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Presented by

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Study of the assignment scheme of water resources in the Tafna watershed

Defended on 05/09/2018 Before the Following Committee:

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Declaration

I SAMIR MORSLI, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules andethics

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Dedication

It is with the help of all powerful that I come to term of this modest work that I dedicate:

To those who have cared for me since my birth to make me a person full of love for science and knowledge; my dear parents who have been able to give me happiness,

Who knew how to guide my steps towards a safe future, who have never stopped encouraging me to undertake these studies and achieve this goal.

To my brothers and sisters and especially my nephews

Merouane and Farah.

To my friends.

To all the promotion of water engineering

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SAMIR. MORSLI

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Abstract

The problem of water is likely to arise sharply for Algeria and especially its western region in a more or less near future. However, the Tafna basin from which are drawn the main conventional and unconventional water resources for the wilaya of Tlemcen and neighboring wilayas. Thus, the preservation of these water resources is one of the fundamental issues of our time. The increase in removals and discards due to population growth and economic development is increasingly threatening the quantity and quality of this vital resource. In Algeria, the climatic hazards observed, combined with a strong demography, contributed to an unavoidable shortage of mobilizable resources.The policies adopted over the last twenty years, in terms of dam construction and desalination of seawater, remain insufficient. A more rational vision needs to be developed regarding the management of these resources. . It is in this sense that this work aims to study the allocation of water resources in the Tafna watershed as part of an integrated management, while calculating the hydraulic balances resource needs for the different uses of water and for different horizons. Assignment scenarios will be proposed for short, medium- and long-term horizons by comparing the supply to the needs of the various water users in the Tafna watershed. Stakeholders such as water users and managers will be involved to manage water in an integrated and sustainable way and meet current demand and prospects for better supply.

Key words: Watershed, integrated management, water resources, assignment scheme, water balance

Résumé

Le problème de l'eau risque de se poser avec acuité pour l'Algérie et surtout sa région Ouest dans un avenir plus au moins proche. Or, le bassin de la Tafna duquel sont puisées les principales ressources en eau conventionnelles et non conventionnelles pour la wilaya de Tlemcen et les wilayas limitrophes. Ainsi, la préservation de ces ressources en eau est l'une des questions fondamentales de notre temps. L'augmentation des prélèvements et des rejets due à la croissance démographique et au développement économique menace de plus en plus la quantité et la qualité de cette ressource vitale. En Algérie, les aléas climatiques observés, conjugués à une forte démographie, ont contribué à une pénurie inévitable de ressources mobilisables. Les politiques adoptées au cours des vingt dernières années, en termes de construction de barrages et de dessalement d'eau de mer, restent insuffisantes. Une vision plus rationnelle doit être développée concernant la gestion de ces ressources. C'est dans ce sens que s'inscrit ce travail qui vise à étudier le schéma d'affectation des ressources en eau au niveau du bassin versant de la Tafna dans le cadre d'une gestion intégrée, tout en calculant les bilans hydrauliques ressources besoins pour les différents usages de l'eau et pour différents horizons. Des scénarios d'affectation seront proposés pour des horizons à court, moyen et long termes en confrontant l'offre aux besoins des divers usagers de l'eau dans le bassin versant de la Tafna. Les acteurs concernés comme les usagers de l'eau et les gestionnaires seront impliqués pour gérer l'eau d'une façon intégrée et durable et satisfaire la demande actuelle et les perspectives pour une meilleure offre.

Mots clés : Bassin versant, gestion intégrée, ressources en eau, schéma d'affectation, bilan hydraulique

Table of contents

List of Figures

List of Tables

Abbreviation

ABH-OCC	Watershed Agency-Oranie Chott Chergui
AGIRE	Integrated Water Resources Management Agency
ANRH	National Agency of Hydraulic Resources
ADE	Algerian Waters
ANAT	National Agency for Spatial Planning
ANBT	National Agency for Dams and Transfers
AA	Agricultural Area
APC	Communal people’s Assembly
BB	Beni Behdel
BC1	Charge socket 1
BSA	Sidi Abdeli dam
DRE	Directorate of Water Resources
DWS	Drinking Water Supply
Ha	Hectare
Hab	Inhabitant
HB	Hammam Bougherara
IWRM	Integrated Water Resource Management
L/d	Liter per day
MREE	Ministry of Water Resources
MF	Meffrouche

Mm^3/y	million cubic meters per year
m^3	Cubic meter
m^3/d	Cubic meter per day
m	Meter
N	Number of inhabitants
Km	Kilometer
Km^2	square Kilometer
Km/Km^2	Kilometer per square Kilometer
ONA	National Office of Sanitation
ONID	National Office of Irrigation and Drainage
ONS	National Office of Statistics
SNAT	National Spatial Planning Scheme
SDP	Seawater Desalination Plant
SDS	Seawater Desalination Station
SMH	Small and Medium Hydraulic
SA	Sidi Abdeli
SK	Sekkak
TW	Tafna Watershed

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 Background

Water is a finite resource, sensitive to external factors and environmental degradation, costly to control and develop. It becomes more valuable as competing uses multiply. Therefore, an integrated and concerted management of water resources is essential within a unit such as the watershed (Traoré, 2012).

Now, many researchers and experts activating in the field of water think that tensions will be born during the next century on and around this resource. These tensions can arise within the same country if the interests of users diverge or between neighboring countries if they share the waters of the same watershed.

Since Algeria is a country in North Africa, it will be faced with the same problem as other countries in the problem of the scarcity of water in the future. Despite the considerable efforts made by the country, particularly in the field the realization of mobilization infrastructures. Recent decades, rapid urbanization, industrialization, population growth, and the increasing competition for scarce natural resources has made Algeria face great water management challenges, especially in watershed.

Water resources scarcity has become one of the determinants, which restricts social and economic sustainable development. Improving water use efficiency by means of optimizing water resources allocation nowadays has been considered as the fundamental method for solving water scarcity in river basin (Zhang et al., 2012).

However,theproblemof insufficient or excessive water allocation within each sector may occur in the traditional water allocation pattern, which distributes water resources based on the current situation and trend of water use.

Inaddition,insufficientknowledgeofavailablewaterresources,lackofcoordinationinwaterresources allocation and management, and drought episodes in the river basin often result in water deficits, which have hampered the harmonious development and destroyed the ecological balance in the basin (Fang et all.,2007). Therefore, water allocation decisions that consider equity, efficiency, and sustainability in every water sector should be treated as the main goal of decision-makers in the riverbasin.

The main aim of water resources allocation is to find a balance for allocation methods among different water use sectors, such as domestic water, agricultural water and industrial water to ensure the sustainable development of society and economy (Zhang et al., 2012).

The evolution of the world has reached a very high rate, to the point that the context itself has become a variable. Therefore, today's decision-making mortgages our future, the best way to predict it, is by making scenarios in this sense the economist Ged Davis says :

"Scenarios are stories about the future, but their goal is to make better decisions in the present ".

Nancy Ramsey said: *"The best scenarios are not necessarily those that come true: they are the ones that upset expectations that make us aware of the changes that are happening around us. The best scenarios are those that allow a better understanding of the present."*

Currently, the Tafna watershed includes five large functional dams (Beni-Bahdel, Meffrouche, El Izdihar to Sidi Abdelli, Hammam Boughrara and Sikkak). This basin also has groundwater (groundwater and aquifers) which favors its hydrographic network. In addition, for a better management of the superficial and underground resources and within the framework of the sustainable development, Tlemcen mobilized the resources of the basin of the Tafna for the purpose to improve and develop the management by creating purification stations and desalination plants.

1.2 Aim of the work

This end of study dissertation attempts to solve the problem of insufficient or excessive water allocation, which may occurunderthetraditionalwayofwaterallocation by evaluating quantitatively all categories of water resources in Tafna watershed. Through resources/needs balance, we will proposeawaterresourcesassignmentscheme taking into account the scenarios for different horizons that can well match water requirements of various competing sectors including domestic water demand, industrial water demand and agricultural water demand in Tafna watershed. To achieve this, the specific objectives are :

- Streamline the use of water resources in a watershed and fight against waste;
- Propose optimized allocation schemes for water stakeholders at the watershed level;
- Preserve the quality and quantity of water;
- Protect subterranean and superficial resources from overexploitation

One of the first hypotheses to be tested during this study will be the non-satisfaction of the water needs of some of the users.

1.3 Literature review

A preliminary literature review shows that past studies are primarily focused on understanding integrated water management into basins. The factors such as population growth, demographic changes, economic development and climate change have a critical impact on water resources (GWP and INBO, 2009).

Recently, watershed management projects have started to take into account climate change; these projects have been designed to cope with high risk watersheds. According to Salah D. and all.,(2008) participatory approaches and community watershed management plans have been widely used with varying success in reconciling the overlay of human activity on watersheds.

In addition to that, Watershed management approaches implemented over the last 15 years have generally been successful in achieving soil and water conservation objectives (Salah D. et al., 2008). Then, Collaborative planning is the best way to give voice to local actors. It requires the commitment of the various interest groups present in the watershed (Georges G., 2004).

Thus, Monitoring and evaluating basin management activities is a key component of basin management. In terms of integrating water management into basins, it is important to understand the water management framework in which decisions about water are made. The relationship between administering water resources within a country and managing water in basins thus becomes dynamic and more responsive to changing circumstances, whether environmental, social or economic(GWP and INBO,2009).

The failures in the service of water translate an insufficient control in the management of the hydraulic resources of the country. A water demand management policy that would control, reduce and adjust consumption to what is necessary, while eliminating losses and wastage, is thus essential (Mohammed B and Gaëlle T., 2010).

To ensure water supply and anticipate the negative impacts of climate change announced for the next decades (Bates et al., 2008, IPCC, 2013), it is necessary to equip ourselves with tools and methodologies capable of optimizing the allocation of water. Jothiprakash and Ganesan (2006) and Suiadee and Tingsanchali (2007) emphasized that there is a great need to improve the efficiency of the use of available resources.

Theaimofoptimalwaterresourcesallocationistoreallocatethelimitedwaterresourcesscientificallyamongdifferentwaterusesectorsbasedonafair,effectiveandsustainableprincipleinagivenregionthroughmeasuressuchasrestrainingwaterdemandreasonably, increasingwatersupplyeffectively,and protectingtheecologicalenvironmentpositively (Zhang et al., 2012).Managers need to find the optimal solutions that meet the demands of demand in terms of volume and quality, while trying to minimize costs throughout the management period (Zhang et al., 2012). Showed that the optimization of water resources allocation is a complex process. Improving the existing methodology or creating new methodology to make the water allocation program more accurate is always the emphasis. Environmental and socio-economic aspects may be additional objectives of management (Giupponi, 2007). Optimal solutions must also satisfy a large number of constraints.

When formulating problems of optimization of the management of water resources, the objective of satisfying the demand for water considered by Nouiri (2016), it is generally minimized a function of not satisfying the sites of request to reach this objective.

To achieve the application of IWRM and to cope with the difficulties, Giopponi (2007) and Fu (2008) recommended the development of models (Growth, production, water needs, hydraulics, etc..) that exchange data and optimization methods could easily integrated to develop Decision Support Systems (DSS) that support policy makers. Giupponi (2007) developed a DSS for IWRM to help the decision maker in the allocation of water between different sectors.

According to (Goyal V. C etal., 2017), the water budget helps to understand the overall water availability and demand scenario, particularly during periods of droughts, so that effective water resources management schemes can be devised.

(Jeniffer et all., 2010)appliedwater evaluation and planning model to evaluate water resources development based on an equilibrium scenario of the current water demand in the Upper Ewaso Ng'iro North Basin, the results showed that high water irrigation demand was the main reason for a regional water shortage.Scenario building allows open but structured learning, raising awareness of future changes and developments. The scenario development process requires several steps that must shape it.

In this sense, Ulrich Golüke says:

"By writing these stories, we reinvent reality, create opportunities and broaden our horizons. We are no longer content to suffer the future: we shape it. "

Scenario building allows open but structured learning, raising awareness of future changes and developments. This approach provides the necessary tools to systematically identify possible alternative evolutions and to analyze the preconditions as well as the consequences of these evolutions, as well as the possibilities of shaping and influencing them. The set of scenarios developed provides a common framework and starting point for conducting strategic discussions.

Research on the optimization of integrated management aims to take into account the objectives of demand satisfaction, in terms of quantity and quality, economic (cost of water and profitability) and environmental (drawdown of aquifers and pollution) taking into account the constraints of the system is also a condition to be able to derive the best solutions to the problems of the management of water resources (Nouiri, 2016).

The synthesis of scientific publications on water resources management provides information on the existence of a range of tools and methods of optimization. It is important for a country subject to aridity in a large part of its territory, such as Algeria, especially the Tafna watershed to have approaches, tools and data sufficient to ensure the best management water resources. This need would felt more and more in parallel with the deterioration of the "Resources-Needs" balance and the amplification of the effects of foreseeable climate change.

As part of this research, it is opted for the choice of a tool ensuring the calculation of optimal scenarios using optimization techniques.

1.4 Structure of the work

The methodology proposed for this study will focus on two main points:

1. Description of the current status around water use / management in the Tafna watershed: inventory of conventional water resources (surface and groundwater), and unconventional resources (desalination water and the reuse of treated wastewater), identification of water users in the basin and estimation of needs.
2. Development of management scenarios based on an analysis taking into account the interests of different user groups to optimize water.

Thestudy is structuredas follows :

Introduction and literature review on optimal water resources allocation is summarized in this same Chapter 1.The study area and data collection are described in Chapter 2. Chapter 3 shows the methodology of optimal water resources allocation under the evaluation of water resources and needs in Tafna watershed. Meanwhile, in Section 4, the derived optimal water resources allocation scheme that includes water allocation scenarios and strategy in tafna watershed among different sectors. Finally, we conclude our study and suggest the possible solutions for future study in optimal water resources allocation of tafna watershed in Chapter 5.

CHAPTERTWO

OVERVIEW OF THE TAFNA WATERSHED

2.1 Introduction

In this chapter, we present in a general way the watershed of the Tafna, namely the geographical, hydrographic, geological and hydrogeological context. Then, we will give a presentation on the geomorphological, soil and climatological aspect of the study area.

2.2 Presentation of the Tafna watershed

The Tafna watershed located (Figure 2.1) in the northwest of the Algerian territory. The total area in the Algerian territory is 5 340 square kilometers. Including the surface located inside the Moroccan territory (1905 Km^2) the basin has a total surface of 7 245 km^2. Two wilayas are integrated in the basin: Tlemcen and Ain Témouchent. Part of the Basin is included in the Moroccan territory.

Thirty-eight municipalities (38) are integrated in the Tafna basin of which 35/53 of the wilaya of Tlemcen and three 03/28 of the wilaya of AinTemouchent.

According to the new structure of hydrographic units in Algeria, the watershed of Tafna belongs to the whole of Oranie -Chott Cherguie. It is limited to the North by the West Coastal sub-basin of Oran, to the North East by the Central Coastal sub-basin Oran, to the East by the Macta basin, to the South by the Chott Chergui basin and to the West by the Morocco (Rahmi, 2014). It carries the code 16 among the 17 basins of Algeria (Benmoussat, 2012).

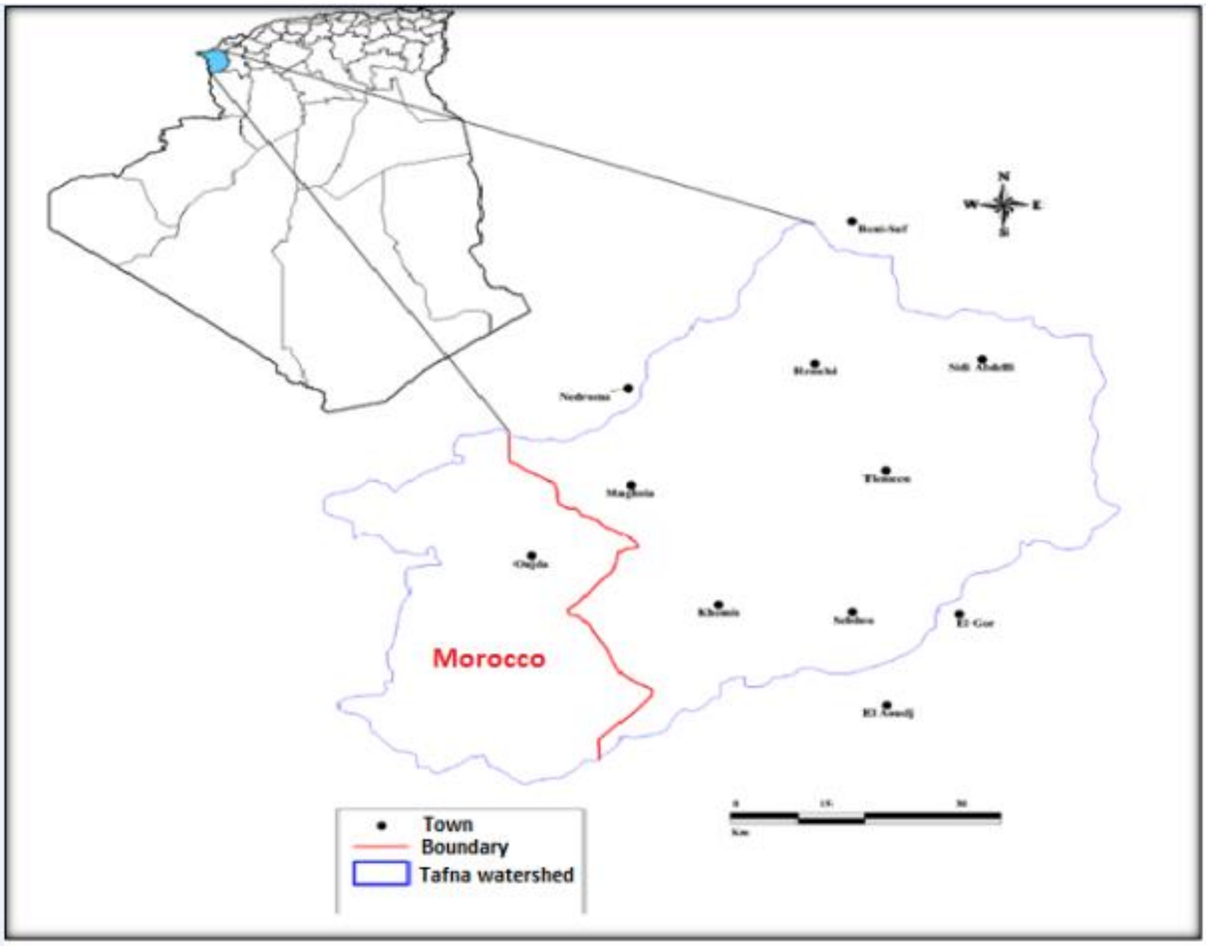

Figure 2. 1: Location of the Tafna watershed (Benblidia et al.,2010)

2.3 Delimitation of the basin

The Tafna watershed is delimited as follows (Figure 2.2 and 2.4):

- In the North-West: Bab el Assa, Djebala, Nedroma, Beni khelad and Honaine municipalities.
- North: the Mediterranean Sea.
- Northeast: Wilaya Ain Témouchent.
- South: The 04 steppe municipalities (Bouihi, El Gor, sidi Djillali, El Aricha).
- In the West: Morocco.
- In the East: wilaya of Sidi Bel Abbes, municipality of Ain Tellout (Benmmoussat, 2012).

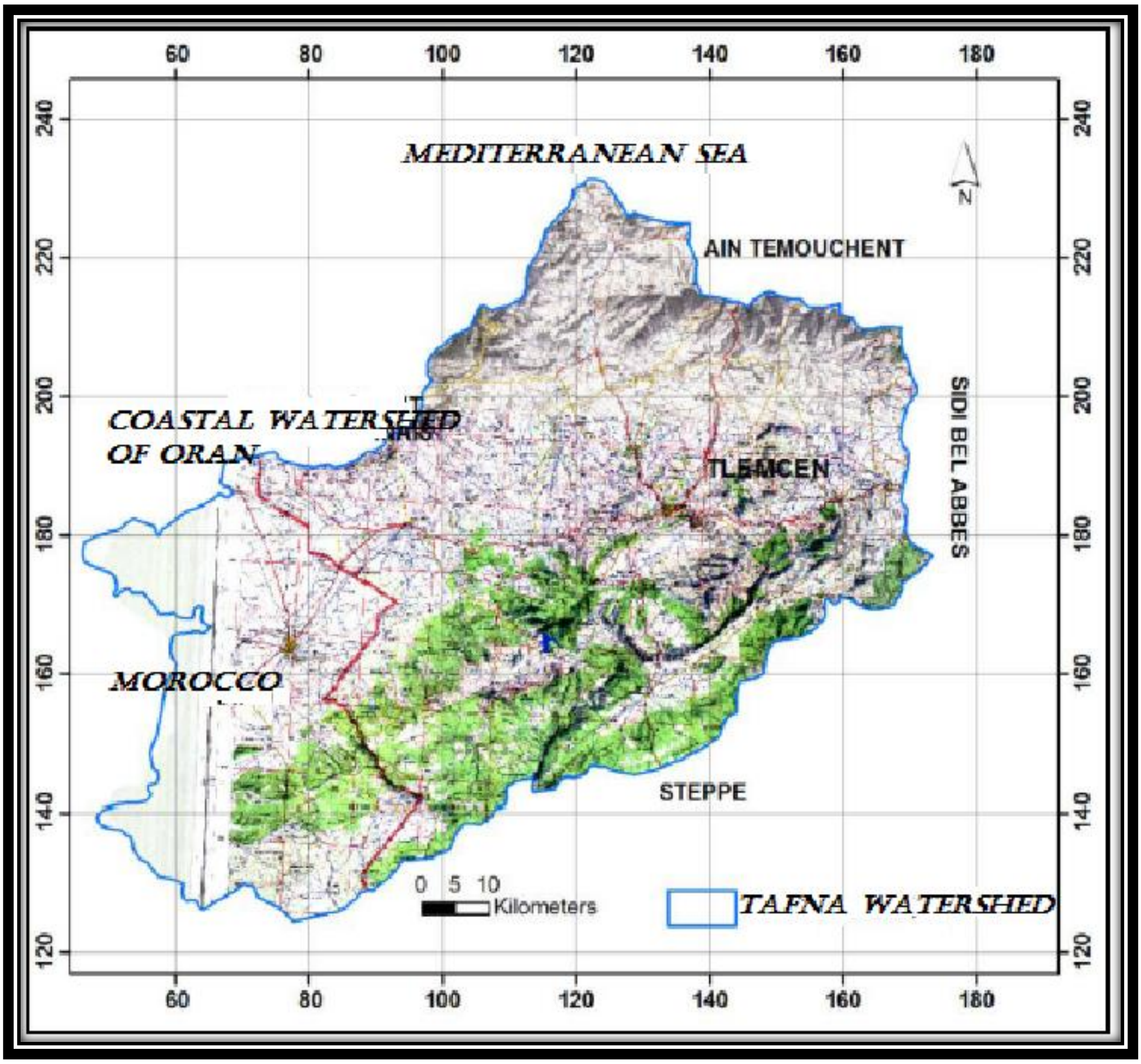

Figure 2. 2: Delineation of the Tafna watershed

The Tafna basin consists of 08 sub-basins, two of which are upstream in Moroccan territory (Figure 2.3). (Rahmi, 2014)

- The Oued Isser sub-basin (Bensekrane).
- The sub-basin of Oued Isser (Remchi).
- The sub-basin of Oued Lakhdar (Chouly).
- The sub-basin of Oued Sikkak.
- The sub-basin of Oued En Nachef.
- The sub-basin Oued Ouardefou.
- The sub-basin of Oued Boukiou.
- The sub-basin of Oued Mouillah.

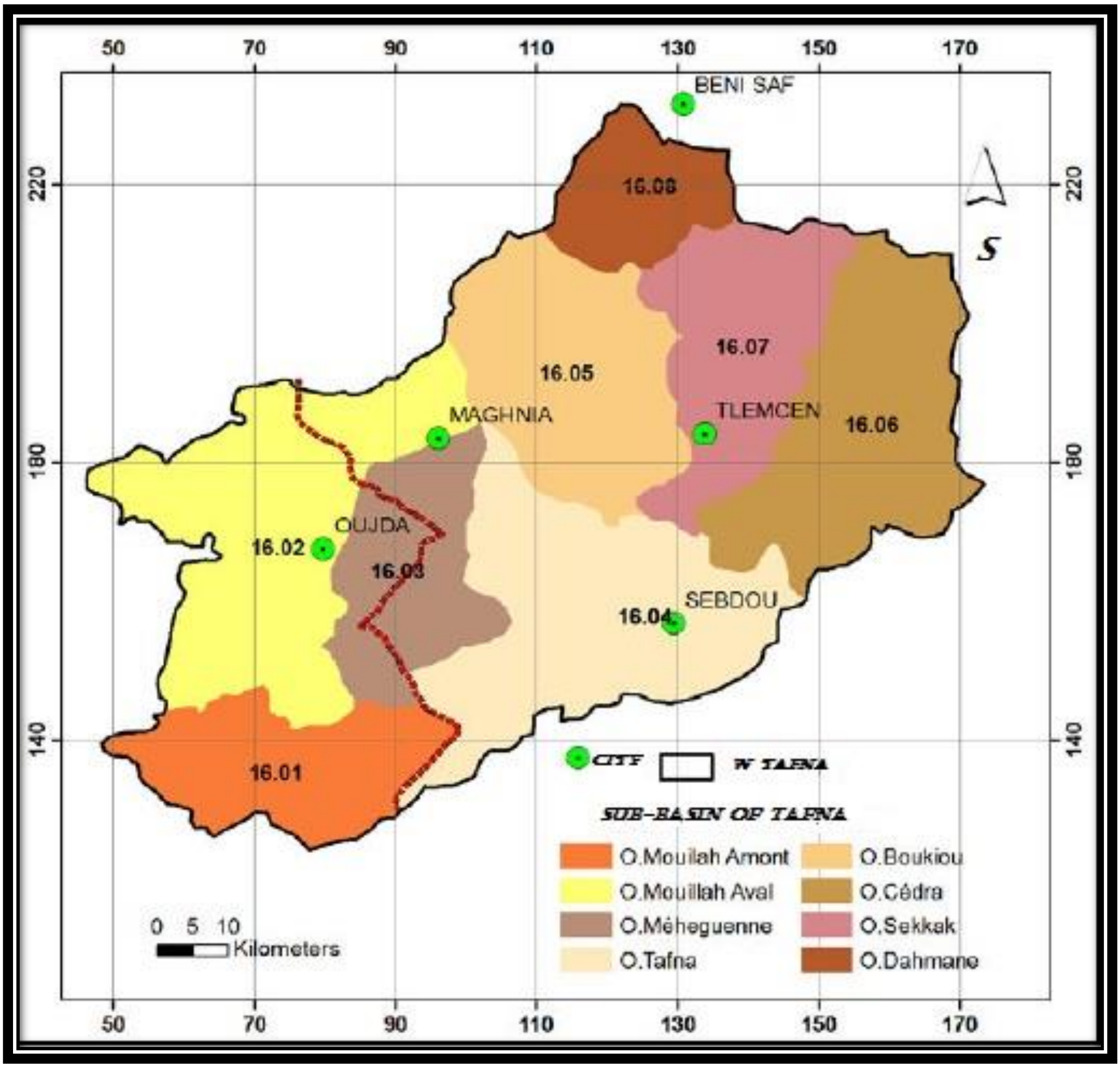

Figure 2. 3:Sub-basins of the Tafna (Benmmoussat, 2012).

Table 2. 1 : Physical characteristics of sub-basins

Code U/ Basin	*Name of Basin*	*Name of under-basins*	*Wadis*	*Area (Km ^{2})*	*Average rainfall (mm/y)*	*Average flow annual wadis (m^3/s)*
1601	TAFNA	Upstream Mouilah	Mouilah	745	299	0,382
1602		Downstream Mouilah	Mouilah	1228	341	
1603		Boughrara	Mehaguène	665	339	
1604		Upstream Tafna	Tafna	1294	389	0,025
1605		Tafna-Boukiou	TafnaBoukiou	978	398	0,0167
1606		Isser-Cedra	IsserCedra	1118	421	0;150
1607		Isser-Sikkak	IsserSikkak	825	432	
1608		Tafna Maritime	Tafna	392	362	0,484
TOTAL	**08**	**-**	**7 245**	**372,625**		

INF: ANRH

The basin of the Tafna has a rather elongated form in the whole.

2.4 Basin Geography

The Tafna watershed is diverse in geography. The following areas are distinguished for the part located in the wilaya of Tlemcen (see figure 2.4):(Benmmoussat, 2012).

- **The mountains of Traras:**It is a coastal mountain chain of 1250 Km2 located northwest of the Wilaya of Tlemcen. Its average altitude varies from 500 to 1000 m, peaking at 1081 m at Jebel Fillaoucene.
- **The mountains of SebaaChioukh:** It is a mountainous chain of 250 Km2 located in the North-East of the Wilaya of Tlemcen of an average altitude between 600 and 800

m. This chain is subject to the influences of the semi-arid climate, which accentuates the threat of erosion. (Benmmoussat, 2012).

- **The mountains of Tlemcen :** It is a mountain range of 3000 Km2 located south of the Wilaya of Tlemcen. It extends west to the Moroccan kingdom (Ghar -Roubane) and east to the Wilaya of Sidi Bel Abbes. Its average altitude varies between 1200 and 1500 m culminating at 1843 m in Djebel Tenouchfi. It is relatively well watered with rainfall ranging from 500 to 700 mm / year (Benmmoussat, 2012).
- **Inland plains and plateaus:** located in the center of the Tafna watershed between the mountainous areas. They are the most important agricultural resource in the region. We distinguish :
  - The plain of Hennaya limited to the South by the northern foothills of the Tlemcen mountains and to the north by the Zenata plateau.
  - The plateau of Zenata - OuledRiah located in the North West of the plain of Hennaya.
  - The Sidi Abdelli- Ain Nehala plateau located on the right bank of Oued Isser north of Ouledmimoun.The water capacity is very important on the plateau.
- **The Maghnia plain**: limited to the north by the southern foothills of the Traras, to the south by the northern foothills of the Tlemcen mountains and to the west by the Angad plain (Morocco).
- **The Grand Tlemcen:** gathers the municipalities of Tlemcen, Mansourah, Chetouane where the urbanization occupies an important space with a high concentration of population.
- **The high steppe plains :** They limit to the south the basin with the highest point Jebel Makaidou at 1320 m altitude. The municipalities of El Bouihi, Sidi Djillali and El Gor occupy this space.

In this zone, the water supply is very low and the underground resources are deep. Despite the fact that forests and maquis cover these massifs, they suffer degradation caused by the intense erosion of the soil (ABH, 2018).

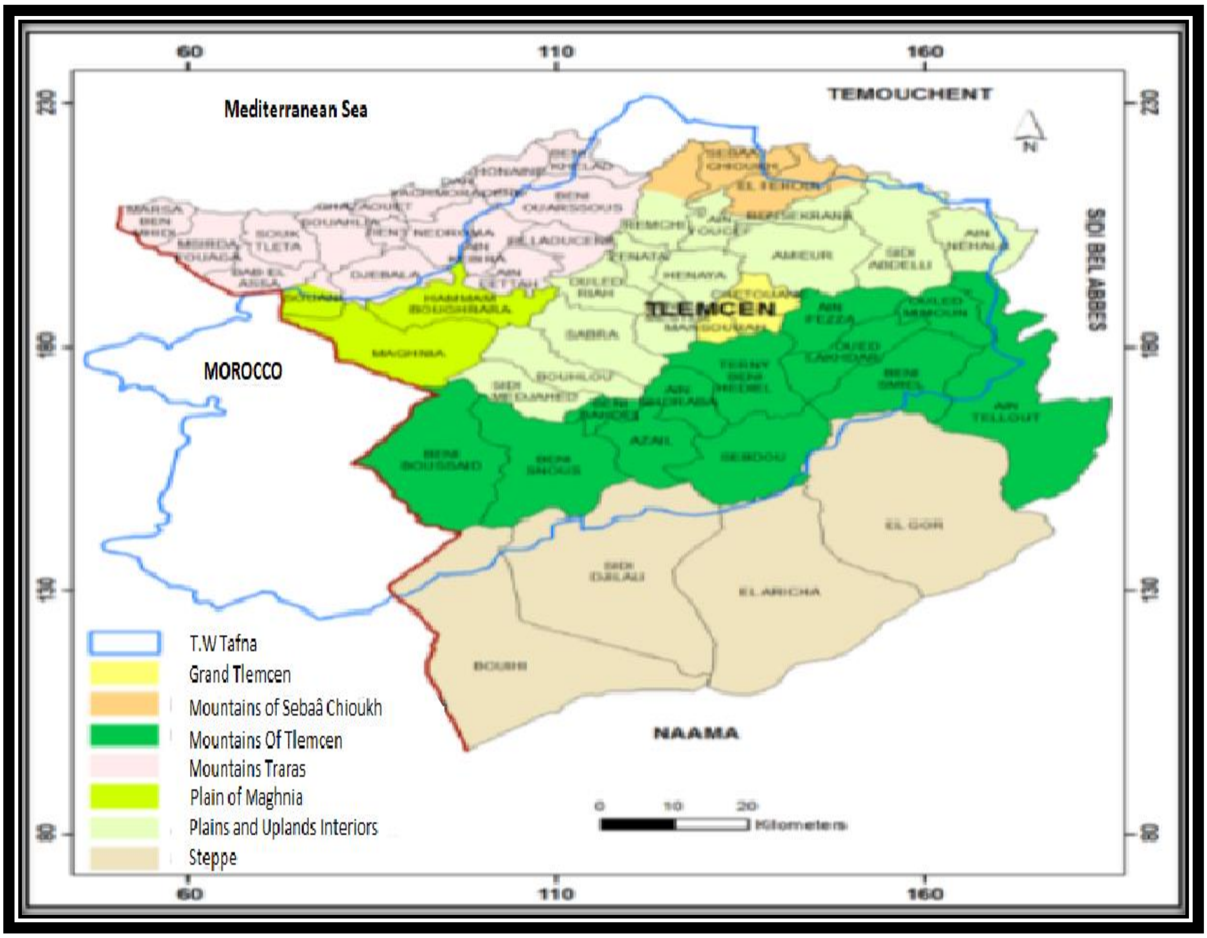

Figure 2.4 : Geographical setting of the Tafna basin and the wilaya of Tlemcen (Benmmoussat,2012).

