INVESTIGATION OF POTENTIAL APPLICATIONS OF RAIN WATER CATCHMENT SYSTEMS IN THE GAZA STRIP AND AN EXPLORATION OF APPROPRIATE SANITATION SYSTEMS

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Investigation of Potential Applications of Rain Water Catchment Systems In the Gaza Strip and an Exploration of Appropriate Sanitation Systems

Report prepared for the
International Water Engineering Centre
University of Ottawa

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Summary

This is a preliminary study of the water supply and sanitation situation in the Gaza Strip with a view to investigating the possibility of rainwater catchment system (RWCS) implementation in the area. The report provides a review of meteorological and hydrological conditions as well as social, cultural and political factors. The appropriateness of RWCS is studied separately for the refugee camps and for other types of dwellings (cities, towns, villages).

Analysis of the water needs of the region and of the capabilities of RWCS reveals that enough rainwater could be captured and stored to provide for the drinking needs of the population. Availability of space for the reservoir determines the suitability of RWCS for any particular household. Outside funding may be required to build some of the units, but the operation and maintenance would be within the capabilities of the owners.

A preliminary design of above-ground and below-ground RWCS is presented, with preliminary cost estimates.

Finally, the sanitation situation in the Gaza Strip is reviewed. It is concluded that small-bore wastewater collection systems could be a very appropriate technology to improve the sanitary conditions of the Gaza Strip.

The International Water Engineering Centre gratefully acknowledges the efforts of the author and the generosity of UNDP Jerusalem in exempting the author from other duties for the duration of this project.

1. INTRODUCTION

With the support of the Expert Advisory Services Fund which CIDA finances and IDRC carries out, this study was undertaken at the request of the International Water Engineering Centre (IWEC) - University of Ottawa. The study is related to the report on the "Enhancement of the Middle East Water Supply: A Literature Survey of Technologies and Applications" which was developed by the IWEC for the Working Group on Water-Resources (WGWR) of the multilateral Middle East talks. That survey presented a summary of the technologies and applications which could enhance the water quantity supplied in the region. Household Rain Water Catchment Systems (RWCS) was cited in the report as one of the most promising applications to augment the availability of drinking water.

The objective of this study is to explore the feasibility of applying community based water supply and sanitation technologies in the Gaza Strip with special emphasis given to RWCS. As defined in the IWEC terms of reference to the author, the study includes the following components:

A review of existing social, economic, and technical background material which will help to determine the appropriateness of low cost water supply and sanitation technologies, especially RWCS;

A survey of representative areas in terms of their relevant social and technical conditions, using a small sample of families;

An examination of local water needs and present water sources and an exploration of low cost technical options for water supply;

A typical RWCS design to illustrate the practicability of applying a relevant technology cited in the literature study;

A preliminary design and cost estimate of a typical RWCS and an exploration of feasible, appropriate sanitation systems.

2. BACKGROUND

The Gaza Strip is located along the Mediterranean Sea and bordered by Israel in the north and Egypt in the south. The strip length is 45 km from Beit Hanoun Town in the north to Rafah city in the south, and its width ranges from 5 km in the northern part to 12 km in the south. The total area is about 365 km^2 (see figure 1).

The climate, which is typically Mediterranean, is characterized by daily average temperatures ranging from 13°C in January to 27°C in August.

The Gaza Strip is lined with sand dunes that extend along the seashore at 40 m altitude above sea level. The width of the coastal dune ridge varies from 1.5 km to 4.3 km. It is

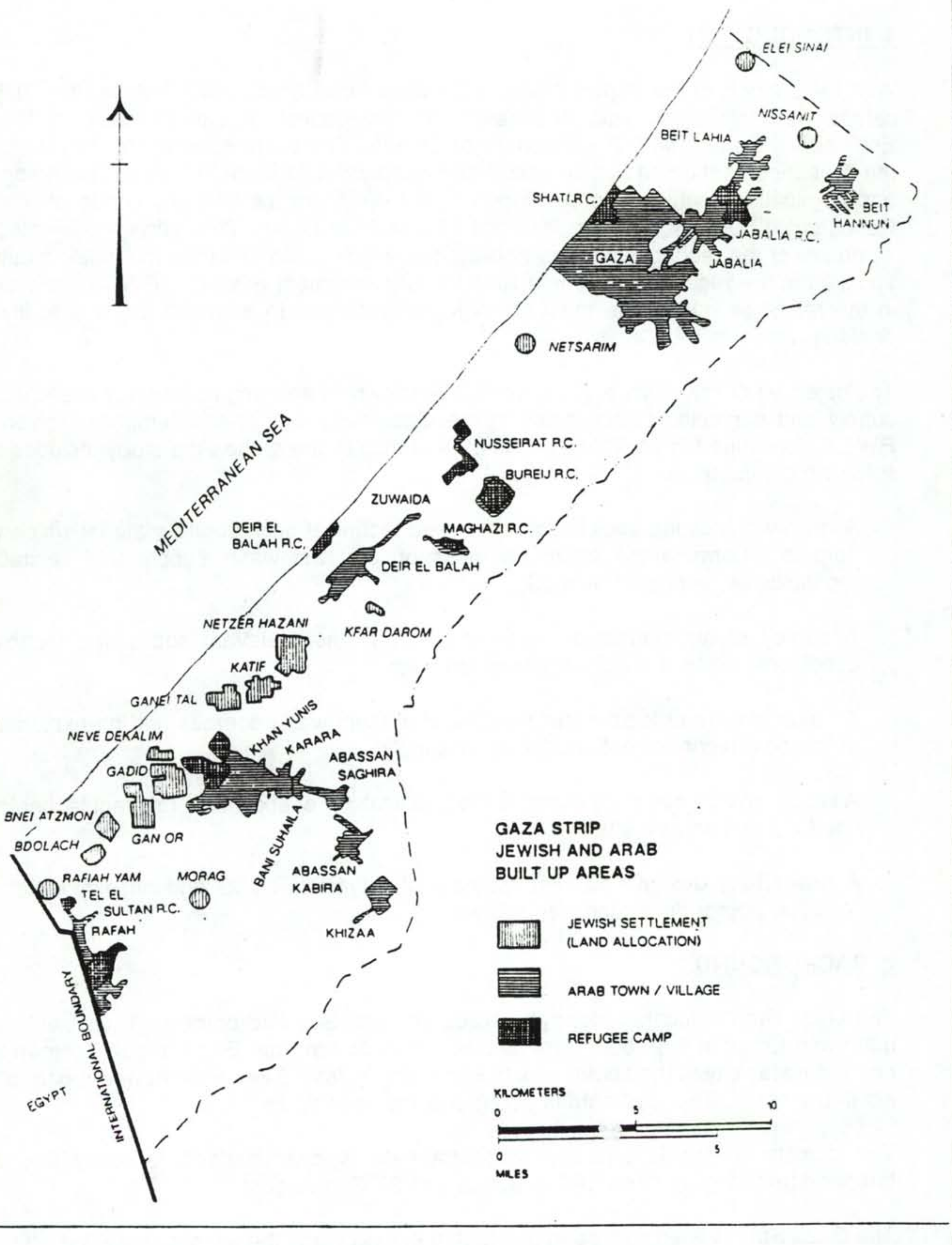


Figure 1. The Gaza Strip built up areas (Netherlands report)

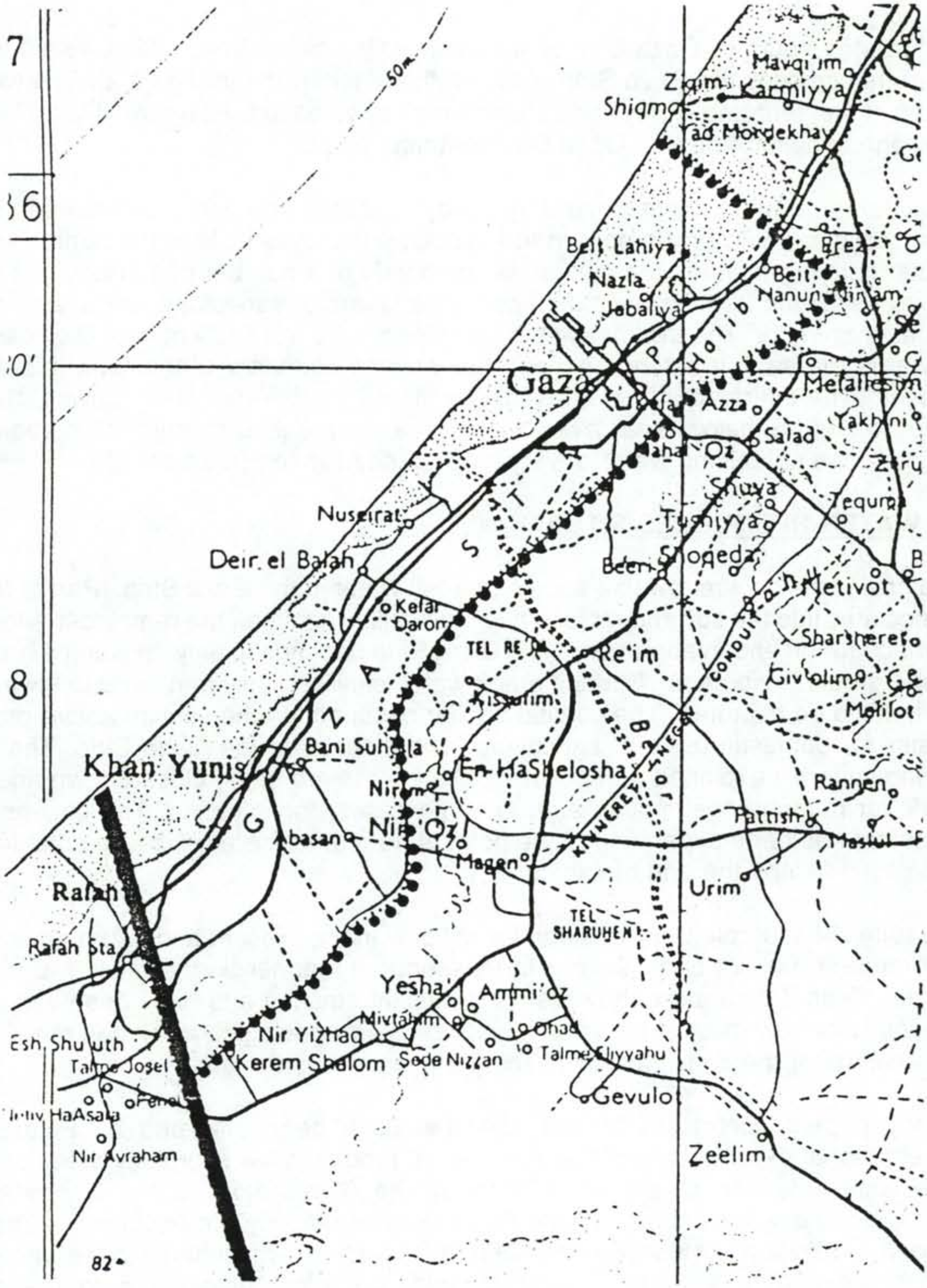


Figure 2. Location of the wadis in the Gaza Strip (The Times Atlas of the World)
Dotted lines indicate the wadis.

interrupted south of Gaza City by a narrow valley called Wadi Gaza, which is the only river that crosses the Gaza Strip reaching the Mediterranean (figure 2). The valley is dry most of the year and it only floods during the rainy season. However, it is polluted by the sewage expelled from the Gaza City treatment plant.

The eastern part is characterized by sandy regosoils and arid brown soils in the south, loesssoils and arid brown soils in the middle, and clayey soils in the north. The ground water carrying stratum, the aquifer, is composed of a number of sub-aquifers separated by clayey layers. The sub-aquifers comprise layers of sandstone, sand, and pebbles of Quaternary age. The thickness of the aquifer ranges from 120 m near the coast to 10 m towards the east. It extends beyond the eastern boundary of the Strip into the Negev Desert. The entire aquifer is underlain by clayey marine formation. Lower, at depths of 200 to 300 m below sea level, there is a permeable stratum of carbonates and sandstones containing water of very high salinity (up to 5000 ppm Cl^-).

3. WATER RESOURCES SITUATION

Rainfall is the only renewable source of fresh water in the Gaza Strip. Part of this rainfall percolates into the soil and replenishes the shallow aquifers, the remainder is lost through surface runoff and evaporation. The Gaza Strip depends mainly on water extracted from underground resources. Surface runoff water is utilized only to a small degree and more of it could be captured. The coastal aquifer described in the section above provides the water for domestic use, for agriculture, and industry in the Gaza Strip. The aquifer is being severely exploited and polluted. Many wells are being closed down and declared unfit for human consumption and, in some cases, for irrigation. The dimension of the problem has been expanding to the point of no return; there will be no potable water for domestic use by the end of this century.

Despite the vital role the Gaza aquifer will play in the present and future development of the area, it has not been studied in as serious a manner as the aquifer to the north in Israel. Even if data exist, they are not public information and have been very difficult to verify. Until now most of the hydrological and hydrogeological work has remained under the control of the Israeli officer heading the water department.

Many papers contracted by aid agencies have been prepared by Palestinian and international experts. One of the most recent reports is the hydrology study prepared on the water situation of the Gaza Strip by the Government of the Netherlands. It is considered a reliable source by the Palestinian community. This section will draw on this report, in addition to other work prepared by Palestinian consultants to the United Nations Agencies and other donor countries, and the information given to the author by Palestinian and Israeli specialists working for the Israeli Civil Administration (CA).

3.1 Rainfall

To start, the only renewable source of fresh water for the Gaza Strip aquifer is rainfall. The average rainfall is higher in the northern part of the Strip and decreases as we move southward to Rafah. This is one of the reasons for the fact that the water quality is better in the northern part of the Strip, near Beit Hanoun and Beit Lahia towns, than in the middle and southern part, near Khan Younis and Rafah. Table #1 gives the average amount of rainfall on Gaza between the years 1967/68-1989/90. The weather station is located in Gaza City.

