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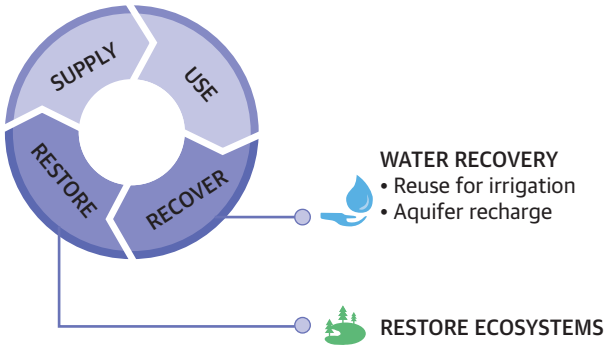
Water in Circular Economy and Resilience (WICER)

The Case of North Gaza

Wastewater Treatment for Aquifer Recharge and Reuse in a Water-Scarce Context Marked by Fragility, Conflict and Violence



This case study is part of a series prepared by the World Bank's Water Global Practice to highlight existing experiences in the water sector. The purpose of the series is to showcase one or more of the elements that can contribute toward a Water in Circular Economy and Resilience (WICER) system. This case focuses on the experience of North Gaza.

Context

Gaza is among the most water-stressed places in the world. Its main source of water is groundwater from the Coastal Aquifer, which is replenished by rainfall. Over the past five years, however, the average annual rainfall in Gaza has decreased by 20 to 30 percent, while the average recharge volume has dropped 10 to 20 percent. In addition, over-pumping of groundwater has increased saline water intrusion, and the lack of appropriate wastewater treatment and disposal has led to aquifer contamination. This case study describes how treated wastewater was used to for aquifer recharge and reuse in a water-scarce and conflict-prone context.

In 1976 the Beit Lahia Wastewater Treatment Plan (BLWWTP) was constructed in North Gaza to serve a population of 50,000 people with a primary and secondary treatment capacity of 5000m³/day. As the population in the served municipalities of Beit Lahia, Beit Hanoum, Um Al Nasser, and Jabalia grew, inflows at the BLWWTP increased to more than 12,000m³/day in 2004, greatly exceeding plant capacity. The original design did not incorporate disposal of treated effluent,

which had been left to seep into the sand dunes surrounding the plant. In the past, this posed no major risks because the effluent quality was adequate and the sandy soil could manage the volume of effluent through natural infiltration. But the increasing volume of sewage inflows, insufficient treatment capacity, and prohibitions on wastewater discharges to the sea meant that poorly treated effluent from the treatment plant overflowed into the nearby sand dunes, creating a growing lagoon of nearly 1.5 million m^3 of wastewater, covering more than 30 hectares (ha).

The partially treated wastewater from the lagoon seeped into the aquifer exposing the nearby population to waterborne diseases and sewage floods. Between 1989 and 2007, on three occasions, the sandy embankments containing the wastewater lagoon were breached.[1] Houses in and around Beit Lahia and Um Al Nasser were flooded with raw sewage. There were multiple casualties after people drowned in the sludge. Aside from the physical threat of flooding, the lagoon provided a natural breeding ground for mosquitoes and parasites, contaminated groundwater, and produced foul-smelling gases. Waterborne diseases meant a large and growing number of children were contracting digestive and respiratory illnesses; infants under the age of six months were the most vulnerable.

Solution

In 2004, the North Gaza Emergency Sewage Treatment Project (NGEST) began implementation. Led by the Palestinian Water Authority (PWA) and supported by the World Bank and other donors, the project was designed to address these health and environmental problems by building an integrated wastewater treatment plant (WWTP) for an effluent recovery-and-reuse scheme (figure 1). The map showing the full geographical scope of the project is shown in figure 2.

