berraine 119 I 8	03/03/71		Al (Sg)	-8.2	-62	1.3 ±0.4	-8.3	31000±3000	28000.0		ERESS, 1972
39.0.9	Guerrara 17 I 9	04/03/71		Al (Sg)	-8.6	-62	1.7 ±0.4	-9.4				ERESS, 1972
42.0.11	Sidi Mehdi 436 I 11	01/04/71	1535-1735	Al (Sg)	-8.1	-56	2.1 ±0.6	-9.9	29000±2000	27000.0		ERESS, 1972
36.0.6	Melika 112 I 8	03/03/71	340 - 430	Al (Sg)	-8.5	-61	2.5 ±0.5	-8.0	25000±2000	25000.0		ERESS, 1972
40.0.2	Zelfana 11 J 9	27/11/69		Al (Sg)			0.0 ±0.8	-9.5	> 35 000	> 33 000		ERESS, 1972
40.0.3	Zelfana 11 J 10	02/03/71		Al (Sg)	8.5	-61						ERESS, 1972
1.1.1	Ouargla 447 J 10	15/02/69	1119 - 1315	Al (Sg)	-8.8	-62						ERESS, 1972
1.1.1	Ouargla1 447 J 11	28/11/69		Al (Sg)			1.4 ±1.8	-11.5	30000±1000	30000.0		ERESS, 1972
4.0.0	Ouargla 2 480 J 10	28/11/69	1149 - 1335	Al (Sg)	-8.8	-63						ERESS, 1972
43.0.12	Daïet Remt 4 K 9	12/03/71	536 - 605	Al (Sg)	-8.4	-63	5.2 ±0.4	-10.6	19000±1000	18000.0		ERESS, 1972
48.0. 33	Hassi Messaoud	28/04/71		Al (Sg)	-8.6	-61	.1 ±0.6	-10.3	21000±2000	20000.0		ERESS, 1972
49.0.34	Rh^{de} El Baguel AB7, 7 K 12	30/04/71	822- 970	Al (Sg)	-8.5	-60	2.4 ±0.6	-11.1	26000.0			ERESS, 1972
Basin of Western Grand Erg												
44.0.13	Hassi Fahl 1 J 8	12/02/71	265 - 306	Al (Sg)	-6.7	-56	0.9 ±0.5	-7.6				ERESS, 1972
CF	El Golea	01/12/70		ind (Sa)	-4.7		32 ±0.3	-7.0				ERESS, 1972
15.0.15	Hassi Maroket 66 L 7	27/03/69	150 - 195	ind (Sa)	-5.0	-50						ERESS, 1972

Code	Name of water point	Date	Depth	Aquifer	^{18}O	^{2}H	^{14}C %	^{13}C%.	Gross age	Adjusted age	Excess ^{2}H	Origin
15.0.16	Hassi Maroket 66 L 8	27/11/69		ind (Sa)			1.0 ±0.7	-5.6				ERESS, 1972
15.0.17	Hassi Maroket 66 L 9	01/12/70		ind (Sa)	-5.7		1.0±0.1					ERESS, 1972
14.14.16	Hassi Enfil P n°5	27/03/69		ind (Sa)	-6.0	-58	59.6 ±4.4	-5.1				ERESS, 1972
13.0.0	Fogg. Amghaier (Timimoun)	26/03/69		ind (Sa)	-7.9	-64						ERESS, 1972
CF	Terr. Aviation (Timimoun)	01/12/70		ind (Sa)	-8.3		30.9 ±0.5	-6.5				ERESS, 1972
8.0.0	Foggara Adrar	24/03/69		ind (Sa)	-7.0	6 60						ERESS, 1972
9.0.0	Ferme exp[ale] Adrar	25/03/69		ind (Sa)	-6.1	-52						ERESS, 1972
CF	Shell - Sonatrach-Adrar	27/04/69		ind (Sa)	-7.1	-54						ERESS, 1972
CF	Adrar	01/12/70		ind (Sa)	-6.5		24.4 ± 0.5	-8.7				ERESS, 1972
CF	Adrar	04/04/68		ind (Sa)	-6.8							ERESS, 1972
CF	Adrar	28/04/68		ind (Sa)	-6.7							ERESS, 1972
CF	Adrar	23/04/68		ind (Sa)	-7.1	-61						ERESS, 1972
CF	Bou Ali	01/12/70		ind (Sa)	-8.7		22.3 ± 0.4	-8.8				ERESS, 1972
CF	Bou Ali	28/04/68		ind (Sa)	-7.7							ERESS, 1972
CF	Bou Ali	28/04/68		ind (Sa)	-7.9							ERESS, 1972
CF	C.A.S (Reggane)	01/12/70		ind (Sa)			33.2 ±2.5					ERESS, 1972
CF	Reggane	14/04/68		ind (Sa)	-7.9							ERESS, 1972
CF	Reggane	01/11/71		ind (Sa)			33.5 ±2.5					ERESS, 1972
CF	OCI, Reggane	14/04/68		ind (Sa)	-7.4							ERESS, 1972
CF	Fogg. Beb Drao, Aoulef El Arab	14/04/68		ind (Sa)	-7.4	-58						ERESS, 1972
CF	Fogg. Beb Drao, Aoulef El Arab	01/12/70		ind (Sa)	-7.4							ERESS, 1972
51.0.0	Tit 101	01/14/71		ind (Sa)	-8.0	-60						ERESS, 1972
51.0.1	Tit 102	01/11/71		ind (Sa)			36.0 ±0.6					ERESS, 1972
CF	Hydraulique In Salah	01/12/70		ind (Sa)	-8.4		21.2 ±1.0	-10.2				ERESS, 1972
CF	In Salah	14/04/68		ind (Sa)	-8.3	-64						ERESS, 1972
CF	Foggara Ez Zoua	13/04/68		ind (Sa)	-9.6							ERESS, 1972
CF	Foggara Gentour (Timimoun)	26/03/69		ind (Sa)+ CT (SC)	-6.6	-57						ERESS, 1972

