

Approach To Integrated Water Management In A Hyper Arid Zone; Case Of The Oasis Of Beni Abbes (South West Of Algeria).

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Abstract

In arid and hyper-arid zones and in all the Saharan oases, the underground reserves represent the only source of water supply. In the Saoura watershed and in particular the oasis of Beni Abbes, the water balance shows an alarming deficit, subject to the continuous increase of needs, due to the rapid growth of the population, to the improvement of the standard of living, the development of the region and the extension of irrigated agriculture, the water resources in the Beni Abbes oasis are experiencing a growing and increasingly serious degradation in terms of quality and quantity.

This study consists of developing an integrated water management approach adapted to a hyper-arid area where the water resources are very limited, poorly known and evil exploited. The approach is an integrated water management concept based on improved hydrogeological knowledge; rehabilitation and development of drinking water distribution networks, improvement of traditional irrigation systems, sanitation and wastewater treatment for reuse and development of a GIS for water resources in water. This concept requires taking into account spatial and thematic diversity based on a GIS to represent this diversity. These geographic databases serve both the organization, the updating and the analysis of spatial data.

This approach to water management in a Saharan area must be a tool an essential basis for effective water management in arid and hyper-arid regions. It reconciles socio-economic development with the preservation of water resources, which guarantees sustainable development.

Key Words: hyperarid- Oasis- Saoura- SIG- Integrated management approach - Beni Abbes.

1. Introduction

The oasis of Béni Abbès extends on the left bank of the Saoura Valley, 6 km long and 5 km wide on average, covering an area of 40 hectares. It draws water from the great source, foggaras and wells dug in the alluvial terraces and inferior-flow of Oued Saoura. However, the phenomenon of groundwater salinity is becoming increasingly threatening. Indeed, the problem of salinization of ground water caused by several human and natural factors, causes serious irrigation problems. This palm grove has lost 60% of its area and about 1/3 of its palms. The Bayoudh disease, socio-economic transformations and sometimes ill-considered decisions have contributed to this deterioration and deterioration of the palm grove.

Groundwater tables are seriously affected by salinity, with 70% of the volume of groundwater bodies with risks of increasing. Due to its geographical position, the atmospheric rainfall at Béni Abbès is low and coupled with high

evaporation (2153 mm / year) (Mékideche *et al.*, 1995).

Such a situation leads to reflection and to propose solutions in order to remedy these constraints on the water resources in this locality.

Like the solutions advocated elsewhere, the concept of integrated water management has been the subject of a very large number of documents, whole websites are devoted to it (UNESCO, 2003, Global Water Partnership, 2000). This mode of water management has largely developed since the international conferences on water and the environment that were held in Dublin (1982), Rio de Janeiro in 1992, Kyoto in 2003, Paris 2015 and Marrakech in 2017. The popularity of the concept is undoubtedly due to its unifying objective, the integrated water management having for end the protection and the restoration of the water resource, the associated ecosystems as well as their uses for the wellbeing citizens (Gangbazo , 2004).

The objective of this work is to develop and validate an integrated water resources management approach adapted to a hyper-arid zone, the aim of which is to achieve a balance between water supply and demand in the area. oasis of Beni Abbès.

In Béni Abbès the process of this management concept took place, in the first step of a global diagnosis of identification of stakeholders in the use and management of the water resource and their concerns about the resource. Then a thorough diagnosis of the existing situation in AEP, irrigation, and sanitation. Followed by a cause and effect analysis according to the logical framework approach. Finally a formulation of objectives with definition of strategies to start the process of improvement and development,

Moreover, in the Oasis of Beni Abbès, water needs become more and more constraining in terms of quality and quantity, linked to several factors:

1. The need for drinking water for different users is constantly increasing.
2. Dissemination of salinity where there is a spectacular spread of salinity (70% of the waters of the alluvial terraces).
3. The human activities that seems to be orienting to remedy the previous points, but actually it contributes effectively to the deterioration of groundwater.
4. Wastewater discharged without prior treatment in Oued Saoura, urban discharges may pollute water resources, which poses a threat to public health, the environment and the ecological balance.

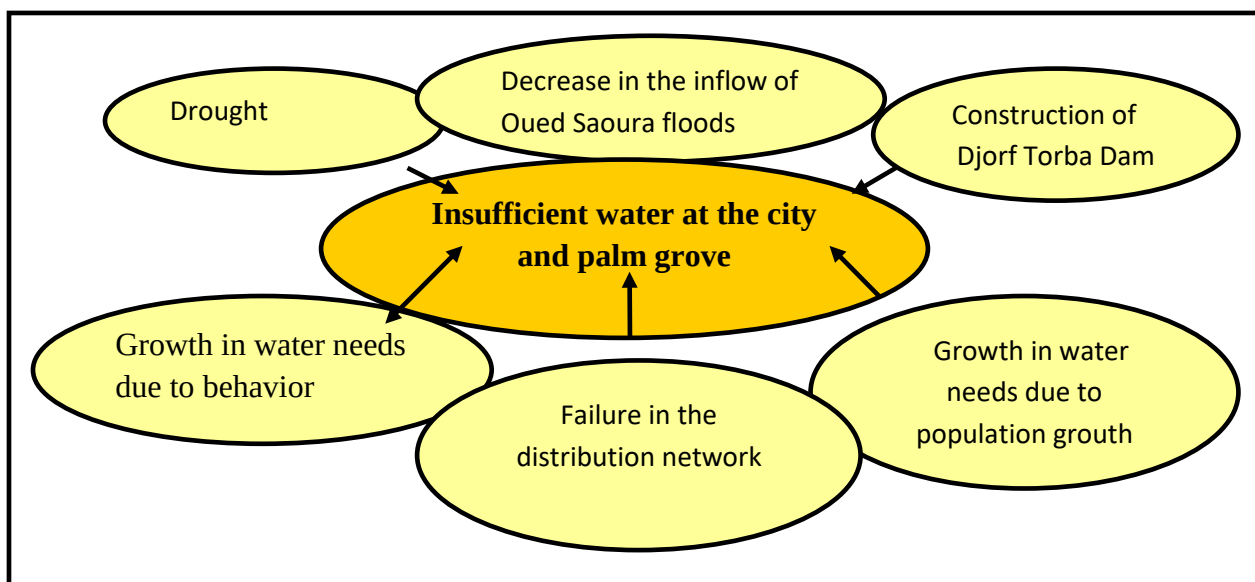


Figure 1. Synthesis of the constraints of urban and agricultural development.

2. Materials And Methods

2.1 Location of the study area

The oasis of Béni Abbès is the capital of the Oases de la Saoura. It is about 240 kilometers southwest of the capital Bechar and 880 kilometers southwest of Algiers (Figure.2). The Saoura Valley, resulting

from the junction of Guir wadis and Zouzfana, represents the main river of the Western Sahara of Algeria. It is bordered in the East by the Great Western Erg, and in the West by the Hamada of Guir and the small Hamada.

