Diagnosis of the Ghiss Nekor aquifer in order to elaborate the aquifer contract

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Abstract. The Ghiss-Nekor aquifer, located in the north-east of the action area of the ABHL, plays a strategic role in the drinkable water supply of the city of Al Hoceima and of the neighboring urban areas. It also participates in the irrigation of PMH. However, this aquifer has problems such as over-exploitation and pollution. In the face of these problems, the only Solution is the establishment of a new mode of governance, which privileges the participation, the involvement and the responsibility of the actors concerned in a negotiated contractual framework, namely the aquifer contract. The purpose of this study is to diagnose the current state of the Ghiss Nekor aquifer, the hydrogeological characterization of the aquifer, the use of the waters of the aquifer, the Problem identification and the introduction of the aquifer contract, which aims at the participatory and sustainable management of underground water resources in the Ghiss-Nekor plain, to ensure sustainable development.

1 Introduction

Morocco has always made the development of the water sector a priority and a strategic choice. This sector, one of the main levers of economic and social development, faces two key challenges: [1]

- The depletion of water resources in relation to the increase in all-purpose water demand, with a tendency towards absolute scarcity by 2025 [1]

- The degradation of water resources that undergo different forms of pollution. [1]

The Ghiss-Nekor alluvial aquifer is one of the most important aquifers in the northeastern part of the ABHL area. This water table plays a strategic role: it currently provides most of the drinking water supply in the city of Al Hoceima and surrounding urban centers. It also participates in the irrigation of the PMH, especially on the right bank of the Nekor wadi.

However, this aquifer is increasingly exploited because it is the only major aquifer in the area. In addition to overexploitation, groundwater is characterized by high ionic concentrations, due to the geological composition of the lands crossed, the mineralized inputs of the returns of irrigation water and the various polluting anthropogenic activities. This implies the need for a radical change in the management of water resources.

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2 Problems of the Ghiss Nekor aquifer

The Ghiss Nekor water table suffers from many problems among which we can mention the pollution. The waters of the aquifer are marked by very high levels of different ions (mainly chlorides and sodium). The high levels come mainly from the accumulation of water supplies of wadis (especially Nekor) rich in dissolved salts from evaporitic and carbonate formations.

The result of the DRASTIC vulnerability index indicates that groundwater resources in the Ghis-Nekor Plain are sensitive to moderate to high levels of pollution [2]. The coastal zone of the study area is characterized by a high vulnerability that could be attributed to the shallow water depth (less than 5 meters below the earth's surface) and high permeability. In addition, the shallow aquifer in this zone consists mainly of interbedded deposits of gravel, sand and silt thin [2]. In addition, aquiferous materials are characterized by a high hydraulic conductivity. Areas with moderate to high vulnerability to groundwater pollution have been found to be correlated with areas of high anthropogenic pollution activity. [2].

The Ghiss Nekor water table has been negatively affected by the succession of years of drought. In recent years, the surface waters of the Ghiss Nekor Plain have been considerably reduced, resulting in high groundwater pressure of the Ghiss Nekor water table, and consequently a decrease in the piezometric level.

Hence the need for immediate implementation of a sustainable management plan based on limiting hazardous activities, restoring groundwater quality and improving environmental good sense [2].

3 Material and methods

3.1 Study zone

The Ghiss-Nekor aquifer covers an area of 100 square kilometers and is located (**fig. 1**) northeast of the ABHL action zone and occupies the downstream part of the two basins of Ghiss and Nekor.

The geographical limits of the study area are: in the North the Mediterranean Sea, in the West the city of Ajdir and the douars of Aït Youssef or Ali and Imrabtene, Douay Bouayach in the Southwest, douars Tessaft and the Dam Mohammed Ben Abdelkarim Al Khattabi in the South, the Southeast Douar of Beni Akki and East the center of Troughout