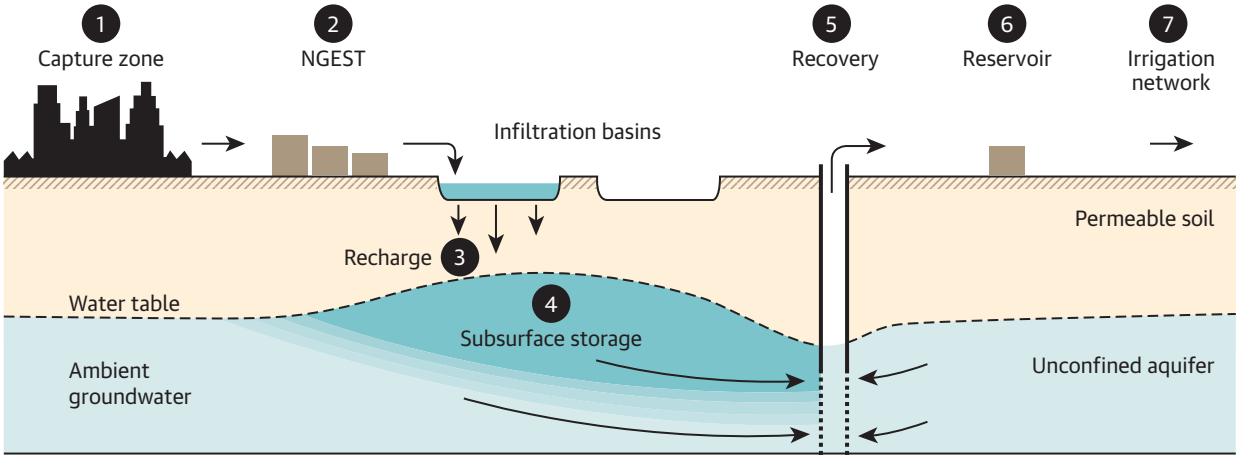
The project was designed to be implemented in three parts to address immediate health and environmental needs as well as to support a longer-term wastewater treatment-and-reuse solution for the four municipalities of North Gaza.

Part A: Beit Lahia–Jabalia effluent transfer: An immediate and temporary solution to the health risks created by the sewage lagoon was to drain it, in this case by transferring the untreated wastewater to infiltration basins. This temporary solution entailed construction of: i) a terminal pumping station (TPS) at the site of the existing BLWWTP (item 1, figure 1); ii) a network of about 7 km of ductile iron pipelines to transfer the effluent from the lagoon to the infiltration basins; and iii) nine infiltration basins (item 3, figure 1). The replacement system began operation in 2009.

Part B: North Gaza Wastewater Treatment Plant: Once the lagoon was drained, the next step was to increase wastewater treatment capacity to treat 100 percent of the wastewater from Beit Lahia, Beit Hanoum, Um Al Nasser, and Jabalia to recharge and clean the aquifer. The North Gaza Wastewater Treatment Plant (NGWWTP) (item 2, figure 1) has been in operation since 2018. With a treatment capacity of 35,600 m^3/day, and able to expand to 65,700 m^3/day, the NGWWTP can meet the needs of the rapid population growth in Gaza. The wastewater treatment plant adheres to an activated-sludge treatment process that includes biological nitrogen and partial phosphorus. Sludge is treated anaerobically. The nine infiltration basins (item 3, figure 1) lie on more than 8 ha at the NGWWTP. Part of the former BLWWTP site will be decommissioned, and some ponds will be rehabilitated to make the NGWWTP more efficient and resilient.

Part C: The effluent recovery-and-reuse scheme. This scheme aims to recover the infiltrated, treated wastewater to irrigate about 1,500 ha of agricultural land near the NGWWTP. Twenty-eight recovery wells will be built near the infiltration basins (item 5, figure 1), along with two groundwater reservoirs with 4,000m^3 of storage capacity to maintain hydraulic balance and manage water distribution for crops (item 6, figure 1). There are in addition, 10 booster pumps with 6,000m^3/hr maximum flow capacity, collection

FIGURE 1. North Gaza Wastewater Treatment Plant and Effluent Recovery-and-reuse Scheme



pipelines, 10 monitoring wells ensuring adequate physical and chemical characteristics of the infiltrated water, and an irrigation water distribution network (of about 106 km) (item 7, figure 1). By 2020, fourteen of the twenty-eight recovery wells had been installed around the infiltration basins, along with one reservoir, five booster pumps, and five monitoring wells.[2] The remaining components are being contracted through the PWA with financing from the Agence Française de Développement (AFD). The implementation of the first stage of the irrigation scheme (500 ha) is planned to start in 2021.

