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Assessment of Rainwater Run-off Due to the Proposed Regional Plan for Gaza Governorates

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Abstract: Throughout the years, Gaza Strip has been experiencing an increasing shortage of water, due to growing demands and its location in a semi-arid region with a small average rainfall of 300 mm/year. The main source of water in the Gaza Strip is the groundwater aquifer that is naturally recharged from rainfall. Over the time, continuous increase of population resulted in dramatic urban expansion, which has a direct influence in reducing groundwater recharge and increasing the surface run-off. To quantify the losses due to run-off, Geographical Information Systems (GIS) as a measurement tool, in addition to the soil conditions and metrological data for more than 20 years is used. The urbanized area represents around 16% in the year of 1998 and 21% in the year of 2005 and is expected to increase in the next years due to the rapid increase in population to represent 33% for the year of 2015. In the meantime, the water demand will increase due to the expansion of water supply systems. The total amount of rainwater losses due to urbanization as surface run-off is estimated 14.5 Mm^3 in the year of 1998 and expected to increase to about 20, 35 Mm^3, for the years of 2005, 2015, respectively. These will results in an increasing pressure on underground water resources, which has lead to an irreversible depletion of the aquifer. Mitigation measures, such as rainwater collection and areas for natural recharge should be protected.

Key words: Groundwater recharge, urban expansion, rainfall, run-off, GIS, Gaza Strip

INTRODUCTION

Urban population growth and rapid urbanization have profound impact on the hydrological cycle, including major changes in groundwater recharge (Lawrence *et al.*, 1998).

The density of population in the Gaza Strip is considered to be the highest population density in the world especially in the refugee camps, which represents more than 70% of Gaza Strip residents. Most of the urban expansion falls outside formal planning domain. In addition, absence of adequate legal and administrative framework for planning, control and enforcement of land use leads to destroy natural resources especially the groundwater.

Increasing urban areas in Gaza Strip like most of the communities in the world causing increase in surface run-off. For a given rainfall, increased volume of run-off and peak discharge is two effects attributable to urban development (Pouraghniaei, 2002).

Many physical characteristics affect run-off: land use, vegetation, elevation, soil type and topography. The changes in recharge caused by urbanization in turn influence groundwater levels and flow regimes in underlying aquifers (Van de Ven, 1990). Infiltration rates are dependent upon texture of the soil material, but more important is the structural condition of the soil material. The infiltration rate is reduced under the highly disturbed urban condition where structure may be nearly destroyed. Consequently, significant decline in infiltration rates is attributed to urban disturbances.

The ministry of planning (MOP, 2005) proposed a regional plan as a basis for the Palestinian future development including the land use. The current research concerns about the amount of the rainfall, which mostly consider as losses due to the future land use and urban expansion of cities and refugee camps. The main aim of the research is the assessment of rainwater run-off due to the proposed regional plan for Gaza Governorates and its effect on groundwater recharge.

MATERIALS AND METHODS

Rainfall: Rainfall occurs only in the winter months (October-March), most of the Rainfall occurs during December to January. The number of rainy days as

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recorded in different weather stations along Gaza Strip is 41 days. The distribution and the availability of rainfall in space and time are important for rainfall-run-off process.

According to Geohydrologists point of view; effective rainfall that part of rainfall which contributes to groundwater storage, in which the extent of the rise in the water table or well levels would be the effective rainfall. Assessments of effective rainfall provide an indication of how much of the rainfall over an aquifer outcrop actually contribute to the recharge of groundwater (UKEA, 2001). This study will be relied on the later concept to calculate the effective rainfall in Gaza Strip for a period of 24 years.

Quantified annual run-off: This study is relied on the basic water balance equation to quantify the annual run-off, Because of that is widely used and perfectly acceptable for calculating the of surface run-off quantity.

$$Q = C\, i\, A$$

Where;

Q is the annual run-off, C is the Run-off coefficient which represents the ratio of run-off to rainfall for the drainage area considered, i is the annual rainfall and A is the drainage area.

Run-off coefficient: The Run-off Coefficients of Paved roads/Parking; Residential Communities and Commercial/Public lots are 0.9, 0.6 and 0.7, respectively (Sogreah and Team, 1999). Based on the representative ratio of these different types of impervious surfaces from the total build up areas which are 11.42, 47.55 and 40.95, respectively (MOLG, 2004), the existing run-off coefficient (C) for these build up areas in Gaza Strip will be equal:

$$C = 11.42 \times 0.9 + 47.55 \times 0.6 + 40.95 \times 0.7 = 67\%$$

While that's for the proposed urban expansions for the years 2015, will be 0.78, in case of constant rate of expansion of different impervious surfaces.

Amount of rainfall infiltrated various soil types: The amount of rainfall reaches the soil surface is calculated by:

$$q = I \times A$$

Where; q is the amount of rainfall reaches the soil surface, I is the annual rainfall measured at the nearest metrological station to the considered area and A is the considered area. The results indicated that, the infiltration rates of the different soil types are high and exceeding the rainfall intensity which is about 26 mm h^{-1} for five years return period. So, the amount of rainfall reaches soil surface will be infiltrated in.

Infiltration rate for the varies soil types: Different types of soil allow water to infiltrate at different rate based on soil structure and texture. Texture of Gaza Strip soil types throughout profiles in different depths (30, 60, 90 and 100 cm), initial infiltration rate and basic infiltration rate by using infiltrometer is measured by Goris and Samain (2001). The computations of the infiltration rate of the different soil types in Gaza Strip derived from infiltrometer reading and Horton's equation is illustrated in Table 1. the estimated infiltration rate of soils is based on Horton's equation:

$$f = f_b + (f_o - f_b)\, e^{-kt}$$

Where; f is the infiltration rate, f_o is the initial infiltration rate, f_b is the final constant infiltration rate at large times and K is the soil parameter .