Al : Albian Ni : Neocomian Sa: Clayey sand

Annex 8 Table 2 – Isotopic characteristics of the Continental Intercalaire waters in Tunisia

Locality	Date	^{18}O	^{2}H	^{14}C (%)	^{13}C (3%)	^{3}H	Gross age	Adjusted age	Excess ^{2}H
(1) O. Nekhla 6664/5	1970	-8.6	-62	0,2±0,6	-8.5	-	46000±12000	44000	6.8
(104) O, Nekhla 6664/5	1970	-	-	±	-	0	21510±500	1949±670	
(31) O, Nekhla 6664/5	1974	-8.5	-	-	-8.6	-	34000±1000	33000	
(2) Chott Fedjej 1 5664/5	1969	-7.9	-62	-	-	-	-	-	1.2
(106) Chott Fedjej 1 5664/5	1969	-	-	-	-	-	27990±790	27530±490	
(3) Chott Fedjej n°3 429/5	1969	-8.2	-60	-	-	-	-	-	5.6
(4) Source Seftini 1948/5	1969	-8.3	-62	-	-	-	-	-	4.4
(50) Seftini n°1 7283/5	1969	-	-	-	-	-	17210±460	16260±920	
(5) Seftini n°2 7305/5	1969	-8.4	-60	6,6±1,5	-10.7	-	1700±2000	17000	7.2
(100) Seftini n°3 7305/5	1969	-	-	-	-	-	27040±610	25490±420	
(28) Seftini n°3 7305/5	1974	-8.7	-	-	-	-	-	-	5.4
(6) Seftini n°3 7305/5	1969	-8.3	-61	-	-	-	-	-	
(6) Seftini n°3 7305/5	1984	-8.4	-	-	-	-	-	-	4.4
(7) Pumping Station 4 SP4	1970	-8.8	-66	-	-	-	-	-	4.4
(8) Borj Bourguiba 5664/5	1970	-8.8	-66	-	-	-	-	-	
(4) Borj Bourguiba 5664/5	1982	-9.4	-	2,7±0,5	-2.63	-	25000±4000	-	10.4
(9) Bir Zobbas BZA-1	1970	-9.3	-64	0,4±0,6	-6.4	-	41000±8000	36000	6.8
(10) El borma A4 KBA4	1970	-9.1	-66	-	-	-	-	-	5.6
(11) Zenlet et Tayara ZTE-1	1970	-8.7	-64	-	-	-	-	-	8.4
(12) Ouu Zab EZA-1	1970	-8.8	-62	2,9±9,2	-9.9	-	24000±12	23000	5.4
(13) Ech Chouech EC-A1	1970	-8.3	-61	6±3,5	-10.5	-	18000±4000	18000	4.6
(14) Pumping Station 3 SP3	1970	-8.2	-61	-	-	-	-	-	
(57) Pumping Station 4 SP4	1970		-	-	-	-	16140±200	14840±430	5.4
(15) O. Lorsot 6511/5	1970	-8.3	-61	0±3	-8.7	-	24000	23000	
(58) O. Lorzot 6511/5	1970	-	-	-	-	-	10950±60	9950±330	4.2
(16) O. Ouni 6855/5	1970	-7.9	-59	53,3±4,5	-8.4	-	Moderne	Moderne	
(101) Aiin el Gnettar 1944/5	1970	-	-	-	-	16±4	14340±250	12740±530	5.08
(51) Aiin el Gnettar 1944/5	1970	-7.9	-	-	-	-	-	-	
(76) Aiin el Gnettar 1944/5	1982	-7.7	-56.6	-	-	0.1	-	-	
(105) Aiin Tenra	1970	-	-	-	-	-	22850±440	20810±650	
(102) Oun el Ferh 5918/5	1970	-	-	-	-	-	24940±710	23440±500	
(29) Oun el Ferh 5918/5	1974	-8.1	-	-	-	-	-	-	
(29) Oun el Ferh 5918/5	1984	-8.4	-	-	-	-	-	-	
(30) Nazraa Naji 5821T/5	1970	-	-	-	-	-	22620±460	21170±480	
(48) Aiin Linaguess 5321/5	1974	-8.2	-	-	-	-	-	-	
(49) Ain Radhouane 1946/5	1974	-8.1							
(50) Aïn Saïdane 2163/5	1974	-9.0							

