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WATER REUSE AND ENVIRONMENTAL CONSERVATION PROJECT

CONTRACT NO. EDH–I–00–08–00024–00 ORDER NO. 04

PRELIMINARY SITE ASSESSMENT FOR WATER REUSE PILOT AT AL-LAJJOUN

December 2014

IMPLEMENTED BY AECOM

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Submitted to:

USAID Jordan

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AECOM

DISCLAIMER:

The authors' views expressed in this document do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

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List of Acronyms

AACA	AL-Lajjoun Agricultural Cooperative Multipurpose Association
AHP	Al Hisa Phosphorite
ASL	Amman Silicified Limestone
BOD	Bioological oxygen demand
ESIA	Environmental and Social Impact Assessment Study
ET	Evapotranspiration
GIR	Gross irrigation requirements
JCC	Jordan Cooperation Corporation
JOHUD	Jordanian Hashemite Fund for Human Development
MCMF	Muwaqqar Chalk-Marl Formation
MoPIC	Ministry of Planning and International Cooperation
MWI	Ministry of Water and Irrigation
MOU	Memorandum of Understanding
TDS	Total Dissolved Solids
WAJ	Water Authority of Jordan
WG	Wadi Umm Ghudran Formation
WRECP	USAID Water Reuse and Environmental Conservation Project
WWTP	Waste Water Treatment Plant

1. Introduction and Baseline Assessment

1.1 Introduction

Water scarcity is one of the most important natural resource constraints on Jordan's economic growth. Rapid increases in population and industrial development have placed unprecedented demands on water resources. This situation has been worsened by the continuous depletion of Jordan's fresh water supply at an alarming rate.

Alternative water sources such as treated wastewater are widely accepted for irrigation water in Jordan. However, treated wastewater as a resource has not been completely deployed yet and can be further promoted and developed. This use would ease the stress on existing freshwater resources and improve the livelihoods of many communities in the vicinity of wastewater treatment plants.

The USAID Water Reuse and Environmental Conservation Project (WRECP) works throughout Jordan in institutional capacity building, pollution prevention (P2) for industries, solid waste and wastewater management, and water reuse. The project's technical assistance at the Wadi Mousa Water Reuse Pilot Project has been highly successful and provides practical experience in ways to save fresh water and improve livelihoods through water reuse. The pilot created more than 50 job opportunities and has benefitted over 200 people from the local community. After having succeeded in establishing such a landmark, USAID is keen to see it expanded and replicated in other regions across the Kingdom.

USAID has requested that WRECP expand its reuse efforts, replicating the success of the Water Reuse Pilot Project at Wadi Mousa. in other regions across the kingdom, to further promote the safe and beneficial use of reclaimed water to enhance community livelihood.

Consequently, the USAID WRECP has investigated the potential for establishing a new water reuse pilot in the Al-Lajjoun area. That investigation is the subject of this report.

1.1.1 Background

Early in the project, the team investigated several potential sites at which to establish water reuse pilot projects. A site selection report was submitted in July 2011, outlining the preliminary assessment of potential pilot project sites near USAID-funded wastewater treatment plants (WWTPs).

At that time, the Al-Lajjoun wastewater treatment plant (WWTP) was in the process of being upgraded. Therefore, Al-Lajjoun was not included in the site selection assessment. However, developments since then have made it a more promising site for a water reuse pilot.

The Al-Lajjoun area is in Karak Governorate, 120 km south of Amman. The total population of Karak Governorate is 254,700 (MoPIC, 2013). According to the DOS report of 2102, Karak Governorate has a high poverty rate, and has one of the highest unemployment rates in the kingdom.

The Al-Lajjoun WWTP is located approximately 25 km east of Karak city. The WWTP was upgraded in 2013, with design capacity of 1200 m3/day and effluent quality complying with JS 893/2006 for Wadi discharge, and irrigating crops of Class B and C (forage and landscape crops). Currently, around 300,000 cubic meter of treated wastewater effluent is discharged to the Wadi without any beneficial use.

In 2013, the AL-Lajjoun Agricultural Cooperative Multipurpose Association (AACA) was established. The Ministry of Planning and International Cooperation (MoPIC) allocated 50 ha adjacent to the WWTP to AACA, for them to use to establish community development agricultural projects. AACA signed a memorandum of understanding (MoU) with WAJ, stating that WAJ would supply the association with reclaimed water. However, AACA was not able to initiate any agricultural projects; constraints included the lack of farming capacity and agribusiness planning, lack of technical experience in using and managing reclaimed water in agriculture, and limited financial resources.

At the request of the Water Reuse Pilot Project Workgroup and local community representatives, the WRECP investigated the potential for establishing a new water reuse pilot in the Al-Lajjoun area. Drawing on the site investigations and meetings with the relevant stakeholders, the project team identified challenges facing AACA and opportunities for providing technical assistance. This preliminary assessment report discusses the availability and quality of reclaimed water, characteristics of lands and soil, potential cropping patterns, and the environmental and socio-economic conditions and potential impacts of a pilot project. It also includes a preliminary water reuse plan for the proposed water reuse pilot. However, further investigations are needed before a detailed design plan for the new project can be prepared.

1.1.2 Summary of conclusions

The investigation concluded that establishing a new pilot site at Al-Lajjoun offers great potential to replicate the success of the Wadi Mousa pilot project; beneficial reuse of treated wastewater in irrigation can support Al-Lajjoun's local communities, improve their living conditions, and promote economic growth in a governorate suffering from high poverty and unemployment rates.

1.2 Baseline Study

A comprehensive baseline study of the physical, chemical, social, and biological environment of a new project provides an information base to facilitate project understanding and assess its feasibility. This section analyzes the baseline conditions of Al-Lajjoun site.

The main objectives of this baseline analysis are to analyze the current situation at the proposed site in the Al-Lajjoun, provide a basis for the project's detailed design study, and investigate the socioeconomic and environmental conditions of the project area, and provide the basis for a more comprehensive Environmental and Social Impact Assessment Study (ESIA), if needed.

Data for the baseline analysis were collected through several site visits, and desktop research. The site visits included meetings with local community, WUA representatives, WWTP operators, and other related stakeholders. In addition, soil and water samples were collected and analyzed for their physical and chemical properties. Desktop research and collected reports included:

- Environmental Impact Assessment Report for The Upgrading and Expansion of Al-Lajjoun Septage Treatment Plant, 2008
- Detailed Design Report for The Upgrading and Expansion of Al-Lajjoun Septage Treatment Plant, 2008
- Annual publications of the Department of Statistics (DOS)
- Jordan Country Study on Biological Diversity, Mammals of Jordan and Plant Biodiversity and Taxonomy (to aid in the identification of flora and fauna in the project area)
- Updated data from WAJ on the existing plant performance
- Jordan Climatological Handbook, 2002
- The Geology of Karak Area, 1988 (and the Karak geological map)
- Karak Annual Reports, WAJ Unit, 2006 and 2008
- Natural Resources Authority/Geology Directorate – Adir 3152 II 1:50,000 (prepared by Khalid Al –Shawbkeh 1991)
- ESIA Study for Al-Lajjoun Oil Shale Project, 2009
- Red Sea – Dead Sea Water Conveyance Study Program, Draft Final Feasibility Study Report, 2011

1.2.1 Site Description

Karak Governorate is located in the southern part of Jordan: north of Al-Tafieleh, south of Wadi Al-Mujib, and around 130 km south-west of Amman as shown in Figure 1-1. The current population of the Governorate was reported as 254,700 in 2013 (MOPIC, 2013), and is divided among 7 districts. The Al-Lajjoun area is located within Karak district. Table 1-1 shows the population of Al-Karak Governorate by District

Table 1-1: Number of Residents at Karak Governorate According to Districts, 2013

District	Population
Karak (including Al-Lajjoun)	80,900
Mazar Janoobee	71,340
Qasr	26,020
Aghwar Janoobiyah	40,470
Ayy Qasabah	12,110
Faqo'e	15,190
Qatraneh	8,670

Source: Department of Statistics (DOS), 2013

By the end of 2010, only 16% of houses in the Al-Karak Governorate were connected to the public sewage network, while 84.0% use cesspools. The percentage of unsewered population in Al-Karak is considered the highest in the Kingdom (DOS, 2010).

