Engineering Journal of Qatar University, Vol. 5, 1992, p. 237 - 248

QUALITATIVE AND QUANTITATIVE ASSESSMENT OF DRAINED WATER FROM URBAN GROUND-WATER

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ABSTRACT

Although the groundwater table in the State of Qatar peninsula is reducing, there is a persistent increasing level of groundwater in some areas in Doha city. This increasing tendency could be attributed to the topography of the area, geological structure, rapid urbanization, increase in water consumption, uncontrolled irrigation of farms and green areas as well as the absence of storm-water drainage system. To lower the groundwater table, a drainage system has been laid through Rayan and Wadi Musheirib which are the worst affected areas. This system drains away the groundwater as well as the stormwater to the Arabian Gulf. A qualitative and quantitative monitoring program was initiated in order to evaluate the possibility of utilizing this drained water. The results obtained indicate that the drainage water could be used for irrigating certain types of trees.

INTRODUCTION

Doha is the capital of Qatar, a peninsula in the Arabian Gulf. It lies within an arid sub-tropical zone and experiences high temperature, high humidity and low annual rainfall. Rainfall over the areas occurs mostly during the winter and spring seasons. The mean annual rainfall based on the last 27 years of record is 77.2 mm with a maximum reported rainfall of 302.8 mm (1). It rains only for a few days (on an average 8 to 9 days) in a year. There is a high degree of variability in total annual rainfall. Inspite of such a low rainfall some areas in the city experience ponding on the streets and some areas are waterlogged (2).

Although the groundwater table in the state of Qatar peninsula is reducing, there is a persistent increasing level of groundwater in some areas in Doha city. Groundwater mounds have been observed in some areas damaging the horticulture and land use which is shown in Fig. 1 (3). This increasing tendency could be attributed to the topography of the area, geological structure, rapid urbanization, increase in water consumption, uncontrolled irrigation of farms and green areas and leakage of water mains and distribution pipes as well as the absence of storm-water drainage system (4).

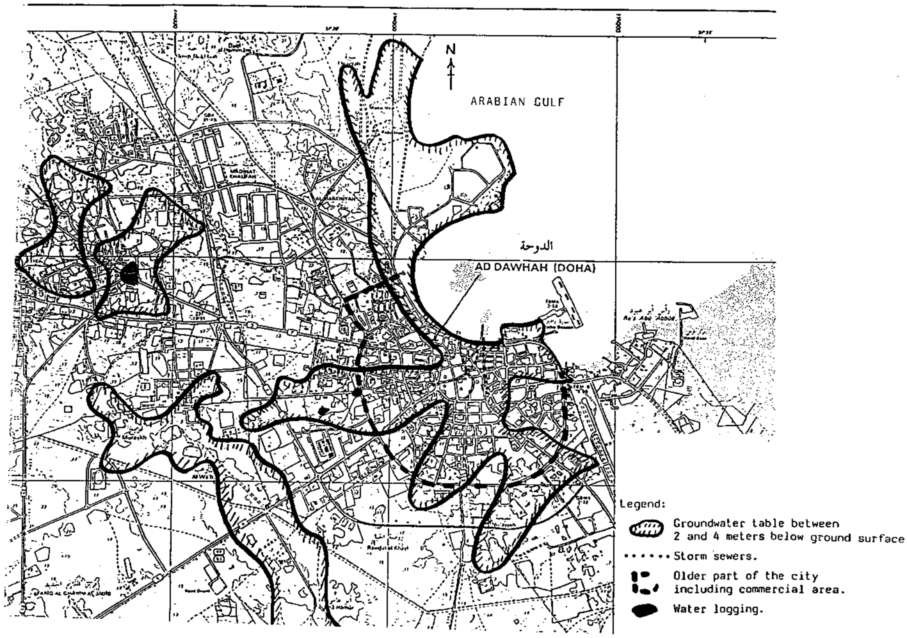


Fig. 1: Existing storm sewers and groundwater table in Doha (1986).

The rapidly growing groundwater level beneath Doha was first recognized in the late 1970 and early 80's following FAO reports on groundwater Resouces in Qatar (5). Since then the Ministry of Industry and Public Works, Civil Engineering Department, "Drainage Division" took the necessary steps to initiate in house and consultancy studies to deal with the problems. A master plan was prepared and the first phase of this plan has been inaugurated in 1991 with a groundwater drainage system being laid through problem areas called Rayan Wadi Musheirib which are the worst affected areas (6). This system drains away the groundwater as well as the stormwater to the Arabian Gulf (Fig. 2).