Based on the Gaza Strip soils classification made by Ministry of Agriculture (MOA) and MOPIC (1997) as shown in Fig. 1, the area of these different soils according to its location is calculated by using GIS measurements.

Topography and run-off directions: The directions and magnitudes of Gaza Strip topographical slope, which are indicated in Fig. 2 and 3, are derived from GIS measurements. Most of Gaza Strip topographical area is described as flat area and gradually sloping with a range from (0-5)%, westward toward the sea allowing for surface runoff. Where these figures illustrate the westward decline to the sea and Fig. 4 show a number of depressions area. These depressions areas detained water during the run-off events. This water will subsequently evaporate or infiltrate into the soil according to the type of the soil surface. Depression area is like interception, has the effect of reducing run-off at the beginning of a rainfall event (McGhee, 1991). From the Figures, it is apparent that's the depressions founded at elevations ranging from 20 to 60 m, wherein the Surfaces type is impervious due to the urbanizations, as consequently the amount of water detained will be losses due to evaporation or run through the storm water collection system, which finally pumped to the sea.

Hydrogeology of the Gaza Strip: There are no permanent surface water resources in the Gaza Strip. Temporary flow of surface run-off owing to rainfall is the only source of ephemeral surface water (Wadis). A major problems associated with Wadis in Gaza Strip include, urbanization with increased building near those natural areas, discharge of untreated sewage, disposal of solid waste in the Wadis coarse and loss of flow due to Israeli interception. Sogreah and Team (1999) reported that the surface water (Wadis) infiltration mount is estimated to be between (1-4) Mm^3/year.

Table 1: Infiltration rate of various soil types in Gaza Strip based on infiltrometer reading and Horton's equation *

Soil type	**Codes, Locations, area of different soil types: Code	Location	Area (m^2)	From the total area (%)	Initial infiltration f_o(mm min^{-1})	Basic infiltration f_b(mm min^{-1})	K	Infiltration rate f(mm min^{-1})
Loess soil	1	Gaza City	18837495	06.6	07.14	2.03	0.08	07.0
	4	Wadi Gaza	5082675					
		Total area = 23920170.75						
Dark brown/reddish brown	2	Gaza, Wadi Gaza	15805892	13.7	17.52	3.48	0.11	16.0
	6	Wadi Alslqa +Al-Qarara	4549557					
	11	Beit Hanoun	29290185					
		Total area = 49645634.95						
Sandy loess soil	3	Deir Albalah + Zaweda+ Maqhazi	26035828	09.0	4.51	1.10	0.06	04.3
	8	Abssan	4615097					
	9	Rafah	1866893					
		Total area = 32517819.55						
Loessial sandy soil	5	Deir Albalah+ Al-Qarara Khanyounis + Rafah	82937834	23.0	8.31	2.43	0.08	07.9
		Total area = 82937834.35						
Sandy loess over loess	7	Khanyounis + Rafah	58324040	16.2	5.96	1.62	0.08	06.0
		Total area = 58324040.84						
Sandy regosols	10	It is founded along the Coastal plain of Gaza Strip	113848480	31.5	21.05	6.69	0.24	18.0
		Total area = 113848480.34						
Total soil types area			361193981 m^2	%100				

*Horton equation: $f = f_c + (f_o - f_c)\, e^{-k_t t}$ ** Code according to the location of the soil

