Case Study 5: Palestine

Jericho wastewater treatment plant and West Bank date palm irrigation

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Acronyms

JICA	Japanese International Cooperation Agency
JM	Jericho Municipality
MOA	Ministry of Agriculture
PFU	Palestinian Farmers' Union
PWA	Palestinian Water Authority
WWTP	Wastewater Treatment Plant

History and project justification

Although it has reasonable long-term average rainfall – 450 mm to 600 mm annually – Palestine experiences serious constraints to accessing water resources. This is due in part to a high dependence on aquifers and hot, dry summers that result in water loss, for example, through increased evaporation. Water access is also challenging due to political unrest in the West Bank[1] area, which impacts on flows to harvesting structures such as dams (PWA 2017). These two factors combined mean that the West Bank has a water deficit – the difference between supply and demand – of 36 MCM/year. This gap is expected to grow significantly if no other sources are developed, and no further demand management is implemented (PWA 2017).

The Jericho Wastewater Treatment Plant (Jericho WWTP) started operations in June 2014 with the dual purpose of treating wastewater generated in the area and providing recycled water as a new source of irrigation water for date palm cultivation (Images 5.1 and 5.2) in the West Bank, to reduce the burden on water availability compared to demand (JICA 2014).

[1]Note: Boundaries and names shown and the designations used on any maps or text within this case study are used as geographical references and do not imply official endorsement or acceptance by the International Water Management Institute (IWMI).

IMAGE 5.1 Date palm (*Phoenix dactylifera* L.) farms in the Jericho district. Photos: the author.

IMAGE 5.2 Jericho WWTP and surrounding date palm farms. Photo: I Abu Seiba

Before its construction, households in the area depended on thousands of cesspits with waste materials discharged into open *wadis* (valleys) and resulting in continuous deterioration of human living and environmental conditions.

Reuse case description at a glance

Jericho WWTP is an extended aeration-activated sludge plant. It started operations in 2014 with a planned daily average capacity of 6,600 m^3/day by 2020, and will reach a maximum of 9,600 m^3/day by 2025, equivalent to 80,000 people. The project included the installation of more than 30 km of new sewers (with a diameter of 200–700 mm) to collect wastewater generated in Jericho City and its surrounding areas (Table 5.1 and Figures 5.1 and 5.2).

TABLE 5.1 Jericho WWTP: Data sheet.

Area (hectares)	10.3
Mean temperature (°C)	15–40
Annual average precipitation (mm)	50–400
Overall mean sea level (m)	-250
Population to be served by the project (capita)	23,600
Number of workers	10
Civil structures	Waste Receiving Tank for Vacuum Trucks Grit Chamber (two channels) Reactor (two tanks) Final Clarifier (two tanks) Sludge Thickener (two tanks) Disinfection Tank Irrigation Tank Sludge-Drying Bed (six beds) In-plant Landscaping In-plant Piping Architectural Structures (Reinforced Concrete/Concrete Block) Administration Building Substation Building Workshop Building, Blower and Electric Room Return-Sludge Pump House Chlorine House Thickened-Sludge Pump House
Type of treatment process	Extended Aeration Activated Sludge Process
Aeration type	Diffusers

SOURCE: JICA 2011.