Instead of allowing the ground water to drain into the Gulf, a qualitative and quantitative monitoring programme has been initiated in order to evaluate the other alternative for better utilization of the drained water. The results obtained indicated the possibility of using this drainage water for irrigating certain types of trees. Further studies of admixtures of groundwater and treated sewage effluent revealed the possibility of utilizing the mixture for a wider varieties of plants and trees.

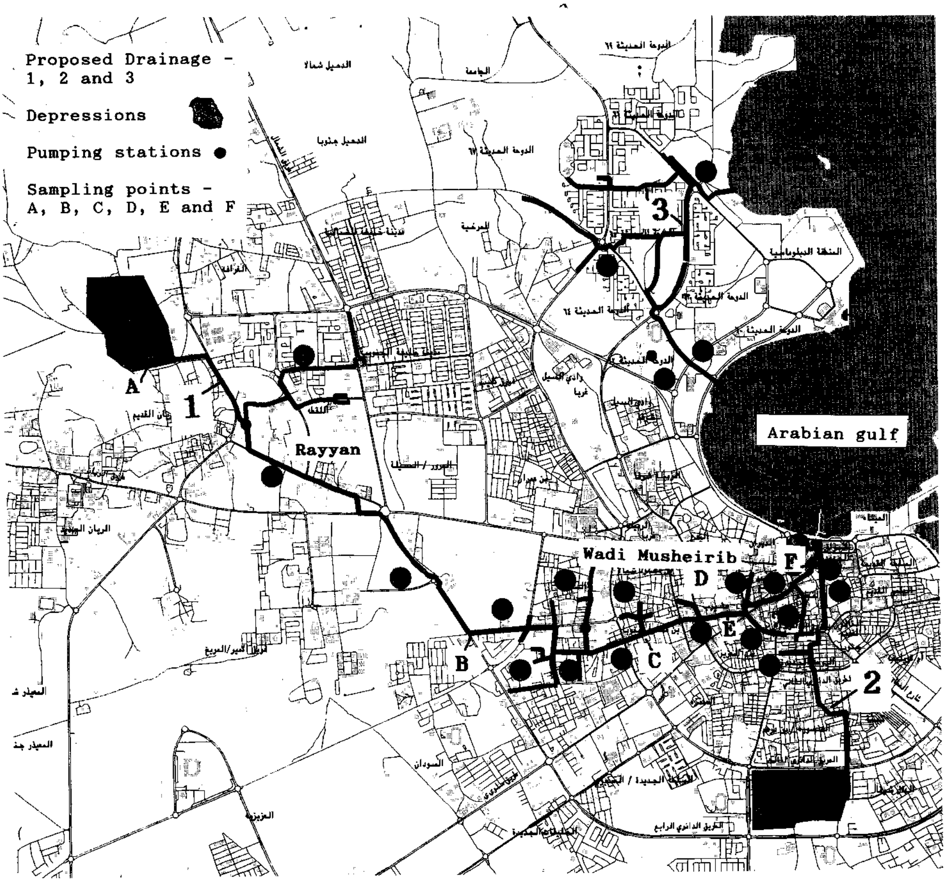


Fig. 2: Surface and Groundwatr Drainage scheme in Doha showing the sampling locations.

Surface Drainage

The design of a storm sewer is based on the maximum rate of run off from a drainage area. The relationship between the rainfall and runoff is given by the rational formula.

$$Q = CiA$$

where,

A = drainage area for the sewer under consideration.

i = average intensity of rainfall corresponding to the period of maximum rainfall of an assumed return period.

C = run off coefficient.

Q = peak rate of run off.

Intensity of rainfall is related to the duration of rainfall and the return period. Based on the rainfall records of the Department of Meteorology, State of Qatar; the relationship between the intensity, duration and return period of rainfall has been developed and is shown in Fig. 3 (1).

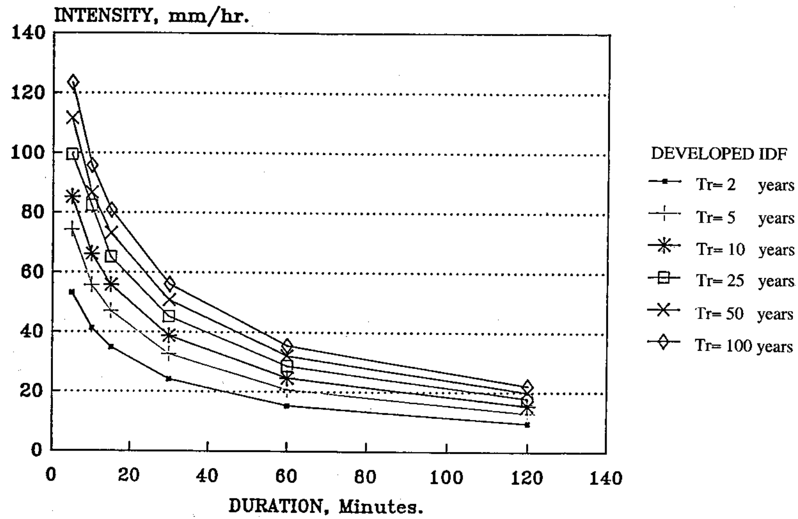


Fig. 3: Intensity, duration and frequency relationship.

