ARCHIVE

DOHA GROUNDWATER UPDATE

1988

WATER BALANCE ASSESSMENT

SECTION 1

SECTION 1

INTRODUCTION

1.1 Background

A report on an investigation into the rising water levels beneath Doha was presented in May 1983 by ASCO's in collaboration with the Institute of Hydrology to the Ministry of Electricity and Water. The Report included maps of the depth to water and water table elevation for February 1983 based on data obtained from 180 boreholes. A mathematical model of the Upper Damman aquifer was developed to infer recharge and flow from the aquifer system.

Only a limited appraisal of the rate of water level change could be undertaken in 1983 as only 22 sites had monitoring data for one year or more. However, since then, water levels have been monitored regularly in a network of about 110 boreholes.

At the request of the Ministry of Public Works, Drainage Division, an update of the original study has been implemented, utilising the new water level data to examine the present recharge situation using the existing model, and a reassessment for the Water balance for the year 1988.

1.2 Methodology

A Overall approach

To provide the basic data for the water balance the update has been sub divided into two parts, the engineering study discussed later in this section, which attempts to quantify the engineering inputs and outputs to the system, and an update of the existing model utilising new water level data.

The results from the engineering water balance and the new water level data were brought together to ascertain the accuracy of the 1983 model and to recalibrate the original model in view of the new data.

B Engineering Water balance

As part of the overall approach the engineering components of the water balance for the Study Area were assessed to identify both recharge and outflow to and from the area. In doing so the Study Area was sub-divided into suitable districts or zones where the recharge and outflow could be accurately estimated, thus differentiating between areas of high and low intensities of net recharge. For this purpose the zones used for the Central Statistical Organisation 1986 Census with the same reference numbers (1 to 69) were utilised. In each zone an assessment of the components of the engineering water balance were made as follows:-

a) Recharge

1. From potable water system losses, storage and conveyance systems.

2. From sewage system losses, septic tanks outflow and treated sewage system losses.

3. From irrigation of farms, gardening, landscaping and treated sewage effluent irrigation.

4. From rainfall

b) Outflow

1. By the storm water drain

2. By groundwater flow to the sea and across the study area boundary.

3. By infiltration into the sewage network.

4. By evaporation and abstraction of groundwater.

To assess the above required the collection of data for some of the components and computation for others.

The overall engineering water balance was achieved by a system analysis procedure. The logic of this system is shown in Fig. GE1 from which it will be noted that the prime requisite was an accurate evaluation of water consumption at each water distribution stage together with number of consumers (population). These two parameters provide the basis for the engineering water balance.

Before describing the methodology adopted in assessing these parameters it should be noted that the output from the computer model, with regard to groundwater flow to the sea and across the study area boundary, were used in the water balance computations. Thus the computer model formed an integral part of the system analysis.

Assessment of consumption and population was initiated by dividing the study area into zones (QARS Zones) enabling a detailed inspection of the water cycle inside each zone. the choice of QARS Zone basic layout enabled us to compare the results of our assessment with those collected during the land use survey with the added advantage of being similar to the groundwater model grid. In each zone all available information regarding housing type and special consumers was collected to enable an assessment of water consumption to be made. the analysis proceeded by projecting the number of properties in each zone to the year of the study (1988). The properties were then divided into four major categories, as follows:-

a) Arab Type houses
b) Flats
c) Villas
d) Large Villas and Palaces

The maximum and minimum rates of occupancy and water consumption in each type of property were then assessed.

In addition to the above the consumption in schools, hotels, restaurants, workshops, offices etc., were calculated separately for each zone. This assessment is described in detail in Appendix "F".

At this stage it was possible to calibrate the accuracy of this approach with the predictions made by other departments and, and also, by comparing the total consumption in the Study Area with the total volume of water actually supplied in 1988. This latter comparison proved to be most effective as the production in 1988 was lower than the water requirements and hence the produced water was supplied and consumed.

Comparison of our computed figures for population with those published (e.g. 1986 Census) show close correspondence indicating that the average occupancy rates provided a suitable basis for establishing a relationship between housing and population which was required to assess water consumption. Losses and wastes were then assessed in each water-carrying structure and conveyance systems.

Having computed these parameters it was then possible to assess the remaining terms of the water balance with some confidence (See Section 2 and Appendix F).

The engineering water balance equation produced a residual equal to the change in aquifer storage.

TO RAYYAN

TO ABU SAMRRA

B RING ROAD

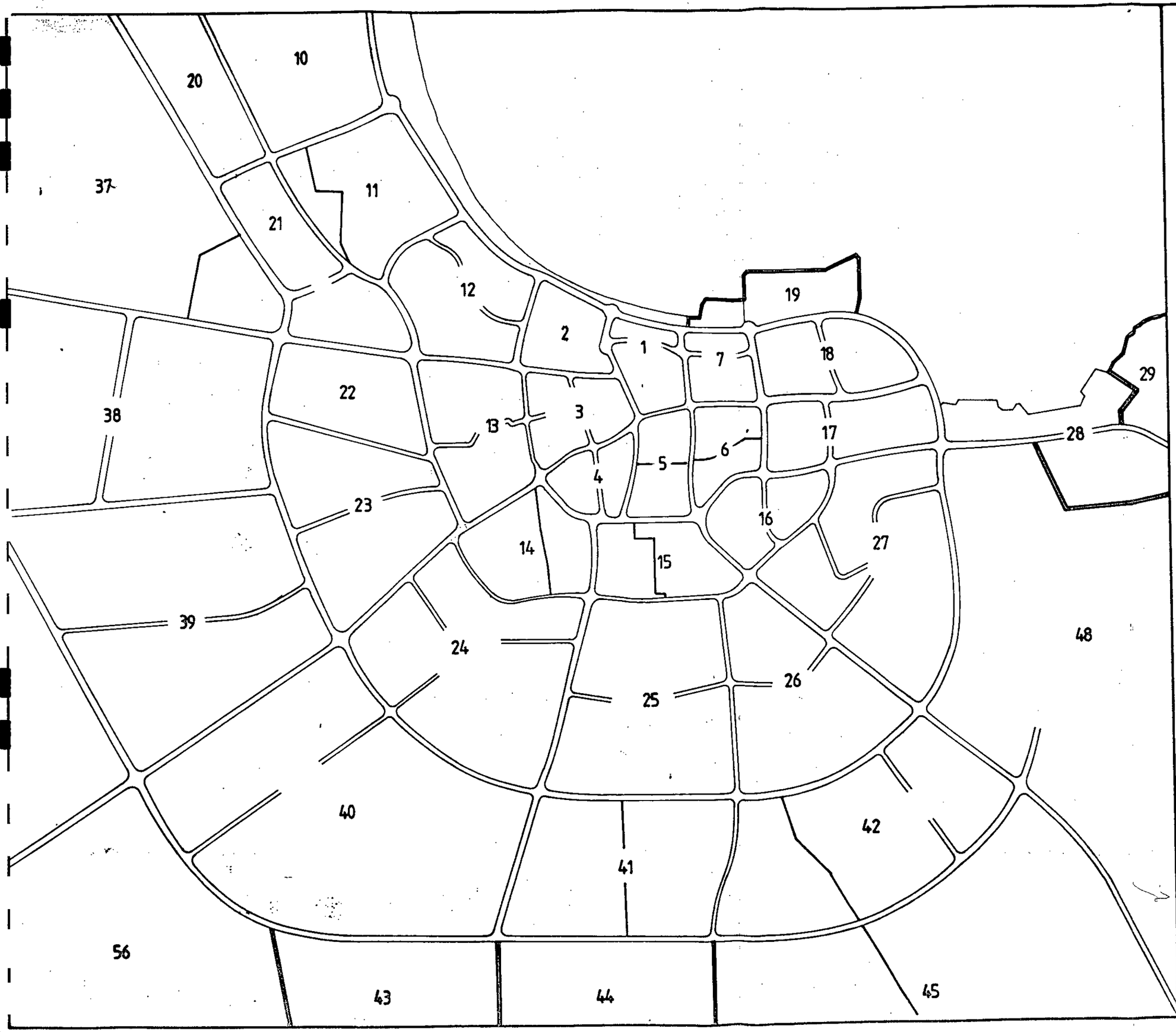
C RING ROAD

D RING ROAD

TO AL WAKRAH

QATS ZONES
ADOPTED BY ASCOS

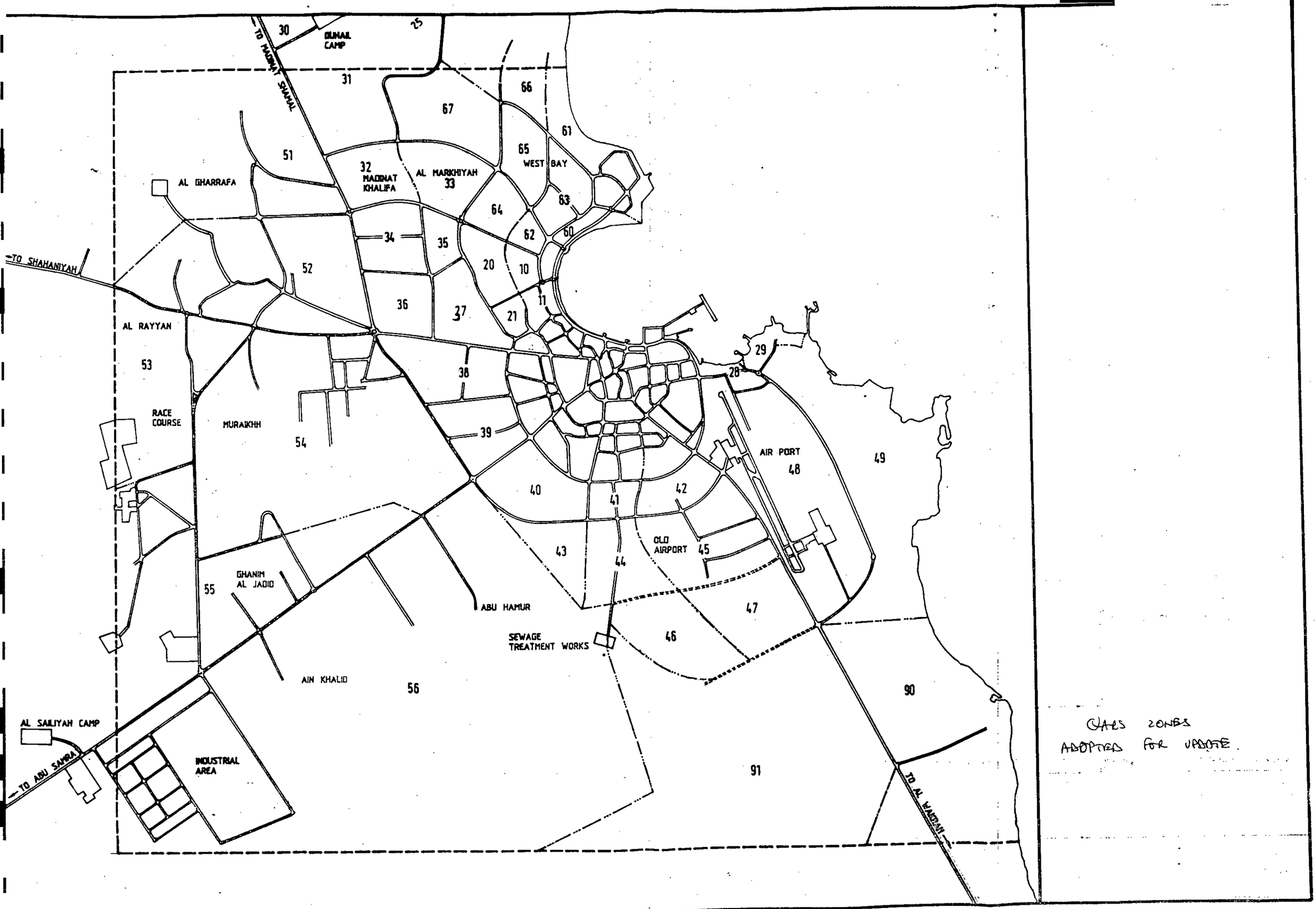
QAT ZONES



QARS ZONES

ADOPTED FOR UPDATE

QARS ZONES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WEST BAY
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TO SHAHANIYAH
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RACE COURSE
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OLD AIRPORT
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GHANIM AL JADID
ABU HAMUR
SEWAGE TREATMENT WORKS
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AIN KHALID
56
90
AL SAILIYAH CAMP
TO ABU SAMRA
INDUSTRIAL AREA
91
TO AL WAKRAH
GAES ZONES
ADOPTED FOR UPDATE.

SECTION 2

SECTION 2

WATER BALANCE

2.1 INTRODUCTION

The water balance of any hydrologic system is, in its simplest form,

$$I + R + O \pm S = O$$

Where I = inflow, R = recharge, O = outflow and S = change in storage

In the case of the present study there is a complex inter-relationship between the various components of the water balance, illustrated in sequential form in Fig. GE1 (refer to Section 1.3). a qualitative estimate of the annual rise in water table, as a direct consequence of percolation losses from the water distribution, sewerage and irrigation systems as a proportion of net inflow, subsequently reduced by outflow from the aquifer, is the independent variable to be evaluated. This is equivalent to the aquifer change in storage over a defined time period (1 year) and transformed into head by the hydrogeological properties of the aquifer. The overall balance for the study area may be therefore evaluated in the following terms:

Where I = inflow, T = transfer, and O = outflow, and the change in aquifer storage S may therefore be evaluated as:

Where C = a Coefficient and CI = Recharge (R)

In an expanded and rearranged form equations (2 and 3) may also be rewritten as.

$$(I_1+I_2+I_3+I_4+I_5+I_6)=(T_1+T_2+T_3)+(O_1+O_2+O_3+O_4+O_5+O_6+O_7) + S$$

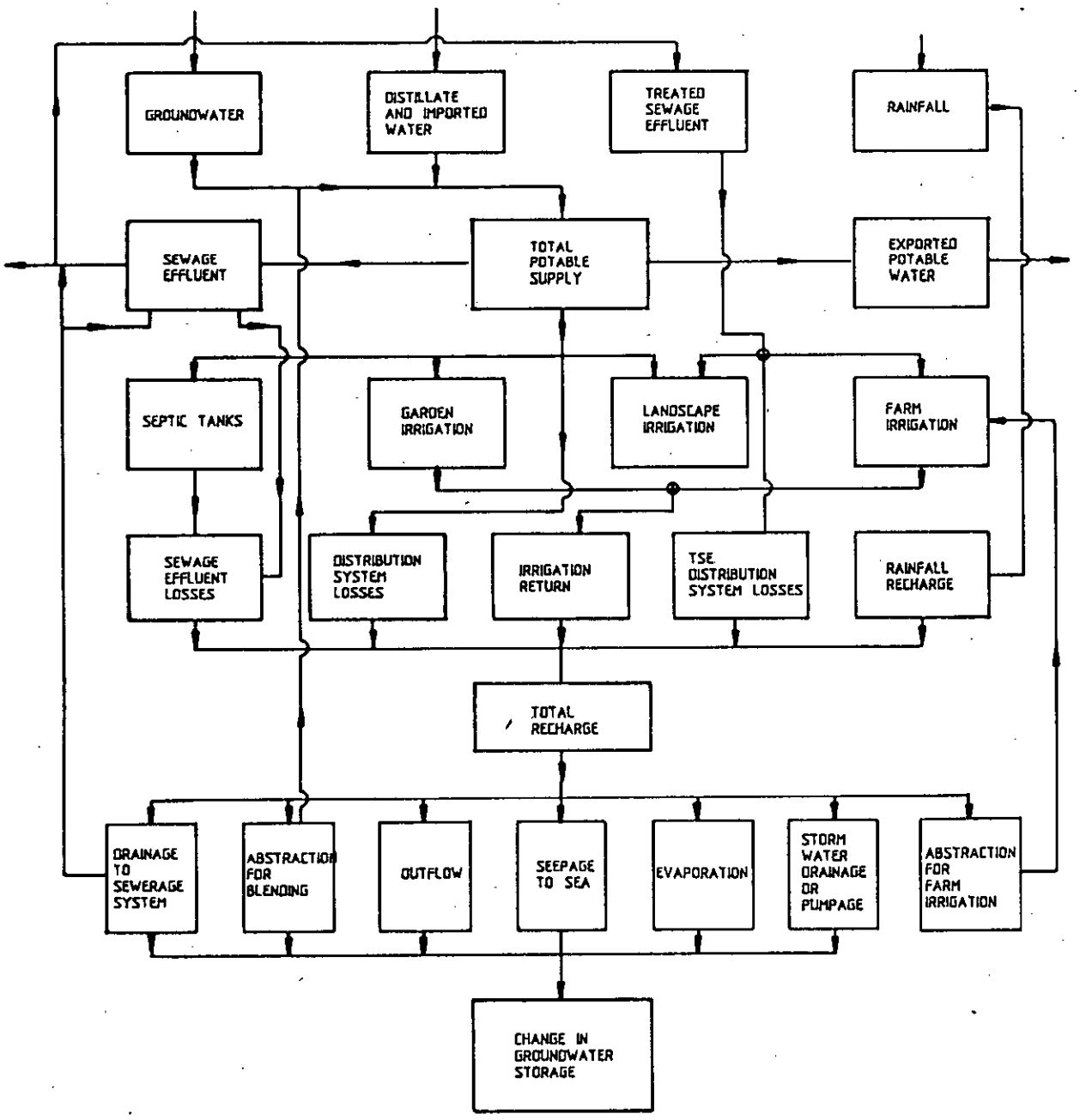
and

$$S = (R_1+R_2+R_3+R_4+R_5)-(O_1+O_2+O_3+O_4+O_5+O_6+O_7)$$

where

I_1 = Distillate from distillation plants
I_3 = Groundwater from study area wells
I_4 = Returned treated sewage effluent
I_5 = Other imported water
I_6 = Rainfall

T_1 = Export of potable water
T_2 = Sewage system outflow
T_3 = Evapo-transpiration



WATER BALANCE LOGIC

STATE OF QATAR
MINISTRY OF PUBLIC WORKS
Civil Engineering Department

BALFOURS International
CONSULTING ENGINEERS
P.O. BOX 6650. DOHA QATAR.

SCHEME
DOHA WATER BALANCE UPDATE - 1988

TITLE
SYSTEMS ANALYSIS LOGIC OF WATER BALANCE

DRAWN	CHECKED	CONTRACT No.	
AAP	JJ		
SCALE		PROJECT No.	
DRAWING No.		JOB No.	ISSUE

R_1 = Distribution system losses
R_2 = Sewage system losses
R_3 = Irrigation return
R_4 = TSE system losses
R_5 = Recharge from rainfall

O_1 = Drainage of groundwater to sewage system
O_2 = Abstraction for blending
O_3 = Groundwater outflow inland
O_4 = Seepage to sea
O_5 = Groundwater evaporation
O_6 = Storm water drainage
O_7 = Farm irrigation abstraction

2.2 EVALUATION OF PARAMETERS

2.2.1 Inflow (I)

2.2.1.1 Distillate from Distillation Plants (I_1)

The total water production from distillation plants delivered to the Study Area in 1988 was 77.144 Mm^3. This is the sum of metered production delivered to Doha from both Ras Abu Abbud and Ras Abu Fontas plants, details of which are given in Appendix A.

2.2.1.2 Groundwater from external well-fields (I_2)

Groundwater is no longer abstracted from wells fields in north-central Qatar.

2.2.1.3 Groundwater from Study Area Wells (I_3)

Within the Study Area groundwater is abstracted from the aquifer for blending with distilled water in addition to groundwater imported from other well field (I_2). In 1988 a total of 2.032 Mm^3 was abstracted from wells sited at each reservoir. This figure was obtained from Water Department records, details of which are given in Appendix A.

Within the Rayyan area and in isolated locations elsewhere in the Study Area there are 52 small farms of total aggregate demarcated area of 357 ha. The indicated area under actual irrigation amounts to 173.2 ha or 72% of the total area and the total groundwater abstracted at these sites amounted to 4.143 Mm^3 in 1986/87. These data are derived from a survey undertaken by the Department of Agricultural and Water Research and Appendix "D" provides a detailed list of each farm, size and groundwater abstraction rates. This is in addition to other well abstraction other than for Farming with amounted to 0.667 Mm^3 in 1988 (refer to Appendix "D").

2.2.1.4 Return treated sewage effluent (I_4)

A proportion of the total sewage effluent from Doha is treated at the Al Naeejah sewage treatment works and returned to Doha where it is used exclusively for the irrigation of public parks, roundabouts and roadside trees within the Study Area. In 1988 the total treated effluent returned to Doha amounted to 5.0 Mm^3, as determined by the Sewage Section of the Engineering Services Department (See Appendix E).

2.2.1.5 Other Imported Water (I_5)

In recent years the habit of drinking bottled water rather than tap water has increased. In 1988, an average of 2,280 cases/day, equivalent to 0.015 $Mm^3 yr^{-1}$ was sold by wholesalers in Doha.

2.2.1.6 Rainfall (I_6)

There are six rain gauges within or adjacent to the Study Area and during 1988 a total of 15 rainfall "events" occurred (A rainfall event is defined as rainfall for any period from less than one hour to a number of consecutive days). Table C.2 (Appendix C) lists the actual data (provided by the Department of Agricultural and Water Research) together with calculated total volume of rainfall for the nine storm events. These data are calculated from separate isohyet map lots shown in Maps R1 to R9 (Appendix "C"). The total rainfall over the Study Area in 1988 amounted to 44.43 Mm^3, equivalent to a mean depth of 153 mm.

From a probability study of annual rainfall data from Doha Airport (FAO, 1982) this total is seen to have been nearly twice the normal average rainfall with an average return period of 17 years.

2.2.2 Transfer (T)

2.2.2.1 Export of Potable Water (T_1)

A proportion of the potable water supply to the Study Area (T_1) is exported to consumers in outlying districts by tanker which amounted to 9.915 Mm^3 in 1988.

2.2.2.2 Sewerage System Outflow (T_2)

In 1988 flow entering the sewage treatment works at Al-Naeejah amounted to 26.346 Mm^3 (CED data). This flow is well in excess of that which would normally be generated by the sewered population and a certain proportion must therefore be derived from groundwater and other sources within the drainage area. To determine this proportion an estimate of sewage generation based on population and potable water supply distribution was therefore undertaken.

From data derived from a number of sources (Ministry of Municipal Affairs, Civil Engineering Dept., and aerial photographs) a detailed analysis based on QARS zones, house types and average occupancy rates was made. This resulted in the finding that properties of 4 different house types and special consumers generated a total sewerage flow of 17.454 Mm^3 in 1988 (See Appendix B). The balance of 8.879 Mm^3 is therefore considered to be drainage from the aquifer. [See para 2.2.4.1 (O_1)].

At the same time the proportion of the population not connected to the sewage system and discharging directly to septic tanks is estimated to have generated a total of 6.283 Mm^3. [See para 2.2.3.2 (R_2) below]. The total sewage outflow from the Study Area is therefore calculated to be 23.828 Mm^3 or 80% of the total domestic water consumption of 29.709 Mm^3 in 1988 (Table A.8, Appendix A). It has been assumed that this difference may be accounted for by losses, and the remainder not reaching the sewerage system having been lost to evaporation from car-washing, cleaning floors, outside walls, driveways, pavements and human perspiration.

2.2.2.3 Evapo-transpiration (T_3)

The annual potential evapo-transpiration rate for the climate of the Study Area is of the order of 1800 mm (FAO, 1981) which represents an approximate upper limit to evapo-transpiration from vegetated surfaces. Actual evaporation and evapo-transpiration can only be deduced by difference with other derived or measured parameters into which residual errors may or may not be accumulated. The estimated evaporation and evapo-transpiration loss may be summarised as follows:-

a) Evaporation from ponding, wet soil, and interception following rainfall 40.19 Mm^3

b) Evaporation of potable water from domestic activities 4.20 Mm^3

c) Evapo-transpiration of potable and TSE water from irrigated gardens, landscaped areas and farms (1300 ha.) 22.87 Mm^3

67.265 Mm^3

Evaporation is equivalent to a mean depth of 137 mm following rainfall of 153 mm and evapo-transpiration is equivalent to a mean depth of 1728 mm from 1300 ha. of vegetated area.

2.2.3 Recharge (R)

2.2.3.1 Potable Water Distribution System Losses (R_1)

Total potable water used in the Study Area is made up of distilled water from the distillation/power plants at Ras Abu Fontas and Ras Abu Abbud and wells at the service reservoirs for blending and a minor quantity of bottled water, less an amount exported by pipeline or tanker to areas outside the Study Area. The total quantity of potable water supplied to the Study Area throughout 1988 amounted to 69.276 Mm^3 made up as follows:-

TABLE 2.1

POTABLE WATER SUPPLIED TO STUDY AREA IN 1988

Source	Total Mm^3/Year	Average m^3/Day	Peak m^3/day
From Distillation Plants to Doha (I_1)	77.144	211,352	
From Blending Boreholes (I_3)	2.032	5,566	
Bottled Water imported (I_5)	0.015	41	
Total Production	79.190	216,960	237,669 (May)
Less quantity supplied outside Study Area (T_1)	9.915	27,163	31,237*
Total potable Supply to Study Area	69.276	189,797	206,432

* Assumed 15% above average rate.

No information is available of the quantity of water actually supplied to clearly defined individual districts in the Study Area during 1988. In order to assess the proportion of the total production used in different localities, use was therefore made of estimates of water requirements contained in the Doha Water Loss Control Report (1986) prepared by ASCO. In this Report, estimates are given for consumption requirements for various property types.

The study area has been sub divided into districts as adopted for the 1986 Census (QARS Zones). The location and extent of each of these zones is shown on Maps M2, M3, in Appendix "F".

The estimates in the Report were based on a survey of dwellings carried out in 1982/83 in selected QARS Zones. Appropriate rates of water consumption were adopted both for domestic and garden watering purposes for each type of dwelling, and allowances were also made for special consumers and losses in each area.

To obtain comparable figures applicable for 1988, the number of dwellings in each area was reviewed and adjustments made to take into account recent development and new housing constructed to accommodate the increased population in the area. These were considered in six components as follows:-

1) Average daily consumption in each zone, taken at 0.87 of peak domestic consumption derived from data provided by sample metering of different types of property, leak detection surveys and assessments made in the Master Plan (See Table A.1, Appendix A).

2) Commercial users such as shops, workshops, offices, schools and other miscellaneous consumers but excluding garden watering. Here too a factor of 0.87 times peak consumption figures with an added 10% allowance for losses was assumed based on sample meterings of different types of consumer (Table A.8 Appendix A).

3) Special consumers, individual hotels large palaces, government guest house, hospitals, army barracks, stadiums and race course, markets, slaughterhouses, the airport and training institutions based on sample meterings of 14 of this type of consumer. In each case the area of garden was also surveyed and the total consumption derived between domestic and irrigation consumption. (Table A.5, Appendix A).

4) Losses by leakage from 5 R.C. reservoirs determined from a test of the West Bay Reservoir and careful inspection of the remainder. (Table A.6, Appendix A).

5) Losses from three tanker filling stations assessed from the number of tanker fillings per day at each station based on data given in Water Department Report No. 2 - Utilisation of Water Tanker Filling Stations (Table A.7, Appendix "A").

6) Losses from the distribution system assessed as a residual after account for all consumption but supported by data from the Leak Detection Pilot Schemes in six sample areas of the Study Area as a separate project undertaken by ASCO (See. 5 (h) Appendix A).

The deduced total quantity of potable water required in each of the QARS Zones as described above amounted to 180,734 m^3/day which is close to the average quantity actually supplied during 1988, estimated to be 189,797 m^3/day, thus confirming the validity of the approach. A small adjustment (4.8%) has therefore been made to each QARS Zone figure to bring the total to an exact balance. The probable consumption of potable water in 1988 may be summarised as follows:-

TABLE 2.2

CONSUMPTION OF POTABLE WATER

1)	The domestic and commercial consumption incl. bottled water	=	29.709 Mm^3 (43%)
2)	Total gardening water		
	- Private	=	17.197 Mm^3
	- Landscaping	=	9.231 Mm^3 (38%)
3)	Total distribution system losses (Reservoirs, TFS, pipe system)	=	13.137 Mm^3 (19%)
	Total Potable Supply	=	69.076 Mm^3 (100%)

The proportion of potable water supplied and which is likely to be lost to the system and re-charge groundwater beneath Doha will vary depending on the way it is used, and for the purpose of this section (which excludes gardening) the following percentages have been used:- (See Section 1.3 Methodology)

Domestic use	2%
Use in shops, offices, etc.	5%
Losses from Reservoirs	90%
Losses from Tanker Filling Stations	60%
Losses from Underground Pipelines	95%

On the basis of the above percentages the total recharge derived from potable water sources under 1988 rates of supply is estimated to be 10.382 Mm^3 summarised in the following Table.

TABLE 2.3

RECHARGE FROM POTABLE WATER DISTRIBUTION SYSTEM
(EXCLUDING GARDENING)
1988

Source			Recharge in 1988 Mm^3
Domestic Use			0.594
Losses	-	Reservoirs	0.035
		T.F.S.	0.280
		Distribution	9.473
		Total	10.382

2.2.3.2 Sewerage System Losses (R_2)

Losses from the sewerage system are composed of direct leakage and from septic tanks, all of which is considered to be recharge. For the purposes of this study it has been assumed that 1% of the total sewage outflow is lost to leakage at service joints at levels above the groundwater table. (Refer to Appendix "B").

On this basis the total leakage would amount to 174,543 m^3/yr.

All outflow from septic tanks is assumed to recharge groundwater. As a result of detailed estimates of sewage outflow, of property but sub-divided into those receiving mains supply (either connected or unconnected to the sewerage system), those outside designated sewerage drainage areas and those served by tanker. Table 2.4 summarises these findings.

TABLE 2.4

RECHARGE FROM SEWERAGE SYSTEM
1988

Source	Mm^3
1) Losses from sewerage system	0.175
2) Septic tanks on mains supply	4.283
3) Septic tanks supplied by tanker	2.000
Total	6.457

2.2.3.3 Irrigation Return (R_3)

Irrigation in the Study Area is practised throughout the year on all private gardens, municipal landscaped areas, public parks and on all farms, except for brief periods following upon rainfall.

In general irrigation efficiency is low and there is evidence that irrigation water (from both potable and TSE sources) applied to private and municipal gardens is well in excess of evapotranspiration demand. In assessing the volume of percolation loss or irrigation return, estimates were made on the basis of a sub-division by source or combination of sources, being (a) private garden irrigation from the potable supply, (b) municipal garden irrigation by potable water, treated sewage effluent, and groundwater and (c) farm irrigation from groundwater and treated sewage effluent.

a) Private Gardens

The average daily requirement of potable water was taken as 0.87 of peak requirements, but with the addition of 66% of the net amount to allow for water actually used in excess of evapotranspiration needs. This figure is based on the difference between sample leak detection surveys of blocks of flats without gardens and villas with gardens together with evapotranspiration data. By this approach it was calculated that 21.502 Mm^3 or 31% of the total potable supply was used for private garden irrigation. Of this total it is deduced that 45% was transmitted to the aquifer by percolation, giving a total of 9.676 Mm^3 in 1988 (See Appendix A).

b) Municipal Gardens

Irrigation of municipal parks, landscaped areas surrounding public and government buildings, roundabouts, afforestation and avenues of trees on major roads is undertaken by reticulated and mobile (tanker) systems using both potable water and treated sewage effluent and by groundwater pumped on site. The total area of public parks and landscaped areas irrigated by potable water in 1988 amounted to 123.983 hectares to which an observed average irrigation rate of 16 $m^3\ d^{-1}$ was applied (Appendix A).

Evapotranspiration demand for these areas is estimated to be of the order of 1100 mm yr^{-1} and recharge is calculated to have amounted to 3.830 $Mm^3\ yr^{-1}$ in 1988. Treated sewage water is applied for irrigation at Muntaza Park (8 hectares) traffic roundabouts and public landscaped areas (32.86 hectares), avenues (22,000 trees) and farms (68.1 hectares). The total amount of treated sewage effluent applied amounted to 3.60 Mm^3 with an additional 0.40 Mm^3 utilised in smaller unaccounted ways throughout the Study Area. Recharge from this source is calculated to be 3.13 $Mm^3\ yr^{-1}$. A number of traffic roundabouts, landscaped areas and palace gardens are irrigated by groundwater pumped on site. Recharge from these areas is calculated to have amounted to 0.442 Mm^3 in 1988.

c) Farm Irrigation

There are 52 active farms within the Study Area where pumped wells abstracted a total of 4.143 Mm^3 in 1986/87. With an assumed average evapotranspiration rate of 1700 mm for the irrigation of alfalfa and date palms, the indicated area under actual irrigation is 175.2 ha. Average irrigation efficiency is estimated from FAO data to be 77% and irrigation return would therefore amount to 1.167 Mm^3. In addition, a small amount of treated sewage effluent is utilised for irrigation on a few farms and return percolation from this source is estimated to be 0.160 Mm^3.

The following table summarises the total irrigation return flow from different sources.

TABLE 2.5

RECHARGE FROM IRRIGATION (Mm^3 yr^{-1})

	Potable Water	T.S.E.	Groundwater
1) Private Gardens	7.738	-	-
2) Municipal Gardens	4.154	3.13	0.442
3) Farms	-	0.16	1.167
	11.89	3.29	1.609
Total recharge from irrigation =	16.79		

2.2.3.4 Treated Sewage Effluent Distribution System Losses (R_4)

The treated sewage effluent distribution system consists of four concrete towers and rising mains and irrigation mains of 300 mm ductile iron pipe. (See Map TSE 1 in Appendix E). An estimate of 15 - 20% loss from the system was adopted. It was further assumed that 95% of this loss would recharge groundwater and which amounted to 0.95 Mm^3 in 1988.