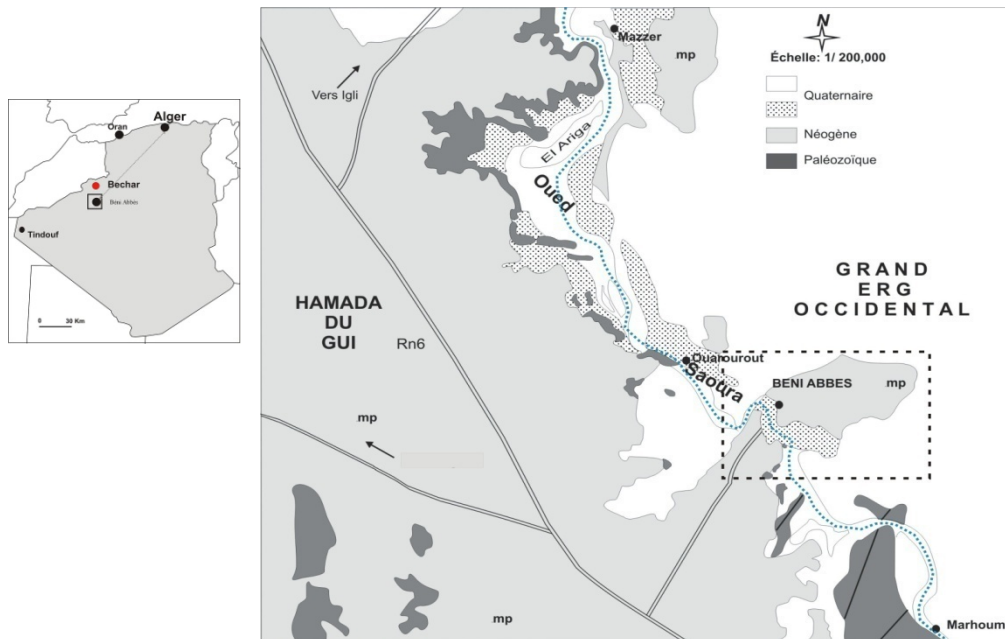


Figure 2. Location of the Oasis of Beni Abbès ..

2.2 Geological and hydrogeological context

The Béni Abbès region is part of the Algerian Sahara, built on a plateau 500 m above sea level. Regionally, geologically this region is related to the mountains of Ougarta, the region of Beni Abbès consists of a range of very varied terrains, from Precambrian to the current (Menchikoff, 1933, Alimen, 1957). It is characterized by a hyperarid climate. This region consists of

a palm grove of 40 hectares, which is located on the alluvial terraces.

The Saoura basin is part of the large Sahara watershed. It is located in the south-west of the Algerian territory and occupies an area of about 100,000 Km². The basin is composed of four sub basins of different sized sizes. They are drained by descending streams of the Moroccan Atlas and the Saharan Atlas and flow from north to south (Figure.3).

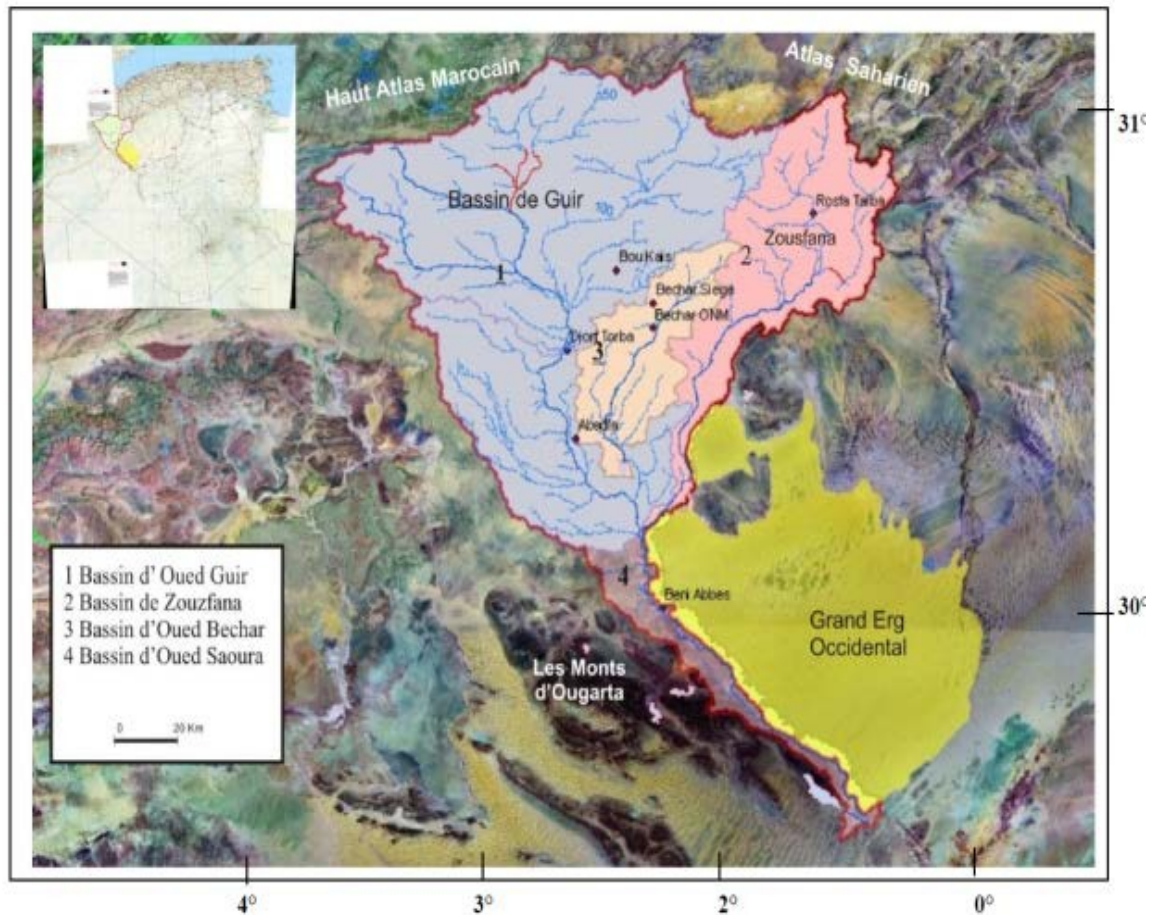


Figure 3 .Watershed of the Saoura (Merzougui, 2007)

The subsoil contains significant groundwater resources. Contains an interconnected system including the Saoura Valley as an umbilical cord (Merzougui 2007).

This system includes (Figure.4):

The water of the Grand Erg Occidental, hydrogeologically well defined, its recharge is to assure mainly by the Namous wadi of the Saharan Atlas. The large source, known as the "source of Sidi Othmane", represents an outlet par excellence of this water table, with a flow of 33 l/s (Merzougui, 2007),it plays a dual

role, the drinking water supply of the city and the irrigation of the palm grove.

- The water table of Hamada du Guir, fed by the rare rainwater and wadis Aicha and Abiod, is contained in the lacustrine limestones of the Tertiary.
- Paleozoic aquifers are known only locally, in the villages of Zéghamra and Ougarta, whose aquifer is Cambrian and Ordovician. These aquifers are partly fed by rainwater and probably by Wadi Saoura.
- The groundwater of the alluvial terraces and inféro-flux, constitute a particular

aquifer system formed by the large spreading of sand and gravel of the Saoura. The aquifer system of the palm grove features two lithological units: limestone and sandy marl of Mio-Pliocene and Quaternary formations. The Moi-Pliocene reservoir is composed of a succession of limestone and sandy marl of 40 m, rests directly on a Devonian impervious substratum. In addition, the reservoir of the alluvial aquifer consists of a quaternary ensemble, composed of four layers (sand,

clay, sand, conglomerate) with a thickness varying between 10 and 30 meters, all of which rests on a higher Devonian schistose substratum. pleated. The average thickness of the alluvial aquifer is fifteen meters.

