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Management of water Issues in Taiz basin, Yemen

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ABSTRACT

Generally, the study area including the city of Taiz, in particular is suffering from an acute shortage of water due to the increase of the growing demand on water for domestic and industrial needs as well as the water needs for agriculture in the region. In addition, the water resources in the study area are limited to the aquifers while water extraction rates exceed the natural recharge and the use is not effective. Therefore, it highlights the importance of water demand management to maintain the quantity and quality of drinking water and domestic use, irrigation and industry. The objectives of this study is to evaluate current and future vulnerability of water sources in the study area; Development of scenarios and analysis of future water balance to find out the best solution to the problem of water in Taiz basin as the study area; Select the appropriate scenario to resolve the water problem. The results of this study will assist decision makers in the field of water resources for better planning and management in the future. During the period 15/1/2013 to 15/4/2013 Implementation of the field study in 1501water points, these water points are distributed between 954 hand-dug well, 479 deep well, 50 springs, five water collection tanks, two dams, and six water retaining walls. For calculating the amount of water supply in the region and the amount of water deficit, in addition to knowing the amount of needs that must be secured in the future, Water Evaluation And Planning (WEAP) application as Decision Support System (DSS) to manage the supply and demand for water in Taiz basin as the study area. The analysis and results using WEAP program include the following themes: Ground water storage in the aquifers: The usable storage for the base year of the model (2013) has been calculated for the five sub-basins in the study area, Estimated ground water storage in alluvial aquifer (in Mm3) ranged 221.52-

415.36 Mm3 at best estimate at 332.29 Mm3, groundwater storage in Volcanic aquifer ranged 129.98-2599.52 Mm3 at best estimate 259.95, whereas groundwater storage in sandstone aquifer ranged 5.044- 50.44Mm3 at best estimate at 10.088; Unmet water demand, The gap between supply and demand for water in the study area was estimated as (47,692,840.9 m3). Preliminary, set of adaptation strategies that address water scarcity; Interpret the proposed set of adaptation strategies to solve water issue from improve water services and water management for the urban area as part of the study in Central and Al Hawban Sub Catchment:
(Increase the coverage rates for water services, Diversify water sources for the city, Efficient water management, Implementation of control and water quality program in water sources and drinking water factories, Development of specialized human cadres technically and administratively for the development of water management, Flow of water services from different water sources….. etc.); and Improve water projects and water management for the rural area as part of the study area Al Dabab Sub Catchment, Al Janad Sub Catchment and Thi- Sufal Al Haimah Sub Catchment: Commitment of the Commission basin management to Upper Rasyan Valley, The formation of committees Sub-water basin to ensure the management of water resources from the lower level, Resolving water conflicts in different regions of the study area and the basin provider of water to the city of Taiz, Community participation by establishment of water users associations (WUAs) in the sub- basin areas.
Keywords: Aquifer, Taiz basin, Water demand, Water supply, WEAP, Water scarcity.

1. INTRODUCTION

The Taiz city being the third largest city in Yemen has a great socio-economic importance. It is experiencing acute shortage of water as a result of increasing rate of water demand for municipal and industrial use, together with increasing agricultural demand. Water resources of the Taiz basin are dependent on rainfall, which varies quite a lot from one sub-area to another within the same catchments. While the mean annual precipitation for the whole area is around 568 mm, the highlands receive a significantly greater amount. Heavy rainfall on the highland areas generates run-off that flows into the valleys, causing flooding. The surface water flowing into the valleys is diverted for irrigation by means of natural ditches called" Sawaagi". The Taiz basin has three main aquifer systems, they are: (a) alluvial aquifers, (b) volcanic aquifers, and (c) Tawilah sandstone aquifers [1] . The water tables have been falling because of continued groundwater use. Some areas are worse hit than others [2]. For Al Haima zone one of the main sources of water supply, as a whole, the average decline in the groundwater level has been nearly 0.5 meter per year in the alluvial aquifer and more than 3 meters in the volcanic aquifer [3].

Water supply constitutes the most pressing problem in Taiz today due to significant shortage of supply (the average consumption is 23 L/d) caused by the depletion of existing water resources and the lack of a clear direction in dealing with the problem. This forces frequent water supply service interruptions (30-40 days) and the service is rarely extended to new users (only 57% of the population are covered). Sanitation is another daunting

problem. The poorly maintained, sewerage network covers only 44% of the population. In Several un-sewered areas to the north, east and west of the city, raw sewage is directly disposed to Valleys, which causes a health hazard and threatens to contaminate groundwater resources.

2. PROBLEM STATEMENT

The water problem in Taiz is complex and multidimensional

- **Request increase**: The population growth in urban Taiz over the past several decades has great pressure on the water supply, Taiz City's population increases by 3.9 % and rural population increases 2.6 % per year.
- **Physical water losses from the urban water supply distribution network** networks losses are assumed to be 25% of total production. However, 17% of this loss is assumed to percolate to shallow ground water and 8% is assumed lost through evaporation. Thus, the net benefit of reduction in transmission losses is only 8%. If the aquifer is deep and water lost from distribution cannot return to the aquifer, then the net benefit of reducing losses is the full 25% of the total consumption. This assumption is an extreme case, since in reality physical losses cannot be brought to zero.
  - 75 % of supplied urban water goes back to the aquifer through the Waste Water Treatment Plant (WWTP) with a 10% system loss.
  - Transmission, (agricultural conveyance) losses are included in the irrigation requirements which are based on overall irrigation "efficiencies."
  - 30 % of applied irrigation water will percolate back to the aquifer.
  - 30% of applied irrigation water is lost in evaporation.
  - 40% of applied irrigation water is actually consumed by plants.
  - Irrigated agriculture area is reduced at the same rate (7%) as the population of Tiaz City grows in the Central and Al Hawban Sub Catchment, indicating displacement of irrigation by urban development.

3. OBJECTIVES

A. Evaluate current and future vulnerability of water sources in the study area;
B. Development of scenarios and analysis of future water balance to find out the best solution to the problem of water in Taiz basin as the study area;
C. Select the appropriate scenario to resolve the water problem.
D. Preliminary, set of adaptation strategies that address water scarcity; Interpret the proposed set of adaptation strategies to solve water issue from Improve water services and water management for the urban and rural areas as part of the study.