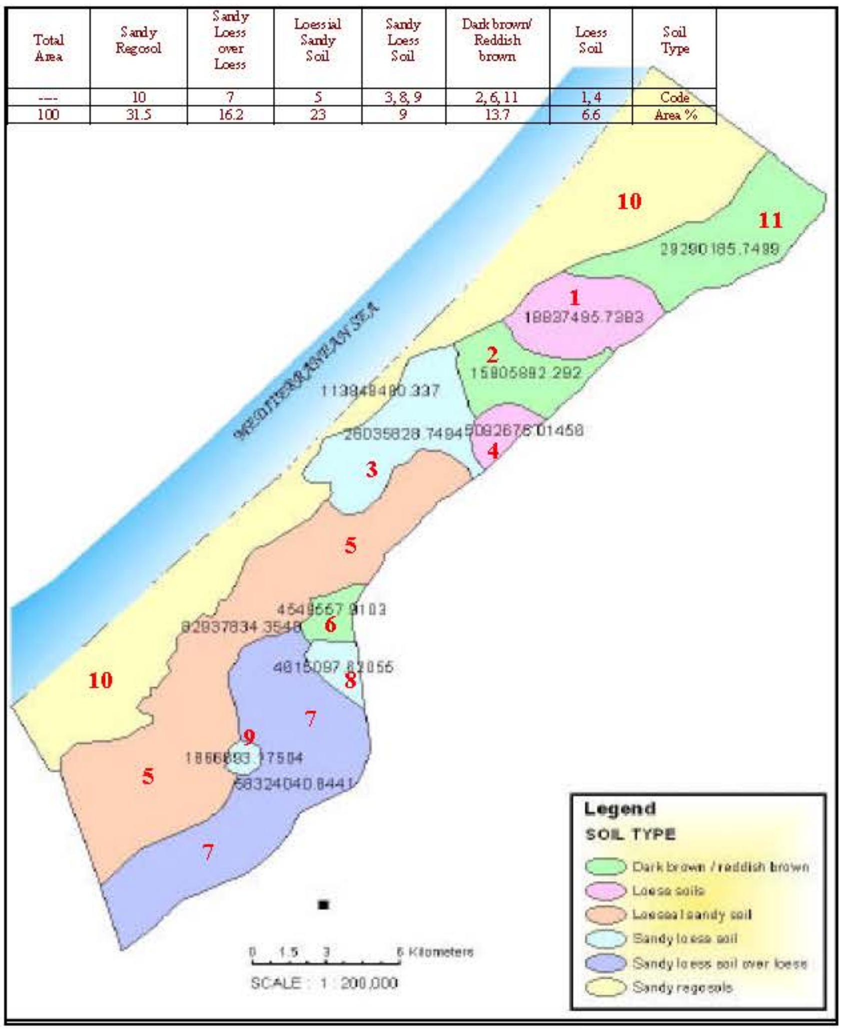

Fig. 1: The area of different soils type in Gaza Strip

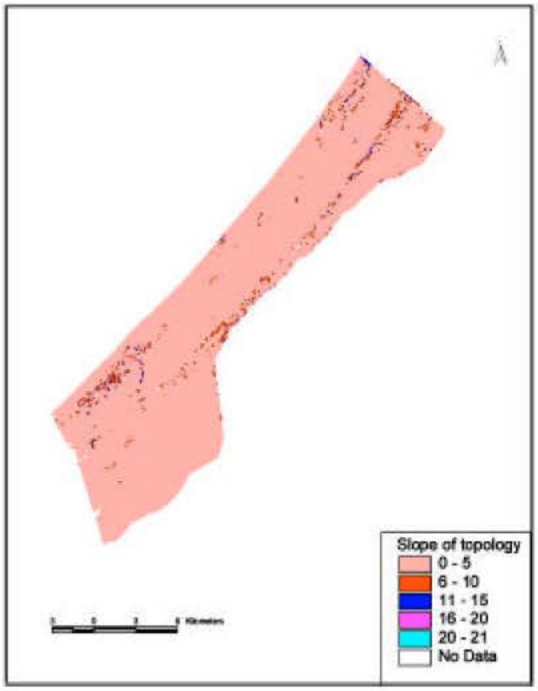

Fig. 2: Topographic slope magnitude

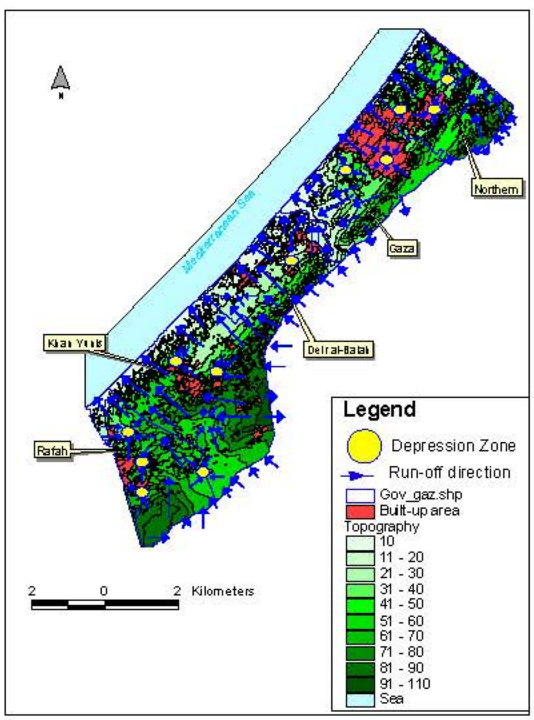

Fig. 3: Topographical map, run-off directions and depression areas

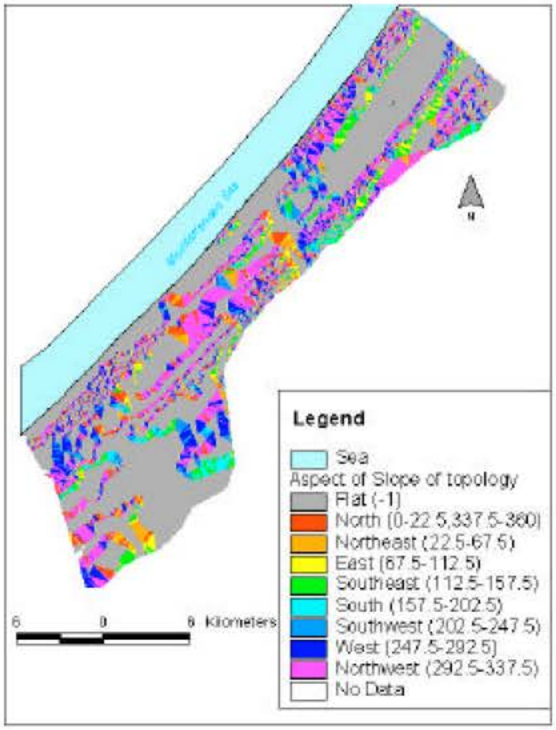

Fig. 4: Topographical slop directions

Groundwater in the Gaza Strip occurs in a system of shallow sub-aquifers, which is made up mainly of quaternary sands; calcareous sandstone and pebbles with inter beds of impervious semi-pervious clay. Approximately 90% of the Gaza Strip water comes from this shallow coastal aquifer (Al-agha, 1995).

Groundwater is found in three aquifers composed mainly of sand, sandstone and pebbles. The three aquifers are divided into sub-aquifers that overlay each other in certain places separated by impervious and semi-impervious clayey layers (Mogheir, 1997), where these aquifers described as follows:

- The upper aquifer lies closest to the sea and extends to 2 km inland at a depth mainly below sea level.
- The middle sub-aquifer is situated below the upper aquifer near the coastline. They rise in an eastward direction according to the general slope of the geological layers.
- The lower sub-aquifers extend further inland.

