CONSULTANCY SERVICES FOR RIVER BASIN MANAGEMENT

REF : 11EKA/D65/ACS/BRT/PRG/18-07-2022

AL ASSI RIVER BASIN

FINAL REPORT

JUNE 2023

HawkaMaa - EU
حوكماء - الإتحاد الأوروبي

Funded by the European Union
بتمويل من الاتحاد الأوروبي

BUREAU TECHNIQUE
POUR LE DÉVELOPPEMENT

To cite this document:

ACTED, WeWorld-GVC, & BTD. (2023). Consultancy Services for River Basin Management: Al Assi River Basin Final Report, Beirut Lebanon.

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List of Abbreviations

AMSL	Above Mean Sea level
ARB	Assi River Basin
BGL	Below Ground level
BWE	Bekaa Water Establishment
CAPEX	Capital Expenditure
CDR	Council for Development and Reconstruction
CSO	Civil Society Organizations
DMA	District Metered Area
IWRM	Integrated Water Resources Management
LULC	LandUse and LandCover
MCM	Million Cubic Meter
Mm^3	Million cubic meters
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MoEW	Ministry of Energy and Water
NA	Not Available/Applicable
NDU	Notre Dame University
NGO	Non-Governmental Organization
NWSS	National Water Sector Strategy
OPEX	Operating Expense
PoM	Programme of Measures
PS	Pumping Station
RBM	River Basin Management
SDG	Sustainable Development Goal
TDS	Total Dissolved Solids
USD	United States Dollar
WBCCKP	World Bank Climate Change Knowledge Platform
WEAP	Water Evaluation And Planning
WHO	World Health Organization
WRMM	Water Resources Management Model
WTP	Water treatment Plant
WWTP	Waste Water Treatment Plant

1 Background

1.1 Project Description

The current report is the final report of the water resources management of Assi River Basin (ARB) located between Baalbek and Hermel districts. It consists of developing a detailed Water Resources Management Model by establishing a node based distributed water balance model using Water Evaluation and Planning WEAP software. The assessment presents the state of the water availability, water demand, water supply, and unmet demand (per sector) in the basin during the last 2 decades, as well as the current state of surface water pollution based on a recently conducted field survey and water sampling.

The work has been conducted in the framework of the project “CONSULTANCY FOR RIVER BASIN MANAGEMENT FOR AL ASSI RIVER BASIN/BEKAA, GHADIR BASIN/ BEIRUT AND MOUNT LEBANON, NAHR AL OSTUAN BASIN/AKKAR”, under EU MADAD funding and as part of the HAWKAMAA-EU Consortium partners.

The purpose of the project is to support effective multi-stakeholder decision making and action through water balance modelling to improve the conservation and management of water resources in the basin and maximize the economic, environmental and social benefits. The overall scope is to improve water management in selected river basins by implementing a bundle of demand management measures which can alleviate the prevailing water stress, increase water availability and network efficiency while decreasing losses.

In parallel to these water quantity issues, the work also focuses on assessing the current pollution levels in the river, in order to mobilize the local community and stakeholders to take action to reduce pollution loads in the basin, and mitigate the current problem.

The project promotes an inclusive participatory approach, not only by disseminating the results and outputs to the various target groups, but by also involving them in the consultation process.

The following activities have been concluded so far after the baseline report phase:

- Finalization of the Groundwater model using MODFLOW and of the semi distributed (node-based) Water Resources Management Model for ARB in WEAP21 software, at monthly timestep and for the period 2020 - 2035.
- Second sampling campaign and laboratory analysis of water samples from 6 sampling sites along ARB for the summer season conducted on February 27th.
- Second participatory workshop with the stakeholders on June 7th 2023 at Hermel Public Library, Hermel.
- Drafting of the Final Report on the assessment of the water resources in ARB, based on the outputs of the WEAP model.

1.2 Link to NWSS

The Ministry of Energy and Water (MoEW) prepared and adopted the Lebanese National Water Sector Strategy (NWSS) in 2010 which was endorsed by the Government of Lebanon in 2012 (Resolution No.2, Date 09/03/2012). Seven years later, in 2019, the MoEW decided to review what has been realized from the original roadmaps and to update the water and wastewater strategies of 2012 by setting a detailed action plan to implement reforms and create a hydrogeological data management system and improve service coverage. The Updated NWSS 2020 merges the National Water and Wastewater strategies of 2012 into one consolidated strategy. It maintains the main strategic principles of the water policies adopted by the Government of Lebanon in 2012, but reassesses the then set priorities in light of today's actual context, and sets the ground for the period extending between 2020 and 2035.

It takes into account the adopted Water Code (law 192/2020) and its structuring principles, which are in turn in line with the water sector organizing Law 221/2000 and its amendments, as well as studies and projects completed between 2012 and 2021 in the fields of potable water, wastewater and irrigation, and management initiatives implemented during the same period. The newly ratified Water Code includes several IWRM implementation principles and aims to regulate, develop, rationalize, and exploit water resources, protect them from depletion and pollution and improve the efficiency of transport, distribution, and maintenance systems for the operation of water installations to ensure the sustainable management of the Lebanese natural water resources.

As per the water code, the Ministry aims at achieving a financially sustainable sector, that is citizen-centered and service oriented, and which would ultimately allow to reach an integrated approach of the water sector.

The updated strategy can be considered as a shift into practical, implementable plans, projects and governance initiatives that set the ground to move towards the UN's Sustainable Development Goal SDG 6 and realize the principles of an Integrated Water Resources Management (IWRM). While doing so, the updated NWSS 2020 targets as well SDG 2 (Zero Hunger), SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), SDG 14 (Life below Water), SDG 15 (Life on Land) and SDG 17 (Partnerships for Goals); these will be explored throughout the document.

Based on the United Nations' SDG 6, the MoEW aims at providing safe, equitable and affordable water and wastewater services to all, and to properly allocate the water resources to the different economic sectors (agriculture, industry, tourism, services, etc..) based on the priorities of the Government's recovery plan.

These commitments are translated by strengthening the IWRM through targeted proposed projects and improved governance at the basin level, thus the river basin management studies of Al Assi, Ghadir and Al Ostuan.

1.3 Methodology

The assessment of the water resources management situation in ARB was carried out following the below methodology:

- Second water quality sampling campaigns in coordination with NDU University water laboratory, carried out on February 27th, 2023. The lab report is attached in Appendix A.
- Development of future water demand and climatic scenarios.
- Suggestion and design of future demand management measures.
- Simulation of the selected future scenario using MODFLOW and WEAP models developed in the baseline phase to assess the future situation of the water resources management within the basin.
- Suggestion of policy relevant targets, Programme of Measures (PoM) and Action Plan based on WEAP model output and in coordination with the outcome of the participatory workshop involving local stakeholders with the purpose of improving the conservation and management of the river basin and optimize the economic, environmental, and social benefits of ARB.
- Drafting of the Final Report based on the overall project area description and the outputs of the WEAP model, including a water quality assessment and the outputs of the field survey and sampling campaign.

2 Second Water Quality Sampling Campaign

2.1 Description

A second sampling campaign for water quality check was carried out on the 27th of February 2023 by NDU Laboratory team in coordination with BTD, ACTED and GVC the local NGO. This section will only present a brief summary of the campaign including main results. The complete report is attached in Appendix A.

The second campaign was made over the wet season to show compliance with established criteria and to highlight any seasonal variability.

The sampling plan and location were prepared in a way to guarantee representative samples, thus providing an accurate description of the overall quality of the water in ARB.

Furthermore, sampling sites were located in areas that are safe to access, accessible under all conditions of flow, and well mixed to ensure a homogenous sampling collected is easily identifiable for later sampling.

Table 1 Sampling location

ID	Name	Latitude	Longitude	Altitude
ID1	Labwe - Main	34.1974	36.3524	910
ID3	Fekha	34.2417	36.4068	1029
ID4	Al Assi – Dardara waterfall	34.4217	36.4573	564
ID6	Ras El Mail	34.3904	36.3713	785
ID7	Al Assi - Hermel Bridge	34.3935	36.4178	590
ID8	Zar2a	34.3524	36.3738	674

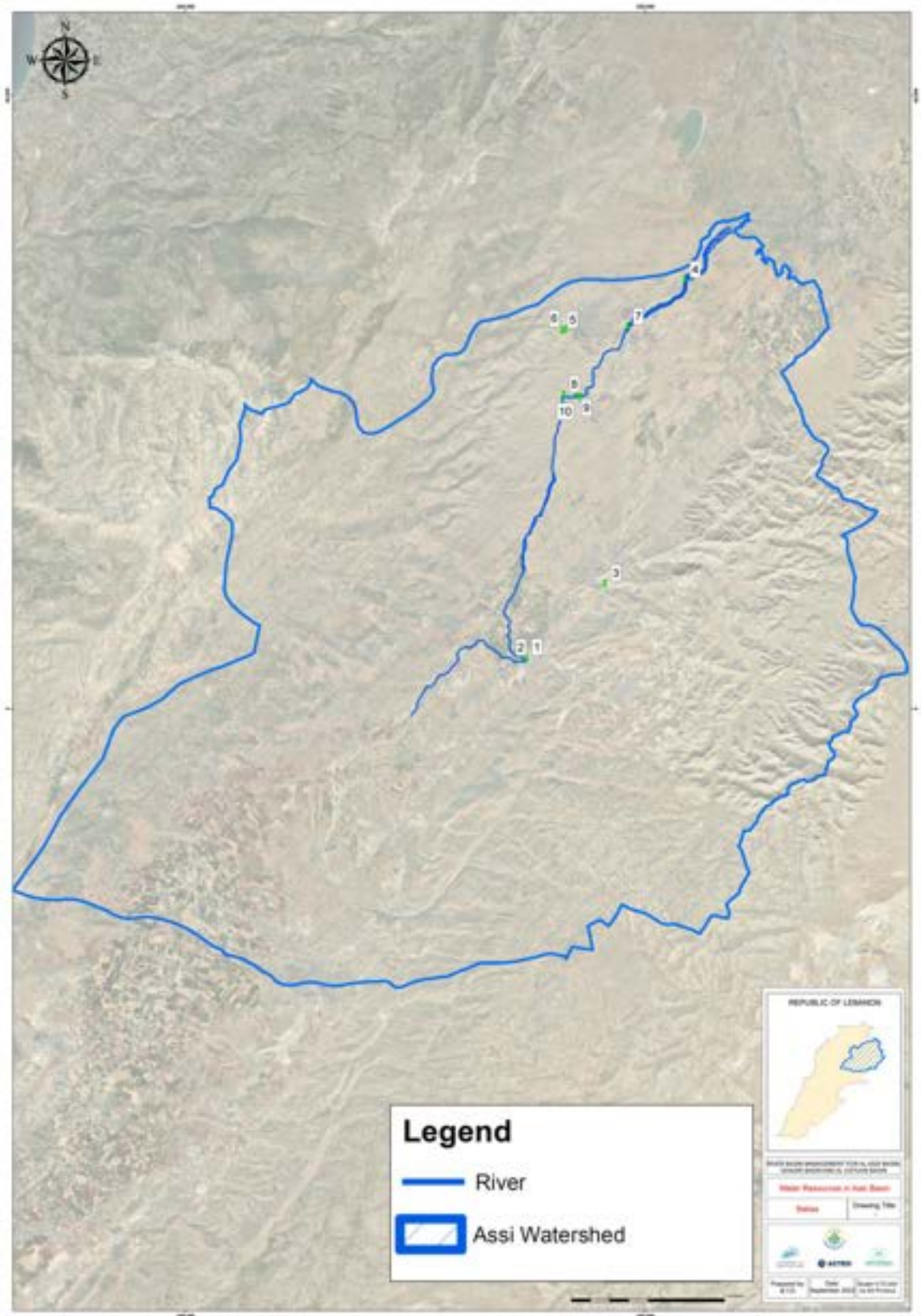

Figure 1 Water quality sampling sites location

2.2 Results

Results obtained following the physical, biological and chemical testing of data collected (Table 2), shows that almost all stations are characterized by median of pH between 7.0 and 8.22; so, the values are generally within appropriate limits for water supply and aquatic life. Total Dissolved Solids are a measure of all ions in a solution (TDS). TDS measurements were less than 251 ppm for all the samples.

The ammonium concentration in the samples carried out during the months of February showed acceptable values compared to WHO international standards. The amounts of nitrate, heavy metals, and chloride have not given values that exceed the accepted standards.

Table 2 Summary results of the water quality sampling campaign

Test/Point ID	Irrigation value	WHO Standards for Drinking	ID1	ID3	ID 4	ID 6	ID7	ID 8
Turbidity (NTU)	**<10**	**<5**	0.01	0.01	10.1	0.05	4.3	0.02
pH (pH)	**6.5-8.4**	**6.5-8.4**	7.9	7.9	7.8	7.6	8.22	7
ORP (mV)	**-**	**-**	357	276	261	268	253	257
RDO (mg/L)	**-**	**-**	7.4	7.5	8.7	8.6	8.4	8.2
S-Cond (µS/cm)	**1000**	**1000**	302	360.9	370	226	370	368
TDS (ppm)	**1000**	**500**	196	235	241	147	241	239
TSS (ppm)	**60**	**-**	52	44	113	15	93	20
TS (ppm)		**1500**	248	279	354	162	334	259
Temperature	**10-30**	**24-30**	15.8	18.2	15.1	12	15.4	14.9
Nitrate (mg/L)	**10**	**10-50**	2.88	4.4	2.79	1.5	3.02	2.82
Lead (mg/L)	**5**	**0.01**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium (mg/L)	**0.01**	**0.01**	0.0008	0.0009	0.002	$18x10^{-4}$	0.001	0.0008
Barium (ųg/L)	**-**	**0.7**	1.7	3.9	3.5	3.2	3.7	3.6
Mercury (ųg/L)	**0.1**	**0.06**	0.022	0.021	0.101	0.126	0.019	0.095
Sodium (ppm)	**150**	**60**	4.4	12.1	10.1	6.1	10.8	9.9
Potassium	-	**12**	1.8	0.1	2.8	1.2	3.1	2.6
Lithium (ppm)	**2.5**	**-**	0	0.1	0.1	0.1	0.1	0.1
Calcium (ppm)	**150**	**100-300**	28.7	29.7	36.2	21.1	36.3	36.5
Phosphorus (mg/L)	**2**	**0.5**	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Chloride (mg/L)	**140-500**	**100-500**	5	12	5	3	7	7
Ammonia (mg/L)	**5**	**1.5**	0.26	0.53	1.22	0.02	0.6	0.4
Sulphate	**200**	**45**	<20	<20	<20	<20	<20	<20
Fluoride	**1**	**0.5**	0.3	0.5	0.2	0.5	0.3	0.35
DO	**Above 5**	**Above 5**	7.2	7.6	6.8	7.2	7.6	7.2
BOD	**25**	**4**	2.3	6.2	30.0	6.1	41.3	1.9
COD	**200**	**0.5**	12	21	101	34	90	19
Total Coliform	**<1000**	**0**	2	2	21	3	20	2
Fecal	**<100**	**0**	0	0	6	0	7	0
Ecoli	**<100**	**0**	0	0	5	0	4	0

2.3 Discussion of results

Water samples were collected from Al-Assi River during the wet season and tested for physical qualities, chemical contents, and microbiological counts. Six sampling points were selected. Water quality parameters, such as conductivity, DO, BOD, COD, pH, TS, DS, and Fecal Coliform were analysed. The concentration of lead, cadmium, mercury, barium, lithium, sodium, potassium, chloride, sulphate, fluoride, ammonia, phosphorus, and nitrate was also analysed at all the points. The examination of the results is shown below:

Measuring **dissolved oxygen (DO)** in drinking water and in irrigation water is important to understand water quality. DO is critical for fish and other aquatic organisms to survive. DO values for Al-Assi river, along our reach varied between 6.8 mg/L to 7.7 mg/L. WHO standard for sustaining aquatic life is <4 mg/L, whereas for drinking purposes it is 6 to 8.5 mg/L. crops perform better with higher levels of DO in the irrigation water. For plant growth a value above 5 mg/L is acceptable, and above 8 is heathy. Therefore, all the examined points are suitable for drinking, irrigation and aquatic life. High dissolved oxygen levels are beneficial for drinking water, as it improves the taste, however, high dissolved oxygen levels are linked to the rapid corrosion of water pipes. Furthermore, the results show that DO concentration is reduced when an increase in temperature occurs as oxygen saturation levels are temperature-dependent.

While in the case of **(BOD) concentration, the results** recorded values ranging from 1.9 mg/L at point ID8 and 41 mg/L at point ID7. Most rivers have BOD_5 below 1 mg/L. Moderately polluted rivers may have a BOD_5 value in the range of 2 to 8 mg/L. However, high BOD_5 levels (>8mg/L) can be a result of high levels of organic pollution, caused usually by poorly treated wastewater or from high nitrate levels (EEA, 2001). WHO standard for drinking purposes is 0.2mg/L, which is exceeded to a great extent. A BOD value less than 25mg/L is considered suitable for irrigation, therefore BOD at points ID1, ID3, ID6 and ID8 is considered suitable water for irrigation. Higher BOD_5 values were detected at sites ID4, and ID7 which may be attributed to recreational activities in the form of restaurants, fisheries, and rafting activities that are located along the river as well as family picnic areas in addition to agricultural runoff. Moreover, this might be due to the discharge of Oil Mill (OM) waste, for example, into the river during the sampling season. OM contains an enormous supply of organic matter which might raise the BOD_5 level (Mekki et al., 2013). More specifically, around 13% of olive oil production in Lebanon takes place in the Bekaa area and Lebanon has 21 registered oil mills in the Bekaa region (Ministry of Agriculture,2016). Based on the report, none of these oil mills is treating its waste before discharging it into the environment, which implies that these mills might be discharging the waste into the Al-Assi river in the bekaa valley (Kinab and khoury, 2015).

Chemical oxygen demand (COD) is another important parameter of water quality assessment. A standard for drinking purposes is 10 mg/L, and 200 mg/L for irrigation for fruits which is acceptable for all the points in terms of our analysed value. Table 2 shows the COD data of six sampling points. High contaminations exist at points ID7 and ID4 with COD values of 90 and 101 mg/L respectively. The highest levels of COD recorded may be also attributed to raw sewage discharge and for the same reasons stated in the BOD examination.

Concerning the **pH** which is an indicator of the acidic or alkaline condition of water status, the standard for any purpose is 6.5-8.5, in that respect; the values of our sampled water conform with the standards as for all the samples it varies between 7.00 at point ID8 and 8.22 at point ID4. PH was found to be lower at all points from the dry season. This might be due to the acidity of the rainfall that has mixed and reduced the PH of the river water. All sites exhibited values of pH within the limits of the natural values that support aquatic life.

Adding to the above, the value of electric **conductivity** (EC) of Al-Assi river varied between 226 and 368 µs/cm. Conductivity depends on the number of ions present in water. In the wet season, the total volume of water increases at Al-Assi, yet the conductivity was within the range for surface water and for irrigation (< 1000 µs). A main observation from the results is that conductivity is directly influenced by TDS, the higher the TDS the higher the EC (Lawson, 2011). A positive correlation was clear between EC and TDS. Highest conductivity and TDS were found at point ID6 and ID7, and lowest values were found at point ID7.

Likewise, **total solids** concentrations in the wet season varied between a minimum of 162 mg/L at point ID6 and a maximum of 354 mg/L at point ID4.

Concerning **Dissolved Solids (DS**), the standard for drinking water is 500 mg/L. The maximum value obtained from the samples in the wet season is 239 mg/L at point ID8. In this respect, we can conclude that Al-Assi river water is acceptable from the drinking and irrigation water perspective. High levels of TDS at some points are caused by the presence of potassium, chlorides, and sodium and by toxic ions (lead arsenic, cadmium, and nitrate), and result in an undesirable taste that could be salty, bitter, or metallic (Lawson, 2011).

Similarly, the WHO standard for **ammonia** in surface water for drinking purposes is 1.5 mg/L and for irrigation water is 5 mg/L. The results yielded from the test results showed much lower values ranging from 0.02 at point ID6 to 1.22 mg/L at point ID4 which means it is quite safe in terms of ammonia pollution. This has increased from the dry season; this might be due to the runoff from Agricultural lands that include fertilizers.

Comparably, the levels of **nitrate** exhibited a clear fluctuation among the sites ranging from the lowest value of 1.5 mg/ at point ID6 to 4.4 mg/L at point ID3 yet falling below the limit for surface water (50 mg/l).

Apart from the above, we have traced **metal detection** water. These chemicals are classified as being potentially hazardous and toxic to most forms of life. Results reported that trace metals' concentration for **lead, mercury, barium, and cadmium** was low.

Moreover, some of the chemical elements like **Sodium, potassium, lithium, and calcium** are essential as micronutrients for the life processes in animals and plants (Kar et al., 2008). Fortunately, acceptable concentrations were found in AL Assi.

Similarly, **phosphorus** concentrations recorded values less than 0.3 mg/L for all the sampled points. Comparing these results with WHO limits, they fall within the acceptable level of phosphorus (1mg/L) in rivers.

The sulphate, as well, recorded a mean value of less than 20mg/L for all the. Compared with WHO guidelines, the results fall within the acceptable range (<200 mg/L).

Similarly, **chloride** concentration documented values varying from 3.00 to 12 mg/L. These were found lower than the values at the dry season for all the points. Compared with WHO guidelines, the level of chloride did not exceed the range (200 mg/L) for drinking water indicating that there are no industrial effluents or urban runoff at the location of the sample.

On the other hand, **calcium** values varied between 21.1 mg/L at point ID6 and 36.5 mg/L at point ID8. Calcium is an important micronutrient in the aquatic environment, and it enters the water mainly through the weathering of rocks. The concentration of calcium in rivers may reach 200 mg/L. Results are within the range.

Moreover, **fluoride** concentrations were recorded at all sites, yet no marked variation was observed, a value lower than 0.5mg/L was found at all sites. These are clearly acceptable as far as drinking and irrigation purposes are concerned. For other activities relating to surface water quality, the values are quite acceptable.

Apart from the physical and chemical parameters, the water was tested for microbiological pollutants. The results of the six sampling points show that for points ID1, ID2, ID3 and ID7 there is no detection of fecal and E-coli. However, fecal and total coliform counts were present at sites ID4 and ID6 indicating the critical condition of excessive microbiological contamination. It is important to note that the values for fecal, E and total coliform were found considerably lower in the wet season than the values found on the dry season. The presence of fecal coliform bacteria in very high levels indicates potential health risks to swimmers and implies the suitability of the water at these critical points for specific water uses such as swimming is restricted. The profiles of the water samples at Id4 and Id7 were found to be unsuitable for human consumption, as the concentrations of faecal coliforms and E. coli exceeded the WHO standards recommended limits for drinking water. The high number of coliforms at points ID4 and ID6 confirms the presence of agricultural runoff, animal waste, or raw sewage in the river. Due to the diffuse nature of runoff across the landscape, the bekaa municipalities should implement multiple structural and non-structural practices that are geared towards improving water quality in streams and rivers. These practices might include Stormwater infrastructure inventory, maintenance and repair, Sewer and septic system inspections.

These coliforms indicate that the source water may have been contaminated by pathogens or disease-producing bacteria or viruses which exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals and water species exposed to this water. Fecal coliform bacteria occurred as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste.

Fecal coliform bacteria can affect fish health in the Al Assi river in the following ways:

- Untreated fecal material adds excess organic material to the water which decays, depleting the water of oxygen. This lowered oxygen may kill fish and other aquatic life.
- Fecal material also contains nutrients and organic matter. Nutrient addition to surface waters, can increase algal growth, decrease water clarity, and increase ammonia concentrations which can be toxic to fish.
- Fecal coliforms are bacteria associated with human or animal waste. The presence of fecal coliforms in water may not be directly harmful; however, it does indicate an increased likelihood of harmful pathogens in the water.
- Eating fish or shellfish harvested from waters with fecal contamination can result in human illness.

Therefore, according to the WHO standards and the European Economic Community, fecal coliforms in drinking water are not tolerated (0 FC/100ml), and bathing water should not exceed 100 FC/100 ml (Servais et al. 2007) and for irrigation <200 FC/100 ml. Several health outcomes such as gastrointestinal infections might be associated with fecally polluted water which may result in a significant burden of disease (WHO 2001). Considering that bacteria densities are greatest during the summer months and the fact that there is no wastewater treatment in the whole catchment area of Al-Assi river, the construction of wastewater treatment systems primarily for large settlements is essential.

To sum up, the results from data analysis show that the water is certainly unfit for drinking purposes without any form of treatment, but for various other surface water usage purposes, such as irrigation it is considered quite acceptable. But as we know, once a trend in pollution sets in, it generally accelerates to cause greater deterioration. So, a few years from now, serious water quality deterioration could take place.

2.4 Conclusion

The water quality of the Al-Assi River was analysed. The physical, bacteriological, and chemical composition of the river was studied in the wet season. Almost all sites exhibited values of pH within the limits of the natural values that support aquatic life. The levels of TDS were fluctuating among the sites with the highest values recorded at site ID4 and ID7 (within the acceptable range) indicating that there is no seawater intrusion. Higher BOD_5 values were detected at sites ID4 and ID7 which may be attributed to recreational activities in the form of restaurants that are located along the river as well as family picnic areas in addition to agricultural runoff. The levels of nitrate exhibited a clear fluctuation among the sites ranging yet falling below the limit for surface water. The levels of sulphate did not exhibit a distinct spatial variation among the sites. The estimated indices at sites ID1 (Laboueh spring) and ID6 (Ras el Mail spring) were generally good. However, sites ID3, ID4, ID7 and ID8 exhibited relatively the worst water quality conditions.

WHO specifies guidelines and imperative values for drinking and aquatic life were used. This assessment was adopted as the Lebanese Ministry of Environment (MOE) Standards for surface waters, do not include all of the parameters reported here.

Results revealed that the water quality of the AL Assi River is generally affected by the activities taking place along its watershed. The best quality was found in the upper sites and the worst at the estuary. The impact of recreational activities in the form of restaurants that are located along the river as well as family picnic areas resulted in poor water quality that is suitable for specific water uses such as swimming is restricted due to the presence of high levels of fecal coliform. Given that recreational use of the river is very important for the development of the area, preventing further deterioration by anticipating and avoiding new impacts is crucial for effective management. If Al-Assi river is to be used as a managed water resource, point source discharges, and primarily sewage require treatment.

Adding to the above, anthropogenic perturbations, the difference in topography among the sampling locations, the actual volume of water in the stream, and flow rate are important factors introducing changes to water quality at several points.

Concerning the temporal variation of the water quality, the turbidity showed to be affected by the total flow of the AL-Assi water river and increases during the winter season when elevated erosion rates are present.

The results on the map confirms that stations situated in the flatland, are encountering organic and bacterial pollution probably due to anthropogenic stress coming from the flat area and the nearby villages. The laboratory results show that the summer or dry season exhibits a higher number of fecal and E coli., this profile confirms the seasonal impact on bacteriological patterns. Several health results such as gastrointestinal infections might be related to polluted water with fecal coliform which may lead to a dangerous burden of disease. The bacteria densities are higher during the summer seasons and since there is no wastewater treatment in the studied area of Al-Assi river, the implementation of wastewater treatment systems primarily for large settlements is highly recommended. To sum up, the results show that, the water is surely unqualified for drinking purposes without the necessary treatment, but for various other surface water usage purposes, water still could be considered acceptable. But as we know, once a trend in pollution commences, it generally increases and causes greater deterioration in the water quality. So, a few years from now, dangerous water quality decay is expected to happen.

3 Future Scenarios

The future water demand scenario for river basin management will depend on various factors such as population growth, urbanization, economic development, and climate change. If no proactive measures are taken, business as usual may result in increased water stress and strain on river basin management. Population growth, urbanization, and economic development could drive increased water consumption, leading to unsustainable use patterns. Climate change could exacerbate water scarcity and alter precipitation patterns, further complicating river basin management.

Inadequate water infrastructure and limited regulatory measures may hinder efficient water allocation and use, potentially resulting in conflicts among stakeholders. This could compromise the ecological health of the river basin, with impacts on biodiversity, habitat degradation, and water-related ecosystem services. Social and economic repercussions, such as reduced water availability for drinking water supply, irrigation, and industrial processes, may affect livelihoods, food security, and economic development in the region.

To avoid these challenges, proactive measures such as water efficiency, demand management policies, water reuse, and recycling initiatives, as well as stakeholder engagement and participatory decision-making processes, are crucial for sustainable river basin management. By taking a proactive approach, river basin management can strive for sustainability, resilience, and equitable allocation of water resources, while safeguarding the ecological health of the river basin for future generations.

Thus, and for the clarity of the report, the future scenarios were divided between business as usual and intervention scenarios which include the demand management scenarios described in section 4.4. The list of future business as usual scenarios that shall be simulated and analyzed for 2035 is presented in Table 3.

Table 3 Future business as usual scenarios for 2035

Name	Description
Domestic Water Demand Increase Scenario	Built on the baseline scenario of 2020 with increase of domestic water demand and supply based on the expected demographic adopted in baseline report
Irrigation Water Demand Increase Scenario	Built on the baseline scenario of 2020 with the increase of irrigation water demand based on the expected cultivation spatial expansion and crop intensification
Climate Change Scenario*	Climate change scenario with incorporation of CMIP6 climate anomalies

* The climate change scenario can be applied either separately or in combination with the other future scenarios.

3.1 Water Demand Scenario

3.1.1 Domestic water demand

As it was described in the baseline report, there are 25 different water distribution systems that are partially or totally included within ARB.

In 2020, ARB accommodated a total of 416,716 residents with the water needs estimated to 83,341 m^3/d. In 2035, the future resident population living within the basin limits is expected to reach a total of 489,470 which water needs were estimated to 97,892 m^3/d.

In 2020, 69 wells are supplying ARB with a total flow of 76,035 m^3/d to feed the resident population. In 2035, 78 wells will be supplying ARB with 7,605 m^3/d extracted additionally from the under-construction or not equipped wells to reach a total flow of 83,640 m^3/d. Tapped springs are supplying a fixed flow of 20,849 m^3/d for domestic demand. It is worth noting that these flows were estimated under optimal operation conditions to cover the deficit with the current infrastructure.

The deficit in ARB water supply is not that obvious as the total cumulative supply between springs and wells in 2020 is 96,884 m^3/d while the total demand is 83,343 m^3/d and while the total demand in 2035 is expected to increase to 97,892 m^3/d, the total supply is also expected to increase to 104,489 m^3/d.

However, at the water distribution system level, some are in excess like Ouyoun Orghosh, Iaat, Qaa systems while other systems are in deficit like Aarsal, Fekha & Jdaide or Laboueh in 2035. These deficits shall be covered by several proposed projects in 2035. Table 4 below shows the deficit within ARB of each water distribution system.

Table 4 ARB water distribution systems (NWSS, 2020)

ID	Water System Name	Served population within ARB		Total Water Demand (m^3/d)		Total Water Supply (m^3/d)		Total deficit/excess (m^3/d)	
		2020	2035	2020	2035	2020	2035	2020	2035
1	Laboueh	57999	66206	11600	13241	12343	12343	743	-898
2	El Qaa system	11240	14048	2248	2810	6998	6998	4750	4188
3	Nabi Sbat	1165	1455	233	291	120	120	-113	-171
4	Ouyoun Orgosh	39195	48159	7839	9632	9021	11955	1182	2323
5	Yammouneh	22465	28082	4493	5616	5328	5904	835	288
6	Younine, Maqne & Nahle	32211	40267	6442	8053	10524	10524	4082	2471
7	Aarsal	49420	55280	9884	11056	4440	4440	-5444	-6616
8	Baalbek, Aamechki & Ain Bourday	66616	74515	13323	14903	15584	15584	2261	681
9	Chaat	13910	17383	2782	3477	3004	3004	222	-473
10	Fekha & Jdaide	17685	19810	3537	3962	838	838	-2699	-3124
11	Harbata	4745	5930	949	1186	2764	2764	1815	1578
12	Moqraq-Amhaz-Toufiquiyeh & En Noqra	9357	11694	1871	2339	3960	3960	2089	1621
13	Iaat	6500	8125	1300	1625	2160	2160	860	535
14	Ras Baalbek	12600	15750	2520	3150	2560	3712	40	562
15	Sbouba	5870	7337	1174	1467	1620	1620	446	153
16	Yammouneh-Local	445	561	90	112	0	69	-90	-43
17	Halbata-El Kharayeb	2675	3342	535	668	1384	1384	849	716
18	Hermel Upper, Ras El Mal & Ain Zarqa Spring	53091	59658	10618	11932	11681	12200	1063	268
19	Ouadi En Naira-Ouadi Bnit-Zoueitini-Wadi El Karem & Kaeb Wadi El Karem	1949	2422	390	484	1095	2250	705	1766
20	Ouadi Faara-Mrah El Aaqabet	102	124	20	25	460	460	440	435
21	Chouaghir	2570	3211	514	642	0	600	-514	-42
22	Haouch Saeid Ali & Haouch Beit Ismail	2642	3296	528	659	180	780	-348	121
23	Jbeb El Homor	236	291	47	58	240	240	193	182
24	Ouadi Et Tourkmane Ouadi El Ratel	887	1107	177	221	580	580	403	359
25	Beit Et Tochem, El Charqe, Mazraat Chelman	1137	1417	227	283	0	0	-227	-283
Total/ Total deficit*		**416712**	**489470**	**83341**	**97892**	**96884**	**104489**	**-9435**	**-11650**

*The total deficit expresses the sum of all deficit of the water systems in deficit

3.1.2 Irrigation water demand

3.1.2.1 Cultivation development and area expansion

The National Agriculture Strategy (NAS) for 2020-2025 aims to transform the agricultural sector in Lebanon into a more productive and profitable industry, ultimately reducing the country's food import bill. This objective encompasses various dimensions, including resilience, efficiency, and profitability. One of the key interventions is to increase the production basis of agrifood products, including increasing access to and availability of land, such as through land reclamation. The strategy also prioritizes the inclusion of women in agricultural production, processing, and marketing. Stakeholders in the sector have requested subsidies for land reclamation and irrigation schemes to expand production, as well as protection of local markets and development of innovative technologies in agriculture. The four programs under this pillar include increasing total agricultural production, adopting good agricultural practices and livestock management, encouraging and supporting innovative and modern technologies, and improving the quality and safety of agricultural and food products. These interventions are aimed at increasing agricultural output quantity and quality to substitute import of selected products according to the country’s comparative advantages.

To take into account the NAS objective, it was assumed that the irrigation extent will be developed and we are likely to witness the following:

<u>Spatial expansion:</u> irrigated area is likely to witness a 15% to 20% increase (2775 Ha to 3700 Ha), most probably an increase of 3250 Ha will lead to a total irrigated area of 21,750 Ha with the gross area of the irrigation zones of the ARB.

<u>Crop intensification:</u> in this case, the tendency would be to increase the overall crop intensification coefficient from 135% to 150%.

In this case, the net irrigation water requirements for 1 representation Ha shall increase as described and shown in Table 5 below. The increase of mixed summer vegetables occupation ratio to 50% leads to the increase of the intensification coefficient to 150%, which consequently shall increase the net water requirement from 5621 m^3/Ha/year to 6876 m^3/Ha/year. The peak irrigation water requirement will remain in July and corresponds to 0.64 l/s/Ha.

Table 5 Net water requirement per representative Hectare with Summer Mixed Vegetables occupation ratio of 50%

	Occupation ratio	**Mar**	**April**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Annual value**
Fruit trees/ vineyard	15%	0.00	3.23	8.98	21.04	26.89	28.76	19.86	4.75	113.5
Wheat and barley	30%	5.48	21.12	33.10	5.88	-0.15	-0.15	0.00	0.15	65.4
Potato	15%	0.00	0.00	0.00	0.00	13.41	18.14	17.57	10.99	60.1
Industrial crops	5%	0.00	2.30	4.68	7.01	7.84	6.05	2.82	0.02	30.7
Mixed Vegetables (Summer)	50%	0.00	29.09	63.58	100.29	123.35	80.69	20.56	0.00	417.6
Mixed Vegetables (Fall)	35%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17
Annual value	150%	30%	100%	100%	100%	85%	85%	85%	100%	
net water requirement	m^3/ha	54.8	557.3	1103.4	1342.2	1714.9	1336.4	608.1	159.2	6876
	L/s/ha	0.02	0.22	0.41	0.52	0.64	0.50	0.23	0.06	

Hence, if irrigation practices and crop solution are kept unchanged thus efficiency remaining at 0.65, gross irrigation water requirements of one representation Ha would increase from 8,700 m^3/Ha/year to 10,600 m^3/ha/year and ARB global water requirements would become 231 Mm^3/year instead of 161 Mm^3/year (21,750 Ha x 10,600 m^3/Ha/year = 231 Mm^3/year)

3.1.2.2 Proposed mitigation measures

The above-mentioned scenario revealed that a 15% to 20% area expansion with a 15% increase in crop intensification led to 40% increase in global irrigation requirements at the ARB basin level.

However, the expansion of cultivated area shall also be accompanied with proposed measures to alleviate this tremendous increase like:

1- To prioritize low demanding crops (cereals) over high demanding crops (summer vegetable crops) while keeping the crop intensification up to 150%. In this case, 1 representative hectare irrigation net water requirements would be 5,952 m^3/ha/year broken-down as follows:

Table 6 Net water requirement per representative hectare with wheat and barley occupation ratio of 45%

	Occupation ratio	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Annual value
Fruit trees/ vineyard	15%	0.00	3.23	8.98	21.04	26.89	28.76	19.86	4.75	113.5
Wheat and barley	45%	8.21	31.67	49.65	8.82	0.00	0.00	0.00	0.22	98.6
Potato	15%	0.00	0.00	0.00	0.00	13.41	18.14	17.57	10.99	60.1
Industrial crops	5%	0.00	2.30	4.68	7.01	7.84	6.05	2.82	0.02	30.7
Mixed Vegetables (Summer)	50%	0.00	29.09	63.58	100.29	123.35	80.69	20.56	0.00	417.6
Mixed Vegetables (Fall)	35%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17
Annual value	150%	45%	100%	100%	100%	70%	70%	70%	115%	
net water requirement	m^3/ha	82.1	575.6	1078.2	1070.8	1344.8	1094.3	546.4	160.0	5952
	L/s/ha	0.03	0.22	0.40	0.41	0.50	0.41	0.21	0.06	

2- Improve the irrigation practices by:

- Favorizing the extension of drip irrigation over traditional irrigation techniques for fruit trees, vineyards and mixed vegetables.
- Favorizing the expansion of sprinkler irrigation over traditional irrigation for cereals, potatoes and industrial crops.
- Increasing mulch material used beneath crops to minimize weed growth and reduce soil water evaporation.
- Promoting organic
- Promoting modern irrigation practices (apply water in the right quantities and timing)
- Metering irrigation water to limit unnecessary water use.
- Intensifying research on adaptivity (drought resistant crops).
- Promote capacity building and education programs and promote cooperative efforts.

If all of the above measures are applied, the gross irrigation water demand of one representative Ha in the ARB would be 7500 m^3/Ha/year considering that the overall efficiency of the irrigation system and practice would rise from 0.65 to 0.8.

Consequently, the global water requirement of ARB would be quasi similar as before expansion and mitigation.

$$21{,}750 \text{ Ha} \times 7500 \text{ m}^3\text{/Ha/year} = 163 \text{ Mm}^3\text{/year}$$

However, if only mitigation measures were applied on baseline scenario without any area expansion then, the global water requirement would decrease to

$$18{,}500 \text{ ha} \times 7500 \text{ m}^3\text{/Ha/year} = 139 \text{ Mm}^3\text{/year}$$

A mix of future scenarios of irrigation development and mitigation measures are presented with their calculation results in the Table 7 below. The detailed calculations are presented in Appendix C.

Table 7 Future irrigation water demand scenarios without climate change

Scenario ID	**Description**	**Irrigated Area (Ha)**	**Crop intensification coefficient**	**Efficiency Coefficient**	**Net Water requirement per representative Ha (m^3/Ha/year)**	**Gross Water requirement per representative Ha (m^3/Ha/year)**	**Global water requirement (Mm^3/year)**
	Baseline 2020	18,500	135%	0.65	5,621	8,700	161
SIR0	Irrigated areas expansion of 15% to 20%	21,750	135%	0.65	5,621	8,700	189
SIR1	Overall crop intensification coefficient increase, without area expansion	18,500	150%	0.65	6,876	10,600	196
SIR2	Overall crop intensification coefficient increase, with area expansion	21,750	150%	0.65	6,876	10,600	231
SIR3	Crop Type Mitigation prioritizing low demanding crops (cereals) over high demanding crops (summer vegetable crops) without area expansion	18,500	150%	0.65	5,952	9,200	170
SIR4	Crop Type Mitigation prioritizing low demanding crops (cereals) over high demanding crops (summer vegetable crops) with area expansion	21,750	150%	0.65	5,952	9,200	200
SIR5	Irrigation Type and Crop Type mitigation prioritizing low demanding crops (cereals) over high demanding crops (summer vegetable crops) without area expansion	18,500	150%	0.80	5,952	7,500	139
SIR6	Irrigation Type and Crop Type mitigation prioritizing low demanding crops (cereals) over high demanding crops (summer vegetable crops) with area expansion	21,750	150%	0.80	5,952	7,500	163

3.2 Climate Change Scenarios

3.2.1 Future climate change in Lebanon

The Second (SNC, 2011), Third (TNC, 2016) and Fourth National Communication (FNC, 2022) to the United Nations Framework Convention on Climate Change (UNFCCC) developed by the MoE in 2011, 2016 and 2022 presented the expected climate change effects in Lebanon obtained from university research programs and scenarios that have been developed for Lebanon through the application of the PRECIS RCM model (SNC), MENA CORDEX RCM (TNC), EURO CORDEX RCM at resolution 12.5 km x 12.5 km (FNC).

SNC

The main results of key climate variables in Lebanon as simulated by PRECIS were presented as changes of the respective periods of the near and distant future compared to the "control" period the last 20-30 years or the "recent past/ present". According to PRECIS model and in relation to the present climate, by 2040 temperatures will increase from around 1°C on the coast to 2°C in the mainland, and by 2090 they will be 3.5°C to 5°C higher. Comparison with Lebanese Meteorological System LMS historical temperature records from the early 20th century indicates that the expected warming has no precedent. Rainfall is also projected to decrease by 10% to 20% by 2040, and by 25% to 45% by the year 2090. This combination of significantly less wet and substantially warmer conditions will result in an extended hot and dry climate. Temperature and precipitation extremes will also intensify. In Beirut, hot summer days (T_{max} > 35°C) and tropical nights (T_{min} > 25°C) will last, respectively, 50 and 34 days more by the end of the century. The drought periods, over the whole country, will become 9 days longer by 2040 and 18 days longer by 2090.