4. THE STUDY AREA

4.1 Location

The study area is located in the upper part of Rasyan Valley, It is one of the seven major Valleys which form the Red Sea drainage basin [4] and which drain the high and mid-

land region of the country and flow in a westerly direction towards the Red Sea. According to [5] the total catchment area of Rasyan Valley "up to the mouth of the river at the sea" is 2,550 km2. However, the area of the upper and middle catchments (i.e., excluding the coastal or Tihama part of the catchment) is only 1,990 km^2 [4] .The study area which is defined as the catchment area upstream from the point 378 UTM E and 1510 UTM N. This area covers approximately 750 km2 (Figure 1).

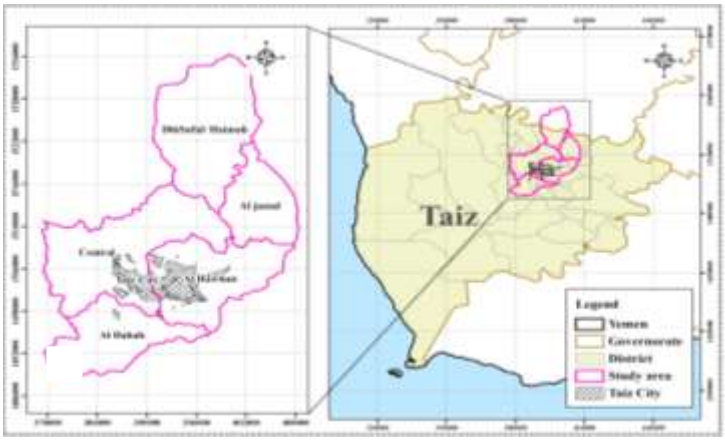

Figure 1: Location of the study area

4.2 Hydrology

Water resources of the area are heavily dependent on rainfall, which varies quite a lot from one sub-area to another within the same catchment. While the mean annual precipitation for the whole area is around 568 mm, the highlands receive a significantly greater amount. For example, the annual rainfall in the Thi-Sufal highlands is 826 mm on average while Jabal Saber sub-area receives about 621 mm. The pattern of rainfall in the region is bimodal with one peak occurring in April-May and the other in August-September. The intermediate months of June and July have fewer rains. The dry period lasts from mid October to mid March.

Heavy rainfall on the highland areas generates run-off that flows into the Valleys, causing flooding in the case of intense rainfall events. The surface water flowing into the Valleys is diverted for irrigation by means of Sawaaqi. These are excavated channels on both sides of the Valleys, which irrigate the adjacent fields. Valley Al-Haima receives about 3 million cubic meters of lateral surface inflow annually. Most of which is from the high rainfall area Thi Sufal. Al-Dhabab Valley receives about 0.5 million cubic meters of run-off water from both Jabal Habashi and Jabal Saber. Some of the run-off from the latter also finds its way into the Hawban zone which receives about half million cubic meters of run-off annually. The Central zone receives surface water flows from all zones in the upper Rasyan Valley catchment. The estimated volume of these flows is about 9 million cubic meters per year. The total volume of flow leaving the upper Rasyan Valley catchment area

every year does not exceed 12 million cubic meters [6] .However, the surface water flowing from the Central zone into the lower Rasyan catchment is highly polluted because of mixing with the untreated industrial and domestic wastewater. Average Annual rainfall at the various monitoring stations in the study area was collected from 1979 to 2012 from eight stations in the study area and given in Table (1).

Table 1: Annual Rainfall (mm) of the study area [7]

Aquifer / Sub basin	Year / Station	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Al Janad	Qurf	283.5	525	564.5	633	556	452.4	448.5	520	546	493.5	120.5	316	344	-		
Thi Sufal	Jadyia	750	43	1283.5	1025	1320.9	1075	871.5	1331.8	1234.5	981.2	-	-	-	-	-	-
	Sahalah	252	316	394.5	633	556	452.4	454.5	520	404.5	493.5	120.5	-	-	759	561	456
Central	Lougba	96	438	362	576.5	420	420	442	537.7	557	535.5	263	256	551.5	-	486	656
	Qurf	283.5	525	564.5	633	556	452.4	448.5	520	546	493.5	120.5	316	344	-		
	Hussien	6	5.5	244	462.8	289	298	381.5	324.3	331	712	213	340	597.5	-	320	0.0
Al Dhabab	Manum	398.5	887	720	734	720	684.4	852	805.8	833.6	727.5	476	536.5	545	551.5	413	681
	Miqap	518.5	1042.5	864	1062	996.5	886.9	754	847.3	943.5	932.5	716.5	102	759		841	595
Al Hawban	Miqap	518.5	1042.5	864	1062	996.5	886.9	754	847.3	943.5	932.5	716.5	102	759		841	595
	Qurf	283.5	525	564.5	633	556	452.4	448.5	520	546	493.5	120.5	316	344	-		
	Oss-aifrah	321	306	617	581.8	281	318	677	303	309	280	285	353.6	645	809	887	613

* The Records of 2013 no measurement

Annual rainfall distribution is record peaks in 1999,2000, and 2001,2002 2004,2005, Whereas less rainfall is measured in 2008 and 2009. The highland part of the upper Rasyan Valley catchment enjoys a higher average rainfall than any other part of Yemen, with the only exception of the Ibb region, which the study area borders. Summer rains occur with convective storms associated with spring inland winds. Cloud cover builds up from mid-day with rains usually in the afternoon. Storms are very localized with considerable differences in rainfall amount from any single event over short distances.

Hydrologic simulation in WEAP included partitioning of rainfall between runoff, infiltration, and evapotranspiration in the five sub-basins using a semi-distributed, lumped parameter hydrologic model embedded in WEAP (Yates et al., 2005). Each of these 5 sub-basins was linked to one of the six aquifers for purposes of simulating groundwater recharge. Irrigated, rain fed, and inactive land cover areas obtained from the National Water Resources Authority (NWRA) were included in this parameterization. Crop types delineated included Qat, grains, maize, and sorghum. Domestic demand was simulated using population projections for each of the sub-basins; see Table (2) and (Figure 2).

The Five Sub Catchments areas are:

1- Al Dabab sub-catchment (Comprising, in addition to Al Dabab, part of Jabal Habashi and part of Jabal Saber),
2- Al Hawban sub-catchment (SE part of the area, comprising Ursum valley , Hawban valley and tributaries),
3- Central sub-catchment (Lower part of Upper Rasyan Valley, downstream of all other sub catchments),
4- Al janad sub-catchment (plateau in eastern part of the area),
5- Thi-Sufal/ Haimah sub-catchment (NE part of the area).