RESULTS AND DISCUSSION

The influence of existing land use: By use of GIS measurements, the build up area which included residential, industrial, commercial and a paved and unpaved road represents about 16%, where an agricultural area represents about 57%, in which it included agricultural, assisting agriculture areas and Israeli settlements area. An open area, which includes sand dunes and unused land, represent an area of about 27% from the area of Gaza Strip.

The calculations is based on the administrative classification, in which Gaza Strip is divided into five governorates which are: Northern, Gaza, Middle, Khanyounis and Rafah, with an area of (60.7, 73.4, 56.2, 110 and 60.5) km^2, respectively.

As indicated in the Table 2, it is clear that from the amount of 88 Mm^3/year, hitting the surface area of Gaza Strip, the net amount infiltrated in all different surface types is estimated to be 76.3 Mm^3/year, while amount of 71.2 Mm^3/year, is infiltrated in situ, about 5.1 Mm^3/year, from the total amount of run-off which estimated to be of about 14.54 Mm^3/year, were infiltrated in an open and agricultural areas after awhile. The total amount of urban runoff in Gaza Strip that drains direct to the sea is 1.1 Mm^3/year.

The amount of rainwater losses either by evaporation or direct run-off to the sea, from the total amount of rainfall hits the surface area is estimated to be 11.7 Mm^3/year, where the total amount of rain water lost by interceptions and evapotranspiration from the total amount of rainfall incidents in Gaza Strip as the average rainfall is 300 mm/year and total amount of rainfall

Table 2: The influence of the existing land use

Governorate	Item	Area calculated by GIS (m^2)	Average rainfall (mm/year)	Rainfall amount Hitting the Surface (Mm^3)	Evaporation 10% (Mm^3)	Infiltration *in situ* (Mm^3)	Run-off amount (Mm^3)
Northern	Build up area	10474960	465	4.9	0.50	1.10	3.30
	Open area	23835750	465	11.1		11.10	
	Agriculture area	26371998	231	6.1		6.10	
	Total area	60682708		22.0	0.50	18.30	3.30
Gaza	Build up area	21972379	436	9.6	1.00	2.20	6.40
	Open area	20370046	436	8.9		8.90	
	Agriculture area	31016425	210	6.5		6.50	
	Total area	73358851		25.0	1.00	17.60	6.40
Middle	Build up area	7501893	363	2.7	0.30	0.60	1.80
	Open area	12368555	363	4.5		4.50	
	Agriculture area	36353273	177	6.4		6.40	
	Total area	56223721		13.6	0.30	11.50	1.80
Khanyounis	Build up area	10388624	306	3.2	0.30	0.70	2.10
	Open area	26340802	306	8.1		8.10	
	Agriculture area	73339147	120	8.8		8.80	
	Total area	110068574		20.0	0.30	17.60	2.10
Rafah	Build up area	5680319	242	1.4	0.14	0.32	0.92
	Open area	15688921	242	3.8		3.79	
	Agriculture area	39118444	55	2.1		2.10	
	Total area	60487683		07.3	0.14	06.20	0.92
Total		360821537		88.0	2.20	71.00	14.50

Governorate	Item	Area calculated by GIS (m^2)	Run-off amount destination (Mm^3) Direct to the sea	Agriculture area	Open area	Impervious area	Direct to Israel	Total losses (Mm^3)	Net infiltration (Mm^3)
Northern	Build up area	10474960	0.05	2.70	0.26	0.07	0.20	0.80	4.1
	Open area	23835750							11.1
	Agriculture area	26371998							6.1
	Total area	60682708	0.05	2.70	0.26	0.07	0.20	0.80	21.2
Gaza	Build up area	21972379	0.06	0.02	0.03	6.30	0.02	7.30	2.3
	Open area	20370046							8.9
	Agriculture area	31016425							6.5
	Total area	73358851	0.06	0.02	0.03	6.30	0.02	7.30	17.7
Middle	Build up area	7501893	0.70	0.50	0.06	0.60		2.00	1.1
	Open area	12368555							4.5
	Agriculture area	36353273							6.4
	Total area	56223721	0.70	0.50	0.06	0.60		2.00	12.0
Khanyounis	Build up area	10388624	0.07	0.90		0.10	1.10	1.60	1.6
	Open area	26340802							8.1
	Agriculture area	73339147							8.8
	Total area	110068574	0.07	0.90		0.10	1.10	1.60	18.5
Rafah	Build up area	5680319	0.18	0.60	0.05	0.10		0.42	1.0
	Open area	15688921							3.8
	Agriculture area	39118444							2.1
	Total area	60487683	0.18	0.60	0.05	0.10		0.42	6.9
Total		360821537	1.10	4.60	0.40	7.10	1.30	12.00	76.0

is 120 Mm^3/year., is estimated to be 32 Mm^3/year. According to a study done by Dutsche Gesellschaft feur Technische Zusasammenarbeit (GTZ) and quoted by (PWA), the total amount of urban run-off in Gaza Strip that run-off directly to the sea is 2.1 Mm^3/year. Moreover, the total amount of runoff lost either by evaporation or drainage to the sea reaches about 7 Mm^3/year. which is expected to increase to 80% in 2010 and 150% in 2020 (PECDAR, 2000).

In case of that the total amount of run-off which estimated to be 14.54 Mm^3/year, were conducting by storm water collection and sewage systems and 37 Mm^3/year., is the intercepted amount of rainfall by the horticulture plants before hitting the surface area and the evaporation amount from the surface is estimated to be 2.2 Mm^3/year, therefore the total losses from 125 Mm^3 of rainfall incidents on Gaza Strip is estimated to be 54 Mm^3/year. Consequently the annual losses represent about 43% from total accumulated amount of precipitations, in which this amount is not included that's amount lost by transpirations from the agricultural areas. And as a result in this case the net amount of rainwater infiltrated into the different soil types is estimated to be 57%.While Abu-Mayla *et al.* (1998) reported that: About 40% of the total annual rainfall infiltrates into the ground and recharges the groundwater system.