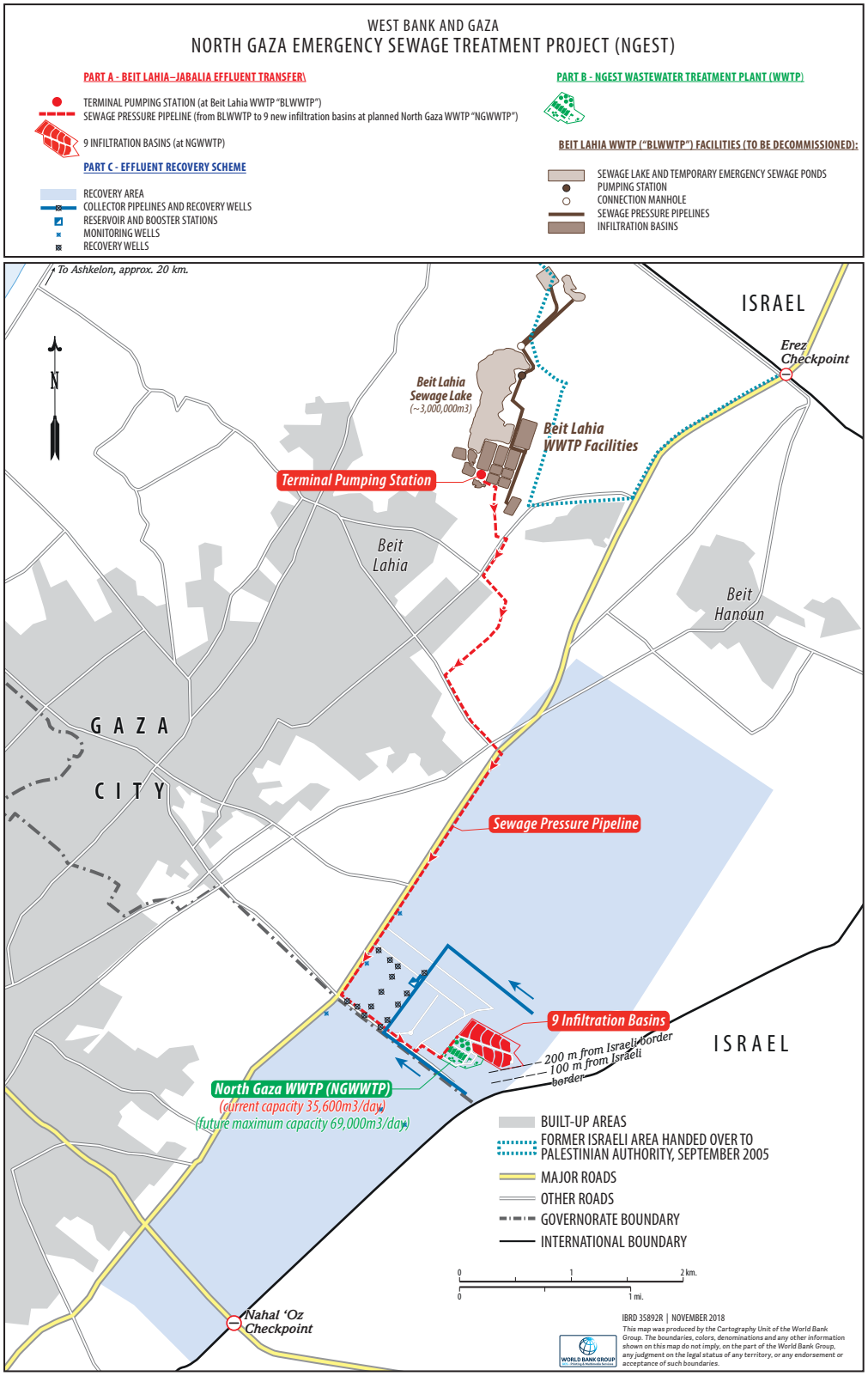
The Water-energy Nexus

With power supply at about 170 MW, Gaza has an acute power shortage—a third of the 500 MW demand. Israel is expected to supply 120 MW, and the Gaza power plant to provide 45-60 MW from diesel generators. Government of Israel restrictions on fuel entry into Gaza, the high cost of fuel, limited capacity, and a fragmented grid combine to keep the Gaza power plant from operating at full capacity.