2.2.3.5 Rainfall Recharge (R_5)

In 1988 there were 15 rainfall events covering or partially covering the study area with above average totals. The annual total recorded at Doha Airport showed a recurrence interval of 17.5 years and the storm of 16 - 17 February to have one of 15 years. The year under study may therefore be considered to have been one of "high rainfall". Of the 15 storm events nine precipitated amounts of less than 5 mm a day and are considered to have been insignificant in terms of recharge. Table C.2 Appendix "C" shows data from rain gauges located within or adjacent to the Study Area.

Recharge from rainfall within the Study Area evidently takes place but in terms of other components of the water balance its effect in normal years is however a minor one. Drawing upon the detailed observations of rainfall and recharge in the desert areas of Qatar carried out by FAO (1981), and taking into account the characteristics of urbanisation of between a fifth and a quarter of the study area, estimates of recharge have been based upon the following percentages of rainfall;

Open desert areas (238 km^2) = 10%
Built up areas incl. gardens (54 km^2) = 7.5%

giving a weighted mean recharge percentage of 9.54%. (For a detailed discussion see Appendix "C"). The total recharge over the Study Area in 1988 is calculated to have been 4.239 Mm^3 equivalent to a mean depth of 13.61 mm. Table 2.6 summaries these data.

TABLE 2.6

RECHARGE FROM RAINFALL

Date	Total Rainfall Mm^3	Recharge Built-up (22%) of Total Area	Recharge Open-Desert (78%) of Total Area	Total Mm^3	Total mm
14/2	3.22	0.07	0.24	0.31	0.99
16-17/2	14.89	0.31	1.11	1.42	4.55
21/2	7.03	0.15	0.52	0.67	2.15
22/2	7.49	0.16	0.56	0.72	2.31
24/2	9.49	0.20	0.71	0.91	2.90
24/4	2.31	0.05	0.17	0.22	0.71
Totals	44.43	0.94	3.31	4.25	13.61

2.2.4 Outflow (O)

2.2.4.1 Drainage of Groundwater to the Sewerage System (O_1)

The proportion of sewage to drainage water discharged to the treatment works at Al Naijah is discussed in para 2.2.2.2 [Sewerage System Outflow (L_2)]. This was deduced to be 8.879 Mm^3 in 1988 or 34% of the total flow.

2.2.4.2 Abstraction for Blending (O_2)

A limited quantity of groundwater from the aquifer within the Study Area is abstracted for blending with distillate and external groundwater. In 1988 this amounted to a total of 2.032 Mm^3.

2.2.4.3 Groundwater outflow inland (O_3)

As a result of the rise in piezometric level under the city of Doha, groundwater flow potentials in all directions emanating from the piezometric "mounds" have become established thus causing groundwater to leave the study area. While approximations of this value may be determined from the hydrogeologic properties of the aquifer under uniform conditions, a more accurate determination was evaluated by the groundwater model (See Section 6:Run A/1) by which all hydrogeologic properties are considered in a series of simultaneous finite difference equations. Details of the mathematical model are given in Section 6 and it will be recalled that the modelled area covers only 54.6% of the Study Area. The modelled value for outflow of 1.370 $mm^3\ yr^{-1}$ was therefore adjusted by a scaling factor of 1.179 which is the ratio of net recharge determined for each area. The outflow from the Study Area, that is across the northern, western and southern boundaries, was therefore calculated to be 1.615 Mm^3 in 1988 by this approach.

2.2.4.4 Seepage to the Sea (O_4)

The rise in piezometric level under Doha reaches its maximum in the Khalifa Town and Muntaza areas of Doha from where relatively steep piezometric gradients towards the seaward boundary of the Study Area have become established. In the same manner as that employed to determine outflow (O_3) the total groundwater flow across this boundary was evaluated to be 14.749 Mm^3 in 1988, after adjustment from a modelled value of 12.51 $mm^3\ yr^{-1}$ by a similar scale factor of 1.179.

2.2.4.5 Groundwater Evaporation (O_5)

Groundwater evaporation probably takes place from minor areas in the Musherib and Garrafa areas where a combination of topographic lows and high piezometric level has resulted in depths to groundwater of less than 1 m. Taking into account the area now built-over and the small restricted area of soils kept permanently moist by capillarity, the total evaporation loss is estimated to be 1.000 Mm^3.

2.2.4.6 Surface Water Drainage (O_6)

Shallow groundwater and seasonal surface run-off is drained through a drain extending from the Corniche near the old Souk to the Water Department, and through a second (south) branch from the Arab Bank Roundabout to the "B" Ring Road in the vicinity of the Mechanical Engineering Department workshops. (See Map S7 in Appendix "B"). The original drain to the Water Department has been blocked for a number of years but is now being re-opened. The discharge of this drain was measured on four occasions at intervals throughout 1988 by the Water Department. The total discharge was calculated to be 2.000 Mm^3 in 1988.

2.2.4.7 Groundwater Abstraction for Irrigation (O_7)

There are 52 active farms within the Study Area of a total aggregate demarcated area of 357.20 ha. The majority of these farms are small and concentrated within the Rayyan - Sailiyah area along the western margins of the Study Area. Each is irrigated by groundwater pumped from one or two wells on each farm. From data provided by the Department of Agricultural and Water Research, the total abstraction amounted to 4.143 Mm^3 in 1988. (See para 2.2.3.3 (c), Appendix "D" and Map A1). This in addition to 0.667 Mm^3 which has been abstracted from other wells for other than Farm irrigation giving a total abstraction of 4.81 Mm^3 in 1988.

2.3 CHANGE IN STORAGE AND RISE IN PIEZOMETRIC LEVEL

The change in storage in 1988 may be derived from the parameters evaluated in the foregoing section as follows:-

WATER BALANCE
1988

Inflow			Mm³	
I_1	Distillate		77.144	
I_3	Internal GW		6.842	
I_4	TSE		5.000	
I_5	Imported		0.015	
I_6	Rainfall		44.430	
			133.430	
Transfer				
T_1	Export		9.915	
T_2	Sewage outflow		17.454	
T_3	Evaporation		67.265	
			94.630	
Recharge				
R_1	Dist. system losses		10.380	(9.238)
R_2	Sewerage system losses		6.457	(6.415)
R_3	Irrigation return		16.790	(13.717)
R_4	TSE distribution system losses		0.950	(0.365)
R_5	Rainfall recharge		4.239	(4.206)
		32,504,149	38.800	
Outflow				
O_1	Drainage of groundwater to sewerage system		8.879 ✓	(5.292)
O_2	Abstraction for blending		2.032 ✓	(1.834)
O_3	Groundwater outflow inland	(1.62)	1.370	(1.815)
O_4	Seepage to sea	(13.79) (16.26)	14.749	(14.487)
O_5	Groundwater evaporation		1.000 ✓	(0.500)
O_6	Storm water drainage		2.000 ✓	(2.000)
O_7	Farm abstraction		4.810	(6.181)
		36.601	34.840	

Therefore $S = (133.43 - 94.630) - (34.84)$ 36.60

$= + 3.96$ Mm³ yr⁻¹ (Say 3.96 Mm³ yr⁻¹)

= 2.20 Mm³ yr⁻¹

.53 Mm³/y

APPENDIX A

APPENDIX "A"

RECHARGE FROM THE POTABLE WATER SYSTEM

A.1 INTRODUCTION

The objective of this Appendix is to assess the quantity of potable water supplied in 1988 to each of the various zones into which the Study Area has been sub-divided, and to estimate the proportion which is likely to constitute a source of re-charge to groundwater.

A.2 TOTAL PRODUCTION OF POTABLE WATER IN 1988

In 1988 the potable water used in the Study Area came from three sources:

a) Distilled water from Desalination Plants at Ras Abu Fontas and Ras Abu Abbud.

b) Groundwater from boreholes at the reservoirs. This was added to the distilled water to make it palatable.

c) Imported bottled water to Study Area.

The total quantity produced from each of the above sources during 1988 is indicated in Table A.1. The figures given in this Table are based on the Water Department's Annual Chart of Potable Water Production.

TABLE A.1

POTABLE WATER PRODUCTION - 1988

Month	Blending (m^3)	Ras Abu Abbud (m^3)	Ras Abu Fontas (m^3)	Distribution Total (m^3)
January	212,200	726,814	5,255,704	6,124,307 (197,558)
February	113,906	599,710	4,965,411	5,701,520 (196,604)
March	87,780	751,570	5,436,210	6,375,800 (205,670)
April	165,707	877,746	5,427,223	6,528,431 (217,614)
May	175,954	922,981	6,187,222	7,367,736 (237,669)
June	171,126	878,192	5,890,136	6,937,214 (231,240)
July	179,784	949,468	6,072,946	7,260,288 (234,203)

TABLE A.1 (Contd.)

POTABLE WATER PRODUCTION - 1988

Month	Blending (m^3)	Ras Abu Abbud (m^3)	Ras Abu Fontas (m^3)	Total (m^3)
August	189,441	963,024	5,984,669	7,179,772
				(231,605)
September	181,127	939,447	5,697,419	6,780,749
				(226,024)
October	186,523	753,462	5,732,111	6,679,839
				(215,479)
November	181,268	647,534	3,394,034	6,173,969
				(205,799)
December	186,930	819,406	5,241,163	6,194,962
				(199,837)
Total	2,031,746	9,859,354	67,284,248	79,304,587
Daily Average	5,566	27,012	184,340	217,273

Note: Average Daily Total for each month shown in brackets

A.3 PROPORTION DELIVERED TO CONSUMERS OUTSIDE THE STUDY AREA

A proportion of the total production from these sources of supply was in fact delivered to consumers outside the Study Area. Most of this was taken by tankers to outlying areas, small quantities supplied to ships at Doha Port and at private jetties, and the remainder transferred from Ras Abu Fontas by pumping to Umm Said and Wakrah.

Estimates of the quantities supplied to various localities outside the Study Area in 1988 are given in Table A.2. The figures given are largely derived from information obtained from the various Tanker Filling Stations regarding the number of tanker trips made daily to the various outlying localities.

TABLE A.2

POTABLE WATER SUPPLIED TO LOCALITIES OUTSIDE THE STUDY AREA
1988

Locality	m^3/day	m^3/year
Al Moidher (50%)	518	189,070
Ferique Mahmmad Soud	380	138,700
Labara	22	8,030
Kirana	27	9,950
Al Kharaitiyat	382	139,430
Shahaniyah Camp	164	59,860
Duhail Camp and Housing	168	61,320
Umm Salal Mohamad	1,606	586,190
Saliyah Camp and Housing	215	78,475
Bunkering (Doha & QPC Ports)	1,300	474,500
Air Craft	32	11,680
Dairy farm	150	54,750
Bani Hajer and Al Attiyah	410	149,650
Salwa road Industrial Estate	4,200	1,533,000
Private Tankers	4,900	1,788,500
Umm Said/Wakrah (Pumped)	(12,689)	4,631,409
Total	27,163	9,914,514

A.4 TOTAL QUANTITY SUPPLIED TO STUDY AREA

On the basis of the figures given in Table A.1 and A.2 the total quantity of potable water supplied to the Study Area throughout the whole of 1988 amounted to 69,276,000 m^3. This figure is made up as indicated in Table A.3 below:-

TABLE A.3

POTABLE WATER SUPPLIED TO STUDY AREA IN 1988

Source	Total m^3/Year	Average m^3/day	Peak m^3/day
From Distillation Plants	77,143,602	211,352	
From Blending Boreholes	2,031,746	5,566	
Bottled Water imported to study area	15,000	41	
Total Production	79,190,348	216,960	237,669 (May)
Deduct quantity supplied outside Study Area (From Table A.2)	9,914,514	27,163	31,237 *
Total Supply to Study Area	69,275,834	189,797	206,432

*Assumed 15% above average rate

A.5 METHOD OF ASSESSING QUANTITY SUPPLIED TO INDIVIDUAL DISTRICTS
(Refer to Methodology)

The estimates are based on a survey of dwellings carried out in the 1986 Census in each of the QARS Zones into which the Study Area is now subdivided. Appropriate rates of water consumptions have been adopted both for domestic and garden watering purposes for each type of dwelling, and allowances were also made for special consumers and losses in each area, these have been based on data obtained from the Ministry of Electricity and Water and reference to ASCO's Leak Detection Study of 1985/86.

To obtain comparable figures applicable for 1988, the number of dwellings in each area was reviewed and adjustments made to take into account recent development and new housing constructed to accommodate the increased population in the area. The resulting figures were divided into components as explained below.

A.5 (a) Average daily quantity used for domestic purposes

Average daily domestic consumption in each zone has been taken at 0.87 x Peak domestic consumption. This implies a peaking factor of 1.15, which has been found to be representative of the pattern of production in recent years and very close to the monthly ratio for 1988 which was 1.09 (See Table A.1).

An additional 10% of the nett figure was added to allow for losses inside the consumers premises (e.g. due to overflowing tanks, taps left running, excessive use of water for car washing etc.)

A.5 (b) Average daily quantity used for garden watering

Here, too the average daily consumption for garden watering purposes has been taken at 0.87 x the peak consumption. In this case, however, an additional 66% of the nett figure was added to allow for the extra quantity of water which is actually used over and above the real needs of the trees, plants and grass.

Note 1 The additional 66% of nett consumption is equivalent to 40% of total consumption, which corresponds to the allowance made for losses (refer to Methodology).

2 Data collected by Ministry of Industry and Agriculture and during the execution of Leak Detection Pilot Schemes indicate that while the evapotranspiration could be equivalent to 11 litre/day/m^2, actual application is in the order of 18 litre/day/m^2.

A.5 (c) Other Uses

This covers consumption in shops, offices, schools and other miscellaneous uses (excluding garden watering). The average quantity is again taken as 0.87 times the peak figures for 1988 given in ASCO's Leak Detection Study with an extra 10% allowance for losses. This is included in the total domestic consumption figure shown in Table A.8.

A.5 (d) Irrigation of Public Open Spaces and Government Properties (Landscaping)

The quantities estimated to have been used for the irrigation of public open spaces and Government properties in 1988 are shown in Table A.4. These are based on data obtained from The Ministry of Municipal Affairs, Doha Municipality and allows for the losses arising from the application of water in excess of plant requirements.

TABLE A.4
POTABLE WATER USED FOR MUNICIPAL IRRIGATION
JANUARY 1988 TO DECEMBER 1988

Qars Zone	Location	Area (m^2)	Total (m^3)
1	Foreign Ministry	20,714	331
2	H.H. Amir's Office Gardens	36,800	565
2	Round about near H.H. Emir's Office	1,405	22
4	Jaidah Flyover Round about	3,000	80
	Cable and Wireless Roundabout	2,000	
5	M.E.D. Round about	2,789	44
6	Flower Clock Round about	1,061	37
	Qatar Central Library	1,256	
19	Customs Dept. Round about	2,240	205
	Government House	3,600	
	Qatar Monetary agency	3,500	
	Qatar National Bank	3,500	
11	Guest Palace	15,000	247
	Guest Palace Round about	452	
12	Ministry of Interior garden	39,376	630
13	Old Diwan Emiri	2,400	38
15	Montaza (Tadamon) Roundabout	1,194	19
16	Volkswagen Roundabout	829	13
17	Doha Stadium	7,875	134
	Flyover at Ras Abu Abbud	500	
18	National Museum Roundabout	614	122
	National Museum Garden	2,000	
	Ministry of Municipal Affairs Garden	5,000	
20	Radio and T.V. Station	2,000	84
21	Rumaillah Hospital	47,000	783
	Rumaillah Roundabout	1,964	
22	Trees and roundabouts	29,309	437
23	Landscaping	10,273	361
	Landscaping	12,328	
24	Ramada Hotel Roundabout	4,000	1527
	Maternity Hospital	6,000	
	Qatar Preparatory School	7,875	
	Montaza Park	65,233	
	Cultivated area (Bukshisha)	4,500	
	Osman bin Affan School	7,875	
25	Landscaping	9,075	199
	Montaza Housing Grassed area	3,379	
26	Peugeot Roundabout	1,175	19
28	Gulf Hotel Roundabout	855	14
32	Khalifa Town North Park (10% potable)	10,060	142
	Khalifa Town North School	7,875	
34	Khalifa Town Secondary School	7,875	232
	Regional Training Centre	1,000	
	Community Centre, Khalifa	5,000	
	Grassed triangle opposite Mosque	650	
35	Kulaib Primary School	7,875	126
36	Trees on roads	-	42

TABLE A.4 (Contd.)
POTABLE WATER USED FOR MUNICIPAL IRRIGATION

Qars Zone	Location	Area (m^2)	Total (m^3)
37	Yarmouk School, Al Hitmi	7,875	535
	Grassed triangle at al Hitmi	750	
	Trees on Road		
	Hamad Hospital	8,000	
	Roadside Plantings near Hamad Hospital	2,000	
	Trees on roads		
	White Palace (20% potable)	37,500	
	White Palace Roundabout	1,018	
38	Trees on roads		386
	Roundabout at H.H. Heir Apparent's Palace	2,800	
	Musherib Primary School	7,875	
	Trees on Roads		
39	Salwa Food Centre (20% potable)	30,000	126
40	Civil Aviation Play Field	5,600	798
40	Grassed Area at New Salata	17,625	
40	Istiqlal Secondary School and Landscaping	26,625	
41	Landscaping	1,712	293
	Landscaping	7,705	
	Landscaping	8,904	
42	Landscaping	8,219	356
	Airport Entrance	14,102	
44	Ahmed Bin Hanbal Secondary School	7,875	126
45	Isolation Hospital		
47	Incinerator (Mahraqa)	3,000	48
48	Airport V.I.P. Wing Gardens	11,800	315
	Arabian Gulf Play Field	7,875	
51	Grassed Semicircle at Gharrafa	500	134
	Gharrafa Boys School	7,875	
52	Trees on Roads		862
	School Dormitories Gharrafa	7,875	
	Rayyan (sheikh) School	7,875	
	Sheikh Ahmed Palace Rayyan	10,000	
	Rayyan Primary School	7,875	
	Rayyan Gardens	3,500	
	Dukhan Roundabouts (Rayyan)	2,000	
54	Amir's Area School	7,875	3,578
	Amir's Area Public	7,875	
	Jaidah petrol Station Roundabout	9,994	
	Trees on road reservations		
55	Khalifa Stadium	9,000	144
56	Wholesale Market	3,100	50
61	Sheraton Hotel	78,180	1,250
	Total	1,239,830	19,387

A.5 (e) Special Consumers

These are Hotels, large palaces, Guest Houses, Hospitals, Army Camps etc. The consumption of these consumers are summarised in Table A.5 below:-

TABLE A.5

SUMMARY OF SPECIAL CONSUMERS - DOHA 1988

Qars Zone	Consumer	Daily Consumption (m^3/day)	
		Domestic	Gardening
2	Emir's Palace and gardens	140	Nil
4	Sofitel Hotel	74	Nil
11	Guest Palace	22	Nil
	Villa opposite Falcon Club	15	74
13	Old Diwan Emir	35	Nil
	Sheikh Ghanim's Villa	21	180
20	Guest Villas	18	Nil
	Radio and T.V. Centre	74	Nil
21	QGPC Housing and Falcon Club	100	466
	Army Housing near Falcon Club	296	Nil
	Rumaillah Hospital	148	Nil
	Large Villa and Gardens near White Palace	15	165
	Doha Hospital	192	15
24	Ramada Hotel	467	716
	Maternity Hospital	346	Nil
	Montazah Clinic	7	22
26	Soft Drinks Factories	230	Nil
	Clinic Centre	7	22
28	Gulf Hotel	400	266
	Oasis Hotel	251	163
	Villa next Oasis Hotel	16	146
	Doha Club	100	44
29	QGPC Installation near Gulf Hotel	355	222
32	Health Centre	7	22
33	Palace at Markiyah	22	244
34	Regional Trading Centre	74	Nil
36	2 Palaces near Jaidah Petrol Station	37	407
37	White Palace	22	Nil
	Hamad Hospital	1110	Nil
38	7 Palaces	100	429
	1 Palace	15	74
39	3 Palaces fronting Salwa Road	34	365
40	1 Palace fronting Salwa Road	15	407
	3 Palaces fronting "C" Ring Road	30	222
43	2 Large properties	22	136
45	Isolation Hospital	52	Nil

TABLE A.5 (Contd.)

SUMMARY OF SPECIAL CONSUMERS - DOHA 1988

Qars Zone	Consumer	Daily Consumption (m^3/day) Domestic	Gardening
48	Airport	74	Nil
53	Clinic at Rayyan	7	22
	Race-course	37	Nil
54	Army Barracks	148	Nil
	Emir's Palaces	108	659
	2 Palaces	15	244
55	Khalifa Stadium	30	Nil
	Pony Stables	22	Nil
56	Dairy Farm	222	Nil
	Police Training College	74	Nil
	Wholesale Market	148	Nil
	ESD Road Dept.	74	Nil
56	Livestock Market	148	Nil
	Slaughterhouse	370	Nil
56	Abu Hamur Light Industrial Area	148	Nil
61	Sheraton	740	Nil
	Total	7234	5732

Note: Gardening Component of Government special consumers are already included in No. A.4.

A.5 (f) Losses from Reservoirs

On the basis of the analysis made in section 1.3 (Methodology) the losses from reservoirs in 1988 are assessed as in Table A.6 below:-

TABLE A.6

ESTIMATED LOSSES FROM RESERVOIRS

Qars Zone	Reservoir	Reservoir Capacity (m^3)	Loss (m^3/day)
	R.C. Reservoirs		
48	Airport	40,500	12
52	New Salwa Road	81,000	24
24	Old Salwa Road	22,500	7
56	Gharrafa	81,000	24
67	West Bay	27,000	8

TABLE A.6 (Contd.)

ESTIMATED LOSSES FROM RESERVOIRS

Qars Zone	Reservoir	Reservoir Capacity (m^3)	Loss (m^3/day)
	Ground Storage Tanks		
	New Rayyan	4,500	13.50
48	Airport	4,500	13.50
24	Old Salwa Road (empty)	4,500	
	Fariq Omran (Demolished)	4,500	
	Total		27

A.5 (g) Losses at Tanker Filling Stations

On this basis, of the analysis made in Section 1.3 (Methodology) the losses at Tanker Filling Stations are assessed at 1218 m^3/day as indicated in Table A.7 below:-

TABLE A.7
LOSSES AT TANKER FILLING STATIONS

Qats Zone	Tanker Filling Station	Estimated No. of Fillings Per day	Estimated Loss (m^3/day)
24	Old Salwa Road	1321	647
56	Gharrafa	568	279
48	Airport	595	292
	Total	2484	1218

A.5 (h) Losses from Underground Pipelines

As mentioned in Section 1.3 (Methodology) and from observations made on a number of typical areas as part of Leak Detection Pilot Schemes carried out by ASCO recently, the losses from underground pipes (mainly service connections) are estimated at (50-60)% of domestic consumption. (Refer to Methodology). Thus an average figure of 56% of total domestic consumption is used.

A.6 ESTIMATED QUANTITY OF POTABLE WATER USED IN 1988 BY QARS ZONES

The resultant total of the quantity of potable water required in each QARS ZONES when estimated as described above amounted to 180734 ~~196,048~~ m^3/day which compares with the average quantity actually supplied during 1988, which has been estimated at 187,797 m^3/day (See Table A.3).

The close correspondence between these two figures indicate that the method adopted for assessing the proportion of water supplied to each QARS ZONE is as accurate as is likely to be achieved with the information available. A small adjustment 4.8% (~~3.3%~~) has been made to the individual QARS ZONE figures to bring the total into an exact balance.

Details of the resultant quantity of water used in each QARS ZONE after adjustment as explained above are given in Table A.9.

A.7 PROPORTION OF POTABLE WATER LIKELY TO RE-CHARGE GROUNDWATER

The proportion of water supplied and which is likely to re-charge groundwater beneath the Study Area will vary depending on the way it is used, and for the purpose of this study the following percentages have been used (refer to Section 1.3 Methodology).

Domestic use	2%
Watering of private gardens	45%
Irrigation of Public open spaces	45%
Use in shops, offices, etc.	2%
Losses from Reservoirs	90%
Losses from Tanker Filling Stations	60%
Losses from Underground Pipelines	95%

On the basis of the above percentages the total recharge derived from potable water sources under 1988 rates of supply is as shown below. Summary of potable water usage is given in Table A.8.

Source		m^3	Recharge in 1988
Domestic Use			593,890.00
Gardening	-	Private	7,738,932.00
		Landscaping	4,154,245.00
Losses	-	Reservoirs	35,150.00
		T.F.S.	280,101.00
		Distribution	9,473,379.00
		Total	22,275,697.00

TABLE A.8
SUMMARY OF POTABLE WATER USAGE

	ITEM	PEAK CONSUMPTION m^3/d	AV. FACTOR	LOSSES FACTOR	AVERAGE m^3/d LOSSES INCLUDED	ADJUSTED BY 4.8% m^3/d
1.	Domestic (A.5a)	67,638	.87	1.1	64,729	67,976
2.	Garden watering (A.5b)	31,067	.87	1.66	44,866	47,117
3.	Other Users (A.5c)	6,596	.87	1.1	6,313	6,629
4.	Landscaping (A.5d)	15,806	-	-	15,806	16,599
5.	Special Consumers (A.5e) a) Domestic	6,716	.87	1.1	6,427	6,750
	b) Gardens	5,732	.87	1.66	8,278	8,693
6.	Reservoirs (A.5f)	102			102	107
7.	T.F.S. (A.5g)	1,218			1,218	1,279
8.	Losses from (A.5h) Underground mains and services	67,638	.87	.56	32,953	34,606
9.	Bottled water	41	-	-	41	41
					180,734	189,797

Table A.9 Lists the recharge in 1988 per each QARS ZONE while Maps W1,2 illustrate the locations of Reservoirs, Tanker filling Stations and major Potable Water consumers.

The above table shows that the consumption in 1988 was as follows:-

1.	Total domestic consumption including other users such as offices, workshops etc. and including consumed bottled water	29,709,484 m^3	% 43%
2.	Total Gardening Water - Private	17,197,627 m^3	
	Landscaping	9,231,655 m^3	38%
3.	Total losses through Distribution System (Reservoirs, Tanker filling Stations, distribution mains and house connections)	13,137,138 m^3	19%
	Total	69,275,905 m^3	100.0

WATER CONSUMPTION DATA 1988

QARS ZONE	CENSUS POP'N	HOUSE TYPE				DOMESTIC CONSUM'N				GARDEN WATER				TOTAL DOMESTIC	TOTAL GARDENING	POPULATION PER HOUSE TYPES					POP AV CONS
	nr	ARABIC nr	FLAT nr	VILLA nr	PALACE nr	ARABIC M3/DAY	FLAT M3/DAY	VILLA M3/DAY	PALACE M3/DAY	ARABIC M3/DAY	FLAT M3/DAY	VILLA M3/DAY	PALACE M3/DAY	M3/DAY	M3/DAY	ARABIC nr	FLAT nr	VILLA nr	PALACE nr	TOTAL nr	m3/day
1	1291	77	170	0	0.00	154.00	187.00	0.00	0.00	23.10	0.00	0.00	0.00	341.00	23.10	847	935	0	0	1782	322.75
2	1168	108	108	5	5.00	216.00	118.80	8.50	35.00	32.40	0.00	5.25	100.00	378.30	137.65	1188	594	33	90	1905	292.00
3	6689	283	596	32	1.00	566.00	655.60	54.40	7.00	84.90	0.00	33.60	20.00	1283.00	138.50	3113	3278	208	18	6617	1672.25
4	5343	250	229	100	0.00	500.00	251.90	170.00	0.00	75.00	0.00	105.00	0.00	921.90	180.00	2750	1260	650	0	4660	1335.75
5	5486	384	293	7	0.00	768.00	322.30	11.90	0.00	115.20	0.00	7.35	0.00	1102.20	122.55	4224	1612	46	0	5881	1371.50
6	3144	327	200	8	0.00	654.00	220.00	13.60	0.00	98.10	0.00	8.40	0.00	887.60	106.50	3597	1100	52	0	4749	786.00
7	1434	75	126	0	0.00	150.00	138.60	0.00	0.00	22.50	0.00	0.00	0.00	288.60	22.50	825	693	0	0	1518	358.50
8	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0.00
9	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0.00
10	3262	341	116	58	0.00	682.00	127.60	98.60	0.00	102.30	0.00	60.90	0.00	908.20	163.20	3751	638	377	0	4766	815.50
11	5170	557	169	68	3.00	1114.00	185.90	115.60	21.00	167.10	0.00	71.40	60.00	1436.50	298.50	6127	930	442	54	7553	1292.50
12	4436	358	517	80	4.00	716.00	568.70	136.00	28.00	107.40	0.00	84.00	80.00	1448.70	271.40	3938	2844	520	72	7374	1109.00
13	3254	163	181	131	8.00	326.00	199.10	222.70	56.00	48.90	0.00	137.55	160.00	803.80	346.45	1793	996	852	144	3784	813.50
14	6612	389	254	291	0.00	778.00	279.40	494.70	0.00	116.70	0.00	305.55	0.00	1552.10	422.25	4279	1397	1892	0	7568	1653.00
15	7693	558	459	43	0.00	1116.00	504.90	73.10	0.00	167.40	0.00	45.15	0.00	1694.00	212.55	6138	2525	280	0	8942	1923.25
16	7255	623	437	19	0.00	1246.00	480.70	32.30	0.00	186.90	0.00	19.95	0.00	1759.00	206.85	6853	2404	124	0	9380	1813.75
17	4460	203	407	34	0.00	406.00	447.70	57.80	0.00	60.90	0.00	35.70	0.00	911.50	96.60	2233	2239	221	0	4693	1115.00
18	883	70	162	42	0.00	140.00	178.20	71.40	0.00	21.00	0.00	44.10	0.00	389.60	65.10	770	891	273	0	1934	220.75
19	279	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	69.75
20	143	2	3	10	0.00	4.00	3.30	17.00	0.00	0.60	0.00	10.50	0.00	24.30	11.10	22	17	65	0	104	35.75
21	696	0	90	118	0.00	0.00	99.00	200.60	0.00	0.00	0.00	123.90	0.00	299.60	123.90	0	495	767	0	1262	174.00
22	4681	161	278	217	0.00	322.00	305.80	368.90	0.00	48.30	0.00	227.85	0.00	996.70	276.15	1771	1529	1411	0	4711	1170.25
23	5833	144	579	498	20.00	288.00	636.90	846.60	140.00	43.20	0.00	522.90	400.00	1911.50	966.10	1584	3185	3237	360	8366	1458.25
24	8035	236	458	498	6.00	472.00	503.80	846.60	42.00	70.80	0.00	522.90	120.00	1864.40	713.70	2596	2519	3237	108	8460	2008.75
25	10658	309	1118	483	22.00	618.00	1229.80	821.10	154.00	92.70	0.00	507.15	440.00	2822.90	1039.85	3399	6149	3140	396	13084	2664.50
26	9141	701	552	230	0.00	1402.00	607.20	391.00	0.00	210.30	0.00	241.50	0.00	2400.20	451.80	7711	3036	1495	0	12242	2285.25
27	13226	838	893	207	0.00	1676.00	982.30	351.90	0.00	251.40	0.00	217.35	0.00	3010.20	468.75	9218	4912	1346	0	15475	3306.50
28	1267	142	109	152	0.00	284.00	119.90	258.40	0.00	42.60	0.00	159.60	0.00	662.30	202.20	1562	600	988	0	3150	316.75
29	1879	100	0	0	0.00	200.00	0.00	0.00	0.00	30.00	0.00	0.00	0.00	200.00	30.00	1100	0	0	0	1100	469.75
30	534	0	100	0	0.00	0.00	110.00	0.00	0.00	0.00	0.00	0.00	0.00	110.00	0.00	0	550	0	0	550	133.50
31	989	0	150	0	0.00	0.00	165.00	0.00	0.00	0.00	0.00	0.00	0.00	165.00	0.00	0	825	0	0	825	247.25
32	5953	36	12	629	3.00	72.00	13.20	1069.30	21.00	10.80	0.00	660.45	60.00	1175.50	731.25	396	66	4089	54	4605	1488.25
33	1419	89	0	111	15.00	178.00	0.00	188.70	105.00	26.70	0.00	116.55	300.00	471.70	443.25	979	0	722	270	1971	354.75
34	16867	255	372	1133	12.00	510.00	409.20	1926.10	84.00	76.50	0.00	1189.65	240.00	2929.30	1506.15	2805	2046	7365	216	12432	4216.75
35	2776	40	155	205	4.00	80.00	170.50	348.50	28.00	12.00	0.00	215.25	80.00	627.00	307.25	440	853	1333	72	2697	694.00

