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Inter-region planning and analysis of water resources by using WEAP model Seybouse (Annaba) and Coastal East of Constantine (El-Taref)

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Abstract

Water is seen as key factor for development. Its scarcity raises concerns at all scales. In regards to water resources, Annaba and El-Taref are intimately connected, the different activities (groundwater and superficial), focused on increasing supply, have been considered as a response to water demand.

The actual system use of water resources is not able to sustain water needs that are more and more growing in different expansion sectors. Consequently, a strategy should therefore be sought to integrate the various sectoral needs in available water resources in order to reach the economic and ecological sustainability. We will try to respond to this problem by use of Water Evaluation and Planning (WEAP) model. This study is the first attempt to estimate water demand and analysis of multiple and competing uses of hydro-system in Seybouse's Wadi basin and to make comparison with proposed water storage estimates. This model was applied according to five different scenarios which reflect the best and worst conditions of the supply and demand, not only to evaluate water demand deficit, but also to help planners to the alternative management.

The model stimulation showed that the area study is sensitive to a serious water scarcity by 2030. It is possible to observe an improvement with integration of other management strategies for a best operating system.

Key words: *analysis of scenarios, planning, Seybouse, water demand, WEAP*

INTRODUCTION

Facing the fast water resources lowering in the region and in the country due to climatic change characterised by important rainfall cycles these impairments are affected by drought long periods, rapid floods, and sometimes violent associated to an intense erosion [KADI 1997], and so groundwater degradation due to discharges of urban waste and industrial. [BENDJAMA *et al*. 2010; HAZOURLI *et al*. 2007; KHADRI 2009], in addition, groundwater pollution and their overexploitation generating saltwater intrusion [DJABRI *et al*. 2003; 2013]. The Integrated Water Resources Management (IWRM) plays a significant role in every field as water is essential for social economic development, up to now, no multidisciplinary systematic work and complete have been developed. The Seybouse's Wadi basin knew an intense demographic and industrial growth facing an insufficient water resource management, older and limited. Annaba will

continue to be the head office of several administrative offices and universities of substantial size. The present difficulties on water supply concerning firstly the water supply regularity. We are far from the purpose of 24-hour door-to-door distribution. In effect facilities are not designed It should be noted that Annaba city about 20% of population benefit water 24 h on 24 h, generally horary bands are fluctuating between 6 to 15 hours through wilaya's municipalities excepted some of them where distribution frequency varies from one day on two to one day on three due to the bad adduction supply (worn-out equipment) also several sectors are supplied from a tank which capacity does allow ensuring daily peaks (inadequate storage) this tank's size default is notably sensitive in Sidi Salem, El Bouni, Sidi Amar and El Hadjar. Leakages are particularly crucial (evaluated to 35%) because it is explained in major part why available water upstream networks of Annaba do not correctly reach users. To prevent water deficit by the year 2030, Several conceptual management models have been developed in Lower Seybouse indicating that the priority parameters of socio-economic variables are to include in water demand management policies as much, if not more, supply management [AOUN SEBAITI 2010] New strategies and management interventions, must be sought to better mobilise superficial water and groundwater resources, So that priority should be given to the reuse of treated wastewater in agriculture followed by water desalination decrease water loss rate and improve available water quality [CHOUCHANE *et al*. 2014].

The successful planning requires effective models of Water Resources Management (WRM) which can resolve these complex problems. The Water Evaluation and Planning (WEAP) model, which is a computer modeling software designed for the simulation and analysis of water resources systems, has been applied and limited to an initial analysis of the Seybouse basin to the basic function of WEAP without using its hydrological process simulation capabilities or water consumption [AOUN SEBAITI *et al*. 2013; LELLAHEM 2013]. WEAP has already been used in Algeria; examples of applications include studies on the assessment of predicted climate change impacts expected on water availability and agricultural production [HAMLAT *et al*. 2012] and assessing the effect of different supply and demand scenarios as well as the assessment of current and future options for water resources [OULED ZAOUI *et al*. 2010].