2.5 Hydrography

The Tafna hydrographic network is made up of an important ensemble of oued and chabat that all pour into the Tafna oued (see figure 2.5), either directly or through one of its tributaries. The number and size of tributaries decrease considerably from south to north (Rahmi M, 2014).

The formation of the hydrographic network is strongly conditioned by the characteristic factors of the lands traversed by the various wadis. Thus lithology intervenes on the degree of ramification of wadis. This is the case of the oued Tafna which crosses the limestones of the Tlemcen Mountains and follows the direction South-West, North-East of the dominant relief represented by the mountain range of the Traras and the Tlemcen Mountains (ABH, 2018).

Several tributaries form a discontinuous hydrographic network in time and space. Others are temporary because they are not fed by springs and thus depend on rainfall. The number and size of tributaries decrease considerably from south to north (Benikhlef A, 2008).

The relief layout and the abundance of impervious rocks combined their effects and resulted in the creation of a major river system. This hydrographic network consists mainly of two fluvial arteries (Benikhlef A, 2008) :

- Oued Tafna in the West
- Oued Isser in the East

- ***Oued Tafna***

  The oued Tafna is a 170 km long river, it has its source in the mountains of Tlemcen. The course of this oued can be subdivided into three parts (Bouanani A, 2003):

  - **High Tafna**: The oued originates in Ouledouriach as far as Sidi Medjahed.
  - **The average Tafna**: from Sidi Medjahed to the Tahouart gorges to the village of Hadjeret El-gat.
  - **Lower Tafna**: Lower lure of Tafna extends from the Tahouret gorge to the village of Pierre Chat at Rachgoun beach, for a distance of 20km.

- ***Oued Isser***

  The Oued Isser is born in the Jurassic lands of the Tlemcen mountains and extends eastwards to the region of the upper Tafna.A 'Ouled Mimoun by the Lakhdar oued (EX: Chouly) (left bank) and the oued Ain Tellout (right bank). (Benikhlef A, 2008)

  The flow in the watershed oueds of Tafna is characterized by (Benikhlef A, 2008) :

  - Heavy dependence on rainfall.
  - A strong irregularity between monthly and interannual.
  - Floods with very high instantaneous flow that can cause flooding (Aziz S., 2011).

  In addition, the flow of low water is very low to zero spreading from May to October.The watershed can be subdivided into three major parts that encompass the main Oueds of Cebassin (Bouanani A, 2003) :

  - Eastern part with Oued Isser, oued Lakhdar and oued Sikkak as main tributaries.
  - Western part including High Tafna (oued Sebdou and oued Khemis) and wadi Mouilah.
  - Northern part: which starts practically from Tafna village and extends to the beach from Rachgoune, the mouth of the Tafna on the sea. Oueds Boukiou,Boumessaoud and Zitoun are the main tributaries of this part.

Table 2. 2 : Density of drainage

Watershed	*Area Km²*	*Linear Total Km*	*Density of drainage Km/ Km²*
Tafna	7 245	3 621	0,50

INF: AGIRE

The graph below represents the main oueds with their respective lengths per sub-basin

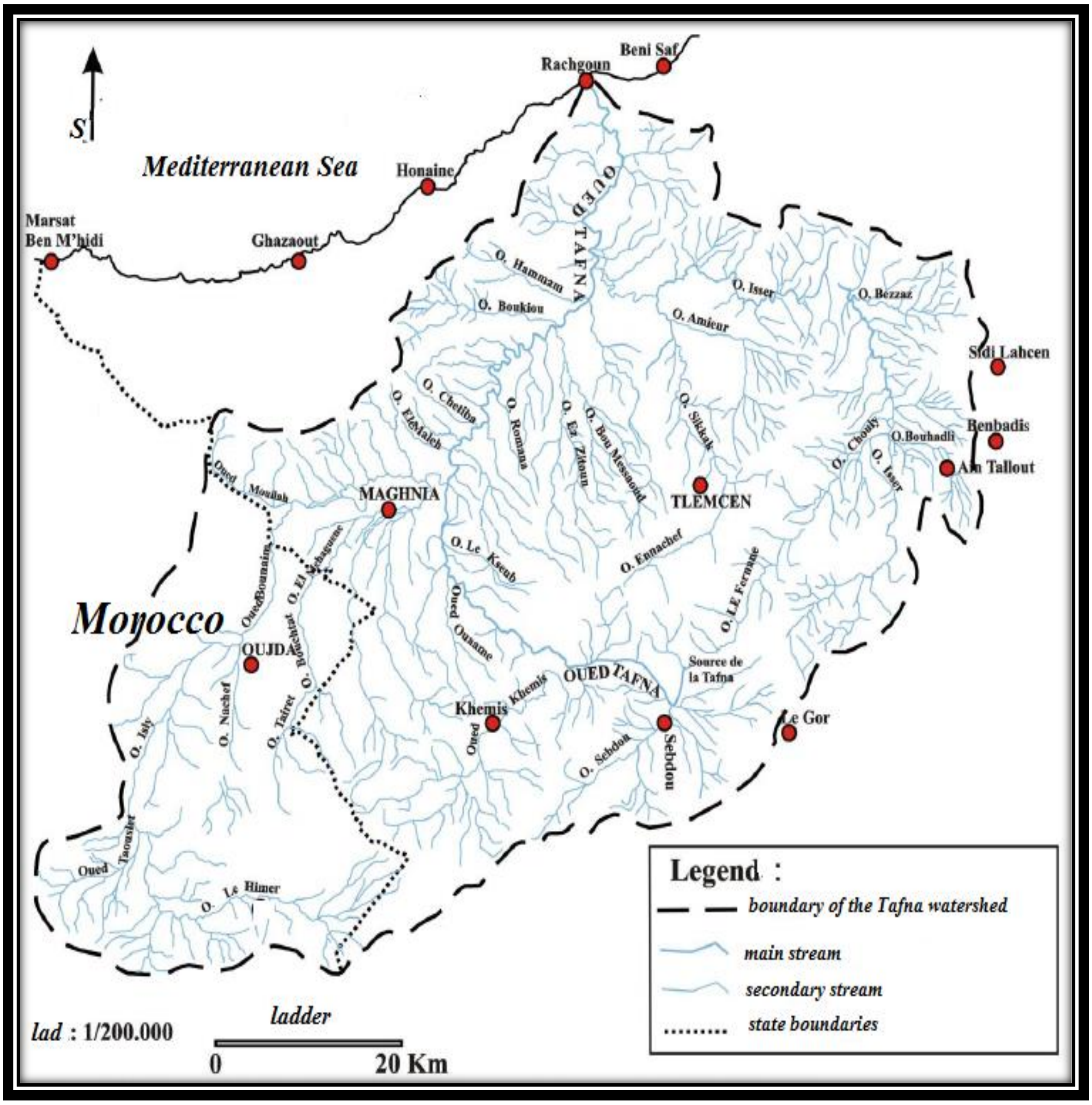

Figure 2. 5 : Hydrographic Network Map of the Tafna Watershed (Gherissi R., 2012)

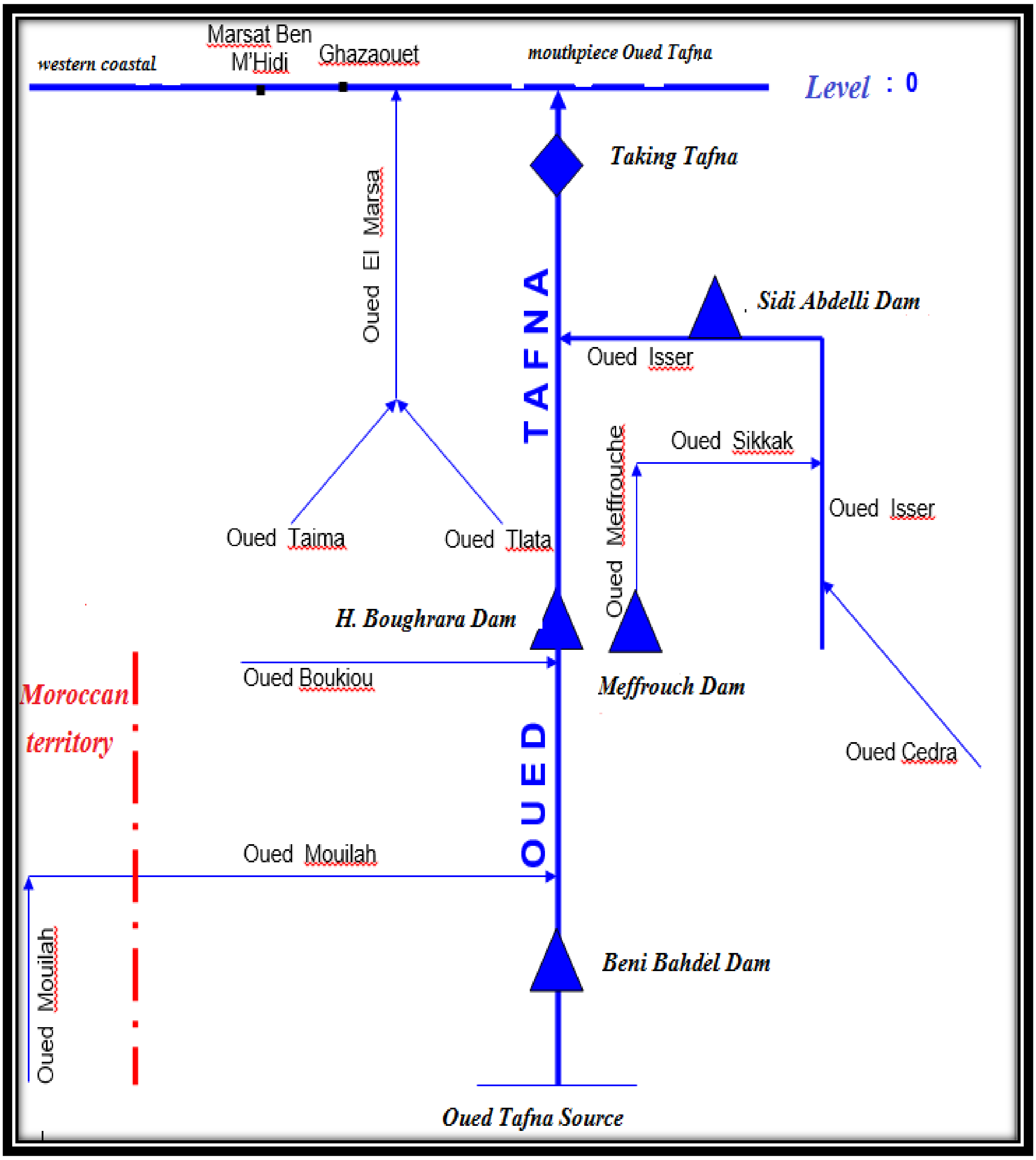

Figure 2.6 : General outline of the hydrographic network (ABH, 2018)

2.6 Geological appearance

From a geological point of view, the Tafna watershed is composed of two structural units (Haicha B, 2008) :

- A Atlasic set in the South
- An Alpine ensemble in the North

With a predominantly Karstic upstream and downstream that is subject to the influence of effusive volcanic activities.

The main geological formations of the basin are (Benmoussat A., 2012) :

- **North:** The mountain ranges of the Traras made up of Jurassic formations composed mainly of limestone, marl and marly limestone which extend under the marly Miocene beds.
- **In the center:** heavy accumulations of ancient alluvial formations covered with upper and lower Miocene marine alluvial deposits and more recent lacustrine deposits. Recent alluvial formations are localized throughout valleys and especially in the lower Tafna.
- **South :**The calcareous massifs of the Tlemcen mountains consist of carbonate and dolomitic Jurassic terrains which present a significant karstification permitting the infiltration of rainwater. This karstic water resurfaces through a large number of springs.

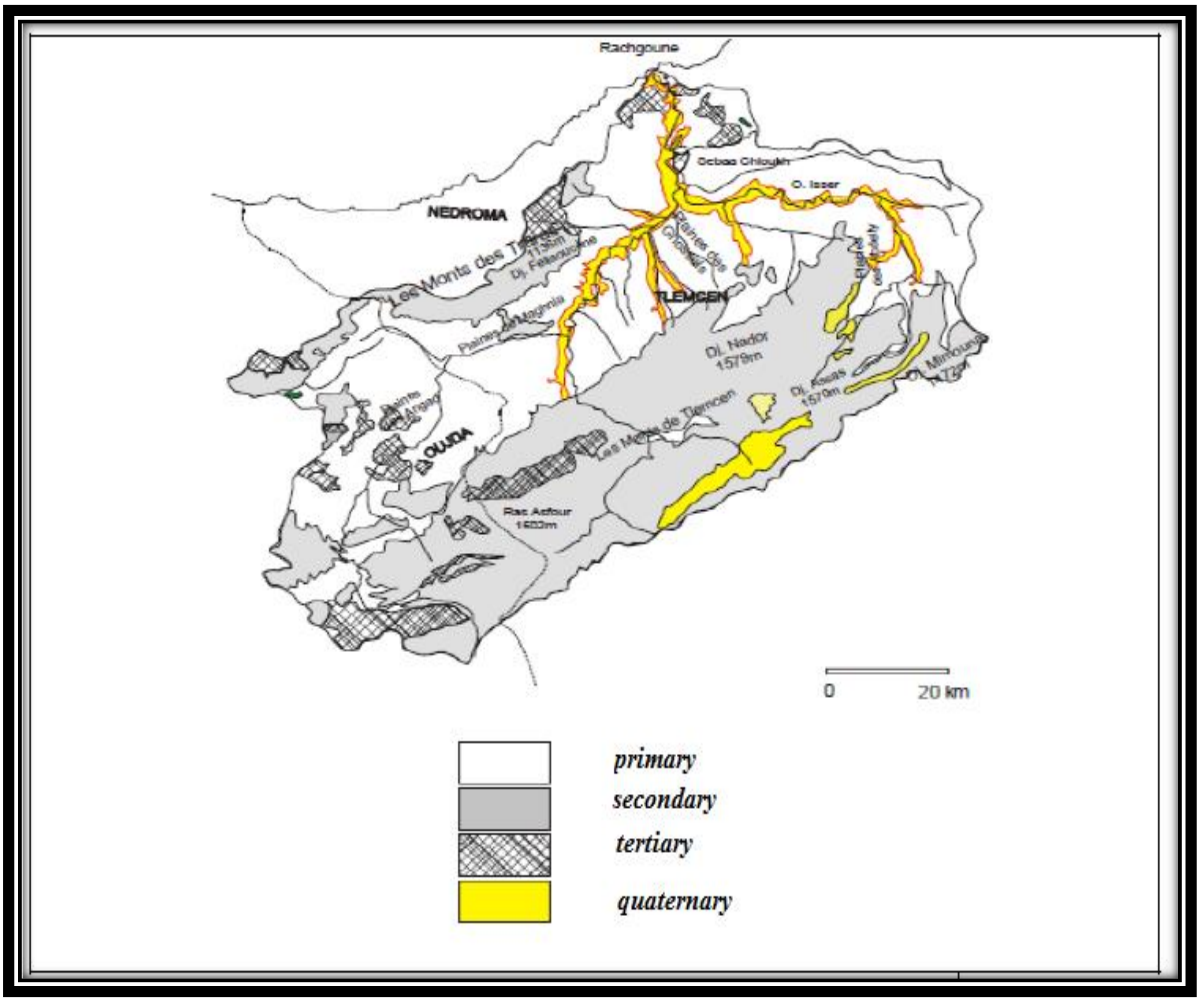

Figure 2. 7 : Geological map extract of the Tafna watershed (Rouissat B, 2015)

2.7 Hydrogeological aspect

The structure and the lithological nature of the geological formations constituting the Tafna basin make it possible to revisit several types of aquifers (Cheriguene I, 2011):

- Phreatic aquifers constituting porous formations (sandstone) occupying restricted areas in the studied basin.
- The aquifers karstic most often lost dominate the zones of reliefs (Khemis, Tlemcen, Sebdou).
- The aquifers captives represented also by carbonated formations but which go deep under the marls of Serravallian.

According to the hydrological data of the region, four regional level aquifers are identified at the basin level at the scale of the Tlemcen wilaya (Rouissat B, 2015). These sheets are located at the level of figure 2.8.

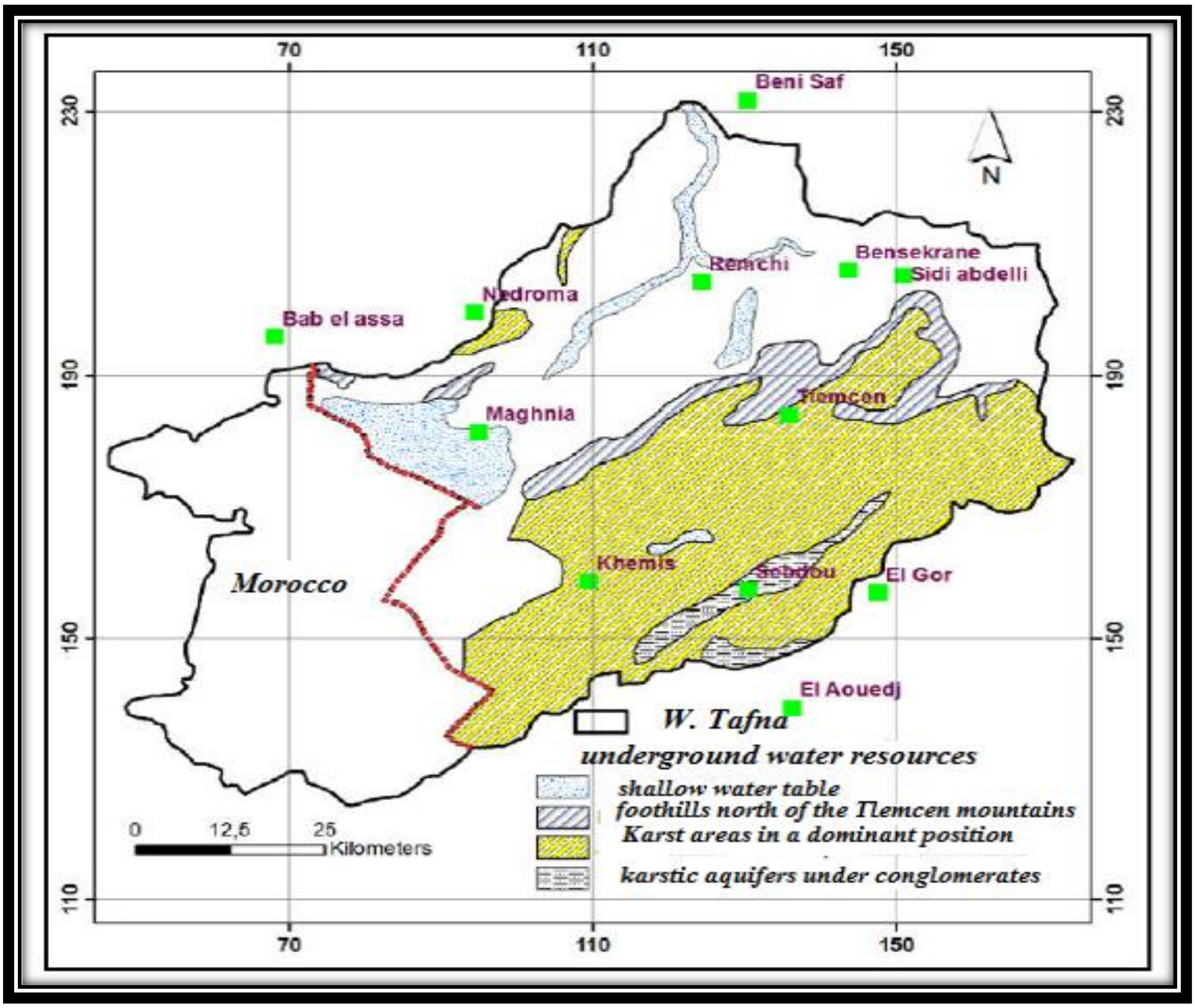

Figure 2.8 : Groundwater Potentialities in the Tafna Basin (ANAT, 2000)

- **The water table of the Tlemcen Mountains:**

The Tlemcen mountains, which cover an area of about 3,000 km^2, are very well watered, between 500 and 800 mm per year. The presence of Jurassic carbonate rocks karstified outcropping that much of the precipitation is infiltrated, between 200 and 400 Mm^3. This sheet, which has a large power, can only be exploited by drilling, the depth varies in places between 100 m and 400 m (Rouissat B, 2015**).**

- **The Maghnia water table:**

This aquifer covers a horizon of 351 km^2 and is fed mainly by precipitation infiltration and the underground discharge of the Jurassic formations of Ras Asfour. The sheet is shallow (between 10 and 20 m), so it is accessible by simple well, which makes it subject to heavy exploitation (Rouissat B, 2015**).**

- **The water tableof Zriga:**

This water table is of the same formation as that of Maghnia since it constitutes the North-West extension of it. Its slightly brackish quality makes it difficult to exploit directly (Rouissat B, 2015**).**

- **The water table of Hennaya :**

It is an alluvial complex that stretches over an area of 14 km^2. This water table is shallow with a power of about 7 to 8 m. Alluvial type plies and smaller power are also identified. This is the tablecloth of the upper and lower Tafna, the water table of Ghezouanah, the tablecloth of Oued Kiss, the water tabke Oued Boukiou and Oued Dahmne (Rouisaat B,2015**)**

The abundance of faults in the study area would be the main cause of the compartmentalization of the different aquifer systems and the first source also of the different resurgences existing in the Tafna basin. These tectonic accidents are also responsible for the especially heterogeneous distribution of the majority of these systems (Bakreti A, 2014).

The underground flow of the Tafna is an underground reservoir of the most important. The majority of the sources are mainly the Karstique cave of Ghar Boumaaza upstream emergent faults and breaks, which have the role of an impermeable screen by marly limestone pinching or Boumediene sandstone or by Brèches sedimentation. The hydrographic network is in the form of a narrow valley with a steep slope (Haicha B, 2008).

Sub-basins are essentially formed by permeable to semi-permeable formations occupying almost the entire surface of the basin, which favors the infiltration of surface water (Cheriguene I, 2011).

The highest concentration of strongly karstified permeable formations is located mainly at the level of the sub-basins of the high Tafna: Khemis, Sebdou or Beni-Bahdel with more than 85%. Other formations with low permeability with absence or little karstification occupy almost 78% from the Maghnia Plain, Zenata (Bakreti A, 2014).

2.8 Geomorphology

Altitude

In the Tafna watershed, the altitude also varies from upstream to downstream, it is maximum at the source (Ghar Boumaaza) or it is 1090m and 1020m upstream of Oued Khemis . It is between 350m and 600m at the dam of Beni Bahdel and Wadi Mouilah. It decreases up to 245m to the wadi of Sikkak and 80m to the wadi of Isser.The altitude value continues to decrease until it reaches 1m at the Rachgoun Estuary (Rahmi A,2014).

Slope

In the Tafna watershed, the slope varies from upstream to downstream (see Figure 2.9). It is weak at the source since it is a plateau (GharBoumaaza), then it becomes important from the town of Sebdou, the high Tafna, to the dam BniBahdel where the slope is greater than 25%.

Downstream the average Tafna continues to have a medium slope that is becoming weaker and weaker. The slope gradually decreases until the mouth at Rachgoun or becomes very weak or even zero (Rahmi A, 2014).

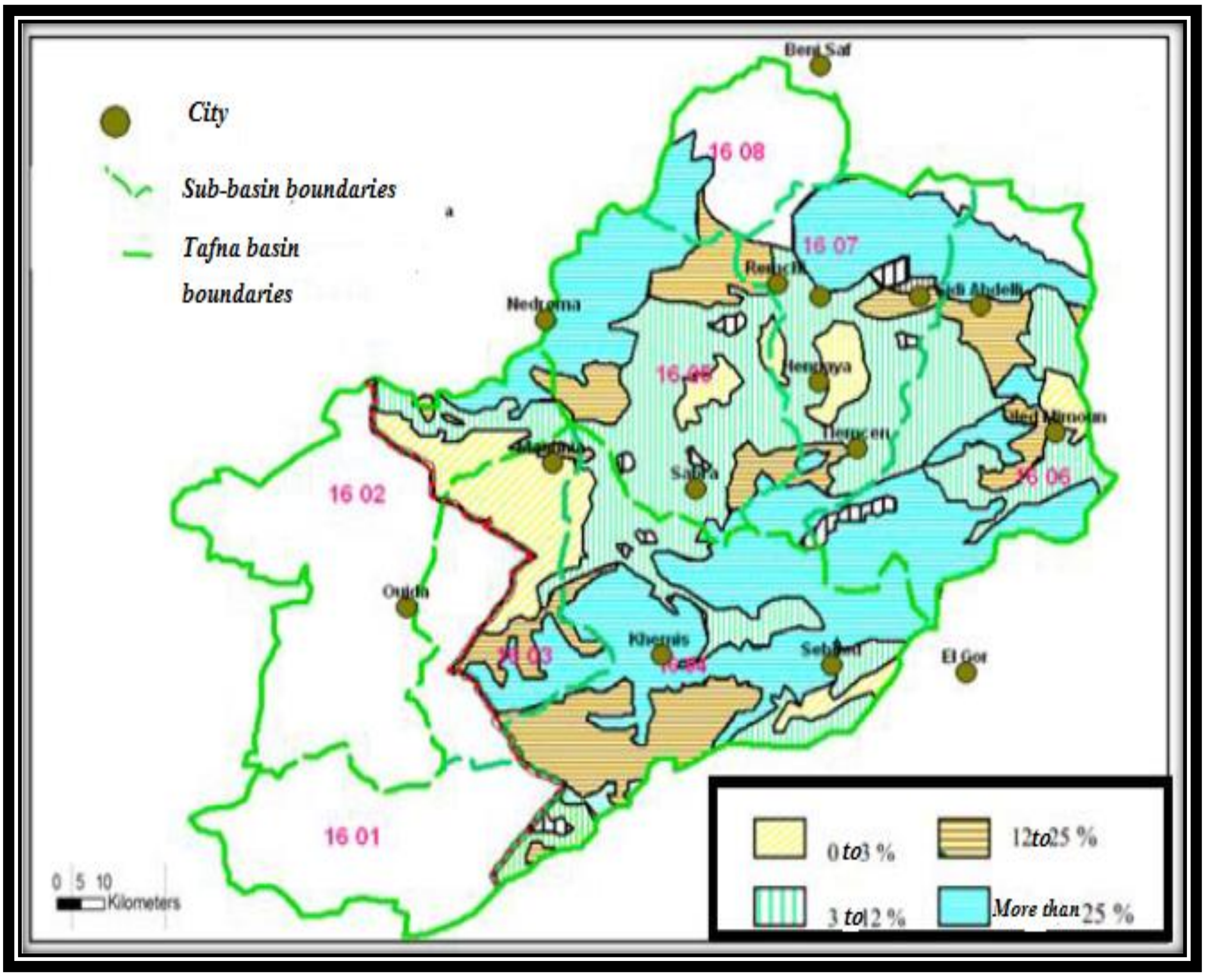

Figure 2.9 : Map of the slopes of the Tafna Watershed (Rahmi A, 2014).

2.9 Soil appearance

The watershed of Tafna consists of four major groups (Bouanini A, 2003):

- Stony lands at the foothills of the Tlemcen and Traras mountains;
- The marly lands, covering a large part of the Tlemcen region;
- The red lands encroutement, located in the plains of Maghnia and OuledRiah ;
- The alluvial lands covering the low terraces and the major beds of the wadis.

2.10 Climatology

In general the Tafna basin is similar to that of the entire Mediterranean region of North Africa, it is soft and wet.The average annual temperature is around 15.50 ° C, the hottest two months are July and August, and have an average temperature of 26 ° C (Benikhlef A,2008).

The general rainfall regime is that of the Mediterranean semi-arid zones of North Africa; characterized by a long period of drought. Winds are moderate predominantly north and northwest (Benikhlef A, 2008).

The bioclimate is of a semi-arid type, modulated by the proximity of the sea to the North and by the increase of altitudes towards the South (see Figure 2.10), the dry period can sometimes extend up to six months (Benikhlef A, 2008).

Rainfall in the Tafna basin is unevenly distributed: the areas with the highest rainfall are the basins at altitude with 400 mm and the plain basins are the least watered with an average less than 300 mm. The irregularity of the precipitations, the strong evaporation and the episodic snow periods are the characteristics of the Tafna basin (Bakreti A, 2014).

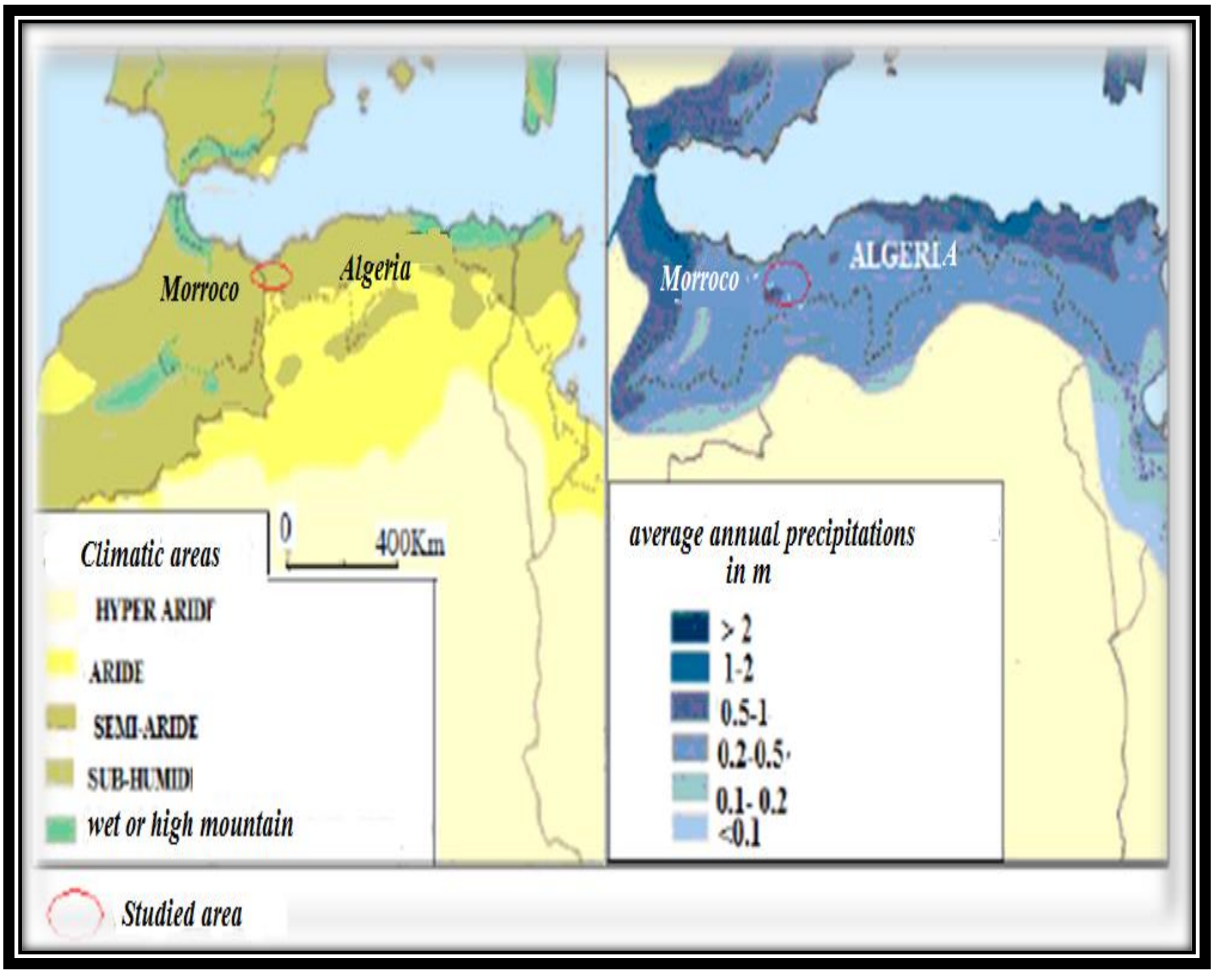

Figure 2.10 : General climate of studied sector (Bakreti A, 2014).

2.11 Conclusion

The Tafna watershed is counted among the major watersheds of North West Algeria, with an area of 7242 km². It consists of 8 sub basins.From a geological point of view, the Tafna watershed is made up of two structural units, an Atlasic group in the South and an Alpine complex in the North.Its hydrographic network consists mainly of two fluvial alterations, namely Tafna wadi in the west and Wadi Isser in the east.

The watershed is characterized by a bioclimate is semi-arid type, modulated by the proximity of the sea to the North and by increasing altitudes to the South.

In water resources; currently, the watershed of Tafna includes five functional dams and four layers are identified at the level of the wilaya of Tlemcen.

This leads us to evaluate these water resources in their different types and to calculate the different water needs in the Tafna watershed. On this basis, the following chapter will be based on this research.

CHAPTER THREE

ASSESSMENT OF WATER RESOURCES AND NEEDS IN THE TAFNA WATERSHED

3.1 Introduction

The rapid increase in the need for drinking water in the Tafna watershed is important. A long period of drought has also led to overexploitation of so-called conventional water reserves until a large part of them has been used up. Faced with such a situation, the public authorities resorted to desalination of seawater as a new alternative to support other resources and fill the gap (MRE). This project involves optimizing the use of the TW water resource.

In this chapter, we will present the hydraulic situation of the Tana watershed during the year 2017, as well as the consumption of drinking water, the calculation of the current water needs and the estimation of the future water needs (domestic, equipment, industry and agriculture) at different horizons to balance water supply and demand in the Tafna watershed.

3.2 Water resources

The basin is of great socio-economic interest for the western region of northern Algeria. It provides water for the populations of many communes and provides for the needs of the agricultural and industrial sectors, which are very active in the region. Transfers of water inside the basin but also outside to the metropolises of Oran and Ain Temouchent (Bakreti A., 2014)

3.2.1 Underground resources

Groundwater is an important part of the water cycle and is part of natural balances. They are also a great renewable resource, exploited for the supply of drinking, industrial use or agricultural water.

