Co-design of a water reuse project around Zahleh WWTP, Lebanon: Methodological learnings and implementation challenges

ReWater MENA Output 2:
Design of two local reuse models in Lebanon

International Water Management Institute

Contributors

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ABBREVIATIONS AND ACRONYMS

BCR	Benefit-Cost Ratio
BOD5	Biological Oxygen Demand
BWE	Bekaa Water Establishment
CAPEX	Capital Costs
CBA	Cost Benefit Analysis
CDR	Council for Development and Reconstruction
CFU	Colony-Forming Unit
CM	Cubic Meter
COD	Chemical Oxygen Demand
CWR	Crop Water Requirements
DI	Ductile Iron
du	Dunum (= 1,000 SM)
EIA	Environmental and Social Impact Assessment
ELVs	Environmental Limit Values
EMP	Environmental and Social Management Plan
ETo	Potential Evapotranspiration
ETc	Crop Evapotranspiration
EU	European Union
FAO	Food and Agriculture Organization for the United Nations
FC	Fecal Coliforms
FTO	Farm Turn Out
GRP	Glass Reinforced Plastic
H	Head
ha	Hectare (=10,0000 SM)
HP	Horse Power
ICU	Institute for University Co-operation
IEE	Initial Environmental Examination
IWMI	International Water Management Institute
Km	Kilometer

kWh	Kilo Watt hour
L	Length
LARI	Lebanese Agricultural Research Institute
LRA	Litani River Authority
MoE	Ministry of Environment
MoEW	Ministry of Energy and Water
MoIM	Ministry of Interior and Municipalities
MoPH	Ministry of Public Health
NPV	Net Present Value
NSEQ	National Standards for Environmental Quality
O&M	Operation and Maintenance
OPEX	Operation and Maintenance Costs
Q	Flow
RKP	Rafik Khoury Partners
SIDA	Swedish International Development Cooperation Agency
SM	Square Meter
TN	Total Nitrogen
TP	Total Phosphate
TSE	Treated Water Effluent also used as treated wastewater
TSS	Total Suspended Solids
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
USD	United States Dollars
VAT	Value-Added tax
WHO	World Health Organization
WWTP	Waste Water Treatment Plant

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1 INTRODUCTION AND OBJECTIVES

Although well-endowed in water compared to its neighboring countries, Lebanon suffers from water shortage, with surface water heavily exploited and groundwater already in overdraft (MEW 2012; MEW 2020; Eid-Sabbagh et al. 2022). Since the 1960s, high demographic growth, urbanization and expansion of agricultural areas, coupled to serious management problems have put high quantitative and qualitative pressure on water resources and the environment. Today, most of the country's river-basins are over-allocated especially during the summer when irrigation needs become high.

Among the many actions needed to improve water management, the reuse of treated domestic sewage has the potential to reduce the water supply gap. The need and relative acceptability of water reuse is demonstrated by informal reuse practices observed in many agricultural regions of the country. At many sites in the Bekaa, Mount-Lebanon, and North-Lebanon farmers intentionally or unintentionally tap into treated effluents discharged into waterways, or even resort to untreated sewage to supplement their water needs and/or reduce the costs of groundwater pumping (Eid-Sabbagh et al. 2022).

In the last decade, improving wastewater management, and developing water reuse in Lebanon were given increased attention both from national and international actors. The 2012 National Water Sector Strategy and its updated version in 2020 states that the expansion of water reuse is a national objective. In 2010, an FAO project developed guidelines for water reuse and sludge reuse in agriculture. In 2015, an EU project implemented an irrigation water reuse system supplied by Ablah WWTP (central Bekaa) to irrigate 20 ha of vineyards in the neighboring plain and replace pumping from depleting groundwater. More recently, another EU project collaborating with the Ministry of Agriculture is planning to develop a reuse system linked to Aitanit WWTP (south Bekaa) to supplement irrigation water needs from the Mashghara spring.

In 2018, the IWMI ReWater MENA project launched several activities to support the expansion of safe water reuse in Lebanon. A national scale study analyzed the potential of implementing water reuse from existing and planned WWTPs and laid a political economy analysis of the wastewater sector (Eid-Sabbagh et al.2022). The report mapped and collected a set of data for the 104 existing WWTPs. At the time of the study (2020-2021), 41 WWTPs were operational, 20 partially operational, 35 not operational and 8 under construction.

The study modelled a 'Reuse Potential Area' (in hectare) for each plant and calculated a 'Reuse Potential Score' based on treatment performance, water quality levels and existing cropping patterns. This was done for two scenarios, the 'Actual Potential scenario' considering current operational status and actual treated volumes and the 'Ideal Potential scenario' where all WWTPs are considered operational at their maximum design capacity. The calculated total Reuse Potential Area for each scenario is 2208 ha and 4993 ha respectively, while currently less than 10 ha are part of a reuse scheme (in Ablah). The study identified around 18 WWTPs having good Reuse Potential Area and Score (**Error! Reference source not found.**).

Another activity of ReWater Project consisted at designing two bankable reuse systems linked to Ablah and Zahleh WWTPs (Central Bekaa) selected in the early stages of the project as part of stakeholder consultation processes and later identified by the cited study as being part of the 18 WWTPs with relatively good reuse potential.

The two studies respectively include detailed technical and socio-economic feasibility studies, as well as an implementation and governance plan proposing the management structure of the two systems in compliance with the Lebanese institutional and legal framework and taking into consideration de-facto governance practices and existing institutional arrangements. Both reuse studies were developed in close consultation with the respective stakeholders based on ReWater MENA's adopted participatory approach.

The following report presents the summary[1] study related to Zahleh WWTP, the largest in the Bekaa region of Lebanon. It currently treats around 20,000 CM/day out of a larger design capacity of 30,000 CM/day. It uses aerated sludge as a secondary treatment and UV as a tertiary treatment. The plant started operating in 2017 and was managed by the CDR through Suez until 2022. It was transferred to the Bekaa Water Establishment (BWE) in September 2022 and its operation contracted to a Lebanese company SUBAL through a grant from the Italian Government. The contract is managed by UNDP. The BWE does not have the financial capacity to operate the plant and has a role in monitoring. Due to the financial and political crisis in Lebanon, the water sector administrations in Lebanon are collapsing and increasingly relying on external donor's money or local donations.

The report starts with an overview of Zahle's site within its geographic environment and explains the rationale of the project. The methodology is then presented with a highlight on its participatory component and in-depth analysis of existing arrangements. The report then presents the different hydraulic development options with their socio-economic feasibility and environmental and social impact assessments and explains the rationale of the adopted scenario. The final section presents the project's envisioned governance and financing and cost-recovery options and elaborates on the implementation and financing constraints that challenge the feasibility of such system. It closes on the methodological learnings of the study and necessity to unpack the diversity of irrigation systems to develop coherent water allocation scenarios and comprehensive cost-benefit assessment.

Table 1: Summary numbers for water reuse potential and main sites with high potential in Lebanon

	MCM/year	MCM/Season	% of total
Total Municipal Wastewater generated	273.7 -328.5	164.2 -198.2	100
Total Treated Water produced	81.2	48.9	25-30%
Total Treated Water discharge to sea	60.2	36.3	18 -22%
Total Treated Water discharge to inland water body	20.9	12.6	6.3 -7.6%
Total direct reuse (2020)	0	0	0
Total indirect reuse	Indirect reuse is widely spread as water from rivers is persistently used for irrigation but cannot be quantified because of a lack of water use and water production data.		
Area potentially irrigable with treated water at present in ha	2208 (ha)		

[1] A full economic feasibility study developed by Ecosystem with the detailed scenario and cost-benefit assessment is available in a larger report (Ecosystem, 2022).

Treatment Plants with high potential (Area and Score)	• Zahleh (527.2 ha), Aitanit (32.6 ha), Ablah (28.6 ha), Fourzol (21.3), Joub Jannine (138.9 ha) (Bekaa), • Chabriha (326.3 ha) (Sour), • Tibnine (23.9 ha) (Bint Jbeil), • Hebarriye (11.2 ha) (Hasbaya) • Ijbaa (87.5 ha), Aintourine (91.9 ha) (Ehden), • Nabaa el Safaa (22.0 ha), Bater (15.6 ha), Barouk (12 ha) Ammantour (9.7 ha) (Chouf), • Hammana (19.5 ha) (Metn), • Qobayat (12.2 ha) (Akkar)

Source: Eid-Sabbagh et al. 2022.

2 Zahleh Site and Project Rationale

2.1 Zahleh Area Town within the Upper Litani River Basin

Zahleh site is part of the Litani River Basin, the largest hydraulic basin in Lebanon, today's subject to serious problems of pollution and over allocation of both surface water and groundwater. Qualitative and quantitative pressure on water resources is evidenced by progressively alarming research (USAID-LRBMS, 2012; Molle et al. 2017; Shaban and Hamzé, 2018; Nassif, 2019) and experienced daily by its residents, especially in the summer months. As shown in Figure 1, the command area of Zahleh WWTP includes agricultural lands located both in Zahleh (upstream of the WWTP) and Barr Elias (downstream)[2].

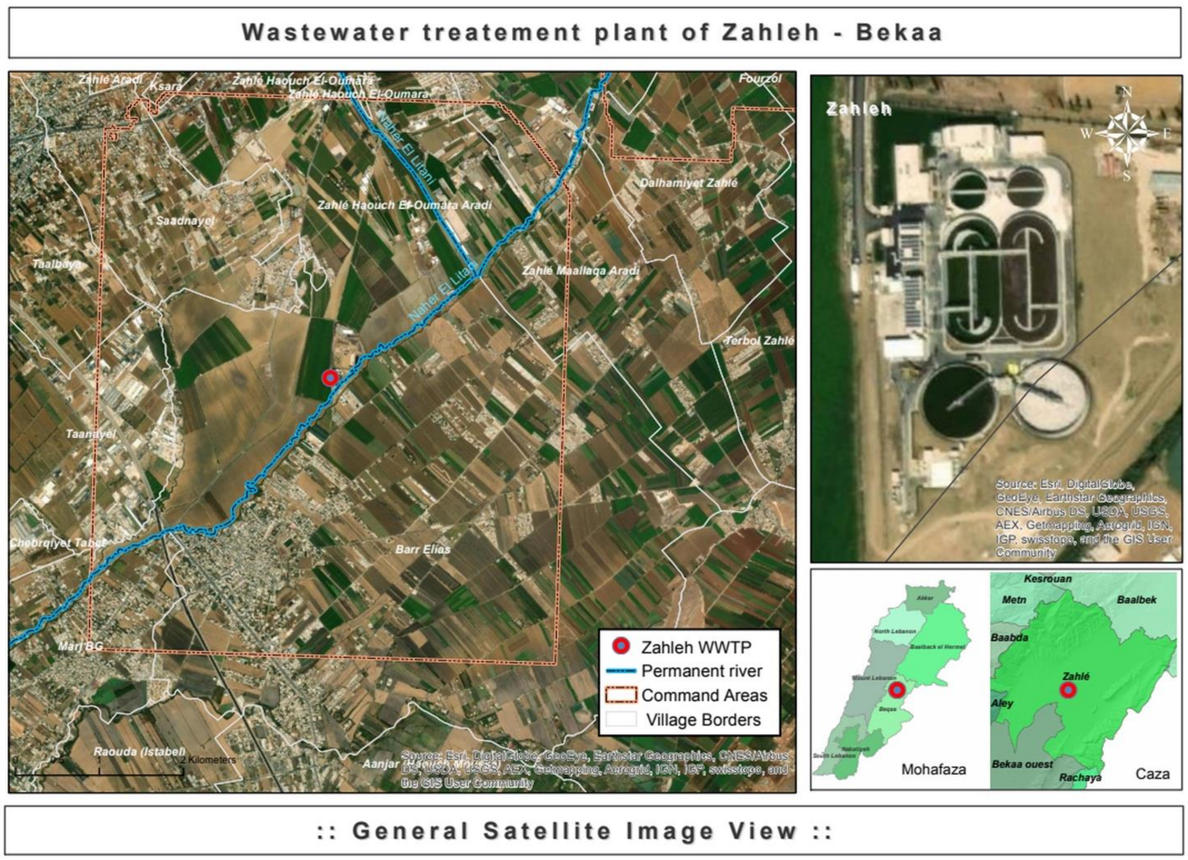
The city of Zahleh is the capital of the Bekaa and one of its largest and most populated cities (150,000 residents). Barr Elias is also an important city in terms of population number (40,000 residents), size of agricultural land and commercial activities. The region is typically an agricultural zone with many small and medium size family farms as well as large intensive commercial vegetable and animal farms. Agricultural lands mostly cultivated with grapes and field crops occupy most of the town's area. There are around 300 farmers in Zahleh and another 200 in Barr Elias. Agriculture is considered a major source of income. Zahleh and its surrounding areas (Chtaura, Saadnayel, Fourzol and Barr Elias) concentrate most of the industrial and commercial activities of the Bekaa (Bennafla, 2006; Al-Ayoubi, 2018). The area is planted with wheat and barley in winter, potato field, vineyards and other fruit trees and a diversity of vegetables in the summer (Figure 2).

Zahleh and Barr Elias residents are from various religious belongings. The majority of Zahleh's population is Christian (different groups) with a Muslim minority and that of Barr Elias is Muslim (mostly Sunni) with a Christian minority. The region is also home to a large population of Syrian refugees. The UNHCR reports that 30,000 Syrian refugees live in each of Zahleh and Barr Elias, but mayors report

[2] As per the National Analysis of Reuse Potential in Lebanon presented in the executive summary (Eid-Sabbagh et al. 2022).