DOHA UPDATE

QARS ZONE	CENSUS POP'N	HOUSE TYPE				DOMESTIC CONSUM'N				GARDEN WATER				TOTAL DOMESTIC	TOTAL GARDENING	POPULATION PER HOUSE TYPE					POP AV CONS
		ARABIC	FLAT	VILLA	PALACE	ARABIC	FLAT	VILLA	PALACE	ARABIC	FLAT	VILLA	PALACE			ARABIC	FLAT	VILLA	PALACE	TOTAL	
	nr	nr	nr	nr	nr	M3/DAY	M3/DAY	M3/DAY	M3/DAY	M3/DAY	M3/DAY	M3/DAY	M3/DAY	M3/DAY	M3/DAY	nr	nr	nr	nr	nr	M3/DAY
36	1460	2	46	274	2.00	4.00	50.60	465.80	14.00	0.60	0.00	287.70	40.00	534.40	328.30	22	253	1781	36	2092	365.00
37	11873	359	484	773	7.00	718.00	532.40	1314.10	49.00	107.70	0.00	811.65	140.00	2613.50	1059.35	3949	2662	5025	126	11762	2968.25
38	3962	148	346	180	17.00	296.00	380.60	306.00	119.00	44.40	0.00	189.00	340.00	1101.60	573.40	1628	1903	1170	306	5007	990.50
39	7365	50	234	899	39.00	100.00	257.40	1528.30	273.00	15.00	0.00	943.95	780.00	2158.70	1738.95	550	1287	5844	702	8383	1841.25
40	5413	24	47	559	21.00	48.00	51.70	950.30	147.00	7.20	0.00	586.95	420.00	1197.00	1014.15	264	259	3634	378	4534	1353.25
41	4796	4	139	270	5.00	8.00	152.90	459.00	35.00	1.20	0.00	283.50	100.00	654.90	384.70	44	765	1755	90	2654	1199.00
42	4907	45	252	340	4.00	90.00	277.20	578.00	28.00	13.50	0.00	357.00	80.00	973.20	450.50	495	1386	2210	72	4163	1226.75
43	1217	0	0	649	1.00	0.00	0.00	1103.30	7.00	0.00	0.00	681.45	20.00	1110.30	701.45	0	0	4219	18	4237	304.25
44	785	0	0	92	0.00	0.00	0.00	156.40	0.00	0.00	0.00	96.60	0.00	156.40	96.60	0	0	598	0	598	196.25
45	13089	367	969	495	5.00	734.00	1065.90	841.50	35.00	110.10	0.00	519.75	100.00	2676.40	729.85	4037	5330	3218	90	12674	3272.25
46	38	3	0	0	0.00	6.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00	6.00	0.90	33	0	0	0	33	9.50
47	319	1	0	67	5.00	2.00	0.00	113.90	35.00	0.30	0.00	70.35	100.00	150.90	170.65	11	0	436	90	537	79.75
48	945	2	89	12	0.00	4.00	97.90	20.40	0.00	0.60	0.00	12.60	0.00	122.30	13.20	22	490	78	0	590	236.25
49	484	30	0	0	0.00	60.00	0.00	0.00	0.00	9.00	0.00	0.00	0.00	60.00	9.00	330	0	0	0	330	121.00
50	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0.00
51	9603	208	17	665	81.00	416.00	18.70	1130.50	567.00	62.40	0.00	698.25	1620.00	2132.20	2380.65	2288	94	4323	1458	8162	2400.75
52	16302	721	87	898	75.00	1442.00	95.70	1526.60	525.00	216.30	0.00	942.90	1500.00	3589.30	2659.20	7931	479	5837	1350	15597	4075.50
53	16248	545	0	1288	37.00	1090.00	0.00	2189.60	259.00	163.50	0.00	1352.40	740.00	3538.60	2255.90	5995	0	8372	666	15033	4062.00
54	9053	127	47	872	48.00	254.00	51.70	1482.40	336.00	38.10	0.00	915.60	960.00	2124.10	1913.70	1397	259	5668	864	8188	2263.25
55	16824	315	6	1645	21.00	630.00	6.60	2796.50	147.00	94.50	0.00	1727.25	420.00	3580.10	2241.75	3465	33	10693	378	14569	4206.00
56	18835	21	130	469	26.00	42.00	143.00	797.30	182.00	6.30	0.00	492.45	520.00	1164.30	1018.75	231	715	3049	468	4463	4708.75
57	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0.00
58	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0.00
59	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0.00
60	8	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	2.00
61	159	0	0	1	0.00	0.00	0.00	1.70	0.00	0.00	0.00	1.05	0.00	1.70	1.05	0	0	7	0	7	39.75
62	30	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	7.50
63	1145	0	204	41	0.00	0.00	224.40	69.70	0.00	0.00	0.00	43.05	0.00	294.10	43.05	0	1122	267	0	1389	286.25
64	1309	33	40	180	0.00	66.00	44.00	306.00	0.00	9.90	0.00	189.00	0.00	416.00	198.90	363	220	1170	0	1753	327.25
65	2001	0	0	336	0.00	0.00	0.00	571.20	0.00	0.00	0.00	352.80	0.00	571.20	352.80	0	0	2184	0	2184	500.25
66	1736	0	0	328	0.00	0.00	0.00	557.60	0.00	0.00	0.00	344.40	0.00	557.60	344.40	0	0	2132	0	2132	434.00
67	2463	0	0	286	0.00	0.00	0.00	486.20	0.00	0.00	0.00	300.30	0.00	486.20	300.30	0	0	1859	0	1859	615.75
TOTAL	304325	10824	17028	12430	497.00	21648.00	12711.60	28947.60	3479.00	3247.20	0.00	17879.40	9940.00	67747.60	31066.60	119064	68365	110682	8946	307057	76081.25

SUMMARY OF POTABLE WATER USAGE

ITEM	PEAK CONSUM'N m3/d	AV FACTOR	LOSSES FACTOR	AV CONSUM'N + LOSS m3/d	ADJUSTED BY 3.3% m3/d	CALCULATIONS TOTAL DOM	TOTAL GAR'N	LANDSC'E	TOTAL LOSSES
PRIVATE DOM	67638	0.87	1.10	64729	67976	67976			
PRIVATE GARDEN	31067	0.87	1.66	44866	47117		47117		
OTHER USERS	6596	0.87	1.10	6313	6629	6629			
LANDSCAPING	15806	1.00	1.00	15806	16599			16599	
SPECIAL CON DOM	6716	0.87	1.10	6427	6750	6750			
SPECIAL CON GARDEN	5732	0.87	1.66	8278	8693			8693	
RESERVOIRS	102	1.00	1.00	102	107				107
TANKER FILLING ST.	1218	1.00	1.00	1218	1279				1279
LOSSES FROM PIPES	67638	0.87	0.56	32953	34606				34606
BOTTLED WATER	41	1.00	1.00	41	41	41			
				180734	189797	29709484	17197627	9231655	13137138
				180692.53692	69275905				

ZONE	SCHOOLS NUMBER	OFFICE GOVERNMENT M2	OFFICE PRIVATE M2	SHOPS M2	WORKSHOPS NUMBER	SPECIAL CONSUMERS DOMESTIC M3/DAY	SPECIAL CONSUMERS GARDENING M3/DAY	OFFICE/ GOVERNMENT CONSUMPTION M3/DAY	OFFICE/ PRIVATE CONSUMPTION M3/D	SHOPS CONSUMPTION M3/D	WORKSHOP CONSUMPTION M3/DAY	SCHOOLS CONSUMPTION M3/DAY	LAND-SCAPING CONSUMPTION M3/DAY	PRIVATE DOMESTIC CONSUMPTION M3/DAY	GARDENING CONSUMPTION M3/DAY	AV DOM CONSUMPTION M3/DAY	AV GARDEN CONSUMPTION M3/DAY	OTHER USERS AV DOMESTIC CONSUMPTION	LOSSES FROM UNDER GRD SERVICES
1	1	15095	22150	27760	3	0	0	90.57	132.90	83.28	6.00	100	331	341.00	23.10	326.34	33.36	395	166
2	1	101330	940	2680	3	140	0	607.98	5.64	8.04	6.00	100	565	378.30	137.65	362.03	198.79	696	184
3	1	2300	6950	36862	14	0	0	13.80	41.70	110.59	28.00	100	0	1283.00	138.50	1227.83	200.02	281	625
4	1	0	1830	22895	15	74	0	0.00	10.98	68.69	30.00	100	80	921.90	180.00	882.26	259.96	201	449
5	1	0	1723	14394	12	0	0	0.00	10.34	43.18	24.00	100	44	1102.20	122.50	1054.81	176.91	170	537
6	1	0	900	6275	19	0	0	0.00	5.40	18.83	38.00	100	37	887.60	106.50	849.43	153.81	155	432
7	1	60500	12275	46755	1	0	0	363.00	73.65	140.27	2.00	100	0	288.60	22.50	276.19	32.49	650	141
10	4	9460	0	890	0	0	0	56.76	0.00	2.67	0.00	400	0	908.20	163.20	869.15	235.69	440	442
11	1	4120	0	3065	2	37	74	24.72	0.00	9.20	4.00	100	247	1436.50	298.50	1374.73	431.09	132	700
12	1	32408	7295	17392	6	0	0	194.45	43.77	52.18	12.00	100	630	1448.70	271.40	1386.41	391.96	385	706
13	1	9945	1110	6270	0	56	180	59.67	6.66	18.81	0.00	100	38	803.80	346.45	769.24	500.34	177	392
14	1	2620	0	3658	1	0	0	15.72	0.00	10.97	2.00	100	0	1552.10	422.25	1485.36	609.81	123	756
15	1	5230	2870	7460	6	0	0	31.38	17.22	22.38	12.00	100	19	1694.00	212.55	1621.16	306.96	175	825
16	1	680	1730	7215	11	0	0	4.08	10.38	21.65	22.00	100	13	1759.00	206.85	1683.36	298.73	151	857
17	1	4300	1260	10285	7	0	0	25.80	7.56	30.86	14.00	100	134	911.50	96.60	872.31	139.51	171	444
18	1	14170	4315	5560	3	0	0	85.02	25.89	16.68	6.00	100	122	389.60	65.10	372.85	94.02	224	190
19	1	3870	0	0	1	0	0	23.22	0.00	0.00	2.00	100	205	0.00	0.00	0.00	0.00	120	0
20	2	0	0	0	0	92	0	0.00	0.00	0.00	0.00	200	84	24.30	11.10	23.26	16.03	191	12
21	1	0	0	0	0	751	646	0.00	0.00	0.00	0.00	100	783	299.60	123.90	286.72	178.94	96	146
22	1	410	2950	3035	3	0	0	2.46	17.70	9.11	6.00	100	437	996.70	276.15	953.84	398.82	129	486
23	0	1200	0	5570	0	0	0	7.20	0.00	16.71	0.00	0	361	1911.50	966.10	1829.31	1395.24	23	931
24	0	0	2310	13796	0	820	738	0.00	13.86	41.39	0.00	0	1527	1864.40	713.70	1784.23	1030.73	53	908
25	0	15588	3835	8330	0	0	0	93.53	23.01	24.99	0.00	0	199	2822.90	1039.85	2701.52	1501.75	135	1375
26	0	420	1080	10655	1	237	22	2.52	6.48	31.97	2.00	0	19	2400.20	451.80	2296.99	652.49	41	1169
27	0	6004	2940	5346	8	0	0	36.02	17.64	16.04	16.00	0	0	3010.20	468.75	2880.76	676.97	82	1467
28	0	870	2025	50	0	767	619	5.22	12.15	0.15	0.00	0	14	662.30	202.20	633.82	292.02	17	323
29	0	7750	0	0	0	355	222	46.50	0.00	0.00	0.00	0	0	200.00	30.00	191.40	43.33	45	97
31	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0	0	165.00	0.00	157.91	0.00	0	80
32	0	0	0	1628	0	7	22	0.00	0.00	4.88	0.00	0	142	1175.50	731.25	1124.95	1056.07	5	573
33	0	0	0	4380	1	22	244	0.00	0.00	13.14	2.00	0	0	471.70	443.25	451.42	640.14	14	230
34	1	1980	0	5940	0	74	0	11.88	0.00	17.82	0.00	100	232	2929.30	1506.15	2803.34	2175.18	124	1427
35	1	0	0	655	0	0	0	0.00	0.00	1.97	0.00	100	126	627.00	307.25	600.04	443.73	98	305

ZONE	SCHOOLS NUMBER	OFFICE GOVERNMENT M2	OFFICE PRIVATE M2	SHOPS M2	WORKSHOPS NUMBER	SPECIAL CONSUMERS DOMESTIC M3/DAY	SPECIAL CONSUMERS GARDENING M3/DAY	OFFICE/ GOVERNMENT CONSUMPTION M3/DAY	OFFICE/ PRIVATE CONSUMPTION M3/D	SHOPS CONSUMPTION M3/D	WORKSHOP CONSUMPTION M3/DAY	SCHOOLS CONSUMPTION M3/DAY	LAND-SCAPING CONSUMPTION M3/DAY	PRIVATE DOMESTIC CONSUMPTION M3/DAY	GARDENING CONSUMPTION M3/DAY	AV DOM CONSUMPTION M3/DAY	AV GARDEN CONSUMPTION M3/DAY	OTHER USERS AV DOMESTIC CONSUMPTION	LOSSES FROM UNDER GRD SERVICES
36	0	0	0	50	0	37	407	0.00	0.00	0.15	0.00	0	42	534.40	328.30	511.42	474.13	0	260
37	1	0	1300	5539	0	1132	0	0.00	7.80	16.62	0.00	100	535	2613.50	1059.35	2501.12	1529.91	119	1273
38	0	2000	0	14072	0	115	503	12.00	0.00	42.22	0.00	0	386	1101.60	573.40	1054.23	828.10	52	537
39	0	5030	10603	5805	0	34	365	30.18	63.62	17.42	0.00	0	126	2158.70	1738.95	2065.88	2511.39	106	1052
40	0	0	0	690	0	45	629	0.00	0.00	2.07	0.00	0	798	1197.00	1014.15	1145.53	1464.64	2	583
41	0	0	0	110	0	0	0	0.00	0.00	0.33	0.00	0	293	654.90	384.70	626.74	555.58	0	319
42	0	0	0	8659	0	0	0	0.00	0.00	25.98	0.00	0	356	973.20	450.50	931.35	650.61	25	474
43	0	0	0	0	0	22	136	0.00	0.00	0.00	0.00	0	0	1110.30	701.45	1062.56	1013.03	0	541
44	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0	126	156.40	96.60	149.67	139.51	0	76
45	0	0	0	7895	0	52	0	0.00	0.00	23.69	0.00	0	0	2676.40	729.85	2561.31	1054.05	23	1304
46	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0	0	6.00	0.90	5.74	1.30	0	3
47	0	0	0	4080	0	0	0	0.00	0.00	12.24	0.00	0	48	150.90	170.65	144.41	246.45	12	74
48	0	0	0	0	0	74	0	0.00	0.00	0.00	0.00	0	315	122.30	13.20	117.04	19.06	0	60
49	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0	0	60.00	9.00	57.42	13.00	0	29
51	0	0	0	9603	0	0	0	0.00	0.00	28.81	0.00	0	134	2132.20	2380.65	2040.52	3438.13	28	1039
52	0	0	0	16302	0	0	0	0.00	0.00	48.91	0.00	0	862	3589.30	2659.20	3434.96	3840.42	47	1749
53	0	0	0	16248	0	44	22	0.00	0.00	48.74	0.00	0	374	3538.60	2255.90	3386.44	3257.97	47	1724
54	0	0	0	9053	0	271	903	0.00	0.00	27.16	0.00	0	3578	2124.10	1913.70	2032.76	2763.77	26	1035
55	0	0	0	16824	0	52	0	0.00	0.00	50.47	0.00	0	144	3580.10	2241.75	3426.16	3237.54	48	1744
56	0	0	0	18835	0	518	0	0.00	0.00	56.51	0.00	0	50	1164.30	1018.75	1114.24	1471.28	54	567
60	0	0	0	8	0	148	0	0.00	0.00	0.02	0.00	0	0	0.00	0.00	0.00	0.00	0	0
61	0	0	0	159	0	740	0	0.00	0.00	0.48	0.00	0	1250	1.70	1.05	1.63	1.52	0	1
62	0	0	0	30	0	0	0	0.00	0.00	0.09	0.00	0	0	0.00	0.00	0.00	0.00	0	0
63	0	0	0	1145	0	0	0	0.00	0.00	3.44	0.00	0	0	294.10	43.05	281.45	62.17	3	143
64	0	0	0	1309	0	0	0	0.00	0.00	3.93	0.00	0	0	416.00	198.90	398.11	287.25	4	203
65	0	0	0	2001	0	0	0	0.00	0.00	6.00	0.00	0	0	571.20	352.80	546.64	509.51	6	278
66	0	0	0	1736	0	0	0	0.00	0.00	5.21	0.00	0	0	557.60	344.40	533.62	497.38	5	272
67	0	0	0	2463	0	0	0	0.00	0.00	7.39	0.00	0	0	486.20	300.30	465.29	433.69	7	237
TOTAL	27	307280	92391	421417	117	6716	5732	1843.68	554.35	1264.25	234.00	2700	15806	67637.60	31066.55	64729.18	44866.31	6313	32953
AVERAGE						6427	8278	1764	531	1210	224	2583.9							

ZONE	AVERAGE DOMESTIC CON'N ADJUSTED	OTHER USERS ADJUSTED	SPECIAL CONSUMERS ADJUSTED	DOMESTIC USE TOTAL ADJUSTED	AVERAGE GARDEN ADJUSTED	SPECIAL CONSUMERS GARDEN ADJUSTED	LAND-SCAPE ADJUSTED	LOSSES FOR UNDERGROUND ADJUSTED
1	343	415	0	758	35	0	348	174
2	380	731	141	1252	209	0	593	194
3	1289	296	0	1585	210	0	0	656
4	927	211	74	1212	273	0	84	472
5	1108	178	0	1286	186	0	46	564
6	892	163	0	1055	162	0	39	454
7	290	682	0	972	34	0	0	148
10	913	462	0	1374	248	0	0	465
11	1444	139	37	1619	453	112	259	735
12	1456	404	0	1860	412	0	662	741
13	808	186	56	1050	525	273	40	411
14	1560	129	0	1689	640	0	0	794
15	1702	184	0	1886	322	0	20	867
16	1768	159	0	1927	314	0	14	900
17	916	179	0	1095	147	0	141	466
18	392	235	0	626	99	0	128	199
19	0	126	0	126	0	0	215	0
20	24	201	92	318	17	0	88	12
21	301	101	755	1156	188	980	822	153
22	1002	136	0	1138	419	0	459	510
23	1921	24	0	1945	1465	0	379	978
24	1874	56	824	2753	1082	1119	1604	954
25	2837	142	0	2979	1577	0	209	1444
26	2412	43	238	2694	685	33	20	1228
27	3025	86	0	3111	711	0	0	1540
28	666	18	771	1454	307	939	15	339
29	201	47	357	605	45	337	0	102
31	166	0	0	166	0	0	0	84
32	1181	5	7	1193	1109	33	149	601
33	474	15	22	511	672	370	0	241
34	2944	130	74	3149	2284	0	244	1499
35	630	102	0	733	466	0	132	321
36	537	0	37	574	498	617	44	273
37	2627	125	1138	3889	1607	0	562	1337
38	1107	54	116	1277	870	763	405	564
39	2169	112	34	2315	2637	554	132	1104
40	1203	2	45	1250	1538	954	838	612
41	658	0	0	659	583	0	308	335
42	978	26	0	1004	683	0	374	498
43	1116	0	22	1138	1064	206	0	568
44	157	0	0	157	147	0	132	80
45	2690	24	52	2766	1107	0	0	1369
46	6	0	0	6	1	0	0	3
47	152	12	0	164	259	0	50	77
48	123	0	74	197	20	0	331	63
49	60	0	0	60	14	0	0	31
51	2143	29	0	2172	3611	0	141	1091
52	3607	49	0	3656	4033	0	905	1836
53	3556	49	44	3650	3421	33	393	1810
54	2135	27	272	2434	2902	1370	3757	1087
55	3598	51	52	3701	3400	0	151	1832
56	1170	57	521	1748	1545	0	53	596
60	0	0	149	149	0	0	0	0
61	2	0	744	746	2	0	1313	1
62	0	0	0	0	0	0	0	0
63	296	3	0	299	65	0	0	139
64	418	4	0	422	302	0	0	213
65	574	6	0	580	535	0	0	292
66	560	5	0	566	522	0	0	285
67	489	7	0	496	455	0	0	249
TOTAL	67976	6629	6750	81355	47117	8693	16599	34605.9495

	CONSUMPTION								RECHARGE						
ZONE	DOMESTIC USE TOTAL (ADJUSTED) m3/yr	GARDENING TOTAL (ADJUSTED) m3/yr	LANDSCAPING TOTAL (ADJUSTED) m3/yr	LOSSES RES (ADJUSTED) m3/yr	LOSSES T.F.S. (ADJUSTED) m3/yr	LOSSES DIST. MAIN & SERVICES	TOTAL LOSSES m3/yr	TOTAL CONSUMPTION	DOMESTIC USES TOTAL	GARDENING TOTAL	LAND-SCAPING	LOSSES RES.	LOSSES TANKER FILLING STATION	LOSSES DIST MAINS & SERVICES	TOTAL RECHARGE
1	276495	12788	126875	0	0	63681	63681	479839	5530	5754	57094	0	0	47761	116139
2	457051	76199	216569	0	0	70647	70647	820466	9141	34290	97456	0	0	52985	193872
3	578516	76670	0	0	0	239597	239597	894784	11570	34501	0	0	0	179698	225770
4	442233	99643	30665	0	0	172163	172163	744703	8845	44839	13799	0	0	129122	196605
5	469435	67813	16866	0	0	205833	205833	759946	9389	30516	7590	0	0	154375	201869
6	385103	58956	14182	0	0	165757	165757	623998	7702	26530	6382	0	0	124318	164932
7	354910	12455	0	0	0	53895	53895	421260	7098	5605	0	0	0	40422	53125
10	501682	90343	0	0	0	169604	169604	761630	10034	40654	0	0	0	127203	177891
11	591109	165242	135642	0	0	268263	268263	1160255	11822	74359	61039	0	0	201197	348417
12	679029	150240	241484	0	0	270542	270542	1341295	13581	67608	108668	0	0	202906	392763
13	383311	191786	114209	0	0	150108	150108	839414	7666	86304	51394	0	0	112581	257945
14	616559	233747	0	0	0	289851	289851	1140157	12331	105186	0	0	0	217388	334906
15	688525	117662	7283	0	0	316351	316351	1129821	13771	52948	3277	0	0	237263	307259
16	703244	114507	4983	0	0	328489	328489	1151223	14065	51528	2242	0	0	246367	314202
17	399736	53475	51363	0	0	170221	170221	674795	7995	24064	23113	0	0	127665	182838
18	228602	36038	46764	0	0	72757	72757	384160	4572	16217	21044	0	0	54568	96400
19	45934	0	78578	0	0	0	0	124512	919	0	35360	0	0	0	36279
20	116027	6145	32198	5523	0	4538	10061	164431	2321	2765	14489	4971	0	3403	27949
21	422070	68588	657739	0	0	55950	55950	1204346	8441	30865	295983	0	0	41962	377251
22	415234	152869	167506	0	0	186132	186132	921741	8305	68791	75378	0	0	139599	292072
23	709959	534808	138374	0	0	356968	356968	1740109	14199	240663	62268	0	0	267726	584857
24	1004974	395086	993849	2761	245555	348173	596489	2990398	20099	177789	447232	2485	147333	261129	1056068
25	1087429	575634	76278	0	0	527170	527170	2266512	21749	259035	34325	0	0	395378	710487
26	983154	250105	19461	0	0	448232	448232	1700952	19663	112547	8758	0	0	336174	477142
27	1135657	259488	0	0	0	562148	562148	1957293	22713	116769	0	0	0	421611	561094
28	530731	111933	348028	0	0	123683	123683	1114375	10615	50370	156613	0	0	92762	310359
29	220646	16607	122893	0	0	37350	37350	397496	4413	7473	55302	0	0	28012	95200
31	60526	0	0	0	0	30813	30813	91340	1211	0	0	0	0	23110	24321
32	435563	404801	66608	0	0	219522	219522	1126495	8711	182160	29974	0	0	164642	385487
33	186656	245372	135072	0	0	88089	88089	655188	3733	110417	60782	0	0	66067	240999
34	1149266	833765	88928	0	0	547040	547040	2618999	22985	375194	40017	0	0	410280	848477
35	267403	170086	48297	0	0	117091	117091	602877	5348	76538	21734	0	0	87818	191438
36	209659	181738	241403	0	0	99798	99798	732599	4193	81782	108632	0	0	74849	269455
37	1419586	586428	205070	0	0	488065	488065	2699150	28392	263893	92281	0	0	366049	750615
38	466168	317419	426405	0	0	205721	205721	1415713	9323	142839	191882	0	0	154291	498335
39	845135	962637	250351	0	0	403132	403132	2461256	16903	433187	112658	0	0	302349	865097
40	456357	561407	654078	0	0	223537	223537	1895379	9127	252633	294335	0	0	167653	723748
41	240355	212960	112309	0	0	122301	122301	687926	4807	95832	50539	0	0	91726	242904
42	366524	249385	136458	0	0	181743	181743	934110	7330	112223	61406	0	0	136307	317267
43	415357	388304	75286	0	0	207346	207346	1086293	8307	174737	33879	0	0	155510	372432
44	57372	53475	48297	0	0	29207	29207	188351	1147	24064	21734	0	0	21906	68850
45	1009536	404026	0	0	0	499812	499812	1913374	20191	181812	0	0	0	374859	576861
46	2201	498	0	0	0	1120	1120	3820	44	224	0	0	0	840	1109
47	59844	94467	18399	0	0	28180	28180	200890	1197	42510	8279	0	0	21135	73122
48	72008	7307	120742	9862	113640	22839	146342	346399	1440	3288	54334	8876	68184	17129	153252
49	22010	4982	0	0	0	11205	11205	38197	440	2242	0	0	0	8404	11086
51	792714	1317865	51363	0	0	398184	398184	2560127	15854	593039	23113	0	0	298638	930645
52	1334589	1472063	330412	9173	107640	670294	787107	3924171	26692	662429	148685	8256	64584	502720	1413366
53	1332071	1248807	155536	0	0	660826	660826	3397240	26641	561963	69991	0	0	495619	1154215
54	888548	1059374	1871354	0	0	396671	396671	4215947	17771	476718	842109	0	0	297503	1634102
55	1350863	1240974	55196	0	0	668576	668576	3315609	27017	558438	24838	0	0	501432	1111726
56	637839	563953	19165	8488	0	217430	225919	1446876	12757	253779	8624	7640	0	163073	445873
60	54299	0	0	0	0	0	0	54299	1086	0	0	0	0	0	1086
61	272250	581	479135	0	0	317	317	752284	5445	262	215611	0	0	238	221556
62	33	0	0	0	0	0	0	33	1	0	0	0	0	0	1
63	109144	23831	0	0	0	54923	54923	187897	2186	10724	0	0	0	41192	54099
64	154040	110106	0	0	0	77687	77687	341833	3081	49548	0	0	0	58265	110894
65	211733	195301	0	0	0	106670	106670	513704	4235	87885	0	0	0	80003	172123
66	206453	190651	0	0	0	104131	104131	501234	4129	85793	0	0	0	78098	168020
67	181061	166238	0	3247	0	90797	94043	441343	3621	74807	0	2922	0	68098	149448
	29694519	17197627	9231655	39055	466835	12631172	13137061	69260863	593890	7738932	4154245	35150	280101	9473379	22275697
	29709484														
				TOTAL	13137061			69275828.01							

APPENDIX B

APPENDIX "B"

RECHARGE FROM SEWERAGE

B.1 INTRODUCTION

The objective of this Appendix is to assess the volumes of sewerage generation which is transported by the sewage network to the treatment plants and volumes which are disposed of in septic tanks. Infiltration from groundwater into the piped system is also assessed in this Appendix along with estimates of storm water drain outflow. The recharge in each of the QARS ZONES to which the study area has been subdivided is also computed.

B.2 POPULATION DISTRIBUTION

Population figures for the study area have been derived from the 1986 Census and projected forward to the year of the Study i.e. 1988.

The occupancy figure for each property type, as indicated in Appendix F Methodology, has been adopted to determine the population within each pumping station zone. A percentage of non connected properties as given by CED has been adopted to determine the sewage flow generated in each Pumping Station zone.

The population distribution for sewered and non sewered areas are given in tables B.1 and B.2.

TABLE B.1

POPULATION SERVED BY DESIGNATED PUMPING STATION ZONES

P.S ZONE	POP CONNECTED	SEWAGE FLOW M^3/D	POP NOT CONNECTED	SEWAGE FLOW M^3/D
1	21,351	3,055	4,270	764
2	847	157	-	-
3	2,331	450	-	-
4	11,029	1,811	551	95
5	17,795	3,121	890	164
6	12,387	2,192	-	-
7	7,209	1,245	-	-
8	13,640	2,329	682	123
9	17,107	2,322	4,277	774
10	8,848	1,624	177	33
11	13,192	2,458	396	76
12	-	-	2,750	550
13	2,655	416	531	104
14	16,959	2,408	4,466	647
15	21,205	3,052	5,301	1,017
16	120	24	24	5
17	7,644	1,143	1,529	286
18	2,403	472	2,067	413
19	-	-	-	-
20	4,281	859	-	-
21	-	-	-	-
22	-	-	-	-
23	14,495	2,792	-	-
24	-	-	-	-
25	11,155	1,851	-	-
26	-	-	-	-
27	2,331	-	-	-
28	-	-	-	-
29	-	-	-	-
30	5,492	1,102	-	-
31	11,101	2,126	2,220	425
Totals	225,577	37,472	30,138	5,479

TABLE B.2

POPULATION OUTSIDE OF PUMPING STATION ZONES
(OUTSIDE DESIGNATED PUMPING STATION ZONES)

QARS ZONE	POPULATION	FLOW M^3/D
10	4,396	760
22	124	25
24	574	115
32	151	36
33	2,260	450
34	1,857	380
35	2,985	590
37	1,320	258
38	457	93
39	2,087	419
40	2,574	544
41	1,300	259
42	196	39
43	126	25
47	479	96
49	300	50
51	8,370	1,750
52	15,431	2,974
53	360	104
54	3,549	705
56	2,158	468
Total	51,054	10,139

B.3 HOUSE TYPE

The house type used are those accepted for the potable water distribution assessment. (refer to Section 1.3 Methodology).

Each different type of dwelling has been counted for the areas covered by the sewerage system. It has been assumed that the connected and unconnected properties for the zone is as given by the CED.

B.4 OCCUPANCY RATES

The occupancy rates used are those listed in the potable water section (Appendix A) and section 1.3 (Methodology) and reference is therefore made to that sections.

B.5 SEWAGE FLOW

As the usage and sewage generation cannot be accurately determined as a per capita figure, certain assumptions had to be made and the results adjusted to conform with the data available.

The sewage flow has been calculated according to the type of dwelling. This allows for both the different occupancy rate and a different usage per capita to be taken for each dwelling type. The total flow from the connected dwellings can then be compared with the total flow that is received at the sewage treatment works.

The theoretical sewage generated can also be compared with the flow calculated from pump run hours to ensure that the assumptions made for sewage flows in the various zones are realistic.

B.6 SEWAGE TREATMENT FLOWS

Table B.4 below lists the record of sewage treatment works in 1988.

TABLE B.4

SEWAGE TREATMENT WORKS RECORD - 1988

Month (1988)	Av. Flow m^3/day	Return Effluent * to Doha m^3/day	Effluent to Abu Naklah/ Rakiyah m^3/day
Jan	73,574	12,700	60,874
Feb	90,603	11,210	79,393
March	93,035	12,530	80,505
April	77,320	14,780	62,540
May	70,763	16,411	54,352
June	65,253	14,600	50,653
July	59,186	14,870	44,316
Aug	66,400	16,120	50,280
Sept	66,937	14,010	52,947
Oct	67,287	14,160	53,127
Nov	64,914	10,890	54,024
Dec	69,271	11,370	57,901
Total	26,345,848	4,996,130	21,349,718
Av. Flow	72,180 m^3/d		

B.7 AVERAGE SEWAGE GENERATION

The overall figure used for design purposes for a sewage reticulation scheme in the Middle East is 270 litres/capita/day.

The design flow allows for a certain amount of infiltration, industrial or high flow rates in particular areas and further zoning alterations, and is also of use for sizing capital works. This figure should not be used for calculating actual flows. For a more detailed flow estimate we have assumed an average water consumption figure on an annual basis, of 87% of the Peak daily water consumption figure derived from the "Qatar National Plan for Water Supply".

The sewage generation has been taken as 95% of the average daily water consumption for each type of dwelling (See Table B.5). This percentage is accepted to be representative of the ratio of water delivery to dwellings and the sewage generation.

TABLE B.5

AVERAGE DAILY WATER CONSUMPTION

Description	Occupancy rate	Total Average Water Cons. m^3/day
Arab House	8 - 10	1·74
Flat	4 - 5	1·04
Villa	5 - 7	1·50
Palace	12 - 20	6·10

B.8 SPECIAL CONSUMERS

Consumers such as hotels, hospitals, colleges etc., are treated as special consumers and the sewage generation from these sources has been added to the domestic sewage generation.

The "special consumers" which are non domestic users are given in Table B.6. The proportion of the total water supply that contributes to sewage generation is considered within the sewage pumping station zones and those that are outside these areas but within the Study Area.

TABLE B.6

SPECIAL CONSUMERS - NON DOMESTIC

QARS ZONE	DESIGNATED DRAINAGE AREAS Description	Water Consumption m^3/day
2	Emir's Palace	140
4	Sofitel Hotel	74
	Two Palaces	25
	Old Diwan and Palace	72
	Guest Villas & T.V. Station	74
	QGPC Housing, Falcon Club & Army Housing	396
	Rumaillah Hospital	148
	Villa near White Palace and Doha Hospital	217
24	Ramada Hotel	467
	Maternity Hospital & Clinic	353
26	Soft Drink Factories	230
	Clinic	7
28	Gulf Hotel, Oasis Hotel and Doha Club	871
29	Ras Abu Abbud Power Station (Accommodation)	355
32	Health Centre	7
33	Palace	22
34	Training Centre	74
36	Two Palaces	37
37	White Palace and Hamad Hospital	1132
38	Seven Palaces	100
	Palace	15
39	Three Palaces	34
40	One Palace	15
	Three Palaces	30
43	Two Palaces	22
45	Isolation Hospital	52
48	Airport	74
52	Rayyan Clinic	7
54	Barracks	148
54	Emir's Palace and Two Other Palaces	123
61	Sheraton Hotel	740
		6061

QARS ZONE	OUTSIDE DRAINAGE AREAS Description	Water Consumption m^3/day
53	Race Course	37
55	Khalifa Stadium	30
54	Pony Stables Dairy Farm and Police Training College	318
56	Wholesale Market & Road Dept.	222
56	Livestock Market Abattoir and Abu Hammur	666
		1273

B.9 INFILTRATION

Infiltration into the sewage reticulation system takes place for a number of reasons, some of the common ones being:-

a) Leakage at joints.

b) Leakage due to illegal connections.

c) Damage due to outside sources such as Service Authorities.

d) Contractor's pumping ground water from excavation into adjacent sewerage manholes.