The influence of proposed land use: The scarcity of land is the largest constraint regarding the future developments of Gaza Strip. Estimation of the future land use for different sectors according to the visions of a number of ministries, especially MOPIC (1998) is illustrated as follow:

Future land use demand for agriculture: Agriculture is the largest sector in the economy of Gaza Strip and contributes to 32% of the economic production. Agriculture has passed through stages of expansion and land reduction. The cultivated area increased from 170 to 198 km^2 from 1966- 1977. In 1978, the cultivated area was reduced to 179 km^2 mainly due to the increase in urban areas. Agricultural land is mostly in private ownership. Seventy three percent of the agricultural land of parcels of less than 9 dunums. (MENA, 2001). Metcalf and Eddy (2000) suggested that, the current land use will not expanded in the future due to that not much land in Gaza Strip left unused, they claimed that the future expansion will be for the residential use on the account of agricultural land already used.

Future urbanized land demand: The present urban expansion is concentrated in the western coastal zones of Gaza. The expansion of buildings and other dwellings is estimated to be 1000-1500 dunums per year (MENA, 2001). The rate of urbanization in Gaza Strip has increased over the last 10 years of about 39%. The percentage increase is estimated as approximately 50% over the next 10 years and over 100% over 20 years (PECDAR, 2000). Table 3 illustrated the demand build up area land per governorate for 1997, 2005, 2015. The projected urbanized area are included all the area needed for housing unit, roads, industry, commerce, service and recreations. Nowadays, the urbanized area represents around 20% while it expected to reach 26% of the total Gaza Strip area by year 2010.

Future urban run-off for Gaza Strip: As mentioned before, increasing urbanization means increasing impervious surfaces and therefore increasing surface run-off. Due to that's the detailed information and maps for the future land use demand; which proposed by MPOIC (1998) is not offered except that's for the year 2015, a detailed computations for the influence of land use demands on surface run-off and rainfall amount infiltrated into different surfaces type for the year 2015, as shown in Fig. 5 and Table 4.

Table 3: The urbanized land demand per governorates (MOPIC, 1998)

	Urban area (km^2)		
Governorates	1997	2005	2015
Northern	13.57	16.72	21.58
Gaza	20.23	28.94	44.12
Middle	7.03	10.34	15.40
Khanyounis	10.82	15.46	34.68
Rafah	05.86	08.35	12.31
Total	57.50	79.80	128.08

According to the regional plan proposed by MOP (2005) and the author calculations depends on GIS measurements, the build up area for the year 2015 will be increased to represent about 33% from the total area of Gaza Strip. In additions to face the population's growth and due to Gaza Strip limited area, these build up areas will be denser than that is in the previous years. As a consequence and by considering the increase in the different types of impervious surfaces from year to year is of a constant ratio, the run-off coefficient will be increased from 0.67 for the years 1998 and 2004, to be about 0.78 for the year 2015. While the open area will be decreased from 26% to be represented about 18%, the agriculture land will be changed from the existing one of about 57% to represent about 48% for the year 2015. Generally, the proposed land use in Gaza governorate for the year 2015 will show an increase in the impervious surfaces as a result of a huge urban expansion that's will be occurred, in contrast decreasing in both agricultural and open areas. Therefore, it is clear that's the total amount of rainfall lost, as a surface run-off in Gaza Strip will be increased to be about 35 Mm^3/year, where the amount of rainfall infiltrated will grade down to be about 55 Mm^3/year, in a case of Gaza Strip having a storm water collection system. Alternatively, in case of Gaza Strip does not have storm water collection system, the amount of surface run-off will be about 28 Mm^3/year, due to that amount of about 7 Mm^3/year, will infiltrate into agricultural and open areas, therefore the net infiltrated amount will increase to be about 62 Mm^3/year. With each passing year, Gaza Strip becomes increasingly urbanized. Agricultural and open areas give way to new housing and business developments. These new developments replace permeable soils with impervious surfaces like concrete, decreasing infiltration and recharge and increasing run-off. Where water once absorbed into the soil and recharged the groundwater system, it now runs- off roofs, sidewalks and parking lots that do not allow infiltration leading to increased flooding and associated non-point-source pollution. Table 5 show the changes in urbanized