Table #1

Year	Average Rainfall mm/yr
67-68	410.0
68-69	435.3
69-70	189.1
70-71	436.4
71-72	436.9
72-73	373.7
73-74	543.9
74-75	469.5
75-76	245.9
76-77	424.2
77-78	367.9
78-79	326.7
79-80	493.7
80-81	242.0
81-82	341.0
82-83	606.4
83-84	212.1
84-85	231.3
85-86	210.2
86-87	628.3
87-88	538.2
88-89	412.8
89-90	492.1
Average rainfall for the period	394.3

Source: Weather observatory - Gaza

The average monthly rainfall measured by the two weather observatory stations in Gaza City over 25 years and Khan Younis over 14 years is given in table #2:

Table #2

Month	Temperature (°C)	Evaporation (mm)	Rainfall Gaza City in mm	Rainfall Khan Younis in mm
January	13.6	63.4	83.3	56.7
February	14.0	73.1	55.3	39.2
March	15.8	94.1	41.2	29.7
April	18.0	116.4	8.9	6.4
May	21.3	133.4	3.7	4.4
June	23.8	135.5	0	0
July	25.7	137.8	0	0
August	26.2	137.8	0	0
September	25.2	124.9	0.7	0.5
October	22.9	113.7	15.6	9.3
November	19.8	91.0	70.9	48.5
December	15.4	78.7	91.8	63.2
Annual	20.1	1299.8	371.0	258.0

Table #3 also provides other general climatic data for the Gaza Strip which help define the aridity of the area and the aquifer replenishment rate.

Table #3

Mean annual rainfall	200-400 mm
Variation in annual rainfall	95-100%
Mean annual evaporation from open water surface	1200-1400 mm
Mean daily relative humidity	70-75%
Mean annual cloudiness	30-35%
Mean annual temperature	19-21°C
Mean temperature of coldest month (January)	12-14°C
Mean temperature of hottest month (August)	26-28°C
Mean annual number of days with minimum temperature of 10°C or less	51-100 days
Mean annual number of days with maximum temperature of 35°C or more	0-10 days
Annual average difference between main daily maximum and minimum temperature	10-12°C
Mean annual solar radiation (incident on horizontal surface) in kcal/cm²/year	189-195

Source: Israel Meteorological service; Atlas of Israel, 1985.

The above table shows that the average rainfall ranges from 200 mm in the south (Rafah) to 400 mm in the north around greater Gaza City. The aridity index, defined as average annual precipitation divided by average annual evapotranspiration,.had been determined in the Netherlands report to be 0.18 in the southern part of the Strip, which classifies it as an arid region, and 0.38 in the northern part, classifying it as a semi-arid region.

3.2 Ground water replenishment

Groundwater in the shallow aquifer under the Gaza Strip is replenished primarily by rainfall over the Strip. The total amount of rainfall on the Gaza Strip (365 km^2) is estimated at 100 million m^3/yr. Part of this is lost through surface runoff and evaporation, and only the remaining portion replenishes the aquifer. The percentage available for recharge is not well established. The Netherlands Report estimates it at 25% of the total rainfall.

Various authors claim that inflow from the aquifer east of the Gaza can also contribute to the replenishment as well as flow through wadis. The Palestinian sources say that the groundwater inflow to Gaza from the eastern border is being reduced due to Israeli over-pumping. Neither the fact of inflow, nor its reduction due to Israeli pumping could be substantiated.

The impact of seasonal flows to the Gaza Strip through the three wadis, particularly Gaza Wadi, also remains unknown. The fact that so much is unknown when we are talking about such a confined and small aquifer is a major part of the problem.

There are a number of estimates for natural replenishment of the Gaza Strip aquifer, ranging from 25 to 80 million m^3/yr. It is not clear if this large difference in estimation reflects in part the possibility that recharge from the eastern aquifer outside the Strip is included. Nonetheless, most estimates of natural water replenishment are in the range of 25-50 million m^3/yr. It constitutes the only renewable source of fresh ground water and it should be considered as the safe yield of underground water.

3.3 Ground water abstraction

Ground water is being abstracted from separate wells for domestic/industrial purposes and for agricultural use. There is no restriction on the quantities that can be pumped from the domestic/industrial wells, but the Israeli Civil Administration and the Water Department have been restricting abstraction from the agricultural wells.

Fifty wells pump water for domestic and industrial purposes and 1791 for agricultural purposes. Table #4 gives the quantity of water pumped for domestic and industrial purposes for the year 1989:

Table #4

Location	No. of wells	Quantity pumped million m^3/yr
Beit Hanoun	2	0.436
Beit Lahia	3	1.269
Jabalia/Nazla - Jabalia Camp	4	1.400
Gaza City	18	13.500
Deir El-Balah	3	0.200
Khan Younis	6	3.900
Bani Suhaila	2	0.37
Abasan	2	0.03
Rafah	3	2.500
UNRWA[1] wells	7	0.610
Total	50	24.215

Source: Agriculture Department - Gaza

[1] UNRWA: United Nations Relief and Works Agency

The quantity of water obtained from the agricultural wells in the Gaza Strip for the year 1989 was 52.751 million m^3/yr (Agriculture Department - Gaza). This brings the total abstraction from the underground water to about 77 million m^3/yr.

The Civil Administration, who have the privilege of monitoring metered abstraction from most wells, present the following figures as their reading of the total abstraction in million m^3/yr:

Table #5

Total abstraction, million m^3/year

Year	1967	1973	1985	1990	1991	1992
Agriculture	110	85	67	63	57	47
Water supply	10	18	23	26	37	37
Total	120	103	90	89	94	84

Other recently published studies cite the total abstraction as ranging between 84 to 130 million m^3/yr for all purposes, domestic, industrial, and agricultural. Typical figures commonly quoted in the literature are 67 million m^3/yr for agriculture, 23 for domestic and industrial supply, for a total of 90 million m^3/yr.

These figures reflect only the consumption by the Palestinian population in the Gaza Strip. As for the Israeli settlers' domestic and agricultural purposes, it is estimated at 3.3 million m^3/yr.

No matter what the real figures for abstraction of the underground water are, the reality remains: abstraction exceeds natural replenishment by far and there is a need to reach the balance between the abstraction and replenishment of the underground water. This requires an increase of replenishment and a decrease of abstraction. Replenishment could be increased by recharging runoff or treated wastewater into the aquifer. As long as groundwater is the main water source, decrease in abstraction could only reasonably be expected from a further decrease in agricultural use of ground water, as domestic and industrial consumption is increasing and expected to increase with population growth. Although the present abricultural demand is estimated at 100 million m^3/yr, the actual agricultural consumption has been decreasing. This is due to the decreasing size of land planted with citrus (the main agricultural produce in the Gaza Strip), the strict quotas set by the Civil Administration, and the increasing salinity of many of the agricultural wells. Further decrease in the use of ground water for agriculture could be achieved by improving the irrigation schemes, diverting the agriculture trends towards cultivating crops which require less water; and utilizing alternative sources of water for irrigation, such as, treated waste water and collected rain water. These issues are discussed in greater detail in Section 10.

3.4 Household water supply system

Ninety-nine percent of the households are supplied with piped water. Some areas where the quality of water is particularly bad (such as Khan Younis city) are supplied with water by Mekoroth, the Israeli water company. This water is transported via the National Carrier and amounts to 5 million m^3/year. Consumers pay NIS[2] 1.5 per m^3. Most of the piped water, however, is ground water abstracted from wells located in the Gaza Strip itself (23-37 million m^3/year). The wells are owned by municipalities, by the UNRWA or by private Palestinian owners. Each well feeds a separate distribution network. Most of the cities, towns and refugee camps are served by a supply network which connects the wells to the reservoirs up to the house connection. Some smaller villages and communities have their own local wells which feed into a storage reservoir and then a small supply network. Especially in the refugee camps, homes are often connected to more than one network, sometimes without permission. Metering of consumption has been difficult under these conditions. In the cities and towns meters have been installed, but they are often not in working order or are tampered with. Most consumers are charged the minimum rate of NIS 17 per month.

A more detailed description of water supply systems is found in Section 8.2.1. Water authorities are further discussed in Section 7.1.

3.5 Ground water quality

The ground water quality in the Gaza Strip is generally poor and continuously deteriorating. The water is very saline and contains high nitrate levels exceeding established WHO standards.

Salinity levels

The over-exploitation in the past decades of the underground water resources of the Gaza Strip has resulted in a large drop in the level of the aquifer. Hence, the water salinity, characterized by the chloride level, has been increasing continuously. This is basically due to the following:

- sea water intrusion;
- movement of saline water from the east;
- up-coning of deeper, saline pocket aquifers;
- progressive salination of the soils due to over irrigation.

The chloride level is higher than 500 ppm in most of the central and southern parts of the Strip, as shown in figure 3. This greatly exceeds the WHO guideline for chloride in drinking water (250 ppm). Tests are carried out regularly by the Water Department, UNRWA, Palestinian researchers, and international consultancy missions. The mission

[2]NIS: New Israeli Shekel, US $1 = NIS 2.8 or NIS 1 = US $0.45

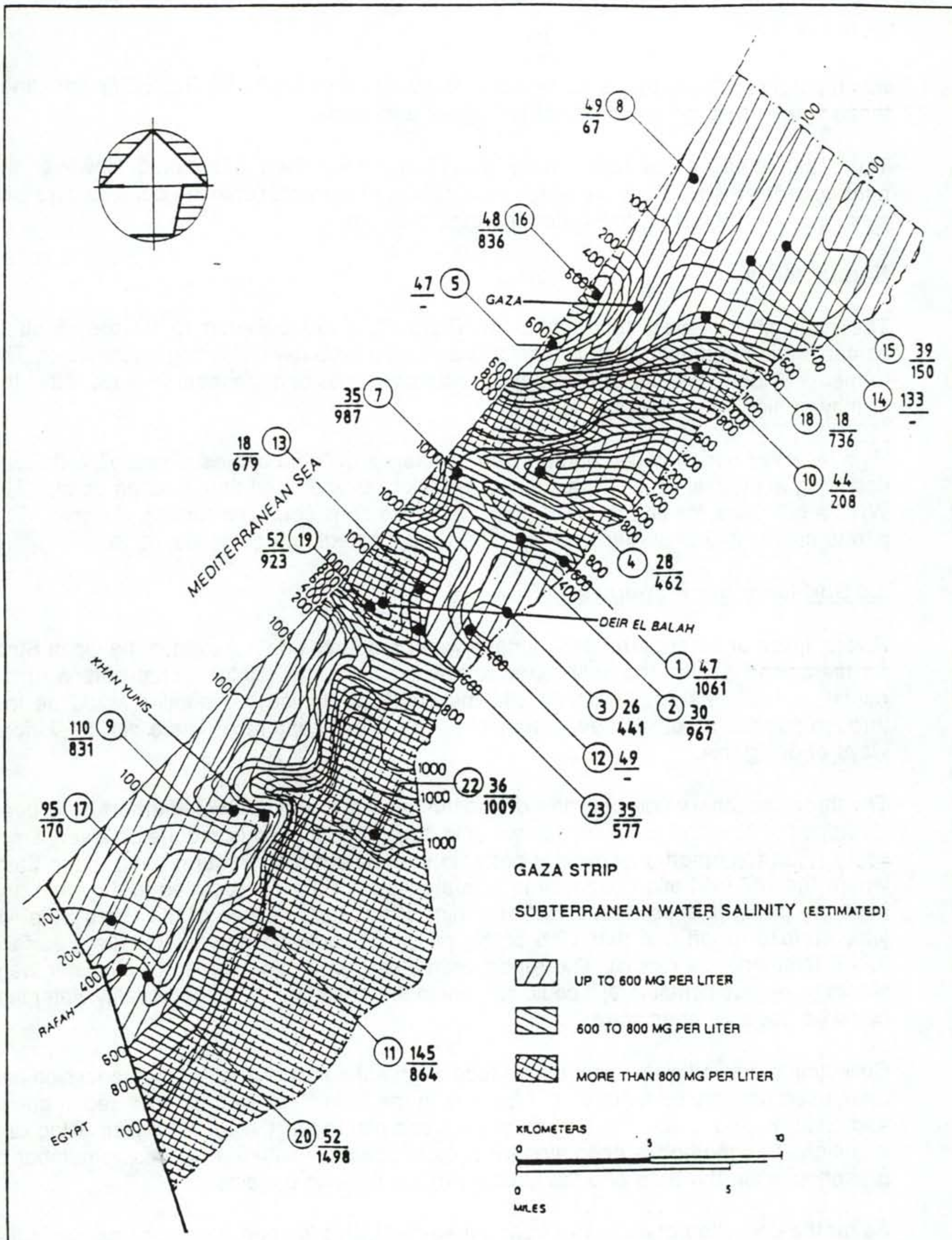


Figure 3. Ground water salinity (Netherlands report)

(11) 35/500

11 : well nr.
35 : nitrate ppm NO_3^-
500 : chloride ppm Cl^-

which prepared the Netherlands report on the water situation in the Gaza Strip confirmed these figures through a number of tests they undertook.

The health impact of the high salinity levels has not yet been determined. However, the primary problems are the increasing unpalatability of the water of many wells, forcing their closure and aggravating the water shortage problem.

Nitrate levels

The high nitrate levels throughout the Gaza Strip are believed to be the result of contamination from nitrogenous fertilizers and most probably infiltrating waste water. The former is evident in wells located near agricultural lands and the latter in wells within the vicinity of highly populated areas.

High levels of nitrate cause methaemoglobinaemia or "blue babies' disease", a disease occurring in infants. It is characterized by lack of oxygen and then sudden death. The WHO's guideline for nitrate is 45 ppm, reflecting considerations for this disease. The nitrate concentration in many wells of the Strip exceeds the guideline value.

3.6 Surface water resources

Rivers, lakes or other permanent surface water resources do not exist in the Gaza Strip. As mentioned earlier, the only renewable water source is rainfall. That portion of the rainfall which does not percolate into the soil to replenish the aquifer would be lost through surface runoff and evapotranspiration, unless captured. There can be various ways of doing this.

The three seasonal wadis only flow during the rain water floods. Some farmers have been diverting the flow and collecting the water in large ponds, but this is done on a very small scale. Surface runoff, however, is better in the eastern and northern parts of the Strip, where the soil infiltration capacity is less than that of the sand dunes in the west and southern parts. It is estimated that one third of the surface area of the Gaza Strip will yield surface runoff and that 10% of the rainwater could be harvested as soil surface runoff (Netherlands report). The report estimates that if this harvested rainwater were stored in various containers, it could amount to 3.6 million m^3/yr of good quality water that could be used for agriculture.

