Management of Storm Water Harvesting in the Gaza Strip

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Ministry of Environment - Palestine
The Palestinian Territory consist of two physically separated land masses.

The West Bank
Area = 5885 km\(^2\)

The Gaza Strip
Area = 365 km\(^2\)

Both represent 22\% of Mandate Palestine.
The Gaza Strip lies at the eastern edge of the Mediterranean, its climate is characterised as semi-arid region and it is a part of one of the scarce water countries. It had a population of 1.7 million people living in 365 km2 area. Because it is separated from the West Bank geographically, its water resources are managed separately; its aquifer is a part of the coastal aquifer whereas the West Bank shares with other three mountain aquifers. Therefore, water resources in each part of Palestine are managed separately to fulfil the growing demand due to increasing population and social–economic development.
Land use

The area of the Gaza Strip is limited, where agricultural sector occupies about 184 km², which amounts to about 50% of the total area of the Gaza Strip.

The former settlements are now under Palestinian control and mostly they are sand dunes. Some of these areas are governed by municipalities and facing danger of urbanization.
The Largest Prison on Earth

The buffer zone in Northern Gaza is 8 Km², however, it is additional to the 53 Km² Israeli security belt wrapped around Gaza eastern side.
Gaza strip is a coastal foreshore plain gradually sloping westward toward the sea allowing for surface run-off to re-infiltrates the soil. A sandy beach stretches all along the coast, bound in the east by a ridge of sand dunes known as Kurkar ridges. This alternating sequence of permeable and impermeable layers serves as a natural catchment area for rainfall and renders the sand favorable for growing crops. The topography in the Gaza Strip is influenced by the ancient kurkar ridges, which runs parallel to the present coastal line. The altitude of the Gaza Strip land surface ranges between zero meters at the shore line to about 90 meters above mean sea level in some places.
Soil Feature of Gaza Strip
The soil of Gaza strip consists of dark to reddish brown silty, clayey soil types and loess soils with different sand content. The coastal area is characterized by sandy regosols showing poorly developed soil horizons. Food and Agriculture Organization (FAO) classifies the soil of Gaza strip as a one type of soil "Loam", which is inaccurate therefore this classification was not used. Ministry of agriculture in Gaza has published a modified soil map for Gaza strip as shown in the Map. It classifies the soil into six types:

- Sandy regosol.
- Loess soil.
- Loessial sandy soil.
- Sandy loessial soil.
- Sandy loess soil over loess.
- Dark brown / reddish brown.
The inflows to aquifer are estimated to be 107.9 Mm3 every year coming from natural infiltration, irrigation return flow, percolation pits of wastewater and artificial recharge of stormwater in the year 2009.

The total demand is estimated to be 162.1 Mm3 in the year 2009 to fulfil the domestic, industrial and agricultural needs. The gap between total demand and total supply gives us a total deficit in the water budget in year 2009 of about 54.2 Mm3.

The accumulating deficit every year led to continuous decrease in the groundwater levels that became few metres below the mean sea levels especially in the south in Khan Younis and Rafah, where groundwater levels reached 5m below sea level. The quality of the groundwater was also deteriorated, where chloride level (salinity) increased in water pumped from almost all the water wells either for domestic or agricultural uses.
The fresh zone is still available in the north of Gaza due to high rainfall amount (450 mm per year) compared to the south (200 mm per year). In some areas, salinity reached more than 1,500 mg /L as chloride ion. According to the groundwater numerical model for the Gaza Strip if the situation continues in the same manner, seawater intrusion with total dissolved solids concentration of 2,000 mg/L at the base of sub-aquifer (A) will move 1.5 km in the year 2020 in the northern part of Gaza. This will affect the quality of domestic wells used for public water supply based on the quality data of domestic wells. The WHO standard for chloride is 250 mg / L and the Palestinian standard is 600 mg / L. Results indicated that out of 99 monitored domestic wells, only 42 wells comply with the WHO standards and only 65 comply with the Palestinian standard.
Water Quality