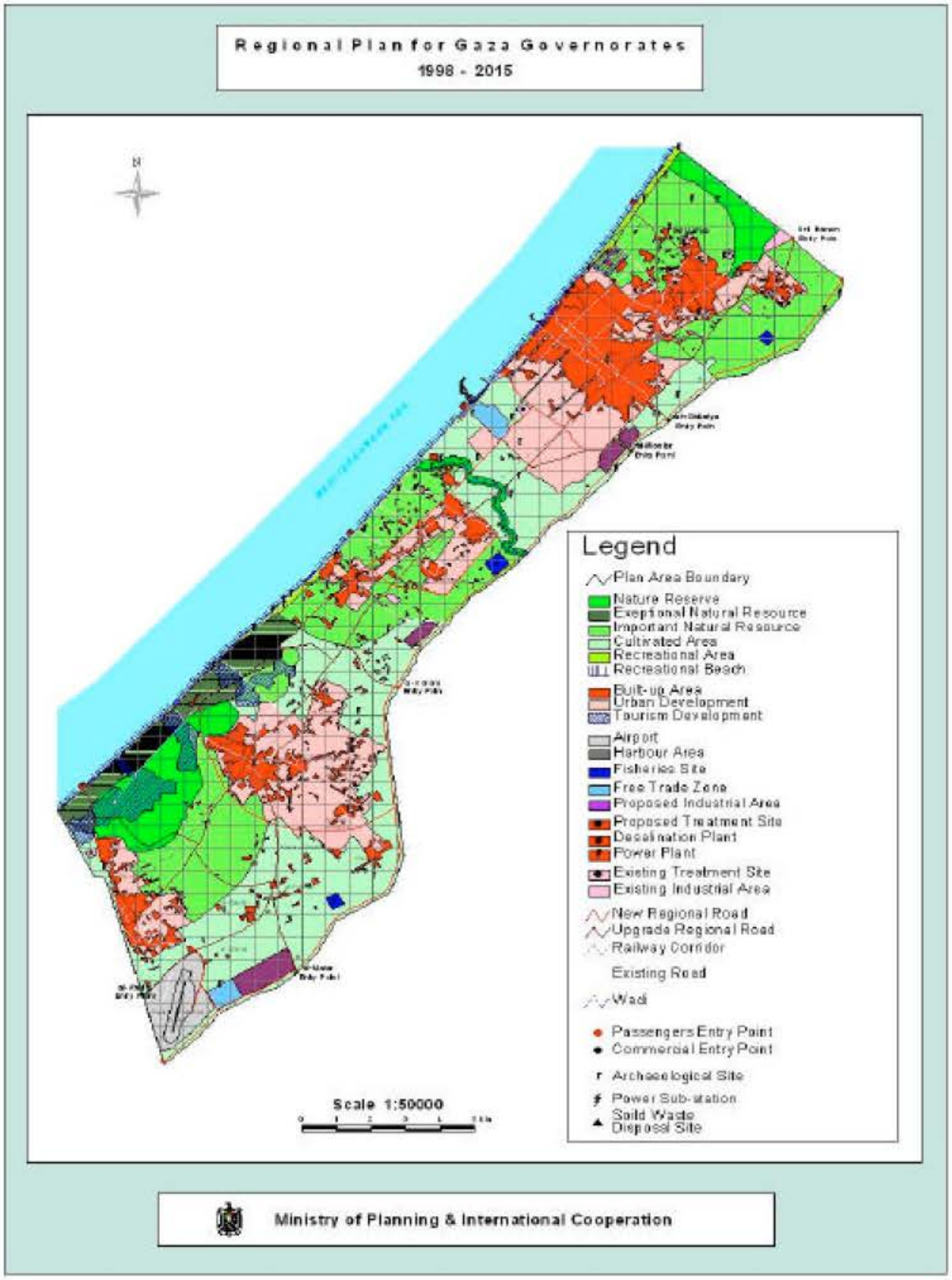

Fig. 5: Regional plan for Gaza Governorates 1998-2015

area and surface run-off per governorate of Gaza Strip for the years, 1998, 2005, 2015. As indicated, the rapid increase in the rainwater losses is due to the expansion of urban areas towards the western side of Gaza Strip, which lead to increase of run-off leaving no chance for infiltration in open areas. In addition, the planning criteria considered Gaza and Khanyounis as two main core cities where Palestinian returnees will be settled.

Table 4: The influence of proposed land use for the year 2015

Governorate	Item	Area calculated by GIS (m^2)	Average rainfall (mm/year)	Rainfall amount hitting surface (Mm^3)	Evaporation 10% (Mm^3)	Infiltration *in situ* (Mm^3)	Run-off amount (Mm^3)
Northern	Build up area	16023448	465	7.0	0.70	0.9	5.8
	Open area	19337385	465	9.0		9.0	
	Agriculture area	25321875	231	6.0		5.8	
	Total area	60682708		22.0	0.70	15.7	5.8
Gaza	Build up area	42448198	436	18.0	1.80	2.2	14.0
	Open area	6302224	436	2.7		2.7	
	Agriculture area	24608429	210	5.2		5.2	
	Total area	73358851		26.0	1.80	10.0	14.0
Middle	Build up area	14671901	363	5.3	0.50	0.6	4.1
	Open area	9520017	363	3.5		3.5	
	Agriculture area	32031802	177	5.7		5.7	
	Total area	56223721		14.0	0.50	10.0	4.0
Khanyounis	Build up area	35154749	306	10.8	1.10	1.3	8.4
	Open area	17031015	306	5.2		5.2	
	Agriculture area	57882809	120	6.9		6.9	
	Total area	110068574		23.0	1.10	13.4	8.4
Rafah	Build up area	11043318	242	2.7	0.27	0.3	2.1
	Open area	13767034	242	3.3		3.3	
	Agriculture area	35675333	55	2.0		2.0	
	Total area	60485684		8.0	0.27	5.6	2.1
Total		360819538		94.0	4.50	55.0	35.0

			Run-off amount destination (Mm^3)						
Governorate	Item	Area calculated by GIS (m^2)	Direct to the sea	Agriculture area	Open area	Impervious area	Direct to Israel	Total losses (Mm)	Net infiltration (Mm^3)
Northern	Build up area	16023448	0.07	3.5		1.5	0.73	3.1	4.0
	Open area	19337385							9.0
	Agriculture area	25321875							6.0
	Total area	60682708	0.07	3.5		1.5	0.73	3.1	19.0
Gaza	Build up area	42448198	1.50		1.6	11.0	0.04	14.3	4.0
	Open area	6302224							3.0
	Agriculture area	24608429							5.0
	Total area	73358851	1.50		1.6	11.0	0.04	14.0	12.0
Middle	Build up area	14671901	2.00	0.6	0.4	1.4		3.7	1.6
	Open area	9520017							3.5
	Agriculture area	32031802							5.7
	Total area	56223721	2.00	0.6	0.4	1.4		3.7	11.0
Khanyounis	Build up area	35154749	0.22	1.4		6.8		8.1	2.7
	Open area	17031015							5.2
	Agriculture area	57882809							6.9
	Total area	110068574	0.22	1.4		6.8		8.1	15.0
Rafah	Build up area	11043318	0.55		0.1	1.4		2.2	0.4
	Open area	13767034							3.3
	Agriculture area	35675333							2.0
	Total area	60485684	0.55		0.1	1.4		2.2	5.7
Total		360819538	4.10	5.4	2.1	22.0	0.8	31.5	62.0