The amount of infiltration is likely to be higher where the standing ground water level is, highest due to hydraulic head or in the case of Contractor's interference with excavation even at shallow depths. The highest water table, of the sewered areas is in central Doha where all of the examples given above will have the highest incidence.

This infiltration has a negative effect on the Rising Water Table as it is helping to alleviate the problem, in the short term, by the transfer of ground water from central Doha, via pumping stations, to the sewage treatment works, on the outer boundary of the study area, and from there out of the study area completely.

From the theoretical flows derived from the connected property types, tests carried out by the CED, and from a comparison with actual flow received at the sewage treatment works the infiltration is assumed to be approximately 34% of the actual flow received at the sewage treatment works.

The infiltration has been proportioned out for each of the QARS zones on the basis of area and proportion of connected properties within that zone for a flow of 8,891,513 m^3/year.

The contributing zones are assumed to be those with a standing water table at ground level down to five metres below actual ground level. This would indicate that the majority of infiltration is in Central Doha with a small contribution from Gharrafa.

Data obtained on pump run hours for each Pumping Station was compared to the theoretical flows, which gave an indication of the proportion of infiltration within each Pumping Station zone, however the accuracy of the hours run meter for the pumps withn some of the pumping station zones are considered to be unacceptable and have been disregarded.

B.12 SEWAGE RECHARGE OF GROUND WATER TABLE

Where properties are not connected to the sewerage system and the sewage discharge is to septic tanks, it can be assumed that all of the flow is recharging the water table.

For the areas outside the designated drainage zones there is a population of 51,054 (See Table B.2). This population is generating a sewage of approximately 4,282,619 m^3/year over the study area. (all on septic tanks).

Within the drainage areas there was a recharge of approximately 1,999,738 m^3 in 1988. (Septic tanks).

There is a negligible amount of recharge from a piped sewage system that is working as designed, since the liquid part of the sewage finds the line of least resistance to be along the pipeline, rather than out of cracked pipes or bad joints. If the pipeline is broken or in surcharged condition, then local discharge could occur, but the places where this happens are not quantifiable. A nominal amount of 1% of the piped sewage has been assigned to this losses giving a recharge of 174,543 m^3/year.

Sewage Generated and connected to Sewerage System m^3/yr		Sewage Generated and Discharging Groundwater m^3/yr	
Properties	13,677,252	Properties within Drainage Areas not connected	1,999,738
Special Consumers	2,133,571	Outside	
Others	1,643,512	D. Area	3,701,100
TOTAL	17,454,335	Others Outside	581,518
Flow received at works	26,345,848	TOTAL	6,282,256

The annual sewage generation per capita in 1988 amount to 213/l/day, which is considered to be acceptable.

B.13 STORM WATER DRAIN

The existing Storm Water Drain runs from the Corniche to the Water Department for one section and to B-ring road for the other section.

At present the drain is being replaced by a box culvert to increase the capacity, but for the purpose of this study the system adopted in the "ASCO" report of 1982/83 will be adopted.

The amount per year that is discharged to the Bay has been estimated from the running of the pump and its rated capacity as 2.0 mm^3/yr.

SUMMARY OF RECHARGE AND OUTFLOW IN EACH QARS ZONE 1988

QARS ZONE	RECHARGE FROM SEWERAGE m^3/d	INFILTRATION	STORM WATER DRAIN m^3/d	
1	64	390	535	195810
2	51	693		
3	125	908	1,158	4235828
4	83	1,239	891	326106
5	194	633	1,336	486976
6	45	216	134	49044
7	26	442	891	326106
8	0	0		
9	0	0		
10	892	0		
11	65	760		
12	68	889		
13	38	502		
14	37	823	535	195810
15	32	963		
16	190	877		
17	67	532		
18	3	218		
19	1	0		
20	11	0		
21	52	0		
22	171	452		
23	293	769		
24	179	1,348		
25	76	1,448		
26	487	0		
27	267	1,334		
28	39	0		
29	13	0		
30	0	0		
31	0	0		
32	136	0		
33	463	0		
34	618	1,022		
35	602	0		
36	60	224		
37	742	1,377		
38	295	420		
39	716	592		
40	575	257		
41	262	145		
42	546	0		
43	34	0		
44	1	0		
45	306	1,057		
46	0	0		
47	106	0		
48	9	0		
49	50	0		
50	0	0		

SUMMARY OF RECHARGE AND OUTFLOW IN EACH QARS ZONE 1988

QARS ZONE	RECHARGE FROM SEWERAGE m^3/d	INFILTRATION	STORM WATER DRAIN m^3/d
51	1,774	0	
52	3,552	0	
53	702	0	
54	1,112 -4055	589	
55	98	0	
56	1,327	232	
57	0	0	
58	0	0	
59	0	0	
60	0	0	
61	14	703	
62	0	0	
63	3	267	
64	4	437	
65	6	630	
66	5	479	
67	5	460	
TOTAL m^3/d	17,690	24,327	5,479 → 5480 × 365 ↓ 2000200
TOTAL m^3/yr	6,456,900	8,879,237	2,000,000

QARS ZONE	PUMPING STATION FLOW DOMESTIC	NOT CONNECTED FLOW DOMESTIC	OUTSIDE DRAINAGE AREAS DOMESTIC	PUMPING STATION FLOW SPECIAL CONS	OUTSIDE FLOW SPECIAL CONS	OTHERS	TOTAL P.S. FLOW	TOTAL OUTSIDE	RECHARGE FOR SEWERS	RECHARGE NOT CONNECTED	RECHARGE OUTSIDE P. STATIONS	TOTAL RECHARGE
1	231	56				341	572	0	6	56	0	62
2	280	41		133		602	1015	0	10	41	0	51
3	1086	112				244	1330	0	13	112	0	125
4	647	65		995		174	1816	0	18	65	0	83
5	781	185				146	927	0	9	185	0	194
6	182	42				134	316	0	3	42	0	45
7	86	20				561	647	0	6	20	0	26
8	0	0					0	0	0	0	0	0
9	0	0					0	0	0	0	0	0
10	0	0	760			132	0	892	0	0	892	892
11	1093	53				114	1207	0	12	53	0	65
12	1079	53				332	1411	0	14	53	0	68
13	643	30				154	797	0	8	30	0	38
14	1200	24				107	1307	0	13	24	0	37
15	1378	17				150	1528	0	15	17	0	32
16	1261	177				131	1392	0	14	177	0	190
17	697	59				148	845	0	8	59	0	67
18	152	0				193	346	0	3	0	0	3
19	0	0				103	103	0	1	0	0	1
20	29	10				83	112	0	1	10	0	11
21	202	49				83	285	0	3	49	0	52
22	671	138	25			112	783	25	8	138	25	171
23	1312	280				20	1332	0	13	280	0	293
24	1486	40	115	802		45	2334	115	23	40	115	179
25	2391	51				117	2508	0	25	51	0	76
26	1474	470		237		36	1746	0	17	470	0	487
27	2238	243				71	2309	0	23	243	0	267
28	512	26		827		14	1354	0	14	26	0	39
29	153	8		337		39	529	0	5	8	0	13
30	0	0					0	0	0	0	0	0
31	0	0					0	0	0	0	0	0
32	818	88	36	7		4	825	40	8	88	40	136
33	0	0	450	21		12	21	462	0	0	462	463
34	1801	194	380	70		25	1871	405	19	194	405	618
35	29	10	590			2	29	592	0	10	592	602
36	375	55		35			410	0	4	55	0	60
37	1426	459	258	1075		21	2522	258	25	459	258	742
38	611	194	93	114		45	770	93	8	194	93	295
39	961	287	419	32		92	1085	419	11	287	419	716
40	425	26	544	44		2	470	544	5	26	544	575
41	266	0	259				266	259	3	0	259	262
42	282	482	39			21	282	60	3	482	60	546
43	867	0	25	21			888	25	9	0	25	34
44	126	0					126	0	1	0	0	1
45	1886	267		49		20	1935	20	19	267	20	306
46	0	0					0	0	0	0	0	0
47	0	0	96			10	0	106	0	0	106	106
48	95	7		70			166	0	2	7	0	9
49	0	0	50				0	50	0	0	50	50
50	0	0					0	0	0	0	0	0
51	0	0	1750			24	0	1774	0	0	1774	1774
52	0	537	2974	7		40	7	3014	0	537	3014	3552
53	0	523	104		35	40	0	180	0	523	180	702
54	791	94	705	265	302	22	1078	1007	11	94	1007	1112
55	2819	0			29	41	2819	70	28	0	70	98
56	378	0	468		855	47	425	1323	4	0	1323	1327
57	0	0					0	0	0	0	0	0
58	0	0					0	0	0	0	0	0
59	0	0					0	0	0	0	0	0
60	0	0					0	0	0	0	0	0
61	0	7		703			703	0	7	7	0	14
62	0	0					0	0	0	0	0	0
63	264	0				2	267	0	3	0	0	3
64	434	0				3	437	0	4	0	0	4
65	625	0				5	630	0	6	0	0	6
66	475	0				4	479	0	5	0	0	5
67	455	0				6	460	0	5	0	0	5
TOTAL m^3/d	37472	5479	10140	5845	1220	4876	47820	11733	478	5479	11733	17690
TOTAL m^3/yr	13677252	1999738	3701100	2133571	445464	1779566	17454335	4282619	174543	1999738	4282619	6456900

PEST.WK1

ARS ONE	CONNECTED F	V	A	P	NOT CONNECTED F	V	A	P	CONNECTE FLOW TOTAL	NOT CONNECTED FLOW TOTAL	ADJ CON FLOW	ADJ NOT CON FLOW
1	136	0	62	0	34		16		237	60	231	56
2	92	4	102	4	16	1	16		289	44	280	41
3	649	10	275	1	70	1	30		1118	120	1086	112
4	265	19	228	0	28	4	22		666	70	647	65
5	272	6	318	0	68	1	79		804	199	781	185
6	45	5	82	0	11	1	20		187	45	182	42
7	54	0	21	0	13		5		88	21	86	20
8	0	0	0	0					0	0	0	0
9	0	0	0	0					0	0	0	0
10	0	0	0	0					0	0	0	0
11	161	63	520	3	8	3	27		1125	57	1093	53
12	462	76	316	4	24	4	17		1110	58	1079	53
13	176	124	158	9	9	7	8		662	32	643	30
14	208	283	382	0	6	8	5		1235	25	1200	24
15	454	42	550	0	5		8		1418	18	1378	17
16	361	15	556	0	71	4	69		1298	190	1261	177
17	361	32	190	0	41	3	11		717	63	697	59
18	70	21	35	0					157	0	152	0
19	0	0	0	0					0	0	0	0
20	2	19	1	0	1	6	1		30	11	29	10
21	72	93	0	1	18	25			208	53	202	49
22	218	181	133	0	48	39	28		690	149	671	138
23	492	395	116	20	97	101	28	3	1350	302	1312	280
24	498	409	258	6	15	11	8		1530	44	1486	40
25	1092	517	317	22	26	14	6		2461	55	2391	51
26	414	170	525	0	138	57	175		1517	506	1474	470
27	779	181	769	1	114	25	69		2304	262	2238	243
28	104	143	135	0	5	8	7		527	28	512	26
29	0	0	95	0			5		157	8	153	8
30	0	0	0	0					0	0	0	0
31	0	0	0	0					0	0	0	0
32	11	554	32	0	1	62	4		842	95	818	88
33	0	0	0	0					0	0	0	0
34	362	771	235	4	40	86	26	1	1854	209	1801	194
35	3	19	0	0	1	7			30	11	29	10
36	41	235	2	2	5	39			386	60	375	55

37	325	499	255	4	108	167	85	2	1468	494	1426	459
38	259	135	86	7	87	45	29	2	629	209	611	194
39	155	425	39	30	49	138	12	8	989	309	961	287
40	11	276	20	1		15	1	1	438	29	425	26
41	30	153	0	5					274	0	266	0
42	96	96	33	1	162	230	11	3	290	519	282	482
43	0	631	0	1					892	0	867	0
44	0	92	0	0					129	0	126	0
45	845	440	290	1	132	47	55		1941	288	1886	267
46	0	0	0	0					0	0	0	0
47	0	0	0	0					0	0	0	0
48	86	8	1	0	5	2			98	8	95	7
49	0	0	0	0					0	0	0	0
50	0	0	0	0					0	0	0	0
51	0	0	0	0					0	0	0	0
52	0	0	0	0	50	360		4	0	579	0	537
53	0	0	0	0	60	350		2	0	563	0	523
54	44	460	12	18	3	46	3	5	814	101	791	94
55	2	1595	332	19					2902	0	2819	0
56	0	260	4	3					389	0	378	0
57	0	0	0	0					0	0	0	0
58	0	0	0	0					0	0	0	0
59	0	0	0	0					0	0	0	0
60	0	0	0	0					0	0	0	0
61	0	0	0	0		1		1	0	7	0	7
62	0	0	0	0					0	0	0	0
63	216	41	0	0	0	0			272	0	264	0
64	40	251	33	0	0	0	0		447	0	434	0
65	0	458	0	0		0			644	0	625	0
66	0	348	0	0		0			489	0	475	0
67	0	333	0	0					468	0	455	0
								TOTAL	38573	5901	37472	5479

QARS ZONE	PUMPING STN 1 CONEC F	V	A	P	NOT CON F	V	A	P	QARS ZONE	PUMPING STN 2 CONEC F	V	A	P	NOT CON F	V	A	P	QARS ZONE	PUMPING STN 3 CONEC F	V	A	P	NOT CON F	V	A	P	QARS ZONE	OUTSIDE DRAINAGE AREA F	V	A	P
1	136 170		78 62		34	0	16	0	18	70	21	35						41	25	3		4					22	1	7	5	1
2	62 77	5 4	66 53		15	1	13	0										42		8							24		82		
3	184 232	4 3	102 82		46	1	20	0										44		92							41	127	95		
4	71 89	21 17	63 50		18	4	13	0										45	98	75	47						42	7	23		
5	272 340	7 6	397 316		68	1	79	0																			43		18		
6	45 56	6 5	102 82		11	1	20	0																			39	139	196		1
7	54 67		26 21		13	0	5	0																			40	36	292	3	16
15	20 25	2	42 34		5	0	8	0																			56	13	209	17	23
16	285 356	18 14	344 275		71	4	69	0																			37	51	125	19	
17	111 139	10 8	3 2		28	2	1	0																			38		1	31	7
26					0	0	0	0																			32		13		3
27	70 87		42 34		17	0	8	0																			33		150	89	16
					0	0	0	0																			34	4	251		4
					0	0	0	0																			35	151	250	40	4
					0	0	0	0																			53				18
																											54		297	111	18
																											52	87	898	721	75
																											51	17	655	208	81
																											10	116	58	341	
																											47		67	1	
																											49			30	
TOTAL	1638	73	1265		328	15	253	0	TOTAL	70	21	35		0	0	0	0	TOTAL	123	178	47		0	0	0	0	TOTAL	749	3687	1616	267
FLOW	1300	82	1673		325	21	418		FLOW	69	30	58		0	0	0		FLOW	122	250	78		0	0	0		FLOW	743	5180	2671	1545
POP	8190	511	12650	0	1638	102	2530	0	POP	350	147	350	0	0	0	0	0	POP	615	1246	470	0	0	0	0	0	POP	3745	25809	16160	5340

FLOW	3055	764	157	0
POP	21351	4270	847	0

FLOW	450	0	
POP	2331	0	

QARS	PUMPING STN 4								QARS	PUMPING STN 5								QARS	PUMPING STN 6							
ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON			
	F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P
2	4		30		0	0	2	0	2	27		22	4	1	0	1	0	14	104	133	297					
11	169	66	547	3	8	3	27	0	3	487	7	203	1	24	0	10	0	15	434	40	516					
12	125	71	281	1	6	4	14	0	4	204	2	187		10	0	9	0	24	4	48						
									12	361	9	52	3	18	0	3	0	25								
									13	185	131	166	9	9	7	8	0	26								
									14	110	158	90		6	8	5	0									
									22	34	28	32		2	1	2	0									
									23	147	15	5	6	7	1	0	0									
									24																	
TOTAL	298	137	858	4	15	7	43	0	TOTAL	1555	350	757	23	78	18	38	1	TOTAL	542	221	813		0	0	0	0
FLOW	281	183	1347	22	15	10	71		FLOW	1465	467	1189	126	77	25	63	7	FLOW	538	311	1344		0	0	0	0
POP	1490	959	8580	80	75	48	429	4	POP	7775	2450	7570	460	389	123	379	23	POP	2710	1547	8130	0	0	0	0	0

FLOW	1811	95	3121	164	2192	0
POP	11029	551	17795	890	12387	0

QARS	PUMPING STN 7								QARS	PUMPING STN 8								QARS	PUMPING STN 9							
ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON			
	F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P
16	76	1	281						17	263	25	198		13	1	10	0	25					0	0	0	0
27	171	51	280						27	310	69	341	1	16	3	17	0	26	552	227	700		138	57	175	0
									28	109	151	142		5	8	7	0	27	325	86	175		81	22	44	0
									29			100		0	0	5	0	42	110	113	44	2	28	28	11	1
									48	87				4	0	0	0									
									45	12	30			1	2	0	0									
TOTAL	247	52	561		0	0	0	0	TOTAL	781	275	781	1	39	14	39	0	TOTAL	987	426	919	2	247	107	230	1
FLOW	245	73	927		0	0	0		FLOW	736	367	1226	6	39	19	65	0	FLOW	734	449	1139	9	245	150	380	3
POP	1235	364	5610	0	0	0	0	0	POP	3905	1925	7810	20	195	96	391	0	POP	4935	2982	9190	40	1233	746	2298	10

FLOW	1245	0	2329	123	2322	774
POP	7209	0	13640	682	17107	4277

QARS	PUMPING STN 10								QARS	PUMPING STN 11								QARS	PUMPING STN 12							
ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON			
	F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P
25	759	279	310	13	15	6	6	0	24	509	372	266	6	15	11	8	0	53					60	350		2
									25	359	252	13	9	11	8	0	0								
									40	11	217	12		0	7	0	0									
TOTAL	759	279	310	13	15	6	6	0	TOTAL	879	841	291	15	26	25	9	0	TOTAL	0	0	0		60	350	0	2
FLOW	738	384	502	74	15	8	10	2	FLOW	846	1146	467	84	26	35	14	3	FLOW	0	0	0	0	60	492	0	12
POP	3795	1953	3100	260	76	39	62	5	POP	4395	5887	2910	300	132	177	87	9	POP	0	0	0	0	300	2450	0	40

FLOW	1624				33					2458				76					0				551			
POP	8848				177					13192				396					0				2750			

QARS	PUMPING STN 13								QARS	PUMPING STN 14								QARS	PUMPING STN 15							
ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON			
	F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P
39	46	55	20	21	9	11	4	4	32	12	616	36		1	62	4	0	20	3	25	2		1	6	1	0
54	16	230	15	23	3	46	3	5	34	402	857	261	5	40	86	26	1	21		23			0	6	0	0
									36	46	194	2	2	5	19	0	0	23	30	85	3	1	8	21	1	0
									52					50	360		4	39	158	508	31	17	40	127	8	4
																		40		32	5	2	0	8	1	1
																		37	433	666	340	6	108	167	85	2
																		38	346	180	115	9	87	45	29	2
																		35	4	26			1	7	0	0
																		36		80			0	20	0	0
																							0	0	0	0
TOTAL	62	285	35	44	12	57	7	9	TOTAL	460	1667	299	7	96	527	30	5	TOTAL	974	1625	496	35	244	406	124	9
FLOW	49	320	46	204	12	80	12		FLOW	361	1602	445	13	95	522	30	5	FLOW	725	1712	615	152	242	571	205	51
POP	310	1995	350	880	62	399	70	176	POP	2300	11669	2990	140	480	3687	299	94	POP	4870	11375	4960	700	1217	2844	1240	175

FLOW	416	104	2408	647	3052	1017
POP	2655	531	16959	4466	21205	5301

QARS	PUMPING STN 16								QARS	PUMPING STN 17								QARS	PUMPING STN 18							
ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON			
	F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P
26					0	0	0	0	48					0	0	0	0	42					132	201		2
27					0	0	0	0	42	6	4			1	1	0	0	45	214	159	22					
48	4	10	1		1	2	0	0	45	653	223	276	1	131	45	55	0									
42	4				1	0	0	0																		
					0	0	0	0																		
TOTAL	8	10	1		2	2	0		TOTAL	659	227	276	1	132	45	55	0	TOTAL	214	159	22		132	201	0	2
FLOW	8	14	2		2	3	0		FLOW	523	255	365	5	131	64	91	1	FLOW	212	223	36		131	282	0	12
POP	40	70	10	0	8	14	2	0	POP	3295	1589	2760	20	659	318	552	4	POP	1070	1113	220	0	660	1407	0	40

FLOW	24	5	1143	286	472	413
POP	120	24	7644	1529	2403	2067

QARS	PUMPING STN 19								QARS	PUMPING STN 20								QARS	PUMPING STN 21							
ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON			
	F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P
									40		42	4						55								
									56		260	4	3													
									54	31	276															
TOTAL	0	0	0		0	0	0		TOTAL	31	578	8	3					TOTAL	0	0	0					
FLOW									FLOW	31	812	13	17					FLOW								
POP	0	0	0	0	0	0	0	0	POP	155	4046	80	60	0	0	0	0	POP	0	0	0	0	0	0	0	0

FLOW	0	0	856	0	0	0
POP	0	0	4281	0	0	0

QARS	PUMPING STN 22								QARS	PUMPING STN 23								QARS	PUMPING STN 24							
ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON			
	F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P
55									55	2	1595	332	19														
TOTAL	0	0	0		0	0	0		TOTAL	2	1595	332	19					TOTAL	0	0	0					
FLOW	0	0	0	0					FLOW	2	2241	549	110					FLOW	0	0	0	0				
POP	0	0	0	0	0	0	0	0	POP	10	11165	3320	380	0	0	0	0	POP	0	0	0	0	0	0	0	0

FLOW	0	0	2792	0	0	0
POP	0	0	14495	0	0	0

QARS	PUMPING STN 25								QARS	PUMPING STN 26								QARS	PUMPING STN 27							
ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON			
	F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P
60									60									67		333						
62									61						1		1									
63	216	41							63																	
64	40	251	33																							
65		458																								
66		348																								
TOTAL	256	1098	33	0					TOTAL	0	0	0		0	1	0	1	TOTAL	0	333	0	0				
FLOW	254	1543	55	0					FLOW	0	-1	0	-6	0	1	0	6	FLOW	0	468	0	0				
POP	1280	7686	330	0					POP	0	0	0	0	0	7	0	20	POP	0	2331	0	0	0	0	0	0

FLOW	1851	0	-1	1	468	0
POP	9296	0	0	7	2331	0

QARS	PUMPING STN 28								QARS	PUMPING STN 29								QARS	PUMPING STN 30							
ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON			
	F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P
																		41	5	150		1				
																		43		631		1				
TOTAL	0	0	0		0	0	0		TOTAL	0	0	0						TOTAL	5	781	0	2				
FLOW	0	0	0	0					FLOW	0	0	0	0					FLOW	5	1097	0	12				
POP	0	0	0	0	0	0	0	0	POP	0	0	0	0	0	0	0	0	POP	25	5467	0	40	0	0	0	0
FLOW	0				0					0				0					1102				0			
POP	0				0					0				0					5492				0			

QARS.	PUMPING STN 31								QARS	PUMPING STN 32								QARS	PUMPING STN 33							
ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON				ZONE	CONEC				NOT CON			
	F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P		F	V	A	P	F	V	A	P
21	90	95		1	18	19	0	0																		
22	232	192	129		46	38	26	0																		
23	412	396	136	16	82	79	27	3																		
24					0	0	0	0																		
TOTAL	734	683	265	17	147	137	53	3	TOTAL	0	0	0						TOTAL	0	0	0					
FLOW	728	960	438	98	146	192	88	6	FLOW									FLOW								
POP	3670	4781	2650	340	734	956	530	68	POP	0	0	0	0	0	0	0	0	POP	0	0	0	0	0	0	0	0

FLOW	2126		425		0		0	
POP	11101		2220		0		0	
					0		0	
					0		0	

CONNECTED		NOT CONNECTED	
F	P	F	P
3661	24529	764	4270
7124	41211	260	1441
5897	37956	897	4959
4082	22040	660	3323
5876	40819	1768	10298
1639	10167	704	3620
856	4281	0	0
2792	14495	0	0
2318	11627	1	7
1102	5492	0	0
2126	11101	425	2220
37472	223718	5479	30138

APPENDIX C

APPENDIX "C"

RECHARGE FROM RAINFALL

C.1 INTRODUCTION

A detailed study of rainfall and recharge over Qatar was published in 1978 (Pike et al) and later brought up to date by the joint Ministry of Industry and Agriculture/FAO project in 1980 (FAO, 1981). In these studies the rainfall record at Doha Airport, maintained since 1962/62, was analysed in detail particularly with regard to its statistical properties. It was concluded that both individual storm and annual rainfall totals conform to a Weibull type distribution with a pronounced negative skewness. The long-term average rainfall at this station over 21 years is 77.8 mm, with a maximum annual fall of 229.7 mm (1964/65) and a minimum of 0.4 (1961/62). An individual storm may account for 65% of the annual total and Table (C.1) shows the probability of annual and storm rainfall totals at Doha Airport. Storm rainfall is defined as an event lasting from a few minutes to several days with continuous or intermittent rain.

TABLE C.1

PROBABILITY OF ANNUAL AND STORM RAINFALL, DOHA

Recurrence Intervals (yrs)	Annual	Storm
	(mm)	(mm)
5	35	7
10	75	18
15	120	40
20	180	62
25	260	105
30	260	170

Source : FAO (1981)

C.2 RAINFALL IN 1988

In 1988 there were 15 rainfall events covering or partially covering the study area with above average totals. The annual total recorded at Doha Airport showed a recurrence interval of 17.5 years and the storm of 16 - 17 February to have one of 15 years. The year under study may therefore be considered to have been one of "high rainfall". Of the 15 storm events ~~nine~~ precipitated amounts of less than 5 mm a day and are considered to have been insignificant in terms of recharge. Table (C.2) shows the data from rain gauges located within or adjacent to the Study Area.

TABLE (C.2)

RAINFALL OVER OR ADJACENT TO STUDY AREA 1988

Date	Mumtaza	Airport	Sailiyah	Wukair	Umm el Afai	Wadi Al Wassa	Port
8/1	2.0	1.0	Nil	0.6	4.0	5.0	Nil
17/1	Nil	4.1	3.8	1.0	0.4	1.0	Nil
18/1	10.6	Nil	Nil	Nil	12.2	14.0	10.4
13/2	1.8	2.5	2.0	1.2	5.6	Nil	Nil
*14/2	5.7	6.7	5.2	16.0	19.6	31.2	10.1
*16-17/2	51.2	41.30	34.4	42.4	66.8	62.0	49.8
*21/2	20.0	30.1	25.0	19.0	31.2	42.0	11.6
*22/2	22.0	22.3	9.4	31.0	31.4	35.0	29.7
23/2	2.6	0.3	2.8	0.2	Nil	3.4	9.9
*24/2	33.4	26.8	27.4	36.0	30.0	30.4	28.0
1/3	2.0	0.4	0.4	3.2	0.8	1.6	0.7
2/3	2.2	2.3	2.6	2.4	4.8	2.4	2.9
23/4	Nil	6.7	0.4	Nil	0.6	1.2	Nil
*24/4	7.0	Nil	8.0	9.4	20.6	25.0	3.6
26/4	6.0	5.6	1.4	0.4	Nil	Nil	8.0

* = Significant Storm

C.3 RECHARGE FROM RAINFALL

Recharge from rainfall within the Study Area evidently takes place but in terms of other components of the water balance its effect is likely to be a minor one. Nevertheless, drawing upon the detailed observations of rainfall and recharge in the desert areas of Qatar carried out by FAO (1981), and taking into account the characteristics of urbanisation of between a fifth and a quarter of the study area, estimates of recharge have been based upon the following percentages of rainfall;

Open desert areas ($238\ km^2$) = 10%

Built up areas incl. gardens ($54\ km^2$) = 7.5%

giving a weighted mean recharge of 9.54%.

The study Area is underlain by the Midra Shales at the base of the Dammam Foundation overlying the sulphate facies of the Rus Formation, in common with much of eastern, western and southern Qatar where recharge is confined to isolated depression areas and estimated by FAO (1981) to be of the order of 6% of annual rainfall. In the study area, however, recharge contributes to a shallow aquifer above the Midra Shales acquitard where subsurface conditions are likely to be similar to that in northern Qatar where recharge is estimated to be of the order of 10% of annual rainfall or 15% of storm rainfall above a certain limit.

However, this percentage refers to recharge after run-off and ponding in depressions where subsurface fracturing associated with collapse structures provides preferred paths and enhanced conditions for recharge. Geological investigations within the Study Area have revealed a high variation in hydraulic transmissivity values in the Simsima Formation and fracturing is therefore likely to be less than that found associated with the widespread and contiguous system of depressions of northern Qatar. For this study therefore a value of 10% of storm rainfall has been adopted.

In estimating recharge from urban areas there are no data to drawn upon but the methods adopted by ASCO's in their study of 1982/83. Within the built-up area there are considerable areas of bare soil along road verges, in villa gardens and on construction sites where disturbance by earth-moving equipment has created large areas of small depressions. Ponding of run-off from adjacent areas is therefore common and recharge in these areas is likely also to be of the order of 10% of storm rainfall. On the other hand, soakaway pits and preponderance of flat-roofed houses, recharge from these areas is likely to be reduced. An average value of 7.5% of storm rainfall is therefore considered to be a reasonable estimate for these built-up areas.

Table (C.3) shows the estimates of recharge from the six significant storms which occurred in 1988.

TABLE (C.3)

RECHARGE FROM RAINFALL

Date	Total Rainfall Mm^3	Recharge Built-up (22%)	Open - Desert (78%)	Total Mm^3	Total mm
14/2	3.22	0.07	0.24	0.31	0.99
16-17/2	14.89	0.31	1.11	1.42	4.55
21/2	7.03	0.15	0.52	0.67	2.15
22/2	7.49	0.16	0.56	0.72	2.31
24/2	9.49	0.20	0.71	0.91	2.90
24/4	2.31	0.05	0.17	0.22	0.71
Totals	44.43	0.94	3.31	4.25	13.61

SUMMARY OF RAINFALL RECHARGE BY ZONE - 1988

QARS ZONE	RAINFALL RECHARGE M^3/YEAR	QARS ZONE	RAINFALL RECHARGE M^3/YEAR
1	3,811	54	310,411
2	5,034	55	244,961
3	4,969	56	958,771
4	6,299	60	15,405
5	2,894	61	61,666
6	3,708	62	9,208
7	3,723	63	28,586
10	12,595	64	20,592
11	12,990	65	31,917
12	10,442	66	31,452
13	9,004	67	98,131
14	4,683	90	194,505
15	6,638	91	375,638
16	5,283		
17	6,661		
18	6,961		
19	8,049		
20	18,620		
21	11,224		
22	9,001		
23	16,097		
24	22,746		
25	20,158		
26	14,520		
27	19,697		
28	10,106		
29	13,373		
31	86,802		
32	37,822		
33	42,013		
34	38,913		
35	15,804		
36	30,342		
37	36,520		
38	50,573		
39	38,223		
40	45,732		
41	16,516		
42	22,895		
43	25,540		
44	42,089		
45	60,368		
46	46,479		
47	42,697		
48	134,792		
49	145,446		
51	304,060		
52	202,705		
53	121,460		

TOTAL = 4,239,043

To be included in report. for Ddlm update.

