(3) Bacteriological analysis result

Total Bacteria Count (TBC): Bacterial contamination can occur any time when the water system is open for repair or maintenance. Therefore, disinfection is required on continuous and systematical basis in the Study Area. Bacteriological analysis indicates the presence of a limited bacteriological contamination. For example, water of Khaw reservoir shows a TBC of 1,000 cells/ml during the first sampling while in the forth sampling shows no TBC.

In general, TBC values in the house taps show sharp variation through the samplings. For example, Awajan house tap sample in the first sampling shows a 2,200 cells/ml, while it shows no count in the forth sampling. The same case occurs in the sampled house taps in Schneller camp, Zarqa and Russaia areas. The above mentioned cases may be attributed to a local and temporary contamination process.
Nearly most of the collected water samples show no contamination with bacterial coliform.

5. Quality of Industrial Waste Water

According to WAJ data bank, forty-two industrial factories are located within Amman-Zarqa area. The products of these factories are chemicals, petrochemicals, metals, paper, acid batteries, paints and food industry.

Thirty factories are not connected to the sewerage system. Their waste water is discharged directly to the nearest wadis or depressions. Discharge rates from these factories range from 0.5 to 2,000 m^3/day, with a total daily discharge rate of 5,321m^3. Two factories, the paper and the refinery factories in Zarqa discharge 2,000 m^3/day and 1,600 m3/day respectively, which in total account for 68% of the total daily discharge rate in the area.

Chemical analysis results of the wastewater samples collected from these factories are presented in Table I-16 , in form of range and average values for TDS, COD, BOD, SS and NH_3.

Comparing the results presented in Table I-16 with the Jordanian standard No. 202 (1991) for industrial waste water (JSIWW-1991), presented in Table I-2, the following statements can be drawn;

- The average TDS value equals to about three times the maximum allowable limit. Only three samples show TDS values below the standard.
- The average BOD value equals to about 84 times the maximum allowable limit.
- The average COD value equals to about 226 times the maximum allowable limit.
- The average NH_3 value equals to about 17 times the maximum allowable limit.

-- The average SS value equals to about 17 times the maximum allowable limit.

These results indicate a catastrophically pollution for ground water resources within the Study Area. This condition must be taken seriously when considering that the major aquifer system "B2-A7" in the Study Area acts as a water table aquifer, overlain by a sequence of permeable clastic sediments of wadi deposits .

To overcome this problem, the following actions must be done.

- Installation of wastewater treatment unit.
- Installation of desalination unit.
- Installation of a water recycling system.
- Treatment of the suspended solids.
- Construction of a waste water storage.

Tables

TABLE I-1 JORDANIAN STANDARD NO. 286 (AMENDED IN 1990) FOR DRINKING WATER

Items	permissible	Maximum
Turbidity[3] (unit)	1	5
Taste	Acceptable to most consumers	
Odor	Acceptable to most consumers	
Color (unit)[4]	10	15
pH	6.5 - 9.0	
Temperature (°C)	8 - 25	
TCC (MPN/100ml)	2.2	
FCC (MPN/100ml)	0	
Protozoa	0	
Helminths	0	
Free Living Organism	0	
Pb		0.05
Se		0.01
As		0.05
Cr		0.05
CN		0.10
Cd		0.005
Hg		0.001
Sb		0.01
Ag		0.01
TDS	500	1.500
Total Hardness as $CaCO_3$	100	500
ABS	0.5	1.0
Al	0.2	0.3
Fe	0.3	1.0
Mn	0.1	0.2
Cu	1.0	1.5
Zn	5.0	15.0
Na	200	400
Ni	0.05	0.1
Cl	200	500
F	1.0	1.5
SO_4	200	500
NO_3	45	70
Alpha Emitters (Bq/l)[5]		0.1
Beta Emitters (Bq/l)		1.0
Endrin		0.0002
Lindain		0.004
Methozychlor		
Toxaphene		
2.4 - 5 Dichloriphenoxy Acetic Acid		0.1
2.4 - 5 Trichlorophenoxy Propionic Acid		0.01

[1] All the units in mg/l except where otherwise mentioned.
[2] Other organic impurities which are not listed should comply with WHO guidelines.
[3] By Jakson Candle Turbidometer.
[4] Platinum-Cobalt Standard.
[5] Except Radon.

TABLE I-2 JORDANIAN STANDARD NO. 202 (1991) FOR INDUSTRIAL WASTEWATER (MAXIMUM ALLOWABLE LIMIT)

Items	Drainage to Streams / Wadis	Sea	Groundwater Recharge	Water Reuse for irrigation[8]
BOD5[9]	50	-	50	-
COD	150	200		-
DO[10]	1	5	1	1
TDS[11]	3000	-	1500	2000[12]
TSS	50	-	-	100
pH	6.5 - 9.0	5.5-9.0	6.5-9.0	6.5-8.4
Color (unit)	15	75	15	-
TC	-	4	-	-
FOG	5	10	Absent	5
Phenol	0.002	1	0.002	0.002
MBAS	25	-	15	-
NO_3	12	-	12[13]	30
NH_3	5	12	5	5
T-N	-	125	-	50
PO_4	15	-	-	-
Cl	500	-	500	350[14]
SO_4	500	-	500	400
F	1.5	-	1.5	-
HCO_3	-	-	-	500
Na	-	-	400	-
Mg	-	-	-	-
Ca	-	-	-	-
SAR	-	-	-	9
Al	5	-	0.3	5
As	0.05	0.1	0.05	0.1
B	1	-	1	1[15]
Cr	0.1	0.3	0.05	0.1
Cu	2	0.1	2	0.2
Fe	1	2	1	5
Mn	0.2	0.2	0.2	0.2
Ni	0.2	0.02	0.1	0.2
Pb	0.1	0.1	0.1	1.0
Se	0.02	0.02	0.05	0.02
Cd	0.01	0.07	0.02	0.01
Zn	15	-	15	2
CN	0.1	1.0	0.1	0.1
Hg	0.001	0.001	0.001	0.001
TCC (MPN/100ml)	-	5000	-	-
TFCC (MPN/100ml)[16]	1000	-	1000	1000
Nematodes (egg/l)	<1	-	-	<1

[6] Maximum allowable limit.
[7] All the units in mg/l except where otherwise mentioned.
[8] Depends upon type and quantity of crops, irrigation methods, soil type, climate & groundwater in the area concerned.
[9] Monthly average.
[10] Minimum value.
[11] TDS allowable limit is subject to TDS concentration in the water supply and the water basin affected.
[12] Allowable limits of wastewater reuse determine the degree of restriction (none, slight to moderate, or severe).
[13] Nitrate concentrations allowed are determined by its concentrations in the effected water basin.
[14] Method of irrigation is determined by wastewater quality being used.
[15] Could reach 3 mg/l.
[16] Geometric mean.

TABLE I-3 WATER QUALITY IN AWAJAN WELL FIELD

(Range & Average yearly value & Last Reading) Data

Well No.	Item	1990		1991		1992		1993		1994			
												Last Reading	
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Value	Date
AJ 21	TDS	1018-1152	1111	979-1161	1087	998-1056	1028	970-1075	1028	988-1052	1037	1135	Nov.6
	Na	6.6-7.7	7	6.2-7.3	6.9	6.1-6.4	5.7	5.7-6.6	6	5.7-6.5	6	6.48	Oct.2
	Cl	8.9-10.3	9.5	7.1-9.7	8.9	7.8-8.9	8.5	7.9-9.0	8.3	7.5-8.5	8.1	8.5	Oct.2
	SO4	1.3-2.0	1.8	1.5-1.8	1.6	1-1.9	1.3	0.8-1.2	1	0.8-1.2	1	1.09	Oct.2
	NO3	51.8-61.5	59.1	52.4-62	56.1	46.9-63.3	60.8	52.9-64.6	60.1	57.3-64.2	61	60.6	Nov.6
AJ 22	TDS	1056-1152	1087	960-1056	1025	967-1075	1035	1050-1125	1075	1000-1176	1078	1176	Nov.6
	Na	6.5-7.3	6.2	6-6.5	6.2	6.1-7.1	6.4	6.4-6.8	6.6	6.1-6.8	6.5	6.8	Oct.2
	Cl	8.5-9.95	9.3	8.2-9.1	8.7	6.1-9.5	8.6	8.7-9.4	9	8.4-9.7	8.9	9.2	Oct.2
	SO4	1.3-2.2	1.6	1.1-1.6	1.3	1.0-1.7	1.2	1.0-1.1	1.05	0.75-1.3	1	1.3	Oct.2
	NO3	55.8-64.8	61.4	52.2-58.6	54.4	49.1-72.8	64.2	64.5-75.3	71.4	63.7-71.7	68.2	63.7	Nov.6
AJ 23	TDS	768-845	787	806-874	832	691-883	791	768-988	878	905-1032	964	1032	Nov.6
	Na	3.3-4.1	3.6	3.7-6.17	4.1	2.9-4.4	3.8	3.6-5.1	4.3	4.4-5	4.7	5	Aug.2
	Cl	5.3-6.3	6	6.2-7.2	6.4	3.2-7.1	5.5	5.4-7.7	6.8	6.8-7.9	7.4	7.9	Aug.2
	SO4	0.2-0.6	0.4	0.2-1.9	0.46	0.2-0.9	0.45	0.1-0.6	0.3	0.2-0.6	0.4	0.63	Aug.2
	NO3	55.8-61.1	58.6	35.2-61.5	57.1	52.4-68	58.4	42-73.5	60.7	61.3-73	68.5	73	Nov.6

*- TDS & No3 concentration in mg/l
*- Na & Cl & So4 concentration in meq/l

TABLE I-4 TDS AND NO3 IN AZRAQ WELL FIELD

Well Name	Total Dissolved Solids (mg/L)							No3 Concentration (mg/L)						
	1988	1989	1990	1991	1992	1993	1994	1988	1989	1990	1991	1992	1993	1994
AZRAQ1	318	346	349	387	402	412	460	4.60	4.60	4.50	5.00	5.00	4.50	3.97
AZRAQ2	336		352	365	363	374	390	2.4	—	5.2	5.5	5.6	5.58	5.65
AZRAQ3	365	410	620	650	419	444	465	5.83	5.11	5.78	6	6	6.4	6.84
AZRAQ4	—	—	300	306	312	313	318	—	—	5	5.1	5.3	4.6	4.94
AZRAQ6	—	—	—	—	255	258	257	—	—	—	—	4.2	3.9	4.09
AZRAQ7	364	346	344	371	348	350	354	6.55	7.88	7.83	7.3	8.1	8.5	7.89
AZRAQ8	330	—	320	343	314	388	347	11.5	—	13.6	12.6	12.1	15.5	13.8
AZRAQ9	—	570	582	435	—	670	621	—	4	4.69	4.7	—	4.18	4.32
AZRAQ10	341	410	416	415	419	427	433	4.2	4.5	4.7	4.9	5	4.8	5.05
AZRAQ11	362	371	388	388	379	375	454	7.85	8.15	9.34	9.21	7.1	9.84	10.3
AZRAQ12	300	—	300	328	337	398	412	9.5	—	10.15	10	9.59	10.6	6.68
AZRAQ13	621	576	590	560	584	590	570	4.8	5.53	5.3	5.7	5.58	5.17	5.39
AZRAQ15	295	—	322	326	373	405	—	10.8	—	12.5	13.4	9.96	8.7	—

TABLE I-5 WATER QUALITY IN HALABAT WELL FIELD

Well No.	Item	1993 Range	1993 Average	1994 Range	1994 Average	1994 Last Reading Value	1994 Last Reading Date
HA 3a	TDS			376-413	386	413	Nov.6
	Na			2.2-3.07	3.02	3.06	Sep.3
	Cl			2.7-2.9	2.8	2.8	Sep.3
	SO4			0.6-1.1	0.8	0.6	Sep.3
	NO3			0.1-10.8	10.4	10.8	Nov.6
HA 3b	TDS			363-413	386.5	413	Nov.6
	Na			2.8-3.1	3.03	3.1	Sep.3
	Cl			2.7-2.9	2.8	2.8	Sep.3
	SO4			0.6-1.1	0.8	0.61	Sep.3
	NO3			9.7-10.8	10.4	10.7	Nov.6
HA 5	TDS	526-603	553	391-657	501.5	627	Nov.6
	Na	4.1-4.3	4.2	3-3.9	3.7	3.7	Sep.3
	Cl	4.3-4.8	4.5	2.9-4.1	3.7	3.7	Sep.3
	SO4	1.1-1.4	1.2	0.8-1.2	1.1	1.04	Sep.3
	NO3	5.1-8.2	7.3	6.7-9.7	8	8.8	Nov.6
HA 6	TDS	570-685	612	563-616	576	616	Nov.6
	Na	4.5-5.4	4.8	4.2-4.6	4.4	4.6	Sep.3
	Cl	4.5-5.6	4.9	4.5-4.7	4.6	4.6	Sep.3
	SO4	1.3-1.8	1.5	1.2-1.4	1.3	1.2	Sep.3
	NO3	8.3-9.9	9.3	8.7-9.4	8.9	8.9	Nov.6
HA 7	TDS	559-634	583	512-638	542	534	Nov.6
	Na	4.4-4.9	4.6	4.1-4.8	4.3	4.15	Sep.3
	Cl	4.5-5.9	4.8	4.2-5.2	4.4	4.2	Sep.3
	SO4	1.3-1.6	1.4	1.1-1.7	1.2	1.1	Sep.3
	NO3	9-9.9	9.3	8.5-9.9	9.4	9.6	Nov.6
HA 8	TDS	638-730	670	634-687	651	687	Nov.6
	Na	5-5.7	5.2	4.7-5.2	4.9	5.1	Sep.3
	Cl	5.1-5.9	5.5	5.1-5.4	5.2	5.4	Nov.6
	SO4	1.4-2.1	1.7	1.3-1.6	1.5	1.6	Nov.6
	NO3	8.2-9.5	8.6	8.4-9.7	9.2	9.3	Nov.6

TDS & No3 concentration in mg/l
Na & Cl & So4 concentration in meq/l

TABLE I-6 WATER QUALITY IN HATTEIN CAMP (1)

DATE	Ec	TDS	PH	Na	Ca	Mg	Cl	So4	No3
	mmos	mg/l		meq/l	meq/l	meq/l	meq/l	meq/l	mg/l
30/4/94	1020	653	7.2	2.81	4.74	2.7	3.39	1	55.3
16/5/94	762	488	7.46	1.51	3.47	2.8	1.96	0.85	18.3
20/6/94	751	481	7.55	1.43	3.5	2.8	1.98	0.84	15.1
7/7/94	764	489	7.63	2.8	3.47	2.8	2.02	0.77	18.7
14/8/94	678	434	7.25	1.23	3.19	2.9	1.51	0.8	6.33
14/9/94	682	436	—	—	—	—	—	—	6.95

TABLE I-7 WATER QUALITY IN HATTEIN CAMP (2)

DATE	Ec	TDS	PH	Na	Ca	Mg	Cl	So4	No3
	mmos	mg/l		meq/l	meq/l	meq/l	meq/l	meq/l	mg/l
3/4/94	1495	957	7.32	8.7	3.83	2.7	2.2	1.6	12.7
16/6/94	1054	675	7.47	4.52	3.6	2.2	4.04	0.87	27.6
22/6/94	1515	970	7.24	7.97	4	2.2	6.56	1.22	43.1
7/7/94	923	591	7.41	3.56	3.49	2.1	3.35	0.88	23.8