This model was chosen in this study, for an in-depth analysis of the sub-system of the Annaba–El-Taref inter-region North-Eastern Algeria, the purpose of this study is to estimate-the sectoral water demand in the Seybouse's Wadi basin, including future population ,agricultural and industrial growth; and help relieving stress of water shortage, a scenario of the actual state and of future year which will be prepared, while attempting to maximise water resources management policy of the region and to safeguard mobilised resources as far as possible, which will result a decrease of dissatisfaction of water demand and raising of recovery rate, in order reaching economic and ecological sustainability.

STUDY AREA

The low plain of Seybouse is located on North-East of Algeria, on downstream of its important Seybouse's watershed which presents its drainage axis and belongs to aquifer system of Annaba–Bouteldja, this zone covers a surface of 1066 km^2 and characterised by a Mediterranean climate type. It reacts by two strongly contrasting seasons, a hot season and dry and a cold season and humid. The spatial pluviometry distribution shows an increase from West to East and from North to South (map of Chaumont Paquin). The winter rainfalls vary from 450 mm in the South and 735 mm on the North. On the contrary, in dry season water level decreases significantly due to the use of West water for irrigation [DEBIECHE 2002; MEBARKI 2005].

RESOURCES AND WATER NEED

WATER RESOURCES

Annaba's region has 3 dams of weak quantity (Bougsaiba) volume can be regularised 0.2 hm^3 Guiss volume can be regularised 3,4 hm^3; Oued el Aneb volume can be regularise 7 hm^3 totalising a regularised volume of about 11 million m^3 [CHAFFAI *et al*. 2005], which are intended solely for the irrigation of the west plain of the wilaya.

Annaba city is supplied by combination of groundwater resources from dams of Cheffia volume can be regularised of 95 hm^3·year^{-1}, this dam allows mobilisation of 45 hm^3·year^{-1} for Annaba and ensures irrigation of Bounamoussa perimeter (16 500 ha). Mexa volume can be regularised of 30 hm^3·year^{-1}, supplies wilayas El-Taref and Annaba (Fig. 1). This dam allows mobilisation of 16 million m^3·year^{-1} for Annaba [DJORFI 2012], and groundwater resources coming from the well-fields of Bouteldja, Salines and Pont Bouchet [LAMROUS 2001].

The well-fields are composed of 32 drillings at Bouteldja producing 28 000 m^3·day^{-1}, 9 drillings at Salines whose 7 functioning 24/24 h ensuring 10 000 m^3·day^{-1} and 5 drillings at Pont Bouchet cay ensure 3000 m^3·day^{-1} (1 forage is currently operating). These last drillings produce poor water quality (dry residue RS = 1.9 to 2.2 g·l^{-1}) for agricultural and industrial due to the absence of surface water in the area, their pumping should be reduced to reduce the interaction of the aquifer of the watercourse [DJORFI 2012; HANI *et al*. 2007]. In reality, the majority of these wells are dry and a substantial portion of drilling is out of service, which decreases with a significant manner water capacity really available. Other studies are underway to achieve new works (dam of Bouhaloufa, salt de-

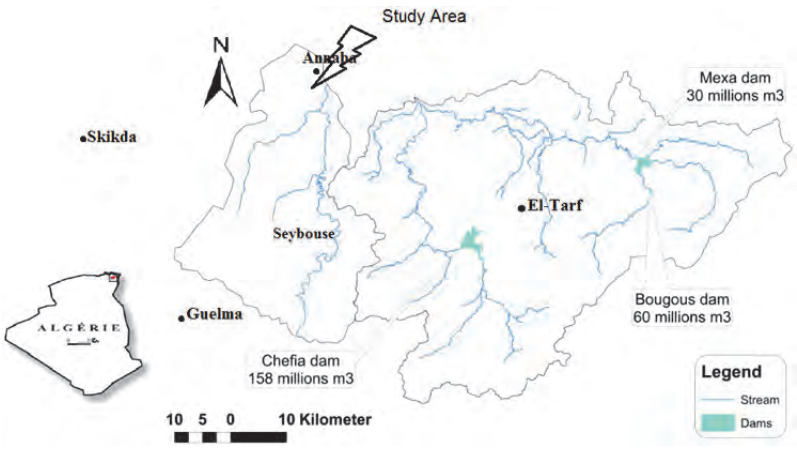

Fig. 1. The study area spreads essentially on wilaya of Annaba (Seybouse Wadi) and reaches municipalities of wilaya El Tard (Chihani, Drean and Chbaita Mokhtar); source: own elaboration

salination and restraint station of Mahcha) in order to reinforce surface water dispositions.