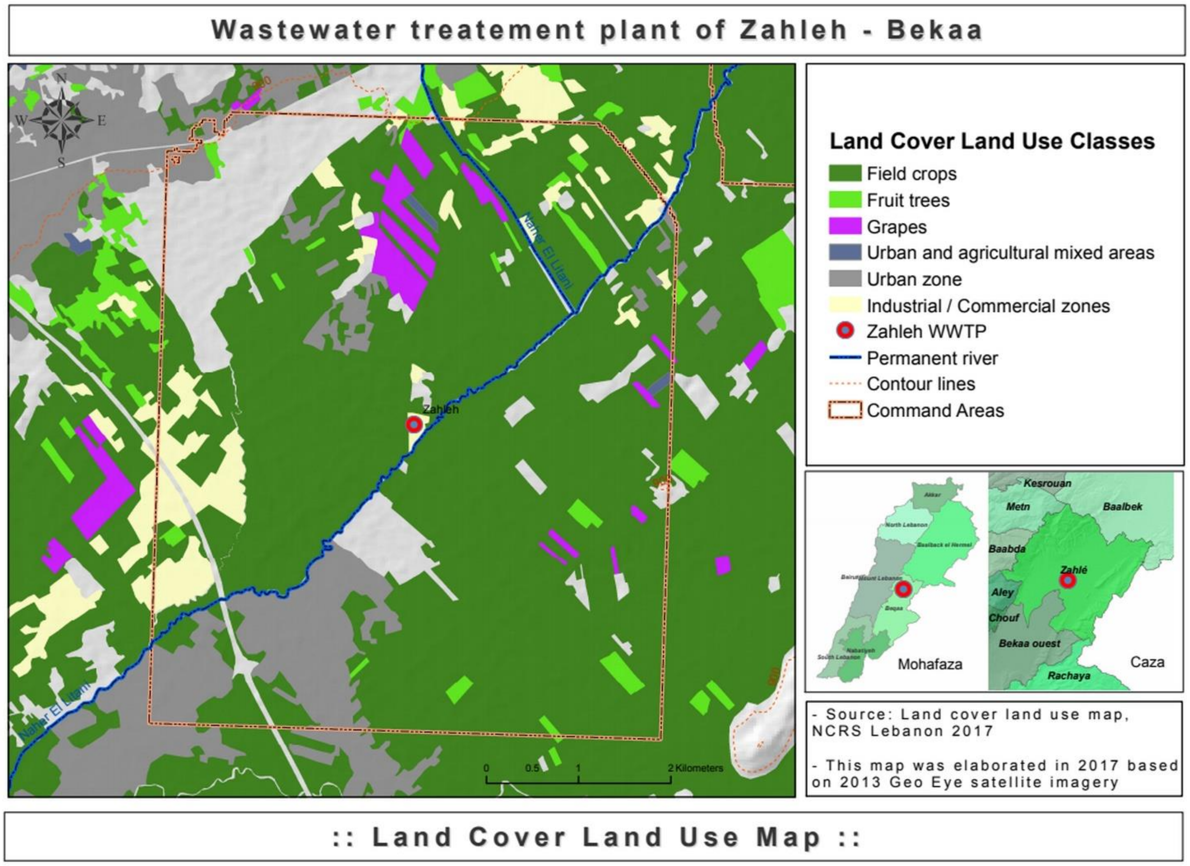
higher numbers i.e. 72,000 in Zahle and 45,000 in Barr Elias (Al-Ayoubi, 2018). Most of the Syrian population (80-90%) work as seasonal labor in the agricultural sector. However, Syrian labors' involvement in agriculture dates well before the Syrian war (Balanche, 2007; Nassif, 2019).

Figure 1: Location and potential command area of Zahleh WWTP



Source: Eid-Sabbagh et al. 2022

Figure 2: Land use map of Zahleh WWTP's command area



Source: Eid-Sabbagh et al. 2022

2.2 WATER SUPPLY CONSTRAINTS

Zahleh area is historically rich in water and benefit from different rivers and aquifer that allowed irrigation to develop and agriculture to intensify. However, all water sources are today overexploited and some heavily polluted. Both Zahleh and Barr Elias villages are located on the banks of the Litani. The river was historically used for the irrigation of neighbouring plots but with the introduction of pumps in the late 1950s and the expansion of irrigation, its flow increasingly decreased. Its flow was considerably reduced since the 1970s which led to increased reliance on wells (Nassif, 2016). There are two other important rivers in the area: the Berdaouni River of Zahleh and the Ghozayel River of Barr Elias. Zahleh historically developed around the Berdaouni River which played a major role in the urban and economic development of the city. The Berdaouni is captured in a large collective irrigation system supplying around 2,000 ha of land, including plots next to the WWTP. But increased allocation upstream for agricultural, industrial and touristic activities considerably reduces its flow, especially in the summer. This pushed farmers at the tail-end of the system to secure their irrigation needs from groundwater.

The region is also rich in groundwater, but this is unevenly distributed in space. Zahleh benefits to a large extent from the Cretaceous aquifer that constitutes most of its hilly parts. This aquifer allowed for the drilling of large productive wells (30-50 l/s) to complement domestic and agricultural water needs. Barr Elias partially benefit from the Eocene aquifer (karstic) which surfaces in a small hill on the eastern part of the village. Farther in the plain, farmers reported failing to establish productive wells (Nassif, 2016). Plots located at the banks of the Litani were still irrigated from the polluted river until the government prevented this practice. Consequently, around 100 ha in this area are left uncultivated.

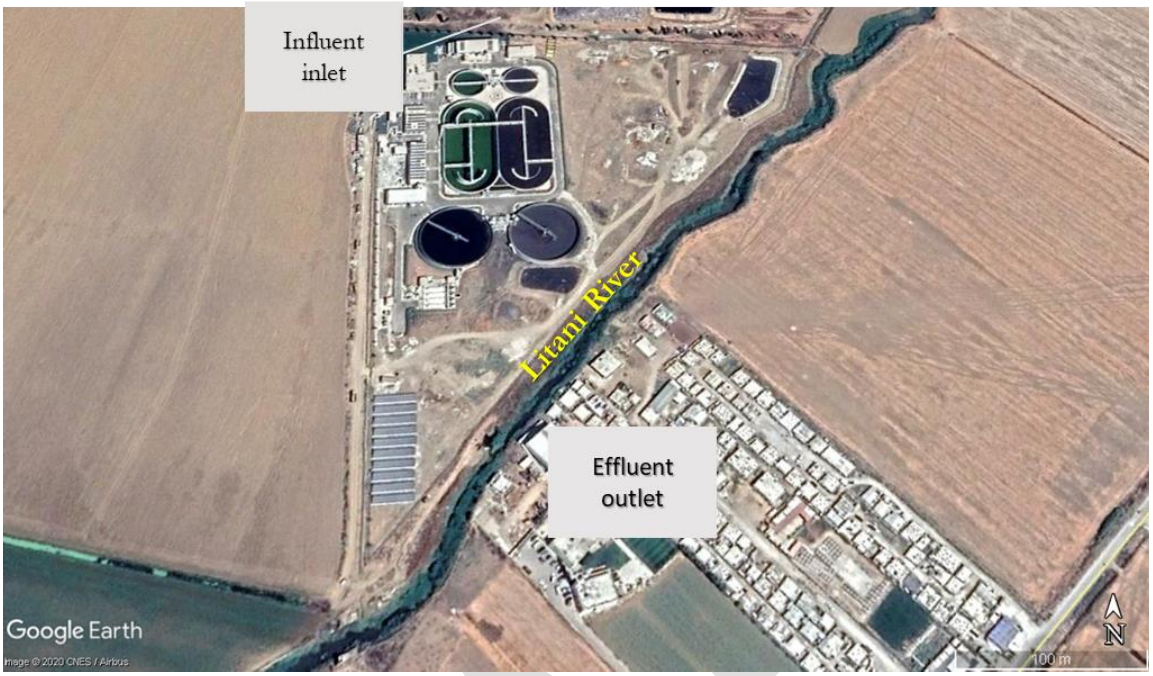
Groundwater has also been showing signs of serious overexploitation. Water levels in central Bekaa have been dropping in all aquifers, pushing farmers to deepen and/or multiply their wells (Nassif, 206; Molle et al. 2017). In Zahleh Maallaqa, several tube wells drilled next to the Litani River (in the Quaternary aquifer) between 1975 and 1980 at 50 to 100 m b.s.l have been deepened to reach up to 200 m in order to sustain yields. In 2014 (year of severe drought), some of these wells were dried in the middle of the summer generating considerable loss. The idea of a water reuse project around Zahleh WWTP stems from these constraints.

2.3 Zahleh WWTP

2.3.1 General description

Zahle WWTP is located in Zahleh town in central Bekaa on the right bank of the Litani River (Figure 3). Like many WWTPs in the Bekaa, the treated effluent discharges into the Litani. The WWTP treats the domestic sewage generated by 205,000 residents of Zahle, Qaa El Reem and Hazerta. It uses the activated sludge technology as a secondary treatment and micromembrane as the tertiary treatment. It is the largest WWTP in the Bekaa with a design flow of 35,000 CM/day but is presently treating around 26,000 CM/day on average. The influent flow is typically higher in the winter than in the summer. In 2020, it varied from 27,328 CM/day in February to 15,018 CM/day in October (see below_. The detailed technical layout of Zahle WWTP is found in Annex 1.

Figure 3: Location of the influent and effluent points of Zahleh WWTP



Source: Ecosystem, 2022

2.3.2 Management and cost-recovery

The Zahleh WWTP was implemented through an international funding of approximatively 18 million Euros provided by the Italian Agency for Development Cooperation, additionally to a contribution of 7 million euros from the Lebanese Government[3]. As most of the large WWTPs implemented by the Government, it is the CDR who implemented the fund, through a Build Operate Transfer contract with Suez company. The implementation started in 2006 and was finalized in 2016. The WWTP started to operate in 2017 and was under the management of the CDR until September 2022 when its management was transferred to the BWE as per Law 221. Due to the incapacity of the BWE to operate the plant, the Italian Government provided another grant to secure its operation for two years. The fund is managed by UNDP and the operation was contracted to a Lebanese company SUBAL who hired the

[3] Information about funding amount differs from one source to another. According to the Italian Cooperation website, the total cost of the works is of 17.287.913 Euros including one year of management and maintenance (https://Zahle.aicsbeirut.org/portal/en-US/infrastructures/21/c/wastewater-treatment-plant-in-zahle/50/). A local journal states that the Italian Cooperation provided "20 million euros in funding, next to the Council for Development and Reconstruction which built the plant with the contribution of the Lebanese State amounting at 7 million euros (http://nna-leb.gov.lb/en/show-news/105760/nna-leb.gov.lb/fr) while the NWSS (2010) mentions that the treatment plant's cost was 32 million USD where networks and house connections cost 20.50 million USD. Total is 52.50 million USD.

team of Lebanese engineers and technicians previously operating the plant under SUEZ. The BWE has a role in monitoring the operator's work.

Due to the financial and political crisis in Lebanon, the water sector administrations in Lebanon are collapsing and increasingly relying on external donor's money or local donations. As per the mandate of Regional Water Establishments, the BWE levies a water fee from residents connected to water networks and a wastewater fee for those connected to sewage networks. This wastewater fee was introduced since the end of 2017 on the water bill of the residential units connected to Zahleh WWTP. According to the BWE, most residents opposed this tax and decided not to pay[4]. In 2022, the water fee was increased from 240,000 L.L to 900, 000 L.L (2.5 times) and the wastewater fee from 60, 000 L.L to 180, 000 L.L (3 times) but the collection rate, which was already low before the crisis dropped considerably. Furthermore, the increase rate is far to be proportional to the loss of value of the Lebanese Lira (L.L) against the dollar (25 times by November 2022) and the complete dollarization of the Lebanese economy, including the cost of fuel.

2.4 RATIONALE OF THE PROPOSED INTERVENTION

Currently, the treated wastewater is discharging to the Litani and -informally and partially- indirectly reused by farmers downstream. Interviews showed that two categories of farmers are using this water: the large landowners managing the big potato farms at the level of Haouch El Oumara Aradi (Zahleh) and farmers in Barr Elias cultivating smaller plots next to the Litani River. In the first case, Zahleh farmers are using this water to complement the use of high yielding wells located in the karstic aquifer. The treated wastewater somehow mixed with the remaining flow of the Litani waters is pumped into ditches and used to irrigate neighboring potato fields. The same seems to happen in Barr Elias as reported by some interviewees in Zahleh but this was denied by Barr Elias farmers who ensure that irrigation from the Litani stopped several years ago because of the pollution problem. In any case, the existing reuse practices in Zahleh, as well as the reported constraint of irrigating from the Litani in Barr Elias show that there is a need for an alternative water resource in this area. It also shows that farmers are not reluctant to use treated wastewater.

The managers of the WWTPs are aware of these practices and in contact with farmers in Zahleh. However, the involvement of governmental authorities in regulating or monitoring these practices seem to be limited. According to the potato farmer using the treated wastewater in Zahleh, the Ministry of Environment intervened a while ago and asked farmers to stop these practices. '*But the Ministry of Agriculture took samples from the treated effluent and showed that the water quality was suitable for irrigation'.*

[4] Interview with an official at the BWE, October 2019.

3 METHODOLOGY

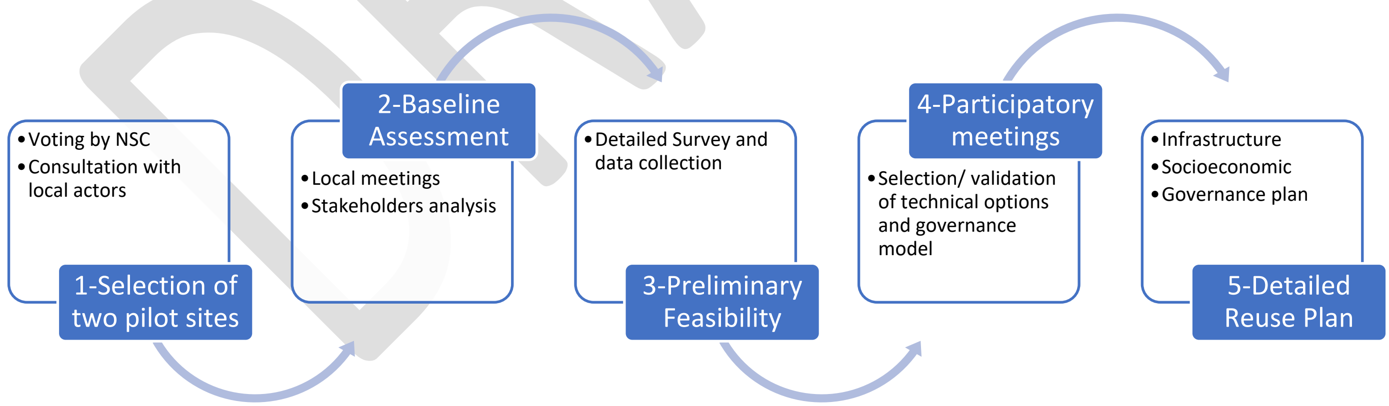
3.1 GENERAL METHODOLOGY

The design of both reuse models in Ablah and Zahleh followed several steps and included a thorough local participatory process to ensure the integration of detailed local data (both technical and social), and tailor the reuse system on needs, opinions, formal and informal relations between stakeholders.

It started with the selection of two local sites based on consultation with local stakeholders and voting by the National Steering Committee (see 3.2.1). It was followed by a Baseline Assessment collecting data on the WWTPs and irrigation in the region, based on a template designed by IWMI researchers. The Baseline Assessment (BA) was supported by Lisode, a social enterprise specialized in participatory processes, and was progressively developed based on several field visits to the two sites and a stakeholder analysis exercise.

This was followed by a technical and socio-economic feasibility study developed by a local engineering company based on further technical assessments and surveys on irrigation in the region (Ecosystem, 2022). This step was divided into a preliminary study where conceptual designs and implementation plans were discussed with stakeholders and then elaborated into detailed feasibility studies (Figure 4).