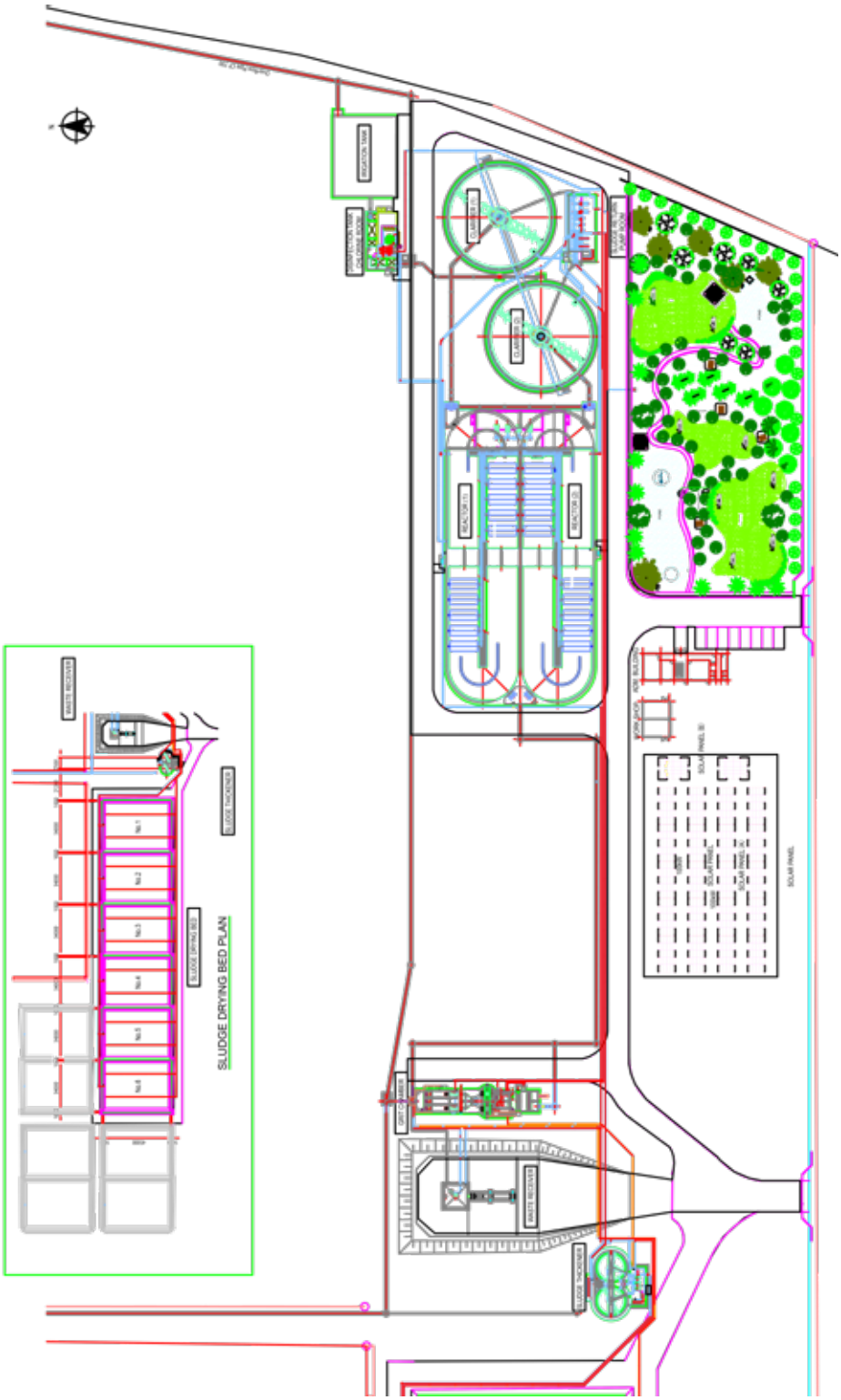

FIGURE 5.1 Jericho WWTP: Schematic diagram. *SOURCE:* Jericho Municipality.

FIGURE 5.2 Jericho location and borders overlaid on a map showing Jericho WWTP and water reuse area.
SOURCE: Google Earth (31°50'23.16" N 35°29'57.60" E).

In terms of water reuse capacities, the Jericho WWTP has an effluent storage tank – the irrigation tank – that is equipped with several pumps that take the treated effluent to the date palm tree farms that use it for irrigation (Image 5.3) using surface drip irrigation. These pumps, installed by the farmers, convey the treated effluent directly into the farms' irrigation networks. The amount pumped to each farm is measured by a flow meter with the volume of reused water averaging is 1,247 m^3/day, which is enough to irrigate 30 ha.