In terms of seasonal changes, temperatures will increase more in summer and precipitation will decrease more in winter, while positive changes are predicted for autumn.

While the actual considered resolution is 25 km, the SNC authors pointed out the need for a finer modelling resolution to help decision makers defining Lebanon's optimal commitments on mitigation and adaptation measures facing Climate Change. Hence the importance of the application of recent RCM models considering new Coupled Model Intercomparison Project Phase 5 - CMIP5 scenarios similar to the ones applied in the Med-CORDEX project which do not rely on downscaling the GCM.

TNC

The TNC included the analysis results of the projected climatic changes in Lebanon and their impacts on natural resources based on the generation of dynamically downscaled regional climate modelling projection covering the Arab/Middle East North Africa (MENA) domain in accordance with the CORDEX program under RCP4.5 and RCP8.5 scenarios. These projections were carried out through the Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources in the Arab Region (RICCAR) led by the United Nations Economic and Social commission for Western Asia (ESCWA). The projections were then linked to two regional hydrological models to specifically analyze the impact of climate change on the region's freshwater resources.

In Lebanon, the projections by the end of the century compared to the baseline period of 1986-2005 results showed an increase in temperature by up to 3.2°C with an increasing warming trend reaching up to 43 additional days with maximum daily temperature higher than 35°C. It also showed a decrease in precipitation by 4% under RCP 4.5 and 11% under RCP8.5 with trends towards drier conditions with an increase in number of consecutive dry days (when precipitation

< 1.0 mm) which indicates the extension of dry summer season. This combination of significantly less wet and substantially warmer conditions will result in hotter and drier climate.

FNC

The FNC, recently published by the MoE, provides an update on the country's greenhouse gas emissions, vulnerability to climate change, and efforts to address climate change. The FNC has presented future climate projections for Lebanon from the IPCC Sixth Assessment Report (AR6) on Impact, Adaptation and Vulnerability as it is the most recent and comprehensive assessment of climate change impacts and future risks at global and regional levels. AR6 report generated for the first-time new scenarios based on a three-dimensional matrix comprised of the Representative Concentration Pathways (RCPs), Socioeconomic Pathways (SSPs), and Climate Shared Policy Assumptions (SPAs).

Several projects (Verner et.al, 2017 and World Bank, 2022b) and research studies (Almazroui, 2019; Bucchignani et al., 2018; Driouech et al., 2020; Ntoumos et al., 2020; Spinoni et al., 2020; Zittis et al. 2021; Varela, et al., 2020; Zittis, et al., 2019; Zittis and Hadjinicolaou, 2017) have examined the climatic profile of Lebanon and/or the Eastern Mediterranean and the Middle East over the years, intending to project probable changes in the near and far future.

In particular, and due to the complex topography and various microclimates in Lebanon and the lack of spatially and temporally complete meteorological records, various external data sources, tools, and models, such as the EURO CORDEX dataset, the CMIP5/CMIP6 datasets, the ARAB Domain dataset generated by RICCAR, the World Bank's Climate Change Knowledge platform CCKP, and others, have been used to conduct climatological studies in Lebanon, yielding a wide range of results.

The IPCC AR6 builds on the four pathways previously developed under the AR5 (2018) (RCP2.6, RCP4.5, RCP6.0, and RCP8.5), which were limited to different levels of greenhouse gases (emissions and other radioactive forcings, and adds five new narratives (SSPs) that take into consideration socioeconomic factors such as global population growth, access to education, urbanization, economic growth, resources availability, technology developments and lifestyle changes (Meinshausen et al., 2020). The results of this more inclusive framework produced the Integrated Assessment Pathways (IAMs), which support the coordination across climate change research communities and provide a basis for systematic analysis of key questions of mitigation and adaptation, under different climate and socioeconomic futures.

- Temperature

Adjusted climate projections from EURO CORDEX show that the annual mean temperature increases ranges from 1.6°C (RCP4.5) to 2.2°C (RCP8.5) by mid-century and from 2.2°C (RCP4.5) to 4.9°C (RCP8.5) by end-century when compared to the reference period 1986-2005.

In the analysis done under RICCAR (ESCWA, 2021), downscaling at 10 km was performed for annual and seasonal air temperatures for an ensemble of six SSP5-8.5 models for the near-term (2021-2040) and midterm (2041- 2060) periods. The increase of annual temperature for the period 2021- 2040 as compared to the reference period (1995-2014) is on the average around 1.2°C, with limited deviations between coastal and mountainous areas (although the increase is most pronounced in the latter ones). The respective increase of annual temperature for the period 2041-2060 is on the average around 2°C, while it ranges from 1.8°C to 3°C depending on the area (coastal/inland south to mountainous respectively) within Lebanon.

CMIP6 is the model ensemble used for the Sixth Assessment Report of IPCC AR6. CMIP6 uses Shared Socioeconomic Pathways (SSPs) and an ensemble of climate models at a resolution 12.5km x 12.5km. The IPCC AR6 CMIP6 climate projections for the region, show that the annual mean temperature is projected to increase by 2.2ºC by mid-century and 4.4ºC by end-century for the SSP5-8.5 scenario.

- Precipitation

Precipitation is expected to decrease by 6.5% to 9% by mid-century and by 9% to 22% by end-century based on RCP scenarios' most recent projections (RCP4.5 and RCP8.5 respectively). It is important to note that previous scenarios from 2014 projected a 4% decrease in precipitation per each degree of global warming, which further highlights the fact that recent projections are showing almost 1.5 times the previously projected impacts for both mid- and end-century scenarios since temperatures are increasing more intensely and within a shorter timeframe. Climate projections for annual precipitation for the SSP5-8.5 scenario show a more severe reduction of 10% to 16% by mid-century and by end-century respectively as compared to the reference period of 1995-2014.

- Consecutive dry days

Increase in all regions for the periods 2021-2040 and 2041- 2060 for SSP5-8.5 is expected, although more pronounced at the southern regions and along the coast. On the basis of several precipitation indicators, drought risk is expected to increase towards 2050 under all scenarios (RCP4.5 and RCP8.5 as well as for SSP5-8.5).

- Heat waves

Increase in duration and intensity is expected, with considerable health impacts to people living in urban areas as well as enhanced needs for energy consumption for cooling needs. In terms of the days with temperature above 35ºC (SU35) and 40°C (SU40), they are expected to almost double for the period 2041- 2060 compared to the reference period 1995-2014 with the increase being more pronounced in the case of summer, at both the coastal and inland regions of Lebanon.

- Extreme events

Compound events of heatwaves and droughts are expected to increase almost fivefold for the period 2041-2060 as compared to the reference period 1986-2005. The increase will reflect up to 15 more incidents for inland Lebanon, and 20+ incidents for the northeast and southeast regions. Increase will be overall less pronounced in coastal regions.

3.2.2 Adopted climate change scenario

In this study, climate projection data from the World Bank CCKP were adopted for climate change scenario. CCKP is a modeled data from the global climate model compilations of the CMIP6 which supports the IPCC's AR6. Projection data is presented at a 1.0º x 1.0º (100km x 100km) resolution, aggregated at both national and sub-national scales.

Climate projections for Lebanon for the SSP2-4.5 scenario show an increase in the annual mean temperature by 0.9°C for 2020-2039 and 2.5°C by end-century. SSP5-8.5 scenario shows an increase in the annual mean temperature by 1.1°C for 2020-2039 and 4.4°C by end-century, which is more or less aligned with the RCP scenario analysis. As for the precipitation, a change between +20% and – 17% for SSP2-4.5 scenario and a change of +5% and -11% is expected for SSP5-8.5 scenario.

<u>TEMPERATURE</u>

Table 8 Projected change of mean temperature for 2020-2039 Bekaa, Lebanon under SSP2 – 4.5 and SSP5 – 8.5 Reference Period: 1995-2014 (WBCCKP, 2022)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Historical Reference Period 1995-2014	4.3	5.2	8.2	12.3	16.5	20.0	22.4	22.7	20.5	16.9	10.6	5.7
SSP2-4.5	5.0	5.9	8.7	13.0	17.6	21.2	23.4	23.7	21.5	18.0	11.6	6.5
Anomaly	0.6	0.7	0.6	0.7	1.1	1.2	1.0	1.1	1.1	1.1	1.0	0.7
SSP5-8.5	5.3	6.3	8.9	13.1	17.6	21.2	23.5	23.8	21.7	18.1	11.6	6.7
Anomaly	0.9	1.0	0.8	0.8	1.1	1.2	1.2	1.1	1.2	1.2	1.1	1.0

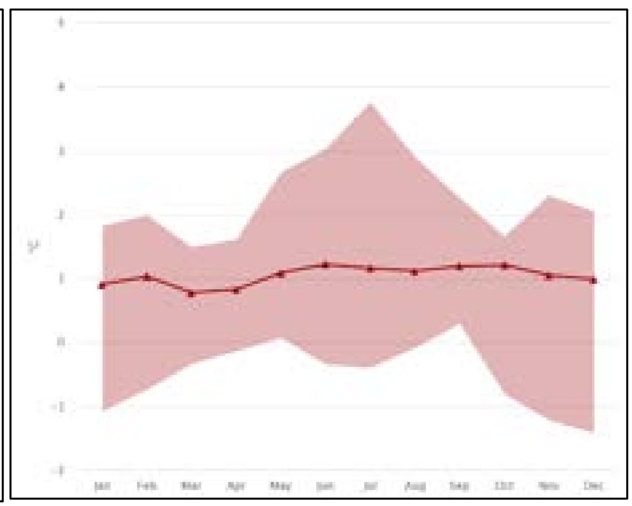

Figure 2 Projected change of mean temperature for 2020-2039 Bekaa, Lebanon under SSP2 – 4.5 and SSP5 – 8.5 Reference Period: 1995-2014 (WBCCKP, 2022)

PRECIPITATION

Table 9 Projected Precipitation percent change for 2020-2039 in Bekaa, Lebanon under SSP2 – 4.5 and SSP5 – 8.5 Reference Period: 1995-2014 (WBCCKP, 2022)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SSP2-4.5	1.6	-6.0	-5.9	0.3	-8.6	17.0	-17.9	-10.2	0.3	-6.3	-3.6	-2.6
SSP5-8.5	-0.7	-1.9	-6.4	-2.4	-6.9	-6.4	-7.0	-9.1	-0.7	4.0	-3.4	-9.7

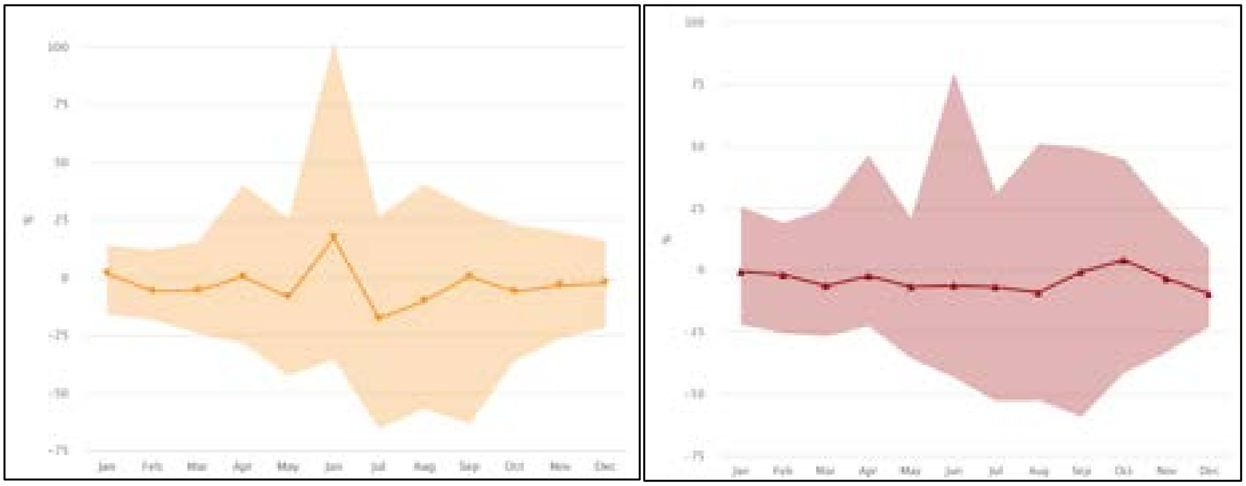

Figure 3 Projected Precipitation percent change for 2020-2039 in Bekaa, Lebanon under SSP2 – 4.5 and SSP5 – 8.5 Reference Period: 1995-2014 (WBCCKP, 2022)

RELATIVE HUMIDITY

Table 10 Projected percent change of humidity for 2020-2039 in Bekaa, Lebanon under SSP2 – 4.5 and SSP5 – 8.5 Reference Period: 1995-2014 (WBCCKP, 2022)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SSP2-4.5	0.35	0.12	-1.05	-0.42	0.18	0.73	0.44	0.2	-0.36	-0.71	-1.39	-2.02
SSP5-8.5	-1.15	-1.14	-0.61	-0.89	-0.53	-0.55	-0.66	-0.07	-0.37	-0.8	-1.05	-1.98

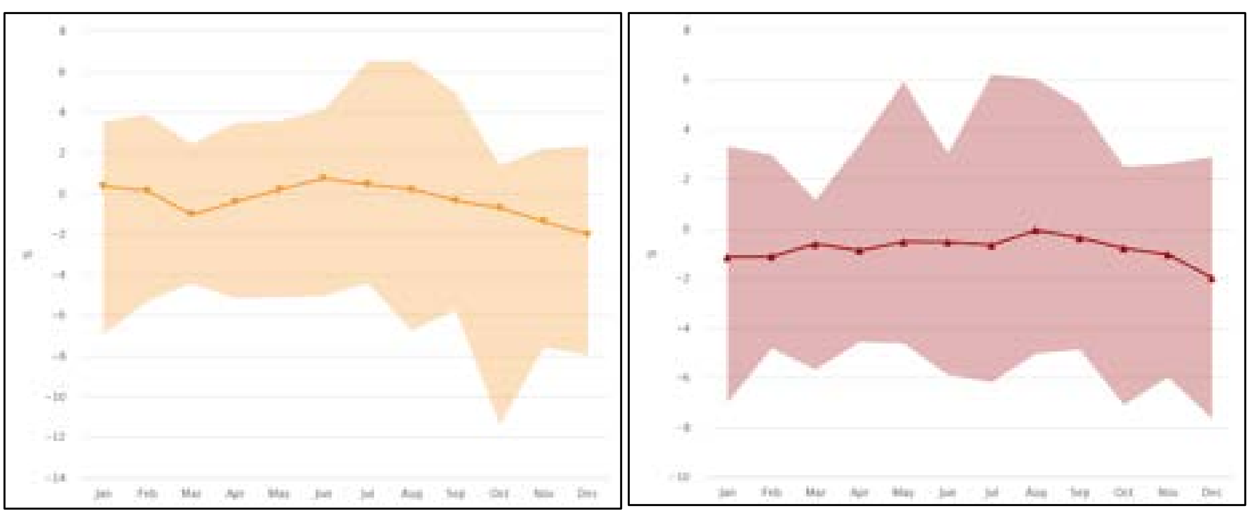

Figure 4 Projected percent change of mean relative humidity for 2020-2039 in Bekaa, Lebanon under SSP2 – 4.5 and SSP5 – 8.5 Reference Period: 1995-2014 (WBCCKP, 2022)

3.2.3 Impact of climate change on domestic water demand

Assessing the impact of climate change on domestic water demand is a complex task that requires considering multiple factors, including the socio-demographic composition of households residing in different types of dwellings, cultural, behavioral, and attitudinal aspects of water consumption, as well as the availability and quality of water resources. Additionally, the impact of climate change on water demand is not uniform across different regions, and it varies based on local climate conditions, water availability, population density, and economic factors.

Moreover, water consumption patterns are not static and are influenced by several complex factors, such as cultural and social norms, economic incentives, technological innovations, and policy interventions. Therefore, understanding the underlying factors driving water consumption and the potential impacts of climate change on water demand requires a multidisciplinary approach that incorporates both quantitative and qualitative research methods.

Furthermore, there are various challenges associated with conducting research on urban home water use behavior, such as the lack of reliable data on water consumption, difficulties in measuring water consumption accurately, and limited public awareness and understanding of the importance of water conservation. Therefore, researchers need to use innovative and robust research methods to overcome these challenges and gain a more comprehensive understanding of the complex factors driving water demand and use in urban settings.

In this regard, a study addressing the impact of climate change on water demand by linking water demand and weather using Coupled General Circulation Models, was conducted in Naples (Italy) and revealed that the total district water demand could increase by 9-10% during the weeks with the highest temperatures, and this increase varied depending on the social characteristics of the users. Moreover, the study highlighted the relevance of disaggregating consumption based on social characteristics to determine the climate change effects on water demand more accurately. Future weather scenarios for 2040-2100 suggest that the daily water demand could increase mainly due to increases in air temperature, which could lead to significant supply and operational failures in water systems (Fiorillo et al. 2021).

However, there is uncertainty regarding the impact of climate change on domestic water demand. While some studies suggest an increase in water demand due to higher temperatures and changes in precipitation patterns, the exact magnitude of this effect is not clear. Furthermore, the seasonality of water demand and water availability in Mediterranean countries is an important factor to consider, with demand typically higher in dry months which is of a relatively minor influence compared to the overall demand throughout the year, especially in moderate countries like Lebanon.

Hence, assuming that the fresh water demand (domestic, industrial and physical losses) shall increase by 10% during summer season (90 days), the overall increase would be only 2.5% increasing the total domestic water demand in 2035 from 97,892 m^3/d to 100,442 m^3/d.

3.2.4 Impact of climate change on irrigation demand

To assess the impact of climate change on irrigation demand, specifically the net water requirement, the climate anomalies of SSP2 – 4.5 and SSP5 – 8.5 scenarios were introduced into the average precipitation, temperature, and relative humidity in Cropwat. As a result, the water requirement per crop, per representative hectare, and per gross irrigation were updated accordingly. Later on, the irrigation water requirement will be reassessed under both climate change scenarios, as well as various irrigation measures such as cultivated area expansion, crop pattern, and irrigation type change.

Under the implementation of the climate change scenarios, effective rain has decreased by 3%, while real evapotranspiration ET_0 has increased by 9% for both SSP2 and SSP5, as shown in Table 11. Consequently, the water balance deficit has increased by a total of 144 mm, particularly between June and September, with a peak in August and a 15% deficit increase. However, the irrigation season remains unchanged.
As a result, the net water requirements per representative hectare have increased from 5621 m^3/ha/year to 6144 m^3/ha/year under SSP2 (6132 m^3/ha/year under SSP5). Assuming the same efficiency of 0.65 and accounting for the identical field and conveyance losses, the irrigation water requirement will be ~ 9500 m^3/ha/year. The global irrigation water requirement for the entire ARB region is estimated at 176 Mm^3/year, for the same irrigated areas of 18,500 Ha, indicating a global increase of 9.3%.

The results of the climate change impact on the irrigation water requirement for all the previously discussed scenarios are presented in the Table 12 below. Detailed calculations can be found in Appendix C.

Table 11 Effective rain, ET0 and water balance in ARB under SSP2 – 4.5

Scenario	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
SSP2-4.5	Eff. Rain	69	62	33	15	7	1	0	0	5	19	26	62	299
	ETo	48	55	90	125	168	213	251	233	167	115	67	51	1579
	Balance	21	8	-57	-109	-161	-212	-251	-232	-162	-96	-41	12	
SSP5-8.5	Eff. Rain	68	65	33	15	7	1	1	1	5	21	26	58	298
	ETo	48	55	89	125	168	214	251	233	167	114	66	51	1582
	Balance	20	9	-56	-110	-161	-213	-251	-232	-163	-93	-41	7	

Table 12 Future irrigation water demand scenarios with climate change

Scenario ID	Description	Irrigated Area (Ha)	Crop intensification coefficient	Efficiency Coefficient	Net Water requirement per representative Ha (m^3/Ha/year)	Gross Water requirement per representative Ha (m^3/Ha/year)	Global water requirement (Mm^3/year)
SCIR0	Baseline 2020	18,500	135%	0.65	6,132	9,500	176
SCIR1	Irrigated areas expansion of 15% to 20%	21,750	135%	0.65	6,132	9,500	207
SCIR2	Overall crop intensification coefficient increase, without area expansion	18,500	150%	0.65	7,504	11,600	215
	Overall crop intensification coefficient increase, with area expansion	21,750	150%	0.65	7,504	11,600	252
SCIR3	Crop Type Mitigation prioritizing low demanding crops (cereals) over high demanding crops (summer vegetable crops) without area expansion	18,500	150%	0.65	6,493	10,000	185
	Crop Type Mitigation prioritizing low demanding crops (cereals) over high demanding crops (summer vegetable crops) with area expansion	21,750	150%	0.65	6,493	10,000	218
SCIR4	Irrigation Type and Crop Type mitigation prioritizing low demanding crops (cereals) over high demanding crops (summer vegetable crops) without area expansion	18,500	150%	0.80	6,493	8,200	152
	Irrigation Type and Crop Type mitigation prioritizing low demanding crops (cereals) over high demanding crops (summer vegetable crops) with area expansion	21,750	150%	0.80	6,493	8,200	178

4 Water Demand Management Measures

4.1 Overview

Water demand management refers to the implementation of policies or measures which serve to control or influence the amount of water used. Effective water demand management requires a combination of measures, such as improving water efficiency and conservation, reducing water losses, promoting water reuse and recycling, and managing demand through pricing and other economic instruments. It is a shift towards more sustainable water use practices and policies to ensure the availability of clean water resources for future generations with a stakeholder engagement and public awareness in achieving sustainable water use.

There are several different water demand management measures that can be implemented to promote sustainable water use. Some of these measures include:

- Integrating water management across sectors: This involves adopting a holistic approach to water management that considers the needs of different sectors, such as agriculture, industry, households, as well as the ecological requirements.
- Improving water efficiency: This involves using water more efficiently through the use of water-efficient technologies, appliances, and practices. For example, installing low-flow showerheads, toilets, and faucets, or using water-efficient irrigation systems can help reduce water consumption.
- Promoting water conservation: This involves encouraging water conservation behaviors among individuals and communities. This can include public awareness campaigns, education and outreach programs, and incentives for water conservation.
- Reducing water losses: This involves reducing the amount of water lost due to leaks, pipe failures, or other issues in water supply systems. This can be achieved through improved maintenance, repairs, and upgrades to water infrastructure.
- Managing demand through pricing and economic instruments: This involves using pricing and other economic instruments to influence water consumption patterns. This can include tiered pricing structures, water-use charges, or water-saving incentives.
- Promoting water reuse and recycling: This involves using treated wastewater or graywater for non-potable uses, such as irrigation or industrial processes.

These measures can be implemented at various levels, from individual households to large-scale water supply systems, to promote sustainable water use and reduce water demand.

4.2 Proposed measures at the participatory approach

On January 18th, a participatory workshop was held at Lazord Hotel, Hermel. The workshop was attended by the mayors and members of municipalities, representatives from the Ministry of Energy and Water, Bekaa Water Establishment, Ministry of Agriculture, Agriculturers, farmers, and CSOs. During the workshop, various challenges faced by the ARB were discussed, including pollution, slaughterhouse violations, random dumps, building irregularities, lack of afforestation, social and environmental problems, torrents, fish farming, tourism, agriculture, governance, human resources, environmental impact, unlicensed wells, desertification, logging, drinking water networks, and non-enforcement of laws.

To address these challenges, the stakeholders has proposed the establishment of a specialized committee comprising various government departments such as the MoEW, BWE, Ministry of Agriculture, Ministry of Environment, Ministry of Public Health, Ministry of Interior, Ministry of Tourism, and Lebanese army. The committee's tasks include adherence to laws and the suppression of violations. A directive plan for the management of natural resources should also be developed, and the committee should meet regularly.

Other solutions discussed during the workshop included wastewater reuse for agriculture, adjusting random well drilling, supporting fish fodder, organizing workshops for farmers, establishing rainwater collection ponds, afforestation, rationalizing water consumption, restoring water channels, maintaining refinery plants, activating existing strategies, establishing treatment plants for tourist facilities, sorting waste from the source and producing energy, encouraging the production of agricultural fertilizers, and involving the Ministry of Education in the awareness-raising process. Overall, the participatory workshop was a success in bringing together stakeholders to address the challenges faced by ARB and develop a collaborative approach to managing its resources.

The suggested solutions were translated into the following measures:

- Wastewater reuse for agriculture
- Adjusting random well drilling
- Rationalizing water consumption
- Restoring water channels
- Establishing rainwater collection ponds and raising the rate of rainwater leakage
- Supporting organic fodder for fish
- Organizing workshops for farmers to guide them in the use of fertilizers and pesticides and the regulation of irrigation
- Afforestation, demonstration and alternative cultivations
- Maintenance of wastewater treatment plants
- Encouraging the production of agricultural fertilizers through aerobic and anaerobic fermentation techniques

Several of these measures are aligned with the measures proposed by the updated NWSS 2020, detailed in the next section.

4.3 Proposed measures in the Updated NWSS 2020

The Updated NWSS 2020 outlines several water management measures that can be implemented to reduce water consumption and promote more efficient use of water resources in ARB. These measures include:

Improved water sector governance

- The legal framework: In-depth revision of all legal documents governing the water sector with identification of overlaps and inconsistencies, with the aim of producing a Code. Prioritization of bylaws required by Law 192/2020 based on importance and urgency. Development of bylaws in consultation with appointed stakeholders.
- The Institutional Framework: develop and implement a human resources strategy for the water sector. This measure aims to address issues related to recruitment and retention, training and development, performance management, and succession planning. Improving the capacity and effectiveness of water institutions in Lebanon through a human resources strategy is seen as a critical measure to ensure the sustainable management and delivery of water services.
- Supervision, Monitoring & Reporting: Creation of a monitoring department within MoEW to enhance the administrative supervision framework of MoEW by focusing on the performance of the Water Establishments (WEs). Standardizing the structure of reports and audits is another measure, including the development of annual and monthly activity reports and annual external audits and evaluations of the WEs. Finally, the establishment of a unified database to include all sector monitoring data and ensure it is regularly updated is recommended.
- The financial and commercial frameworks: Establishment of financial and commercial frameworks to support the sustainable management of water resources in Lebanon. This includes the development of a cost-recovery strategy, the establishment of water tariffs based on cost and service level, and the introduction of a transparent and efficient financial management system.
- Operation and maintenance: establishment of a comprehensive operation and maintenance plan for the water sector facilities and equipment. This includes the development of an asset management system, routine and preventative maintenance procedures, and training programs for staff.

<u>Integrated water resources management</u>

- Integrated Water Resources Management (IWRM): Development and implementation of IWRM through the establishment of basin schemes and the enforcement of the water code. This measure involves the adoption of an integrated approach to manage water resources, where different stakeholders from various sectors are engaged in planning and decision-making processes to ensure the sustainability of water resources in the country. The basin schemes refer to the delineation of water resources based on river basins or aquifers, and the development of plans for the management of water resources in these areas. These plans take into consideration the different uses of water resources, such as agricultural, industrial, and domestic use, and aim to ensure the optimal allocation of water resources while preserving the environmental and ecological balance.
- Integrated Hydrological Information System (IHIS): Creating IHIS that consists of data measurement at all types of water resources and the establishment of a data center at MoEW, interlinked with data centers at the level of the WEs
- Groundwater resources management: Establishment of a comprehensive groundwater monitoring network to manage the country's groundwater resources. This includes developing a database of groundwater wells and measuring water levels, quality, and quantity at regular intervals to ensure sustainable use of groundwater resources. The data collected will be used to inform decision-making, identify areas of concern, and develop appropriate management strategies. Additionally, the measure also includes the development of a groundwater protection strategy to safeguard the quality and quantity of the resource.
- Water quality monitoring: establishing a comprehensive water quality monitoring network to identify and assess the quality of water resources in Lebanon. This network will be used to monitor the quantity and quality of water resources, identify pollution sources, and measure the impact of pollution on water quality. The information obtained from the network will be used to develop effective management strategies to maintain and improve the quality of water resources in Lebanon.
- Disaster risk management (DRM): implementation of DRM measures in order to reduce the negative impacts of natural disasters on water resources and water-related infrastructure such as floods, droughts and forest fires. The DRM measures include emergency response plans, risk assessments, early warning systems, capacity building and public awareness campaigns, as well as collaboration with other sectors and stakeholders. The objective is to improve the resilience of the water sector to disasters and ensure the continuity of water supply services.
- Non-conventional water resources: promotion of the use of non-conventional water resources such as artificial aquifer recharge, wastewater reuse and rainwater harvesting. The strategy emphasizes the need for regulations, incentives, and awareness campaigns to encourage the adoption of non-conventional water resources.

Service Coverage

In order to satisfy the water needs of the population residing in Assi river basin up to 2035 and cover the water deficit occurring, the Updated NWSS 2020 highlights several proposed projects as part of its implementation. These proposed projects include the expansion of surface water storage through dams and hill lakes, drilling new wells, the construction of wastewater treatment plants enhancing water quality and reducing pollution and the rehabilitation of water networks hence improving network efficiency. These projects aim to improve the water sector's efficiency, sustainability and reliability in meeting the growing demand for water in Lebanon.

In summary, the projects selected for the priority 1 phase in Baalbek district include:

- 131.5 km of transmission lines,
- 9 wells to be drilled and equipped,
- 23 reservoirs to be constructed,
- 63 old reservoirs to be rehabilitated,
- 1 new tunnel,
- 1 new WTP.

The projects selected for the priority 1 phase in Hermel district include:

- 22.5 km of transmission lines,
- 1 well to be drilled and equipped,
- 1 well to be equipped and a new control room to be built,
- 4 reservoirs to be constructed,
- many old reservoirs to be rehabilitated,
- 1 spring to be rehabilitated,
- 1 well and PS to be rehabilitated.

Furthermore, the projects selected for the priority 2 phase consist of the installation or extension of distribution networks where needed. In Baalbek district, 346 km are proposed to be executed while in Hermel district, 100 km have to be installed. Moreover, the implementation of SCADA and DMA systems is suggested to connect all the components and facilitate the control and monitoring. The proposed projects are detailed in Table 13 to Table 16.

Table 13 List of the projects proposed in the updated NWSS 2020 within ARB which objective is to increase domestic and irrigation water supply

Sector	District	Distribution/Collection System	Proposed Project
WATER	BQ-W A. District of Baalbek	Laboueh	Drilling 1 well
		Aarsal	Drilling of 6 new wells
		Yammouneh local	Drilling 1 well
	BQ-W B. District of Hermel	Beit Et Tochem, El Charqe, Mazraat Chelman	Drilling 1 well
WASTEWATER	BQ-WW A. District of Baalbek	Yammouneh	1 WWTP activated sludge
		Qaa	1 WWTP activated sludge
		Ras Baalbeck	1 WWTP activated sludge
		Chaat	1 WWTP activated sludge
		Deir el Ahmar	1 WWTP activated sludge
		Boudai	1 WWTP activated sludge
		Chlifa	1 WWTP MBRR
		Ouyoun Orghoch	1 WWTP MBRR
		Ainata	1 WWTP MBRR
	BQ-WW B. District of Hermel	Hermel Phase 1	1 WWTP activated sludge
		Hermel Phase 2	1 WWTP activated sludge
		Wadi Faara	1 WWTP (Mrah Yassine) 1 WWTP MBBR
IRRIGATION	BQ-IR A. District of Baalbek	Younine Dam	Capacity 5.8 Mm^3
	BQ-IR A. District of Hermel	Assi Dam (Phase 1)	Capacity 63 Mm^3
		Assi Dam (Phase 2)	Capacity 37 Mm^3

Table 14 List of water projects proposed in the updated NWSS 2020 within ARB

Project code	Description		Estimated cost (USD)
BQ-W A. District of Baalbek			
BQ-W. A.1	Laboueh distribution scheme, Including:		
	Priority 1	- 34.5 km transmission lines	
		- Drilling of 1 new well	4,014,600 $
	Priority 2	- 115 km Distribution network	5,485,500 $
BQ-W. A.2	Ouyoun Orghosh distribution scheme Including:		
	Priority 1	- 5.75 km transmission lines	
		- Construction of 3 new reservoirs	
		- Rehabilitation of 26 existing reservoirs	1,892,100 $
	Priority 2	- 55 km Distribution network	1,874,800 $
BQ-W. A.3	Younine, Maqne and Nahle distribution scheme, including:		
	Priority 1	- 20.25 km transmission lines	
		- Construction of 1 new reservoir	2,835,400 $
	Priority 2	- 25 km Distribution network	1,192,500 $
BQ-W. A.4	Yammouneh distribution scheme Including:		
	Priority 1	- 20 km transmission lines	
		- Construction of 8 new reservoirs	
		- Construction of a new tunnel	
		- Construction of a WTP	
		- Rehabilitation of 24 existing reservoirs	17,774,700 $
	Priority 2	- 65 km Distribution network	
		- Rehabilitation of networks	3,581,700 $
BQ-W. A.7	Aarsal distribution scheme Including:		
	Priority 1	- 16 km transmission lines	
		- Drilling of 6 new wells	4,884,500 $
	Priority 2	- 50 km Distribution network	2,385,000 $
BQ-W. A.8	Yammouneh local distribution scheme Including:		
	Priority 1	- 4 km transmission lines	
		- Drilling of 1 new well	
		- Construction of 1 new reservoir	954,000 $
	Priority 2	- 1 km Distribution network	47,700 $
BQ-W. A.9	Halbata - El Kharayeb distribution scheme Including:		
	Priority 1	- 3 km transmission lines	
		- Construction of 1 new reservoir	297,900 $
	Priority 2	- 6.75 km Distribution network	322,000 $
BQ-W. A.10	Fekha & Jdeideh distribution scheme Including:		
	Priority 1	- 4 km transmission lines	606,400 $
	Priority 2	- 8.5 km Distribution network	405,500 $
BQ-W. A.11	Baalbeck, Aamechki & Ain Bourday distribution scheme Including:		
	Priority 1	- Drilling of 1 new well	
		- 4 km transmission lines	
		- Construction of 1 new reservoir	954,000 $
BQ-W. A.12	Ras Baalbeck local distribution scheme Including:		
	Priority 1	- 4 km transmission lines	339,200 $
BQ-W. A.14	Local distribution separate system - Including:		
	Priority 1	- 16 km transmission lines	
		- Rehabilitation of 13 existing reservoirs	
		- Construction of 8 new reservoirs	3,683,500 $
	Priority 2	- 20 km Distribution network	954,000 $
BQ-W. A.15	For All Systems:		
	Priority 1	- Remote Control And Monitoring Of Water Systems (SCADA And DMA)	10,000,000 $
	Priority 2	- Remote Control And Monitoring Of Water Systems (SCADA and DMA)	5,000,000 $
		Total Baalbek district	**69,485,000**
		Out of which: Priority 1	48,236,300
		Priority 2	21,248,700

Project code	Description	Estimated cost (USD)
BQ-W B. District of Hermel		
BQ-W. B.1	Upper Hermel, Ras El Mai & Ain Zarqa distribution scheme Including : Priority 1 - 10 km transmission lines - Ras El Mal spring rehabilitation - Rehabilitation of existing reservoirs	3,528,000 $
	Priority 2 - 71 km Distribution network	4,648,700 $
BQ-W. B.4	Beit Et Tochem, El Charqe, Mazraat Chelman distribution scheme Including : Priority 1 - 4 km transmission lines - Construction of 1 new reservoir - Drilling and equipping 1 new well	954,000 $
	Priority 2 - 9 km Distribution network	421,400 $
BQ-W. B.5	Ouadi En Naira, Ouadi Bnit-Zouetini, Wadi El karem, Kaeb Wadi El Karem distribution scheme Including : Priority 1 - 4.5 km transmission lines - Construction of 1 new reservoir - Equipment of Wadi el Naira existing well + new control room - Rehabilitation of Zoueitini existing well and pumping station	976,800 $
	Priority 2 - 12 km Distribution network	572,200 $
BQ-W. B.6	Ouadi Faara, Mrah El Aaqbet distribution scheme Including: Priority 2 - 8 km Distribution network	355,000 $
BQ-W. B.13	Haouch Saeid Ali & Haouch Beit Ismaiil local distribution scheme Including: Priority 1 - 2 km transmission lines - Construction of 1 new reservoir	296,800 $
BQ-W. B.14	Jbeb El Homor local distribution scheme Including: Priority 1 - 2 km transmission lines - Construction of 1 new reservoir	254,400 $
BQ-W. B.15	For All Systems: Priority 1 - Remote Control And Monitoring Of Water Systems (SCADA And DMA)	10,000,000 $
	Priority 2 - Remote Control And Monitoring Of Water Systems (SCADA and DMA)	5,000,000 $
	Total Hermel district	**27,007,300**
	Out of which: Priority 1	16,010,000
	Priority 2	10,997,300
	Total ARB	**96,492,300**
	Out of which: Priority 1	64,246,300
	Priority 2	32,246,000

Table 15 List of wastewater projects proposed in the updated NWSS 2020 within ARB

Project code	Description	Estimated cost (USD)
BQ-WW A. District of Baalbek		
BQ-WW. A.1	Yammouneh collection system - 7 km Collection network - 1 WWTP activated sludge 700 m^3/d	2,591,700
BQ-WW. A.2	Iaat collection system - 10 km Collection network	1,431,000
BQ-WW. A.3	Qaa collection system - 145 km Collection network - 1 WWTP activated sludge 2,318 m^3/d	24,883,500
BQ-WW. A.4	Ras Baalbek collection system - 207 km Collection network - 1 WWTP activated sludge 19,895 m^3/d	60,361,700
BQ-WW. A.5	Chaat collection system - 135 km Collection network - 1 WWTP activated sludge 11,893 m^3/d	37,338,500
BQ-WW. A.6	Deir el Ahmar collection system - 82 km Collection network - 1 WWTP activated sludge 6,870 m^3/d	24,136,200
BQ-WW. A.7	Boudai collection system - 115 km Collection network - 1 WWTP activated sludge 4,220 m^3/d	23,876,500
BQ-WW. A.8	Chlifa collection system: - 50 km Collection network - 1 WWTP activated sludge 1,281 m^3/d	8,745,000
BQ-WW. A.9 Priority 2	Ouyoun Orghoch collection system - 6 km Collection network - 1 WWTP activated sludge 103 m^3/d	1,070,600
BQ-WW. A.10 Priority 2	Ainata collection system - 7 km Collection network - 1 WWTP activated sludge 618 m^3/d	1,743,700
	Total Baalbek district	**186,178,400**
	Out of which: Priority 1	183,364,100
	Priority 2	2,814,300
BQ-WW B. District of Hermel		
BQ-WW. B.1	Hermel Phase 1 Collection system - 354 km Collection network - 1 WWTP activated sludgee 19,144 m^3/d	70,267,400
BQ-WW. B.2 Priority 2	Hermel Phase 2 Collection system - 111 km Collection network - 1 WWTP activated sludgee 19,144 m^3/d	35,494,100
BQ-WW. B.3 Priority 2	Wadi Faara Collection system - 70 km Collection network - 1 WWTP (Mrah Yassine) MBBR 275 m^3/d	10,229,000
	Total Hermel district	**115,990,500**
	Out of which: Priority 1	70,267,400
	Priority 2	45,723,100
	Total ARB	**302,168,900**
	Out of which: Priority 1	253,631,500
	Priority 2	48,537,400

Table 16 List of irrigation projects proposed in the updated NWSS 2020 within ARB

Project code	Description	Estimated cost (USD)
BQ-IR A. District of Baalbek		
BQ-IR. A.1	Ayneta Baalbeck Scheme - 2 km Concrete channels to rehabilitate	28,000
BQ-IR. A.2	Baalbeck Plain Scheme - 8 km Concrete channels to rehabilitate - 4 km Earth channels to concrete	830,000
BQ-IR. A.8	Labboue Scheme - 20 km Concrete channels to rehabilitate - 40 km Earth channels to concrete	3,900,000
BQ-IR. A.11	Ras Baalbeck Scheme - 2 km Concrete channels to rehabilitate - 0.5 km Earth channels to concrete	200,000
BQ-IR. A.14 Priority 2	Wadi Nahle and Maqne Scheme - 6 km Concrete channels to rehabilitate - 10 km Earth channels to concrete	2,600,000
BQ-IR. A.16	Yammoune Scheme - 1.5 km Concrete channels to rehabilitate - 11 km Earth channels to concrete	3,500,000
BQ-IR. A.17	Younine Scheme - 2.5 km Concrete channels to rehabilitate - 1.2 km Earth channels to concrete	330,000
BQ-IR. A.19	Assi Dam Phase I related irrigation network - Network to cover 3 254 ha of land to irrigate	84,272,000
BQ-IR. A.20 Priority 2	Assi Dam Phase II related irrigation network - Network to cover 3 870 ha of land to irrigate	83,000,000
	Total Baalbek district	**178,660,000**
	Out of which: Priority 1	95,660,000
	Priority 2	83,000,000
	Priority 3	

4.4 Mitigation/Intervention scenarios

Three mitigation/intervention scenarios can be defined based on the different water demand management measures previously presented in sections 4.2 and 4.3. These scenarios and their combinations shall be built over the future business-as-usual scenarios.

The first is a scenario that takes into account the impact of the proposed water supply increase infrastructure under the updated NWSS 2020 in 2035.

The second is a scenario that assumes complete coverage of domestic and irrigation water demand by additional infrastructure to meet unmet demand.

The third is an irrigation related scenario that focuses on the implementation of irrigation mitigation measures such as crop type and irrigation type modification, etc.

Below in Table 17 and Table 18 the complete list of scenarios and their combinations that shall be simulated and analyzed in WEAP for 2035.

Table 17 Description of future scenarios with mitigation and intervention measures

Scenarios Name	Description	Combination ID
Business as Usual	Increase of domestic water demand and supply according to demographic expansion	S0
Irrigation water Demand Increase	Increase of irrigation water demand based on crop intensification in 2035	S2 to S11
	Increase of irrigation water demand based on spatial expansion in 2035	S1, S3, S4, S5, S7, S9 & S11
NWSS Proposed	Implementation of water supply infrastructure and water conservation measures as proposed in the NWSS for 2035	S4 to S11
Domestic Complete Coverage	Simulation with the implementation of additional infrastructures to meet unmet domestic demand	S5 to S11
Irrigation Mitigation	Simulation with the implementation of irrigation mitigation measures using crop type modification	S6, S7, S10 & S11
	Simulation with the implementation of irrigation mitigation measures using irrigation type modification	S8, S9, S10 & S11
Climate Change*	Climate change scenario with incorporation of CMIP6 climate anomalies	S0CC to S11CC

* The climate change scenario will be applied in combination with all the other scenarios.