TABLE I-8 WATER QUALITY IN HASHEMEYEH WELL FIELD

Well No.	Item	1988 Range	1988 Average	1989 Range	1989 Average	1990 Range	1990 Average	1991 Range	1991 Average	1992 Range	1992 Average	1993 Range	1993 Average	1994 Range	1994 Average	1994 Last Reading Value	1994 Last Reading Date
	TDS	1229-1463	1291	1229-1389	1293	1152-1536	1387	1267-1603	1419	1344-1420	1383	1075-1536	1363	1376-1696	1555	1696	Nov.12
	Na	10.2-10.5	10.32	9.8-11.2	10.5	9.5-12.1	11	9.9-13.5	11.4	10.4-11.6	11.02	10.4-12.6	11.4	11.3-13.5	12.4	13.4	Nov.12
Hm2	Cl	10.9-12.3	11.5	11-12.1	11.6	10.9-13.5	12.3	10.9-14.7	12.8	11.8-12.3	12.03	11.7-13.8	12.5	11.9-15.1	13.6	15.1	Nov.12
	SO4	3.1-4.9	3.8	3.8-4.0	3.9	3.3-5	4.2	3.8-5.5	4.6	3.9-4.8	4.4	4.2-4.7	4.5	4.3-5.5	4.8	5.5	Nov.12
	NO3	38.8-49.6	44.6	40-46.9	42.3	36.5-49.3	43.67	38.5-48.9	42.94	37.2-44.3	40.21	25.2-49.6	37.6	24.5-52	41.9	36.5	Nov.12
	TDS	1267-1385	1337.6	1326-1541	1413	1382-1478	1430	1440-1632	1548	1536-1680	1581	1414-1632	1538	1363-1613	1497	1478	Nov.12
	Na	10.2-10.7	10.5	10.3-12.1	11.2	10.8-12.2	11.6	11.5-14.1	12.7	12.3-13.4	12.8	11.7-13.5	12.4	10.6-12.4	11.89	11.3	Nov.12
Hm3	Cl	11.36-11.7	11.6	11.7-13.16	11.2	11.9-13.4	12.7	12.8-15	13.9	13.5-14.8	12.6	12.9-14.8	13.6	11.9-14.1	13.03	13.1	Nov.12
	SO4	3.4-4.4	3.9	3.9-4.4	4.2	3.9-4.6	4.24	4.3-5.6	4.9	4.6-5	4.8	4.3-4.9	4.6	3.9-4.8	4.48	4.52	Nov.12
	NO3	46.2-48.9	48.1	44-50.7	47.3	46.2-53.3	49.7	48-56.70	50.9	47.8-56.4	52.4	45.1-55.1	49.5	29.6-52.2	44.2	40.7	Nov.12
	TDS	1325-1463	1385	1365-1482	1439	1463-1550	1508	1498-1670	1592	1536-1689	1589	1440-1657	1588	1382-1632	1508	1523	Nov.12
	Na	10.8-11.4	11.1			11.4-12.6	12.2	11.9-14.3	13.2	12.6-13.9	13.2	11.98-13.8	12.7	11.3-13	12.2	11.95	Nov.12
Hm5	Cl	11.6-12.5	12			12.5-14	13.5	13.3-15.9	14.4	13.8-15.2	14.2	12.9-15.2	13.7	12.4-14.3	13.2	13.32	Nov.12
	SO4	3.8-4.8	4.1			4.3-5.0	4.6	4.5-5.7	5.05	4.8-5.2	4.9	4.3-5.1	4.7	4.1-5	4.6	5.01	Nov.12
	NO3	46.7-52.1	49.8	47.4-52.7	50.1	47.1-54.9	50.8	46.5-58	51.7	49.6-58.4	53.6	47.2-55.3	50.2	29.9-57.1	45.4	41.1	Nov.12

TDS & No3 Concentration are in mg/l
Na & CL & So4 Concentration are in meq/l

TABLE I-9 WATER QUALITY IN MURHIB WELL FIELD

Well No.	Item	1993 Range	1993 Average	1994 Range	1994 Average	1994 Last Reading Value	1994 Last Reading Date
Mr 1	TDS	466-489	476.5	468-481	472.6	472	Oct.6
	Na	2-2.29	2.1	2-2.3	2.1	2.1	Sep.26
	Cl	2.1-2.5	2.3	2.1-2.3	2.2	2.2	Sep.26
	SO4	0.5-0.7	0.6	0.5-1	0.7	0.6	Sep.26
	NO3	8.4-10.1	8.6	7.7-9.3	8.8	8.9	Oct.6
Mr 2	TDS	485-514	492.8	484-530	496.6	488	Oct.6
	Na	2.2-2.9	2.3	2.2-2.8	2.3	2.3	Sep.26
	Cl	2.4-2.8	2.5	2.3-2.8	2.5	2.7	Sep.26
	SO4	0.5-0.8	0.7	0.6-0.8	0.7	0.8	Sep.26
	NO3	11.6-18.1	13.4	10.8-17.6	13.6	12.4	Oct.6
Mr 3	TDS	511-553	547	541-558	548	547	Oct.6
	Na	2.6	2.6	2.5-2.6	2.6	2.6	Sep.26
	Cl	3-3.3	3.1	2.9-3.1	3.1	3.1	Sep.26
	SO4	0.6-0.8	0.7	0.7-1	0.8	0.9	Sep.26
	NO3	25.2-28.7	26.8	24.3-28.9	27	26.6	Oct.6
Mr 4	TDS	539-548	544.5	538-573	551.2	538	Oct.30
	Na	2.5	2.5	2.5-2.7	2.6	2.65	Oct.30
	Cl	2.9-3.1	3	3-3.5	3.2	3.54	Oct.30
	SO4	0.5-0.8	0.7	0.6-1	0.8	0.7	Oct.30
	NO3	25-27	25.8	12.1-28	25.1	12.1	Oct.30

TABLE I-10 WATER QUALITY IN DEEP PHOSPHATE WELL

DATE	Ec	TDS	PH	Na	Ca	Mg	Cl	So4	No2
	mmos	mg/l		meq/l	meq/l	meq/l	meq/l	meq/l	mg/l
22/8/94	613	392	7.34	0.85	2.69	2.8	1.12	0.4	0.31
4/9/94	616	394	7.46	0.86	2.69	2.8	1.07	0.28	0
14/9/94	601	385	7.65	0.86	2.75	2.7	1.12	0.35	0.22
15/.10./94	615	394	7.19	—	—	—	—	—	0.08

TABLE I-11 WATER QUALITY IN RUSAIFA (18) WELL

DATE	Ec	TDS	PH	Na	Ca	Mg	Cl	So4	No3
	mmos	mg/l		meq/l	meq/l	meq/l	meq/l	meq/l	mg/l
26/3/94	930	595	7.29	2.83	4.07	2.2	3.29	0.54	31
2/4/94	1218	780	7.5	4.3	5.31	2.1	5.23	0.87	52.7
5/5/94	919	608	7.69	2.78	4.26	2.1	3.22	0.63	35.5
2/6/94	961	615	7.55	2.99	4.36	2.2	3.35	0.7	35.5
7/7/94	964	617	7.98	2.91	4.48	2.2	3.47	0.67	35.4
2/8/94	953	610	7.69	2.91	4.28	2.3	3.33	0.86	36.1
4/9/94	626	401	7.45	1.02	2.75	2.7	1.24	0.36	4.45
30/10/94	616	394	7.55	1	3.16	2.8	1.03	1.03	1.99

TABLE I-12 WATER QUALITY IN NEW UM AL-BASATIN WELL

DATE	Ec	TDS	PH	Na	Ca	Mg	Cl	So4	No3
	mmos	mg/l	mg/l	meq/l	meq/l	meq/l	meq/l	mg/l	mg/l
26/3/ 94	985	630	7.18	2.92	4.56	1.8	3.34	0.75	41.4
2/4/94	985	630	7.39	3.04	4.79	1.1	3.5	0.81	44.3
5/6/94	1020	653	7.8	3.05	4.94	1.7	3.72	0.62	49.81
16/6/94	1032	660	7.35	3.17	4.62	2	3.81	0.81	50
7/7/94	1015	650	7.28	3.79	4.77	2	3.79	0.8	45.9
2/8/94	1036	663	7.46	3.12	4.91	1.9	3.74	0.78	48.7
4/9/94	1067	683	7.34	3.31	5.06	2	3.92	0.67	44.3

TABLE I-13 WATER QUALITY IN OLD UM AL-BASATIN WELL

DATE	Ec	TDS	PH	Na	Ca	Mg	Cl	No3
	mmos	mg/l	mg/l	meq/l	meq/l	meq/l	meq/l	mg/l
26/3/94	1114	713	7.25	4.04	4.74	1.9	4.37	47.8
2/4/94	1156	740	7.23	4.46	4.78	2.2	4.91	50.5
2/12/94	1190	762	7.82	4.56	4.87	2	4.89	55.5
21/6/94	1225	784	7.22	4.67	4.92	2.2	4.96	56.7
7/7/94	1225	784	7.22	4.67	4.92	2.2	4.96	53.6
2/8/94	1235	790	7.46	4.85	5.08	2.2	5.22	59.8
4/9/94	1257	804	7.35	4.94	5.1	2.1	5.18	52.9
15/10/94	1237	797						59.1
6/11/94	1237	728	_	_	_		_	56.6

TABLE I-14 WATER QUALITY IN ZARQA 14 WELL (1990 - 1993)

Date	TDS	No3
	mg/L	Mg/L
Feb.1990	1650	58.4
Mar.1990	1764	65.5
Nov. 1991	1702	56.7
Dec. 1991	1735	57.6
Jan. 1992	1762	58.7
Feb. 1992	1811	59.8
Aug. 1993	1507	49.9
Sep. 1993	1485	50.9

TABLE I-15 WATER QUALITY IN ZARQA 14 WELL (1994)

	EC	TDS	Ca	Mg	K	CL	So4	pH	No3	Na
Jun	2248	1439	6.44	5.15	0.29	11.72	4.03	7.31	48.45	10.62
Mar	2300	1472	6.78	5.15	0.29	11.99	3.97	7.4	45.15	11.08
May	2463	1572	6.73	5.5	0.28	13.24	4.35	7.26	50.08	0.33
Jun.	2550	1632	7.15	5.88	0.26	14.75	5.12	7.35	56.48	14.31
Jul.	2745	1757	7.4	5.85	0.285	14.76	5.31	7.83	59.65	14.19
Aug.	2746	1757							58.05	
Sep.	2744	1756							60.88	
Oct.	2763	1768							60.15	

Ec in mmos
TDS in mg/l
Cations & Anions concentration in meq/l

TABLE I-16 WATER QUALITY OF COLLECTED INDUSTRIAL WASTEWATER

Item	Range (mg/L)				Average	No. of Collected
	Min.		Max.		mg/day	Samples
		Discharge * rate m3/day		Discharge * rate m3/day		
TDS	2662	50	40512	0.5	11032	15
COD	450	2000	347197	0.5	33858	21
BOD	124	2000	34944	0.5	4202	21
S.S	1.33	4	116596	0.5	12823	24
NH3	7.3	30	385	35	87	11

Tabl e (4 - 16) Chemical analysis results of the collected Industrial waste water Samples, including Range, Average, Discharge rate and no. of collected samples, (WAJ Data Bank)

* Discharge rate of the presented value only.