National institutional and policy environment

One of the most important agricultural strategic objectives for Palestine is to conserve and rehabilitate its natural resources essential to supporting production systems. To this end,

IMAGE 5.3 Effluent storage and irrigation tank and the effluent pumps and the flow meters at Jericho WWTP. Photos: I Abu Seiba.

the Ministry of Agriculture is looking to increase the availability of both conventional and unconventional water resources for both crop producers and livestock breeders (MOA 2016), including a substantial increase in the use of recycled water from wastewater treatment plants (PWA 2014; MOA and PWA 2014). The government officially recognizes this water as an agricultural water resource (Palestinian Agricultural Law No 2/2003) and its use is included in the Palestinian National Climate Change Adaptation Plan (Smithers 2016). Its use also supports one of the main objectives of the National Agriculture Sector Strategy (2017–2022), which requires that natural and agricultural resources are sustainably managed and better adapted to climate change (MOA 2016).

In 2003, the Palestinian Standards Institute issued a Treated Wastewater Standard (PSI 742-2003). This sets out the important parameters and requirements concerning its use as irrigation water and for discharge to the *wadis*. It also issued Obligatory Technical Regulations (PSI TR 34, 2012) that divide the quality of recycled water specialized for irrigation into four categories: high quality (A), good quality (B), moderate quality (C) and low quality (D). The regulations also set out obligatory requirements and technical instructions for controlling, permitting, conveying and reusing recycled water from wastewater treatment plants for irrigation. The most recent standard of treated effluent use for irrigation issued by the Palestinian Standards Institute was the Treated Wastewater – Treated Wastewater Effluent for Agricultural Purposes (Restricted) (PSI 742-2015) in 2015 (PSI 2015).

Stakeholders involved and management model

Several stakeholders at different levels are involved in the Jericho WWTP and water reuse project (Figure 5.3).

At the national level, the Palestinian Water Authority (PWA) is the main actor at the water policy-making level. PWA owns Jericho WWTP and is the national body responsible for policy, planning and monitoring of water-related service delivery including monitoring effluent quality. They are also responsible for future upgrades of the plant.

Day-to-day operations at the Jericho WWTP are managed by staff. Staff also carry out analysis on effluent quality, report results back to the PWA and manage the process of supplying recycled water to the farmers including the related contractual and financial administration responsibilities.

Matters relating to irrigated water come under the authority of the Ministry of Agriculture (MOA), which issues licenses to permit farmers to use recycled water from WWTPs. It also monitors the quality of water used for irrigation and the standards of the marketed crops that are produced through its use. In conjunction with the PWA, they also grant licenses to the water users' association, which is a coordinated group for the farmers who are the main end-users. Currently, the farmers make individual agreements in terms of purchasing recycled water from the Jericho WWTP, but it is expected that the water users' association will soon

become active and manage the use of all irrigation water sources including recycled water (Figure 5.3).

In terms of relationships between the various stakeholders, coherence is low and not fully functional at a practical level, particularly when it comes to follow-up activities, such as checking the recycled water quality, reporting and sharing data, and managing the distribution of recycled water to farmers.