Figure 4: General methodology for the local reuse studies



3.2 Public participation and co-design

3.2.1 Selection of the pilot sites

Stakeholders' participation was an essential component of ReWater MENA. Participatory processes were designed and facilitated by professionals in participation, using concepts rooted in the academic literature on public participation and tools demonstrated to foster inclusive project and policy designs (Dionnet et al. 2017) and more harmonious governance of reuse projects (Nassif and Tawfik, forthcoming). Representatives from the different public administrations with mandates in wastewater treatment management and agriculture were met several times in the inception phase of ReWater to develop the project's program. Some municipalities, private companies, and development agencies were also consulted.

3.2.1.1 The National Steering Committee

A National Steering Committee (NSC) (Annex 1) was formed in the beginning of the project and validated the different project activities, including the proposed design of two reuse systems. Eight sites, located in different Lebanese regions, were proposed by the project based on preliminary interviews and site visits and according to criteria of performance, proximity to agricultural areas, needs for additional water resources and social acceptance of reuse. In May 2019, each member of the NSC voted for two sites: Joub Jannine and Tyr (West-Bekaa, and Southern coastal area) but these two sites were later substituted after the Litani River Authority (LRA) changed its opinion. The Litani River Authority (LRA) changed its opinion and expressed its distrust in the performance of these two WWTPs and was reluctant to discuss a potential (partial) substitution of freshwater with treated effluents in the public schemes it manages (Canal 900 and Qasmieh Ras-El-Ain)[5]. The LRA later withdrew its participation to the project's meetings.

Zahleh and Ablah WWTPs were then adopted as the final pilot sites since they came as third and fourth choice of the NSC. They were also considered by ReWater MENA as useful pilots to comparatively analyze the two main governance models for collective wastewater treatment in Lebanon (State/Community-based). Opting for Zahleh and Ablah also allowed to diversify criteria of treatment capacity (respectively 25,000 CM/ day and 2500 CM/day), treatment technology (aerated sludge v/s trickling filters), existing irrigation sources (river-based v/s groundwater), modality of irrigation governance (collective/individual) and types of dominant crops (vegetables /fruit trees).

[5] The Litani River Authority (LRA) changed its opinion and expressed its distrust in the performance of these two WWTPs and was reluctant to discuss a potential (partial) substitution of freshwater with treated effluents in the public schemes it manages (Canal 900 and Qasmieh Ras-El-Ain). See Eid-Sabbagh et al. (2022) for more details on this case.

3.2.2 Stakeholders' participation in the study

In both Zahleh and Ablah sites, governmental and community stakeholders played an active role in designing both the system's technical layout and the way it would be managed and financially sustained. The Stakeholder Analysis supported by LISODE allowed to design a plan for stakeholder engagement throughout the process. In Zahleh, the CDR provided provided access to information and field visits. Suez company welcomed IWMI consultants for field visits, provided farmers' contacts and hosted focus groups with farmers. The Bekaa Water Establishment (BWE) who was playing at the time of the study a role in monitoring was kept informed about the study and gave its consent on the final plans. Representatives from Zahleh and Barr Elias municipalities were also visited and interviewed and helped identifying key farmers. Two representatives from the Berdaouni Irrigation Committee collaborated with the study and helped mapping existing infrastructure and identifying farmers for the survey (see section 5.2).

Several key farmers were consulted at the Baseline Assessment stage (Step 2) and 45 farmers as part of the detailed survey (Step 3). In November 2021, the results of the Pre-feasibility study were presented to Zahleh stakeholders at the WWTP (**Error! Reference source not found.**). The meeting allowed to discuss the different scenarios of water allocation/hydraulic development and led to the selection of a consensual scenario for Zahleh farmers (Figure 5). The meeting was also an occasion to discuss come aspects of the governance plan, cost-recovery options and challenges (Step 4).

Table 2: List of participants to Zahleh participatory meeting in November 2021

	Name	Position
1	Jean Al Mounassab	Farmer- Maallaqa
2	Abdo Baroudi	Farmer - Mallaqa
3	Michel Nassif Hjeij	Farmer- Mallaqa Aradi
4	Kaysar Georges Abou Hanna	Farmer-Maallaqa Aradi
5	Fadi Skaff	Farmer-Haouch El Oumara Aradi
6	Georges Mallo	Farmer- Maallaqa
7	Elie Youssef	Farmer – Haouch El Oumara
8	Jamil Youssef Andass	Farmer – Haouch El Oumar
9	Georges Al Sakr	Farmer- Syndicate of Potato farmers
10	Charbel Al Sakr	Farmer-Al Sakr Leltanmiya El Ziraaiya
11	Antoine Gharios	Farmer and Chawwa of Haouch El Oumara sector
12	Gerges Rizk	Bekaa Water Establishment

13	Ghassan Mezeraani	Bekaa Water Establishment
14	Antoine Abou Younes	Zahleh Municipality
15	Sandra Yanni	Professor- American University of Beirut- NAWAMED Project
16	Lena Abou Jaoude	Researcher – American University of Beirut NAWAMED Project
17	Ghida Khrist	Researcher – American University of Beirut NAWAMED Project
18	Bahaa Kain	UN-Habitat
19	Tony Zabboughi	Agricultural engineer- Ecosystem
20	Marie-Helene Nassif	Coordinator of ReWater MENA in Lebanon
21	Antoine Slim	Ecosystem director Irrigation Engineer
22	Hussein Assi	Suez
23	Shamoun Mallo	Suez
24	Solange Ghantous	Suez
25	Ali Arfan	Suez

Figure 5: Final consultation workshop in Zahleh, November 2021

Credit: Tony Slim

3.3 HYDRAULIC DESIGN

The different hydraulic design scenarios were developed with the support of a Lebanese consultancy firm, Ecosystem S.A.R.L. specialized in irrigation system design. Ecosystem and IWMI team performed several visits to Zahleh WWTP and collected records on treatment volumes and quality. The team also performed full walk-through surveys on the existing irrigation systems in Zahleh in collaboration with Zahleh municipality and the Berdaouni irrigation committee. The same was done for Barr Elias area with the collaboration of Barr Elias municipality and key farmers from the area.

The technical visits allowed to collect existing maps of irrigation systems located within the command area of the potential reuse system (mainly for the Berdaouni system available at the municipality) and map the main private wells and groundwater networks in Zahleh (see Annex 3 and 4). In Barr Elias, only the area irrigated from the Litani was targeted as the rest of the plain was considered outside of the command area of the potential reuse system. An in-depth survey with 45 farmers allowed to deepen the understanding of existing irrigation practices (see section 3.4.1).

3.4 SOCIO-ECONOMIC FEASIBILITY AND ESIA

3.4.1 Survey with farmers

A survey was conducted in 2021 with the objective to collect most data needed for the socio-economic feasibility study and the EISA. The survey was conducted with 45 farmers representing the different water sources used (Berdaouni, Litani and groundwater), types of irrigation systems described above (Collective system, individual wells, collective wells) and located in different geographic areas. Care was given to diversify plot size and land tenure. 12 questionnaires were filled in Maalaqa, 24 farmers in Haouch El Oumara and 9 in Bar Elias. After data collection, some figures were re-checked with the farmers, edited where necessary and kept unchanged if advised so by the farmers.

The survey included qualitative and quantitative data on current livelihoods, agricultural practices, and willingness to use and pay for the treated effluent. The questionnaire was developed by IWMI researchers in collaboration with Ecosystem. It included questions needed for the cost-benefit assessment (CBA) and the Environmental and Social Impact Assessment (EISA). The survey also aimed to assess farmers' concerns about the impacts of treated effluents on their crops, soil and personal health. It included gender questions analyzed in ReWater MENA gender reports. The survey template is provided in Annex 5 and results are presented in Annex 6.

3.4.2 Cost-Benefit Assessment

The socio-economic feasibility study is based on the application of the cost-benefit theory and tools to the different options for a given intervention. The cost-benefit theory calls for the adoption of an option only if it satisfies certain investment criteria as detailed here below.

- Components of the discounted techniques of Cost- Benefit Analysis include:

  - ***Costs***

    The investment costs include estimates of construction of civil works, electro-mechanical works (pumping stations), pipes, turnouts, storage reservoirs and connecting pipes. With respect to recurrent costs, they include operation and maintenance. The maintenance costs are estimated at 3% of the investment cost per year for the pumping system, and at 0.5% for the storage and pipes. When calculating operation costs the labor cost of technician's support and pumping energy costs have been considered, with a pumping energy consumption for each type of suggested pumps during the proposed operation period (kWh for x month). These values were adopted by Declercq et al. (2020) for a similar reuse project in France: The average price of kWh was taken as 0.30$ referring to the price collected by small private generators in Lebanon in Summer 2021[6].

  - ***Benefits***

[6] Lebanon is facing an electricity crisis and currently relies on small generators for the provision of electricity and the situation is unlikely to change soon. This number represents the cost of Khw in 2021.

With respect to incremental benefits, farm gate prices for all crops and fertilizers are based on the results of the field survey and discussion with agriculture engineers experienced in fertilizations needs and practices in the Bekaa.

- ***<u>Interest Rate (Discounted Rate)</u>***
  Interest Rate: also called the discounted rate. It is the interest rate used to find present and future values, often equal to the opportunity cost of capital. It was taken as 10%.

- ***<u>Life span of the project</u>***
  The life span of the Project was taken as 15 years.

- The major criterion of the CBA used is the **Net Present Value (NPV)**. The NPV reduces a steam of costs and benefits to a single number in which costs or benefits projected to occur in the future are discounted. This implies that both incremental benefits and costs of the project should be discounted at the appropriate cost of capital in order to calculate the net percent value. In other words:

$$\boldsymbol{NPV = \Sigma\, discounted\ benefits - \Sigma\, discounted\ costs}$$

A project is considered feasible if the NPV is greater than zero NPV ≥ 0. Project with highest NPV is best.

- The **Benefit-Cost Ratio (BCR**) was also calculated. The BCR is normally defined in terms of discounted values. It is calculated using the following equation:

$$\boldsymbol{BCR = \Sigma\, discounted\ benefits / \Sigma\, discounted\ costs}$$

Project with highest BCR is best. BCR ≥ 1 is accepted

3.4.3 Project Boundaries Identification

The boundary adopted for the CBA is the command area of the reuse project as identified by IWMI national assessment (Eid-Sabbagh et al. 2022). Potential impacts on the River Basin's environment and downstream users were only considered in the Environmental and Social Impact Assessment (EISA).

3.4.4 Environmental and Social Impact Assessment

Valuing the environmental and social impacts of a project raises complex and controversial issues. The environment is of value to the actual users, to potential users, and to those who do not use it but consider its existence to have an intrinsic value (perhaps to their "quality of life"). Clearly it is difficult to quantify such values. Nevertheless, attempts were made to semi quantify the environmental and social impacts of the proposed intervention. The parameters that were semi-quantified are listed in Table 3.

Table 3: Parameters used for the Environmental and Social Impact Assessment

Environmental parameters	Social parameters
• Impact on groundwater use/water conservation. • Impact on energy consumption. • Impact on pollution • Environmental risks in case of system breakdown	• Aesthetic and touristic impact • Impact on rural life and agriculture stability • Creation of job opportunities • Impact on social cohesion. • Health risks in case of system breakdown

The proposed interventions were assessed for their environmental and social impacts (such as magnitude, significance, acceptability, reversibility and severity) and then finally weighted on a scale that ranges from "Strongly Positive" to "Strongly Negative" where:

- 2P means Strongly Positive
- P means Positive
- 0 means Neutral
- N means Negative
- 2N means Strongly Negative

4 Proposed Reuse Systems

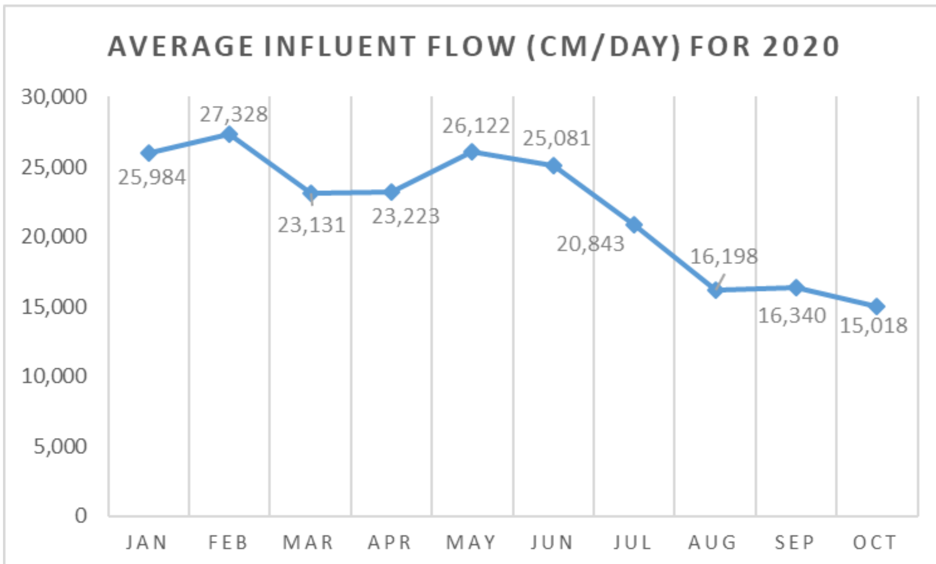
4.1 Hydraulic Design

Currently, part of the treated wastewater effluent from Zahle WWTP is being pumped from the WWTP discharging point to irrigate plots nearby the plants (under Skaff and Sakr families' management in Haouch El Oumara) in conjunctive use with the use of wells. The exact area currently supplied from the treated wastewater is unknown. As per Eid-Sabbagh et al. (2022), the actual reuse potential area from Zahle WWTP is 572 ha based on an average 25,000-28,000 CM/day. The Reuse Potential Area is calculated by dividing the volumes produced by the WWTPs by an average gross irrigation requirement of the agricultural land cover within its command area. Irrigation efficiency is estimated at 55%.

However, during the peak demand (July and August), the flow of the influent was around 16,200 CM/day as shown in Figure 6. The potential evapotranspiration (ETo), calculated from the climatic data and using the FAO-CROPWAT computer program, is 1,469 mm/year varying between a lowest value of 2.1mm/day in January and 6.4 mm/day in July and August. Based on the actual cropping pattern, the area that can be irrigated exclusively from Zahle WWTP during peak demand is around 140 ha. The area that can be irrigated in June and July based on a flow of 25,000 CM/day and an ETo of 5mm is 275 ha.

Five different scenarios were investigated for the reuse of treated wastewater from Zahle WWTP. For each option the following sections were developed: (i) Basic engineering layout, (ii) Estimated capital cost of construction, (iii) Operation and Maintenance (O&M) activities and costs, (iv) Estimated socioeconomic Impacts and risks and (v) Economic Feasibility. These alternatives were discussed with the stakeholders during the public participation session organized in November 2021.

Figure 6: Zahleh WWTP's influent records



Source: Ecosystem, 2022 collected from Suez.