Taking this into consideration, the NGWWTP design incorporated co-generation facilities with an 800 kW capacity, using the biogas produced in the anaerobic process at the treatment plant. Around 38 percent of the plant's electricity requirements can be covered through biogas co-generation. But the biogas container was damaged during the escalation of the conflict in 2019, making the co-generation system inoperable. It is expected to come back online in 2021.

In 2015 the World Bank commissioned a feasibility study on solar energy installations at the NGWWTP site. The goal was to bring reliable electricity supply to the treatment plant while lowering the costs of operations and maintenance (O&M). By 2020 the AFD, Green Climate Fund, and the Irish government had approved financing to install up to 8.5 ha of ground-mounted photovoltaic panels to be placed at the premises of NGWWTP (2 ha), near the recovery scheme (3 ha) and in the restricted access area[3] next to NGWWTP (3.5 ha). With total installed capacity of 7.5 MWp, the three solar parks will produce an average useful 9,411 MWh/year, in comparison with the 10,659 MWh/year needed for the reuse scheme (TPS + WWTP + recovery + irrigation network). The PV panels are expected to be operational by August 2022. The O&M arrangements will depend on the location of the solar panels.

FIGURE 2. North Gaza Emergency Sewage Treatment Project: Various Projects



Policy, Institutional, and Regulatory Environment

The PWA was established in 1995 as the principal water institution in the West Bank and Gaza (at ministerial level). It has overarching responsibilities for the preparation and implementation of policies, strategies, and plans; investment planning and implementation; and accountability and performance of the entire water sector. At the time of the NGEST project approval in 2004, PWA recognized the reuse-and-recovery scheme for treated wastewater as an essential element of the NGWWTP. Therefore, the PWA fully supported and encouraged wastewater reuse as part of its policy. In addition, Israel's prohibitions for the discharge of untreated wastewater into the Mediterranean meant any short-term solution to prevent the collapse of the embankments at Beit Lahia would require a fallback option: the temporary underground infiltration of wastewater, for which the infiltration basins were built and put into operation in 2009. The medium-term solution involved building the NGWWTP and connecting it to the existing infiltration basins. With this done, treated wastewater can be introduced underground to mitigate the legacy of groundwater contamination and recharge the aquifer with good-quality water for future irrigation. This phased approach reflects implementation constraints and the challenges posed by fragility, conflict, and violence.

Since 1996, the World Bank and other donors have been supporting the development of an institutional and legal framework for the water and wastewater sector. Through the Gaza Water Sector Capacity Building Project (P117443), the Bank supported the PWA with the development of the National Water Policy and Strategy for Palestine 2013-32 and the 2014 Water Law as part of a larger water sector reform agenda. These documents make explicit that treated wastewater represents a potential resource and should be optimized for agricultural, recharge, and aquaculture purposes. The policy states that wastewater shall be treated to a quality suitable for safe and productive reuse, in line with national standards, and shall support the distribution and productive reuse of treated wastewater, a practice that is regulated by the 1999 Environmental Law (Article 29). To enforce these regulations, the Palestinian Environmental Quality Authority (EQA) in 2000 proposed draft standards for the reuse of treated wastewater; the quality standards for reuse and recycle of treated wastewater (PS/742/2003) were established in 2003. The standards cover sanitary matters (pathogens, nematodes, and fecal coliforms), environmental matters (limits on heavy metals, nitrogen, and phosphorus concentrations), and agro-technical quality requirements (limits on salts and several anion and cation concentrations). At the NGWWTP, effluent quality measured in terms of biochemical oxygen demand (BOD), total suspended solids (TSS), and total nitrogen (TN), is in compliance with the PS/742/2003 standards for biological parameters of treated wastewater and is fit for aquifer recharge and unrestricted reuse in agriculture.[4]

The status of sector institutions is guided by the principles embedded in the 2014 Water Law, which are meant to adjust and reform current settings of the sector. The law (i) delineates the responsibilities of each institutional stakeholder, encouraging private participation; (ii) establishes clear and enforceable accountabilities; and (iii) fosters financial independence and self-sufficiency among service providers. At the national level, two institutions already exist: (i) the PWA, which is responsible for managing water resources, sector planning, and development; and (ii) the Water Sector Regulatory Council, which regulates and monitors the operation of water service providers. A third entity was recently created—National Water Company (NWC)—which will assume the role of bulk water provider to service providers.