Collection of run-off water from the surface of greenhouses is another method which has been used recently by a number of farmers in the Strip. The water is collected in ponds and cisterns and re-used in irrigating the crops planted in the greenhouses using drip irrigation. This method is becoming even more attractive with the increasing number of greenhouses in the Strip and the success of the existing projects.

As for the collection of rainwater from house-roofs, this is not a common practice in the Gaza Strip as in the West Bank. Probably, this is due to the traditional availability of underground water at shallow depths, the connection of most of the households to the water supply networks, and the lack of space available around the houses.

4. DEMOGRAPHY

4.1 Data sources

The Gaza Strip is physically isolated from the rest of the Occupied Palestinian Territories (OPT). No population census has been conducted in the area during the past years of occupation. Hence, all the available figures on population characteristics are based on official Israeli statistics. Scientists and researchers have been estimating the present population figures using various methods. Presently, there is still no consensus on the figures.

The Centre for International Social Science Research in Norway (FAFO) recently conducted a survey of Palestinian living conditions. The figures they based their survey on and their projections are believed to be the closest to the real situation. Most of the figures used in this report reflect what is published in the FAFO survey.

4.2 Population size

The composition of the population of the Gaza Strip was dramatically altered by the 1948 war. The influx of approximately 200,000 refugees almost tripled the population in the area.

While the population of the OPT as a whole is estimated to be 2,118,000 persons, about 790,000 are believed to reside in the Gaza Strip.

4.3 Population density and type of locality

The Gaza Strip comprises less than 6% of the OPT area, yet it holds 37% of the total area population. The population density is considered to be the highest after Arab Jerusalem, reaching to 2,149 persons per square km. This high population density is due to a large extent to the high percentage of refugees. Approximately, two out of three persons are UNRWA refugees. Less then half of the refugees still reside in refugee camps.

Although the Strip was originally an agriculture society, the high population density has given the area a distinctive urban appearance. Four out of five persons in the Gaza Strip live in urban areas.

Greater Gaza City, comprising Gaza City and the surrounding refugee camps, is the largest urban area in the OPT. The third largest urban area is also in the Gaza Strip, consisting of the towns of Khan Younis and Rafah, and the adjacent camps (figure 1).

4.4 Mobility and growth rate

The overall growth of the Gaza population is determined by the fertility, mortality and migration characteristics of the population.

There is a high degree of uncertainty amongst Palestinian researchers about the fertility and mortality rates provided in the Israeli statistics; Palestinians believe that they are under-estimated. Additionally, due to the prevailing political conditions in the OPT, no particular mobility pattern can be assumed with a high degree of accuracy. Some believe that the current deteriorating economic situation will influence people to seek a better future outside. Others think that the current peace process is giving some Palestinians living outside the OPT some encouragement to return and invest in the local economy.

The Israeli Ministry of Health (IMH) report of 1991 stated that the annual birth rate in the Gaza Strip is 54.6 per thousand. The percent of migration is reported to be -0.7 (Statistical Abstract of Israel, 1991).

Most of the researchers assume the Gaza Strip average annual growth rate to be 3.7%, as compared to 3% for the West Bank.

4.5 Household size and composition

Gaza has an average of 9 persons per household compared to 7 in the West Bank; approximately 50% are children (14 years or younger). Age and sex are the main factors considered in selecting a household head. This is shown in the results of the FAFO survey which found that 96% of the heads of household were the oldest male of the family. Despite the fact that in a number of cases the females of the family were the providers of income, they were not decision-makers at the family level. However, the informal influence of women, particularly the wife of the household head, on decision-making should not be underestimated.

5. HEALTH

The official reported infant mortality rate (IMR) in the Gaza Strip is 26.1 per 1000 live births (IMH, 1991). There is a great possibility of under-reporting, especially in recent years, due to the disruption of all aspects of routine life during the Palestinian Intifada (the Uprising). The existing data from other sources such as UNRWA, suggest an overall IMR of about 37, with about half of these deaths caused by diarrhoeal or respiratory diseases.

In addition to the high infant and child mortality rates, the community faces health problems such as parasitic diseases, which reflect the socio-economic status of the population.
Parasitic diseases like ascariasis and trichuriasis are transmitted through the faecal-oral pathway via the soil and sand. Amoebae infections are probably predominantly transmitted person to person and by contaminated food. While it is possible that these diseases are transmitted by contaminated drinking water (i.e. "water-borne"), there is no conclusive evidence to support this hypothesis at present.

While there are no detected cases of schistosomiasis, malaria, or guinea worm in the population, trichuriasis and ascariasis are very common in the Gaza Strip. A survey carried out in Shatti Camp showed a 40% incidence of ascariasis and a 26% incidence of trichuriasis in children below 10 years of age. The persistence of infections was attributed to:

a) inadequate sanitation causing the flooding of the sandy streets by sewage;

b) poor infant excreta management; and

c) ineffective use of anti-helminth drugs.

Therefore, in order to curtail the persistence of such parasitic diseases, it is imperative that the sanitary situation in the Gaza refugee camps be improved.

6. EMPLOYMENT AND ECONOMY

6.1 Overview

Household income in the Gaza Strip is obtained mostly from three sources: labour activity, which generates wages and salaries; business enterprise and land cultivation and animal husbandry. Wage labour is by far the most frequent source of household income.

The total work force in the Gaza Strip is estimated at 100,000-110,000 workers. The employment opportunities in the Gaza Strip itself are very scarce. The few industries and agricultural activities cannot absorb the existing labour force, especially amongst the refugee population. This has led a large percentage of Gaza workers to seek employment in Israel, even on a daily basis, contributing to the process whereby the Palestinian economy has been gradually integrated into the Israeli economy during the occupation years. A significant dependence on Israel developed in terms of currency, legislation, extension of services, and infrastructure (water, electricity and transportation networks), as well as Israeli goods and employment of Palestinian workers. Any reduction, therefore, in the number of Gaza workers employed in Israel has a major impact on the affluence of the Gaza population.

Before the Intifada 70,000 workers were working in Israel and 30,000 in the Gaza Strip. In the last few years, however, the OPT in general and the Gaza Strip specifically have been suffering from an economic recession, resulting in a lower household income level. It started with the beginning of the Intifada due to the extended curfews, strikes, and more importantly the restriction on employment in Israel. The last factor reduced the number of workers in Israel to about 60,000. Despite this, work in Israel remained the main source of income for the Gaza Strip with a 40% share of the GDP.

The Gulf War was another blow to the economy of the OPT, particularly in the Gaza Strip, for it deprived many households of the remittances and financial assistance they used to receive from family members working in the Gulf. Moreover, the Israeli authorities imposed more restrictions on the employment of Gaza workers in Israel, reducing the allowed number to 30,000 workers. This aggravated the unemployment crisis even further.

Furthermore, the recent political developments in the OPT which led to the closure of the West Bank and the Gaza Strip from Israel and Jerusalem, and the restrictions imposed on the employment of Palestinian workers in Israel have had the most serious effect on the Palestinian economy and consequently the household income level. For the first weeks of the closure the entire Gaza Strip labour force employed in Israel was prohibited from leaving the Strip. Presently, the Israeli authorities have given permits to about 23,000 workers to work in Israel.

The construction field is by far the largest sector of employment of Gaza Strip workers, absorbing 50% of the labour force. Second is the agricultural sector at 22%, and third is industry at about 19%. The remaining labourers are employed in various other service occupations. Many workers have become skilled construction labourers who could implement any type of construction work which may be required in the Gaza Strip.

6.2 Regional differences

Economic conditions in the Gaza Strip are clearly worse than the rest of the Occupied Palestinian Territories. Within the Strip itself, the economic situation varies according to region and locality.

The northern part of the Gaza Strip, including greater Gaza City, is significantly better-off than the southern region, which includes the towns of Rafah and Khan Younis. The reason for this is the proximity and accessibility of the northern region to the Israeli labour market.

Due to the high degree of urbanization of the Gaza Strip, the disparities between urban and rural areas are not clearly marked. This is in contrast to the West Bank, where the rural-urban classification is more distinct.

On the other hand, differences in household wealth between refugee camps, refugees living outside camps, and non-refugees are very clear. The refugee households in the camps are clearly less wealthy than both the refugees outside the camps and the non-refugees. Additionally, the refugee households outside the camps also have lower wealth levels than the non-refugees. Hence, on average, there exists a marked difference between the wealth of refugee households in the Gaza Strip and that of the non-refugees. This is largely due to the refugees' loss of all their assets and agricultural lands during the 1948 war.

6.3 Sharing of household wealth

The Palestinian household is family-based in all its aspects. A network of economic obligations and privileges links family members, even if there is more than one individual income earner in the household. The share of economic resources and wealth of the household is mainly determined by the age and sex of its members. The final decision on the earning and expenditure of resources lies with the head of household.

7. ORGANIZATION AND PARTICIPATION

7.1 Local government

Since 1967, the Gaza Strip has been under the direct control of the Israeli occupation forces. The Israeli Military Government, and since 1981 the Israeli Civil Administration (CA), has acquired immense powers over the lives of the Palestinians in the Occupied Territories. The CA acts as a proxy for the central government and incorporates various specialized departments; these include: Health, Education, Interior, Planning, Water, and Agriculture. Each department is headed by a senior military officer who reports to the head of the CA[3].

At the city, town, and village level, there are municipal or local councils responsible for providing the necessary infrastructure services to the residents. These include the construction and maintenance of local roads, water supply, sewage collection and disposal, solid waste collection and disposal. In general, they are bulk purchasers of electricity from the Israeli Electricity Company and serve as supply institutions responsible for the maintenance of the local networks, and billing and collection.

The local institutions in the Gaza Strip are weak in various ways: financially, with respect to public support and regarding the efficiency of their operation.

The funds available for development projects and recurrent costs are very limited and many institutions have accumulated large debts to the Israeli main suppliers of water, electricity, and fuel. This is due mainly to two factors.

- All of the local the institutions experience financial problems due to the very small amount of central funding received from the CA and the sharp cuts in the funds received from the Arab countries and the PLO.

- Since the Intifada the institutions have been facing tremendous difficulty in collecting taxes and utility fees. This is only partially caused by the deteriorating economic situation of the population. More importantly, during the Intifada when the elected councils resigned the public considered not paying utility bills as a form of civil disobedience. Since then no new elections have taken place and a number of councils were appointed by the Israeli authorities. This decreased the public support for these institutions and raised a lot of questions about their legitimacy.

[3]For any activity a Palestinian plans to undertake, a permit from the CA or one of the sector departments is required. Usually, this is not an easy task, especially when the utilization of the natural resources - such as land and water - is involved.

The overall management capability of the local municipal institutions is very weak. It is reflected in the lack of planning, poor financial management, and the low efficiency of the staff.

7.2 Non-governmental organizations

The absence of a Palestinian government structure geared to meet the various social and economic needs of the population, as well as mobilizing them politically, has been the reason for the emergence of a number of non-governmental organizations in the OPT. This informal sector is very influential in the Palestinian community. The role of the different organizations varies from organizing the community members to the provision of a number of social services.

There are various types of organizations, they are usually grouped as follows:

- Voluntary societies;
- Cooperative movement;
- Popular committees, divided according to sector (e.g. health, agriculture, and women) and mainly politically oriented;
- Zakat committees (religiously oriented);
- Village or local committees, specifically in areas without elected councils.

The cooperation and support of one or more of the organizations active in the community concerned is of the utmost importance for the success of any project. Some of these organizations can even assist in the formulation, implementation, and monitoring of projects. Also, they can occasionally assist in funding certain projects which meet their objectives.

8. PHYSICAL STRUCTURES

The Gaza Strip can be divided into three distinct localities: the refugee camps, the cities, and the villages. They are distinct in their physical land and their socio-economic conditions. Thus, in order to be able to analyze the data relevant to RWCS feasibility, it is important to examine each locality separately. In the following section, the technical infrastructure of these localities will be described. The cities, towns, and villages will be examined in the same section since they have numerous similarities.