Chloride concentration

Nitrate Concentration

Water Quality in the Gaza Strip

Chloride Concentration

mg/l
- 10.8 - 167.7
- 167.7 - 346
- 346 - 545.8
- 545.8 - 738.4
- 738.4 - 916.7
- 916.7 - 1,102.2
- 1,102.2 - 1,316.2
- 1,316.2 - 1,551.6
- 1,551.6 - 1,837

Nitrate Concentration

mg/l
- 45.5 - 66.5
- 66.5 - 80.5
- 80.5 - 93.2
- 93.2 - 104
- 104 - 115.4
- 115.4 - 129.44
- 129.4 - 147.9
- 147.9 - 174
- 174 - 208.3
Groundwater is the only water resource that is used to serve the people in the Gaza Strip. This water resource has been much exploited in the last three decades due to over abstraction. The renewable amount of water from rainfall that replenishes the aquifer is much less than the water demand, which has been increased due to increasing population. The per capita consumption is 138 L every day for both domestic needs. The population increased from 1,167,359 in the year 2000 to 1,515,924 in the year 2005, which increased domestic water demand from 57 Mm$^3$ in year 2000 to 75 Mm$^3$ in year 2005. The deteriorated water quality in terms of chloride and nitrate concentrations was reflected in the water services that are supplied in the public water supply system through 22 local municipalities distributed in five governorates in the Gaza Strip.
Storm Water Quantities

Gaza strip is located in a semi-arid region with limited rainfall quantities in autumn and winter seasons. In the past, the porous soil in large areas of Gaza strip easily absorbed most of the rainfall and it was considered as a Primary source for recharging the groundwater aquifer of the region. This is Especially true along the western “coastal” and the eastern part of Gaza strip, where sand dunes predominate the soil structure.

Annual average rainfall varies considerably across Gaza Governorates. It Varies from 450 mm per year at the north-eastern border to around 200 mm in Rafah at the south-western border with Egypt.
Storm water Quality

A recent study which was conducted by Hamdan, et al., 2010 (Quality Risks of Storm Water Harvesting in Gaza) concluded that, the quality of harvested Rooftop storm water runoff in Gaza has proved to be suitable for artificial recharge and it matches drinking water standards. The harvested storm water has low concentrations of chloride and nitrate so groundwater recharge will improve the quality of the existing brackish groundwater. The risk of heavy metal contamination of groundwater is low, since the measured pH in all rainwater runoff was close to 7.0. This reduces the risk of solution and mobilization of heavy metals in the infiltrating water.
Storm water Quality

Another study which was carried out by RAMLAWI, 2010 (Modelling & Monitoring the Impact of Storm water Artificial Recharge on Groundwater Case study: Beit-Lahia Municipality Infiltration Basin), the results showed that the quality of storm water in Beit Lahia infiltration basin is acceptable according to World Health Organization (WHO) in many parameters as No3 -, Cl-, Mg+2, Ca+2, Na+1, k+, detergent, turbidity, TSS, TDS, and hardness. However, the Fecal Coliform in storm water is not acceptable. The results were obtained from the analysis of storm water in the laboratory are shown in the next table for storm water in the infiltration basin, and The another for storm water after it penetrates 2 meters of sand.
# Results of Lab. Analysis of Storm water of the infiltration Basin