Locality	Date	^{18}O	^{2}H	^{14}C (%)	^{13}C (3%)	^{3}H	Gross age	Adjusted age	Excess ^{2}H
(27) Menchia 9346/5	1974	-8.7							
(94) Menchia 9346/5	1985						24820±700	23050±590	
(58) Puits S. Hamed (Chott)	1974	5.5							
(130) Ksar Ghilane 7810/5	1970					4±3	21020±370	18490±810	
(130) Ksar Ghilane 7810/5	1984	-7.2		3.9±1.3	-8.57				
(110) Bir Chareb 8592/5	1970						29839±760	27970±620	
(111) Brigua Kébira 8581/5	1970						22490±350	20860±540	
(2) Bir Recifa 3bis	1982	-6.4	-34.3	44.9±1.6	-6.12				
(3) El Benia 2 16736/5	1982	-6.4	-38.3		-6.92				
(6) Chenini 1 18815/5	1982	-5.7	-41.3		-6.74				
(8) Gareat Tebourt TE-1	1982	-7.9	-61.1	2.8±0.4	-11.3		26000 ± 3500		
(12) Ksar O.[led] Debbab 13784/5	1982	-5.9	-39.4		-1.25				
(101)Nefta CI 1 19084/5	1995	-7.1	-58	5.8±1.00					
(102) Nefta CI2 19227/5	1995	-7.7	-50						
(103) Tozeur CI 1 19162/5	1995	-7.0	-57	8.8±0.60	-7.85				
(104) Tozeur CI 2 19224/5	1995	-7.7	-62	2.5±0.60	9.05				
(105) Tozeur CI 3 19225/5	1995	-7.6	-61						
(106) El Hamma CI1 19233/5	1995	-6.8	-67	7.3±0.80	-11				
(107) El Hamma CI 19792/5	1995	-6.8	-57						
(108) Tazrarit 19793/5	1995	-7.5	-62		-10.3				
(109) Seddada 19791/5	1995	-8.0	-53						
(110) Ech Cheurfa 19304/5	1995	-8.8	-60						
(111) Ez Zouia CI1 19348/5	1995	-8.2	-81						
(112) Mansoura CI 3 19140/5	1995	-8.3	-64	3.7±0.80	-11.43				
(113) Mansoura CI 13 19893/5	1995	-8.4	-77	2.2±9.00	-10.77				
(114) Kébili CI 10 19400/5	1995	-8.4	-64	1.5±9.90	-10.44				
(115) Kébili CI 16 20051/5	1995	-8.3	-77						
(116) Taourgha CI 2 19199/5	1995	-8.6	-59	5.3±0.80	-11.49				
(117) El Bahaïer CI 9 19484/5	1995	-8.1	-59						
(118) Limaguess CI8 19394/5	1995	-8.5	-61						
(119) Debabcha CI 4 19916/5	1995	-8.1	-58						
(120) Souk Lahad CI 17 20109/5	1995	-8.4	-60						
(121) Menchia CI 6 19452/5	1995	-8.4	-59						
(122) Seftimi CI 7 19452/5	1995	-8.4	-59	6.6±1.50	-9.5				
(725) Douz CI12 19450/5	1995	-8.7	-80						
(728) Djemna CI 11 19468/5	1995	-8.6	-54						
(716) Saïdane 19272/5	1995	-8.4	-61	8.9 ± 0.60	-11.45		19470 ± 560		
Mahbes 19432/5	1995	-7.7	-57	5.0 ± 0.44	-9.9		24240 ± 720		

Locality	Date	^{18}O	^{2}H	^{14}C (%)	^{13}C (3%)	^{3}H	Gross age	Adjusted age	Excess ^{2}H
(738) Ksar Ghilane 19009/5	1995	-6.8	-47						
Oued Nekhla 19529/5	1995	-8.4	-60	15.4 ± 0.9	-10.5		15030 ± 1110		
Chott Fedjej 2bis 19482/5	1995	-8.4	-59	9.3 ± 0.60	-11.2		19130 ± 540		
Pumping Station SP4 19682/5	1995	-8.2	-65						