Figures

FIG. I-1 SALINITY VALUE IN AWAJAN WELL FIELD

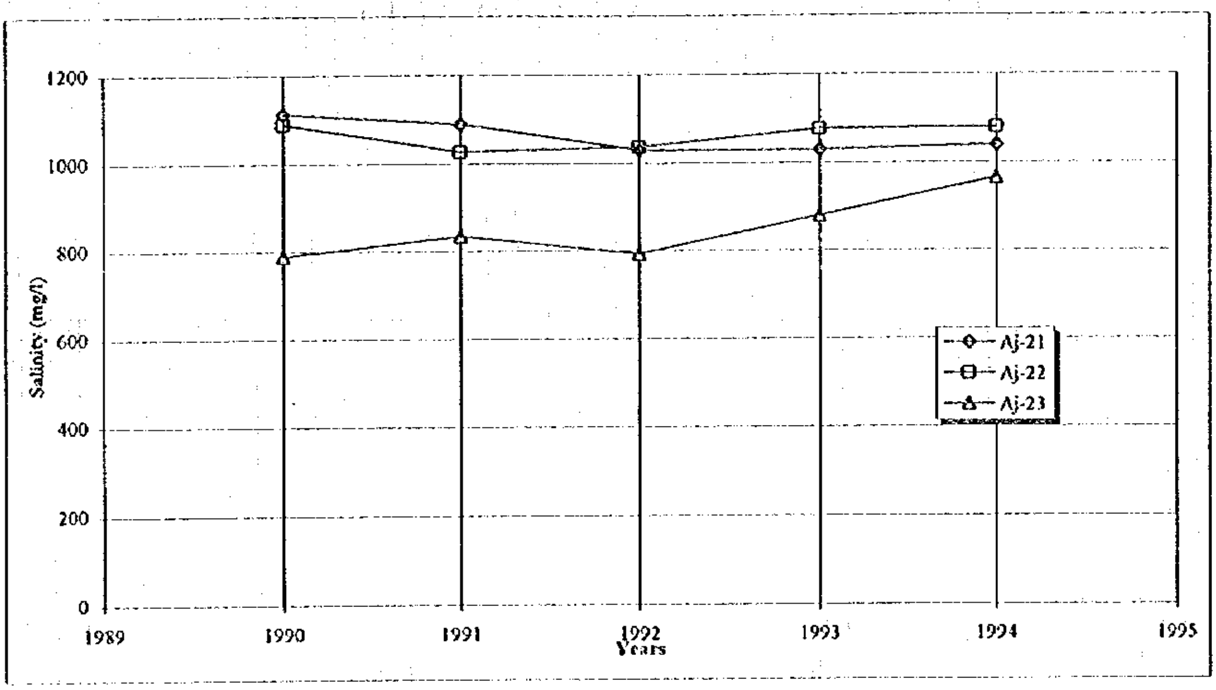


FIG. I-2 NO3 VALUE IN AWAJAN WELL FIELD

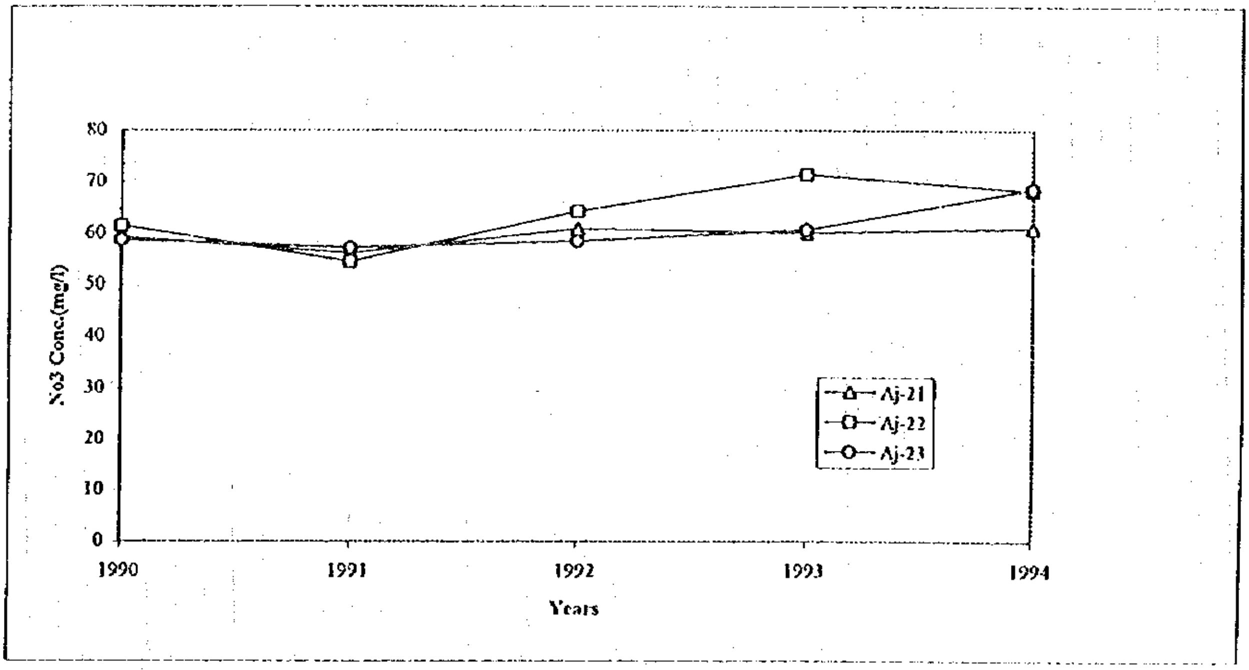


FIG. I-3 SALINITY VALUE IN HASHEMEYEH WELL FIELD

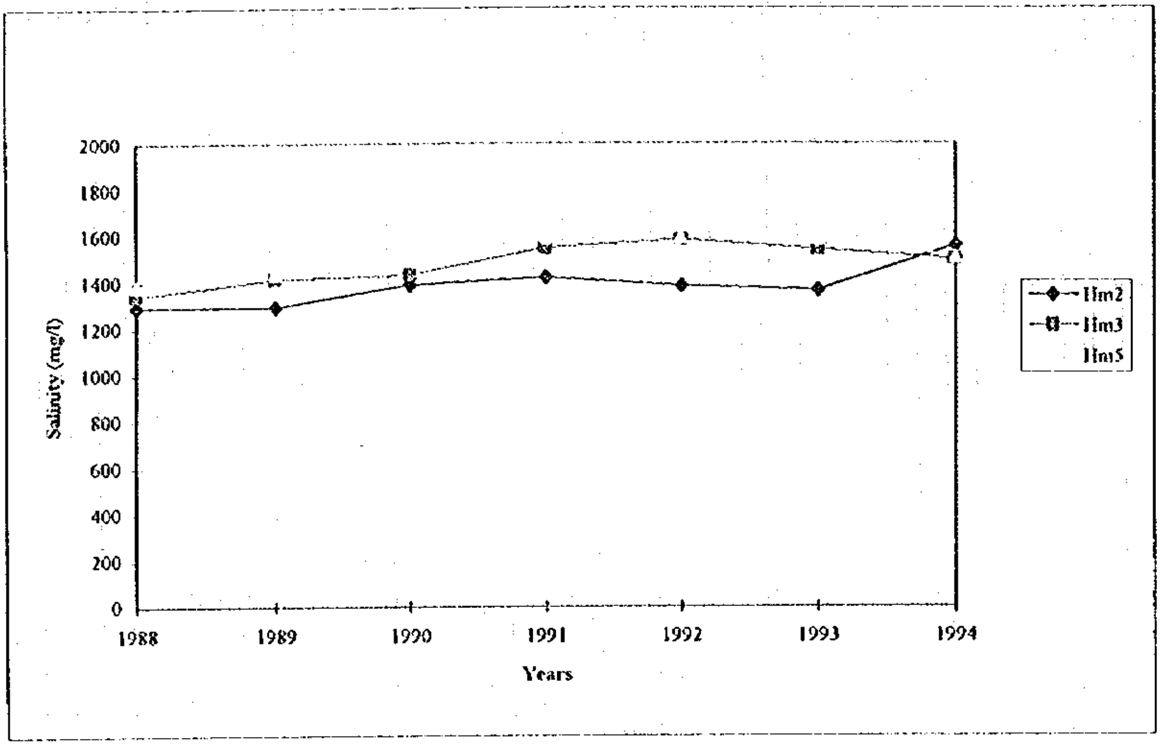


FIG. I-4 NO3 VALUE IN HASHEMEYEH WELL FIELD

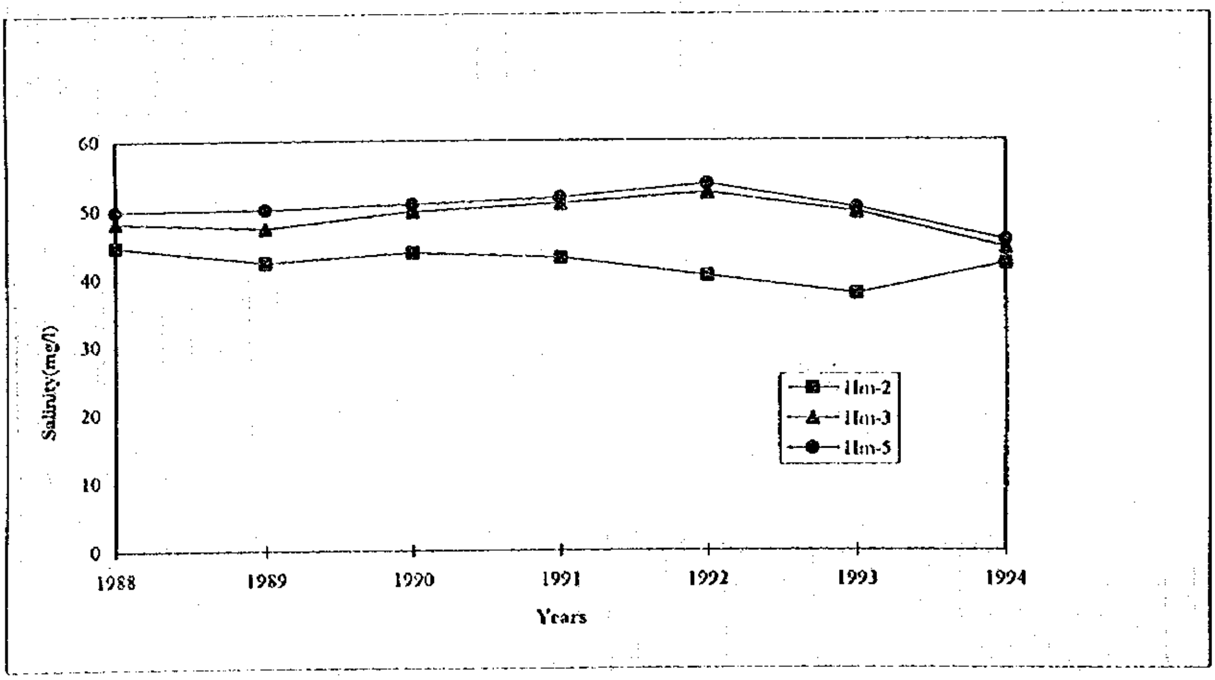


FIG. I-5 SALINITY VALUE IN ZARQA WELL (14)

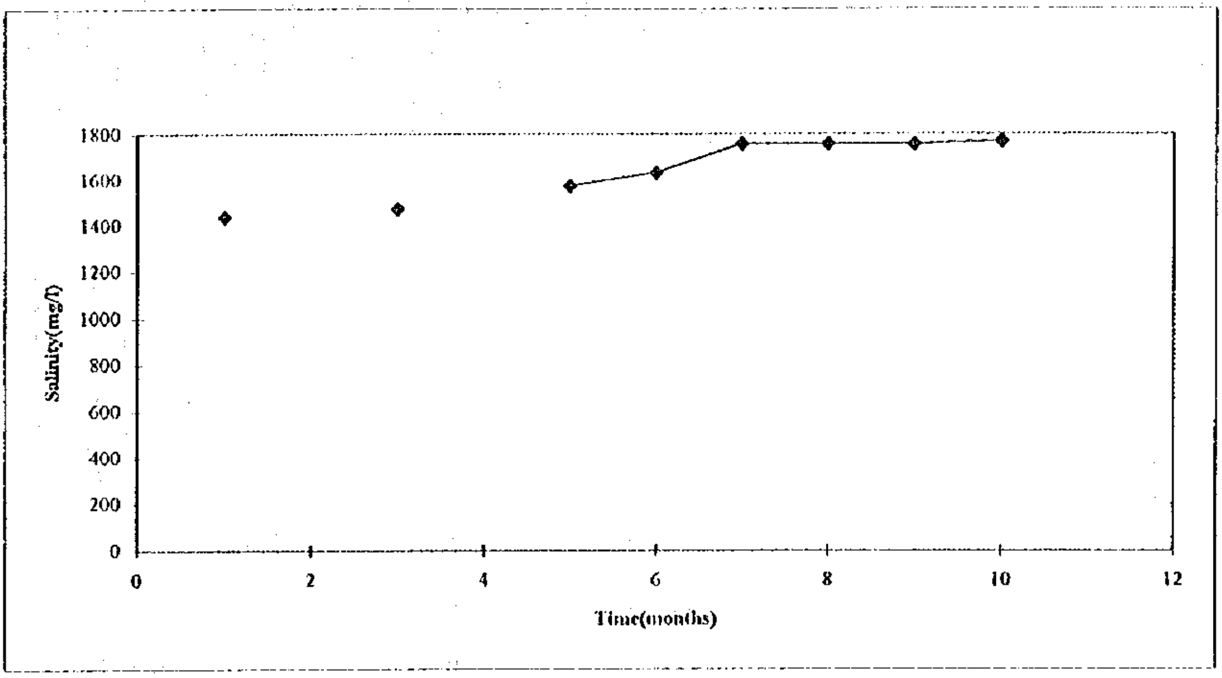
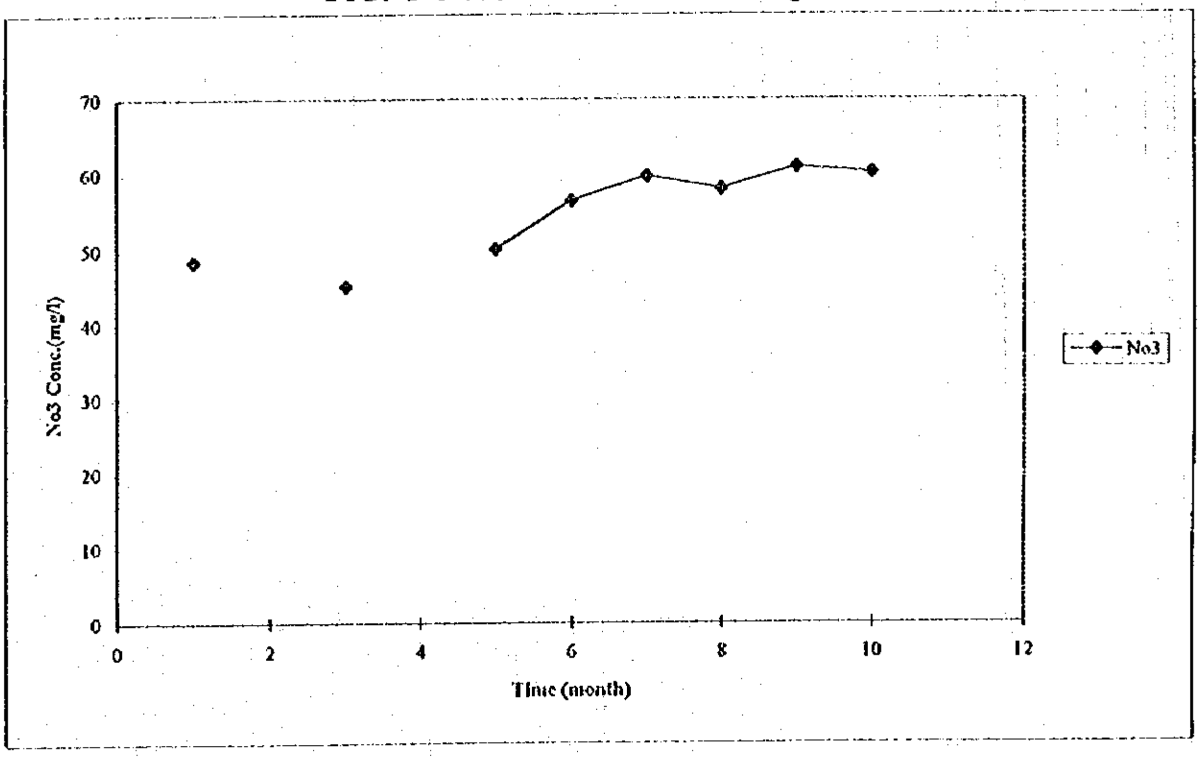


FIG. I-6 NO3 VALUE IN ZARQA WELL (14)



Attachment Water Quality Survey

ATTACHMENT WATER QUALITY SURVEY[1]

1. GENERAL

This sampling program includes the collection of four water sampling sets from major reservoirs, pumping stations and boosters, as well as house taps within the Study Area. The sampling points are listed in Table below. The four sampling sets were collected during the period of January 1995 to August 1995 (two sets for wet season and two sets for dry season).

Chemical and biological samples were collected from the locations and sent to the laboratories for chemical and biological analysis. Meanwhile field measurements of EC, pH, residual chlorine and DO were measured on sites.

TABLE SAMPLING POINTS

TYPE	LOCATION		No.
RESERVOIR	Awajan		1
	Batrawi		1
	Khaws Nos. 1 and 2		1
	Zarqa		1
PUMP STATION OR BOOSTER	Al-Azraq	(Outlet)	1
	Al-Hallabat	(Outlet)	1
	Al-Khaldeya	(Inlet)	1
	Al-Khaldeya	(Outlet)	1
	Al-Zatari	(Inlet)	1
	Al-Zatari	(Outlet)	1
	Al-Rusaifa Booster 18	(Outlet)	1
	Al-Rusaifa Booster 4	(Outlet)	1
	Al-Zarqa	(Inlet from Hashmyeh)	1
	Al-Zarqa	(Inlet from Khaw)	1
	Al-Zarqa	(Outlet to Rusaifa)	1
	Al-Zarqa	(Outlet to Zarqa)	1
	Khaw	(Inlet from Azraq)	1
	Khaw	(Inlet from Zatari)	1
	Murhib	(Outlet)	1
HOUSE TAP	Zarqa area		4
	New Zarqa area		3
	Ruseifa area		3
	Schniller area		3
	Awajan area		1
	Hashmyeh area		1
	Sukhnah area		1

[1] This survey was conducted by Hydrotech International.

2. ITEMS MEASURED

In order to study 1) characteristics of the drinking water from the source to the consumer, and 2) any changes in its chemical composition during water stay in the reservoirs and/or the boosters and pumping stations, two types of tests were conducted. These are general test and special test.

2.1 General Test

The purpose of carrying these tests is to study the physical, chemical and biological characteristics of water. Water quality analysis items for the samples from pumping stations, reservoirs and house taps are as follows:

a) **Physical**

- Temperature (at sampling point)
- pH (at sampling point)
- Odor
- Taste
- Color
- Turbidity

b) **Chemical**

- Dissolved Oxygen (at sampling point)
- Chloride
- Sulfate
- Total dissolved substances
- Alkalinity
- Chlorine residual (at sampling point)
- Nitrogen NH_4^+
- Hardness
- Fe^{++}
- Mn^{++}
- Nitrate
- Nitrite

c) **Biological**

- Fecal coliforms
- Bacteria

2.2 Special Test

The purpose of these tests is to study a specific change in the chemical composition of water. These tests include:

(1) Langelier Index

The purpose of this test is to estimate the corrosiveness and the tendency towards scaling and fouling behavior of water. This test is important for long steel piping. This test is applied on the following three sites among which the longest steel pipes are laid.

- Al-Azraq station (outlet).
- Khaw station (inlet from Za'atari).
- Al-Zarqa station (outlet to Rusaifa).

(2) Aeration

This method is used normally to remove dissolved gases from water. The process in most cases results in oxidation of iron and other metals, which will precipitate and thus TDS of water will decrease although slightly. Zarqa well No. 14 was selected for this test since both its productivity and TDS are high.

(3) Stability of Chlorine

This test was done to determine the decrease in the concentration of chlorine in water after storage in roof tanks of the consumers and how long the chlorine concentration will remain within the desired range. Three sites were selected to apply this test. These are Zarqa, Rusaifa and Hashemeyeh.

(4) Chemical Dosage

The purpose of this test is to study whether or not the water hardness can be reduced by adding soda ash. This test was applied on Zarqa well No. 14.

(5) Fluoride

Water that contains fluoride higher than the health recommendations may require deflouridation in order to prevent fluorosis. This test was applied in Al-Zarqa station (outlet to Zarqa).

(6) Chlorine

This test was done to determine the rate of consumption of chlorine along the distance from the chlorinating point for the main source of drinking water for the majority of the population of Zarqa district. This test was applied on three points along the outlet of Al-Zarqa station and Rusaifa booster.

3. METHOD OF WATER QUALITY SURVEY

3.1 Water Sampling

For a well with pumping equipment, reservoirs and house taps water are sampled from the outlet pipe of the well directly into the water sample container. The water sampler, water sample containers and buckets are kept clean before using, and are washed with the water to be sampled at the sampling point before sampling. Measures are taken to prevent the water sample from being contaminated during transportation.

3.2 Water Quality Analysis

Laboratory analysis of the water quality items are based on the related sections of 'Standard Methods for the Examination of Water and Wastewater (18th edition, 1992)' published by APHA (American Public Health Association) and AWWA (American Water Works Association).