WATER NEEDS

The study area is located in the north-east region, characterized by intensive agriculture, significant industrial development and a rapidly growing population [SADOUNE 2012]; in 2010 its population was of 586.869 inhabitants. The available data are these of the plan updated in 2010 (NWP – National Water Plan) following to the information treatment and data population published by the National Office of Statistics (NOS) from general census of the population and habitat (GCPH) of 1966 to 2008. Across the country, different indicators advocat in favour of a population growth support until 2020 then a stabilisation phase on the period 2020–2025 and a growth rhythm mitigation from 2025.

The total agricultural area in Annaba is of 48 171 ha whose 42 007 in dry and 6 170 ha are irrigated. The potential permanently irrigable no yet estimated, the irrigation perimeter has over 80% of the equipped surfaces which are irrigable with a seasonal way whose 1 010 ha for large perimeters and 5 160 ha for small and medium hydraulics demand and detail in water needs of industrial units are obtained by WPU document which summarises that over 2/3 of the water demand are collected by the Steel Complex of El Hadjar, this demand is explained by the large required needs for their functioning.

METHODS

The water management challenges are more and more common. Allocation of limited water resources between agriculture, municipal and environmental uses, require now offer integration, of demand, of water quality and ecological considerations. The Evaluation and Water Planning (WEAP) system is developed by Stockholm Environment Institute's WEAP supplies a maintenance system of demand and distribution information. As a forecasting tool, WEAP simulates water demand, offer, flow, storage, pollution generation, treatment and distribution. As policy analysis tool WEAP evaluates a full range of development options and water management, and considers multiple competing uses of water systems. The model will simulate water system functioning in the study zone of Seybouse Wadi in short term period (2010–2030). Implementation of WEAP necessitates injection of large database for each item of network. Data structure and the detail level can easily be personalised to respond the requirements of a particular analysis and to take into account of the imposed limits when data are limited [YATES *et al.* 2005]. The model configuration is made by monthly periods whose hydrological simulation is compatible with existent data on a monthly basis. Database of the study zone which allows model application is carried out from NWP's information (2010) and gathered from several administrations, such as HBA (Hydrographic Basin Agency), NHRA (National Hydraulic Resources Agency), NMO (National Meteorology Office), ASD (Agricultural Services Direction), ONS (Office for the National Statistics), ONID (Office for the National Irrigations perimeters and Drainage) and AOW (Algerian of Waters). Hydrology of watershed of WEAP gathers hydrologic critical processes using of some parameters. Those one include a plant culture coefficient (*Kc*) which in combination with a potential evapotranspiration estimation determines loss by evaporation; a resistance factor to conceptual flow (*RRF*) linked to factors such as index of the plan surface and the slope of the ground, with higher values *RRF* reducing a rapid surface run-off and water-holding capacity and hydraulic conductivity parameters. The model also allows checking that the water demand is met. Hydrological data entered in WEAP are based on information collected at level of the two existing meteorological stations at the sub-watershed (station of Pont Bouchet and the Salines). The observation period is from 1977 to 2005 in order the model calibrated by using data of the single gauging station that one of Mirbek (stopped from 2005) that controls Oued Seybouse in its lower part. Flows of wadis studied are measured for serial 1991–2007 at the gauging station of Ain Barda (Ressoul Wadi).

RESULTS AND DISCUSSION

Authors show Seybouse Wadi with existing water resources, the hydrographic network, basins and demand sites, towns and irrigation perimeter of the

study zone. We identify as resources: the two basins presented in the model, this of Chafia and Mexa (Wilaya of El-Taref), drillings (The Salines, Pont Bouchet, Drean and Ain El Berda). The sites demand are municipalities located in sub-watersheds of Seybouse Wadi and irrigation perimeters of Bounamoussda and so irrigation of the small and medium hydraulics.