The 2014 Water Law also envisages service delivery at the local level provided through a few utilities. Regional Water Utilities are to be formed through the aggregation of existing small service providers (water departments at the local government units) so

as to yield economies of scale. The new organizations are to be autonomous and financially self-sustaining, owned by participating local governments. In Gaza, PWA's goal is to transform the Coastal Municipalities Water Utility (CMWU). First established as a Joint Service Council under the Local Authorities Law of 1997, the CMWU will become the Gaza Regional Water Utility and assume operation and maintenance of the NGWWTP and associated facilities.

Financial and Contractual Arrangements

The project was financed by pooling grant resources from several donors, including the World Bank, the Belgium Directorate General for International Cooperation, the European Commission, the Swedish International Development Cooperation Agency (SIDA), the AFD, and the European Investment Bank. The total cost of the project from 2004 to 2018, excluding Part C (which is still being implemented), amounted to USD 82 million. The Green Climate Fund, the AFD, and Irish Aid will finance Part C of the project—including the irrigation and solar PV scheme—for approximately EUR 45 million.

The NGWWTP was built by an international joint venture contractor. With respect to O&M for the plant and associated facilities, the agreement with the joint venture included a two-year O&M contract through February 2020. To ensure the sustainability of operations once the JV contractor moved on, the contract also specified that the CMWU staff would be provided with technical training and assistance. This two-year O&M contract was to be financed by the PWA until the CMWU entered into an institutional agreement with the four North Gazan municipalities to establish cost-recovery.

This two-year O&M contract was never finalized, however. Water and sewerage tariffs in the four municipalities do not cover the costs of water production and distribution, let alone wastewater treatment, estimated at USD 277,000 per month. The financial collapse of the Palestinian economy in 2018 compromised the PWA's already weak capacity to continue funding the NGWWTP's operating expenditures. As a result, the contractor was not paid on time and terminated the contract unilaterally in July 2019. The ensuing uncertainty surrounding impaired the orderly transfer of O&M responsibilities to the NGWWTP. Although outside its institutional mandate, the PWA has been operating the system with its own staff and resources since July 2019.

In June 2020, to cover O&M costs the PWA was unable to bear, the World Bank approved a USD 13.7 million grant for the Wastewater Management Sustainability project. This intervention played out under emergency conditions to finance the O&M for the NGWWTP and facilities for four years and lay the basis for sustainable wastewater treatment services in Gaza. The project is financing activities to enhance the sustainability of the O&M of wastewater treatment services in Gaza over the medium and long terms. It includes upgrading the NGWWTP for operational gains in efficiency, resilience, and flexibility to respond to manmade hazards, climate change, and conflict. For this, one of the ponds at the former BLWWTP site will be rehabilitated into a lined and aerated equalization basin to improve operations. The basin will allow to maintain a consistent flow, 24 hours a day, by storing excess wastewater at peak flows and returning it to the terminal pumping station during low flows. Another section of the pond is to be rehabilitated as an emergency reservoir. In the event conflict damages the treatment plant or there is some malfunction, the emergency reservoir is able to retain about six days of wastewater inflows. These inflows would then gradually be pumped back into the equalizer pond and ultimately into the terminal pumping stations.

The new Wastewater Management Sustainability project is also providing technical assistance to build capacity. Sustainable institutional and financial arrangements for O&M are the goals, in conjunction with the PWA, the four municipalities in North Gaza, and the CMWU. The CMWU will operate the

NGWWTTP and associated facilities once a number of agreements are in place: 1) an agreement between the PWA and CMWU outlining the conditions and obligations of both parties to instrumentalize arrangements to transfer to CMWU the O&M responsibilities and the assets of the NGWWTP, 2) service agreements with each of the four benefiting municipalities, outlining their contribution to the O&M costs of the NGWWTP.