Figure 1-1: Al-Lajjoun Location Map

1.2.1.1 Al-Lajjoun WWTP

Al-Lajjoun WWTP (coordinates 31° 9'0.94" N and 35°52'36.11" E) is located around 25 km south of the Al-Lajjoun area, in the south-east of Al-Karak Governorate. The WWTP is operated by a private contractor under WAJ supervision (WAJ, 2013).

The current population served by the WWTP is around 88,820, which implies that the average per capita septage contribution to the WWTP is 7.4 L. This population figure excluded Al-Aghwar Al-Janoobiyah district, Al-Karak city and Al Mazar Al-Janoobee, because they are either far away or connected to the Al-Karak and Al-Mazar sewage network.

Al-lajjoun WWTP was upgraded to mechanical treatment in 2013, with design capacity of 1,200 m3/day and BOD concentration of 3,000 mg/l. The WWTP consists of anaerobic ponds, aerated lagoons, maturation ponds, drying beds, constructed wetlands, and irrigation storage, as shown in Figure 1-2. The treatment stages are described below.

Figure 1-2: Al-Lajjoun WWTP Layout

Anaerobic Ponds

There are two anaerobic ponds in AL-Lajjoun WWTP (Figure 1-3) with a total capacity of 17,850 m^3, and a detention time of 15 days. This high detention time allows for the accumulation and decomposition of sludge and a reduction of BOD concentration to 50%.

Figure 1-3: Anaerobic Pond

Aerated Lagoons

Seven surface aerators, constructed before the upgrade of the WWTP, were installed in each of the two old facultative ponds (Figure 1-4) to boost dissolved oxygen levels. The total volume of these ponds is 48,380 m^3, with a total surface area of 24,190m^2. The detention time in these ponds is around 42.5 days.

Figure 1-4: Aerated Lagoon

Maturation Ponds

There are two maturation ponds that are filled with 1,200 m^3 "Rock Filter" media at the outlet end of the maturation ponds. The total area of these ponds is 5,040 m^2, with a volume of 10,080 m^3. Detention time in the maturation ponds is around 10 days.

Constructed Wetlands

AL-Lajjoun WWTP uses two constructed wetlands (Figure 1-5) for the removal of remaining BOD, nitrogen and other nutrients. These constructed wetlands, which have a total surface area of around 4 ha and are 1.5 m deep, are capable of removing up to 85% of nitrogen, 50% of phosphorus, and the remaining BOD that was not removed in aerated lagoons.

Irrigation Storage Pond

A storage pond was constructed within the WWTP, (Figure 1-6). The total volume of the irrigation storage pond is 10,000 m^3. A pumping station was also installed, with four pumps: two operating pumps at 40-meter head and flow rate of 75 m^3/hr and two standby pumps at 40-meter head and flow rate of 50 m^3/hr each. An irrigation water distribution network was also installed within the WWTP; however, as there is no green area within the WWTP, it has been used only for the purpose of preventing water in the irrigation pond from turning stagnant.

Figure 1-5: Constructed Wetlands

Figure 1-6: Irrigation Storage Pond

Figure 1-7: Sludge Drying Beds

Sludge Drying Beds
Sludge that settles down at the bottom of the ponds within the different treatment units is collected in drying beds by dredging machine, as shown in Figure 1-7. There are 16 drying beds in AL-Lajjoun WWTP, each with an area of 0.1 ha, which can store a combined sludge volume of 1,000 m^3. The sludge is applied in 25-cm-thick layers on the drying beds. The dryness of the sludge ranges from 20%-50% depending on the weather. The dried sludge is then removed and disposed of at a nearby dump area in accordance with the Jordanian Standard for Uses of Treated Sludge and Sludge Disposal JS 1145/2006.

1.2.1.2 Proposed Water Reuse Site

The proposed reuse pilot is located on land adjacent to the Al-Lajjoun WWTP. Part of Wadi Al-Dabbeh village, this was originally governmental land. However in 2007, 50 ha of the land were allocated to Al-Lajjoun Agricultural Cooperative Association (AACA) for forage production under reclaimed water as shown in Figure 1-8.

Figure 1-8: The Proposed Reuse Pilot Site near Al-Lajjoun WWTP

The project area is treeless, with few scattered small shrubs. The project area and the surrounding areas are uninhibited, except for a very few Bedouin families and shepherds who camp near to the project area. The closest village to the proposed project site is Al-Lajjoun village.

1.3 Biophysical Environment

1.3.1 Climate

The project area is located within the Irano-Turanian bioclimatic subdivision and the Badia (semi-desert) agro-ecological zone. Based on 2007 climate data collected at the closest weather station ("Qatraneh" – see Table 1-2), the annual rainfall is 85.2 mm. The summer season is dry and hot with a mean maximum air temperature of 33.9 °C in July. Winter is relatively wet and cold, with a mean minimum temperature of about 2.0 °C in January. The average annual temperature is 17.8°C.

Table 1-2: Climatic Information for Selected Parameters at Al-Qatraneh Weather Station

Month	M. Maximum Temperature (°C)	M. Minimum Temperature (°C)	Total Monthly Rainfall (mm)	M. Relative Humidity (%)	M. Wind Speed (Knots)
January	14.0	2.0	29.3	72.0	5.1
February	15.6	4.8	28.5	75.0	4.8
March	18.0	5.4	18.0	66.0	5.2
April	23.2	9.4	1.9	59.7	4.7
May	31.3	14.9	4.1	52.7	3.9
June	33.0	16.2	0.0	50.5	3.0
July	33.9	18.0	0.0	43.1	2.9
August	33.8	17.6	0.0	50.1	4.3

September	31.4	15.8	0.0	59.2	4.3
October	28.8	13.0	0.0	56.2	2.3
November	22.3	6.9	0.0	57.4	2.4
December	16.5	2.1	3.4	65.7	2.7

Source: Jordan Climatological Handbook / Jordan Meteorological Department, 2007.

1.3.2 Geology

The project area is situated to the east of the Dead Sea rift. It is dominated by Cretaceous sedimentary rocks. Quaternary and more recent deposits are also present at the area. Al-Lajjoun WWTP site-specific geology includes outcrops of alluvial deposits underlain by the Al Hisa Formation.