Annex 8 Table 3 – Isotopic characteristics of the Kiklah waters in Libya

Zone	Nom	Depth	Aquifer		δ18O‰	δD‰	14C %	δ13C	Ages	3H in T.U.
Al Jufrah - Zmam	Socna	400	Crétacé sup.	Ks	-10.20	-79.6	0.8 ± 0.3	-5.6	>23700	
Al Jufrah - Zmam	Socna well S-1	300	Crétacé sup.	Ks	-10.51	-76.6	0.0 ± 0.5	-5.39	>24900	
Al Jufrah - Zmam	Al Jufrah		Mizdah	Miz	-10.53	-77.6	0.6 ± 0.4	-4.96	>20500	
Al Jufrah - Zmam	Al Jufrah J18 A	193	Mizdah	Miz	-10.34	-75.5	0.0 ± 0.3	-4.66	>27500	
Al Jufrah - Zmam	Well WS-8	460	Paléozoique	P	-9.58	-69.0		-3.4		
Al Jufrah - Zmam	Wadi Zimam N° 1	519	Paléozoique	P	-9.88	-72.7		-3.35		
Al Jufrah - Zmam	Al Jufrah J18	380-700	Paléozoique	P	-10.67	-79.4	0.3 ± 0.4	-5.55	>16500	
Catchment wadi Sufajjin	Beni Walid, well Nora1	975	Kiklah	Ki	-6,94	-45,7	-	-7,25		
Catchment wadi Sufajjin	P8 bis	86-108	Mizdah	Miz	-5	-28.5				2 ± 1
Catchment wadi Sufajjin	P39 W. Mardum	223	Mizdah	Miz	-5.9	-39.6				
Catchment wadi Sufajjin	P12	120-180	Mizdah	Miz	-7.1	-54.7				
Catchment wadi Sufajjin (w. Maymun)	P10	63-110	Miocene	Mio	-6.8	-45.5				<1
Catchment wadi Sufajjin (w. Maymun)	P9	226-296	Nalut	Na	-6.9	-44.6				<1
Eastern flank Hamadah	Wadi Qirzah, well WS-2	1000	Kiklah	Ki	-9,5	-69,5	0,0 ± 0,4	-4,8	25400	
Eastern flank Hamadah	Well B1-39	1000-1400	Kiklah	Ki	-9,21	-68,1	0,2 ± 0,4	-6,85	10700	
Eastern flank Hamadah	Wadi Zamzam ZZ13	920-1002	Kiklah	Ki	-9,42	-68,9	0,2 ± 0,4	-6,23	9900	
Eastern flank Hamadah	Wadi Zamzam ZZ8	861-935	Kiklah	Ki	-9,37	-67,8	-	-	-	
Eastern flank Hamadah	Zamzam 2 ZZ2	887-950	Kiklah	Ki	-9.2	-68.2				
Hamadah al Hamra	Ash Shuwayref W-6	650	Kiklah	Ki	-9,68	-70,7	0,2 ± 0,4	-5,96	9600	
Jabal Nafusa	Wadi Marmuta	341-460	Kiklah	Ki	-7,13	-45,9	2,4 ± 1,4	-8,55	15000	
Jabal Nafusa	Wadi Faysal well n° 3	422-482	Kiklah	Ki	-6,82	-43,8	3,2 ± 0,5	-8,31	22700+3800	
Jabal Nafusa	Wadi Faysal well n° 1-A		Crétacé sup.	Ks	-6.20	-41.0				
Khums-Misratah	P13	205-238	Mizdah	Miz	-7.4	-56.6				<1
Khums-Misratah	P13	496-587	Nalut	Na	-7.9	-58.4				3 ± 1
Khums-Misratah	T4	235-265	Nalut	Na	-7.8	-58.0				6 ± 1
Khums-Misratah	P20	250-437	Nalut	Na	-7.9	-60.3				
Khums-Misratah (w. Sasu)	P11	75-139	Mizdah	Miz	-7.7	-57.1				<1
West Hamadah	T/64/78 (Sinawan)		Kiklah	Kiw	-8.57	-64.4	6.55 ± 1.2		16800 ± 2300	
West Hamadah	T96/76 (Derj)		Kiklah	Kiw	-908	-64.5	6.28 ± 1.3		17000 ± 2500	
West Hamadah	T/159/89 (SE Derj)		Kiklah	Kiw	-8.69	-61.4				