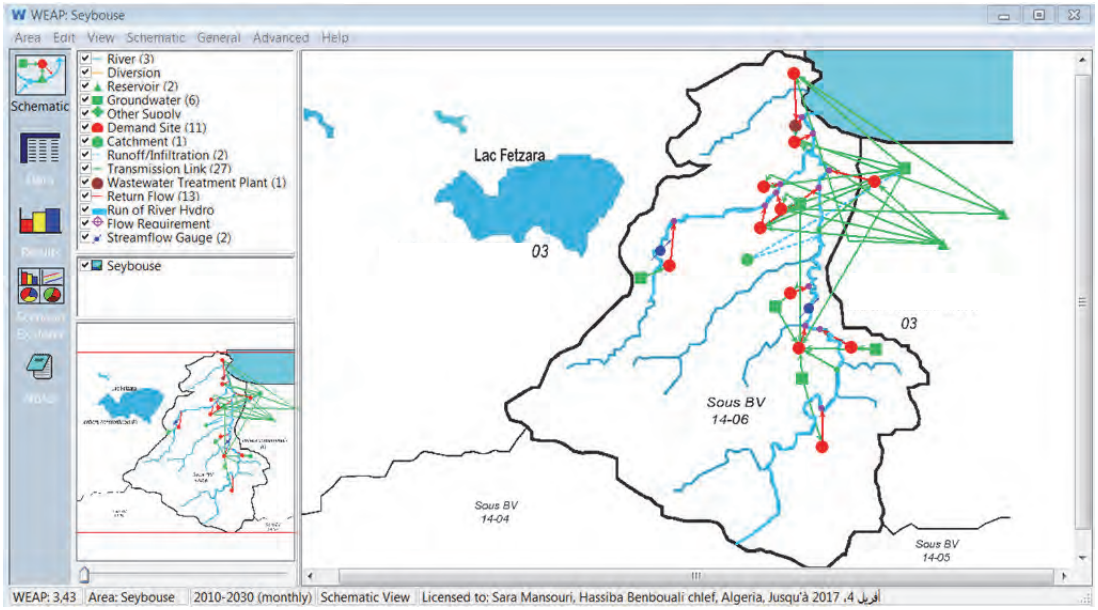

Fig. 2. Final map presentation of watershed by Evaluation and Water Planning (WEAP) model; source: own elaboration

SCENARIOS

Climatic and socio-economic variables will be in the future the two main drivers of water deficit in the basin, none have been developed for integrated supply and demand management [LALLAHEM 2013], in this study we have integrated a set of scenarios based primarily on re-use of treated wastewater, industrial wastewater re-use and desalination of seawater for unmet demand mitigation.

SCENARIO 1: REFERENCE

The scenario Reference takes data of current accounts in the specified project period and is used as comparison point for other scenarios in which amendments are made to the system data. The following results for the sub-basin of Seybouse Wadi have been made based of five scenarios.

The water demand increases during the second and third quarter the fact that Office for the National Irrigations perimeters and Drainage (ONID) begins its irrigation program which is supplied by the same source than other demand sites, and reaches in August (Fig. 3) a value of 38 mln m^3 which results a deficit of 4,6 mln m^3 in the same annual period (Fig. 4) with coverage of 50% of the water demand, the demand sites coverage suffers in summer period compared to the rest of the year, by contrast, demand sites of Drean, Ain El Barda, Chihani Ain Ben Beida their recovery of water demand is nearly stagnant since they are supplied from drillings and wells (Fig. 5).