The litho-stratigraphical nomenclature followed in this text is that adopted by the Natural Resources Authority/Geology Directorate – Adir 3152 II 1:50,000 (prepared by Khalid Al –Shawbkeh 1991). The chronological sequence of lithological units exposed is as follows in increasing age order:

1. Soil, alluvium and wadi gravels
2. Muwaqqar Chalk Marl Formation (Maastrichtian Paleocene)
3. Al Hisa Phosphoric Formation (Companion – Maastrichtian)
4. Amman Silicified Limestone Formation (Santonian Companion)
5. Wadi Um Ghudran Formation (Santonian)

Soil, Alluvium and Wadi Gravels:
Please see discussion in 1.3.3 below.

Muwaqqar Chalk-Marl Formation (MCMF):
Outcrops of this formation occur in the Al-Lajjoun area. It overlies the Al Hisa Phosphorite. The soft marly beds which predominate make this an easily weathered formation. The lower strata is characterized by a uniform distribution of bitumen. The remaining beds consist of chalk marls containing layers rich in bitumen. The lithology comprises yellow to pale red marl, chalky marl and chalks. Rounded micritic concretions occur in parts. Gypsum is found as thin bedded laminae and also filling vertical and sub vertical joints.

Al Hisa Phosphorite (AHP):
The Al Hisa Phosphorite Formation is covered in many places by soil. The formation is lithologically heterogeneous and consists of phosphatic chert, phosphatic limestone (microcrystalline), chert, limestone (micritic, microcrystalline and oyster-shell grainstone type) and dolomitic marl. The chert beds vary in color from grey to brown-black and show sub-concretionary pinch-and-swell structures along the bedding planes. Limestone of this formation ranges in texture from micritic lime-mudstone (frequently found interbedded with phosphatic chert) to shelly packstones and grainstone.

Amman Silicified Limestone (ASL):
This formation consists predominantly of pale to dark grey and brown, thin- to thick-bedded chert intercalated with limestone, chalk, marl, oyster-rich coquina limestone and phosphatic chert. (Shawabkeh, 1998).

Wadi Umm Ghudran Formation (WG):

This formation overlies the older Ajlun Group and consists of chalk, chert, tripolized chert and limestone. The age of this formation is Coniacian-Santonian.

Structural Geology

The structure of the Al-Lajjoun area is dominated by faulting with a predominate NW-SE trend with N-S and NE-SW faults. The Al-Lajjoun Graben is located in the central northern part of the area and is part of a fault block complex which has formed at the intersection of NS, NW-SE and NE-SE fault trends such that three down-faulted blocks have developed adjacent to a number of other unfaulted areas.

1.3.3 Soil

Superficial deposits, Fluviatile and Lucustrine Gravels of Pliestocene age and soil are dominant at the area. These sediments include coarse grained sand and gravel which is composed of sub angular to sub rounded pebbles and cobbles. Clasts of chert, phosphatic chert, limestone and phosphatic limestone are also present.

The gravels are poorly sorted, loose or weekly cemented. They range in thickness from 0-10 m. Soil, which covers extensive areas of bedrock, is composed of loess-like silt and residual calcareous bedrock.

For analyzing the soil's physical and chemical characteristics, four soil samples were collected from the land allocated to the planned reuse activities as shown in Figure 1-9. Samples were collected for the surface soil layer, and at 15 and 30 cm depths.

Figure 1-9: WUA Chief Helping in Soil Sampling

Table 1-3 shows the results of analyzing the samples for soil physical and chemical properties.

Table 1-3: Analytical Results of Various Parameters in Soil Samples from the Project Site in 2014

Parameter	Sample 1	Sample 2	Sample 3	Sample 4
Extract PH	7.7	8.2	7.8	8.0
Extract EC (dS/m)	38.3	1.66	6.55	3.17
Ca (m_{eq}/L)	125.30	7.90	30.90	7.50
Mg (m_{eq}/L)	102.90	3.40	20.90	7.10
Na (m_{eq}/L)	195.65	8.70	26.26	17.39
K (m_{eq}/L)	0.51	0.37	0.44	0.01
Cl (m_{eq}/L)	125.00	7.50	32.50	12.50
CO3 (m_{eq}/L)	0.00	0.00	0.00	0.00
HCO3 (m_{eq}/L)	2.50	2.50	2.50	2.50
SO4 (m_{eq}/L)	296.86	10.37	43.50	17.00
Total Cations	424.36	20.37	78.50	32.00
Na%	46.11	42.69	33.45	54.34
SAR	18.32	3.66	5.16	6.44
ESP	20.08	3.88	5.83	7.43
P (ppm)	8.8	11.0	15.6	5.0
K (ppm)	228.9	359.0	303.3	154.5
Fe (ppm)	1.152	0.794	0.978	1.004
Cu (ppm)	1.014	0.810	0.764	0.468
Zn (ppm)	0.262	0.265	0.329	0.214
Mn (ppm)	0.808	1.086	0.938	1.084
Boron (ppm)	1.87	0.85	0.68	0.68
O.M%	0.99	1.28	2.17	1.31
N%	0.064	1.073	0.073	0.056
Na/CEC (m_{eq}/100g)	20.76	22.46	23.59	23.59
$CaCO_3$	22.2	26.8	30.2	28.3
B.D	0.928	0.923	0.923	0.902
Clay	18.2	22.8	25.1	25.7
Silt	44.8	47.6	49.8	35.4
Sand	36.9	29.6	25.1	38.9
Texture	Loam	Loam	Loam	Loam

1.3.4 Hydrogeology

Water Resources

The annual total production of the main drinking water sources in Al –Karak Governorate for the year 2008 is presented in Table 1-4. Water is pumped from the wells to pump stations that supply Al-Karak towns and feed reservoirs.

Table 1-4 : Main Drinking Water Sources in Al-Karak Governorate

Source	Annual Production in m^3
Sultani wells	4,664,132
Muhey wells	1,106,744
Ghweir wells1 +2+3	512,078
Ain Sarah Springs	697,250
Yarout spring	31,532
Shuhabaih spring	44,523
Rabba well	35,676
Abyad well	45,736
Shihan well	153,766
Al-Mazra'a well (2)	317,981
Al-Mazra'a well (3)	247,182
Fifa well (2)	139,809
Safi well (4)	99,361
Safi well (10)	160,518
Safi well (14)	110,723
Safi well (16)	463,215
Safi well (18)	162,346
Lajjoun wells	110,563
Qatraneh wells	1,851,104
Al-Damkhi wells	87,616
Al-Ghwaibeh wells	4,042

Source: WAJ, Karak Annual Report, 2008.

Surface Water

The project area is located in the center of the southern catchment area of Wadi Mujib. The catchment consists of three sub drainage basins: the Sultani ,Qatrana and Swaqa-Al-Lujjoun basins. Rainfall occurs generally between October and May with an average annual rainfall of around 110 mm. The evaporation rate in the project area ranges from 1,500 to 2,000 mm per year.

Springs and water streams are mostly fed by rainfall and primarily used for irrigation, with amounts that exceeds 50 MCM/yr. Approximately 1.0 MCM/yr of surface water is used to supplement the municipal demands in Karak City and Al-Qasr area (EIA Study for the upgrading and expansion of Al-Lajjoun WWTP, 2008). The flow of water in Wadi Al-Lajjoun is maintained by the Al-Lajjoun spring (Ain Al-Lajjoun). This is the closest spring to the project area, about 13 km north to north west of Al-Lajjoun WWTP, and it has a mean flow of 44 cubic meters per hour. The spring water is used partly for irrigation. Excess water runs down toward either Wadi Lajjoun or Wadi Mujib, and some is ponded in depressions downstream. On the other hand, the effluent of the WWTP is being discharged into one of the wadis near to the irrigation pond.