Table 18 Complete list of future scenarios combinations

Combination ID	Business as Usual	Climate Change	Irrigation Demand		NWSS Measures	Complete Domestic Coverage	Irrigation Demand Mitigation	
			Intensification	Expansion			Low demanding crop	Efficiency improvement
S0	X							
S1	X			X				
S2	X		X					
S3	X		X	X				
S4	X		X	X	X			
S5	X		X	X	X	X		
S6	X		X		X	X	X	
S7	X		X	X	X	X	X	
S8	X		X		X	X		X
S9	X		X	X	X	X		X
S10	X		X		X	X	X	X
S11	X		X	X	X	X	X	X
S0CC	X	X						
S1CC	X	X		X				
S2CC	X	X	X					
S3CC	X	X	X	X				
S4CC	X	X	X	X	X			
S5CC	X	X	X	X	X	X		
S6CC	X	X	X		X	X	X	
S7CC	X	X	X	X	X	X	X	
S8CC	X	X	X		X	X		X
S9CC	X	X	X	X	X	X		X
S10CC	X	X	X		X	X	X	X
S11CC	X	X	X	X	X	X	X	X

5 MODFLOW Future Scenario

5.1 Main Outcomes from the Inverse Modelling

As mentioned in the Baseline Report, inverse modelling was performed to estimate the unknown parameters, in particular hydraulic conductivity, drain, and General Head Boundary conductance, as well as the recharge rates. Log-transformation was applied for the hydraulic conductivity to allow this parameter to be log-transformed throughout the estimation process. Typically, calibration should be performed under natural conditions. However, old data on groundwater were not continuously available for an extended period. Relying on spot measurements from different months and years normally leads to temporal inconsistency in terms of calibration targets, especially since interannual climate variations are expected in the study area. The used spring discharge values, mainly representing the phase before the year 1970, were obtained from multiple sources (USBR, 1957; MoEW and UNDP, 2014; LRA data). Hence, those values were cautiously used. Although the aforementioned uncertainty remains valid, this temporal selection tries to consider a scenario where anthropogenic influence is minimal. The selection of the phase before the year 1970 for the calibration was made due to the expected relatively low anthropogenic impacts during that period.

The calibration process gave a perfect fit for the considered main springs as shown in Figure 5. The relative residual flow varied between 0.1 (Laboueh spring) and 1.8% (Nabaa ech Chaghour spring). The most important estimated model parameters were the recharge rates and the hydraulic conductivities. The estimated horizontal hydraulic conductivity (HK) and vertical hydraulic conductivity (VK) were the following: HK=1.87 m/d and VK=0.12 m/d for the Quaternary-Neogene aquifer, HK=13.01 m/d and VK=0.56 m/d for the Eocene aquifer, HK=0.1 m/d and VK=0.04 m/d for the Senonian aquiclude. The Cenomanian-Turonian aquifer had a VK of 7.7 m/d and was subdivided into 5 horizontal hydraulic conductivity zones: the eastern part of this aquifer had a horizontal hydraulic conductivity of 10 m/d while the south-western and north-western parts had values of 33 and 97 m/d, respectively. In the central subsurface, the estimated HK was 15 m/d while the small outcropping patches of this aquifer in the southern part of the valley showed an HK value of 41 m/d.

Groundwater recharge, expressed as a percentage of the precipitation, varied between 33 and 42% where the Quaternary-Neogene aquifer is outcropping, 65 to 77% for the eastern Cenomanian-Turonian aquifer, and 77 to 85% for the western Cenomanian-Turonian aquifer. This is consistent with the reported presence of karstic features as the western side of the study area is characterized by the presence of more karstic features, mainly sinkholes. Zwahlen et al. (2014) mentioned that El Assi basin contains significant karstic water resources. On the other hand, the relatively high recharge rate for the Quaternary-Neogene aquifer might be indicating irrigation return flows most likely occurring in the agricultural areas of the Bekaa valley. Other outcropping formations were represented as one zone. Hence, the recharge parameters of the Eocene aquifer and Senonian aquiclude were estimated to be 23% and 5% of the precipitation, respectively. The recharge rates were particularly useful as they are, among other groundwater-related parameters, required as input to the WEAP component of this project.

Generally, the estimated parameter values seem to be realistic. In fact, an assisted calibration approach was adopted by setting the minimum and maximum values for the different parameters by relying on the literature and previous studies to avoid unrealistic calibration results.

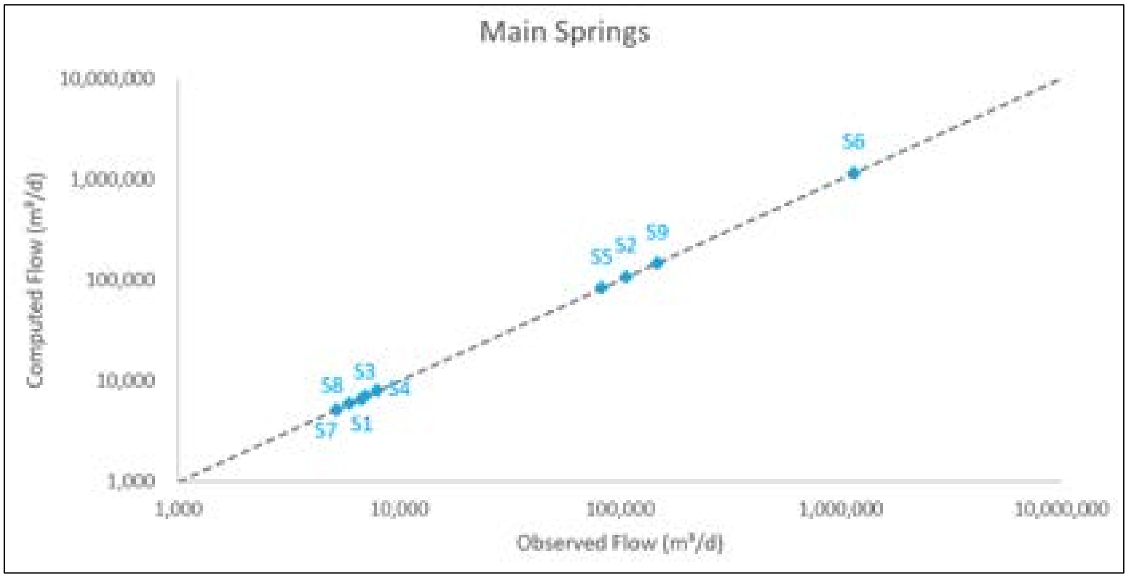

Figure 5 Computed and observed flows of the main springs S1: Nabaa Ras el Mal, S2: Nabaa Raayane, S3: Nabaa ech Chaghour, S4: Ain Ahla, S5: Nabaa el Fekehe, S6: Ain ez Zarqa, S7: Ain Quardine, S8: Nabaa Aaddous, S9: Laboueh

5.2 Forward Modelling/Projections

Following the inverse modelling phase, forward modelling was carried out to assess the potential impacts of the different scenarios on groundwater. Hence, the following projected scenarios were simulated:

a. S0: Business as Usual including private wells, operating public wells, and under-construction wells;

b. S3: Increase of irrigation water demand based on spatial expansion in 2035 leading to an increase in groundwater abstractions, mainly from private wells;

c. S4: Increase of irrigation water demand based on spatial expansion in 2035 and implementation of NWSS measures including the proposed public wells in Laboue, Yammouneh, Aarsal, and Beit Et Tochem, as well as Assi and Younine dams leading to a decrease in groundwater abstractions from private wells in the neighboring areas;

d. S5: Increase of irrigation water demand based on spatial expansion in 2035, implementation of NWSS measures, and additional measures to meet unmet domestic demand by 2035;

e. S11: Increase of irrigation water demand based on spatial expansion in 2035, implementation of NWSS measures, additional measures to meet unmet domestic demand by 2035, and irrigation mitigation measures low demanding crops and efficiency improvement.

In addition, the aforementioned scenarios were also simulated while assuming the impact of climate change and climate variabilities.

5.2.1 Groundwater level change for the Quaternary-Neogene aquifer under average historical climate conditions

The results presented in this section were obtained for the Quaternary-Neogene aquifer while considering the historical climate conditions used for the calibration phase of the model. The relevant maps showing the change in groundwater level are included in Figure 6.

The total groundwater abstractions for Scenario 0 (Business as Usual) amount to approximately 187,000 m^3/d. Specifically, the abstractions from the Quaternary-Neogene aquifer are estimated to be around 55,000 m^3/d.

In comparison to S0, a noticeable larger decrease in groundwater levels can be generally seen in the northern part of the study area, specifically between El Qaa and El Qasr under scenario S3. This decrease is primarily attributed to an increase of about 8% in abstractions from the Quaternary-Neogene aquifer.

S4 shows a minimal decrease in groundwater levels when compared to S0 and S3. In fact, overall groundwater abstractions in S4 amount to only 47% of those in S0. In particular, abstractions from the Quaternary-Neogene aquifer in S4 amount to only 27% of those in S0.

Groundwater abstractions in S5 account for only 39% of those in S0, resulting in a minimal decrease in groundwater levels (see Figure 9) as compared to S0 and S3. In particular, abstractions from the Quaternary-Neogene aquifer in S5 amount to only 26% of those in S0.

Similarly, groundwater abstractions from the Quaternary-Neogene aquifer in S11 account for only 21% of those in S0, resulting in a minimal decrease in groundwater levels.

5.2.2 Groundwater level change for the Quaternary-Neogene aquifer considering climate change

The results presented in this section were computed while considering a 3% decrease in precipitation by 2035 (obtained for both SSP2-4.5 and SSP5-8.5 scenarios). This decrease is directly affecting groundwater recharge since the latter was calibrated as a percentage of precipitation. As compared to the scenarios under average historical climate conditions, groundwater level decrease is more pronounced when considering climate change effects and their corresponding groundwater abstractions rates. The relevant maps showing the change in groundwater level are included in Figure 7.

The total groundwater abstractions for Scenario S0 under climate change, reported as S0CC, amount to approximately 190,000 m^3/d. Specifically, abstractions from the Quaternary-Neogene aquifer are estimated to be around 55,500 m^3/d.

For Scenario S3 under climate change (reported as S3CC), an increase of 12% in groundwater abstractions from the Quaternary-Neogene is simulated.

Under climate change conditions, abstractions from the Quaternary-Neogene aquifer in S4 amount to 73% of those in S0 from the same aquifer. This scenario is reported as S4CC.

For S5CC (i.e., Scenario S5 under climate change conditions), abstractions from the Quaternary-Neogene aquifer amount to 71% of those in S0 from the same aquifer.

On the other hand, for S11CC (i.e., Scenario S11 under climate change conditions), abstractions from the Quaternary-Neogene aquifer account for only 23% of those in S0, resulting in a minimal decrease in groundwater levels.

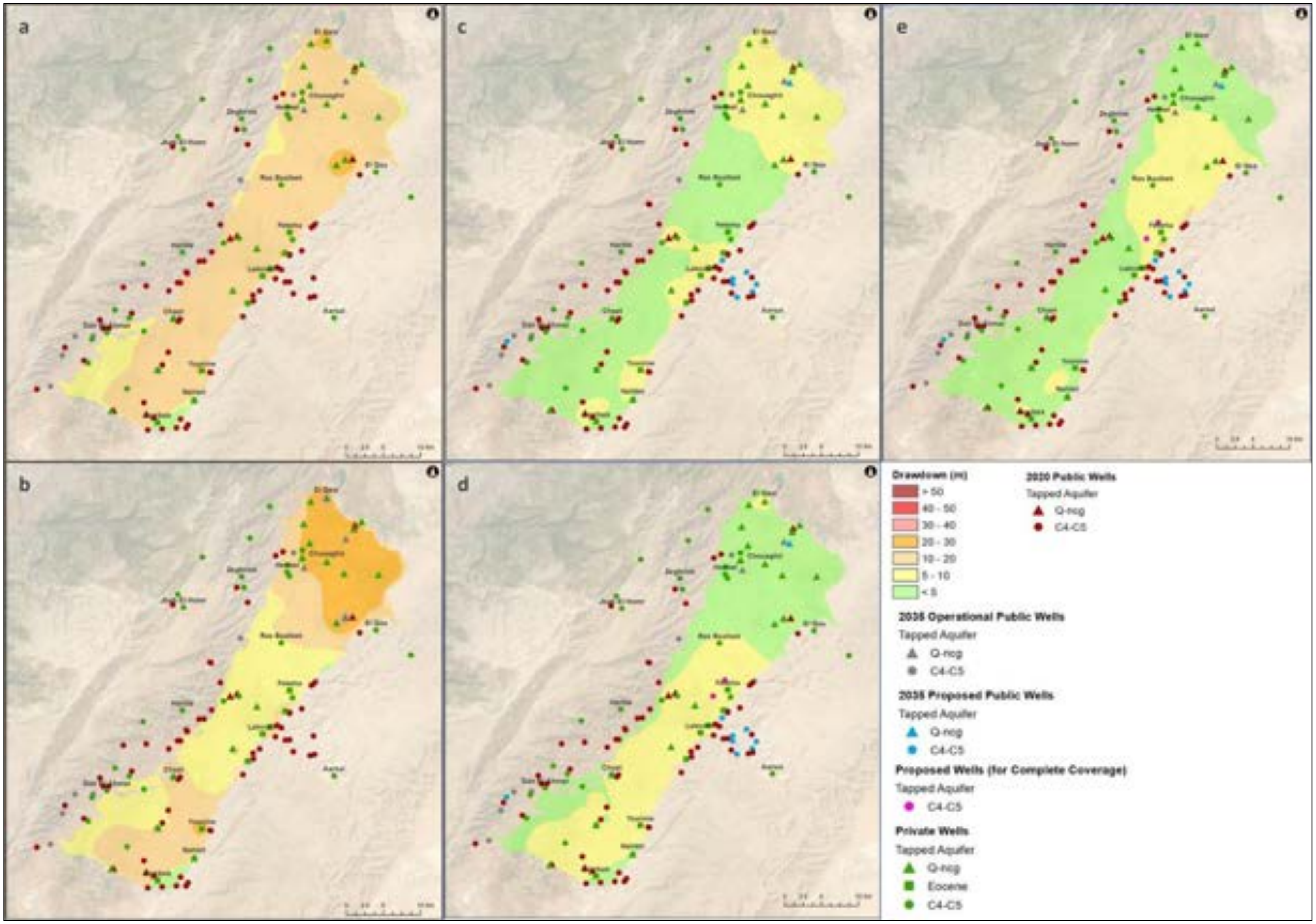

Figure 6 Groundwater level change in the Quaternary-Neogene under average historical climate conditions for: a) S0, b) S3, c) S4, d) S5, and e) S11

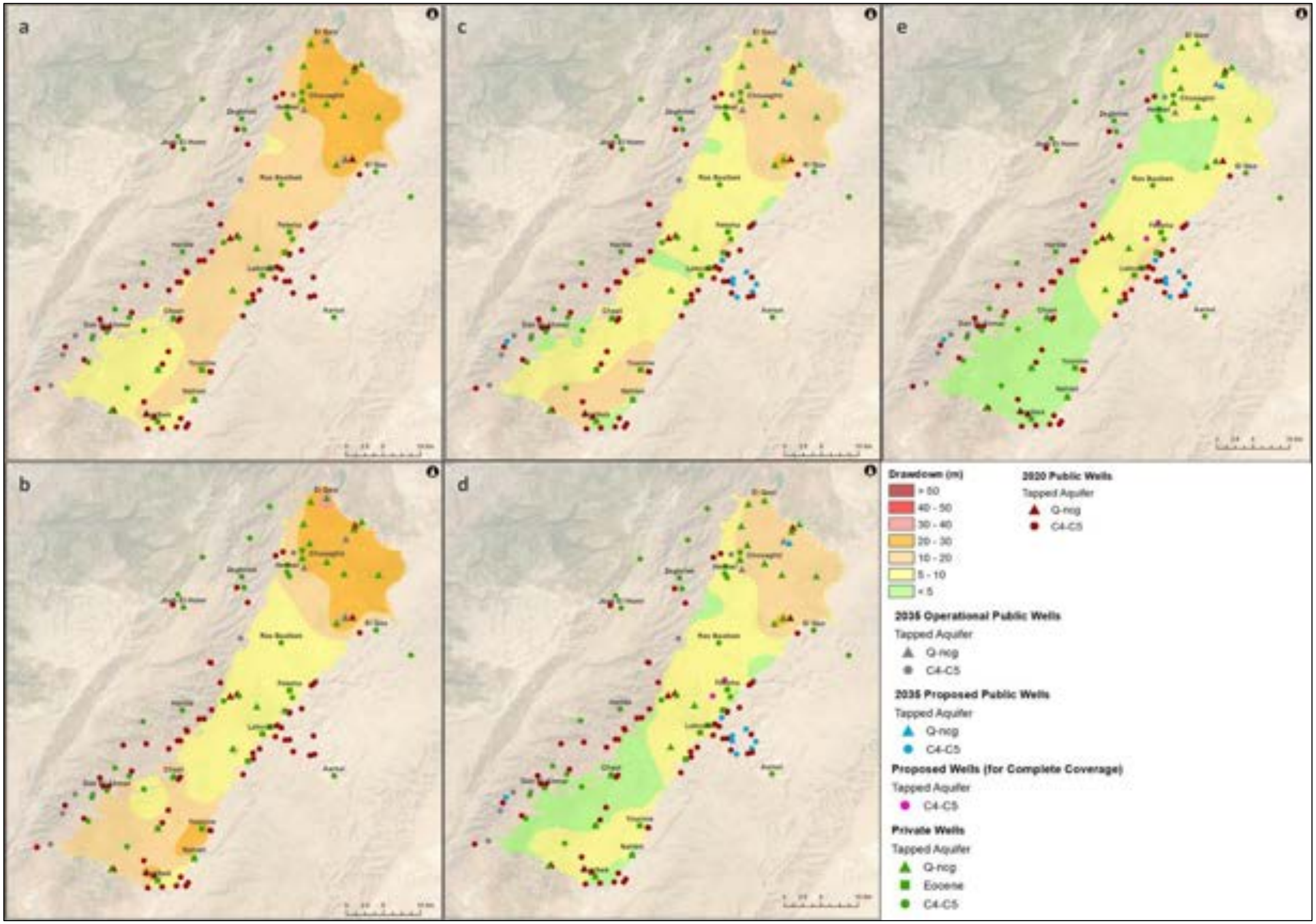

Figure 7 Groundwater level change in the Quaternary-Neogene considering climate change for: a) S0, b) S3, c) S4, d) S5, and e) S11

5.2.3 Groundwater level change for the Quaternary-Neogene aquifer considering consequent dry years

Based on historical climate data from Hermel and Deir El Ahmar meteorological stations, the 10th percentile annual total precipitation was assumed as a representative value for a dry year. Specifically, it was assumed that during a dry year, Hermel would receive 62% less precipitation compared to a typical year, while Deir El Ahmar would receive 46% less precipitation. It is important to highlight that the values obtained for Hermel were considered for the recharge zones mostly located in the valley while those obtained for Deir El Ahmar were adopted for the mountainous areas (this also applies for Section 5.2.4). The relevant maps showing the change in groundwater level are included in Figure 8. These maps show a more significant decline in groundwater levels compared to scenarios that took historical average climate conditions into account (i.e. scenarios of Section 5.2.1.

5.2.4 Groundwater level change for the Quaternary-Neogene aquifer considering consequent wet years

On the other hand, the 90th percentile annual total precipitation was assumed as a representative value for a wet year: it was assumed that during a wet year, Hermel would receive 62% more precipitation compared to a typical year, while Deir El Ahmar would receive 46% more precipitation. The relevant maps showing the change in groundwater level are included in Figure 9. These maps indicate a lower decrease in groundwater levels when compared to the scenarios that considered historical average climate conditions (specifically, the scenarios discussed in Section 5.2.1).

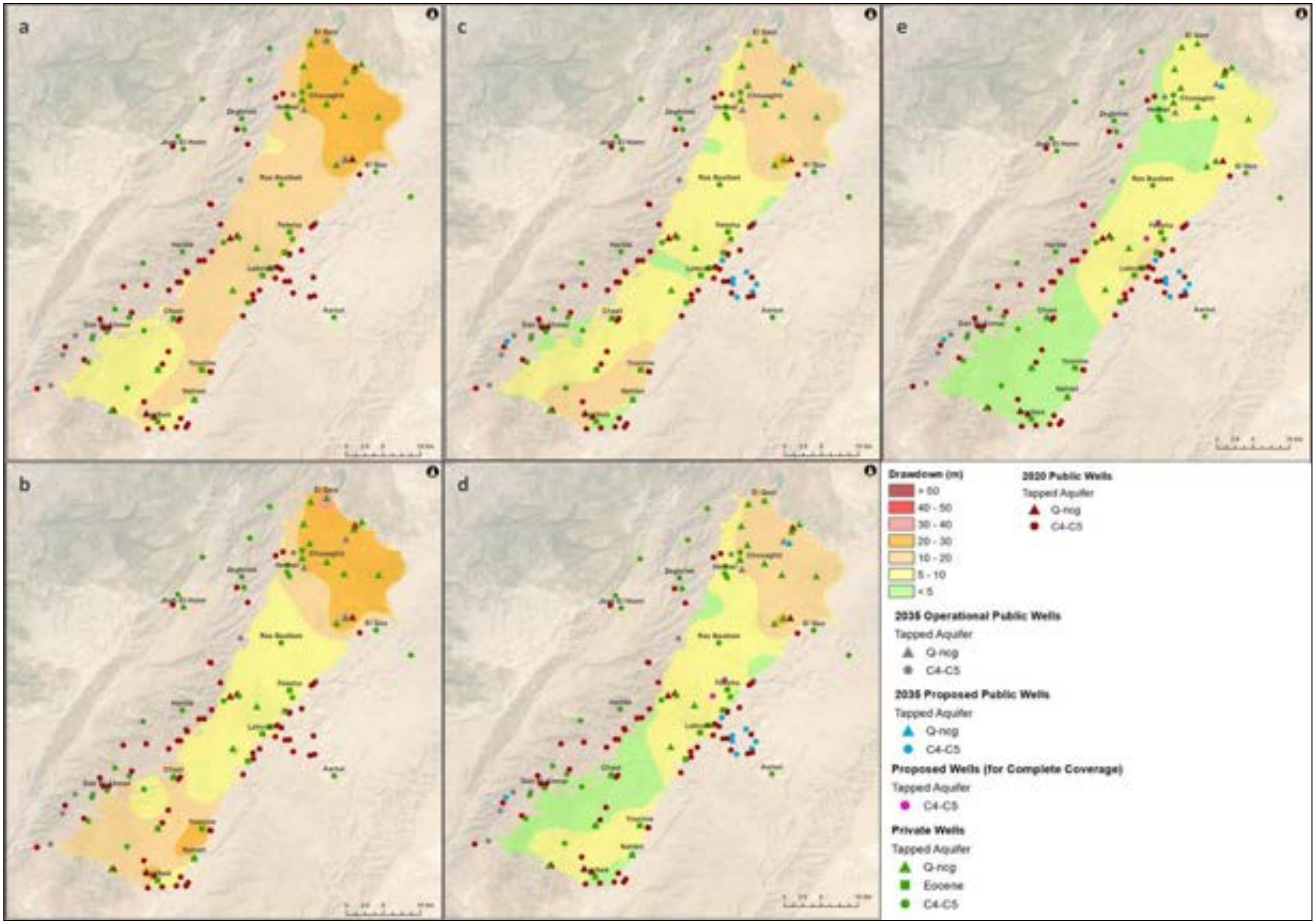

Figure 8 Groundwater level change in the Quaternary-Neogene considering consequent dry years for: a) S0, b) S3, c) S4, d) S5, and e) S11

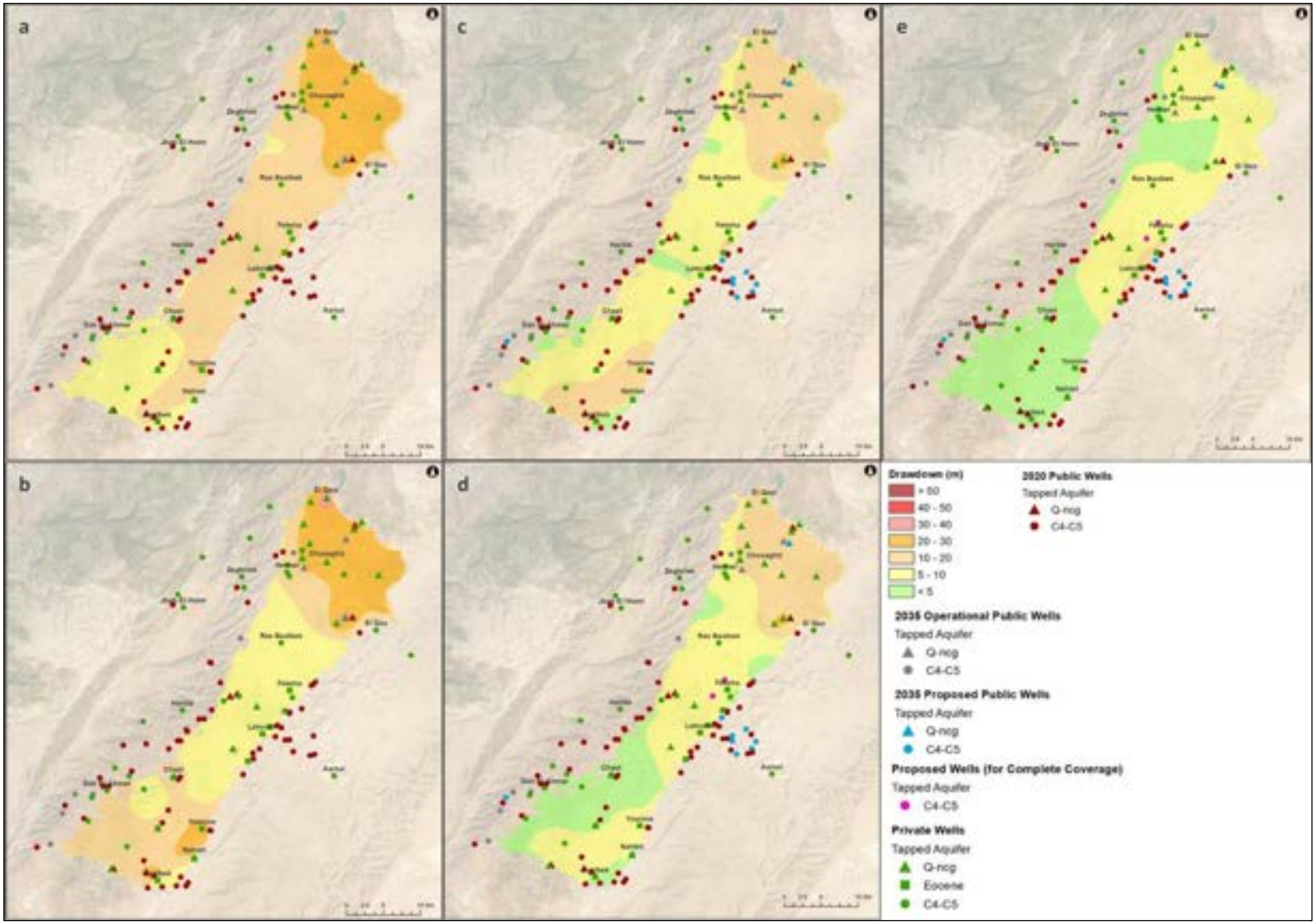

Figure 9 Groundwater level change in the Quaternary-Neogene considering consequent wet years for: a) S0, b) S3, c) S4, d) S5, and e) S11

5.2.5 Spring discharges under average historical climate conditions

Figure 10 shows the projected spring discharge values under average historical climate conditions for the different considered scenarios (S0, S3, S4, S5 and S11). In general, the discharges of the main springs were not highly affected by the changing abstraction conditions. However, smaller springs (not simulated in this model since they only account for 1% of the total springs' discharge) are expected to be more sensitive to pumping, especially if occurring in their close vicinity.

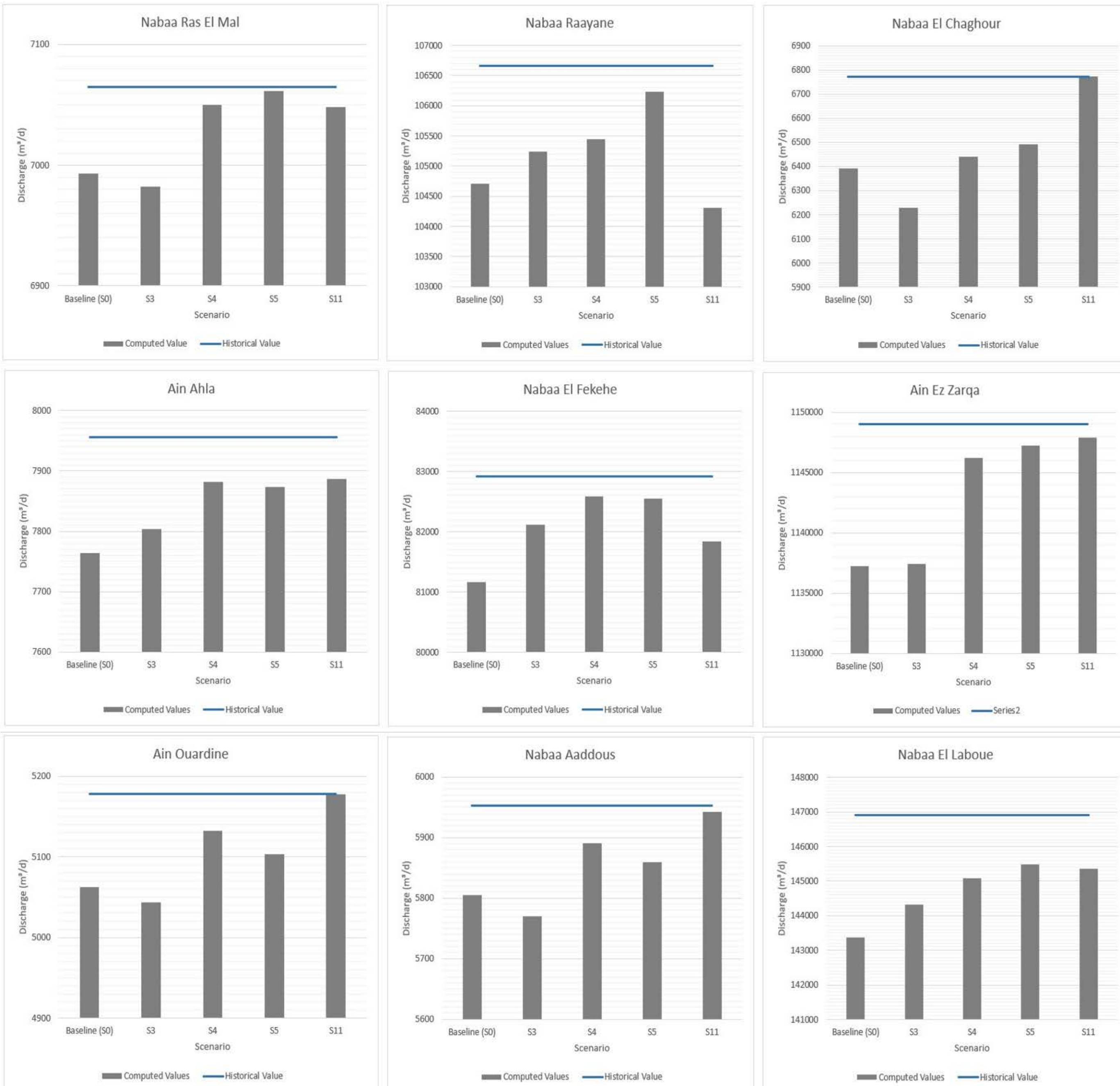

Figure 10 Projected spring discharge values under average historical climate conditions for different scenarios

5.2.6 Spring discharges considering climate change

Figure 11 shows the projected spring discharge values considering climate change for the different considered scenarios (S0, S3, S4, S5, and S11). A decrease in spring discharge values was noticed under climate change. For instance, the discharge of Ain Ez Zarqa and Nabaa Raayane respectively decreased by about 2 and 6% for S0.

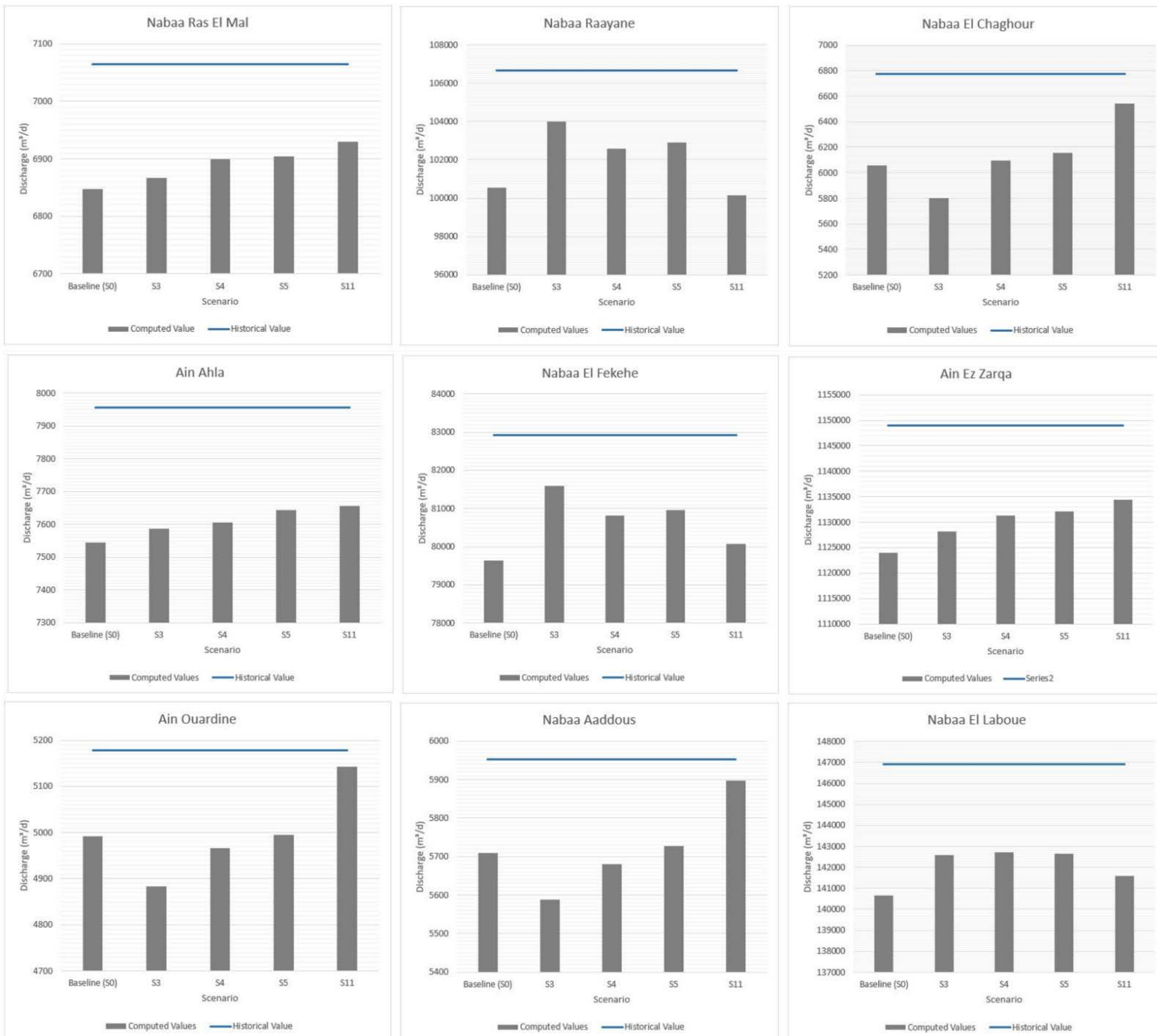

Figure 11 Projected spring discharge values considering climate change for different scenarios

5.2.7 Spring discharges considering consequent dry years

Figure 12 shows the projected spring discharge values considering consequent dry years for the different considered scenarios (S0, S3, S4, S5, and S11). A greater decrease in spring discharge values was noticed if consequent dry years are considered. For instance, the discharge of Ain Ez Zarqa and Laboueh respectively decreased by about 29 and 37% for S3.

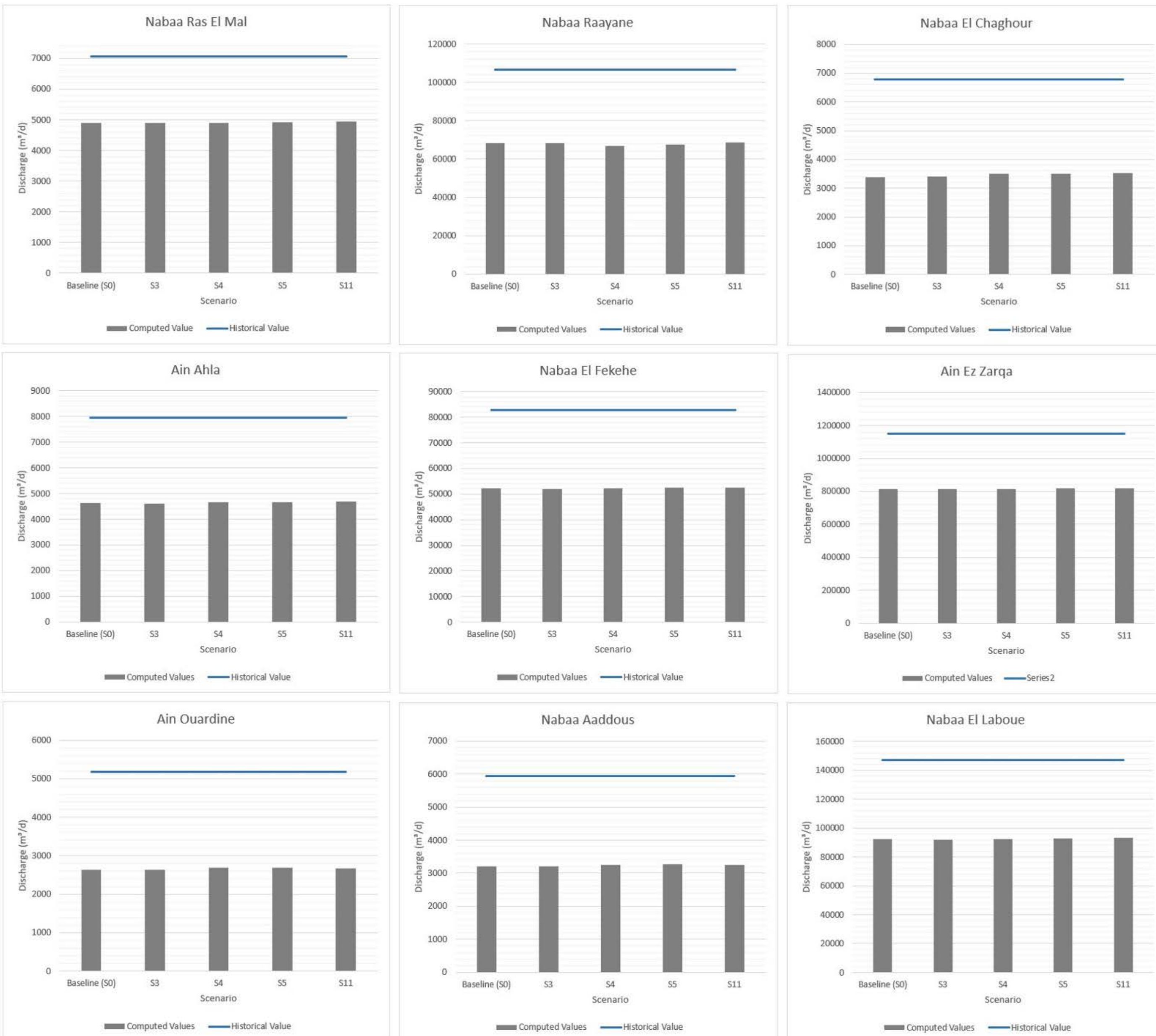

Figure 12 Projected spring discharge values considering consequent dry years for different scenarios

5.2.8 Spring discharges considering consequent wet years

Figure 13 shows the projected spring discharge values considering consequent wet years for the different considered scenarios (S0, S3, S4, S5 and S11). If consequent wet years are simulated, an increase in spring discharge values will be expected. For instance, the discharge of Ain Ez Zarqa and Nabaa Ras El Mal respectively increased by about 25 and 29% for S4.