The O&M arrangements for the irrigation scheme have yet to be settled. The idea is that the PWA would own and, for the first few years, operate the recovery-and-reuse systems with the ultimate goal of transferring the operation and management of the irrigation scheme to a Water Users Association (WUA)[5] in line with the 2014 Water Law. The creation of the new WUA is underway, supported by the Palestinian Ministry of Agriculture and the Food and Agriculture Organization (FAO), which will provide technical assistance to increase the WUA's capacity to operate and maintain the irrigation scheme, as well as technical assistance to farmers to improve their on-farm facilities. The WUA will contract with individual farmers, who will pay for the water distribution services based on their metered consumption. The recovery scheme (wells, pumping stations, and main pipelines) will be managed by the NWC once it is fully established, as the entity responsible for bulk water supply. The WUA will also have an agreement with the NWC to buy the bulk water produced from the recovery scheme. Costs for the O&M of the recovery-and-reuse schemes will initially be subsidized by the Palestinian Authority through coverage of electricity costs until farmers are able to cover the costs of the system (in approximately three years), estimated to be ILS 0.63/m^3 (USD 0.19/m^3). The tariff should be lower once the solar scheme is operational—ILS 0.40/m^3 (USD 0.12/m^3).

The O&M arrangement for the PV scheme depends on the location of the panels. Those located around the recovery scheme (3 ha) and in the restricted access area adjacent to NGWWTP (3.5 ha) will eventually be operated by the NWC. The CMWU will operate the PV panels located on the NGWWTP premises once it takes over O&M of the entire wastewater treatment system. Until then, the PWA will operate the solar scheme during a transitional period. Once the solar PV system is operational, the electricity costs of the NGWWTP and the irrigation and recovery schemes should plummet. A net metering agreement between the Gaza Electricity Distribution Company (GEDCO) and the PWA (and later the CMWU and the NWC) should show an annual balance of what the system has produced and consumed. Any over-production will be discounted from the electricity bills of other wastewater facilities in Gaza.

Benefits

Improved sanitation services. The NGWWTP and associated facilities are providing wastewater treatment services to some 370,000 people in the four municipalities of North Gaza. Of these, 52,000 from the communities surrounding the old BLWWTP benefit directly from the drained effluent lagoon, which no longer poses health and environmental safety threats.

Improved health outcomes. An assessment[6] was conducted in 2018 with project beneficiaries and data from local clinics. The assessment showed positive trends in the incidence of water-borne diseases (diarrhea, skin diseases, and typhoid), especially among children. Thus, on average, 64 percent of the respondents noted improvement in the incidence of these diseases (Beit Lahia, 70 percent; Jabalia, 70 percent; Jabalia Camp, 70 percent; Beit Hanoun, 60 percent; and Um Al Nasser, 50 percent). Insect populations have decreased, along with the number of households affected by wastewater accumulation and flooding, as reported by respondents.

Cleanup of historical aquifer pollution and aquifer recharge. Adequately treated wastewater can replenish the aquifer and clean up polluted underground water plumes. In turn, the cleanup prevents downstream contamination of municipal wells. These are

important environmental and public health co-benefits, as 13 million m^3 per year of good-quality water has been filtering into the aquifer since 2018. The project translates into benefits for 200,000 people, who will not only reduce their climate-risk exposure but also increase their access to usable domestic water. A cost-benefit analysis quantified the financial, social, and environmental costs if the NGWWMF were to be shut down for 48 months—also taking into consideration the flood risk posed by a possible breach of the resulting sewage lake at Beit Lahia. The median pollution scenario generated a net present value of US$9.8 million and an economic rate of return of 21 percent.[7]

Production of nonconventional water resources. The construction of the new NGWWTP allowed the production of 35,600m^3/day of treated effluent suitable for aquifer recharge and unrestricted reuse in irrigation. This result offers opportunities for treated effluent to be reused for irrigation purposes to improve agricultural production and increase economic opportunities in Northern Gaza. The later reuse of replenished water from the aquifer (rather than direct use of treated wastewater) is, in addition, a more acceptable way to reuse wastewater—especially in Muslim-majority countries where fresh, pure water plays a central role in Islamic spirituality. The irrigation scheme will provide water to 1,500 ha of agricultural land, benefiting about 4,200 farmers.