There are approximately 10 dams in Al-Karak Governorate, three of which are constructed concrete dams, while the others are either Rock Fill or Earth Fill dams. The largest dam in AL-Karak is Al-Mujib Dam which is located in the north of the governorate. The nearest dams to the project area are Al-Lajjoun dam, Wadi khebra dam, Al Shareef dam and Al Maqamat dam.

Ground Water
More than 30 water wells have been drilled in the area (10). Most were drilled in the vicinity of Karak Graben and in the Al Lajjoun area. The majority of wells were drilled by NRA during oil shale exploration, but more recently the Water Authority has drilled several wells.

There are two aquifers in Al-Karak:

- The Upper Aquifer (A7/B2): This is the most important aquifer in Jordan; it is formed mainly in well bedded silicified limestone, chert, phosphatic chert, phosphorite rock, sandy limestone, cherty limestone and calcareous sand, with carbonate rocks predominating. The more massive, competent rocks are jointed and the intensity of jointing increases in the vicinity of faults .Renewable groundwater in this shallow aquifer is abstracted at Sultani, Gweir, Muhey, Abyad and Sheihan wells, and it is the main source of supply for local areas as well as other parts of Al-Karak Governorate. The production of these wells was around 6.5 MCM in the year 2008. Figure 1-10 shows the locations of the main groundwater wells and pump stations near to the project area.

- The Lower Aquifer: This aquifer is located in the Al-Lajjoun area, 250 m below the base of the upper aquifer. This fresh fossil groundwater supplies Al-Karak and Amman Governorates. The production of these wells reached 8.3 MCM in 2008.

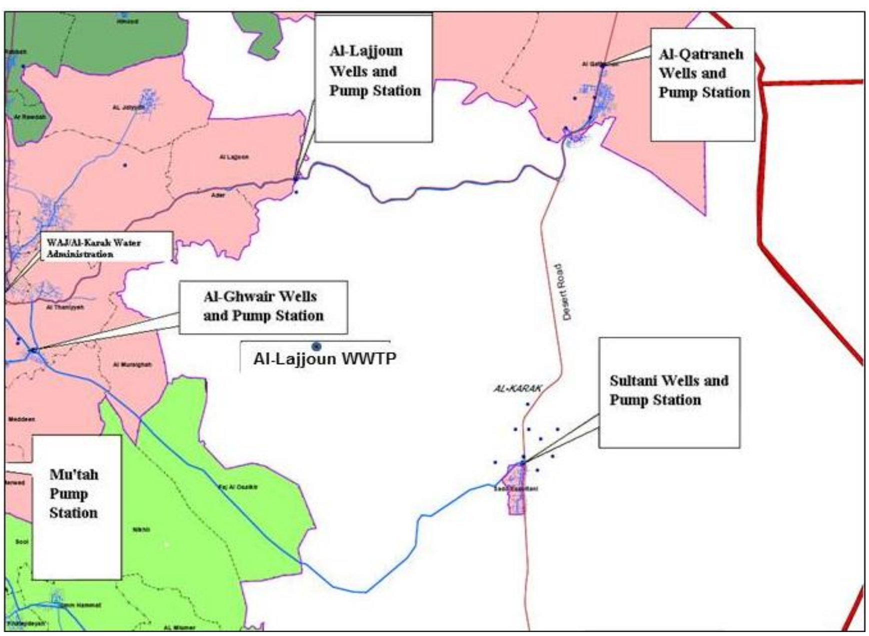

Figure 1-10: Locations of Grouundwater Wells Near to Al-Lajjoun WWTP

Within Al-Lajjoun WWTP boundaries there is one monitoring well that the operator uses to inspect any impact from the WWTP on the ground water. There are, however, two wells that are close to the WWTP and the project site. The two wells are used to cover the water requirements of the livestock being herded at the site. These two wells are:

- Al-Lajjoun Solar Powered Well This well (coordinates 31°12'47.99"N and 35°53'20.27"E) is around 7.7 km from the project area; its annual production in 2006 was 275,048 m^3.

- Al-lajjoun Well. This well (for potable uses) is located around 3.7 km north to the project site. The well coordinates are 31°10'44.76"N and 35°53'15.48"E.

Figure 1-11: Al-Lajjoun Solar Powered Well

1.3.5 Flora and Fauna

The project area is located within the Irano-Turanian bioclimatic subdivision and shows mainly the Steppe vegetation type. Generally, there are no trees or cereal crops. However, natural vegetation is present near wadis. Fauna within the project area are mainly small shrubs.

Earlier studies identified several types of mammals that exist in Al-Karak Governorate, including:

- The long-eared Hedgehog
- The Lesser White-toothed Shrew
- The Peter's Horseshoe Bat
- Hemprich’s Long Eared Bat
- The Red Fox
- The Large-eared Stone Marten
- Wild Goat, Nubian Ibex
- Cairo Spiny Mouse
- The Black Rat
- The House Mouse

The studies also show that there are no protected birds within the project area, and no significant habitat degradation has occurred in the last 20 years.

Dogs, camels, and sheep were observed near to the project area. No endanger animals noticed within the project area. The livestock belong to the AACA are being herded at the pilot site as shown in Figure 1-12.

Figure 1-12: Sheep Belonging to AACA Being Hered at the Pilot Site

1.4 Socio-economic Analysis

Al-Lajjoun and Adir villages are the closest villages to the project site. The villages' residents are Bedouins, and work as farmers. However, there are no households in the vicinity of the project site, although one tent was observed near to the project site during the field visit in April 2014. It is believed that this is a temporary settlement for shepherds who only move to the area on a seasonal basis.

1.4.1 Population

As mentioned previously, the current population of Al-Karak Governorate is 254,700, while the population of the Al-Karak district (of which Al-Lajjoun village is a part) is 80,900 people. The total population of Al-Lajjoun village is estimated at approximately 800 people living in around 100 households/tents (EIA Study for Al-Lajjoun Oil Shale Project, 2009).

1.4.2 Water and Electricity Services

Al-Lajjoun treatment and pump station receive water abstracted from Al-Lajjoun wells through the local network and pump it to supply Al-Karak and Amman Governorates. Most of Al-Karak Qasaba District is covered by the water network supply. Though the network is old, there were around 16,967subscribers in the network as of the end of 2008, while only 4,393 residences are connected to the public sewage network. Residents that do not have water connections use private water tankers, and sometimes rainfall collection tanks.

Al- Karak Water Authority runs around 45 wells and springs, to supply Al-Karak Governorate. Water pumped for domestic consumption in Al-Karak Governorate was around 11 MCM in the year 2008, while 2.6 MCM per year was pumped for irrigation uses.

Until the end of 2008, three irrigation projects in Al-Karak Governorate were conducted by Al- Karak Water Authority, irrigating a total area of 245 ha and requiring 585 m^3 per day of water. It is estimated that in the year 2020 the irrigation requirements will be around 64 MCM per year in Al-Karak Governorate and the Gross Municipal Water Demand will be 17 MCM per year (Red Sea – Dead Sea Water Conveyance Study Program, Draft Final Feasibility Study Report, 2011).