QARS ZONE	RAINFALL RECHARGE 14 m3	16/17 m3	21 m3	22 m3	24 m3	24A m3	TOTAL RECHARGE m3	mm	TOTAL ZONE AREA
1	264	1416	389	776	819	148	3811	13.10	0.291
2	345	1872	523	1010	1084	200	5034	13.21	0.381
3	320	1833	552	959	1085	219	4969	13.32	0.373
4	387	2321	728	1195	1403	265	6299	13.21	0.477
5	180	1070	321	561	646	116	2894	13.04	0.222
6	234	1392	400	744	813	124	3708	12.83	0.289
7	261	1387	371	769	811	124	3723	12.93	0.288
10	1041	4553	1301	2593	2515	593	12595	13.86	0.909
11	997	4758	1344	2628	2674	589	12990	13.67	0.950
12	744	3832	1116	2084	2232	434	10442	13.39	0.780
13	573	3277	1082	1686	1973	414	9004	13.50	0.667
14	250	1720	601	835	1060	217	4683	13.38	0.350
15	366	2462	804	1219	1519	268	6638	12.99	0.511
16	314	1946	629	1022	1186	187	5283	12.82	0.412
17	427	2464	729	1383	1458	201	6661	12.64	0.527
18	498	2562	682	1495	1513	210	6961	12.66	0.550
19	573	3045	724	1748	1718	241	8049	12.74	0.632
20	1509	6727	1991	3772	3678	943	18620	14.13	1.318
21	818	4092	1247	2182	2338	546	11224	13.74	0.817
22	584	3225	1106	1720	1905	461	9001	13.98	0.644
23	891	5850	2173	2781	3566	836	16097	13.78	1.168
24	977	8382	3174	3799	5249	1166	22746	13.33	1.706
25	860	7165	2770	3918	4585	860	20158	13.42	1.502
26	704	5256	2113	2599	3360	488	14520	12.78	1.136
27	1179	7075	2653	3852	4348	590	19697	12.75	1.545
28	727	3634	1243	2181	2130	191	10106	12.60	0.802
29	1068	4729	1627	2949	2746	254	13373	12.55	1.066
31	8450	28678	12291	16131	14851	6401	86802	16.17	5.368
32	3540	13099	4720	7199	6845	2419	37822	15.29	2.474
33	3754	14526	5229	8179	7777	2548	42013	14.95	2.811
34	3270	13836	4528	7613	7358	2306	38913	14.76	2.637
35	1351	5610	1766	3169	3026	883	15804	14.51	1.089
36	2184	10886	3871	5559	6055	1787	30342	14.58	2.081
37	2705	13158	4304	7007	7378	1968	36520	14.17	2.578
38	3039	18237	6923	8612	10722	3039	50573	14.29	3.540
39	1887	13955	5486	6056	8513	2326	38223	13.85	2.760
40	1992	16766	6640	6972	10873	2490	45732	13.14	3.480
41	716	5963	2504	2683	3935	716	16516	13.21	1.250
42	1019	8066	3990	3877	5178	764	22895	12.86	1.780
43	1296	9069	3702	4072	6108	1296	25540	13.17	1.940
44	2282	14912	6543	7152	10043	1877	42809	13.42	3.190
45	3119	20494	11138	10470	13366	1782	60368	12.93	4.670
46	2988	15272	7636	8134	10624	1826	46479	13.36	3.480
47	2549	13861	8444	7647	9400	796	42697	12.78	3.340
48	7650	46953	24795	25851	28488	1055	134792	12.19	11.060
49	9114	49368	28861	28482	29621	0	145446	12.18	11.942
51	29827	103283	40957	55203	51641	23150	304060	16.29	18.666
52	15015	71322	28779	35035	37538	15015	202705	15.45	13.116
53	9225	41512	19603	17681	23831	9609	121460	15.07	8.058
54	18645	108765	48340	46613	66295	21753	310411	14.29	21.716
55	16535	82675	43174	30314	55116	17147	244961	12.72	19.258
56	65801	303418	158106	138996	233960	58490	958771	12.51	76.638

60	1372	5487	1583	3218	3060	686	15405	13.93	1.106
61	6026	20890	7432	12454	11650	3214	61666	14.64	4.211
62	806	3256	992	1891	1798	465	9208	14.17	0.650
63	2644	9917	3306	5761	5478	1480	28586	14.44	1.980
64	1829	7248	2371	4132	3929	1084	20592	14.50	1.420
65	3062	10786	3981	6329	5921	1837	31917	14.91	2.140
66	3646	11474	3692	5409	4980	2252	31452	17.47	1.800
67	9662	32610	12983	19022	17513	6341	98131	15.50	6.330
90	14025	62005	42444	36170	39861	0	194505	12.57	15.475
91	29410	114964	66839	69513	84218	10694	375638	13.40	28.025
							4239043	850.00	312.372

RECHARGE FOR RAINFALL
EVENT OF 14th FEB 1988

QARS ZONE	TOTAL ZONE AREA (Km2)	RAIN A m	RAIN B m	RAIN C m	AREA A Km2	AREA B Km2	AREA C Km2	TOTAL RAIN m3	RECHARGE URBAN (22%) m3	RECHARGE DESERT (78%) m3	TOTAL RECHARGE m3	TOTAL RECHARGE mm
1	0.291	0.0095	0.0000	0.0000	0.291	0.000	0.000	2765	58	206	264	0.91
2	0.381	0.0095	0.0000	0.0000	0.381	0.000	0.000	3620	76	269	345	0.91
3	0.373	0.0095	0.0085	0.0000	0.186	0.187	0.000	3357	70	250	320	0.86
4	0.477	0.0085	0.0000	0.0000	0.477	0.000	0.000	4055	85	302	387	0.81
5	0.222	0.0085	0.0000	0.0000	0.222	0.000	0.000	1887	40	140	180	0.81
6	0.289	0.0085	0.0000	0.0000	0.289	0.000	0.000	2457	52	183	234	0.81
7	0.288	0.0095	0.0000	0.0000	0.288	0.000	0.000	2736	57	204	261	0.91
10	0.909	0.0115	0.0125	0.0000	0.454	0.455	0.000	10909	229	812	1041	1.14
11	0.950	0.0105	0.0115	0.0000	0.475	0.475	0.000	10450	219	778	997	1.05
12	0.780	0.0105	0.0095	0.0000	0.390	0.390	0.000	7800	164	580	744	0.95
13	0.667	0.0085	0.0095	0.0000	0.333	0.334	0.000	6004	126	447	573	0.86
14	0.350	0.0075	0.0000	0.0000	0.350	0.000	0.000	2625	55	195	250	0.72
15	0.511	0.0075	0.0000	0.0000	0.511	0.000	0.000	3833	80	285	366	0.72
16	0.412	0.0075	0.0085	0.0000	0.206	0.206	0.000	3296	69	245	314	0.76
17	0.527	0.0085	0.0000	0.0000	0.527	0.000	0.000	4480	94	333	427	0.81
18	0.550	0.0095	0.0000	0.0000	0.550	0.000	0.000	5225	110	389	498	0.91
19	0.632	0.0095	0.0000	0.0000	0.632	0.000	0.000	6004	126	447	573	0.91
20	1.318	0.0115	0.0125	0.0000	0.659	0.659	0.000	15816	332	1177	1509	1.14
21	0.817	0.0105	0.0000	0.0000	0.817	0.000	0.000	8579	180	638	818	1.00
22	0.644	0.0095	0.0000	0.0000	0.644	0.000	0.000	6118	128	455	584	0.91
23	1.168	0.0075	0.0085	0.0000	0.584	0.584	0.000	9344	196	695	891	0.76
24	1.706	0.0055	0.0065	0.0000	0.853	0.853	0.000	10236	215	762	977	0.57
25	1.502	0.0055	0.0065	0.0000	0.751	0.751	0.000	9012	189	671	860	0.57
26	1.136	0.0055	0.0065	0.0075	0.284	0.568	0.284	7384	155	549	704	0.62
27	1.545	0.0075	0.0085	0.0000	0.772	0.773	0.000	12361	259	920	1179	0.76
28	0.802	0.0095	0.0000	0.0000	0.802	0.000	0.000	7619	160	567	727	0.91
29	1.066	0.0105	0.0000	0.0000	1.066	0.000	0.000	11193	235	833	1068	1.00
31	5.368	0.0155	0.0165	0.0175	1.789	1.789	1.790	88573	1859	6591	8450	1.57
32	2.474	0.0145	0.0155	0.0000	1.237	1.237	0.000	37110	779	2761	3540	1.43
33	2.811	0.0135	0.0145	0.0000	1.406	1.405	0.000	39354	826	2928	3754	1.34
34	2.637	0.0125	0.0135	0.0000	1.318	1.319	0.000	34282	720	2551	3270	1.24
35	1.089	0.0125	0.0135	0.0000	0.544	0.545	0.000	14158	297	1053	1351	1.24
36	2.081	0.0105	0.0115	0.0000	1.040	1.041	0.000	22892	480	1703	2184	1.05
37	2.578	0.0105	0.0115	0.0000	1.289	1.289	0.000	28358	595	2110	2705	1.05
38	3.540	0.0095	0.0085	0.0000	1.770	1.770	0.000	31860	669	2371	3039	0.86
39	2.760	0.0075	0.0065	0.0000	1.840	0.920	0.000	19780	415	1472	1887	0.68
40	3.480	0.0065	0.0055	0.0000	1.740	1.740	0.000	20880	438	1554	1992	0.57
41	1.250	0.0055	0.0065	0.0000	0.625	0.625	0.000	7500	157	558	716	0.57
42	1.780	0.0055	0.0065	0.0000	0.890	0.890	0.000	10680	224	795	1019	0.57
43	1.940	0.0065	0.0075	0.0000	0.970	0.970	0.000	13580	285	1011	1296	0.67
44	3.190	0.0065	0.0075	0.0085	0.798	1.594	0.798	23925	502	1780	2282	0.72
45	4.670	0.0065	0.0075	0.0000	2.335	2.335	0.000	32690	686	2433	3119	0.67
46	3.480	0.0085	0.0095	0.0000	1.740	1.740	0.000	31320	657	2331	2988	0.86
47	3.340	0.0075	0.0085	0.0000	1.670	1.670	0.000	26720	561	1988	2549	0.76
48	11.060	0.0080	0.0065	0.0000	5.530	5.530	0.000	80185	1683	5967	7650	0.69
49	11.942	0.0070	0.0090	0.0000	5.971	5.971	0.000	95536	2005	7109	9114	0.76
51	18.666	0.0155	0.0180	0.0000	9.333	9.333	0.000	312656	6562	23265	29827	1.60
52	13.116	0.0110	0.0130	0.0000	6.558	6.558	0.000	157392	3303	11712	15015	1.14
53	8.058	0.0120	0.0000	0.0000	8.058	0.000	0.000	96696	2029	7195	9225	1.14
54	21.716	0.0080	0.0100	0.0000	10.858	10.858	0.000	195444	4102	14543	18645	0.86

55	19.258	0.0080	0.0100	0.0000	9.629	9.629	0.000	173322	3638	12897	16535	0.86
56	76.638	0.0070	0.0110	0.0000	38.319	38.319	0.000	689742	14476	51325	65801	0.86
60	1.106	0.0125	0.0135	0.0000	0.553	0.553	0.000	14378	302	1070	1372	1.24
61	4.211	0.0140	0.0160	0.0000	2.105	2.106	0.000	63166	1326	4700	6026	1.43
62	0.650	0.0125	0.0135	0.0000	0.325	0.325	0.000	8450	177	629	806	1.24
63	1.980	0.0135	0.0145	0.0000	0.990	0.990	0.000	27720	582	2063	2644	1.34
64	1.420	0.0135	0.0000	0.0000	1.420	0.000	0.000	19170	402	1426	1829	1.29
65	2.140	0.0145	0.0155	0.0000	1.070	1.070	0.000	32100	674	2389	3062	1.43
66	2.248	0.0165	0.0175	0.0000	1.124	1.124	0.000	38216	802	2844	3646	1.62
67	6.330	0.0155	0.0165	0.0000	3.165	3.165	0.000	101280	2126	7536	9662	1.53
90	15.475	0.0085	0.0095	0.0105	5.158	5.158	5.159	147014	3086	10940	14025	0.91
91	28.025	0.0100	0.0120	0.0000	14.012	14.013	0.000	308276	6470	22939	29410	1.05
			TOTAL					3223562	67656	239872	307528	

RECHARGE FOR RAINFALL
EVENT OF 16/17th FEB 1988

QARS ZONE	TOTAL ZONE AREA (Km2)	RAIN A m	RAIN B m	RAIN C m	AREA A Km2	AREA B Km2	AREA C Km2	TOTAL RAIN m3	RECHARGE URBAN (22%)	m3	DESERT (78%)	TOTAL RECHARGE m3	mm
1	0.291	0.0505	0.0515	0.0000	0.146	0.145	0.000	14841	311		1104	1416	4.87
2	0.381	0.0515	0.0000	0.0000	0.381	0.000	0.000	19622	412		1460	1872	4.91
3	0.373	0.0515	0.0000	0.0000	0.373	0.000	0.000	19210	403		1429	1833	4.91
4	0.477	0.0515	0.0505	0.0000	0.238	0.239	0.000	24327	511		1810	2321	4.87
5	0.222	0.0505	0.0000	0.0000	0.222	0.000	0.000	11211	235		834	1070	4.82
6	0.289	0.0505	0.0000	0.0000	0.289	0.000	0.000	14595	306		1086	1392	4.82
7	0.288	0.0505	0.0000	0.0000	0.288	0.000	0.000	14544	305		1082	1387	4.82
10	0.909	0.0525	0.0000	0.0000	0.909	0.000	0.000	47723	1002		3551	4553	5.01
11	0.950	0.0525	0.0000	0.0000	0.950	0.000	0.000	49875	1047		3711	4758	5.01
12	0.780	0.0515	0.0000	0.0000	0.780	0.000	0.000	40170	843		2989	3832	4.91
13	0.667	0.0515	0.0000	0.0000	0.667	0.000	0.000	34351	721		2556	3277	4.91
14	0.350	0.0515	0.0000	0.0000	0.350	0.000	0.000	18025	378		1341	1720	4.91
15	0.511	0.0505	0.0000	0.0000	0.511	0.000	0.000	25806	542		1920	2462	4.82
16	0.412	0.0495	0.0000	0.0000	0.412	0.000	0.000	20394	428		1518	1946	4.72
17	0.527	0.0485	0.0495	0.0000	0.263	0.264	0.000	25824	542		1922	2464	4.67
18	0.550	0.0495	0.0485	0.0000	0.183	0.367	0.000	26858	564		1999	2562	4.66
19	0.632	0.0505	0.0000	0.0000	0.632	0.000	0.000	31916	670		2375	3045	4.82
20	1.318	0.0535	0.0000	0.0000	1.318	0.000	0.000	70513	1480		5247	6727	5.10
21	0.817	0.0525	0.0000	0.0000	0.817	0.000	0.000	42893	900		3192	4092	5.01
22	0.644	0.0525	0.0000	0.0000	0.644	0.000	0.000	33810	710		2516	3225	5.01
23	1.168	0.0525	0.0000	0.0000	1.168	0.000	0.000	61320	1287		4563	5850	5.01
24	1.706	0.0515	0.0000	0.0000	1.706	0.000	0.000	87859	1844		6538	8382	4.91
25	1.502	0.0505	0.0495	0.0000	0.751	0.751	0.000	75100	1576		5588	7165	4.77
26	1.136	0.0495	0.0485	0.0475	0.284	0.568	0.284	55096	1156		4100	5256	4.63
27	1.545	0.0485	0.0475	0.0000	0.773	0.772	0.000	74161	1556		5518	7075	4.58
28	0.802	0.0475	0.0000	0.0000	0.802	0.000	0.000	38095	800		2835	3634	4.53
29	1.066	0.0465	0.0000	0.0000	1.066	0.000	0.000	49569	1040		3689	4729	4.44
31	5.368	0.0565	0.0555	0.0000	2.684	2.684	0.000	300608	6309		22369	28678	5.34
32	2.474	0.0555	0.0000	0.0000	2.474	0.000	0.000	137307	2882		10217	13099	5.29
33	2.811	0.0545	0.0535	0.0000	1.874	0.937	0.000	152263	3196		11330	14526	5.17
34	2.637	0.0555	0.0545	0.0000	1.319	1.318	0.000	145036	3044		10792	13836	5.25
35	1.089	0.0545	0.0535	0.0000	0.545	0.544	0.000	58807	1234		4376	5610	5.15
36	2.081	0.0555	0.0545	0.0000	0.694	1.387	0.000	114109	2395		8491	10886	5.23
37	2.578	0.0535	0.0000	0.0000	2.578	0.000	0.000	137923	2895		10263	13158	5.10
38	3.540	0.0535	0.0545	0.0000	1.770	1.770	0.000	191160	4012		14225	18237	5.15
39	2.760	0.0525	0.0535	0.0000	1.380	1.380	0.000	146280	3070		10885	13955	5.06
40	3.480	0.0515	0.0505	0.0495	1.160	1.160	1.160	175740	3688		13077	16766	4.82
41	1.250	0.0495	0.0505	0.0000	0.625	0.625	0.000	62500	1312		4651	5963	4.77
42	1.780	0.0485	0.0475	0.0465	0.593	0.593	0.594	84549	1775		6291	8066	4.53
43	1.940	0.0485	0.0495	0.0000	0.970	0.970	0.000	95060	1995		7074	9069	4.67
44	3.190	0.0485	0.0495	0.0000	1.595	1.595	0.000	156310	3281		11631	14912	4.67
45	4.670	0.0470	0.0450	0.0000	2.335	2.335	0.000	214820	4509		15985	20494	4.39
46	3.480	0.0475	0.0445	0.0000	1.740	1.740	0.000	160080	3360		11912	15272	4.39
47	3.340	0.0445	0.0425	0.0000	1.670	1.670	0.000	145290	3049		10811	13861	4.15
48	11.060	0.0460	0.0430	0.0000	5.530	5.530	0.000	492170	10330		36623	46953	4.25
49	11.942	0.0420	0.0430	0.0450	3.980	3.981	3.981	517488	10861		38507	49368	4.13
51	18.666	0.0590	0.0570	0.0000	9.333	9.333	0.000	1082628	22722		80561	103283	5.53
52	13.116	0.0560	0.0580	0.0000	6.558	6.558	0.000	747612	15691		55631	71322	5.44
53	8.058	0.0560	0.0520	0.0000	4.029	4.029	0.000	435132	9133		32379	41512	5.15
54	21.716	0.0550	0.0500	0.0000	10.858	10.858	0.000	1140090	23928		84836	108765	5.01
55	19.258	0.0440	0.0460	0.0000	9.629	9.629	0.000	866610	18188		64486	82675	4.29
56	76.638	0.0380	0.0450	0.0000	38.319	38.319	0.000	3180477	66752		236666	303418	3.96

60	1.106	0.0525	0.0515	0.0000	0.553	0.553	0.000	57512	1207	4280	5487	4.96
61	4.211	0.0525	0.0515	0.0000	2.105	2.106	0.000	218972	4596	16294	20890	4.96
62	0.650	0.0525	0.0000	0.0000	0.650	0.000	0.000	34125	716	2539	3256	5.01
63	1.980	0.0525	0.0000	0.0000	1.980	0.000	0.000	103950	2182	7735	9917	5.01
64	1.420	0.0535	0.0000	0.0000	1.420	0.000	0.000	75970	1594	5653	7248	5.10
65	2.140	0.0525	0.0535	0.0000	1.426	0.714	0.000	113064	2373	8413	10786	5.04
66	2.248	0.0535	0.0000	0.0000	2.248	0.000	0.000	120268	2524	8949	11474	5.10
67	6.330	0.0535	0.0545	0.0000	3.165	3.165	0.000	341820	7174	25436	32610	5.15
90	15.475	0.0420	0.0000	0.0000	15.475	0.000	0.000	649950	13641	48364	62005	4.01
91	28.025	0.0420	0.0440	0.0000	14.012	14.013	0.000	1205076	25292	89672	114964	4.10
			TOTAL					14888456	312479	1107880	1420359	

RECHARGE FOR RAINFALL
EVENT OF 21st FEB 1988

QARS ZONE	TOTAL ZONE AREA (Km2)	RAIN A m	RAIN B m	RAIN C m	AREA A Km2	AREA B Km2	AREA C Km2	TOTAL RAIN m3	RECHARGE URBAN (22%) m3	RECHARGE DESERT (78%) m3	TOTAL RECHARGE m3	TOTAL RECHARGE mm
1	0.291	0.0135	0.0145	0.0000	0.146	0.145	0.000	4074	85	303	389	1.34
2	0.381	0.0135	0.0145	0.0150	0.095	0.190	0.096	5478	115	408	523	1.37
3	0.373	0.0145	0.0155	0.0165	0.093	0.186	0.094	5783	121	430	552	1.48
4	0.477	0.0155	0.0165	0.0000	0.238	0.239	0.000	7633	160	568	728	1.53
5	0.222	0.0145	0.0155	0.0000	0.074	0.148	0.000	3367	71	251	321	1.45
6	0.289	0.0145	0.0000	0.0000	0.289	0.000	0.000	4191	88	312	400	1.38
7	0.288	0.0125	0.0135	0.0145	0.072	0.144	0.072	3888	82	289	371	1.29
10	0.909	0.0145	0.0155	0.0000	0.454	0.455	0.000	13636	286	1015	1301	1.43
11	0.950	0.0145	0.0155	0.0000	0.633	0.317	0.000	14092	296	1049	1344	1.42
12	0.780	0.0145	0.0155	0.0000	0.390	0.390	0.000	11700	246	871	1116	1.43
13	0.667	0.0165	0.0175	0.0000	0.333	0.334	0.000	11340	238	844	1082	1.62
)	0.350	0.0175	0.0185	0.0000	0.175	0.175	0.000	6300	132	469	601	1.72
15	0.511	0.0165	0.0000	0.0000	0.511	0.000	0.000	8432	177	627	804	1.57
16	0.412	0.0155	0.0165	0.0000	0.206	0.206	0.000	6592	138	491	629	1.53
17	0.527	0.0145	0.0000	0.0000	0.527	0.000	0.000	7642	160	569	729	1.38
18	0.550	0.0125	0.0135	0.0000	0.275	0.275	0.000	7150	150	532	682	1.24
19	0.632	0.0115	0.0125	0.0000	0.316	0.316	0.000	7584	159	564	724	1.14
20	1.318	0.0155	0.0165	0.0000	0.878	0.440	0.000	20869	438	1553	1991	1.51
21	0.817	0.0155	0.0165	0.0000	0.408	0.409	0.000	13073	274	973	1247	1.53
22	0.644	0.0175	0.0185	0.0000	0.322	0.322	0.000	11592	243	863	1106	1.72
23	1.168	0.0185	0.0195	0.0205	0.389	0.389	0.390	22777	478	1695	2173	1.86
24	1.706	0.0200	0.0190	0.0000	0.853	0.853	0.000	33267	698	2475	3174	1.86
25	1.502	0.0210	0.0190	0.0180	0.500	0.501	0.501	29037	609	2161	2770	1.84
26	1.136	0.0185	0.0205	0.0000	0.568	0.568	0.000	22152	465	1648	2113	1.86
27	1.545	0.0170	0.0190	0.0000	0.773	0.772	0.000	27809	584	2069	2653	1.72
28	0.802	0.0155	0.0170	0.0000	0.401	0.401	0.000	13033	274	970	1243	1.55
29	1.066	0.0160	0.0000	0.0000	1.066	0.000	0.000	17056	358	1269	1627	1.53
31	5.368	0.0250	0.0230	0.0000	2.684	2.684	0.000	128832	2704	9587	12291	2.29
32	2.474	0.0195	0.0205	0.0000	1.237	1.237	0.000	49480	1038	3682	4720	1.91
33	2.811	0.0205	0.0195	0.0185	0.937	0.937	0.937	54815	1150	4079	5229	1.86
	2.637	0.0175	0.0185	0.0000	1.319	1.318	0.000	47466	996	3532	4528	1.72
35	1.089	0.0175	0.0165	0.0000	0.545	0.544	0.000	18514	389	1378	1766	1.62
36	2.081	0.0205	0.0195	0.0185	0.694	0.694	0.693	40581	852	3020	3871	1.86
37	2.578	0.0165	0.0175	0.0185	0.859	0.859	0.860	45116	947	3357	4304	1.67
38	3.540	0.0195	0.0205	0.0215	1.180	1.180	1.180	72570	1523	5400	6923	1.96
39	2.760	0.0210	0.0205	0.0000	1.840	0.920	0.000	57500	1207	4279	5486	1.99
40	3.480	0.0200	0.0000	0.0000	3.480	0.000	0.000	69600	1461	5179	6640	1.91
41	1.250	0.0215	0.0205	0.0000	0.625	0.625	0.000	26250	551	1953	2504	2.00
42	1.780	0.0245	0.0235	0.0225	0.593	0.593	0.594	41829	878	3113	3990	2.24
43	1.940	0.0200	0.0000	0.0000	1.940	0.000	0.000	38800	814	2887	3702	1.91
44	3.190	0.0205	0.0215	0.0225	1.063	1.063	1.064	68586	1439	5104	6543	2.05
45	4.670	0.0240	0.0260	0.0000	2.335	2.335	0.000	116750	2450	8688	11138	2.39
46	3.480	0.0220	0.0240	0.0000	1.740	1.740	0.000	80040	1680	5956	7636	2.19
47	3.340	0.0255	0.0275	0.0000	1.670	1.670	0.000	88510	1858	6586	8444	2.53
48	11.060	0.0200	0.0270	0.0000	5.530	5.530	0.000	259910	5455	19340	24795	2.24
49	11.942	0.0300	0.0260	0.0200	3.980	3.981	3.981	302526	6349	22512	28861	2.42
51	18.666	0.0230	0.0000	0.0000	18.666	0.000	0.000	429318	9011	31946	40957	2.19
52	13.116	0.0210	0.0250	0.0000	6.558	6.558	0.000	301668	6331	22448	28779	2.19
53	8.058	0.0255	0.0000	0.0000	8.058	0.000	0.000	205479	4313	15290	19603	2.43
54	21.716	0.0240	0.0220	0.0000	14.478	7.238	0.000	506708	10635	37705	48340	2.23
55	19.258	0.0225	0.0235	0.0245	6.420	6.420	6.418	452561	9498	33676	43174	2.24
56	76.638	0.0215	0.0200	0.0235	38.319	19.160	19.159	1657295	34783	123323	158106	2.06

60	1.106	0.0145	0.0155	0.0000	0.553	0.553	0.000	16590	348	1234	1583	1.43
61	4.211	0.0200	0.0170	0.0000	2.105	2.106	0.000	77902	1635	5797	7432	1.76
62	0.650	0.0155	0.0165	0.0000	0.325	0.325	0.000	10400	218	774	992	1.53
63	1.980	0.0185	0.0175	0.0165	0.660	0.660	0.660	34650	727	2578	3306	1.67
64	1.420	0.0165	0.0175	0.0185	0.473	0.473	0.474	24851	522	1849	2371	1.67
65	2.140	0.0205	0.0195	0.0185	0.713	0.713	0.714	41729	876	3105	3981	1.86
66	1.800	0.0205	0.0215	0.0225	0.600	0.600	0.600	38700	812	2880	3692	2.05
67	6.330	0.0225	0.0215	0.0205	2.110	2.110	2.110	136095	2856	10127	12983	2.05
90	15.475	0.0295	0.0280	0.0000	7.737	7.738	0.000	444906	9338	33106	42444	2.74
91	28.025	0.0270	0.0230	0.0000	14.012	14.013	0.000	700623	14705	52135	66839	2.38
					TOTAL			7026689	147476	522870	670346	

RECHARGE FOR RAINFALL
EVENT OF 22nd FEB 1988

QARS ZONE	TOTAL ZONE AREA (Km2)	RAIN A m	RAIN B m	RAIN C m	AREA A Km2	AREA B Km2	AREA C Km2	TOTAL RAIN m3	RECHARGE URBAN (22%) m3	RECHARGE DESERT (78%) m3	TOTAL RECHARGE m3	TOTAL RECHARGE mm
1	0.291	0.0275	0.0285	0.0000	0.160	0.131	0.000	8134	171	605	776	2.67
2	0.381	0.0275	0.0285	0.0000	0.273	0.108	0.000	10586	222	788	1010	2.65
3	0.373	0.0275	0.0265	0.0000	0.173	0.200	0.000	10058	211	748	959	2.57
4	0.477	0.0265	0.0255	0.0000	0.362	0.115	0.000	12526	263	932	1195	2.51
5	0.222	0.0265	0.0000	0.0000	0.222	0.000	0.000	5883	123	438	561	2.53
6	0.289	0.0265	0.0275	0.0000	0.144	0.145	0.000	7804	164	581	744	2.58
7	0.288	0.0275	0.0285	0.0000	0.144	0.144	0.000	8064	169	600	769	2.67
10	0.909	0.0300	0.0295	0.0000	0.734	0.175	0.000	27183	571	2023	2593	2.85
11	0.950	0.0285	0.0295	0.0000	0.475	0.475	0.000	27550	578	2050	2628	2.77
12	0.780	0.0275	0.0285	0.0000	0.390	0.390	0.000	21840	458	1625	2084	2.67
13	0.667	0.0255	0.0265	0.0275	0.167	0.334	0.166	17675	371	1315	1686	2.53
14	0.350	0.0245	0.0255	0.0000	0.175	0.175	0.000	8750	184	651	835	2.39
15	0.511	0.0245	0.0255	0.0000	0.255	0.256	0.000	12776	268	951	1219	2.39
16	0.412	0.0255	0.0265	0.0000	0.206	0.206	0.000	10712	225	797	1022	2.48
17	0.527	0.0275	0.0000	0.0000	0.527	0.000	0.000	14493	304	1078	1383	2.62
18	0.550	0.0285	0.0000	0.0000	0.550	0.000	0.000	15675	329	1166	1495	2.72
19	0.632	0.0290	0.0000	0.0000	0.632	0.000	0.000	18328	385	1364	1748	2.77
20	1.318	0.0295	0.0305	0.0000	0.659	0.659	0.000	39540	830	2942	3772	2.86
21	0.817	0.0275	0.0285	0.0000	0.409	0.408	0.000	22876	480	1702	2182	2.67
22	0.644	0.0275	0.0285	0.0000	0.322	0.322	0.000	18032	378	1342	1720	2.67
23	1.168	0.0255	0.0245	0.0235	0.616	0.475	0.077	29155	612	2169	2781	2.38
24	1.706	0.0245	0.0235	0.0225	0.365	0.710	0.631	39825	836	2963	3799	2.23
25	1.752	0.0245	0.0235	0.0225	0.500	0.652	0.600	41072	862	3056	3918	2.24
26	1.136	0.0245	0.0235	0.0000	0.550	0.586	0.000	27246	572	2027	2599	2.29
27	1.545	0.0275	0.0265	0.0255	0.200	0.580	0.765	40378	847	3005	3852	2.49
28	0.802	0.0285	0.0000	0.0000	0.802	0.000	0.000	22857	480	1701	2181	2.72
29	1.066	0.0285	0.0295	0.0000	0.533	0.533	0.000	30914	649	2300	2949	2.77
31	5.368	0.0315	0.0000	0.0000	5.368	0.000	0.000	169092	3549	12582	16131	3.01
32	2.474	0.0305	0.0000	0.0000	2.474	0.000	0.000	75457	1584	5615	7199	2.91
33	2.811	0.0305	0.0000	0.0000	2.811	0.000	0.000	85736	1799	6380	8179	2.91
34	2.637	0.0305	0.0295	0.0000	2.012	0.625	0.000	79804	1675	5938	7613	2.89
35	1.089	0.0305	0.0000	0.0000	1.089	0.000	0.000	33215	697	2472	3169	2.91
36	2.081	0.0275	0.0285	0.0000	1.040	1.041	0.000	58269	1223	4336	5559	2.67
37	2.578	0.0275	0.0285	0.0295	0.859	0.859	0.859	73445	1541	5465	7007	2.72
38	3.540	0.0245	0.0255	0.0265	1.180	1.180	1.180	90270	1895	6717	8612	2.43
39	2.760	0.0240	0.0220	0.0000	1.380	1.380	0.000	63480	1332	4724	6056	2.19
40	3.480	0.0210	0.0000	0.0000	3.480	0.000	0.000	73080	1534	5438	6972	2.00
41	1.250	0.0225	0.0000	0.0000	1.250	0.000	0.000	28125	590	2093	2683	2.15
42	1.780	0.0225	0.0235	0.0000	1.187	0.593	0.000	40643	853	3024	3877	2.18
43	1.940	0.0210	0.0230	0.0000	0.970	0.970	0.000	42680	896	3176	4072	2.10
44	3.190	0.0235	0.0000	0.0000	3.190	0.000	0.000	74965	1573	5578	7152	2.24
45	4.670	0.0235	0.0000	0.0000	4.670	0.000	0.000	109745	2303	8166	10470	2.24
46	3.480	0.0245	0.0000	0.0000	3.480	0.000	0.000	85260	1789	6344	8134	2.34
47	3.340	0.0240	0.0000	0.0000	3.340	0.000	0.000	80160	1682	5965	7647	2.29
48	11.060	0.0230	0.0260	0.0000	5.530	5.530	0.000	270970	5687	20163	25851	2.34
49	11.942	0.0230	0.0270	0.0000	5.971	5.971	0.000	298550	6266	22216	28482	2.39
51	18.666	0.0315	0.0305	0.0000	9.333	9.333	0.000	578646	12145	43058	55203	2.96
52	13.116	0.0270	0.0290	0.0000	6.558	6.558	0.000	367248	7708	27328	35035	2.67
53	8.058	0.0215	0.0245	0.0000	4.029	4.029	0.000	185334	3890	13791	17681	2.19
54	21.716	0.0210	0.0240	0.0000	10.858	10.858	0.000	488610	10255	36358	46613	2.15
55	19.258	0.0180	0.0150	0.0000	9.629	9.629	0.000	317757	6669	23645	30314	1.57
56	76.683	0.0150	0.0230	0.0000	38.341	38.342	0.000	1456981	30579	108417	138996	1.81

60	1.106	0.0305	0.0000	0.0000	1.106	0.000	0.000	33733	708	2510	3218	2.91
61	4.211	0.0315	0.0305	0.0000	2.106	2.105	0.000	130542	2740	9714	12454	2.96
62	0.650	0.0305	0.0000	0.0000	0.650	0.000	0.000	19825	416	1475	1891	2.91
63	1.980	0.0305	0.0000	0.0000	1.980	0.000	0.000	60390	1267	4494	5761	2.91
64	1.420	0.0305	0.0000	0.0000	1.420	0.000	0.000	43310	909	3223	4132	2.91
65	2.140	0.0315	0.0305	0.0000	1.070	1.070	0.000	66340	1392	4936	6329	2.96
66	1.800	0.0315	0.0000	0.0000	1.800	0.000	0.000	56700	1190	4219	5409	3.01
67	6.330	0.0315	0.0000	0.0000	6.330	0.000	0.000	199395	4185	14837	19022	3.01
90	15.475	0.0245	0.0000	0.0000	15.475	0.000	0.000	379138	7957	28212	36170	2.34
91	28.025	0.0260	0.0000	0.0000	28.025	0.000	0.000	728650	15293	54220	69513	2.48
			TOTAL					7495468	157315	557753	715068	