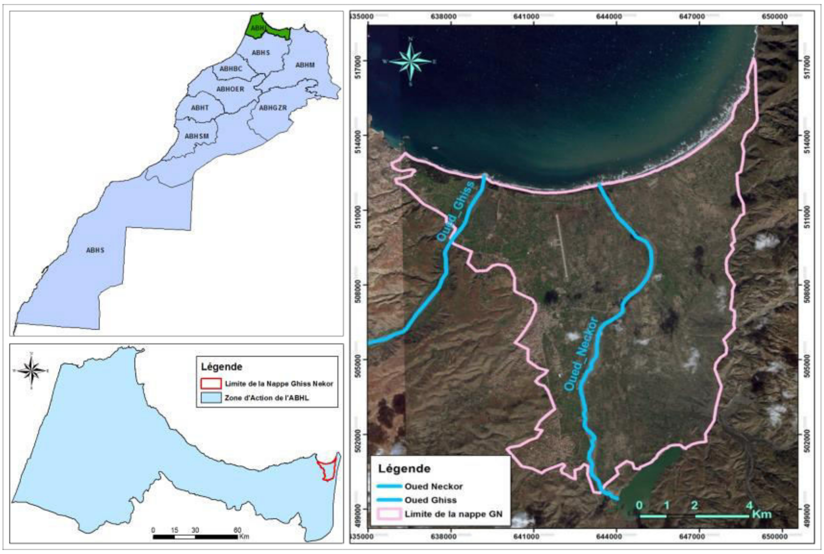

Fig. 1: Ghiss Nekor water table situation map at the national level and at the scale of the ABHL action zone

3.2 Demographic characteristics

The evaluation of the demographic characteristics and the socio-economic conditions of the study area contributes to the valorization of human and natural resources with a view to a better exploitation for a sustainable development adapted to the peculiarities of the region.

According to Morocco's regional breakdown of 2014, the study area falls under two provinces that are part of two different regions Tangier-Tetouan-Al Hoceima region for the province of Al Hoceima and the Oriental region for the province of Driouch.

The population of the Tangier-Tetouan-Al Hoceima region according to the General Population and Housing Census of 2014 is 3556729 inhabitants and the province of Al Hoceima has 399,654 inhabitants or 11.2%.

The population of the Oriental region is 2314346 inhabitants while the province of Driouch has 211059 inhabitants or 9.1%.

The two provinces share similarities despite the fact that Driouch Province is younger, and has a very pronounced rural character, with 68% of the population living in rural areas.

3.3 Geology of the Plio-Quaternary of Ghiss Nekor

Overall, the plio-quaternary Ghiss-Nekor aquifer consists of a complex of alluvial deposits with vertical and lateral facies passages. These deposits store a generalized free web, which in some places is captive. Stratigraphically, we distinguish from bottom to top [3] :

- The Plio-Villafranchian: is represented by a heterogeneous material consisting of conglomerates, sandstones and silts that are outcropping to the west of the plain at the level of the Oued Ghiss and Imzourène plateaus [3];
- The ancient Quaternary: outcrops on the lower Ghiss plateau and is made up of

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heterogeneous material with conglomerates at the base [3];

- The Middle Quaternary: is represented by terraces encrusted on gravel Tensiftien-Amirien outcropping to the south of the plain in the region of Beni Bouayach to the west of Oued Nekor, downstream of Oued Tifaouine [3];
- The recent Quaternary: covers almost all of the plain and deposits consist of the gray silts of Rharbien and laterally evolve to the silty deposits of coastal glacis and low terrace (of Soltan age) south of the plain at from the left bank of Oued Nekor and to the east of Plio-Villafranchien d'Imzourène [3].

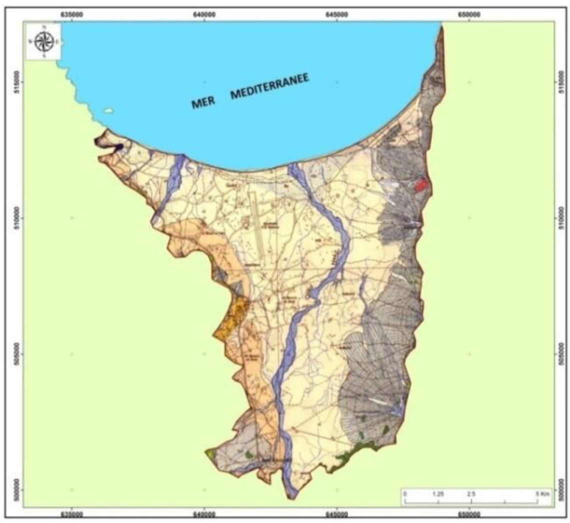

Fig. 2: Geological map of the Ghiss Nekor plain, (Extracted from the geological map 1/50000 of El Hoceima)

The geological, geophysical and hydrogeological study has identified an aquifer consisting of alluvium plio-quaternary age with an average thickness of 240m. Its schistose substratum sinks from south to north under the plio-quaternary cover [9].