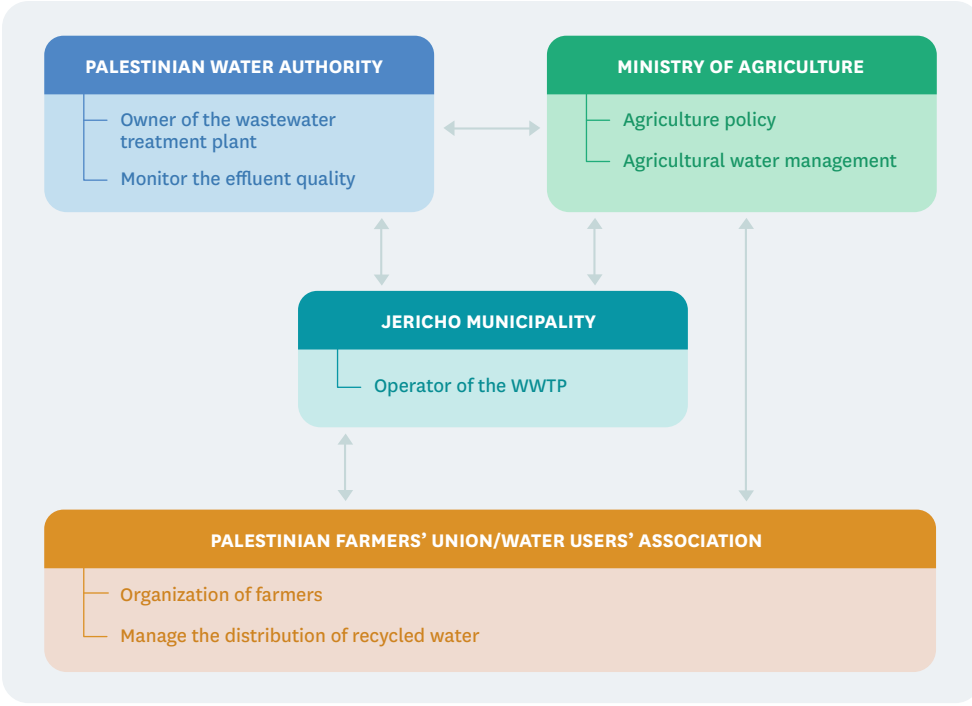

FIGURE 5.3 Jericho WWTP and West Bank Date Palm Irrigation Project: Stakeholders and management model.

Funding and financial outlook and cost recovery

The Japanese International Cooperation Agency (JICA) sponsored the Jericho WWTP and West Bank Date Palm Irrigation Project as a Grant Aid Project by the Japanese Government at a total cost of USD 32 million. Around 30% of Jericho WWTP's operational costs are recovered by selling treated effluent for reuse (Figure 5.4, Table 5.2). This benefits farmers who receive a reduced tariff for wastewater services.

In Jericho, there is a high demand for irrigation water, which still has limited supplies. Now this is resulting in more than 80% of recycled water produced at the plant being reused. A questionnaire revealed that the cost of recycled water (USD 0.20/m^3 including the 0.16 USD paid to the Jericho WWTP and the pumping cost of around USD 0.02/m^3) is cheaper than the

cost of groundwater (USD 0.3-0.7/m³). On some days, the percentage of reused effluent quantity is higher than 100% due to the accumulation of water from previous days. The percentages of cost recovery increase with time as treatment operational unit costs decrease due to flow increases. Jericho WWTP is expected to make more profit with time.

Socioeconomic, health and environmental benefits and impacts

Date palm cultivation is a fundamental part of the development of the agricultural economy in Jericho, yet its potential has been limited by the low availability of water resources for irrigation. The Jericho WWTP provides an attractive new non-conventional water resource that is already almost fully utilized for supplementary irrigation on date palm farms, representing 8–25% of the total irrigation water used for date palm cultivation in Jericho. The areas of the farms partially irrigated with recycled water from wastewater treatment plants range from 10 to 300 ha, with the average area exceeding 85 ha. Each hectare is typically planted with 140 palm trees.

Most of the farmers (80%) mix the recycled water with groundwater. This reduces the salinity of the groundwater. 20% of these farmers have also reduced the volume of chemical fertilizers they add to their soils due to the increased nutrients in the recycled water – all farmers in the area use both chemical and organic fertilizers. The farmers have not observed any

FIGURE 5.4 Percentage of treatment operational cost due to effluent selling for reuse.

negative impacts on the soil since irrigation through the reuse project started and likewise, all of them affirmed that they had never witnessed any disease outbreaks in humans, animals or the irrigated date palms.

In terms of employment, each farm has 2–30 full-time workers and represents the main source of livelihood for both owners and employees so are hugely important. The marketed

TABLE 5.2 Capital expenditure, operating costs and cost recovery.