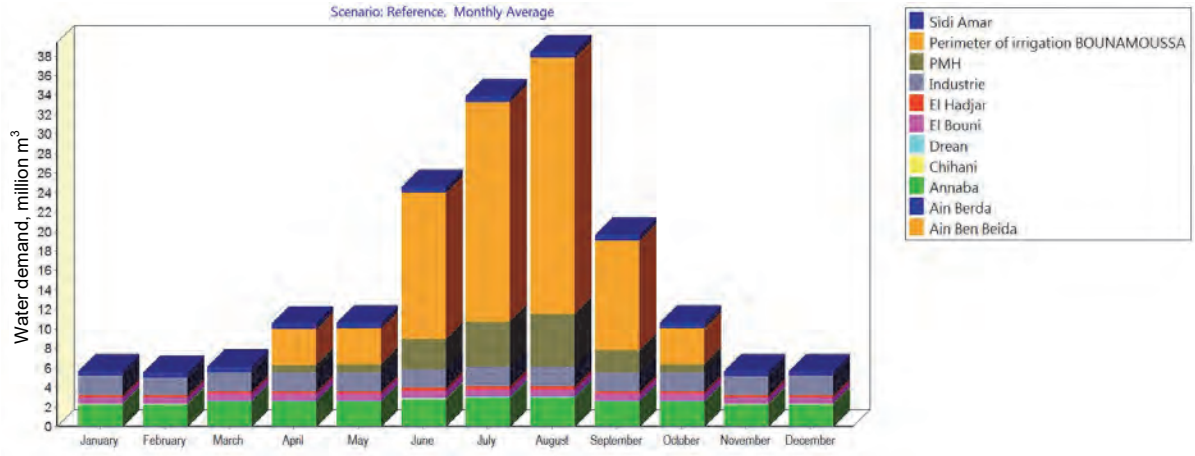

Fig. 3. Monthly water demand – scenario Reference; source: own study

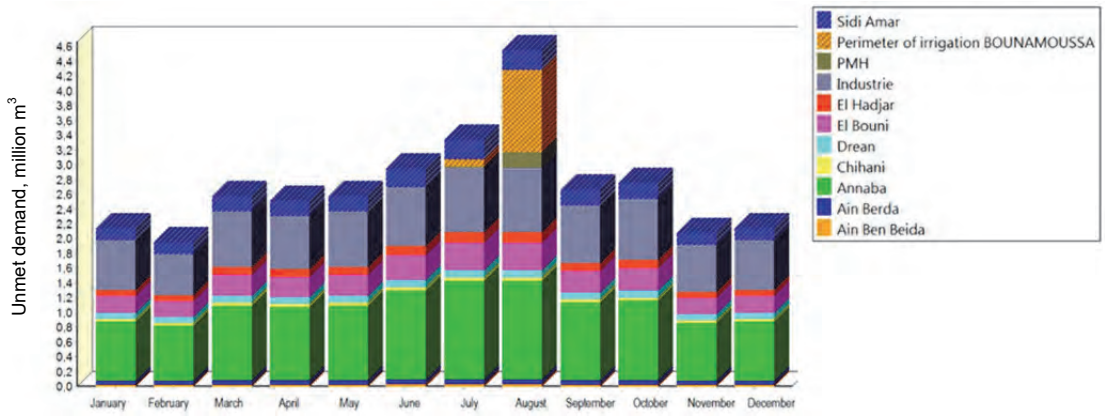

Fig. 4. Unmet demand – scenario Reference; source: own study

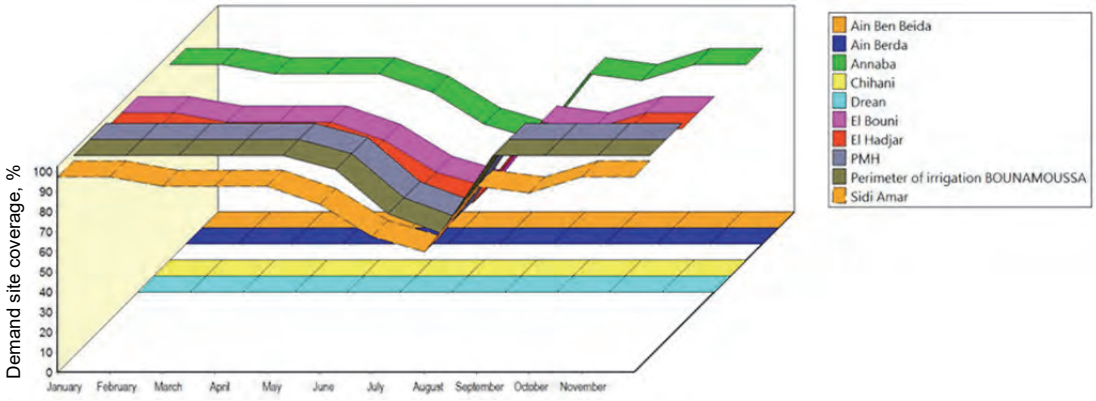

Fig. 5. The water demand coverage of different demand sites – scenario Reference; source: own study

SCENARIO 2: HIGHER POPULATION GROWTH (HPG)

Population growth on the basic scenario of reference is 1.8% in this scenario. The population rate has increased about 5% compared to year 2010.