Zone	Nom	Depth	Aquifer		$\delta^{18}O$‰	δD‰	14C %	$\delta^{13}C$	Ages	$_3H$ in T.U.
West Hamadah	T203/80 old (Ghadamis)		Kiklah	Kiw	-8.74	-67.9				
West Hamadah	T203/80 new (Ghadamis)		Kiklah	Kiw	-9.05	-66.3	5.68 ± 0.74		18000 ± 1900	
West Hamadah	T276/77 (Ghadamis)		Kiklah	Kiw	-8.82	-66.9	1.09 ± 1.15		31500 ± 9500	
West Hamadah	T277/77 (Ghadamis)		Kiklah	Kiw	-9.12	-69.4	16.88 ± 3		8600 ± 2300	
West Hamadah	1285/3/1 (c.s.)(Ghadamis)		Kiklah	Kiw	-9.29	-68.0	5.92 ± 0.72		18400 ± 1800	
West Hamadah	WG8 (SE Derj)		Kiklah	Kiw	-8.2	-55.9				
West Hamadah	WG10 (SO Sinawan)		Kiklah	Kiw	-7.65	-55.2				
West Hamadah	WG12 (S Derj)		Kiklah	Kiw	-8.99	-61.5				
West Hamadah	WG22 (Ghadamis)		Kiklah	Kiw	-9.19	-69.9	3.5 ± 0.83		21900 ± 2800	
West Hamadah	Agrn Proj (Ghadamis)		Kiklah	Kiw	-8.8	-66.0	3.05 ± 0.41		22500 ± 1900	
West Hamadah	Sebkha Mezezen			S	-2.59	-42.3	36.32 ± 4.36		2200 ± 1800	
West Jabal Nafusa	T25/87 (SE Nalut)		Kiklah	Kiw	-8.69	-66.5	3.15 ± 2.37		22200 ± 7000	
West Jabal Nafusa	Kartom (E Nalut)		Kiklah	Kiw	-6.86	-42.7				
West Jabal Nafusa	Zintan (E Nalut)		Kiklah	Kiw	-7.27	-47.0	4.82 ± 1		19100 ± 2500	
West Jabal Nafusa	T358/89 (Nalut)		Kiklah	Kiw	-6.33	-39.5				
West Jabal Nafusa	T359/89(Wazzen)		Kiklah	Kiw	-8.37	-59.3	1.35 ± 2.63		29800 ± 16900	
Tawurgha-Misratah	Tawurgha		Miocene	Moi	-7.92	-58.2	18.6 ± 1.9	-4.3		
Tawurgha-Misratah	P18	77-357	Miocene	Mio	-7.6	-56.1				
Tawurgha-Misratah	P16	180-197	Miocene	Mio	-7.6	-57.0				
Tawurgha-Misratah	P22	54-300	Miocene	Mio	-7.8	-57.0				
Tawurgha-Misratah	Tawurgha well P-18		Mizdah	Miz	-9.39	-67.8	0.8 ± 0.5	-3.08		
Tawurgha-Misratah	Tumminah Projet		Mizdah	Miz	-9.55	-68.3	1.0 ± 0.5	-5.29		
Tawurgha-Misratah	P16	325-486	Mizdah	Miz	-8.1	-60.0				
Tawurgha-Misratah	P15	210-415	Mizdah	Miz	-8.2	-65.1				
Tawurgha-Misratah	P17	357-460	Mizdah	Miz	-8.8	-64.0				
Tawurgha-Misratah	P22	300-585	Mizdah	Miz	-8.7	-67.0				
Tawurgha-Misratah	TD6/700 Kararim	366-458	Mizdah	Miz	-9	-67.4				3 ± 1
Tawurgha-Misratah	P18	477-503	Mizdah	Miz	-9.4	-67.8				

Zone	Nom	Depth	Aquifer		δ[18]O‰	δD‰	14C %	δ[13]C	Ages	3H in T.U.
Tawurgha-Misratah	P22	300-585	Mizdah	Miz	-9.5	-68.3				
Tawurgha-Misratah	Tawurgha well P-22		Nalut	Na	-9.49	-68.4		-6.72		
Tawurgha-Misratah	P22	645-715	Nalut	Na	-7.8	-59.1				
Tawurgha-Misratah	TW1		Nalut	Na	-8.7	-65.7				
Tawurgha-Misratah	Source Tawurgha		Source	S	-7.6	-58.0				
Tawurgha-Misratah	Tawurgha source				-8.21	-60.4	2.8 ± 0.8	-3.38		
Khums-Misratah (w. Sasu)	P11	483-492	Nalut	Na	-7.5	-61.4				

Annex 8 Table 4 – Isotopic characteristics of the Complexe Terminal waters in Algeria

Code	Name of water point	Date	Depth	*Aquifer*	^{18}O	^{2}H	^{3}H	^{14}C %	^{13}C%.	Gross age	Adjusted age	Excess ^{2}H
109	Taïebet (Souf) 32 H 12	15.2.69		MP(sc)	-4	-46	1.9±0.4					
110	Oumih Ouenssa	15.2.69		Eor(sc)	-3	-34	11.4±0.9					
111	Blidet Amor D46 F 64	3.4.71		E	-6.8	-52		1.7±0.6	4.8			
112	Aïn Louise 519 J 10	15.2.69	140-180	MP (szc)	-9	-64	1.6±0.5					
		17.3.71						1.7±0.9	6.8			
113	Djedida D 4 F 15	15.2.69	30-60	MP (sc)	-9.1	-64	1.0±0.3					
		18.3.71						8.7±8.7	6.8			
114	Fogg. Ouled Aïssa	26.3.69		MP+Eoc(sc)	-5.6	-52	1.1±0.6					
89	Fogg. Ouled Saïd	26.3.69		CI+CT (sc)	-4.4	-49						
	(Timimoun)											
116	Grande source	1965-68		Eoc (sc)	-4.9	-50						
	(Beni Abbes)	12.70			-5.9	-47		32.8±0.2	5.5			
117	Fogg. Laboratoire CNRS	12.70		Eoc (sc)	-4.6			104±0.9	9.5			
	(Beni Abbes)											
118	Igli	12.70		Eoc (sc)	-5.2			38.8±0.6	7.2			
119	CevtreElect. Kerzaz	12.70		Eoc (sc)	-5.2			38.3±0.8	4.9			
120	Ksabi	12.70		Eoc (sc)	-4.6				4.8			
11	El-Alia	1996	160	CT	-9.2	-72						
13	DASE	1996	100	CT	-7.1	-60						
15	Blidet Omar 1964	1996	168	CT	-7.3	-59						
19	Sidi Slimane	1996	180	CT	-5.1	-50		2.4				
21	Touggourt	1996	170	CT	-6.7	-58		4	-5.05			
23	Djemaa (Ain Zarrouk)	1996	180	CT	-7.1	-55		2.1	-1.68			
24	Sidi Khelil	1996	230	CT	-7.6	-50						
25	El Meghaier (El-Ali) 1987	1996	271	CT	-4.9	-47						