3.4 Climatology

The study of the factors governing the climate of the Rhis-Nekor Plain, namely, precipitation, temperature, and evapotranspiration, is necessary because these elements are a strong condition for the expression of the water balance and therefore the volumes exchanged between the aquifer system and its environment [9].

Given its geographical location in the extreme north of Morocco and the variability of the reliefs around its limits, the water table of Ghiss-Nekor is subject to a climate of the Mediterranean type. It is located in the semi-arid bioclimatic stage (dry summers) at relatively temperate winter. The rains usually occur for eight months, from October to May, while the dry season runs from June to September.

Figure n°3 gives the annual rainfall at the SMBAK Dam station. There is a fairly marked year-to-year fluctuation with very critical minimum inputs of 196 mm in the 2013/2014 year and significant rainfall with a maximum of 844 mm recorded during the 2009/2010 rainy year. The annual average is estimated at 396.9 mm.

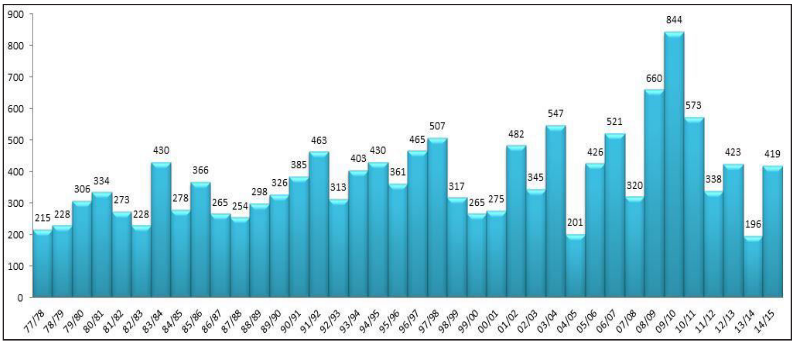

Fig. 3: Annual precipitation variation

3.5 Piezometry

The piezometric map (**fig. 4**) shows feeding areas in the South and East. The feeding follows the superficial flow of the Nekor wadi. This diet is remarkable at the dike dam SMBAK where the diet is due to the released of the latter. Isopipe curves are open downstream, and increasingly spaced (decrease in hydraulic gradient) from upstream to downstream and from east to west.

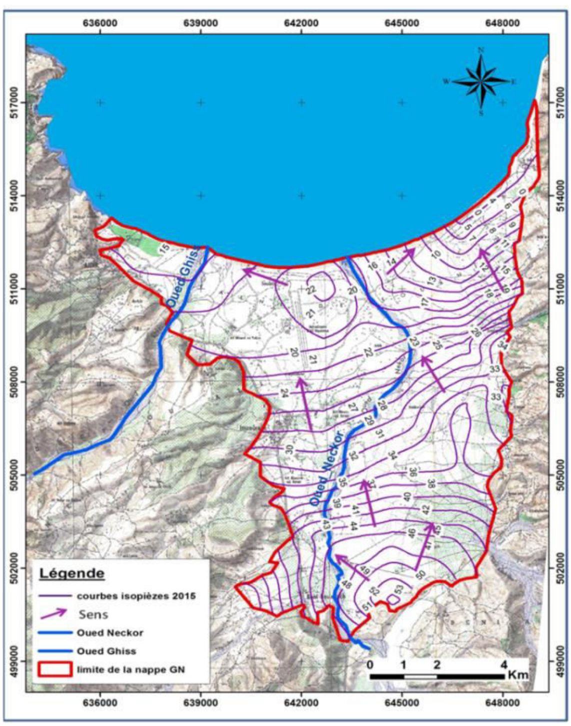

Fig. 4: Piezometric map of the Ghiss Nekor aquifer (2015)

3.6 Hydrodynamic characteristics

The transmissivity values of the aquifer range from 6,65*10^{-5} to 6,4*10^{-2} m^2/s around an average of 2*10^{-2} m^2/s [3].

The measured permeability values at 25 wells range from $3{,}7*10^{-8}$ m/s to $8{,}5*10^{-4}$m/s around an average of $1{,}8*10^{-4}$m/s [3].

The values of the storage coefficient evaluated at four wells are between 0,65 and $5{,}3\cdot10^{-2}$ [3].