8.1 Physical layout

8.1.A Refugee camps

The shelter units have been built on lots allocated by UNRWA to the refugees. The housing style adopted by UNRWA in the early years of camp construction is based on terraced housing. In this style of housing each shelter shares its walls with the adjacent shelters, most of the time forming dual shelter units on each lot (see figure 4). Each lot then includes more than one shelter and is separated from neighbouring lots by sand

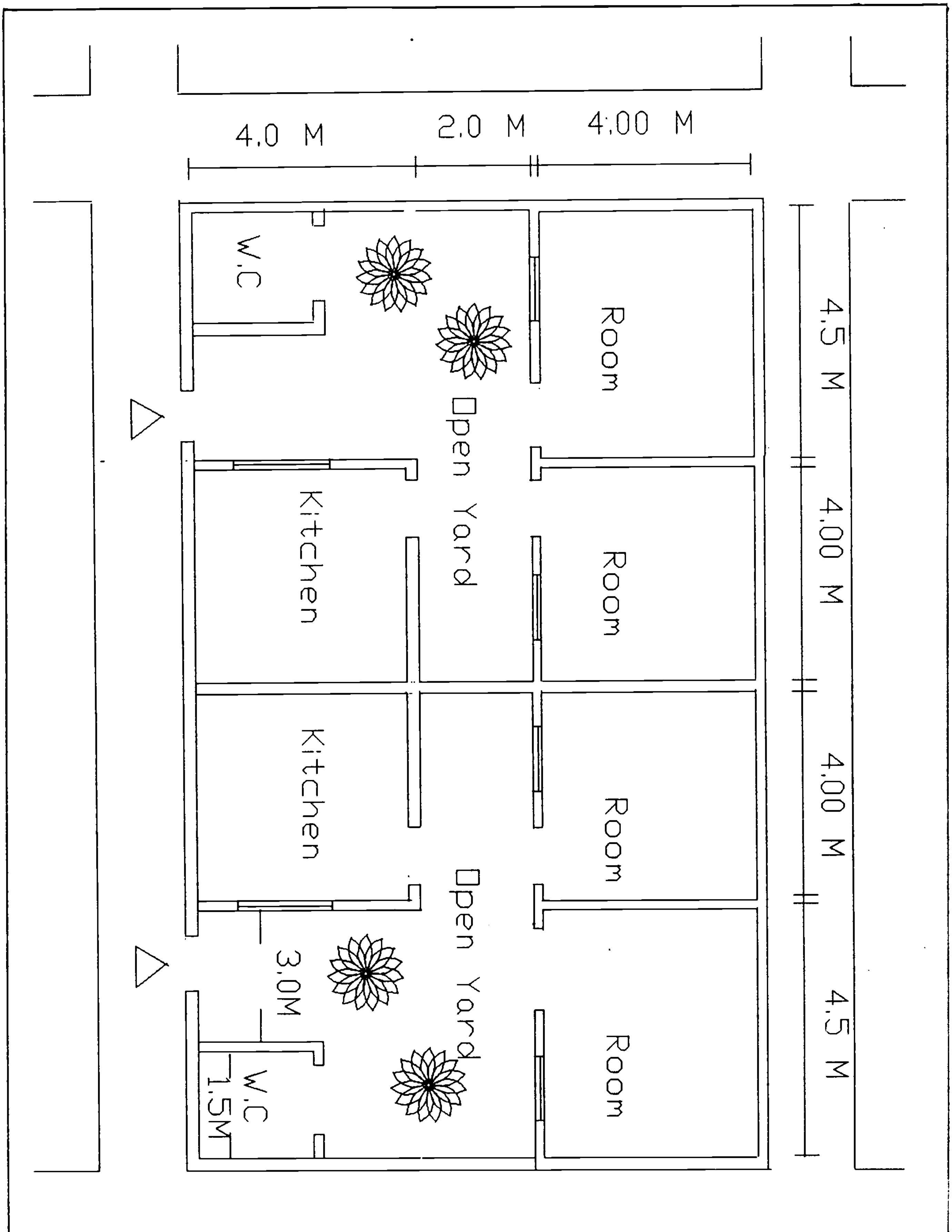


Figure 4. Layout of a double shelter unit

pathways or narrow walkways. Several lots form a residential block. Each block may contain only shelter units or shelter units with some of the public buildings and schools spread through out the camp. Residential blocks are separated from one another by main or secondary roads.

Each shelter houses one or more families, i.e. the extended family. It mainly consists of two bedrooms, a kitchen and a toilet. The bedrooms have a common wall and are separated from the kitchen and the bathroom by an open yard. The spaces between the exterior walls of the different rooms are connected by a wall which completely encloses the unit. In the dual units the shelters are separated by a wall which divides the lot in half. The entire shelter unit is surrounded by pathways on all sides. On average, each shelter has an area of 50 m^2.

In order to accommodate population growth, the courtyards in the camp dwellings were in many cases built up and roofed to increase the living area. Additionally, the refugees have expanded their shelters into the adjacent pathways, narrowing most of the pathways to less than 1.0 meter.

The expansion of the shelters is continuous and follows an irregular pattern. This has resulted in a non-uniform physical layout and increased density tremendously. Hence, in most of the camps the areas available for the shelters expansion or for the addition of new facilities are very limited.

The shelter units are constructed of cement blocks and clay bricks. The roofing is mainly zinc or asbestos cement corrugated sheets. The shelters are constructed on simple shallow foundations over sandy soil. Any excavations in the narrow pathways pose extreme danger to the structural safety of the shelters.

The road network consists mainly of sand pathways, walkways, and narrow alleys. Some wider paved roads separating the blocks were opened in the 1970's to facilitate the movement of military vehicles. Some of the main roads have been paved with asphalt but are presently in very poor condition because they are old and have not been maintained. The secondary roads and walkways have been paved with concrete by the residents. Their widths vary between 2-4 meters. The foot paths are still mainly sandy and their widths vary between 1-1.5 meters.

This situation gives the refugee camps a distinctly maze-like character. The shelter units are very closely packed in residential blocks, resulting in a high density. This presents very difficult living and working conditions.

8.1.B Cities, towns, and villag_ ;

The housing style in the cities and larger towns differs tremendously from that of the refugee camps. Most of the houses are multi-storied, two to four on average. Usually, each story is divided into two or four flats with a mean of 3.7 rooms per flat. The mean area of the housing unit in greater Gaza City is about 91 m^2 and 76 m^2 in the villages and towns. The majority of the buildings are occupied by extended families containing up to three generations. The total number of persons per building could reach up to 50 persons. In order to increase the usable space, terraces (open or closed off), usable roof areas, and courtyards have become common architectural features in most of the Gaza Strip towns and villages. In the highly condensed and poor residential blocks of the cities, the buildings are built close together and directly adjacent to the road, leaving no space for gardens or future expansion.

In the economically better off areas in Gaza City or the villages, small independent houses are also common. Some of these are built in one storey, while others are built on top of shops or garages. These types of buildings have some space surrounding them which is used as a garden or sitting area. However, in the past few years, and due to the lack of space available for city and town expansion, the house owners have been extending their houses both horizontally and vertically. This has given the cities and towns the distinct look of a single, large, over-crowded residential block.

The streets in the cities and villages are wider than those in the camps. They are mainly paved with asphalt but are in very poor condition due to lack of maintenance and development works. The main road networks divide the towns and cities into large residential blocks penetrated by narrower streets which are also paved with asphalt.

The houses in the cities and towns of the Gaza Strip are constructed mainly of concrete blocks with reinforced concrete roofs. Many of the roofs are sloped to drain the rain water and prevent pooling. However, most merely drain the rain water and dispose of it in the streets or alleys.

8.2 Infrastructure services

8.2.1 Water supply

8.2.1.A Refugee camps

The refugee camps are all connected to piped water supplies. The water is pumped from groundwater resources through a number of wells owned either by UNRWA, the local councils of adjacent towns or municipalities, the Israeli national water supply company (Mekoroth), or private owners.

Each water source (well) feeds a separate distribution network. The type and condition of the water pipes vary tremendously, further affecting the quality of the piped water. Different types of steel pipes, asbestos cement and plastic (PVC) pipes are installed. Some of the pipes are old and deteriorating while others are relatively new and sound. A number of shelters are sometimes connected to multiple networks in order to guarantee continuous and sufficient supply. Such connection are done on an ad-hoc basis without any prior planning and in most cases without any permission from the source owners. This situation makes it difficult to estimate the water consumption per shelter from any one source. Therefore, the usual practice is to estimate the average consumption based on the camp's overall consumption figures and population.

8.2.1.B Cities, towns and villages

About 99% of the houses in the cities and towns are supplied with piped water. Most of the water for domestic use in the Gaza Strip is supplied by local groundwater resources. The wells and distribution networks are operated and administered by the municipalities, local councils, and sometimes private owners.

The house connections are usually metered and the cost of the water quantity consumed in a certain period of time has to be paid in accordance with a set tariff. However, it was found that most of the meters have been tampered with or are not working; therefore, the majority of the consumers only pay the minimum charge regardless of their consumption rate.

8.2.2 Sanitation practices

The following table gives the type of household sewage disposal system by locality and percentage of household with each system:

Table #6

Locality	Septic tank	Sewage network	Other
Greater Gaza City	21	78	2
Gaza Towns/villages	57	34	10
Gaza camps	52	37	11

Source: FAFO report

Almost all houses use cistern-flush toilets.

8.2.2.A. Refugee camps

In the early stages of camp construction, UNRWA constructed communal pit-latrines for the refugees' use. They were maintained by labourers employed by the agency. However, due to a number of factors, such as the poor standard of the latrines and the insufficient water supply at the time, the conditions of the latrines have deteriorated and they have become a public health hazard.

At a later stage in the early 1960s, the refugees with financial help from UNRWA, constructed private pit-latrine units within the boundary of their shelters. Whenever the pits were full they were emptied by vacuum tankers.

The developing water supply networks in the camps combined with the high population growth resulted in a sharp increase in the water consumption rates. This, however, was not accompanied by parallel development in the sewage collection and disposal infrastructure. In whatever way the increased volume of wastewater is disposed of, it causes problems.

When refugees dispose of their grey water from domestic activities (kitchen, laundry, bathroom, etc.) into the percolation pits which were designed for excreta disposal only, the pits fill rapidly. The development of dry sludge layers in the pits clogs the surrounding soil, forming an impervious layer which limits the percolation of the liquid waste. The refugees are not emptying the pits regularly, which results in frequent flooding of the sewage into the adjacent streets and walkways. In addition, even if the pits are emptied regularly, the tanker drivers often dump their load at the outskirts of the locality.

A large number of the refugees dispose of their grey water into the drains and open channels passing near their shelters. These channels were constructed originally by the refugees with UNRWA help for the purpose of draining storm water. The waste water running in the channels is usually collected in the lowest areas inside or outside the camps' boundaries, forming large lakes of sewage water. In the rainy season, the open drains often overflow into the pathways and walkways, forming pools of stagnant water mixed with sewage.

This practice of sewage disposal in the camps is causing serious health hazards to the residents. Furthermore, it poses a contamination threat to the shallow underground water. A number of locations have been cited where sewage lakes are forming adjacent to water supply wells and high levels of nitrate are appearing in the quality tests undertaken by the water supply authorities.

Out of the eight refugee camps in the Gaza Strip, Jabalia Camp which has the largest population (70,000 inhabitants), is the only one served by a conventional sewage collection network. The network is part of a complete sewage collection, conveyance and treatment scheme for the northern region of the Gaza Strip. The project was implemented by the United Nations Development Programme (UNDP) between the years 1989 and 1992. Since that time, the improvement of the sanitary situation in the camp, and hence the health condition of its residents, has been tremendous.

8.2.2.B Cities, towns and villages

As in the refugee camps, the majority of the houses in the cities and towns has private latrines. With the increasing water consumption, waterborne sewerage systems became a high priority. A number of towns and cities are partially served by a sewage collection network or even a full scheme of sewage collection, disposal and recycling, as in Gaza City and the major part of the northern region of the Strip. However, the majority of the households still dispose of sewage in septic tanks or percolation pits (table 6).

The household sanitation facilities and practices in the Gaza Strip are considered satisfactory. Hygiene is an important concept to the family members which is reflected in the high maintenance and cleanliness levels the latrines are kept in. However, this does not apply largely to the disposal systems.

Septic tanks

The septic tanks are in many cases inadequate both in size and in type. In many cases they are not maintained or emptied regularly, which results in the continuous flooding of the sewage to the adjacent streets and alleys causing public annoyance and health hazards to the neighbourhood. The municipalities and local councils rent out vacuum tankers to the residents to empty the waste water from the filled septic tanks. Many families cannot afford to rent these tankers and thus do not do it often enough. Furthermore, it is a common practice for the tanker drivers to dispose of their loads on open land at the outskirts of the city or town. This creates pools of raw sewage which present a serious contamination threat to the underground water and to the surrounding environment.

Sewage networks

It is the responsibility of the municipalities and local councils to maintain and upgrade the sewage collection networks. The institutional arrangements for such a purpose are very poor and often disputed with the public. Due to political and economic reasons, often the local councils find difficulty in raising the necessary revenues from the public to operate and maintain the sewage schemes. Consequently, maintenance is inadequate, sewers are blocked, and treatment plants, when they exist, do not function. Particularly in the rainy season and due to the lack of a proper rain water drainage schemes in most of the localities, the sewage collection systems are used as combined drainage systems for both the sewage and rain water. This increases the potential for pipe and manhole blockage, and it floods the unequipped pumping stations and treatment plants with large quantities of mixed rain water, sewage, and grit.

Sewage is thus a feature of the Gaza Strip urban environment. The health consequences are very clear in the high level of intestinal parasites. Moreover, the risk of the spread of epidemics is always there, specifically in the highly populated urban areas. The impact on the underground water resources is indicated in the high level of nitrates reported in the tests carried out on wells in the vicinity of some population centres.

8.3 UNRWA plans for improvement

Recently, UNRWA have been preparing a report on strategic actions to meet the water supply, sewerage, and drainage requirements of the eight refugee camps and adjacent municipal areas in the Gaza Strip. The report will cover the following:

- A review of the environmental health conditions in the camps and the status of the relevant existing facilities and institutions;
- An assessment of the needs in environmental health related areas;
- Identification of strategic actions aiming at addressing the identified needs;

- An identification and evaluation of appropriate technological options for meeting needs identified, institutional development requirements, costs, and constraints;

- Guidance for development of the water supply and sanitation sector;

- Project identification with rough cost estimate;

- Definition of feasibility studies required to carry out the projects in more detail.

The report has not yet been published. However, UNRWA intends to start planning and implementing projects in accordance with the availability of funds.

9. SURVEY OF A REPRESENTATIVE AREA

The area of Khan Younis was selected for this survey due to the following characteristics:

- It includes the three different types of localities: city, refugee camp, and village;

- It is located within an area with average rainfall quantities, about 300 mm/yr;

- It suffers from water shortage and poor quality water.

The validity of this selection was verified with a number of experts in the Strip. The area includes the city of Khan Younis; Khan Younis Refugee Camp; and the adjacent villages of Al-Karara, A'basan Kabira, Khiza'a, and Bani Suhaila.

A total of thirty families were surveyed, ten from each locality. A questionnaire for the purpose of the survey was prepared covering social and technical issues relevant to RWCS. Two Palestinian engineers from the Gaza Strip helped in filling out the questionnaires by conducting direct interviews with one member of each family, in most cases the head of the family.

The English translation of the families' responses to the questionnaire are presented in annexes I-III. Analysis of the answers to the questionnaire gave the following results:

9.1 Khan Younis Refugee Camp

Average number of family members: 9

Head of family:
the father in 80% of the cases

Roof area:
about 104 m^2

Roof construction material:
mostly asbestos corrugated sheets

Paved area around the house:
almost none

Water sources: only one main source, from the municipality wells. However, 80% of the sample depends on carrying their drinking water from another source, namely, the Mekoroth line supplying Khan Younis Hospital.

Average water consumption:
difficult to compute in the camps due to the lack of meters and the multiple water supply networks serving the refugees. However, it is estimated at between 1.5-2.0 m^3/capita/month.