The recharge of the alluvial layer of the palm grove is ensured by a natural drain by the inflow of water from the Grand erg aquifer on the one hand, and by the infiltration of the irrigation water from the great source (flow 08 l / s) and wells and occasionally by the floods of Oued Saoura.

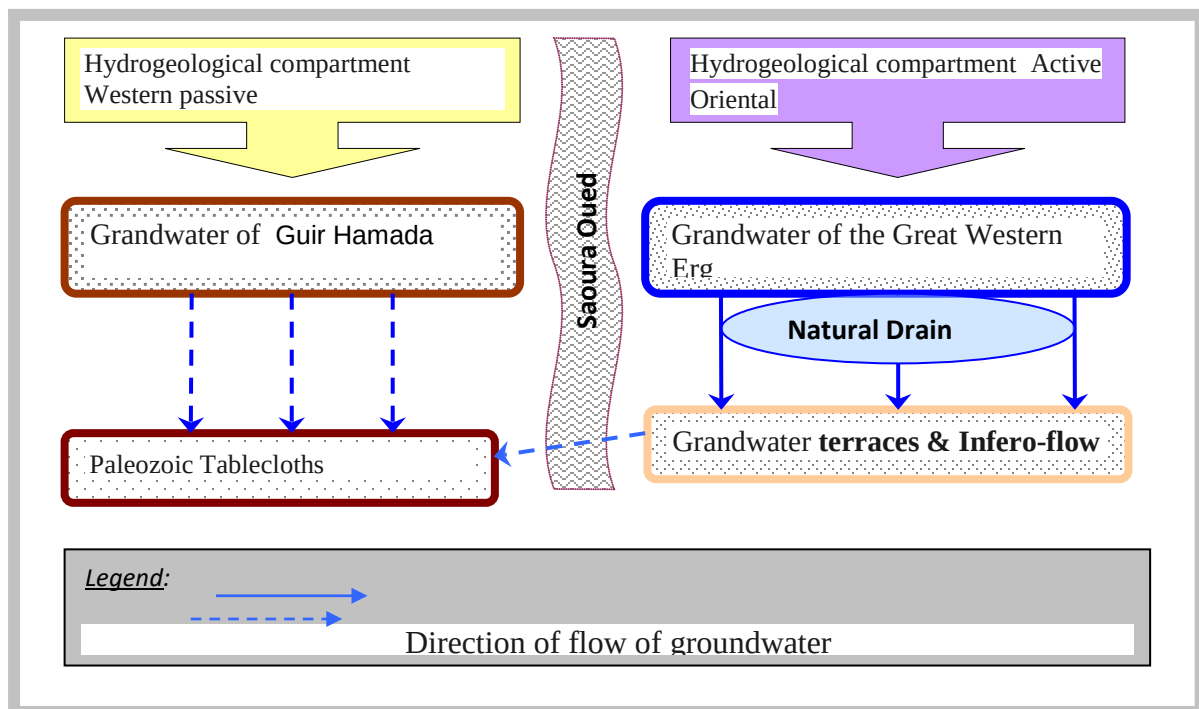


Figure 4 . Schematic sketch of the Beni Abbas aquifer system (Merzougui, 2007).

2.2.1 Hydrodynamics and piezometry

The waters of the great source irrigate the palm grove and the withdrawal of wells dug in the alluvial aquifer. The continuously discharged flow is close to 8 l/s (2008, 2016), presents 1/3 of the

quantity dumped during the sixties, 0.22 l/s/ha or an irrigated 683.35 mm/year.

The sources and foggara draining the water in the neogenous slope provide a total flow of less than 3 m³ / h, the other flow through the lower Mio-Pliocene beds and

then into the quaternary terraces (80 l/s). a total flow of 83 l/s.

The transmissivity of the quaternary formations, calculated on two piezometers one located 200 m north of the ksar and the other near the pool, is equal to 2.10^{-4} and $4.4.10^{-4}$ m/s (Merzougui, 2007). The values of the storage coefficients at the level of

the palm grove vary from 2.10^{-2} and 6.10^{-2} in the North, south the values range between 10^{-2} and 10^{-3} .

The piezometric map made in 1991 (Figure .5), more or less it gathers to that established in April 2016 . It presents a general flow from North-East to South-West.

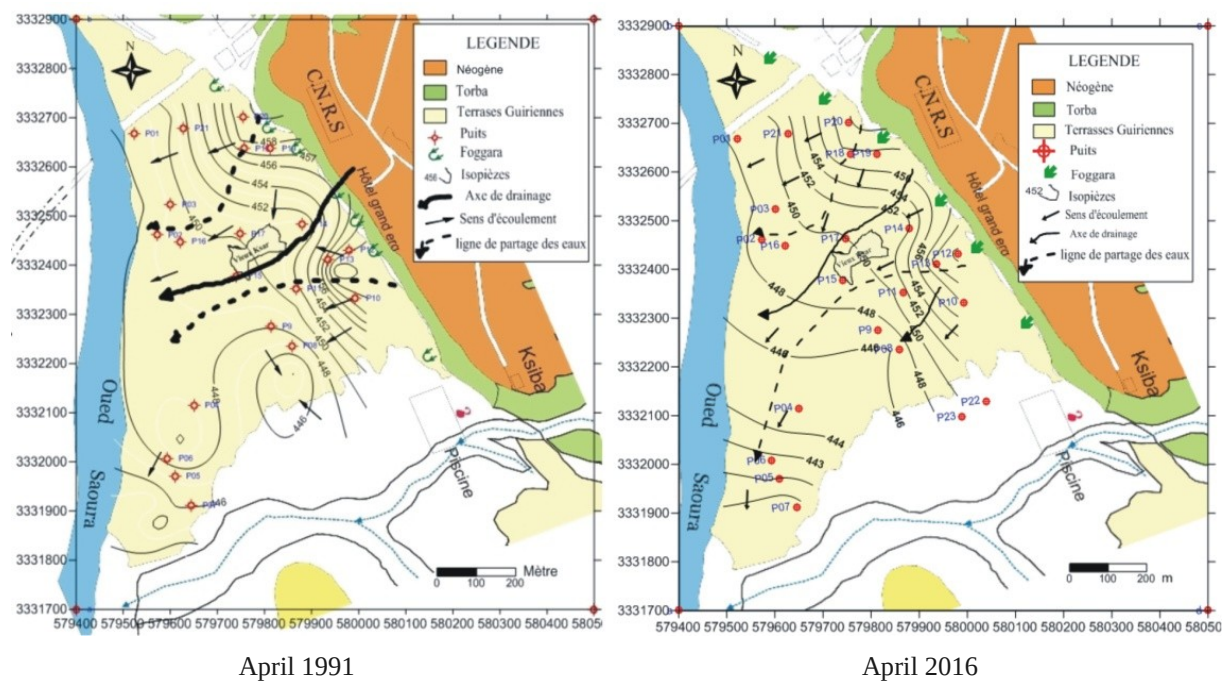


Figure.5. Piezometry of the alluvial layer

The contributions to the water table come from the slab of Haiti (15 l/s), the waters pass through a natural drain and seguias, all along the slope and by infiltration of irrigation water from the great source (the reserved share palm grove 11 l/s), a total flow of 26 l/s.

In the palm grove, the average depth of the body of water relative to the ground is of the order of 2 to 10 meters.