RECHARGE FOR RAINFALL
EVENT OF 24th FEB 1988

QARS ZONE	TOTAL ZONE AREA (Km2)	RAIN A m	RAIN B m	RAIN C m	AREA A Km2	AREA B Km2	AREA C Km2	TOTAL RAIN m3	RECHARGE URBAN (22%) m3	RECHARGE DESERT (78%) m3	TOTAL RECHARGE m3	TOTAL RECHARGE mm
1	0.291	0.0295	0.0000	0.0000	0.291	0.000	0.000	8585	180	639	819	2.81
2	0.381	0.0295	0.0305	0.0000	0.254	0.127	0.000	11367	239	846	1084	2.85
3	0.373	0.0305	0.0000	0.0000	0.373	0.000	0.000	11377	239	847	1085	2.91
4	0.477	0.0305	0.0315	0.0000	0.318	0.159	0.000	14708	309	1094	1403	2.94
5	0.222	0.0305	0.0000	0.0000	0.222	0.000	0.000	6771	142	504	646	2.91
6	0.289	0.0295	0.0295	0.0000	0.144	0.145	0.000	8526	179	634	813	2.81
7	0.288	0.0295	0.0000	0.0000	0.288	0.000	0.000	8496	178	632	811	2.81
10	0.909	0.0290	0.0000	0.0000	0.909	0.000	0.000	26361	553	1962	2515	2.77
11	0.950	0.0295	0.0000	0.0000	0.950	0.000	0.000	28025	588	2085	2674	2.81
12	0.780	0.0295	0.0305	0.0000	0.390	0.390	0.000	23400	491	1741	2232	2.86
13	0.667	0.0305	0.0315	0.0000	0.333	0.334	0.000	20678	434	1539	1973	2.96
14	0.350	0.0325	0.0315	0.0000	0.088	0.262	0.000	11113	233	827	1060	3.03
15	0.511	0.0305	0.0315	0.0000	0.170	0.341	0.000	15927	334	1185	1519	2.97
16	0.412	0.0295	0.0305	0.0000	0.137	0.275	0.000	12429	261	925	1186	2.88
17	0.527	0.0295	0.0285	0.0000	0.263	0.264	0.000	15283	321	1137	1458	2.77
18	0.550	0.0295	0.0285	0.0000	0.183	0.367	0.000	15858	333	1180	1513	2.75
19	0.632	0.0285	0.0000	0.0000	0.632	0.000	0.000	18012	378	1340	1718	2.72
20	1.318	0.0290	0.0295	0.0000	0.659	0.659	0.000	38552	809	2869	3678	2.79
21	0.817	0.0295	0.0305	0.0000	0.408	0.409	0.000	24511	514	1824	2338	2.86
22	0.644	0.0305	0.0315	0.0000	0.322	0.322	0.000	19964	419	1486	1905	2.96
23	1.168	0.0315	0.0325	0.0000	0.584	0.584	0.000	37376	784	2781	3566	3.05
24	1.706	0.0315	0.0330	0.0000	0.853	0.853	0.000	55019	1155	4094	5249	3.08
25	1.502	0.0315	0.0325	0.0000	0.751	0.751	0.000	48064	1009	3577	4585	3.05
26	1.136	0.0315	0.0305	0.0000	0.568	0.568	0.000	35216	739	2620	3360	2.96
27	1.545	0.0305	0.0285	0.0295	0.386	0.386	0.773	45578	957	3392	4348	2.81
28	0.802	0.0285	0.0275	0.0000	0.267	0.535	0.000	22322	468	1661	2130	2.66
29	1.066	0.0275	0.0265	0.0000	0.533	0.533	0.000	28782	604	2142	2746	2.58
31	5.368	0.0290	0.0000	0.0000	5.368	0.000	0.000	155672	3267	11584	14851	2.77
32	2.474	0.0290	0.0000	0.0000	2.474	0.000	0.000	71746	1506	5339	6845	2.77
33	2.811	0.0290	0.0000	0.0000	2.811	0.000	0.000	81519	1711	6066	7777	2.77
34	2.637	0.0290	0.0295	0.0000	1.318	1.319	0.000	77133	1619	5740	7358	2.79
35	1.089	0.0295	0.0290	0.0000	0.272	0.817	0.000	31717	666	2360	3026	2.78
36	2.081	0.0295	0.0315	0.0305	0.520	0.520	1.041	63471	1332	4723	6055	2.91
37	2.578	0.0295	0.0305	0.0000	1.289	1.289	0.000	77340	1623	5755	7378	2.86
38	3.540	0.0315	0.0320	0.0000	1.770	1.770	0.000	112395	2359	8364	10722	3.03
39	2.760	0.0330	0.0320	0.0000	0.920	1.840	0.000	89240	1873	6641	8513	3.08
40	3.480	0.0325	0.0330	0.0000	1.740	1.740	0.000	113970	2392	8481	10873	3.12
41	1.250	0.0325	0.0335	0.0000	0.625	0.625	0.000	41250	866	3069	3935	3.15
42	1.780	0.0315	0.0305	0.0295	0.590	0.590	0.600	54280	1139	4039	5178	2.91
43	1.940	0.0325	0.0335	0.0000	0.970	0.970	0.000	64020	1344	4764	6108	3.15
44	3.190	0.0335	0.0325	0.0000	1.595	1.595	0.000	105270	2209	7833	10043	3.15
45	4.670	0.0315	0.0305	0.0290	1.168	1.168	2.334	140102	2940	10425	13366	2.86
46	3.480	0.0320	0.0000	0.0000	3.480	0.000	0.000	111360	2337	8287	10624	3.05

QARS ZONE	TOTAL ZONE AREA (Km2)	RAIN A m	RAIN B m	RAIN C m	AREA A Km2	AREA B Km2	AREA C Km2	TOTAL RAIN m3	RECHARGE URBAN (22%)	m3	DESERT (78%)	TOTAL RECHARGE m3	mm
47	3.340	0.0295	0.0000	0.0000	3.340	0.000	0.000	98530	2068		7332	9400	2.81
48	11.060	0.0270	0.0000	0.0000	11.060	0.000	0.000	298620	6267		22221	28488	2.58
49	11.942	0.0260	0.0000	0.0000	11.942	0.000	0.000	310492	6517		23104	29621	2.48
51	18.666	0.0290	0.0000	0.0000	18.666	0.000	0.000	541314	11361		40280	51641	2.77
52	13.116	0.0300	0.0000	0.0000	13.116	0.000	0.000	393480	8258		29280	37538	2.86
53	8.058	0.0310	0.0000	0.0000	8.058	0.000	0.000	249798	5243		18588	23831	2.96
54	21.716	0.0320	0.0000	0.0000	21.716	0.000	0.000	694912	14585		51710	66295	3.05
55	19.258	0.0300	0.0000	0.0000	19.258	0.000	0.000	577740	12126		42991	55116	2.86
56	76.638	0.0320	0.0000	0.0000	76.638	0.000	0.000	2452416	51471		182489	233960	3.05
60	1.106	0.0290	0.0000	0.0000	1.106	0.000	0.000	32074	673		2387	3060	2.77
61	4.211	0.0290	0.0000	0.0000	4.211	0.000	0.000	122119	2563		9087	11650	2.77
62	0.650	0.0290	0.0000	0.0000	0.650	0.000	0.000	18850	396		1403	1798	2.77
63	1.980	0.0290	0.0000	0.0000	1.980	0.000	0.000	57420	1205		4273	5478	2.77
64	1.420	0.0290	0.0000	0.0000	1.420	0.000	0.000	41180	864		3064	3929	2.77
65	2.140	0.0290	0.0000	0.0000	2.140	0.000	0.000	62060	1303		4618	5921	2.77
66	1.800	0.0290	0.0000	0.0000	1.800	0.000	0.000	52200	1096		3884	4980	2.77
67	6.330	0.0290	0.0000	0.0000	6.330	0.000	0.000	183570	3853		13660	17513	2.77
90	15.475	0.0270	0.0000	0.000	15.475	0.000	0.000	417825	8769		31091	39861	2.58
91	28.025	0.0300	0.0330	0.000	14.012	14.013	0.000	882789	18528		65690	84218	3.01
			TOTAL					9490167	199180		706182	905362	

RECHARGE FOR RAINFALL
EVENT OF 24th APRIL 1988

QARS ZONE	TOTAL ZONE AREA (Km2)	RAIN A m	RAIN B m	RAIN C m	AREA A Km2	AREA B Km2	AREA C Km2	TOTAL RAIN m3	RECHARGE URBAN (22%)	m3	DESERT (78%)	TOTAL RECHARGE m3	mm
1	0.291	0.0050	0.0055	0.0000	0.097	0.194	0.000	1552	33		115	148	0.51
2	0.381	0.0055	0.0000	0.0000	0.381	0.000	0.000	2096	44		156	200	0.52
3	0.373	0.0055	0.0065	0.0000	0.124	0.249	0.000	2301	48		171	219	0.59
4	0.477	0.0055	0.0065	0.0000	0.318	0.159	0.000	2783	58		207	265	0.56
5	0.222	0.0055	0.0000	0.0000	0.222	0.000	0.000	1221	26		91	116	0.52
6	0.289	0.0045	0.0000	0.0000	0.289	0.000	0.000	1301	27		97	124	0.43
7	0.288	0.0045	0.0000	0.0000	0.288	0.000	0.000	1296	27		96	124	0.43
10	0.909	0.0065	0.0075	0.0000	0.606	0.303	0.000	6212	130		462	593	0.65
11	0.950	0.0065	0.0000	0.0000	0.950	0.000	0.000	6175	130		459	589	0.62
12	0.780	0.0055	0.0065	0.0000	0.520	0.260	0.000	4550	95		339	434	0.56
13	0.667	0.0065	0.0000	0.0000	0.667	0.000	0.000	4336	91		323	414	0.62
14	0.350	0.0065	0.0000	0.0000	0.350	0.000	0.000	2275	48		169	217	0.62
15	0.511	0.0055	0.0000	0.0000	0.511	0.000	0.000	2811	59		209	268	0.52
16	0.412	0.0045	0.0055	0.0000	0.308	0.104	0.000	1958	41		146	187	0.45
17	0.527	0.0045	0.0035	0.0000	0.263	0.264	0.000	2108	44		157	201	0.38
18	0.550	0.0045	0.0035	0.0000	0.275	0.275	0.000	2200	46		164	210	0.38
19	0.632	0.0035	0.0045	0.0000	0.316	0.316	0.000	2528	53		188	241	0.38
20	1.318	0.0075	0.0000	0.0000	1.318	0.000	0.000	9885	207		736	943	0.72
21	0.817	0.0065	0.0075	0.0000	0.408	0.409	0.000	5720	120		426	546	0.67
22	0.644	0.0075	0.0000	0.0000	0.644	0.000	0.000	4830	101		359	461	0.72
23	1.168	0.0075	0.0000	0.0000	1.168	0.000	0.000	8760	184		652	836	0.72
24	1.706	0.0065	0.0075	0.0000	0.569	1.137	0.000	12226	257		910	1166	0.68
25	1.502	0.0055	0.0065	0.0000	0.751	0.751	0.000	9012	189		671	860	0.57
26	1.136	0.0055	0.0045	0.0035	0.284	0.568	0.284	5112	107		380	488	0.43
27	1.545	0.0035	0.0045	0.0000	0.773	0.772	0.000	6180	130		460	590	0.38
28	0.802	0.0025	0.0000	0.0000	0.802	0.000	0.000	2005	42		149	191	0.24
29	1.066	0.0025	0.0000	0.0000	1.066	0.000	0.000	2665	56		198	254	0.24
31	5.368	0.0135	0.0125	0.0115	1.789	1.789	1.790	67099	1408		4993	6401	1.19
32	2.474	0.0105	0.0095	0.0000	1.856	0.618	0.000	25359	532		1887	2419	0.98
33	2.811	0.0105	0.0095	0.0085	0.703	1.405	0.703	26705	560		1987	2548	0.91
34	2.637	0.0095	0.0085	0.0000	1.758	0.879	0.000	24173	507		1799	2306	0.87
35	1.089	0.0085	0.0000	0.0000	1.089	0.000	0.000	9257	194		689	883	0.81
36	2.081	0.0095	0.0085	0.0000	1.040	1.041	0.000	18729	393		1394	1787	0.86
37	2.578	0.0085	0.0075	0.0000	1.289	1.289	0.000	20624	433		1535	1968	0.76
38	3.540	0.0095	0.0085	0.0000	1.770	1.770	0.000	31860	669		2371	3039	0.86
39	2.760	0.0095	0.0085	0.0000	0.920	1.840	0.000	24380	512		1814	2326	0.84
40	3.480	0.0075	0.0000	0.0000	3.480	0.000	0.000	26100	548		1942	2490	0.72
41	1.250	0.0065	0.0055	0.0000	0.625	0.625	0.000	7500	157		558	716	0.57
42	1.780	0.0055	0.0045	0.0035	0.593	0.593	0.594	8009	168		596	764	0.43
43	1.940	0.0075	0.0065	0.0000	0.970	0.970	0.000	13580	285		1011	1296	0.67
44	3.190	0.0065	0.0055	0.0000	2.127	1.063	0.000	19672	413		1464	1877	0.59
45	4.670	0.0050	0.0030	0.0000	2.335	2.335	0.000	18680	392		1390	1782	0.38
46	3.480	0.0065	0.0055	0.0045	1.160	1.160	1.160	19140	402		1424	1826	0.52
47	3.340	0.0035	0.0025	0.0015	1.113	1.113	1.114	8349	175		621	796	0.24
48	11.060	0.0020	0.0000	0.0000	5.530	5.530	0.000	11060	232		823	1055	0.10
49	11.942	0.0000	0.0000	0.0000	11.942	0.000	0.000	0	0		0	0	0.00
51	18.666	0.0120	0.0140	0.0000	9.333	9.333	0.000	242658	5093		18057	23150	1.24
52	13.116	0.0130	0.0110	0.0000	6.558	6.558	0.000	157392	3303		11712	15015	1.14
53	8.058	0.0135	0.0125	0.0115	2.686	2.686	2.686	100725	2114		7495	9609	1.19
54	21.716	0.0115	0.0105	0.0095	7.238	7.238	7.240	228016	4786		16967	21753	1.00
55	19.258	0.0090	0.0100	0.0000	12.839	6.419	0.000	179741	3772		13375	17147	0.89
56	76.638	0.0085	0.0075	0.0000	38.319	38.319	0.000	613104	12868		45622	58490	0.76

60	1.106	0.0065	0.0000	0.0000	1.106	0.000	0.000	7189	151	535	686	0.62
61	4.211	0.0070	0.0080	0.0090	1.404	1.404	1.403	33687	707	2507	3214	0.76
62	0.650	0.0075	0.0000	0.0000	0.650	0.000	0.000	4875	102	363	465	0.72
63	1.980	0.0075	0.0085	0.0000	1.320	0.660	0.000	15510	326	1154	1480	0.75
64	1.420	0.0075	0.0085	0.0000	0.710	0.710	0.000	11360	238	845	1084	0.76
65	2.140	0.0085	0.0095	0.0000	1.070	1.070	0.000	19260	404	1433	1837	0.86
66	2.248	0.0095	0.0105	0.0115	0.562	1.124	0.562	23604	495	1756	2252	1.00
67	6.330	0.0095	0.0105	0.0115	2.110	2.110	2.110	66465	1395	4946	6341	1.00
90	15.475	0.0000	0.0000	0.0000	15.475	0.000	0.000	0	0	0	0	0.00
91	28.025	0.0040	0.0000	0.0000	28.025	0.000	0.000	112100	2353	8342	10694	0.38
					TOTAL			2310053	48483	171896	220379	

TOTAL RAINFALL = 3.22 Mm³

Recharge = 0.31 Mm³.

ISSUE	REVISION	DATE

STATE OF QATAR
MINISTRY OF PUBLIC WORKS
Civil Engineering Department

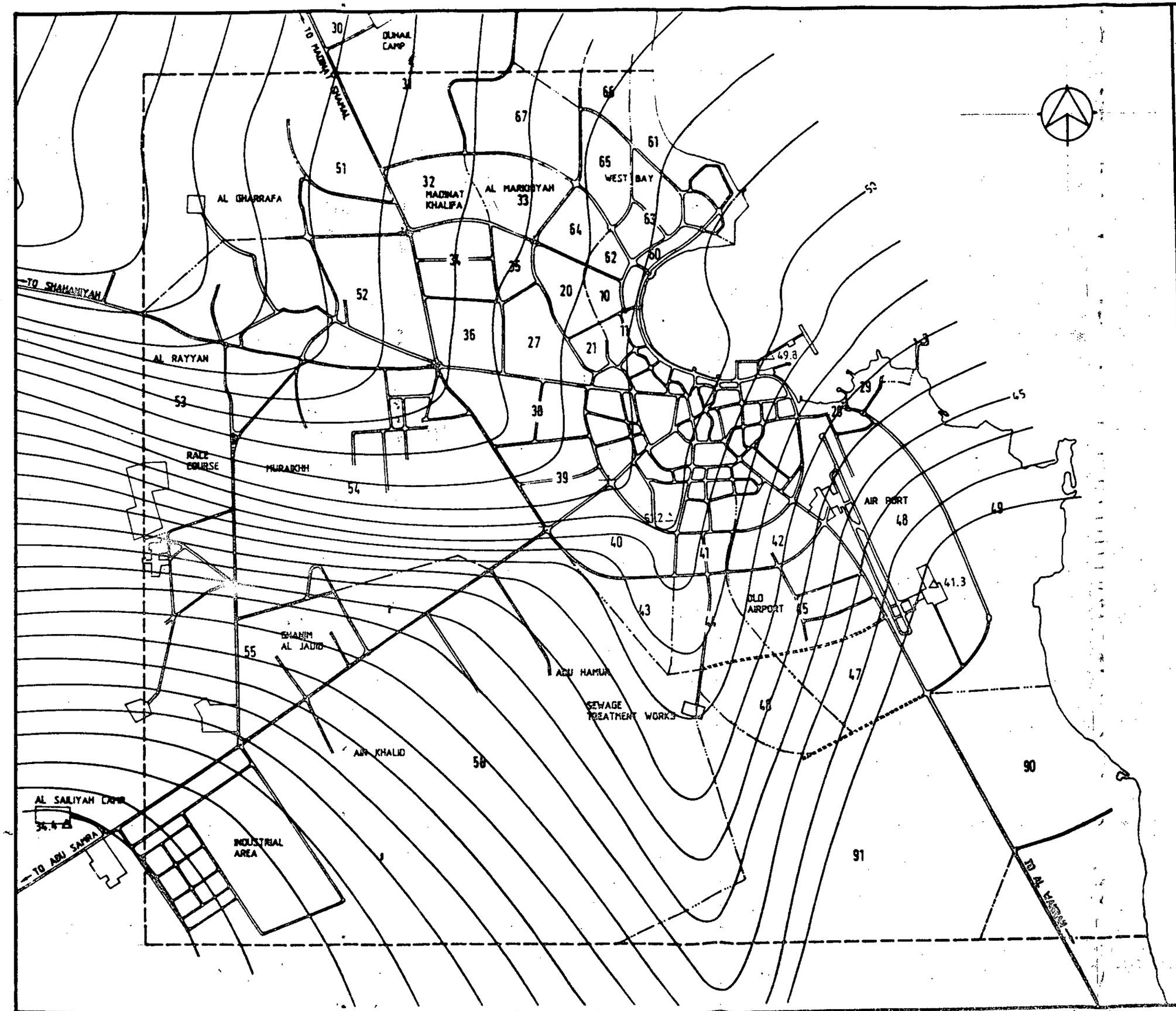
BALFOURS International
CONSULTING ENGINEERS
P.O. BOX 6850. DOHA QATAR.

SCHEME
~~WEST BAY~~ DOHA
GROUNDWATER STUDY

TITLE
RAINFALL EVENT ON FEBRUARY 14, 1988

DRAWN	CHECKED	CONTRACT No.
AAP		
SCALE 1:75,000		PROJECT No.
DRAWING No.	JOB No.	ISSUE

14 FEB 88



TOTAL RAINFALL = 14 89 Mm^3

Recharge = 1 42 Mm^3

ISSUE	REVISION	DATE

STATE OF QATAR
MINISTRY OF PUBLIC WORKS
Civil Engineering Department

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SCHEME
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GROUNDWATER STUDY

TITLE
RAINFALL EVENT ON
FEBRUARY 16 - 17, 1988

DRAWN	CHECKED	CONTRACT No.
AAP	JJ	
SCALE 1:75,000		PROJECT No.
DRAWING No.	JOB No.	ISSUE

16-17 FEB 88

TOTAL RAINFALL = 7.03 Mm^3

Recharge = 0.67 Mm^3

ISSUE	REVISION	DATE

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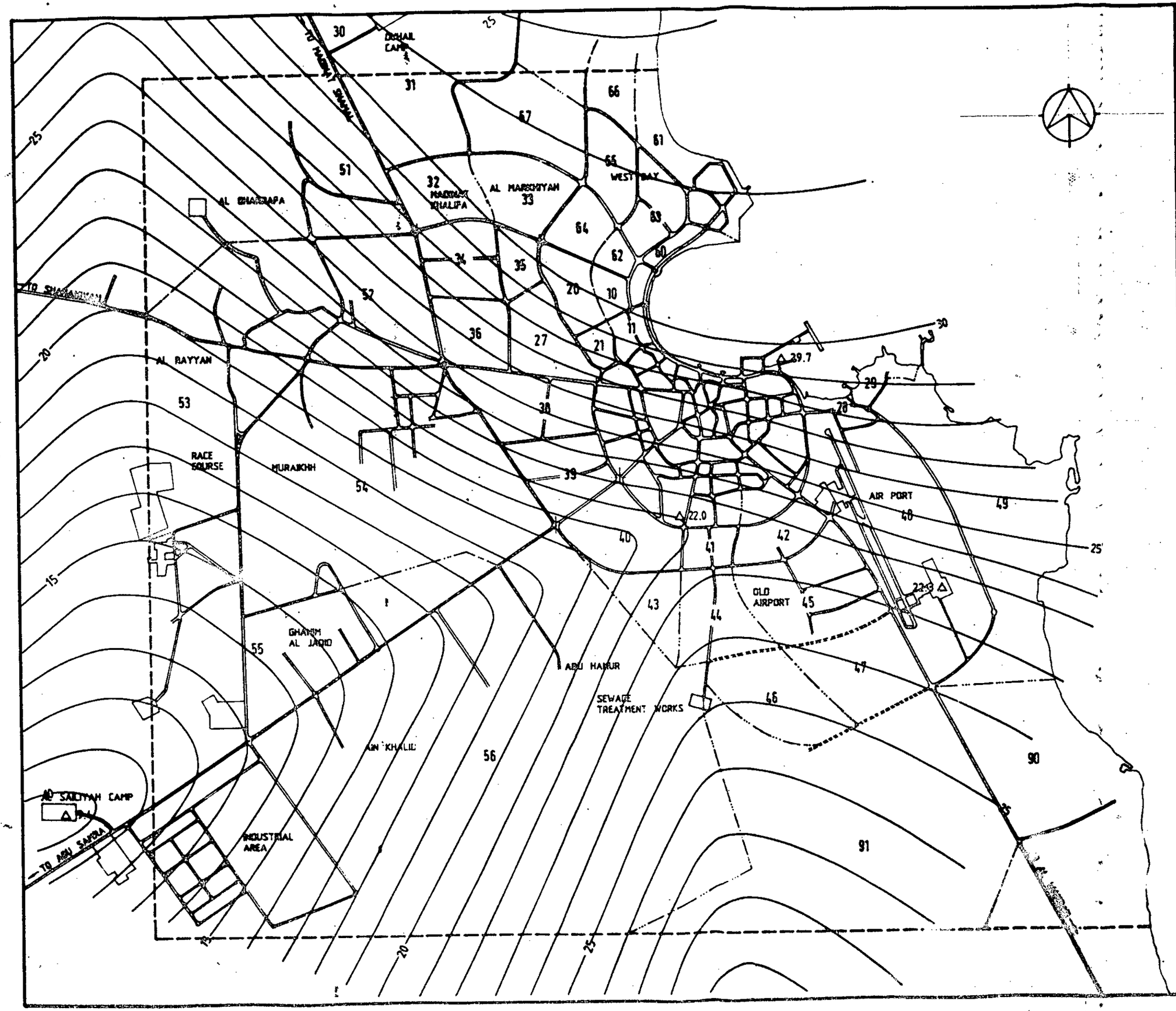
SCHEME
~~WEST BAY~~ DOHA
GROUNDWATER STUDY

TITLE
RAINFALL EVENT ON
FEBRUARY 21, 1988

DRAWN	CHECKED	CONTRACT No.
AAP	JJ	
SCALE 1:75,000		PROJECT No.
DRAWING No.	JOB No.	ISSUE

21 FEB 88



TOTAL RAINFALL = 7.49 Mm³

Recharge = 0.72 Mm³

ISSUE	REVISION	DATE

STATE OF QATAR
MINISTRY OF PUBLIC WORKS
Civil Engineering Department

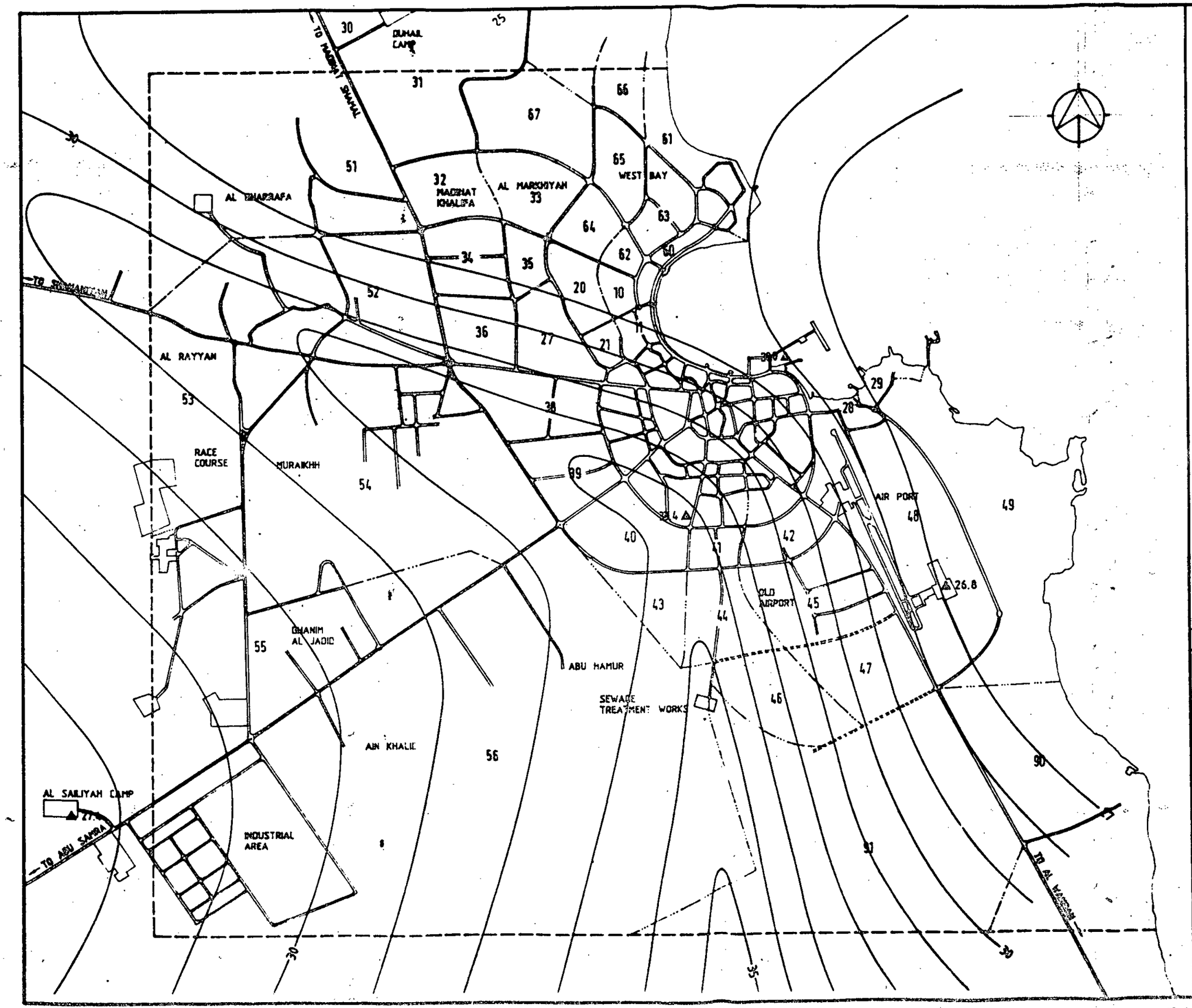
BALFOURS International
CONSULTING ENGINEERS
P.O. BOX 6650. DOHA QATAR.

SCHEME
~~WEST BAY~~ DOHA
GROUNDWATER STUDY

TITLE
RAINFALL EVENT ON FEBRUARY 22, 1988

DRAWN	CHECKED	CONTRACT No.
AAP	JJ	
SCALE 1 : 75,000		PROJECT No.
DRAWING No.	JOB No.	ISSUE

22 FEB 88



TOTAL RAINFALL = 9.49 Mm³

Recharge = 0.91 Mm³

ISSUE	REVISION	DATE

STATE OF QATAR
MINISTRY OF PUBLIC WORKS
Civil Engineering Department

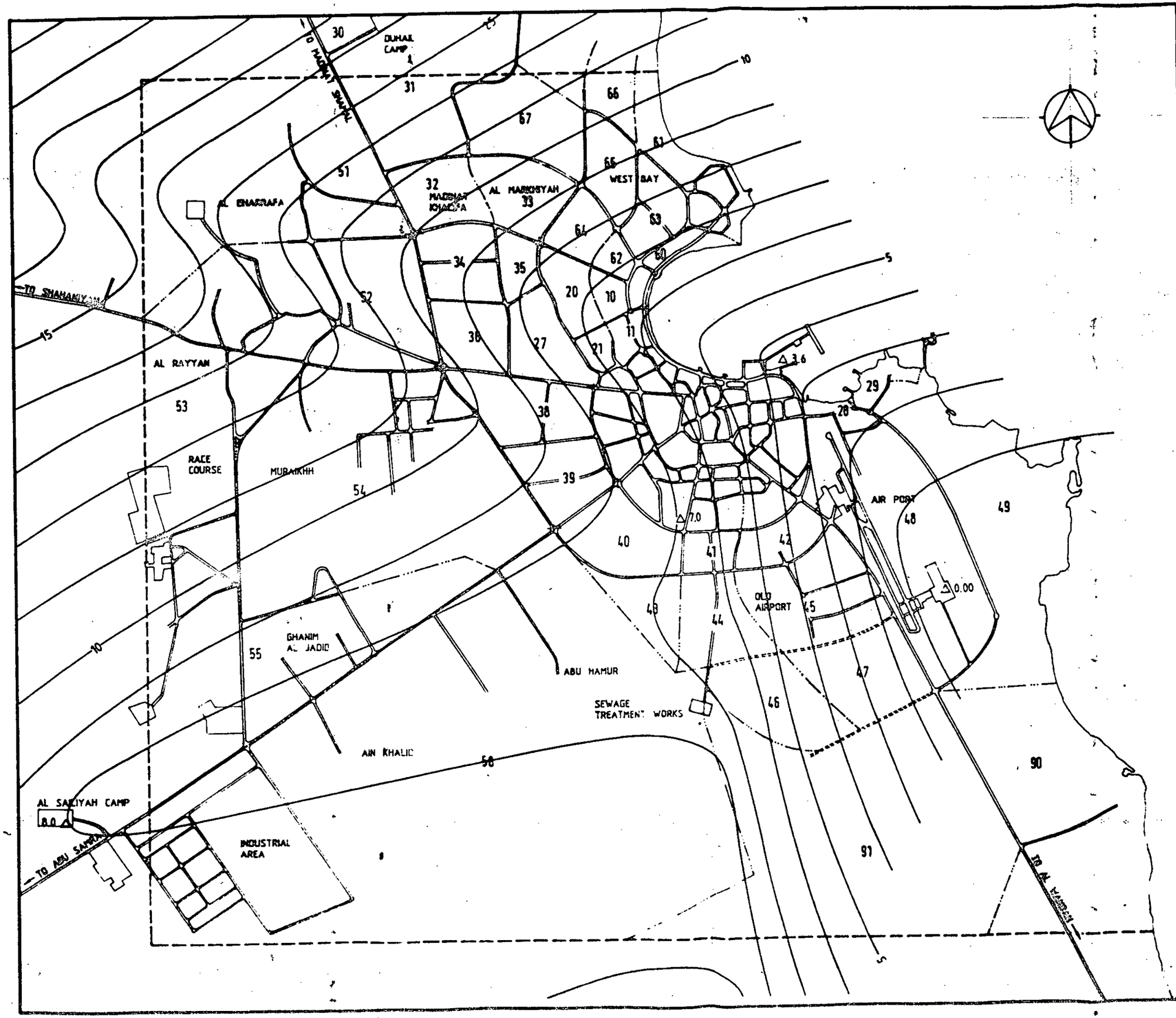
BALFOURS International
CONSULTING ENGINEERS
P.O. BOX 6650. DOHA QATAR.

SCHEME
~~WEST BAY~~ DOHA
GROUNDWATER STUDY

TITLE
RAINFALL EVENT ON FEBRUARY 24, 1983

DRAWN	CHECKED	CONTRACT No.
AMP	JJ	
SCALE 1:75,000		PROJECT No.
DRAWING No.	JOB No.	ISSUE

24 FEB 83



TOTAL RAINFALL = 2·31 Mm³

Recharge = 0·22 Mm³

ISSUE	REVISION	DATE

STATE OF QATAR
MINISTRY OF PUBLIC WORKS
Civil Engineering Department

BALFOURS International
CONSULTING ENGINEERS
P.O. BOX 6650. DOHA QATAR.

SCHEME
~~WEST BAY~~ DOHA
GROUNDWATER STUDY

TITLE
RAINFALL EVENT ON
APRIL 24 1988

DRAWN	CHECKED	CONTRACT No.
AAP	JJ	
SCALE 1:75,000		PROJECT No.
DRAWING No.	JOB No.	ISSUE

24 APRIL 88

APPENDIX D

APPENDIX "D"

RECHARGE FROM WELL ABSTRACTION

D.1 INTRODUCTION

There are 52 active farms within the Study Area of a total aggregate demarcated area of 357.20 ha. Total groundwater abstracted from wells on site amounted to 4.143 Mm^3 in 1986/87 and with an assumed average evapotranspiration demand of 1,700 mm for the irrigation of alfalfa and date palms, the indicated area under actual irrigation is 175.2 ha. or 49% of the total area. Average irrigation efficiency is 72% and irrigation return would therefore amount to 1.167 Mm^3. Table D.1 lists each of these farms against their Ministry of Agriculture number who also provided the basic data on farm size and well abstraction rates.