4. FIRST SAMPLING SET RESULT[2]

The results of the water quality analysis and special testing experiments for the first sampling set (January 1995) are shown in the Tables 1 to 9.

4.1 Field test result

The taste and odor for all the samples were acceptable, except for the two samples collected from Khaldiya Station.

Temperature of all the collected samples range between 10.2 and 30.9 °C.

The pH values range between 7.14 and 8.02.

The Electrical Conductivity range from 0.495 to 1.404 mS/cm.

The Cl_2 concentration range from less than 0.1mg/l up to 2.5mg/l. In the reservoirs, the Cl2 concentration range between 1.5 to 2 mg/l with an average of 1.7mg/l, while in the pumping stations inlets, Cl_2 concentration range between <0.1mg/l at the inlet of Za'atari Station to 1.8mg/l at the Zarqa Station inlet from Khaw.

The samples collected from the outlets show a Cl_2 concentration range of <0.1mg/l in Russaifa booster 4 to 2.5mg/l in Azraq Station outlets, where the average value of 1.47mg/l. For the samples collected from house taps, Cl_2 concentration range between <0.1mg/l in Russaifa, Awajan and Shneller Camp areas to 1.5mg/l in Zarqa, New Zarqa and Hashemeyeh, with an average value of 0.84mg/l.

The Dissolved Oxygen values were among the range of 3.5mg/l to 9.5mg/l with an average value of 7.01mg/l.

[2]Jordanian standard No. 286 for drinking water that was put in 1988 and amended in 1990 (JSDW, 1990) is used as an evaluation standard for the collected samples, in the following discussion, it will be notified by the expression "the standard".

4.2 Laboratory Analysis Result

Reservoir

Samples were collected from the four major water reservoirs in the Area (Awajan, Batrawi, Khaw and Zarqa) and the results are presented in Table 2.
Water salinity within these reservoirs range between 530mg/l in Zarqa to 695mg/l in Awajan. According to the standard, this water salinity is around and above the permissible limit of 500mg/l (Fig. 4).

Hardness values for house taps reflect those from the supplied reservoirs. Water in Awajan and Khaw reservoirs are very hard (330 and 270ppm respectively) while that in Zarqa and Batrawi are less harder -- about 175ppm --, however, 70% higher than the standard (Fig. 5).

The same reflection appears for chloride, however the values are around the standard with an average of 203mg/l (Fig. 6).

Nitrogen, nitrate and sulfate concentrations are bellow the permissible limit, and the alkalinity is less than 68mg/l. The turbidity values are less than 0.57NTU. These values are below the permissible limit.

Pumping stations and Booster

A total of 15 samples were collected from the inlets and outlets of the major pumping stations and boosters. The results are shown in Table 3. Khaldiyah station water is considered a special case among these stations, since its water is very saline having a TDS values 2,870 mg/l (Fig. 7).

The remaining stations show two problems; one is Hashmiyah water input to Zarqa station (755ppm), the other one is Russaifa boosters (about 900ppm). The average salinity of all the stations is 1,041 ppm which may not reflect the real situation as the average without Khaldiyah water is 535ppm, slightly above the standard.

Only Azraq water have total hardness values below the permissible limit, and the rest of the samples were very hard especially those collected from Russaifa and Hashmiyah (Fig. 8).

For chloride concentration, about 85% of the collected samples are below the permissible limit (Fig. 9).

The average concentrations of nitrate and sulfate are 13.9 and 8.3mg/l respectively. The alkalinity of these samples is less than 78mg/l, and the turbidity is less than 0.58NTU, all these values are far below the standard.

House Taps Water

Table 1 presents the analysis results for the samples collected from the house taps.

House tap water shows values of salinity between 432 ppm and 870 ppm. The salinity is represented in Fig. 1 where only two samples are within the standard permissible limit with the average being 683.8ppm, higher than the standard by about 37%.

The problem is worse for hardness, as the average for the collected samples is about three times higher than the standard and all the values are above 200mg/l, double the permissible limit (Fig. 2). Russaifa and surroundings areas specifically show very high hardness values.

As for chloride values, all of the samples from Russaifa, Shneller and Awajan were found to be 30% above the standard, while the samples form Zarqa city (including new Zarqa) are about 10% more or less than the standard. The sample collected from Hashmiyah is 40% lower than the standard on the contrast from those collected from Sukhna (Fig. 3).

The nitrate and sulfate concentrations were far below the permissible limits, where the average concentrations of the nitrate and sulfate are 20mg/l and 10.6mg/l respectively.

The alkalinity ranges between 52mg/l in Zarqa and Hashmiyah to 78mg/l in Shneller.

The concentration of Fe^{+2} and Mn^{+2} is very low and traced only in seven and four samples respectively; the Fe^{+2} concentration is less than 0.009mg/l and the Mn^{+2} concentration is less than 0.087mg/l.

The turbidity value is less than 0.57NTU which is bellow the standard.

4.3 Bacteriological test

Total bacterial count (TBC) and fecal coliform count tests were conducted on the samples for reservoirs, house taps, boosters and pumping stations.

The results for total bacterial count shows that:

- 5 samples with no growth.
- 8 samples less than 10 cells/ml.
- 11 samples between 10 and 100 cells/ml.
- 7 samples between 100 and 1000 cells/ml.
- 2 samples more than 1000 cells/ml.

No trace of any probable number of coliforms was found in the samples.

4.4 Special Test

Langelier Index

The calculated results for the Langelier Saturation Index for the three sites are negative values as shown in Table 4. This is clear from the high hardness values for all the samples included in this survey. Negative value means that the water have tendency of dissolving calcium carbonate and hence the sampled water is considered to be corrosive. The values for Za'atari station inlet into Khaw station and Azraq station outlet are -1.39 and -1.2 respectively which is considered to be a moderate corrosion problem.

Aeration

The result is shown in Table 5 and indicates that the Electrical conductivity of Zarqa Well No. 14 water is reduced only by 2% within one hour; Aeration is inadequate for TDS reduction.

Stability of Chlorine

Values for this test are shown in Table 6, and represented in Fig. 10.

A decrease of about 0.6mg/l was obtained for the three samples after 36 hours. The curve fitting for these experiment shows a correlation factors for the three experiments in the range of 0.935 to 0.953 which is acceptable.

What is not sufficient is that the substitution of time 0 in the obtained equations -- that must give the initial concentration -- gives a value of about 0.15 less than the actual, which means that the obtained equations are not accurate for low time intervals, but for long time intervals, the calculated values will be much more accurate.

Chemical Dosage

Lime soda dosage experiment was carried out for Zarqa well No. 14 and its result is shown in Table 8.

The result shows a sufficient decrease in total hardness of 58%. The amount of lime added is the stoechiometric limiting reactant, and the yield was very encouraging.

Fluoride

The fluoride test conducted for Zarqa station outlet shows an acceptable fluoride concentration of 0.1mg/l, which is 10% of the permissible limit.

Chlorine

The result shows that chlorine concentration decreases from 1.6mg/l at Zarqa station to 0.6mg/l after 6km and to 0.3mg/l at a distance of 10km from the station in the direction of Russaifa (Table 7)

Curve fitting is shown in Fig. 11 and the correlation factor is 0.96, and the equation shows to be stable for all the distance range.

5. SECOND SAMPLING SET RESULT

5.1 Field tests result

Field tests were conducted in March 1995 in the specified locations and the following results were obtained :

The taste and odor for all the samples were acceptable, except for the two samples collected from Khaldiyah Station.

Temperature of all the collected samples range between 11.2 and 27.8 °C.

The pH values range between 7.0 and 8.4.

The Electrical Conductivity ranges from 0.54 to 1.275 mS/cm.

The Cl_2 concentrations range from less than 0.1mg/l up to 1.6mg/l. In the reservoirs, the Cl_2 concentrations range between 1.2 to 1.55mg/l with an average of 1.39mg/l, while in the pumping stations inlets Cl_2 concentrations range between <0.1mg/l in Zarqa and Za'atari stations to 1.6mg/l in Khaw station inlet from Zatari. The samples collected from the outlets show a Cl_2 concentration range of 0.5mg/l in Zarqa to 1.6mg/l in Za'atari Station outlets, with an average value of 1.22mg/l.

For the samples collected from house taps, Cl_2 concentrations range between <0.1mg/l in Russaifa and Shneller Camp areas to 1.5mg/l in Awajan, with an average value of 0.54mg/l.

The Dissolved Oxygen values are among the range of 4.2mg/l to 9.9mg/l with an average value of 7.6mg/l.

5.2 Laboratory Analysis Result

Reservoir

Results are presented in Table 11.

Water Salinity in the reservoirs ranges between 430mg/l in Batrawi to 805 mg/l in Awajan. According to the standard, this water salinity is above the permissible limit of 500mg/l (Fig. 15).

Hardness values have an average of 326 mg/l and all of the four samples are above the limit. In Batrawi the total hardness is 210 mg/l but the hardness in Zarqa is around 459 mg/l. Total Hardness values are shown in Fig. 16.

Fig. 17 represents the chloride ion concentration for the four reservoirs. The chloride concentration is normal in Zarqa, Batrawi and Awajan, with an average of 177.5mg/l, however it is slightly high in Khaw reservoir (24% higher than the llimit).
Nitrate and sulfate concentrations are far below the permissible limits, so as for alkalinity -- which is less than 56mg/l -- and turbidity which is less than 0.28NTU.

Pumping stations and Booster

Table 12 shows the results for the boosters and pumping stations. The average salinity of 509 mg/l in all the boosters and pumping stations as shown in Fig. 18 is similar to the first sampling results of 527 mg/l.
Water of Khaldieh station shows a salinity value of 3,013 mg/l. For the rest of the stations, the values are almost the same with a range of 370 mg/l in Zatari outlet to 952 mg/l in Russaifa booster No. 4. Five values out of the 15 points are above the permissible limit, two of which are for Russaifa boosters.

Every total hardness values in the second set exceed the standard, the lowest is 101.1mg/l and the average is 301.6mg/l as shown in Fig. 19.

Chloride ion concentration for all the stations are within the limit, with an average of 136mg/l, except for Khaldiyah.

The nitrate concentrations range from 4.2 mg/l at Khaw inlet from Azraq to 55 mg/l at Rusaifa booster 4. The sulfate concentrations are below the permissible limit with an average value of 9.9 mg/l.

The alkalinity values are less than 60 mg/l, and the turbidity is less than 0.46NTU.

House Taps Water

The salinity for house taps presented in Fig. 12 are all above 500 mg/l, ranging from 510 in Zarqa I to 878ppm in Russaifa with the average of 667 mg/l. Salinity is higher than the standard except in Hashmiyah. Salinity in Russaifa and surroundings are more saline.

The problem for hardness reappeared also in the second set of house tap samples, as the average (316 mg/l) for the collected samples is more than three times harder than the standard and most of the values are above 200mg/l (Fig.13). Russaifa and surroundings areas also show high hardness values.

As for chloride values, all of the samples from Russaifa, Shneller and Awajan -- except for one -- are found to be 30% above the standard, with the samples form Zarqa city and new Zarqa are about 10% more or less than the standard. The same thing applies for the sample collected from Hashmiyah and that collected from Sukhna (Fig. 14).

For the rest of the items, the values are far below the standard (Table 10).

The average values for nitrate and sulfate concentrations are 12.86mg/l and 11.6mg/l respectively. The alkalinity is less than 62mg/l and the turbidity is less than 0.57NTU.
Iron concentration observed is very low -- less than 0.1mg/l -- and is traced only in one sample, while manganese was absent from all the samples.

5.3 Bacteriological test

Total Bacterial Count and Fecal Coliform Count tests are conducted for reservoirs, house taps, boosters and pumping stations.

The results for total bacterial count shows that:

- 10 samples with no growth.
- 5 samples less than 10 cells/ml.
- 10 samples between 10 and 100 cells/ml.
- 7 samples between 100 and 1000 cells/ml.
- 2 samples more than 1000 cells/ml.

In this set of samples, 29% of the samples are of 0 bacterial count while in the first sampling set, about 15% of the samples are of 0 bacterial count.

No trace of any probable number of coliforms was found in the tested samples.

Special Test

Langeller Index

The calculated results in Table 13 for the three sites indicate water tendency towards dissolving Calcium Carbonate and hence the water for these samples is considered to be aggressive.

6. THIRD SAMPLING SET

6.1 Field Test Result

Following are a summary of the field measurements conducted in the water sampling locations in June 1995. The detailed measurements are presented in Tables 14 to 22.

- The taste and odor for all the samples are acceptable, except for the two samples collected from Khaldiya station.
- Temperature of all the samples range between 24°C to 39°C.
- The EC range from 0.618 dS/m to 1.575 dS/m while the pH value range from 7.34 to 8.06.
- The Cl_2 concentration range between 0.25mg/l to 2.1mg/l while DO values are of the range of 5mg/l to 8.9mg/l.

6.2 Laboratory Analysis Result

Reservoir

Results for the major reservoirs are presented in Table 15.

Water salinity in these reservoirs range from 463mg/l in Awajan to 815mg/l in Zarqa. Salinity of these waters is above the permissible limit, except for Awajan reservoir.

Chloride concentration range between 120.5mg/l to 275.5mg/l, with an average of 235mg/l. Cl concentration only in Awajan reservoir is below the permissible limit.

Hardness values range between 251mg/l to 307mg/l showing a very hard water.

Nitrate and sulfate concentrations are low with an average of 14.8 mg/l and 8.16mg/l respectively. Meanwhile, the alkalinity are less than 81mg/l and the turbidity values are less than 0.25 NTU.

Pumping Stations and Booster

A total of 15 samples were collected from the inlets and outlets of the major pumping stations and boosters. The analysis results are presented in Table 16.

Samples collected from Khaldiya station were not considered in the following discussion, since its water is very saline having a TDS values >3,000 mg/l.

Salinity range from 355 mg/l in Za'atari to 973 mg/l at Rusaifa booster 4. About 69 % of the salinity are above the permissible limit.

Chloride concentration range from 103 mg/l in Khaw inlet from Azraq to 475 mg/l in Zarqa outlet to Zarqa. About 46% samples have higher Cl concentration than the permissible limit.

Total hardness values are above the permissible limit. They range from 120 mg/l in Za'atari outlet to 301 mg/l/l in Zarqa outlet to Rusaifa.

Sulfate concentration is below the permissible limit, with values less than 15mg/l. Also the same condition can be stated for NO_3 where the concentration values is less than 10mg/l except at Rusaifa 4 where it is 53 mg/l.

Alkalinity values are less than 90mg/l and the turbidity values are less than 0.45 NTU.

House Tap

Sixteen samples are collected from the house taps in the Study Area. Results are presented in Table 14.

Water Salinity ranges from 555 mg/l in Zarqa to 917 mg/l in Hashemeyeh, all of which are above the permissible limit.

Chloride concentration are above the permissible limit, ranging from 224 mg/l in Rusaifa to 292 mg/l in Awajan with an average of 264mg/l.

The total hardness range from 199 mg/l in Hashemeyeh to 376mg/l in Rusaifa, with an average of 311 mg/l, above the permissible limit.

All nitrate concentrations but at Awajan (54 mg/l) are below the permissible limit. Sulfate concentrations with an average value of 15.1 mh/l are below the permissible limit.

Alkalinity values are less than 90mg/l and Turbidity values are less than 0.35 NTU.

6.3 Bacteriological Analysis Result

About 68% of the collected samples show no count of total Bacteria, while the rest of samples show a total bacterial count range from 4 cell/ml to 73 cell/ml.

- As for the most probable Number (MPN) of Bacterial coliform, at 37 C about 91% of the samples show no bacterial coliform and the rest of samples show values of (MPN) of bacterial coliform range between (25-80) / 100 ml.

Special Test

Langelier Index

Results show that LI of water from Zarqa station outlet to Ruseifa is -0.64 while LI of water form Khaw station inlet from Za'atari is 0.01. Water from Azraq station outlet has LI of -0.88.

Chlorine

This test was conducted for the Zarqa Ruseifa water line. Test results show that Cl_2 concentration decreased from 1.6 mg/l at the beginning of the line, to 1.2 mg/l after 11.8 km distant on this line.