In the Oasis of Beni Abbes, the exploitable water resources are limited namely: The Great Source gives a flow of 28 l/s, the Flow of the Foggaras 5 l/s, the Flow of Drilling 10 l/s, the water from wells loaded with salts of a flow rate is evaluated of 2 l/s each, a total of 50 wells are dug in the alluvial terraces

The diffusion of salinity where we observe a spectacular propagation of salinity which

affects 70% in the mass of water of the alluvial terraces.

The non-irrational use of the water resource due to the change in the compartmentalization of users: inadequate irrigation system, wastage and social change that have effectively contributed to the deterioration of groundwater.

Wastewater discharged without prior treatment in Oued Saoura may pollute groundwater resources, posing a threat to public health, the environment and the ecological balance.

2.2.2 Balance and use of water

The question of availability and access to water is without a doubt one of the major problems facing the Beni Abbes agglomeration. Today one in three houses in the city does not have access to satisfactory water. Irrigation water is also insufficient in the palm grove. The availability of drinking water (2808 m³ / d) from the four boreholes and the large source mobilized for the city exceeds the needs (figure .6), however, it is requested to further develop the distribution network. On the other hand, the needs of the palm grove are only satisfied at 06%.

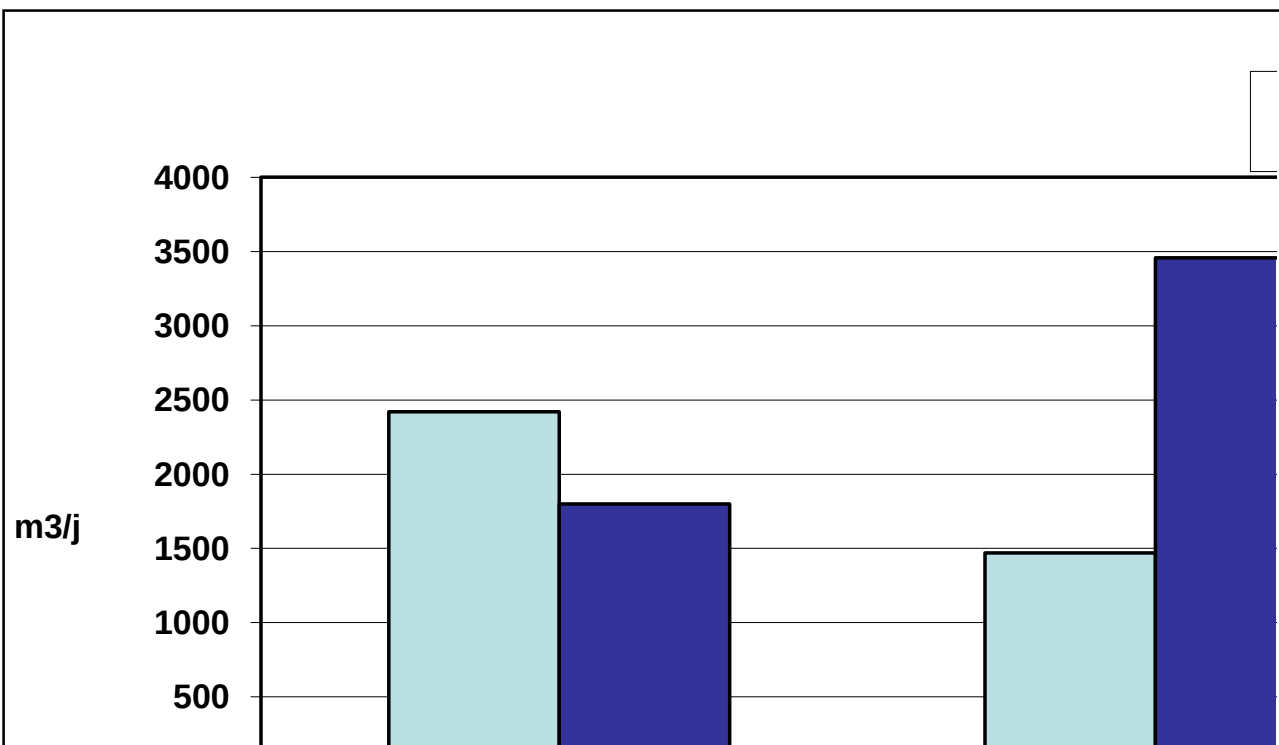


Figure 06. Assessment and use of water in Beni Abbes (Merzougui,2018)

2.3. Hydrodynamic modeling (figure 7 et 8)

The objectives of the modeling are the quantification of the natural flows

transiting the aquifer and the knowledge of the permeability distribution allowing the reconstitution of the piezometry and thus better apprehend the hydrodynamic functioning of the aquifer system in such a way as to manage well the underground reservoir in all the situations. To do this, we used the ASMWIN (Aquifer Simulation Model) modeling program

developed in Germany by ETH (Kinzelbach & Rausch, 1995).

The analysis of these products will allow a better hydraulic knowledge of the network of the city and hydrogeological of the aquifer system of the Béni Abbes region as well as a qualitative and quantitative monitoring of the groundwater.

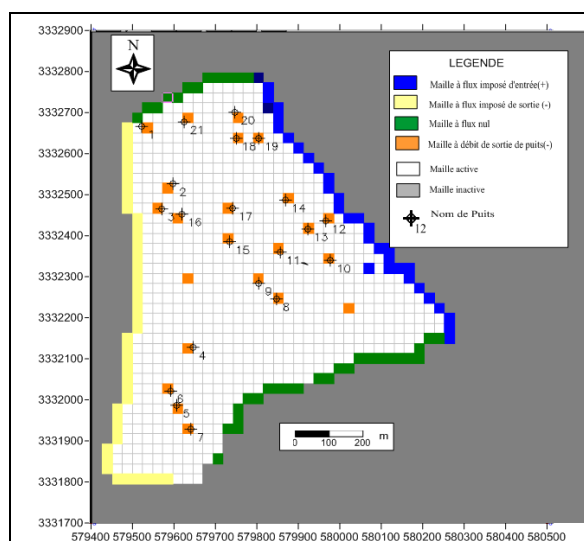


Figure 07. Discretization and boundary conditions of the model.

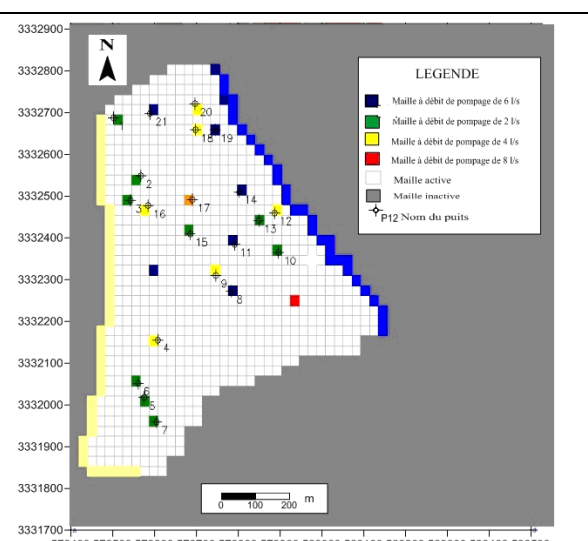


Figure 08. The distribution of the pumping rates of the palm grove wells

3. Results and discussions

3.1. Hydrogeology of the Beni Abbes Aquifer System

The aquifer system features two lithological units: A reservoir composed of limestone and sandy marl of the Mio-Pliocene with a thickness of 30 to 100m on

the Beni Abbes plateau. A second reservoir consists of quaternary deposits composed of three layers (sand, sand clay, conglomerate) with an average thickness of fifteen meters, all of which rests on a pleated upper Devonian schistose substratum (figure.9).