<table>
<thead>
<tr>
<th>Parameters</th>
<th>NAME OF SAMPLE</th>
<th>STORM WATER IN BASIN</th>
<th>STORM WATER IN BASIN</th>
<th>STORM WATER IN BASIN</th>
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<tbody>
<tr>
<td></td>
<td>SYMBOL OF SAMPLE</td>
<td>B1</td>
<td>B2</td>
<td>B3</td>
</tr>
<tr>
<td></td>
<td>UNIT / DATE</td>
<td>February</td>
<td>March</td>
<td>April</td>
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<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>39.8</td>
<td>36</td>
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<tr>
<td>TDS</td>
<td>Ppm</td>
<td>220</td>
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<td>TSS</td>
<td>Ppm</td>
<td>296</td>
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<td>595</td>
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<tr>
<td>NO3-</td>
<td>Ppm as No3-</td>
<td>13</td>
<td>12</td>
<td>7</td>
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<tr>
<td>CL-</td>
<td>Ppm as CL-</td>
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<td>39</td>
<td>20</td>
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<tr>
<td>Hardness</td>
<td>Ppm as CaCo3-2</td>
<td>119</td>
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<td>125</td>
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<tr>
<td>Ca+2</td>
<td>Ppm as Ca+2</td>
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<td>28</td>
<td>24</td>
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<tr>
<td>Mg+2</td>
<td>Ppm as Mg+2</td>
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<td>13</td>
<td>21</td>
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<tr>
<td>K+</td>
<td>Ppm as K+</td>
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<td>4</td>
<td>2.7</td>
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<tr>
<td>Na+</td>
<td>Ppm as Na+</td>
<td>23</td>
<td>18</td>
<td>16</td>
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<tr>
<td>Fecal Coliform</td>
<td>Colony / 100 ml</td>
<td>150</td>
<td>190</td>
<td>135</td>
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<tr>
<td>Detergent</td>
<td>ml / L</td>
<td>0.27</td>
<td>0.21</td>
<td>0.18</td>
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</table>
Results of Lab. Analysis of Storm water after penetrating 2 m of sand

<table>
<thead>
<tr>
<th>Parameters</th>
<th>NAME OF SAMPLE</th>
<th>STORM WATER IN BASIN</th>
<th>STORM WATER IN BASIN</th>
<th>STORM WATER IN BASIN</th>
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<td></td>
<td>SYMBOL OF SAMPLE</td>
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<tr>
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<td>B2</td>
<td>B3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UNIT / DATE</td>
<td>February</td>
<td>March</td>
<td>April</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>3.6</td>
<td>3.1</td>
<td>2.8</td>
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<td>TDS</td>
<td>Ppm</td>
<td>222</td>
<td>206</td>
<td>195</td>
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<tr>
<td>TSS</td>
<td>Ppm</td>
<td>45</td>
<td>53</td>
<td>63</td>
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<tr>
<td>NO3-</td>
<td>Ppm as No3-</td>
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<td>11</td>
<td>7</td>
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<tr>
<td>Cl-</td>
<td>Ppm as Cl-</td>
<td>43</td>
<td>35</td>
<td>28</td>
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<tr>
<td>Hardness</td>
<td>Ppm as CaCo3-2</td>
<td>125</td>
<td>130</td>
<td>130</td>
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<tr>
<td>Ca+2</td>
<td>Ppm as Ca+2</td>
<td>34</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Mg+2</td>
<td>Ppm as Mg+2</td>
<td>20</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>K+</td>
<td>Ppm as K+</td>
<td>3.2</td>
<td>3.5</td>
<td>2.9</td>
</tr>
<tr>
<td>Na+</td>
<td>Ppm as Na+</td>
<td>23</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Fecal Coliform</td>
<td>Colony / 100 ml</td>
<td>100</td>
<td>120</td>
<td>130</td>
</tr>
<tr>
<td>Detergent</td>
<td>ml / L</td>
<td>0.25</td>
<td>0.2</td>
<td>0.18</td>
</tr>
</tbody>
</table>
Catchment Areas:

Gaza Strip is divided into 24 catchment areas according to the topography as shown in the Figure. Each governorate has more than one catchment area.
As priority in the Palestinian policy, stormwater harvesting is considered as a major part of every large-scale project implemented, e.g. roads, port, industrial estates, etc. There will be local infiltration sites in each project. However, large-scale infiltration schemes were considered in the last ten years as a major component of the water resources management in Palestine in general, and in the Gaza Strip in particular. Artificial recharge became a priority after the Israeli disengagement from the Gaza Strip. Most of the disengaged areas are sand dunes.
Proposed Strategy for Storm Water Harvesting

The consultants propose different levels of strategies for storm water harvesting in Gaza. There are three levels of strategies proposed in this plan which are:

• At home level
• At street level
• At governorate level.