The electricity network is available in most of Al-Karak Qasabah District, However the network is generally weak and the electricity is interrupted for long periods.

1.4.3 Employment and Development

According to the Department of Statistics annula reports, Al-Karak suffers from high rate of unemployment (17.7%), in comparison to the unemployment rate around the Kingdom, which is 12.2%. The unemployment rate in Al-Karak is higher among females and reached 29.9% in 2012.

Poverty rate in Al-Karak Governorate is 13.4%, while the percentage of poor people in the Governorates is 3.6%. In 2008 one district and two sub-districts in Al-Karak Governorate were considered “poverty pockets”:

- Qatraneh District, with poverty rate of 33.2%
- Ghwawr Al-Mazra’a Sub-District, with poverty rate of 44.1%
- Safi Sub-District, with poverty rate of 40.8%

Most of Al-Karak residents work in the public sector, including the armed forces and the educational sector. There has been, however, a significant increase in labour forces that work in the agricultural sector: in 2007 there were a total of 7896 people that work in the agricultural sector in Al-Karak Governorate.

Main agricultural activities in the Governorate include olive oil production, dairy production, and fruits production.

1.4.4 Archaeological Resources

There are no archaeological remains or resources within the project area; however; Al-Karak Governorate contains one of the important castles in Jordan, Al-karak Castle. Al-Karak Castle is located in the southern part of the Governorate. Al-Karak Archaeological Museum is located within the lower court of the Castle.

In Muta town, there are many of Al-Sahabah (Prophet Mohammad Companions) Tombs, which give the town a religious value for Muslims.

1.5 AL-Lajjoun Agricultural Cooperative Multipurpose Association

AL-Lajjoun Agricultural Cooperative Multipurpose Association (AACA) was established in 2004. The main goal of AACA is to support the local communities at Al-Lajjoun, and increase their income by commencing new projects. The association was first supported

by the “Deutsche Gesellschaft für Internationale Zusammenarbeit” GIZ, with a 22,000 USD fund to purchase the first 73 head of livestock (sheep).
In 2009, the association started a reuse project that uses the reclaimed water from Al-Hussien ben Abdullah the second Industrial Treatment Plant in producing yellow corn in the summer, and barley in the winter. The project was stopped in 2011, because the land was rented for 2 years and then sold by the land owner.

The association later got the support of the Jordanian Hashemite Fund for Human Development (JOHUD) and Jordan Cooperation Corporation (JCC) and was able to purchase 200 head of livestock (sheep). Currently, the association owns a 273 head of livestock.

1.5.1 Regulatory Framework

AL-Lajjoun Agricultural Cooperative Multipurpose Association (AACA) has been a registered Association in the Jordan Cooperation Corporation (JCC) since 2004. The association was registered In accordance with the provisions of Law No. 18 of 1997.

In 2007, and with the assistance of the MoPIC and WAJ, 50 ha of the land adjacent to Al-Lajjoun WWTP were allocated to AACA to establish community development agricultural project utilizing the effluent from WWTP (see Figure 1-13).

In 2013, AACA signed a Memorandum of Understanding (MoU) with the Water Authority of Jordan (WAJ) that allows the association to use the reclaimed water produced at Al-Lajjoun WWTP for forage production. The MoU stipulates that 800 m^3 of reclaimed water will be provided on daily basis, with a price of 0.01 JD/ m^3.

According to the MoU, the association has to provide the irrigation network as well as the pumping unit. The association will also be responsible for the costs of electricity used for pumping the reclaimed water, as well as for constructing an irrigation pond, or providing a storage tank. The association should also provide the irrigation network with warning signs to distinguish it from the potable water network.

Figure 1-13: Area Allocated to AACA for Establishing Reuse Activities

1.5.2 Memberships

The association has no specific membership requirements. However the applicant should be an adult and have no criminal record. In addition, the member should not be a member of any other association. Membership fees are 100 JDs per year with a monthly subscription of 10 JDs. The association consists of 52 members, including 16 female members.

Currently, no data is available regarding the financial records of AACA. However, the financial records will be provided during the detailed design of the water reuse pilot project.

1.5.3 AACA Current Activities

AACA's main goals are to improve the economic, social, and cultural development of the Al-Lajjoun local community. Based on AACA internal law, the association's main duties include but are not limited to:

- Provide guidance, direction and facilitate access to sources of financial support for new development projects
- Provide technical assistance to the association's members
- Cooperate and coordinate with the relevant parties to enable the implementation of development projects

Currently, the association is managing a livestock production project and owns a total number of 273 heads of livestock. The proposed water reuse project will be very important to sustain the livestock production project through reducing the feed costs and to increase the generated income of AACA and its members.

2. Water Reuse at Al-Lajjoun

Worldwide, reclaimed water originating from treated municipal wastewater is reused most commonly for non-potable applications such as agriculture and landscape irrigation, industrial and urban uses, and groundwater recharge.

The main benefit of using reclaimed water is saving valuable fresh groundwater for potable uses. In addition, treated wastewater reuse decreases potential environmental pollution by discharging water into groundwater and coastal systems with corresponding ecosystem and tourism benefits. However, the feasibility of using reclaimed water is affected by the local conditions and environment.

This section describes and analyzes the main conditions that are considered in planning for water reuse at Al-Lajjoun. Reclaimed water (effluent) quality and quantity were assessed to quantify the maximum water productivity that can be achieved.

2.1 Quantity of Reclaimed Water

As mentioned earlier, Al-Lajjoun WWTP was upgraded in 2013 with a design capacity of 1,200 m^3/d and BOD concentration of 3,000 mg/l. According to an Al-Lajjoun WWTP operator, the WWTP receives around 32 septic tanks daily, with an average daily inflow of around 655 m^3 over the last five months. The daily inflows for the period between November 2013 and March 2014 are presented in Table 2-1.

Table 2-1: The Daily Inflow Recorded for Al-Lajjoun WWTP Between November 2013 and March 2014

Day	November	December	January	February	March
1	290	741	525	905	754
2	855	840	795	883	975
3	601	615	300	825	833
4	750	632	795	786	723
5	870	840	585	720	821
6	735	265	585	976	830
7	260	780	690	465	418
8	260	555	435	850	833
9	750	675	885	1,040	675
10	855	855	150	1,030	535
11	675	345	346	778	645
12	895	0	405	720	318
13	660	0	690	601	520
14	600	0	585	210	255
15	300	0	825	600	807
16	630	90	510	650	885
17	890	263	270	760	805
18	695	345	660	925	686
19	616	555	616	638	550
20	915	200	570	841	865
21	770	615	625	315	525
22	275	585	540	1,286	845
23	510	565	564	1,038	968
24	653	495	225	1,007	698
25	855	825	943	660	913
26	655	640	708	770	983
27	885	160	1,152	760	984
28	690	735	1,019	330	445
29	190	585	976		700
30	975	780	858		1,059
31		645	675		1,010
Average	652	491	629	763	738

Source: Records of the Al-Lajjoun WWTP daily inflow rate.

The inflow for the period between November 2013 and March 2014 at Al-Lajjoun WWTP ranges between 491 m^3/day in December and 763 m^3/day in February, with an average of 655 m^3/day. Currently, the effluent is being discharged to the adjacent Wadi, as shown in Figure 2-1.