Reduction in O&M costs. The installation of the photovoltaic cells at the NGWWTP will cover all the electricity costs of the treatment and recovery-and-reuse schemes. The electricity costs at the NGWWTP amount to about half the total costs of O&M. The scheme will therefore slash these costs and help the CMWU achieve full recovery of O&M costs, making the system more sustainable.

Lessons Learned

In conflict situations, active engagement and flexibility to adapt to unforeseen circumstances are the key factors for achieving results. While precautions relating to a fragile situation can be projected, conflict and wars bring unforeseen delays and complications. The project started as an emergency intervention to ensure the health and safety of the communities surrounding the effluent lake. It was well known that the project was prepared in a challenging context, but developments such as Israel's disengagement from Gaza in 2005 and the wars in 2008-09, 2012, and again in 2014, were hard to foresee.

Despite fragility, projects can be implemented, and results achieved, when readiness is high among the World Bank and client teams. The project was able to achieve significant results, despite the context of fragility and conflict, through the strong commitment and proactivity of both the client and World Bank teams. Fragile, conflict-prone and violent environments produce ever-changing conditions, so the adaptability and flexibility of teams are vital

To help boost the sustainability of investments in settings marked by fragility, conflict, and violence, it is helpful to apply a life-cycle costing approach during project design. In Gaza, where uncertainty exists about the financial resources available for the operation and maintenance of water and wastewater infrastructure, a life-cycle costing approach should be used to ensure that capital, O&M, and replacement costs over the entire life of an infrastructure facility are considered as part of the technology selection process. In this case, the technology selection was driven by the need to respond quickly to the public health emergency in Beit Lahia, the restrictions on discharges of untreated wastewater into the Mediterranean, and the PWA policy that encourages wastewater treatment recovery and reuse. The chosen technology has high O&M costs. Despite attempts to ensure O&M cost recovery—difficult in the presence of conflict—this issue is still unresolved. Despite the undisputable environmental and societal benefits of the project, careful and practical consideration of O&M costs (and who will bear them) must be part of subsequent discussions of circular economy.

Where energy can be an unreliable resource, less energy-intensive solutions should be carefully considered. In Gaza, where energy is a particular challenge, particularly in view of the high O&M cost burden, it is necessary to consider alternative energy sources or less energy-intensive treatment technologies. In North Gaza, this led to considering solar panels to cover the electricity needs of the project and so to reduce the plant's O&M costs.

Long-term engagement on the institutional aspects of the water and wastewater sector can lead to legal and regulatory advancements more conducive to good water management. The long-term partnership between the Palestinian Authority and international financing institutions has led to a sound legal framework and capacity building that encourages the circular economy in water and wastewater investments. This is particularly relevant in water-scarce countries.

Note: This case study was prepared before the 11-day armed conflict in May 2021. Some of the estimated dates and operational arrangements might change as a result.

Notes

1. See, for example, https://www.worldbank.org/en/news/video/2018/08/06/delivering-life-saving-sanitation-services-in-gaza.
2. These are being operated for maintenance purposes every ten days to allow water to circulate through the system. The tank is emptied every four weeks, and the water used by nearby farmers.
3. Also known as the "buffer zone," the restricted access area (RAA) is a military no-go area that extends along the entire northern and eastern perimeter of the Gaza Strip, about 100m from the border with Israel.
4. Parameters are further specified in the technical specification TS 34/2012.
5. The WUA is a group of water users, like farmers or irrigators, organized to formally manage a shared irrigation system. A WUA elects leaders, handles disputes internally, collects fees, and maintains the system. According to the 2014 Law, WUAs have a legal personality, are financially independent, and have the right to own, use, and dispose of assets, movable and immovable, with the aim of achieving their objectives. The WUA for this irrigation scheme is being created.
6. The assessment included group discussions with about 400 beneficiaries representing 60 households from targeted villages and towns living in areas around the project, focusing on families with children. The assessment was complemented by observations and other secondary data previously collected by Water, Sanitation, and Hygiene (WASH) stakeholders and other monitoring groups.
7. Project Appraisal Document for the Wastewater Management Sustainability Project (P172578).

Background Documents

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