Table 1. Values of the storage coefficient evaluated at four Boreholes

Boreholes	X	Y	S ($.10^{-2}$)
252 /5	638 350	510 140	4.6
256/5	646 650	505 400	5.3
310/5	640 700	510 800	2.2
F4	640 338	500 105	0.65

3.7 Hydric balance of the aquifer

The current balance is deficit of a volume of 2.31 Mm^3 / year [3] following the reduction of wadis' contributions, and the increase of the demand for the drinking water supply and industry and for the irrigation of the irrigated perimeters.

The water balance of the aquifer has a deficit due to natural losses from outflow to the sea and direct evaporation in the littoral zone, and because of water withdrawal from the water table, especially farmers who generally tend to exaggerate pumping time and use water that far exceeds the actual needs of the crop.

Table 2. Water balance of the de Ghiss Nekor aquifer [3]

Inputs (Mm3/ year)		**Outputs (Mm^3/ year)**	
Infiltration of rainwater	**3,16**	**Outings to the sea**	**2,57**
lateral inputs	**5,26**	**Evaporative Outputs**	**5,16**
Inputs from wadis	**2,98**	**Agricultural pumps**	**3,3**
Return of irrigation water	**0,66**	**Water withdrawal by ONEE**	**3,34**
Total	**12,06**	**Total**	**14,37**
Variation of the Stock (m^3/ year)		**- 2,31**	

3.8 Water quality of the water table

Overall, and taking into account chemical and bacteriological parameters, it can be considered that the overall quality of the groundwater is poor to medium.

The dry residue is 1.5 to 5 g / l [3]. The salinity of the water varies from 2100 to 2600 µS/cm. PH values range from 6.7 to 8.1 around an average of 7 to 8 during the period 2004-2014 [3]. The very high sulphate levels in the aquifer are a limiting factor for the exploitation of groundwater for the drinking water of the populations of the city of Al Hoceima and the surrounding centers and douars. The degradation of quality comes mainly from marine intrusion, the presence of salt levels in the aquifer and the return of irrigation water [3].

Moreover, it is necessary to protect the collecting fields of drinking water by close protection perimeters to limit pollution caused by human activities.

3.9 Water use

The 2014 inventory identified 299 farms (**Table 3**), almost equally distributed, between the two provinces of Al Hoceima and Driouch. Including 261 sampling points for agriculture to irrigate an area of about 378 ha, which consumes an annual volume of 3.34 Mm^3, 9 boreholes for the National Office of Water and Electricity that use an annual volume of 721 172 m^3 and 69 sampling points for rural drinking water with a volume of approximately 183 887 m^3. With a total of 0.91 Mm^3 for drinking water [4].

Table 3. Sampling points from the Ghiss Nekor water table according to the inventory 2014 [4]

Total number of points	**Designation**				
	Agriculture			**Drinking Water Supply (DWS)**	
	Number of points	**Area (ha)**	**Volume (Mm^3/ year)**	**Number of points**	**Volume (m^3/ year)**
299	**261**	**378**	**3.34**	**ONEE-BE 9**	**721 172**
				rural DWS 69	**183 887**