Results shows that water demand on 2030 relating to the highest population growth rate is nearly three times more compared to 2010 (Fig. 6). It is clear that population growth requires more and more important water resources without taking into account the probable climatic dry changes which lead to the vast water shortage.

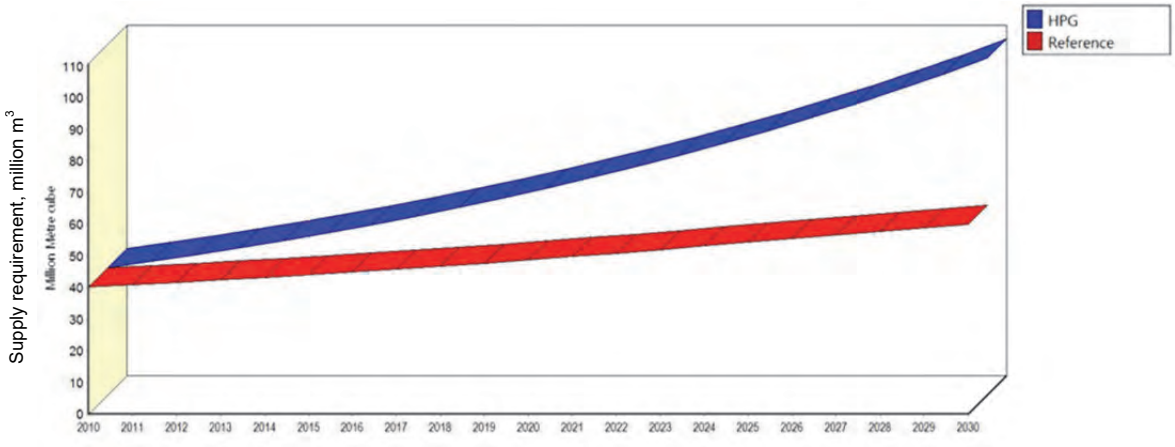

Fig. 6. Supply requirements of both scenarios Reference and Higher Population Growth (HGP); source: own study

SCENARIO 3: WATER REUSE (REU)

This scenario illustrates a monthly decrease of about 1 million m^3 on unsatisfied demand and about less 3 million m^3 in August (Fig. 7). The scenario of Water Reuse wastewater approaches water recycling; the non-conventional water resources mobilisation becomes a sector's priority to compensate the deficits which not applied in this region up to now.

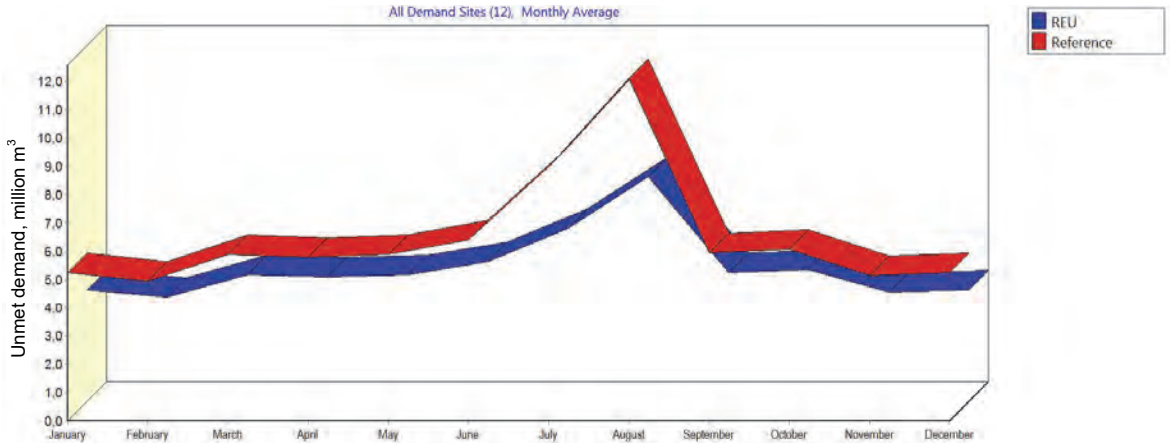

Fig. 7. Unmet demand of the two scenarios Reference and Water Reuse (REU); source: own study

SCENARIO 4: INDUSTRIAL WATER REUSE (REUI)

About 50% of water is presently discharged by Steel Complex of El Hadjar will be the subject of internal reuse, which can reduce industrial water needs.