4.1.1 Scenario 1: Exclusive pumping to Berdaouni-based irrigation system

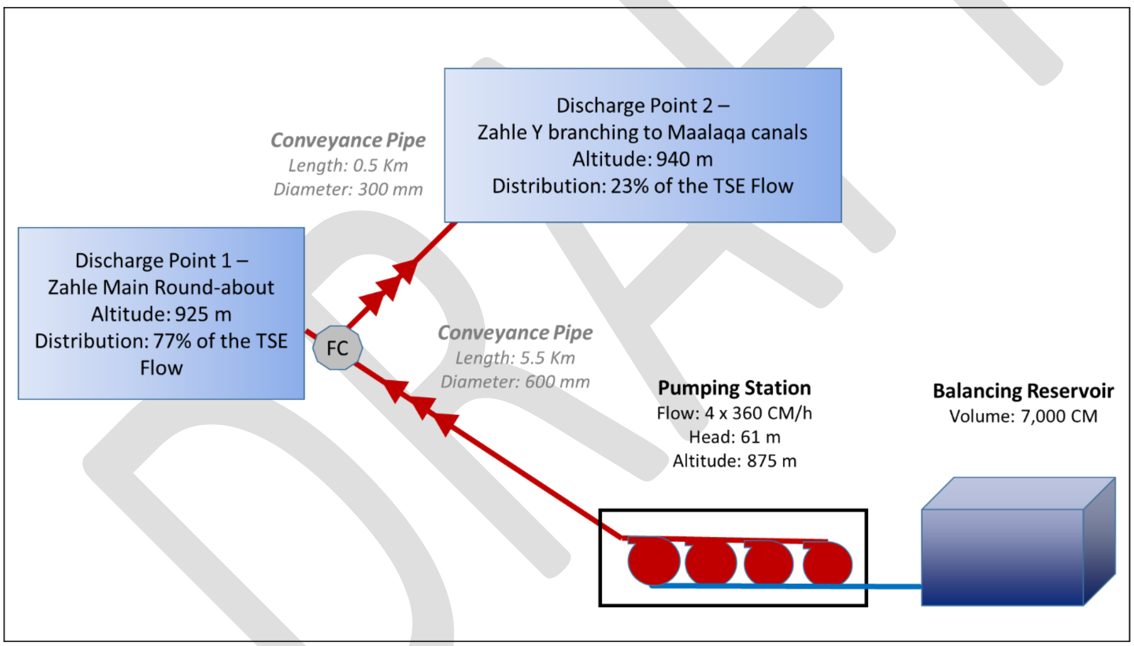
The treated wastewater would be used to irrigate the plots that are currently served by Berdaouni Irrigation Network canals located in Maalaqa and Haouch El Oumara. Two options are then possible: the first one consists at discharging water at the highest point of the irrigation system, where water would supply the different branches of the irrigation system. The second one was recommended by Zahleh municipality and consists at discharging the treated effluent at a higher point where the river flows within a touristic area and this for touristic impact (2 Km farther upstream relatively the irrigation system intake).

4.1.1.1 Scenario 1.1: Lower discharge point (without touristic impact)

The design flow shall be 25,000 CM/day to be sure to capture all the available water in the early summer season. It will be discharged into the Berdaouni existing network and will provide supplementary irrigation to agricultural flows in Maalaqa (693 ha) and Haouch El Oumara (1,371) ha based on aerial photos. The gross irrigation command area is estimated at (2,064) ha. **The beneficiaries from this option will be farmers in Zahle located within the Berdaouni scheme only**. This engineering design option comprises:

- A reinforced concrete balancing reservoir at the WWTP. Capacity 7,000 CM;
- A pumping station including 4 pumps to lift 360 CM/h (100 l/s) of water each from 875m to two discharging points. The head of the pumping station shall be 61m;
- The main conveyance pipe shall be 5.5 km in length and 600mm in diameter;
- The first discharging point is at 925m altitude (the difference in head is ΔH=50m). It shall include an energy dissipation structure. It will discharge 77% of the treated waste water (TSE) at this point;
- A branch of pipe shall be connected to the main conveyance and controlled by a flow control valve. This branch shall discharge 23% of the treated waste water flow at (940m) just before the Y branching that will distribute water to higher Maalaqa canals. This branch of pipe shall be 0.5 km in length and 300mm in diameter;
- The second discharging point shall also be an energy dissipater structure.
- The schematic of proposed Option 1.1 is presented in Figure 7 below.

Figure 7: Hydraulic design option 1.1



4.1.1.2 Scenario 1.2: Higher discharge point (includes touristic impact)

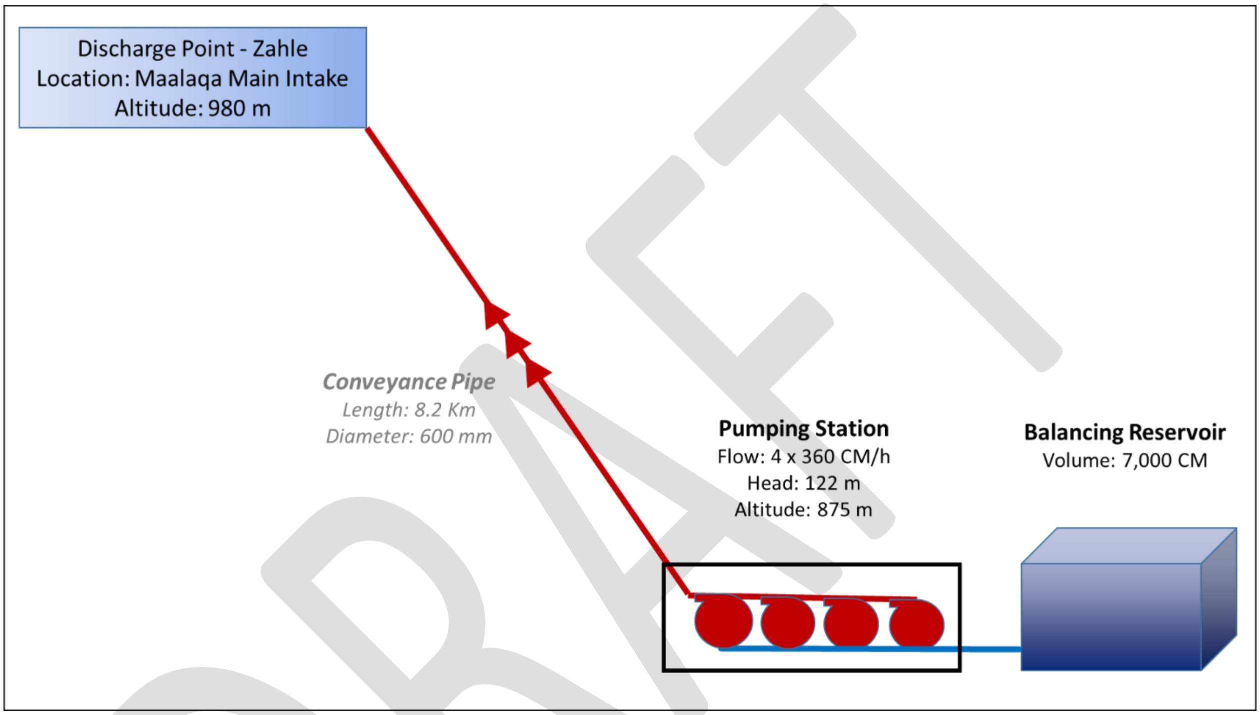
The design flow shall be 25,000 CM/day. It will be discharged in the Berdaouni upstream of the Maalaqa main irrigation network intake. This option provides supplementary irrigation to agricultural flows in Maalaqa (693 ha) and Haouch el Oumara (1,371) ha. The irrigation command area is estimated at (2,064 ha). **The beneficiaries from this option will be farmers in Zahle located within the Berdaouni scheme only**. The proposed option comprises:

- A balancing reservoir at the WWTP of a capacity of 7,000 CM;

- A pumping station including 4 pumps to lift 360 CM/h (100 l/s) of water each from 875m to 945m altitude (ΔH=120m) with a head of 140m;
- A conveyance pipe, 8.2 km length, 600 mm in diameter;
- One energy dissipater discharging structure.

The schematic of proposed Option 1.2 is presented in Figure 8 below

Figure 8: Hydraulic design option 2.1



4.1.2 Scenario 2: Exclusive distribution to Barr Elias area (downstream)

Season 1: (from May to end of July) 25,200 CM/day will be used to irrigate plots in Bar Elias. The ETo being around 5.0 mm/day, around 275 ha can be irrigated at an overall efficiency of 55%.

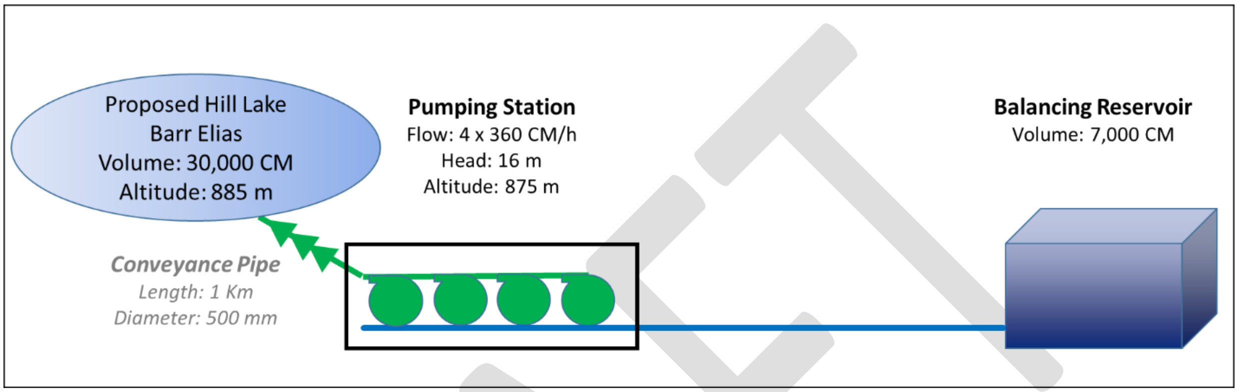
Season 2: (from August to October) 16,200 CM/day will be used to irrigate plots in Bar Elias. The ETo being around 6.5mm/day, around 140 ha can be irrigated at an overall efficiency of 55%

The design flow shall be 25,200 CM/day. It will be discharged into a lake 30,000 CM and farmers will use their own pumps to get the water from the lake. **The beneficiaries from this option will be farmers in Barr Elias only**. The proposed option comprises:

- A balancing reservoir at the WWTP. Capacity 7,000 CM.

- A pumping station including 4 pumps to lift to lift 360 CM/h (100 l/s) of water each from 875m to 885m altitude (ΔH=10m) with a head of 16m.
- A conveyance pipe, 1 km length, 500 mm in diameter.
- One lake 30,000 CM capacity.
- Farmers in Barr Elias will have to use their own pumps to get the water from the lake to their lands using the existing ditches (Figure 9).

Figure 9: Hydraulic design option 2

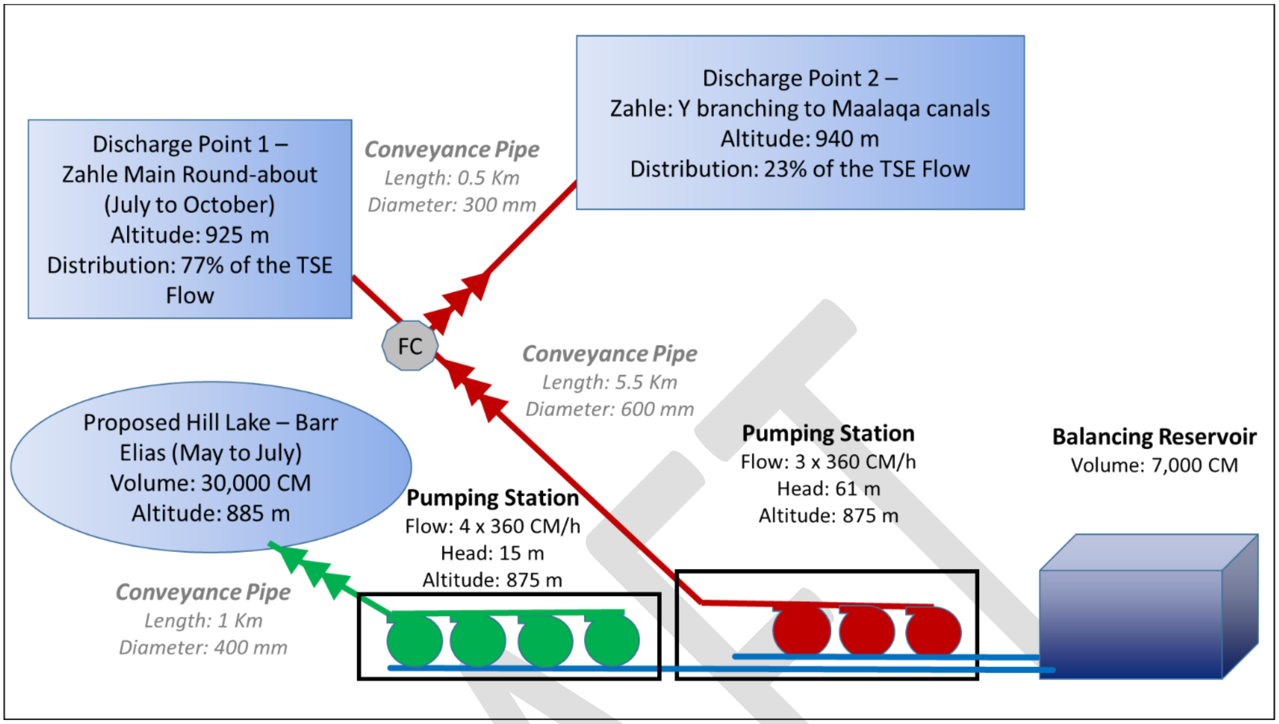


4.1.3 Scenario 3: Distribution between Bar Elias and Zahleh

4.1.3.1 Scenario 3.1: Lower discharge point (without touristic impact)

From May to Mid –July, when water is still available in Berdaouni, from 20,000 to 26,000 CM/day will be used to irrigate plots in Bar Elias. The ETo being around 5mm/day, around 275ha can be irrigated at an efficiency of 55%. Starting Mid-July until October, 16,200 CM/day will be used to irrigate plots in Zahle (140 ha). **The beneficiaries from this option will be farmers in Barr Elias for the earlier irrigation season and farmers in Zahle located within the Berdaouni scheme for the later irrigation season.** The following option is the one that was adopted by users during the consultation meeting held in November 2021. The design is presented in Figure 10.