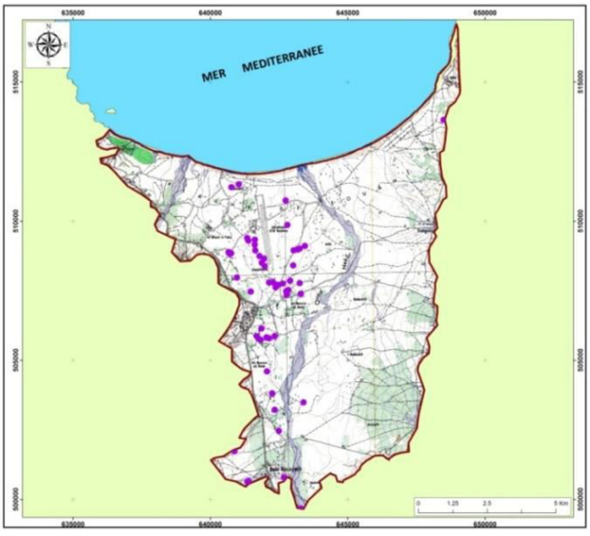

Fig. 5. Map of location of sampling points for irrigation and drinking water

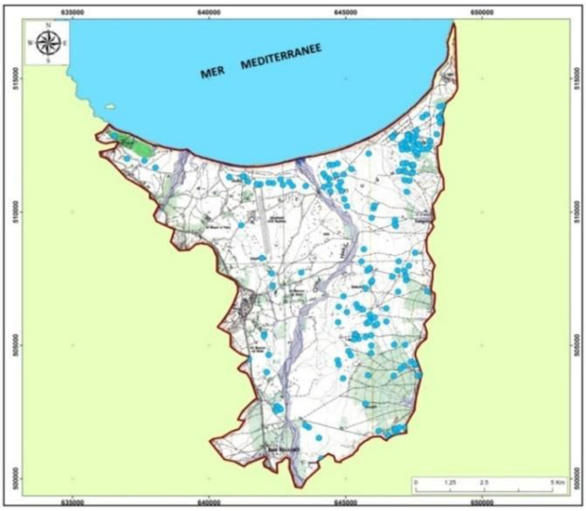

Fig. 6. Map of location of sampling points for Irrigation

3.9.1 Drinking water supply (DWS)

The groundwater resources from the fields of Ghiss wadi and Nekor wadi consist of 9 boreholes and two wells with a global flow rate of 185 l/s [4].

The adduction, coming from the catchment field of Ghiss wadi, includes the following works:

- A discharge pipe, DN 400 mm diameter, connecting the Ghiss wadi station to the connection with the pipe from the Ajdir booster station;
- A discharge pipe, connecting borehole N°IRE 1083/5 to the Imzouren reservoir.

The adduction from the Nekor catchment field consists of discharging the water from the boreholes to the existing loading tank of 3500 m^3, with two pumping stations and a discharge pipe, diameters DN 315 and DN 400 mm. , and total length of about 12 Km.

The following graph (**fig. 7**) shows the evolution of the volume produced by the wells and boreholes (385/5, 1768/5, 1085/5, 573/5, 510/5, 576/5, 514/8, 514/9, 514/10, 515/2, 1086/5, 1083/5, 578/5, 1691/5, 797/10, 673/10, 1692/8) intended for the supply of drinking water during the period April 2016 to January 2017, which tends towards the increase of pumping.

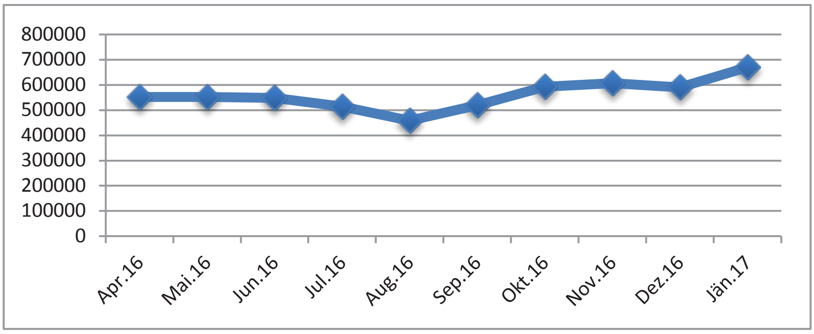

Fig. 7. Evolution of the volume of water produced by wells and boreholes during the period April 2016 - January 2017

3.9.2 Irrigation

Agriculture is the sector that consumes a large share of water resources, hence the need to study irrigation water consumption and possible measures to better manage this use.

Table 4 represents the areas occupied by the irrigated perimeters located in our study area.

Table 4. Areas of irrigated perimeters of the Ghiss Nekor Plain (Provincial Directorate of Agriculture of El Hoceima)

N°	Perimeter	Area (ha)
1	Boukhlifa	70
2	Tazaghine	12
3	Boujbour	20
4	Boumassous	25
5	Handoune	40
6	Takhsaste	10
7	Boumakek	30
8	Touna	15
9	KhmisAghzar	15
10	Arnas	22
11	Bougzour	35
12	Tighza N'romane	10
13	Ait Hicham Tourthoute	10
14	Aarbi	75
15	AzgharTafournoute	16
16	Ghis	900
Total		**1305**

According to the inventory made by the Loukkos Watershed Agency (2014), the number of water fetching points for irrigation is 214 points for purely agricultural use, in addition to 63 water fetching points used for drinking water supply and irrigation at the same time. The irrigated area is 1305 ha (El Hoceima PDA) and the annual volume consumed is of the order of 3.34 Mm^3.