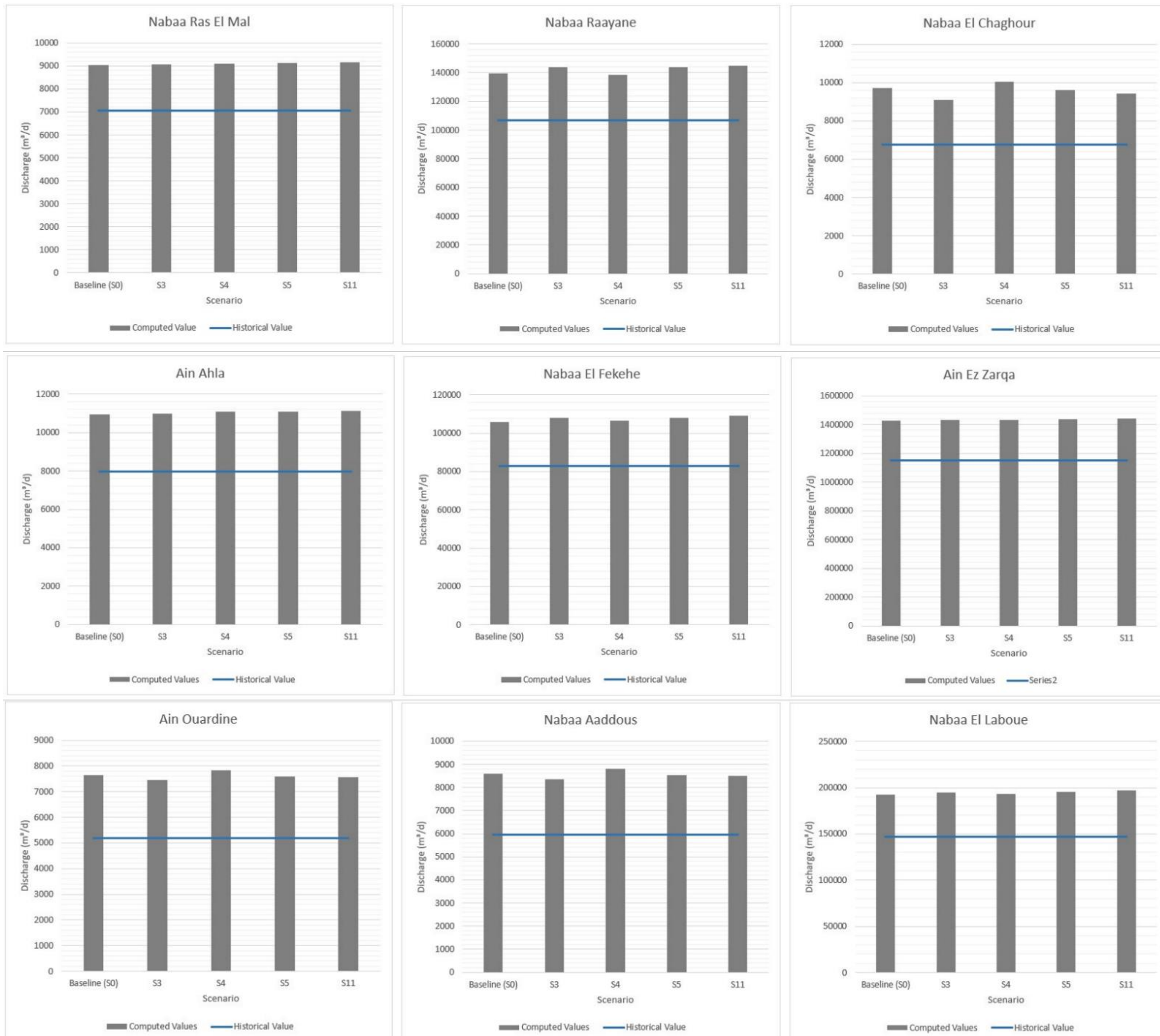

Figure 13 Projected spring discharge values considering consequent wet years for different scenarios

5.3 Summary

The previously presented simulations provided insights regarding the potential impacts of different scenarios as well as climate change and climate variabilities on groundwater levels and spring discharges in the study area.

Scenario S3, simulating the impacts of the increase of irrigation water demand based on spatial expansion in 2035, resulted in a noticeable decrease in groundwater levels of the Quaternary-Neogene aquifer particularly in the northern part of the basin. This is primarily due to the increase in abstractions from private wells tapping this shallow aquifer. After implementing NWSS measures, included in Scenarios S4, S5 and S11, a minimal decrease in groundwater levels of the Quaternary-Neogene aquifer was obtained since abstractions were lower than those of the business-as-usual scenario S0. Moreover, Scenario S11 showed the lowest negative impact on the groundwater table since it also included irrigation mitigation measures that further reduced groundwater abstractions from private wells.

Considering climate change, the decrease in precipitation by 2035 led to a more pronounced groundwater level decrease. The possible occurrence of consequent dry years may further exacerbate the decline in groundwater levels and spring discharge values. Conversely, consequent wet years resulted in a lower decrease in groundwater levels and higher spring discharge values as compared to historical average climate conditions.

Finally, monitoring groundwater quality is crucial in this study area, as contamination can arise from human activities such as waste and wastewater disposal, agriculture, and industries.

6 WEAP Results of Future Scenarios

6.1 Results Exploration

6.1.1 Results of Hydrological model under Climate Change effects

Within ARB the river is not being used for domestic water supply purposes currently, but it is used for irrigation purposes. The baseflow component is the predominant contribution to the flow of river Assi, which originates from the karstic spring Ain ez Zarka. As a consequence, the hydrological modelling of surface flow has not a great impact on water resources as its contribution is less than 5%, often with a null discharge arriving to the conjunction with Ain ez Zarka. Nevertheless, we have assessed the potential impact in the hydrological model due to climate change. Within Table 19 we can observe the adopted effects of climate change within precipitation and evapotranspiration as opposed to the reference values used during the calibration of the baseline.

Table 19 Climate Change effects in hydrological model inputs

Month	Precipitation (mm)			Reference Evap (mm)	
	SSP5-8.5 (%)	Prec Hist	CC Prec	EtRef	EtR CC
Jan	-0.7	83.3	82.7	39	48
Feb	-1.9	80.1	78.6	53	55
Mar	-6.4	41.4	38.8	97	89
Apr	-2.4	17.3	16.9	121	125
May	-6.9	11.6	10.8	171	168
Jun	-6.4	0.4	0.4	217	214
Jul	-7	0.3	0.3	231	251
Aug	-9.1	0.9	0.8	204	233
Sep	-0.7	5.8	5.8	150	167
Oct	4	14.2	14.8	109	114
Nov	-3.4	37.0	35.7	68	66
Dec	-9.7	86.6	78.2	43	51

As a consequence, results presented in Figure 14 show a 4.2% reduction in the component of runoff reaching Assi river. This reduction is mainly perceived in March and December. The overall discharge volume is 7.4 Mm^3/year within projected reference scenario, dropping to 7.1 Mm^3/year in climate change projected scenario.

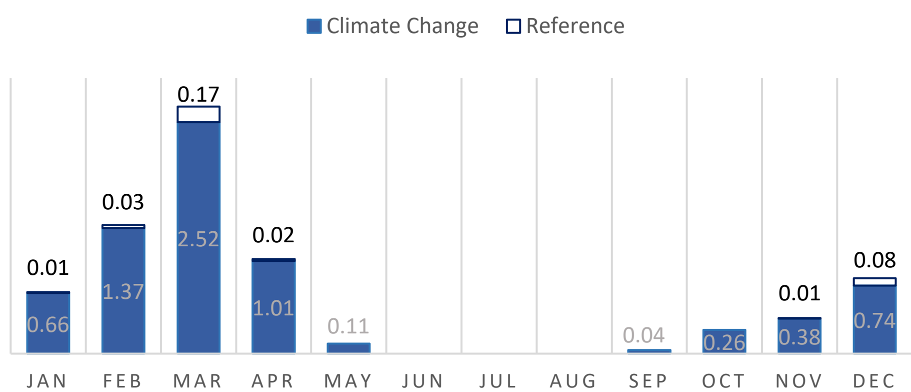

Figure 14 Hydrological model results with climate change expressed in average discharge volume in Mm^3

6.1.2 Results of WEAP Node based model

It is important to recall at this point, that scenarios described in section 3 were modelled, with and without climate change. Within this section we will focus only on key scenarios including climate change: S0CC, S3CC, S4CC, S5CC and S11CC. We understand that there is a high chance of climate change occurring and these scenarios present different possibilities to provide a relevant scope into ARB.

The starting point of our assessment is the S0CC Business as Usual scenario which serves as a baseline under climate change. As a reminder, Figure 15 shows the WEAP schematic for the node-representation of ARB.

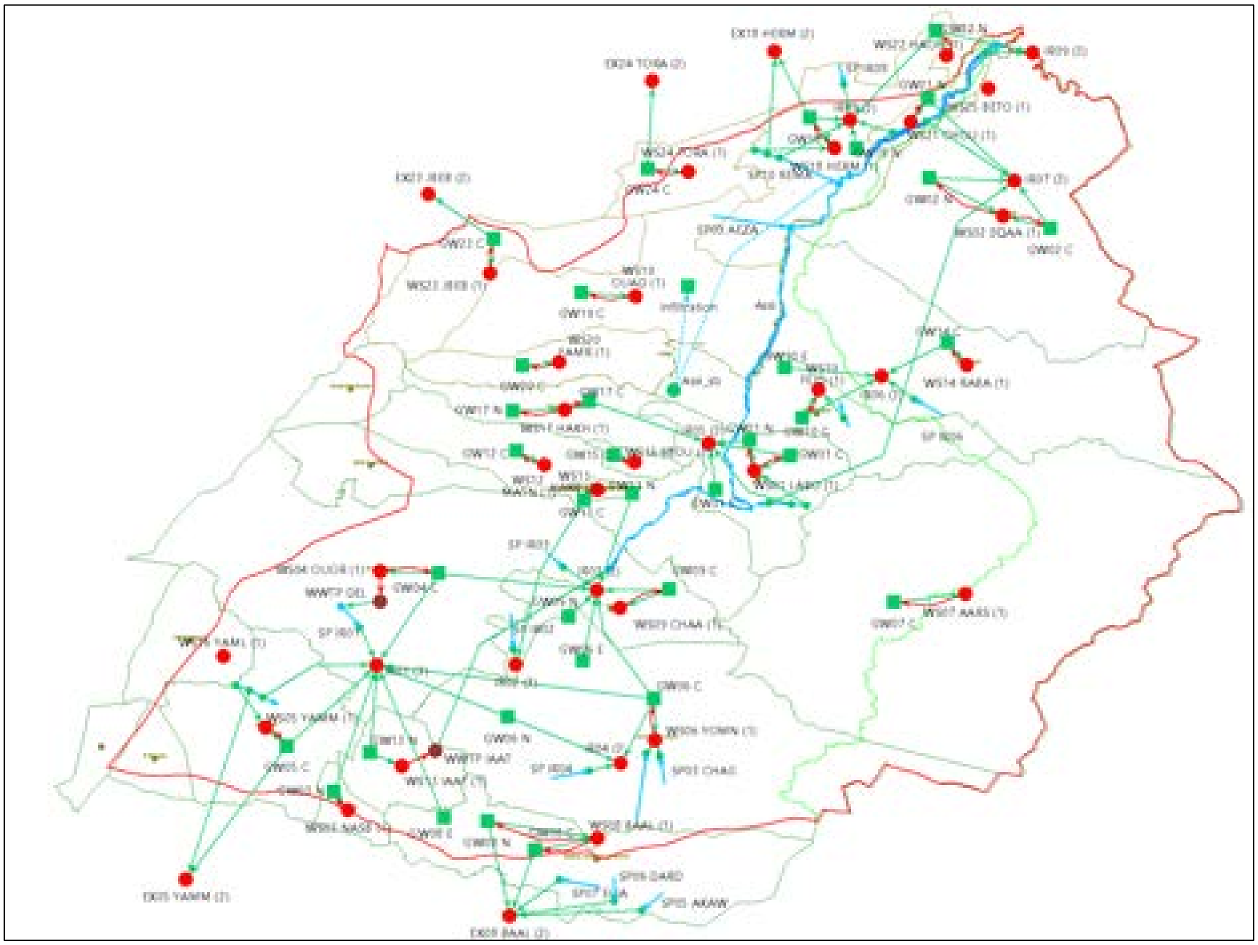

Figure 15 WEAP node-based representation for ARB

6.1.2.1 S0CC – Business as usual Scenario under Climate Change

Within the irrigation sector, the effect of Climate Change is manifested over the Net Water requirement per representative hectare, increasing from 5621 to 6132 m^3/Ha/year (see Table 12). When it comes to climate change effects in water systems' demand, a 10% increase is foreseen during the summer months noticed within the domestic supply of water systems.

Therefore, domestic supply increases from 125 l/cap/day to 137.5 l/cap/day during summer, averaging around a year consumption of 46.8 m^3/cap. As a result, the total demand of ARB is the following:

- Total Demand 2020 = 127 Mm^3/year
- Total Demand 2035 = 141 Mm^3/year

These demands do not account for losses.

Figure 16 shows the augmentation of the demand for the different water systems. On the other hand, Figure 17 shows the corresponding demand for the irrigation sector and Figure 18 a comparison between the demands of Water Systems and Irrigation Zones.

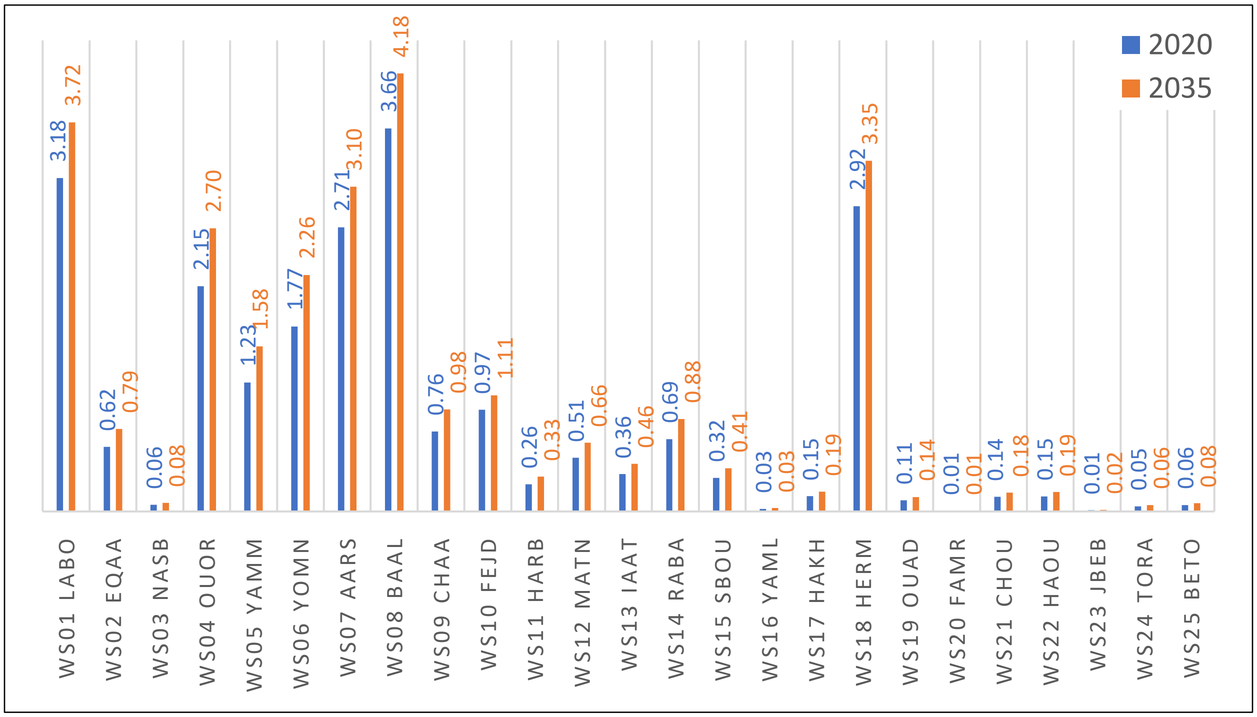

Figure 16 Water Systems demand under S0CC for 2020 and 2035 (Mm^3/year)

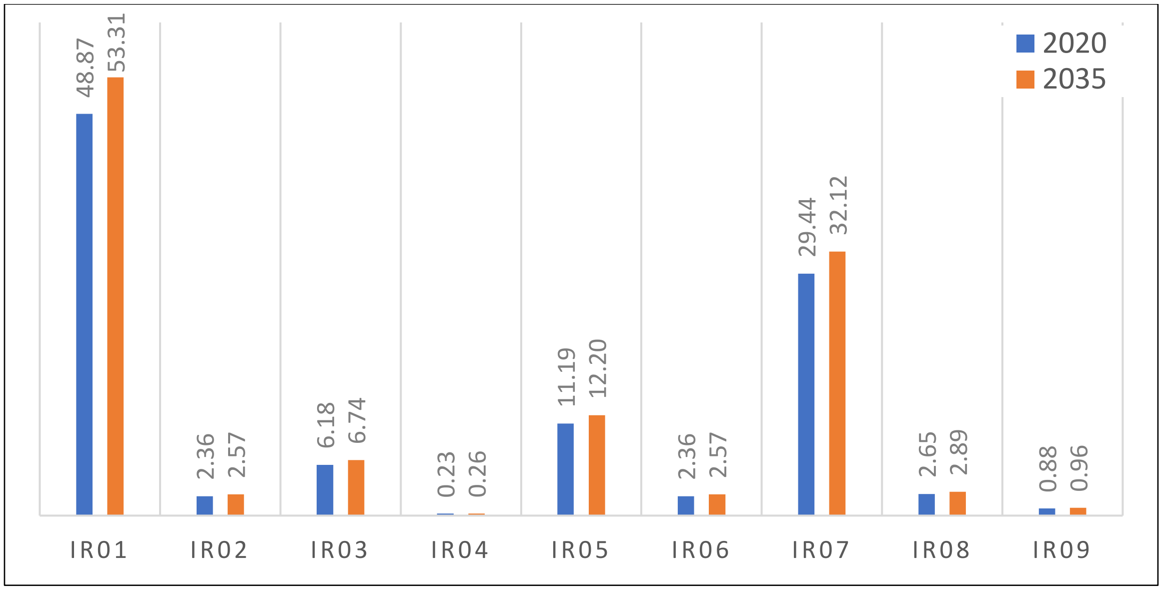

Figure 17 Irrigation Zones' demand under SOCC for 2020 and 2035

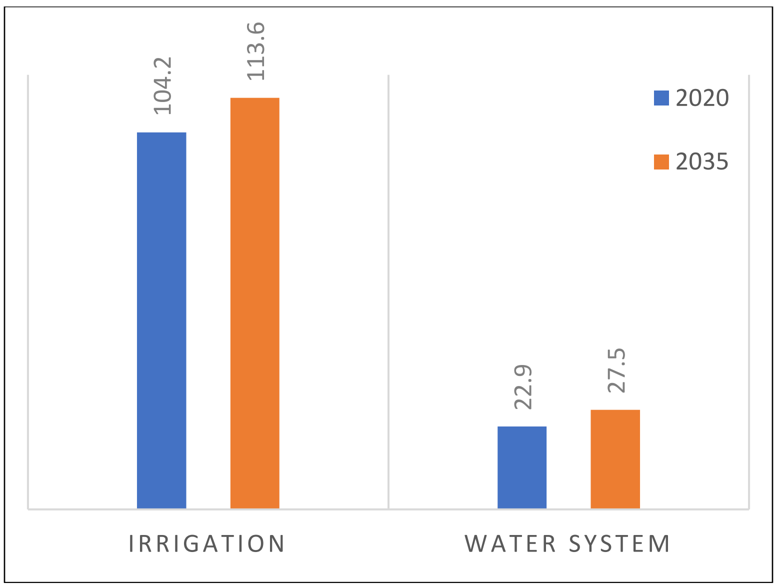

Figure 18 Comparison of total water demand by sector under SOCC for 2020 and 2035

On the other hand, Figure 19 shows the water supply by source type, classified into reservoirs, springs and wells. There is a slight augmentation in supply following the augmentation of demand up to the limit that the corresponding sources can provide.

As a result, the total supply of ARB is the following:

- Total Supply 2020 = 155 Mm^3/year
- Total Supply 2035 = 163 Mm^3/year

These demands do account for losses.

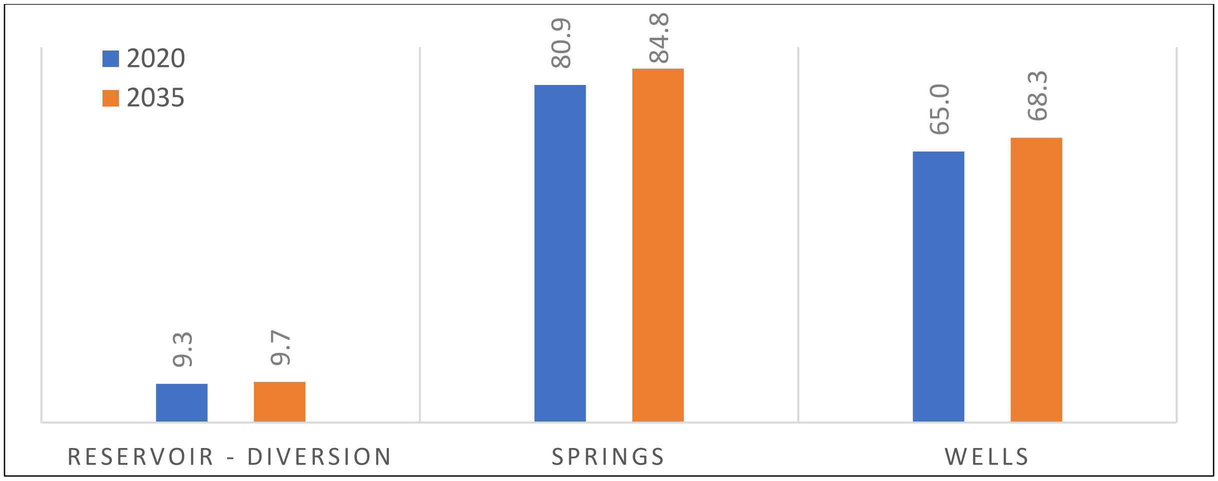

Figure 19 Water supply under SOCC for 2020 and 2035 (Mm³/year)

When comparing water demand, water supply and the actual water delivered after the losses occur, we obtain the coverage represented in Figure 20. It is important to mention that for our baseline scenario we have considered losses of 50% for Water Systems supply, which account for all the losses in the system, from extraction, conduction, storage and distribution losses. Regarding irrigation losses, a 65% effectiveness was estimated, or 35% losses.

As a result, the total coverage of ARB is the following:

- Total Coverage 2020 = 77% & Total Unmet Demand = 30 Mm^3/y
- Total Coverage 2035 = 72% & Total Unmet Demand = 39 Mm^3/y

These coverages and unmet demands do account for losses.

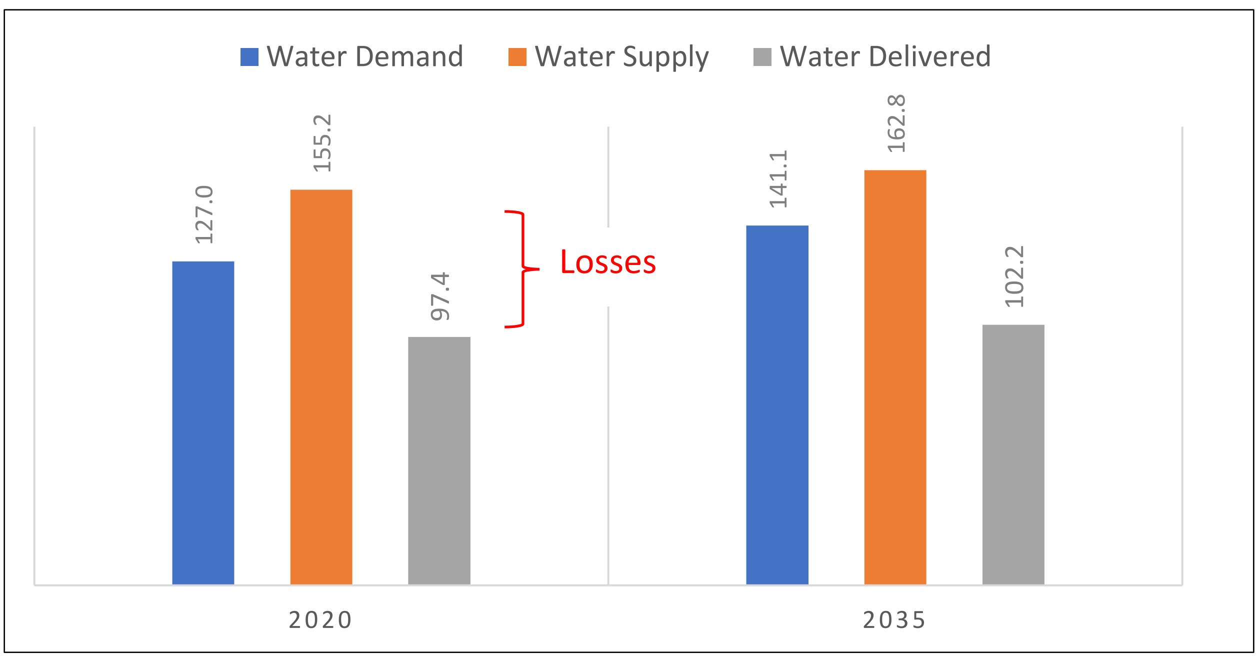

Figure 20 Coverage representation under SOCC for 2020 and 2035 (Mm³/year)

This unmet demand is shared between different systems, as represented in Figure 21. Being Aarsal, Laboueh, Baalbeck - Aamechki & Ain Bourday, and other systems affected by shortages. With regards to the irrigation sector, Figure 22 shows the corresponding unmet demand, mainly composed of the Yammouneh Irrigation Zone (IR01) and Qaa Irrigation Zone (IR07). Additionally, Figure 23 shows the comparison between the WS and Irrigation Zones.

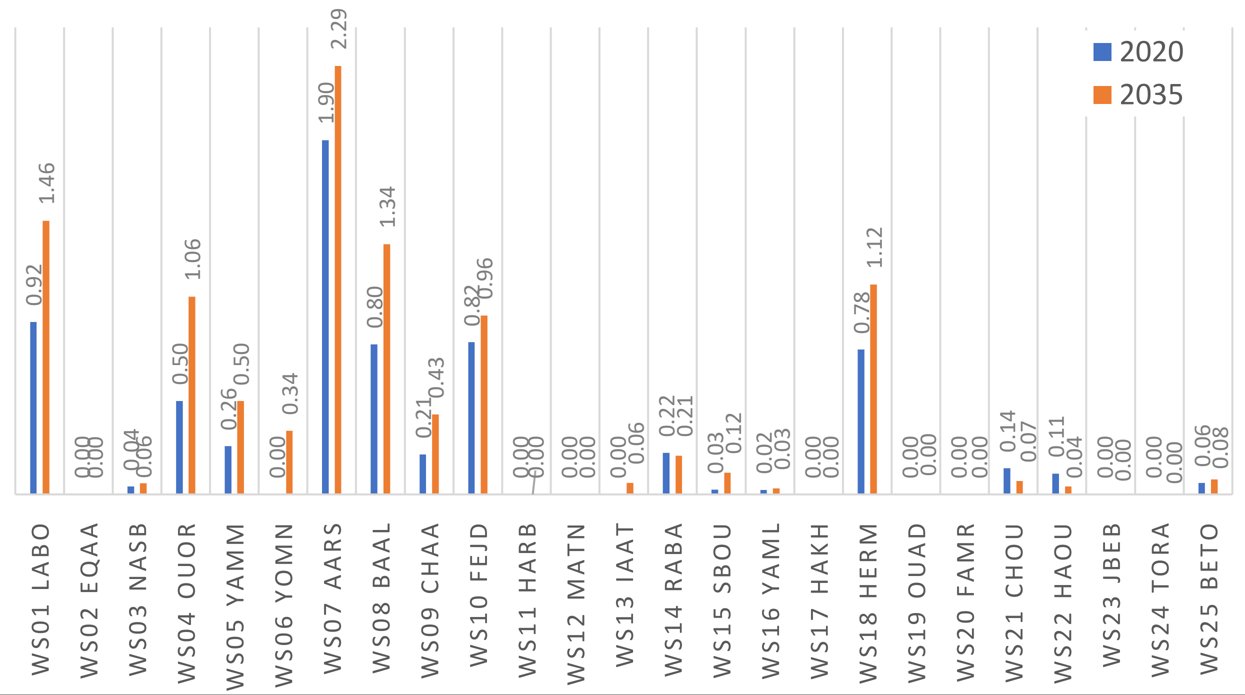

Figure 21 WS Unmet Demand under S0CC for 2020 and 2035 (Mm³/year)

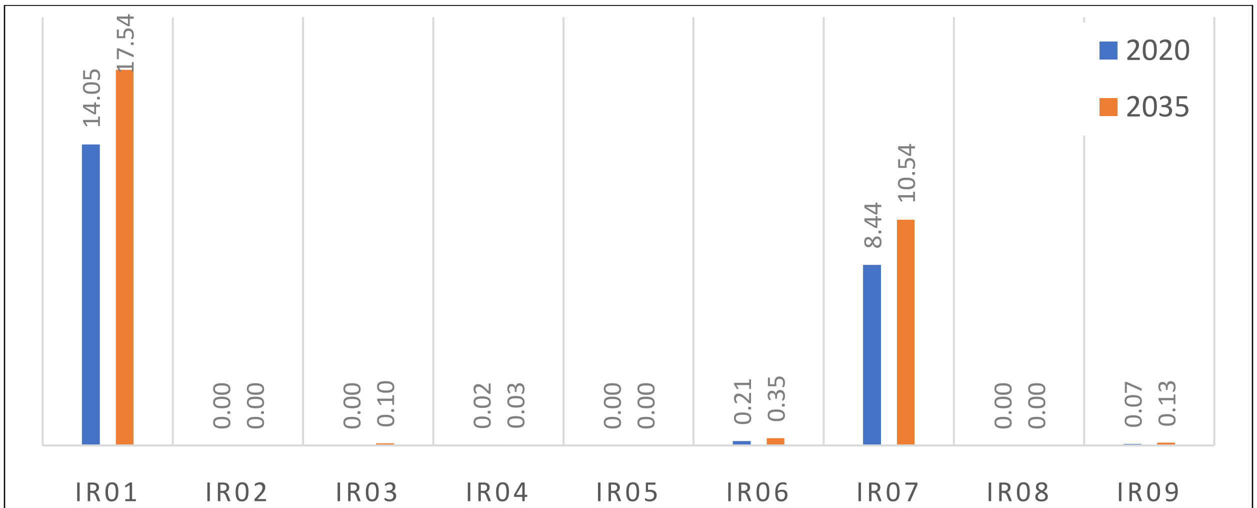

Figure 22 Irrigation Unmet Demand under S0CC for 2020 and 2035 (Mm³/year)

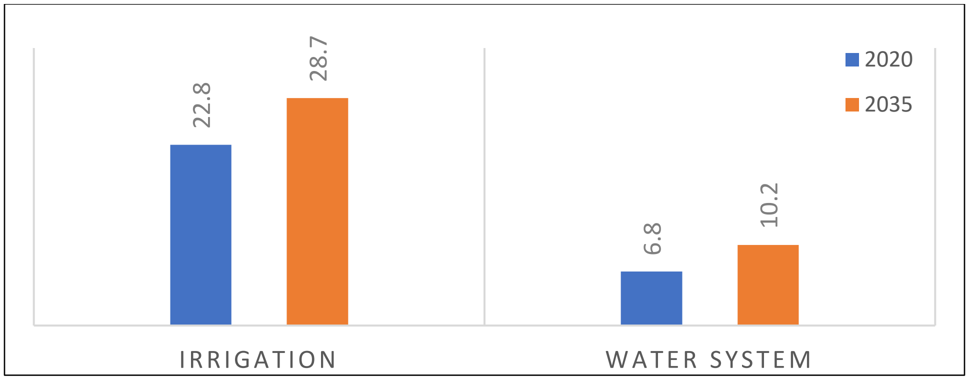

Figure 23 Comparison of total water demand by sector under S0CC for 2020 and 2035

6.1.2.2 S3CC – Agriculture expansion and intensification scenario under Climate Change

Within this scenario, agriculture demand is increased due to an expansion of the number of hectares requiring irrigation and an intensification of the crop rotation within each parcel. The expansion mainly occurs in irrigation zones IR07, IR08 and IR09 around Qaa and Hermel, while the intensification occurs throughout the catchment. Resulting values are shown in Table 12 (SCIR2) and the coverage in Figure 24. The Total Coverage of S3CC drops to 60%.

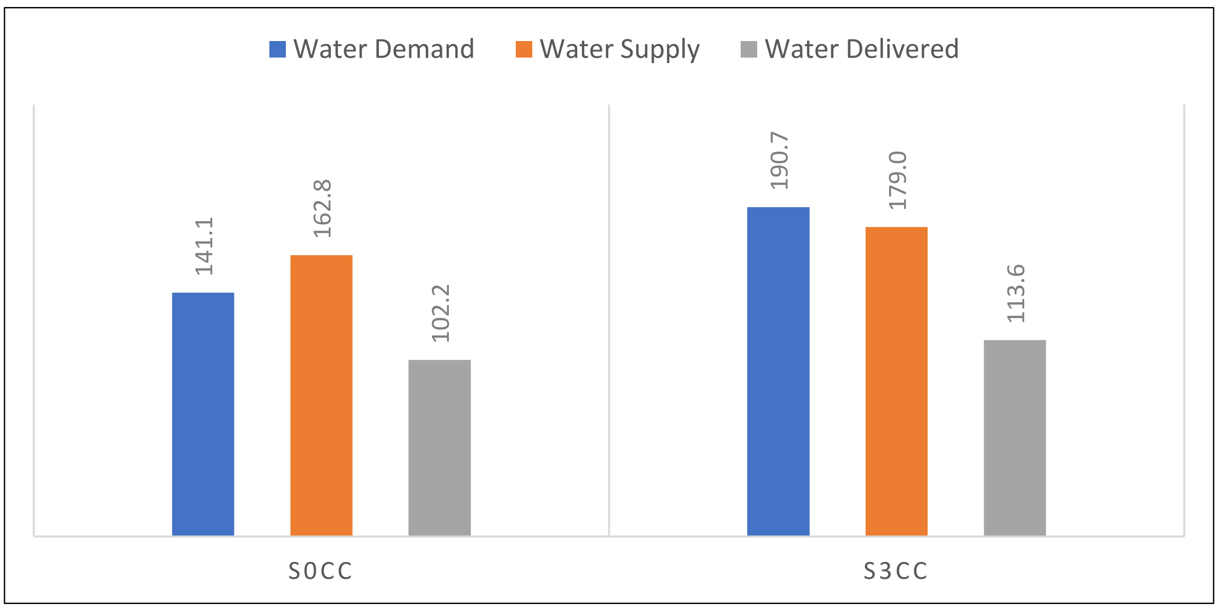

Figure 24 Coverage representation under S0CC and S3CC for 2035 (Mm^3/year)

6.1.2.3 S4CC – NWSS scenario under Climate Change

To deal with this unmet demand, several measures were proposed and described in the previous sections. Within the WEAP model, we have included the following:

- Losses reduction from 50% to 25%
- Additional supplies:
- Assi dams:
- Phase 1 = 63 Mm^3/year as a diversion.
- Phase 2 = 37 Mm^3/year as a reservoir.
- Younine dam: 5.8 Mm^3/year
- Wells supplying the following systems:
- WS01 LABO
- WS07 AARS
- WS16 YAML
- WS25 BETO
- Wastewater Treatment Plants outflow reuse for Irrigation purposes (80%)
- A safe yield limit to promote sustainable groundwater abstraction, based on a bibliography review set to be 75% of the recharge of each aquifer.

Figure 25shows the Assi dams included in the model, while Figure 26shows the different WWTP and their reuse for irrigation.

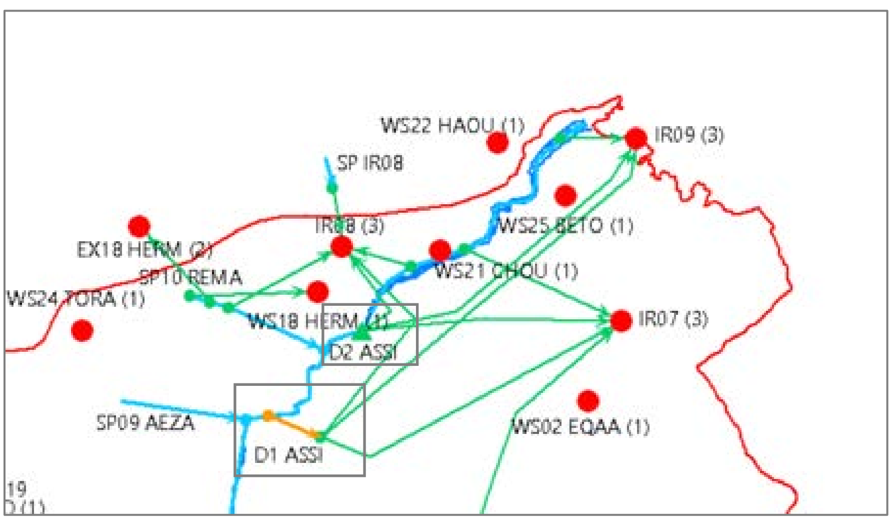

Figure 25 NWSS measures - Assi dams

As a result, from these additions, the unmet demand was reduced significantly, however there are still some water systems presenting unmet demand as well as the Yammouneh irrigation zone (IR01). Since the baseline scenario under climate change is not modified for 2020 within the scenarios, we will only present the changes for 2035.

Figure 27 shows the increase of supply as part of the measures and the important of the effect of reducing losses within ARB coverage. As a result, the total coverage is the following:

- Total Coverage S4CC = 84%
- Total Unmet Demand S4CC = 30 Mm^3/y

These coverages and unmet demands do account for losses.

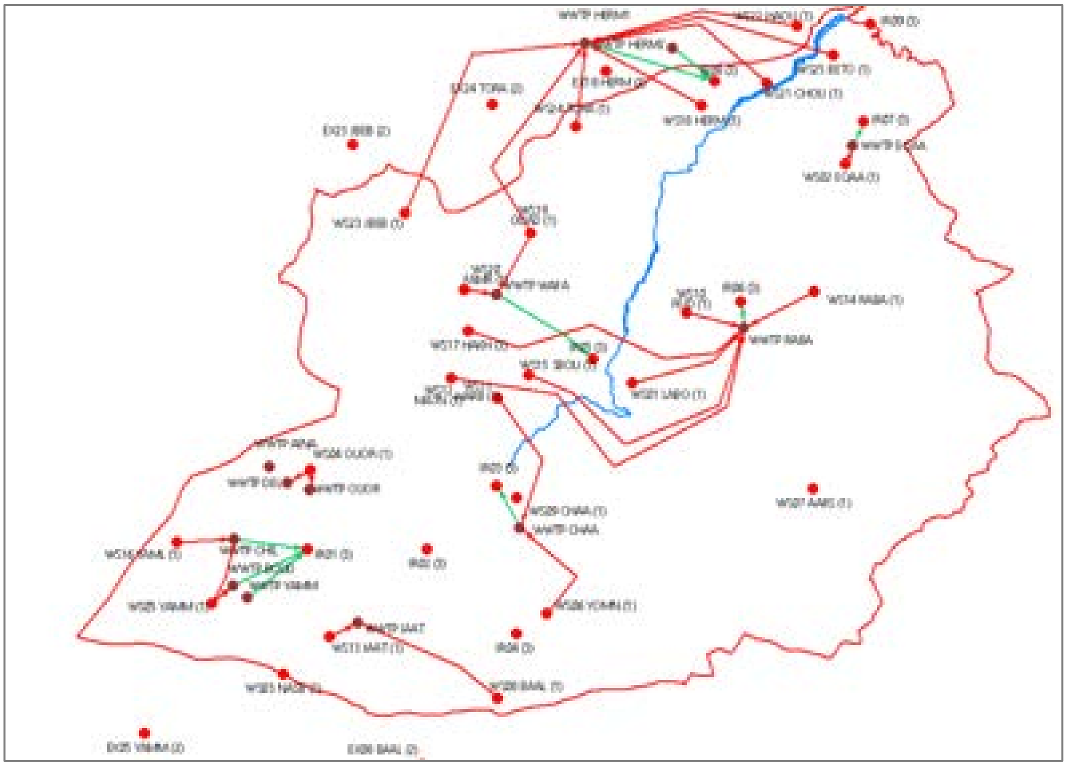

Figure 26 NWSS measures - WWTP outflows for reuse

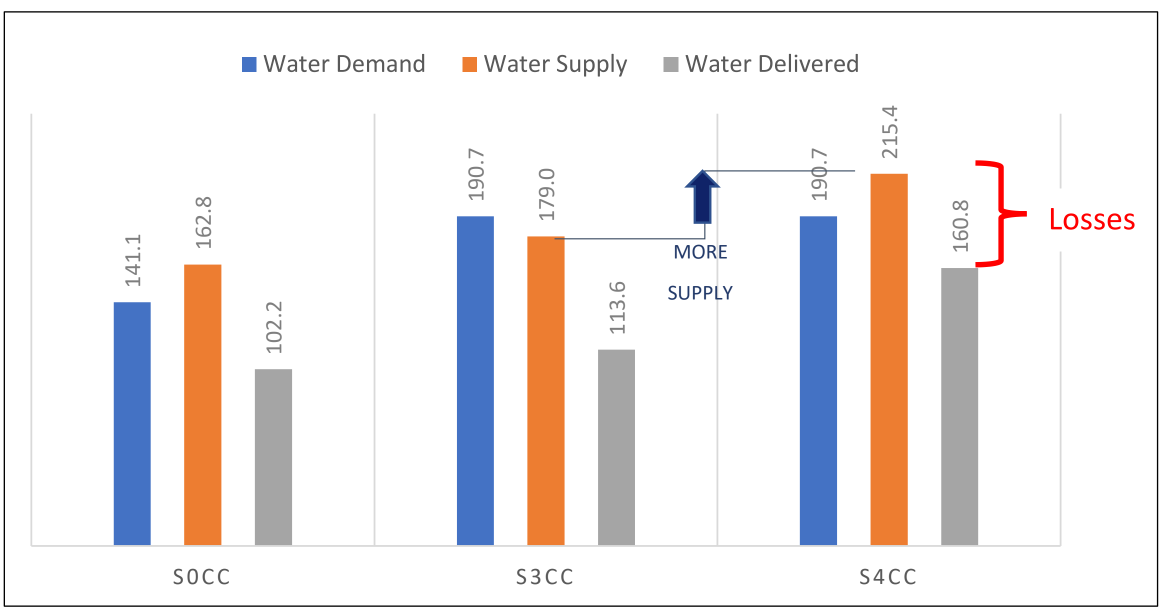

Figure 27 Coverage representation under S0CC, S3CC and S4CC for 2035 (Mm^3/year)

It is worth mentioning as well that the addition of the Safe Yield criteria for sustainable groundwater abstraction did not limit the current use.

Within the unmet demand, the Irrigation zone of Yammouneh (IR01) accounts for 28 Mm^3/d and the Water Systems that present unmet demand can be seen in Figure 28. Figure 29 shows the comparison between the water systems and irrigation.