Aeration

In this test, the Ec of the water decreased from 2,800 mmhos/cm to 2,730 mmhos/cm after 3 hours of the test start.

Chemical Dosage

After adding lime soda to the water, the hardness of the water decreased from 1,080 mg/l to 940 mg/l, with a percentage reduction of 14.9%.

Fluoride

This test was conducted at Zarqa station (outlet to Zarqa). The measured Fluoride concentration was 0.1 mg/l, where this value is less than the Fluoride permissible limits in the drinking standard of 1 mg/l.

7. FOURTH SAMPLING SET

7.1 Field tests Result

Field tests were conducted in August 1995 in the specified locations according to the water survey program. Results of these field measurements are shown in Tables 23 to 26. Following are a summary of these results.

- Temperature of all the collected samples range between 23°C to 32°C.
- The measured Ec value range between 0.589 ds/m to 1.537 ds/m. while the pH value range 6.92 to 8.07.
- The Cl2 concentration range from 0.00mg/l to 2mg/l.
- The dissolved oxygen values range from 5.1mg/l to 8.9mg/l.

7.2 Laboratory Analysis Result

Reservoir

Results for the four reservoirs are presented in Table 24. Salinity of these reservoirs water is above the permissible limit ranging from 700 mg/l to 819 mg/l.

Chloride and total hardness concentrations are also above the permissible limit, ranging in concentration from (205mg/l - 274mg/l) and (385mg/l - 480mg/l).

Nitrate and Sulfate concentration is below the permissible limit with an average of 33.65mg/l and 11mg/l respectively.

Alkalinity is less than 60mg/l and the Turbidity is less than 0.25 NTU.

Pumping Stations and Booster

15 samples were collected from the pumping stations and boosters. Results are presented in Table 25. Samples collected from Khaldiya station were not included in our discussion, due to their high water salinity > 3,000mg/l. Evaluation shows that :

- About 69% of the samples is above the permissible limit in salinity.
- Total hardness concentrations are above the permissible limit ranging from 188mg/l to 600mg/l.
- About 53% of the samples is less than the permissible limit in Chloride concentration.
- Nitrate concentrations are less than the permissible limit, ranging from 7.7 mg/l to 39 mg/l except at Rusaifa 4 with 48 mg/l.
- Sulfate concentration is below the permissible limit, ranging from 1.9mg/l to 17.1mg/l.
- Alkalinity concentration ranges from 19mg/l to 61mg/l, and the turbidity values is less than 0.25 NTU.

House Tap

Analysis results for the 14 samples are presented in Table 23. Evaluation of these results show the following findings :

- Salinity of all the samples is above the permissible limit. The salinity ranges from 719 mg/l to 1,156 mg/l with an average value of 883 mgmg/l, where the highest salinity value are recorded in Awajan area.
- The total hardness concentration is very high, with three to six times the permissible limit, and an average value of 485 mg/l
- Chloride concentration of about 88% of the collected samples are above the permissible limits, with an average value of 260 mg/l.
- Nitrate and Sulfate concentrations are below the permissible limit. Their concentrations range between (16.4 mg/l to 39 mg/l) and (1.4 mg/l to 19.5 mg/l) respectively.
- Average alkalinity is 22.4 mg/l, while the avrage turbidity is less than 0.20 NTU.

7.3 Bacteriological Analysis Result

About 57% of the samples are of no total bacterial count. In general the total bacterial count is low in the pumping stations, ranging from 0 to 30 cell /ml. Large variation is noticed in the total bacterial count for the house taps, ranging from 0 to 3,800 cell /ml at Schniller House tap II. About 86 % of the collected samples show nil in the most probable number (MPN) for bacterial coliform at 37°C. For the remaining 15% the MPNs range from 5 to 80 cell of coliform per 100 ml.

At 45°C, no presence of bacterial coliform are indicated for all the samples.

Special Test

Langelier Index

Three samples were collected to conduct this test. Results show that water from Zarqa station out let to Ruseifa is of LI equal to -0.52 while LI was -0.42 for the water collected form Khaw station inlet from Zatari. Water from Azraq station outlet has LI equal to -0.4.

First Campaign Water Quality Analysis Results

- Water samples collected during the period (1-2-1995 & 7-2-1995)

General Items

Table 1: House Taps

Test	Unit	Sukhna	Hashmie	Awajan	Sh. Camp I	Sh. Tap II	Sh. Camp III	Rusaifa I	Rusaifa II	Rusaifa III	Zarqa I	Zarqa II	Zarqa III	Zarqa IV	New Zarqa I	New Zarqa II	New Zarqa III
EC	mS/cm	0.941	0.685	1.182	1.38	1.2	1.145	1.25	1.18	1.28	0.67	0.797	0.867	0.781	0.859	0.929	0.857
pH		7.71	8	7.68	7.65	7.3	7.4	7.45	7.76	7.65	7.85	7.8	7.72	7.84	7.93	7.68	7.63
Temp.	°C	11.8	17.8	13.3	13.1	12.8	13	13.4	12.2	13.8	15	13.7	16.8	24,6	30.9	15.9	18.5
Cl_2	mg/l	0.5	1.5	< 0.1	< 0.1	0.3	< 0.1	0.4	< 0.1	0.1	0.6	1.5	1.5	1.2	1.2	1.5	1
DO	mg/l	8	8	7.2	8	6	7	7.2	8.8	6.7	7.3	6.5	9.5	8	8	7.9	7.2
Taste		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.57	0.46	0.22	0.22	0.23	0.29	0.23	0.21	0.23	0.27	0.25	0.26	0.25	0.24	0.27	0.31
Color		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
TDS	mg/l	655.0	432.0	815.0	785.0	835.0	785.0	855.0	850.0	870.0	465.0	550.0	600.0	545.0	595.0	645.0	590.0
Alk.	mg/l	75	52	73	78	75	78	70	75	68	54	56	52	61	60	65	64
T.H.	mg/l	244.2	200.2	392.4	380.4	410.4	386.4	390.4	396.4	390	200	224.2	251.3	200.2	206.2	252.3	268.3
Cl	mg/l	284	106.5	266.3	248.5	266.3	266.3	266.3	266.3	266	178	213	213	195.2	213	230.7	213
SO_4	mg/l	6.85	3.78	5.94	35.6	3.4	37.95	2.03	0.61	1.43	5.78	14.92	1.7	1.6	15.78	30.74	1.4
NH_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	mg/l	0.009	0.0	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mn	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO_3	mg/l	12.2	9.3	30.5	31.5	31.7	26.9	30.1	28.7	25.4	12.4	15.2	16.5	10.5	13.2	14.8	13.7
NO_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TBC	Cells per ml	12	80	2200	0	36	2	0	80	1	560	0	50	0	146	0	32
TFC	MPN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2: Reservoirs

Test	Unit	Zarqa St.	Batrawi	Awajan	Khaw
EC	mS/cm	0.821	0.769	1.007	0.945
pH		7.71	7.55	7.45	7.72
Temp.	°C	25	23.6	18.1	16.8
Cl_2	mg/l	1.5	1.5	2	1.8
DO	mg/l	7.5	6.3	6.2	8.1
Taste		Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.34	0.43	0.39	0.57
Color		Acc.	Acc.	Acc.	Acc.
TDS	mg/l	530.0	535.0	695.0	650.0
Alk.	mg/l	65	68	67	60
T.H.	mg/l	174.2	170.1	330.3	270.3
Cl	mg/l	177.5	188.7	213	230.7
SO_4	mg/l	46.7	1.91	35.5	1.75
NH_4	mg/l	0.0	0.0	0.0	0.0
Fe	mg/l	0.0	0.0	0	0.0
Mn	mg/l	0.0	0.0	0	0.0
NO_3	mg/l	12.1	12.2	26.5	14.2
NO_4	mg/l	0.0	0.0	0.0	0.0
TBC	Cells per ml	1	11	11	1000
TFC	MPN	0	0	0	0

Table 3: Boosters and pumping stations

Test	Unit	Zarqa (Inlet from Hashmie)	Zarqa (Inlet from Khaw)	Zarqa (Outlet to Zarqa)	Zarqa (Outlet to Rusaifa)	Rusaifa Booster "4" (Outlet)	Rusaifa Booster "18" (Outlet)	Murhib (Outlet)	Khaw (Input from Azraq)	Khaw (Input from Zatari)	Hallabat (Outlet)	Azraq (Outlet)	Khaldiah (Inlet)	Khaldiah (Outlet)	Zatari (Inlet)	Zatari (Outlet)
EC	mS/cm	1.095	0.63	0.801	0.797	1.404	1.251	0.632	0.521	0.495	0.718	0.553	6.251	6.193	0.505	0.497
pH		7.52	8.02	7.91	7.78	7.14	7.33	7.71	7.97	7.75	7.77	7.86	7.61	7.63	7.99	7.72
Temp.	°C	23.7	24.8	24.5	24.7	10.2	18	22	24.6	27.9	23.1	23.4	23.1	23.2	24	30
Cl_2	mg/l	0.8	1.8	1.5	1.5	< 0.1	1.5	0.9	1.5	1.8	1.57	2.5	< 0.1	< 0.1	< 0.1	2.2
DO	mg/l	5	7.2	6.7	6.4	3.5	6.9	6	5.8	6.6	7	6	6.4	5.9	7.1	7
Taste		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.31	0.35	0.48	0.26	0.58	0.44	0.22	0.45	0.31	0.47	0.35	0.45	0.35	0.51	0.42
Color		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
TDS	mg/l	755.0	435.0	550.0	610.0	915.0	875.0	455.0	385.0	355.0	406.0	390.0	2870.0	2296	385.0	340.0
Alk.	mg/l	72	59	59	69	78	67	68	72	65	58	61	35	32	66	73
T.H.	mg/l	306.3	156.2	250.2	250.2	422.4	420.4	298.3	100.1	140.1	176.2	84.1	1411	1077	120.1	134.1
Cl	mg/l	284	142	213	195.2	284	242	106.5	142	124.2	177.5	109.7	954	721	130.7	106.5
SO_4	mg/l	2.1	1.86	1.71	7.9	2.97	2.29	2.54	17.72	11.77	27.7	21.31	26.48	33.34	3.13	5.5
NH_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
Mn	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
NO_3	mg/l	19.0	9.43	13.1	10.7	31.9	38.3	12.9	6.06	7.36	7.07	6.9	59.4	53.9	8.12	10.5
NO_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TBC	Cells per ml	4	600	0	2800	1	7	10	150	0	1000	4	88	5	172	60
TFC	MPN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Special tests and experiments

Table 4: Langelier Saturation Index Results

Site	Langelier Saturation Index	Comments
Al-Azraq Station (Outlet)	-1.2	Tendency to dissolve CaCO3 (Corrosive)
Khaw St. (Input from Zatari)	-1.39	Tendency to dissolve CaCO3 (Corrosive)
Al-Zarqa Station (Outlet to Zarqa)	-0.54	Tendency to dissolve CaCO3 (Corrosive)

Table 5: Aeration Experiment Results

Electrical Conductivity Before Experiment (mS/cm)	*2180*
Electrical Conductivity After Experiment (mS/cm)	*2140*
Percentage Reduction	*1.835 %*

Chlorine Stability Experiments Results

Table 6: Chlorine stability with storage time

Time (min.)	Zarqa	Russaifa	Hashmieh
0	0.8	1.6	1.2
5	0.78	1.42	1.1
10	0.69	1.45	1.1
20	0.72	1.43	1.1
30	0.71	1.43	1.1
60	0.69	1.39	1.1
120	0.65	1.38	1
240	0.5	1.36	1
360	0.5	1.27	0.9
720	0.45	1.2	0.8
1200	0.29	1.01	0.8
2160	0.22	0.93	0.6

Table 7: Chlorine stability with transportation distance

Site	Distance From Zarqa Station (km)	Chlorine Conc. (mg/l)
Point 1	0	1.6
Point 2	2	1.5
Point 3	4	0.8
Point 4	6	0.6
Point 5	10	0.3

Table 8: Lime Soda Dosage Experiment

Hardness After Experiment	*620*
Hardness Before Experiment	*260*
Percentage Reduction	*58.065 %*

Table 9: Fluoride Test Results

Site	Fluoride Concentration (mg/l)
Zarqa Station (Outlet to Zarqa)	0.1
Permissible Standard	1.0

Second Campaign Water Quality Analysis Results

- Water samples collected during the period (2-3-1995 & 11-3-1995)

General Items

Table 10: House Taps

Test	Unit	Sukhna	Hashmie	Awajan	Sh. Camp I	Sh. Tap II	Sh. Camp III	Rusaifa I	Rusaifa II	Rusaifa III	Zarqa I	Zarqa II	Zarqa III	Zarqa IV	New Zarqa I	New Zarqa II	New Zarqa III
EC	mS/cm	0.864	0.707	1.13	1.09	1.275	1.225	1.26	1.22	0.788	0.765	0.98	0.952	0.793	0.799	0.766	0.767
pH		7.6	8.12	7.61	7.83	7.62	7.47	7.53	7.53	8.06	8.04	7.62	7.8	7.89	7.79	7.91	7.8
Temp.	°C	11.2	17.9	16.5	16.6	15.6	14.9	15.5	16.2	14.3	14.8	17	13.8	15	12.7	12.8	12.7
Cl_2	mg/l	0.7	0.1	1.5	< 0.1	< 0.1	0.4	< 0.1	< 0.1	< 0.1	0.85	1.1	0.4	0.75	0.8	0.75	0.75
DO	mg/l	8.3	7.7	8.6	8	7.6	9.8	7.4	7.53	8.9	9.6	8.5	7.3	8.3	9.4	9.9	9.7
Taste		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.21	0.37	0.31	0.22	0.21	0.2	0.22	0.2	0.18	0.26	0.22	0.18	0.2	0.19	0.17	0.3
Color		No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
TDS	mg/l	580.0	545	773.0	734.7	868.0	878.0	875.0	854.0	575.0	510.0	685.0	665.0	545.3	549.4	516.3	527.4
Alk.	mg/l	48	61	54	58	62	56	58	60	60	58	48	54	44	54	50	57
T.H.	mg/l	240.2	191.2	293.3	448.4	463.5	460.5	476.5	430.4	362.4	224.2	282.3	242.2	226.2	235.2	240.2	236
Cl	mg/l	195	160	248.5	195	248.5	266.2	266.2	266.2	124	177.5	213	230.7	195.2	177.5	195.2	177.5
SO_4	mg/l	12.7	9.93	12.81	10.78	9.71	9.07	10.67	9.39	12.17	13.02	13.87	14.3	13.77	13.23	9.5	10.67
NH_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	mg/l	0.0	0.005	0.007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mn	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO_3	mg/l	10.7	14	18.3	20.4	17.2	17.6	16.8	18.7	15.9	7.4	9.5	10.2	6.8	9.2	10.4	8.3
NO_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TBC	Cells per ml	30	18	180	300	4400	50	640	3	1640	3	350	100	0	1	10	0
TFC	MPN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 11: Reservoirs

Test	Unit	Zarqa St.	Batrawi	Awajan	Khaw
EC	mS/cm	0.623	0.764	0.841	0.928
pH		7.76	7.51	7.75	7.78
Temp.	°C	25.5	24.6	24.9	19.9
Cl_2	mg/l	1.3	1.5	1.2	1.55
DO	mg/l	6.5	7	8.1	8.1
Taste		Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.28	0.23	0.18	0.18
Color		No	No	No	No
TDS	mg/l	678	525.4	805.0	669.0
Alk.	mg/l	52	50	56	47
T.H.	mg/l	459.2	210.2	322.3	312.3
Cl	mg/l	356	177.5	142	248.5
SO_4	mg/l	8.96	11.42	10.24	11.93
NH_4	mg/l	0.0	0.0	0.0	0.0
Fe	mg/l	0.1	0.08	0.0	0.0
Mn	mg/l	0.0	0.001	0.0	0.0
NO_3	mg/l	18.4	10.5	41.4	21
NO_4	mg/l	0.0	0.0	0.0	0.0
TBC	Cells per ml	0	29	0	0
TFC	MPN	0	0	0	0