According to the hydrological data of the region, seven regional water tables are identified at the basin level at the scale of the Tlemcen wilaya. They are listed in Table 3.1 with exploitation volumes of these underground reserves (DRE, 2018).

Table 3.1 : Fishable volumes of groundwater resources in the Tafna watershed (DRE, 2018)

Name of water table	*Potentials (Mm³/y)*	*Volume in operation (Mm³/y)*	*Operated volume AEP (Mm³/y)*
Mountains of Tlemcen	80.00	12.00	7.11
Mountains of Traras	6.50	0.90	/
Plains.Maghnia+Zrigua	17.00	14.15	0.90
Ghazouanah water table	1.70	1.00	0.90
Boukiou water table	1.50	1.20	0.20
Hennaya water table	3.20	2.10	0.20
Total	109.90	31.35	9.31

INF : DRE

3.2.2 Superficial resources

3.2.2.1 Large dams

The Tafna watershed contains five large dams in operation: Béni Bahdel Dam, Meffrouche Dam, Sidi Abdelli Dam, Hammam Boughrara Dam and Sekkak Dam.The table 3.2 summarizes the capacity of dams in the Tafna Basin and Figure 3.1 shows the distribution of surface resources in this watershed.

Table 3.2: Fishable volumes of surface water resources in the Tafna Basin (DRE, 2018)

Dam name	*Ability of detention (Mm³)*	*Regularized volume (Mm³)*	*Survey Bathy-metric in 2004 (Mm³)*	*Volume at 01/03/ 2018 (Mm³)*	*Volume of water allocated for AEP in 2017 (Mm³)*	*Volume of water allocated for irrigation in 2017 (Mm³)*
Meffrouche	15	15	15	2.828	06	2
Béni Behdel	56	56	45	13.123	19	8
Sidi Abdeli	110	57	106	69.946	25	6
Hammam Boughrara	177	59	175	158.892	24	15
Sekkak	27	22	27	25.5	6	3
	385	209	377	270.289	80	34

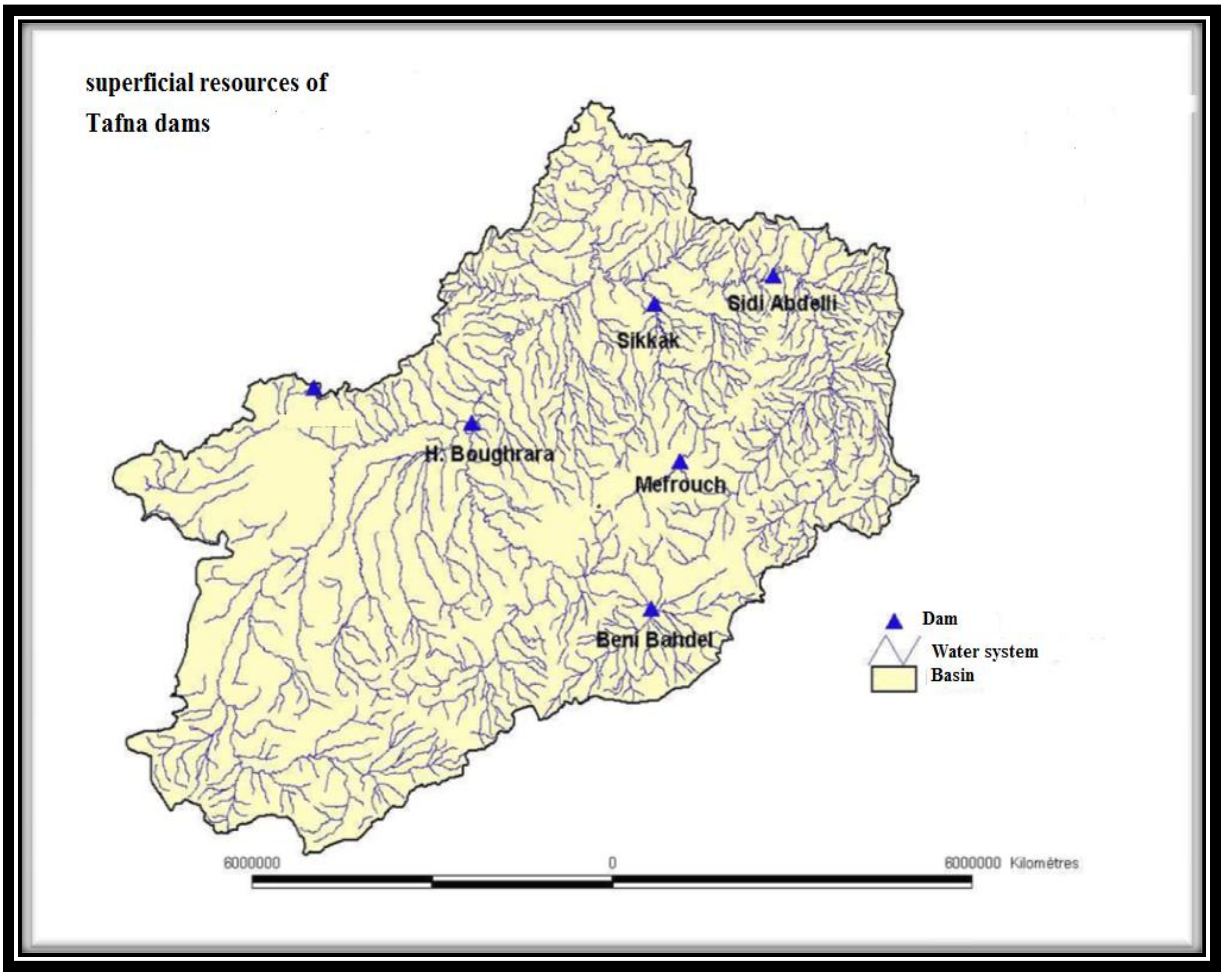

Figure 3.1 : Surface mobilization by large dams in the Tafna watershed (Rouissat B., 2015)

3.2.2.2 Small dams and hill dams

Small dams are of local importance, they are generally intended for the irrigation of small perimeters. With a number of 12 small dams and reservoirs in the Tafna basin, the mobilization capacity is 7.59 Mm³. There are other hillside reservoirs in the Tafna watershed, but the majority of these structures have had pathologies related either to their accelerated siltation or to the degradation of the flood evacuation structures (DRE, 2018).The table below represents the capacity of small dams in the Tafna basin.

Table 3.3: Capacity to mobilize small dams and reservoirs in the Tafna basin (DRE, 2018)

N°	*Year of realization*	*Name of the strucure(OUED)*	*Height (m)*	*Current capacity (m³)*	*Superficie irriguée Ha*
1	1990	Oued Atchane	18,00	500 000	89
2	1990	Oued Tiloua	18,50	350 000	60
3	1984	Sidi Snouci	13,00	400 000	25
4	1980	Chaàbet Alia	14,00	400 000	20
5	1990	Guettara	14,50	300 000	66
6	2004	Oued Khalfoun	16,00	1000 000	125
7	2008	Oued Zouia	23,60	2000 000	30
8	2013	Bahloula	14,90	1200 000	50
9	2010	Oued Mazer	4,25	140 000	3
10	1991	Oued Aich	18,00	750 000	50
11	1988	Magoura	8,30	300 000	60
12	2010	El Abed	9,30	250 000	10
Total				**7590 000**	**588**

3.2.3 Unconventional resources

In recent decades, water supply has been gradually reduced in all regions of the country. Several factors have contributed to the depletion of this resource, particularly the decline in rainfall. Unconventional water resources, and especially seawater desalination, have been developing strongly for two decades. They offer solutions to secure water resources for cities, their potential for development is considerable if we consider the demands they could meet.

Like the Tafna basin at the border of the Mediterranean Sea, Tlemcen benefited from two seawater desalination plants, which are currently in operation to strengthen its hydraulic potential, in the last ten years, it has also adapted wastewater treatment technology for reuse for agricultural purposes.

3.2.3.1 Desalination of seawater

The desalination of seawater could, in the framework of the renovation of the choices and modes of management, to be promoted as a strategic alternative to secure supply of drinking water to certain coastal towns and nearby towns (Brahami I. et al., 2016).

Desalination objectives:

- Security of the water needs of the population, industry and irrigation to the short, medium and long-term horizon, and the satisfaction of all the localities concerned,
- Improved drinking water supply in the Tafna basin,
- Improvements of the living conditions,
- Increased time range in drinking water supply.

At the level of the Tafna basin, two seawater desalination plants are present. . These are Souk Tlata and Honaine stations with an average daily capacity of 200000 m3 / d for each station. The table shows the production capacities of the two deesalination plants in the Tafna Watershed (DRE, 2018).

Table 3.4 : Production Capacities of Desalination Stations in the Tafna Watershed

BALANCE OF PRODUCTION OF WATER RESOURCES OF DESALINATION PLANTS YEAR «2017»				
MONTH	**PRODUCTION SDP SOUK TLETA (m^3 /month)**	**PRODUCTION SDP HONAINE (m^3 /month)**	**AVERAGE DAILY PRODUCTION SDP SOUK TLETA (m^3/ d)**	**AVERAGE DAILY PRODUCTION SDP HONAINE TLETA (m^3 / d)**
January	928 171	5 177 093	29 941	167 003
February	1099 644	5 355 140	39 273	191 255
March	1226 160	5 607 690	40 872	186 923
April	1974 000	4 865 460	65 800	162 182
May	2183 330	5 165 902	70 430	166 642
June	2298 000	5 082 240	76 600	169 408
July	2228 900	5 772 944	71 900	186 224
August	2517 200	5 770 340	81 200	186 140
September	2114 700	4 545 270	70 490	151 509
October	2 286 870	5 158 648	73 770	166 408
Total	**18 856 975**	**52 500 727**	**62 028**	**173369**

A. Souk Tlata

The seawater desalination station (SDS) Souk Tlata is located northwest of the Wilaya of Tlemcen, it is commissioned since May 19, 2011, for the purpose of the drinking water supply of nineteen (19) municipalities of the wilaya of Tlemcen is a population of 310 000 inhabitants (see Figure 3.2). Its average daily production is 62,028 m³ / d, ie 22.64Mm³ / year less than its real capacity because of the technical constraints, after the commissioning of the SDS, an average daily improvement of 60 L/d/hab is passed at 150L/d/hab and an improvement in the average distribution time range from 1 day/3 to a daily distribution (Brahami I.et al., 2016).

Figure 3.2 : Suk Tlata desalination Plant

B. Honaine Station

In North-West Algeria, the Wilaya of Tlemcen was the subject of the installation of a station of desalination of seawater in the area of 'Honaïne' (see Figure 3.3). Its average daily production is 173396.m³/d is 63.28 Mm³/ y less than its real capacity, ensuring the drinking water supply of 24 municipalities and the Urban Group of Tlemcen, a population of about 555,000 inhabitants (Brahami I and all.,2016).

Figure 3.3 : Honaine Desalination Plant

3.2.3.2 Wastewater treatment

At the level of the Tafna basin, 08 treatment stations will be exploited in the future. Only 03 stations are functional, these are the Maghnia wastewater treatment stations, the Tlemcen urban group (WTP Ain El Houtz) and Sidi Snoussi. Table 3.5 and Table 3.6 summarizes the details of the wastewater treatment stations in operation and the capacity of the proposed treatment stations in the Tafna basin (DRE, 2018).

Table 3. 5 : Production capacities of operating wastewater treatment plants in the Tafna basin

Infrastructure	*Capacity*	*Water production '2017 'purified wastewater (m³/y)*	*Administrator*
WTP AIN EL HOUTZ	31 000 m³/d	3 887 264	ONA
WTP MAGHNIA	29 000 m³/d	8 531 415	ONA
LAGOON STATION SIDI SNOUCI	1 440 m³/d	379 665	ONA

Table 3.6 : Production capacities of the proposed treatment stations in the Tafna

Wastewater Treatment Plants	*Type*	*Capacity of purification Mm³/y*	*State*
Hennaya	activated sludge	13.04	In project
Remchi	activated sludge	3.504	In project
Sebdou	activated sludge	2.63	In project
Ghazaouet,Nedroma	activated sludge	3.504	In project
Marsat Ben M'hidi		3.504	In project

3.3 Water balance of water resources

Figure 3.4 and Table 3.7 Summarizes, in terms of production capacity of water resources of the Tafna basin in 2017 for the various needs and are respectively.

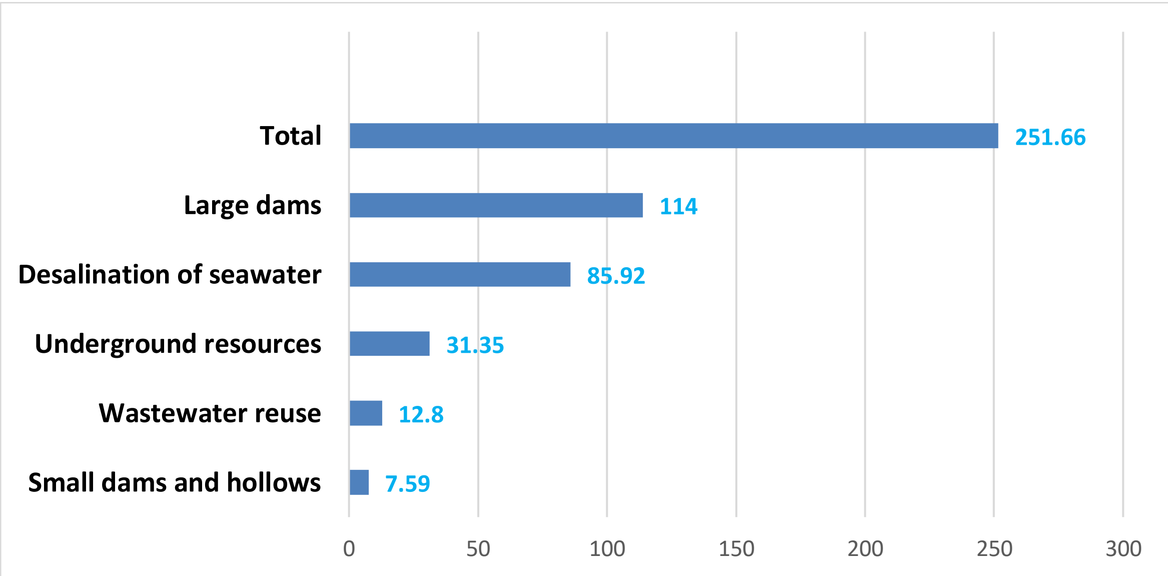

Figure 3.4 : Mobilizable Resources (Mm³) of the Tafna Watershed (2017)

Table 3. 7 : Production according to resources allocated to the Tafna watershed

Year	*Type of water resource*	*Production Mm³/y*
2017	Superficial	121,59
	Underground	31,35
	Reuse of treated wastewater	12,8
	Desalination station	85,92

The table 3.7 represents the volumes produced according to the origin, for the supply of drinking water and irrigation of the TW during the year 2017. The results are represented in the figure below :

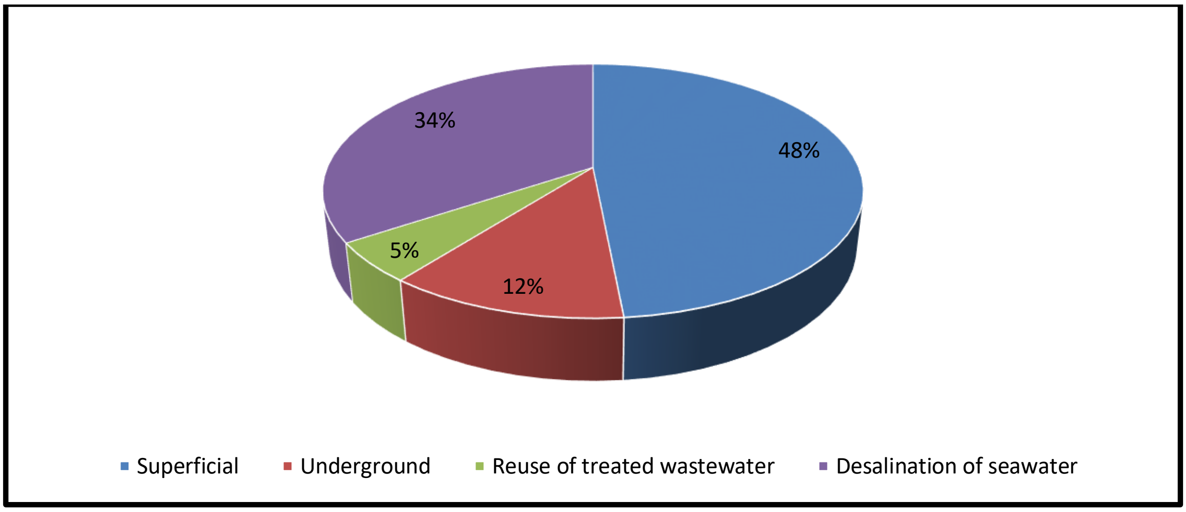

Figure 3.5 : Production according to the resource

According to the figure3.5, the Tafna watershed is currently largely supplied by surface resources 48%, seawater desalination 34%, groundwater 13% and reuse of treated wastewater 5% are exploited only to strengthen or cover the needs of drinking water and agriculture.

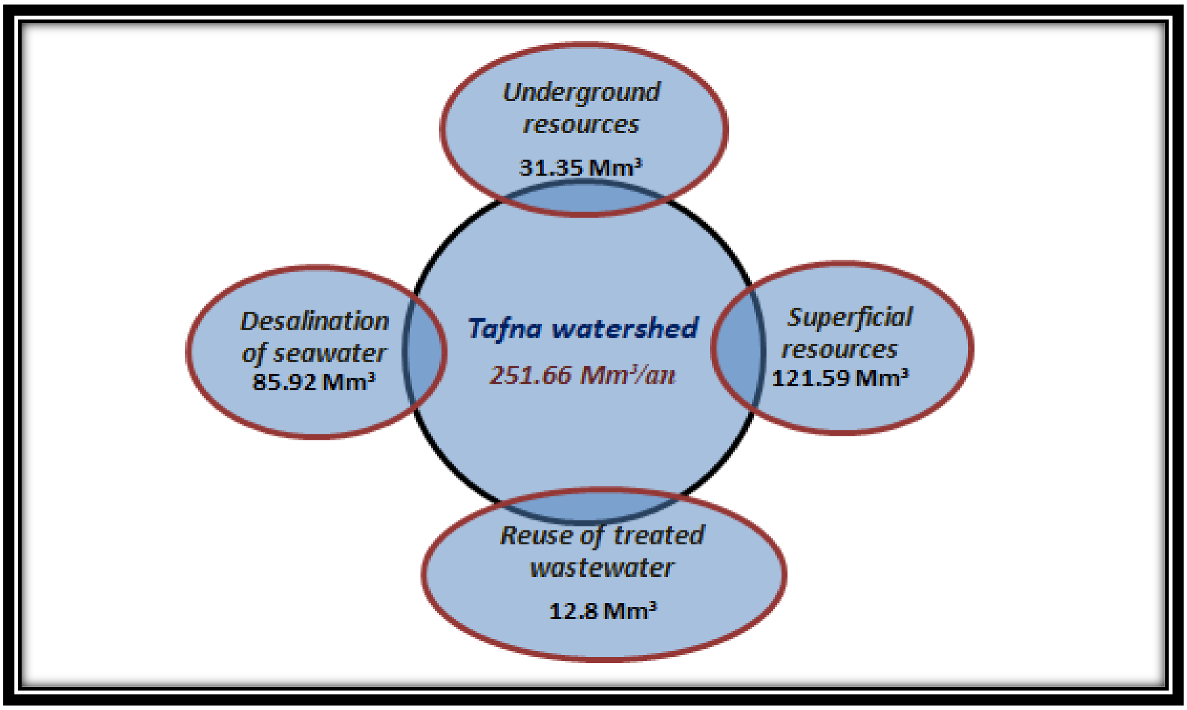

Figure 3.6 : Diagram of the current situation of the Tafna watershed 2017

3.4 Water needs of the Tafna watershed

The establishment of the water policy of a country or region is based on the knowledge of the demand with the greatest possible exactitude so we will try to make a balance between the supply and the demand of water in the Tafna watershed.

3.4.1 Calculation of current water needs

- The water needs of the Tafna watershed include :
- The domestic water needs;
- The industrial and equipment water needs;
- The irrigation water needs.

In order to know the current needs of the TW, we must take into account the evaluation of the current population (2017) as well as the water consumption.

3.4.1.1 Domestic needs

The total population of the wilaya in 2010 was 956,030 inhabitants, a density of 106.6 inhabitants / km². The boundaries of the TW do not constitute a constraint for calculating domestic water requirements since almost all the resources of the Tlemcen wilaya are located within the boundaries of the Tafna basin. Figure 3.7 illustrates the administrative division of the wilaya into communes and agglomerations with respect to the Tafna watershed.

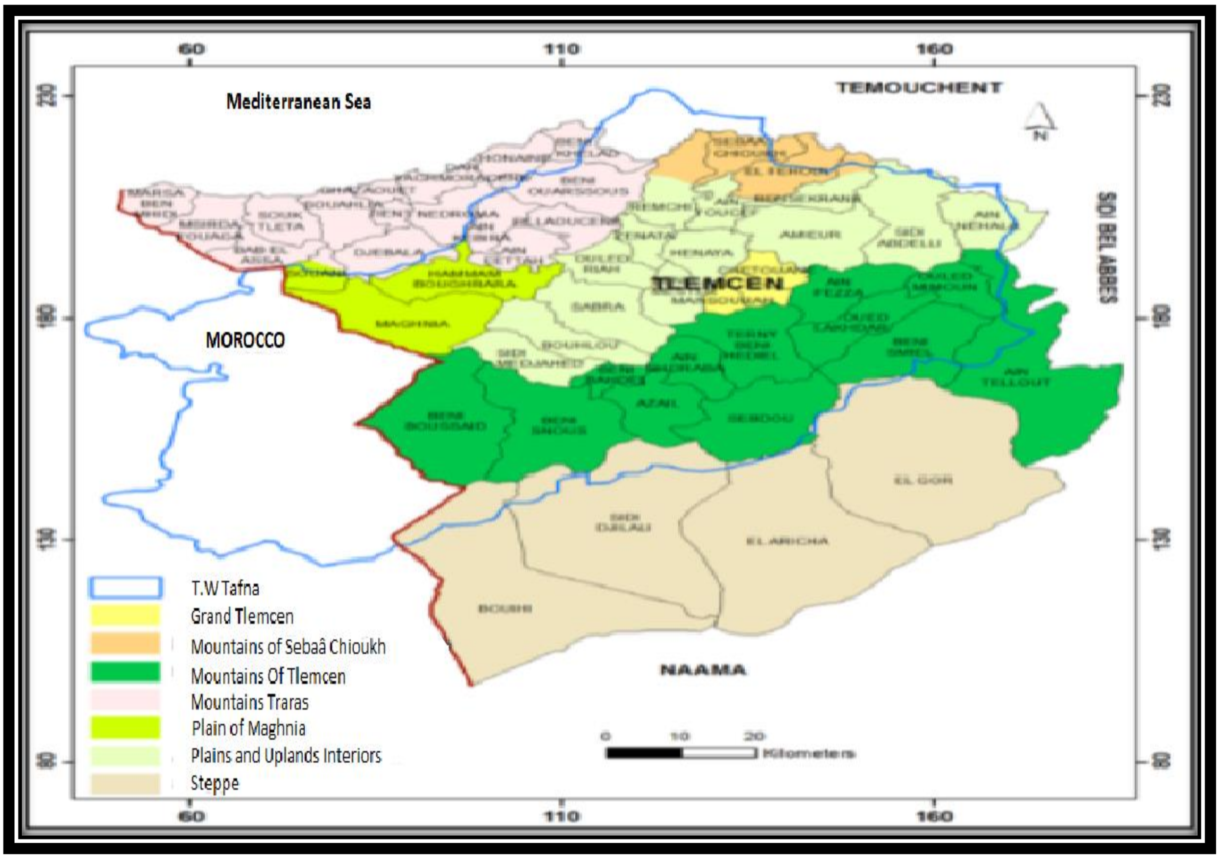

Figure 3.7 : Administrative division of the Tlemcen wilaya with respect to the Tafna watershed.

Table 3.8 : Evolution of the Tafna watershed population at the scale of the Tlemcen wilaya and water needs.

Areas		***Population 2017***
Tlemcen		280655
Lower plains		240726
Mountains of Traras		189644
Mountains of Tlemcen		160472
Maghnia Plain		152180
Steppic zone		37052
Mountains of Sebaa chioukh		12670
Total Wilaya		**1 073 399**
Water needs Mm³/y	***150 l/d/hab***	**59**
	200 l/d/hab	***78***
	250 l/d/hab	***98***

Table 3.8 summarizes the current needs of the population in 2017. These drinking water needs are calculated for the year 2017 using three allocations.

$$\mathbf{Q1 = E * N} \qquad (\mathbf{3.1})$$

$$\boldsymbol{Q1 = 250 * 1073399}$$

$$\boldsymbol{Q1 = 268.349 \frac{m^3}{d} = 97.95\ Mm^3/y}$$

Q1 : Is the water needs of the population in 20017

N: Is the number of inhabitants

E: Is Endowment

The volume of water allocated for drinking water supply (DWS) by surface water (dams), groundwater and desalination of seawater is 197.27 Mm^3. This figure indicates that the population according to the endowments is sufficient but that poses a problem when one adds the agricultural needs.

3.4.1.2 Agricultural needs

Agriculture is the most important sector in terms of water demand. Reductions in this demand can be achieved with different measures such as more efficient irrigation techniques, user training, and type of crop rotation.

During the period 1998-2007, the volume of water resources allocated to the agricultural sector is from 34.10 Mm^3 / year to 50.10 Mm^3 / year, while demand was 120 Mm^3 / year in 2010.

The Tafna watershed at the scale of the Tlemcen wilaya has a total agricultural area (T.A.A) of 537,274 Ha composed as follows (DRE, 2018) see Table 3.9 :

Table 3.9: Distribution of the total and useful area of the Tafna watershed

Total Area Willaya (T.A)	901 769 Ha	
Total Agricultural Area (T.A.A)	537 274 Ha	60% compared to the total area of wilaya
Useful Agricultural Area (U.A.A)	350 285 Ha	65% compared to the total agricultural area

This area is spread over 04 major areas of the wilaya:

- The TLEMCEN Mountains, Beni Snous, and Haute Tafna.
- The TRARAS mountains and the coastline.
- The Middle, low Tafna, plains and plateaus.
- The steppe zone.

The irrigated area at the end of 2017 is 29,605 ha (DRE, 2018) detailed in the table 3.10:

Table 3.10 : Estimation of irrigation requirements in Tafna watershed

Irrigation system	*Number*	*Irrigated area (ha) of 13/11/2017*	*Endowment ($m^3/y/ha$)*	*Needs (Mm^3/y)*
Irrigation from Beni Bahdel dam (Maghnia perimeter)	1	1 350	6000	*8,1*
Irrigation from small dams	12	588	6000	*3,528*
Irrigation from the Ain Houtz STEP	1	735	6000	*4,41*
Irrigation from boreholes	1723	10 843	6000	*65,058*
Irrigation from wells	1460	4 250	6000	*25,5*
Irrigation with water	1603	10 242	6000	*61,452*
Irrigation by sources	222	1 597	6000	*9,582*
TOTAL		**29 605**		***177,63***

According to the table 3.10, we note that the agricultural sector is the largest consumer of water for a capacity of 177.63 Mm³ / year. The participation of recycled water through the purification allows covering more than 2.5% of agricultural needs.The figure 3.8 represent the different sources of water for irrigation in TW.

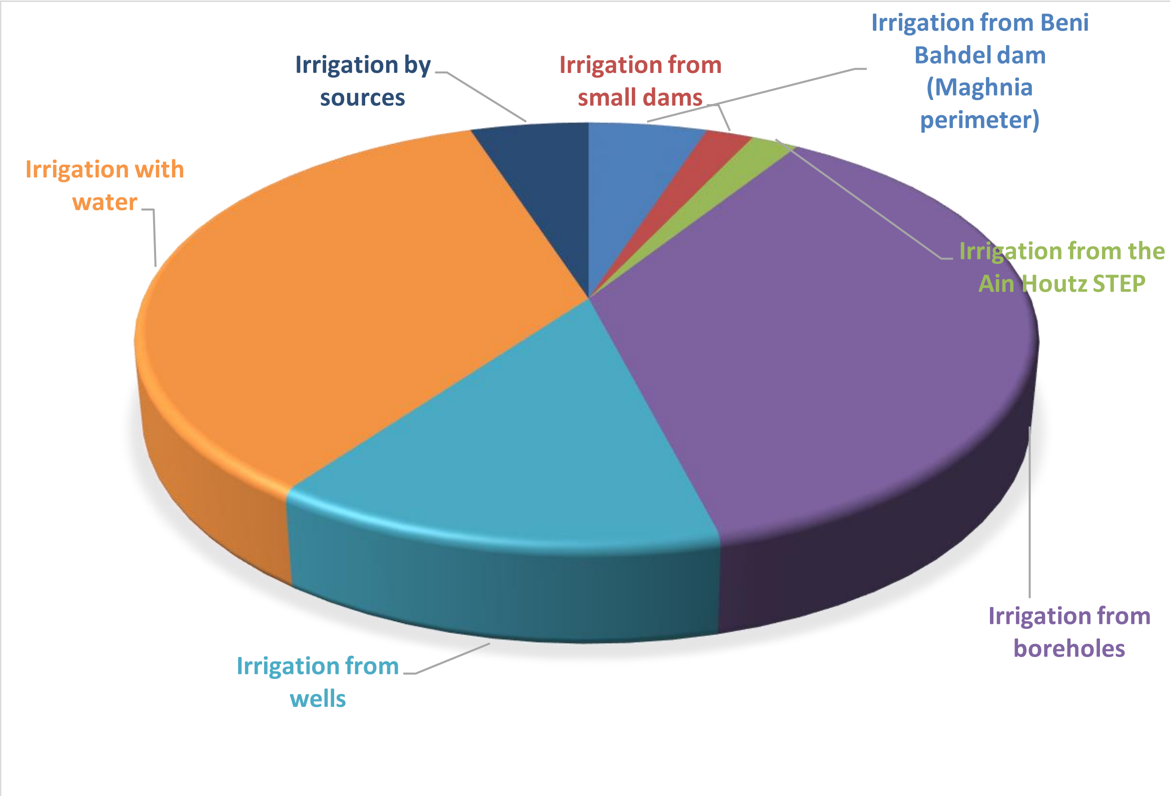

Figure 3.8 : Distribution of Irrigated Areas by Irrigation System

The objective set by the central directorates of the Ministry of Water Resources to increase the irrigated area carrying the irrigated area through the wilaya of Tlemcen of more than 35000 Ha by 2019. (Including the perimeter of irrigation of Tafna Yasser and the remaining area of Maghnia perimeter).

3.4.1.3 Industrial and equipment needs

The water consumption of large industry depends mainly on the following parameters:

- Type of industry and production process.
- Industrial development,

- Reduction of losses in the distribution system,
- Procedures for saving water.

In order to know the current needs of the industry, we used the calculation of a coefficient of proportionality. This coefficient is in fact a ratio of the annual consumption of the sector to study on the annual consumption of the population (Yala M et al, 2006). We thus give an idea of the consumption of the sector concerned in relation to consumption of the population.

We obtained the consumptions of the three different categories by the services of the ADE unit of Tlemcen.

Table 3.11 : Annual consumption of the three types in the Tafna watershed

Annual consumption in 2017 (m^3)	
Domestic	34730958
Industry	3836987
Equipment	1227888

We calculate the consumption coefficients from the following equations:

$$K1=\frac{\text{THE ANNUAL CONSUMPTION OF THE INDUSTRY}}{\text{THE ANNUAL CONSUMPTION OF THE POPULATION}}= \textbf{0.04 i.e. 4 \%} \quad \textbf{(3.2)}$$

$$K2=\frac{\text{THE ANNUAL CONSUMPTION OF THE EQUIPMENT}}{\text{THE ANNUAL CONSUMPTION OF THE POPULATION}}= \textbf{0.11 i.e. 11 \%} \quad \textbf{(3.3)}$$

With:

K1: Consumption coefficient of the industry

K2: Consumption coefficient of the equipment.

The water service in Tlemcen predefines quotas in advance to ensure the supply of the three categories.

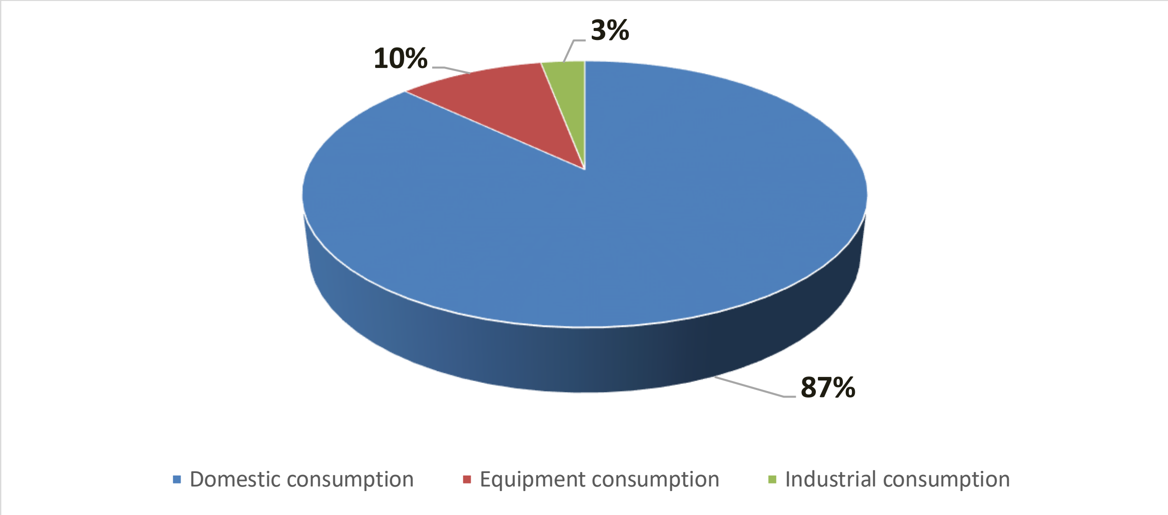

Figure 3.9 : Water supply shares by user category for the year 2017

We note from the figure 3.9 that priority is given to domestic needs with nearly 3 quarters of the volumes of water distributed, while the rest is destined to meet equipment needs 10% and needs in industry 3 %.