This scenario shows this reuse and water recycling of the industrial sector without taking into consideration water recycling which has been presented in the previous scenario (Fig. 7).

It clearly appears the difference between not met demand of scenario Reference of 2010 until 2030 and the scenario REUI along the 21 years due to water recycling of the industrial sector which will allow mitigating the unmet demand in the other sectors (domestic and agricultural water) which are supplied by the same source (Fig. 8). Both scenarios REU and REUI will concentre on solution research with the view to provide a response to the problem of the treated water reuse (TWR) notably in agriculture.

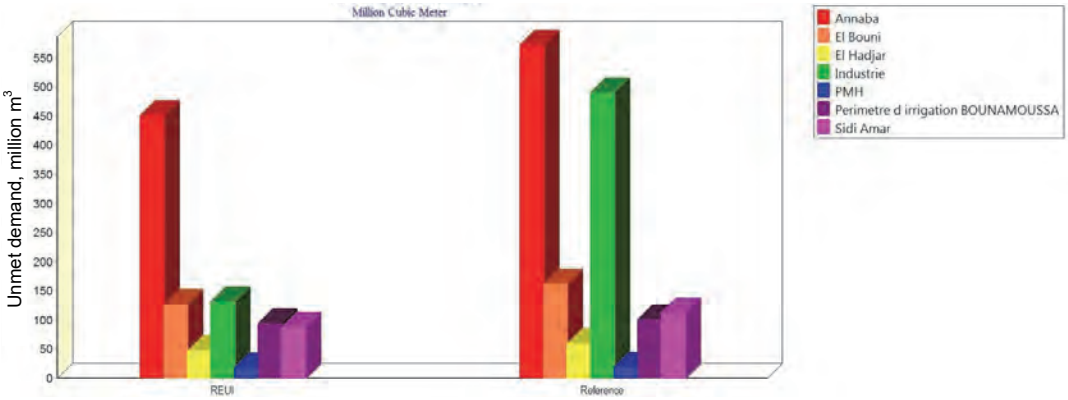

Fig. 8. Comparison of unmet demand of both scenarios Reference and Industrial Water Reuse (REUI); source: own study

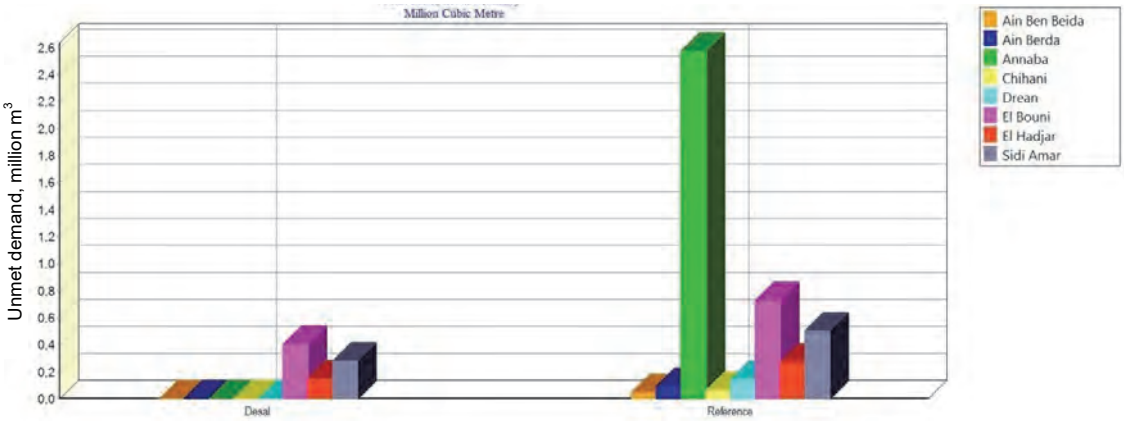

Fig. 9. Comparison of unmet demand of both scenarios Reference and seawater Desalination (Desal) – January 2030; source: own study

SCENARIO 5: DESALINATION (Desal)

A desalination station of seawater is being built and to be launched in construction work at El Chatt (El-Taref) for a total capacity of 100 000 $m^3 \cdot day^{-1}$, which is an annual volume of 36 $hm^3 \cdot year^{-1}$ is integrated in this scenario from year 2016.