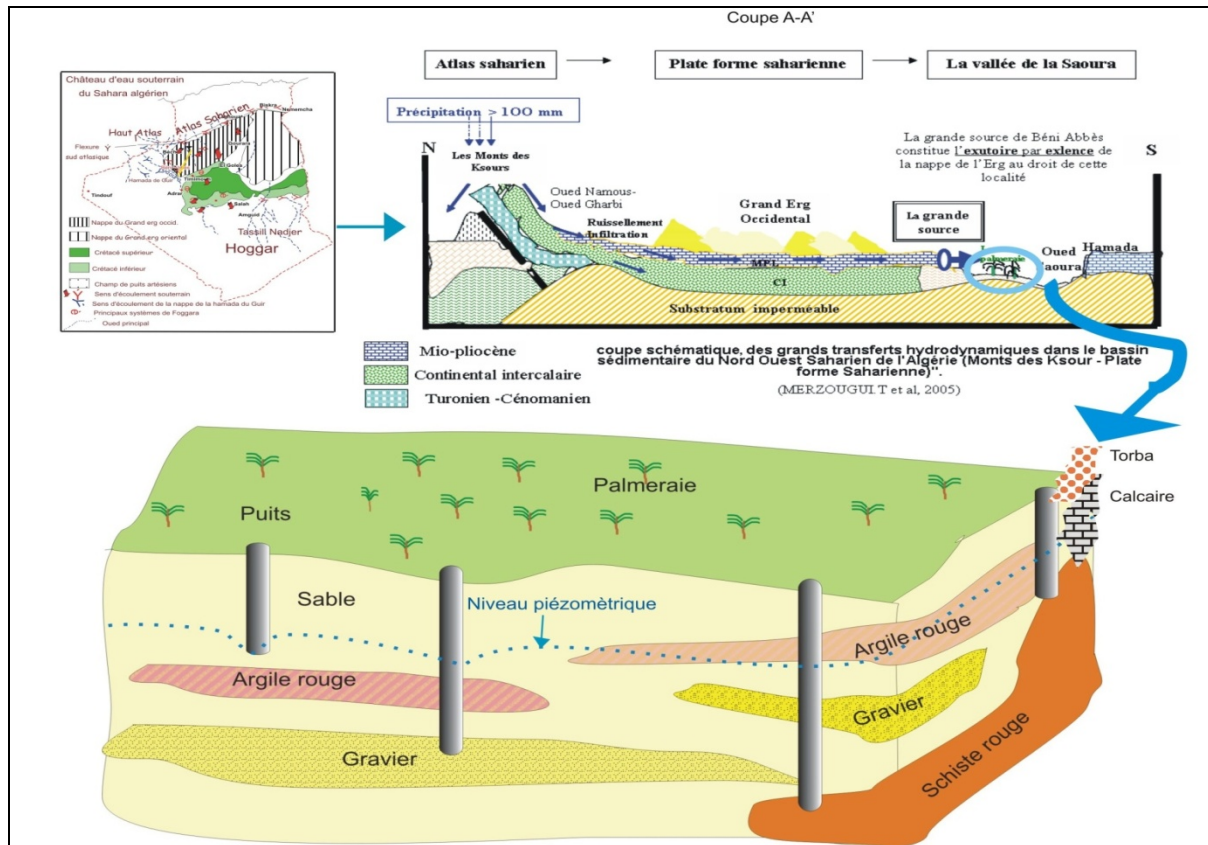


Figure 9: Condition and deposit of the alluvial aquifer of the palm grove

The transmissivity of the quaternary formations, calculated on two piezometers one located 200 m north of the ksar and the other near the pool, is equal to $2 \cdot 10^{-4}$ and $4.4 \cdot 10^{-4} \text{ m}^2 / \text{s}$.

The results of the hydrochemical study on a profile, confirm a slow underground flow; the average values make it possible to distinguish three types of behavior of the elements analyzed:

The first set of elements, including pH, EC, RS, HCO_3^- , Ca^{2+} , Mg^{+2} , Na^+ , K^+ , and Cl^- . The second set is characterized by

very clear changes in salinity. The degree of salinity has been evaluated by a campaign of qualitative measurements; Dry residue distribution maps were developed to give an idea of the distribution of dry residue in the palm grove. Low values (0.3 g/L) were measured at the edge of the erg, on the other hand maximum values were recorded (20 g / at the level of the wadi (Figure.10)

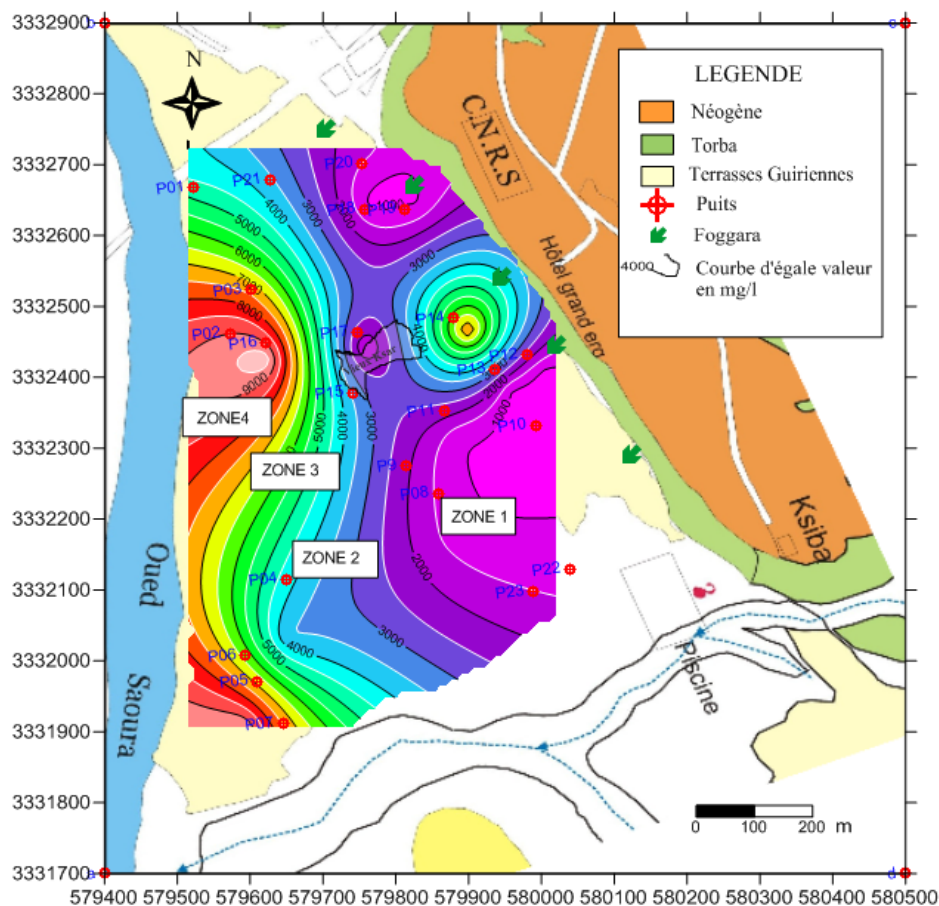


Figure 10. Map of TDS of the alluvial layer of the Beni Abès palm grove

Anthropogenic pollution comes from multiple sources: wastewater discharges not connected to the sewerage network, formation of wastewater tides and intensive use of fertilizers in irrigated areas In direct contact with the aquifer. The development prospects of the palm grove, which plays a vital role (Tourism and agriculture) in the Beni Abbes oasis, are highly recommended.