Table 3.12 : Annual needs of the three types in the Tafna watershed

Horizon	Endowment l/d/hab	Population	Domestic needs Mm³/y	Equipment needs Mm³/y	Industry needs Mm³/y
2017	150	1 073 399	59	6	2
	200		78	9	3
	250		98	11	4

The needs are calculated for the year 2017 using three different endowments, the results obtained in table 3.11 above are determined from the following formulas.

$$\boldsymbol{Q1 = E * N}$$

$$\boldsymbol{Q2 = K1 * Q1} \qquad (3.4)$$

$$\boldsymbol{Q3 = K2 * Q1} \qquad (3.5)$$

Q1 = Domestic needs.

Q2 = Equipment requirements.

Q3 = Industry needs

3.4.1.4 Estimation of needs

According to the numbers provided by theADE and DRE the total production is 252 Mm³, including all types of resources (see Table 3.12), as well as the needs for the year 2017 are indicated in the following table:

Table 3.13 : Current needs of the three categories according to the proposed endowments

Year	Endowment l/d/hab	Domestic needs Mm^3/y	Equipment needs Mm^3/y	Industrial needs Mm^3/y	Agricultural needs Mm^3/y	Total needs Mm^3/y	Excess Mm^3/y	Deficit Mm^3/y	Satisfaction rates %
2017	150	59	6	2	178	245	7	-	103
	200	78	9	3	178	268	-	16	94
	250	98	11	4	178	291	-	39	87

Calculation of Total Needs = Domestic Need (Q1) + Equipment Need (Q2) + Industry Need (Q3) + Irrigation Need (Q4).

$$\textbf{Total needs} = Q1 + Q2 + Q3 + Q4$$

Excess = Volume produced - total requirements

We note from the results in Table 3.12 that there is sufficient water for 2017 only for the proposed allocation of 150 l / d / capita. For the other endowments of 200 and 250 l / d / hab there was a significant deficit.

According to Figure 3.10 we note that the satisfaction rate decreases when the endowment increases but with a fixed product volume and this rate must be greater than or equal to 100% to say that the volume produced could satisfy the need.

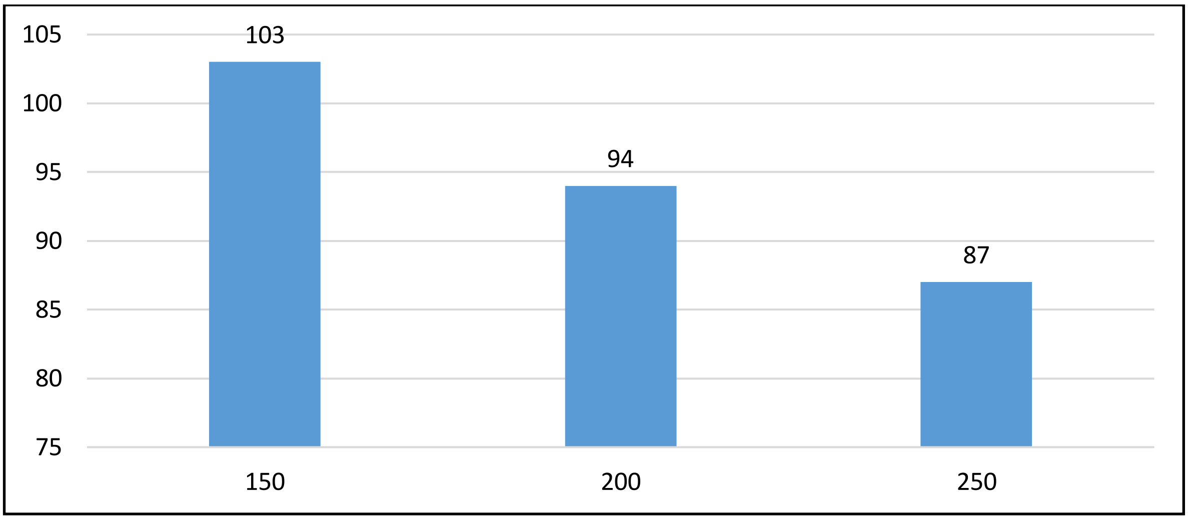

Figure 3.10 : Satisfaction rates for 2017 according to the proposed endowments

3.4.1.5 The balance resource current needs

Current resource-demand balance calculations are used to determine the demand supply for 2017:

Year	Current total production Mm³/y	Current total needs Mm³/y	Excess Mm³/y
2017	252	245	7

The volume currently produced is 252 Mm3 / year and the current water demand is estimated for a population of 1 073 399 inhabitants and an allocation of 150 l / d / day is 245 Mm³ / y, this volume is sufficient for domestic users, the equipment industry and irrigation. Therefore, we have a surplus in the production of water resources in the Tafna watershed.

3.4.2 Calculation of future water needs

To know the future needs of the TW, we must take into account the evaluation of the future population as well as the estimation of the water consumption.

3.4.2.1 Assessment of the future population

The forecast of population growth is estimated according to the following assumptions:

- For each region of the Tafna watershed, a rate of increase is given.
- The population with different horizons is estimated by the projection formula.

- The population of the moment considered (origin) is that of the year 2017 which is 1 073 399 inhabitants.
- The calculations are made with three endowments 150,200 and 250 l/d/hab
- The evolution of the future population of the Tafna watershed is on the horizons:
    - Short term,
    - Middle term
    - Long term.

The population with different horizons is calculated according to the formula of the increments finished:

$$\boldsymbol{Pn = P0\left[1+\left(\frac{T}{100}\right)\right]^{n}} \qquad (\mathbf{3.6})$$

Pn : Population on the horizon

$P0$: Population of the reference year

T : The rate of increase

n : The difference between the reference year and the projected horizon year.

Table 3.14 : Population (2017) of the Tafna watershed (ONS, 2008)

Areas	Population 2017	Rate of increase
Tlemcen	280655	2.2
Lower Plains	240726	2.16
Mountains of Traras	189644	1.29
Mountains of Tlemcen	160472	1.3
Maghnia Plain	152180	1.17
Steppic Zone	37052	2.3
Mountains of Sebaa chioukh	12670	0.9
Total	**1 073 399**	

Table 3.15 : Number of inhabitants with different horizons of the Tafna watershed

Areas	Population 2018	Horizon 2025	Horizon 2040	Horizon 2050
Tlemcen	286 829	334 026	462 960	575 509
Lower Plains	245 926	285 608	393 535	487 295
Mountains of Traras	192 090	210 122	254 666	289 492
Mountains of Tlemcen	162 558	177 940	215 981	245 760
Maghnia Plain	153 960	167 021	198 860	223 390
Steppic Zone	37 904	44 444	62 510	78 470
Mountains of Sebaa chioukh	12 784	13 611	15 569	17 029
Total	**1 092 051**	**1 277 522**	**1 604 081**	**1 916 945**

3.4.2.2 Estimation of future water needs

The drinking water needs are determined according to the following formulas:

$$\boldsymbol{Q(domestic) = E * N} \qquad (\mathbf{3.7})$$

E: Endowment.

N: Number of inhabitants.

Water requirements for equipment will be estimated at 11% of domestic needs.

$$\boldsymbol{Qequipment = 11\% * Q(domestic)} \qquad (\mathbf{3.8})$$

Water requirements for equipment will be estimated at 4% of domestic needs.

$$\boldsymbol{Qequipment = 4\% * Q(domestic)} \qquad (\mathbf{3.9})$$

Table 3.16 : Evolution of the needs of the four categories according to the proposed endowments.

Horizon	Endowment l/d/hab	Population	Domestic needs Mm³/y	Equipment needs Mm³/y	Industrial needs Mm³/y	Agricultural needs Mm³/y	Total needs Mm³/y
2017	150	1 073 399	59	6	2	178	245
	200		78	9	3	178	268
	250		98	11	4	178	291
2025	150	1 277 522	70	8	2	210	290
	200		93	10	3	210	317
	250		117	13	4	210	344
2040	150	1 604 081	88	10	3	210	311
	200		117	16	4	210	347
	250		146	12	5	210	373
2050	150	1 916 945	105	12	4	210	330
	200		140	15	5	210	370
	250		175	19	6	210	410

Values in Table 3.16 above, the needs increase because of population growth and endowments. In terms of satisfaction of water needs, we have proposed a case where the production of 2017 will be the same during the projected horizons.

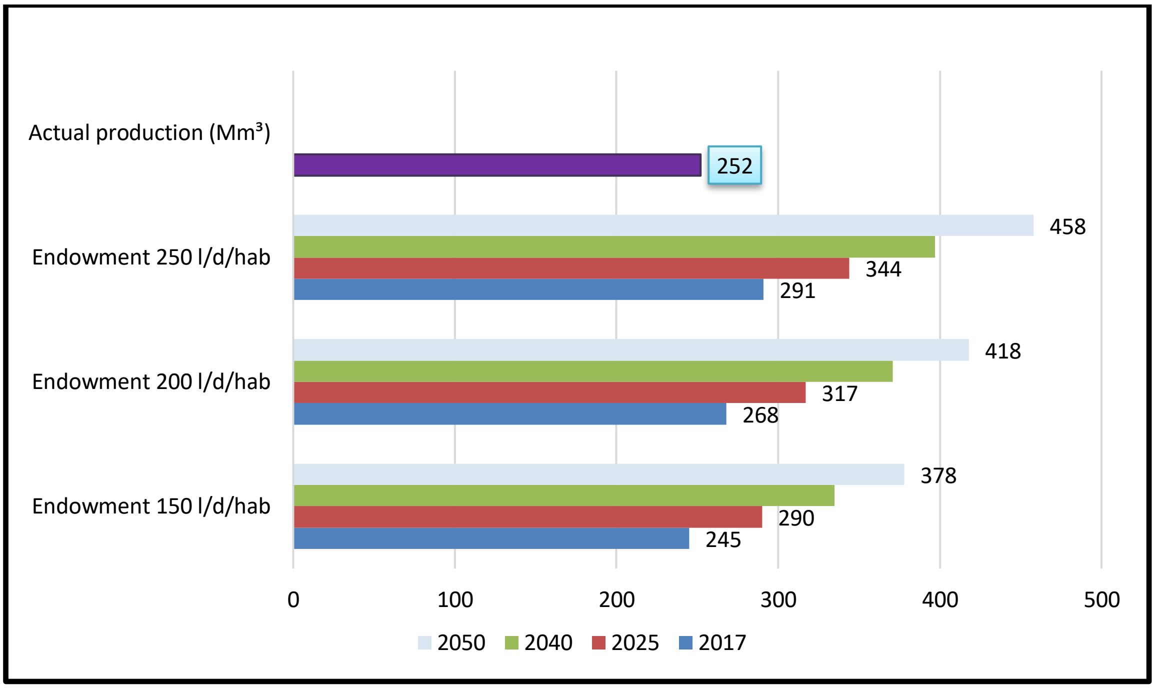

Figure 3.11 : Water needs on different horizons with proposed endowments.

It is remarkable that the water needs will continue to grow until they exceed the current product volume, and thus according to Figure 3.11 the deficit will start to appear by the year 2017 with an allocation of 200l /d /Hab. If we want to ensure endowments to different horizons ie in 2025, 2040 and 2050 it is necessary to mobilize still more volumes of water to satisfy the needs of the inhabitants. It is therefore important to anticipate this growth in order to increase the volume of product needed to meet this demand for water.

Table 3.17 : Calculation of the excess and future deficit with the proposed endowments

Horizon	Endowments l/d/hab	Population	Volume produced Mm³/y	Total needs Mm³/y	Deficit Mm³/y	Excess Mm³/y
2017	150	1 073 399	252	245		7
	200			268	16	/
	250			291	39	/
2025	150	1 277 522	252	290	38	/
	200			317	65	/
	250			344	92	/
2040	150	1 604 081	252	335	59	/
	200			371	95	/
	250			397	121	/
2050	150	1 916 945	252	378	78	/
	200			418	118	/
	250			458	158	/

According to Table 3.17 we find that the deficit begins to appear as soon as the future need exceeds the volume produced in 2017:

In 2017 the future needs calculated by an allocation of 200 l / d / hab give us a deficit of 16 Mm³ / year

In 2025 the future needs calculated by an allocation of 200 l / d / hab give us a deficit of 65 Mm³ / year.

In 2040 the future needs calculated by an allocation of 200 l / d / hab give us a deficit of 95 Mm³ / year.

In 2050 the future needs calculated by an allocation of 250 l / d / hab give us a deficit of 158 Mm³ / year.

The needs calculated by an allocation of 150l / d / hab give us a deficit for all horizons except the year 2017.

3.5 Assignment of water resources in the Tafna watershed

Taking into account the irregularity of the resources at the level of the Tafna watershed, multiple transfers are made and ensure the transport of the resource for different zones of the TW, notably the western zone registering a significant deficit in resources (Rouissat B,2015)

Figure 3.12 illustrates the materialization of these transfers from the different sources of mobilization. Figures 3.13, 3.14 and 3.15 schematize all transfers at the Tafna watershed area indicating the source of mobilization and destinations transfers.

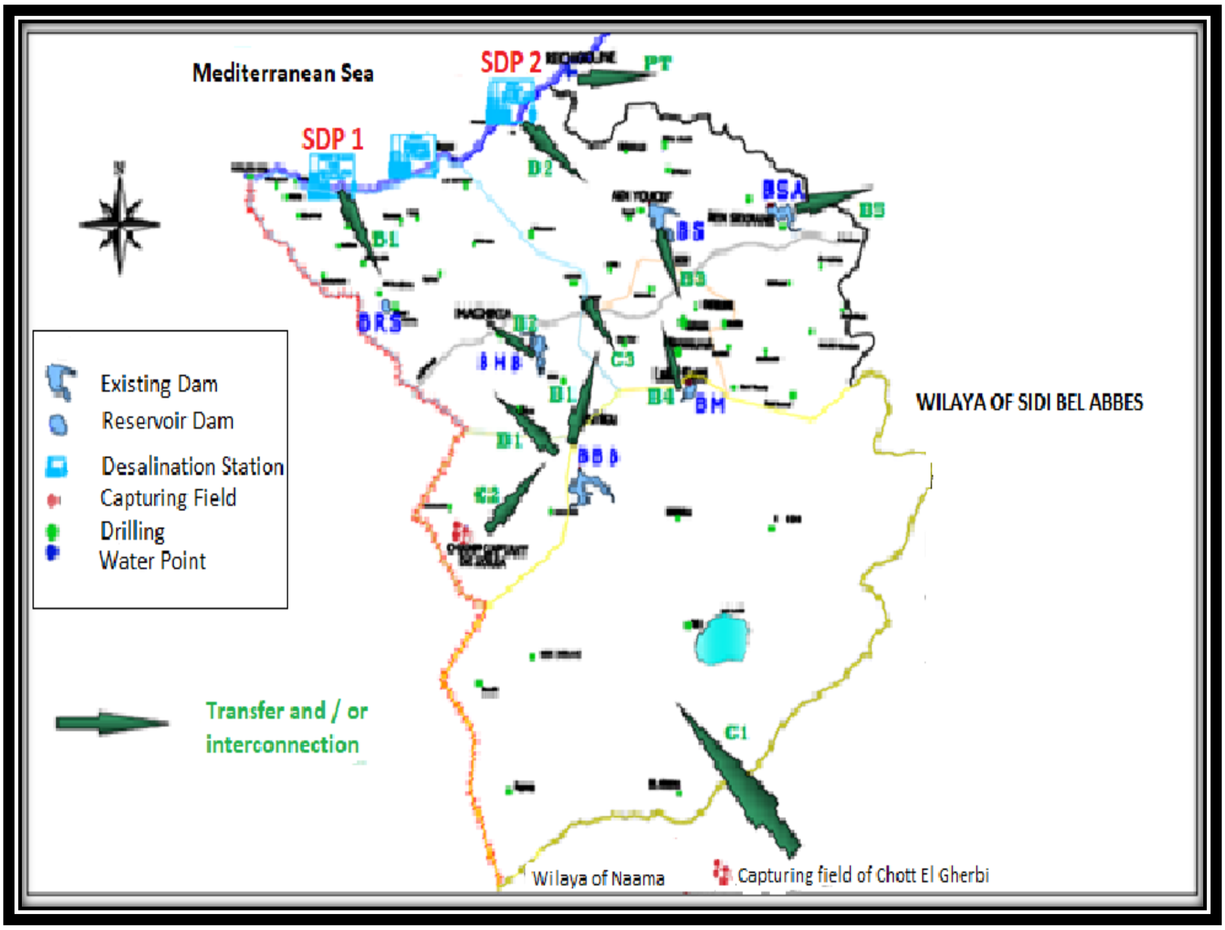

Figure 3.12 : Interconnections and transfers in the Tafna watershed area (Rouissat B.,2015)

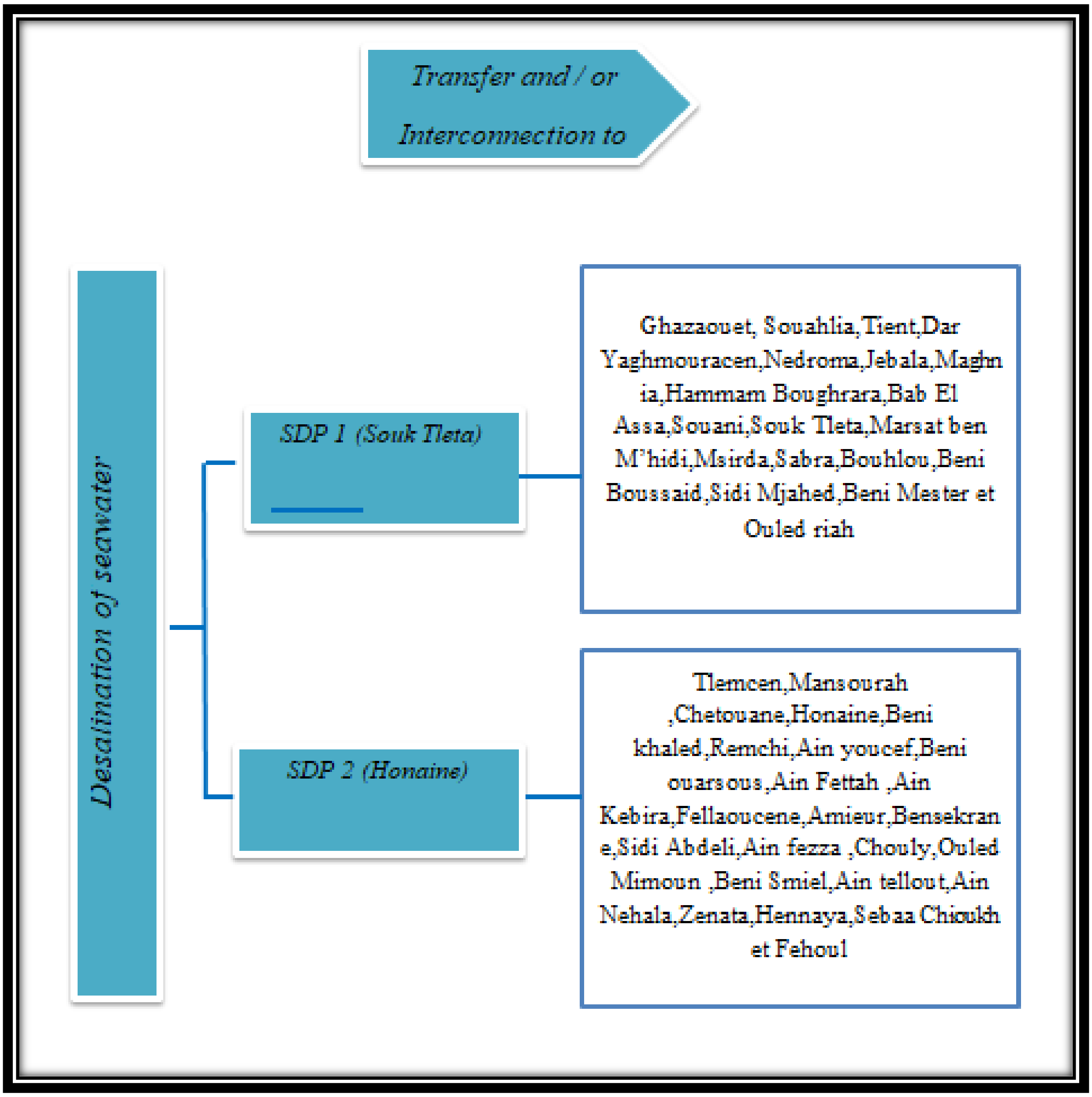

Figure 3.13 : Transfers in the Tafna watershed from desalinated water (Rouissat B.,2015)

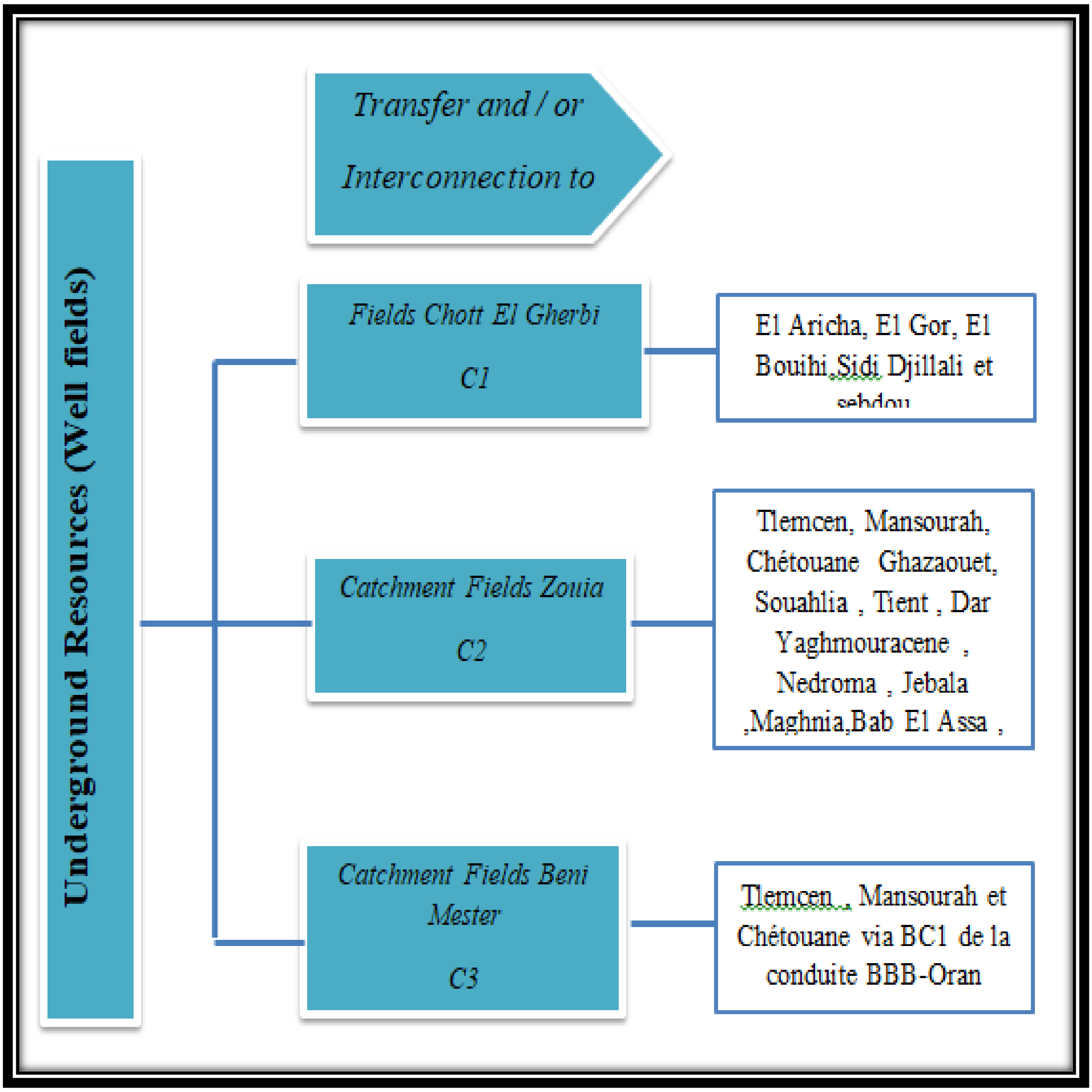

Figure 3.14 : Transfers in the Tafna watershed from groundwater (Rouissat B.,2015)

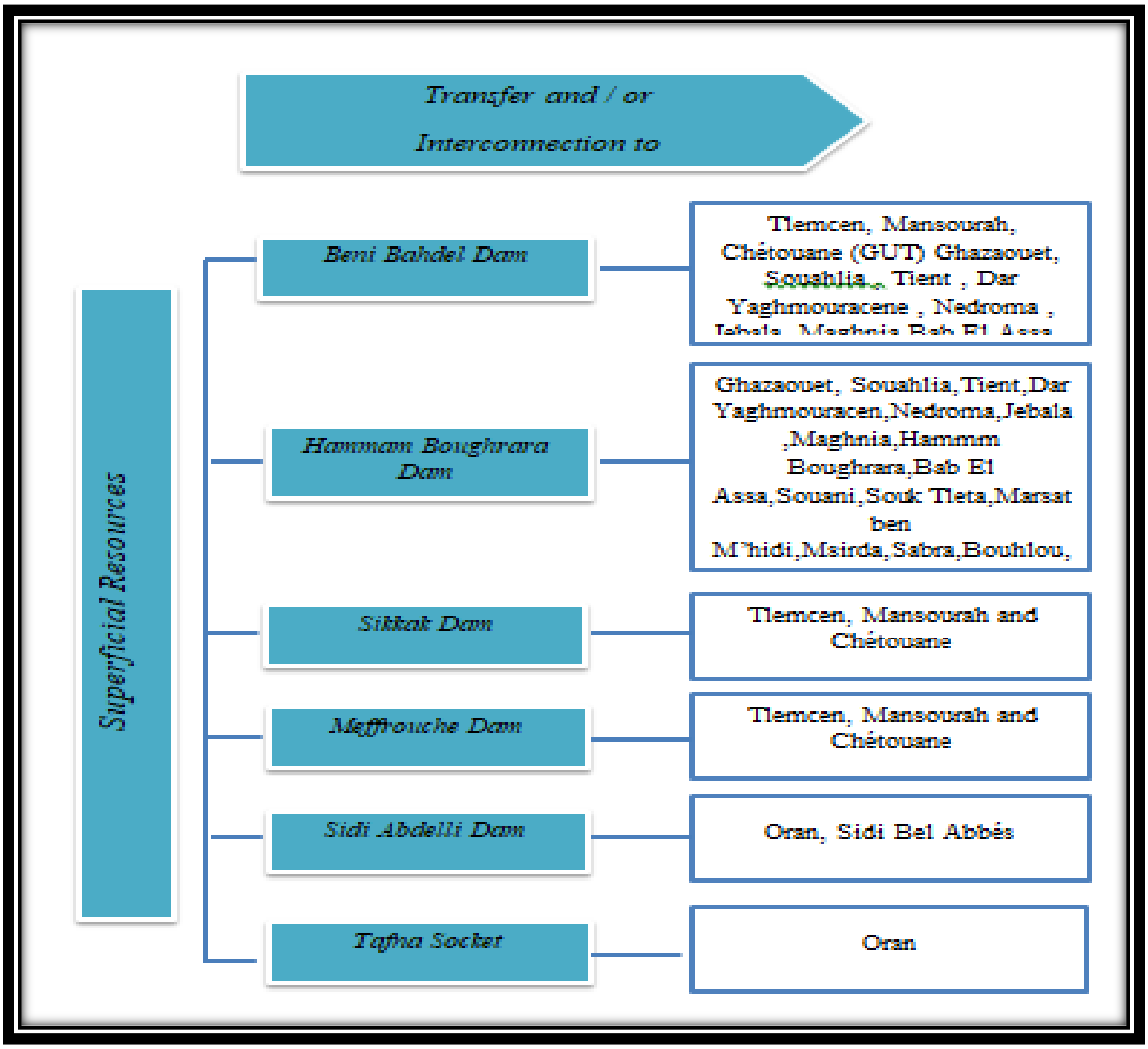

Figure 3.15 : Transfers in the Tafna watershed from surface water (Rouissat B.,2015)

3.6 Interactions of the Tafna watershed in its hydrographic Region

Part of the water resources of the Tafna basin is transferred to other basins. These are transfers to the Wilaya of Sidi Bel Abbés and Oran. As part of the transfer of water Chott el Gherbi well field, this transfer serves some agglomerations of the Tafna watershed. Figure 3.16 illustrates the interactions of the Tafna watershed with the other basins of the Oranie Chott Chergui hydrographic region and the figure 3.17 shows the interactions that occur in the TW with respect to incoming and outgoing flows.

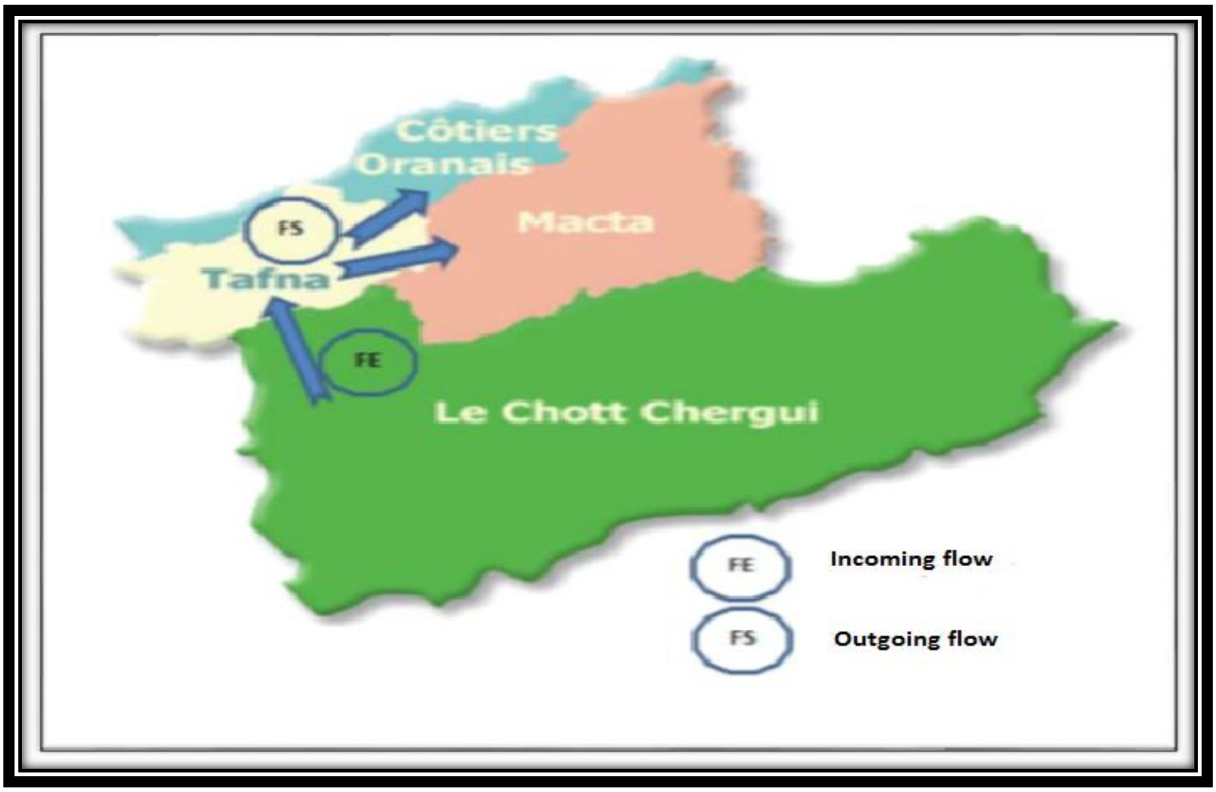

Figure 3.16 : Interaction of the Tafna watershed with its external environment

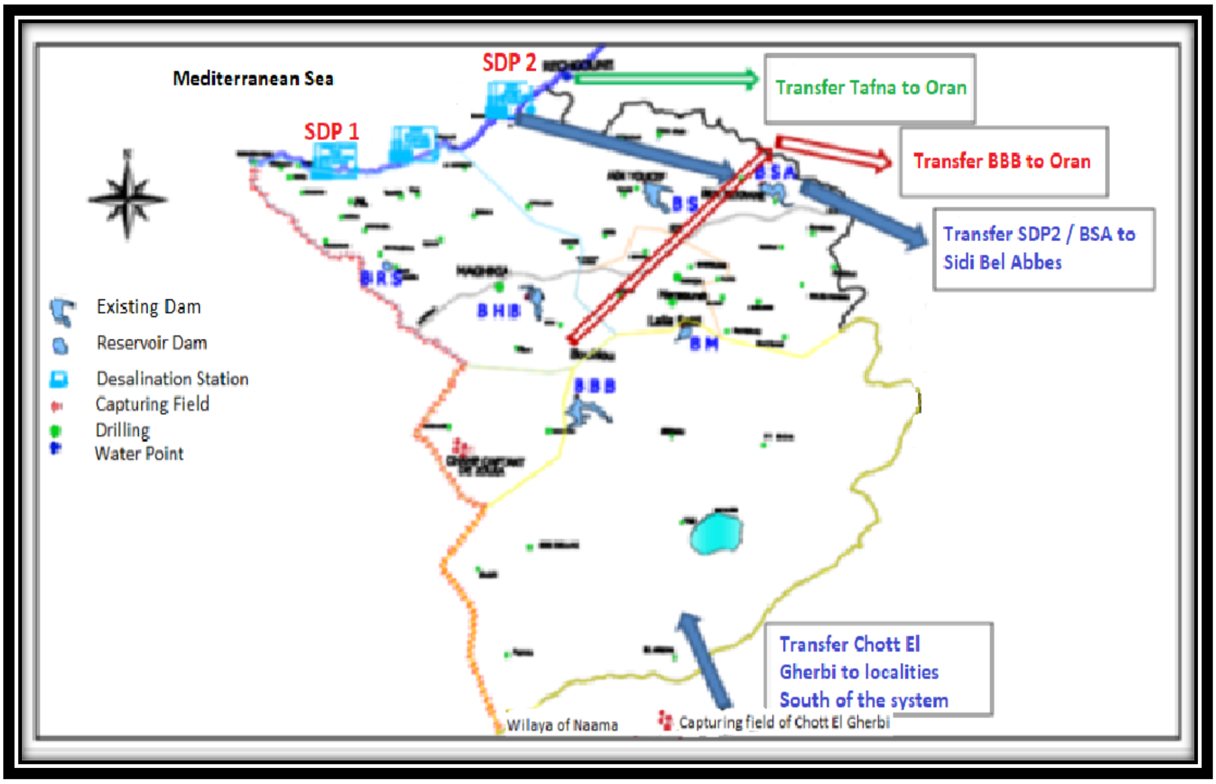

Figure 3.17 : Assessment of Inflow and Outflow from the Tafna Watershed (Rouissat B.,2015)

Table 3.18 : Transfer Capacity of the Tafna Basin and their Destinations.