Storm sewers in residential areas are generally designed for a return period of 2 years (7, 8). For high value commercial districts, industrial zones and areas with greater social or amenity value, a higher standard of protection from flooding due to rainfall may be needed. This increased protection can be achieved by designing such districts for longer return period. An appropriate value of the return period can be selected from Table 1.

According to the ASCE Manual (8), a sewer system designed for a 10-year storm return period may cost only about 6 to 11% more than the system designed for the 5-year storm (8).

The entire stormwater that falls on the ground does not enter the sewer. Some of it is stored in depression and gets intercepted by the surface vegetation, while other gets lost due to evaporation, and infiltration into the ground. It is difficult to quantify the amount of water lost in these processes. The overall effect of these factors may be accounted for in the design of storm sewers by using a suitable value of C, the run off coefficient (Table 2).

The run off depends upon the run off coefficient and the rainfall intensity which generally varies with time. Consequently the discharge at a given point in the

Table 1
Storm Return Periods Recommended for Drainage Design in Doha

Category	Storm Return Period
Residential areas (low and medium cost housing) Parks Playgrounds Local Business Areas Natural Areas	2 years
Major and Junctions Commercial, Community and District Centers	5 years
Government, Institutional and Other Official Developments Property technically sensitive to flooding e.g. buildings with basements, power stations, etc. High cost housing	10 years
High Prestige or Ceremonial Developments	20 years

Table 2
Run-off Co-efficients

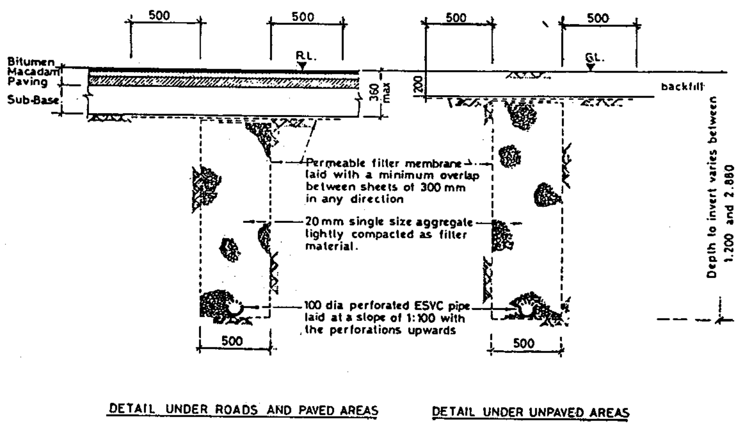
Residential Density			Business & Commercial Areas	Light Indust. Areas	Up-paved Areas	Roads & Paved Areas
Low	Med.	High				
0.20	0.30	0.40	0.70	0.50	0.10	0.70

drainage system takes time to build up to its peak value, which happens when the entire drainage area begins contributing to the flow. This time is known as the time of concentration, which is composed of the time of entry and the time of flow in the drainage system. The time of entry mostly depends upon the size, shape and topography of the drainage area and may vary between 1 and 15 minutes. The larger value applies to larger, flatter sub-catchments and vice versa. However in case of a single storm gully which collects run off from a large area, the time of entry will be extended and should be estimated from the general catchment slope and roughness.

The time of flow is dependent on the physical properties and design characteristics of the drainage system. While selecting the intensity of rainfall, the duration of rainfall is taken as equal to the time of concentration.

Groundwater Drainage

The groundwater drainage system consists of the main sewer line and manholes to which perforated laterals are connected to drain the underground water. A typical section of the lateral is shown in Fig. 4. The street inlets are also connected to the drainage sewer to carry the storm water. The storm trunk main runs through Rayyan and Wadi-Musharib where the ground water level is sometimes less than 1.5 m below the ground surface. The total length of the drainage pipes already constructed is about 17 km. About 7 km of pipework is under construction and 16 km is proposed in future. The drainage network within the project area is expected to lower the groundwater level by 5.0 m below the ground surface.