Table 2: List of Sub basins, Area (Km^2) and average slope (Dar El-Yemen and SOAS, 1997)

No	Sub Basin	Area (km^2)
1	Al Dhabab	115
2	Al Hawban	144
3	Central	217
4	Al Janad	86
5	Thi- Sufal/ Haimah	188
	Total	750

4.3 Groundwater

The Ta'iz region has three main aquifer systems. They are (a) alluvial aquifers, (b) volcanic aquifers, and (c) Tawilah sandstone aquifers. To exploit these aquifers, a total of 1993 dug wells and 306 boreholes had been constructed until 1996, some of which have become dry due to high rate of abstractions.

The alluvial aquifers are the uppermost layer. They are composed of sediments of varying sizes, ranging from boulders to silt, found along the Valley beds and filling up depressions. The primary means of alluvium recharge is from floods and from irrigated areas. The alluvial aquifers are quite shallow. In most areas, their thickness does not exceed 30 to 40 m although, they locally can be up to 70 m in thickness. The thickest alluvium is found in Thi-Sufal/Al-Haima and Ad-Dhabab areas. The depth to water in alluvial aquifers is less than 20 meters but in most cases, water can be found at 11 to 13 meters below the ground surface. The smaller depth to water makes this aquifer exploitable by hand-dug wells, which are found in abundance in the area. In many zones, the alluvial aquifers are prone to over exploitations. The quality of water is generally good especially in the alluvial wells in Thi- Sufal, Al-Haima, Al-Dhabab and in upstream areas of Shara'b zone. However, being the uppermost water bearing formation, the alluvial aquifers are vulnerable to manmade pollution. This is specially the case in Al-Hawban and Central zones [6] . In addition to the alluvium deposits, water is also found in fractures in the volcanic rocks that dominate the sub-surface in the study area. The thickness of these rocks in the study area is estimated to be 600-700 meters. The Volcanics are generally not a very productive source and yields of wells dug in these strata are low. The water is also low quality. This is specially the case where the fractures are connected to overlying alluvial aquifers in the polluted zones, although poor water quality in the Volcanics also has natural causes (e.g. naturally occurring salinity in some zones). Major source of groundwater in the area is the

deep-seated Tawilah sandstone. This formation has proved very productive elsewhere in Yemen and is the focus of exploratory efforts in Ta'iz region as well. However, the sandstone aquifer in the planning area is not fully exploited except in Thi- Sufal zone where NWSA wells, in addition to some farmers' wells, tap into this aquifer. These wells have high yields and quality of water is also good. In other areas, the presence of the sandstone aquifer is indicated by studies. However, exploratory efforts in other locations have not met with a lot of success. This is at least in part due to the difficulties in carrying out exploratory drilling in the face of growing opposition from local communities.

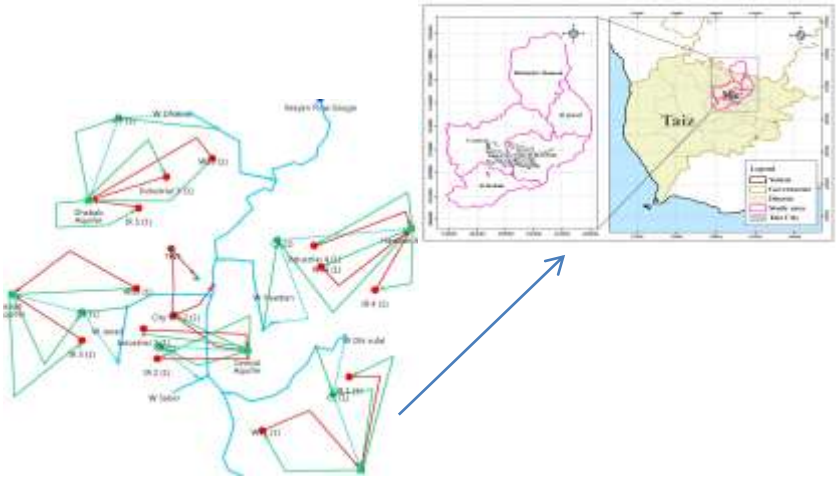

Figure 2: Schematic Representation of Zones with Demand Supply for Taiz Basin.

5. METHODOLOGY

We have used data from WEAP model and formulated a simple method to quantify increases in aquifer life for the five aquifer zones. We developed an Excel Microsoft that presents the results of our alternative scenarios in a very understandable way. We implement each scenario in the WEAP and transfer the results to the Excel model. We maintain the WEAP model as a tool to look at monthly variations and effects of climate change on the aquifer lives. In this study we identified the following scenarios to help improve water availability to Taiz Basin:

- Improve Urban Water Supply;
- Irrigation improvement;
- Improving industrial production technology;
- Rainwater harvesting from rooftops; City streets; streams Valleys; Dams, and Barriers water.
- Importing desalinated Red Sea water;
- Re- use Waste water from treatment plant.

- WEAP Model Application

On the basis of hydrologic and physiographic characteristics, the study area was divided into six main sub-areas or sub-catchments. The boundaries were chosen and plotted to help delineate the quite complex drainage pattern of the area and to provide a framework for discussing various land and water characteristics of the study area, which would facilitate the subsequent use of the data for management planning [6] , Boundaries of the study area included the following areas within the divisions of the study mentioned above.

- **WEAP input**

- Long term climate data (rainfall, runoff, temp. evaporation, Evaport. etc.).
- Land use and cropping pattern.
- Groundwater abstraction and use.
- Irrigation area.
- Estimated groundwater storage and spring flow in area.
- Estimated groundwater storage in the three aquifers.
- Annual natural recharge and water use in Ta'iz Region.

6. RESULTS and DISCUSSIONS

Tables (3) and (4) show the estimation of the groundwater storage in the aquifers of the study area, whereas Table (5) shows the estimated annual natural recharge and water use in study area.

Table 3: Estimated groundwater storage in the alluvial aquifer

Aquifer/ Sub basin	Alluvial area, km^2	Average depth to water, m	Average alluvium thickness, m	Average saturated thickness, m	Volume of saturated alluvium, Mm^3	Storage of Sub Catchment Mm^3/Year	Total Spring Flow m^3/Year
Al Dhabab	9.8	8	39	31	303.8	36.456	1803.903
Al Hawban	41.7	11.59375	16.3	4.70625	196.25063	23.550075	677.075
Central	55	5.754559	24	18.245441	1003.4993	120.41991	184.59875
Al janad	36.4	9	17	8	291.2	34.944	184.59875
Thi- Sufal/ Haimah	34.7	9.9221649	38	28.077835	974.30088	116.91611	
					2769.0508	332.28609	

Table 4: Estimated groundwater storage in the three aquifers.