OUTGOING RESOURCE FLOW		
Transfers	***Capacities (Mm³ /y)***	***Destinations***
BB.Dam	7,3	Oran
SA.Dam	14,6	Sidi Bél Abbés
Tafna Socket	10	Oran
SDP	14,6	Sidi Bél Abbés
Total outgoing resource flows	31,9	
INCOMING RESOURCE FLOW		
Chott El Gherbi	18,2	South locations El Aricha, Sebdou,Elgor, Sidi Djillali et El Bouihi
Total incoming resource flows	18,2	

Table 3.18summarizes the balance of resource flows in relation to the wilayas served.

Figure 3.18 shows the balance of water resource flows in the Tafna watershed area.

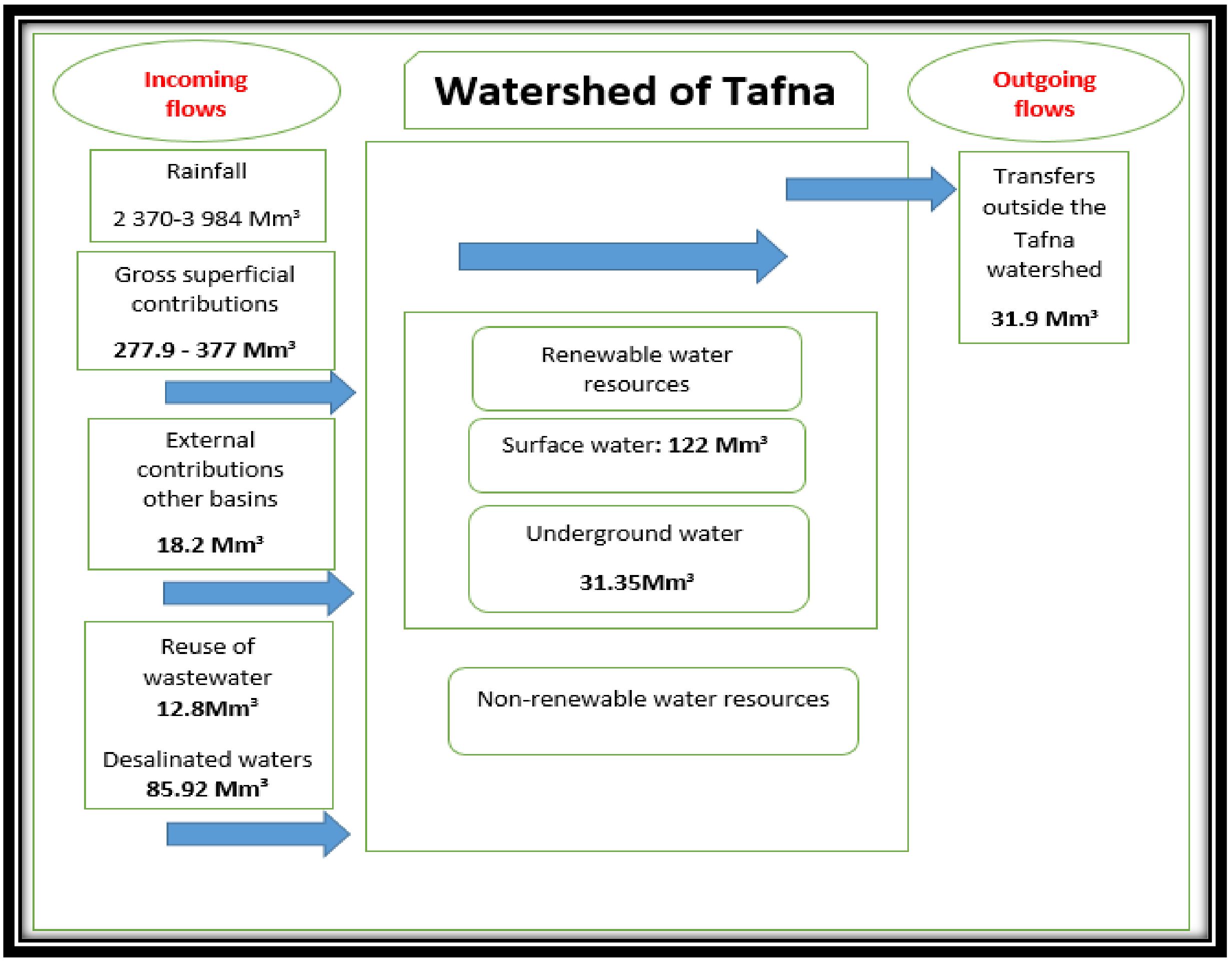

Figure 3.18 : Annual review of water resources flows at the level of the Tafna watershed

3.7 Conclusion

What has just been staged in this chapter is that the water issue, in the Tafna watershed, is facing two major concerns. The first concerns the problems of production capacity, which are limited and insufficient to meet the different needs, particularly because of the shortage of water in recent years, the silting of dams and their pollution, the overexploitation of underground aquifers, not to mention the technical problems and faults of desalination plants due to mismanagement. Therefore, the water services are called upon to address the second concern rises from the field of anticipation to ensure a continuous and rational water distribution for the TW, in the short, medium and long term. Because according to our calculations, in almost the years that they come the volumes produced will not be more satisfactory to ensure a correct water supply for the inhabitants of the TW as well as the industrial and agricultural needs. As it became clear that the agricultural sector is the largest consumer of water, which has led to a significant deficit. Therefore, it is now necessary to establish scenarios for the optimization of water resources for efficient use.

CHAPTER FOUR

DEVELOPMENT OF WATER RESOURCE MANAGEMENT SCENARIOS IN THE TAFNA WATERSHED

4.1 Introduction

The Tafna river basin contains significant water resources that are divided between domestic needs, irrigation needs, industrial needs and equipment. This solicitation of the water resources of the Tafna watershed can reach a deficit starting from the current year and could be at the origin of conflicts within the same type of use of the water, hence the need for a management system to be developed quickly enough to prevent future conflicts due to, among other things, declining rainfall and population growth, as well as socio-economic activities that use water and poor water management.

4.2 Water management in the Tafna watershed

Basin management requires good stakeholder knowledge: those involved in decision-making in basin-wide water and soil management, and those who will be affected by decisions. Once the context is analyzed, it is possible to seek to involve the right combination of water actors at the appropriate levels in basin management. In order to identify the actors involved in basin management and those affected by the decisions, it is useful to establish a support for the actors, their roles and their responsibilities (Rouissat, 2015).This tool can be a useful first step in understanding decision-making processes at different levels of basin management. Some actions allow this coordination between actors for basin-wide management:

- Ensure that key players are represented in basin management,
- To distinguish between information, consultation, participation and association with decision-making,
- Find a happy medium between informing all actors and involving a small number,
  Ensure that administrative processes do not compromise the real participation of water stakeholders,
- Ensure that participation is transparent,
  Strengthen the ownership of the basin action plans by the partners by ensuring their participation,
- Devote sufficient resources to the involvement of stakeholders,
- Ensure good communication between the actors of local management plans, officials of public water agencies and managers of basin organizations,

At the level of the Tafna watershed, multiple agencies and organizations are involved for the management of water resources; from design and construction projects to the exploitation of infrastructure, Figure 4.1 summarizes stakeholder involvementacross the Tafna Basin.

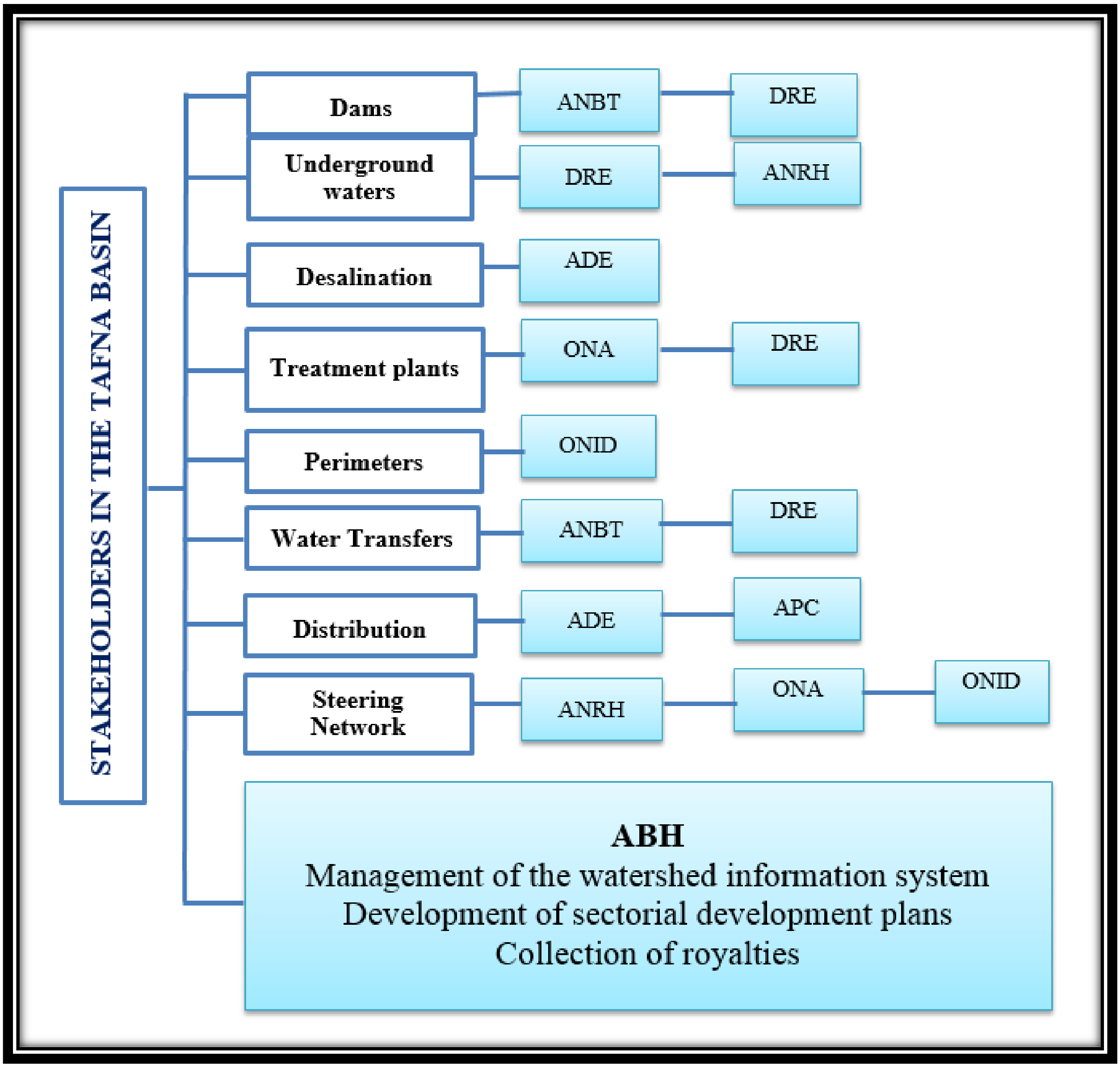

Figure 4.1 : TW stakeholders involved by sector of activity

4.3 Demand control measures in water management

4.3.1 Reduction of losses

4.3.1.1 Drinking water

Measures to reduce the loss and waste of drinking water are all the more necessary and important in the Tafna watershed as their total consumption represents a margin between 10 and 15% depending on the total production capacity. Figure 4.2 gives the domestic exploitation volume in relation to the mobilizable productions of the water resources in the Tafna watershed.

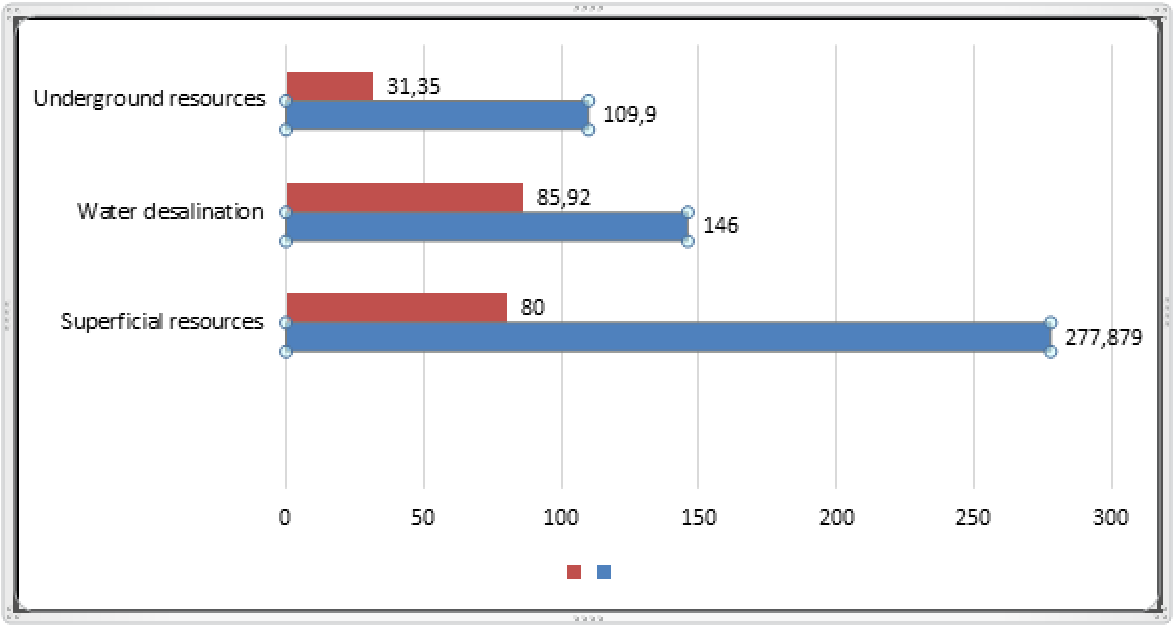

Figure 4.2: Quote parts of domestic consumption in relation to eligible productions by category of resources in the TW

4.3.1.2 Irrigation

The National Office must carry out repair, rehabilitation and renovation programs for irrigation water supply and distribution systems for Irrigation and Drainage (ONID) on the public irrigation schemes. Actions to modify farming techniques intended to reduce the consumption of irrigation water, especially for small and medium-sized farms, are compulsory, particularly the drop-in method. The participation of wastewater recycling through the purification of water in the satisfaction of needs is crucial.

Figures 4.3, 4.4 and 4.5 show that the purification capacity of the completed and planned stations, theyrepresent 23% of the requirements. An increase in the sewage treatment rate to 70% of rejected domestic waste raised the rate of satisfaction of needs to 34.7%, 42.1% and 51.7% respectively for horizons 2025, 2040 and 2050 for an allocation of 250 l / d / inhabitant. Considering that, 80% of domestic waters are discharged into sanitation networks.

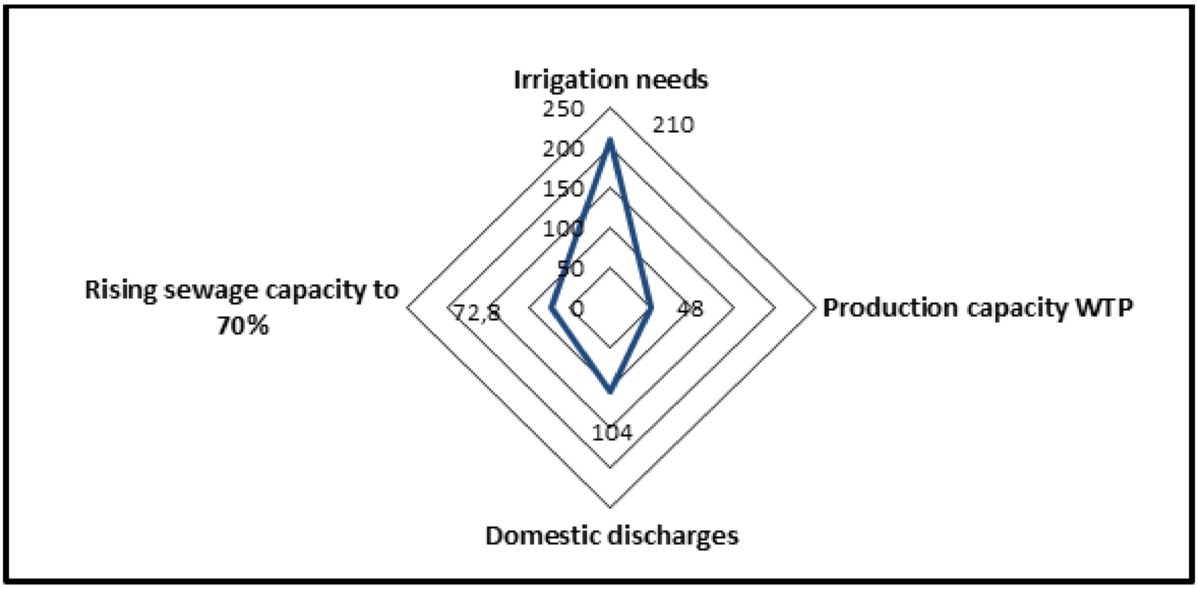

Figure 4.3 : Influence of purified volumes (Mm³) on meeting agricultural needs-Horizon 2025

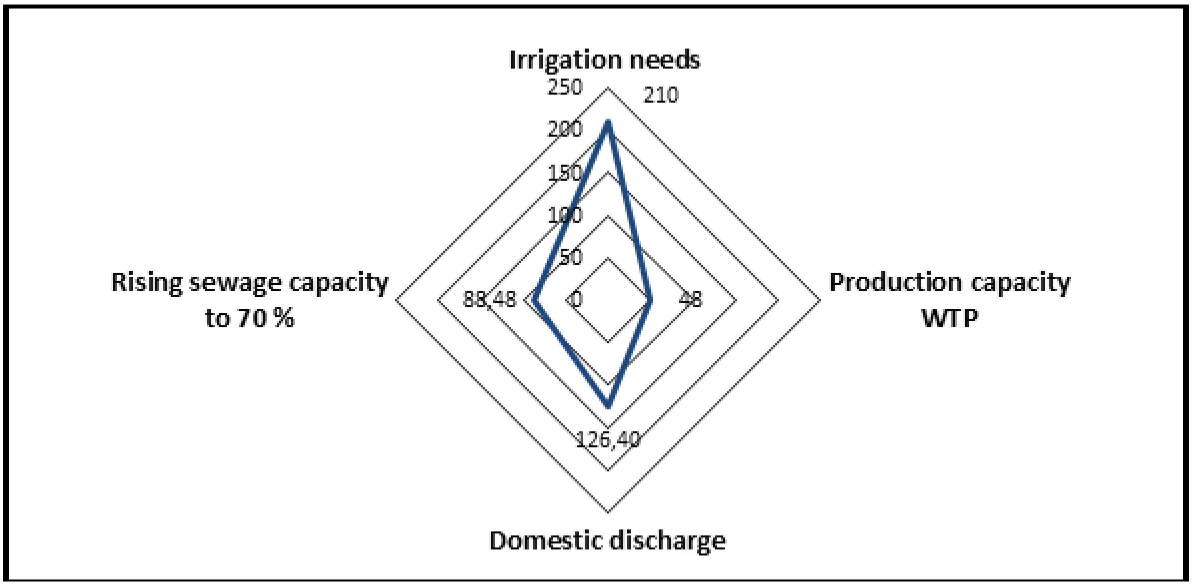

Figure 4.4 : Influence of purified volumes (Mm³) on meeting agricultural needs-Horizon 2040

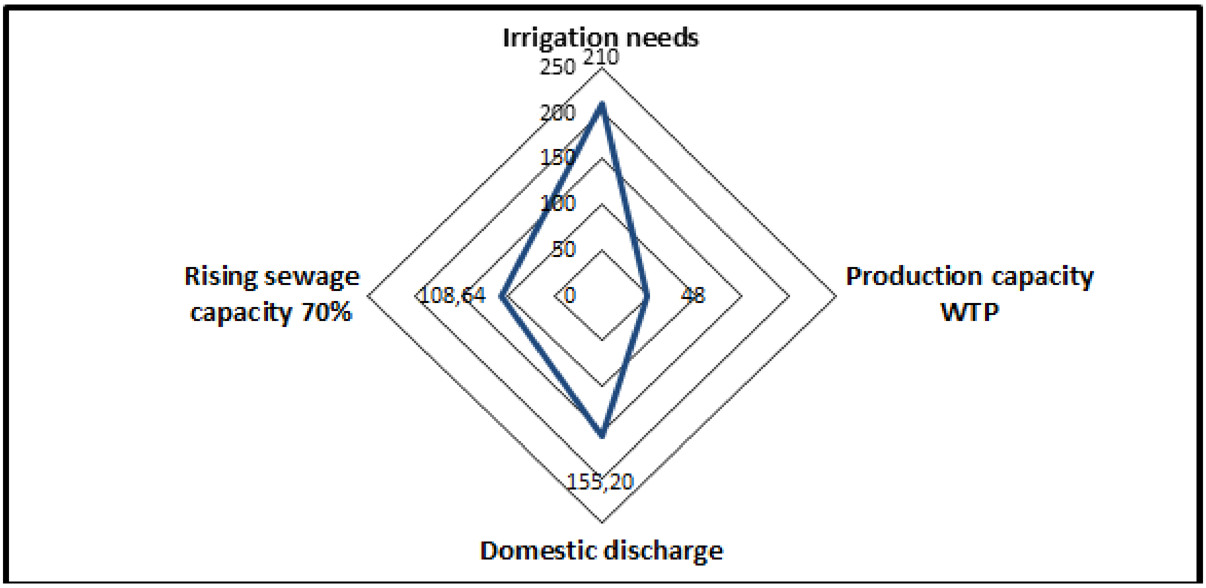

Figure 4.5 : Influence of purified volumes (Mm³) on meeting agricultural needs-Horizon 2050

4.3.1.3 Industry

The annual industrial water requirements estimated at the end of 2025 amount to more than 4 Mm³. Industrial units must rehabilitate their treatment plants or acquire new treatment plants if they are nonexistent. These units, however, need to address the water recycling issue.

Figures 4.6, 4.7 and 4.8 illustrate the influence of industrial water recycling on meeting needs. With a recycling rate of only 30%, the volume rejected for industrial needs is approximately 1.20 Mm³.

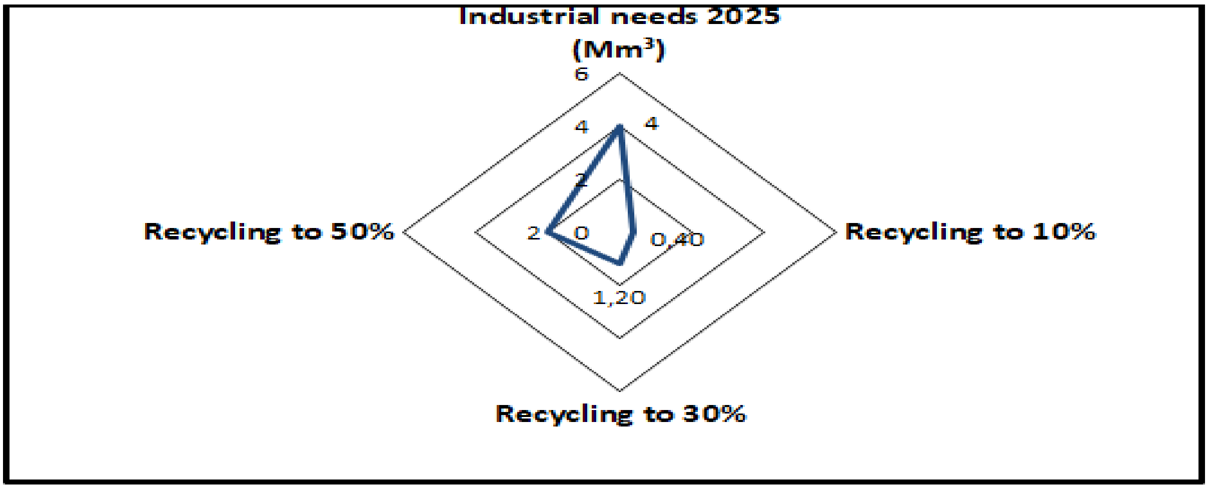

Figure 4.6 : Influence of recycled volumes by industry on meeting needs-Horizon 2025

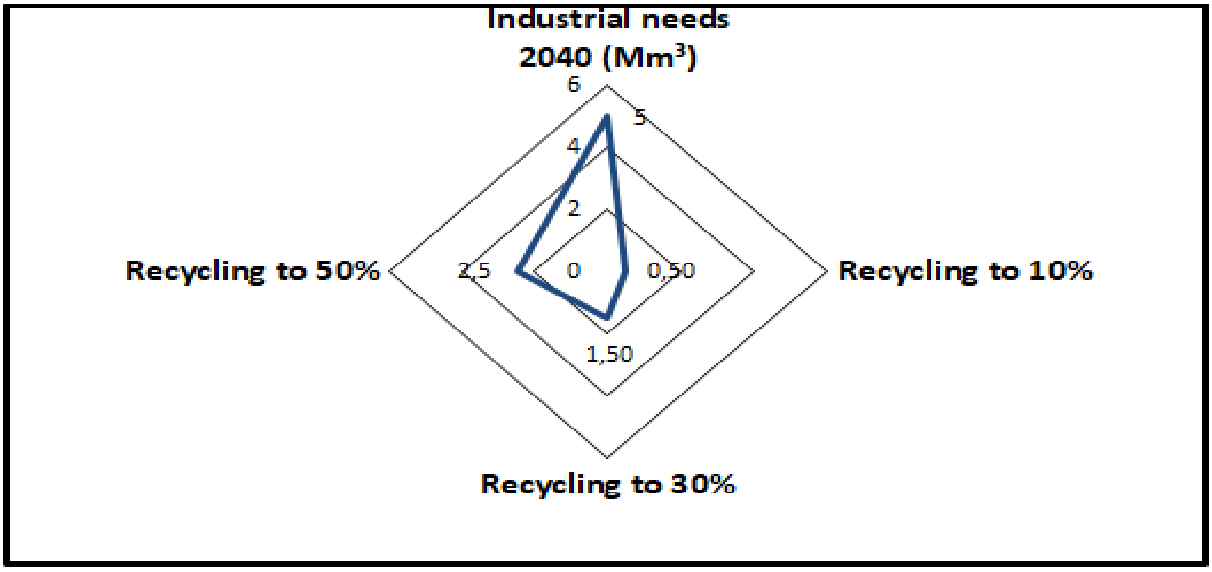

Figure 4.7 : Influence of recycled volumes by industry on meeting needs - Horizon 2040

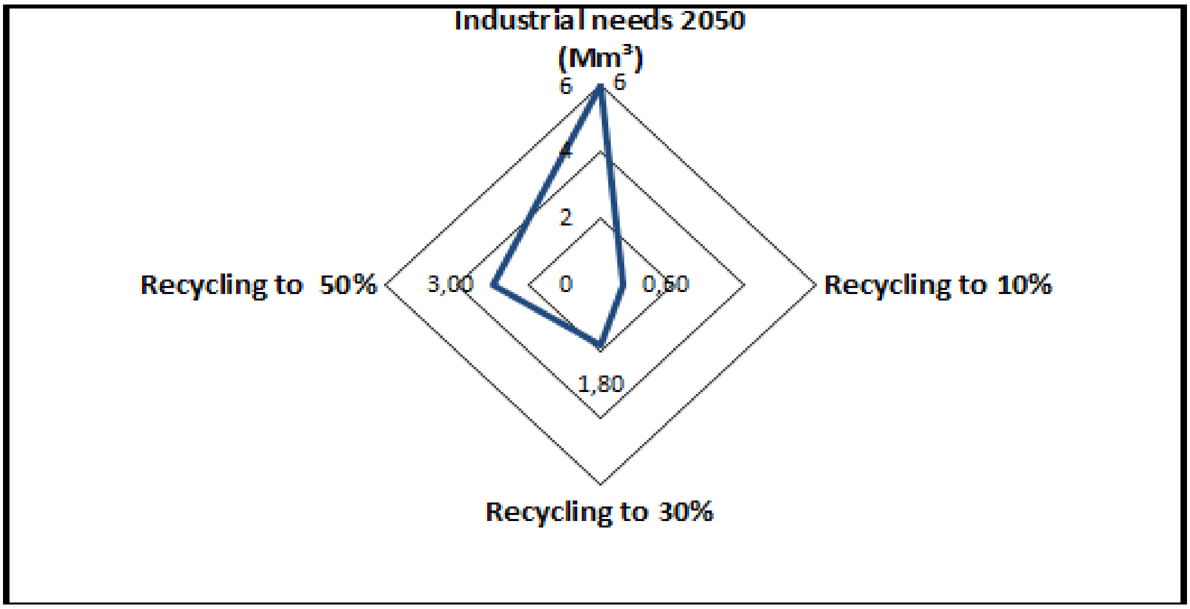

Figure 4.8 : Influence of recycled volumes by industry on meeting needs - Horizon 2050

4.3.2 Pricing

Pricing can be one of the ways to encourage users to save more money in their water consumption and to avoid losses and waste. A new pricing of drinking water will achieve this goal. It also responded to the principle of covering the real costs of the water service by the fees paid by users. The pricing of irrigation water is defined for farms supplied from facilities whose management is the responsibility of the public authorities.

It mainly concerns large perimeters, irrigation areas and perimeters of small and medium hydraulic systems, equipped by the State or on its behalf, whose management is granted to associations or cooperatives of irrigators (Benblidia M, 2011).

There are no special fees for private farms supplied by individual installations carried out by the owners themselves (wells, boreholes, and catch in rivers ...). The agricultural water tariff covers the costs and expenses of maintenance and operation of irrigation and drainage-drainage works and infrastructure and contributes to the financing of investments for renewal and extension. However, the levels of the tariffs fixed by decree and applied are far from meeting these requirements of balance of the charges in almost all the perimeters.

4.3.3 Actions on the request

In the hypothesis of a demand management with an individual endowment reduced from 150 l / d.Hab to about 250 l / d.Hab, the demand for water differs and increases according to the endowments.

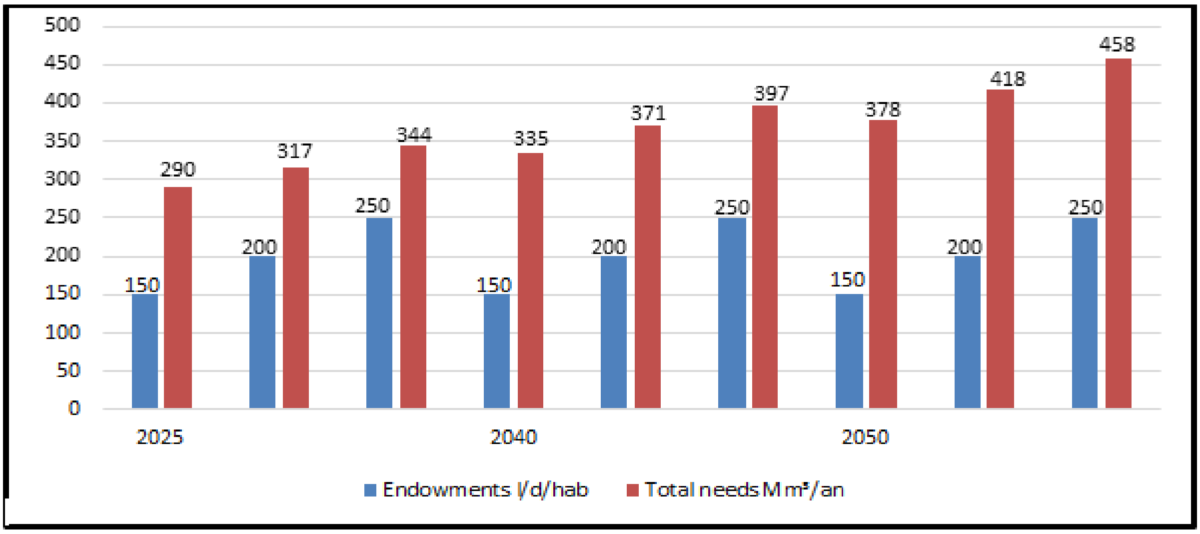

Figure 4.9 : Influence of allocations on total water requirements in TW at different horizons.

In addition, for contributing to the optimization of the use of resources for drinking, irrigation and industrial production in the Tafna watershed, it is necessary to develop management scenarios that aim to analyze the different possible cases in terms of drinking water supply.

4.4 Management scenario for the water deficit on the horizon

The future scenario of the water distribution is based on three (3) hypotheses were created:

- Domestic water needs.
- Annual Water Utilization Ratio (Instant Resources Available / Total Needs Peak <1).
- Population growth rate of the population (Sascha Meinert).

The results of application of chapter 3 make it possible to project in the different horizons a water management plan in the form of diagrams. In addition, to establish a water balance and offers / requests taking into account a reference scenario (current situation), after having followed a method of scenario development.

4.5 The development of scenarios

Scenario building is a useful and interesting exercise, but it is only the starting point for the strategic planning process.The scenarios help to think outside the box and greatly extend the scope of short-term planning. Their main advantage lies mainly in the possibility of playing the role of "wind tunnel tests", or test benches, for the rigorous analysis of strategies (Julien P and al., 1975)

The scenario development process requires several steps that must shape it. In this sense, Ulrich Golüke says:

"By writing these stories, we reinvent reality, create opportunities and broaden our horizons. We are no longer content to suffer the future: we shape it".

The scenario development process can be divided into six stages: This checklist summarizes the steps we have just described in the table below.