Figure 10: Hydraulic design option 3.1



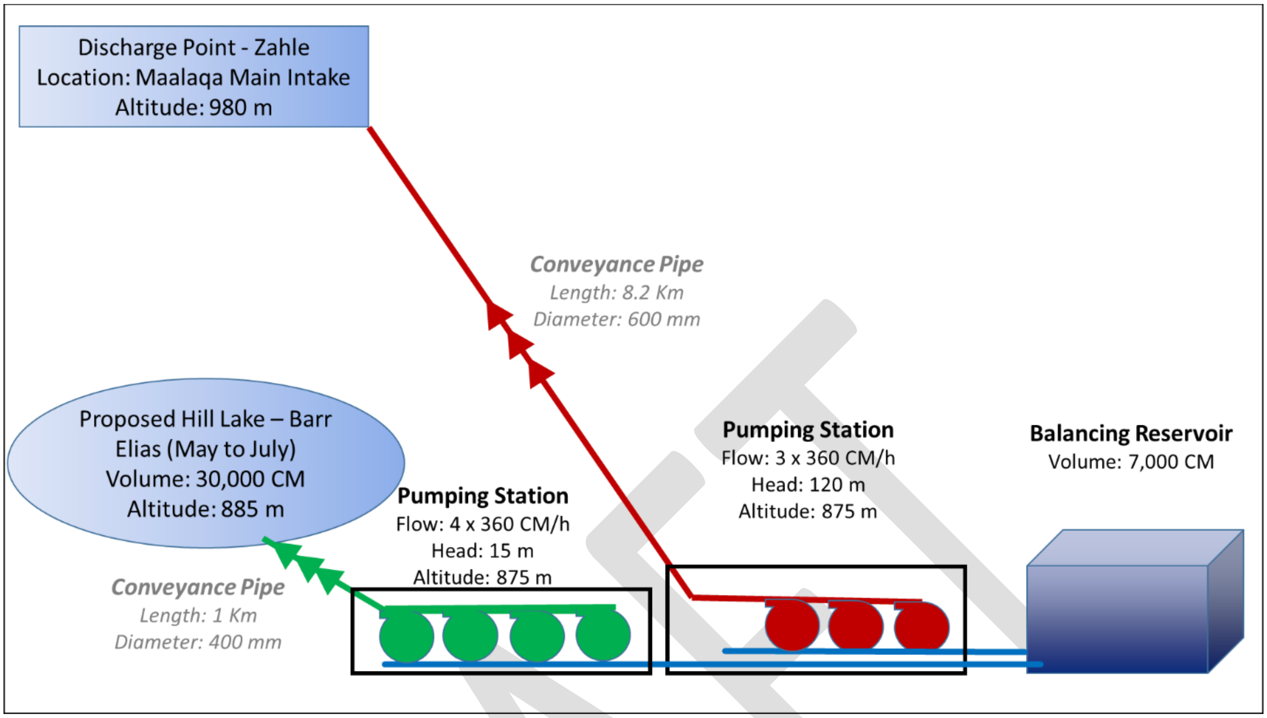
4.1.3.2 Scenario 3.2: higher discharge point (includes touristic impact)

From May to Mid –July, when water is still available in Berdaouni, from 20,000 to 26,000 CM/day will be used to irrigate plots in Bar Elias. The ETo being around 5mm/day, around 275ha can be irrigated at an overall efficiency of 55%.

Option 3.2: Starting Mid-July, water will be used in Zahle (from early July to October) 16,200 CM/day will be pumped to Maalaqa main intake and used to irrigate plots in Zahle.

The beneficiaries from this option will be farmers in Barr Elias for the earlier irrigation season and farmers in Zahle located within the Berdaouni scheme for the later irrigation season. The hydraulic design is presented in Figure 11.

Figure 11: Hydraulic design option 3.2



4.2 Socio-economic feasibility

4.2.1 Scenario comparison and adopted option

A clear comparison between different options has been to inform discussions with local stakeholders and their choice of one of the design options. As mentioned above, Zahleh Municipality and farmers agreed to adopt option 3.1 as this would allow both communities to benefit from the treated effluent. This option ranks low in terms of CAPEX (3/5) and OPEX (4/5) .

The most expensive options in terms of investment and O&M are the options 1.2 and 3.2 proposed by the municipality, where the pumping would be done at the highest point to increase the Berdaouni flow for touristic impact. The most economically feasible option is Option 2 (exclusive distribution downstream to Barr Elias area), followed by Option 1.1 which consists at distributing the to Zahleh irrihation system all year long and where pumping is done at a lower point, high enough to supply the collective system but without impact on the touristic area upstream.

Table 4: Economic comparison of hydraulic development options for Zahleh water reuse system

Option	CAPEX (USD)	Rank according to CAPEX (5 being the strongest)	OPEX USD/year	OPEX USD/CM	Ranking according to OPEX (5 being the strongest	NPV (M US$)	BCR	Ranking according to NPV & BCR (5 being the

								strongest
1.1	$2,768,350	4	$353,222	0.10	2	-4.25	0.44	2
1.2	$3,321,000	2	$689,585	0.19	1	-7.01	0.46	1
2	$1,879,260	5	$73,420	0.02	5	7.80	2.60	5
3.1	$3,302,710	3	$187,653	0.05	4	4.15	1.62	4
3.2	$3,845,760	1	$315,828	0.09	3	2.80	1.31	3

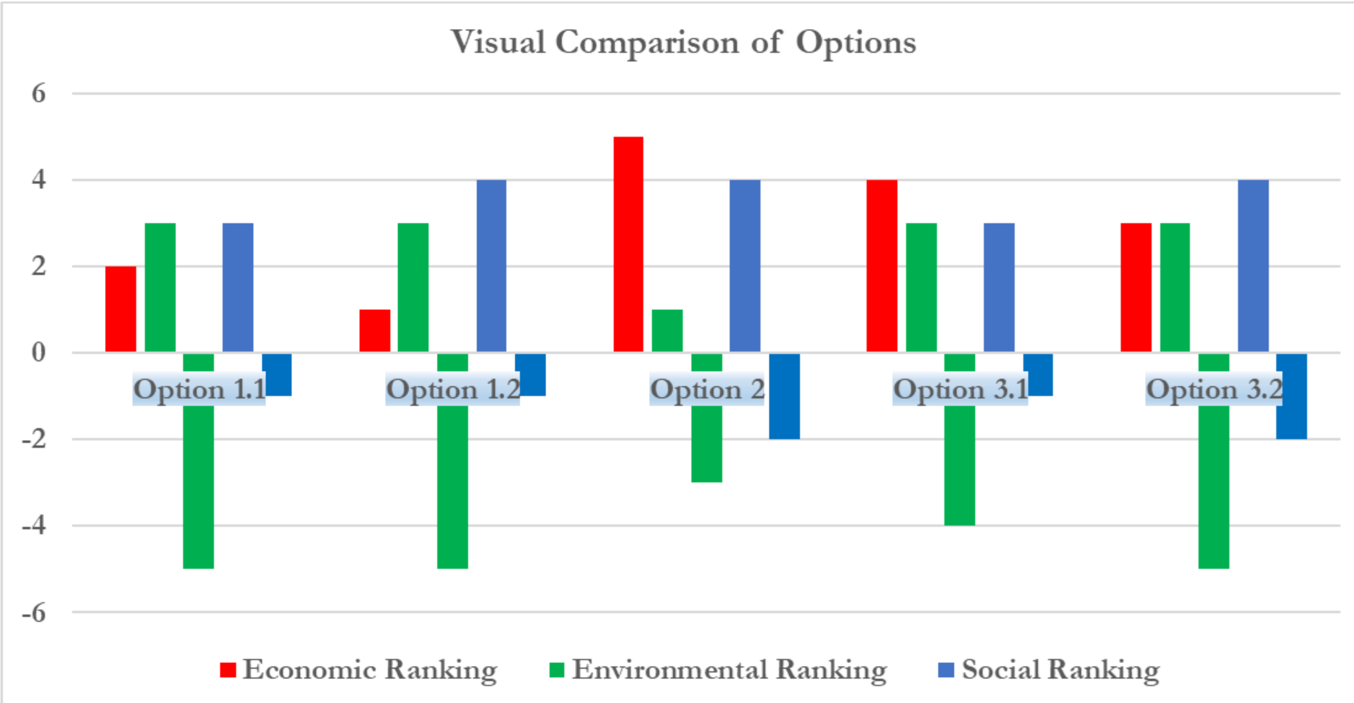
4.2.2 Environmental and social impacts

The comparison of the assessment of the Environmental and Social Impacts for the different proposed options is provided in **Error! Reference source not found.** below.

Table 5: Comparison the ESIA between the different hydraulic development options

Impact	Option 1.1	**Option 1.2**	**Option 2**	**Option 3.1**	**Option 3.2**
Environmental					
Water conservation due to reduction of groundwater extraction	2P	2P	0	2P	2P
Energy consumption due to the operation of pumps	2N	2N	N	N	2N
Environmental impact on the Litani	N	N	N	N	N
Social					
Aesthetic and touristic impact	P	2P	0	P	2P
Potential reuse of agricultural lands and generation of income for users	P	P	2P	P	P
Sustainability of agriculture and rural life	P	P	2P	P	P
Social conflict due to increased inequity between farmers in Zahle and farmers in Barr Elias	N	N	2N	N	2N

Figure 12: Economic, environmental and social ranking of the proposition hydraulic development options



5 GOVERNANCE AND COST-RECOVERY PLANNING AND RISKS

Before investing in any new reuse system, it is crucial to have an elaborate governance and cost-recovery plan designed and negotiated with the different stakeholders. For this it is important to consider both the official regulatory framework and the socially embedded arrangements (Cleaver 2002; Nassif and Tawfik., 2022). In Lebanon, while the discussion of water and wastewater governance is often centered on central-state administrations, community-based institutions and private arrangements have long had a primordial role in managing irrigation schemes (Nassif 2019), drinking water systems (Allès 2019) and sanitation services (Machayekhi et al. 2014; Eid-Sabbagh et al. 2022). Zahleh area is a good example where treatment and irrigation governance are (in practice) under the management of both state actors (treatment) and community actors (irrigation). Furthermore, it is illustrative of an area where different irrigation systems co-exist and options for water allocation are not straightforward. It thus represents an interesting study case to reflect on possible governance options linking different stakeholders with different mandates and claims on water rights (Nassif and Tawfik., 2022). Given this complexity, the absence of clear legal framework specific to water reuse governance and the lack of formal water reuse standards, the proposed governance plan should be taken as a first attempt to organize management tasks in a potential reuse system in Zahleh.

The following sections provide an overview of the legal framework organizing water and wastewater management in Lebanon and elaborates on the role of municipalities and irrigation committees in both wastewater and irrigation governance[7]. It also includes an update on the water sector administration under the current financial crisis in Lebanon and its substantial impact on the performance of state administrations and their capacity to sustain the management of infrastructure on the long run.

5.1 STATE ADMINISTRATIONS

The formal governance of the water and wastewater sector in Lebanon is organized by Law 221/2000 and the Water Code (2018)[8]. Based on these legal texts, **the Ministry of Energy and Water (MEW)** is on the top of the hierarchy. It is responsible for policies and planning with regards to sanitation and water management in the country, including drinking water and irrigation. It is also responsible for the qualitative and quantitative protection of freshwater and groundwater resources. In coordination with the MEW, the **Council of Development and Reconstruction (CDR)** is also responsible for planning and executing water and wastewater infrastructure financed by international funds. The CDR has been directly in charge of executing most large hydraulic and sanitation works since the 1990s (Eid-Sabbagh et al. 2022).

Under the MEW, four **Regional Water Establishments (RWEs)** created by Law 221/2000 are tasked with planning, executing, and operating drinking water, sanitation and irrigation systems, in each of the following regions: Bekaa, Beirut and Mount-Lebanon, South-Lebanon, and North-Lebanon. RWEs are supposed to recover the costs of operation through levying fees from residential units. Under the oversight of the MEW, **the Litani River Authority (LRA)** is in charge of developing and managing irrigation systems on a part of the Litani Basin. It also has responsibilities in monitoring freshwater flows on national scale, and groundwater levels on the Litani River Basin. The (LRA) has also competencies in qualitative water monitoring on parts of the Litani River Basin (Nassif 2019).

The **Ministry of Environment (MoE)** is responsible for setting environmental laws and regulations including water pollution. It is also officially in charge of enforcing environmental regulations through an affiliated 'Environmental Police' within the Ministry. This executive body was recently institutionalized as part of the MoE's organigram but was not enacted on the ground.

The **Ministry of Agriculture (MoA)** is responsible for planning small-scale irrigation systems and providing extension services to farmers for on-farm agricultural and irrigation practices. The **Lebanese Agricultural Research Institute (LARI)** acting under the MoA is responsible for developing research to support agricultural and irrigation development. LARI has water and soil testing labs in different regions in Lebanon including in central Bekaa in Tel Amara, close to Ablah WWTP.

The **Lebanese Standards Institution (known as LIBNOR)** acting under the Ministry of Industry is responsible for developing national standards to regulate products' quality, methods of testing and other processes related to private businesses and public administrations. LIBNOR has been recently

[7] A more detailed overview can be found in ReWater MENA's national report as well as a detailed analysis of the governance barriers of wastewater management and reuse within the political economy context of the country (Eid-Sabbagh et al. 2022).

[8] The water code was established by Law 77 on 13/4/ 2018 and modified by Law 192 on 16/10/2020.

leading the development of official standards for water reuse in collaboration with the other Ministries, the RWES, LARI and other stakeholders. ReWater MENA has been supporting this process but the timeline of the standards' final development and ratification is unclear under the current political situation.

5.2 Community-based institutions

Municipalities are public institutions elected at town level and manage a number of public services. Their mandate is organized by Law 118 of 1977 that grants them (among others) the authority to implement water and wastewater projects. In 2000, the implementation of Law 221 reduced the agency of municipalities over water and wastewater governance by tasking RWEs to manage drinking water, wastewater, and irrigation services. But in practice, many municipalities still govern their water and wastewater systems. This happens due to the weak administrative capacity of the state to take over and operate infrastructure (see below), and/or the reluctance of municipalities to give away their water rights over local sources and infrastructure for distrust in state-managed water services and power contestation by local elites (Allès, 2019; Nassif, 2019).

Nevertheless, although priority over planning and funding lies at the central level, municipalities still detain legal responsibility in water and wastewater governance. Law 347/2001, amending the reform Law 221/2000, states that the latter does not in any way diminish the responsibilities and competencies of the municipalities as enshrined in the municipal law and the law on municipal taxes. They retain their responsibility (as enshrined in Law 118) to manage wastewater networks within municipal boundaries. Within their mandate also lies the protection of public health. This has been interpreted as a legal permission to manage wastewater treatment (Machayekhi et al. 2014).

Municipalities receive a relatively small amount of funds from the central government[9] and levy a local residential tax related to the rental value of properties as well as the maintenance of sidewalks and sewer networks. For a municipality with a medium population size (like Ablah), such funds allow to operate and maintain infrastructure but are not sufficient to pay for capital costs for which they usually rely on external donors' money (Telvizian and Aoun, 2021).

Unions (or Federations) of Municipalities are public institutions that group several municipalities to allow them to undertake projects that exceed the financial possibilities of municipality. They can be in the form of major urban works, firefighting, slaughterhouse management, waste management, sanitation, sewerage systems development, road safety etc. Zahleh is member of the Federation of Zahleh Union of Municipalities (localiban.org).