Figure 2-1: Al-Lajjoun WWTP Effluent Discharged to the Adjacent Wadi

2.2 Quality of Reclaimed Water

The design criteria of Al-Lajjoun WWTP follow the JS 893/2006 for discharging effluent into Wadis. To ensure that the effluent is being produced under this standard, effluent quality is monitored through WAJ as well as the operating company of the WWTP. The effluent is sampled and analyzed on a monthly basis.

The suitability of reclaimed water use depends on its quality, i.e. the physical and chemical characteristics of the effluent. For the assessment of the suitability of the effluent produced at Al-Lajjoun WWTP, four effluent samples were collected from the irrigation pond, as shown in Figure 2-2. The four samples were analyzed as one composite sample.

Figure 2-2: Collecting Effluent Samples

The results of the effluent analysis can be found in Table 2-2. In addition, the Table presents the results of the effluent analysis performed through WAJ. As the upgraded WWTP was set into operation only recently, data for effluent analysis through WAJ was found only for January and February. However, the results showed that the quality of the produced effluent complies with the design criteria for the WWTP.

Table 2-2 also compares the effluent analysis results with the JS 893/2006 for different activities of reclaimed water use. Those activities are Wadi discharge into streams, valleys or lakes; recharge of groundwater; and irrigation of different crop classes. Crops were divided into three classes according to their tolerance of specific parameters of irrigation water. Those classes are:

- **Class A:** Cooked vegetables, parks, playing ground and sideways
- **Class B:** Fruit trees, highway trees and Landscape
- **Class C:** Field crops, industrial crops and forest trees

The table shows that the effluent produced at Al-Lajjoun WWTP is allowed to be used for irrigating crops under all three crop classes with one exception: the total Nitrogen (T-N) in the produced effluent exceeded the allowable limits for irrigating the three classes. However, negative effects of this parameter on the forage yield production can be decreased through planting crops with high Nitrogen requirements, such as barley.

The water sample collected from the irrigation pond was taken in March 2014. The results of the sample analysis revealed high TDS concentration. Further investigations revealed that an industrial facility was illegally disposing of the wastewater generated at the facility into Al-Lajjoun WWTP. This was taken into consideration once the results of the analysis were delivered to WAJ. This means that the TDS of the produced effluent will remain within the design criteria for the WWTP, which is close to the TDS value for the water sample analyzed by WAJ. Therefore, the average TDS value of 727 mg/l was considered for the design of the reuse pilot.

Table 2-2: Allowable Limits for Reclaimed Water Use According to JS 893/2006, and Al-Lajjoun WWTP Effluent Analysis

Parameter			pH		BOD_5	BOD_F	COD	TSS	TDS	NH_4	T-N	NO_3	PO_4	FOG	Turbidity	E.Coli
			Max	**Min**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**		**NTU**	**MPN/100 ml**
Crops	**Class A**		9	6	30	-	100	50	1500	-	45	30	30	8	10	100
	Class B		9	6	200	-	500	200	1500	-	70	45	30	8	-	1000
	Class C		9	6	300	-	500	300	1500	-	70	70	30	8	-	1000
Discharge to Wadies			9	6	60	-	150	60	1500	-	70	80	15	-	-	1000
Groundwater Recharge			9	6	15	-	50	50	-	5	45	30	15	8	2	>2.2
Al-Lajjoun WWTP (outlet)																
Month	**Jan**	**Effluent***	7		-	40	83	27	748	73	76	3	18	-	-	<1.8
	Feb		8		-	13	46	15	706	60	115	2	24	-	-	45
Al-Lajjoun WWTP (Irrigation Pond)																
Irrigation pond**			9		15	-	100	26	1726	-	74	21	-	<8	12	170

*WAJ, 2014

2.3 Water Balance and Irrigation Requirements

Water balance with respect to irrigation refers to the amount of water that enters and leaves a cropped area over a period of time. In a cropped field, water enters the soil either as irrigation water or rainfall; it may leave the soil surface as evaporation and transpiration, run off and percolation below the root zone.

The irrigation requirements vary among different crops. For Al-Lajjoun reuse pilot, the most common forage crops grown in Jordan were considered. Alfalfa is the most preferable perennial crop, while barley and yellow corn are the most preferable seasonal crops. However, the water balance considered two scenarios;

- Perennials (alfalfa) along with winter crop (barley)
- Seasonal crops as barley (winter) and yellow corn (summer)

2.3.1 Inputs for the Water Balance Study

Rainfall varies in amount, frequency and intensity around the year. The useful or the utilized portion of rainfall is refered to as “effective rainfall.” Rainfall, recorded at Al Qatraneh weather station, and estimates of effective rainfall are presented in Table 2-3.

Table 2-3: Rainfall and Effective Rainfall at Al Qatraneh Weather Station

Month	Rainfall*	Effective rainfall**
	mm	mm
January	25.9	24.8
February	22.5	21.7
March	20.9	20.2
April	6.4	6.3
May	3.1	3.1
June	0.0	0.0
July	0.0	0.0
August	0.0	0.0
September	0.0	0.0
October	4.1	4.1
November	8.4	8.3
December	19.6	19.0
Total	110.9	107.5

Source (1): Jordan Climatological Handbook, 2002
Source (2): CROPWAT 8.0

Evapotranspiration (ET) from a cropped field refers to evaporation from the soil surface in addition to plant transpiration, which varies among different types of crops. For the Al-Lajjoun pilot, reference evapotranspiration (ET_o) was considered for the water balance study. However, crop coefficients (K_c) were considered to estimate evapotranspiration for the proposed crops (ET_c). Additional crops and the associated crop coefficients will be incorporated into the water balance when the cropping pattern is decided.

For the Al-Lajjoun water reuse pilot, the calculation of ET_o is performed by means of the so-called Class (A) Pan Evaporation (E_{pan}) method. Such data reflects the integrated effect of solar radiation, wind and relative humidity on evaporation from an open water surface. Local reference evapotranspiration (ET_o) is estimated by multiplying measured E_{pan} by pan-coefficient (K_p). The value for K_p was estimated according to FAO drainage and irrigation paper number 56. The estimated value considers the climatic data collected for Al-Qatraneh weather station mentioned in the first chapter. The average Relative Humidity (RH) and the average wind speed are 58.97% and 1.95 m/s respectively. Accordingly, the K_p value for a Class A pan was estimated as 60%.

Estimated mean monthly ET_o and K_p are presented in Table 2-4. The table also presents the values of E_{pan} evaporation recorded at Qatraneh weather station. This station is the closest weather station to the treatment plant and located within the same agro-climatic zone.

Table 2-4: Evapotranspiration Calculations for Al-Lajjoun WWTP Area

Parameters	E_{pan}* (mm)	K_p	ET_o (mm)
Jan	68.0	0.6	40.80
Feb	89.7	0.6	53.82
Mar	133.6	0.6	80.16
Apr	210.5	0.6	126.30
May	291.1	0.6	174.66
Jun	309.9	0.6	185.94
Jul	327.3	0.6	196.38
Aug	297.4	0.6	178.44
Sep	228.6	0.6	137.16
Oct	163.0	0.6	97.80
Nov	114.6	0.6	68.76
Dec	73.4	0.6	44.04
Total	2307.1		1384.26

Source: Jordan Climatological Handbook, 2002

2.3.2 Irrigation Water Requirements

The gross irrigation requirements (GIR) are the amount of water to be added to soil in order to compensate for the reduction in soil moisture at the root zone of a cropped field. It considers the addition of moisture to the root zone as effective rainfall. The estimation of the GIR depends on the climatic conditions, type of crops, salinity of the irrigation water, and efficiency of the irrigation system used. For the available effluent quality, surface irrigation will be proposed for growing forages at the Al-Lajjoun pilot site, with an estimated efficiency of 65%.