Table 4.1 : Checklist for scenario development (Sascha Meinert)

Step 1	Delimit the problematic and the time horizon of the scenarios;
Step 2	Identify and classify the uncertainties and influencing factors related to this problem;
Step 3	Describe possible alternative evolutions (for the two most important and uncertain factors of influence);
Step 4	Calibrate a "compass of the future" from the results;
Step 5	Write a scenario for each quadrant of the compass
Step 6	Reflect on the implications of the scenarios: impact and room for maneuver.

4.5.1 Delimitation of the problem

How can we cover the deficit due to increasing drinking water needs and irrigation in the Tafna watershed from available resources?

Answering it implies putting in place mechanisms that allow us to identify and classify the uncertainties and the factors of influence, which we will support, the approach below.

4.5.2 Indentification and clasification the uncertainties and influencing factors related to this problem

As part of a project dealing with our problematic "study of the assignment scheme of water resources in the Tafna watershed", we are obliged to take into account the uncertainties regarding future rainfall, i.e. the quantification of current resources and the increasing demography in the study area.

Therefore, we assure in this step that the production and the needs related to the rainfall and the demography are very important factors that will influence the development of the scenarios of use of the water resource in the Tafna watershed .The following factors will also influence this issue:

- Choice of staffing related to the population.

- Groundwater depletion due to drought or excessive pumping of water at the TW.
- Silt the dams that feed the TW.
- Pollution of the dams that feed the TW.
  Irregularity of the production yield of HONAINE and Souk Telata stations.
- Leakage of drinking water supply systems at the level of the TW at the scale of the Tlemcen wilaya.

4.5.3 Description alternative evolutions at the Tafna watershed level

The Willaya of Tlemcen has two seawater desalination plants, namely Honaïne and Souk Tlata.However, as the latter is characterized by irregular water production. As proof, in 2017, this station produced only 62,028 m³ per day, which resulted in the SDP yield in July 2017 of almost 31%.This production cannot suffice the water needs of the populations of the urban centers of the west of the wilaya (Maghnia, Ghazaouet, Nedrouma, ...).These irregularities are due to recurrent malfunctions due to:

1. Malfunction of the "Nano Filter" filters of the pretreatment system that led to an advanced deterioration of reverse osmosis.
2. Various technical problems of equipment.
3. Turbidity of the seawater at the level of the water intake (outlet of an Oued carrying large quantities of clay).

This situation is often accentuated by the issue of power cuts as well as by production shutdowns of the transport system (downstream desalination system managed by ADE).

Faced with this situation, the water supply of the TW is ensured by the water coming from the SDP of Honaïne and Souk Telata with an annual volume of 86 Mm³, supported by the surface waters with a production of 114 Mm³ / year and the groundwater with a production of 31 Mm³ / year at TW level to cover the water demand. These figures are reported by the Directorate of Water Resources of Tlemcen wilaya (DRE, 2018).

According to the estimation of the Tafna watershed population in the previous chapter we have noticed that there is a growth of needs in the future.

We also see a drinking water deficit that increases according to the endowments chosen and the number of dwellings in the Tafna watershed, which will force us to cover this deficit from other water resources.

To develop supply scenarios, we are forced to use resources that can power the Tafna watershed. The following table represents the maximum capacity that each resource of the Tlemcen wilaya can produce according to the figures and information gathered from the management of the water resource of the Tlemcen wilaya as shown in table below.

Table 4.2 : Hydraulic infrastructures of TW (DRE,2018)

Resources	**Maximum production capacity for the TW (m³/d)**
Downstream Honaïne	200 000
Downstream Souk Tlatta	200 000
Meffrouche Dam	20 000
Beni Bahdel Dam	100000
Sekkak Dam	20 000
Boughrara Dam	50 000
Sidi Abdelli	100 000
Chott El Gharbi	$6,57*10^9$
Zouia	3500

A. Location of the boreholes

The Chott El Gharbi basin, which covers approximately 7000 km2, constitutes the end Western high plains Oran. It is limited by:

- The mountains of Tlemcen in the North.
- The Saharan Atlas in the South.
- The Antar and Amrag Djebels to the East.
- The mountains of Moroccan Tedrara in the West.

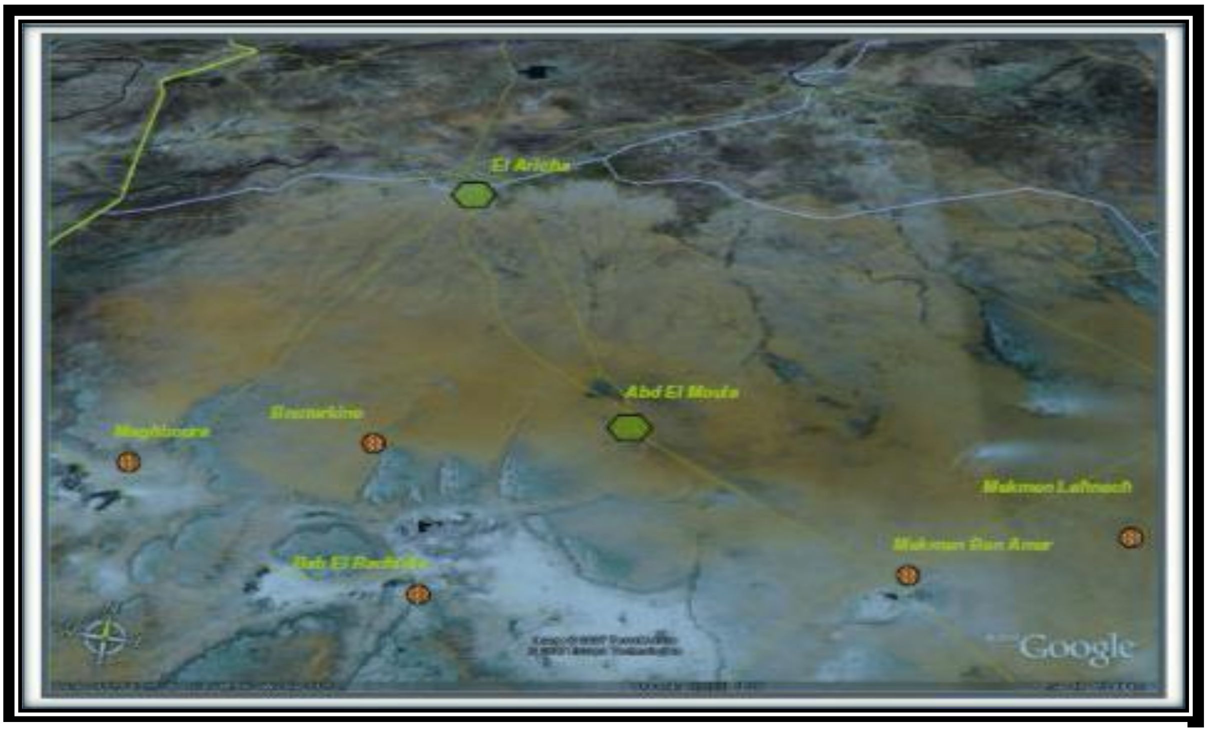

Figure 4.10: Location of Chott El Gharbi boreholes (DRE, 2018)

The area of Chott El Gharbi is well served by the road infrastructure, both in the primary network by 03 national roads:

- NR 22: Tlemcen - Sebdou - El Aricha - Mechria - Bechar.
- NR 13: Sidi Bel Abbes - El Aricha - Morocco.
- RN 7: which connects Tlemcen - Sidi Bel through Ben Badis.The railway line [25] also crosses it.

B. Drilling

Drilling whose location and unit flows were identified by the ANRH are 60, distributed in the following fields:

Table 4.3 : Drilling Fields Capturing

Capturing field	Number of holes	Unit flow
El Errachidia	13 (+ 3 rescue)	38
Bouterkine	12 (+ 3)	28
Maghboura	3 (+ 1)	40
Mekmen Ben Amar	8 (+ 2)	30
MekmenLahnech	13 (+2)	31
Total	60	

INF: DRE

11 relief drillings will be planned spread over the 5 fields capturing to reach the total number of 60 drillings (Belmahi A et al.,2018).

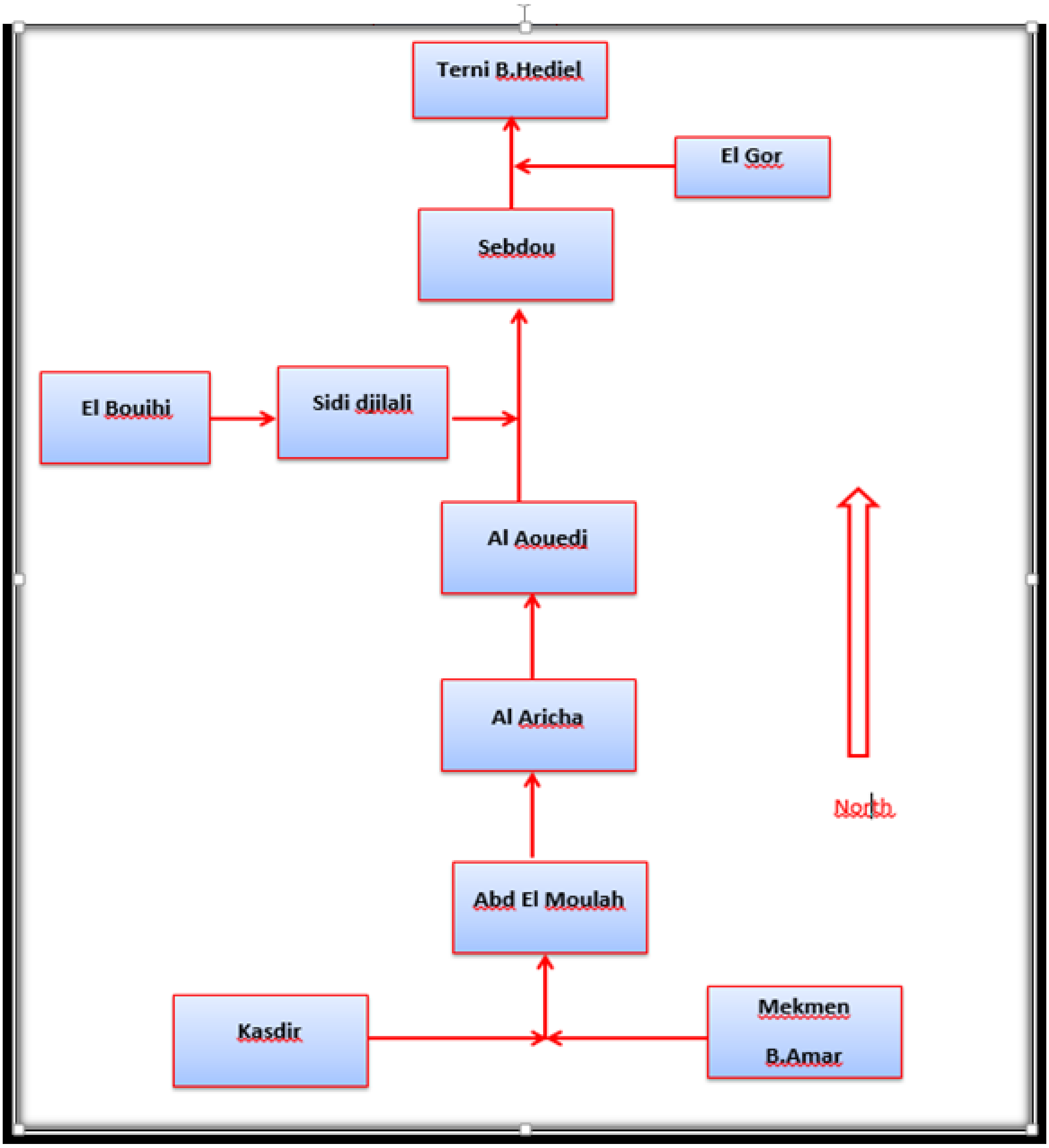

Figure 4.11 : Chott El Gharbi transfert summary schema(Belmahi A et al.,2018)

4.5.4 Description of possible alternative issues

We consider that the rainfall that is conditioned by the semi-arid climate of Tlemcen will force us to study its effect on future production in the Tafna watershed, also based on our calculations in Chapter 3, we found the influence of staffing choices on the future estimate of needs in the Tafna watershed to fill the deficit.

Firstly, it is better to change the allocation in the horizons considered to cover the total needs of the Tafna watershed.

Secondly, it is necessary to study the cases of shortage of drinking water in dams, boreholes and springs because of drought in the future.

Thirdly, the performance of Honaine and Souk Telata desalination plants linked to a specific lifetime and a single failure can change its production completely.

Therefore, these influencing factors in Tlemcen watershed production are more important in developing water use scenarios across different horizons. Figure 4.12 shows the identification of the two most important and uncertain factors of influence.

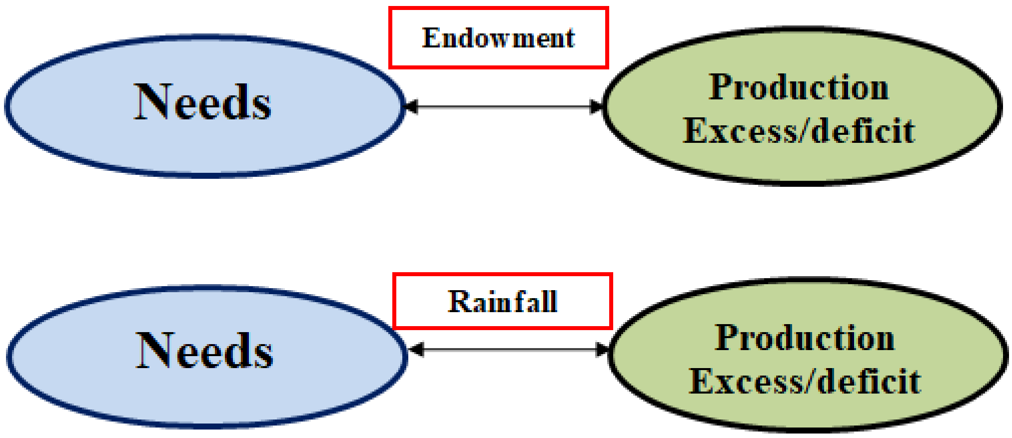

Figure 4.12 : Identifying the two most important and uncertain factors of influence

4.5.5 Calibration of a "compass of the future" for different horizons

In the manner of a compass, whose North-South and East-West axes make it possible to orient in space, the endowment, the rainfall and their respective opposite projections (issues) can be used to orient themselves in the horizon 2025, 2040 and 2050 in which the scenarios are written.

The following figure shows the calibration scheme for horizons 2025, 2040 and 2050 in the Tafna Basin

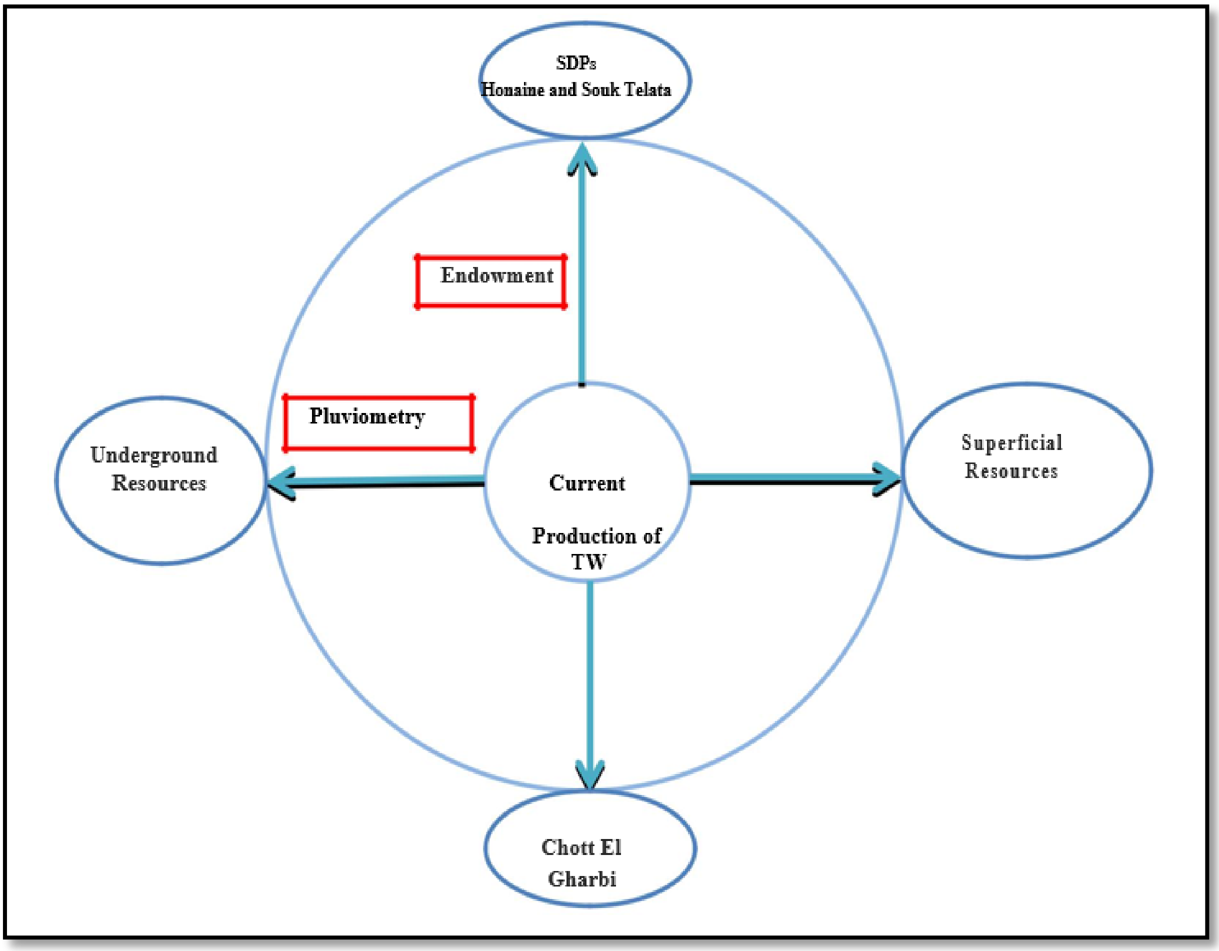

Figure 4.13 : Diagram of identification of the possible alternative outcome in the TW

The two factors of influence in our problematic "Study of the assignment scheme of water resources in the Tafna watershed" are staffing and rainfall.The latter are used as the axis of a coordinated system. The intersection of the two axes represents the current production at the TW level.

The seawater desalination plant at Honaine, the groundwater, the surface water and the Chott El Ghabi project will be considered as the only resources for water production in the TW in the future. These water resources are not the same in terms of quantitative characteristics and their sustainable availability can not be confirmed because the underground and surface resources are conditioned by the rainfall and the unavailability of the desalination water of Honaine will be able to meet breakdowns and performance disturbances.

4.5.6 Writing scenarios for each quadrant of a "compass of the future" for horizons

4.5.6.1 Supply scenario of the Tafna watershed

The drinking water supply scenarios will be for the different horizons, short term 2030, medium term 2040 and long term 2050, with different endowments as shown the table 4.4.We are trying to use Tlemcen's water resources to meet future needs in the Tafna watershed.

Table 4.4 : Drinking Water Supply Scenarios

N°	Horizon	Endowment (l/d/hab)	Supply scenario	
			Conventional Water	Unconventional Water
1	2050	150	Without	With
2	2050	150	With	With
3	2040	200	Without	With
4	2040	200	With	With
5	2025	250	Without	With
6	2025	250	With	With
7	2050	250	With	With

4.5.6.2 Scenario for filling TW deficit

We assume that the drinking water supply and irrigation of the TWis made at the base of the production according to the available resources of the current situation '2017'.

Underground resources: 31.35 Mm^3 / year.

The superficial resources: 121.59 Mm^3 / year.

The SDPs Honaine and Souk Telata produce for consumption of the TW a volume of 85.92 Mm^3 / year.

Reuse of treated wastewater: 12.8 Mm^3 / year and the total for the TW is approximately 252 Mm^3 / year.

Therefore, we will look for other resources to fill the deficit in order to balance the needs and the supply of the projected horizons as shown the table below.

Table 4.5 : Scenarios for bridging the deficit

N°	**Horizon**	**Endowment (l/d/hab)**	**Scenario to fill the deficit**	
			Conventional Water	**Unconventional Water**
8	2050	150	Without	With
9	2050	150	With	Without
10	2040	200	Without	With
11	2040	200	With	Without
12	2025	200	Without	With
13	2025	200	With	Without
14	2050	250	With	Without

Scenario N ° 1: for a staffing of 150 l / d / hab and feeding by unconventional water resources in 2050

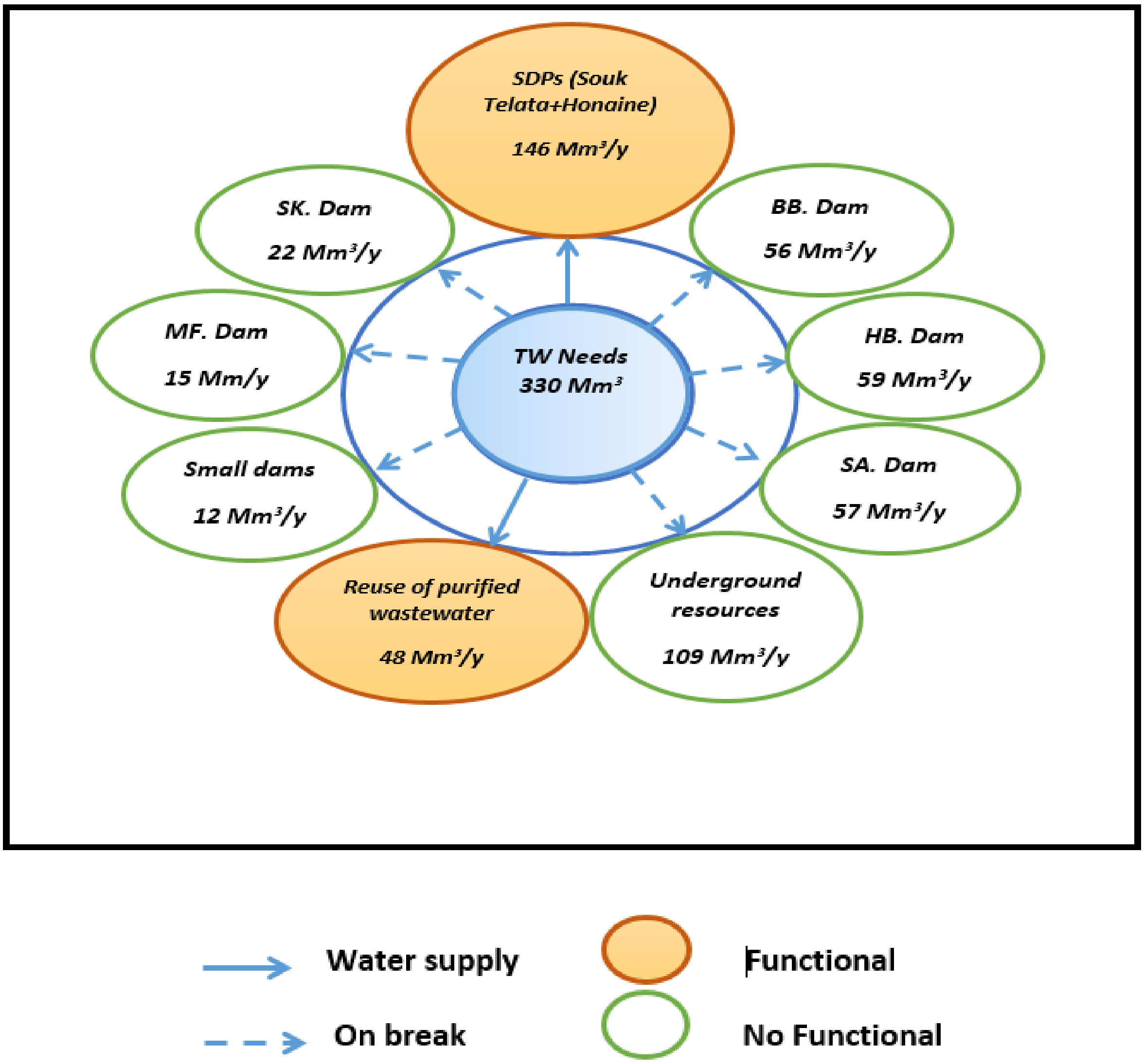

Figure 4.14 : Scenario N°1

We try in Figure 4.14 to cover the water needs in 2050 in the watershed of Tafna with the endowment used of 150 m³/d using the unconventional water resources of the wilaya ofTlemcen with the integration of treated wastewater to cover the future needs. We have assumed that in 2050 the SDPs will be exploited with a maximum capacity of 146 Mm³/y.In this case, this scenario is rated favorable

Scenario N ° 2: for an allocation of 150 l / d / inhabitant and feeding by conventional and unconventional water resources in 2050

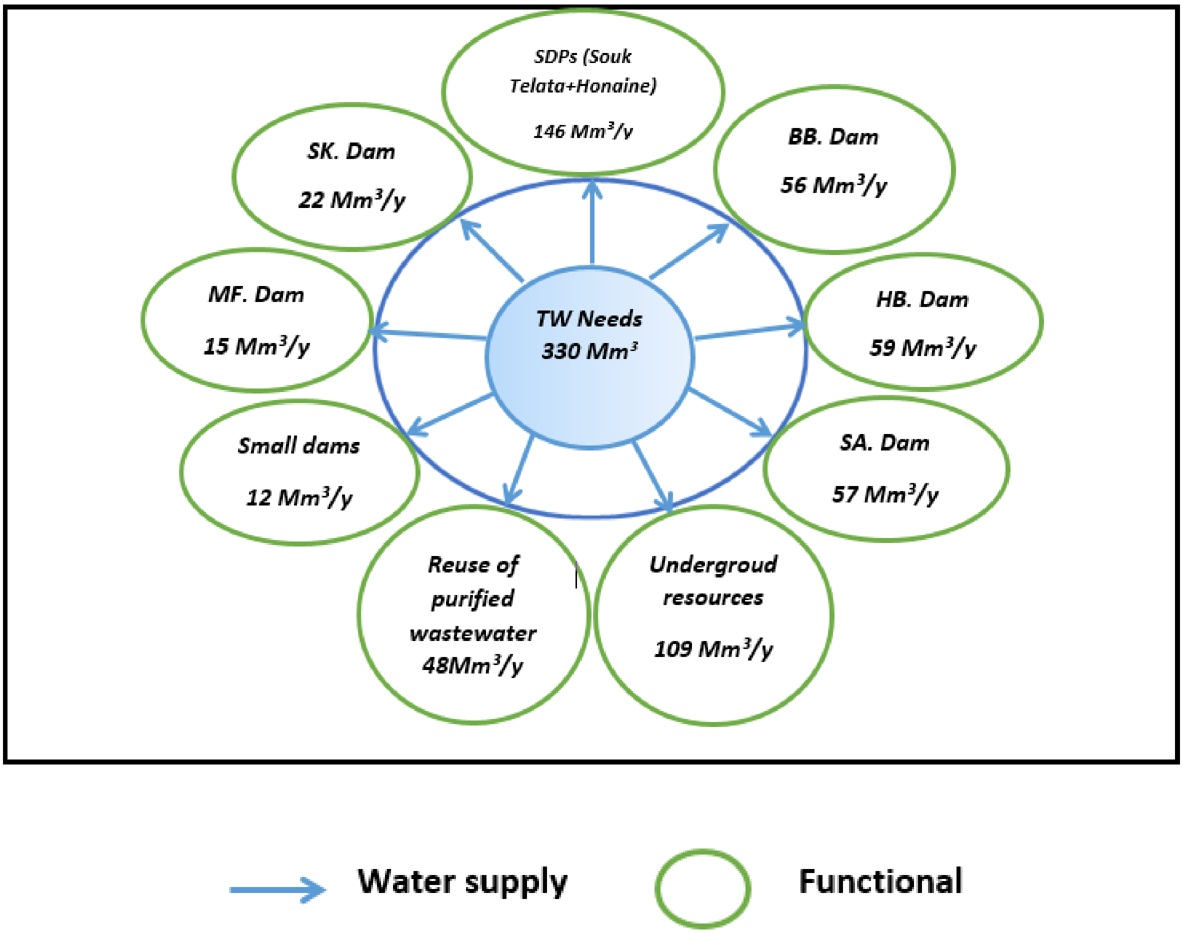

Figure 4.15 : Scenario N°2

Based on the development of this scenario in Figure 4.15, we propose as a drinking water supply solution in the Tafna watershed in 2050, an endowment of 150 l / d, which can be ensured only by a production the two desalination stations Honaine and Souk Telata, which are 146 Mm^3 / year. To cover the future water needs for agriculture and the TW industry surface and ground water resources are used to meet demand, especially for the agricultural sector that consumes the most water.

This scenario will require a great performance from the SDPs Honaine and Souk Telata, knowing that they are limited by a life span of 25 years. Therefore, this scenario is a favorable case if the rehabilitation of these desalination plants will be ensured for the stations to function properly even in the 2037.

As the rehabilitation of the SDPs of Honaine and Souk Telata, is an operation that can be foreseen and realized, fact that it is included in the field of maitrisable although we had performance problems in recent years including the station Souk Telata Unlike climatic hazards which are not part of this domain.

Therefore, their mastery is impossible; hence, the scenarios that depend only on the subterranean and superficial resources are ranked unfavorable

Scenario N ° 3: for an allocation of 200 l / d / inhabitant and feeding by conventional water resources in 2040 with the integration of the reuse of treated wastewater

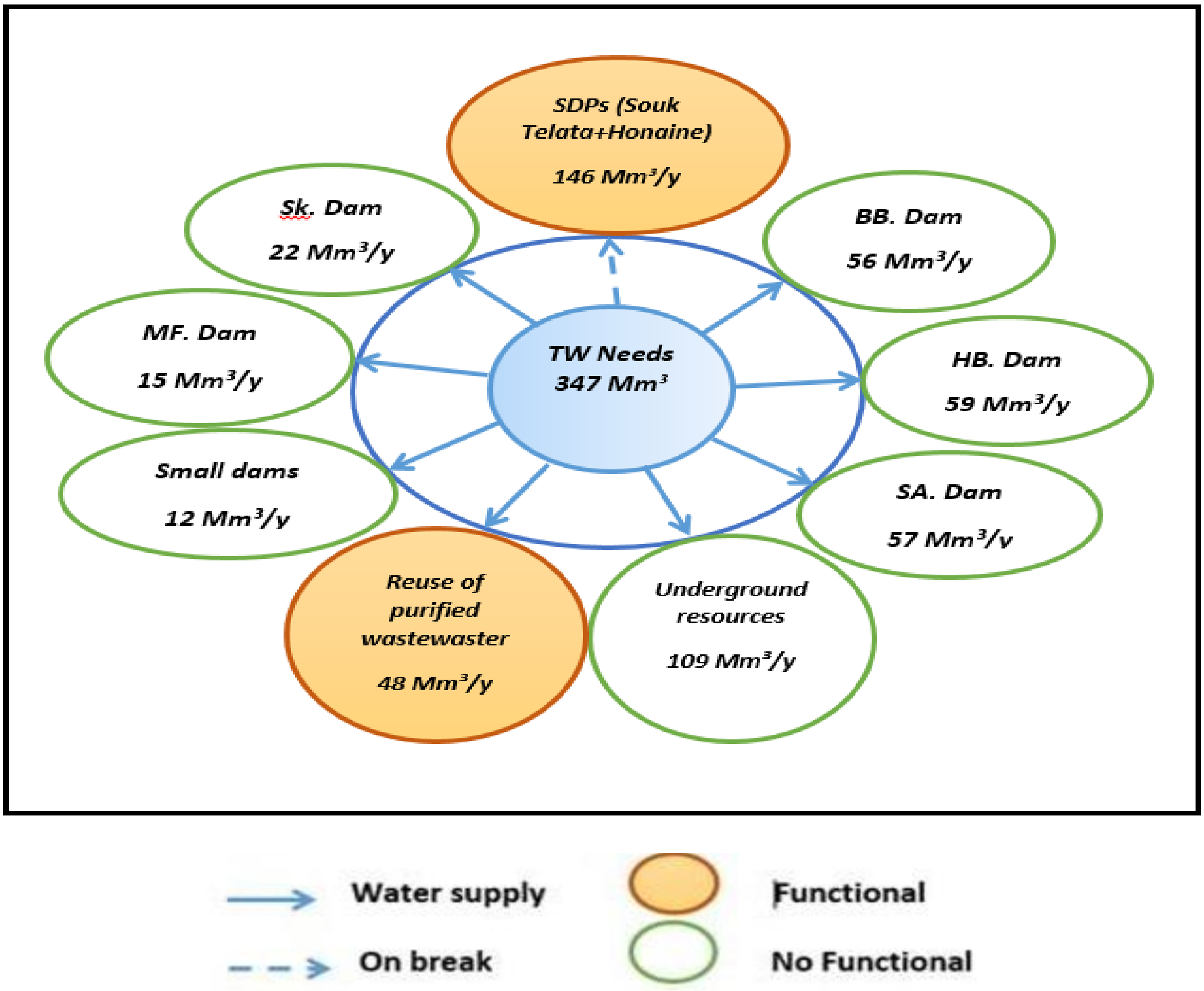

Figure 4.16 : Scenario N°3

The scenario developed in Figure 4.16 represents a collaboration of conventional resources (dams, boreholes and springs) to cover future drinking water needs by 2040 with the integration of the reuse of treated wastewater. If we encounter problems in these resources such as the siltation of dams, the scarcity of rainfall, the malfunction of sewage treatment plants, we can cover the desalination stations.

This scenario is very dependent on climatic hazards, and therefore the satisfaction of needs will be compromised, which classifies. This scenario is unfavorable.