Wastewater collection and transport	WW treatment	Transport of treated wastewater	Additional wastewater treatment for reuse	Distribution of reclaimed water to end-users
Construction and equipment services (description and dimensions)	Wastewater treatment plant, land leasing, fence, access road, and power cable, engineering services, equipment, bank commission.	Treated effluent is stored in an irrigation tank (1,000 m^3) that is located at the site of Jericho WWTP. Farmers directly pump the effluent onto their farms. Capital cost and recovery are mixed with the wastewater treatment costs.	Chlorination unit – capital cost and recovery are mixed with the wastewater treatment costs.	Small pumps and main pipes – the cost of units is paid by the farmers. There are 10 systems, each with a cost of around USD 300.
Stakeholder that delivers the service	JM PWA	JM PWA	JM PWA	PFU
CAPEX (in USD)	23 million	Cost and recovery are mixed with the wastewater treatment	Cost and recovery are mixed with the wastewater treatment	3,000
CAPEX recovery (in USD and % of subsidy	0 (100%)	0	0	0
Operations & Management Services (description)	Electricity, diesel, chlorine and staff costs		Chlorine	Pumping of treated wastewater to the farms
Stakeholder that delivers the service	JM	JM	JM	PFU
OPEX in USD/year	268,755[+]	0	3,232	Note: pumping cost is pre-paid by the farmers at USD 39,850
OPEX recovery in USD/year and % of subsidy	211,143[++] (Average) water charges/tariffs to households (and other urban users) for wastewater services (USD/m^3 used)			80,000[+++] (0% subsidy) 498,130 m^3 reclaimed water sold/year x 0.16/m^3

NOTES: Capital expenditure (CAPEX), Jericho Municipality (JM), Israeli New Shekel (NIS), Operational expenditure (OPEX), Palestinian Farmers' Union (PFU), Palestine Water Authority (PWA). + Based on May 2021 data. ++Domestic water calculated for 2021 based on wastewater amount entering WWTP multiplied by 1.165 (annual increase speculated based on 2019 and 2020 data), divided by 0.427 (percentage of water converted to wastewater based on previous studies in Jericho); 0.16 USD is equivalent to NIS 0.5 that is charged for each 1 m3 of water supply as a wastewater fee. +++Reused wastewater calculated for 2021 based on the data available for 2020 multiplied by 1.27 as speculated from the increase based on the previous year (2019).

effluent is beneficial for the farmers and the general public as it brings back revenues that cover almost 30% of operational costs.

Gender equality

All of the farmers involved in the project, including farmer-owners and workers, are male. Work on remote date palm farms is considered to be extremely laborious and socially unacceptable for women. There are opportunities for women in segregating and packing the dates, a period which lasts for five months and where female workers represent 75–100% of the workforce. However, as the farms are family businesses, while owned by men, women are involved in managing the business.

At the Jericho WWTP, all the staff members are male, even though there are no institutional barriers to women working there. Low participation of women in the workforce is a national issue in Palestine, reaching only 18% of total women of work age (PCBS 2020). Additionally, a recent study showed the percentage distribution of 20–29-year-olds with an intermediate diploma or bachelor's degree who had qualified in engineering was 4% of the females compared to 11% of the males (PCBS 2019).

Resilience to COVID-19

While the COVID-19 pandemic did not have a clear impact on the Jericho WWTP's performance, the profits of the farmers and three date factories were negatively impacted. The factories had extra health safety expenditures that increased operational costs by at least 3% while some workers at the factories infected by COVID-19 were placed in quarantine on full salary. Of particular consequence were the mobility restrictions including on international travel, which negatively impacted date sales and increased shipping costs. Moreover, local and international demand decreased simply because of reduced social gatherings and events, which resulted in a reduction in the sale price of around 30% and a market that was largely localized. However, despite the negative economic effects of the pandemic, the date palm agro-industry has managed to withstand the crisis, even with reduced profits during this period.

Scalability and replicability potential

The demand for treated effluent produced at the Jericho WWTP is such that the recycled water is used to its maximum limit for date palm irrigation, in an area with limited availability of other water resources. In fact, there is a waiting list of farmers who want to join the scheme as soon as capacity increases. Those that are already receiving the recycled water are highly satisfied. They have not experienced any negative impacts on either the quantity or the quality of the dates, or the general environment. On the contrary, farmers are seeing positive impacts.