Code	Name of water point	Date	Depth	*Aquifer*	^{18}O	^{2}H	^{3}H	^{14}C %	^{13}C%.	Gross age	Adjusted age	Excess ^{2}H
26	El Meghaier	1996	278	CT	-5.6	-48		0	-6.44			
41	Kechem Er Rih	1996	120	CT	-7.7	-60						
43	Sidi Belkhir	1996	125	CT	-7.2	-66						
44	El Bekrat	1996	115	CT	-7.3	-65						
46	Istikama	1996	110	CT	-7.5	-70		8.4	-7.58			
48	Ain Djrad	1996	112	CT	-7.4	-64						
51	Gassi Touil GT3	1996	160	CT	-6.9	-61						
52	Gassi Touil TH4	1996	150	CT	-6.8	-56		24.7	-7			
53	Gassi Touil GT2	1996	170	CT	-6.7	-58		31.4	-9.4			
60	Gassi Touil M3 (FP,OAIC)	1996	165	CT	-6.4	-57						
61	Gassi Touil M3 (FP,OAIC)	1996	165	CT	-6.12	-49.5						
62	Rhourd El Baguel MP	1996	100	CT	-5.3	-53		28				
63	Rhourd El Baguel MP	1996	95	CT	-5.3	-53						
70	Rhourd El Baguel P	1996	95	CT	-5.1	-48						
71	Rhourd El Baguel MP	1996	100	CT	-5.3	-52						
74	Hassi Messaoud SAGRA S2	1996	90	CT	-7.4	-59						
75	Hassi Messaoud H2	1996	95	CT	-7.6	-62		38.9	-9.01			
77	Djamaa Sidi Yahia MP5	1996	170	CT	-7.3	-53						
80	MP Hamraia HAM6	1996	584	CT	-4.9	-49						
81	MP Hamraia HAM4	1996	517	CT	-5.9	-47						
82	MP M'Guebra BUEB	1996	600	CT	-6.9	-56						
4	El Djaad	1996	50	CT	-5.1	-54						
27	Tejdid 3 (Sidi Okba)	1996	250	CT	-7.7	-52						
28	Tejdid 2 (Sidi Okba)	1996	250	CT	-7.3	-56						
29	sidi Okba (Ferme pilote)	1996	600	CT	-8.1	-54						
30	Faidh Essella (Ain Naga)	1996	800	CT	-8.1	-55						
31	Ain Naga	1996	1200	CT	-7.9	-52						
32	Zribet El Oued	1996	900	CT	-7.3	-53						
33	Zribet El Oued	1996	200	CT	-5.9	-39						

Code	Name of water point	Date	Depth	Aquifer	^{18}O	^{2}H	^{3}H	^{14}C %	^{13}C%.	Gross age	Adjusted age	Excess ^{2}H
34	El Faidh Chott Melghigh	1996	900	CT	-6.8	-50						
35	Rouldjel	1996	200	CT	-7.8	-54						
36	Oumache	1996	800	CT	-7.8	-51						

Annex 8 Table 5 – Isotopic characteristics of the Complexe Terminal waters in Tunisia