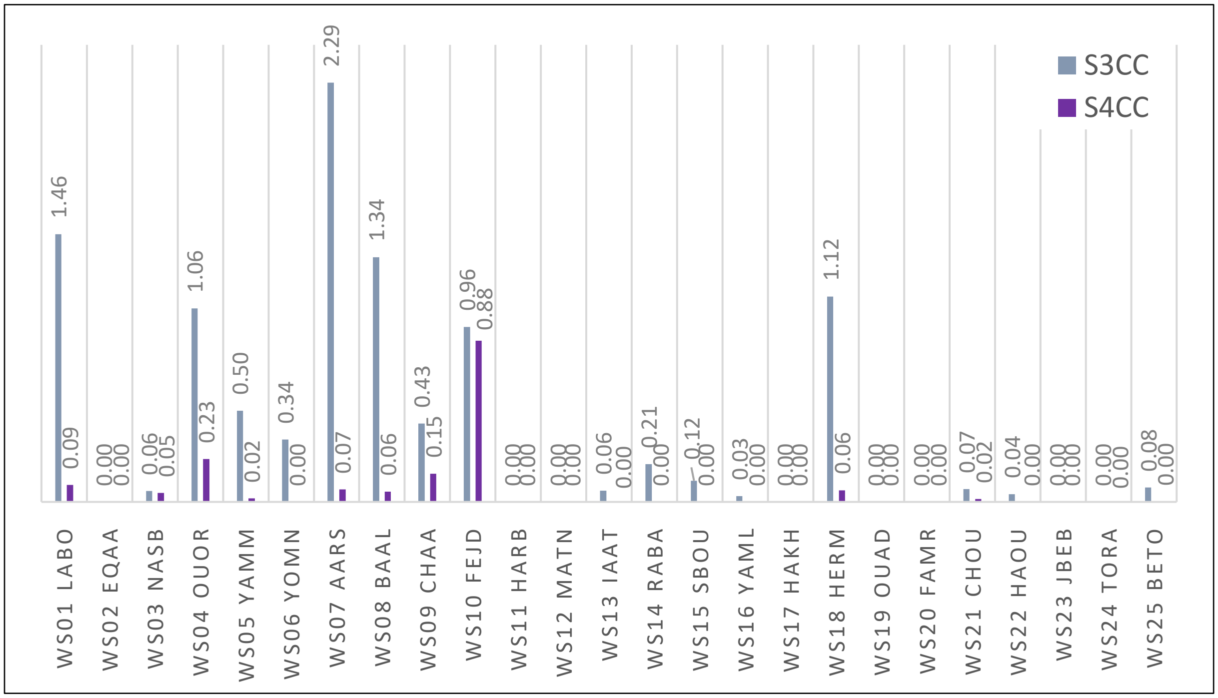

Figure 28 WS unmet demand under S3CC and S4CC for 2035 (Mm^3/year)

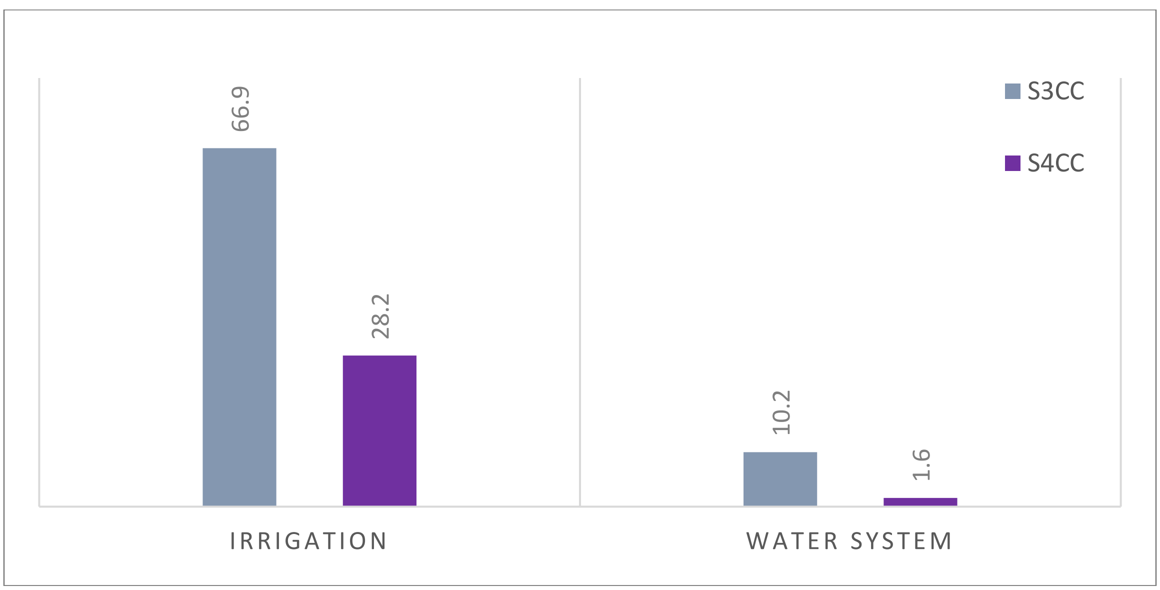

Figure 29 Comparison of total water unmet demand by sector under S3CC and S4CC for 2035

6.1.2.4 S5CC – Complete Domestic Coverage scenario under Climate Change

Several measures were proposed in addition to the ones included in the NWSS. To address the gap in the water systems' demand, the following were included:

- Water saving artifacts to reduce domestic use (25.5 % reduction)
- 5 new wells in Fekha & Jdaide, with a combined flow of 2700 m^3/d
- Additional 605 m^3/d from Fekha spring.

For the irrigation demand, additional hill lakes were proposed supplying IR01, IR03, IR04 and IR05. As a result, the coverage can be seen in Figure 30 and the improvement is the following:

- Total Coverage S5CC slightly improves to 85%

There was no significant improvement in irrigation unmet demand, as IR01 still has similar gap of 28 Mm^3/y.

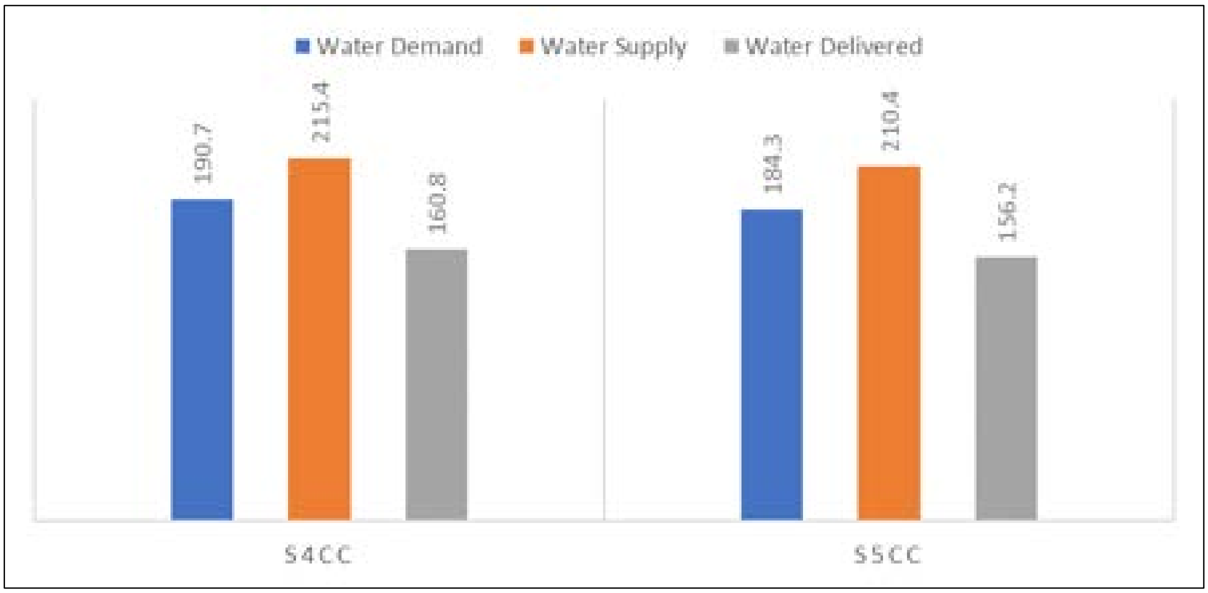

Figure 30 Coverage representation under S4CC and S5CC for 2035 (Mm^3/year)

6.1.2.5 S11CC – Crop mitigation and irrigation efficiency improvement

Within this scenario, agriculture demand is reduced due to the use of less water demanding crops and the losses are reduced through an efficiency on irrigation. Resulting values are shown in Table 12 (SCIR4) and the coverage in Figure 31.

- Total Coverage of S11CC improves to 91%

The Unmet demand of IR01(Yammouneh scheme) reduces to its half 14 Mm^3/year achieving a 75% of individual coverage.

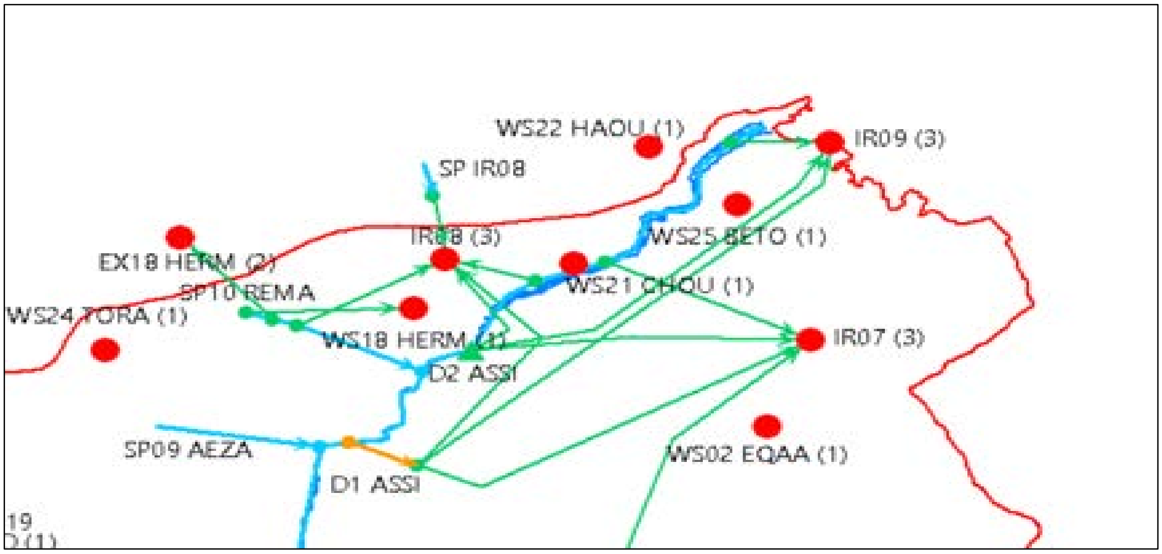

Figure 31 Coverage representation under S5CC and S11CC for 2035 (Mm^3/year)

6.1.2.6 Variation of water supply under different scenarios

The different sources of water supply have been classified into different groups. These classes vary depending on the scenarios and measures imposed.

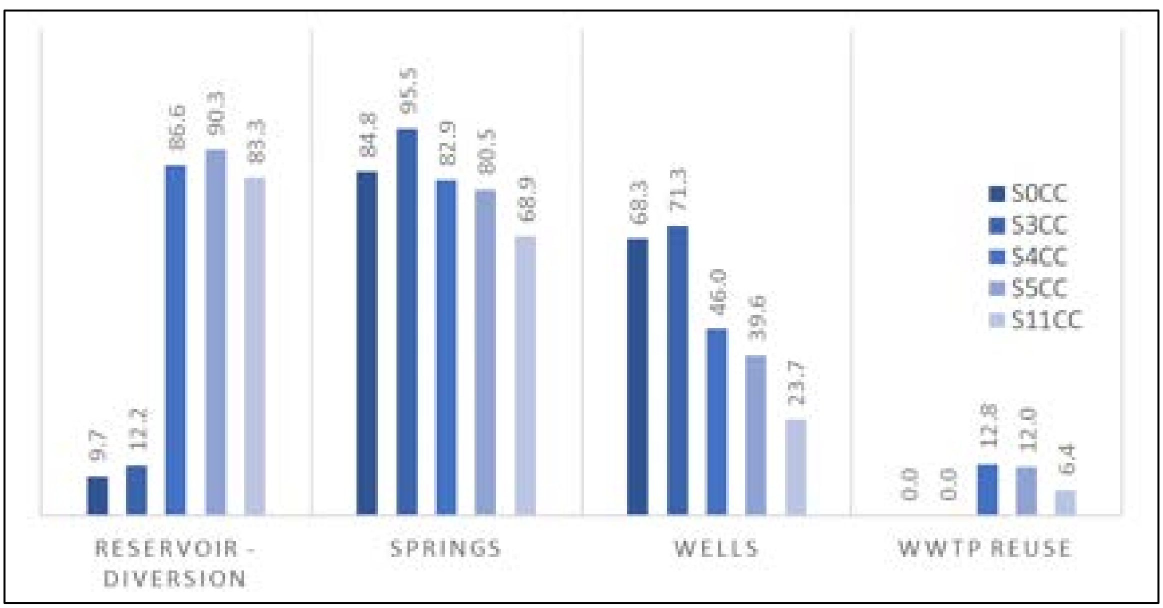

Figure 32 Water supply under S0CC, S3CC, S4CC, S5CC and S11CC for 2035 (Mm^3/year)

The resulting total supplies and coverage for 2035, under the different scenarios are the following:

- S0CC: 162.8 Mm^3/year with 72% coverage
- S3CC: 179.0 Mm^3/year with 60% coverage
- S4CC: 224.4 Mm^3/year with 84% coverage
- S5CC: 219.3 Mm^3/year with 85% coverage
- S11CC: 176.5 Mm^3/year with 91% coverage

Within the S4CC, S5CC and S11CC scenarios, in particular, it is possible to see the augmentation of reservoirs and diversions from surface water in terms of the preferred supply reducing the water pressure on private wells within the irrigation sector. In this sense, the water use from river Assi reaches a maximum of 80 Mm^3/year in scenarios S4CC and S5CC then drops to 73.2 Mm^3/year in scenario S11CC.

6.1.2.7 Summary of WEAP scenarios and results

The following Table 20 presents the main modifications within the scenarios and their impact. The modifications analyzed within each scenario represent the effect of the different measures proposed in the Action Plan.

Table 20 Summary of the WEAP scenarios and results

Combination & ID	S0CC	S3CC	S4CC	S5CC	S11CC
Business as Usual	X	X	X	X	X
Climate Change	X	X	X	X	X
Increase in Irrigation Demand		X	X	X	X
NWSS Measures			X	X	X
Complete Domestic Coverage				X	X
Irrigation Demand Mitigation					X
Main modifications	Business as Usual considering climate change effects: Water systems demand = 10% demand increase during summer Irrigation demand increase from 5621 to 6132 m^3/Ha/year	Irrigation demand increase: Intensification of crop rotation from 135% to 150% Irrigation area expansion (17.5%) in IR07, IR08 and IR 09 (Qaa and Hermel)	Network efficiency (50 to 75%) New Sources: Assi Dams: Phase 1 = 63 Mm^3/y Phase 2 = 37 Mm^3/y Younine dam = 5.8 Mm^3/y Wells supplying: WS01 LABO / WS07 AARS / WS16 YAML / WS25 BETO Safe yield limit = 75% recharge of aquifers	Water Saving artifacts = 25.5% reduction of domestic water demand 5 new wells in Fekha & Jdaide, with a combined flow of 2700 m^3/d Additional 605 m^3/d from Fekha spring Additional Hill Lakes supplying IR01, IR03, IR04 and IR05	Reduction of irrigation demand: Irrigation efficiency improved from 65% to 80% Net water requirement reduce due to crop type mitigation from 7504 to 6493 m^3/Ha/year
Water Demand Total (Mm^3/year)	141.1	190.7	190.7	184.3	162.3
Water Demand Systems (Mm^3/year)	27.5	27.5	27.5	21.1	21.1
Water Demand Irrigation (Mm^3/year)	113.6	163.2	163.2	163.2	141.2
Water Supply (Mm^3/year)	162.8	179	215.4	210.4	175.9
Water Delivered (Mm^3/year)	102.2	113.6	160.8	156.2	148
Unmet Demand (Mm^3/year)	38.9	77.1	29.9	28.1	14.3
Average coverage	72.4%	59.6%	84.3%	84.8%	91.2%
Net Present Value (M USD)	-47	-45	-241	-290	-368

7 ARB Policy Targets, Programme of Measures and Action Plan

7.1 Policy Targets and Programme of Measures

When designing a PoM, each measure comes with an associated investment cost. On top of the results of any assessment of measures, additional socio-economic factors come into interplay, such as the readiness of the technological solution, social acceptability, equitability, any constraints related to the implementation of the measures, etc. which can facilitate or impede the uptake and effectiveness of the measure. It is thus of paramount importance to stimulate a discussion with various stakeholders who bring in their local knowledge and expertise, and can verify the applicability of the findings, or highlight relevant constraints.

In this context, the objectives of the participatory approach in the ARB were:

- Assess the level of awareness of stakeholders within the basin on the problem of unmet demand and water quality, its drivers and root causes, and future projections.
- Discuss and define, together with relevant stakeholders, a bundle of measures which are deemed adequate to tackle the issues of water supply reliability and water pollution in the basin, in order to safeguard their relevance and acceptability.
- Define relevant policy targets and an associated Programme of Measures (PoMs) in ARB based on a participatory process with stakeholders from all levels (central, regional, local), and draft an Action Plan with their relevant roles.

Following the site visits, the participatory workshop, the analysis of the basin characteristics, WEAP results, and the water quality campaigns, we concluded that ARB faces several challenges that impacts its water resources and overall management, mainly:

- Groundwater Overexploitation: Excessive extraction of groundwater, often due to unsustainable water supply and unregulated private wells, lead to groundwater depletion.
- Water Scarcity: Assi experiences water scarcity and management difficulties due to increasing water demands from domestic use and agriculture. Climate change and population growth further exacerbate the scarcity issue.
- Poor Water Quality: Pollution from improper wastewater and solid waste management practices lead to water pollution and degradation of ARB water resources. This deteriorates water quality, affecting both human health and ecosystem health.
- Flood: The recurrence of flash flood events mainly in Ras Baalbek has led to grave consequences affecting the urbanized and cultivated areas in terms of property damages and, in a few cases, the unfortunate loss of human life.
- Lack of Collaboration and Integration: The absence of effective collaboration and coordination among relevant stakeholders, such as the MoE, MoEW, Municipalities, hinders comprehensive mitigation efforts.

As a result of the participatory process, a set of five (5) policy targets have been defined for the ARB. These policy targets would be subsequently addressed through a comprehensive action plan with relevant Programme of Measures. The primary purposes would be mitigating the issues of unmet demand and prevailing water stress conditions in the basin, as well as improving the water quality and limiting water pollution which can affect socio-economic growth and welfare. These are presented in Table 21 below.

Table 21 Policy targets resulting from participatory approach

Target Name	Target Code	No. of measures
Increase water use Efficiency and water Supply Reliability	ERS	11
Promote Water COnservation	WCO	2
Protection of the Water resources and the Environment	PWE	9
PARticipatory water management	PAR	3
Socio-economic DEVelopment	DEV	2

To achieve these targets, a bundle of measures has been defined for each target, spanning from technical (infrastructure) and regulatory measures, to financial, educational and socio-economic measures, and addressing multiple sectors (i.e. the urban, agricultural, industrial, touristic, environmental). A total of 27 measures have been elaborated as presented in Table 22 below.

Table 22 Programme of Measures for ARB

Measure ID	Name of the Measure	Category	Sector
Measures linked to the target "Increase water use efficiency and water supply reliability" (ERS)"			
ERS_U1	Actions to modernize the operation of water supply networks and improve water efficiency	Infrastructure	Urban
ERS_U2	Drafting / Updating of the BWE Water Supply Masterplan	Regulatory	Urban
ERS_A1	Irrigation network modernization and maintenance projects	Infrastructure	Agriculture
ERS_A2	Construction of Irrigation dams (Assi phase I & II, Younine)	Infrastructure	Agriculture
ERS_A3	Natural Water Retention Measures (NWRM) for agricultural, including Community Hill Lakes and flash floods retention lakes	Infrastructure	Agriculture
ERS_A4	Thresholds of the required quantities of irrigation water	Regulatory	Agriculture
ERS_M1	Water metering and subscription to BWE, flow meters for irrigation water	Infrastructure	Mix
ERS_M2	Reuse of treated wastewater for agricultural uses	Infrastructure	Mix
ERS_M3	Regulating water tariffs, achieving cost recovery	Regulatory	Mix
ERS_M4	Monitoring and control of illegal abstractions and private wells, and definition of safe yield per groundwater body	Regulatory	Mix
ERS_M5	Technical specifications for wastewater reuse	Regulatory	Mix
Measures linked to the target "Promote Water Conservation (WCO)"			
WCO_U1	Water saving in households and buildings (public, commercial)	Infrastructure	Urban
WCO_A1	Subsidies for change of irrigation systems	Financial	Agriculture
Measures linked to the target "Protection of the Water resources and the Environment (PWE)"			
PWE_U1	Conduct necessary environmental studies	Regulatory	Urban
PWE_U2	Drinking water protection perimeters	Regulatory	Urban
PWE_U3	Municipal solid waste management	Regulatory	Urban
PWE_E1	Flood protection and mitigation (check dams, reforestation, …)	Infrastructure	Environment
PWE_E2	Quantitative and qualitative water resources monitoring programme, Meteorological and Hydrometric network expansions and improvement	Infrastructure	Environment
PWE_E3	Register of all pollution sources, estimation of pollution loads, assessment of significant pressures, and control of illegal dumping activities	Regulatory	Environment
PWE_E4	Support fish feed as alternative to contaminating feed	Financial	Environment
PWE_UI1	Wastewater collection and treatment, maintenance of existing WWTP	Infrastructure	Urban, Industry
PWE_UI2	Drafting/Updating of BWE Wastewater Masterplan	Regulatory	Urban, Industry
Measures linked to the target "Participatory Water Management (PAR)"			
PAR_M1	Development of Al Assi River Basin Committee	Regulatory	Mix
PAR_M2	Raising awareness and sensitizing the community on the water resources and environmental related issues in Al Assi	Education	Mix
PAR_M3	Strengthen environmental program actions in primary education	Education	Mix
Measures linked to the target "Socio-Economic Development (DEV)"			
DEV_M1	Capacity building activities	Education	Mix
DEV_T1	Promotion of eco-tourism	Socio-Economic	Tourism

7.1.1 Urban sector

Measure ID and Name	ERS_U1: Actions to modernize the operation of water supply networks and improve water efficiency
Description	This measure focuses on modernizing the operation of water supply networks and improving water efficiency through the use of advanced technologies, upgraded infrastructure, and optimized operations. It aims to reduce water losses and enhance overall water management practices to achieve more sustainable water use. It includes: Leakage detection and control, rehabilitation of existing networks (incl. storage reservoirs), expansion of the BWE water supply network branches and connections. Improving network efficiency from 50% to 75%. The installation of solar panels in pumping stations is to be assessed.
Target	Residents, Municipalities, BWE
Activity Breakdown	In the Updated NWSS - 2020, there is a number of proposed rehabilitation/ expansion projects for BWE (see section 4.3). It includes the implementation of new distribution networks, wells, storage reservoirs, pumping stations, treatment plant, etc. until 2035. In summary, the proposed projects in Baalbek district include: - 131.5 km of transmission lines, - 346 km distribution network (priority 2) - 9 wells to be drilled and equipped, - 23 reservoirs to be constructed, - 63 old reservoirs to be rehabilitated, - 1 new tunnel, - 1 new WTP. The proposed projects in Hermel district include: - 22.5 km of transmission lines, - 100 km distribution network (priority 2) - 1 well to be drilled and equipped, - 1 well to be equipped and a new control room to be built, - 4 reservoirs to be constructed, - many old reservoirs to be rehabilitated, - 1 spring to be rehabilitated, - 1 well and PS to be rehabilitated. Moreover, the implementation of SCADA and DMA systems is suggested to connect all the components and facilitate the control and monitoring.
Timespan/Timeline	Medium - Long term, planned to be executed before 2035. Once the measure is implemented the expected results/impact will be immediate.
Budget breakdown	CAPEX Baalbek 69,485,000 USD Hermel 27,007,300 USD Total ARB 96,492,300 USD

<table>
<tr><td>Constraints</td><td>Financial constraints, Stakeholder resistance</td></tr>
<tr><td>Measure ID and Name</td><td>ERS_U2: Drafting / Updating of the BWE Water Supply Masterplan</td></tr>
<tr><td>Description</td><td>Drafting/updating of the BWE Water Supply Masterplan to meet water supply needs in the medium and long term</td></tr>
<tr><td>Target</td><td>Residents, Residential areas, households, BWE</td></tr>
<tr><td>Activity Breakdown</td><td>Both the MoEW and BWE are responsible for establishing long term consolidated planning for water, irrigation and wastewater

Act 1: Review existing policies and regulations
Act 2: Conduct water demand assessment
Act 3: Evaluate water supply
Act 4: Develop wastewater management plan
Act 5: Engage stakeholders
Act 6: Develop implementation strategies</td></tr>
<tr><td>Timespan/ Timeline</td><td>Short term
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th></tr>
<tr><td>1</td><td>Review existing policies and regulations</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Conduct water demand assessment</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Evaluate water supply</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Develop wastewater management plan</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Engage stakeholders</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Develop implementation strategies</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>Cost of the Masterplan: internal work of the engineers of the BWE
Subcontracting cost for specific expertise</td></tr>
<tr><td>Constraints</td><td>Financial crisis, Stakeholder resistance, BWE shortage of staff</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>ERS_M1: Water metering and subscription to BWE, flow meters for irrigation water</th></tr>
<tr><td>Description</td><td>Water metering is essential to identify how much water is actually used/ consumed in households, commercial or public buildings, etc., and thus better plan water allocation. Subscribing to the BWE can support better water supply management, and increase of the economic resources for the rehabilitation or expansion of water supply networks. Includes: installation of water meters in households, public buildings (e.g. schools), camps, commercial buildings.

This measure also includes the installation of district water meters to monitoring main transmission and distribution lines in order to better control the distribution and address leakage issues.

Approximately 38,000 meters have been installed within BWE, but billing made on a flat rate. Only 3,000 meters are read for monitoring purpose.</td></tr>
<tr><td>Target</td><td>Residents, farmers, cultivation schemes, BWE</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Identify water users
Act.2: Conduct site assessments
Act.3: Design the metering system
Act.4: Procure equipment
Act.5: Install water meters and flow meters
Act.6: Train water users
Act.7: Integrate with billing system
Act.8: Monitor and maintain</td></tr>
<tr><td>Timespan/ Timeline</td><td>Medium term
Once the measure is implemented the expected results/impact will be immediate. Yet, this requires that the meters’ measurements are read at regular basis and the respective volumes recorded are properly organized into a central database. Automatic data acquisition systems can be installed to facilitate the activity.

<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th><th>Month 7</th><th>Month 8</th><th>Month 9</th><th>Month 10</th><th>Month 11</th><th>Month 12</th></tr>
<tr><td>1</td><td>Identify water users</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Conduct site assessments</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Design the metering system</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Procure equipment</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Install water meters and flow meters</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Train water users</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Integrate with billing system</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>Monitor and maintain</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>Installation of 25,000 Service Connections + 75,000 Water Meters shall be foreseen. The associated investment cost is 40,000,000$
O&M is the responsibility of the BWE.</td></tr>
<tr><td>Constraints</td><td>Financial, infrastructure limitations, cost implications, lack of awareness, lack of political will.</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>ERS_M3: Regulating water tariffs, achieving cost recovery</th></tr>
<tr><td>Description</td><td>Water pricing reform usually involves a modification in the rate structure and/or the water tariffs in order to influence the consumers' water use. This economic instrument needs a very careful design as it can easily raise conflicts among users and trigger many disputes. It also must be noted that there is always a price elasticity that needs to be considered, and that beyond a certain threshold any further increase in water price might not bring any further decrease in the water consumption. Includes: Establishment of Volumetric water tariffs.</td></tr>
<tr><td>Target</td><td>BWE, MoEW, NGOs, CSOs, Residents/Municipalities</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Review existing tariff structure
Act.2: Conduct a cost-of-service study
Act.3: Develop alternative tariff scenarios
Act.4: Stakeholder engagement
Act.5: Establish volumetric water tariffs
Act.6: Monitor and evaluate</td></tr>
<tr><td>Timespan/Timeline</td><td>Short term
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th></tr>
<tr><td>1</td><td>Review existing tariff structure</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Conduct a cost-of-service study</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Develop alternative tariff scenarios</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Stakeholder engagement</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Establish volumetric water tariffs</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Monitor and evaluate</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>The CAPEX is related to the installation of water meters in order to be able to apply volumetric pricing.
Also, a water pricing elasticity study to establish fair and equitable water tariffs, which also achieved costs recovery, is necessary, which has some associated cost if additional experts, outside the BWE staff, are used.</td></tr>
<tr><td>Constraints</td><td>Political consideration, resistance from stakeholders, legal and regulatory framework, lack of data,</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>WCO_U1: Water saving in households and buildings (public, commercial)</th></tr>
<tr><td>Description</td><td>A variety of available technologies designed to deliver domestic water saving targeting the urban water uses (e.g. low flow flush, taps and showerhead, aerators, etc.) can be installed in households, offices, schools, hospitals, public buildings, etc.</td></tr>
<tr><td>Target</td><td>Residents, households, BWE</td></tr>
<tr><td>Activity Breakdown</td><td>The purchase and installation of the water saving fixtures in the households can be undertaken by the households, or the municipalities, or the BWE, or the MoEW, or NGOs, depending on funding mechanisms (e.g. subsidies, reduction in water fees, donors’ funds, etc.)

The operation and good maintenance of the fixtures is the responsibility of the household or public building operators and end-users (in case of schools, etc.)</td></tr>
<tr><td>Timespan/Timeline</td><td>Short-Medium term.
Once the measure is implemented the expected results/impact will be immediate.</td></tr>
<tr><td>Budget breakdown</td><td>CAPEX varies from 2.5 million USD to 70 million USD depending on the solution/ measures applied and target reduction in the unmet demand that is aimed to achieve.
The CAPEX needs to be paid up-front, either by each household or through Programmes, incentives, subsidies, etc.
<table>
<tr><th>Total CAPEX ($)</th><th>Water saving ($Mm^3$)</th><th>Water Saving per HH (%)</th><th>Shower Heads (1 Item)</th><th>Dual Flash Toilet</th><th>Low flow taps (2 Items)</th><th>Efficient Washing Machine</th><th>Dish Washer</th></tr>
<tr><td>$ 2,500,260</td><td>3.9</td><td>20.4%</td><td>X</td><td></td><td></td><td></td><td></td></tr>
<tr><td>$ 6,667,360</td><td>5.1</td><td>26.9%</td><td>X</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>$ 16,668,400</td><td>5.8</td><td>30.0%</td><td>X</td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>$ 20,835,500</td><td>7.0</td><td>37.0%</td><td>X</td><td>X</td><td>X</td><td></td><td></td></tr>
<tr><td>$ 70,840,700</td><td>8.1</td><td>42.5%</td><td>X</td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td>$ 129,180,100</td><td>8.9</td><td>46.5%</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
</table>
Table 23 Annual Equivalent Cost (AEC) of the urban demand management measures based on a 7% discount rate
<table>
<tr><th>Water Saving Measure</th><th>Unit Cost $</th><th>N (Useful life in years)</th><th>AEC ($)</th></tr>
<tr><td>Dual Flush Toilet</td><td>$ 170</td><td>7</td><td>$ 32</td></tr>
<tr><td>Showerheads (1 item)</td><td>$ 30</td><td>3</td><td>$ 11</td></tr>
<tr><td>Low flow taps (2 items)</td><td>$ 50</td><td>3</td><td>$ 19</td></tr>
<tr><td>Efficient washing machine</td><td>$ 600</td><td>7</td><td>$ 111</td></tr>
<tr><td>Dishwasher</td><td>$ 700</td><td>7</td><td>$ 130</td></tr>
<tr><td>TOTAL</td><td></td><td></td><td></td></tr>
<tr><td>Per household (HH)</td><td>$ 1,550</td><td></td><td>$ 303</td></tr>
<tr><td>Per capita (cap)</td><td>$ 310</td><td></td><td>$ 61</td></tr>
</table>
</td></tr>
<tr><td>Constraints</td><td>Cost consideration, lack of awareness, resistance to change, lack of incentives</td></tr>
</table>

Toilet flushes, usually accounting for one third of the domestic water use on average can deliver reductions up to 50% of the water used. Common options include the replacement of older style single-flush models (14 lt/flush) with low-flush gravity toilets (6 lt/flush), dual-flush valve operated toilets (4 lt/flush), air-assisted pressurised toilets (2 lt/flush). Evidence exists that flush volumes down to 4 lt do not cause any problems in the drains and sewers in terms of the waste disposal.

Taps and Showerheads can be adjusted and render saving by installing water saving devices and inexpensive retrofits. Various options are available for retrofitting kitchen and bathroom taps, which are estimated to account for more than 15% of domestic indoor use, with respective savings of 20-30% and less than 2 years paybacks: fitting of new water efficient tap-ware (spray taps, push taps, etc.), low-flow aerators, durable tap washers, flow restrictors and regulators, automatic shutoff. Showerheads are usually gravity fed, electric or pumped (power showers). The average consumption of showers ranges across the households as it depends on many interrelated factors: frequency of use (from 0.75-2.5 showers/day) average shower time duration (2-5 minutes), type of shower, flow rate (6-16 lt/minute), etc. Yet, evidence exists that showers and baths account for 20-35% of the household water consumption and installing water saving devices (flow restricting devices, low-flow showerheads - aerating or laminar-flow, cut-off valves, etc.) can secure around 30-40% water savings. It worth mentioning that the expected savings from the installation of smart water saving devices in taps and showerheads is also highly influenced by the use patterns and habits of the users.

Washing Machines and Dishwashers can be replaced with more efficient ones delivering water and energy savings. Washing of clothes is probably the third largest consumer of domestic water, around 20%. Installing high-efficient washing machines can save up to 40% of the volume need per cycle. Modern washing machines use about 50 lt/cycle or 35 l/cycle for the most efficient ones, as opposed to 150 lt/cycle in the 1990's, due to technological advances (i.e. intelligent sensor systems, advanced and customized washing programmes, improved time functions, etc.). Dishwashers manufactured prior to the year 2000 typically consume 15-50 lt/load, while modern dishwashers consume 7-19 lt/load under normal setting and as low as 8-12 lt/load under the eco-setting, which means average water savings at the range of 40-60%. The share of water use consumed by dishwashers varies from 6-14% as it depends on the cycle time, the frequency of use and their degree of penetration in the households, the latter being influenced by e.g. lack of space, conception that this investment is not necessary due to small load of dishes feasible to be hand-washed, etc.

Water pricing reform usually involves a modification in the rate structure and/or the water tariffs in order to influence the consumers' water use. It often includes the shifting from decreasing block rates to uniform block rates, the shifting from uniform rates to increasing block rates, the increasing of rates during summer months, or the imposing excess-use charges during times of water shortage. This economic instrument needs a very careful design as it can easily raise conflicts among users and trigger many disputes.

Measure ID and Name	**PWE_U1: Conduct necessary environmental studies**
Description	Screening from Ministry of Environment, and conduct EIA studies where required
Target	MoE, BWE, MoEW, Municipalities, NGOs/CSOs
Activity Breakdown	In reference to decree 8633/2012, principles of Environmental Impact Assessment studies, conducting screening for all new components of the water supply systems to be implemented; Conducting IEE and EIA for all required infrastructures (WTP, WWTP, Hill lakes, etc.)
Timespan/Timeline	Medium term Once the measure is implemented the expected results/impact will be immediate
Budget breakdown	Variable per study
Constraints	Time constraint, lack of awareness

<table>
<tr><th>Measure ID and Name</th><th>PWE_U2: Drinking water protection perimeters</th></tr>
<tr><td>Description</td><td>Detailed demarcation of protection zones around groundwater abstraction points (springs, wells) for water abstraction > 1,000,000m³ per year</td></tr>
<tr><td>Target</td><td>MEW, BWE, NGOs/CSOs</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Vulnerability and risk assessment
Act.2: Demarcation of protection zones
Act.3: Development of protection plans
Act.4: Enforcement and control
Act.5: Awareness-raising</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th></tr>
<tr><td>1</td><td>Vulnerability and risk assessment</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Demarcation of protection zones</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Development of protection plans</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Enforcement and control</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Awareness-raising</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>Budget breakdown</td><td>Internal staff work of MoEW
Study costs if a relevant study is sub-contracted</td></tr>
<tr><td>Constraints</td><td>Legal and regulatory framework, lack of awareness</td></tr>
</table>

Measure ID and Name	**PWE_U3: Municipal solid waste management**
Description	Solid waste management is limited to municipalities and usually in exposed dumpsites. Out of the 39 dumpsites, only 24 are operational, and out of the operational 9 are located in private lands and the remaining 15 are situated in communal land (e.g., Mashaa land belonging to the monasteries).
Target	BWE, Municipalities, MoEW, MoE, MoA, MoH, NGOs/CSOs.

<table>
<tr><td>Activity Breakdown</td><td>Includes: Development of action plans for the rational management of municipal waste in settlements not served by central waste disposal facilities. Identification of financial resources for the implementation of the action plans
Act.1: Assessment of existing solid waste management practices and infrastructure
Act.2: Identification of suitable sites
Act.3: Development of solid waste management plan
Act.4: Establishment of collection systems
Act.5: Implementation of waste segregation and awareness campaigns
Act.6: Procurement and installation of equipment and facilities
Act.7: Monitoring and enforcement of waste management regulations
Act.8: Closure and rehabilitation of existing dumpsites
Act.9: Monitoring and maintenance of new waste management facilities</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th><th>Sem. 2</th><th>Sem. 3</th><th>Sem. 4</th></tr>
<tr><td>1</td><td>Assessment of existing solid waste management practices and infrastructure</td><td>■</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Identification of suitable sites</td><td></td><td>■</td><td>■</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Development of solid waste management plan</td><td></td><td>■</td><td>■</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Establishment of collection systems</td><td></td><td></td><td>■</td><td>■</td><td>■</td><td>■</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Implementation of waste segregation and awareness campaigns</td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Procurement and installation of equipment and facilities</td><td></td><td></td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td>■</td></tr>
<tr><td>7</td><td>Monitoring and enforcement of waste management regulations</td><td></td><td></td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td>■</td></tr>
<tr><td>8</td><td>Closure and rehabilitation of existing dumpsites</td><td></td><td></td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td>■</td></tr>
<tr><td>9</td><td>Monitoring and maintenance of new waste management facilities</td><td></td><td></td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td>■</td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>The budget for municipal solid waste management can vary widely depending on the specific needs and circumstances of the municipality, and the range of the budget breakdown provided earlier reflects this variability. The total budget for municipal solid waste management can range from 650,000 USD to 3,000,000 USD excluding the dumpsite construction.</td></tr>
<tr><td>Constraints</td><td>Limited facilities, lack of awareness, institutional and governance challenges, financial.</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>PWE_UI1: Wastewater collection and treatment, maintenance of existing WWTP</th></tr>
<tr><td>Description</td><td>Expansion of the BWE wastewater collection network.
Assessment of the current operational status and capacities of existing WWTPs and identification of necessary actions for their proper operation. Building of new WWTPs.
There is no wastewater collection service within ARB except for Iaat WWTP collecting Baalbek sewer. However, residents use septic tanks or dispose waste directly in the streams.
Also, many of the septic tanks do not have proper technology and the cost of building one is very high for the people in this area (~ 15,000-20,000 $ for a 3-compartments tank), so there is need to find alternative cheap ways.</td></tr>
<tr><td>Target</td><td>Residents, Residential areas, BWE</td></tr>
<tr><td>Activity Breakdown</td><td>Act 1: Assessment of the current wastewater infrastructure, networks and WWTP and their operational status.
Act 2: Identification and prioritization of necessary actions
Act 3: Design of new collection networks and WWTP
Act 4: Rehabilitation and expansion of existing collection networks and construction of WWTP as cited in Table 15 section 4.3.</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be immediate.
<table>
<tr><th>Activity</th><th>Description</th><th>Year 1</th><th>Year 2</th><th>Year 3</th><th>Year 4</th><th>Year 5</th><th>Year 6</th></tr>
<tr><td>1</td><td>Assessment of the current wastewater infrastructure, networks and WWTP and their operational status.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Identification and prioritization of necessary actions</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Design of new collection networks and WWTP</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Rehabilitation and expansion of existing collection networks and construction of WWTPs</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>According to the Updated NWSS 2020, the total cost of the wastewater projects in the BWE District of Baalbek and Hermel amount to 303 million USD and will serve a population of 635,838 people. Thus, the ratio of projects cost per capita is estimated at 569 USD/capita.
O&M cost 11,5 million USD</td></tr>
<tr><td>Constraints</td><td>Financial, political resistance, operation and maintenance, lack of awareness</td></tr>
</table>

Measure ID and Name	PWE_UI2: Drafting/Updating of BWE Wastewater Masterplan
Description	Drafting/updating of the BWE Wastewater Collection and Treatment Masterplan to meet future needs in the medium and long term
Target	All main stakeholders agree on the institutional framework that is based on the responsibility of WE for managing wastewater system. However, the effective framework for wastewater management is not clear and needs to be refined.

<table>
<tr><td></td><td>Several actors may be involved in wastewater management (WEs, municipalities, and private operators) but the process of identifying modalities of involvement and the financing method still needs to be defined.

MEW: According to Law 221 and its amendments by Law 241 (7/08/2000) and Law 377 (14/12/2001), the MoEW has (among its other missions) to prepare and continuously update the National Water and Wastewater General Master Plan and submit it through the Minister for approval by the Council of Ministers

BWE: Develop and implement Wastewater Collection and Treatment Masterplan
Municipalities: provide data on any current municipal waste collection and treatment systems</td></tr>
<tr><td>Activity Breakdown</td><td>The activity breakdown for drafting/updating the BWE Wastewater Collection and Treatment Masterplan:

Act. 1: Data collection and analysis
Act. 2: Technical and financial feasibility studies
Act. 3: Stakeholder consultations
Act. 4: Development of wastewater treatment options
Act. 5: Development of wastewater collection options
Act. 6: Cost-benefit analysis
Act. 7: Drafting of the wastewater masterplan
Act. 8: Review and approval process</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th><th>Month 7</th><th>Month 8</th></tr>
<tr><td>1</td><td>Data collection and analysis</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Technical and financial feasibility studies</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Stakeholder consultations</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Development of wastewater treatment options</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Development of wastewater collection options</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Cost-benefit analysis</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Drafting of the wastewater masterplan</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>Review and approval process</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>Internal staff resources of BWE
Subcontracting costs if the study needs to be supported by external consultants
In the NWSS, in the Water Governance Priority Action Plan the adoption of a shared wastewater management framework is planned, with goals to address the issue of the organization(s) responsible for managing the WW network and treatment plants (WEs, municipalities, private operators.) and determine the financing method (estimated cost 250,000$ for all Lebanese territory)</td></tr>
<tr><td>Constraints</td><td>Financial, stakeholder engagement, regulatory framework, lack of will</td></tr>
</table>

7.1.2 Agricultural sector

The main options for reducing irrigation demand are linked to decreasing losses and increasing the irrigation efficiency, i.e. conveyance and field application efficiency. This is generally achieved by replacing open channels with closed pipes, by switching to drip irrigation and/or sprinklers from furrow irrigation systems, by implementing precision agriculture, and by applying deficit irrigation. However, besides the areas of formal collective irrigation networks, additional self-supplied irrigated areas often exist, and illegal abstractions (illegal wells) might also be a problem. The main options to increase water supply for agricultural purposes is to retain water in detention basins and retention ponds.