Table 12: Boosters and pumping stations

Test	Unit	Zarqa (Inlet from Hashmie)	Zarqa (Inlet from Khaw)	Zarqa (Outlet to Zarqa)	Zarqa (Outlet to Rusaifa)	Rusaifa Booster "4" (Outlet)	Rusaifa Booster "18" (Outlet)	Murhib (Outlet)	Khaw (Input from Azraq)	Khaw (Input from Zatari)	Hallabat (Outlet)	Azraq (Outlet)	Khaldiah (Inlet)	Khaldiah (Outlet)	Zatari (Inlet)	Zatari (Outlet)
EC	mS/cm	0.749	0.588	0.659	0.66	0.977	0.93	0.678	0.575	0.61	0.796	0.572	4.55	3.74	0.63	0.54
pH		7.6	7.9	7.89	7.89	7.01	7.43	7.5	8.09	7.68	7.74	8.18	7.85	7.88	8.4	8.21
Temp.	°C	24	20.8	24.1	24	21.1	24.5	21.4	25.5	27.8	23.4	19.2	18.9	19.1	18.8	19
Cl_2	mg/l	< 0.1	1.2	0.5	0.5	1.5	1.5	1.5	1.55	1.6	1.38	1.3	< 0.1	< 0.1	< 0.1	1.6
DO	mg/l	6.5	6.5	6.4	6.5	4.2	6.3	6.1	7.3	5.7	8.5	8.3	8.7	8.3	5.7	6.8
Taste		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	N. A	N. A	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	N. A	N. A	Acc.	Acc.
Turb.	NTU	0.21	0.29	0.38	0.38	0.24	0.22	0.31	0.2	0.19	0.24	0.17	0.46	0.44	0.29	0.23
Color		No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
TDS	mg/l	504.8	404.3	460.0	460.0	952.0	760	510	395.4	420.0	525	420	3013.0	2413.0	431.0	370.0
Alk.	mg/l	54	48	56	56	60	58	65	48	52	50	52	30	32	52	46
T.H.	mg/l	178.2	126.1	144.2	144.2	366.4	306.3	288.3	101.1	217	270.3	180.2	1263	1242.5	232.2	224.2
Cl	mg/l	177.5	124	124	124	195	106.5	106.5	142	123	195.2	142	956	738.7	124	88.7
SO_4	mg/l	11.09	9.18	12.49	12.49	6.51	5.98	6.94	10.14	16.44	11.85	11.95	35.33	22.52	8.32	6.08
NH_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	mg/l	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.07	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Mn	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0
NO_3	mg/l	6.7	8.9	12.5	12.5	55	41	21.3	4.2	5.9	6.8	7.7	58.3	60.2	6.9	8.5
NO_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TBC	Cells per ml	0	0	128	0	18	8	10	0	1	0	90	160	10	30	0
TFC	MPN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Special tests and experiments

Table 13: Langelier Saturation Index Results

Site	Langelier Saturation Index	Comments
Al-Azraq Station (Outlet)	-1.23	Tendency to dissolve $CaCO_3$ (Corrosive)
Khaw St. (Input from Zatari)	-0.83	Tendency to dissolve $CaCO_3$ (Corrosive)
Al-Zarqa Station (Outlet to Zarqa)	-1.18	Tendency to dissolve $CaCO_3$ (Corrosive)

Third Campaign Water Quality Analysis Results

- Water samples collected during the period (21-6-1995 & 29-6-1995)

General Items

Table 14: House Taps

Test	Unit	Sukhna	Hashmie	Awajan	Sh. Camp I	Sh. Tap II	Sh. Camp III	Rusaifa I	Rusaifa II	Rusaifa III	Zarqa I	Zarqa II	Zarqa III	Zarqa IV	New Zarqa I	New Zarqa II	New Zarqa III
EC	mS/cm	1350	1575	1695	1418	1453	1450	1305	1525	1418	828	1343	1349	1330	1351	1370	1381
pH		7.38	7.34	7.09	7.1	7.16	7.26	7.8	7.02	7.36	7.61	7.17	7.3	7.23	7.2	7.42	7.3
Temp.	°C	39	34.8	33.8	24.5	23.6	27.8	27.2	25.1	27.3	28.8	29.3	34.8	30.3	31.5	33.8	28.5
Cl_2	mg/l	0.5	0.2	1.4	1.3	1.4	1.1	0.15	1.4	0.3	0.25	1.5	0.15	1.4	1.1	0.3	1.6
DO	mg/l	7.5	5	4.3	4.6	4.3	4.5	4.5	7.5	5.5	6.3	7.9	4.9	7.1	8.4	8.2	7.4
Taste		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.35	0.25	0.16	0.21	0.25	0.0.24	0.21	0.27	0.23	0.25	0.2	0.22	0.23	0.28	0.2	.0.19
Color		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
TDS	mg/l	810	917	729	815	835	820	860	875	820	555	785	800	770	865	780	875
Alk.	mg/l	65	60	60	58	60	50	78	70	50	90	57	50	55	62	55	58
T.H.	mg/l	276.3	199	322.3	372.4	354.3	312.3	306.3	376.4	332.3	252.2	280.2	300.3	276.2	282.3	320.3	292.3
Cl	mg/l	275.5	265	292.7	241	224	275.5	224	275.5	258.3	258.3	258.3	258.3	258.3	258.3	275.5	275.5
SO_4	mg/l	7.47	6.5	17.07	9.82	1.28	7.68	13.34	14.83	9.28	8.22	21.98	26.89	24.87	13.66	31.27	27.21
NH_4	mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fe	mg/l	0	0.003	0	0.0	0.0	0	0.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Mn	mg/l	0	0	0.0	0.0	0.0	0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO_3	mg/l	6.95	22.1	54.2	7	6.52	6.98	6	7.02	7	6.77	6.91	6.87	6.89	6.91	7.1	6.98
NO_4	mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TBC	Cells per ml	0	0	28	0	0	0	36	15	73	0	0	0	0	0	0	0
TFC	MPN	0	0	0	0	0	0	0	25	80	0	0	0	0	0	0	0

Table 15: Reservoirs

Test	Unit	Zarqa St.	Batrawi	Awajan	Khaw
EC	mS/cm	1370	1392	815	1184
pH		7.37	7.25	7.91	7.76
Temp.	°C	28.1	28.6	27.1	27.8
Cl_2	mg/l	1.4	1.1	1.4	1.2
DO	mg/l	8.6	6	8.3	8.7
Taste		Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.2	0.2	0.22	0.24
Color		Acc.	Acc.	Acc.	Acc.
TDS	mg/l	839.0	750.0	465.0	698.0
Alk.	mg/l	78	60	80	60
T.H.	mg/l	291.2	307.2	251	301.2
Cl	mg/l	206.6	275.5	120.5	223.9
SO_4	mg/l	9.6	3.2	2.64	2.74
NH_4	mg/l	0	0	0	0
Fe	mg/l	0.0	0.0	0.0	0.0
Mn	mg/l	0.0	0.0	0.0	0.0
NO_3	mg/l	22.1	8.35	7.8	21.0
NO_4	mg/l	0	0	0	0
TBC	Cells per ml	0	0	0	0
TFC	MPN	0	0	0	0

Table 16: Boosters and pumping stations

Test	Unit	Zarqa (Inlet from Hashmie)	Zarqa (Inlet from Khaw)	Zarqa (Outlet to Zarqa)	Zarqa (Outlet to Rusaifa)	Rusaifa Booster "4" (Outlet)	Rusaifa Booster "18" (Outlet)	Murhib (Outlet)	Khaw (Input from Azraq)	Khaw (Input from Zatari)	Hallabat (Outlet)	Azraq (Outlet)	Khaldiah (Inlet)	Khaldiah (Outlet)	Zatari (Inlet)	Zatari (Outlet)
EC	mS/cm	1296	1104	1358	1358	1256	959	821	1697	1817	850	698	485	425	618	625
pH		7.59	7.99	7.34	7.34	7.1	7.36	7.56	7.86	7.18	7.76	7.77	7.59	7.59	8.06	7.71
Temp.	°C	27.3	28.4	27.6	27.6	21.5	23	26.7	29.9	30.6	24.2	28.1	27.2	27.6	32.5	31.6
Cl_2	mg/l	0.6	1.1	1.4	1.4	0	1.3	1.5	1.35	1.2	1.5	1.6	0	0	0	2.1
DO	mg/l	7.8	7.9	7.8	7.8	7	5.6	6.4	8.1	7.3	8.9	6.1	7.8	7.6	6.5	8
Taste		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.23	0.2	0.22	0.21	0.2	0.19	0.19	0.22	0.28	0.23	0.22	0.45	0.36	0.22	0.24
Color		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
TDS	mg/l	700	635	835	830	973	541	514	440	927	525	410	3160	2680	355	425
Alk.	mg/l	80	70	75	75	85	90	76	52	50	65	60	50	48	81	70
T.H.	mg/l	260.1	281.1	285.1	301.3	249	267.1	249	131.1	132	176.7	110.4	1396	1550	120.4	132.5
Cl	mg/l	172.8	241.1	475.5	275.5	154.9	120.5	103.3	103.7	316	172.2	309.1	1024.1	772.8	120.5	206..6
SO_4	mg/l	11.5	5.9	10.03	9.6	14.19	11.61	2.7	2.07	2.85	2.13	3.28	4.2	3.3	5.2	3.38
NH_4	mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fe	mg/l	0.0	0.1	0.1	0.1	0	0.0	0.0	0	0.1	0.0	0.0	0.0	0.1	0.1	0.0
Mn	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO_3	mg/l	8.2	8.22	8.26	8.35	53	23	15	7.7	33.4	5.0	6	8.69	8.69	7.92	7.82
NO_2	mg/l	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TBC	Cells per ml	0.0	0	0	0	42	4	3	0	8	0	0	4	0	31	0
TFC	MPN	0.0	0	0	0	0	0	0	0	0	0	0	0	0	25	0

Special tests and experiments

Table 17: Langelier Saturation Index Results

Site	Langelier Saturation Index	Comments
Al-Azraq Station (Outlet)	-0.64	Tendency to dissolve $CaCO_3$ (Corrosive)
Khaw St. (Input from Zatari)	0.01	Noble
Al-Zarqa Station (Outlet to Zarqa)	-0.88	Tendency to dissolve $CaCO_3$ (Corrosive)

Table 18: Aeration Experiment Results

Chlorine Stability Experiments Results

Table 19: Chlorine stability with storage time

Time (min.)	Zarqa	Russaifa	Hashmieh
0	1.4	1.5	0.9
5	1.32	1.4	0.85
10	1.3	1.42	0.8
20	1.29	1.4	0.7
30	1.29	1.4	0.7
60	1.29	1.42	0.75
120	1.26	1.35	0.6
240	1.23	1.3	0.6
360	1.1	1.22	0.6
720	1	1.1	0.45
1200	0.9	1	0.35
2160	0.8	0.9	0.32

Table 20: Chlorine stability with transportation distance

Site	Distance From Zarqa Station (km)	Chlorine Conc. (mg/l)
Point 1	0	1.6
Point 2	3.5	1.5
Point 3	10.5	1.3
Point 4	11.8	1.2

Table 21: Lime Soda Dosage Experiment

Hardness After Experiment	*940*
Hardness Before Experiment	*1080*
Percentage Reduction	*14.894%*

Table 22: Fluoride Test Results

Site	Fluoride Concentration (mg/l)
Zarqa Station (Outlet to Zarqa)	0.1
Permissible Standard	1.0

Fourth Campaign Water Quality Analysis Results

- Water samples collected during the period (2-8-1995 & 9-8-1995)

General Items

Table 23: House Taps

Test	Unit	Sukhna	Hashmie	Awajan	Sh. Camp I	Sh. Camp II	Sh. Camp III	Rusaifa I	Rusaifa II	Rusaifa III	Zarqa I	Zarqa II	Zarqa III	Zarqa IV	New Zarqa I	New Zarqa II	New Zarqa III
EC	mS/cm	1399	998	1510	1233	1207	1529	1524	1184	1537	1384	1396	1385	1382	1343	1423	1530
pH		7.32	7.82	7.04	7.7	7.9	6.92	7.17	7.03	7.03	7.32	7.16	7.18	7.23	8.03	7.29	7.35
Temp.	°C	31	30	25.4	30.5	30.5	24.5	27	29.3	26.3	28.6	28.3	31.2	29.2	28.5	32.1	31
Cl_2	mg/l	0	1.3	1.3	1.2	1.1	1	1.4	0	1.2	1.2	1	0.9	1.4	0.6	1.1	1.3
DO	mg/l	5.1	8.7	5.7	8.5	6.1	5.1	5.9	6.4	6.4	8.2	7.7	6.7	7.2	7.1	8.2	8.6
Taste		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.18	2.5	0.19	0.25	0.18	0.18	0.18	0.28	0.17	0.18	0.18	0.19	0.21	0.17	0.16	0.18
Color		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
TDS	mg/l	870.0	1124.0	1156.0	740.0	719.0	855.0	940.0	825.0	990.0	835.0	780.0	845.0	770.0	930.0	805.0	940.0
Alk.	mg/l	19	27	28	70	26	25	35	90	25	23	25	28	18	23	18	18
T.H.	mg/l	512.5	129.7	660.8	346	500.5	440.4	600.6	442	640.3	488.5	424	481	420.5	421.7	500	540
Cl	mg/l	257.1	231.2	308.6	274	171	187.8	274	281	291.4	274.2	204	274	282	257.1	291.4	325.6
SO_4	mg/l	19.5	5.9	6	11.6	4	13.4	1.4	16.5	10.7	14	13.9	2	34.4	12.4	8	17.4
NH_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	mg/l	0	0.2	0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Mn	mg/l	0	0	0.0	0.0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO_3	mg/l	24	16.4	61.4	31	36	36	34	35.6	33	22	39	20.8	22	22	20.6	28
NO_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TBC	Cells per ml	3680	0	0	320	6	0	0	3800	6	0	0	10	0	13	3	0
TFC	MPN	0	0	0	80	0	0	0	35	2	0	0	0	0	0	0	0

Table 24: Reservoirs

Test	Unit	Zarqa St.	Batrawi	Awajan	Khaw
EC	mS/cm	1342	1327	810	1236
pH		7.23	7.21	7.85	7.76
Temp.	°C	28.2	29.2	27.2	26.7
Cl_2	mg/l	1.5	0.5	1.5	1.6
DO	mg/l	7.7	6.3	8.5	8.3
Taste		Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.18	0.25	0.17	0.17
Color		Acc.	Acc.	Acc.	Acc.
TDS	mg/l	819.0	790.0	700.0	745.0
Alk.	mg/l	48	51	60	20
T.H.	mg/l	386	428	385	480
Cl	mg/l	249.2	274.23	205.67	205.67
SO_4	mg/l	14.4	2.02	12.8	14.94
NH_4	mg/l	0.0	0.0	0.0	0.0
Fe	mg/l	0.0	0.0	0.0	0.0
Mn	mg/l	0.0	0.0	0.0	0.0
NO_3	mg/l	20.4	34	30	35
NO_4	mg/l	0.0	0.0	0.0	0.0
TBC	Cells per ml	0	0	0	0
TFC	MPN	0	0	0	0