Aquifer/ Sub basin	Groundwater Storage Mm^3	
	range	best estimate
Alluvium	221.52- 415.36	332.29
Volcanic	129.98- 2599.52	259.95
Sandstone	5.044- 50.44	10.088
Total quantity of GW storage =		602.328

In the Reference scenario, the climate sequence for future years was developed by repeating historical data for the period 1979 to 2013 and assuming a similar periodicity through 2050.

The results show WEAP program used for decision support systems in the study area development and scenarios Options for multiple development and water resources development and management of the multiple uses to solve the water problems in the city of Taiz and the overall study over the years 2013-2050. Table (6) presents a synopsis of our hydrologic for the various scenarios for the Study area. The following are the implications of the results of our analyses in our proposed priority of implementation.

The current water situation sub-basins of the study area and the extent to keep up with water needs, as results showed that the age of aquifers in the central region will supply the city of Taiz with water to the year 2024, equivalent to 11 years, while the sub-Hawban basin supply the city 3.1 year, which calls for urgent interventions to supply the city water, in order to ensure the continuation of human life and the living of the population.

Desalination of sea water of Mokha area on the Red Sea are necessary to meet the needs of Taiz City by water amount of up to 27,375,000 m^3 / year first phase, extend the life of aquifers in urban areas from 10.3 to 17.7 years, and the countryside more than 50.6 years old level, providing a steady source to supply the city with water for all uses, ensuring attract local and foreign investment to the city to ensure that more of the standard of living and social stability of the population of the province in general, the development of towns and villages stretching from Mokha and even the city of Taiz and to ensure the improvement of living style to these communities by providing water needs and operating efficiencies technical, administrative and professional during and after the implementation of the project. Note that the desalination process is too expensive to maintain irrigated agriculture, as well as support the implementation of the project components, excess population growth for the city of Taiz with desalinated water to provide a permanent basis and the possibility of the worsening security and administrative risks during operation of the project Figure (3).

Rainwater harvesting from rooftops scenario and the construction of dams and barriers of water is a practical solution to cover agricultural, domestic and industrial needs at the level of rural and urban areas, as it flows into the water resources in the region, including the equivalent of 16,450,000 m^3 / year, extend the life of aquifers 25.35 - 85.35 years for water sources in rural areas of the study area, but in urban society stretching 2.1 years, the use of surface water for irrigation, for industries and with preventing the continued use of groundwater in these areas, the implementation of this option save the right amount of water to the city of Taiz, including droughts, sub-surface storage of the water, will have a positive effect on water quality in Al-Hawgalah and Hawban water fields whom suffer from high in salinity and will greatly reduces the evaporation rate, recharging aquifers, surface waters and aquifers for wells in the same area. Reduce the flash floods on the soil in the valleys and therefore drains towards the sea without benefitting from the water, Reduce the amount of sediment carried by the flood to Al-a'amerah Dam Lake at the central region of the study area, maintaining the cleanliness of channels and corridors valleys from pollutants associated with floods. Ensure social stability of the population and thus the provision of

health conditions. Stimulate and attract local investment, which will ensure increased per capita income. Decrease employment, migration and the operation of labor during and after the implementation of the project. Knowing that implementation of the project need large tracts of land in the eastern and western areas of the city, to issue regulations necessary and binding on Population and legislation city building tanks to harvest rain water within the private courtyard housing spaces, provide adequate funding to buy land and design of technical and environmental studies etc and implementation of components of the project, as well as that this option is affected by changing natural conditions from one season to another and from one year to another Figure (4).

Table 5: Estimated annual natural recharge and water use in the Study Area.

Aquifer	Al Dabab Sub Catchment	Al Hawaban Sub-Catchment	Central Sub-catchment	Al Janad Sub Catchment	Thi- Sufal Al Haimah Sub Catchment
Natural recharge MCM	2.3	2.15	4.28	1.54	4.2
Urban (2013) pop	0	133302.4	769940.1	0	0
Rural (2013) pop	33927.5	0	0	108416.6	36878.9
Commercial Urban (2013) pop	0	47834.3	111272.3	0	0
Commercial Rural (2013) pop	4799	0	0	3287.3	1364
Industrial Urban (2013) production Unit	0	96	96	0	0
Industrial Rural (2013) production Unit	48	0	0	0	0
Urban use in 2013 MCM	0	1.2	28.1	0	0
Rural use in 2013 MCM	2.4	0	0	1.98	0.67
Commercial Urban use (2013) MCM	0	0.72	3.2	0	0
Commercial Rural use (2013) MCM	0.02	0	0	0.02	0.02
Industrial use (MCM in 213)	4.3	10.9	10.1	0	0
Irrigated area in 2013 (ha)	392.3	450.1	590.7	123.4	90.9
Irrigated use in 2013 MCM	5.3	49.8	47.2	1.2	1.1
Water balance in 2013					
Available storage	303.8	196.3	1003.5	291.2	957

Improvement of water distribution networks in the urban areas of the City of Taiz extends the life of the aquifer in the central region at a rate of 11.1years, in general and in Al Hawban estimated for supplying water resource application of this scenario is 3.7 years, although the cost is too high to improve the network, but as a priority for the city because it reduce losses of water purchase prices are expensive and that are currently being brought in to cover the existing deficit in the city of Taiz, it provides and maintains improvement of the system of distribution amount of water by 5,163,837.3 m^3/year, reduce operating and maintenance cost of the current system of distribution, save pro extra waste from water loss etc.

Table 6: Output from WEAP Scenario in the study area.

Scenario	Extended Life of Aquifer		Priority
	In Urban	In Rural	
Improve urban water supply delivery	3.7 to 11.1		Medium to High
Improving irrigation Efficiency	7.4 to 11.84	6.7 to 18.5	Medium to High
Improving industrial production technology	1.7 to 2.6	2.7	Medium
Rainwater harvesting	2.1	25.35 to 85.35	Medium to high
Importing desalinated water from Mocha City	10.3 to 17.7	50.6	High
Re- use Wastewater from treatment plant	1.1 to 2.1	0.8 to 1.1	Low