Table 5: The changes in urbanized area and surface run-off per governorate for 1998, 2005, 2015

	1998		2005		2015	
Governorates	Urban area (km^2)	Urban run-off (Mm^3)	Urban area (km^2)	Urban run-off (Mm^3)	Urban area (km^2)	Urban run-off (Mm^3)
Northern	10.48	3.26	13.58	4.22	16.23	5.88
Gaza	21.97	6.41	28.94	8.44	42.45	14.42
Middle	07.50	1.82	10.34	2.51	14.67	04.15
Khanyounis	10.39	2.13	15.46	3.17	35.15	08.39
Rafah	05.68	0.92	8.35	1.35	11.04	02.64
Total	56.02	14.54	76.67	19.69	119.54	34.84
% from the Gaza Strip total area	16.00		21.00		33.00	

The conflict between urban expansion and groundwater protection: Urbanization is furnished by addition of more roads, houses, commercial and industrial buildings. As a result, an increasing in impermeable surfaces for infiltration and therefore increase run-off. The water table may fall because of decreased water infiltration. In contrast, the water table may rise since of decreased evapotranspiration, e.g. following urbanization. In Gaza Strip, increasing urbanization has brought forth change in land use thus decreasing the net area available for natural recharge and increasing groundwater abstraction at the same time. Abdul Hadi (1997) indicated that's the quantity of the rainfall recharge has been reduced from 90 Mm^3 in the 1970's to 46 Mm^3/year and is decreasing continuously, due to Israeli wells dug all around the Gaza Strip since the 1980's and the increasing in impervious area as a result of urban expansion. Over the years rising populations, growing urbanizations, have pushed up the demand for water.

The groundwater level in some areas of Gaza Strip has declined below sea level over a period of two decades, with half of the decline occurring in the past 8 years. Combined with deep water levels, the natural recharge has become less effective, thus increasing the demand-supply gap. Consequently, some existing wells are not deep enough to get water and might run dry. The water level declines are mostly apparent in the South and the Middle and are most likely a reflection of the lower recharge from rainfall due a high rate of urban expansion in these areas. In the North, most wells exhibit relatively slow declines with partial or complete recovery due to higher rainfall recharging in this area (PWA, 2003). Increasing water scarcity in both rural and urban areas, combined with increasing demand, degraded natural environment. The extensive depletion of fresh groundwater with little natural recharge has led to excessive seawater intrusion into that aquifer which, if not corrected, will become a drastic problem that cannot be easily remediate.

With the above scenario, the protected areas for ground water recharge are a matter of priority, but it is conflict mainly with the urban development. Gaza with the borders of today and the dramatically increase in population growth can never be sufficient for environmental sound urban expansion (Al-Najar and Adeloye, 2005). According to topographical and soil classification maps the following areas are proposed for groundwater protection:

- All sites represents natural depression zones especially that's closest to the shore line.
- The location of previous Israeli settlements.

Where, the Israeli occupation force started to build up on the Palestinian lands after the 1967 war. Today the Israelis evacuated 26 Colonies in the Gaza Strip, which occupied around 7.4% of the total area of Gaza Strip. Where the total areas controlled by Israel in the Gaza Strip was about 106.32 km^2, which constitutes about 30% of Gaza total area (PWA, 2004). It is worthwhile to mention that, these settlements were located on the best ground water locations

The eastern side of the Gaza Strip, which considered being hillside locations, was used in the former time as citrus agricultural lands. The ministry of agriculture reported that: land use for citrus reduced 60% due to limited marketing and the high salinity of water for irrigation (Al-Najar and Adeloye, 2005). Therefore, the future urban expansion should be directed to these areas reserves the sandy dunes as basins to recharge the ground water.

Storm water mitigation measures: Due to urbanization, the cities are becoming overcrowded with population as a result over exploitation of groundwater, which in future may result in depletion of groundwater. Urbanization cleared large areas of agricultural and open land, with the result high rainfall intensities, increased surface runoff with high velocity. The storm water runoff from the increased urbanization, which used to immerse into the ground, goes into storm water collection system, streets, causing flooding. Which then ended in the sea without giving enough time for infiltration to the ground water due to that Gaza Strip is a foreshore plain gradually sloping westward toward the sea.

Based on the authors calculations as given in Table 2, the surface run-off result from the existing urban areas in Gaza Strip is estimated to be 14.5 Mm^3/year.

In Gaza Strip like most developing countries appropriate urban storm water mitigation measures has not been appropriately addressed. Funding for storm water run-off collections from urban areas is relatively ignored by both local and donated international agency resulting in failure of both storm water collection system and sewage system. Nowadays, storm water run-off may be conveyed in pipes, conduits and in paved streets between curbs in densely developed areas, but few of these systems are seen in the urban areas of the Gaza

Strip. When an intense rainfall occurs, the water quickly flows from flat or pit chides roofs to the streets often mixing with silage flow or untreated sewage. Such flows soon become a nuisance with potential health hazardous or a major flooding problem (LYSA, 1995). By these problems the basic needs are not met, lack of infrastructure and treatment facilities. Sustainable Storm water management can be achieved by several mitigations measures like storm water harvesting for future reuse.