Replacing open channels with closed pipes targets to reduce leakage and increase conveyance efficiency. Water conveyance loss consists mainly of operation losses, evaporation, and seepage into the soil from the sloping surfaces and bed of the canal. Open channel networks are usually characterized by high levels of channel seepage, which lead to high water losses, and depends mainly on the length of the channel, the soil type or permeability of the channel banks and the condition of the canals. In large irrigation schemes more water is lost than in small schemes, due to a longer canal system. From canals in sandy soils more water is lost than from canals in heavy clay soils. The losses in channels lined with bricks, plastic or concrete are very small. If channels are badly maintained, bund breaks are not repaired properly and rats dig holes, a lot of water is lost. Indicative values of conveyance efficiency in opens canals range from 60-80% for long (>2,000 m) to short (<200 m) sand earthen canals, from 70-85% for long to short loam earthen canals, from 80-90% for long to short clay earthen canals, and around 95% for lined canals. These values do not consider the level of maintenance, which, in case of bad maintenance, may lower these values by as much as 50%.

Switching to drip irrigation and/or sprinklers from furrow irrigation systems targets to increase the field application efficiency. The field application efficiency mainly depends on the irrigation method, as well as on the level of the farmers' discipline. Irrigation water losses, illustrated include air losses, canopy losses, soil and water surface evaporation, runoff, and deep percolation. The magnitude of each loss is dependent on the design and operation of each type of irrigation system. Surface irrigation losses (furrow) include runoff, deep percolation, ground evaporation and surface water evaporation. Sprinkler irrigation losses include air losses (drift and droplet evaporation), canopy losses (canopy evaporation and foliage interception) and surface water evaporation. Indicative values of the average field application efficiency are around 60% for surface irrigation (basin, border, furrow), 70% for sprinkler irrigation (traveling gun, center pivot, etc.), and 80% for drip irrigation. Lack of farmers' discipline may lower these values.

Table 24**.** presents an overview of different literature values on the efficiency of irrigation methods. The values range, but in all cases, it is demonstrated that, when considering single field irrigation efficiencies, sprinkler systems are generally better than furrows, and drip irrigation systems are generally the best. In any case, attainable water application efficiencies vary greatly with irrigation system type, management practices and site characteristics. The analysis of the application efficiency of irrigation systems is thus important to identify potential places where improvements can be made and plan for interventions.

Table 24 Field application efficiencies of different irrigation methods. Source: Kossida, M., 2015 (adopted from Canessa et al., 2011)

Authors / Methods	Solomon, 1988	Tanji and Hanson, 1991	Morris and Lynne, 2006	Rogers et al., 1997	Howell, 2003	Hanson et al., 1999	Sandoval-Soli et al., 2013
Surface irrigation							Low/Mean/High
Furrow	60-75	60-90	60-80	50-90	50-80	70-85	60/73/85
Furrow with tailwater				60-90			
Border	70-85	65-80	55-75	60-90	50-80	70-85	62/73/83
Basin	80-90			60-95	80-65		72/83/93
Sprinkler							
Hand-more or portable	65-75						60/70/80
Periodic move		65-80	60-75	65-80	60-85	70-80	
Continuous move		75-85		70-95	90-98	80-95	
Traveling gun	60-70						
Center pivot	75-90		65-90		75-98		70/80/90
Linear move	75-90		75-90		70-95		73/82/90
Solid set or permanent	70-80	85-90	70-85	70-85		70-80	70/78/85
Drip/Trickle							
Trickle (point source emitters)	75-90						
Subsurface drip			85-95	70-95	75-95		77/86/95
Microspray			85-90		70-95		
Line source products	70-85						

Land use/ crop changes involve the changes in the existing crop mix in agricultural areas, either by abandoning some areas under agricultural cultivation, or by changing the mix of existing crops, and planting less water demanding varieties. Form an economic productivity point of view it may be more beneficial to plant crops which are more drought tolerant and do not require excessive irrigation. Such a land reform requires a thorough design process to investigate the full market potential of the new crops, and a long stakeholders' process in order to showcase the benefit of such an intervention and boost its acceptability.

Rainwater Harvesting (RWH) is defined as "the capture, storage and management of water flowing on the roofs of buildings and river basins that exist on the ground with the purpose of growing crops, regeneration of pasture for animal feed production and farming in general, horticulture and domestic use". Typical RWH systems consist of three basic elements: the collection system (area which produces runoff because the surface is impermeable or infiltration is low), the conveyance system (through which the runoff is directed, e.g. by bunds, ditches, channels, pipes) and the storage system (where water is accumulated or held for use). The storage system consists of tanks or impermeable soil and subsoil, as well as larger reservoirs.

Detention basins are part of the so-called Natural Water Retention Measures (NWRM) and Sustainable Urban Drainage Systems (SUDS). They are vegetated depressions designed to hold runoff from impermeable surfaces and allow the settling of sediments and associated pollutants. Stored water may be slowly drained to a nearby watercourse, using an outlet control structure to control the flow rate. Detention basins do not generally allow infiltration. The capacity to store runoff is dependent on the design of the basin, which can be sized to accommodate any size of rainfall event (CIRIA, 2007 identify up to a 1 in 100 year event as being not uncommon). Detention basins can provide water quality benefits through physical filtration to remove solids/trap sediment, adsorption to the surrounding soil or biochemical degradation of pollutants. Detention basins are landscaped areas that are dry except in periods of heavy rainfall, and may serve other functions (e.g. recreation), hence have the potential to provide ancillary amenity benefits. They are ideal for use as playing fields, recreational areas or public open space. They can be planted with trees, shrubs and other plants, improving their visual appearance and providing habitats for wildlife. A detention basin should be designed to be appropriate for the contributing catchment area (as well as rainfall characteristics). In theory they can be designed to accommodate any volume of runoff, from any catchment area, desired, and CIRIA (2007) states that there is no maximum catchment area. However, in general, sustainable drainage principles promote managing runoff close to source, i.e. with a relatively small catchment area, and therefore it is not envisaged that a contributing area greater than 1 km_2 would be likely.

Detention basis are high land-take measures used within the urban environment. The primary cost is therefore the cost of land acquisition or the opportunity cost of not using that land for development. This will depend on the land values at the site under considerations and cannot be generically quantified. Due to the higher costs of land, it is usually more expensive to retrofit these basins to already developed areas as compared to constructing one in an undeveloped region. (Source: NWRM project (http://nwrm.eu/measure/detention-basins; for more information refer to the NWRM Detention Basins Factsheet)

Retention ponds (also including **Hill Lakes**) are part of the so-called Natural Water Retention Measures (NWRM) and Sustainable Urban Drainage Systems (SUDS). They are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events. They consist of a permanent pond area with landscaped banks and surroundings to provide additional storage capacity during rainfall events. They are created by using an existing natural depression, by excavating a new depression, or by constructing embankments. Existing natural water bodies should not be used due to the risk that pollution events and poorer water quality might disturb/damage the natural ecology of the system. Retention ponds can provide both storm water attenuation and water quality treatment by providing additional storage capacity to retain runoff and release this at a controlled rate. Ponds can be designed to control runoff from all storms by storing surface drainage and releasing it slowly once the risk of flooding has passed. Runoff from each rain event is detained and treated in the pond. The retention time and still water promotes pollutant removal through sedimentation, while aquatic vegetation and biological uptake mechanisms offer additional treatment. Retention ponds have good capacity to remove urban pollutants and improve the quality of surface runoff.

Ponds should contain the following zones: (a) a sediment forebay or other form of upstream pre-treatment system (i.e. as part of an upstream management train of sustainable drainage components); (b)a permanent pool which will remain wet throughout the year and is the main treatment zone; (c) a temporary storage volume for flood attenuation, created through landscaped banks to the permanent pool; (d) a shallow zone or aquatic bench which is a shallow area along the edge of the permanent pool to support wetland planting, providing ecology, amenity and safety benefits. Additional pond design features should include an emergency spillway for safe overflow when storage capacity is exceeded, maintenance access, a safety bench, and appropriate landscaping. Well-designed and maintained ponds can offer aesthetic, amenity and ecological benefits to the urban landscape, particularly as part of public open spaces. They are designed to support emergent and submerged aquatic vegetation along their shoreline. They can be effectively incorporated into parks through good landscape design.

The drainage area required to support a retention pond can be as low as 0.03-0.1 km^2 (Environment Agency, 2012), or possible smaller if the retention pond has another resource of water such as a spring.

There are no specific constraints on the maximum drainage area for retention ponds, although typically 3-7% of the upstream catchment area will be required for the pond (CIRIA, 2007). Larger retention ponds (>25,000 m_3 volume) require significant impoundment and may be subject to additional inspection and structural requirements (e.g. 1975 Reservoirs Act in UK). Ponds would typically be sited at a low point in the catchment where it can receive drainage by gravity. Several ponds may be required at a large site, split into topographic sub catchments. The position chosen should allow safe routing of flows above the design event for the pond, and the consequence of any pond embankment failure considered.

Retention ponds reduce peak runoff through storage and controlled outflow release. They must be appropriately sized to the catchment area and critical storm depth. They do not infiltrate runoff and therefore provide very little runoff volume reduction (with the exception of evaporation and evapotranspiration, which can be significant in some cases). Typically, retention ponds will be designed to attenuate runoff for events up to at least the 1 in 30-year storm for the drainage area (sometimes greater), with the excess storm volume drained within 24 to 72 hours (CIRIA, 2007).

Retention ponds are high land-take measures used within the urban environment. The primary cost is therefore the cost of land acquisition or the opportunity cost of not using that land for development. This will depend on the land values at the site under considerations and cannot be generically quantified. Due to the higher costs of land, it is usually more expensive to retrofit these basins to already developed areas as compared to constructing one in an undeveloped region.

(Source: NWRM project (http://nwrm.eu/measure/detention-basins; for more information refer to the NWRM Retention Ponds Factsheet)

Measure ID and Name	**ERS_A1: Irrigation network modernization and maintenance projects**
Description	This measure targets to reduce canal leakage and increase conveyance efficiency. It includes: mapping and assessment of the status of the existing networks, rehabilitation of existing concrete channels, conversion from earth to concrete open channels or closed pipes and expansion of the BWE irrigation water supply network branches and connections. The updated NWSS 2020 has proposed the following irrigation projects: Rehabilitation of concrete channels: 44 km Conversion of earth to concrete channels: 78 km Construction of new irrigation networks: 7124 ha In addition to the proposed projects, on farm infrastructure shall be rehabilitated including irrigation systems and storage reservoirs.
Target	Farmers, agricultural schemes, LARI, BWE, MoA, MWE
Activity Breakdown	Act. 1: Mapping and assessment of the status of the existing networks, of available resources and of irrigation demand. Act. 2: Prioritization of activity areas Act. 3: Rehabilitation and maintenance of existing irrigation systems (incl. storage reservoirs) 3.1 Irrigation water intake structure 3.2 Main channel 3.3 Secondary channel 3.4 On farm infrastructure: 3.4.1 Farm diversion structure (Pump) 3.4.2 Farm reservoir (Concrete tank or lined natural pond) 3.4.3 Pressurized farm irrigation system (conversion to closed pipe) Act. 4: Construction of new irrigation networks
Timespan/Timeline	Medium-long term (approved and planned by the BWE) Once the measure is implemented the expected results/impact will be immediate.

Activity	Description	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
1	Mapping and assessment of the status of the existing networks, of available resources and of irrigation demand.						
2	Prioritization of activity areas						
3	Rehabilitation and maintenance of existing irrigation systems						
4	Construction of new irrigation networks						

Budget breakdown	CAPEX: 186 million USD
Constraints	Financial crisis, lack of coordination between BWE, MoEW, MoA on assessing the status of networks and their efficiencies and planning for rehabilitation and expansion projects.

Measure ID and Name	**ERS_A2: Construction of Irrigation dams (Assi phase I & II, Younine)**
Description	Construction of the irrigation dams Assi phase I, Assi phase II, and Younine.
Target	Farmers, BWE, LARI
Activity Breakdown	Assi Dam (Phase I) Capacity 63 Mm^3 Assi Dam (Phase II) Capacity 37 Mm^3 Younine Dam Capacity 5.8 Mm^3
Timespan/Timeline	Medium-long term Once the measure is implemented the expected results/impact will be immediate. Assi Phase I, Priority 1, needed in 2030, the construction of which should therefore start as soon as possible. Assi Phase II, Priority 2, needed in 2035, the construction of which should therefore start before 2030. Younine, Priority 1, needed in 2030, the construction of which should therefore start as soon as possible.
Budget breakdown	Younine Dam 69,960,000 USD Assi Dam (Phase 1) 52,000,000 USD Assi Dam (Phase 2) 150,000,000 USD
Constraints	Land availability, cost, financial crisis, environmental impact, stakeholder engagement, regulatory and permitting process, O&M.

<table>
<tr><th>Measure ID and Name</th><th>ERS_A3: Natural Water Retention Measures (NWRM) for agricultural, including Community Hill Lakes and flash floods retention lakes</th></tr>
<tr><td>Description</td><td>Detention/ Retention ponds are part of the so-called Natural Water Retention Measures (NWRM). They are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events. Includes: construction of NWRM - detention/retention ponds and Community Hill Lakes</td></tr>
<tr><td>Target</td><td>Farmers, Agricultural schemes, BWE, MoE, MWE, MoE</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Feasibility study
Act.2: Design and Planning
Act.3: Land Acquisition
Act.4: Construction
Act.5: Operation and Maintenance
Act.6: Community engagement and awareness</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term
Once the measure is implemented the expected results/impact will be immediate.
<table>
<tr><th>Activity</th><th>Description</th><th>Year 1</th><th>Year 2</th><th>Year 3</th><th>Year 4</th><th>Year 5</th></tr>
<tr><td>1</td><td>Feasibility study</td><td>■</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Design and Planning</td><td>■</td><td>■</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Land Acquisition</td><td></td><td>■</td><td>■</td><td></td><td></td></tr>
<tr><td>4</td><td>Construction</td><td></td><td></td><td>■</td><td>■</td><td></td></tr>
<tr><td>5</td><td>Operation and Maintenance</td><td></td><td></td><td>■</td><td>■</td><td>■</td></tr>
<tr><td>6</td><td>Community engagement and awareness</td><td></td><td></td><td>■</td><td>■</td><td>■</td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>Retention/ detention ponds are high land-take measures. The primary cost is therefore the cost of land acquisition or the opportunity cost of not using that land for agricultural or other purposes.</td></tr>
</table>

	The capital costs for the construction of detention basins, retention ponds, hill lakes of 100,000-150,000 m^3 capacity are about $30 per m^3 of volume provided for storage.
Constraints	Land availability, cost, financial crisis, environmental impact, Stakeholder Engagement, Regulatory and permitting process, O&M.

<table>
<tr><th>Measure ID and Name</th><th>ERS_A4: Thresholds of the required quantities of irrigation water</th></tr>
<tr><td>Description</td><td>Definition of the thresholds and ceilings of the required quantities of irrigation water per crop type (considering the local climatic conditions, the soil types, etc.). This measure intends to eliminate over-irrigation.</td></tr>
<tr><td>Target</td><td>Farmers, Agricultural schemes, MoA, BWE, MoEW</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Review Existing Regulations
Act.2: Stakeholder Consultation
Act.3: Data Analysis
Act.4: Technical Assessment
Act.5: Regulatory Framework Development
Act.6: Public Consultation
Act.7: Adoption and Implementation</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be shown if these defined/ correct quantities are applied by the farmer and no over-irrigation or deficit irrigation are practiced.
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th><th>Month 7</th><th>Month 8</th></tr>
<tr><td>1</td><td>Review Existing Regulations</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Stakeholder Consultation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Data Analysis</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Technical Assessment</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Regulatory Framework Development</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Public Consultation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Adoption and Implementation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>The cost of a relevant study.
The CAPEX is zero if this study is undertaken by existing staff of MoA, MoEW, LARI, etc.</td></tr>
<tr><td>Constraints</td><td>Lack of awareness; stakeholder resistance, economic consideration, legal and institutional framework, climate change,</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>ERS_M2: Reuse of treated wastewater for agricultural uses</th></tr>
<tr><td>Description</td><td>Reusing wastewater for irrigation helps achieve water efficiency and conservation, reduces the need for pumping from private wells, saving on energy and decreasing the cost of crops, and positively impacts the livelihood of farmers.</td></tr>
<tr><td>Target</td><td>Farmers, Agricultural schemes, MoA, MoE, BWE, MoEW, MoPH.</td></tr>
<tr><td>Activity Breakdown</td><td>The proposed WWTP within ARB which effluent could be reused for irrigation are
BQ-WW A. District of Baalbek
Qaa 1 WWTP activated sludge
Ras Baalbeck 1 WWTP activated sludge
Chaat 1 WWTP activated sludge
Deir el Ahmar 1 WWTP activated sludge
Boudai 1 WWTP activated sludge
Chlifa 1 WWTP MBRR
BQ-WW B. District of Hermel
Hermel Phase 1 1 WWTP activated sludge
Hermel Phase 2 1 WWTP activated sludge

The actual annual flow of treated wastewater suitable for irrigation was estimated to 12 Mm^3/year from 8 WWTP over 6 months/year.

Act. 1: Feasibility Study;
Act. 2: WWTP upgrade to meet irrigation requirement;
Act. 3: Establish a distribution network for the treated wastewater to be used for irrigation network;
Act. 4: Implementing and testing of a monitoring plan;
Act. 5: Provide training and technical assistance to farmers and other stakeholders;
Act. 6: Conducting outreach and education campaigns to increase public acceptance and participation in the program;</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be immediate

<table>
<tr><th>Activity</th><th>Description</th><th>Sem.1</th><th>Sem.2</th><th>Sem.3</th><th>Sem.4</th><th>Sem.5</th><th>Sem.6</th></tr>
<tr><td>1</td><td>Feasibility study</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Upgrading the WWTP for irrigation reuse</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Implementing the distribution network for the treated wastewater</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Implementing and testing of a monitoring plan</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Providing training and technical assistance to farmers and other stakeholders</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Conducting outreach and education campaigns to increase public acceptance and participation in the program</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>-</td></tr>
<tr><td>Constraints</td><td>Water quality and safety, Public Perception and Acceptance, Regulatory Framework, Infrastructure and Distribution, lack of awareness, Institutional coordination</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>WCO_A1: Subsidies for change of irrigation systems</th></tr>
<tr><td>Description</td><td>This measure targets to increase the field application efficiency through the change of irrigation systems. The field application efficiency mainly depends on the irrigation method, as well as on the level of the farmers’ discipline. When considering single field irrigation efficiencies, sprinkler systems are generally better than furrows, and drip irrigation systems are generally the best.</td></tr>
<tr><td>Target</td><td>Farmers, Agricultural schemes, MoA, LARI, BWE, MoEW</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Feasibility and assessment study
Act.2: Capacity building and technical assistance to farmers
Act.3: Financial support
Act.4: Procurement and supply
Act.5: Monitoring and Evaluation
Act.6: Stakeholder collaboration
Act.7: Awareness and promotion</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium-long term.
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th><th>Month 7</th><th>Month 8</th><th>Month 9</th></tr>
<tr><td>1</td><td>Feasibility and assessment study.</td><td>■</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Capacity building and technical assistance to farmers</td><td></td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td></tr>
<tr><td>3</td><td>Stakeholder collaboration</td><td></td><td></td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td></tr>
<tr><td>4</td><td>Awareness and promotion</td><td></td><td></td><td>■</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Financial support</td><td></td><td></td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td></tr>
<tr><td>6</td><td>Procurement and supply</td><td></td><td></td><td>■</td><td>■</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Monitoring and Evaluation</td><td></td><td></td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td><td>■</td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>The total irrigated area in the ARB basin is expected to increase to 21,750 hectares with +15% conveyance efficiency, hence switching the total area to modern irrigation (drip, sprinklers) and the conveyance from open channels to closed pipes; According to Ostuan study; for the drip irrigation, the Annual Equivalent Cost (AEC) for a useful life of 20 years is 347$/ha and the CAPEX is 3680$/ha
Hence, to switch the overall ARB area to modern irrigation
AEC = 21,750 ha * 347$/ha = 7.5 mio $ or
CAPEX = 21,750 ha * 3680$/ha = 80 mio $
The purchase and installation of the drip irrigation in the households can be undertaken by the farmers through subventions, or at municipal level, or the BWE, or the MoEW, or MoA, or NGOs, depending on funding mechanisms (e.g. subsidies, reduction in water fees, donors’ funds, etc.)
Farmers are responsible for the proper operation and maintenance of the drip irrigation systems</td></tr>
</table>

Constraints	Financial Constraints, Limited Resources, Lack of Awareness and Knowledge, Resistance to Change, Policy and Regulatory Frameworks, Maintenance and Operation Costs, Implementation and Coordination Challenges

7.1.3 Other regulatory and mixed measures

<table>
<tr><th>Measure ID and Name</th><th>ERS_M3: Regulating water tariffs, achieving cost recovery</th></tr>
<tr><td>Description</td><td>Water pricing reform usually involves a modification in the rate structure and/or the water tariffs in order to influence the consumers’ water use. This economic instrument needs a very careful design as it can easily raise conflicts among users and trigger many disputes. It also must be noted that there is always a price elasticity that needs to be considered, and that beyond a certain threshold any further increase in water price might not bring any further decrease in the water consumption.</td></tr>
<tr><td>Target</td><td>BWE, MoEW, NGOs, CSOs/ Municipalities</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Tariff analysis
Act.2: Cost assessment
Act.3: Stakeholder consultation
Act.4: Regulatory framework
Act.5: Tariff setting and tariff approval process
Act.6: Public awareness and communication</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th><th>Month 7</th><th>Month 8</th><th>Month 9</th></tr>
<tr><td>1</td><td>Tariff analysis</td><td>■</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Cost assessment</td><td></td><td>■</td><td>■</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Stakeholder consultation</td><td></td><td></td><td>■</td><td>■</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Regulatory framework</td><td></td><td></td><td></td><td></td><td>■</td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Tariff setting and tariff approval process</td><td></td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td>■</td><td>■</td></tr>
<tr><td>6</td><td>Public awareness and communication</td><td></td><td></td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td>■</td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>Also, a water pricing elasticity study to establish fair and equitable water tariffs, which also achieved costs recovery, is necessary, which has some associated cost if additional experts, outside the BWE staff, are used</td></tr>
<tr><td>Constraints</td><td>Political resistance, Socio-economic, Lack of awareness, administrative and institutional capacity, technical and financial, Legal and regulatory framework</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>ERS_M4: Monitoring and control of illegal abstractions and private wells, and definition of safe yield per groundwater body</th></tr>
<tr><td>Description</td><td>Illegal abstractions from groundwater cause drawdown of the aquifer, while jeopardize the safe yield. The measure includes: field surveys to register all illegal abstractions, measures to control these abstractions, as well as the installation of water meters in private wells for subsequent monitoring of the abstracted volumes. Creation and operation of a single registry of licensed water wells from the water permitting process, shared among the relevant authority. Definition/ update of groundwater safe yield for each groundwater body. Additionally, the requirements (regulatory framework) for granting permits for new wells need to be revised in view of the groundwater sustainability.</td></tr>
<tr><td>Target</td><td>Municipalities, BWE, MoEW, CSO, NGOs</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Review and update existing legislation and regulations
Act.2: Capacity Building and Training
Act.3: Illegal Abstraction Identification and Mapping
Act.4: Awareness and outreach
Act.5: Stakeholder Engagement and Collaboration
Act.6: Enforcement and compliance
Act.7: Regular monitoring and reporting</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th><th>Month 7</th><th>Month 8</th><th>Month 9</th></tr>
<tr><td>1</td><td>Review and update existing legislation and regulations</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Capacity Building and Training</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Illegal Abstraction Identification and Mapping</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Awareness and outreach</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Stakeholder Engagement and Collaboration</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Enforcement and compliance</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Regular monitoring and reporting</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>Internal costs of the BWE. Additional staff (inspectors) is required</td></tr>
<tr><td>Constraints</td><td>Lack of legal framework, lack of coordination between stakeholders, Political and administrative challenges, Informal practices and resistance, Lack of awareness,</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>ERS_M5: Technical specifications for wastewater reuse</th></tr>
<tr><td>Description</td><td>In Lebanon, there is no legal basis for reuse of wastewater. There are no regulations, guidelines and standards for the reuse of treated wastewater for different purposes. Two propositions for Lebanese Guidelines on Sewage Sludge Use in Agriculture and for Lebanese Wastewater Reuse Guidelines have been prepared by FAO in 2010. However, these have not been officially enforced yet.</td></tr>
<tr><td>Target</td><td>MEW, MoE, MoPH, MoA, BWE, Municipalities, NGOs/CSOs.</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Review of Existing Standards and Guidelines
Act.2: Stakeholder Consultation and Engagement
Act.3: Identification of Reuse Scenarios
Act.4: Technical Assessment and Research
Act.5: Development of Technical Specifications
Act.6: Integration with Existing Regulations and Guidelines
Act.7: Documentation and Dissemination
Act.8: Training and Capacity Building
Act.9: Monitoring and Evaluation</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th><th>Month 7</th><th>Month 8</th><th>Month 9</th></tr>
<tr><td>1</td><td>Review of Existing Standards and Guidelines</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Stakeholder Consultation and Engagement</td><td></td><td>■</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Identification of Reuse Scenarios</td><td></td><td></td><td>■</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Technical Assessment and Research</td><td></td><td></td><td>■</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Development of Technical Specifications</td><td></td><td></td><td>■</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Integration with Existing Regulations and Guidelines</td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Documentation and Dissemination</td><td></td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td>■</td><td></td></tr>
<tr><td>8</td><td>Training and Capacity Building</td><td></td><td></td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td>■</td></tr>
<tr><td>9</td><td>Monitoring and Evaluation</td><td></td><td></td><td></td><td></td><td></td><td></td><td>■</td><td>■</td><td>■</td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>Internal costs of the MoEW, MoE, MoH, MoA
The development of the studies shall be done in a collaboration between MoEW, MoE, MoPH, MoA. BWE shall support, as well as the Municipalities by providing specific data on irrigated areas and crops per Municipality</td></tr>
<tr><td>Constraints</td><td>Lack of consensus, water quality, regulatory framework, infrastructure and treatment capacity, public perception and acceptance, lack of awareness, monitoring and enforcement.</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>PWE_E1: Flood protection and mitigation (check dams, reforestation, …)</th></tr>
<tr><td>Description</td><td>This measure aims to minimize the impacts of flooding on communities and ecosystems through a combination of proactive planning, infrastructure development, community engagement, and sustainable practices. Construction of hill lakes, check dams, NBS, soil conservation, reforestation, etc. Also, the implementation of Early Warning Systems (EWS)</td></tr>
<tr><td>Target</td><td>Municipalities, BWE, MoEW, CNRS, CSOs, NGOs</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Flood risk assessment
Act.2: Infrastructure design and development (check dams, hill lakes, etc.)
Act.3: Ecosystem and Wetland restoration, floodplain
Act.4: Establish Monitoring and Early Warning Systems
Act.5: Awareness campaigns
Act.6: Stakeholder engagement</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Sem. 1</th><th>Sem. 2</th><th>Sem. 3</th><th>Sem. 4</th><th>Sem. 5</th><th>Sem. 6</th></tr>
<tr><td>1</td><td>Flood risk assessment</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Infrastructure design and development</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Ecosystem and Wetland restoration,</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Establish Monitoring and Early Warning Systems</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Awareness campaigns</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Stakeholder engagement</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>-</td></tr>
<tr><td>Constraints</td><td>Lack of awareness;</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>PWE_E2: Quantitative and qualitative water resources monitoring programme, Meteorological and Hydrometric network expansion and improvement</th></tr>
<tr><td>Description</td><td>Procurement, purchase and installation of a monitoring network to monitor the quantitative status of surface and groundwater bodies, as well as their water quality. Operation and maintenance of the network, and entry of all collected data into a water database to be shared among the relevant stakeholders.
Implementation of the IHIS proposed in the Updated NWSS 2020</td></tr>
<tr><td>Target</td><td>MEW, BWE, LRA, LARI, Municipalities, NGOs/CSOs, Universities</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Assessment study of the current situation of the hydrometric, climatic and water quality monitoring and stations
Act.2: Planning and design for the expansion and improvement of the monitoring networks
Act.3: Procurement
Act.4: Installation of the monitoring equipment and software
Act.5: Training of the staff for the monitoring and operation of the network
Act.6: Data Collection
Act.7: Analysis and Reporting
Act.8: Operation and Maintenance</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Sem. 1</th><th>Sem. 2</th><th>Sem. 3</th><th>Sem. 4</th><th>Sem. 5</th><th>Sem. 6</th></tr>
<tr><td>1</td><td>Assessment study</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Planning and design</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Procurement</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Installation of the monitoring equipment and software</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Training of the staff</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Data Collection</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Analysis and Reporting</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>Operation and Maintenance</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>CAPEX
MH A. Meteorological and Hydrometric network expansions and improvements: 6,066,400 $
MH-B. Integrated Hydrological Information System 9,548,400 $</td></tr>
<tr><td>Constraints</td><td>Financial crisis, lack of awareness, priority,</td></tr>
</table>

<table>
<tr><th>Measure ID and Name</th><th>PWE_E3: Register of all pollution sources, estimation of pollution loads, assessment of significant pressures, and control of illegal dumping activities</th></tr>
<tr><td>Description</td><td>Many illegal wastewater outfalls exist within ARB. (i.e. direct disposal of untreated domestic sewage into the river). A first step is to identify and map all these outlets, and then to ban and control illegal wastewater discharges. Similarly, uncontrolled waste damping occurs in ARB. It is thus also relevant to identify and map all these uncontrolled sites, and then to ban and control illegal waste dumping.</td></tr>
<tr><td>Target</td><td>MoE, MoEW, Municipalities, CSO, NGOs.</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Mapping and recording of all wastewater outfalls (Licensed and illegal) and waste dumping sites (legal and uncontrolled)
Act.2: Estimation of all pollution loads, from point sources and agricultural
Act.3: Analysis of the discharged wastewater characteristics, including chemical and biological analysis
Act. 4: Monitoring and control of wastewater discharge into the river/ fields
Act. 5: Updating and reviewing of the relevant permits for waste disposal
Act. 6: Monitoring and control of waste dumping into the river/ landscape.</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Month 1</th><th>Month 2</th><th>Month 3</th><th>Month 4</th><th>Month 5</th><th>Month 6</th></tr>
<tr><td>1</td><td>Mapping and recording</td><td>■</td><td>■</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Estimation of all pollution loads</td><td></td><td>■</td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Analysis of the discharged wastewater</td><td></td><td></td><td>■</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Monitoring and control of wastewater discharge</td><td></td><td></td><td>■</td><td>■</td><td>■</td><td></td></tr>
<tr><td>5</td><td>Updating and reviewing of the relevant permits</td><td></td><td></td><td>■</td><td>■</td><td>■</td><td></td></tr>
<tr><td>6</td><td>Monitoring and control of waste dumping</td><td></td><td></td><td></td><td></td><td>■</td><td>■</td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>-</td></tr>
<tr><td>Constraints</td><td>Lack of awareness;</td></tr>
</table>

Measure ID and Name	PWE_E4: Support fish feed as alternative to contaminating feed
Description	Promoting the use of sustainable and environmentally friendly feed options for fish farming. This measure aims to address the issue of contamination in fish feed, which can have detrimental effects on aquatic ecosystems and human health.
Target	Fish farmers, MoA, BWE
Activity Breakdown	Act.1: Environmental assessment Act.2: Market assessment and funding Act.3: Collaboration with feed manufacturers Act.4: Education and training Act.5: Regulatory measures Act.6: Market support Act.7: Awareness campaigns
Timespan/Timeline	Medium term. Once the measure is implemented the expected results/impact will be immediate
Budget breakdown	-
Constraints	Lack of awareness;

Measure ID and Name	PAR_M1: Development of Al Assi River Basin Coordination Committee
Description	Define the modalities, roles and operational framework for the formation of a ARB committee, charged with safeguarding the water resources and the environment
Target	Municipalities, BWE, MoEW, MoE, MoA, MoPH, NGOs/CSOs:
Activity Breakdown	-
Timespan/Timeline	Short - Medium term. Once the measure is implemented the expected results/impact will be immediate
Budget breakdown	-
Constraints	Legislation and regulatory framework, lack of engagement, lack of awareness,

Measure ID and Name	PAR_M2: Raising awareness and sensitizing the community on the water resources and environmental related issues in Al Assi
Description	Promote water conservation, educate people on water use efficiency, raise awareness on the impacts of illegal abstraction and over-abstraction, raise awareness on the impact of illegal wastewater discharge and waste dumping, sensitize people to act in favor of the river, build sense responsibility and ownership. Includes: awareness campaigns, outreach activities to the community
Target	BWE, Municipalities, NGOs/CSOs
Activity Breakdown	-
Timespan/Timeline	Medium term. Once the measure is implemented the expected results/impact will be immediate
Budget breakdown	Human resources and staff of the involved parties
Constraints	Limited data, lack of awareness, limited engagement, lack of coordination, socio economic conditions, resistance to change,

Measure ID and Name	PAR_M3: Strengthen environmental program actions in primary education
Description	Educate the youth on water conservation, the impacts of illegal abstraction and over-abstraction, the impacts of illegal wastewater discharge and waste dumping, Includes: education programmes in schools, students as "gradients" of ARB future
Target	NGOs/CSOs, Local Universities, Municipalities,
Activity Breakdown	-
Timespan/Timeline	Medium term. Once the measure is implemented the expected results/impact will be immediate
Budget breakdown	-
Constraints	Limited curriculum integration, teaching material, institutional support, funding, social and cultural factors,

Measure ID and Name	DEV_M1: Capacity building activities
Description	Capacity building mainly for the staff on the BWE and the technical staff of the municipalities
Target	BWE, MoEW, NGOs/CSOs,
Activity Breakdown	-
Timespan/Timeline	Medium term. Once the measure is implemented the expected results/impact will be immediate
Budget breakdown	-
Constraints	Funding, community engagement, lack of awareness;

<table>
<tr><th>Measure ID and Name</th><th>DEV_T1: Promotion of eco-tourism</th></tr>
<tr><td>Description</td><td>Promotion of eco-tourism</td></tr>
<tr><td>Target</td><td>Municipalities, CSOs/NGOs, MoT, MoYS,</td></tr>
<tr><td>Activity Breakdown</td><td>Act.1: Assessment and inventory of natural and cultural resources
Act.2: Infrastructure development of eco-tourism sites
Act.3: Conservation and restoration of eco-tourism sites
Act.4: Stakeholder engagement
Act.5: Marketing and Promotion
Act.6: Visitor Experience engagement
Act.7: Monitoring and Evaluation</td></tr>
<tr><td>Timespan/Timeline</td><td>Medium term.
Once the measure is implemented the expected results/impact will be immediate
<table>
<tr><th>Activity</th><th>Description</th><th>Sem. 1</th><th>Sem. 2</th><th>Sem. 3</th><th>Sem. 4</th><th>Sem. 5</th><th>Sem. 6</th></tr>
<tr><td>1</td><td>Assessment and inventory of natural and cultural resources</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Infrastructure development of eco-tourism sites</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Conservation and restoration of eco-tourism sites</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Stakeholder engagement</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Marketing and Promotion</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Visitor Experience engagement</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Monitoring and Evaluation</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Budget breakdown</td><td>Variable</td></tr>
<tr><td>Constraints</td><td>Limited infrastructure, environmental, funding and investment, community engagement, lack of awareness, political and security factors,</td></tr>
</table>

7.2 Action Plan

ARB PoM and Action Plan were developed taking into account the necessity for socio-economic growth while simultaneously mitigating potential threats to human health and riverine ecosystems mainly caused by absence of a sustainable solid waste and wastewater management plans and from flood events. It encompasses key stages of Assi RBM planning, including basin characterization, evaluation of current and future water management practices, and formulation of appropriate measures.

The updated National Water Sector Strategy NWSS 2020 has taken into account the adopted Water Code (law 192/2020) and set the ground to move towards UN's Sustainable Development Goal SDG 6 and realize the principles of an IWRM at the river basin level as main approach with all its implementation principles, in particular the principle of sustainable development. This shall optimize water resources distribution according to its availability now and in the future, taking into consideration climate change and urban development scenarios. The developed PoM as defined and discussed with different stakeholders (MEW, BWE, MoA, MoE, Municipalities, etc.) are aligned with all three pillars of the Updated NWSS 2020.

Pillar 1: Implementing Reforms and Improving Sector Governance

Pillar 2: Achieving IWRM

Pillar 3: Service Coverage

Thus, the action plan corresponding to Assi RBM shall also be aligned with the NWSS action plan. Hence the following:

At the regulatory, reform and governance level, the

- MoEW shall regulate water tariffs and reform the water pricing in order to influence the consumers' water use (ERS_M3). It shall monitor and control illegal abstractions and private wells and define the safe yield per groundwater body (ERS_M4). It shall prepare technical specifications for wastewater reuse and with the help of MoA, identify the agricultural and urban green areas which can be receptors of treated effluent (ERS_M5). Also at the regulatory level, the MoEW shall ensure protection zones around groundwater abstraction points (PWE_U2).
- BWE shall work on drafting a new Water Supply Masterplan to meet water supply needs in the medium and long term (ERS_U2). It shall draft a wastewater collection and treatment Master Plan (PWE_UI2).
- MoA shall define the thresholds and ceilings of the required quantities of irrigation water per crop type (ERS_A4).
- MoE shall conduct EIAs for all proposed infrastructure works where required (PWE_U1)

At the IWRM level, the:

- MoEW shall work on developing water resources monitoring programs (PWE_E1), developing River Basin Coordination Committees of Al Assi and all Lebanese rivers (PAR_M1).

- BWE shall work on implementing water metering for domestic and irrigation water to identify actual consumption and subscription (ERS_M1).
- MoE shall register all pollution sources, estimate pollution loads, assess significant pressures, and control illegal dumping activities (PWE_E3).
- Municipalities shall work on rational management of municipal waste (PWE_U3).
- The MoA shall support fish feed as alternative to contaminating feed (PWE_E4).
- All stakeholders, mainly municipalities, NGO's, CSO's and schools shall work on raising awareness and sensitizing the community on the water resources and environmental related issues in Al Assi (PAR_M2), on strengthening environmental program actions in primary education (PAR_M3).

At the Service Coverage level, the:

- MoEW and BWE shall take actions to modernize the operation of water supply networks (ERS_U1), rehabilitate existing wastewater collection networks and treatment plants and expand new networks (PWE_UI1) and reuse treated wastewater for agricultural uses (ERS_M2).
- MoA and BWE shall modernize irrigation networks to reduce canal leakage and increase conveyance efficiency (ERS_A1), build Assi irrigation dams (Phase I and II) and Younine dam (ERS_A2), implement natural water retention measures (NWRM) like ponds and hill lakes (ERS_A3) and flood protection infrastructure (PWE_E1), ensure subsidies for change of irrigation systems to increase the field application efficiency (WCO_A1).
- Municipalities with the help of the Ministry of Tourism and active NGOs shall work on promoting eco-tourism (DEV_T1).
- All stakeholders, mainly MoEW, BWE and Municipalities shall work towards implementing water saving in households and buildings by using a variety of available technologies designed for this purpose (WCO_U1), they shall also work on capacity building of the technical staff (DEV_M1).

Essentially, Assi Action Plan (Table 25) coordinates the PoM and other relevant programs within the river basin district such as the updated NWSS 2020, and forms the basis for river basin projects plans, which suggests estimated costs and benefits for each proposed measure, and institutional responsibility clarified, and classified according to a priority scale set from 1 to 3 based on the Urgency, Risk and Impact of the measure with 1 represent High Urgency, High Risk, High Impact; 2: Medium Urgency, Medium Risk, Medium Impact; and 3: Low Urgency, Low Risk, Low Impact;

Table 25 ARB Action Plan

ID	Name of the Measure	Implementer	Budget	Timeline			Priority
				2025	2030	2035	
ERS_U1	Actions to modernize the operation of water supply networks and improve water efficiency	BWE	$ 96,492,300				1
ERS_U2	Drafting / Updating of the BWE Water Supply Masterplan	BWE	NA				1
ERS_A1	Irrigation network modernization and maintenance projects	BWE, MoA	$ 186,000,000				1
ERS_A2	Construction of Irrigation dams (Assi phase I & II, Younine)	MEW, BWE	$ 272,000,000				1
ERS_A3	Natural Water Retention Measures (NWRM) for agricultural, including Community Hill Lakes and flash floods retention lakes	BWE, MoA	30$/m^3				1
ERS_A4	Thresholds of the required quantities of irrigation water	MoA	NA				2
ERS_M1	Water metering and subscription to BWE, flow meters for irrigation water	BWE	$ 40,000,000				2
ERS_M2	Reuse of treated wastewater for agricultural uses	BWE, MoA, MoEW	$ 6,000,000				2
ERS_M3	Regulating water tariffs, achieving cost recovery	MEW	NA				2
ERS_M4	Monitoring and control of illegal abstractions and private wells, and definition of safe yield per groundwater body	BWE	NA				1
ERS_M5	Technical specifications for wastewater reuse	MEW, MoA	NA				1
WCO_U1	Water saving in households and buildings (public, commercial)	BWE	$ 2,500,000 to $ 70,000,000				3
WCO_A1	Subsidies for change of irrigation systems	MoA	$ 80,000,000				2
PWE_U1	Conduct necessary environmental studies	MoE	NA				2
PWE_U2	Drinking water protection perimeters	BWE, MoEW	NA				2
PWE_U3	Municipal solid waste management	Municipalities	$ 650,000 to $ 3,000,000				1
PWE_E1	Flood protection and mitigation (check dams, reforestation, …)	MoEW, CNRS, MoA					1
PWE_E2	Quantitative and qualitative water resources monitoring programme, Meteorological and Hydrometric network expansions and improvement	MoEW	$ 15,500,000				2
PWE_E3	Register of all pollution sources, estimation of pollution loads, assessment of significant pressures, and control of illegal dumping activities	Municipalities	NA				1
PWE_E4	Support fish feed as alternative to contaminating feed	MoA	NA				1
PWE_UI1	Wastewater collection and treatment, maintenance of existing WWTP	BWE/ MoEW	$ 303,000,000				1
PWE_UI2	Drafting/Updating of BWE Wastewater Masterplan	BWE	NA				1
PAR_M1	Development of Al Assi River Basin Committee	MoEW	NA				3
PAR_M2	Raising awareness and sensitizing the community on the water resources and environmental related issues in Al Assi	BWE	NA				2
PAR_M3	Strengthen environmental program actions in primary education	Ministry of Education	NA				3
DEV_M1	Capacity building activities	BWE	NA				3
DEV_T1	Promotion of eco-tourism	MoT	NA				3

8 Cost Benefit Analysis

The cost-benefit analysis was adopted from the BWE point of view. Thus, benefits were associated with more revenues from:

- domestic water tariffs or an increase in the domestic water supply efficiency;
- revenue from supplying irrigation water from springs, hill lakes and reuse from water treatment plants.