The Jericho WWTP is not yet operating at full capacity, which is predicted to reach four times current production. This means the scalability potential of reclaimed water use in the date palm farms in Jericho is very high. Likewise, because of the great success of Jericho the wastewater treatment and reuse scheme, from socio-economic and environmental perspectives, the high replicability of the project is foreseen not only in Palestine but also in other countries in the region with similar conditions.

SWOT analysis

Table 5.3 presents the strengths, weaknesses, opportunities and threats of treated wastewater and its use as a recycled water source for date palm irrigation in Jericho.

TABLE 5.3 Jericho WWTP and West Bank date palm irrigation: SWOT analysis.

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ■ Minimum water quantity can be guaranteed ■ Benefits of side product ■ Low energy requirements ■ Advanced system of water purification ■ Associated social, environmental and economic benefits	**WEAKNESSES** ■ High price of treated effluent ■ Not enough storage is available for surplus water during some seasons
EXTERNAL FACTORS ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ■ Water conservation policy ■ Demand for reclaimed water is higher than plant potential ■ High acceptance of treated wastewater as a water source ■ Public awareness of the water scarcity problem and the potential of the new source ■ Increasing drought period ■ Increased use of bio-solids (sludge) is possible ■ Emphasis on alternative sources of water ■ Easy social marketing of the benefits of the product	**THREATS** ■ Improper operations and management arrangements can endanger functioning ■ Possible health risks to operators, neighbors, farmers and consumers ■ If the team does not fully appreciate the potential benefits of monitoring and reflection, it will not be implemented adequately ■ No full recovery of CAPEX and OPEX ■ Low coherence of stakeholders

Key factors for success along the project and lessons learned

During the design, construction and operation of the project, key factors of success in the Jericho WWTP and West Bank date palm irrigation project include:

- The Jericho WWTP successfully provided the agreed quantities of wastewater to farmers, satisfying their needs and creating a client base, as well are reusing all of its wastewater.
- Wastewater reuse creates income for Jericho WWTP and as such contributes to the financial sustainability of this important environmental infrastructure and reduces the tariff charges to the serviced population.
- Recycled water from the Jericho WWTP is an additional source of water that has enhanced the potential of date palm agribusinesses in the Jericho district.
- No negative impacts were reported on date palms, humans and animals from the use of recycled water from Jericho WWTP. The soil also appears to be unaffected although this is based only on visual observations comparing it to other parts of the farms where treated effluent is not used.

Lessons learned include:

- Stakeholders require more knowledge on treated effluent and better coordination, which can be achieved through workshops and meetings that are better organized and more frequent.
- Farmers have indicated the need for training on the use of treated effluent for more productive and safer use of the resource.

Methods

Reports were collected about the status of water in the West Bank and wastewater treatment and reuse and reviewed. These included monthly reports on the Jericho WWTP for the period January 2019 to May 2021, which contained data about influent, effluent and reuse quantities, and the treatment cost and power consumption recorded by the plant operators.

A structured questionnaire was designed to collect data from each of the seven farmers in the irrigation area. It was designed after consultation with key people concerned with water reuse at the Ministry of Agriculture and the Jericho WWTP. The farmers, who own and manage large date palm tree farms, are using recycled water from Jericho WWTP to irrigate their farms. Interviews were carried out with each farmer, five of which were carried out in person. Other interviewees included the chief operator of Jericho WWTP and the Director of the Wastewater Reuse Department of the Ministry of Agriculture (MOA).

The questionnaire included 58 structured questions, in addition to open questions, grouped in the following main categories:

- General information about the farmers and the irrigated farms
- Knowledge level of the farmers
- Practices of recycled water reuse from wastewater treatment plants
- Monitoring reuse process on farms
- Prices and quantity of water
- Incentives and obstacles
- Impacts of using recycled water from wastewater treatment plants

The collected data were analyzed and processed using Microsoft Excel.

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