CONCLUSION AND RECOMMENDATIONS

The high infiltration rate of Gaza Soils which is higher than the 5 years storm occurrence emphasis that's the groundwater naturally recharged from rainfall.

The direction and magnitude of Gaza Strip slope is shown that's most of Gaza Strip area is described as flat area and gradually sloping ranging between (0-5)% westward toward the sea allowing for surface runoff.

The amount of rainfall infiltrated into the sandy regosol soil which represents about 35% from the total infiltrated amount is considered to be the greatest amount among the different soil types.

At the existing land use situation the net amount of rainwater infiltrated into the different soil types is estimated to be 57% from the total accumulated amount of precipitations which estimated to be 125 Mm^3/year, where the annual losses represent about 43%, in which this amount is not included that's amount lost by transpirations from the agricultural areas.

The urbanized area represents around 16% in the year of 1998 and 20% in the year of 2004 and is expected to increase in the next years due to the rapid increase in population to represent 33% for the years of 2015. In the meantime, the water demand will increase due to the expansion of water supply systems.

The total amount of rainwater losses due to urbanization as surface run-off is estimated 14.5 Mm^3 in the year of 1998 and expected to increase to about 20, 35 Mm^3 for the years of 2005, 2015, respectively.

The high infiltration rate of various soil types in the area of Gaza Strip emphasizes the need for groundwater protection from the different sources of pollutions.

Legal and bylaws steps should be taken by relevant institutions to deal with rainwater run-off as a main source to feed the groundwater.

Further studies are needed to determine the best locations for groundwater recharge including the geology of deeper soil layers.

Assessing the quality of urban surface run-off.

Reduce impervious surface area by using permeable pavement materials where appropriate, including: pervious concrete/asphalt; unit pavers, i.e. turf block; and granular materials.

REFERENCES

Abdul Hadi, A., 1997. Gaza Water Crisis Worsening. Palestine Report. Vol. 2. Issue 49. Online: http://www.igc.org/desip/GazaWater.html., Visited at February 10, 2005.

Abu-Mayla, Y., M. Abu-Jabbal and M. El-Baba, 1998. Water resources management and development in Gaza Strip-Palestine. Paper Presented at the Conference of Water and Food Security in the Middle East 20-23 April 1998. Nicosia, Cyprus.

Al-Agha, M.R., 1995. Environmental contamination of ground water in the Gaza strip. Environ. Geol., 75: 109-113.

Al-Najar, H. and B. Adeloye, 2005. The effect of urban expansion on groundwater recharge as renewable resource in Gaza Strip. RICS., 5: 8.

Goris, K. and B. Samain, 2001. Sustainable irrigation in the Gaza Strip. M.Sc. Thesis. Katholieke University Leuven, Belgium.

Lawrence, A.R., B.L. Morris and S.S.D. Foster, 1998. Hazards Induced by Groundwater Under Rapid Urbanization. In: Geohazards in Engineering Geology. Maunds, J.G. and M. Eddleston (Eds). Geological Society, London, Engineering Geology Special Publications, 15: 319-328.

LYSA, 1995. Assessment of Water and Sewerage Public Services in the Gaza Strip. Palestine.

McGhee, T.J., 1991. Water Supply and Sewage. International Edition. McGraw-Hill Book Company, Inc. New York, NY.

Metcalf and Eddy Consultant Co. (Camp Dresser and McKee Inc.), 2000. Coastal Aquifer Management Program, Integrated Aquifer Management Plan (Gaza Strip), USAID Study Task 3, Executive Summary and Appendices B-G. Gaza, Palestine, Vol. 1.

Ministry of Environmental Affairs (MENA), 2001. Assessment of Land Based Pollution Sources, Palestinian National Authority.

Ministry of Local Governorates (MOLG), 2004. Maps of Urban Development of Gaza Governorates in 2004. Department of Urban Planning. Gaza, Palestinian National Authority (Unpublished).

Ministry of Planning and International Corporation (MOPIC), 1997. Technical Maps Atlas for Gaza Governorate, First Version. Gaza, Palestinian National Authority.

Mogheir, Y., 1997. Salt Water intrusion modeling and monitoring in the Gaza strip aquifer. M.Sc. Thesis, IHE, Delft, the Netherlands.

MOP, 2005. Regional Plan for Gaza Governorates. Palestine National Authority.

MOPIC, 1998. Regional Plan for Gaza Governorates 1998-2015. Palestinian National Authority.

Palestinian Economic Council for Development and Reconstruction (PECDAR), 2000.Tatf-Water Sector Strategic Planning Study, Final Report, Vol. 3: Specialist Studies, Part B: Focal Areas. Technical Assistance and Training Department (TAT), Palestinian National Authority.

Palestinian Water Authority (PWA), 2003. Groundwater Levels Decline Phenomena in Gaza Strip. Final Report. Water Resources and Planning Department-Hydrology Section. February, 2003. Gaza, Palestinian National Authority.

Palestinian Water Authority (PWA), 2004. Palestinian Vision for Water Management in the Israeli Colonies Area in the Gaza Strip, Strategic Planning Department Water Resources Directorate, Palestinian National Authority.

Pouraghniaei, M.J., 2002. Effects of Urbanization on Quality and Quantity of Water in the Watershed, Natural Resources Research Center of Semnan, Semnan Province, Iran.

Sogereah, B.R.L. and Team, 1999. Master Plan for Sewage and Storm water Drainage in the Gaza Governorates, Final Report, Palestinian National Authority.

United Kingdom Environment Agency (UKEA), 2001. Thames Region Hydrological Summary, March 2001. Thames Region.

Van de Ven, F.H.M., 1990. Water balances of urban areas. IAHS Publ., 198: 21-32.