Figure 9 shows that the mobilizing approach and the transfer of desalinated Sea Water allowed decreasing significantly the unmet demand volume and improving supply conditions of deficit regions and suburban.

DISCUSSION

The first analysis of the study area presented a projection of annual unmet needs, composed of four socio-economic demand scenario and a climate change scenario, this simplified approach shows that over the next 20 years, we can expect much greater reductions in water availability and increased demand for irrigation water in the region due to climate change and socio-economic development [AOUN SEBAITI *et al*. 2013; LELLAHEM 2013] In this research with the same WEAP model which allowed analysing more detailed scenarios and testing the different water management strategies to understand the situation and identify existing problems and weakness that affect the system in order to improve them, we further analyzed to communicate and report to water managers the results that confirm that the management of water resources in the region required considerable improvements in order to respond to the spatial and temporal availability of water.

Thanks to these scenarios we have been able to show that water reuse which is up to now not applied in this study area, increases water resources and supply flexibility while decreasing the global demand, which returns mobilisation need of other water resources (for irrigation, the largest consumer of water) and economise drinking water for domestic use, and so mobilisation and transfer of desalinated seawater reinforces the drinking water needs. Promote water resources and create other strategies is important to mitigation of demand rate not met, anticipate new resources as rehabilitation of dams of Annaba and so of new dams to cover at long term the water deficits.

CONCLUSIONS

Water use diversity requires more and more water volume mobilisation which far exceeds current capacities and necessitates a careful planning in the medium and long term to deal with this deficit. The purpose of this study is to undertake how establish relations prediction to be used as tools of decision making. The global impact is to ensure a future security in term of water mobilisation and to face to water resource scarcity against insufficient resources at short term. The Water Reuse, Industrial Water Reuse and Desalination scenarios chosen for this study show that their integration with the system would lead to a significant reduction in unmet demands.

The next step of this research is to study this problem under all its aspects such as irrigation systems development, living standard development, water quality and its impact on water management in Algeria. This project aims to be a contribution in the investigation, understanding and valuation of water resources on the one part and on other part a tool to aid in hydraulic works management.

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Międzyregionalne planowanie i analiza zasobów wodnych z użyciem modelu oceny i planowania (WEAP) dla rzeki Seybouse (Annaba) i przybrzeżnych obszarów na wschód od Konstantyny (El-Taref)

STRESZCZENIE

Woda jest uznawana za kluczowy czynnik rozwoju. Jej brak rodzi problemy w wielu wymiarach. W odniesieniu do zasobów wodnych prowincje Annaba i El-Taref są ściśle powiązane. W odpowiedzi na rosnące potrzeby rozważane są różne działania (w stosunku do wód podziemnych i powierzchniowych) zmierzające do zwiększenia zasilania.

Istniejące systemowe użytkowanie zasobów wodnych nie jest w stanie zaspokoić potrzeb wodnych, które ciągle rosną w rozwijających się sektorach gospodarki. Należy więc poszukiwać strategii integrowania różnych branżowych potrzeb celem osiągnięcia równowagi gospodarczej i środowiskowej. Autorzy podjęli próbę rozwiązania tego problemu, stosując model oceny i planowania zasobów wodnych (WEAP – ang. Water Evaluation and Planning). Te badania są pierwszą próbą oszacowania potrzeb wodnych oraz analizy rozlicznych i konkurujących ze sobą użytkowników zlewni rzeki Seybouse oraz próbą porównania ich z przeprowadzonym szacunkiem zasobów. Modelowanie realizowano według pięciu różnych scenariuszy, które odzwierciedlają najlepsze i najgorsze warunki dostawy i zapotrzebowania nie tylko na potrzeby oceny deficytu wody, ale także, by wspierać planistów w alternatywnych formach zarządzania.

Symulacja modelu wykazała, że obszar badań będzie podatny na poważne niedobory wody do roku 2030. Można zaobserwować poprawę wynikającą z integracji innych strategii zarządzania w celu osiągnięcia najlepszego systemu operacyjnego.

Słowa kluczowe: *analiza scenariuszy, model WEAP, planowanie, rzeka Seybouse, zapotrzebowanie na wodę*