The highest GIR within the peak month is the basis for estimating the maximum areas that can be planted under the available effluent, considering the design capacity of Al-Lajjoun WWTP as 1,200 m^3/day. For forage crops, July represents the peak month for perennials and summer crops, while April is the peak month for winter crops.

When reclaimed water is used for agricultural purposes, it is important to understand the potential impact of salinity on the plant growth. To avoid detrimental effects of salinity, part of the irrigated water must be leached out from the root zone. The fraction of water to be leached out was determined for each scenario based on the expected TDS level in reclaimed water and the salinity impact on alfalfa growth.

Thus, in this assessment, the leaching factor was calculated using the following equations (Garcia, 2008):

For surface irrigation: $LF = 0.3086/Fc^{1.702}$
For drip irrigation: $LF = 0.1794/Fc^{3.0417}$

Where:
LF: minimum leaching fraction needed to control salts within the tolerance of the crop threshold salinity (EC_e) in dS/m
Fc: ratio of the EC_e to the electrical conductivity of irrigation water (EC_{iw})

$$Fc = \frac{EC_e}{EC_{iw}}$$

The values of EC_e were applied for alfalfa, barley and yellow corn at 100% production according to the FAO drainage and irrigation paper number 56. Electrical conductivity of the irrigation water (EC_{iw}) can be approximated from TDS using the following equation (Ayres and Westcot 1994):

$$TDS\ (mg/l) = EC\ (dS/m\ ) \times 640$$

Given the design TDS of the treated effluent (727 mg/L), the EC_w can be estimated as 1.1 dS/m. Based on the above calculations, leaching fractions of 25%, 2% and 33% was applied for alfalfa, barley and yellow corn.

Based on the above mentioned assumptions, the estimated gross irrigation requirements (GIR) for one hectare of alfalfa is estimated as 3,762 m^3 in July (peak month), with an annual GIR of 24,461 m^3. For barley, one ha requires 1,132 m^3 in March (peak month) with an annual GIR of 3,202 m^3. And for yellow corn, one ha requires 4,807 m^3 in July (peak month) with an annual GIR of 11,992 m^3.

Accordingly, the maximum areas that can be planted under the available effluent is estimated as follows:

- Perennial along with winter crop: 9.9 ha of alfalfa along with 22.8 ha of barley
- Seasonal crops: 7.7 ha of yellow corn and 32.9 ha of barley

2.3.3 Water Balance Output

The preliminary water balance study for Al-Lajjoun pilot considered the maximum area that can be planted under the available effluent. The study considers the available effluent rate, irrigation system efficiency, leaching fraction and cropping pattern as follows:

- Available effluent rate: 1,200 m^3/day
- Irrigation efficiency: 65% for surface irrigation system
- Crops: alfalfa, barley and yellow corn
- Leaching fractions:
    - Alfalfa: 25%
    - Barley: 2%
    - Yellow corn: 33%
- Areas: the maximum that can be planted under the available effluent rate
- Cropping patterns: two scenarios as:
    - Perennial (alfalfa) along with winter crop (barley)

- Seasonal crops as summer (yellow corn) and winter (barley)

Perennials along with winter crops

The average available effluent at Al-Lajjoun is 37,200 m^3 in both July and March (peak months). Since one ha of alfalfa requires 3,760 m^3 in July, the available effluent is sufficient to irrigate approximately 10 ha of Alfalfa as described in Table 2-5.

Table 2-5: Water Balance and GIR for 10 ha Reference Crop

Month	Available Effluent m3/month	GIR	Balance
Jan	37,200	3,031	+34,169
Feb	33,600	6,084	+27,516
March	37,200	11,358	+25,842
April	36,000	22,731	+13,269
May	37,200	32,498	+4,702
June	36,000	35,222	+778
July	37,200	37,200	0
Aug.	37,200	33,802	+3,398
Sept	36,000	25,982	+10,018
Oct.	37,200	17,749	+19,451
Nov.	36,000	11,453	+24,547
Dec.	37,200	4,743	+32,457
Total	**438,000**	**241,855**	**+196,145**

Based on the above table, the annual available effluent is 438,000 m^3 per year, and the annual GIR for the 10 ha of alfalfa is estimated as 241,855 m^3 per year. As a result, an annual surplus of 196,145 m^3 is available. In order to increase the water productivity, planting winter crops is recommended. March is the peak month for barley with an annual GIR of 3,202 m^3 per hectare per year. Therefore, the surplus is sufficient to irrigate an extra area of 22.8 ha in winter. Hence, the total available effluent is sufficient to irrigate approximately 10 ha of alfalfa with an additional 22.8 ha in winter planted with barley, with the total maximum area that can be planted under the available effluent of 32.7 ha.

Table 2-6 summarizes the water balance for the 32.7 ha planted around the year at the Al-Lajjoun pilot. Also, it represents the estimated monthly GIR for the maximum area that can be planted. The maximum monthly GIR values were estimated as 37,200 m^3 in July alfalfa in July, and 25,842 m^3 in March for barley. The annual GIR for the alfalfa and barley were estimated as 241,855 and 73,072 m^3 respectively. However, the annual surplus for this scenario was estimated as 123,073 m^3.

Table 2-6: Water Balance and GIR for 9.9 ha alfalfa and 22.8 ha of barley for Al-Lajjoun Reuse Pilot

Month	Available Effluent m^3/month	Total area (ha)	GIR (m^3\month)		Total GIR (Demand) m^3\month	Balance
			Alfalfa	Barley		
Jan	37,200	32.7	3,031	7,941	10,972	+26,228
Feb	33,600	32.7	6,084	14,429	20,514	+13,086
Mar	37,200	32.7	11,358	25,842	37,200	0

Apr	36,000	32.7	22,731	9,074	31,805	+4,195
May	37,200	9.9	32,498	-	32,498	+4,702
Jun	36,000	9.9	35,222	-	35,222	+778
Jul	37,200	9.9	37,200	-	37,200	0
Aug	37,200	9.9	33,802	-	33,802	+3,398
Sep	36,000	9.9	25,982	-	25,982	+10,018
Oct	37,200	9.9	17,749	-	17,749	+19,451
Nov	36,000	32.7	11,453	4,426	15,879	+20,121
Dec	37,200	32.7	4,743	11,361	16,104	+21,096
Total	438,000	32.7	241,855	73,072	314,927	+123,073

Summer and winter crops

As mentioned above, one ha of barely requires 1,132 m^3 in March (peak month), and one ha of yellow corn requires 4,807 m^3 in July (peak month). Accordingly, the available effluent can be sufficient to irrigate 32.9 ha of barley in winter and 7.7 ha of yellow corn in summer. In other words, the total area that can be planted around the year under the available effluent was estimated as 40.6 ha. Table 2-7 represents the estimated GIR values for both barley and yellow corn.