Opinion of the water quality:
all agree it is bad quality water, and even from the small sample there were two reported cases of kidney problems, which might be connected to consumption of saline water.

Need for another water source:
all agree on the urgent need, but could not define an alternative source.

Sanitary situation:
not satisfactory due to the improper sewage disposal systems used. Out of the 10 families, eight reported disposing of their sewage into the septic tanks, and two families were disposing of it in the open channels adjacent to the shelters. However, it was noticed that the septic tanks were always full and overflowing into the alleys.

The idea of collecting rain water was accepted by 80% of the families. Also, the majority expressed concern about the cleanliness of the collected water and the need for close monitoring by the health department, the municipality, or any other responsible body.

The willingness to contribute was expressed by seven families but only with the needed labour.

It was very difficult for the families to decide on the RWCS system they prefer, since none of them had the space required for under- or above-ground cistern. Nonetheless, if space was available, most preferred the above-ground cistern.

9.2 Khan Younis City

Average number of family members: 12.6

Head of family:
: the father in 70% of the cases, but 100% of heads of household are male

Roof area:
: about 193 m^2

Roof construction material:
: 100% reinforced concrete

Paved area around the house:
: in 50% of the houses there are paved areas which could be used as an extra collection basin or as a space in which to construct the collection cistern

Water sources:
: 80% depend on the municipality wells, three of them have a private well as a supplementary source. Two families depend only on a private well.

Opinion of the water quality:
: 80% thought the water quality was bad; however, none reported any diseases connected to the water.

Average water consumption:
: about 2.1 m^3/capita/month

Need for another water source:
: 90% agreed on the urgent need

Sanitary situation:
: better than in the refugee camps, all the families dispose of their sewage into septic tanks which are larger in size and better constructed than those in the camps

The idea of collecting rain water was accepted by all the families. However, 30% of them were not confident of the quality and said they would only use it for irrigating their gardens.

The willingness to contribute was expressed by nine families, basically with the needed labour, and two families said they would provide the materials also.

Half the houses had enough space around them to construct the cistern. Seven out the ten said they preferred the above-ground system.

9.3 Villages around Khan Younis

Average number of family members: 10.9

Head of family:
: the father in all cases

Roof area:
: about 174 m^2

Roof construction material:
: 100% reinforced concrete

Paved area around the house:
: There are paved areas around 40% of the houses which could be used as an extra collection basin or as a space to construct the collection cistern.

Water sources:
: 40% depend on the municipality wells, 40% on Mekoroth supply line and 20% on private wells. The two families who use private wells also use Mekoroth or the municipality wells as a supplementary source for the drinking water.

Average water consumption:
: about 2.3 m^3/capita/month

Opinion of the water quality:
: 80% thought the water quality was not good; however, none reported any diseases connected to the water.

Need for another water source:
: 90% agreed on the urgent need

Sanitary situation:
: better than in the refugee camps, all the families dispose of their sewage into septic tanks which are larger in size and better constructed than those in the camps.

The idea of collecting rain water was accepted by all the families. However, two of them thought it is important to treat the water and monitor its quality

The willingness to contribute was expressed by nine families, whether in labour, money, or materials.

Most of the houses had enough space surrounding them to construct the cistern. 60% preferred the underground system and 40% the above-ground system.

General conclusions

It was obvious from the survey that most of the households are charged the minimum rate of about NIS 17.5, regardless of their level of consumption. The only exceptions were those using the water from the Mekoroth line; the charges are a little higher, about NIS 1.5/m^3.

The quality of water from the municipal wells in the Khan Younis area as well as the Mekoroth line supplying the hospital are presented in table #7. The tests were carried out in March 1993.

Table #7

Results chemical analysis	Sadeh well	Jadeed well	Ahrash well	Eastern well	Amal well	Hospital line from Mekoroth
Ph	7.45	7.66	7.43	7.3	7.24	7.3
E.C. μS/cm	2360	1075.2	1478.4	2707.2	1280	262.4
Cl^- ppm	877.7	359	499.8	839.74	489.85	59.98
NO_3^- ppm	325	51.32	232	200	354.98	15.49

Source: Municipality of Khan Younis

These chemical tests show the high content of chloride and nitrate in the water from the local wells as compared to the water imported through Mekoroth.

As for the quantity of rainfall in the year 1992/93, it amounted to 436.7 mm (Khan Younis Observatory station).

10. SUMMARY OF THE WATER SITUATION

10.1 Present water sources

Presently, the groundwater resource is the major supplier of water for all purposes. The safe yield of this water is determined by the replenishment rate. Most sources estimate this at 25-50 million m^3 per year.
The water is extracted through wells which are operated by either the municipalities and local councils, UNRWA, private owners, or Mekoroth. For domestic and industrial purposes, the estimates for abstracted Gaza groundwater range between 23 and 37 million m^3 per year. In addition, the Israeli National Water Carrier (Mekoroth) pipeline transports 5 million m^3 of water per year to the Gaza Strip for domestic use. For agricultural purposes the abstraction of groundwater is estimated at 47-67 million m^3 per year. Estimates for total abstraction range between 84 and 130 million m^3 per year. Other water sources are not at present utilized to a significant degree.

10.2 Present and projected water needs

The water demand in the Gaza Strip is mainly for domestic and agricultural purposes. The amount of water required for industry is still very limited. As mentioned earlier, agriculture is the main consumer of water in the Strip, about 60% of the total supply.

Domestic water demand

The domestic water demand in the Gaza Strip is rising with the increasing population. The present population size is estimated at 790,000, which is projected to rise to 1000,000 by the year 2000 (Netherlands report). The average daily demand for domestic purposes is approximately 100 L/capita/day. This might seem low compared to other parts of the world or even to Israel (275 L/capita/day). However, taking into consideration the low standard of living in the Strip, especially with such a high percentage of refugees, it is believed such a consumption rate is close to reality.

The present domestic water demand is estimated about 29 million m^3/yr. The projected future demand at the end of the century is expected to be about 37 million m^3/yr.

Industrial water demand

The industrial water demand is presently very limited (5 million m^3/yr) and included as part of the domestic demand. Depending on the changes in the political situation, the industry in the Gaza Strip might grow and consequently its share of water consumption will grow too. This should be well-synchronized with the reduction in the agricultural water demand.

Agricultural water demand

As for the agricultural water demand, presently it is estimated at 100 million m^3/yr. Hence, the present consumption rate (about 50 million m^3/yr) does not reflect the real demand of the sector. This is due to the restrictions imposed by the CA on the extraction rates from the agricultural wells. Even with the restrictions, the water consumption of agriculture still exceeds the safe yield of the underground water (25-50 million m^3/yr). However, in the future it is expected that the agricultural water demand is going to decrease. This is due to the reduction in the land size available for agriculture, improved irrigation methods, and a proper management strategy for the distribution of the water resources.

10.3 The 'Water Problem'

The large deficit between the water demand and the safe yield of the underground water is the core of the water crisis in the Gaza Strip. If groundwater is to continue to be utilized, the balance between abstraction and replenishment must be restored. Alternatively, other sources of water must be developed. Both are long-term processes, and water the needs of the public must be satisfied in the interim period.

10.3.1 Public perception of the problem

The above formulation is a technical description of the water problem in the Gaza. However, the public is only aware of this problem to the degree that it is directly impacted by it. This impact has been, until now, mediated by various factors, and therefore consumers are just beginning to perceive the seriousness of the problem.

Traditionally, residents of the Gaza Strip have had easy access to unlimited quantities of good quality water. The shallow aquifer provided a convenient supply, only a well was needed. This easy access continued with the introduction of the pipe distribution systems. As mentioned before, about 99% of all households receive piped water. Furthermore, water prices have traditionally been low. In most cases, due to the difficulty in identifying the actual water quantities consumed by each household, the household is only charged the minimum rate of about NIS 17 per month. Such a price does not reflect the actual cost of water and certainly does not allow the municipalities to accumulate funds for the inevitable change in water supply practices. Political factors have also contributed to the difficulties local authorities experienced in establishing and maintaining a metering, billing and collection system that would transfer the cost of water to the customer. Consequently, the overexploitation of the Gaza aquifer was invisible to the general public until the increasing salinity began to be noticeable in the taste of the water. The problem of the quality of Gaza's underground water is only gradually becoming apparent to the average person in the Strip. Awareness is greater in areas with especially high salinity level which is affecting the water taste to the degree that people walk distances to obtain a few litres of drinking water from alternative sources (for example, in Khan Younis refugee camp). However, the community does not yet consider this a very serious health hazard and the magnitude of the crisis is still not apparent to the public. As a result, the level of interest of the Gaza Strip population in improving their water supply situation is not high. Popular interest is concentrated on other improvements in the community where the need is more obvious, e.g. sewage and solid waste collection and disposal facilities, school construction, projects linked to improving the economic conditions of the population, etc. The water problem would come after employment and health issues on the priority list of the public.

10.3.2 Recognition of the problem by the leadership

The situation differs at the leadership and local government levels. Their awareness of the water crisis in the Gaza Strip is much higher and they consider it a priority. However, there is still no consensus on the action required to solve the problem. All agree, however, that the first action to be taken is to collect all the necessary data which would help to assess the water situation clearly. And this should take place prior to the implementation of any water related projects, specifically the ones with direct implications for the underground water resources.

Nonetheless, many of the community leaders, scientists, funding agencies, and the CA are promoting a number of short and long term solutions to the problem in the Gaza Strip. Most of the proposed solutions deal with high cost technologies or projects such as desalination technologies. Very little is being mentioned about low cost technologies related to water supply and waste treatment, such as RWCS or stabilization ponds.

10.4 Possible solutions

Two aspects of the problem must be addressed.

1) To be able to continue to use groundwater for domestic and other purposes, the water balance of the Gaza aquifer must be restored. To achieve this goal, groundwater abstraction must be decreased and replenishment increased. These measures would also help alleviate the potable water shortage.

Groundwater abstraction can be decreased if agricultural demand for ground water is curtailed. Better irrigation practices and the cultivation of crops with lower water needs than the present citrus crops would further this goal. Also, water from alternative sources (treated wastewater, collected runoff water) could be substituted for groundwater in agricultural use.

Groundwater replenishment could be increased by recharging the aquifer with runoff water or treated wastewater.

2) The various water needs of the population must be satisfied, both short term and long term. The main concern is providing potable water.

Groundwater could be treated to improve its quality.
Rainwater could be captured and stored for drinking purposes.
Water could be transported to the Gaza.
Seawater could be used after desalination.

Of these possibilities, a number of technical options are being currently explored. It is, however, believed that without setting a sound water resources management strategy and implementing it, none of these options will be effective.

The following are some of the technical options which are being discussed. Some of these are already implemented to various degrees, others are under consideration.

• Short term:

a. Rainwater catchment systems (RWCS)

In the West Bank, rainwater catchment is a historic practice. Almost every household in the rural and the areas peripheral to the urban areas has an RWCS. Even the households which have been connected to the water supply network maintain their RWCS as supplementary water sources. The reasons for this include: the high quantities of rainfall, the very deep underground water, and the high cost of the water supplied by the different authorities.

The same does not apply in the Gaza Strip, where people have taken the accessibility of water for granted. It is just below the surface of the ground, and thus the digging of wells is easy. The price of water is low. In addition, the quantity of rainfall is much lower than in the West Bank. Recently, however, due to the deteriorating water quality in the

Gaza Strip, alternative water sources have been sought by the communities, especially for drinking purposes. RWCS, the subject of this study, is a practical solution where the physical conditions are appropriate, and could help solve the drinking water problem of a number of households in the Strip.

b. Collection of run-off rainwater from greenhouses and reuse of it for irrigation.

A number of farmers using greenhouses have been collecting the runoff water from the surface of the houses. This is a very practical method, especially since the number of greenhouses is rapidly increasing in the Strip and the runoff yield is high, approximately 80% of the annual rainfall (the greenhouses are usually covered by plastic sheets).

c. Collection of runoff water from the natural soil surface.

Depending on the soil nature, its infiltration rate and the quantity of rainfall, the surface runoff in certain parts of the Strip might be worth harvesting. The soil types in the Gaza Strip show that one third of the area will yield surface runoff and that 10% of the rainwater might be harvested. Some farmers are already doing that by constructing ponds to collect the water and use it for irrigation.

d. Utilizing treated waste water for irrigation.

Treated waste water could be one of the major resources for irrigation. A number of treatment plants have been constructed in the Gaza Strip with the aim of re-using the purified water for irrigation, artificially recharging the underground water, and reducing the possibility of untreated waste water polluting the underground water.

In the northern region of the Gaza Strip where two treatment plants were constructed, one with oxidation ponds and the other with aerated lagoons, over 14 million m^3/yr of treated waste water could be produced. This quantity, if used for irrigating the citrus orchards of the northern region, could reduce tremendously the amount of fresh water extracted from the groundwater sources. The same projects should be replicated in the middle and southern parts of the Strip, where there is a shortage of good quality water and citrus agriculture is diminishing.

However, major technical, cultural, and educational obstacles still hinder the farmers' acceptance of the use of treated waste water. In addition, farmers fear losing their established fresh water rights to the private wells. Such obstacles have to be overcome through training, community education campaigns, and political decisions before waste water reuse could become wide-spread in the Gaza Strip.

e. Artificial recharge of the aquifer with surplus water.

The groundwater could be artificially recharged in three ways:

- Capturing the seasonal wadi flows, mainly Wadi Gaza, and recharging the aquifer at carefully located places. Care should first be taken that the water is not contaminated.

- Collecting storm water from the major cities and towns into spreading basins and using it to recharge the aquifer. There is a similar project in Gaza City.

- Recharging the aquifer with treated waste water.

f. Desalination of brackish water extracted from underground sources using the Reverse Osmosis (RO) method.

This alternative is being discussed extensively by the CA and a number of donor countries, and the CA intends to construct one RO pilot plant at one of the wells near Khan Younis. It is, however, important to select the right well points in order to minimize the risk of local over-abstraction.

g. Improvement of water delivery systems and water use practices.