3.2. Hydrodynamic modeling and management of the palm grove

The calibration of the model consists in reproducing the most important structures of the flow of the alluvial layer of the palm

grove. Calibration was done by optimizing permeability values according to the classical trial-and-error method. It was then a question of determining the optimal permeability to be assigned to each zone of the model and which allows the simulation of the piezometry closest to the measured piezometry. We also tried during calibration to adjust, to a lesser degree, the values of the water table recharge.

The hydrodynamic modeling of the permanent alluvial aquifer system has made it possible to reach the objectives set satisfactorily. The calibration of the three-dimensional steady-state model for the

1991 baseline is considered satisfactory, with a small mean difference between the measured values and those returned by the model.

At the end of the calibration operation, the simulated balance of the aquifer made it possible to evaluate the different terms of entry and exit of the aquifer . The main entrances are entirely provided by a natural drain of the waters of the erg aquifer (90% of the entrances) and the feeding from irrigation water (large spring and foggara and the wadi Saoura occasionally (10%). % entrances. The outflows of the aquifer are mainly constituted by the samples at

the level of the wells (50% of the outflows), the evaporation, the overflow of the aquifer presents 40% and the remainder is shared between the lateral and horizontal losses towards the south of the palm grove and the drainages to the Wadi Saoura with a rate of 10.%. The water balance of the alluvial water table of the Beni Abbes palm grove calculated by the model at the end of the steady state simulation compared to the approximate budget (Table 1) shows that the calculated flows are relatively lower than the approximate flows but remain acceptable.

Table 1. Assessment of the water table of the alluvial aquifer of the Beni Abbes palm grove

	natural Drain	wells	emptying of the tablecloth	Evaporation	Recharge	TOTAL
the entrees m ³ /s	0.08	-	-	-	0.009	0.089
the exits m ³ /s	-	0.052	0.01	0.041	-	0.102
Deficit						0.013

3.2.1. Assessment of the water table

Calibration of the transient model allowed the spatial distribution of the storage coefficient of the aquifer to be refined. The zonation of this parameter coincides with the geological nature and thickness of the aquifer.

3.2.2. Exploitation of the Hydrodynamic Model

After stalling the hydrodynamic model, it seems interesting to carry out some simulations in order to estimate the potential in groundwater of the Beni Abbes palm grove.

Four simulation scenarios were tested:

1. A long-term operation (20 years) with the same current regime.

2. The construction of an underground dam perpendicular to the flow direction of the water table(Figure 11).
3. Artificial recharge by treated water with dam during a hydrological year.
4. Recharge with treated water in ponds (Figure 12) without dam.

All the scenarios present a exploitation of the aquifer with the same current regime. The results of the simulation for the four scenarios are presented in Figures 12 by the evolution of the piezometric level in three zones, at the edge of the erg in the center and the west of the palm grove.

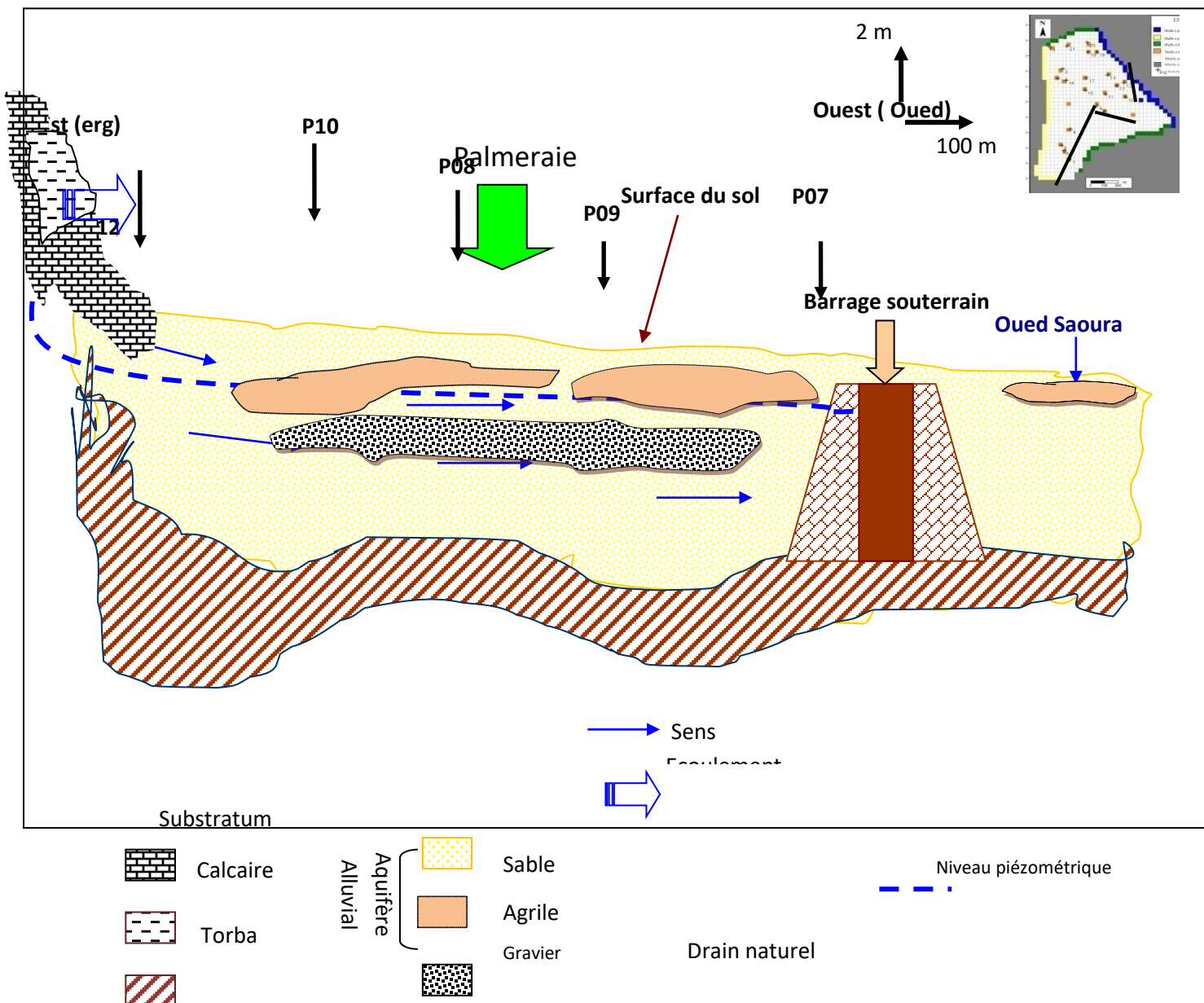


Figure 11. Transverse schematic section of the alluvial aquifer with underground dam.