8.1 Capital Expenses

The CApital EXpenses CAPEX of the new infrastructures and investments to be implemented by measures as included in WEAP are shown in Table 26.

Table 26 List of the estimated Capital cost by measure and correspondent scenario

ID	Name of the Measure / Action	Implementer	Budget	Scenario	Impact
ERS_U1	Actions to modernize the operation of water supply networks and improve water efficiency	BWE	$ 96,492,300	S4CC to S11CC	Increase Network Efficiency to 75%
ERS_A1	Irrigation network modernization and maintenance projects	BWE, MoA	$ 179,000,000	S8CC to S11CC	Improve Irrigation Efficiency
ERS_A2	Construction of Irrigation dams (Assi phase I & II, Younine)	MEW, BWE	$ 272,000,000	S4CC to S11CC	Increase Irrigation Water Supply
ERS_A3	Natural Water Retention Measures (NWRM) for agriculture, including Community Hill Lakes and flash floods retention lakes	BWE, MoA	$ 30/m^3	S5CC to S11CC	Increase Irrigation Water Supply
ERS_M1	Water metering and subscription to BWE, flow meters for irrigation water	BWE	$ 40,000,000	S4CC to S11CC	Increase Network Efficiency to 75%
ERS_M2	Reuse of treated wastewater for agricultural uses	BWE, MoA, MoEW	$ 6,000,000	S4CC to S11CC	Increase Irrigation Water Supply
WCO_U1	Water saving in households and buildings (public, commercial)	BWE	$ 2,500,000 to $ 70,000,000	S5CC to S11CC	Decrease Domestic water consumption
WCO_A1	Subsidies for change of irrigation systems	MoA	$ 80,000,000	S8CC to S11CC	Improve Irrigation Efficiency
PWE_UI1	Wastewater collection and treatment, maintenance of existing WWTP	BWE/ MoEW	$ 303,000,000	S4CC to S11CC	Increase Irrigation Water Supply/ Improve water quality

8.2 Operation and Maintenance Expenses

The analysis takes into account the OPeration EXpenses OPEX for both new and existing infrastructures. The inclusion of existing infrastructure allows for the identification of the advantages associated with enhancing the efficiency of water conveyance.

The O&M cost analysis includes the expenses related to pumping groundwater from public wells, both for existing wells and newly constructed ones. The average O&M cost has been evaluated as follows:

- Average energy cost (fuel for the pumps) of 0.40 $/kWh.
- Average energy requirement to extract groundwater of 0.68 kWh/m^3.

The product of both terms yields an **average O&M cost of 0.27 $/m^3**. This cost per volume unit was added in WEAP to compute the O&M cost based on the volume of pumped groundwater. By doing so, the cost will decrease as measures are implemented to minimize losses, allowing for an assessment of the net benefits associated with these measures. It is emphasized that O&M costs associated with pumping irrigation water from groundwater and springs are not considered in the analysis, as these are private costs, born by farmers.

8.3 Benefits

The benefits were based on the water tariff as provided by BWE, the served population and projected collection rate:

- Water tariff: 40 $/household/year (equivalent to 2,000,000LL for an average USD rate of 50,000LL set in 2023).
- Collection rate after measures: 80%.
- Served population based on demographic growth.

The benefit per cubic meter was computed with the assumption that the collection rate is 80%.

- Assuming a household hosts on average five persons, the average benefit is 6.4 $/cap/year.
- With the domestic water demand of 150 L/cap/day actually delivered to household, the average benefit is 0.15$/m$^{3.}$ With collection rate 80% the **average benefit** becomes **0.12$/m^3**.

It can be noted that the volumetric benefit of 0.12 $/m^3 is smaller than the volumetric O&M cost (0.27 $/m^3). Adding the fact that part of pumped groundwater is lost through leakages (50% in the current situation), i.e., more water is being pumped than delivered to households, it is clear the current the situation is a deficit.

Benefits for supplying irrigation water were accounted for if the sources are surface water and springs, as these are in the public domain. A volumetric benefit of **0.05 $/m^3** was accounted for these two supplies of irrigation water. On the contrary, benefits for supplying irrigation water from groundwater was not accounted for, as these supplies are in the private domain (from private wells).

8.4 Financing the CAPEX and implementation phases

CAPEX was represented in WEAP as a yearly loan payment, with the following parameters:

- 25 years of payments, starting in the first year of construction or implementation;
- 2% interest annual rate;
- uniform annual installments.

For simplicity, it was assumed that all activities would be completed by 2030. The construction or implementation phases vary as follows:

- Increasing water efficiency to 75% through modernization and metering: 5 years, starting in 2025.
- Assi Dam, phase 1 and 2: 7 years, starting in 2023.
- Younine Dam: 5 years, starting in 2025.
- Natural Water Retention Measures (NWRM) for agriculture, including Community Hill Lakes and flash floods retention lakes: 5 years, starting in 2025.
- Water metering and subscription to BWE, flow meters for irrigation water: 5 years, starting in 2025.
- Wastewater collection and treatment, maintenance of existing WWTP: 5 years, starting in 2025.
- Reuse of treated wastewater for agricultural uses: 5 years, starting in 2025.
- Irrigation network modernization and maintenance projects: 5 years, starting in 2025
- Subsidies for change of irrigation systems: 5 years, starting in 2025
- Water saving in households and buildings (public, commercial): 5 years, starting in 2025.
- Finally, a discount rate of 7% annually was assumed.

8.5 Results

Figure 33 shows the Net Benefit Results on an annual basis, considering the upper mentioned analysis for scenarios S0CC, S4CC, S5CC and S11CC.

- In the baseline situation, but with climate change (scenario S0CC), the costs are greater than the benefits and the yearly net benefit is around $ -4.9 million.
- In scenario S4CC, there are significant CAPEX costs, on top of existing OPEX in S0CC. New infrastructures (e.g., new dams, new WWTPs)., also come with additional OPEX. Improving the domestic water supply system's efficiency, or reducing the leakages, reduces the OPEX in 2030 (after works have been completed to reduce the leakages) but to a much smaller extent compared to the CAPEX of implementing this improvement in efficiency. Moreover, this reduction is dwarfed by the additional OPEX associated with the new infrastructures. The Benefits increase after the implementation of new wells, but to a much smaller extent than the increase in cost. So all in all, the Net benefit is greatly negative, especially after implementing the new dams and WWTPs and eventually reaches a yearly value close to - 41 million USD.

- Results of scenario S5CC are similar to those of S4CC, with a greater negative net benefit after the implementation of hills lakes. The Net benefit reaches a yearly value close to - 49 million USD.
- Finally, scenario S11CC further reduces the Net benefit to - 62 million USD/year, with the cost of improving the Irrigation efficiency, without any substantial reduction in OPEX or increase in Benefits.

The same computations but with Present Value, using a discount rate of 7%, are shown on Figure 34. The equivalent Net Present Value (NPV), shown in Figure 35, is negative:

- S4CC: -240.5 Million USD
- S5CC: -289.9 Million USD
- S11CC: -368.0 Million USD

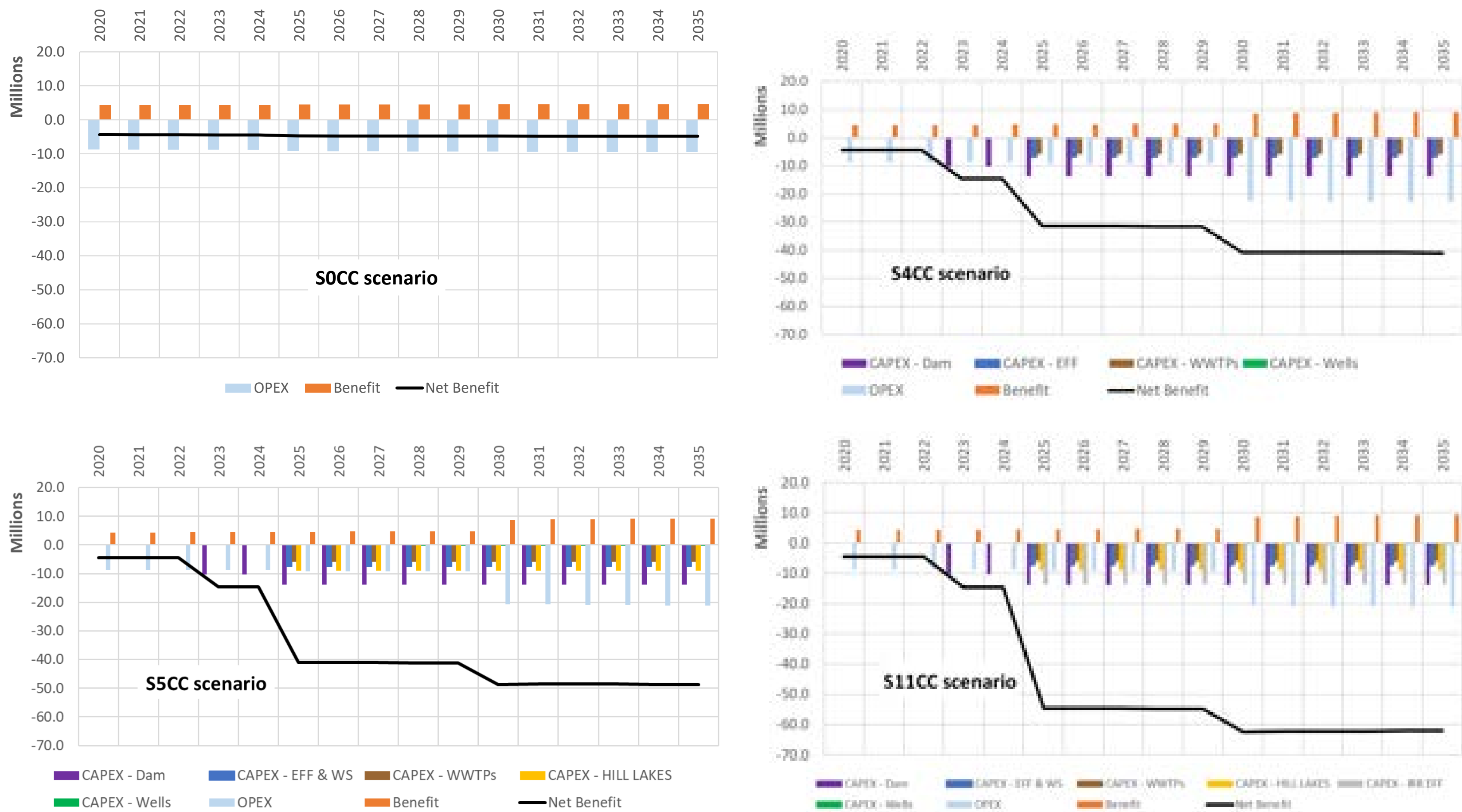

Figure 33 Costs and Benefits of the scenarios S0CC, S4CC, S5CC and S11CC.

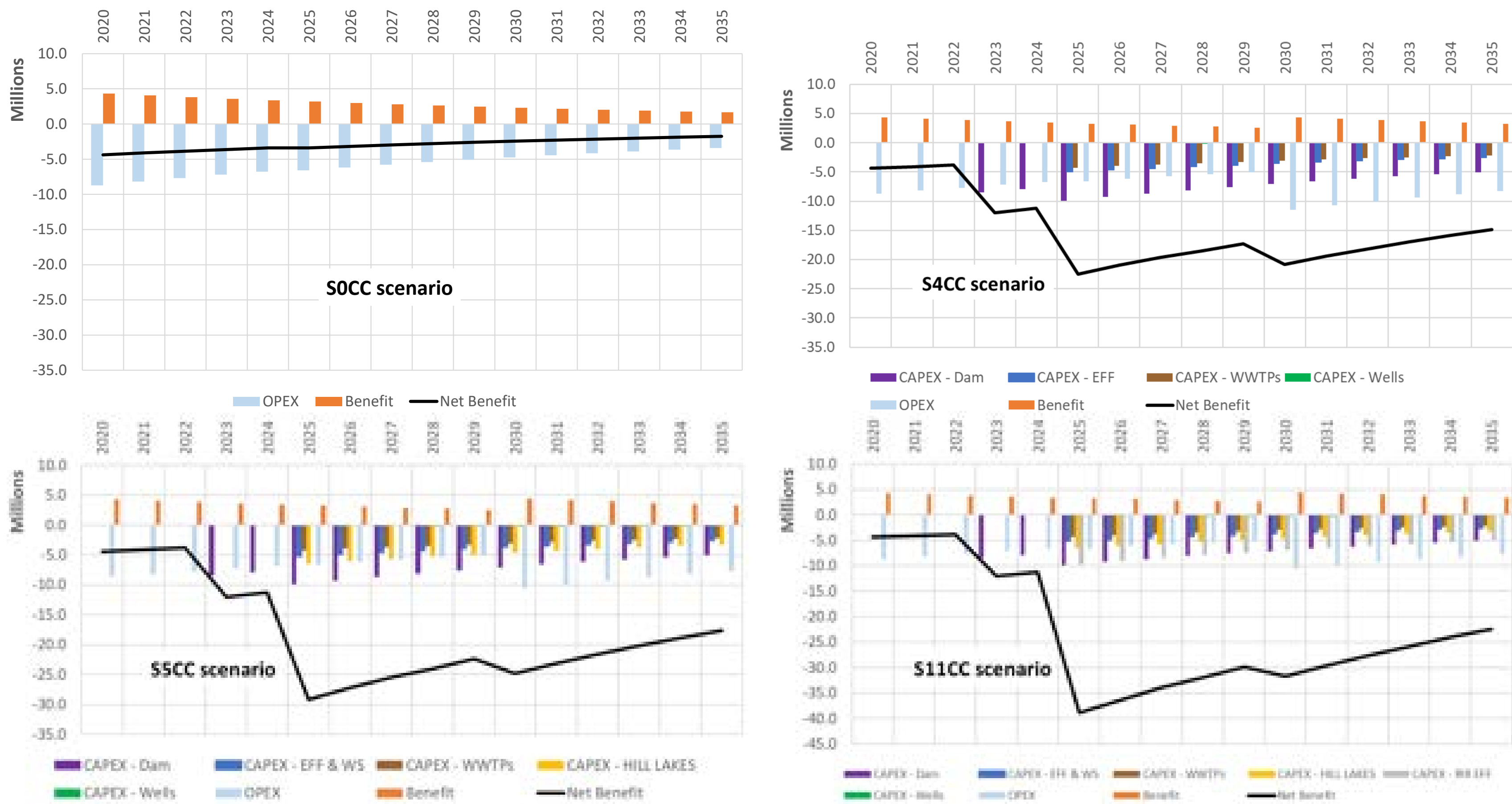

Figure 34 Present Value Costs and Benefits of the scenarios S0CC, S4CC, S5CC and S11CC, with a discount rate of 7%.

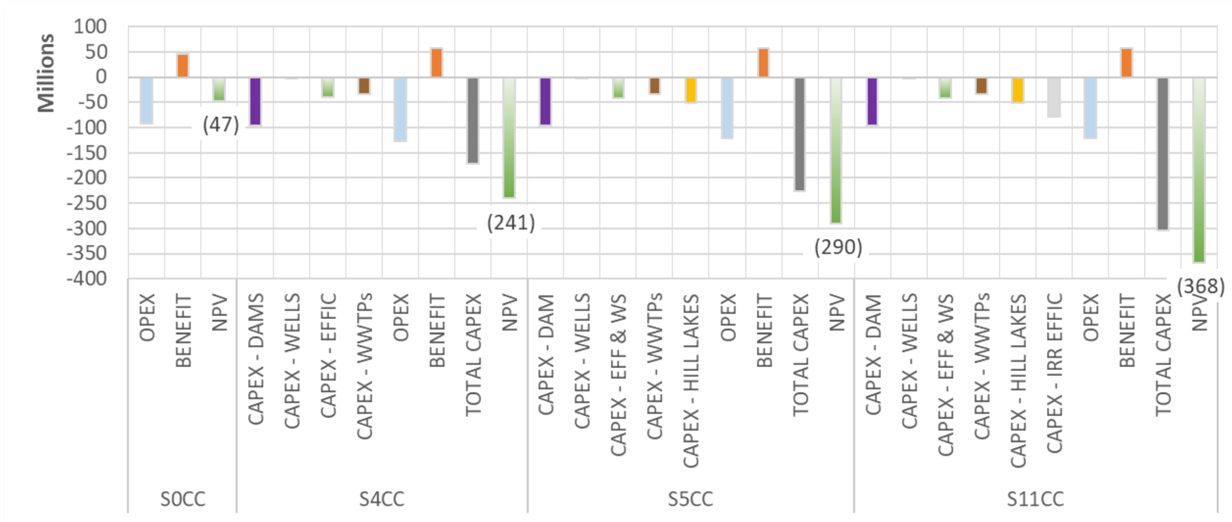

Figure 35 Net Present Value (NPV) of S0CC, S4CC, S5CC and S11CC, with a discount rate of 7%.

The financial indicators are highly negative after investments. It shows that, as long as price for drinking water is maintained as it is currently, the decision for investment should not be based solely on a financial outlook, but also, and importantly, on the need for equitable access to water.

9 Conclusion

A detailed water balance model has been developed for ARB for the period 2020-2035, allowing the representation of the components of the hydrological cycle and groundwater processes along with the water demand and use aspects in the catchment. The WEAP model was used to simulate future supply scenarios with the purpose of improving the conservation and management of the river basin and optimize the economic, environmental, and social benefits of the river taken into consideration suggestions from the participatory approach and proposed projects from the Updated NWSS 2020. The future water balance was developed, assessed, and translated into policy relevant targets to further support the design corresponding PoM and action plan in coordination with key stakeholders in the region.

During this study, four main challenges were identified within ARB: Insufficient water supply, groundwater extraction, water and wastewater pollution and flooding.

On the **water supply** level and after WEAP modelling of scenario S3CC and S4CC, it is safe to say that most of the expected demand increase (191 Mm^3/year) can be covered by the implementation of the projects suggested in the Updated NWSS 2020 especially Assi dams which will decrease the reliance on private groundwater extraction for irrigation purposes (84% coverage under S4CC). Nevertheless, it is also crucial to increase the network efficiency to 75% and reduce the water losses throughout the systems to achieve full coverage. Besides the major investment required to secure the construction of Assi dams, coordination between different stakeholders to achieve the vital and required loss reductions is paramount.

Moreover, an ambitious scenario S5CC was modeled where water saving artifacts are set in place in the households throughout the whole system to reach full domestic demand coverage, which would yield significant benefits but would also require an even further articulation and challenges for implementation. Amongst the main benefits of the addition of the water saving artifacts, we could mention, less water supply needed, less pumping and treatment costs, less water losses, leading to better efficiency in pumping and treatment costs, less wastewater to be treated or disposed and more environmental benefits.

On the irrigation level, the addition of the Assi dams helped in covering the current shortages and the potential increasing demand in Qaa region (IR07). Nevertheless, the proposed hill lakes and the reuse of treated wastewater do not help significantly in reducing the irrigation demand in IR01 (Yammouneh scheme). However, crop mitigation provides a significant decrease in unmet demand for this particular region.

On the **groundwater** level, MODFLOW was used to simulate the effects of the different scenarios on the groundwater levels and spring discharges. S3 which simulated the increasing irrigation water demand in 2035, resulted with increased abstractions from private wells, leading to a significant decrease in groundwater levels especially in the northern part of ARB. However, implementing measures that reduces groundwater abstractions in S4, S5, and S11 minimized the decline in groundwater levels. The potential decrease in precipitation by 2035 and the possible occurrence of consequent dry years intensified the decrease in spring discharges and groundwater levels of the Quaternary-Neogene aquifer. Most importantly, the long-term monitoring of spring discharge as well as groundwater level and quality is strongly advised.

On the **pollution** level, two sampling campaigns for water quality check were carried out during dry and wet seasons by NDU Laboratory team in coordination with BTD and ACTED. The field observations and interpretation of laboratory results revealed that it is influenced by human activities along the river like recreational activities, agricultural runoff and contaminated fish feed which contribute to higher BOD_5 levels, while certain sites showed fluctuating nitrate levels. Effective management is needed to prevent further deterioration and address sewage discharges, considering anthropogenic impacts.

On the **flooding** level, Arsal, Fekha, Ras Baalbek and Qaa, has witnessed several flash floods on a regular basis causing injuries and mortalities, a huge loss in properties, severe damage to farmers by degradation of vegetation cover. Several previous studies have assessed the hydrology and flood risk management potentialities in the study area. These studies have recommended measures such as detailed hydrological investigations, development of potential irrigation schemes, expansion of domestic water supply, dam construction and rehabilitation of collection basins, and sustainable irrigation practices through comprehensive master plans.

9.1 Recommendations

To effectively tackle the water supply, groundwater abstraction, pollution, and flood challenges in ARB, the following recommendations have been put forth:

- Enhance Assi RBM through collaboration, coordination, and long-term stakeholder engagement.
- Increase water availability through strategic infrastructure investments and projects as proposed in the Updated NWSS 2020 such as the construction of the Assi dams.
- Promote water-efficient agricultural practices, including the use of drip irrigation and sprinkler systems. Support the use of drought-tolerant crop varieties and sustainable farming practices
- Improve infrastructure development by constructing/rehabilitating water supply networks, wastewater treatment plants, irrigation systems, and flood protection measures. Ensure compliance with regulatory standards, long-term planning considering wastewater reuse for irrigation, and sustainable funding mechanisms.
- Monitor and control illegal abstractions and private wells, and define of safe yield per groundwater body.
- Raise public awareness on the importance of water conservation by implementing campaigns to educate communities, schools, and businesses about the value of water resources and the consequences of water scarcity and impacts of climate change.

9.2 Perspective

The continuous development of the WEAP model is of paramount importance to ensure the sustainability and success of the proposed measures and projects within ARB. This comprehensive water balance model, which has been instrumental in representing the intricate water resources, along with water demand and usage patterns, has significantly contributed to the formulation of future supply scenarios.

10 Appendix

A.Water quality sampling campaign report

AL ASSI RIVER
WATER QUALITY MONITORING
2nd water testing campaign

May 2023

NDU Team Members
Dr. Jacques Harb/Quality Assurance-Reporting
Dr. Claudette Hajj/Monitoring and Testing
Mr. Elie Lahoud/Sampling

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1 Overview of the followed Monitoring Process in Al Assi River

Notre Dame University of Louaize (NDU) team abided by the EPA (2013) guidelines during the monitoring and testing of the water quality in Al Assi River. The monitoring steps followed by NDU are presented in Figure 1 below.

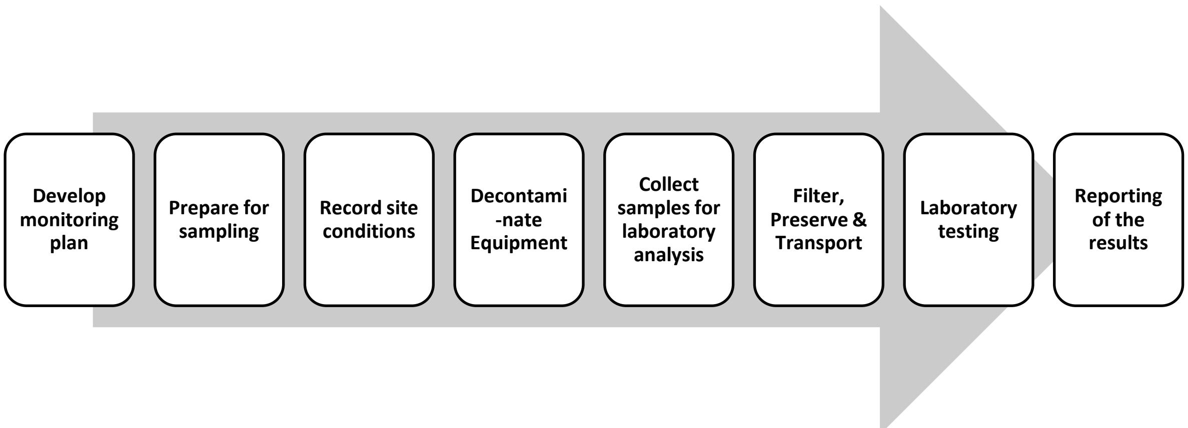

Figure 1 Stages of monitoring Process followed by NDU Team

1.1 Developing the Monitoring Plan

To guarantee that monitoring of Al Assi river basin is relevant, accurate, targeted, and cost-effective, a monitoring plan was developed by Notre Dame University after coordination with BTD. The last documents contained all the details of the actions, responsibilities, and timeframes that enables a delivery that meets the project objectives. Figure 2 shows the elements of the monitoring plan.

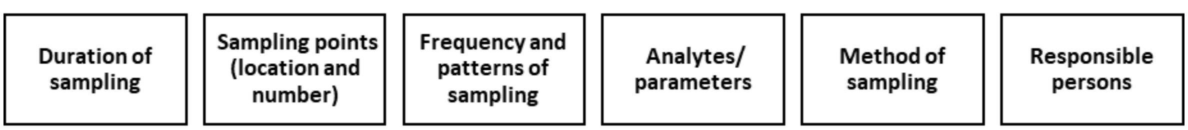

Figure 2 Elements of the Monitoring Plan

To accurately reflect the quality of the water in Al Assi, sampling was planned in a way that reflects water quality during both the dry and the wet seasons. The locations of the samples were chosen by BTD and GVC. The second sampling, during the wet season, from Al Assi river took place on February 2023.

1.1.1 Location and Duration of sampling

For this report, sampling was made over the wet season from the Al Assi river to show compliance with established criteria. Sampling Locations

The sampling plan to monitor water composition in Al Assi river was prepared in a way to guarantee that samples are collected at sites and times that provide a representative sample, thus providing an accurate description of the overall quality of the water in the river.

Furthermore, sampling sites were located in areas that are safe to access, accessible under all conditions of flow, and well mixed to ensure a homogenous sampling collected is easily identifiable for later sampling. During the wet season the number of samples were reduced to focus on the critical one. 6 samples were taken in triplicates from 6 different locations.

Permanent sampling locations were chosen by BTD and GVC to ensure that representative samples can be compared over time.

Table 1, and Figure 1 show the coordinates and Name of the points chosen for sampling in Al Assi River.

Table 1 Coordinates and location of the sampling location

ID	Name	Latitude	Longitude	Altitude
ID1	Labwe - Main	34.1974	36.3524	910
ID3	Fekha	34.2417	36.4068	1029
ID4	Al Assi – Dardara waterfall	34.4217	36.4573	564
ID6	Ras El Mail	34.3904	36.3713	785
ID7	Al Assi - Hermel Bridge	34.3935	36.4178	590
ID8	Zar2a	34.3524	36.3738	674

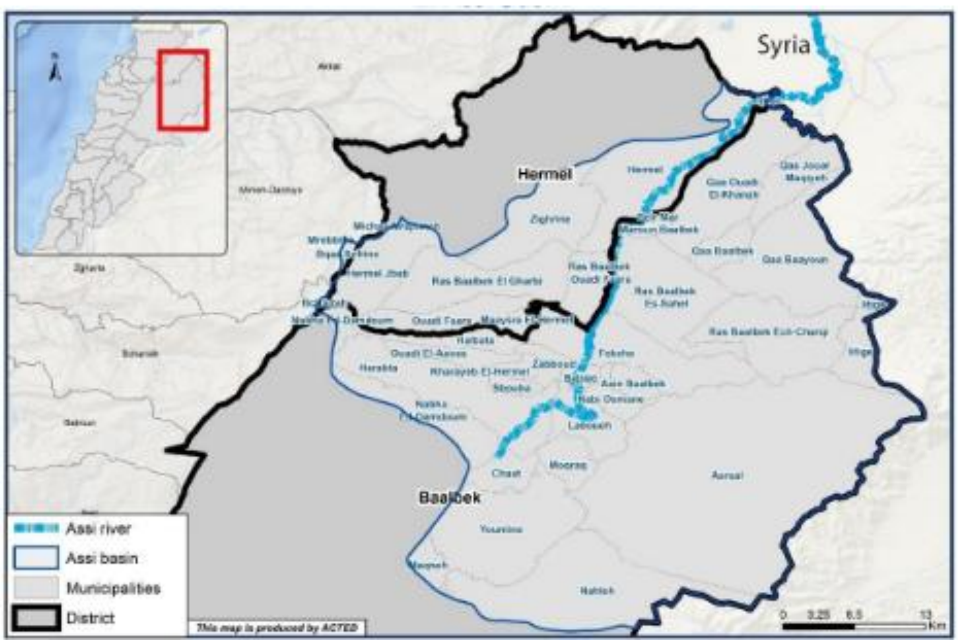

Figure 3 Broad representation of the Assi river between Syria and Lebanon

1.1.2 Water sampling and Procedures

The number of samples needed to determine the composition of water defines the accuracy/precision of the project (Griffiths, 2012). During the AL Assi first visit on February 27 (2023), six sampling points were chosen and agreed upon by the NDU, BTD and ACTED team. The grab sampling technique was used in AL Assi. This method is recommended when the parameters to be tested are not expected to greatly vary over time.

Grab samples were chosen for this trip as they are considered samples that provide a 'snapshot' of the water quality characteristics at the time of sampling (wet season). Therefore, grab sampling was used as it shows the concentrations at the six points location (differently) and time of sampling. The sampling of all the six points in al Assi was performed in one day over four hours. This method helps in showing the worst-case scenario situations, eg in the presence of surface scums of algae or oil and greases, or even very high pollution.

A sample of water was taken directly from the rivers in all the points using both plastic and glass containers.

Sub-surface samples were taken from approximately 20 to 35 cm depth, with cares taken to ensure that no floating films or organic material were collected unless they were of specific interest. NDU team tried to collect the sample at a reasonable distance from the edge. In most points, NDU team collected the samples directly into the sample container.

1.1.3 Sampling frequency and patterns of sampling

NDU team agreed with the stakeholders that two sampling campaigns will occur in Al Assi River. The first during August (2022) and the second during January (2023). The purpose of sampling during both wet and dry seasons aims at determining the variability of water quality. This sampling frequency (twice a year in two different seasons) ensures that the characteristics of the waters are adequately described resulting in a good understanding of the system and potentially accurate reporting of compliance or noncompliance with the standards (Hespanhol, & Prost, 1994).

1.1.4 Analytes

The choice of analytes with ACTED team depended on the contaminants present in Al Assi River and the criteria against which the monitoring is to be evaluated. Preserving a sound environmental condition of water as well as load discharge within limit is the main concern

Table 2 below includes the final list of analytes to be examined on Al Assi river:

Table 2 Final list of analytes

Turbidity (NTU)	Phosphorous (mg/L)
pH (pH)	Chloride (mg/L)
ORP (mV)	Ammonia (mg/L)
RDO (mg/L)	Sulphate
Conductivity (µS/cm)	Fluoride
TDS (ppt)	Lithium
TS (ppt)	Calcium
Temp (°C)	Potassium
Nitrate (mg/L)	Sodium
Lead (mg/L)	DO
Cadmium (mg/L)	BOD
Barium (ɥg/L)	COD
Mercury (ɥg/L)	Total Coliform
Ecoli	Fecal Coliform

2 Planning the Sampling Event

Careful planning and preparation of the sampling event amongst NDU, BTD, and ACTED is important and help to save time and resolve the number of problems that might occur during sampling. Overall, the sampling event was very smooth, and no unexpected hurdle occurred. This was the result of careful preparation of the trip that constitutes of the following:

2.1 Logistics

The basic steps followed by NDU for planning the sampling event are as follows:

1. NDU team reviewed the monitoring plan before the trip, including monitoring locations, number of samples required, sampling methods, and Occupational Health, Safety and Welfare (OHS&W) issues.
2. NDU team informed the personnel at NDU laboratories of the intended schedule.
3. NDU team prepared a list of the needed logistics such as the containers of suitable material and volume that contain preservatives. Table 3 shows a sample of the table that describes the followed procedure to do the testing.
4. BTD team scheduled the monitoring event. NDU team planned for the day including planning how and when NDU will transport the samples back to the laboratory. NDU team prepared a template to be taken on-site that aimed to show how samples are to be preserved and delivered to the laboratory as quickly as possible and within recommended holding times. This is especially relevant for samples with holding times of 24 hours or less (see Table 3).
5. NDU team checked all equipment required for the sampling event. It ensures that the equipment is operational and calibrated and checked one day before the sampling event. Moreover, Dr. Claudette Hajj and her team from NDU have decontaminated the equipment and the sample containers to be used or even reused between samples.

Table 3 Containers, Preservation Methods and Holding times

Analyte	Container Type	Volume (ml)	Filling Technique	Preservation	Holding time
Conductivity	Glass or Plastic	100	Fill container completely to exclude air	Not required	24 Hrs.
BOD	Glass	1000	Do not pre-rinse container with sample	Refrigerate and store in the dark	24 Hrs.
PH	Glass or Plastic	100	N.A.	Refrigerate	6 Hrs.
Solids	Glass or Plastic	500	Fill a container to exclude air	Refrigerate	24 Hrs.
Turbidity	Glass or Plastic	100	Fill container completely to exclude air	Not required	24 Hrs.
Metals	Glass or Plastic	100	N.A.	Acidify with nitric acid to pH 1 to 2	1 month
Fecal,E coliforms	Sterilized Glass or plastic,	200	Do not completely fill a container	Refrigerate	preferably < 6 hrs.

Figure 4 Autoclaving the Containers

2.2 Preparation of the Equipment before and during the Sampling

Major items of equipment that were prepared by the NDU team before the sampling process are:

1. Prepare and print the Records of observations and actions sheet. On-site records were taken to guarantee that a complete record of each sampling site and event is kept. For example, Water depth, presence of surface film, order, debris, algae, among many others

Table 4 Records of observations and actions sheet Sample

Sampling summary

Sampler	Claudette	Project number	Acted- Trip 1
Date	February 27, 2023	Time (begin and end)	9:15 am

Site information

Site ID	Point 4	GPS	Table 1
Location	Al Assi	Photo numbers	

Field observations

Weather	Temperature	23 C	
	Wind and direction Cloud cover/rain	Not present-Sunny	
Water	Tide/depth	1m	
	Flow Choppy/mixed/calm	Flow	
Observations examples	Surface film?	Yes	
	Algae/phytoplankton? Debris? Odour?	No Yes Yes	
Other/additional			

During every sampling event, observations of field conditions that could assist in the interpretation of monitoring data were recorded by NDU team. This provides useful information about the water being sampled, which can help diagnose the source and potential impact of pollutants found by chemical analysis.

Examples of such field conditions recorded by the NDU team are as follows:

- Presence of Wind and Rain: YES/**NO**
- Shading from clouds and vegetation YES/**NO**
- Any abnormalities that indicate pollution or affect water quality, such as the absence of flow, presence of surface scum, **watercolor or odors**, excessive algal or plant growth, dead fish, or invertebrates should also be noted. The above were recorded at each point.

2. Prepare and print all Chain of Custody forms that includes all the details about each sample (sampler name, time, date, type of tests, preservation method used, container type and size, type of analysis needed) and labels and packed them for the trip.
3. Use Navigational aids (NAVA 400 GPS) to accurately locate the sampling site for future reference.
4. Decide before the trip on the field testing meters.

Decide on the analytes that quickly degrade after they are sampled and therefore must be tested in the field. Some field measurements were undertaken in situ. The following analytes were measured in the field as concentrations of these analytes can be significantly changed during transport and storage:

• Dissolved oxygen (DO)

• Temperature

• PH

• Conductivity

• Redox (reduction/oxidation potential)

• Turbidity

• Chlorine

• Salinity

The above analytes were measured using multi-parameter meters. Field meters were calibrated one day before use. In particular, dissolved oxygen, pH, and turbidity that drift from day to day were calibrated using a standard solution twice during the sampling day.

Figure 5 Field measurement of the parameters using the In-Situ Aqua troll 500 multimeter

5. To preserve the integrity of the sample, the team ensured appropriate sample containers for each of the various parameters. The sample containers and preservation methods are presented in Table 2.
6. Prior to heading to the site, the team decontaminated the sampling equipment. All sampling equipment presents a risk of cross-contamination and therefore are thoroughly cleaned between samples with ethanol and distilled water. Moreover, multiple-use equipment are decontaminated prior to each sampling and between the collection of samples.
7. Most types of the sample require chilling as a means of preservation. NDU team prepared the needed esky. Samples are stored on ice in a car refrigerator, and the temperature maintained between 1°C and 4°C by adding two packs of ice every 2 hrs.

2.3 Collection of samples for analysis

Samples were collected using grab sampling from all the points in triplicates as shown in figures 5 to 10. Before the samples collection, the team made sure that the equipment is inert, and does not cause contamination or interference with the sample.

As organics have a tendency to adsorb to plastic, stainless steel equipment such as buckets and sampling rods were used. Glass sample containers were used in most cases, additional samples were taken in plastic containers. The team followed EPA Appendix 2 for information on the type of sampling container (eg glass, plastic), typical required volume, filling technique and preservation requirements for common analytes.

2.4 Sample Identification, Transport, and Storage

All samples were labelled by NDU team so they can be readily identified at all times. Sample containers were marked using permanent markers in such a way that they can be identified and distinguished from other samples in the laboratory. Care was taken when packing samples, as samples are often subject to vibration during transport. Sample labels have specified a clear and unique identifying code that can be cross-referenced to the monitoring location and time of sampling and includes: the date of sampling, time of sampling, location, name of sampling site, and name of a sampler.

Figure 6 Sampling directly into the container

During sample transport and storage, the NDU team followed key precautions to ensure effective transport and storage:

- Samples appropriately packed to avoid breakage and cross-contamination.
- Ensure the time between sampling and analyzing not to exceed holding time.
- Sample containers sealed, carefully packed with appropriate packing material, chilled or frozen (as required), and transported in an appropriate cooler or fridge.

2.5 Lab testing

Table 5 shows the test methods used at NDU labs to perform the needed testing. The procedure followed in these sections were accurately followed.

Table 5 Test methods

Parameter	Test Method
BOD 5	EMDC1 1173: Part 3 ± Five-day BOD Method
COD	EMDC1 1173: Part 4 ± Dichromate Digestion Method
PH	EMDC1 1173: Part 2 ± Electrometric Method
Temperature	EMDC1 1173: Part 1 ± Electrometric Method
Total Suspended Solids	EMDC1 1173: Part 1 ± Gravimetric Method
TS	EMDC1 1173: Part 3 ± Gravimetric Method
Turbidity	APHA Standard Methods:2130 B. Nephelometric Method
Chlorides (Cl -)	APHA Standard Methods: 4110 B. Ion Chromatography with Chemical Suppression of Eluant Conductivity
Cadmium	EMDC1 1173: Part 7 ± Flame Atomic Spectrometry Absorption Spectrometry
Barium (Ba)	EMDC1 1173: Part 7 ± Direct Nitrous Oxide-Acetylene Flame Atomic Absorption
Fluorides (F-)	APHA Standard Methods: 4110 B. Ion Chromatography with Chemical Suppression
Lead	EMDC1 1173: Part 7 ± Flame Atomic Absorption Spectrometry
Mercury (Hg)	EMDC1 1173: Part 10 ± Cold-Vapor Atomic
Nitrates (NO3 -)	APHA Standard Methods: 4110 B. Ion Chromatography with Chemical Suppression
Phosphorus	EMDC1 1173: Part 6 ± Colorimetric
Lithium	EMDC1- Flame photometry
Calcium	EMDC1 Flame photometry
Sodium	EMDC1 Flame photometry
Potassium	D992 Flame photometry
Nitrate	D1254 11C2: Flame Atomic Absorption Spectrometry
Ammonia	D1426: Flame Atomic Absorption Spectrometry
Total Coliform Organism	ISO 6222:1999, Microbiological method

3 Lab Results

Results obtained following the physical, biological and chemical testing of data collected (Tables 6 to 12), shows that almost all stations are characterized by median of pH between 7.0 and 8.22; so, the values are generally within appropriate limits for water supply and aquatic life. Total Dissolved Solids are a measure of all ions in a solution (TDS). TDS measurements were less than 251 ppm for all the samples.

The ammonium concentration in the samples carried out during the months of February showed acceptable values compared to WHO international standards. The amounts of nitrate, heavy metals, and chloride have not given values that exceed the accepted standards.