The table shows that the annual GIR values for 32.9 ha of barley and 7.7 ha of yellow corn are 105,189 and 92,798 m^3 respectively. The total annual GIR for both crops was estimated as 197,987 m^3, with the annual surplus adopting this scenario was estimated as 240,013 m^3.

In comparison, planting perennials along with winter crops can minimize surplus effluent water that might be discharged to Wadi, while planting winter crops along with summer crops can increase the surplus effluent.

Table 2-7: Monthly GIR values and water balance for 7.7 ha yellow corn and 32.9 ha barley for Al-Lajjoun reuse pilot.

Month	**Available Effluent m^3/month**	**Total area (ha)**	**GIR (m^3\month)**		**Total GIR (Demand) m^3\month**	**Balance**
			Yellow corn	Barley		
Jan	37,200	40.6	-	11,431	11,431	+25,769
Feb	33,600	40.6	-	20,771	20,771	+12,829
Mar	37,200	40.6	-	37,200	37,200	0
Apr	36,000	40.6	-	13,062	13,062	+22,938
May	37,200	0	-	-	0	+37,200
Jun	36,000	7.7	8,806	-	8,806	+27,194
Jul	37,200	7.7	37,200	-	37,200	0
Aug	37,200	7.7	33,802	-	33,802	+3,398
Sep	36,000	7.7	12,991	-	12,991	+23,009
Oct	37,200	0	-	-	0	+37,200
Nov	36,000	40.6	-	6,371	6,371	+29,629
Dec	37,200	40.6	-	16,354	16,354	+20,846
Total	**438,000**	**40.6**	**92,798**	**105,189**	**197,987**	**240,013**

2.4 Potential production

Developing proper cropping patterns can maximize water productivity under effluent irrigation. However, selecting cropping patterns usually depends on the following:

- Availability of land
- Topography
- Availability and quality of irrigation water
- Financial situation and available equipment
- Skills and interests/ strategies of farmers

2.4.1 Proposed Crops

Alfalfa and barley are the preferred fodder crops for herders. Alfalfa was proposed as a perennial crop to provide feed stuff for sheep almost all over the year. Barley was proposed to maximize the volume of effluent used for irrigation and to provide the added nutritional requirements for sheep in winter. Sheep producers prefer to include yellow corn as feed stuff while it is relatively cheap and produces high yield per unit area. In addition, it can be used as an option for crop rotation to improve the soil productivity.

2.4.2 Potential yield for the proposed crops

The potential yield of the proposed crops was estimated based on the data documented within the “Forage Production Model for Subsistence Farming using Reclaimed Water in Semi-arid Regions of Jordan”. The model was developed under WRECP in 2013, as part of the technical assistant role of the project in supporting water reuse activities around WWTPs in Jordan. It also represents a theoretical model for production of different forage types (green fodder, grains, hay, and straws) using reclaimed water to nourish small ruminants (sheep and goats).

According to the forage model, one ha of alfalfa can produce on average 45 ton of hay (DM) and 120 tons of fresh fodder. On average, 8 cuts can be taken from the alfalfa stand per season. The herbage production of alfalfa extends over 8-9 months (February-October). Alfalfa is usually fed to livestock as fresh forage without being dried but may also be sold as bales (dry hay).

Barley is usually cut twice a season. The first cut is fed to sheep as fresh fodder; the second cut produces hay and grains. Production of fodder barley is around 27 tons fresh fodder and 6 tons of dry fodder along with 3 ton grains per ha. Fresh fodder is expected to be collected in late winter-early spring (February-April). Many farmers prefer producing grains and straw from barley plants.

In comparison, the yellow cron production was estimated according to local experts who contributed to the forage model development. According to Taiseer Al Masri, one ha of yellow corn can produce 4 tons of fresh fodder and 6 ton straw. Yellow corn is usually sold as fresh forage.

Potential yield production is discussed within this preliminary assessment of Al-Lajjoun pilot in terms of the two scenarios discussed earlier.

Perennials along with winter crops

Perennials (alfalfa) are planted all around the year, with the maximum area that can be planted of 10 ha. Winter crops (barley) are usually grown between November and April, with the maximum area that can be planted being 22.8 ha. This cropping pattern can produce:

- Alfalfa hay: 3,600 ton hay
- Barely: 616 ton fresh, 137 ton hay and 68 ton grains

The forage production model also documented the net profit for planting alfalfa and seasonal crops as follows:

- Alfalfa: 10,208 JD/ha
- Barley: 280 JD/ha for fresh forage (fresh cut) and 1,243 JD/ha for grains and hay (second cut)

Accordingly, 9.9 ha of alfalfa can generate a net profit of 101, 059 JD/year. While 22.8 ha of barely can generate a net profit of 34,724 JD/year. The annual income to be generated adopting these two crops will be 135,783 JD.

Summer and Winter Crops
As mentioned earlier, the most preferable seasonal crops from the prospective of the sheep producers are winter barley and summer yellow corn. The available effluent can be sufficient to irrigate 7.7 yellow corn along with 32.9 ha barley. The production for this cropping pattern was estimated as:

- Fresh barley: 888 tons
- Barley grains: 99 tons
- Barley hay: 197 tons
- Fresh yellow corn: 31 tons

As per the forage production model, the net profit for barley is 1,523 JD/ha. As barley and yellow corn requires the same agricultural procedures, with the same cost and close fresh production, yellow corn is expected to generate the same net profit for fresh production as barley with 280 JD per hectare. Accordingly, 32.9 ha barley can generate a net profit of 50,107 JDs, while 7.7 ha yellow corn can generate 11,727 JD. The total income expecting adopting these two crops will be 61,834 JD.

3 Conclusion

As discussed in this report, 2.6 MCM of ground water was pumped in 2008 for irrigation uses. It is expected that in 2020, the irrigation requirements will be around 64 MCM in Al-Karak Governorate. The proposed water reuse project at Al-Lajjoun area will help in reducing the amount of fresh water used for irrigation in Al Karak Governorate. It will also minimize the potential negative impacts of the WWTP effluent that is being discharged into Wadis near the Al-Lajjoun WWTP. The project will also have positive environmental impacts such as increasing the vegetative cover, and enhancing the aesthetic conditions of the project area.

Al-Karak suffers from a high rate of unemployment (17.7%), and the rate is higher among females. The poverty rate in Al-Karak Governorate is 13.4%. The local community of Al-Lajjoun and the AACA showed their interest and willingness to participate in the proposed project. They form a strong base for establishing a community-based water reuse pilot. It is anticipated the local community will benefit from the proposed project through forage production using the reclaimed water, and their overall living conditions will be improved through reduced unemployment and increased income.

The preliminary water reuse plan for Al-Lajjoun pilot indicates that approximately 32.7 to 40.6 ha of forage area (depending on cropping patterns) can be planted using the available effluent produced from the WWTP, beneficially using of 197,987 to 314,927 m^3 per year of treated wastewater (without seasonal storage). The income generated for the local community is expected to range from 61,834 to 135,783 JD per year, depending on the cropping pattern and farm practices.

Based on the above, it can be concluded that establishing a new pilot site at Al-Lajjoun offers great potential to replicate the success story at Wadi Mousa pilot project; beneficial reuse of treated wastewater in irrigation will support the local communities, improve their living conditions, and promote economic growth in a governorate suffering from high poverty and unemployment rates.

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