This would take place through:

- effective demand and asset management in municipal supply. The inefficient water supply systems, which are presently leaking and improperly designed, have to be rehabilitated. The unaccounted-for water quantities have to be reduced through the establishment of proper tariff structures, and billing and collection systems. Community education on the importance of saving water has to be carried out and water saving techniques have to be promoted. All this requires institutions which are well-established technically, financially and politically.

- Changing the agricultural crops presently planted in the Strip, such as citrus, to less water-consuming and better salt-tolerant crops. Further, replacing the old irrigation techniques which lead to high water losses to modern more efficient ones. This can be achieved through proper agriculture extension, offering economic incentives to farmers, changing the irrigation quota system (which is a very sensitive issue), etc.

h. Importing water from Israel through Mekoroth's National Water Carrier;

Presently, Mekoroth is supplying about 5 million m^3/yr to a number of localities facing high shortage of good quality water, such as Khan Younis city. This could be one of the alternatives but not necessarily a strategic one on the long term. It could not be relied on for meeting growing demands and prices are subject to change.

- <u>Long term:</u>

a. Desalination of sea water. This is an expensive solution but is nevertheless considered a future alternative.

b. Importing water from other countries within the region as part of an overall solution to the problem of regional water scarcity.

11. PRELIMINARY DESIGN OF AN RWCS IN THE GAZA STRIP

In order to determine the practicability of RWCS in the Gaza Strip, it is important to decide on its overall technical and economic feasibility and the purposes for which the collected water could be used.

11.1 Technical considerations

To start, the following data (gathered from the preceding sections) and assumptions will be used:

Supply
Average rainfall: 300 mm/yr
Average rainwater catchment area: 76 m^2 (average of the towns and villages)
Runoff coefficient: 0.85

- Approximate water supply from the catchment area is 23 m^3/yr.

Demand
Average household size: 9 persons
Average water demand: 100 L/capita/day
Average drinking water demand: 5 L/capita/day

- The average water demand per household is approximately 27.4 m^3/month or 329 m^3/yr.
- The average drinking water demand per household is about 1350 L/month or 16.5 m^3/yr.

It is obvious that the water demand exceeds by far the possible supply. Therefore, the collected water through RWCS would not be sufficient to meet the overall demand. Since the Gaza Strip water crisis basically has to do with the quality of water, it would be practical to consider the collected rainwater as a supplementary water supply which is of good quality and could be used for drinking purposes.

Thus, the calculations would be based on the drinking water demand which is estimated at 5 L/capita/day. This means that the drinking water demand of the household is 1,350 litre per month, or 16.5 m^3 per year. Recall that the possible quantity of rainwater to be collected is 23 m^3/yr. Thus, the supply would be sufficient to meet the drinking water demand. Consequently, it would be possible to use the collected rainwater for drinking purposes only or to mix it with the saline water from other sources to reduce its salinity.

Naturally, the size of the catchment area is going to vary between the refugee camps, the cities, and the towns. It will be larger in the cities and villages than in the refugee camps. Still, the fact remains that the number of persons sharing one catchment area is larger in the cities and villages, because the buildings are multi-storey and house more than one family.

An average storage tank size could be computed using the mass curve method and the average data mentioned above. The tank size is necessarily a rough estimation since it is based on an average of 15 year rainfall data. Actual yearly rainfall data was difficult to acquire from Khan Younis observatory station.

Table #8

Month	Rainfall Khan Younis (mm)	Monthly supply (litres)	Cumulative supply (litres)	Monthly demand (litres)	Amount stored (litres)	Total amount stored
Nov.	48.2	3,113.72	3,113.72	1,350.00	1,763.72	1,763.72
Dec.	67.9	6,002.36	9,116.08	1,350.00	4,652.36	6,416.08
Jan.	57.7	5,100.68	14,216.76	1,350.00	3,750.68	10,166.76
Feb.	47.5	4,199.00	18,415.76	1,350.00	2,849.00	13,015.76
March	29.4	2,598.96	21,014.72	1,350.00	1,248.96	14,264.72
April	6.4	565.76	21,580.48	1,350.00	-784.24	13,480.48
May	4.4	388.96	21,969.44	1,350.00	-961.04	12,519.44
June	0	0.00	21,969.44	1,350.00	-1,350.00	11,169.44
July	0	0.00	21,969.44	1,350.00	-1,350.00	9,819.44
Aug.	0	0.00	21,969.44	1,350.00	-1,350.00	8,469.44
Sept.	0.5	44.20	22,013.64	1,350.00	-1,305.80	7,163.64
Oct.	9.3	822.12	22,835.76	1,350.00	-527.88	6,635.76

The required tank volume is the difference between the least amount stored in the dry season and the largest amount stored during the wet season. Therefore:

Storage tank size = 14,264.72 - 6,635.76 = 7,628.96 m^3
Approximately 8 m^3.

The above selected size is based on the household drinking requirement. Thus, in order to avoid loss of water in the rainy season when the rainfall is plentiful, the household members could utilize the rainwater for other purposes. In the dry season, the use should be restricted to drinking purposes.

11.2 Economic considerations

To compute the average cost of a RWCS, it is important first to define the most appropriate system to be used in the Gaza Strip. The physical, technical, social, and economic conditions must be kept in mind, as well as the locally-available skills and the available materials which are usually used in similar constructions. The system will be composed of:

• roof catchment areas (asbestos sheets in the camps and reinforced concrete in the cities and villages);

• galvanized gutters in the camps and PVC drain pipes in the cities and villages;

• above ground reinforced concrete or PVC storage tanks in the camps and reinforced concrete tanks (above or underground, in accordance with space availability) in the cities and villages;

More details justifying the above system are provided below:

a. Roofs and gutters

Most of the roof catchment areas need minimal rectification, whether corrugated asbestos sheets or reinforced concrete.

The asbestos sheets roofs usually slope in one direction; therefore, the gutters could be installed at the low edge. In such cases the gutters would be galvanized metal, available in the local market. The piping would be from plastic (PVC) which is available, cheap, and easy to install.

The reinforced concrete roofs are a different case. A sloping sheet needs to be laid on the roof to drain the rainwater in the direction of the drainage pipe. This could be done using cement mortar with the labour of the household members. However, many of the houses already have roofs which slope so much that they prevent pooling of rainwater, which will minimize the required work.

b. Storage tanks

Two types of storage tanks could be used in the Strip using local material and utilizing local skills: reinforced concrete or plastic tanks (PVC).

Reinforced concrete tanks are the most frequently used for similar purposes, especially in the West Bank, where rainwater roof catchment systems are a historic practice. The required material is available locally and the construction work could be carried out by the residents, amongst whom many skilled construction labourers could be found. The cost, although relatively high, is still more appropriate compared to other available options.

As for the PVC tanks, the cost depends on the size; for example, a 10 m^3 PVC tank manufactured in Gaza costs about NIS 6,500. This is not affordable in local standards, especially after the recent deterioration in the economic conditions. Furthermore, we have to consider the relatively cheap prices of water in the Strip (NIS 17.5/month), which amounts to NIS 210/yr regardless of the consumed quantities.

Therefore, at least for the tank, the cost would have to be subsidized by a local or international funding agency, in order to make it affordable. The economic aspect should not be the main consideration due to the importance of providing better quality water for the inhabitants of the Gaza Strip. Even if the capital investment might seem un-economic to the consumer, making good quality drinking water available in such a crisis situation is invaluable.

11.3 Social considerations

The fact that almost every household in the Gaza Strip is supplied with large quantities of cheap water promotes a false sense of abundance and hinders the raising of community interest in finding alternative sources of water. Community interest in RWCS and support for any future project depends on the following:

a. Increasing the community's sense of the need for palatable drinking water by raising their awareness of the nature and seriousness of the water crisis.

b. Convincing the community members of the potability of rainwater, its future economic feasibility, and its attractiveness as a water source independent from any outside control. Rooftop rainwater catchment is an unfamiliar technology in the Gaza and local experience is indispensable for establishing the residents' confidence in this technology. The construction of pilot and demonstration systems is recommended for this purpose.

c. Educating the community members about their contribution to the successful implementation of any future national water resources management strategy. Such a strategy would aim at reaching the balance between the extraction and recharging rates of the underground water resources by: controlling the extraction from the underground water, controlling agriculture and domestic consumption rates through setting appropriate tariffs, and finding alternative supplementary water sources. The public needs to be informed about this overall strategy and the possible technical options, so that the comparative advantages of rainwater catchment systems and their role within the strategy can be understood and appreciated.

The above can be achieved through community awareness campaigns and close working relations between the technical and political personnel and the community representatives. Only thus can the social acceptance of RWCS be guaranteed.

12. PRELIMINARY DESIGN AND COST ESTIMATE OF A TYPICAL RWCS PILOT PROJECT IN THE KHAN YOUNIS AREA

For the purpose of designing a typical RWCS, the area of Khan Younis where the survey was conducted was chosen. The data collected from the three different localities, Khan Younis City, villages, and camp, will be used as the base data of the design.

This should be considered as a pilot design to be implemented on a pilot scale in demonstration projects. After evaluation it could be replicated in other areas of the Gaza

Strip where need and appropriate conditions prevail. At that stage site-specific modifications may be necessary.

12.1 Sizing of the storage tank

The first design stage involves sizing the storage tank. The method of mass curve analysis will be used. The result will be approximate since the monthly rainfall quantities considered are an average of 15 years of rainfall rather than actual monthly values.

a. <u>Khan Younis Refugee Camp:</u>

Average household size: 9 persons
Average roof size: 104 m^2
Type of roof: Asbestos corrugated sheets
Runoff coefficient: 0.85
Daily drinking water demand: 5 L/capita
Monthly demand (assumed to be constant): 1,350 litres

Table #9

Month	Rainfall Khan Younis (mm)	Monthly supply (litres)	Cumulative supply (litres)	Monthly demand (litres)	Amount stored (litres)	Total amount stored
Nov.	48.2	4,260.88	4,260.88	1,350.00	2,910.88	2,910.88
Dec.	67.9	6,002.36	10,263.24	1,350.00	4,652.36	7,563.24
Jan.	57.7	5,100.68	15,363.92	1,350.00	3,750.68	11,313.92
Feb.	47.5	4,199.00	19,562.92	1,350.00	2,849.00	14,162.92
March	29.4	2,598.96	22,161.88	1,350.00	1,248.96	15,411.88
April	6.4	565.76	22,727.64	1,350.00	-784.24	14,627.64
May	4.4	388.96	23,116.60	1,350.00	-961.04	13,666.60
June	0	0.00	23,116.60	1,350.00	-1,350.00	12,316.60
July	0	0.00	23,116.60	1,350.00	-1,350.00	10,966.60
Aug.	0	0.00	23,116.60	1,350.00	-1,350.00	9,616.60
Sept.	0.5	44.20	23,160.80	1,350.00	-1,305.80	8,310.80
Oct.	9.3	822.12	23,982.92	1,350.00	-527.88	7,782.92

The required tank volume is the difference between the least amount stored in the dry season and the largest amount stored during the wet season. Therefore:

Storage tank size = 14,627.64 - 7,782.92 = 6,844.72 m^3
Approximately 7 m^3.

The shallow foundations will forbid carrying out any deep excavations in the vicinity of the shelters. Underground storage tanks could thus be constructed only for those shelters that are adjacent to the wider main roads. Otherwise, installation of an above-ground storage tank is recommended. The PVC type would be ideal, however the reinforced concrete is more economical. The cost estimate will be calculated for this latter type. Space around the refugee shelters is very limited and each unit will have to be evaluated individually with respect to the possibility of placing a storage tank. Units with sufficient space are in the minority and the application of this project will be confined to these selected shelters. Multiple tanks of smaller size located within the shelters' yards may be considered in certain cases. Such design would increase the cost of the system.

b. <u>Khan Younis City:</u>

Average household size: 12.6 persons
Average roof size: 193 m^2
Type of roof: Reinforced concrete
Runoff coefficient: 0.85
Daily drinking water demand: 5 L/capita
Monthly demand (assumed to be constant): 1,890 litres

Table #10

Month	Rainfall Khan Younis (mm)	Monthly supply (litres)	Cumulative supply (litres)	Monthly demand (litres)	Amount stored (litres)	Total amount stored
Nov.	48.2	7,907.21	7,907.21	1,890.00	6,017.21	6,017.21
Dec.	67.9	11,139.00	19,046.21	1,890.00	9,249.00	15,266.21
Jan.	57.7	9,465.69	28,511.90	1,890.00	7,575.69	22,841.90
Feb.	47.5	7,792.38	36,304.28	1,890.00	5,902.38	28,744.28
March	29.4	4,823.07	41,127.35	1,890.00	2,933.07	31,677.35
April	6.4	1,049.92	42,177.27	1,890.00	-840.08	30,837.27
May	4.4	721.82	42,899.09	1,890.00	-1,168.18	29,669.09
June	0	0.00	42,899.09	1,890.00	-1,890.00	27,779.09
July	0	0.00	42,899.09	1,890.00	-1,890.00	25,889.09
Aug.	0	0.00	42,899.09	1,890.00	-1,890.00	23,999.09
Sept.	0.5	82.03	42,981.12	1,890.00	-1,807.97	22,191.12
Oct.	9.3	1,525.67	44,506.79	1,890.00	-364.33	21,826.79

Storage tank size = 31,677.35 - 21,826.79 = 9,850.56 m^3
Approximately 10 m^3

c. <u>Khan Younis Villages:</u>

Average household size: 10.9 persons
Average roof size: 174 m^2
Type of roof: Reinforced concrete
Runoff coefficient: 0.85
Daily drinking water demand: 5 L/capita
Monthly demand (assumed to be constant): 1,635 litres

Table #11

Month	Rainfall Khan Younis (mm)	Monthly supply (litres)	Cumulative supply (litres)	Monthly demand (litres)	Amount stored (litres)	Total amount stored
Nov.	48.2	7,128.78	7,128.78	1,635.00	5,493.78	5,493.78
Dec.	67.9	11,139.00	18,267.78	1,635.00	9,504.00	14,997.78
Jan.	57.7	9,465.69	27,733.47	1,635.00	7,830.69	22,828.47
Feb.	47.5	7,792.38	35,525.85	1,635.00	6,157.38	28,985.85
March	29.4	4,823.07	40,348.92	1,635.00	3,188.07	32,173.92
April	6.4	1,049.92	41,398.84	1,635.00	-585.08	31,588.84
May	4.4	721.82	42,120.66	1,635.00	-913.18	30,675.66
June	0	0.00	42,120.66	1,635.00	-1,635.00	29,040.66
July	0	0.00	42,120.66	1,635.00	-1,635.00	27,405.66
Aug.	0	0.00	42,120.66	1,635.00	-1,635.00	25,770.66
Sept.	0.5	82.03	42,202.69	1,635.00	-1,552.97	24,217.69
Oct.	9.3	1,525.67	43,728.36	1,635.00	-109.33	24,108.36

Storage tank size = 32,173.92 - 24,108.36 = 8,065.56 m^3
Approximately 8 m^3.