Below are the results of the field measurement:

Table 6 Results of Point ID1

Point Number	**Point Name**			**Nb of readings**
ID1	**Labwe Spring**			**3**
Report Properties	Start Time = 2023-02-27 10:36:36 Duration = 00:00:30			
Sample Number	1a - Labwe	1b-Labwe	1c-Labwe	**Average**
Turbidity (NTU)	0.01	0.01	0.01	**0.01**
RDO (mg/L)	7.4	7.4	7.3	**7.4**
S Conductivity (µS/cm) (935638)	301.1	301.6	303.5	**302.1**
Salinity (PSU)	0.1	0.1	0.1	**0.1**
Resistivity (Ω·cm)	4023	4019	4008	**4017**
Density (g/cm³)	1.0	1.0	1.0	**1.0**
TDS (mg/L)	196	200	192	196
TSS (mg/L)	52	58	42	52
TS (mg/L)	248	240	255	248
pH (pH)	7.9	7.9	7.9	7.9
ORP (mV)	353.8	354.3	363.3	**357.1**
Temperature (°C)	15.9	15.9	15.8	**15.8**
Nitrate (mg/L)	2.88	2.87	2.89	**2.88**
Lead (mg/L)	<0.1	<0.1	<0.1	**<0.1**
Cadmium (mg/L)	0.0008	0.0008	0.0008	**0.0008**
Barium (ųg/L)	1.7	1.8	1.68	**1.7**
Mercury (ųg/L)	0.022	0.021	0.023	**0.022**
Sodium (ppm)	4.4	4.4	4.4	**4.4**
Potassium	1.8	1.7	1.88	**1.8**
Lithium (ppm)	0	0	0	**0**
Calcium (ppm)	28.7	28.6	28.8	**28.7**
Phosphorus (mg/L	<0.3	<0.3	<0.3	**<0.3**
Chloride (mg/L)	5	4.7	5.3	**5**
Ammonia (mg/L)	0.26	0.26	0.26	**0.26**
Sulphate	<20	<20	<20	**<20**
Fluoride	0.3	0.32	0.28	**0.3**
DO	7.2	7.1	7.3	**7.2**
BOD	2.0	2.6	2.3	**2.3**
COD	15	10	17	**12**
Total Coliform	2	2	2	**2**
Fecal	0	0	0	**0**
Ecoli	0	0	0	**0**

Figure 7 Sampling at point ID1

Table 7 Results of Point ID3

Point Number		Point Name		Nb of readings
ID3		Fekha		3
Sample nb	3a-Fekha	3b-Fekha	3c-Fekha	Average
Date Time	2/26/2023 11:31	2/26/2023 11:31	2/26/2023 11:31	
Turbidity (NTU)	0.01	0.01	0.01	0.01
RDO (mg/L)	7.5	7.5	7.5	7.5
S-Conductivity (µS/cm)	360.7	360.9	361.0	360.9
Salinity (PSU)	0.2	0.2	0.2	0.2
Resistivity (Ω·cm)	3185.1	3184.4	3183.6	3184.4
TDS (mg/L)	235	230	240	235
TSS (mg/L)	40	48	44	44
TS (mg/L)	289	279	267	279
pH (pH)	7.9	7.9	7.9	7.9
ORP (mV)	275.7	276.7	277.9	276.7
Temperature (°C)	18.2	18.2	18.2	18.2
Nitrate (mg/L)	4.0	4.8	4.4	**4.4**
Lead (mg/L)	<0.1	<0.1	<0.1	<0.1
Cadmium (mg/L)	0.0009	0.0008	0.0009	0.0009
Barium (ɥg/L)	4	3.9	3.9	3.9
Mercury (ɥg/L)	0.023	0.021	0.021	0.021
Sodium (ppm)	12.0	12.2	12.1	12.1
Potassium	0.1	0.1	0.1	0.1
Lithium (ppm)	0.1	0.1	0.1	0.1
Calcium (ppm)	29.0	30.4	29.7	29.7
Phosphorus (mg/L	<0.3	<0.3	<0.3	<0.3
Chloride (mg/L)	11	12	13	12
Ammonia (mg/L)	0.55	0.51	0.53	0.53
Sulphate	<20	<20	<20	<20
Fluoride	0.4	0.5	0.6	0.5
DO	7.9	7.2	7.6	7.6
BOD	6.0	6.2	6.4	6.2
COD	22	22	19	21
Total Coliform	2	2	2	2
Fecal	0	0	0	0
Ecoli	0	0	0	0

Figure 8 Sampling at point ID3

Table 8 Results of Point ID4

Point Number	Point Name			Nb of readings
ID4	Al Assi Dardara			3
Sample Nb	4a **Al Assi**	4b **Al Assi**	4c **Al Assi**	Average
Date Time	2/26/2023 12:22	2/26/2023 12:22	2/26/2023 12:22	
Turbidity (NTU)	8.7	10.4	11.3	10.1
RDO (mg/L)	8.7	8.7	8.7	8.7
Specific Conductivity (µS/cm)	370.1	370.9	371.0	370.7
Salinity (PSU)	0.2	0.2	0.2	0.2
Resistivity (Ω·cm)	3327.7	3328.4	3327.0	3327.7
Density (g/cm³)	1.0	1.0	1.0	1.0
TDS (mg/L)	238	241	244	241
TSS (mg/L)	118	113	107	113
TS (mg/L)	356	354	358	356
pH (pH)	7.9	7.8	7.8	7.8
ORP (mV)	260.4	260.5	262.0	261.0
Temperature (°C)	15.2	15.1	15.1	15.1
Nitrate (mg/L)	2.79	2.83	2.77	2.79
Lead (mg/L)	<0.1	<0.1	<0.1	<0.1
Cadmium (mg/L)	0.002	0.002	0.002	0.002
Barium (ɥg/L)	3.5	3.5	3.5	3.5
Mercury (ɥg/L)	0.101	0.105	0.100	0.101
Sodium (ppm)	10.1	10.5	9.5	10.1
Potassium	2.8	3.0	2.9	2.9
Lithium (ppm)	0.1	0.1	0.1	0.1
Calcium (ppm)	36.2	35.8	36.6	36.2
Phosphorus (mg/L	<0.3	<0.3	<0.3	<0.3
Chloride (mg/L)	5	5	5	5
Ammonia (mg/L)	1.02	1.22	1.42	1.22
Sulphate	<20	<20	<20	<20
Fluoride	0.2	0.2	0.2	0.2
DO	6.8	6.7	6.6	6.8
BOD	33	27	30.0	30.0
COD	101	91	111	101
Total Coliform	21	20	22	21
Fecal	6	7	6	6
Ecoli	5	5	5	5

Figure 9 Sampling point ID4

Table 9 Results of Point ID6

Point Number	Point Name			Nb of readings
ID6	Ras El mail			3
Sample nb	6a- Ras El mail	6b- Ras El mail	6c- Ras El mail	Average
Date Time	2/26/2023 12:53	2/26/2023 12:53	2/26/2023 12:53	
Turbidity (NTU)	0.05	0.05	0.05	0.05
RDO (mg/L)	8.6	8.6	8.6	8.6
S-Conductivity (µS/cm)	226.4	227.1	227.0	226.8
Salinity (PSU)	0.1	0.1	0.1	0.1
Resistivity (Ω·cm)	5830.9	5830.4	5834.0	5831.8
Density (g/cm³)	1.0	1.0	1.0	1.0
TDS (mg/L)	147	150	144	147
TSS (mg/L)	15	10	20	15
TS (mg/L)	160	160	166	162
pH (pH)	7.6	7.6	7.6	7.6
ORP (mV)	266.0	268.2	269.0	267.7
Temperature (°C)	12.3	12.2	12.2	12.2
Nitrate (mg/L)	1.5	1.5	1.5	1.5
Lead (mg/L)	<0.1	<0.1	<0.1	<0.1
Cadmium (mg/L)	0.00002	0.000016	0.000018	0.000018
Barium (ɥg/L)	3.3	3.1	3.2	3.2
Mercury (ɥg/L)	0.126	0.130	0.122	0.126
Sodium (ppm)	6.0	6.2	6.1	6.1
Potassium	1.6	0.8	1.2	1.2
Lithium (ppm)	0.1	0.1	0.1	0.1
Calcium (ppm)	21.8	20.5	21.1	21.1
Phosphorus (mg/L	<0.3	<0.3	<0.3	<0.3
Chloride (mg/L)	3	3	3	3
Ammonia (mg/L)	0.02	0.02	0.02	0.02
Sulphate	<20	<20	<20	<20
Fluoride	0.5	0.5	0.5	0.5
DO	7.0	7.4	7.2	7.2
BOD	6.1	5.5	6.5	6.1
COD	34	34	34	34
Total Coliform	3	3	3	3
Fecal	0	0	0	0
Ecoli	0	0	0	0

Figure 10 Sampling point ID6

Table 10 Results of Point ID7

Point Number	Point Name			Nb of readings
ID7	Mizen			3
Sample Nb	7a- **Mizen**	7b- **Mizen**	7c- **Mizen**	**Average**
Date Time	2/26/2023 11:51	2/26/2023 11:51	2/26/2023 11:51	
Turbidity (NTU)	4.4	4.8	3.7	4.3
RDO Concentration (mg/L)	8.4	8.4	8.4	8.4
RDO Saturation (%Sat)	89.1	89.1	88.9	89.1
S-Conductivity (µS/cm)	370.2	370.2	370.1	370.2
Salinity (PSU)	0.2	0.2	0.2	0.2
Resistivity (Ω·cm)	3302.1	3302.1	3302.3	3302.2
Density (g/cm³)	1.0	1.0	1.0	1.0
TDS (mg/L)	241	246	235	241
TSS (mg/L)	93	96	90	93
TS (mg/L)	339	334	330	334
pH (pH)	8.2	8.2	8.2	8.2
ORP (mV)	253.3	253.2	253.1	253.2
Temperature (°C)	15.5	15.5	15.5	15.5
Nitrate (mg/L)	3.06	2.98	3.02	3.02
Lead (mg/L)	<0.1	<0.1	<0.1	<0.1
Cadmium (mg/L)	0.001	0.001	0.001	0.001
Barium (ɥg/L)	3.5	3.7	3.7	3.7
Mercury (ɥg/L)	0.019	0.02	0.018	0.019
Sodium (ppm)	10.5	11.1	10.8	10.8
Potassium	3.2	3.1	3.0	3.1
Lithium (ppm)	0.1	0.1	0.1	0.1
Calcium (ppm)	36.5	36.3	36.1	36.3
Phosphorus (mg/L	<0.3	<0.3	<0.3	<0.3
Chloride (mg/L)	7.1	7.0	7.0	7.0
Ammonia (mg/L)	0.6	0.6	0.6	0.6
Sulphate	<20	<20	<20	<20
Fluoride	0.3	0.3	0.3	0.3
DO	7.6	8	7.4	7.6
BOD	41.0	42.0	41.1	41.3
COD	90	93	87	90
Total Coliform	20	20	20	20
Fecal	7	7	7	7
E coli	4	4	4	4

Table 11 Results of Point ID8

Point Number		**Point Name**		**Nb of readings**
ID8		**Zar2a**		**3**
Sample nb	8a- **Zar2a**	8b- **Zar2a**	8c- **Zar2a**	**Average**
Date Time	2/26/2023 1:30	2/26/2023 1:30	2/26/2023 1:30	
Turbidity (NTU)	0.02	0.02	0.02	0.02
RDO (mg/L)	8.2	8.2	8.2	8.2
Specific Conductivity (µS/cm)	368.7	368.9	368.9	368.8
Salinity (PSU)	0.2	0.2	0.2	0.2
Resistivity (Ω·cm)	3361.1	3361.9	3362.7	3361.9
Density (g/cm^3)	1.0	1.0	1.0	1.0
TDS (mg/L)	239	235	243	**923**
TSS (mg/L)	20	25	15	20
TS (mg/L)	249	271	260	260
pH (pH)	7.0	7.0	7.0	7.0
ORP (mV)	256.4	256.9	257.2	256.8
Temperature (°C)	14.6	15.2	14.9	14.9
Nitrate (mg/L)	2.88	2.77	2.82	2.82
Lead (mg/L)	<0.1	<0.1	<0.1	<0.1
Cadmium (mg/L)	0.0008	0.0008	0.0008	0.0008
Barium (ųg/L)	3.6	3.6	3.6	3.6
Mercury (ųg/L)	0.092	0.099	0.095	0.095
Sodium (ppm)	10.0	9.8	9.9	9.9
Potassium	2.6	2.6	2.6	2.6
Lithium (ppm)	0.1	0.1	0.1	0.1
Calcium (ppm)	36.0	36.5	37.0	36.5
Phosphorus (mg/L	<0.3	<0.3	<0.3	<0.3
Chloride (mg/L)	7	7	7	7
Ammonia (mg/L)	0.4	0.4	0.4	0.4
Sulphate	<20	<20	<20	<20
Fluoride	0.40	0.30	0.35	0.35
DO	7.6	7.8	7.7	7.7
BOD	1.6	1.9	2.2	1.9
COD	21	17	19	19
Total Coliform	3	3	3	3
Fecal	0	0	0	0
Ecoli	0	0	0	0

Figure 11 Sampling point ID8

Table 12 WHO Standards Limit Table (Boyd,2019) for drinking water.

Chemical Product	WHO Limit	Chemical Product	WHO Limit
Ph	6.5-8.45	CL- (mg/L)	250
Temp °C	15-21	F^{-} (mg/L)	1.5
EC (ɥS/cm)	1500	$PO_4{}^{3-}$ (mg/L)	1
TDS (mg/L)	500	Ca^{2+} (mg/L)	200
BOD (mg/L)	25	Mercury (mg/L)	0.002
COD (mg/L)	25	Barium (mg/L)	1.3
Na^{2+} (mg/L)	150	Cadmium (mg/L)	0.005
$K+^{+}$(mg/L)	12	Lead (mg/L)	0.015
$NH_4{}^{+}$ (mg/L)	1.5	Total Nitrogen	50
$SO_4{}^{2-}$ (mg/L)	250	$NO_3{}^{-}$ (mg/L)	50

Table 13 Summary of the results

Test/Point ID	Irrigation value	WHO Standards for Drinking	ID1	ID3	ID 4	ID 6	ID7	ID 8
Turbidity (NTU)	**<10**	**<5**	0.01	0.01	10.1	0.05	4.3	0.02
pH (pH)	**6.5-8.4**	**6.5-8.4**	7.9	7.9	7.8	7.6	8.22	7
ORP (mV)	**-**	**-**	357	276	261	268	253	257
RDO (mg/L)	**-**	**-**	7.4	7.5	8.7	8.6	8.4	8.2
S-Cond (µS/cm)	**1000**	**1000**	302	360.9	370	226	370	368
TDS (ppm)	**1000**	**500**	196	235	241	147	241	239
TSS (ppm)	**60**	**-**	52	44	113	15	93	20
TS (ppm)		**1500**	248	279	354	162	334	259
Temperature	**10-30**	**24-30**	15.8	18.2	15.1	12	15.4	14.9
Nitrate (mg/L)	**10**	**10-50**	2.88	4.4	2.79	1.5	3.02	2.82
Lead (mg/L)	**5**	**0.01**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium (mg/L)	**0.01**	**0.01**	0.0008	0.0009	0.002	$18x10^{-4}$	0.001	0.0008
Barium (ųg/L)	**-**	**0.7**	1.7	3.9	3.5	3.2	3.7	3.6
Mercury (ųg/L)	**0.1**	**0.06**	0.022	0.021	0.101	0.126	0.019	0.095
Sodium (ppm)	**150**	**60**	4.4	12.1	10.1	6.1	10.8	9.9
Potassium	-	**12**	1.8	0.1	2.8	1.2	3.1	2.6
Lithium (ppm)	**2.5**	**--**	0	0.1	0.1	0.1	0.1	0.1
Calcium (ppm)	**150**	**100-300**	28.7	29.7	36.2	21.1	36.3	36.5
Phosphorus (mg/L)	**2**	**0.5**	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Chloride (mg/L)	**140-500**	**100-500**	5	12	5	3	7	7
Ammonia (mg/L)	**5**	**1.5**	0.26	0.53	1.22	0.02	0.6	0.4
Sulphate	**200**	**45**	<20	<20	<20	<20	<20	<20
Fluoride	**1**	**0.5**	0.3	0.5	0.2	0.5	0.3	0.35
DO	**Above 5**	**Above 5**	7.2	7.6	6.8	7.2	7.6	7.2
BOD	**25**	**4**	2.3	6.2	30.0	6.1	41.3	1.9
COD	**200**	**0.5**	12	21	101	34	90	19
Total Coliform	**<1000**	**0**	2	2	21	3	20	2
Fecal	**<100**	**0**	0	0	6	0	7	0
Ecoli	**<100**	**0**	0	0	5	0	4	0

4 Discussion and Interpretations

Water samples were collected from Al-Assi River during the wet season and tested for physical qualities, chemical contents, and microbiological counts. Six sampling points were selected. Water quality parameters, such as conductivity, DO, BOD, COD, pH, TS, DS, and Fecal Coliform were analysed. The concentration of lead, cadmium, mercury, barium, lithium, sodium, potassium, chloride, sulphate, fluoride, ammonia, phosphorus, and nitrate was also analysed at all the points. The examination of the results is shown below:

Measuring **dissolved oxygen (DO)** in drinking water and in irrigation water is important to understand water quality. DO is critical for fish and other aquatic organisms to survive. DO values for Al-Assi river, along our reach varied between 6.8 mg/L to 7.7 mg/L. WHO standard for sustaining aquatic life is <4 mg/L, whereas for drinking purposes it is 6 to 8.5 mg/L. crops perform better with higher levels of DO in the irrigation water. For plant growth a value above 5 mg/L is acceptable, and above 8 is heathy. Therefore, all the examined points are suitable for drinking, irrigation and aquatic life. High dissolved oxygen levels are beneficial for drinking water, as it improves the taste, however, high dissolved oxygen levels are linked to the rapid corrosion of water pipes. Furthermore, the results show that DO concentration is reduced when an increase in temperature occurs as oxygen saturation levels are temperature-dependent.

While in the case of **(BOD) concentration, the results** recorded values ranging from 1.9 mg/L at point ID8 and 41 mg/L at point ID7. Most rivers have BOD_5 below 1 mg/L. Moderately polluted rivers may have a BOD_5 value in the range of 2 to 8 mg/L. However, high BOD_5 levels (>8mg/L) can be a result of high levels of organic pollution, caused usually by poorly treated wastewater or from high nitrate levels (EEA, 2001). WHO standard for drinking purposes is 0.2mg/L, which is exceeded to a great extent. A BOD value less than 25mg/L is considered suitable for irrigation, therefore BOD at points ID1, ID3, ID6 and ID8 is considered suitable water for irrigation. Higher BOD_5 values were detected at sites ID4, and ID7 which may be attributed to recreational activities in the form of restaurants, fisheries, and rafting activities that are located along the river as well as family picnic areas in addition to agricultural runoff. Moreover, this might be due to the discharge of Oil Mill (OM) waste, for example, into the river during the sampling season. OM contains an enormous supply of organic matter which might raise the BOD_5 level (Mekki et al., 2013). More specifically, around 13% of olive oil production in Lebanon takes place in the Bekaa area and Lebanon has 21 registered oil mills in the Bekaa region (Ministry of Agriculture,2016). Based on the report, none of these oil mills is treating its waste before discharging it into the environment, which implies that these mills might be discharging the waste into the Al-Assi river in the bekaa valley (Kinab and khoury, 2015).

Chemical oxygen demand (COD) is another important parameter of water quality assessment. A standard for drinking purposes is 10 mg/L, and 200 mg/L for irrigation for fruits which is acceptable for all the points in terms of our analysed value. **Error! Reference source not found.** shows the COD data of six sampling points. High contaminations exist at points ID7 and ID4 with COD values of 90 and 101 mg/L respectively. The highest levels of COD recorded may be also attributed to raw sewage discharge and for the same reasons stated in the BOD examination.

Concerning the **pH** which is an indicator of the acidic or alkaline condition of water status, the standard for any purpose is 6.5-8.5, in that respect; the values of our sampled water conform with the standards as for all the samples it varies between 7.00 at point ID8 and 8.22 at point ID4. PH was found to be lower at all points from the dry season. This might be due to the acidity of the rainfall that has mixed and reduced the PH of the river water. All sites exhibited values of pH within the limits of the natural values that support aquatic life.

Adding to the above, the value of electric **conductivity** (EC) of Al-Assi river varied between 226 and 368 µs/cm. Conductivity depends on the number of ions present in water. In the wet season, the total volume of water increases at Al-Assi, yet the conductivity was within the range for surface water and for irrigation (< 1000 µs). A main observation from the results is that conductivity is directly influenced by TDS, the higher the TDS the higher the EC (Lawson, 2011). A positive correlation was clear between EC and TDS. Highest conductivity and TDS were found at point ID6 and ID7, and lowest values were found at point ID7.

Likewise, **total solids** concentrations in the wet season varied between a minimum of 162 mg/L at point ID6 and a maximum of 354 mg/L at point ID4.

Concerning **Dissolved Solids (DS**), the standard for drinking water is 500 mg/L. The maximum value obtained from the samples in the wet season is 239 mg/L at point ID8. In this respect, we can conclude that Al-Assi river water is acceptable from the drinking and irrigation water perspective. High levels of TDS at some points are caused by the presence of potassium, chlorides, and sodium and by toxic ions (lead arsenic, cadmium, and nitrate), and result in an undesirable taste that could be salty, bitter, or metallic (Lawson, 2011).

Similarly, the WHO standard for **ammonia** in surface water for drinking purposes is 1.5 mg/L and for irrigation water is 5 mg/L. The results yielded from the test results showed much lower values ranging from 0.02 at point ID6 to 1.22 mg/L at point ID4 which means it is quite safe in terms of ammonia pollution. This has increased from the dry season; this might be due to the runoff from Agricultural lands that include fertilizers.

Comparably, the levels of **nitrate** exhibited a clear fluctuation among the sites ranging from the lowest value of 1.5 mg/ at point ID6 to 4.4 mg/L at point ID3 yet falling below the limit for surface water (50 mg/l).

Apart from the above, we have traced **metal detection** water. These chemicals are classified as being potentially hazardous and toxic to most forms of life. Results reported that trace metals' concentration for **lead, mercury, barium, and cadmium** was low.

Moreover, some of the chemical elements like **Sodium, potassium, lithium, and calcium** are essential as micronutrients for the life processes in animals and plants (Kar et al., 2008). Fortunately, acceptable concentrations were found in AL Assi.

Similarly, **phosphorus** concentrations recorded values less than 0.3 mg/L for all the sampled points. Comparing these results with WHO limits, they fall within the acceptable level of phosphorus (1mg/L) in rivers.

The sulphate, as well, recorded a mean value of less than 20mg/L for all the. Compared with WHO guidelines, the results fall within the acceptable range (<200 mg/L).

Similarly, **chloride** concentration documented values varying from 3.00 to 12 mg/L. These were found lower than the values at the dry season for all the points. Compared with WHO guidelines, the level of chloride did not exceed the range (200 mg/L) for drinking water indicating that there are no industrial effluents or urban runoff at the location of the sample.

On the other hand, **calcium** values varied between 21.1 mg/L at point ID6 and 36.5 mg/L at point ID8. Calcium is an important micronutrient in the aquatic environment, and it enters the water mainly through the weathering of rocks. The concentration of calcium in rivers may reach 200 mg/L. Results are within the range.

Moreover, **fluoride** concentrations were recorded at all sites, yet no marked variation was observed, a value lower than 0.5mg/L was found at all sites. These are clearly acceptable as far as drinking and irrigation purposes are concerned. For other activities relating to surface water quality, the values are quite acceptable.

Apart from the physical and chemical parameters, the water was tested for microbiological pollutants. The results of the six sampling points show that for points ID1, ID2, ID3 and ID7 there is no detection of fecal and E-coli. However, fecal and total coliform counts were present at sites ID4 and ID6 indicating the critical condition of excessive microbiological contamination. It is important to note that the values for fecal, E and total coliform were found considerably lower in the wet season than the values found on the dry season. The presence of fecal coliform bacteria in very high levels indicates potential health risks to swimmers and implies the suitability of the water at these critical points for specific water uses such as swimming is restricted. The profiles of the water samples at Id4 and Id7 were found to be unsuitable for human consumption, as the concentrations of faecal coliforms and E. coli exceeded the WHO standards recommended limits for drinking water. The high number of coliforms at points ID4 and ID6 confirms the presence of agricultural runoff, animal waste, or raw sewage in the river. Due to the diffuse nature of runoff across the landscape, the bekaa municipalities should implement multiple structural and non-structural practices that are geared towards improving water quality in streams and rivers. These practices might include Stormwater infrastructure inventory, maintenance and repair, Sewer and septic system inspections.

These coliforms indicate that the source water may have been contaminated by pathogens or disease-producing bacteria or viruses which exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals and water species exposed to this water. Fecal coliform bacteria occurred as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste.

Fecal coliform bacteria can affect fish health in the Al assi river in the following ways:

- Untreated fecal material adds excess organic material to the water which decays, depleting the water of oxygen. This lowered oxygen may kill fish and other aquatic life.
- Fecal material also contains nutrients and organic matter. Nutrient addition to surface waters, can increase algal growth, decrease water clarity, and increase ammonia concentrations which can be toxic to fish.
- Fecal coliforms are bacteria associated with human or animal waste. The presence of fecal coliforms in water may not be directly harmful; however, it does indicate an increased likelihood of harmful pathogens in the water.
- Eating fish or shellfish harvested from waters with fecal contamination can result in human illness.

Therefore, according to the WHO standards and the European Economic Community, fecal coliforms in drinking water are not tolerated (0 FC/100ml), and bathing water should not exceed 100 FC/100 ml (Servais et al. 2007) and for irrigation <200 FC/100 ml. Several health outcomes such as gastrointestinal infections might be associated with fecally polluted water which may result in a significant burden of disease (WHO 2001). Considering that bacteria densities are greatest during the summer months and the fact that there is no wastewater treatment in the whole catchment area of Al-Assi river, the construction of wastewater treatment systems primarily for large settlements is essential.

To sum up, the results from data analysis show that the water is certainly unfit for drinking purposes without any form of treatment, but for various other surface water usage purposes, such as irrigation it is considered quite acceptable. But as we know, once a trend in pollution sets in, it generally accelerates to cause greater deterioration. So, a few years from now, serious water quality deterioration could take place.

5 Conclusion

The water quality of the Al-Assi River was analysed. The physical, bacteriological, and chemical composition of the river was studied in the wet season. Almost all sites exhibited values of pH within the limits of the natural values that support aquatic life. The levels of TDS were fluctuating among the sites with the highest values recorded at site ID4 and ID7 (within the acceptable range) indicating that there is no seawater intrusion. Higher BOD_5 values were detected at sites ID4 and ID7 which may be attributed to recreational activities in the form of restaurants that are located along the river as well as family picnic areas in addition to agricultural runoff. The levels of nitrate exhibited a clear fluctuation among the sites ranging yet falling below the limit for surface water. The levels of sulphate did not exhibit a distinct spatial variation among the sites. The estimated indices at sites ID1 (Laboueh spring) and ID6 (Ras el Mail spring) were generally good. However, sites ID3, ID4, ID7 and ID8 exhibited relatively the worst water quality conditions.

WHO specifies guidelines and imperative values for drinking and aquatic life were used. This assessment was adopted as the Lebanese Ministry of Environment (MOE) Standards for surface waters, do not include all of the parameters reported here.

Results revealed that the water quality of the AL Assi River is generally affected by the activities taking place along its watershed. The best quality was found in the upper sites and the worst at the estuary. The impact of recreational activities in the form of restaurants that are located along the river as well as family picnic areas resulted in poor water quality that is suitable for specific water uses such as swimming is restricted due to the presence of high levels of fecal coliform. Given that recreational use of the river is very important for the development of the area, preventing further deterioration by anticipating and avoiding new impacts is crucial for effective management. If Al-Assi river is to be used as a managed water resource, point source discharges, and primarily sewage require treatment.

Adding to the above, anthropogenic perturbations, the difference in topography among the sampling locations, the actual volume of water in the stream, and flow rate are important factors introducing changes to water quality at several points.

Concerning the temporal variation of the water quality, the turbidity showed to be affected by the total flow of the AL-Assi water river and increases during the winter season when elevated erosion rates are present.

The results on the map confirms that stations situated in the flatland, are encountering organic and bacterial pollution probably due to anthropogenic stress coming from the flat area and the nearby villages. The laboratory results show that the summer or dry season exhibits a higher number of fecal and E coli., this profile confirms the seasonal impact on bacteriological patterns. Several health results such as gastrointestinal infections might be related to polluted water with fecal coliform which may lead to a dangerous burden of disease. The bacteria densities are higher during the summer seasons and since there is no wastewater treatment in the studied area of Al-Assi river, the implementation of wastewater treatment systems primarily for large settlements is highly recommended. To sum up, the results show that, the water is surely unqualified for drinking purposes without the necessary treatment, but for various other surface water usage purposes, water still could be considered acceptable. But as we know, once a trend in pollution commences, it generally increases and causes greater deterioration in the water quality. So, a few years from now, dangerous water quality decay is expected to happen.

Table 14 Various drinking water quality standards

Parameter	Drinking water quality as per EQS standard	WHO standard	EC standard
pH	6.0-8.5	6.5-8.5	6.5-8.5
TDS (mg/L)	1,000	1,000	1,000
Iron (mg/L)	0.3-1.0	0.3	0.20
Sodium (mg/L)	200	200	175
Chloride (mg/L)	150-600	250	250
Sulphate (mg/L)	400	400	25
Fluoride (mg/L)	1.0	1.5	1.5
Arsenic (mg/L)	0.05	0.05	0.05
Ammonium (mg/L)	0.5	1.5	0.5
Nitrate (mg/L)	10	10	10
Phosphate(mg/L)	6.0	--	5.0
Potassium (mg/L)	12.0	--	10
Endrin (µg/L)	0	0.2	0.2
Heptachlor (µg/L	0	0.1	0.1
DDT (µg/L)	0	1.0	0.1

6 Quality Assurance and Performance

Quality assurance (QA) plan contains the policies, procedures and actions established to provide and maintain a degree of confidence in data integrity and accuracy. For the monitoring trip to AL Assi River to successfully meet its objectives, NDU took rigorous and thorough steps to ensure that its testing campaign is reliable. The team followed EPA standards for monitoring and sampling procedures. The QA system shown in Table 15 was followed.

Moreover, Water sampling quality control ensures that the monitoring data taken sufficiently represents the in-situ conditions of the Al Assi River. Any significant change of contamination to the sample due to containers, handling and transportation is identified through the incorporation of QC. Therefore, all labs tests at NDU were taken in triplicates and a comparison of the results was examined. In all cases no outliers was found, and the average was taken for all the parameters

Table 15 Quality control in monitoring

Monitoring Step	QC protocols	Purpose	Refer to Compulsory
Develop monitoring plan	Various, including control sites, multiple sample locations, duplicate samples, sampling times	Ensure the sample collected is representative of the body from which it was taken	Section 1 in this report
Sample collection	Appropriate containers, filling, and preservation techniques	Minimize changes to sample (physical and chemical)	Section 2
	Sample blanks—field, transport, equipment, and container	Quantify contamination of samples during the sampling process	Section 3
	Decontamination of sampling equipment	Minimize contamination	Section 3
Field testing	Equipment calibration	Minimize and quantify bias and error in-field equipment	Section 3
Transport and storage	Appropriate preservation techniques	Minimize physical and chemical changes to sample	Section 4
Analysis	NDU lab accredited by ABET for required analysis	Ensure the laboratory undertakes appropriate QC including spikes, calibration of equipment, and make sure the results are reported in triplicates	Section 5 and 6
Reporting	Peer review validation	Validate that sampling is undertaken as per the monitoring plan and by sampling guidelines	Section 5 to 7

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B.First participatory workshop report

المشاكل المائية المتعلقة بحوض العاصي

1. مخالفات بناء على مجرى النهر
2. مخالفات المسالخ
3. المكبات العشوائية
4. قلة التحريج في المناطق (الغطاء النباتي)
5. التعديات على مجرى النهر
6. عرقلة الحلول المطروحة بسبب المشاكل الاجتماعية و المناطقية و اختيار المتعهدين
7. تحديث الدراسات القديمة (التي تمت مسبقا)
8. تلوث الينابيع و مصادر العاصي
9. السيول
10. تربية السمك و مخاوف من ارتفاع حرارة المياه جراء السدود على تربية الاسماك
11. السياحة
12. الزراعة
13. فشل الادارة الحكيمة و ضعف سلطة الدولة
14. مياه الصرف الصحي (محطات الصرف الصحي)
15. الحوكمة و قلة الموارد البشرية
16. دراسة الاثر البيئي لكل مشروع
17. الابار العشوائية
18. التصحر و قطع الاشجار
19. عدم وجود شبكات مياه شفة و تهالكها
20. عدم تطبيق القوانين

الحلول المقترحة المتعلقة بحوض العاصي:

- انشاء لجنة مختصة لحوض العاصي :
  - وزارة الطاقة
  - وزارة الزراعة
  - وزارة البيئة
  - وزارة الصحة
  - وزارة الداخلية
  - مؤسسة المياه
  - وزارة السياحة
  - الجيش اللبناني والقوى الأمنية المختصة

  مهامها : التقييد بالقوانين و قمع المخالفات

  وضع مخطط توجيهي لادارة الموارد الطبيعية

  اجتماع اللجنة دوريا
- استغلال مياه الصرف بالزراعة
- ضبط الابار العشوائية
- دعم اعلاف المسامك لتكون بديل عن الاعلاف الملوثة
- ورش عمل للمزارعين وذلك لارشادهم بطريقة استعمال الاسمدة والمبيدات وتنظيم الري
- انشاء برك تجميع مياه الامطار و رفع نسبة تسريب مياه الامطار
- التشجير, تجليل و الزراعات البديلة
- ترشيد استهلاك المياه
- ترميم اقنية المياه
- صيانة محطات التكرير
- تفعيل الاستراتيجيات الموجودة
- انشاء وحدات تكرير للمنشات السياحية على ضفاف النهر
- فرز النفايات من المصدر وانتاج الطاقة / تشجيع إنتاج السماد الزراعي عبر تقنيات التخمير الهوائي واللاهوائي
- العمل على اشراك وزارة التربية والتعليم في عملية التوعية

C.Climate change impact on irrigation water demand

i. Water requirement for 2035 under SSP2 - 4.5

Table 27 Effective rain, ET0 and water balance in ARB under SSP2 – 4.5

Scenario	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	Eff. Rain	69	62	33	15	7	1	0	0	5	19	26	62	299
SSP2-4.5	ETo	48	55	90	125	168	213	251	233	167	115	67	51	1579
	Balance	21	8	-57	-109	-161	-212	-251	-232	-162	-96	-41	12	

The net water requirements for each dominant crop can be calculated taking into consideration the agroclimatological data, the existing cropping pattern representative of the study area as well as the corresponding crop coefficients Kc for the appropriate growth stage of each cultivated plant in the study area, see Table 28 below.

Table 28 Net water requirements per crop

	Month	**Jan**	**Feb**	**Mar**	**April**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual value**	
														mm	**m^3/Ha**
	Eto	48	55	90	125	168	213	251	233	167	115	67	51	1583	15830
	Eff.Rain	69	62	33	15	7	1	0	0	5	19	26	62	299	2990
Fruit trees/ Vineyard	Kc	0.2	0.2	0.3	0.3	0.4	0.7	0.8	0.95	0.9	0.5	0.3	0.2		
	Etc mm	0.0	0.0	0.0	22.5	60.2	148.1	200.8	221.4	145.3	38.5	0.0	0.0	837	8368
Wheat and barley	Kc	0.5	0.65	0.65	0.7	0.7	0.1				0.2	0.3	0.4		
	Etc mm	0.0	0.0	25.5	72.5	110.6	20.3	0.0	0.0	0.0	4.0	0.0	0.0	233	2329
Potato	Kc							0.4	0.6	0.8	0.9	0.6			
	Etc mm	0.0	0.0	0.0	0.0	0.0	0.0	100.4	139.8	128.6	84.5	0.0	0.0	453	4533
Industrial crops	Kc		0.2	0.3	0.5	0.6	0.7	0.7	0.6	0.4	0.2				
	Etc mm	0.0	0.0	0.0	47.5	93.8	148.1	175.7	139.8	61.8	4.0	0.0	0.0	671	6707
mixed Vegetables (Summer)	Kc			0.4	0.6	0.8	1	1.1	0.8	0.3					
	Etc mm	0.0	0.0	0.0	60.0	127.4	212.0	276.1	186.4	45.1	0.0	0.0	0.0	907	9070
mixed Vegetables (Fall)	Kc	0.9	0.3								0.2	0.5	0.8		
	Etc mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	4	40

Taking into consideration the crop occupation ratio (%) of each crop variety within ARB we can calculate the net water requirement of a representative Ha as follows. The Net water requirement is equal to weighted sum of Crop Evapotranspiration multiplied by Crop Occupation Ratio. Table 5 above shows that the intensification coefficient is 1.35 in the basin as it takes into consideration the crop rotation. The peak irrigation water requirement is in July and corresponds to 0.55 l/s/Ha.

Table 29 Net water requirement per representative Hectare

		Occupation ratio	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Annual value
Fruit trees/ vineyard		15%	0.00	3.38	9.03	22.22	30.12	33.20	21.80	5.78	125.51
Wheat and barley		30%	7.65	21.75	33.18	6.09	0.00	0.00	0.00	1.20	69.87
Potato		15%	0.00	0.00	0.00	0.00	15.06	20.97	19.29	12.68	68.00
Industrial crops		5%	0.00	2.38	4.69	7.41	8.79	6.99	3.09	0.20	33.54
Mixed Vegetables (Summer)		35%	0.00	21.00	44.59	74.20	96.64	65.24	15.79	0.00	317.45
Mixed Vegetables (Fall)		35%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.40	1.40
Annual value		135%	30%	85%	85%	85%	70%	70%	70%	100%	
net water requirement		m^3/ha	76.5	485.0	914.9	1099.1	1506.0	1264.0	599.6	198.5	6144
		L/s/ha	0.03	0.19	0.34	0.42	0.56	0.47	0.23	0.07	

According to prevailing irrigation practices, bibliography and field observations, we have adopted the following efficiencies taking into consideration, the adopted weighted efficiency coefficient is 0.65.

Table 30 Gross irrigation water requirement per 1 representative hectare

		Mar	April	May	Jun	Jul	Aug	Sep	Oct	Annual value
Net water requirement	L/s/ha	0.03	0.19	0.34	0.42	0.56	0.47	0.23	0.07	
Net water requirement with field & conveyance losses	L/s/ha	0.04	0.29	0.53	0.66	0.87	0.73	0.36	0.11	
Irrigation water requirement m^3/ha	Day	3.8	25.0	45.6	56.6	75.1	63.0	30.9	9.9	
	Month	118	750	1414	1699	2327	1953	927	307	9494

The global irrigation water requirement all over ARB can be calculated based on total irrigated area (18,500 ha) obtained from and the irrigation water needs of a representative hectare. Hence the irrigation water demand is estimated to:

18,500 x 9,500 m^3/Ha/year = 176 Mm^3/year that can be broken-down per month and per irrigation zone.

Due to the prevailing water scarcity, it is believed that the effective irrigation water consumption does hardly exceed 75% of the global irrigation water requirement specially during peak season.

ii. Water requirement for 2035 under SSP5 - 8.5

The climate anomalies under SSP5-8.5 for 2020-2039 has not presented major change on ET0 from that under SSP2-4.5 resulting with same Gross Net Water Requirement of 9475 m^3/Ha/year.

Table 31 Effective rain, ET0 and water balance in ARB under SSP5 – 8.5

Scenario	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	Eff. Rain	68	65	33	15	7	1	1	1	5	21	26	58	298
SSP5-8.5	ETo	48	55	89	125	168	214	251	233	167	114	66	51	1582
	Balance	20	9	-56	-110	-161	-213	-251	-232	-163	-93	-41	7	

Table 32 Net water requirements per crop

	Month	**Jan**	**Feb**	**Mar**	**April**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual value**	
														mm	**m^3/Ha**
	Eto	48	55	89	125	168	214	251	233	167	114	66	51	1582	15820
	Eff.Rain	68	65	33	15	7	1	1	1	5	21	26	58	298	2978
Fruit trees/ vineyard	Kc	0.2	0.2	0.3	0.3	0.4	0.7	0.8	0.95	0.9	0.5	0.3	0.2		
	Etc mm	0.0	0.0	0.0	22.8	60.2	149.0	200.4	220.7	146.2	36.2	0.0	0.0	835	8354
Wheat and barley	Kc	0.5	0.65	0.65	0.7	0.7	0.1				0.2	0.3	0.4		
	Etc mm	0.0	0.0	25.1	72.9	110.5	20.9	-0.5	-0.5	0.0	1.9	0.0	0.0	230	2302
Potato	Kc							0.4	0.6	0.8	0.9	0.6			
	Etc mm	0.0	0.0	0.0	0.0	0.0	0.0	99.9	139.2	129.4	82.0	0.0	0.0	450	4505
Industrial crops	Kc		0.2	0.3	0.5	0.6	0.7	0.7	0.6	0.4	0.2				
	Etc mm	0.0	0.0	0.0	47.9	93.7	149.0	175.3	139.2	62.5	1.9	0.0	0.0	669	6694
mixed Vegetables (Summer)	Kc			0.4	0.6	0.8	1	1.1	0.8	0.3					
	Etc mm	0.0	0.0	0.0	60.4	127.3	213.1	275.7	185.7	45.7	0.0	0.0	0.0	908	9079
mixed Vegetables (Fall)	Kc	0.9	0.3								0.2	0.5	0.8		
	Etc mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	2	19

Table 33 Net water requirement per representative Hectare

	Occupation ratio	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Annual value
Fruit trees/ vineyard	15%	0.00	3.42	9.03	22.35	30.06	33.10	21.92	5.43	125.32
Wheat and barley	30%	7.54	21.86	33.15	6.26	-0.15	-0.15	0.00	0.56	69.07
Potato	15%	0.00	0.00	0.00	0.00	14.99	20.88	19.41	12.29	67.57
Industrial crops	5%	0.00	2.39	4.69	7.45	8.76	6.96	3.12	0.09	33.47
Mixed Vegetables (Summer)	35%	0.00	21.13	44.54	74.59	96.50	65.01	16.00	0.00	317.77
Mixed Vegetables (Fall)	35%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.66
Annual value	135%	30%	85%	85%	85%	70%	70%	70%	100%	
net water requirement	m^3/ha	75.4	488.0	914.1	1106.5	1501.6	1258.0	604.6	183.8	6132
	L/s/ha	0.03	0.19	0.34	0.42	0.56	0.47	0.23	0.07	

Table 34 Gross irrigation water requirement per 1 representative hectare

		Mar	April	May	Jun	Jul	Aug	Sep	Oct	Annual value
Net water requirement	L/s/ha	0.03	0.19	0.34	0.43	0.56	0.47	0.23	0.07	
Net water requirement with field & conveyance losses	L/s/ha	0.04	0.29	0.53	0.66	0.87	0.73	0.36	0.11	
Irrigation water requirement	Day	3.8	25.1	45.6	57.0	74.8	62.7	31.1	9.2	
	Month	116	754	1412	1710	2320	1944	934	284	9475

D.WEAP detailed results

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