3.9.3 Industry

According to the 2014 inventory there is only one point of water withdrawal from the aquifer that is intended for industry, located in the municipality of Imzouren, and which uses a flow of 15 l/s.

Otherwise, the waters of the Ghiss-Nekor aquifer are used for cleaning the gravels extracted from the Nekor wadi bed, which is carried out by excessive pumping. The residues of the sands are thus a source of pollution of the aquifer but also lead to a saturation of the soil by the fines and reduces the infiltration of rainwater into the aquifer [6].

The quarry and the pumping area are 400m from the sea; this creates a high risk of invasion of the aquifer by marine waters [6].

3.10 Aquifer contract

Independently of any climate change, water management is one of the major problems that shape the future of Morocco [1]. The Nekor Ghiss aquifer is among the most exposed aquifers to the problem of pollution and overexploitation. Theoretically, the exploitation of groundwater results in the modification of the state of the aquifer and its dynamics in a more or less extended space according to the impulses exerted and the nature and parameters of the aquifer [1].

To face these problems the only way out is to set up a new mode of governance of groundwater which privileges the participation, the implication, the responsibility and the commitment of the actors concerned and the regional and local partners in the management of water resources, using a participatory approach and in a negotiated contractual framework.

A water table contract can be defined as a technical and financial agreement between the different users of the water table for the purpose of exploitation and especially of sustainable management. And must be signed between the different partners: Local Authorities, Water Basin Agency, water users and also scientific institutions.

The aquifer contracts constitute, at the scale of the aquifer, the operational tools best adapted in terms of programming. They set targets for a given water table in terms of the quality and quantity of water, the development of the aquatic environment and the balanced management of water resources. It provides in an operational way (5-year action program, designation of project owners, financing method, deadlines for works, etc.) the arrangements for carrying out the work required to achieve these objectives [7].

3.10.1 The objectives of the Ghiss-Nekor aquifer contract

The long-term objectives of the Ghiss-Nekor aquifer contract are:

- The diagnosis of the current state of the water table;
- The fight against water scarcity in the region of Al Hoceima and the surrounding area
- Preserving groundwater in the long term and rebalancing the aquifer balance;
- Prevention of water resources pollution;

- Guarantee the security of water supply for the local population and the agricultural, industrial and tourist sector;
- Reducing vulnerability to risks related to extreme events and climate change;
- Guarantee sustainable socio-economic development especially in the agricultural sector;
- Engaging a reflection to all stakeholders for setting up a convention aquifer contract;
- Improving the monitoring of water resources and controlling their use.

3.10.2 The strategic axes of the aquifer contract

Table 5. Strategic axes of the aquifer contract

Axes	Specific objectives
Development of the supply of water resources	- Mobilization of additional water resources: Dams. - Gradual reduction of the use of groundwater and its replacement by surface water: drinking water supply and irrigation.
Demand management and protection of groundwater resources.	- Strengthening control: water police. - Rationalization of water uses. - Valorization of water resources. - Preservation of the quality of the water. - Reuse of treated wastewater in irrigation. - Artificial recharge of the water table.
Improvement of the knowledge framework.	- Monitoring the qualitative and quantitative status of water resources. - Establishment of an information exchange system - Development of scientific research.
Strengthen communication and training.	- Development of cooperation and partnership. - Awareness, communication and coaching. - Capacity Building.

4. Conclusion

The Rhiss Nekor aquifer is considered to be the most important alluvial aquifer in the Mediterranean zone. Nevertheless, it is confronted with major natural and anthropogenic pressures, namely the aridity of the region, the development of agricultural activity, the vulnerability to marine intrusion as well as its chloride-sodium and / or potassium sulphate facies. What constitutes a major challenge for its water resources [5].

In the face of this critical situation, the only solution is to implement a sustainable, integrated and participative management of water resources, which involves all stakeholders, who generally have conflicting interests, and which takes into account the particularities of the region.

Finally, insofar as integrated management is always an attempt to reconcile different or even contradictory interests or rights, conflicts of use, territories with multiple legitimacies, it seems interesting to look more closely at the way in which groundwater has been progressively integrated into public water management policies [8]. And subsequently make the changes that make this management more suitable to the particularities of each region, and based on a partnership and contractual approach.

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