Table 25: Boosters and pumping stations

Test	Unit	Zarqa (Inlet from Hashmie)	Zarqa (Inlet from Khaw)	Zarqa (Outlet to Zarqa)	Zarqa (Outlet to Rusaifa)	Rusaifa Booster "4" (Outlet)	Rusaifa Booster "18" (Outlet)	Murhib (Outlet)	Khaw (Input from Azraq)	Khaw (Input from Zatari)	Hallabat (Outlet)	Azraq (Outlet)	Khaldiah (Inlet)	Khaldiah (Outlet)	Zatari (Inlet)	Zatari (Outlet
EC	mS/cm	1570	915	1306	1306	1668	860	825	692	1220	840	702	4140	3630	589	608
pH		7.28	7.88	7.25	7.25	7.01	7.2	7.51	7.89	7.62	7.68	7.77	7.58	7.64	8.07	7.79
Temp.	°C	26.3	30.2	27.6	27.6	23	27.7	26.1	31.1	30.8	25.1	28.5	28.4	28.3	32.4	31.5
Cl_2	mg/l	0.25	1.2	1.4	1.4	1.1	0.8	1.5	1.4	2	1.4	1.6	---	---	---	1.6
DO	mg/l	5.1	7.9	7.6	7.6	6.2	7	6.9	7.9	8.2	8.8	7.6	8.9	7.5	6.8	6.7
Taste		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Odor		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
Turb.	NTU	0.17	0.25	0.22	0.2	0.21	0.22	0.18	0.19	0.18	0.2	0.14	0.3	0.19	0.18	0.19
Color		Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.	Acc.
TDS	mg/l	810.0	580.0	800.0	755.0	941.0	549.0	509.0	400.0	900.0	540.0	435.0	3220.0	2965	389.0	400.0
Alk.	mg/l	60	50	58	50	51	61	42	24	45	19	24	20	20	28	25
T.H.	mg/l	470	285.2	401.6	390.25	600	410.3	384	188.1	544	280.1	172.1	1681	1749.7	200.2	240.24
Cl	mg/l	274.3	205.7	274.2	239.9	308.5	137.1	102.87	171.4	240	154.3	120	1114.1	801.6	102.8	102.8
SO_4	mg/l	5.54	6.18	17.07	16.01	13.34	13.87	9.07	4.26	1.92	6.08	13.87	59.1	16.54	4.6	3.7
NH_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	mg/l	0.0	0.0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mn	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO_3	mg/l	34.0	25.9	34.6	33.4	48.3	24	14.4	18	34	10.3	7.7	38	39	25.8	27.6
NO_4	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TBC	Cells per ml	0	30	0	6	0	0	0	8	7	0	0	30	0	20	8
TFC	MPN	0	0	0	0	0	0	0	0	0	0	0	8	0	5	0

Special tests and experiments

Table 26: Langelier Saturation Index Results

Site	Langelier Saturation Index	Comments
Al-Azraq Station (Outlet)	-0.52	Tendency to dissolve $CaCO_3$ (Corrosive)
Khaw St. (Input from Zatari)	-0.42	Tendency to dissolve $CaCO_3$ (Corrosive)
Al-Zarqa Station (Outlet to Zarqa)	-0.52	Tendency to dissolve $CaCO_3$ (Corrosive)