Scenario N ° 4: for an allocation of 200 l / d / inhabitant and feeding by conventional and unconventional water resources in 2040

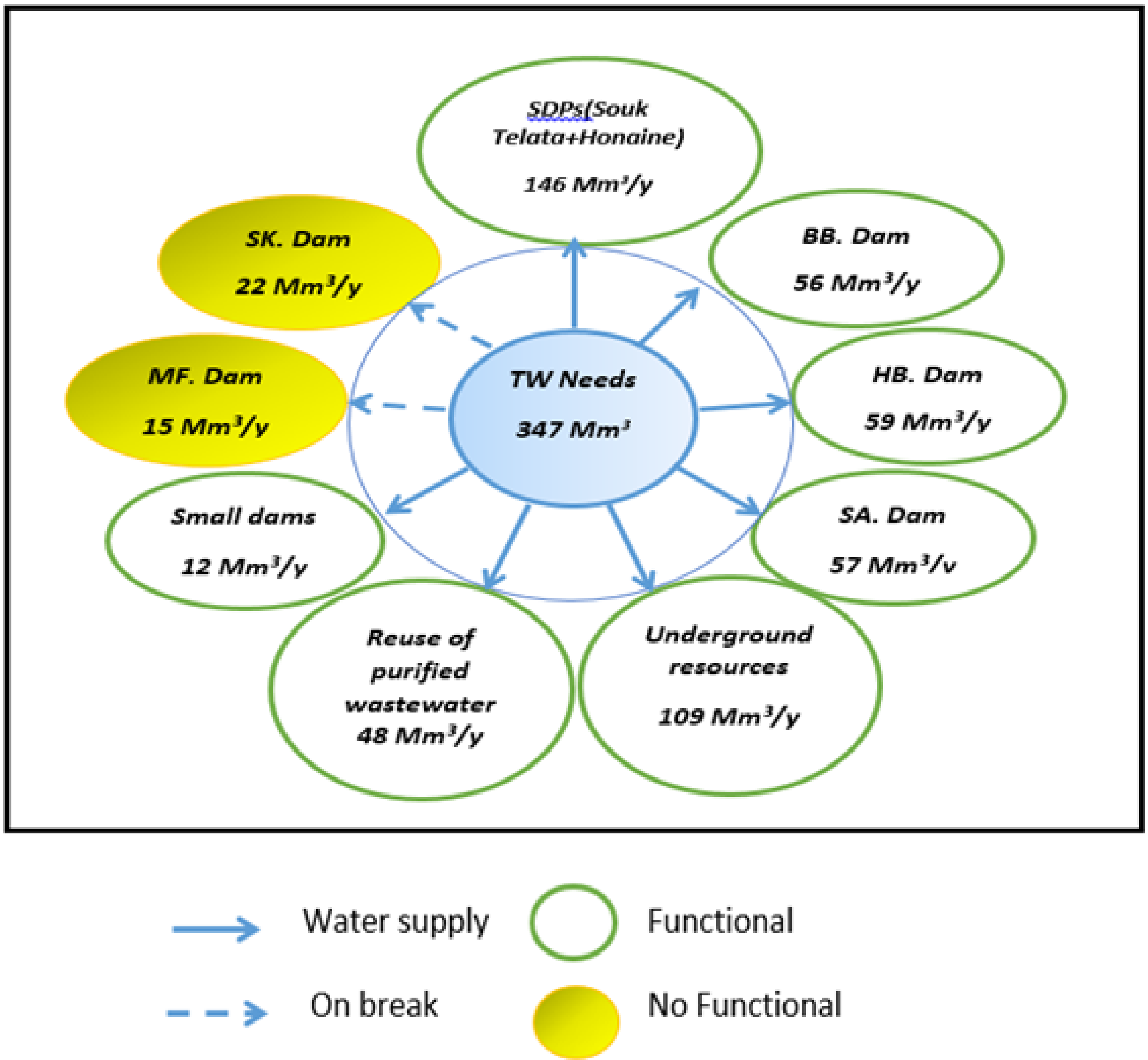

Figure 4.17 : Scenario N°4

The scenario developed in Figure 4.17 represents a collaboration of conventional resources (dams, boreholes and springs) and unconventional resources (seawater desalination and sewage treatment) to cover future water requirements at the 2040 horizon. If we encounter problems in resources, we can cover the other dams as Meffrouche and sekkak dams.

Water supply will be produced from the desalination plants of Honaine and Souk Telata (400 000 m³ / d) if its rehabilitation will be carried out and its performance will be improved, so the case of this scenario in point of view of the use of unconventional waters is a favorable case.

On the other hand, this scenario is very dependent on climatic hazards and especially drought, and therefore the satisfaction of domestic, agricultural and industrial needs will be compromised, which ranks this scenario in the adverse case.

Scenario N ° 5: for an endowment of 250 l / d / hab and feeding by unconventional water resources in 2025 with the integration of the reuse of treated wastewater

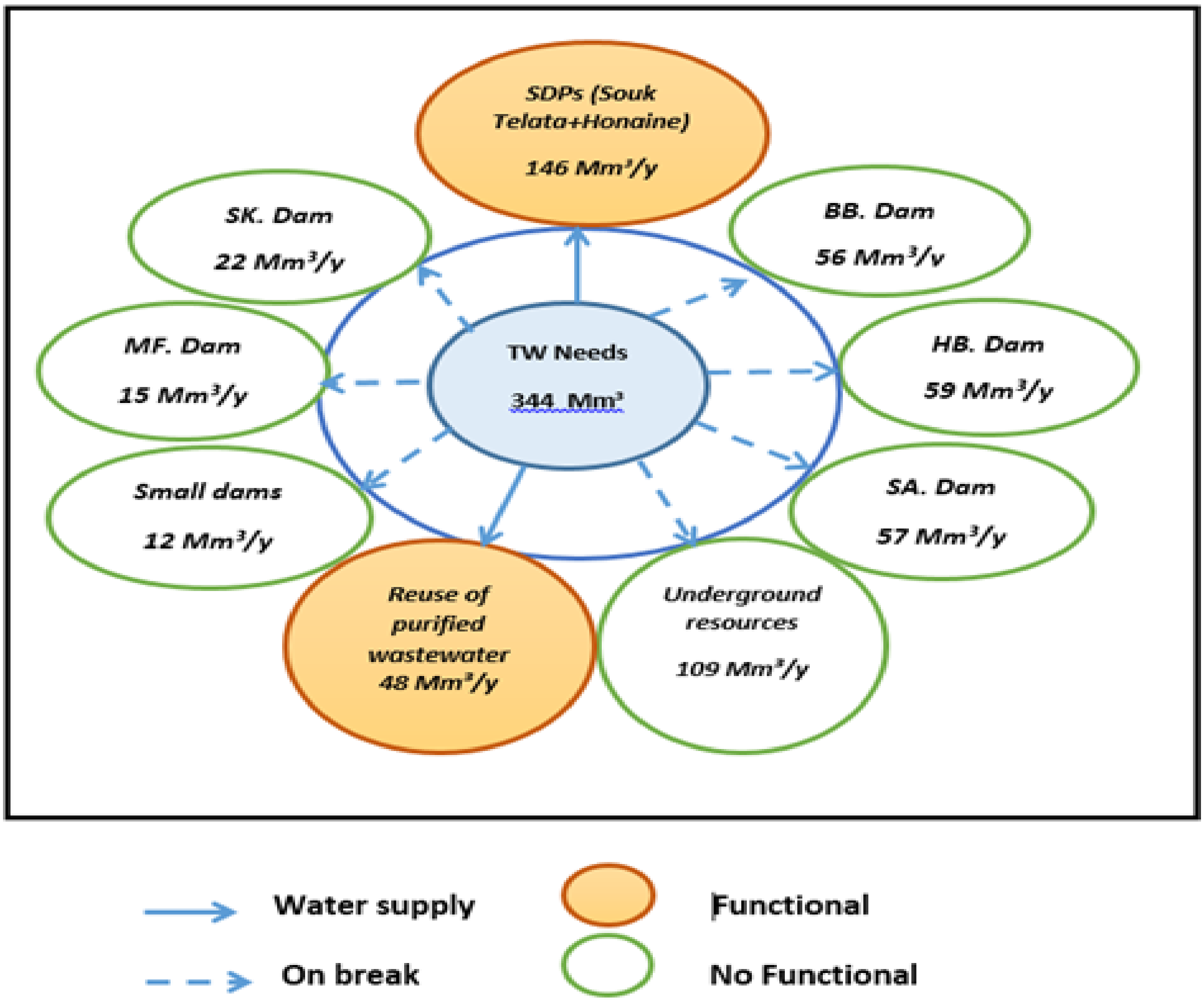

Figure 4.18 : Scenario N°5

In this scenario below which is illustrated in figure 4.18 we increase the production of the conventional water resource with the integration of treated wastewater to cover the future needs of the Tafna watershed with an endowment of 250 l/d/hab.

This solution is valid in 2025 because the SDP Honaine does not reach its lifetimes and in case of drought, we can support the production with a volume of 28 397 m³ / d from capture of Zouia and Chott El Gharbi. Therefore, this case is favorable as a scenario.

Scenario N ° 6: for an endowment of 250 l / d / hab and feeding by conventional and unconventional water resources in 2025

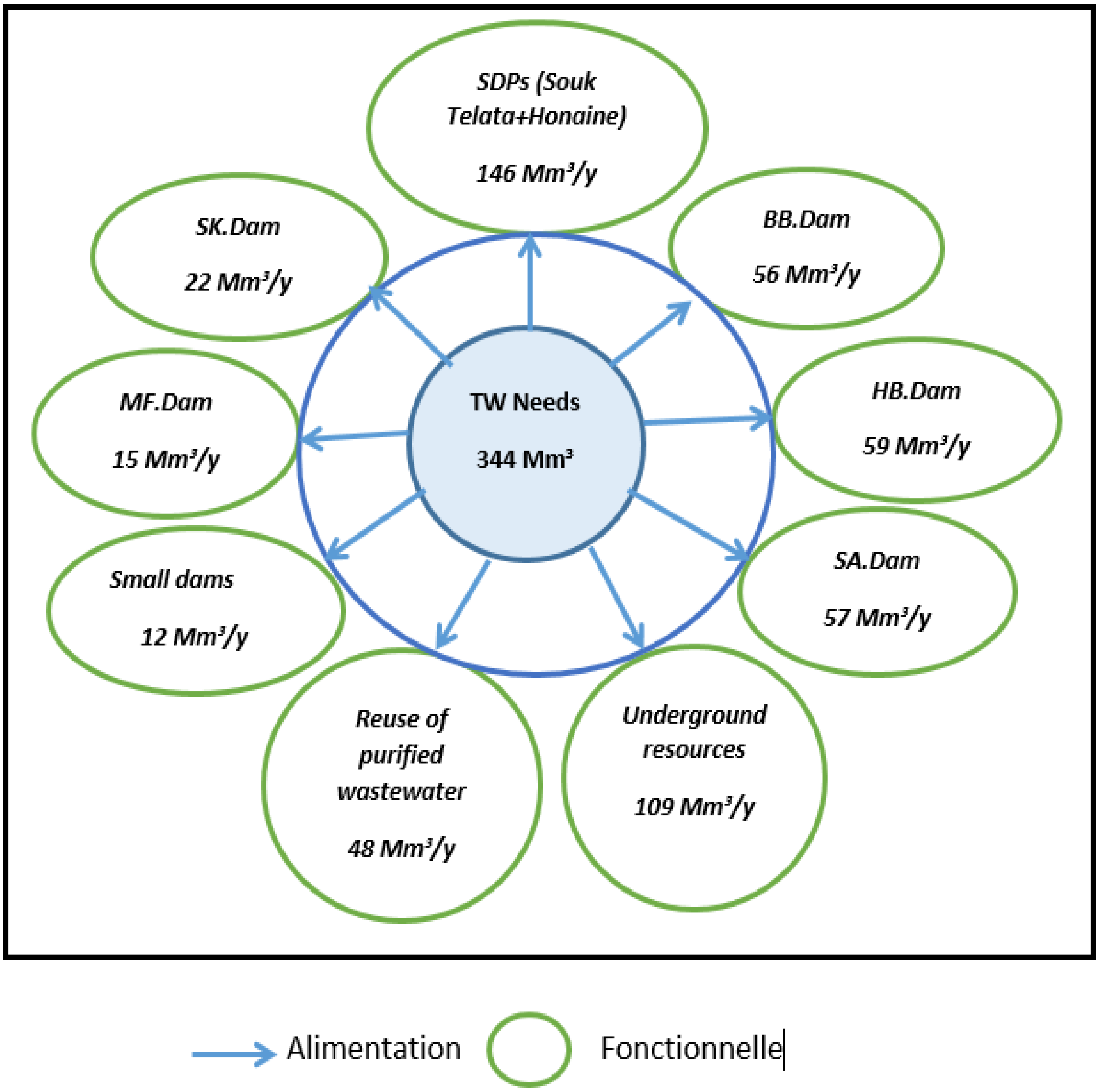

Figure 4.19 : Scenario N°6

Figure 4.19 shows the scenario developed for the Tlemcen watershed with an allocation of 250 l / d /hab and based on the use of conventional water (dams, boreholes and springs) and unconventional water (desalination seawater for the supply of drinking water and the reuse of treated wastewater to cover agricultural needs).

This solution is not so valid because underground and surface resources are conditioned by climate change (drought, groundwater pollution, siltation of dams) in 2050. However, with the increase the production of desalination stations up to 400 000 m³ / d the future needs of the Tafna watershed can be covered an endowment of 250l/d/hab.

This solution is valid in 2025 because the SDPs do not reach its life yet. Therefore, this case is favorable as a scenario.

Scenario N ° 7: for an endowment of 250 l / d / hab and feeding by conventional and unconventional water resources in 2050

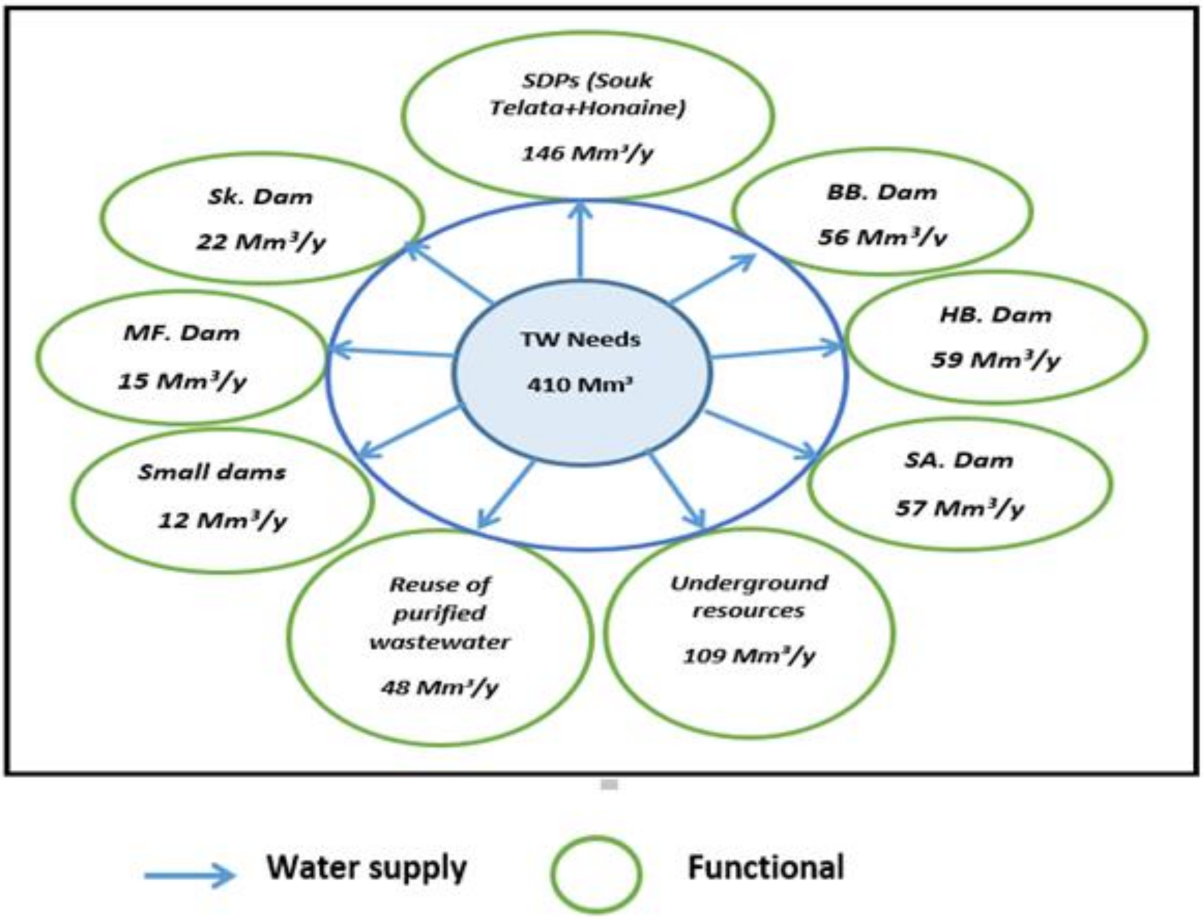

Figure 4.20 : Scenario N°7

The scenario developed in Figure 4.20 represents a collaboration of conventional and unconventional resources to cover future drinking water needs by 2050.These are the operating constraints related to the use of desalinated water.

Currently desalination is the main resource that feeds the TW but by 2050 we will register a significant deficit and this resource will not meet the needs of the entire population of the TW if it will be affected for the whole Wilaya Tlemcen and even to other neighboring wilayas (Sidi Bel Abes, Ain Temouchent).

Also the question concerning the unplanned stops of the desalination station caused by the turbidity of the water or the rupture of the electric energy and which greatly disturb the distribution of drinking water requires a solution.

Therefore, the re-supply of surface water and groundwater (boreholes and springs) will be necessary to compensate the desalination water to meet different future needs whether domestic, industrial or agricultural.This scenario is unfavorable.

Scenario N ° 8: for an allocation of 150 l / d / inhabitant and filling of the deficit by unconventional water resources in 2050

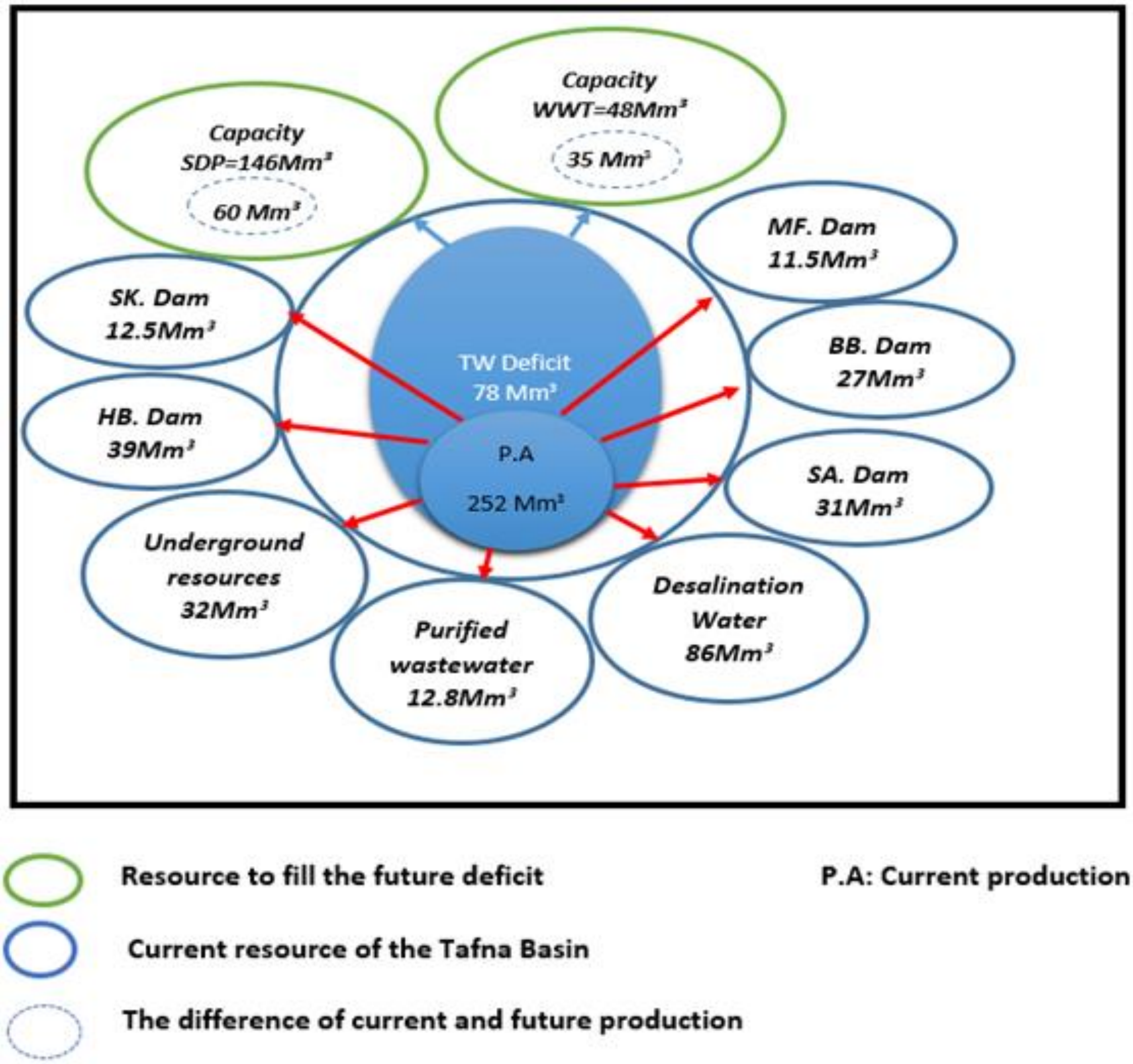

Figure 4.21 : Scenario N°8

On the one hand, we consider that the SDPs produce water with a maximum capacity of 400,000 m3/d. Currently the SDPs Honaine and Souk Telata produce a daily water volume of 235 397 m³/d, i.e. 86 Mm³ / year, we have assumed that in 2050 the SDPs will be exploited with a maximum capacity of 400 000 m³ /d.

On the other hand, we consider that the wastewater treatment plants (WTP) that are in operation and those that are in production produce purified water with a maximum capacity of 131 507 m³ / day or 48 Mm³ / year. By 2050, the difference in current and future production of SDP and WTPis intended to fill the gap of 78 Mm³ / year with an allocation of 150l / d /

hab.While guaranteeing the maintenance operations and rehabilitation of the desalination plants and the operating performance of the treatment plants in question.

In this case, this scenario is rated favorable. Figure 4.21 shows the allocation of the Honaine desalination water in 2050, solely to cover the water requirements of the TW

.**Scenario N ° 9: for an allocation of 150 l / d / inhabitant and filling the deficit by the conventional water resources in 2050**

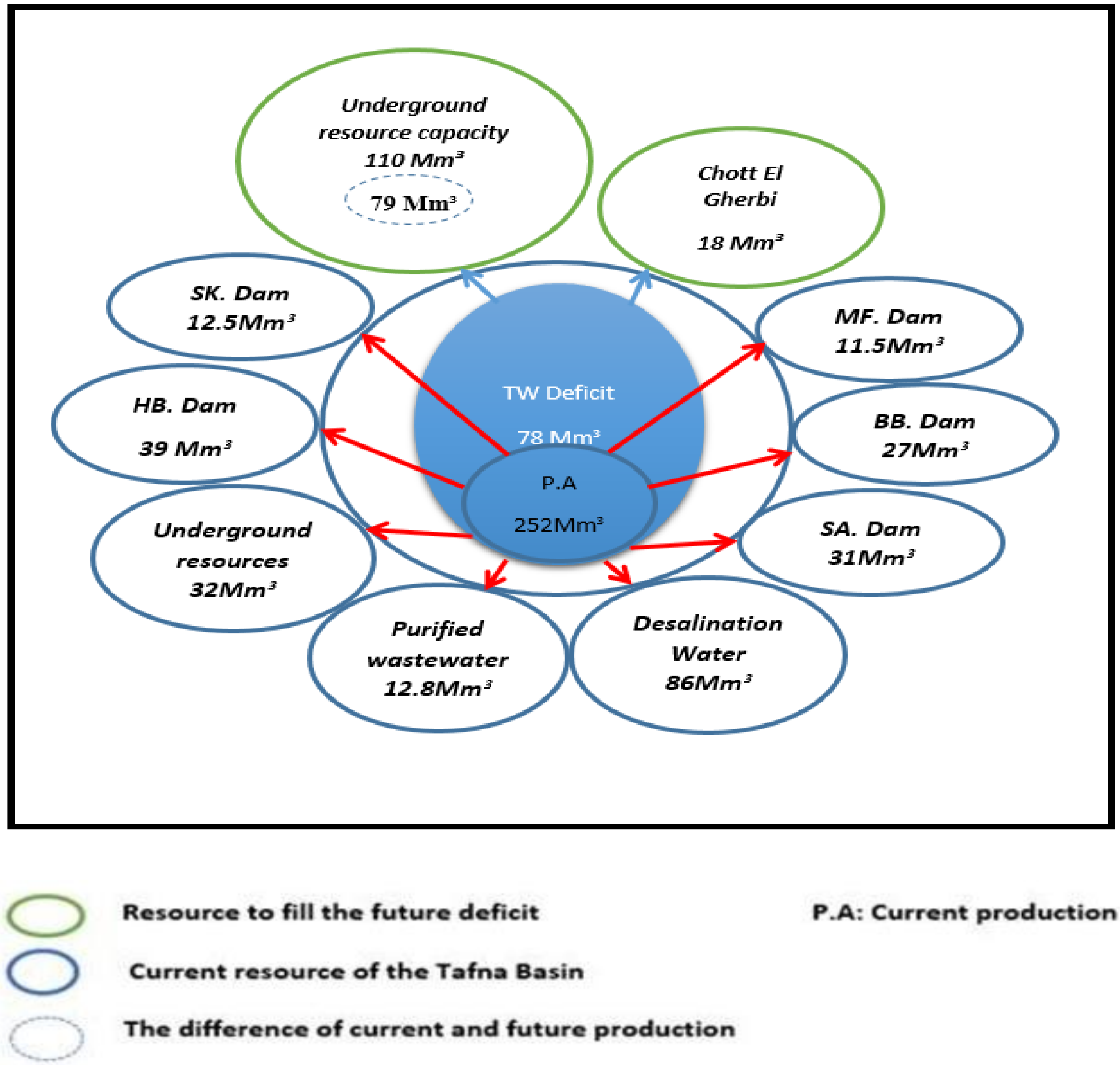

Figure 4.22 : Scenario N°9

This scenario is developed for the 2050 horizon with an allocation of 150 l / d / inhabitant. We are using the underground resource capacity of TW which is currently inoperative with a production of 79 Mm³ and Chott El Gharbi with a capacity of 18 Mm³ remains as a backup case in the case of drawdowns to fill the deficit of 78 Mm³ / year ,

Therfore, the case is favorable. Figure 4.22 shows the allocation of different resources for TW in 2050.

Scenario N ° 10: for an allocation of 200 l / d / inhabitant and filling of the deficit by unconventional water resources in 2040

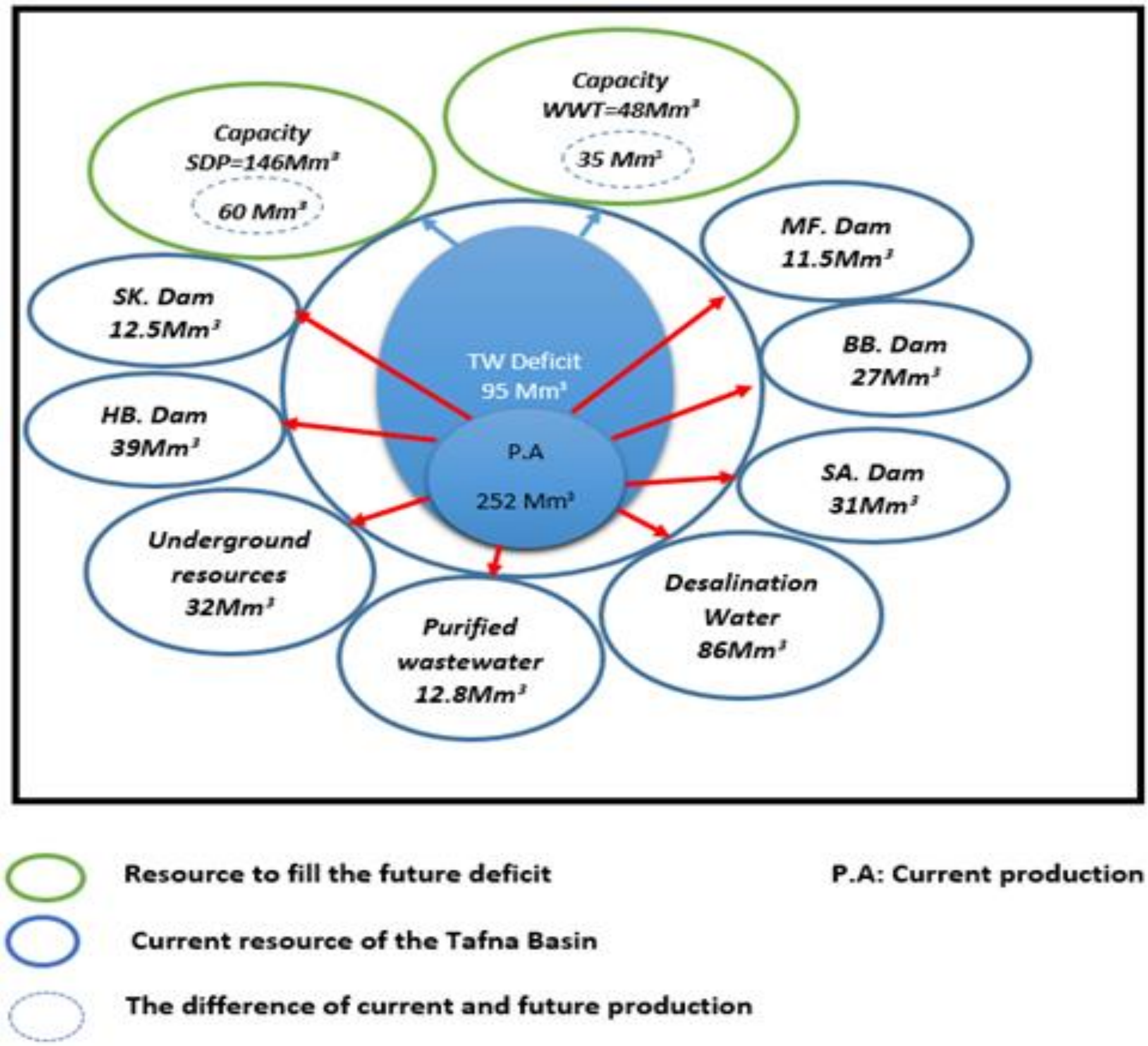

Figure 4.23 : Scenario N°10

We are trying to fill the future gap in 2040 from Tlemcen unconventional urban water resources. This deficit of 260 274m³/ d or 95 Mm³ will be filled from the desalination plants of Honaine and Souk Telata on the assumption that they will have good performance after 2037 to provide water for domestic use by adding treatment plants in TW for the reuse of treated water for irrigation. Therefore, this case is favorable. Figure 4.23 shows the allocation of the Honaine desalination water in 2040.

Scenario N ° 11: for an allocation of 200 l / d / inhabitant and filling of the deficit by the conventional water resource in 2040

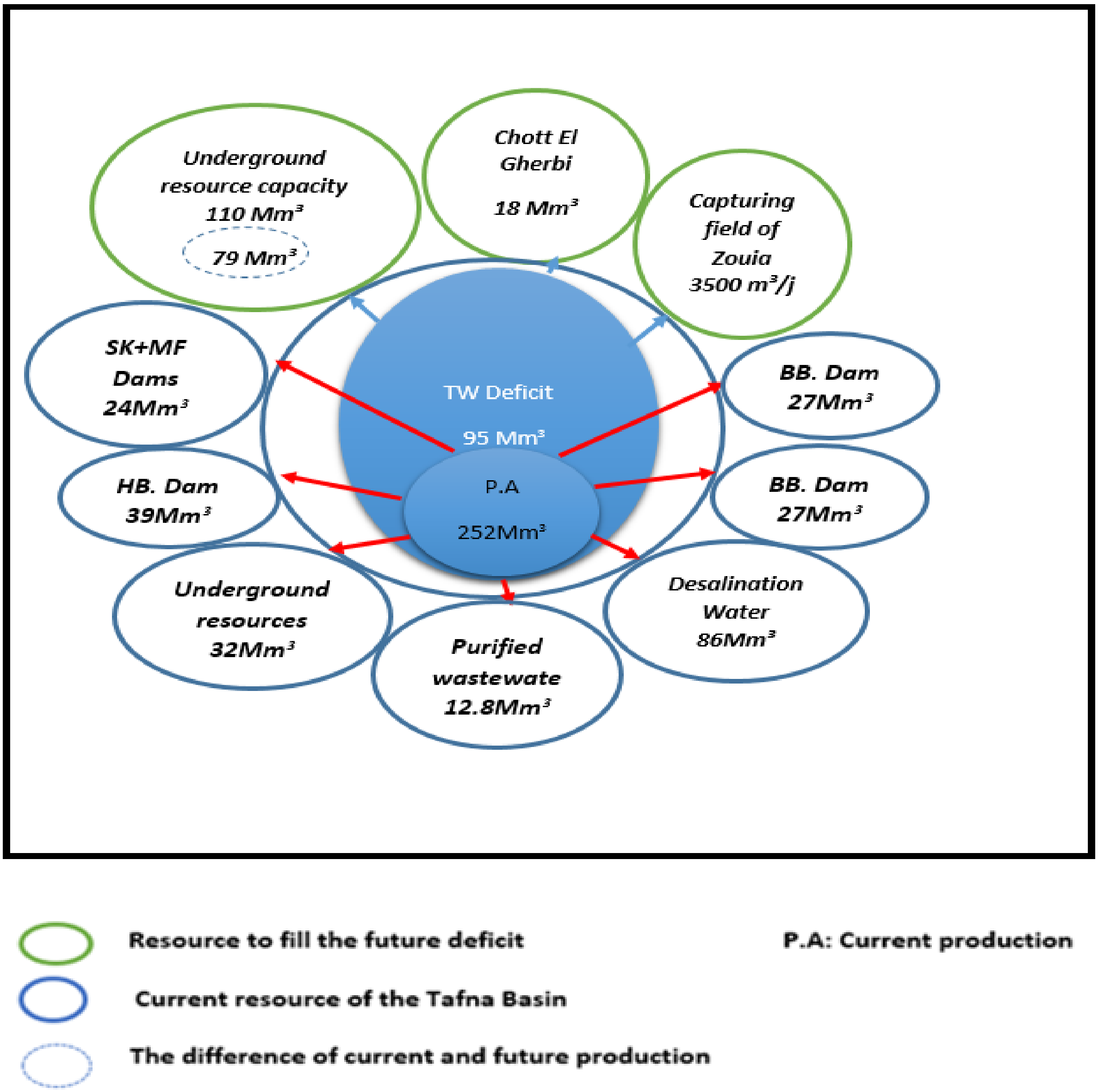

Figure 4.24 : Scenario N°11

This scenario is developed for the 2040 horizon with an allocation of 200 l / d / inhabitant. We use the TW borehole water, which is on standby with a production of 79 Mm³ / year and the catchment field of Zouia with capacity of 3500 m³ / d and Chott El Gharbi to fill the deficit of 260 274 m³ / d or 95 Mm³ / year, so the case is favorable. Figure 4.24 shows the allocation of different resources for TW in 2040.