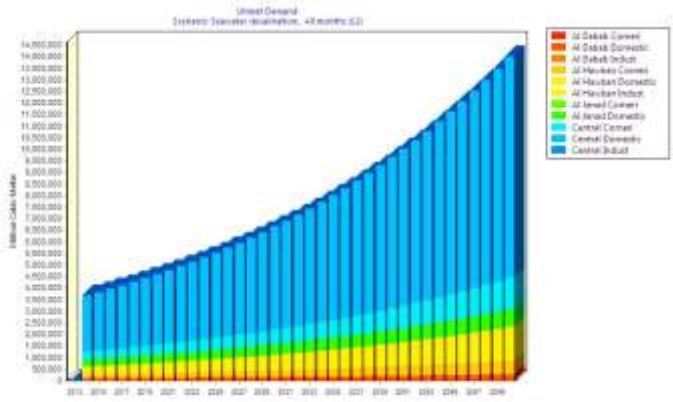

Figure 3: Water Balance with Importing desalinated water from Mokah city scenario

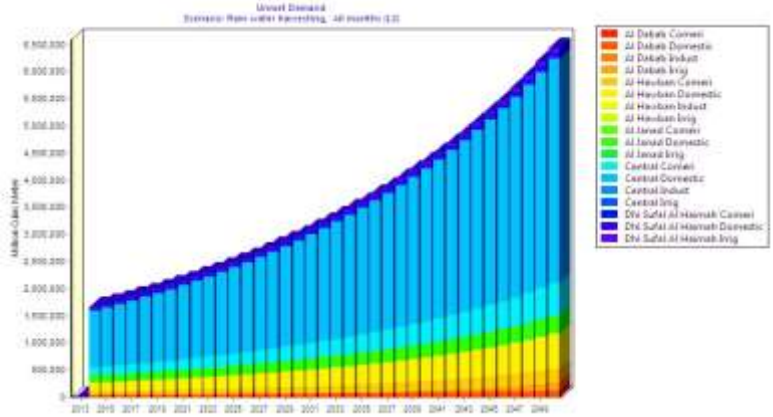

Figure 4: Water Balance with Importing Rain water harvesting.

Improving irrigation means contributes to reduce the amount of used water to irrigate crops, by 40% (42,277,451.3) m^3 / year and extends the life of the aquifers in Thi Sufal and

Haimah area by 18.5 years and in Hawban area increased by 11.84 years, and extends the life of the aquifer in Central region to 7.4 years. Knowing that localization of modern irrigation technology, which requires high-cost funding addition to the lack of awareness among farmers of the importance of the use of modern irrigation techniques. Figure (5).

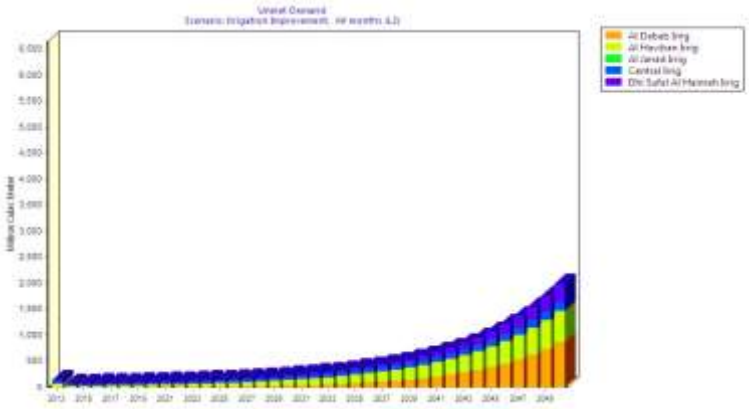

Figure 5: Water Balance with Irrigation improvement Scenario

Improving industrial production technology extends the life of the aquifer at a rate of 2.6 years in Hawban, Central region at a rate of 1.7 years The Al-Dhabab estimated prolongation 2.7 years equal to 5,065,294.26 m3 / year, it contributes to reducing the cost of industrial products by reducing the amount used of water in production processes and reduce the cost of pollutants resulting from these processes in the industrial facilities. Knowing that the replacement of old technology by modern techniques of high cost and lack of awareness on the importance of the industrial sector for adopting of the technology of water rationalization at industries Figure (6).

Re-use of treated wastewater to reduce the allocated water and kept for drinking a fresh water, to supplement the water resources in the central region of the study area and additional vendor estimated 7,200,000 m3 / year, providing water sources alternative less expensive can be used in agriculture, especially after treatment, water containing treatment on Nitrogen, Phosphorus and other nutrients for the growth of nutritious component. Reduce of waste and thus prevent pollution, which costs a great financial burden for re-contaminated water body rehabilitation. This option has disadvantage such as the rehabilitation of part of the sewerage networks and existing treatment plants. Extension of the city which does not accompanied by expansion of the sewage network. The lack of funds for the establishment of sewerage networks, treatment plants, low environmental and health awareness with regard to the use of wastewater by the neighboring population to the main pipe and the treatment plant in Al Burayhi area Figure (7).

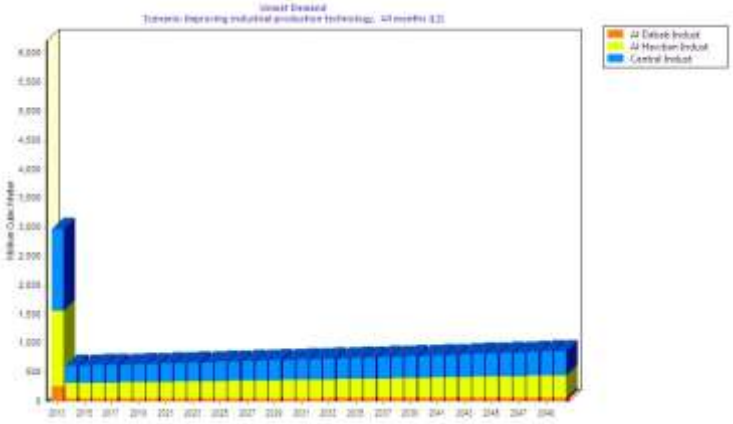

Figure 6: Water Balance with improving industrial production technology Scenario

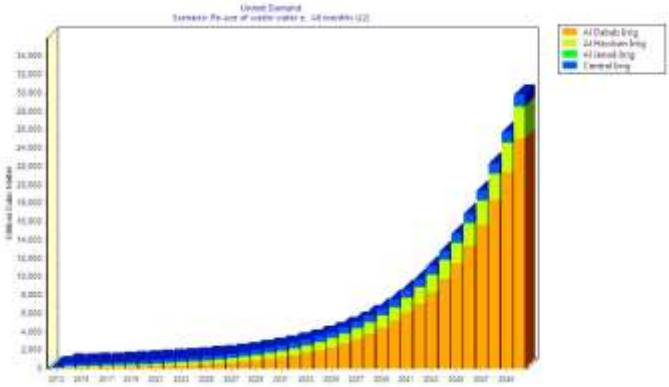

Figure 7: Water Balance with Re- use Wastewater from treatment plant Scenario

Figures (8 and 9) forms illustrate summary of results of the discussion:

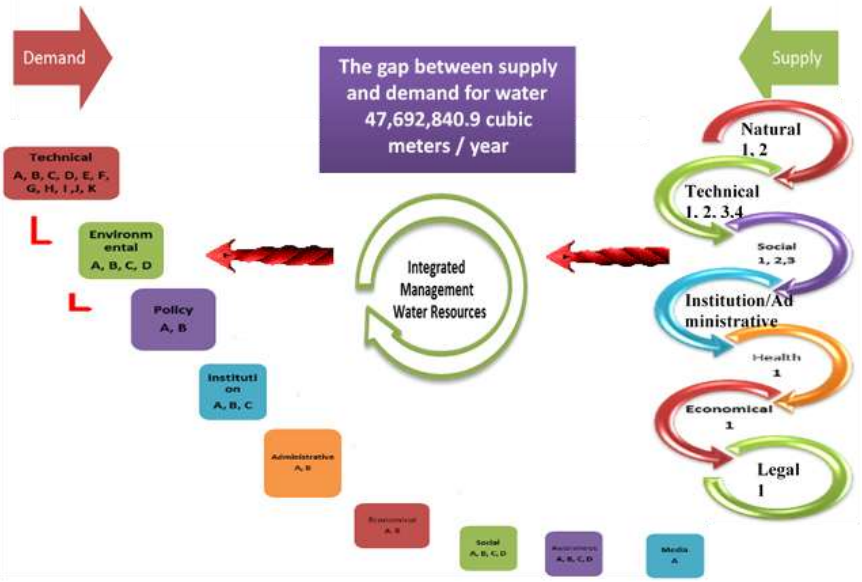

Figure 8: Integrated Water Resource Management in region Taiz Basin.

Supply

Natural

1-Scarcity of available water resources

2- Available Water in the study area is 112m^3 /capita. year

Technical

1-Degradation of water quality

2-The absence of enough wastewater treatment

3-Random Urbanization

4-Soil pollution

Social

1-Increase of population growth

2-Migration from the countryside to the city

3-Conflicts and competition on available water resources

4- Random drilling

Institution/Administrative

1-Gap between water users and policy makers

2-The absence of applying IWRM principles

Health

-Transmissions of diseases due to low water quality

Economical and Environmental

1-Excessive use of agriculture pesticides

Legal

1-The absence of enforcing laws and implementation of rules

Demand

Technical :

A- Rainwater harvesting.

b- Desalination of sea water at Mokha City.

c- Improve water transfer and distribution system

D- Improving industrial production technology based on rational water use.

e- Adoption of modern irrigation technology.

f- Development and maintenance of agriculture terraces in the jabal Saber watershed.

g- Implementing reservoirs and agriculture terraces upstream of the wells at the areas of water basin.

h- Replace damaged sewage networks.

i- Complete sewerage system for Taiz city

j- Rehabilitation of the existing wastewater treatment plant

k- Construct new WWTP in Taiz city

Environmental:

A- Applying environmental and health guidelines in water and wastewater services

b- Manage the solid waste emerging from the city

c - Force Industries, Labs and hospitals to treats their effluents according to the environmental guidelines

d- Re-use of treated wastewater.
Policy:
a-Water sector governance.
b- limit urban and industrial expansion in the water basin area.
Institution:
A-Restructuring of water resources management.
B- Institutional Development of the water management sector.
C-Activating the role of the commission basin.
Administrative:
a- Decentralization of Management of main and sub water basins.
b-Recognizing the role of women in the provision and management and conservation of water
Economical:
a- Dealing with water as a commodity and as a depleted natural resource.
b- Reconsider the water tariff to cover the real cost.
Social:
a- Activating the role of the private sector in the field of water service .
b- Resolve social conflicts by applying the participatory approach with beneficiaries .
C-Formation of WUAs at the water basins
d- Formation of water and environment friends at the city
Awareness:
a- Introduction of water awareness in the curriculum of all education stages
b- Take advantage of the role of mosques and religious scholars in raising awareness of the need for rationalization of water use.
c- Activating the role of lectures and seminars on Water
d - Implementation of awareness campaign for risks and threats to water resources.
e- Supporting research themes to solve different issues of water and environmental problems
Media:
A-The adoption of the official media to the theme of water as a fundamental and vital issue

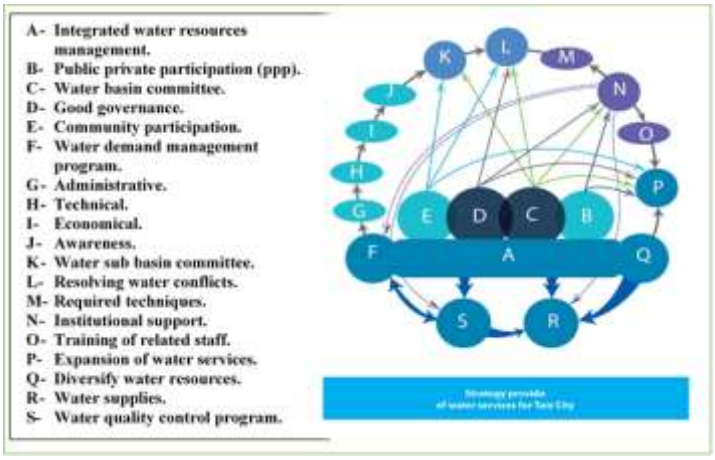

Figure 9: Improvement of water service, water projects and water management in Taiz basin.

7. CONCLUSIONS

Through what was presented in the context of the study on the current status of water in the region, we conclude the following:

- The amount of water available currently in the water resources of the study area is not enough to various water needs, according to the few water points' data.

- Observed during the study and a large gap between supply and demand for water in the study area, with the deficit reaching 29%.
- Scarcity of available water sources in order to meet the demand for water for various uses in the study area and therefore the per capita water does not exceed in the study area 112 m^3 / year:

Increase of population growth for Taiz City amounting to 3.85% , Rural area 2.6%, migration from the countryside to the city, and urbanization random ... etc., which offset a lack of available water resources and the emergence of social, economic, environmental and health problems in the city

-Sum of water points that have been counted in the study area 1501 point, divided between: (wells (954 Hand-dug, 479 Deep), 50 Springs, 10 water tank collections, 2 dams and 6 water retaining walls).