ESVC - Extra Strength Vitrified Clay

Fig. 4: Land drainage details (6)

Due to the flat topography of the area, the entire drainage system could not operate under gravity. Three pumping stations are installed in the drainage system at suitable locations. The average capacity of the pumping stations is 150 L/s. Two main pumps and a stand-by have been installed in each pumping station. Finally the drained water is pumped into the Doha Bay through a culvert.

To date the drainage project has costed 90 million Qatari Riyal and the proposed extension of the drainage network is estimated to cost 61 million Qatari Riyals.

Groundwater Monitoring

In order to account for any seasonal variation in the quality and quantity of the drained groundwater, a monitoring program was taken up for the one year starting in April 1991 and ending in March 1992.

Six sampling points were located on the trunk sewer starting from the pumping and collection station at Al-Rayyan (A) to the main disposal pumping station PS1 at F (Fig. 2). It was not possible to measure the flow rate at each sampling point for lack of flow measuring devices. However the total flow rate at PS1 was measured and found to be on an average 350,000 m^3/month. Samples were collected on every Sunday from the six assigned points simultaneously. In all 52 samples were collected. All the samples were analyzed for pH-value, electrical conductivity (EC), total dissolved solids (TDS), chloride (Cl^-), Sulfate ($SO_4^=$), Salinity (SAL), Alkalinity (ALK), Total Hardness (T. HAR), nitrogen, phosphate, boron, sodium ion (Na^+), calcium ion (Ca^+), magnesium ion (Mg^{++}), and potassium ion (K^+). Sodium absorption ratio (SAR) was determined by calculation. Nitrogen and phosphorous compounds were negligible and boron was not present in the sample analyzed. The analysis was carried out according to the Standard Methods (9).

RESULTS AND DISCUSSIONS

Monthly average characteristics and flow rate of ground water are presented in Table 3. Such characteristics are typical of the groundwater quality in Doha.

Some of the groundwater constituents during April 1991 are shown in Figure 5. The concentration of all the constituents in general decrease from A to F. This phenomenon can be explained by the presence of freshwater infiltration into the trunk sewer, which was confirmed by the analysis of samples taken from the laterals randomly.

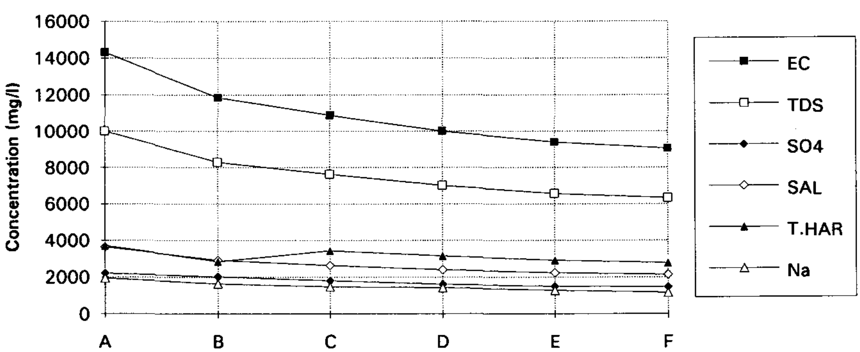


Fig. 5: Variation in the concentration of groundwater constituents from sampling point A to F.

Table 3

Monthly average characteristics and flow rate of groundwater (All the values are in mg/L except pH-value, SAR, flow rate in 100 m^3/month and EC in μmhos/cm)

	Apr	May	Jun	Jul	Aug	Sep
Flow Rate	3616	4687	3525	3616	3750	3499
pH value	7.69	7.68	7.73	7.80	7.62	7.72
EC	10,914	12,288	13,018	11,045	9,367	11,048
TDS	7,639	8,607	9,112	7,722	6,550	7,733
Cl^-	1,477	3,273	2,907	2,703	2,550	2,957
$SO_4^=$	1,768	2,713	2,798	2,547	2,925	2,874
SAL	2,658	5,933	5,248	4,837	4,587	5,347
ALK	153	138	141	145	137	142
T.HAR	3,140	2,960	3,043	2,880	2,863	2,913
Ca^{++}	713	717	717	707	697	762
Mg^{++}	357	284	305	280	273	243
Na^+	1,485	1,598	1,395	1,113	1,483	1,455
K^+	778	83	69	71	79	82
SAR	10.6	10.4	10	11	11	11