Nefzaoua

N°	Locality	Date	Tapped Aquifer	^{18}O	^{2}H	^{3}H	^{14}C (%)	^{13}C (3%)	Gross age	Origin
53	Ain Taourgha 2051T/5	7.1.70	53-178				0.4± 0.6	-2.60		ERESS, 1972
		16.11.70		-6.70	-53					ERESS, 1973
54	Ras El Aïn 6756/5	18.2.69	32 – 98	-6.10	-50	1.0± 0.5				ERESS, 1974
		7.1.70					0.0± 0.6	-3.9		ERESS, 1975
55	Source bechelli 55/5	18.2.69		-5.70	-48	1.4± 0.4				ERESS, 1976
56	Bechelli 8/5	18.2.69	89-115	-6.10	-48	0.4± 0.3				ERESS, 1977
57	Djemna 29/5	18.2.69		-6.00	-49	0.1± 0.5				ERESS, 1978
58	Sce de Djemna 2042/5	18.2.69		-5.40	-46	3.1± 0.6				ERESS, 1979
59	Douz 2b 30b/5	18.2.69	53-75	-5.70	-47					ERESS, 1980
		7.1.70					9.9± 4.1	-3.5		ERESS, 1981
60	Rhélissia 5840/5	18.2.69	58-150	-5.90	-47					ERESS, 1982
61	Zarcine 6906/5	7.1.70	96-149				0.5± 3.5	-4.5		ERESS, 1983
Tun 20	F. Oum Chiah2 18145/5	1984	120-201	-6.76			0.5±3.5	-3.8	14 000±5500	A. Mamou, 1985
Tun 66	F. Bechni 18681/5			-6.20	-46.5		8.9±0.9	-4.0	8 000±5 000	A. Mamou, 1986
Tun 28	F. El Gounna EG.1a						16.5±1.8	-4.7		A. Mamou, 1987
Tun 79	El Mehdeth	1984	671	-6.69						A. Mamou, 1988
Tun 29	El Fehidia	1984	60.5	-5.75	-45.7			-3.48		A. Mamou, 1989
Tun 31	Dar Kouskoussi 5193/5	1984	50 – 81	-6.1	-44.6			-4.46		A. Mamou, 1990
Tun 33	Fatnassa 18827/5	1984	120-230	-5.50	-45.2					A. Mamou, 1991
Tun 67	Redjem maatoug 18745/5	1984	130-200	-4.67	-42.5		5.6±0.8			A. Mamou, 1992
Tun 15	Matmata 6552/5	1984	150-398	-5.75			24.3±2.8	-7.83	5 500±3700	A. Mamou, 1993
943741	Redjem Maatoug 2 18745		164-220	-4.3	-46					A. Mamou, 1994
943742	Matrouha		190-288	-4.6	-44					A. Mamou, 1995
943743	Firdaous 19380		225-303	-5.3	-43					A. Mamou, 1996

Djérid

N°	Locality	Date	Tapped Aquifer	^{18}O	^{2}H	^{3}H	^{14}C (%)	^{13}C (3%)	Gross age	Origin
62	Hazoua 6090/5	14.11.70	462-585	-4.6	-47		0.0±0.6	-6.3		ERESS, 1972
63	Sce Nefta	16.2.69		-4.8	-46	1.1±0.3				ERESS, 1973
64	El Louah	14.11.70	587-625	-4.8	-44					ERESS, 1974
65	Zaafrana 9959/5	14.11.70	540-632	-4.2	-44					ERESS, 1975
66	Tozeur 3	15.11.60	491-602	-3.9	-45					ERESS, 1976
67	Sce El Hamma	16.2.69		-4.1	-42					ERESS, 1977
68	Oued Koucha 1 8729/5	15.11.70	454-534	-5.2	-49					ERESS, 1978
69	El Hamma 10139/5	15.11.69	90-223	-5	-45		0.0±0.6	-5.6		ERESS, 1979
70	Gouifla 6139/5	15.11.70		-7.9	-56					ERESS, 1980
71	Kriz 3 10452/5	15.11.70	81-160	-6	-52					ERESS, 1981
72	El Moncef	16.11.70		-4.2	-44					ERESS, 1982
Tun 26	F. Nefta 2b 8262b/5	1984					0.0±0.9	-5.5	24 000±7 000	A. Mamou, 1985
Tun 27	Menachi 8982/5	1984					2.3±0.4	-5.4	22 000±5 000	A. Mamou, 1986
Tun 36	Hazoua 3 17625	1984	390-441	-4.56			1.9±1.0	-5.1	22 500±8 000	A. Mamou, 1987
Tun 37	Chakmou3 18648/5	1984	423 - 510	-6.86	-46.4		1.4±0.8	-5.6	25 000±9 000	A. Mamou, 1988
Tun 69	Gouifla 3 18754/5	1984	623-700	-6.69	-46.5		0.6±0.5	-3.8	30 000±15000	A. Mamou, 1989
Tun 68	Deghoumess 13981/5	1984	-510	-5.53	-46.2		12±0.9	-4.4	6 600±4 600	A. Mamou, 1990
Tun 30	Draa Nord 18801/5	1984	530-603	-4.71				-4.2		A. Mamou, 1991
Tun 32	El Hamma 15 18786/5	1984	20-72	-4.36				-5.37		A. Mamou, 1992
Tun 75	El Moncef 14394/5	1984	530 - 636	-4.12	-40.7					A. Mamou, 1993
Tun 8I	Chamsa 14395/5	1984	532- 601	-4.81						A. Mamou, 1994
943737	Marbah sandoug 19418	1996	112-298	-6.7	-40		18.10±0.5	-6.9	13710+210	BGS, 1997
943740	Tamezret	1996	375-548	-7	-48		12.6±0.8	-5.2	16630+480	BGS, 1998
943736	Bir Hadj Brahim	1996		-6.8	-48			-5		BGS, 1999