TABLE D.1

Farm No.	Extraction ($m^3 \times 10^3$) 1986-87	Area m^2	ET m^3 (x 1.7m)	Loss (m^3)	Remarks
341	45	88,000	149,600	6,738	
369	179	86,000	146,200	32,800	
373	86	6,000	78,200	7,800	
376	45	53,000	90,100	6,738	
376-A					Abandoned
377					Abandoned
379	73	122,000	207,400	10,930	
381		(38,000)	(64,600)		Potable
382	76	22,000	37,400	38,600	
383	43	21,000	35,700	7,300	
390	42	87,000	147,900	6,289	
393	105	120,000	204,000	15,722	
403	26	15,000	25,500	500	
405					Abandoned
407	178	89,000	151,300	26,700	
408-A					Abandoned
410					Abandoned
411	52	16,000	27,200	24,800	
412	26	11,000	18,700	7,300	
413	86	6,000	10,200	75,800	
420	33	20,000	34,000	4,941	
421	48	52,000	88,400	7,187	
422	67	101,000	171,700	10,032	
424					
426	73	34,000	57,800	15,200	
427	43	31,000	52,700	6,439	
429	130	40,000	68,000	62,000	
430					Abandoned
432	31	43,000	73,100	4,642	
436	85	175,000	297,500	12,727	
437	29	99,000	168,300	4,342	

TABLE D.1 (Contd.)

Farm No.	Extraction ($m^3 \times 10^3$) 1986-87	Area m^2	ET m^3 (x 1.7m)	Loss (m^3)	Remarks
441	67	85,000	144,500	10,032	
444	143	53,000	90,100	52,900	
445	336	100,000	170,000	166,000	
447	14	44,000	74,800	2,096	
449					Abandoned
450	82	440,000	748,000	12,278	
453	48	49,000	83,300	7,187	
456					Abandoned
457					Abandoned
459	55	28,000	47,600	7,400	
463	17	16,000	27,200	2,545	
465	125	137,000	232,900	18,716	
466	198	101,000	171,700	26,300	
470	125	153,000	260,100	18,716	
471					Abandoned
472	24	7,000	11,900	12,100	
473	32	21,000	35,700	4,791	
474	91	44,000	74,800	16,200	
475	48	27,000	45,900	2,100	
479	29	37,000	62,900	4,342	
482	66	40,000	68,000	9,882	
483	110	128,000	217,000	16,470	
488	74	9,000	15,300	58,700	
492	318	62,000	105,400	212,600	
496		(255,000)	(433,500)		Potable
497	188	147,000	249,900	28,149	
497-A	59	124,000	210,000	8,834	
498	129	260,000	442,000	19,315	
588-A					Abandoned
595	86	36,000	61,200	24,800	
644	35	36,000	61,200	5,241	
644-A	43	11,000	18,700	24,300	
Total	4,143,000	3,572,000	2,975,476	1,167,524	

OTHER WELLS

The following table has been extracted from the original Report as no current data could be obtained.

WELL NO.	EXTRACTION M^3	AREA M^2	ET. M^3 (X 1.7 M)	LOSS
1	44,869	11,000	14,358	30,511
2} } 3}	203,947	50,000	65,263	138,684
4	367,106	90,000	117,474	249,632
5	16,272	3,600	5,207	11,065
6	16,272	3,600	5,207	11,065
7	18,356	4,500	5,874	12,482
Total	666,822	162,700	213,383	453,439

SUMMARY OF ABSTRACTION RECHARGE BY ZONE - 1988

QARS ZONE	FARM WELLS WITHIN STUDY AREA NO	RECHARGE M^3/YEAR	TOTAL	OTHER WELLS IN STUDY AREA NO	RECHARGE M^3/YEAR
1				FARM AT GULF CINEMA	12,482
35				TV ROUNDABOUT	11,065
37				HITMI PARK	30,511
38	463	2,545	2,545		
40	488	58,700	58,700		
51	376	6,738	100,457		
	379	10,930			
	382	38,600			
	383	7,300			
	390	6,289			
51	369	32,800			
	373	7,800			
51					
52	412	7,300	137,003		
				LUCKTAHA PARK (I,II)	138,684
	413	75,800			
	420	4,941			
	421	7,187			
	422	10,032			
	432	4,642			
	436	12,727			
	437	4,342			
	441	10,032			
53	393	15,722	151,360		
	403	500			
	407	26,700			
	411	24,800			
	426	15,200			
	427	6,438			
53	429	62,000			
54	465	18,716	292,877		
	466	26,300			
54	444	52,900		EMIRS PALACE	249,632
54	445	166,000			
	447	2,096			
	450	12,278			
	453	7,187			
	459	7,400			

Farm

other

SUMMARY OF ABSTRACTION RECHARGE BY ZONE - 1988 (Contd.)

QARS ZONE	FARM WELLS WITHIN STUDY AREA NO	RECHARGE M^3/YEAR	TOTAL	OTHER WELLS IN STUDY AREA NO	RECHARGE M^3/YEAR
55	470	18,716	377,146		
	472	12,100			
	473	4,791			
	474	16,200			
	475	2,100			
	595	24,800			
	644	5,241			
	644-A	24,300			
55	492	212,600			
	497	28,149			
	497-A	8,834			
	498	19,315			
56	482	9,882	30,694		
56	479	4,342			
	483	16,470			
60					
62					
63					
64					
65					
66					
67	341	6,738	6,738		
TOTAL			1,167,523		442,374
			1157520		

Farm

SUMMARY OF ABSTRACTION RECHARGE BY ZONE - 1988 (Contd.)

QATS ZONE	FARM WELLS WITHIN STUDY AREA NO	RECHARGE M^3/YEAR	TOTAL	OTHER WELLS IN STUDY AREA NO	RECHARGE M^3/YEAR

The location of the Farm wells and other wells are shown on Map A/1.

FARM.WK1

FARM No.	EXTRACTION m3 1986-87	AREA m2	E.T m3 (x 1.7m)	LOSS 1 (m3)	CALC LIST	LOSS 2 (m3)	TOTAL LOSS (m^3)
341	45000	88000	149600	0	45000	6738	6738
369	179000	86000	146200	32800	0	0	32800
373	86000	46000	78200	7800	0	0	7800
376	45000	53000	90100	0	45000	6738	6738
376-A	0	0	0	0	0	0	0
377	0	0	0	0	0	0	0
379	73000	122000	207400	0	73000	10930	10930
381	0	0	0	0	0	0	0
382	76000	22000	37400	38600	0	0	38600
383	43000	21000	35700	7300	0	0	7300
390	42000	87000	147900	0	42000	6289	6289
393	105000	120000	204000	0	105000	15722	15722
403	26000	15000	25500	500	0	0	500
405	0	0	0	0	0	0	0
407	178000	89000	151300	26700	0	0	26700
408-A	0	0	0	0	0	0	0
410	0	0	0	0	0	0	0
411	52000	16000	27200	24800	0	0	24800
412	26000	11000	18700	7300	0	0	7300
413	86000	6000	10200	75800	0	0	75800
420	33000	20000	34000	0	33000	4941	4941
421	48000	52000	88400	0	48000	7187	7187
422	67000	101000	171700	0	67000	10032	10032
424	0	0	0	0	0	0	0
426	73000	34000	57800	15200	0	0	15200
427	43000	31000	52700	0	43000	6438	6438
429	130000	40000	68000	62000	0	0	62000
430	0	0	0	0	0	0	0
432	31000	43000	73100	0	31000	4642	4642
436	85000	175000	297500	0	85000	12727	12727
437	29000	99000	168300	0	29000	4342	4342
441	67000	85000	144500	0	67000	10032	10032
444	143000	53000	90100	52900	0	0	52900
445	336000	100000	170000	166000	0	0	166000
447	14000	44000	74800	0	14000	2096	2096
449	0	0	0	0	0	0	0
450	82000	440000	748000	0	82000	12278	12278
453	48000	49000	83300	0	48000	7187	7187
456	0	0	0	0	0	0	0
457	0	0	0	0	0	0	0

FARM No.	EXTRACTION (~~m3x1000~~) 1986-87 (m^3)	AREA m2	E.T m3 (x 1.7m)	LOSS 1 (m3)	CALC LIST	LOSS 2 (m3)	TOTAL LOSS (m^3)
459	55000	28000	47600	7400	0	0	7400
463	17000	16000	27200	0	17000	2545	2545
465	125000	137000	232900	0	125000	18716	18716
466	198000	101000	171700	26300	0	0	26300
470	125000	153000	260100	0	125000	18716	18716
471	0	0	0	0	0	0	0
472	24000	7000	11900	12100	0	0	12100
473	32000	21000	35700	0	32000	4791	4791
474	91000	44000	74800	16200	0	0	16200
475	48000	27000	45900	2100	0	0	2100
479	29000	37000	62900	0	29000	4342	4342
482	66000	40000	68000	0	66000	9882	9882
483	110000	128000	217600	0	110000	16470	16470
488	74000	9000	15300	58700	0	0	58700
492	318000	62000	105400	212600	0	0	212600
496	0	0	0	0	0	0	0
497	188000	147000	249900	0	188000	28149	28149
497-A	59000	124000	210800	0	59000	8834	8834
498	129000	260000	442000	0	129000	19315	19315
588-A	0	0	0	0	0	0	0
595	86000	36000	61200	24800	0	0	24800
644	35000	36000	61200	0	35000	5241	5241
644-A	43000	11000	18700	24300	0	0	24300
TOTAL	4143000	3572000	2975476	1167524	1772000	265323	
			TOTAL COL 1	902200			
			DIFFERENCE	265324	0.149731	1167523	1167523

TOTAL OF CALC LIST 1772000

% PRO RATA $\frac{265324}{1,772,000}$ = 0.149731

APPENDIX E

APPENDIX "E"

RECHARGE FROM TREATED SEWAGE EFFLUENT T.S.E.

E.1 INTRODUCTION

Treated Sewage Effluent is produced at the Naeejah Sewage Treatment Works, located South of Doha. The T.S.E. is pumped back to Doha through rising mains into the T.S.E. Towers. This T.S.E. is then delivered to vegetation areas in Greater Doha through irrigation pipelines or tankers.

The treated sewage effluent is exclusively used by the Doha Gardens Section of the Doha Municipality for the irrigation of public parks, roundabouts and roadside trees. The irrigation network is constructed and commissioned by the Civil Engineering Department of the Ministry of Public Works; and is handed over to the Garden's Section for Operation. The network is continually expanding as it is planned to completely phase out the tanker service. Daily production figures of the T.S.E, Irrigation pipelines details and layouts were obtained from CED engineers.

Data obtained from The Doha Municipality included an indication of where TSE, desalinated water and well water was used for irrigation. In addition estimates of irrigation demand for planted areas were given and have been adopted for this study. This section of the report only covers T.S.E. usage and other types of water used for irrigation will be covered in other appropriate sections.

E.2 T.S.E. PRODUCTION

The daily average production of T.S.E. at the Naeejah Sewage Works for the summers and winters of 1988 and 1989 were as follows:-

Year	Summer	Winter
	m^3/day	m^3/day
1988	15,200	12,520
1989	14,748	11,803

The average daily production of T.S.E. at the Naeejah Sewage Treatment Works for 1988 is given below in Table No. E.1.

TABLE E.1

THE AVERAGE DAILY RETURN OF TSE TO DOHA

Year	Month	Treated Return Effluent to Doha m^3/day	Comments
1988	January	12,700	
	February	11,210	
	March	12,530	
	April	14,780	
	May	16,411	1988 Total TSE
	June	14,600	Retruned to
	July	14,870	Doha =
	August	16,120	4,996,130 m^3
	September	14,010	
	October	14,160	
	November	10,890	
	December	11,370	
1989	January	11,340	
	February	11,780	
	March	10,690	
	April	12,550	
	May	11,800	1989 Total TSE
	June	15,150	Returned to
	July	15,760	Doha =
	August	15,850	4,846,516 m^3
	September	15,250	
	October	14,680	
	November	13,090	
	December	11,370*	

* Assumed figure

Sources : CED, Doha South Sewage Treatment Works

E.3 THE T.S.E. IRRIGATION SYSTEM

The TSE Irrigation System consists of four concrete Towers, rising mains and irrigation mains which have been extended since the ASCO study of 1982/83, refer to drawing TSE1.

On a similar basis as adopted for the water mains in Doha and allowing for deterioration of mains over the last 7 years we would estimate a loss from the system of 15 - 20% of annual flow. It is assumed that 95% of this loss recharge the groundwater and taken as 0.95 m^3/yr distributed evenly over the routes of the TSE mains.

E.4 T.S.E. TANKER SERVICE

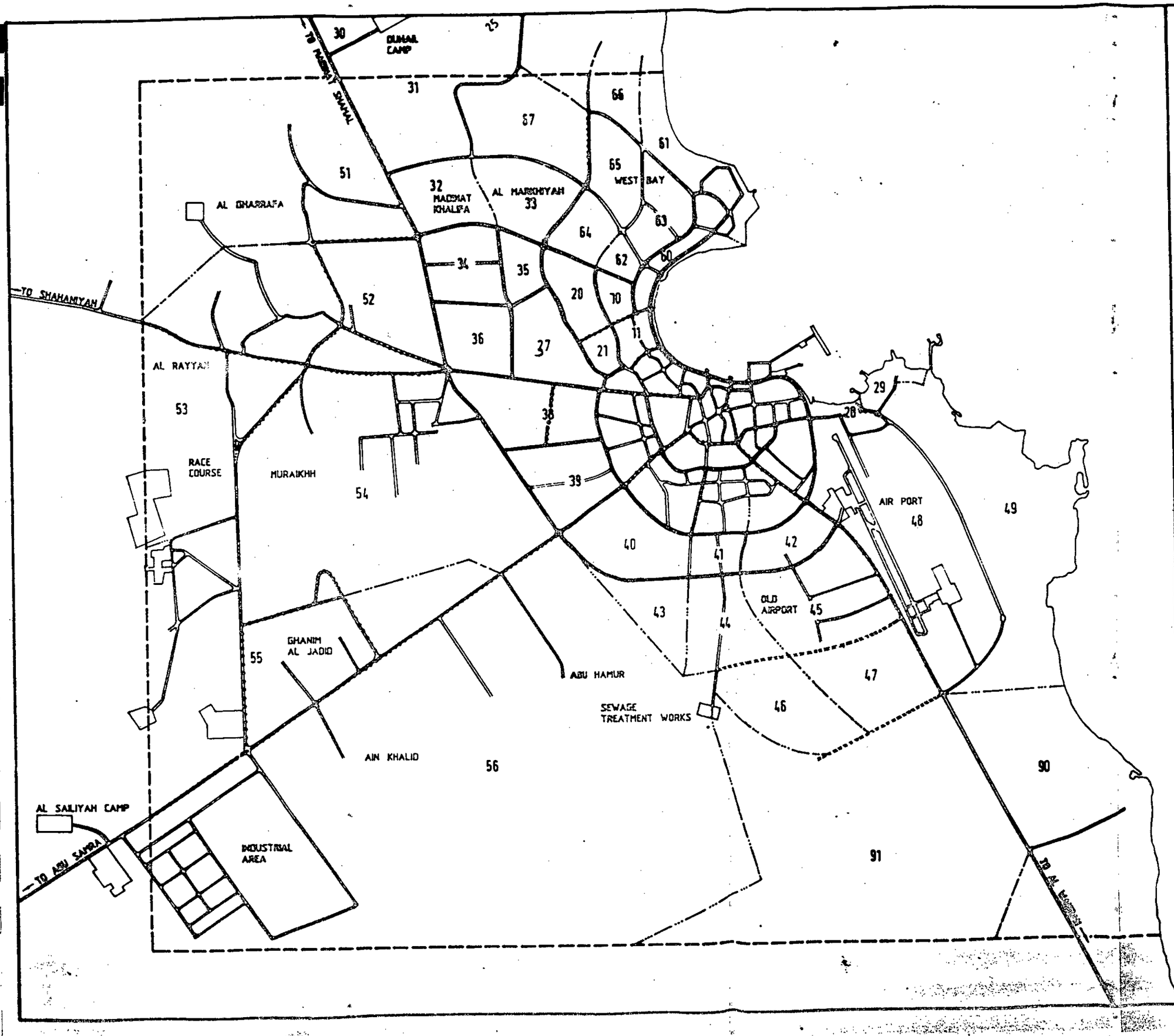
A number of roads in Doha, and all planted roads in Rayyan, Gharrafa, Salwa and Ghanim Jadeed areas are still supplied by tankers.

E.5 VEGETATION

T.S.E. is basically used in watering two types of vegetation (a) roads trees and (b) parks, gardens and roundabouts. Both types of vegetation are described below.

E.5.1 Road Trees

Generally roads are planted with three rows of trees, one along the central reservation and one row along each side of the carriageway. Arrangement of trees and their densities vary from road to road and so does the tree and flower bed species. The following types of tree arrangements were identified in the study area and are shown in Table E.2.



NOTES:

LEGEND:

——— ROADS WATERED BY TSE IRRIGATION SYSTEM

••••••••• ROADS WATERED BY TSE TANKERS

STATE OF QATAR
MINISTRY OF PUBLIC WORKS
Civil Engineering Department

BALFOURS International
CONSULTING ENGINEERS
P.O. BOX 6650. DOHA QATAR.

SCHEME

~~WESTERN~~ DOHA GROUNDWATER STUDY

TITLE

TSE WATERED ROADS

DRAWN	CHECKED	CONTRACT No.	
AAP	JJ		
SCALE		PROJECT No. 0/6[illegible]3	
DRAWING No. TSE 1		JOB No.	ISSUE

TABLE E.2

TYPES OF TREE ARRANGEMENTS
ALONG ROADS (DENSITIES)

Type	Central Reservation: Row of Trees	Sides: Rows of Trees
A	Two	Two: One each side
B	One + Grass	Two: One each side
C	One	Two: One each side
D	One	Not Planted
E	Flower Beds only	Not Planted
F	Not Planted	Two: One each side
G	Flower Beds	One: One each side
H	One + Grass	Not planted

E.5.2 Public Parks

The main park where T.S.E. is used at the present time is Montazah Park. Montazah Park, which is located between the "B" and "C" Ring Roads in Doha. Doha Gardens Section indicated that the older part (approximately 40,000 m^2) of which about 37,000 m^2 is planted mainly depends on T.S.E. for its watering while the new part is entirely watered with potable water from the distribution system.

E.5.3 Gardens and Roundabouts

The majority of roundabouts and gardens for Government Buildings are watered with potable water direct from the Water Distribution Mains but there are a few which depend upon the T.S.E. These are listed in Table E.3.

E.5.4 Farms

Four farms in the Central Doha area are watered by T.S.E. and they have a combined gross area of 68.1 hectares. From the water used on the other farms in the area it can be estimated that the application rate on this area is 4.473 metres/year on the 10% effective area.

The annual applied volume is therefore:-
10% x 68.1 x 4.473 m = 304,658 m^3/year

The evapotranspiration is 1,700 m of the effective area:
10% x 68.1 x 1.700 m = 115,770 m^3/year

Giving a recharge in the area of the farms of 188,888 m^3/year

E.6 WATERING POLICY AND DAILY CONSUMPTION

As mentioned earlier the Doha Garden Section uses T.S.E. to water two types of vegetation (a) Road Trees and (b) Parks, Gardens and Roundabouts. As indicated in ASCO's report Doha Gardens Section policy is to water parks, gardens and roundabouts daily, six days a week, and to water trees twice a week during the winter months and three times during summer months. There are approximately (22,000) trees within the study area, which are watered by the irrigation mains and tankers.

From the ASCO study it was indicated that the Doha Garden Section provide between 60 and 200 gallons of T.S.E. for every tree per week. For the purpose of this study the same applicatons rate of 550 l/wk in the winter and 820 l.wk in the summer for tree watering has been adopted. The spacing of trees along roads was also investigated and it was found that trees are spaced a 8 m apart on average. Various roads were found to have different types of tree arrangements along the central reservation and sides, these are listed in Table E.2.

Where quantities of T.S.E. used were not given by the Doha Gardens Section it was calculated in the following manner:-

a) Trees

Number of trees in row
1 km long = 1000 m

= 125 trees

8 m/tree

Number of gallons of T.S.E.
used per week in a road with
3 rows of trees 2 kms long = 125 x 3 x 2 x 820
= 307 m^3/wk

TABLE E.3

PARKS, GARDENS, ROUNDABOUTS AND
ROADS WATERED WITH T.S.E.

Name/Ref	Type	Area (m^2) [No. of trees]	Av. Consumption m^3/D
A-Ring Road			
A2 - A3	D	[110]	12.55
A3 - A4	D	[110]	12.55
A9 - A10	H	(5,000) [44]	72.00
A10 - A11	E	(4,500) [28]	65.00
A11 - A12	H	(10,500) [83]	152.00
A12 - A13	H	(5,400) [25]	78.00
B-Ring Road			
B2 - B5	D	[220]	25.00
B5 - B6	E	(1,379)	20.00
B8 - B9	E	(1,860)	27.00
B9 - B10	E	(2,700)	39.00
B10 - B11	E	(1,620)	23.00

Name/Ref	Type	Area (m^2) [No. of trees]	Av. Consumption m^3/D
C-Ring Road			
CR1 - C2	D/1	[331]	44.45
C2 - C6	D	[850]	114.16
C6 - C7	B	(8,962) [532]	153.50
C7 - C8	C	[107]	14.37
C9 - C12	H	[395]	53.05
C12 - C13	C	[763]	102.47
D-Ring Road			
D1 - D2	D/1	(1,212) [319]	67.97
D2 - D3	D/1	(610) [149]	33.51
D3 - D4	H	(1,310) [358]	74.68
D4 - D5	C	[123]	13.40
D5 - D6	C	[159]	17.23
D6 - D9	C/D	[644]	69.89
D9 - D11	C	[808]	88.08
D11 - D12	D	[151]	17.23
Corniche			
CR1 - CR4	C	(3,593) [367]	52.27
CR4 - CR6	B	(2,195) [200]	31.93
CR6 - CR7	B	(31,070) [96]	451.98
CR7 - CR9	A	(65,520) [436]	950.00
CR9 - CR10	A	(22,483) [213]	326.00
CR10 - CR11	A	(41,379) [356]	600.00
CR11 - CR12	C	[662]	75.51

Name/Ref	Type	Area (m^2) [No. of trees]	Av. Consumption m^3/D
Muntazah Road			
C4 - B4	E	(2,320)	33.65
G. H. Avenue			
CR5 - A3	E	(4,000) [76]	64.00
Rayyan Road			
C8 - D9	D/C	(3,602) [358]	52.40
D9 to Dukhan R/A	D	[401]	45.74
Salwa Road			
BC5.1 - C6		[63]	7.19
C6 - S4	D	[2,050]	233.83
Rayyan Area			
Gharrafa R/A to MOE Dormitories	C	[568]	64.75
MOE Dormitories to Sh Khalid Roundabout	C	[554]	63.19
Sh Kalid R/A to Attiyah P. Station	F	[107]	12.20
Attiyah P. Station to Racecourse	C	[874]	99.69
Ghanim El Jadid			
Khalifa Stadium Road and Zoo Roads	D	[778]	88.74

Name/Ref	Type	Area (m^2) [No. of trees]	Av. Consumption m^3/D
Miscellaneous Roads			
D11 - C12 - A10	D/C/A	[1,428]	162.88
D10 - V2	C	[820]	93.53
V2 - C11	C	[196]	22.36
V4 - V2	C	[425]	48.48
V2 - V1	C	[837]	95.47
C10 - A9	E	(2,124)	30.80
CD7.1 - CD8.1	F	[343]	39.29
D7 - C7	D	[397]	45.28
C2 - B3	H	(4,389) [163]	63.84
C2 - D1	E	(1,175) [97]	17.09
B2 - GH2	H	[276]	31.48
D7 - FI	C	[1,113]	126.95
C1 - AIR/RA	-	[147]	16.77
BC5.1 - BC6.1	D	[135]	15.40
B7 - CR8	D	[108]	12.32
CRA1 - CRA2	C	[120]	13.69
A12 - CR11	G	(3,793) [46]	55.00
CR6 - CR6.2	E	(700)	10.00
CR12 - A13	E	(2,069)	30.00
R/Abouts			
A-Ring Road			120
B-Ring Road			100
C-Ring Road			324
D-Ring Road			550
Corniche			358
Miscellaneous		(12,000)	256

Name/Ref	Type	Area (m^2) [No. of trees]	Av. Consumption m^3/D
Special Cons.			
H.H. Emirs Office Northern Garden		(34,000)	228
Montazah Park		(37,000)	420
Hamad Hospital		(12,533)	27
Khalifa Park		(85,050)	278
Khalifal Al Jadded		(24,641)	218
Racecourse		(4,551)	66
Attiyah Petrol Station		(3,850)	46
Wholesale Market		(42,660)	436
Wholesale Market		[235]	26
Rumaillah Hospital		[252]	29

b) Parks and Roundabouts

As for parks and roundabouts it was attempted to establish a rate (litres/square meter) from bulk quantities of T.S.E. used in parks of known areas given by the Gardens Section, but it was found that these rates varied widely. The rate of 11 litres per metre square per day for winter and 18 litres per square metre per day based on a six day week was used. This rate was established in the Qatar Water Master Plan.

The estimated annual usage of T.S.E. is therefore calculated as:-

Losses	1.00 Mm^3/year
Farm Irrigation	0.30 Mm^3/year
Watering	3.30 Mm^3/year
Total	4.60 Mm^3/year

This compares with an amount supplied of 5.0 Mm^3/year. The difference is assumed to be a recharge uniformly spread over the irrigated areas.

E.7 EVAPOTRANSPIRATION AND RECHARGE

E.7.1 Evapotranspiration for a mature date palm under ideal watering conditions varies between 900 - 1300 mm per annum and for a deciduous tree from 700 - 1050 mm per annum. The measurement being per square metre of spread of the branches.

The majority of the trees under consideration are mature and therefore a figure of 1000 mm/year for evapotranspiration will be taken as an average on a spread of four square meters per tree. The total evapotranspiration is therefore:-

$$22{,}000 \times 4\ m^2 \times 1.0\ m = 88{,}000\ m^3/year \text{ or } 0.088\ Mm^3/year.$$

Due to the "ponding" method of irrigation there is a loss due to direct evapotranspiration which is taken as 25% of the pond (i.e. 4 square meters/tree) at 67.5% of the Mean Open Water Evaporation which takes account of the number of waterings during the year.

$$25\% \times 22{,}000 \times 4\ m^2 \times 67.5\% \times 2.52\ m = 37{,}422\ m^3/Year = 0.037\ Mm/Year$$

This gives a total evapotranspiration and ponding losses of 0.125 Mm^3/year.

E.7.2 Grassed Areas

The watering for grassed areas is above that required for maximum growth and therefore the evapotranspiration is the annual amount for grass used elsewhere in the report (i.e. 1100 mm/year) plus an amount for ponding. This amount for ponding is taken as 67.5% of the Mean Open Water Evaporation on 10% of the area.

This gives a total evapotranspiration for grassed areas of:-

$491,688\ m^2 \times 1.100\ m + 10\% \times 491,688\ m^2 \times 67.5\% \times 2.526\ mm$

$= 540,856 + 83,835$
$= 0.625\ Mm^3/Year$

The recharge to ground water is the amount used for irrigation less evapotranspiration and losses. Thus the recharge to groundwater is as follows:-

$4.99 - (0.123 + 0.12 + 0.05 + 0.625) = 4.07\ m^3/year.$

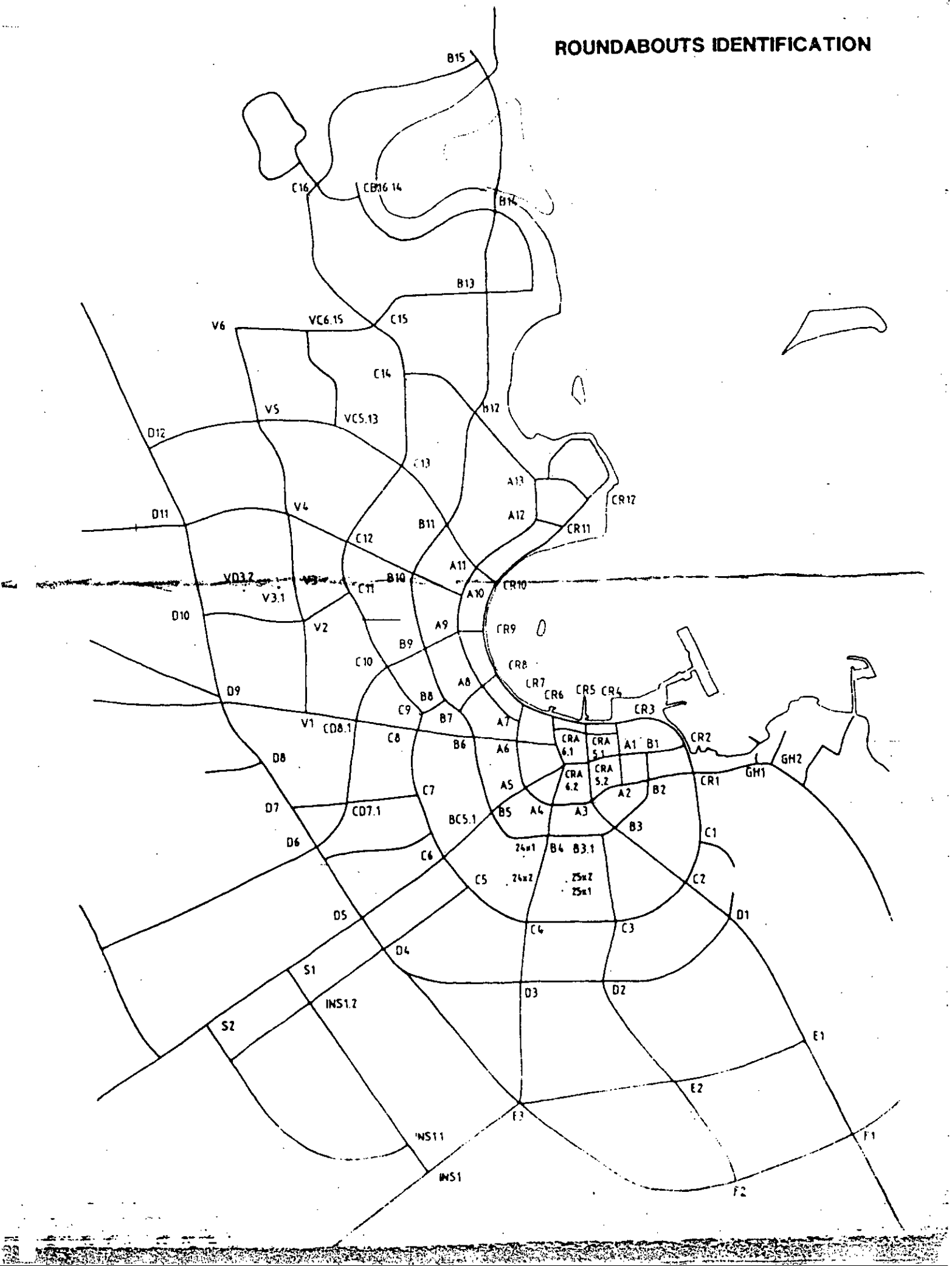
E.9 ZONAL RECHARGE TO GROUNDWATER

The following table lists the total recharge from TSE in each QARS Zone which consists of recharges from irrigation return and system losses as estimated for 1988.