-Despite the paramount importance of rainwater harvesting projects in the study area, the interest and make use of them is still limited, with carrying capacity of the dams and ponds established in the study area 1542000 m^3.

Despite the issuance of the Water Law No. (33) for the year 2002 and the declaration of the national strategy for water for the year 2009-2014 AD by the Ministry of Water and Environment, however, that those texts are still read-only and did not then turn to the plans and executive programs for the water sector in the Ministry and its affiliated bodies and government institutions at the central level and localities in the provinces, as well as the existing gap in the general structural and planning, implementation and control of water resources at the country level between water users on the one hand and policy makers and legislation on the other.

Despite the existence of a committee to manage the water basin of the Upper Rasyan Valley from a number of bodies of water relationship, headed by the governor of the province (Taiz) and a number of water users associations in the study of the basin water area, but the practice of the principles of integrated management of water resources in the basin unrealized.

Weakness of groundwater recharge in the urban part of the city of Taiz as a result of the realization of the asphalt pavement and streams valleys area of 81 km^2 of the study area amounting to an area of 750 km^2.

Observed Qat cultivation in the north-eastern areas of the city of Taiz (Al-Haimah and Habir) a total area of 90.9 hectares and the spread of fodder crops in the central region of the study area with a total area reaches 208 hectares using rain water and seasonal water available from water wells and springs, as well as using wastewater in parts of the Central Catchment area (AL-Bureihi and parts of AL-Aamerah), knowing that the amount of this water is used without treatment.

The water conflicts in different parts of Taiz water basin (Jabal Saber, Al-Haimah and Habir .... etc.) due to of the scarcity of water resources, population growth and neglecting the traditional systems concerning the water rights and arrange its uses for drinking water ... etc. and the intensive competition for water resource according to property rights and group influence in different areas of the basin

The present and future of water supply in different sectors needs to be calculated (domestic, agricultural, industrial ... etc) for the base year 2013, according to the standards

of the World Health Organization (WHO) and Food and Agriculture Organization (FAO) and the Indian Specifications and American (APHA, ASTM), and long-term climate data in the study area for the years from 1979 to 2013, and hydrologic data for the region, agricultural land used and the pattern(s) of crops and groundwater extracted and their use .... Etc as an input necessary for the implementation of decision support systems program WEAP in the field of water resources management.

❖ The best choice to solve the problem of water supply for the city of Taiz and the provision of adequate water of the study area is generally over the years 2050 -2013 is to improve agricultural irrigation system. This will contribute to reduce the amount of used water in irrigation by 40% and extends the life of aquifers in a region Thi -Sufal and Al Haimah by 18.5 years, in Hawban area by 11.84 years, in the Central region by 7.4 years, and will reduce the gap between supply and demand in the study area by 89%. It is worth noting that the adopting of modern irrigation technology has high cost and lack of awareness among farmers of the importance of the use of modern irrigation techniques to accomplish the challenges in implementing this option.

8. RECOMMENDATIONS

8.1 Improve water services and water management strategy for; Central and Al Hawban Sub Catchments:

1. Increase the coverage rates for water services include all Beneficiaries service during a specific period of time.
2. Diversify water sources for the city for the purpose of continuity and sustainability in the provision of water service for all consumers and all uses of quantity and quality required.
3. Efficient water management in order to achieve the concept of good governance, so that lead to optimal use of water sources available, implement guidelines, awareness programs to rationalize water consumption , reducing losses and optimum exploitation of water projects …etc.
4. Implementation of control and water quality program in water sources and treatment drinking water Units multiple mobilize so as to prevent any contamination during transportation, distribution or storage and ensure the safety of those sources,
5. Development of specialized human cadres technically and administratively for the development of water management, in addition to providing supplies of techniques and materials required.... etc.
6. To ensure flow of water services from different water sources through the transport, storage, distribution and purification systems, wherever it is required.
7. Implementation of water demand management program for the purpose of economy in the consumption of water, the implementation of economic, technical and awareness programs..
8. Partnership with the private sector for the purpose of providing water service to the entire population. Implementation and operation of water projects, management of water service, participate in institutional development for entities operating in the water service.

9. Community participation through the formation of committees of Water and Environment friends in the Harrah and Neighborhood of the city to help TWSLC to prepare proposals to improve water services ... etc.
10. Ensure necessary investments to cover the expansion of water services in the urban area and the implementation of the proposed programs in the framework of these recommendations.

8. 2 Improve water projects, water services and water management strategy for; AL-Dabab area;

1- Increase the coverage rates for water services include all Beneficiaries service during a specific period of time.
2. Commitment of the Commission basin management to Upper Rasyan Valley, its functions in accordance with the Water law No (33)2003, and its implementing rules direct supervision on water basin management in the governorate.
3. To ensure flow of water services from different water sources across the transport, storage, distribution and purification system, wherever it is required.
4. Community participation through the formation of committees of Water and Environment friends in the Harra and Neighborhood of the part (Al-mudaffar district) from the city to help Taiz Water Supply Corporation to make proposals to improve water services ... etc.
5. The formation of committees Sub-water basin to ensure the management of water resources from the lower level to the top level with the principle of community participation, sustainability of the local development and the preservation of water resources.
6. Resolving water conflicts in different regions of the study area, by popular demand, given their economic, political, security and social effects. So it has to create community dialogues by the main Commission basin and sub- basin Committee in region conflict and representatives of water users associations in the same area to develop lasting solutions that ensure water transfer to other areas or the Taiz city and dealing the economic, social and environmental effects etc, as a result of transporting water or passing through region.
7. Community participation complete establishment of water users associations in the sub-basin areas to help provide practical suggestions to combat the random drilling of wells and development of water sources in the sub-basins areas and priorities for water use and rationalization of uses in the sub-basin water area.
8. Encourage of the house women on the participation of communities in the water management.
9. Limit urban and industrial expansion in the water sub-basin area.
10. Implementing reservoirs and agriculture terraces upstream of the wells at the area of water sub- basin.
11. Development and maintenance of agriculture terraces in the Jabal Saber watershed.
12. Necessary investments to ensure the implementation of the water projects, as well as water supply, sanitation systems, construction of water harvesting and irrigation technology, and proposed programs in the framework of these recommendations, in countryside of the study area.