Irrigation committees in Lebanon are local institutions through which a group of farmers manage a collective irrigation system. They are found around spring-based systems, where landowners have

[9] Municipalities (and Union of Municipalities) receive support from the 'Independent Municipal Fund' which is a form of central government funding mechanism using taxes and fees on telecommunications and electricity. It is managed by the Ministry of Finance. Funds received by Municipalities depend on the size of the local population.

‘water rights’ linked to land ownership[10]. Irrigation committees do not have a sophisticated organizational framework. Their functioning depends on customary rules with some influence by Ottoman law and they operate under the supervision of the respective municipality. In the Bekaa region, farmers elect yearly ‘water distributors’, in Arabic ‘Shawwa’, that are approved by the Municipality and the Mohafez. Their role is to manage water within a branch of the collective system. Shawwa organize water turns, operate the gates, and manage canal’s maintenance works. They collect irrigation fees from farmers (based on the irrigated area) and are compensated a percentage of this fee. The Berdaouni Irrigation Committee manages the Berdaouni collective irrigation system to which part of the effluent would be supplied. Two ‘Shawwa’ appointed by farmers respectively manage the two main branches of the system. The municipality supervises the process and contributes to the maintenance of the canals.

A **Water Users Association (WUA)** is as an institutionalized for community irrigation governance promoted worldwide in the last 30 years to transfer the operation of state-built irrigation systems at farmers’ level (Vermilion, 1997; Ghazouani et al. 2012). In Lebanon, a legal framework for WUAs was envisioned in 2012[11] and the main concepts adopted in the Water Code (2018). However, no WUAs are legally established in Lebanon. Furthermore, different attempts to form farmers’ associations in a state-based irrigation system (Canal 900, South-Bekaa) proved unsuccessful due to technical deficiencies within the system, reluctance of the irrigation administration (the LRA) to delegate tasks, and failure to integrate existing social arrangements (Nassif 2019). Given the absence of a collective irrigation institution in Barr Elias area, this type of institution can be established to collectively manage the irrigation network envisioned in Barr Elias. Water allocation rules should take into consideration customary water rights and existing institutional arrangements around land and water (Nassif, 2016).

5.3 CRISIS IMPACT AND STRUCTURAL DEFICIENCIES

5.3.1 Crisis impact on the water sector and the Bekaa Water Establishment

The financial crisis in Lebanon (starting 2019) had serious repercussions on the functioning on the water sector administration and its capacity to provide public water and wastewater services (MEW 2022). In summer 2021, UNICEF warned that Lebanon’s water supply system is ‘on the verge of collapse’ (UNICEF 2021), and the situation has worsened today with no reforms envisioned and the weakening government’s capacity to pay for salaries and fuel. Lebanon’s civil servants are leaving in droves and those who stayed are commuting to their offices one or two days a week (Salame, 2022). This includes

[10] These water rights (to surface water) were recorded on property titles under land reforms conducted by the French Mandate around the 1920’s and represent water use in that period. They were shaped by socio-economic factors and political power of that historical period (Ghiotti and Riachi, 2013; Nassif, 2019).

[11] Within the ‘Hydro agricultural project for Marjeyoun area’, a UNDP project in partnership with the LRA and AFIAL association. The aim of the project was to develop detailed feasibility studies for one of the sub-areas of the Canal 800 irrigation system planned as part of the Litani Project in South Lebanon and establish Water Users Association to manage the future systems.

the case of the Bekaa Water Establishment (BWE) where dozens of employees left mostly to work with NGOs where the pay is in 'fresh' dollars. The latest Director General resigned in 2021 and since then 13 out of the 17 engineers he had hired to strengthen the capacity of his administration before the crisis left as well[12].

The BWE essentially relies on NGOs funds, individual and political parties' donations to pay for infrastructure operation and sometimes salary compensations[13]. Several WWTPs managed by the establishment stopped operating (e.g. Iaat) or operate thanks to donors' funds. Zahleh WWTP is an illustrative case with its operation being ensured by a UNDP fund since the beginning of September 2022[14]. According to the MEW, donors such as UNICEF, USAID and AFD will be supporting the operation of 30 medium to large WWTPs throughout Lebanon.

Small WWTPs such as Ablah are not considered part of this list of priority. Ablah WWTP operates only during hours of public electricity supplied by EDZ (12/24 hours)[15] and there are no funds available to operate the local generator. As an alternative, solar panels are being installed with the support of an NGO and should be connected to EDZ grid, which is expected to reduce the electricity bill. The management of Ablah WWTP is further complicated by the resignation of the municipal board in summer 2022. Municipal services continue under the supervision of the Region (Mohafaza) but are slowed down. This has a consequence on the financial compensation of staff among whom the operator of Ablah WWTP whose pay was interrupted for several months. One needs to mention that this comes as an additional burden to the reduction of his salary's value (which is still in the L.L). and his lack of access to the 'social allocation' disbursed by the government to public employees.

In May 2022, the Ministry of Energy and Water issued a 'Road Map to Recovery of the Water Sector' with the support of the Agence Française de Développement (AFD) but the plan has not yet been officially approved (MEW 2022). With no financial recovery plan for Lebanon and no government formed since the latest parliamentary elections (May 2022), it is not clear whether this plan would be implemented and if one could expect a close recovery of the state apparatus.

5.3.2 Structural deficiencies of the water sector

It should be highlighted that the governance problems of the water sector do not result from the crisis. Long before the financial collapse, the different public administrations struggled to implement their legal mandates which should be taken in due consideration to avoid unsustainable investments in

[12] Most of them were hired under a non-permanent status and do not benefit from the 'social allocated' allocated provided to permanent employees. Information provided from an official in the BWE interviewed in November 2022.

[13] According to the same informant, local stations in Zahleh provided fuel for free for technicians operating water networks. The initiative was taken by a dynamic department director asking fuel stations' owners from the community to support 'those who are providing water'. In the Northern part of the BWE's territory, where most residents are from Hezbollah constituents, the party is paying for the operation of wells. Interviewed in November 2022.

[14] Information provided by a high-level official interviewed at the Ministry of Energy and Water in November 2022.

[15] Field visit to Ablah in November 2022.

infrastructure. The four Regional Water Establishments (RWEs) supposed to take over drinking water, sanitation and irrigation services were only operating a part of drinking water networks (MEW 2020). Irrigation was largely community-managed except for some schemes managed by the LRA on the LRB the BWE in North-Bekaa (Nassif 2019). Furthermore, among the 104 WWTPs implemented, only 10 were managed by the RWEs and 5 are well operational. The rest is still managed by the CDR, and many are governed by municipalities (Eid-Sabbagh et al. 2022).

The incapacity of RWEs to operate infrastructure essentially lies in their incapacity to recover costs of O&M from residential units as per the model imagined by the reform (MEW 2020). They are poorly staffed, have weak political power to levy fees, and subject to interference from the various political fractions (Eid-Sabbagh, 2015; Allès, 2019; Nassif, 2019; Eid-Sabbagh et al. 2022). Amongst the four RWEs, the Bekaa Water Establishment (related to our case study) has the weakest cost-recovery rate (around 30% in 2020 according to the Update of the National Sector Strategy (MEW 2020)). The crisis has further impacted its capacity to levy fees, with an estimated reduction of 25% in 2020 (Eid-Sabbagh et al. 2022). Today, the BWE functions without a Director General, and employees struggle on daily basis to operate infrastructure.

In addition to issues of infrastructure operation, the governance of wastewater management in the country suffers from fragmented planning, and weak monitoring of treatment processes and treated effluent's quality. As detailed and illustrated in ReWater's national study, planning has long been fragmented and mostly managed by the CDR with weak coordination with the MEW and little involvement of RWEs and municipalities. On the other hand, many small scale WWTPs such as Ablah were implemented in partnership with municipalities and no involvement of the central government (Eid-Sabbagh, 2022).

The monitoring of treated effluents' quality is also a shared responsibility between different administrations, namely the MEW, the MoE, and the RWEs (see Annex 4). However, the Ministry of Environment has not been granted the executive mandate. At present, water sampling and testing is not unified and differ from case to case depending on donor funds and technical assistance. In recent years, different international organizations equipped RWEs (including the BWE) with water quality labs which improved their monitoring capacities. Municipalities such as Ablah and Aitanit have small labs on site which allow them to test the most important parameters for process management. Zahleh WWTP is also equipped with a water quality lab with testing capacity that allow to test the different parameters included in the FAO proposed reuse guidelines (FAO 2010, see Annex 6).

5.4 ZAHLEH GOVERNANCE PLAN

The proposed governance plan for the management of Zahleh Reuse System was developed based on the official legal framework of the water and wastewater sector (mainly Law 221 and the Water Code), current governance practices, and the consultations with the different national and local stakeholders (see 3.2).

- A **Reuse Steering Committee** shall be established to give general direction of the reuse project. It shall be headed by the BWE and composed of one delegate from Zahle Municipality, one delegate from Barr Elias Municipality, the two ‘Shawwa’ from the Berdaouni Irrigation Committee and representatives from the group of farmers that will benefit from Barr Elias network. This committee should consider including representatives from LARI and the Ministry of Agriculture to provide extension services to farmers with regard to cropping practices and on farm risk management practices to reduce health and agronomic hazards.

- **The Bekaa Water Establishment** is the owner of the treatment plant. In collaboration with the UNDP project, it monitors the operation of the WWTP recently contracted to SUBAL, a Lebanese contracting firm. As per its mandate on irrigation governance on its territory, the BWE will be responsible for supervising the implementation of the reuse hydraulic infrastructure. It will also manage (in partnership with SUBAL) the primary infrastructure conveying the treated effluent to the different parts of the irrigation system, namely the main pumping stations located withing the WWTO premises, and the maintenance of the pipe network. The Bekaa Water Establishment would also regularly monitor the water quality of the treated effluent and make sure they comply with the FAO proposed guidelines (FAO 2010). The BWE will also play a role in tariff collection in collaboration with the Municipality of Zahleh, the Berdaouni Irrigation Committee, and the WUA that would be established to manage the irrigation network proposed in Barr Elias. It will also have a role in the resolution of conflict that may arise over water allocation between Zahleh and Barr Elias farmers.

- **The Municipality of Zahleh and the Berdaouni Irrigation Committee** will supervise the implementation of the hydraulic infrastructure in Zahleh and make sure it corresponds to the points of water allocation needed by farmers. The two entities will be responsible for distributing water to the Berdaouni irrigation system according to the existing water rights and customary rules. The timing of irrigation supply from the main pumping stations will be coordinated with the Bekaa Water Establishment.

- **The Municipality of Barr Elias and Barr Elias WUA** will supervise the implementation of the hydraulic infrastructure in Barr Elias and make sure it corresponds to the points of water allocation needed by farmers. The two entities will be responsible for distributing water to the Barr Elias irrigation system according to allocation rules to be developed. The timing of irrigation supply from the main pumping stations will be coordinated with the Bekaa Water Establishment.

- **The Ministry of Energy and Water and the Ministry of Environment** should develop a clear water quality monitoring plan to monitor the performance of the WWTP and ensure compliance of the BWE to the standards. Given LARI’s experience in conducting research related to water reuse and the on-going development of reuse standards, it is suggested that water testing is conducted at LARI’s premises.

- **LARI and the Ministry of Agriculture** would develop and implement an extension program to guide farmers in their cropping and risk management practices.

5.5 Funding and Cost recovery options and challenges

The funding and cost recovery options have not been discussed in depth in the consultation process and need to be studied with care by the project owners, potential investors, and beneficiaries. Nevertheless, this section summarizes the main costs and discusses some funding and cost-recovery options based on information collected from the survey and insights from stakeholder interviews. Results challenge the objective of covering the reuse system's operation costs from users and generating income for operators as hoped by State administrations and sometimes promoted by donors. They also show the necessity of setting other financing options and developing a flexible tariff tailored to the array of costs different farmers' groups currently pay for their existing access to water to create incentives for using the system.

5.5.1 Infrastructure financing

The hydraulic development option selected by stakeholders has an estimated capital cost of around 3,300 USD and. Given the current crisis, the Bekaa Water Establishment and other local stakeholders will not be able to pay for such cost and will need an external investor such as international development organization. Currently, UN-Habitat has a potential fund under a Climate Change Impact Mitigation project and is considering financing the capital cost for reuse system in Zahleh. The project is currently in discussion with the MEW, the Municipality of Zahleh and the BWE.

5.5.2 Operation and maintenance financing

The cost of operation and maintenance has an estimated operation cost of 187,653 USD/year for the whole hydraulic system and would be equally divided between Zahleh and Barr Elias farmers as calculated in the economic feasibility study. The total potentially irrigable area in Zahleh is 1,400 du in the summer (140 ha), and the one in Barr Elias 2,750 du in the spring season. Zahleh farmers would then have to pay around 135 USD/dunum/season and Barr Elias farmers around 35 USD/dunum/season.

This raises two questions: the cost for Zahleh farmers is considerably higher than the average cost farmers reported to be willing to pay (61$/du/season). Second, the survey showed a large variability in the cost farmers pay for their access to water (between 7 to 67 USD/du) which depends on whether they use/need a well to complement their water needs (the lower cost is paid by farmers relying only on water supply by gravity) and in the case they use a well, on the depth of the well and the length of the conveyance system (which depends on the well location relatively to the plot). It is thus unlikely that farmers irrigating by gravity will accept paying for the cost of the treated effluent. Farmers located at the tail-end of the system would only accept paying the required cost of 135/dunum/season if they pay a lower cost of pumping, which, according to the interviews, is higher than the average price of pumping from wells. This means that more than half of the cost of operation will need to be subsidized. This conclusion joins what has been found in other cases in MENA and worldwide, where most water reuse projects are unlikely to achieve full cost recovery and might only recover part of the operation costs (Hanjra et al. 2015; Gebrezgabher et al. 2022). Options of reducing the cost of pumping (by installing solar systems for example) are recommended to be explored (Gebrezgabher et al. 2022) but this would require additional capital investment.

More generally, the question of cost-recovery opens the topic of who can and who should pay for the cost of water supply in general and irrigation water and reuse more specifically. Many options exist (subsidies from central government based on levied income tax, taxes on big farms/commercial enterprises in the Bekaa, and others) but would be challenging to implement given the ultra-liberal policies of the Lebanese government and the neo-liberal logic of full-cost recovery from users (Eid-Sabbagh, 2015). This study is an opportunity to open the debate around these questions.

6 CONCLUSION

The design exercise for a reuse system supplied by Zahleh WWTP was done based on a multi-disciplinary approach combining public participation concepts and human geography with the more classical tools of cost-benefit analysis and environmental impact assessments. Mapping and analyzing in close collaboration with local communities the diversity of socio-technical arrangements around irrigation in the study area revealed five different possible scenarios for water allocation. Comparing these scenarios thanks to cost-benefit tools allowed to rank the different options according to their economic feasibility and revealed that conveying water exclusively downstream was the most feasible economically. But assessing these options from a social point of view showed that the most economically reasonable option was totally rejected by upstream users and runs the risk of complete project failure. Consultation with users and efforts done by ReWater MENA to reach consensus allowed to adopt a win-win scenario where the treated effluent would be conveyed to downstream farmers in the first irrigation season and allow them to crop lands kept fallow, and then distributed to upstream farmers in the second season as an alternative to pumping groundwater.