Scenario N ° 12: for an allocation of 200 l / d / inhabitant and filling of the deficit by unconventional water resources in 2025

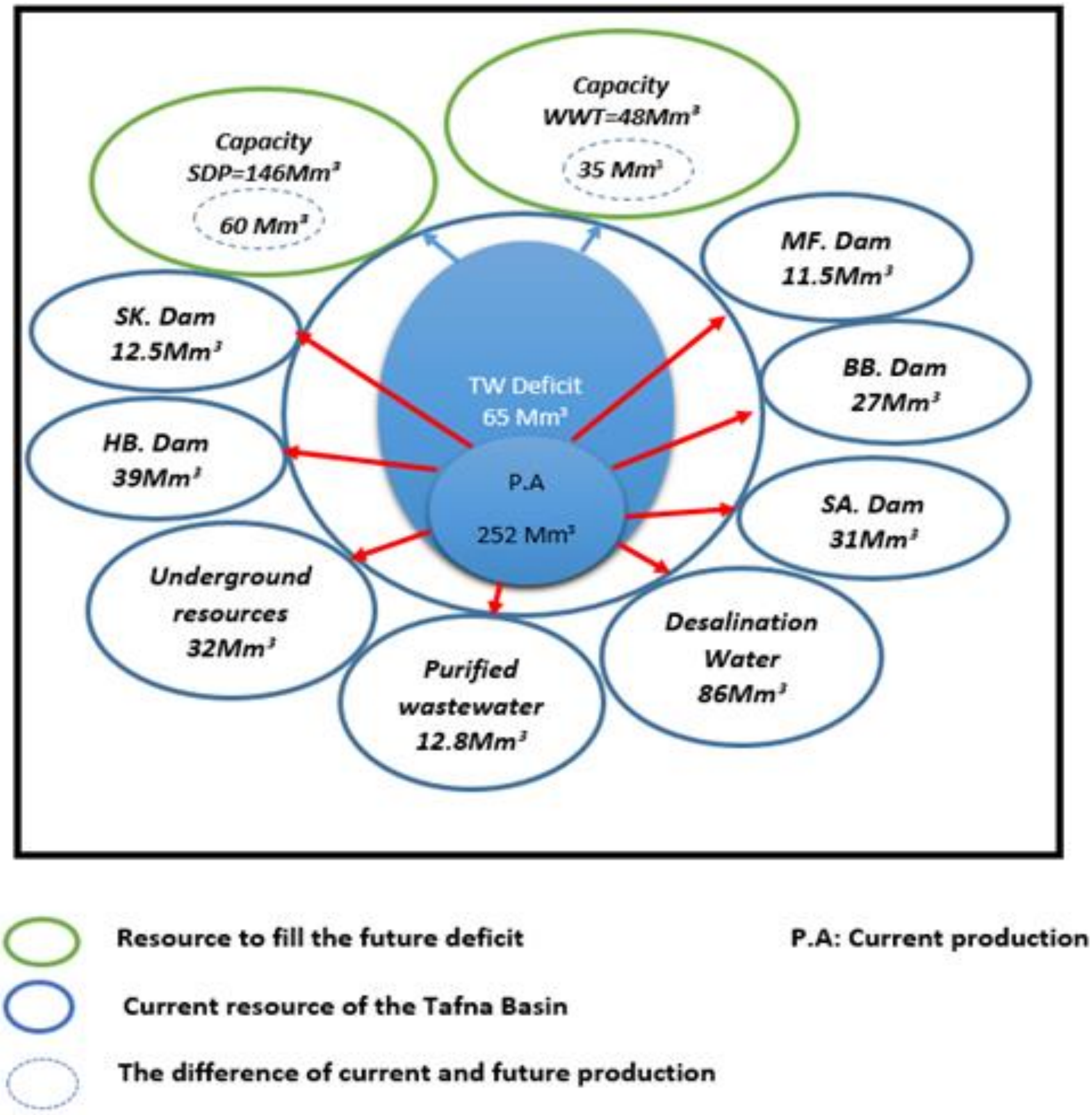

Figure 4.25 : Scenario N°12

This scenario is developed for the 2025 horizon with an allocation of 200 l / d / inhabitant. We will increase the current production of Honaine and Souk Telata desalination plants to fill the TW deficit of 178,082 m³ / d. Therefore, this scenario is very favorable because the SDP of Honaine should work properly and its life will not be reached yet and provided that the SDEM Souk Telata should follow a rigorous maintenance to resume its performance capacity. Figure 4.25 shows the allocation of desalination water to cover TW deficits in 2025.

Scenario N ° 13: for an allocation of 200 l / d / inhabitant and reduction of the deficit by conventional water resources in 2025

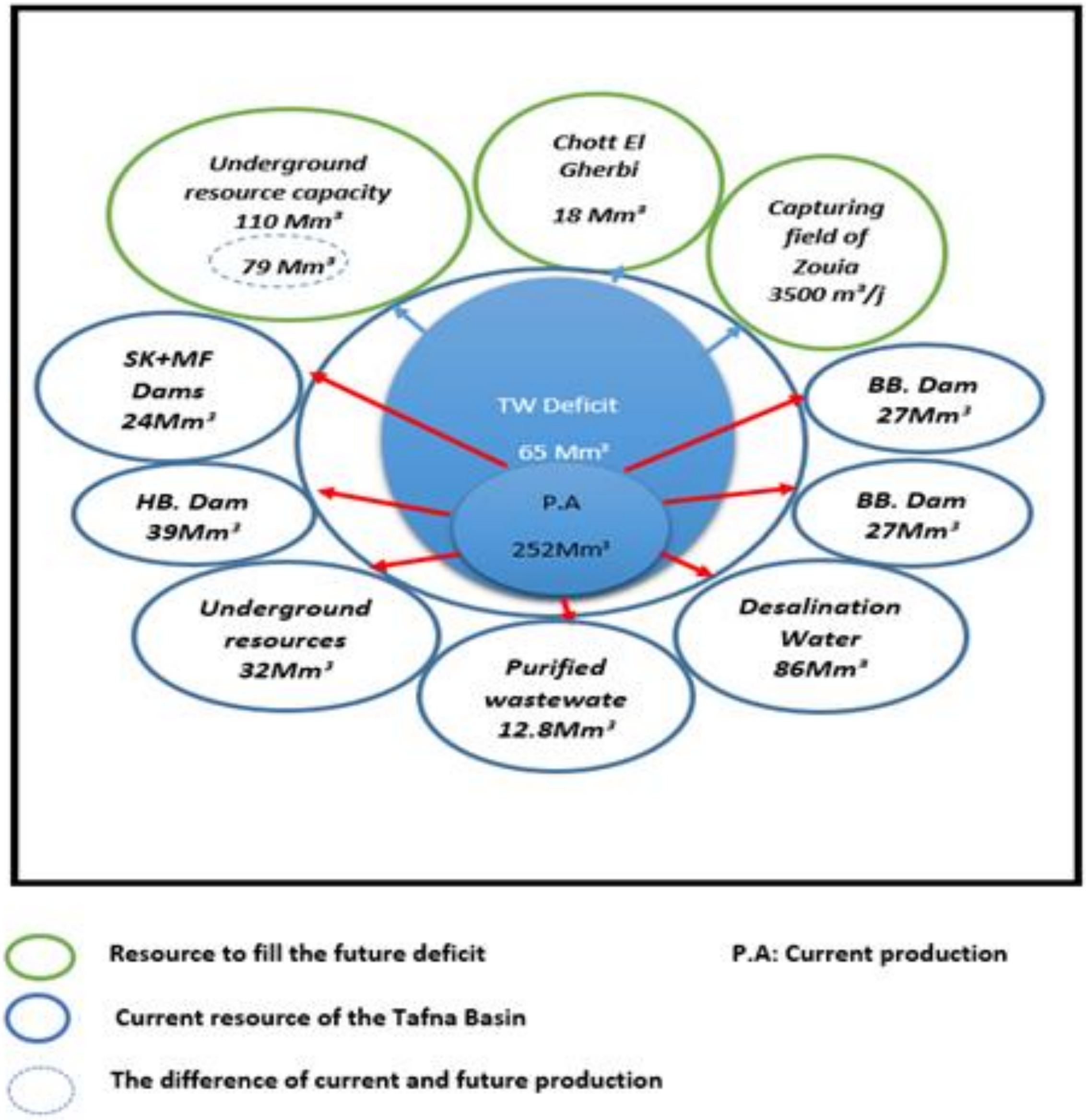

Figure 4.26 : Scenario N°13

This scenario is developed for the 2025 horizon with an allocation of 200 l / d / inhabitant. We will increase the production of TW boreholes and the wellfield of Zouia and Chott El Gharbi remains as a backup case to fill the TW deficit of 178,082 m³ / d or 65 Mm³ / year.So we can cover the estimated needs in 2025 in the Tafna watershed from this scenario, which can only be favorable. Figure 4.26 shows the allocation of different resources for the TW in 2025

Scenario N ° 14: for an allocation of 250 l / d / inhabitant and filling the deficit by conventional water resources in 2050

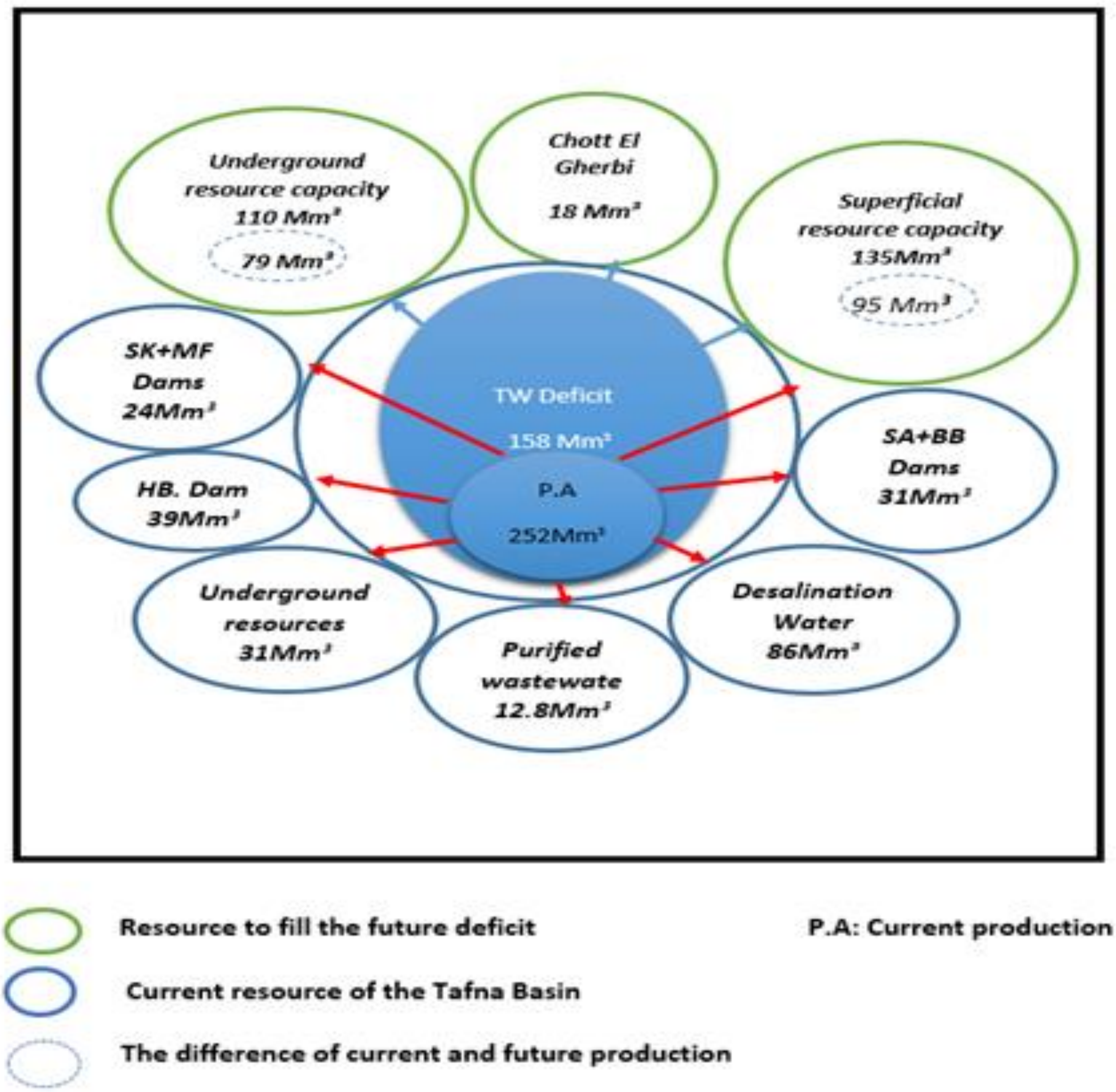

Figure 4.27 : Scenario N°14

Figure 4.27 shows the allocation of conventional resource in the Tafna watershed in 2050. We use the dams, TW and Chott El Gharbi boreholes to fill the deficit but if this period will experience drought we will not be able to solve this problem so this scenario will be unfavorable.

4.5.6 Writing scenarios scoreboards

Table 4.6 : Ranking Scenarios for Supply and Deficit Reduction.

N°	*Horizon*	*Endowment (l/d/hab)*	*Supply Scenario*		*Scenario to fill the deficit*		*Case*
			Conventi-onal Water	*Unconventi-onal Water*	*Conventi-onal water*	*Unconvent-ional water*	
1	2050	150	Without	With	/	/	Unfavorable
2	2050	150	With	With	/	/	Un/favorabe
3	2040	200	Without	With	/	/	Unfavorable
4	2040	200	With	With	/	/	Un/favorabe
5	2025	250	Without	With	/	/	Favorable
6	2025	250	With	With	/	/	Favorable
7	2050	250	With	With	/	/	Unfavorable
8	2050	150	/	/	Without	With	Favorable
9	2050	150	/	/	With	Without	Favorable
10	2040	200	/	/	Without	With	Favorable
11	2040	200	/	/	With	Without	Favorable
12	2025	200	/	/	Without	With	Favorable
13	2025	200	/	/	With	Without	Favorable
14	2050	250	/	/	With	Without	Unfavorable

The proposed scenarios for drinking water supply describe the resources that will be exploited to meet future needs, adding new conventional water resources like Chot El Gharbi and Zouia on these scenarios could give us an idea of what the Tafna watershed will eat in the future.

Scenarios were ranked according to the needs of the population for each horizon. The scenarios proposed for filling the deficit for each horizon are made by the conventional water resources Chot El Gharbi and Zouia but taking into account the water production with the current resources, namely: SDP of Honaïne (170 000 m³ / d), SDP Souk Telata (65 000 m³ / d) groundwater (31.39 Mm³/ year) and surface water (114 Mm³ / year).

4.6 Choice of favorable scenarios

The choice of scenarios has been made in relation to the availability of the resource and the need for water, since conventional water resources are directly linked to climatic hazards, then it is difficult to say if the volume produced by 2050 will meet the needs. For this purpose, our choice was directed towards the supply and filling of the unconventional water resource, as long as the SDP of Honaine is included in the domain of the mastery.

Therefore, it is the preferable solution in terms of product volume and needs satisfaction and for that, we chose two scenarios in each part with an allocation of 150 l / d / hab and a theoretical endowment of 250 l / d / Hab.

For Part 1 of the supply scenarios we chose two scenarios made by unconventional resources

- Scenario N ° 1 for an allocation of 150 l / d / Hab.
- Scenario N ° 5 for an allocation of 250 l / d / Hab.

For Part 2 of the Scenarios for Bridging the Deficit we chose two scenarios made by unconventional resources

- Scenario N ° 8 for an allocation of 150 l / d / Hab.
- Scenario N ° 12 for an allocation of 250 l / d / Hab.

4.7 Interpretation

From the scenarios developed in this chapter, we show that Tlemcen's water resources can cover the needs of the agglomerations in the study area by 2050, But on the condition of continuity of performance of the desalination station of Honaine in the future and good hydrological years in the future.

The writing of the scenarios for the projected horizons (short term 2030, medium term 2040, and long term 2050) was done in the base of two parts: TW supply scenario, and to fill the deficit, from conventional and unconventional resources, according to different proposed endowments.These so-called adverse scenarios can be developed in future studies. Other sources of drinking water supply can be considered to fill the deficits registered.

4.8 Tafna catchment scale constraints and challenges

Factors such as growth and demographic changes, economic development and climate change are clearly having a major impact on water resources (Adjim H, 2004). Similarly, water resources have a significant impact on production and economic growth, on health and livelihoods, and on national security. Given the intensification of pressures on water resources, it is essential to properly manage any renewable resource. This management becomes, however, more and more complex and conflictual (Rouissat B, 2015).

In some basins, climate change will result in reduced rainfall, while it will cause an increase in the frequency and strength of floods in others. These changes will be exacerbated by other variations, such as population and economic growth, urbanization and increased demand for food products that increase water and degrade watercourses and aquifers in basins already facing water scarcity.

The search for a balance between economic development and the preservation of water resources subjects the basin manager to enormous pressures, risks and conflicts (Rouissat B, 2015).Basin managers must also fight against pollution caused by household and industrial discharges.

Agricultural progress is accompanied by greater use of fertilizers and pesticides by farmers, which increases pollution. However, areas where water resources have already been extensively developed also face major challenges. Water resources are often overexploited.Basin managers must manage very complex interactions between what happens upstream and downstream (Rouissat B, 2015).

Because of the inherent and multiple links between different uses and users of water, water management at the basin level has a direct impact on the communities, administrative regions and political territories of this basin. Communities that share a basin are particularly interdependent. Basin managers need to identify ways to address water challenges to avoid problems such as social unrest, conflict, economic slowdown and degradation of vital resources.

4.9 Analysis of water management in the Tafna watershed

4.9.1 Background

Over the past decade, Algerian water management policy has focused more on the mobilization of new resources than on the search for a better use of the resources already available. Priority has been given to the development of "supply" and not to demand management. Evidenced by the predominant role in investment budgets in increasing storage capacity and developing major transfer and supply infrastructure, low funding for maintenance and upkeep of facilities, or improved performance of water and irrigation systems(Rouissat B,2015).

However, the new water policy is moving towards a more rational and more economical management of water, with the search for greater water efficiency in all consumption and use sectors. The range of possible improvements in this efficiency is still considerable if one refers; for example, to the area of domestic water, where the ratio between the volume of water supplied and the volume of water actually used by users is around 50% (Benblidia et al.,2010).

4.9.2 Water law

The management of the water sector in Algeria is mainly organized within the framework of

the law relating to water (law 05 12 of August 4, 2005).

The 2005 Water Act enshrines the right of access to water and sanitation for all and defines the principles on which the use, management and sustainable development of water resources are based:

- The right of access to water and sanitation for all,
- The right to use water resources for all within the limits of the general interest,
- Planning of distribution and development within natural hydrographic units,

- Taking into account the real costs of domestic, agricultural and industrial water supply services and sanitation services,
- The recovery of public intervention costs related to the quantitative and qualitative protection of water resources, through water conservation and quality protection royalty systems,
- Systematization of water saving and reclamation practices through appropriate processes and equipment, as well as the counting of water produced and consumed, to combat losses and waste.

4.9.2 The Tafna watershed and the territorial balance

Population and demography are key determinants of human activity in general and economic activity in particular. The analysis of growth trends will undoubtedly be based on the spatial distribution by planning area. Based on the major issues, four guidelines are issued by the Algerian state within the framework of the National Plan of Spatial Planning 2030, namely (Official Journal N ° 61 of 21.10.2010, SNAT 2030):

- Create a sustainable territory,
- Create territorial rebalancing dynamics,
- Create conditions of attractiveness and competitiveness of the territories, Realize territorial equity.

In the Wilaya Development Plan Study (ANAT, 2012), seven planning areas were targeted by socio-economic balance analyzes, these are the areas shown in Figure 4.28 .These areas constitute TW hydrographic units in terms of resources (mobilization, allocation and use) and uses of the resource (DWS, irrigation, industry).

Figure 4.28 shows the decomposition of the Tafna basin into hydrographic units in relation to the mobilization, uses and users of the water resource.

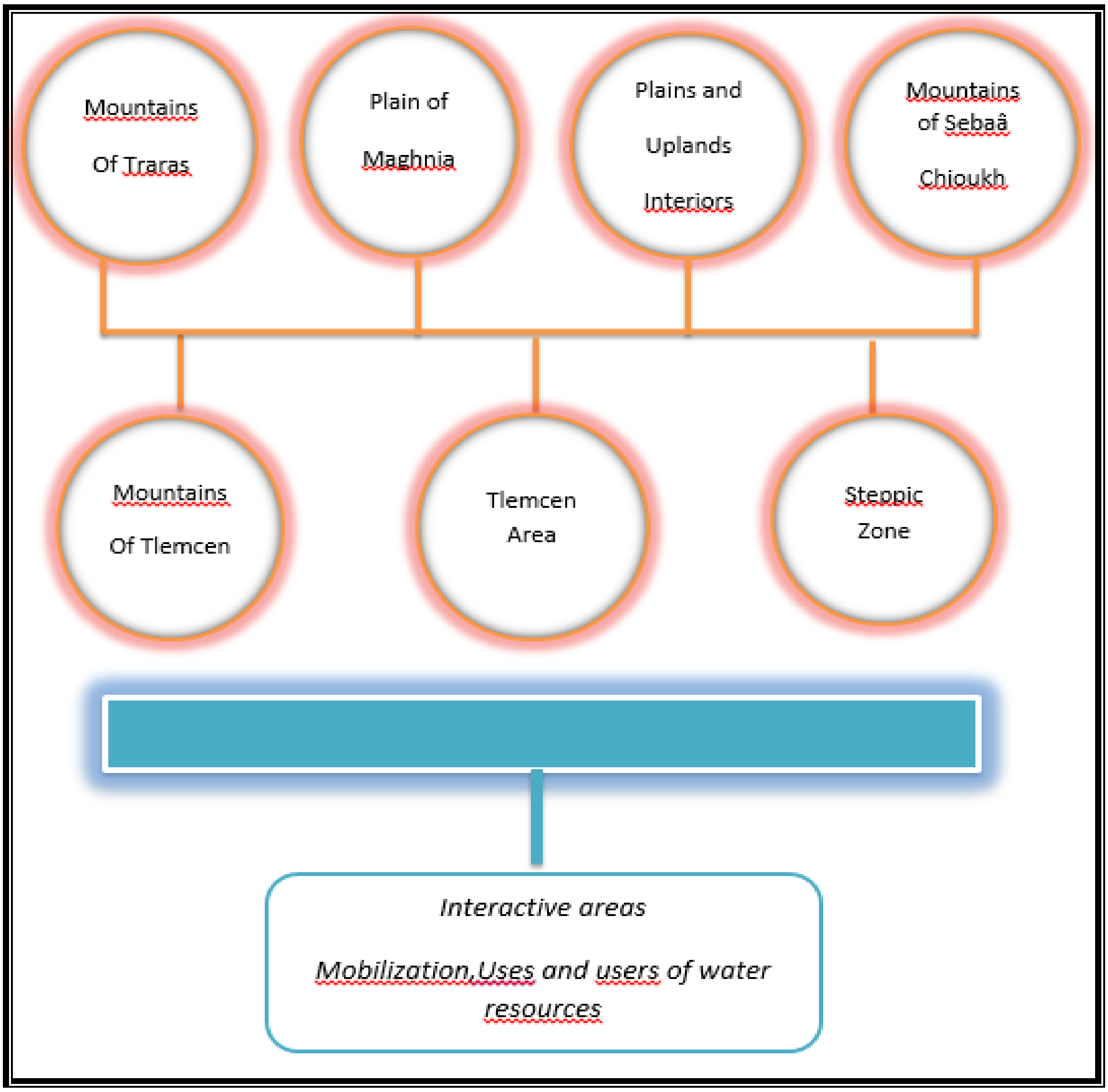

Figure 4.28 : Decomposition of the Tafna watershed in interactive units depending on the mobilization, uses and users of the water resource

Water resource systems support the needs of different interest groups or users, but also involve different systems, which generates conflicting and competitive responses because of the near-total satisfaction of all users, so the optimal solution for a complex system is not the sum of the subsystem optimums but rather the integration of divergent viewpoints resulting in optimized trade-offs between users.

Having easy access to information on the state of water resources and ecosystems, as well as the changing uses and users of water and pollution, is at the root of effective water management. Basin managers must be able to obtain reliable, up-to-date and relevant information when they need it and in a form, that suits them.

Therefore, water information systems of basins need to improve data access and interoperability among all relevant stakeholders. They must benefit all stakeholders to support the management of water resources.

4.10 Conclusion

As for the monitoring of the state of the water resources and the uses, it is fundamental to determine what must be followed, Basin-wide water resources management requires decision-makers to easily access detailed information, representative and reliable, at all levels, on:

- The quality and quantity of water resources, both superficial and underground, as well as their seasonal and annual variations,
- Biotopes and aquatic environments, and their degrees of sensitivity,
- The use of water (withdrawals), particularly for irrigation, industry and drinking water, and sources of pollution (discharges), diffuse or occasional,
- Risks related to recurrent extreme events, such as floods, droughts and pollution,
- Socio-economic indicators, for example costs, prices and taxes.

Where, when, and how often, the references and indicators for monitoring the state of water resources must be linked to the objectives and targets defined in the basin management plan. Indicators for, for example, progress in the implementation of integrated water resources management, could be designed to show:

- Changes in processes,
- Reforms in the integrated management of water resources,
- The impacts and results of integrated water resources management,
- Evolution and sustainability.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The transfer works essentially in the direction Tlemcen-other agglomerations. Estimating the needs of various water users in the Tafna watershed showed that these needs increase over time and there will be a time when the offer will not cover the request in a suitable manner.

Moreover, it is this reason which pushed us to consider the demographic evolution of the population for the estimation of the current and future total water needs of the TW, which are divided into four domains (domestic, industrial, equipment and agricultural) which we calculated for three different endowments: 150,200 and 250 l / d / hab .

Therefore, we made scenarios based firstly on the use of the resources of the TW at the scale of the wilaya of Tlemcen to cover all the needs of the inhabitants in the future.These resources may be unconventional (desalination of seawater and reuse of treated wastewater) and / or conventional (dam, boreholes and springs). We also tried to generate the uncertainty factors of each scenario in order to be able to classify each scenario case by ensuring that the climate changes in our study area and the performance of the Honaine and Souk Telata desalination stations are important in the conduct of the scenarios.

These scenarios highlight future difficulties if other means are not implemented to save water on one side and mobilize more on the other. The desalination of seawater and the reuse of water are the solutions that must be used. The first technique is an inexhaustible resource; the second will also protect the natural environment against pollution. It would be very wise to think about improving the efficiency of drinking water systems. In fact, the large proportion of water produced is lost due to leaks. Agriculture must also be geared towards techniques that do not waste water such as drip irrigation.

Prospects for demand satisfaction various water users are not optimistic given the size of the deficit. A very important effort must be made and geared towards saving water so that the coverage rate is appreciable. If we only refer to the numbers, desalination of seawater becomes the inevitable solution whatever price to pay.

Effort must be made to develop the technique of recharging groundwater artificially, in order to ensure the regularity of production of these waters to fill the deficit in surface water and do not fall into the problem of groundwater after overuse.

Finally, we hope that this modest work will be considered as support for decision-making by the water services of our region, for the optimization of the water resource or we have received the prior attention of some water management actors to include it in the planning.

5.2 Summary and Recommendation

As a summary, the practical implementation of the Tafna integrated watershed management approach focuses on the quantitative and qualitative assessment of resources (natural side), the categories and capacities of their mobilization (technical side), assessment of the various needs (socio-economic side) as well as all the actors with their matrix of responsibility (administrative and institutional side).

5.2.1 Efficiency actions

Efficient and economical management of water resources requires the setting up in each sector of use of systems of regular collection of technical and economic information on production, sampling, distribution and consumption of water.

This information must be based on indicators common to the various operators and stakeholders. Algeria's national water policy has so far focused more on supply management rather than demand management.

The rapid increase in needs and rapid urbanization explains this orientation. However, the very strong water conservation concerns expressed by policy makers have resulted in policy directions, regulatory decisions and some actions to reduce wastage and water loss throughout the production-use process, control consumption and reduce it as much as possible (Benblidia M, 2010).

To make these orientations effective and efficient, they should be translated into a National Demand Management Strategy, setting efficiency targets for each sector, defining the actions to achieve them, specifying the tools and regulatory, technical and economic means,and recommending the participation of the population.

For the Tafna watershed, and while articulating this strategic vision some combined, actions oriented mainly towards.

- Actions based on the control of the demand for drinking water,

- Actions related to the rate of satisfaction of agricultural needs,
- Actions encouraging the recycling of industrial water,
- Actions articulated on the need for the purification of wastewater for agricultural needs.

5.2.2 Preservation and protection of resources

In addition to the climatological aspect inducing quantitative constraints, resource weakness is further aggravated by the poor spatial and temporal distribution of these resources, soil erosion and siltation of dams, losses due to dilapidated distribution networks and inadequate management, the ever-increasing costs of the investments required for mobilization and transfers, the various forms of pollution of surface and underground resources. To overcome these shortcomings, several actions are therefore to be considered in terms of actions and new institutional and regulatory organizations (Rouissat,2015).

Figure 5.1 illustrates a summary of these actions for the preservation and protection of water resources.

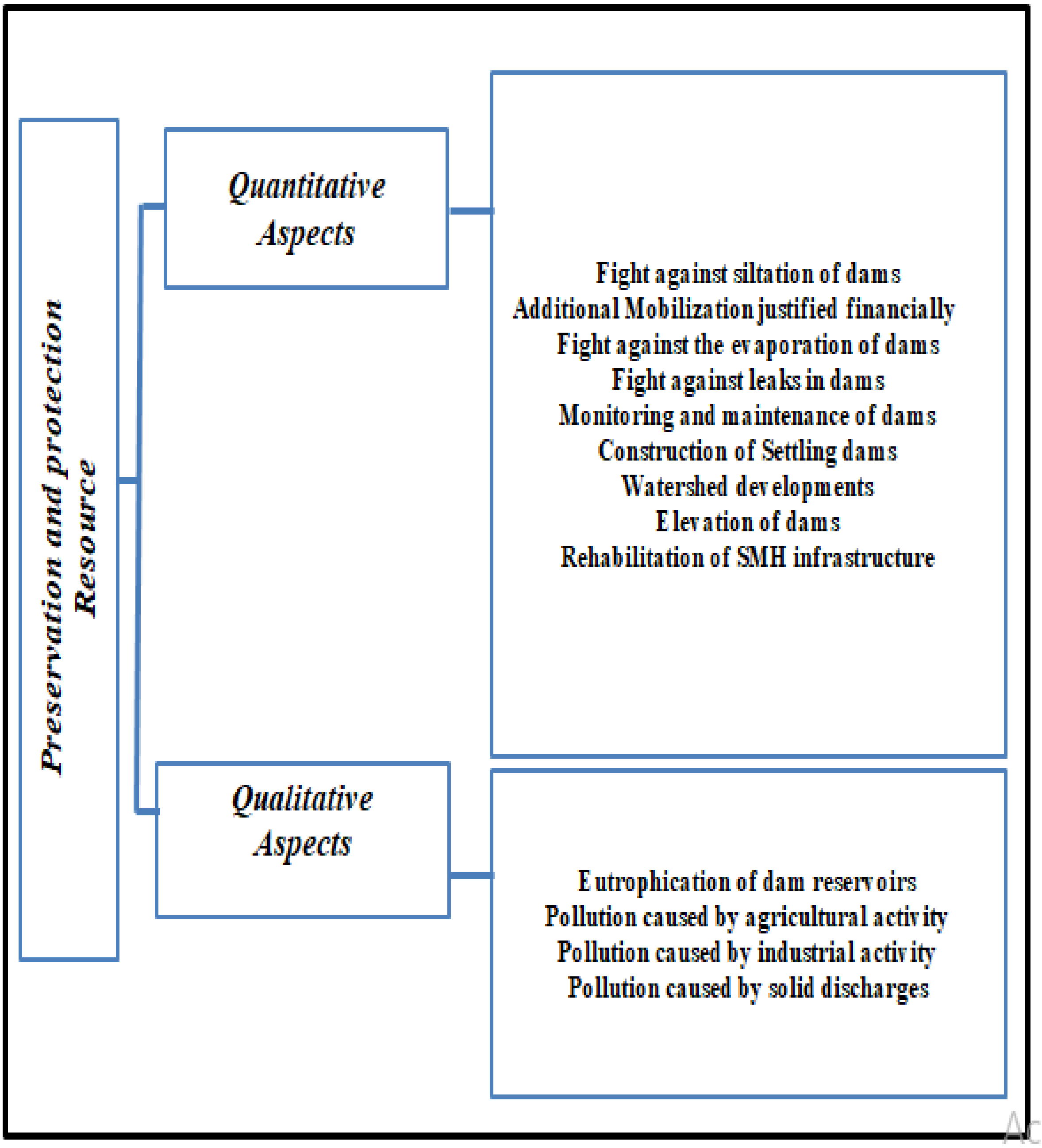

Figure 5.1 : Actions to preserve and protect water resources

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Annex

Annex 1 : Description on research grant use

Items	Expenses	
	DZD	USD
Transportation expenses to go to the places included in the research plan (Fields visits)	68 650	582
The expenses of the trips and the hotel	231 500	1962
Expenses of auxiliary devices in the preparation and storage of research work	18 200	154
Communication credit for phone and Internet subscriptions expenses	25 400	215
Printing and binding thesis expenses	12 700	108
Total	356 450	3 021