8.2 Improve water projects, and water management strategy for; AL Janad area;

1. Commitment of the Commission basin management to Upper Rasyan Valley, its functions in accordance with the Water law No (33) 2003, and its implementing rules direct supervision on water basin management in the governorate and the formation of sub- water basin committees and approve operational plans and financial budgets for the development of water sources for the city and sub-basin areas supplied it generally and prioritize the use of water sources.
2. The formation of committees Sub-water basin to ensure the management of water resources from the lower level to the top level with the principle of community participation and sustainability of the local development and the preservation of water resources.
3. Community participation complete establishment of water users associations in the sub-basin areas to help provide practical suggestions to combat the random drilling of wells and development of water sources in the sub-basins areas and priorities for water use and rationalization of uses in the sub-basin water area.
4. Encourage of the house women on the participation of communities in the water management.
5. Limit urban and industrial expansion in the water sub- basin area.
6. Necessary investments to ensure the implementation of the water projects, as well as water supply, sanitation systems, construction of water harvesting and irrigation technology, and proposed programs in the framework of this strategic ,in countryside of the study area.

8.4 Improve water projects, and water management strategy for; Thi-Sufal area;

1. Commitment of the Commission basin management to Upper Rasyan Valley, its functions in accordance with the Water law No (33)2003, and its implementing rules direct supervision on water basin management in the governorate and the formation of sub- water basin committees and approve operational plans and financial budgets for the development of water sources for the city and sub-basin areas.
2. The formation of committees Sub-water basin to ensure the management of water resources from the lower level to the top level with the principle of community participation, sustainability of the local development and the preservation of water resources.
3. Resolving water conflicts in different regions of the study area, by popular demand, given their economic, political, security and social effects. So it has to create community dialogues by the main Commission basin and sub- basin Committee in region conflict and representatives of water users associations in the same area to develop lasting solutions that ensure water transfer to other areas or the Taiz city and dealing the economic, social and environmental effects etc, as a result of transporting water or passing through region.
4. Community participation complete establishment of water users associations in the sub-basin areas to help provide practical suggestions to combat the random drilling of wells, development of water sources in the sub-basins areas and priorities for water use and rationalization of uses in the sub-basin water area.

5. Encourage of the house women on the participation of communities in the water management.
7. Implementing reservoirs and agriculture terraces upstream of the wells at the area of water sub-basin
8. Necessary investments to ensure the implementation of the water projects, as well as water supply, sanitation systems, construction of water harvesting and irrigation technology, and proposed programs in the framework of these recommendations ,in countryside of the study area.

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إدارة قضايا المياه في حوض تعز/ اليمن

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ملخص

تشمل منطقة الدراسة مدينة تعز التي يعاني سكانها من نقص حاد في المياه بسبب الطلب المتزايد على المياه لتلبية الاحتياجات المنزلية والصناعية فضلا عن الاحتياجات المائية للزراعة في المنطقة، بالإضافة إلى ذلك، تقتصر الموارد المائية في منطقة الدراسة على طبقات المياه الجوفية في حين تتجاوز معدلات استخراج المياه التغذية الطبيعية واستخدامها بشكل غير فعال. يركز البحث على أهمية إدارة الطلب على المياه للحفاظ على كمية ونوعية مياه الشرب والاستخدام المنزلي والزراعة والصناعة.

تهدف الدراسة إلى تقييم الوضع الحالي والمستقبلي لمصادر المياه في منطقة الدراسة، تطوير سيناريوهات وتحليل الموازنة المائية لمعرفة أفضل الحلول لمشكلة المياه في حوض تعز بالإضافة إلى اختيار السيناريو المناسب لحل مشكلة المياه. نتائج هذه الدراسة تساعد متخذي القرار في مجال الموارد المائية لتحسين التخطيط والإدارة للموارد المائية في هذه المنطقة مستقبلا. خلال الفترة 2013/1/15 إلى 2013/4/15 تم تنفيذ دراسة ميدانية لـ 1501 نقطة مائية موزعة هذه النقاط ما بين 954 بئر محفورة يدويا، 479 بئر عميقة، 50 ينبوع، 5 صهاريج تجميع المياه، 2 سد مائي، 6 أحواض مائية بجدران ساندة. تم حساب كمية المياه في المنطقة ومقدار العجز المائي، بالإضافة إلى معرفة كمية الاحتياجات المائية التي يجب تأمينها في المستقبل في إطار منطقة الدراسة، تم تطبيق DSS في نطاق نظم دعم القرار لإدارة العرض والطلب على المياه في حوض تعز. ولتحليل النتائج تم استخدام برنامجWEAP للمواضيع التالية: المخزون المائي في الطبقات الحاملة للمياه، كمية المياه القابلة للاستخدام لسنة الأساس 2013"م، تم احتساب كمية المخزون للأحواض الفرعية الخمسة في منطقة الدراسة ، حيث تراوحت في طبقة المياه الجوفية الغرينية 221,52الى 415,36 مليون متر مكعب، بينما أفضل تقدير بلغ 332,29 مليون متر مكعب وفي الطبقة البركانية تراوحت بين 129,98 و2500,52 مليون متر مكعب، بينما أفضل تقدير بلغ 295 مليون متر مكعب، في حين أن مخزون المياه الجوفية في طبقة الحجر الرملي تراوحت بين 5,044 إلى 50,44 مليون متر مكعب وأفضل تقدير لها بلغت 10,088 مليون متر مكعب، وقدرت الفجوة بين العرض والطلب على المياه في منطقة الدراسة 47,7 مليون متر مكعب. لحل قضية المياه في منطقة الدراسة اقترحت استراتيجية لتحسين خدمات المياه وإدارتها بكفاءة في المناطق الحضرية التي تشمل منطقتي الأحواض الفرعية للمياه الوسطى والحوبان وتتمثل بالاتي: زيادة معدلات التغطية لخدمات المياه ، تنويع مصادر المياه، الإدارة الرشيدة للمياه، تنفيذ برنامج التحكم والمراقبة على نوعية المياه ومصادرها ووحدات معالجة مياه الشرب المعبأة، تنمية الكوادر البشرية فنيا وإداريا لتطوير الإدارة المائية وضمان ضخ المياه بالكمية والنوعية المطلوبة من مصادرها المختلفة...الخ. كما تتضمن الاستراتيجية تطوير المشاريع الريفية بما فيها ضمان الإدارة الرشيدة لها في مناطق الأحواض الفرعية في الضباب، الجند ودي السفال والحيمة والمتمثلة بالاتي: تنمية مصادر المياه، تشكيل لجان للأحواض المائية الفرعية لإدارة الموارد المائية من المستوى الأدنى، حل النزاعات في قضايا المياه والمشاركة المجتمعية من خلال استكمال تأسيس جمعيات مستخدمي المياه في مناطق الأحواض الفرعية من منطقة الدراسة ....الخ.