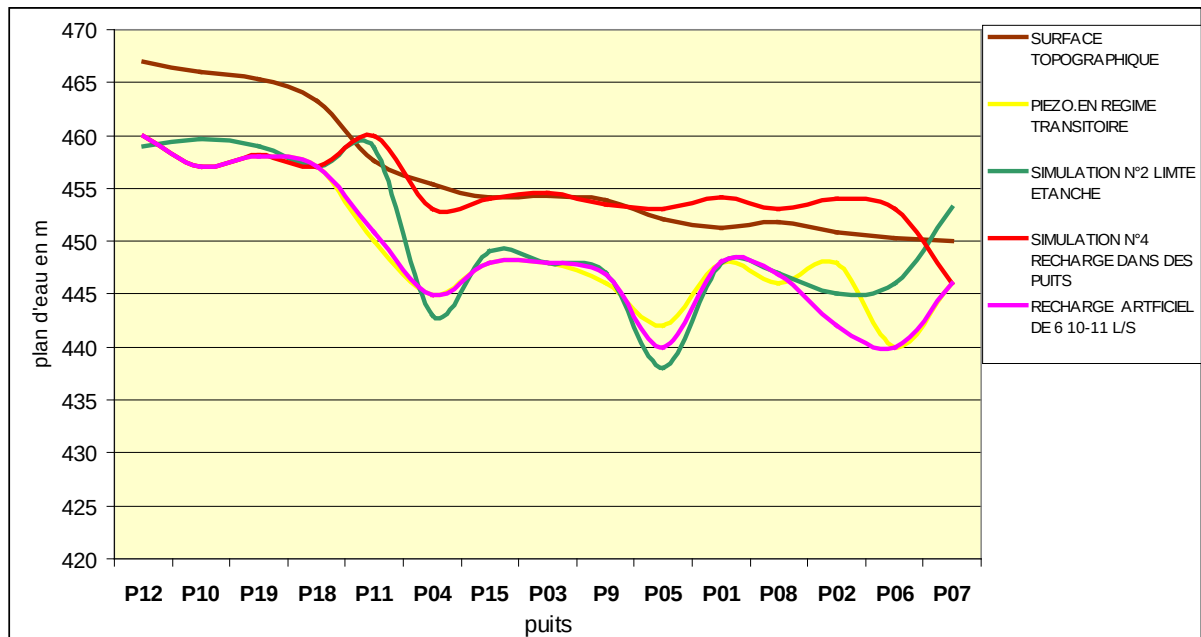


Figure 12. Graphical representation of the different simulated scenarios (recharge with dam).

3.3 Improvement of the traditional irrigation system and recovery of wastewater

An improvement of the traditional irrigation system "Tighira" in the palm grove, which plays a vital role in Beni Abbes oasis, by the realization of four large storage basins. an improvement of the traditional hydrotechnical, so as to modernize this system, keeping the sharing of the quantity of water inherited from each owner of the palm grove.

The peasants have applied the ingenious foggara system to bring water from the Great Western Erg water to their garden in the valley of the wadi. These are two main well lines with a length of 10 m to 50 m, with depths of 1.5 m to 8 m, established

within the aquifer of the great Erg Occidental. The profile has a slight slope towards the Saoura.

Note that this technique is completely neglected in our region. The foggaras capture the waters of the tablecloth of the great Western Erg.

The recovery and reuse of treated wastewater in irrigation has a plausible alternative, for this we propose an optional lagoon system for the treatment of wastewater that takes into account the quantitative elements of the discharges and qualitative waters.

3.4. Development of a water database for Beni Abbes

The data on groundwater observations (piezometry, quality) as well as rainfall and

runoff from the floods of Oued Saoura are available from Bechar's ANRH. These data and information relevant to the oasis of Beni Abbés essential for the estimation of water resources are available in GIS form. The following information, among others, is already required:

Climatological, geological, geophysical, hydrogeological and hydrochemical data of the Beni Abbés region, measurement water points, hydrodynamic parameters of the aquifers (T, K, S), data on Djorf Torba dam management (monthly volumes, contributions , flows and releases), hydrological data of the Saoura watershed

(Guir, Zouzfana and Saoura), rainfall data. These data will be imported from the database of the project (Beni Abbes Database) and serve as a basis for subsequent investigations of the oasis of Beni Abbes.

3.5 .The participatory approach

In order to achieve better integrated water management, these suggestions make it possible to develop a framework for a participatory approach that brings together all the water stakeholders at the Beni Abbes oasis. This participatory approach considers farmers as true partners and seeks to take into account their knowledge and the formulation of action proposals (figure.13). of the city -AEP, Sanitation-

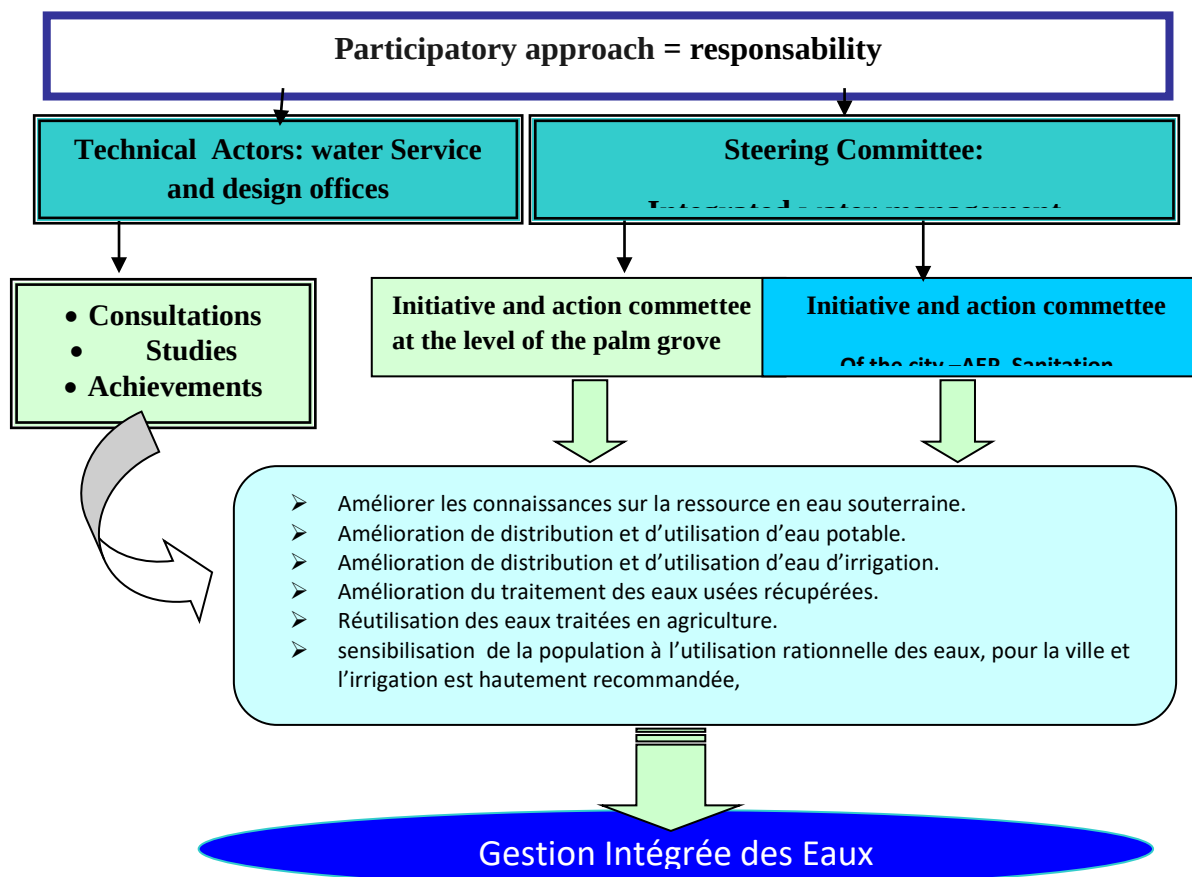


Figure. 13 Canvas of the functioning of the participative approach.