Qars Zone No.	Total TSE Recharge m^3
1	36,220.32
2	216,632.88
3	2,731.73
4	0.00
5	13,581.62
6	15,519.89
7	30,756.86
8	0.00
9	0.00
10	65,115.37
11	230,283.18
12	209,511.53
13	6,221.16
14	20,276.68
15	26,797.77
16	20,013.09
17	40,626.76
18	26,405.69
19	19,587.79
20	45,376.03
21	118,986.31
22	37,854.80
23	73,134.24
24	218,397.83
25	48,520.18

Qars Zone No.	Total TSE Recharge m^3
26	49,405.69
27	63,976.15
28	28,206.97
29	0.00
30	0.00
31	0.00
32	232,858.70
33	47,418.38
34	79,182.39
35	49,651.05
36	85,763.61
37	40,553.36
38	89,343.21
39	110,027.53
40	108,424.13
41	58,614.92
42	72,356.89
43	36,190.32
44	26,118.47
45	47,801.54
46	0.00
47	13,247.47
48	65,747.94
49	0.00
50	0.00
51	34,416.67
52	93,616.47
53	133,403.01
54	119,003.33
55	36,351.59
56	259,526.76
57	0.00
58	0.00
59	0.00
60	523,484.34
61	101,605.14
62	37,993.44
63	58,516.74
64	55,091.50
65	0.00
66	0.00
67	0.00
TOTAL	4,080,449.00

ROUNDABOUTS IDENTIFICATION



QARS ZONE	RECHARGE	A-RING	B-RING	C-RING	D-RING	CORN	MISC	FARMS	TOTAL
1	14026.12					16379.37	5814.83		36220.32
2	198315.23					16379.37	1938.28		216632.88
3	793.45						1938.28		2731.73
4									0.00
5	7358.34	4285.00					1938.28		13581.62
6	7358.34	4285.00					3876.55		15519.89
7	12439.21					16379.37	1938.28		30756.86
8									0.00
9									0.00
10	36544.88	4285.00	4029.58			16379.37	3876.55		65115.37
11	210027.26					16379.37	3876.55		230283.18
12	207573.26						1938.28		209511.53
13	2191.58		4029.58						6221.16
14	2755.10		4029.58					13492	20276.68
15	4991.19	4285.00	4029.58					13492	26797.77
16	2236.09	4285.00						13492	20013.09
17	8817.12					16379.37	1938.28	13492	40626.76
18	10026.32					16379.37			26405.69
19	3208.42					16379.37			19587.79
20	27605.81		4029.58	9864.09			3876.55		45376.03
21	103154.36		4029.58	9864.09			1938.28		118986.31
22	8530.86		4029.58	9864.09			1938.28	13492	37854.80
23	41872.02		4029.58	9864.09			3876.55	13492	73134.24
24	189073.88		4029.58	9864.09			1938.28	13492	218397.83
25	17257.96		4029.58	9864.09			3876.55	13492	48520.18
26	20081.74		4029.58	9864.09			1938.28	13492	49405.69
27	26879.42			19728.18			3876.55	13492	63976.15
28	6012.77					16379.37	5814.83		28206.97
29									0.00
30									0.00
31									0.00
32	13047.47				17872.96		1938.28		32858.70
33	35616.02			9864.09			1938.28		47418.38
34	55494.60				17872.96		5814.83		79182.39
35	33972.14			9864.09			5814.83		49651.05
36	62075.83				17872.96		5814.83		85763.61
37	40553.36								40553.36
38	55791.33			9864.09	17872.96		5814.83		89343.21
39	84921.93			9864.09	17872.96		3876.55	13492	110027.53
40	47383.85			9864.09	35745.91		1938.28	13492	108424.13
41	17385.87			9864.09	17872.96			13492	58614.92
42	29189.56			9864.09	17872.96		1938.28	13492	72356.89
43	18317.36				17872.96				36190.32
44	8245.51				17872.96				26118.47
45	27990.31				17872.96		1938.28		47801.54
46									0.00
47	11309.19						1938.28		13247.47
48	48130.75			9864.09			7753.10		65747.94
49									0.00
50									0.00
51	14605.44				17872.96		1938.28		34416.67
52	67990.40				17872.96		7753.10		93616.47
53	129526.46						3876.55		133403.01
54	75504.32				35745.91		7753.10		119003.33
55	32475.04						3876.55		36351.59
56	239715.52				17872.96		1938.28		259526.76
57									0.00
58									0.00
59									0.00
60	475932.31	12855.01				32758.74	1938.28		523484.34
61	79002.49	4285.00				16379.37	1938.28		101605.14
62	27740.58	4285.00	4029.58				1938.28		37993.44
63	49946.73	8570.01							58516.74
64	39259.56		4029.58	9864.09			1938.28		55091.50
65									0.00
66									0.00
67									0.00

REF/ NAME	QARS ZONE	TOTAL IRRIGATION m^3/d	TOTAL IRRIGATION m3/yr	TOTAL ADD IRR m3/yr	TREES (NO.)	AREA IRRIGATED (m^2)	EVAPOR TREES	EVAPOR GRASS	NET IRRIGATION	NET IRRIGATION MAINS	LOSSES	RECHARGE m3/yr
A2 - A3	6, 16	12.55	4580.75	5099.28	110	0	627.11	0.00	4472.17		0.00	4472.17
A3 - A4	5, 15	12.55	4580.75	5099.28	110	0	627.11	0.00	4472.17		0.00	4472.17
A9 - A10	10, 60	72.00	26280.00	29254.85	44	5000	250.84	6352.53	22651.48	22651.48	8500.11	31151.59
A10 - A11	62, 60	65.00	23725.00	26410.62	28	4500	159.63	5717.27	20533.72	20533.72	7705.41	28239.14
A11 - A12	63, 60	152.00	55480.00	61760.23	83	10500	473.18	13340.30	47946.75	47946.75	17992.33	65939.07
A12 - A13	63, 61	78.00	28470.00	31692.75	25	5400	142.53	6860.73	24689.50	24689.50	9264.89	33954.39
B2 - B5	14, 15, 24, 25, 26	25.00	9125.00	10157.93	220	0	1254.22	0.00	8903.71	8903.71	3341.18	12244.89
B5 - B6	13, 22, 23	20.00	7300.00	8126.35	0	1379	0.00	1752.03	6374.32	6374.32	2392.00	8766.32
B8 -B9	21	27.00	9855.00	10970.57	0	1860	0.00	2363.14	8607.43	8607.43	3229.99	11837.42
B9 - B10	10, 20	39.00	14235.00	15846.37	0	2700	0.00	3430.36	12416.01	12416.01	4659.19	17075.20
B10 - B11	64, 62	23.00	8395.00	9345.20	0	1620	0.00	2058.22	7287.08		0.00	7287.08
CR1 - C2	27, 48	44.45	16224.25	18060.89	331	0	1887.03	0.00	16173.77	16173.77	6069.31	22243.09
C2 - C6	26, 42, 25, 41, 24, 40	114.16	41668.40	46385.18	850	0	4845.85	0.00	41539.33	41539.33	15587.90	57127.24
C6 - C7	39, 23	153.50	56027.50	62369.71	532	8962	3032.93	11386.27	47950.51	47950.51	17993.74	65944.25
C7 - C8	38, 22	14.37	5245.05	5838.78	107	0	610.01	0.00	5228.77	5228.77	1962.13	7190.90
C9 - C12	21, 20, 35, 37	53.05	19363.25	21555.13	395	0	2251.90	0.00	19303.24	19303.24	7243.67	26546.90
C12 - C13	33, 64	102.47	37401.55	41635.33	763	0	4349.86	0.00	37285.47	37285.47	13991.62	51277.09
D1 - D2	42, 45	67.97	24809.05	27617.39	319	1212	1818.62	1539.85	24258.92	24258.92	9103.32	33362.23
D2 - D3	41, 44	33.51	12231.15	13615.69	149	610	849.45	775.01	11991.24	11991.24	4499.79	16491.03
D3 - D4	40, 43	74.68	27258.20	30343.78	358	1310	2040.96	1664.36	26638.46	26638.46	9996.25	36634.71
D4 - D5	40, 56	13.40	4891.00	5444.65	123	0	701.22	0.00	4743.43	4743.43	1780.00	6523.43
D5 - D6	39, 54	17.23	6288.95	7000.85	159	0	906.46	0.00	6094.39	6094.39	2286.96	8381.35
D6 - D9	38, 54	69.89	25509.85	28397.52	644	0	3671.44	0.00	24726.07	24726.07	9278.62	34004.69
D9 - D11	52, 34, 36	88.08	32149.20	35788.43	808	0	4606.41	0.00	31182.02	31182.02	11701.26	42883.28
D11 - D12	51, 32	17.23	6288.95	7000.85	151	0	860.85	0.00	6140.00		0.00	6140.00
CR1 - CR4	17, 28, 19, 18	52.27	19078.55	21238.21	367	3593	2092.27	4564.92	14581.01	14581.01	5471.62	20052.63
CR4 - CR6	1, 7	31.93	11654.45	12973.71	200	2195	1140.20	2788.76	9044.75	9044.75	3394.10	12438.86
CR6 - CR7	2	451.98	164972.70	183647.30	96	31070	547.30	39474.59	143625.41	143625.41	53896.37	197521.78
CR7 - CR9	11, 12	950.00	346750.00	386001.44	436	65520	2485.64	83243.49	300272.32	300272.32	112679.14	412951.46
CR9 - CR10	60	326.00	118990.00	132459.44	213	22483	1214.31	28564.76	102680.37	102680.37	38531.47	141211.84
CR10 - CR11	60	600.00	219000.00	243790.38	356	41379	2029.56	52572.23	189188.60	189188.60	70994.25	260182.85
CR11 - CR12	61	75.51	27561.15	30681.02	662	0	3774.06	0.00	26906.96	26906.96	10097.01	37003.97
C4 - B4	24, 25	33.65	12282.25	13672.58	0	2320	0.00	2947.57	10725.01		0.00	10725.01
CR5 - A3	1, 7, 5, 6	64.00	23360.00	26004.31	76	4000	433.28	5082.02	20489.01		0.00	20489.01
C8 - D9	36, 37, 38	52.40	19126.00	21291.03	358	3602	2040.96	4576.36	14673.71	14673.71	5506.40	20180.11
D9 - Dukhan R/A	52, 53, 54	45.74	16695.10	18584.95	401	0	2286.10	0.00	16298.85		0.00	16298.85
BC5.1 - C6	23, 24	7.19	2624.35	2921.42	63	0	359.16	0.00	2562.26	2621.00	983.55	3545.81
C6 - S4	56, 55, 54, 39, 40	233.83	85347.95	95009.18	2050	0	11687.05	0.00	83322.13		0.00	83322.13
			0.00	0.00			0.00	0.00	0.00		0.00	0.00
Gharrafa R/A			0.00	0.00			0.00	0.00	0.00		0.00	0.00
to NOE			0.00	0.00			0.00	0.00	0.00		0.00	0.00
Dormitories	51, 52	64.75	23633.75	26309.05	568	0	3238.17	0.00	23070.88		0.00	23070.88
			0.00	0.00			0.00	0.00	0.00		0.00	0.00
NOE Dormitories			0.00	0.00			0.00	0.00	0.00		0.00	0.00
to Sh Khalid R/A	52	63.19	23064.35	25675.19	554	0	3158.35	0.00	22516.84		0.00	22516.84
			0.00	0.00			0.00	0.00	0.00		0.00	0.00
Sh Khalid R/A			0.00	0.00			0.00	0.00	0.00		0.00	0.00
to Attiyah P. Station	52	12.20	4453.00	4957.07	107	0	610.01	0.00	4347.06		0.00	4347.06
			0.00	0.00			0.00	0.00	0.00		0.00	0.00
Attiya P. Station			0.00	0.00			0.00	0.00	0.00		0.00	0.00
to Racecourse	53, 54	99.69	36386.85	40505.77	874	0	4982.67	0.00	35523.10		0.00	35523.10
			0.00	0.00			0.00	0.00	0.00		0.00	0.00
Khalifa Stadium			0.00	0.00			0.00	0.00	0.00		0.00	0.00
Road and Zoo Road	54, 55	88.74	32390.10	36056.60	778	0	4435.38	0.00	31621.22		0.00	31621.22
			0.00	0.00			0.00	0.00	0.00		0.00	0.00
D11 - C12 - A10	32, 33, 64, 62, 34, 35, 20, 10	162.88	59451.20	66180.96	1428	0	8141.03	0.00	58039.93	58039.93	21779.86	79819.80
D10 - V2	34, 36	93.53	34138.45	38002.86	820	0	4674.82	0.00	33328.04	33328.04	12506.56	45834.60
V2 - C11	35, 37	22.36	8161.40	9085.25	196	0	1117.40	0.00	7967.86	7967.86	2989.99	10957.85
V4 - V2	34, 35	48.48	17695.20	19698.26	425	0	2422.93	0.00	17275.34	17275.34	6482.68	23758.02
V2 - V1	36, 37	95.47	34846.55	38791.11	837	0	4771.74	0.00	34019.38	34019.38	12765.99	46785.37
C10 - A9	20, 10, 21, 11	30.80	11242.00	12514.57	0	2124	0.00	2698.55	9816.02		0.00	9816.02
CD7.1 - CD8.1	38	39.29	14340.85	15964.21	343	0	1955.44	0.00	14008.76		0.00	14008.76
D7 - C7	38, 39	45.28	16527.20	18398.05	397	0	2263.30	0.00	16134.75	16134.75	6054.67	22189.42
C2 - B3	26, 27	63.84	23301.60	25939.30	163	4389	929.26	5576.25	19433.79		0.00	19433.79
C2 - D1	42, 48	17.09	6237.85	6943.96	97	1175	553.00	1492.84	4898.12	4898.12	1838.05	6736.17
B2 - GH2	17, 28, 48	31.48	11490.20	12790.87	276	0	1573.48	0.00	11217.39		0.00	11217.39
D7 - F1	45, 47, 48	126.95	46336.75	51581.98	1113	0	6345.21	0.00	45236.77		0.00	45236.77
C1 - AIR/RA	48	16.77	6121.05	6813.94	147	0	838.05	0.00	5975.89	5975.89	2242.49	8218.39
BC5.1 - BC6.1	22, 23	15.40	5621.00	6257.29	135	0	769.64	0.00	5487.65		0.00	5487.65
B7 - CRA2	11, 12, 1, 7	12.32	4496.80	5005.83	108	0	615.71	0.00	4390.12		0.00	4390.12
A12 - CR11	60, 61	55.00	20075.00	22347.45	46	3793	262.25	4819.03	17266.18	17266.18	6479.25	23745.43
CR6 - CR6.2	1, 2, 3	10.00	3650.00	4063.17	0	700	0.00	889.35	3173.82		0.00	3173.82
CR12 - A13	61	30.00	10950.00	12189.52	0	2069	0.00	2628.67	9560.84	9560.84	3587.77	13148.61
A-Ring Road		120.00	43800.00	48758.08	0	2000	0.00	2541.01	46217.07	13865.12	5202.98	51420.04
B-Ring Road		100.00	36500.00	40631.73	0	2000	0.00	2541.01	38090.72	38090.72	14293.79	52384.51
C-Ring Road		324.00	118260.00	131646.81	0	2000	0.00	2541.01	129105.80	129105.80	48447.79	177553.59
D-Ring Road		550.00	200750.00	223474.52	0	2000	0.00	2541.01	220933.51	220933.51	82906.73	303840.24
Corniche		358.00	130670.00	145461.60	0	2000	0.00	2541.01	142920.59	142920.59	53631.88	196552.46
Miscellaneous		256.00	93440.00	104017.23	0	2000	0.00	2541.01	101476.22	101476.22	38079.61	139555.83
			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
H.H. Emirs Office			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Northern Garden	21	228.00	83220.00	92640.35	0	34000	0.00	43197.17	49443.18	49443.18	18553.87	67997.05
			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Montazah Park	24	420.00	153300.00	170653.27	0	37000	0.00	47008.69	123644.58	123644.58	46398.43	170043.02
			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Hamad Hospital	27	50.00	18250.00	20315.87	0	12533	0.00	15923.24	4392.63	4392.63	1648.36	6040.99
			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Khalifa Park	56	300.00	109500.00	121895.19	0	85050	0.00	108056.45	13838.74	13838.74	5193.08	19031.82

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			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Khalifal Al Jadded	53	218.00	79570.00	88577.17	0	24641	0.00	31306.51	57270.66	57270.66	21491.19	78761.85
			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Racecourse	53	66.00	24090.00	26816.94	0	4551	0.00	5782.07	21034.87	21034.87	7893.47	28928.35
			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Attiyah Petrol Station	56	46.00	16790.00	18690.60	0	3850	0.00	4891.44	13799.15	13799.15	5178.22	18977.37
			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Wholesale Market	56	436.00	159140.00	177154.35	0	42660	0.00	54199.74	122954.60	122954.60	46139.51	169094.12
			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Wholesale Market	56	26.00	9490.00	10564.25	235	0	1339.74	0.00	9224.51	9224.51	3461.56	12686.07
			0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00
Rumaillah Hospital	21	29.00	10585.00	11783.20	252	0	1436.65	0.00	10346.55	10346.55	3882.61	14229.16
		9087	3316792	3692246	21486	491750	122492	624771	2944983	2529640	949264	3894247
				999226					949264		2944983	188888
				304658					188888		3894247	
				4996130					4083135			4083135

APPENDIX F

APPENDIX "F"

METHODOLOGY

F.1 METHOD ADOPTED TO ASSESS PRESENT WATER CONSUMPTION

In order to produce a basis for the estimation of water consumption, it is clearly necessary to obtain full information regarding present consumption, not only in overall terms, but district by district in the case of the study area. Unfortunately no district meters have been installed anywhere in Doha or for that matter elsewhere in the country, and thus no direct information was available on which to base estimates of present consumption.

The usual approach in these circumstances is to sub-divide the whole study area into districts of similar characteristics, to estimate the population in each district, and then to apply a per capita allowance appropriate to districts with those particular characteristics. Additions are then made for special consumers and to allow for losses.

If reliable data is available on the total quantity of water supplied, an overall check can be carried out by comparing this with the aggregate of the estimated consumption of all the various districts. This gives at least some assurances that the estimates are of the right order.

F.2 UTILISATION OF LAND USE SURVEY

The above procedure was in fact followed, but with certain modifications due to difficulties in determining representative per capita allowances for individual districts. This difficulty arose from three special circumstances:-

a) One somewhat unusual characteristic of housing development in Qatar is that individual districts frequently contain houses of many different types. In many cases large villas are in close proximity to blocks of flats or low income housing.

b) Domestic consumption per capita varies widely ranging from 50 litres per day for immigrant workers in crowded living quarters rising probably to 500 litres per day for the residents of large villas with all modern water - using appliances and frequently with swimming pools.

c) A large proportion of the total water consumption is used for watering gardens, and the quantity used is related more to the type of house and area of the garden than on the number of occupants.

In view of the above factors, it was considered that better results could be obtained by assessing appropriate water consumption for each type of house rather than on a per capita basis. The adoption of this variation to the normal procedure was facilitated as far as the study area was concerned by data on housing, which was given in the 1986 Census conducted by the Central Statistical Organisation.

F.3 WATER CONSUMPTION FOR STANDARD TYPES OF PROPERTY

A) Classification of property

The Census for Doha referred to above subdivides dwellings into four categories:

a) Arab type houses
b) Flats
c) Villas
d) Large Villas and Palaces

Table F.1 below summarises the characteristics of each type of dwelling:

TABLE F.1

TYPE OF DWELLING	DESCRIPTION	OCCUPANCY RATE	WATER CONSUMPTION RATE DOMESTIC m^3/day	GARDEN m^3/day	REMARKS
1 Arab House	This is a traditional Arab house with wide internal size-able open spaces often planted with trees for shade These are found in older parts of the Study Area.	6 to 8 depending upon location and nature of neighbour-hood	2.0	0.30	The high rates of occupancy and water consumption were used for such areas as Doha Jadeed, Farique Abdul-Aziz and Umm Ghuwailina where large number of immigrant labour are concentrated.
2 Flats	Mainly new residential blocks	5.0	1.20	0	-
3 Villas (Small & medium size)		5 to 6	1.70	1.00	Considerably high rate of water consumption was registered at Villas with gardens

TABLE F.1 (Contd.)

TYPE OF DWELLING	DESCRIPTION	OCCUPANCY RATE	WATER CONSUMPTION RATE DOMESTIC m^3/day	GARDEN m^3/day	REMARKS
4 Large Villas & Palaces		12 - 20	7.0	20.0	The major part of potable water consumption is used in gardening.
5 Special consumers	These are hotels guest palaces, extra large palaces, army and labour camps	see note below	see note below	see note below	

B. Method of Assessment

Normally consumption can be established reasonably accurately from records of water consumed at a number of dwellings of each type. Not all dwellings in the study area are metered, however, sample meter readings for each house type were obtained from the Ministry of Electricity and Water, Consumer Affairs Section. From the information obtained estimates of water consumption were made for the various types of dwellings in the study area.

It should be appreciated that the unit quantities estimated represent nett consumption (i.e. the quantity needed for use). It does not include water which is wasted either in the form of leakage from service pipes, overflowing tanks, or excessive watering of gardens. An allowance for this wasted water under the heading of "Losses" is made separately.

C. Arab Type Houses in Study Area

The number of occupants of this type of house varies appreciably. An average of 7.5 persons per house was adopted by the Town Planners for houses within the "C" Ring Road and 5 persons per dwelling elsewhere. We have used somewhat similar figures ranging from 8 persons per house for central areas to 6 persons per house near the outskirts of the town. On this basis, the nett consumption per house would range from 2000 litres per day to 1500 litres per day.

However, many of the Arab type houses, particularly those outside the "B" Ring Road have small gardens for a few trees, and it would be reasonable to allow 200 - 300 litres per day for watering these.

An overall consumption of between 1800 and 2300 litres per day has therefore been made for this type of house in the Doha area. The higher figures are used for houses nearer the town centre, as these are frequently occupied by large numbers of immigrant workers and the occupancy rate may possibly be even higher than the average of 8.0 adopted above.

D Flats

For the assessment of peak consumption a figure of 1200 litres per day per flat has been used, which represents a per capita usage of 266 litres per day during peak periods.

E Villas

For purposes of assessing water consumption, as no distinction between large and small villas is made in the Census, Villas have been considered all the same but consumption has been taken as the average for small and large villas:

a) Small Villas

These are usually constructed in estates with plots averaging 400 square metres in area. Occupants have generally a low/medium income. Usually a small amount of garden watering is carried out.

For this type of villa a peak consumption of 1700 litres per day has been allowed based on:-

Domestic consumption 5 occupants @ 250 lpd.	=	1250 lpd.
Garden watering 40 m^2 irrigated @ 11 lpd. (see for excess irrigation)	=	440 lpd.
Total	=	1690 lpd.

It will be noted in this respect that the per capita domestic allowance made for these small villas (250 litres per day) is similar to that adopted for the occupants of flats, which is what might be expected.

b) Medium size Villas

Typical villas of medium size are on plots of about 1000 square metres in area, of which perhaps 150 square metres are irrigated. The occupants of this type of villa have generally a medium/high income, and the villas are usually provided with modern water using appliances.

The peak allowance considered appropriate for this type of villa is 3500 litres per day made up from:-

Domestic consumption
6.5 occupants @ 300 lpd = 1950 lpd.

Garden watering
150 m^2 irrigated @ 11 lpd per m^2 = 1650 lpd.
(see L for excess irrigation)
Total = 3450 lpd.

In the 1986 Census, no distinction is made between small villas and medium sized villas, and for purposes of assessing water consumption, the average consumption for small and medium sized villas has been applied.

F. Large Villas and Palaces

The fourth type of classification which is used in the 1986 Census comes under the heading of "Large Villas and Palaces". Many of these have recently been constructed, and no doubt incorporate extensive water using facilities and in many cases have swimming pools.

No reliable information is available on the average number of occupants of these palaces. The Town planners have estimated an average occupancy rate of 10. It is probable that there is a wide variation in occupancy between different palaces, and it is believed that some palace complexes might well have 50 or more occupants.

However, the number of occupants is probably not very significant insofar as by far the largest use for water is for garden watering. The water consumption for this purpose depends on the area irrigated, and it was possible to make an estimate of this from air photographs.

An estimate of consumption for these large villas and palaces has been made on the following bases:-

a) Palaces in small compounds (not exceeding 5000 square metres in area)
Domestic requirements 12 occupants
@ 500 lpd = 6.0 m^3/day
Garden watering
1250 m^2 irrigated @ 11 lpd
per m^2 = 13.75 m^3/day

Total (approx) = 20.0 m^3/day

b) Palaces in large compounds (exceeding 5000 square metres in area)

Domestic requirements 15 occupants
@ 500 lpd = 7.5 m^3/day

Garden watering
2500 m^2 irrigated @
11 lpd. per m^2 = 27.5 m^3/day

Total = 35.0 m^3/day

Note: Some very large Palace complexes or Palaces with an exceptionally large area under irrigation have been treated as "special consumers", and their requirements individually assessed.

G. Water Consumption in Offices

Although comprehensive data is given in the Land Use Survey regarding the amount and distribution of office space in the study area, no direct information was available to determine a suitable figure for water consumption per 1000 square metres of office accommodation. A somewhat indirect method was therefore used to arrive at this figure as follows:

The usual consumption for office workers in the U.K. is 45 - 55 lpd. In Doha, in view of the hotter climate, a slightly higher figure is considered appropriate, and a figure of 60 lpd. has been used.

The Annual Statistical Abstract 1987 gives a total of 32,549 people in Government employment. It is estimated that about 30,000 of these occupy offices in Doha. This figure of 30,000 is similar to that quoted in the 1987 Traffic Study Up-date. This Traffic Study also gives an estimate of the number of people in private offices in Doha (10,000), and having regard to this, the total number of office workers in Doha in 1988 is taken as 40,000.

On the above basis, the total water consumption for office workers amounts to 40,000 @ 60 lpd. = 2400 m^3/day. The total area of office space as derived from the data given in the 1986 Census amounts to 400,000 m^2. A figure of 6.0 m^3/day per 1000 m^2 of office space has therefore been used to assess water consumption in offices in the Doha area.

H. Water consumption in Shops

A similar procedure has been used to estimate the water consumption in shops.

The allowance per shop worker is taken as 60 l.p.d. i.e. similar to that for office workers.

The number of workers in retail and wholesale occupation is taken as 13,000 based on the figure given in the Traffic Study Up-date. The total water consumption for shops would thus amount to 780 m^3/day.

According to the 1986 Census the total shop area in Doha in 1986 amounted to 300,000 m^2, and thus the water requirement per 1000 m^3 of shop area works out at 2.6 m^3/day. An allowance of 3.0 m^3/day has in fact been used for the purpose of the estimates made in this Study.

J. Water consumption in Workshops

The same method of computation was also used to assess the water consumption in workshops per 1000 m^2 of workshop space.

The number of employees in workshops in the Doha area was taken as 5000 based on the figure quoted in the 1987 Traffic Study Update. Allowing a daily consumption rate of 60 l.p.d. as for shop and office workers, then the total consumption in workshops would amount to 300 m^3/day.

The total workshop area in 1986 according to the Census amounted to 260,000 m^2, and the average consumption thus works out at 1.16 m^3/day per 1000 m^2. An allowance of 1.0 m^3/day has in fact been used in the estimates made in this study.

K. Water consumption for Schools

Schools in Qatar are not metered and thus there is no reliable information regarding their water consumption.

In the U.K., a rate of 25 l.p.d. per pupil is frequently adopted as representative of consumption in schools, and the same figure has been adopted as applicable to Qatar.

Available information suggests that the average number of pupils per school in Doha at present is around 1000. On this basis the present water consumption per school is taken as 25 m^3/day.

The Government's present policy is that new schools should be built to accommodate fewer pupils ranging from 480 in Elementary Schools to 360 in Secondary Schools. On this basis, water consumption at such schools would be reduced to between 10 and 12 m^3/day.

However, it is also understood that it is the Government policy to provide all schools in future with a grassed playing area. The water required for the irrigation of this is assessed at 86 m^3/day (based on an area 105 m x 75 m with a rate of application off 11 litres/m^2). Thus the total water consumption at schools in the future is likely to be in the region of 100 m^3/day, and this figure has been adopted for all schools, except those in which there is insufficient space available for such a playing area.

L. Consumption for watering gardens, parks and public open spaces

Data has been obtained from the Doha Municipality which indicates the irrigation demandfor all planted areas within the study area, and has been adopted for this study.

M. Special consumer

There are always a number of special consumers of water, the consumption of whom cannot be estimated by the method applicable to standard types of dwellings as described above, and these have to be assessed on the basis of their individual circumstances.

Normally any major consumers of this type are metered, in which case there is no difficulty in identifying them and assessing their consumption from the meter records. In Doha, however, only a limited number are metered, and the requirements for the others have therefore been estimated largely by judgment and comparison with similar consumers for which information was available. In many instances, the major proportion of consumption is for the watering of large gardens, in which case the estimates were based on the potential area to be irrigated.

A list of the special consumers is given in Water Balance Section together with estimates of their consumption in 1988.

F.4 COMPUTATION OF WATER CONSUMPTION IN THE STUDY AREA

The results obtained by applying the consumption as described above to the data on housing given in the Land Use Survey (projected to 1988) are given in table A.9 (Appendix "A").

As far as the study area is concerned it was convenient to use the same districts (QARS zones) as were used in the Up-dated Land Use Survey with the same reference numbers. The system of sub-division is shown on Figs. M2, M3. This system has an added advantage of similarity with the computer model grid. The 1988 consumption in each Zone were determined by applying the appropriate allowance per house (as assessed above) to the number of dwellings of each type as given in the Land Use Survey. The consumption of any special consumers in each Zone have also been included.

F.5 COMPARISON OF COMPUTED CONSUMPTION IN 1988 WITH TOTAL QUANTITY ACTUALLY SUPPLIED

The average daily total supply in 1988 was 216,960 m^3/day inclusive of blending water and imported bottled water. Out of this amount a total of 27,163 m^3/day was supplied outside the study area giving a net supply of 189,797 m^3/day to the study area.

The computed total consumption in the study area by the method described above is 196,048 m^3/day on average. Hence a difference of 3.3% between supply and computed consumption which we consider to be acceptable considering the complexity involved in consumption computation.

F.7 COMPUTATION OF AVERAGE DAILY CONSUMPTION

By Inspecting the records of potable water production it was possible to arrive at a peaking factor of 1.15. Hence the average daily consumption was taken to be 0.87 of peak consumption. This peaking factor was found to be representative of the pattern of production in recent years and very close to the monthly ratio for 1988 which was 1.09.

F.8 COMPUTATION OF LOSSES

An overall assessment was first made of the total losses which include:

a) Leakage from Reservoirs.
b) Losses at Tanker filling Stations and Tankers spillage.
c) Losses through distribution system and service connections.
d) Domestic losses which include:

Overflow from Tanks
Excessive car wash
Taps left running
other forms of domestic wasteful use.

e) Losses in gardening by excessive application of water.

The assessments of losses from various activities as indicated in the 1985 Leak detection Study by ASCO's have been adopted for the purpose of this study, as no other information is available at present.

However it is understood that the Water Department are currently investigating leakage in Doha and will have information available on completion of the study, at which time leakage assessment could be reassessed.

F.9 LOSSES IN DOMESTIC USE

Over and above the domestic consumption as allowed for using dwelling types an allowance of 10% has been made to account for domestic losses. These are the losses which occur inside the consumer's premises (e.g. due to overflowing tanks, taps left running, excessive use of water for car wash etc.,). The users include shops, offices, schools and other miscellaneous uses (excluding garden watering) while special consumers include Hotels, large palaces, guest houses, hospitals, army camps etc.

F.10 LOSSES ATTRIBUTABLE TO GARDENING

These losses were assessed in two different ways. Firstly by comparing winter and summer months consumption; and secondly by reference to previous studies.

An analysis of the estimates of water consumption for the year 1988 indicates that approximately 58,000 m^3/day out of the total requirement of 189,797 m^3/day can be attributed to garden watering or other irrigation usages. It is interesting to compare this figure with the difference in consumption between winter and summer months. In 1988, for example, the peak monthly rate of production averaged 238,000 m^3/day in May, whilst the minimum monthly production (in February/March) averaged only 196,000 m^3/day. It will be noted that the difference (42,000 m^3/day) is very close to the estimated quantity of water needed for the irrigation of gardens.

F.11 LOSSES FROM RESERVOIRS AND TANKER FILLING STATIONS

There is at present no indication that significant quantities of water are being lost by leakage from reservoirs. This conclusion was borne out by a test carried out at West Bay Reservoir in January 1983 and from a careful inspection of other reservoirs.

Nevertheless, it is considered advisable to assume a small loss from all reservoirs based on the rate normally considered to be acceptable i.e. 10 mm drop per week in the reservoir water level. This is equivalent to a loss of approximately .03% of the nominal capacity.

On this basis the losses from reservoirs in 1982 are assessed as in Table A.6 – (Appendix "A").

Three Tanker Filling Stations within the Study Area were in operation during 1988. The number of tanker fillings taking place per day at each station is assessed. This assessment is based on data given in Water Department Report No. 2 (Utilisation of Water Tanker Filling Stations).

From observations of filling operations it is estimated that the quantity of water lost through spillage is in the region of 0.7 m^3 per filling operation. On this basis, losses at Tanker Filling Stations are assessed at 1740 m^3/day.

F.12 LOSSES FROM UNDERGROUND PIPELINES INCLUDING SERVICE CONNECTIONS

It is believed that by far the largest proportion of losses which occur in the potable water system results from leakage from buried service pipes which supply individual houses from the distribution system. Losses from the transmission pipelines and distribution mains themselves are thought to be relatively small, except possibly in the older parts of the town where asbestos cement pipes have been used.

From observations made on a number of typical areas as part of Leak Detection Pilot Scheme carried out by ASCO recently, the losses from underground pipes are estimated at (50 - 60)% of domestic consumption.

F.13 RECHARGE TO AQUIFER

In Water Balance Section a number of factors have been used to generate the recharge to the aquifer from all sources. This section is concerned with the basis for selecting these factors.

The proportion of water supplied and which is likely to recharge the aquifer beneath the Study Area vary depending on the what it is used, and for the purpose of this study the following factors have been chosen:

a) Domestic use - (2%)

We have assessed the losses through domestic usage to be 10% and we consider that only these quantities of water losses which reach the ground generates recharge to the aquifer. From observations and analysis of the mechanics of these losses we estimated that 50% approximately of the losses reach the ground surface (i.e. overflowing tank, cleaning of patios, car wash etc.) only 40% of this amount is assumed to recharge the aquifer giving an overall factor of 2% of the total domestic consumption. The factor has also been applied to losses from water usage in shops offices etc.

b) Watering of Private Gardens and Public Open Spaces - (45%)

This factor is supported by data collected by Ministry of Agriculture/FAO regarding irrigation return as obtained from Iysimetry Studies (Pike et al). The same factor has been used for farm irrigation losses.

c) Losses from Reservoirs - 90%

As far as the losses from Reservoir are concerned it could be assumed that 100% of the losses result in aquifer recharge. However we have allowed for the proportion of losses which does not reach the aquifer and evaporate or end in blending wells and is re-used.

d) Losses from Tanker Filling Station - 60%

The losses from Tanker filling Stations are in the form of over-spillage during the filling operation. These quantities of lose water ends either on the surfaced court-yard and evaporates or form a run-off towards the drains and the soakaway. Thus the recharge is partially similar to surface water recharge and partially similar to recharge from Reservoirs. Therefore a factor between 45% and 90% was selected (i.e. 60%).

e) Losses from underground pipes and service connections (95%)

In selecting this factor we have allowed for a proportion of the losses to evaporate through ponding when service connections are relatively shallow or run on the surface. Thus a factor of (95%) was selected.

f) Losses from sewage system, septic tanks and rainfall

For a nominal loss of (1%) from the sewage network it is assumed that a factor of 100% to generate recharge could be used. This is borne by the depth of the pipework. For septic tanks a factor of (100%) have been used firstly due to their depth and secondly due to the saturation condition around the tanks and continuity of flow. As for rainfall recharge factors these are discussed in detail in Water Balance Section.