12.2 Construction

Roofs and gutters

The catchment areas in the camps are the asbestos cement roofs which are sloped in one direction, and in the cities and villages the sloping reinforced concrete roofs. Constructing the roofs with a slope is a local practice in the West Bank and Gaza.

The gutters in the camps are galvanized steel with a cross section of 100 cm^2. They are bolted to the roofs using steel hooks spanned every 50 cm. The roof overhangs the gutter by 2 cm. The gutter extends beyond the roof edge by 7 cm.

In the reinforced concrete roofs, the rainwater would drain to a trap near one of the edges which would lead the runoff through PVC pipes down to the storage tank.

At the storage tank, the first 1-2 mm of rainwater (usually very dirty) would be diverted away from the tank via a 'first flush device' and later drained by opening the drain valve on the device.

Storage tanks

In the cities and villages the use of the underground storage tank is practical due to the different house foundations and construction types. It is preferable to construct the underground tank from reinforced concrete which is usually used in the Gaza Strip for similar structures. The materials and skills are locally available.

To lift the water, a small electric pump could be installed. The pump could be connected directly to the tap. Preferably, it would be used to lift the water to a small intermediate reservoir on the roof, from which the water would flow by gravity at the opening of the tap. Similar arrangements are common in the West Bank. The use of an electric pump rather than a handpump is preferred by the local residents due to its cheap price, availability in the market and effortless operation. Hand pumps are out of use in the country, very expensive to custom make them and there is no local experience in maintaining them.

A covered opening in the top of the tank is made to allow a person to go inside it for cleaning purposes.

12.3 Maintenance and monitoring

The house owners have to maintain and clean the system. The roof should be cleaned before the expected first rains and the proper disposal of the first-flush is essential. The gutters and pipes have to be kept clean and unclogged. The tank has to be cleaned if the house owner suspects it has gotten dirty for any reason. The opening cover has to be kept well-closed for cleanliness and safety reasons.

It is preferred that an organization or a local authority would carry out a small training programme on the maintenance and safety procedures required for RWCS. In the first stages of the project implementation, the local responsible authority could monitor the progress of the work and its actual operation until the household members are used to doing it on their own.

12.4 Cost estimate of RWCS

The cost of constructing the RWCS (as described above) in the Gaza Strip is estimated in this section. The estimate takes into consideration the prevailing unit prices of the needed materials and workmanship. The quantities might vary from one household to the other, according to the physical setting.

1) The first estimate is for the RWCS system in the refugee camps, where the use of the above ground reinforced storage tank is recommended.

Table #12

Item	Description	Unit	Quantity	Unit Price US$	Total US$
1.	Reinforced concrete f_{cu} 25 N/mm², steel f_y 425 N/mm², work include concrete, steel, formwork	m^3	4	200	800
2.	Plastering the inside floor and walls with cement, sand and a water repellant additive mix	m^2	21	6	126
3.	Galvanized metal rainwater gutter for roof including fixing in place	m	15	16	240
4.	ϕ3" P.V.C. drain pipe from roof gutter to tank including fixing in place	m	7	8	56
	Total				1,222

f_{cu}: Concrete compression strength in Newton/mm²
f_y : Steel yield in Newton/mm²

2) The second estimate is for the RWCS in cities and towns, where the use of the underground reinforced concrete tank is recommended.

Table #13

Item	Description	Unit	Quantity	Unit Price US$	Total US$
1.	Excavation for concrete, size of excavation 2.6 x 2.6 m, 2.7 m depth	Job	1	200	200
2.	Reinforced concrete f_{cu} 25 N/mm^2, steel f_y 425 N/mm^2, work include concrete, steel, formwork	m^3	8	200	1600
3.	Plastering the inside floor and walls with cement, sand and a water repellant additive mix	m^2	25	6	150
4.	Electric water pump 0.5 hp, 1" inlet and outlet, including connection to electricity	Job	1	100	100
5.	Galvanized steel pipes ϕ1" from tank to pump and water tap ϕ1" include supply and installation	Job	1	80	80
6.	ϕ3" P.V.C. pipe for drain from roof to tank as detailed including fixing complete	m	7	8	56
7.	Steel cover with hinge and lock size 60x60cm include fixing and painting	Job	1	80	80
	Total				2,266

f_{cu}: Concrete compression strength in Newton/mm^2
f_y : Steel yield in Newton/mm^2

In some cases the repair of the roof may be necessary:

8.	Repairing the concrete roof, laying concrete mix to slope, minimum thinkness 3 cm	m^2	200	7	1400
	Total including roof repair				3,666

13. APPROPRIATE SANITATION SYSTEMS

The present sanitation practices and infrastructure in the Gaza Strip are described under Section 6 above (Physical structures). The environmental health problems caused by the inadequate sewage collection and disposal systems are highly apparent all over the Strip. The problems are aggravated by the growing population and the increasing water consumption.

Attempting to improve the water situation in the Gaza Strip cannot take place without also addressing the sanitation problem. The contamination of many of the ground water sources is due to the infiltrating sewage, which is apparent from the high nitrate content in the analyzed water samples.

To address such problems it is vital to start implementing appropriate sewage collection, disposal and treatment systems wherever needed in the Gaza Strip. It is important, however, when deciding on the appropriate systems to keep in mind the following:

- The high water consumption rate in the Strip (100 L/capita/day). This is considered low when compared to consumption rates in Israel, but it is high from the point of view of the amount of waste water it generates, and which has to be safely disposed of.

- The limited space available within the residential areas and within the Strip as a whole.

- The weak institutions (technically, financially, and managerially) in charge of the sanitation services and the lack of interest in improving the sanitation infrastructures (sewage installations are not envisioned as income generating, unlike the water installations).

- The absence of a regional or national body which would coordinate the water and sanitation development activities taking place in such a small and crowded area.

- The importance of evaluating the existing operational systems and practices, disposal into septic tanks, percolation pits, open channels, also the present treatment plants (oxidation and aeration lagoons). The evaluation should aim at learning about the faults, assessing the needs, and planning better for the future, at the same time trying to make use of the present structures.

The sewage disposal systems that could be considered include septic tanks, conventional sewer systems and small-bore sewage collect' n systems. Within the above context the following is recommended:

- Especially in the refugee camps and in residential areas that are highly populated space is limited for the construction of septic tanks. The area is almost flat, generally unfavourable to conventional sewer system. Further, the people cannot afford the cost of conventional sewers. Under these circumstances small-bore sewerage could be a viable option. This technology has all the advantages of conventional water-borne sewerage but costs far less to construct. The basic components of the system are the following:

a. House connections which collect the household waste water;

b. Interceptor tanks which remove the suspended solids and the floating solids from the waste water;

c. The small-bore sewer network which consists of small diameter pipes collecting the waste water and discharging it into an existing sewerage system or treatment plant serving the adjacent cities or towns.

In the interceptor tank the lighter solids rise and form a scum blanket while the heavy ones settle and form a sludge layer. The solids are digested anaerobically in the sludge layer. This sludge has to be removed, usually once every five to ten years.
Due to the settling of solids in the interceptor tank, there is no need to ensure the self-cleaning velocity in the sewers as in the conventional systems. Therefore, the small-bore sewers can be much smaller in diameter and with lower slopes.

The maintenance of such systems requires minimal skills, usually not beyond those required for on-site sanitation.

- In the larger cities, which are at present partially served by conventional sewerage, it is advisable to complete the networks and connect the remaining areas, specifically, the commercial and industrial ones. The areas distant from the centre of the town could still be served by small-bore sewerage connected to the conventional system and to the treatment plant.

However, it is important to realize the high expense involved in the construction, operation, and maintenance of conventional sewage collection systems. The technical, economic, and social implications of using such systems have to be well-evaluated, not only by engineers, but also by social scientists and politicians.

- In the towns and areas where space is available, the present practice of disposing sewage into septic tanks could be continued. However, it is important to have the local authority supervise the design and construction of the septic tanks in order to guarantee their appropriateness. Additionally, they have to ensure that the house owner empties the tank when needed and does not allow it to overflow into the adjacent streets.

Where site conditions are suitable and do not pose any contamination threat to groundwater resources, the effluent in the septic tank could be disposed off through sub-surface soil absorption. This is usually done by connecting the tank to a distribution box which is then connected to perforated pipes laid in trenches. The trenches are constructed in an absorption field, over a layer of gravel and soil.

This sub-surface drainage technique has been implemented by the Save the Children Foundation, both in the West Bank and in the Gaza Strip. They have evaluated it as an appropriate technique, specifically in the areas where land is available, the soil type is suitable, and the water consumption rates are average.

- As for sewage treatment systems presently used in the Gaza Strip, specifically the one serving the Gaza City, at present the plants are not operating properly due to the following:

  the designs were based on the use of conventional technology, aerated lagoons, sensitive gaseous chlorinators, electro-mechanical grit removal devices, etc. Such designs depend on sophisticated imported equipment which requires highly skilled labour to operate and maintain it, in addition to high capital and running costs. Further, the designers did not take into account the physical conditions of the Gaza Strip. It is sandy, has few paved roads, no storm water collection systems, etc. This causes serious grit and sludge problems at the treatment lagoons.

However, due to lack of space in the Gaza Strip, other low cost treatment systems, such as waste stabilization ponds might be difficult to use. Therefore, to minimize the area used for treatment, aerobic systems with minimum retention times should be used. Such systems usually produce high quantities of sludge, which when accumulated in the ponds, hinder their proper operation (as in the case of the Gaza City treatment plant).

Therefore, technical precautions should be included in the designs to allow for the continuous cleaning of the ponds without any interruptions in the treatment process. Such precautions include dual settling basins with the potentiality for flow diversion and sludge removal. Provisions for sludge handling, processing, and disposal should also be included.

The training of technical personnel to operate and maintain the systems should be an integral part of any project. Furthermore, setting an overall management structure including a running cost recovery system from the sanitation bills and the selling of the purified wastewater to farmers is imperative.

Taking into consideration the cultural obstacles connected with sewage treatment projects, their success could only be realized if combined with an intensive community awareness campaign aiming at educating the population and the farmers about the importance of treatment systems and the viability of treated waste for irrigation.

14. CONCLUSIONS

The water crisis of the Gaza Strip can be described as a chronic and increasing shortage of water, especially potable water, due to the continuous decline of the ground water table and its increasing salinity. The present situation is the result of years of mismanagement of the underground water resources and under-utilization of other resources available. This in turn is partially due to the fact that information and applied research regarding the Gaza aquifer, on which sound water management practices could be based, have been lacking.

Without setting a sound water resources management strategy and an implementable action plan, the prevailing water quality and quantity problem in the Gaza Strip will be aggravated further. The main objective of such a strategy would be to arrive at a balance between the extraction and replenishment rates of the underground water in order to guarantee the continuous availability of fresh water for the inhabitants of the area.

Maximum exploitation of all possible water resources, fresh or re-used, should be ensured. The identification of such resources and their potential uses has to take place through adequate research. No alternative resources, whether primary or supplementary, should be ruled out without appropriate justification.

14.1 Feasibility of RWCS

This study has demonstrated the appropriateness of a very important water resource, namely rainwater. If harvested and utilized, it would assist in meeting part of the water demand for drinking and agricultural purposes in the Gaza Strip.

Specifically, it ascertained the appropriateness of using household rainwater harvesting techniques to augment the availability of good quality drinking water to the residents of the Gaza Strip. This technique have numerous advantages that make it favourable to implement under the conditions present in the Gaza:

a. the high quality of rainwater, compared to the quality of water presently used in large parts of the Strip;

b. low operation costs and required maintenance, which even compete with the present low water prices;

c. accessibility of water, which would save a considerable amount of work and time presently invested in carrying the drinking water from the few good quality sources available;

d. the system independence, making it practical to implement on individual household basis, where the conditions are appropriate;

e. the required material and skills to construct the system are available locally;

f. the roofs in the Strip are suitable catchment areas and, therefore, require minimal preparation work.

On the other hand, the following factors make the Gaza Strip unfavourable for RWCS:

a. the high capital investment involved, which might discourage some families from constructing a RWCS. Therefore the idea of subsidizing part of the required investment should be explored, without neglecting the importance of the community contribution;

b. The limited amount of rainfall in the Strip, especially in the southern part. RWCS can be expected to supply water only for drinking needs.

c. Insufficient catchment area and space around many of the houses limits the potentiality of spreading the system to a large number of houses.

It is clear that the Gaza Strip does not provide ideal conditions for rooftop rainwater catchment and this technology could not be applied to all households. However, there a number of households in the Gaza, in the refugee camps as well as in cities and villages, where the space requirement for the storage tank is met. The rainfall, though far from abundant, is enough to satisfy the drinking water needs of the household - and it is the lack of good quality drinking water that is the most burning problem.
Therefore it is recommended that RWCS be implemented at those sites where conditions permit, with subsidies provided for the tank construction.

14.2 Sanitation

Combined with augmenting the availability of drinking water in the Strip, emphasis should be put on improving the environmental health conditions of the population, and protecting the underground water resources from contamination. This is wholly related to improving the sanitary situation dominant in the Gaza Strip.

Low cost small-bore water based sanitation system might be the only solution which could be offered to highly condensed, low income residential areas, whether refugee camps or suburban areas. This technology could be very appropriate since almost all houses use cistern-flush toilets.

Sewage treatment for environmental reasons and for re-use, is very essential. The most appropriate technologies to be used should be identified through evaluation of the existing systems and applied research.