There are several proposed options for each strategy level.

The following table indicates these strategies for storm water harvesting for Gaza Strip
# Proposed Strategy for Storm water Infiltration

<table>
<thead>
<tr>
<th>Strategy level</th>
<th>Requirements</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>level one:</strong></td>
<td>The majority of buildings do not separate storm water outlets from wastewater outlets. There are no relevant Building Regulations dealing such issue. Also the technical problems of separation in existing buildings have to be identified.</td>
<td>Draft the required regulation. Conduct a pilot project among number of houses to determine the most practical separation process and the possibility of infiltrating storm water in home yards. Socio economic survey will be conducted to examine the socioeconomic impact of storm water separation.</td>
</tr>
<tr>
<td>Level two:</td>
<td>The consultant will select certain places in Gaza and construct several soak away systems to examine its practicality in Gaza and the impacts on groundwater aquifer through constructing observation wells.</td>
<td>Storm water harvesting from the streets using soak away system.</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>The quantities of storm water that cannot be infiltrated into home yards will be examined to use streets as infiltration land for these quantities using soak away. The width of roads in Gaza have been taken more than 12 m.</td>
<td></td>
</tr>
<tr>
<td>level three:</td>
<td>Infiltration plan with possible infiltration basins will be determined based on previous studies.</td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Storm water harvesting at the neighborhoods using storm water networks with reservoirs and infiltration basins</td>
<td>There are many storm water networks in Gaza with storage reservoirs and infiltration basins. The consultant will study the need for several infiltrations basins where access storm water is not infiltrated through home yards and street soak away.</td>
<td></td>
</tr>
</tbody>
</table>
An infiltration basin is a shallow artificial pond that is designed to infiltrate storm water though permeable soils into the groundwater aquifer. This process is believed to have high pollutant removal efficiency and can also help in recharging the groundwater.

Infiltration basins can be challenging to apply on many sites, because of soil requirements. In addition, some studies show relatively high failure rates compared with other management practices.
Sand
Kurcar
Gravel

Proposed in-site storm water infiltration system
Soakaways for each Governorate
Conclusions and recommendations

Urban stormwater harvesting is an important water resource that plays a significant role in enhancement of water resources management in Palestine in general, and in the Gaza Strip in particular. It has a potential input of about 22 Mm$^3$ every year from urban areas only and about 28 Mm$^3$ per year as runoff from the whole Gaza Strip in its current landuse. This will help in bridging of about 60% of existing water deficit in the water budget.

These amounts of stormwater in the Gaza Strip will reach about 37 Mm$^3$ per year from planned urban areas. The amount of runoff of the completely planned area is calculated to be about 43 Mm$^3$. When urban expansion is implemented as planned, the natural infiltration of rainfall to the aquifer will decrease, and these amounts of runoff are good resources to be utilised.
So, more stormwater harvesting projects are needed to help in decreasing the water deficit in the water resources budget. Some large-scale stormwater harvesting projects were constructed in north and south of Gaza Strip, but there was not perfect control to avoid risky behaviours of the local people that hinder the function of these projects. Some small infiltration schemes were implemented too to allow local infiltration from nearby areas.