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N°	Locality	Date	Tapped Aquifer	^{18}O	^{2}H	^{3}H	^{14}C (%)	^{13}C (3%)	Gross age	Origin
943724	Oued Sehili3	1996	505-585	-7.5	-50		25.9±0.87	-7.9	10850±870	BGS, 2000
943720	Segdoud	1996		-7.3	-48					BGS, 2001
943745	Oum Chiah 18845/5	1996		-6.9	-45					BGS, 2002
951685	Oued Sehili3 19083	1996		-7.2	-49		25.9±0.87	-7.9	10850±870	BGS, 2003
951686	Gouifla 7-8 19716	1996		-6.6	-47					BGS, 2004
951687	Sce Taslja	1996		-6.2	-39					BGS, 2005
951688	Gouifla8 19717	1996		-6.6	-49		7.3±0.60		21070±620	BGS, 2006
951689	Oued Sehili'	1996		-7.7	-51					BGS, 2007
951690	Sce Soundes	1996		-6.8	-47					BGS, 2008
951691	Hadjra Bidha	1996		-6.6	-47		34.5±0.50	-5	8555±120	BGS, 2009
951692	Ain Goussiba	1996		-6.2	-46					BGS, 2010
951693	Ain Tahar	1996		-6.9	-48					BGS, 2011
951694	Foum Khangua	1996		-6.6	-50					BGS, 2012
951695	Ain Laachech	1996		-6.3	-45					BGS, 2013
951696	Ain Chebika	1996		-7.1	-49					BGS, 2014
943702	Dhafria 1	1996	1174-1306	-7.9	-68					BGS, 2015
943703	Dhafria 2	1996	1064-1130	-7.1	-60	±	6.30±0.50	-8.7	22200±630	BGS, 2016
943704	Dhafria 3	1996	1052-1203	-7.5	-56					BGS, 2017
951697	Dhafria 3 19330	1996		-7.1	-59					BGS, 2018
951698	Dhafria 2 19270	1996		-12.2	-60					BGS, 2019
951699	Dhafria 1 19242	1996		-8.1	-60					BGS, 2020
951700	Bir Lahnek	1996		-4.5	-30					BGS, 2021
951701	Ain Hamda	1996		-3.5	-34					BGS, 2022
951702	Ain Merchen	1996		-5.9	-46					BGS, 2023
951703	Segdoud 1 19269	1996		-6.5	-52					BGS, 2024
951704	Segdoud 2 19426	1996		-7	-53		8.70±0.60	-11.2	19660-580	BGS, 2025
951705	Segdoud 3 19491	1996		-7.9	-58					BGS, 2026
	Krichet Naam	1996					40.50±0.70		7270-140	BGS, 2027

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N°	Locality	Date	Tapped Aquifer	^{18}O	^{2}H	^{3}H	^{14}C (%)	^{13}C (3%)	Gross age	Origin
951073	Tozeur Aeroport	1996		-7.7	-59		9.30±0.10	-6.75	10100-890	BGS, 2028
943733	Garaat Jaballah 19091	1996	325-395	-5.2	-48					BGS, 2029
943734	Es Salem 19734	1996	195-261	-5.3	-46					BGS, 2030
943735	En Nasr 19379	1996		-5.6	-48					BGS, 2031
943735	Hazoua4 HZ4 19116	1996	477-532	-4.7	-38					BGS, 2032

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THE NORTH-WESTERN SAHARA AQUIFER SYSTEM

BASIN AWARENESS

HYDROGEOLOGY, VOLUME II - FEBRUARY 2004

Serving as a driving and facilitating force, OSS, in carrying out the SASS Programme, relies first and foremost on the expertise available in specialised, well experienced institutions of the three countries as well as on broad international partnership.

The North-Western Sahara Aquifer System, (NWSAS), shared by Algeria, Tunisia and Libya, has considerable water reserves that cannot be totally exploited and are only very partially renewed. The NWSAS stretches over a million km2 and is composed of two major water-bearing layers, the Continental Intercalary and the Terminal Complex. Over the last thirty years, abstraction by drilling has risen from 0.6 to 2.5 billion m3/yr. This rate of abstraction involves many risks: strong impact on neighbouring countries, salinisation, elimination of artesianism, drying up of outlets, etc. Simulations on the NWSAS Model have enabled OSS to pinpoint the location of the most vulnerable areas and map the risks facing the aquifer system. The three countries concerned by the future of the NWSAS will need to work together to develop a joint management system for the basin. A consultation mechanism needs to be instituted and gradually put into operation.

The present report is part of a set of three volumes which sum up the scientific activity of the project "North-Western Sahara Aquifer System" (SASS/OSS). It present the physiographic and hydrogeological data which have been taken into consideration in developing the digital model that simulates the hydrodynamic behaviour of the Saharan aquifers.

The present report presents respectively:

- the aquifer formations of the North-Western Sahara and their schematisation with a view to their hydrogeological modelling;

- the various hydrogeological characteristics of the aquifers of this system through an analysis that is focused on hydraulic exchanges and the impact of the exploitation on piezometry and on water salinity;

- the chemical quality of the water and its isotopic characteristics allowing a better understanding of the hydrodynamic operating of the system.

PARTNERS

Agence Nationale des Ressources Hydrauliques (ANRH, Algérie)

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Observatoire du Sahara et du Sahel (OSS)
Boulevard de l'Environnement - BP 31, 1080 Tunis Cedex, Tunisie
Tél.: 216 - 71 806 522 ∎ Fax. 216 - 71 807 310 ∎ E-mail : boc@oss.org.tn ∎ URL : **www.unesco.org/oss**