Annexes

Legend:	RC:	Reinforced Concrete
	MW:	Municipality Well
	PW:	Private Well
	D :	Domestic
	G :	Gardening
	A :	Animals
	ST:	Septic Tank
	PP:	Percolation Pit
	OD:	Open Drains

Khan Younis Refugee Camp

#	Question	1	2	3	4	5	6	7	8	9	10
1	# of family members	5	5	12	5	17	9	5	10	8	15
2	Head of family	father	Son	father	father	Brothers	father	father	father	father	father
3	Roof area in m²	110	60	140	120	120	100	58	90	85	90
4	Roof construction material	Asbestos	Asbestos	Asbestos	RC	Asbestos	RC	Asbestos	Asbestos	Asbestos	C.Metal
5	Area of paved yards m²	0	0	0	0	0	0	6	0	0	0
6	Paving material	-	-	-	-	-	-	Tile	-	-	-
7	Water supply source	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
8	Any other water source?	Yes, from Mekoroth	Yes, from Mekoroth	Yes, from Mekoroth	Yes, from Mekoroth	Yes, from Mekoroth	Yes, from Mekoroth	Yes, from Mekoroth	No	Yes, from Mekoroth	No
9	Family consumption rate m³/month	8	No meters	No meters	4	45	24	No meters	No meters	20	20
10	Amount of water bill	17.5	15	17,5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
11	Water uses	D	D	D	D	D+G+A	D	D	D	D+G	D
12	Their opinion of the water quality	Salty	Not good	Not good	Not good	Not good	Not good	Not good	Salty	Not good	Salty
13	Did it cause them any diseases	No	Yes (kidney failure)	No	Yes	Yes	No	No	No	Yes, Kidney problems	No
14	Do they feel the need for another water source	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
15	Do they know the quantity of the rainwater in their area	No	No	No	No	No	No	No	No	No	No
16	What type of sewage disposal system they use	PP+OD	PP+OD	ST	ST	ST	ST	ST	ST	ST	ST
17	What is their opinion of collecting rainwater to be used for various purposes	good	very good	good	Not sure	good	good	good	good	good	No good
18	Would they use collected rainwater for domestic purposes if they know it is of good quality?	Yes	Yes	Yes	Not clean	Yes, if monitored	Yes, if monitored	Yes	Yes	Yes	No
19	If the collected rainwater is available for free, would they prefer it to wells water?	Yes	Yes	Yes	No	Yes, if monitored	Yes, if monitored	Yes	Yes+MW	Yes	No (not clean)
20	Are they willing to contribute to the construction of RWCS?	Yes	-	Yes	No	Yes	yes	Yes	Yes	Yes	No
21	If yes, what?	Work	-	Work		Work	work	work	work	work	
22	Which type of system they prefer? underground or aboveground cistern	under (no space)	No space for the tank	No space		above	no space	above	above	above	

City of Khan Younis

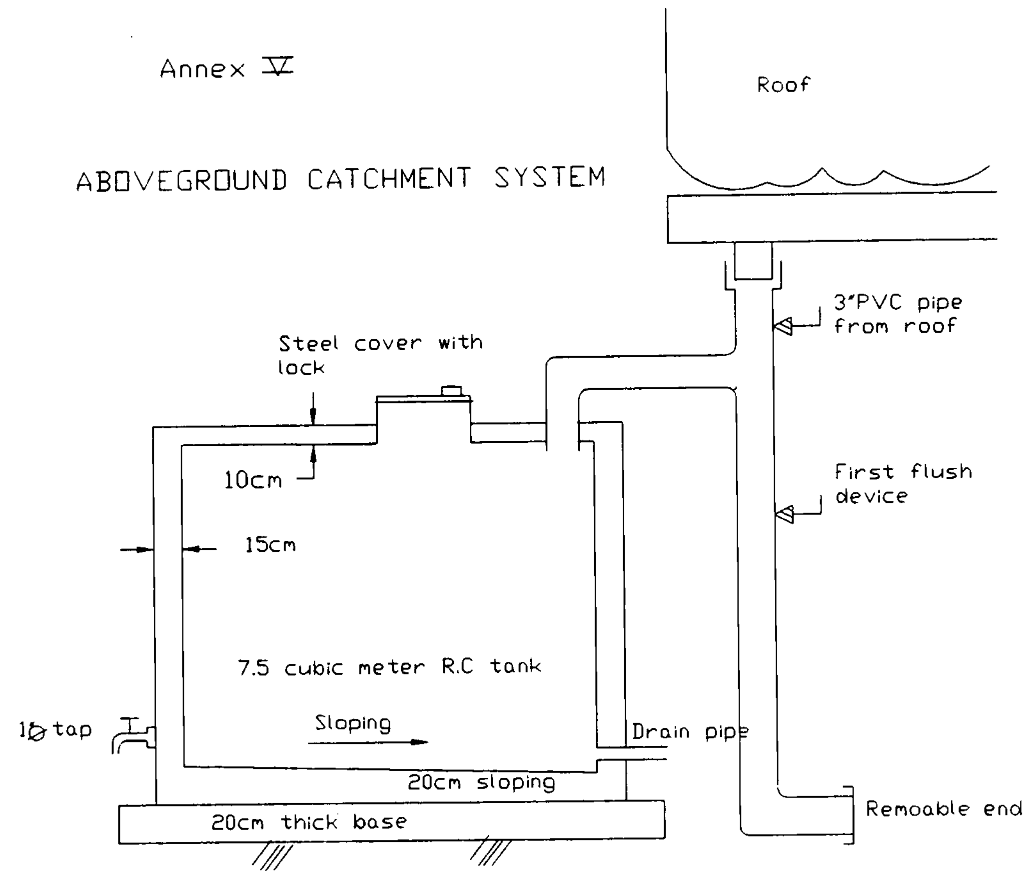
#	Question	1	2	3	4	5	6	7	8	9	10
1	# of family members	18	30	10	8	5	6	6	9	22	12
2	Head of family	father	Brother	father	father	father	Brother	father	Brother	father	father
3	Roof area in m^2	170	350	250	120	104	60	150	80	350	300
4	Roof construction material	RC	RC	RC	RC	RC	RC	RC	RC	RC	RC
5	Area of paved yards m^2	0	0	100	40	0	0	80	20	0	100
6	Paving material	-	-	Tiles	Cement	-	-	Cement	Cement	-	Tiles
7	Water supply source	MW	MW	MW	PW	MW	MW	MW	PW	MW	MW
8	Any other water source?	No	No	Yes,PW	No	No	No	No	No	Yes,PW	Yes,PW
9	Family consumption rate m^3/month	20	50	20	30	20	20	20	30	30	30
10	Amount of water bill? NIS	17.5	24	17.5	0.0	17.5	17.5	17.5	0.0	15	17.5
11	Water uses	D	D	D+G+A	D	D	D+G	D	D+G+A	D+G	D+G+A
12	Their opinion of the water quality	Polluted	good	good	Salty	Salty	Salty	Salty	Salty	Bad	Salty
13	Did it cause them any diseases	No	No	No	No	No	No	No	No	No	No
14	Do they feel the need for another water source	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
15	Do they know the quantity of the rainwater in their area? mm/yr	300-400	300	400-600	No	No	No	No	No	No	No
16	What type of sewage disposal system they use	ST	3 ST	ST	ST	ST	ST	ST	ST	ST	ST
17	What is their opinion of collecting rainwater to be used for various purposes?	good	good	good	good	good	good	good	good	good	good
18	Would they use collected rainwater for domestic purposes if they know it is of good quality?	Not sure of its cleanliness	Yes	Yes, for gardening	Yes	Yes	Yes	Yes	Yes	Yes	Yes, for gardening
19	If the collected rainwater is available for free, would they prefer it to wells water?	No	yes	No	yes	Yes	Yes	Yes	Yes	Yes	No
20	Are they willing to contribute to the construction of RWCS?	No	yes	yes	yes	Yes	Yes	Yes	Yes	Yes	Yes
21	If yes, what?		work	work	mat.+work	Work	Work	mat.+work	Work	Work	Work
22	Which type of system they prefer? underground or aboveground cistern		under	above	above	above	above	above	above	under	above

Villages around Khan Younis

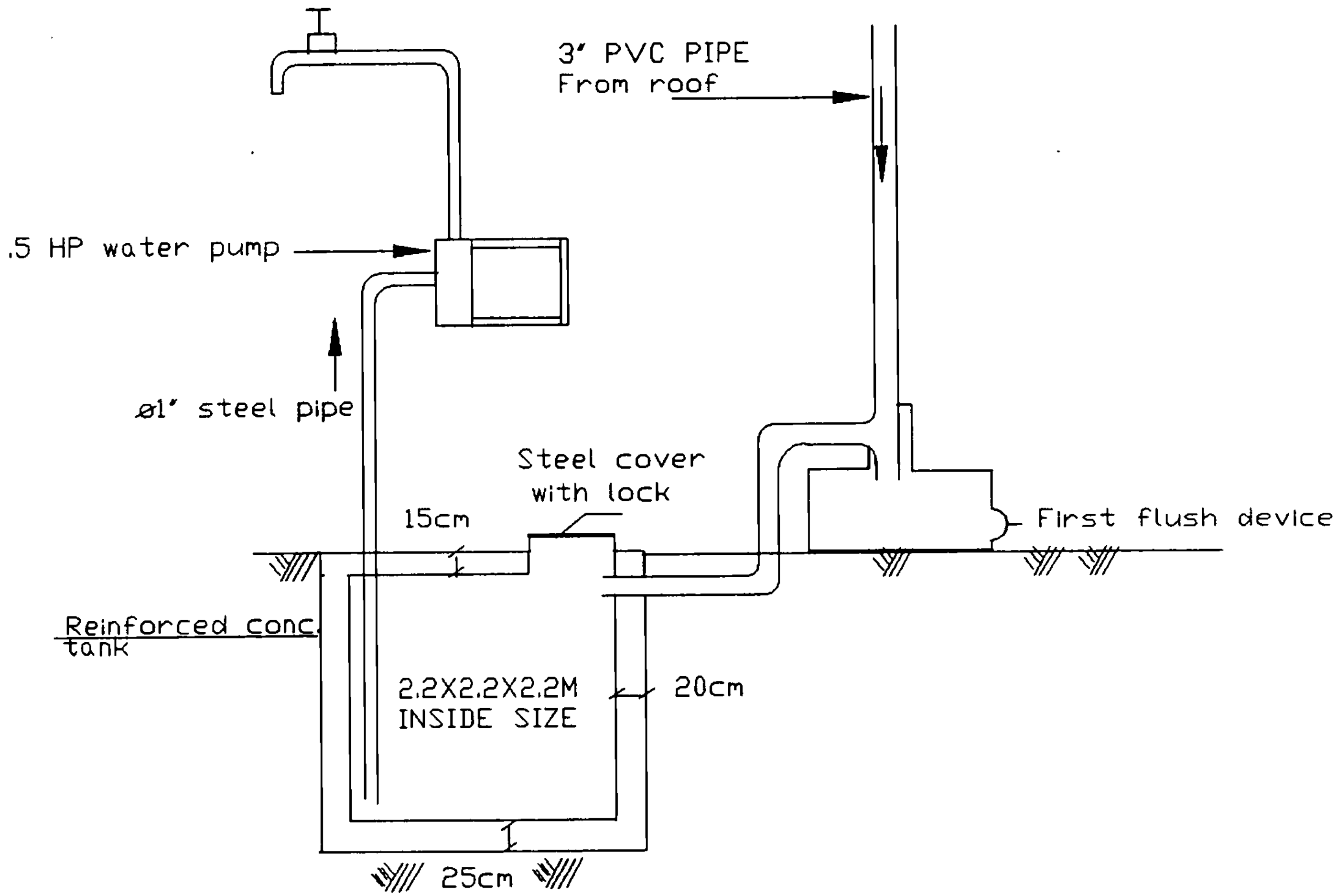
#	Question	1	2	3	4	5	6	7	8	9	10
1	# of family members	6	5	11	10	14	17	12	5	11	18
2	Head of family	father	father	father	father	father	father	father	father	father	father
3	Roof area in m²	110	120	276	260	165	180	200	190	120	120
4	Roof construction material	RC	RC	RC	RC	RC	RC	RC	RC	RC	RC
5	Area of paved yards m²	100	0	115	0	120	0	0	70	0	0
6	Paving material	Tiles	-	Tiles	-	Tiles	-	-	Tiles	-	-
7	Water supply source	PW	MW	MW	MW	MW	PW	Mekoroth	Mekoroth	Mekoroth	Mekoroth
8	Any other water source?	Yes, Mekoroth	No	No	No	No	Yes, MW for drinking	No	No	No	No
9	Family consumption rate m³/month	30	10	30	25	25	-	50	20	20	25
10	Amount of water bill	25	18	22	17.5	17.5	-	65	35	25	30
11	Water uses	D+G+A	D	D+G+A	D+G	D	D	D+G+A	D	D+G+A	D+G+A
12	Their opinion of the water quality	Not good	good	good	Salty, occasionally	Salty	Salty and polluted	Polluted	Polluted	Not good	fair
13	Did it cause them any diseases	Not sure	No	No	No	No	Yes	No	No	No	No
14	Do they feel the need for another water source	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
15	Do they know the quantity of the rainwater in their area	300	No	300-400	No	800-1000	No	No	No	170	No
16	What type of sewage disposal system they use	ST	ST	ST	ST	ST	ST	ST	ST	ST	ST
17	What is their opinion of collecting rainwater to be used for various purposes	good	good	good	good	Excellent	Excellent	good	good	good	good
18	Would they use collected rainwater for domestic purposes if they know it is of good quality?	Yes	Yes	Yes, after treatment	Yes	Yes	Yes	Yes	Yes	Yes, if well monitored	Yes
19	If the collected rainwater is available for free, would they prefer it to wells water?	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
20	Are they willing to contribute to the construction of RWCS?	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
21	If yes, what?	money+work	Money+work	20% of cost		25% of cost	Work	Money+work	Work	Work	Work
22	Which type of system they prefer? underground or aboveground cistern	under	above	above	above	under	under	under	under	above	under

Annex V

ABOVEGROUND CATCHMENT SYSTEM



Annex 1V



UNDERGROUND CATCHMENT SYSTEM

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