This option was found to be economically profitable, and a donor (UN-habitat) is interested to fund the capital needed for the hydraulic works. However, our study found that the cost of the system's operation will not be possible to be recovered fully from users. First, it shows the necessity of developing incentivized tariff tailored to the array of costs different farmers' groups currently pay for their existing access to irrigation water. Second, other financing sources are necessary to recover the full cost of operation. Financing options are limited given the financial collapse of the country, the current incapacity of government to enforce possible taxes or contribution on polluters and more generally, given the country's vision for financing the water sector in the past 30 years. This study is an opportunity to open the debate around these questions.

The future governance of the reuse system is yet another substantial challenge. Due to the financial and political crisis in Lebanon, the water sector administrations in Lebanon are collapsing and increasingly relying on external donor's money or local donations. The BWE is struggling to ensure the operation of drinking water and unable to operate Zahleh WWTP. Since September 2022, the Italian Government provided a two-year grant to operate the plant, but it is not clear how the cost will be covered beyond this period.

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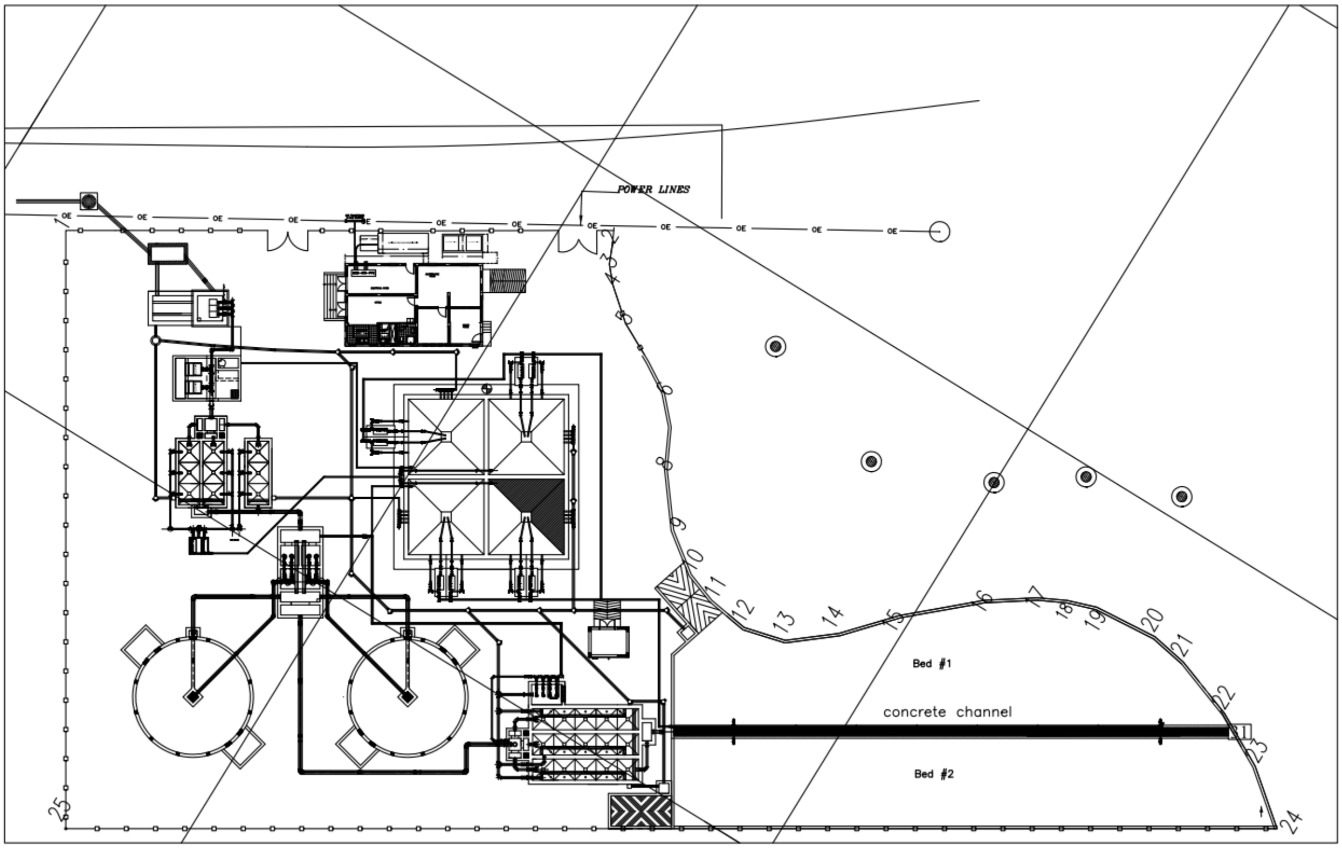
ANNEX 1: MEMBERS OF THE NSC MEETING IN MAY 2019

Institution	Name	Position
MEW	Mr. Moufid Dheini	Head of Wastewater Department
	Mr. Yasser Suleiman	Engineer in Directorate of Exploitation
	Mr. Benoît Fahed	Advisor to the Minister
MoE	Mrs. Sabine Ghosn	Head of Urban Environment and Pollution Control Department
	Mrs. Jamila El Hadi	Environmental Engineer in the same department
LRA [Note]	Mr. Nassim Abou Hamad	Head of Governance Department
CDR	Mr. Roy Yazbeck	Assisting BWE in coordinating with donors
BWE	Mr. Souheil Rouphael	Engineer working on WWTPs
BMLWE	Mr. Fady Eid	Engineer
SLWE	Mr. Maarouf Mezher	Engineer working on WWTPs
LARI	Dr. Marie-Thérèse Abi-Saab	Head of Water and Climate Unit
	Mr. Salim Fahed	Research assistant in the same department

Note: the LRA withdrew its participation from the NSC in July 2019

ANNEX 2: GENERAL LAYOUT OF ZAHLEH WWTP



Source: Provided by the operator of Zahleh WWTP

Annex 3: Zahleh updated irrigation network Layout (in a separate volume)

Annex 4: Zahleh existing irrigation network- Photographic Documentation (in a separate volume)

ANNEX 5: FARMERS SURVEY TEMPLATE

Source of water: Berdaouni

GENERAL					
1	Village				
2	Name of the farmer				
3	Cadastral area and No.				
4	Agricultural area	Ha			
5	Type of irrigated crops and cultivated areas by season	Season 1		Season 2	
		Crops	Cultivated area / Ha	Crops	Cultivated area / Ha
		1:		1:	
		2:		2:	
		3:		3:	
6	Land tenure (ownership, land rental)	Own [ ] Rental [ ] Other (specify) [ ]			
7	Gender	Male [ ] Female [ ]			
PRODUCTION AND ON-FARM IRRIGATION SYSTEM					
8	Do you have any livestock? Number	Yes [ ] [ ] No [ ]			

9	Current on farm irrigation system	Surface [ ] Sprinkler [ ] Drip [ ] Other (specify) [ ]	
10	**On-farm irrigation system cost**	**LL or US$**	
11	On-farm pumping station cost (Per your project)	LL or US$	

PRODUCTION AND ON-FARM IRRIGATION SYSTEM

12	On-farm annual pumping cost (Choose one of the 2 options)	LL or US$	Per Ha: Per your project:
13	On-farm filtration station cost (Per your project)	LL or US$	
14	Annual cost of maintenance of the on-farm irrigation system (Choose one of the 2 options)	LL or US$	Per ha: Per your project:
15	Annual fertilization cost (Choose one of the 2 options)	LL or US$	<u>Crop 1:</u> Per ha: Per your project: <u>Crop 2:</u> Per ha: Per your project: <u>Crop 3:</u> Per ha:
16	Annual production quantity (Fill for each crop)	Tons	Crop 1: Crop 2: Crop 3:

17	Selling price at farm gate per ton (Fill for each crop)	LL or US$	Crop 1: Crop 2: Crop 3:
18	Annual gross return (Choose one of the 2 options)	LL or US$	Per ha: Per your project:

MAIN SOURCE OF WATER

19	Water source	Berdaouni Collective System	
20	Sector of water distribution from Berdaouni		
21	Do you face any problem of water scarcity for agricultural use?	Yes [ ] No [ ]	
22	Are you satisfied with your access to water? If no, please elaborate why	Yes [ ] No [ ]	
23	-		
24	-		

MAIN SOURCE OF WATER

25	-		
26	-		
27	Water charges (Fill for each crop, per ha or per your project)	LL or US$	Crop 1: Per ha: Per your project: Crop 2: Per ha: Per your project: Crop 3: Per ha:
28	-		

29	-	
30	-	
31	-	
32	-	
33	-	
34	-	
35	Do you experience a decrease in the river yield in the summer and/or in years of low rainfall?	Yes [ ] No [ ]
36	When does water from Berdaouni stop being available?	
37	-	
38	Does this prevent you from planting a second season crop?	Yes [ ] No [ ]
39	Does this condition your choice of crop?	Yes [ ] No [ ]

SECONDARY SOURCE OF WATER

40	Do you have a second source of water? (well). If yes answer the question related to the well	Yes [ ] No [ ]
41	Well ownership	Direct / owned [ ] Indirect / collective [ ]
42	date of well drilling	
43	Well depth (m)	
44	well yield / flow	CM/h: Inch:

45	Well water charges (Fill for each crop, per ha or per your project)	LL or US$	Crop 1: Per ha: Per your project: Crop 2: Per ha: Per your project: Crop 3: Per ha:
46	Pump ownership and use	Direct / owned [ ] Indirect / collective [ ]	
47	Pump power/flow	HP [ ] CM/h [ ] Inch [ ]	
48	Cost / cost share of the pump of the well	LL or US$	
49	Annual pumping cost / cost share (Choose one of the 2 options)	LL or US$	Per Ha: Per your project:
50	Conveyance infrastructure associated to well		

SECONDARY SOURCE OF WATER

51	In case of a shortage of water, what do you do?	[ ] Reduce pumping, [ ] Lower the pump, [ ] Buy water from another well, [ ] Rent another plot in case not owner
52	Did you ever deepen the secondary well?	Yes [ ] No [ ]

53	Did you have to drill another well?	Yes [ ] No [ ]

WILLINGNESS TO USE TREATED WASTEWATER

54	Will you be willing to use treated wastewater instead of Berdaouni or as a complement to water from Berdaouni?	Yes [ ] No [ ]
55	Who do you think owns the treated wastewater?	
56	Will you accept that the treated effluent is injected in the Berdaouni Canal and mixed with fresh water?	Yes [ ] No [ ]
57	Willingness to pay (WTP) for wastewater reuse	Yes [ ] No [ ]
58	If willing to pay then for what?	• Capital cost of new on-farm drip irrigation system required for the treated waste water reuse [ ] • For the volume of treated waste water reuse provided [ ]
59	How much are you willing to pay for wastewater reuse?	LL or US$ / CM

WILLINGNESS TO USE TREATED WASTEWATER

60	Are you aware of water quality and potential implication on human, animal and environmental health? If yes, please elaborate.	Yes [ ] No [ ]
61	Do you know what are the limitations of the reuse of wastewater? If yes, list the limitation on the reuse of water.	Yes [ ] No [ ]

GENDER

62	Household head structure: male-headed, female-headed, couple-headed household.
63	Number, sex and age of all household members.
64	What were the most important problems/ health, natural, economic or social, your household aced as far as negative impacts to your household, household members' livelihoods and/or the household's agriculture/livestock during the last 12 months were concerned?
65	What effect, do you expect, will the new treated wastewater quantities have on the labour input of [women/men/boys/ girls/male farm worker/female farm worker]?

Source of water: Litani river or Ghzayel

GENERAL

1	Village				
2	Name of the farmer				
3	Cadastral area and No.				
4	Agricultural area	Ha			
5	Type of irrigated crops and cultivated areas by season	Season 1		Season 2	
		Crops	Cultivated area / Ha	Crops	Cultivated area / Ha
		1:		1:	
		2:		2:	
		3:		3:	
6	Land tenure (ownership, land rental)	Own [ ] Rental [ ] Other (specify) [ ]			
7	Gender	Male [ ] Female [ ]			

PRODUCTION AND ON-FARM IRRIGATION SYSTEM

8	Do you have any livestock? Number	Yes [ ] [ ] No [ ]
9	Current on farm irrigation system	Surface [ ] Sprinkler [ ] Drip [ ] Other (specify) [ ]
10	**On-farm irrigation system cost**	**LL or US$**

11	On-farm pumping station cost (Per your project)	LL or US$	

PRODUCTION AND ON-FARM IRRIGATION SYSTEM

12	On-farm annual pumping cost (Choose one of the 2 options)	LL or US$	Per Ha: Per your project:
13	On-farm filtration station cost (Per your project)	LL or US$	
14	Annual cost of maintenance of the on-farm irrigation system (Choose one of the 2 options)	LL or US$	Per ha: Per your project:
15	Annual fertilization cost (Choose one of the 2 options)	LL or US$	<u>Crop 1:</u> Per ha: Per your project: <u>Crop 2:</u> Per ha: Per your project: <u>Crop 3:</u> Per ha:
16	Annual production quantity (Fill for each crop)	Tons	Crop 1: Crop 2: Crop 3:
17	Selling price at farm gate per ton (Fill for each crop)	LL or US$	Crop 1: Crop 2: Crop 3:
18	Annual gross return (Choose one of the 2 options)	LL or US$	Per ha: Per your project:

MAIN SOURCE OF WATER

19	Water source	Litani [ ] Ghzayel [ ]	

20	-	
21	Do you face any problem of water scarcity for agricultural use?	Yes [ ] No [ ]
22	Are you satisfied with your access to water?	Yes [ ] No [ ]
	If no, please elaborate why	

MAIN SOURCE OF WATER

23	-	
24	-	
25	-	
26	-	
27	Water charges (Fill for each crop, per ha or per your project)	LL or US$ Crop 1: Per ha: Per your project: Crop 2: Per ha: Per your project: Crop 3: Per ha:
28	Type of pump	Fixed [ ] Mobile [ ]
29	Pump ownership and use	Direct / owned [ ] Indirect / collective [ ]
30	Pump power/flow	HP [ ] CM/h [ ] Inch [ ]
31	Cost / cost share of the pump	LL or US$

32	Annual pumping cost / cost share (Choose one of the 2 options)	LL or US$	Per Ha: Per your project:
33	Date of pump installation		
34	Conveyance infrastructure associated to pump		
35	Do you experience a decrease in the river yield in the summer and/or in years of low rainfall?	Yes [ ] No [ ]	
36	When does water from the river stop being available?		