	Oct	Nov	Dec	Jan	Feb	Mar
Flow Rate	3589	3369	3509	3750	3758	4687
pH value	7.67	7.72	7.65	7.80	7.85	7.70
EC	8,921	10,993	11,482	10,150	11,478	11,200
TDS	6,244	7,698	8,037	7,103	8,052	7,850
Cl^-	2,351	2,936	3,263	3,028	3,060	2,950
$SO_4^=$	2,693	2,928	3,046	3,102	3,317	2,580
SAL	4,242	5,312	5,888	5,463	5,535	5,310
ALK	151	145	142	144	147	138
T.HAR	2,512	2,833	3,267	3,232	3,312	2,730
Ca^{++}	617	697	772	757	805	656
Mg^{++}	267264	324	328	321	264	
Na^+	1,186	1,336	1,570	1,478	1,603	1,445
K^+	75	100	100	90	100	78
SAR	10	11	11	10	12	10

Absence of nitrogen and phosphorous compounds in the samples confirmed that the water infiltrating into the laterals and trunk-sewer consisted of fresh water and not sewage.

A comparison between the flow rate, TDS, Cl, Salinity and Total Hardness as shown in Figure 6, indicated that there is a direct relationship between the TDS and salinity of the groundwater, whilst the flow rate remains nearly constant. Referring to Table 4, the obtained analytical results indicated that although the average salinity is 5000 mg/l it could still be used for irrigating a large variety of plants, especially the Phoenix Dacylifera which is widely spread in the Gulf region. Brackish water having TDS values in the range of 3000-4500 mg/l have been successfully used to grow a variety of vegetables and crops over a period of several years in Kuwait (10).

The hazard of using the irrigation water having high sodium concentration can be evaluated in terms of SAR value. Irrigation water must not have SAR value higher than 8 to 10. However the ground water under consideration has an average SAR value between 10 to 12, (Table 3). Groundwater of such a quality can be made suitable for irrigation through dilution with a better quality water e.g. fresh water or treated sewage effluent. Use of freshwater for dilution may not be justified because neither it is surplus in arid region like Doha nor it is cheap. Therefore treated sewage effluent having an average TDS of 2000 mg/l may be used for dilution. Moreover the treated sewage effluent is being used in Qatar and the Gulf countries for more than a decade in landscape and farm irrigation without any public health hazard (2, 4).

In order to use these findings comprehensive studies and field tests are planned in cooperation with the Agriculture Department.

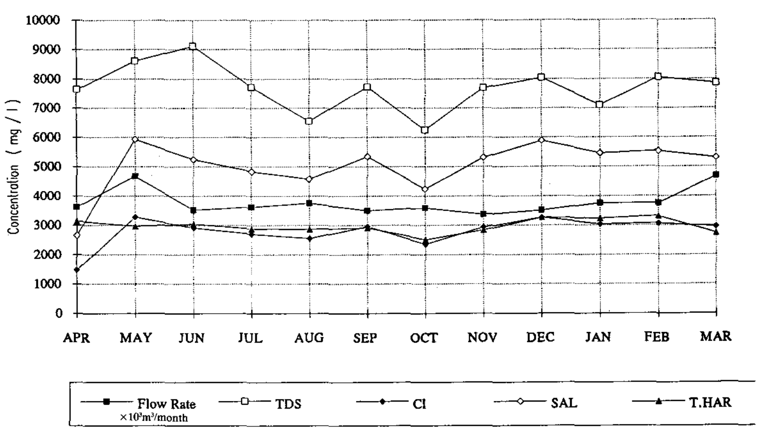


Fig. 6: Comparison between the flow rate and groundwater constitutents at PS1.

Table 4
Salinity Tolerant Plants (5, 11)

Salinity Tolerance Level (mg/l)	Plants
30,000	Aricennia manna Prosopis juliflora Sueda spp
25,000	Altriplex nummularia Nitraria retusa Phoenix dactylifera Prosopis tamarugo Tamarix passerinoides Washingtonia filifera
20,000	Casuarina equisetifolia Kochia indica Tamanix aphylla
9,000	Acacia farnesiana Acacia pendula Acacia salicina Casuarina glauca Eucalyptus camaldulensis Eucalyptus sargentii Nerium oleander Zizyphus jujuba Zizyphus spina-christi
8,000	Acacia arabica Acacia cyanophylla Acacia nilotica
6,000	Albizzia julibrissin Albizzia lebbek Albizzia berijamina Ficus carica
4,500	Ficus bengalensis Ipomoaa pes-capre (Bahrain Creeper) Prosopis spicigera
2,000	Acacia tortilis

Table 4 Contd.

1,500	Duranta plumieri Lavandula spica Myrtus communis Plumbago capensis
600	Bougainvillea spp Citrus spp Hibiscus rosa-sinensis Jacaranda minosiaefolia Jasminum spp Mangifera indica Plumeria acutifolia

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