All of these elements make it possible to establish a diagram of the cycle of integrated water management adapted to the oasis environment of Beni Abbes (figure.14)

The Sustainable Management Plan (IWRM) in the oasis environment is a socio-economic model, with the aim of

ensuring a balance between needs and availability. Our oasis model is based on the following points:

- Preserve water resources for future generations (sustainability)
- Satisfy the needs of drinking water supply and irrigation (rational use).
- Ensure the balance of the oasis ecosystem.

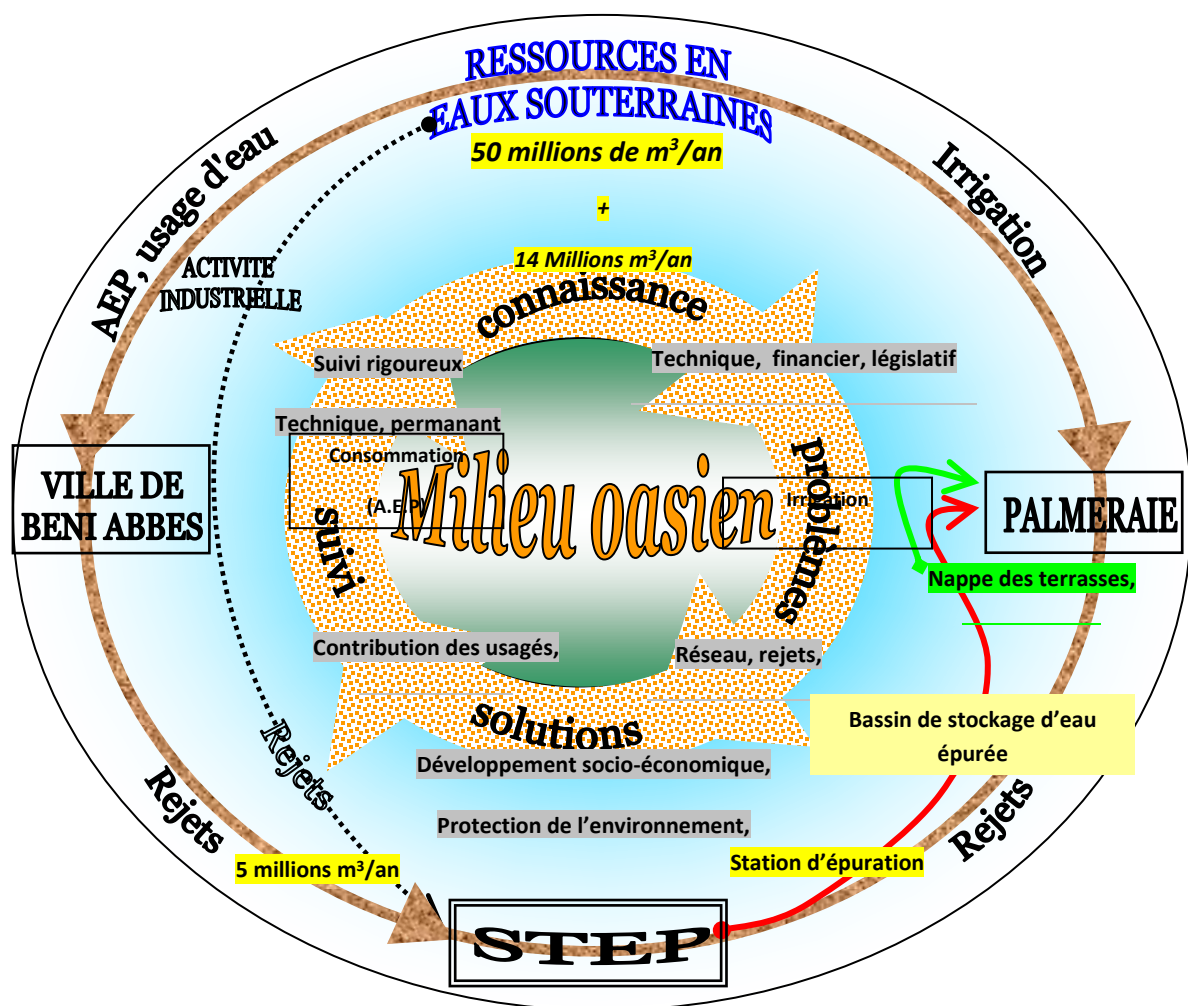


Figure14. diagram of the cycle the integrated management of water resources for the oasis of beni abbots (oasian model) .(Merzougui, 2011)

4 Recommendations

4.1 IWRM Management Plan

The Integrated Water Resources Management Plan (IWRM) can be summarized as follows:

- A better knowledge of the underground water resources in the Beni Abbas Oasis based on investigations, namely:
- The emergence of the Great Source (sources, foggaras and resurgences),
- deepen the knowledge of the local aquifer system (limits, heterogeneity, feeding, exploitability mechanisms, functioning, water quality ...)
- Rehabilitation of the AEP network
- Wastewater treatment
- Improvement of the traditional irrigation system
- The participatory approach

4.2 Risk estimation

The estimation of salinity risk in two-thirds of the alluvial aquifer surface and the catchment area of the large source is an important element in the identification of a protection zone.

4.3 Realization of the management plan

The degree of flexibility of the realization of the plan by a municipality like the oasis of Beni Abbés is high but the realization must be directed towards the objective that the operation of the AEP and public AEI guarantee the supply of the population and

the palm grove in a safe way and in sufficient quantity.

The commune of Béni Abbés must draw up a management plan describing, among other things, the local regulations and requirements, zoning requirements and follow-up program including the other local initiatives during the realization of the management plan. The plan should have regulatory mechanisms to define and monitor minimum distances for pipelines, to study the supply of water on agricultural parcels that allows the leaching of salts accumulated in soils.

It is also a question of whether and to what extent water can be captured in the foggaras to be rehabilitated in the upstream end of the palm grove and whether it can be used for irrigation of the plots threatened by salinisation. To do this an underground dam perpendicular to the flow direction of the alluvial layer is highly recommended to minimize the salinity of the water.

5. Conclusion

Hydrodynamic modeling has confirmed that

- The construction of an underground dam and its impact in changing the behavior of the water table;
- The influence of artificial recharge by treated water during a hydrological year.

- The drawdown of the water table and the influence of each recharge device, to minimize the risk of the salinity of the water tables thereafter

Our approach is not the end; it presents a contribution for an integrated water management in an arid and fragile environment. It is based on a strategy based on global thinking that includes three priority areas:

- Reserve water from the Great Western Erg water table for drinking water supply.
- Reuse of wastewater for irrigation with a plausible alternative.
- Develop distribution networks for drinking water supply,
- Improve the traditional irrigation system and reuse wastewater after treatment for irrigation purposes.
- Implementation of a policy encouraging water saving and promotion of techniques and attitudes of water saving.

The integrated management of the water resources of the Saharan areas today confronted between tradition and modernity, it becomes a necessity for the preservation of the arid and fragile environment. This approach is a sustainable solution for water management in the Oasis. This inescapable approach ensures better governance of water, especially in the Saharan environment.

This socio-economic approach must be implemented and constitutes an essential basis for effective water management in oasis environments. It makes it possible to become aware of the need to manage and preserve the underground water resource, in order to reconcile socio-economic development, the preservation of the Beni Abbes palm grove and to balance the various uses to guarantee sustainable development.

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