MAIN SOURCE OF WATER

37	In case of a shortage of water, what do you do in this case?	[ ] Reduce pumping, [ ] Buy water from another source (specify) [ ], [ ] Rent another plot in case not owner
38	Does this prevent you from planting a second season crop?	Yes [ ] No [ ]
39	Does this condition your choice of crop?	Yes [ ] No [ ]

SECONDARY SOURCE OF WATER

40	Do you have a second source of water? (well). If yes answer the question related to the well	Yes [ ] No [ ]
41	Well ownership	Direct / owned [ ] Indirect / collective [ ]
42	date of well drilling	
43	Well depth (m)	

44	well yield / flow	CM/h: Inch:
45	Well water charges (Fill for each crop, per ha or per your project)	LL or US$ <u>Crop 1:</u> Per ha: Per your project: <u>Crop 2:</u> Per ha: Per your project: <u>Crop 3:</u> Per ha:
46	Pump ownership and use	Direct / owned [ ] Indirect / collective [ ]
SECONDARY SOURCE OF WATER		
47	Pump power/flow	HP [ ] CM/h [ ] Inch [ ]
48	Cost / cost share of the pump of the well	LL or US$
49	Annual pumping cost / cost share (Choose one of the 2 options)	LL or US$ Per Ha: Per your project:
50	Conveyance infrastructure associated to well	
51	In case of a shortage of water, what do you?	[ ] Reduce pumping, [ ] Lower the pump, [ ] Buy water from another well, [ ] Rent another plot in case not owner
52	Did you ever deepen the secondary well?	Yes [ ] No [ ]

53	Did you have to drill another well?	Yes [ ] No [ ]

WILLINGNESS TO USE TREATED WASTEWATER

54	Will you be willing to use treated wastewater instead of Litani or Ghzayel or as a complement to Litani or Ghzayel?	Yes [ ] No [ ]
55	Who do you think owns the treated wastewater?	
56	Will you accept that the treated effluent be conveyed in your irrigation system?	Yes [ ] No [ ]
57	Willingness to pay (WTP) for wastewater reuse	Yes [ ] No [ ]

WILLINGNESS TO USE TREATED WASTEWATER

58	If willing to pay then for what?	• Capital cost of new on-farm drip irrigation system required for the treated waste water reuse [ ] • For the volume of treated waste water reuse provided [ ]
59	How much are you willing to pay for wastewater reuse?	LL or US$ / CM
60	Are you aware of water quality and potential implication on human, animal and environmental health? If yes, please elaborate.	Yes [ ] No [ ]

61 Do you know what are the limitations of the reuse of wastewater?

If yes, list the limitation on the reuse of water.

Yes [ ]

No [ ]

GENDER

62 Household head structure: male-headed, female-headed, couple-headed household.

63 Number, sex and age of all household members.

64 What were the most important problems/ health, natural, economic or social, your household aced as far as negative impacts to your household, household members' livelihoods and/or the household's agriculture/livestock during the last 12 months were concerned?

65 What effect, do you expect, will the new treated wastewater quantities have on the labour input of [women/men/boys/ girls/male farm worker/female farm worker]?

Source of water: Well

GENERAL

1 Village

2 Name of the farmer

3 Cadastral area and No.

4 Agricultural area Ha

5 Type of irrigated crops and cultivated areas by season Season 1 Season 2

		Crops	Cultivated area / Ha	Crops	Cultivated area / Ha
		1:		1:	
		2:		2:	
		3:		3:	
6	Land tenure (ownership, land rental)	Own [ ]			
		Rental [ ]			
		Other (specify) [ ]			
7	Gender	Male [ ]			
		Female [ ]			

PRODUCTION AND ON-FARM IRRIGATION SYSTEM

8	Do you have any livestock? Number	Yes [ ] [ ]	
		No [ ]	
9	Current on farm irrigation system	Surface [ ]	
		Sprinkler [ ]	
		Drip [ ]	
		Other (specify) [ ]	
10	On-farm irrigation system cost	LL or US$	
11	On-farm pumping station cost (Per your project)	LL or US$	
12	On-farm annual pumping cost (Choose one of the 2 options)	LL or US$	Per Ha:
			Per your project:

PRODUCTION AND ON-FARM IRRIGATION SYSTEM

13	On-farm filtration station cost (Per your project)	LL or US$	
14	Annual cost of maintenance of the on-farm irrigation system (Choose one of the 2 options)	LL or US$	Per ha:
			Per your project:

15	Annual fertilization cost (Choose one of the 2 options)	LL or US$	Crop 1: Per ha: Per your project: Crop 2: Per ha: Per your project: Crop 3: Per ha:
16	Annual production quantity (Fill for each crop)	Tons	Crop 1: Crop 2: Crop 3:
17	Selling price at farm gate per ton (Fill for each crop)	LL or US$	Crop 1: Crop 2: Crop 3:
18	Annual gross return (Choose one of the 2 options)	LL or US$	Per ha: Per your project:
MAIN SOURCE OF WATER			
19	Water source	Well	
20	-		
21	Do you face any problem of water scarcity for agricultural use?	Yes [ ] No [ ]	
22	Are you satisfied with your access to water? If no, please elaborate why	Yes [ ] No [ ]	
23	Well ownership	Direct / owned [ ] Indirect / collective [ ]	
24	date of well drilling		

MAIN SOURCE OF WATER

25	Well depth (m)		
26	well yield / flow	CM/h: Inch:	
27	Well water charges (Fill for each crop, per ha or per your project)	LL or US$	<u>Crop 1:</u> Per ha: Per your project: <u>Crop 2:</u> Per ha: Per your project: <u>Crop 3:</u> Per ha:
28	-		
29	Pump ownership and use	Direct / owned [ ] Indirect / collective [ ]	
30	Pump power/flow	HP [ ] CM/h [ ] Inch [ ]	
31	Cost / cost share of the pump of the well	LL or US$	
32	Annual pumping cost / cost share (Choose one of the 2 options)	LL or US$	Per Ha: Per your project:
33	-		
34	Conveyance infrastructure associated to well		
35	Do you experience a decrease in well yield in the summer and/or in years of low rainfall?	Yes [ ] No [ ]	

36	When does water stop being available in the well?		
37	-		
MAIN SOURCE OF WATER			
38	Does this prevent you from planting a second season crop?	Yes [ ] No [ ]	
39	Does this condition your choice of crop?	Yes [ ] No [ ]	
SECONDARY SOURCE OF WATER			
40	Do you have a second source of water? (well). If yes answer the question related to the well	Yes [ ] No [ ]	
41	Well ownership	Direct / owned [ ] Indirect / collective [	
42	date of well drilling		
43	Well depth (m)		
44	well yield / flow	CM/h: Inch:	
45	Well water charges (Fill for each crop, per ha or per your project)	LL or US$	Crop 1: Per ha: Per your project: Crop 2: Per ha: Per your project: Crop 3: Per ha:
46	Pump ownership and use	Direct / owned [ ] Indirect / collective [ ]	

47	Pump power/flow	HP [ ] CM/h [ ] Inch [ ]	
48	Cost / cost share of the pump of the well	LL or US$	
49	Annual pumping cost / cost share (Choose one of the 2 options)	LL or US$	Per Ha: Per your project:
SECONDARY SOURCE OF WATER			
50	Conveyance infrastructure associated to well		
51	In case of a shortage of water, what do you?	[ ] Reduce pumping, [ ] Lower the pump, [ ] Buy water from another well, [ ] Rent another plot in case not owner	
52	Did you ever deepen the secondary well?	Yes [ ] No [ ]	
53	Did you have to drill another well?	Yes [ ] No [ ]	
WILLINGNESS TO USE TREATED WASTEWATER			
54	Will you be willing to use treated wastewater instead of your well or as a complement to your well?	Yes [ ] No [ ]	
55	Who do you think owns the treated wastewater?		
56	Will you accept that the treated effluent be conveyed in your irrigation system?	Yes [ ] No [ ]	
57	Willingness to pay (WTP) for wastewater reuse	Yes [ ] No [ ]	

58	If willing to pay then for what?	• Capital cost of new on-farm drip irrigation system required for the treated waste water reuse [ ] • For the volume of treated waste water reuse provided [ ]
59	How much are you willing to pay for wastewater reuse?	LL or US$ / CM
60	Are you aware of water quality and potential implication on human, animal and environmental health? If yes, please elaborate.	Yes [ ] No [ ]

WILLINGNESS TO USE TREATED WASTEWATER

61	Do you know what are the limitations of the reuse of wastewater? If yes, list the limitation on the reuse of water.	Yes [ ] No [ ]

GENDER

62	Household head structure: male-headed, female-headed, couple-headed household.	
63	Number, sex and age of all household members.	
65	What were the most important problems/ health, natural, economic or social, your household aced as far as negative impacts to your household, household members' livelihoods and/or the household's agriculture/livestock during the last 12 months were concerned?	

65 What effect, do you expect, will the new treated wastewater quantities have on the labour input of [women/men/boys/girls/male farm worker/female farm worker]?

ANNEX 6: FARMERS SURVEY SUMMARY RESULTS

General Information	• Some of the lands are owned, other are rented. • The majority of the farmers interviewed were male. One of the farmers was a female.
Production and on-farm irrigation system	• Most of the interviewees do not have livestock, very few have some chicken and sheep. • Most of the potato crops are irrigated by sprinklers. Fruit trees are mainly irrigated by flooding. Vegetables and grapes are generally irrigated by flooding too. • The cost of the on-farm irrigation system ranges between 125 US$/du and 327 US$/du depending on the type of system. • On-farm pumping station cost ranges between 38 and 145 US$/du due to the economy of scale. • On-farm annual pumping cost ranges between 10 and 207 US$/d depending on the economy of scale, single or multiple pumping and source of water. • The annual cost of maintenance of on-farm irrigation system ranges between 7 and 250 US$/du depending on the type of irrigation. • The annual fertilization cost ranges between 50 and 332 US$/du for potatoes depending on the production season (early or late). • The annual fertilization cost ranges between 30 and 100 US$/du for wheat. • Average annual production of potatoes is 2.5 t/du ranging from 2 to 4 t/du. • Average annual production of wheat is 0.5 t/du. • Selling price at farm gate for potatoes is ranging between 995 and 1990 US$/ton. • Selling price at farm gate for wheat is on average 1291 US$ /ton.
Main source of water	• The main source of water is the Berdaouni collective system. The farmers responded unanimously that this fresh water source is scarce and that they are not satisfied with their access to water. They also pointed out that the infrastructure is not well maintained and that they are not satisfied with the management of the distribution. They also unanimously answered that they experience decrease in the yield of the river during summer and in years of low rainfall and that the water from Berdaouni starts to be unavailable by the end of July. The water scarcity prevents the farmers from planting a second crop and condition their choice of crops. • Water charges from Berdaouni are ranging between 11 and 35 US$/du over the irrigation season. It is not fixed and depends on the willingness and capacity ?of the farmers to pay for the operator.
Secondary source of	• 50% of the interviewees have another source of water (private well). These

water	wells were drilled between 1965 and 2002 and have a depth ranging from 60 to 150m. • The annual cost of pumping varies from 7 to 67 $ per du depending on its depth. • In case of shortage of water 25% of the farmers buy water from another well and 17% of the farmers reduce the pumping hours with an impact on plant health and consequently yields.
Willingness to use treated wastewater	• 100% of the interviewees are willing to use the treated wastewater instead of Berdaouni or as a complement to water from Berdaouni. • 58% of the interviewees stated that they think the Municipality of Zahle owns the treated wastewater, 17 % of the interviewees think that the MoEW owns the treated waste water and 25 % of the interviewees stated that they did not know who owns the treated waste water. • 84% of the interviewees accept that the treated waste water be injected in the Berdaouni Canal and mixed with fresh water. • 100% of the interviewees are willing to pay for wastewater. 75% of the interviewees are willing to pay for the volume of wastewater provided and 25% of the interviewees are willing to pay for the capital cost of on-farm irrigation system required for the treated water reuse. • The farmers are willing to pay on average 0.15 $/CM for treated waste water which translate in equivalent to 61$/du/season or 122$/year. • 92% of the interviewees replied that they were not aware of treated water quality and potential implication on human, animal and environmental health and that they did not know the limitations of the reuse of the wastewater.
Gender	• The majority of the interviewees is married. The household is couple-headed at 59%. The man is considered as head of the household at 33% and at 8%, the issue of household head was considered a private and was not answered. • The age of the household head ranges from 35 to 75 years and the average age is 59 years. • 67% of the interviewees stated that the most important health problems they encountered in the last 12 months was COVID-19 Pandemic. • 50% of the interviewees stated that the pollution and climate change affected their household members' livelihoods and/or the household's agriculture/livestock during the last 12 months. • 92% of the interviewees confirmed that the economic situation and the confinements affected their financial situation drastically. • 84% of the interviewees are expecting an increase in their production due to the use of treated wastewater for irrigation and consequently an improvement of their financial situation and that of their families. However, 17% of the interviewees feared that the use of the treated wastewater may cause allergic reactions to the male farm workers.

Annex 7: Administrative overlaps in the Water and Wastewater sector

Role	CDR	MoEW	MoF	MoE	MoA (irrigation)	MoPH (drinking water)	Municipalities	WE	WB	Donors	NGOs	Research	Media	Water Users
Funding	X		X					Cost recovery?	X	X				
Policy & Strategy	X Master Plan	X National		X	X	X		X Regional	X	X		X		
Planning	X	X			X			X	X	X		X		
Contracting/ Constructing	X	X			X		X	X	X	X	X			
Development & Implementation	X	X					X	X		X	X			
Operation & Maintenance	X						X	X		X				
Tariff/ Tax Collection			X				X	X Propose tariffs						X
Legislation, rules and regulation		X		X	X	X					X Lobby	X		
Services & interactions with water users		X		X	X		X			X	X		X	X
Monitoring & Evaluation		X		X	X	X		X		X	X	X		

Source: Machayekhi et al. 2014.

ANNEX 8: FAO PROPOSED GUIDELINES FOR WASTEWATER REUSE IN AGRICULTURE

Class	I	II	III
Restrictions	Produce eaten cooked; irrigation of greens with public access	Fruit trees, irrigation of greens and with limited public access; impoundments with no public water contact	Cereals, oil plants, fiber and seed crops, canned crops, industrial crops, fruit trees (no sprinkler irrigation), nurseries, greens and wooden areas without public access
Proposed treatment	Secondary + filtration + disinfection	Secondary + storage or maturation ponds or infiltration percolation	Secondary + storage/oxidation ponds
BOD5 (mg/L)	25	100	100
COD (mg/L)	125	250	250
TSS (mg/L)	60 (200 WSP)	200	200
pH	6- 9	6 - 9	6 - 9
Residual Cl2 (mg/L)	0.5 - 2	0.5	0.5
NO3-N (mg/L)	30	30	30
FC(/100ml)	<200	<1000	None required
Helminth eggs (/1L)	<1	<1	<1

Source: FAO, 2010.

Note: Irrigation of vegetables eaten raw is not allowed