The natural recharge of rainfall is about 40% of the total bulk rain quantities fallen on the Gaza Strip with an average of 117 Mm³ every year. The rest of water that flows to the sea or evaporated could be harvested through the constructed infiltration basins. Owing to the existing deficit in the water budget, the groundwater quality was deteriorated and salinity reached more than 1,500 mg / L as chloride ion. Moreover, the groundwater levels were declined continuously and reached a level of 5 m below sea levels. If no action is taken in resources management, the groundwater system will reach a point, where remediation becomes very difficult. Therefore, stormwater harvesting together with other new resources such as large-scale desalination and reuse of wastewater will bridge the gap in the water deficit and protect the groundwater system and will be used in a sustainable state.
Israeli Occupation

Despair & Extremism
Water Depletion

Poverty

Limited Economic Opportunities

Investment shortages

Social and Health Problems
Decrease in Agricultural Production

Increase Unemployment Rate

Closure
Uprooting Trees

Land Confiscation

Absence of Geographical Integrity

Obstacles against Overall Development Planning

Migration

Land Fragmentation
Lack of Open Space
Increased Urban density
Abu Ghunaim Mountain
March 1997

The only forest in Bethlehem

Abu Ghunaim mountain
January 2001

New Israeli
Colony of
Har Homa

Degradation of the Palestinian Environment
Municipal Wastewater Management

• In the West Bank:
  – An annual wastewater volume of 29.5 MCM is generated
  – Sewage networks serve around 28% of the total population

• In Gaza Strip:
  – An annual wastewater volume of 21.4 MCM is generated
  – Sewage networks serve around 66% of the total population

• The remaining population uses cesspits for wastewater disposal.
The Palestinian Economy

- The Palestinian economy depends on remittances. **Industry and agriculture contribute 7 and 12 % to the GNP. Tourism** was supposed to become the largest productive sector but has collapsed.
- The OPT imports from Israel four times as much as it exports to Israel.
- Israel set restrictions on the type of products that could be imported.
- The customs union with Israel and the dependency on remittances from Palestinians working in Israel, coupled with the lack of control of the PA ’s borders and, with it, trade, has made the Palestinian economy vulnerable to Israeli constraints (**Distorted Economy**)
- The Paris Protocol formalized the Palestinian- Israeli economic relationship.
- Israel kept control of the levers of the Palestinian economy:
  - control of borders and ports of entry;
  - power of veto over certain imports; regulation of the movement of labour;
  - and the ability to withhold disbursement of taxes due to the PNA.
Today, there are more than 450,000 Israeli settlers living in the Occupied Palestinian Territory of whom, 235,000 are in East Jerusalem.
• The *Western Basin* is the largest and has an annual safe yield of 362 MCM. Palestinians consume only about 7.5% of its safe yield.

• The *Northeastern Basin* has an annual safe yield of 145 MCM. Palestinians consume about 18% of its safe yield.

• The *Eastern Basin* has an annual safe yield of 172 MCM. Palestinians are utilizing 50% of the waters of this basin.

• 485:115
The Myth of natural growth

Actual Settler Population and Growth Rates during the years 1992 & 2004
“A state exists chiefly in the hearts and minds of its people; if they do not believe it is there, no logical exercise will bring it to life.”
The People

• The Occupied Palestinian Territory of East Jerusalem, the West Bank, and Gaza Strip have a population of around 3.5 million.

• The natural growth rate is > 4%.

• Half of the population is under the age of eighteen.

• The OPT would, under normal circumstances, be categorized as middle rather than low income.

• The Palestinian society is well-educated with a sizeable middle class, and a tradition of a strong and vibrant civil society.
Base Population Projection
1997 PA Census and Projection
(1997 - 2004)

Source: Palestine Central Bureau of Statistics 1997 Census and Projection (2)
Depletion of Water Resources

- Palestinians are denied their historic right to the Jordan River waters.

- Israel is currently utilizing more than 82% of the Palestinian groundwater resources by piping this resource to the illegal colonies and into Israel proper and thus inducing water scarcity in the area.

- In Gaza, Palestinians are forced to over-pump the shallow coastal aquifer leading to sea water intrusion and consequently, deteriorating water quality.

- More than 220 Palestinian communities (25% of the total population) is not served by the public water network.
• The Gaza coastal aquifer has an annual safe yield of 55 MCM but is over-extracted at a rate of 120 MCM which led to seawater intrusion.
• 95% of water in Gaza is not suitable for domestic consumption.