First campaign charts

Figure 1: House taps TDS values representation

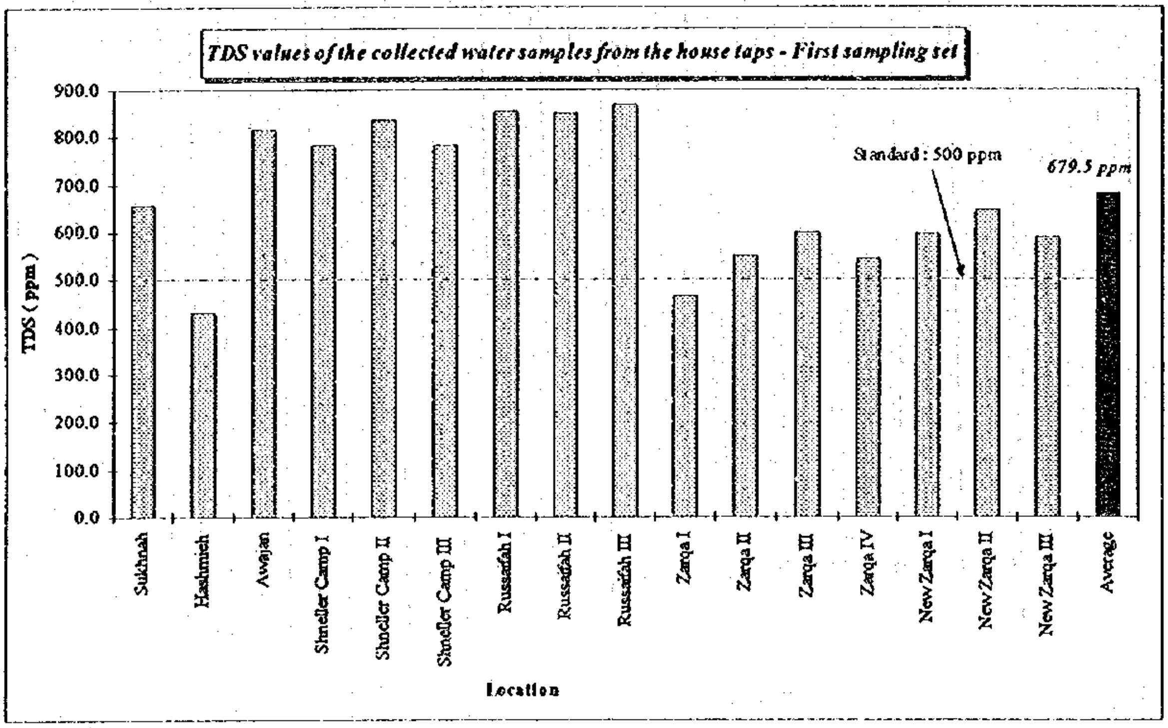


Figure 2: House taps Total Hardness values representation

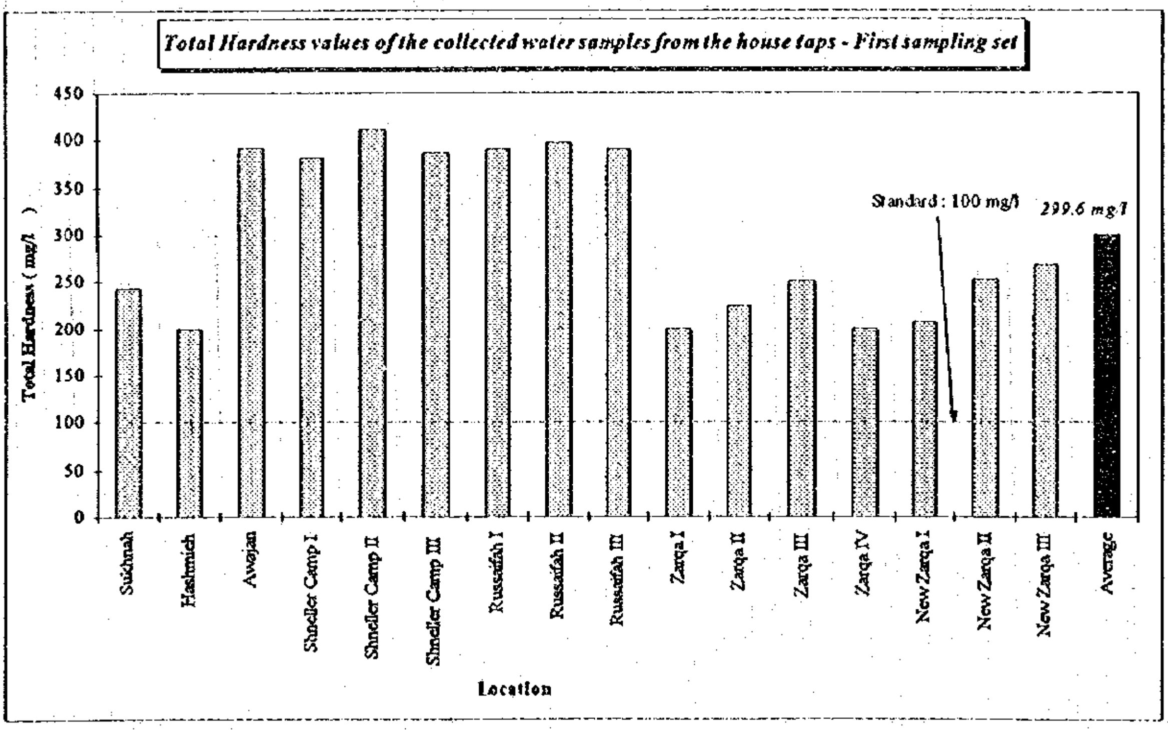


Figure 3: House taps Chloride ion concentration values representation

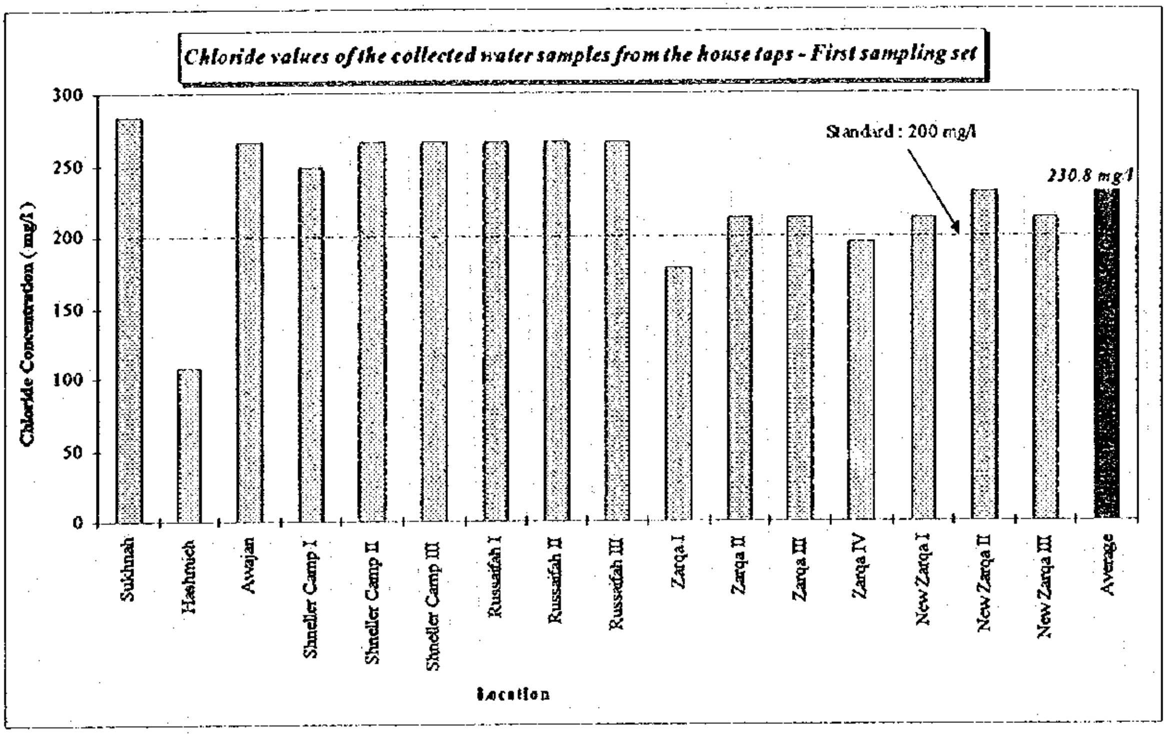


Figure 4: TDS values representation

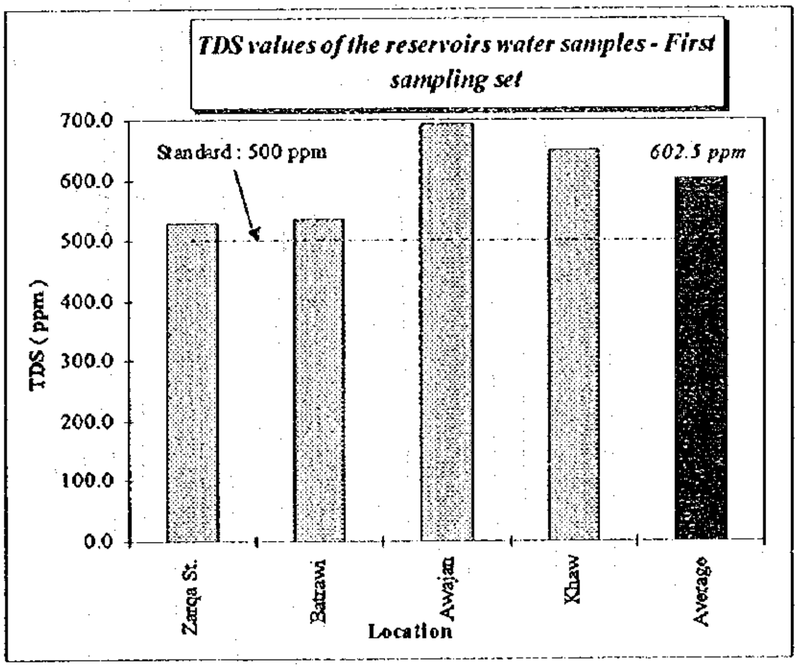


Figure 5: Reservoirs Total Hardness values representation

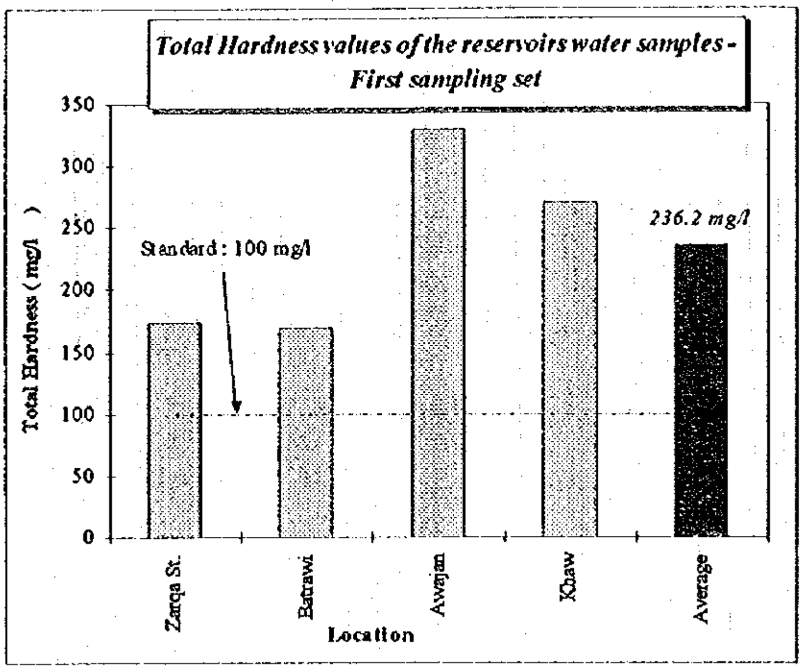


Figure 6: Reservoirs Chloride ion concentration values representation

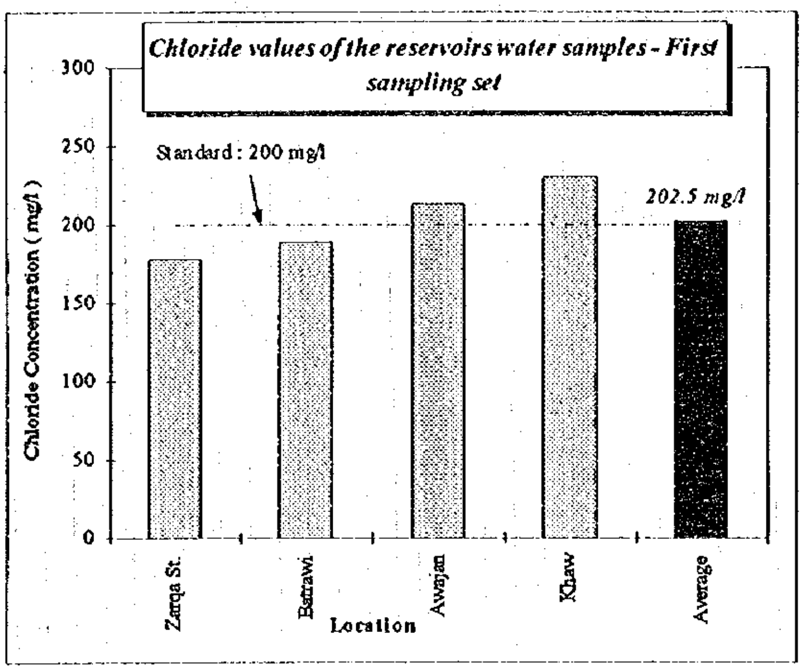


Figure 7: Boosters and Pumping Stations TDS values representation

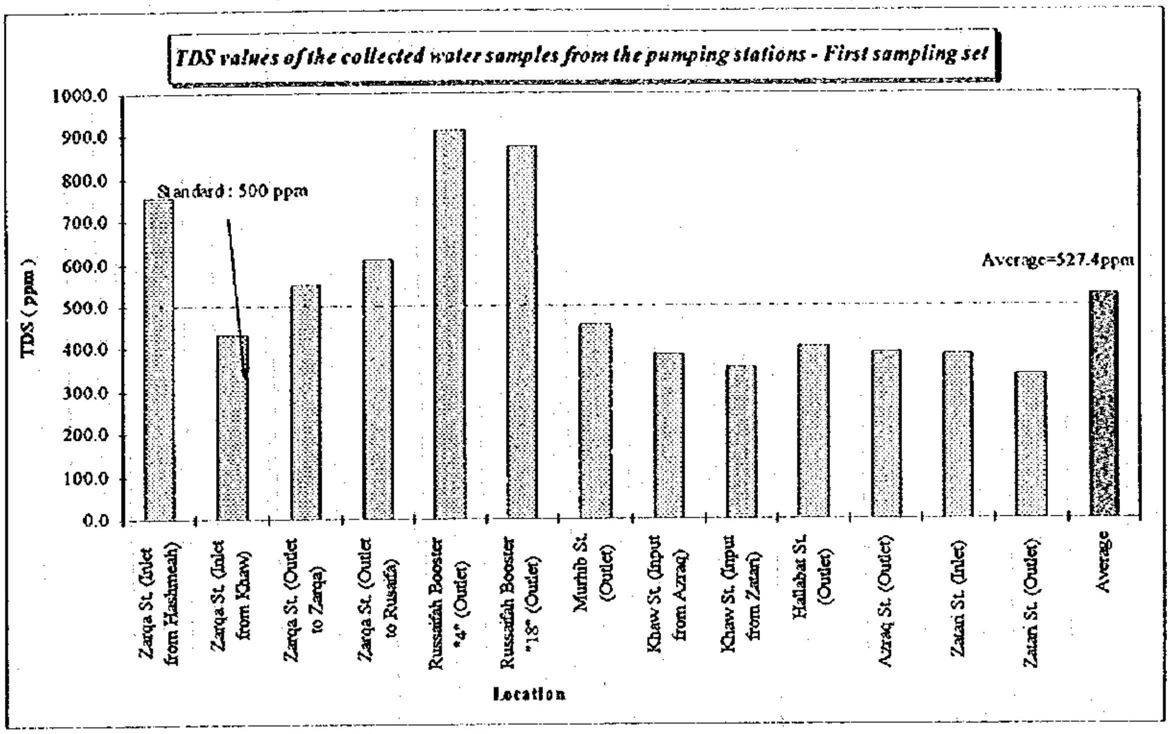


Figure 8: Boosters and Pumping Stations Total Hardness values representation

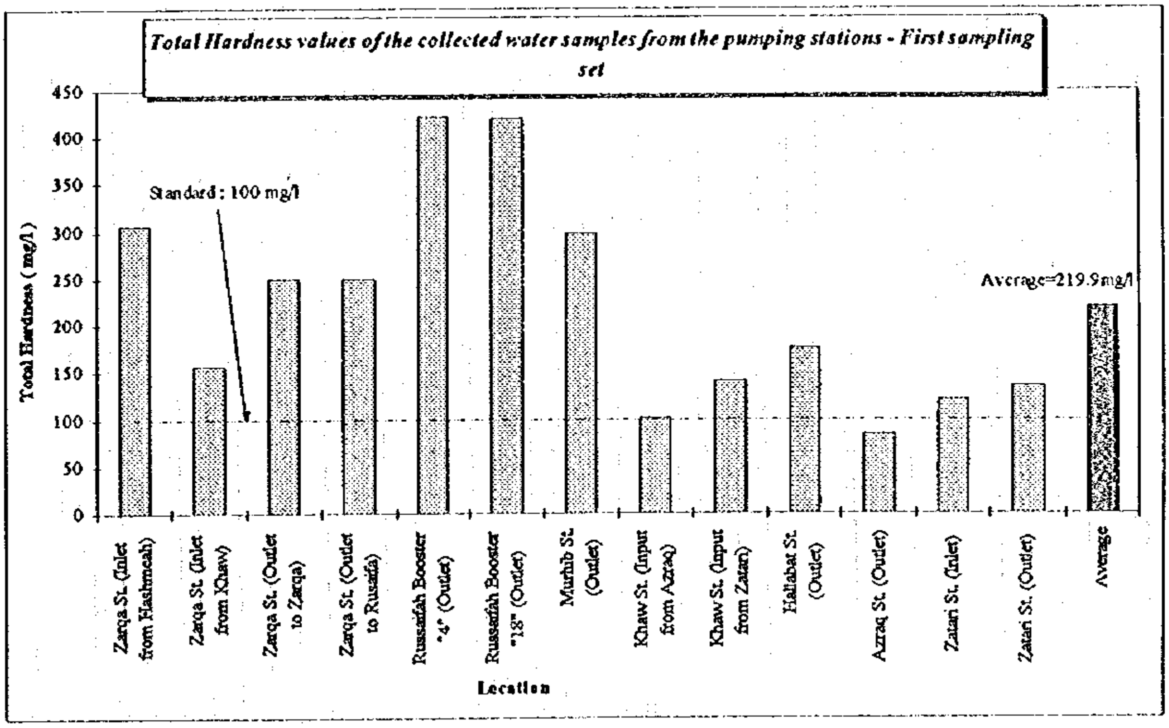


Figure 9: Boosters and Pumping Stations Chloride ion concentration values representation

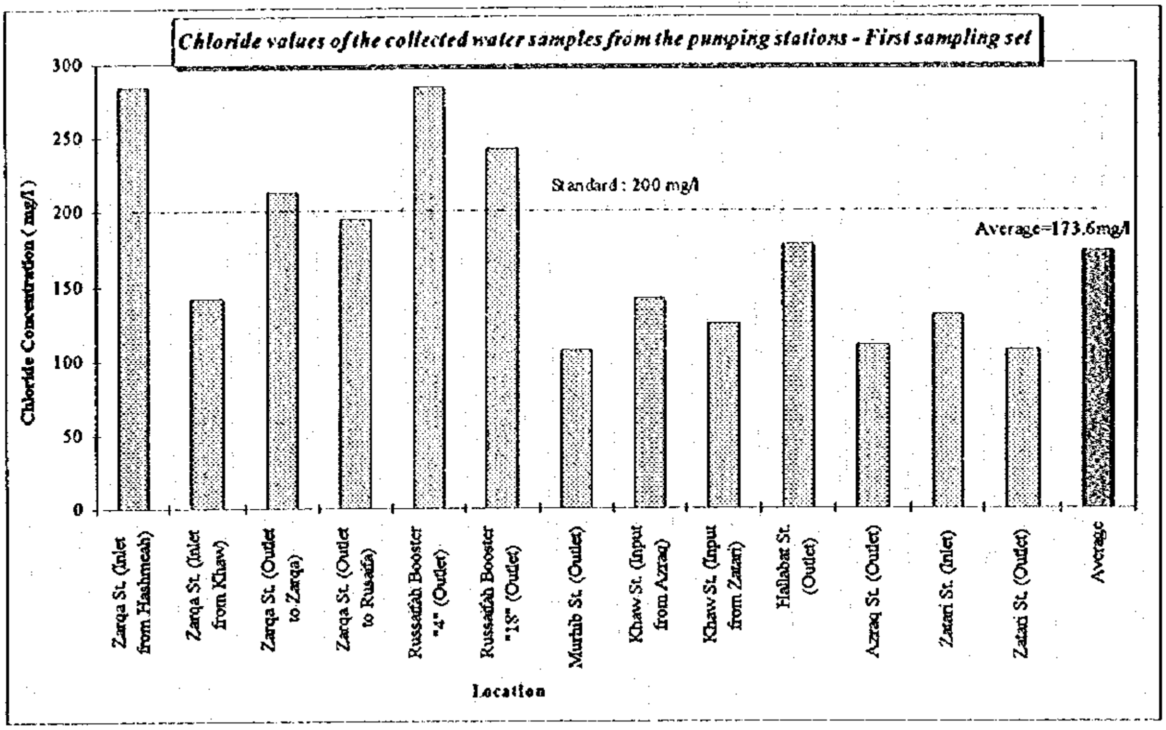
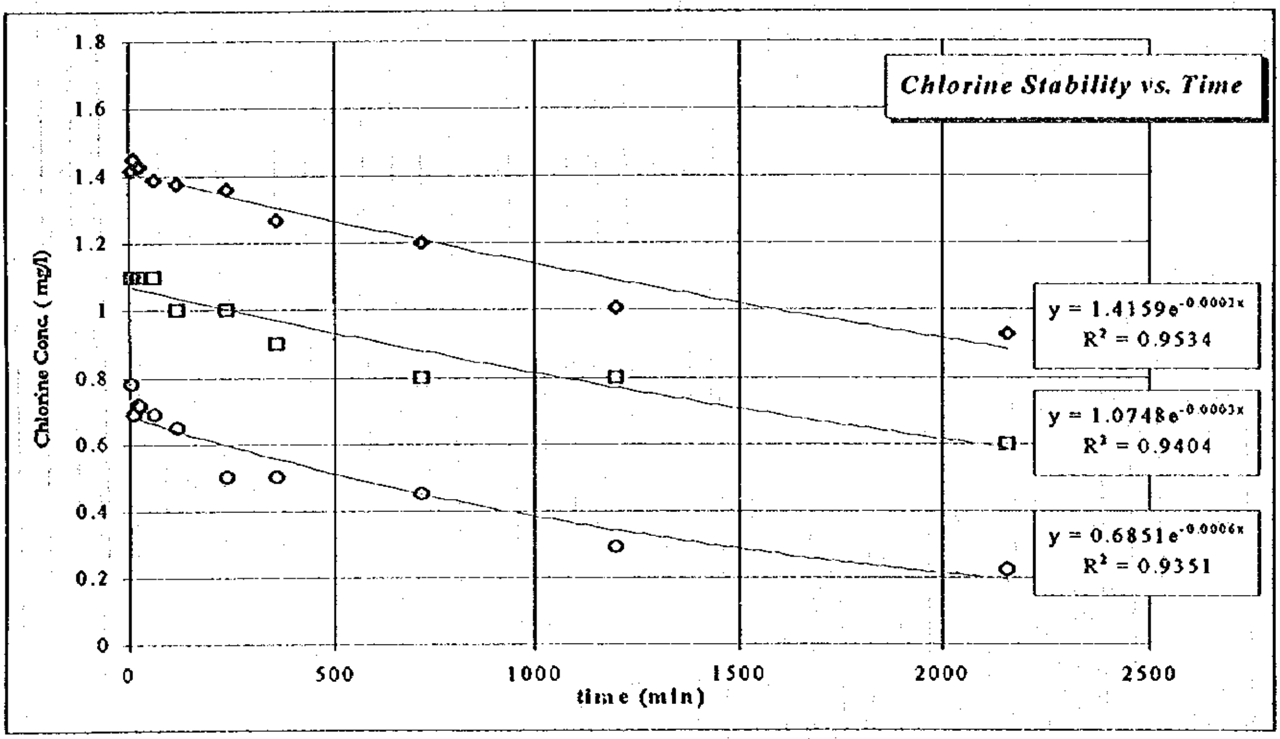


Figure 10: Chlorine stability vs. time curve fitting



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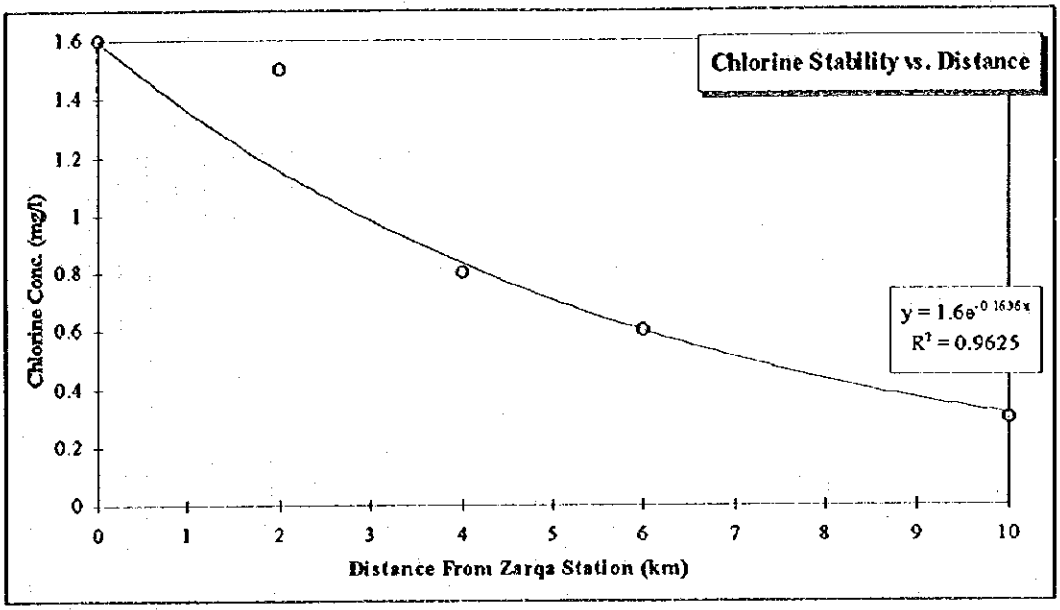


Second campaign charts

Figure 12: House taps TDS values representation

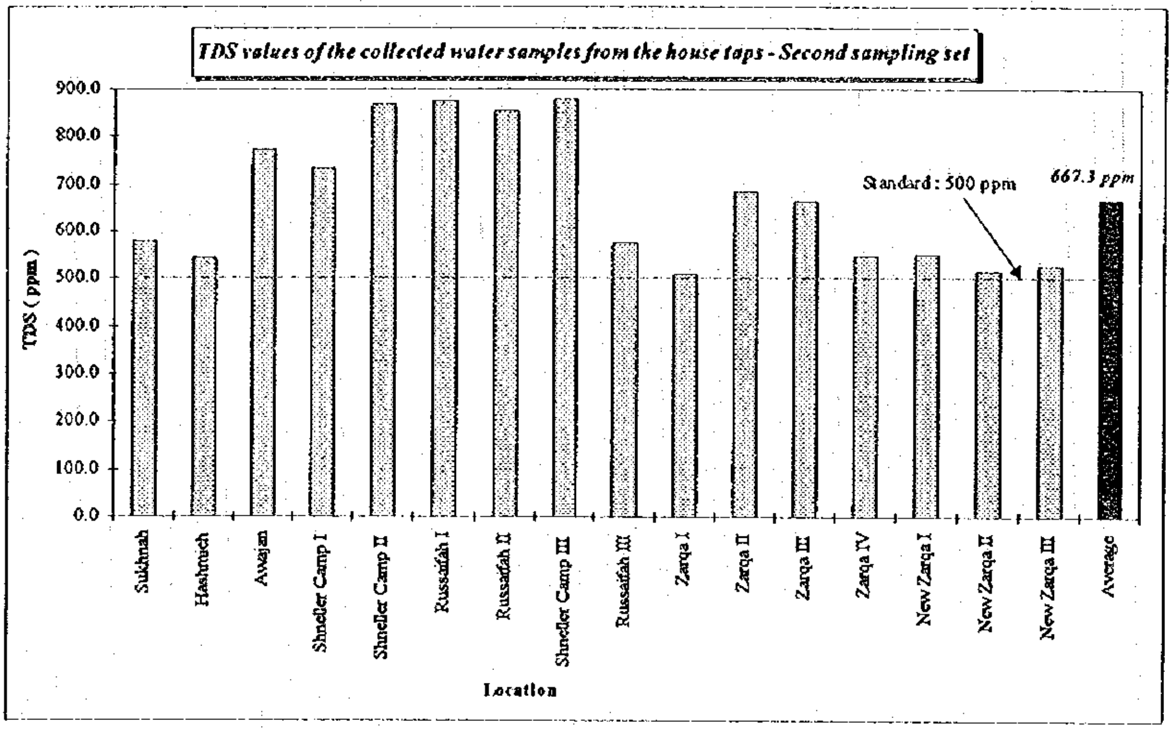
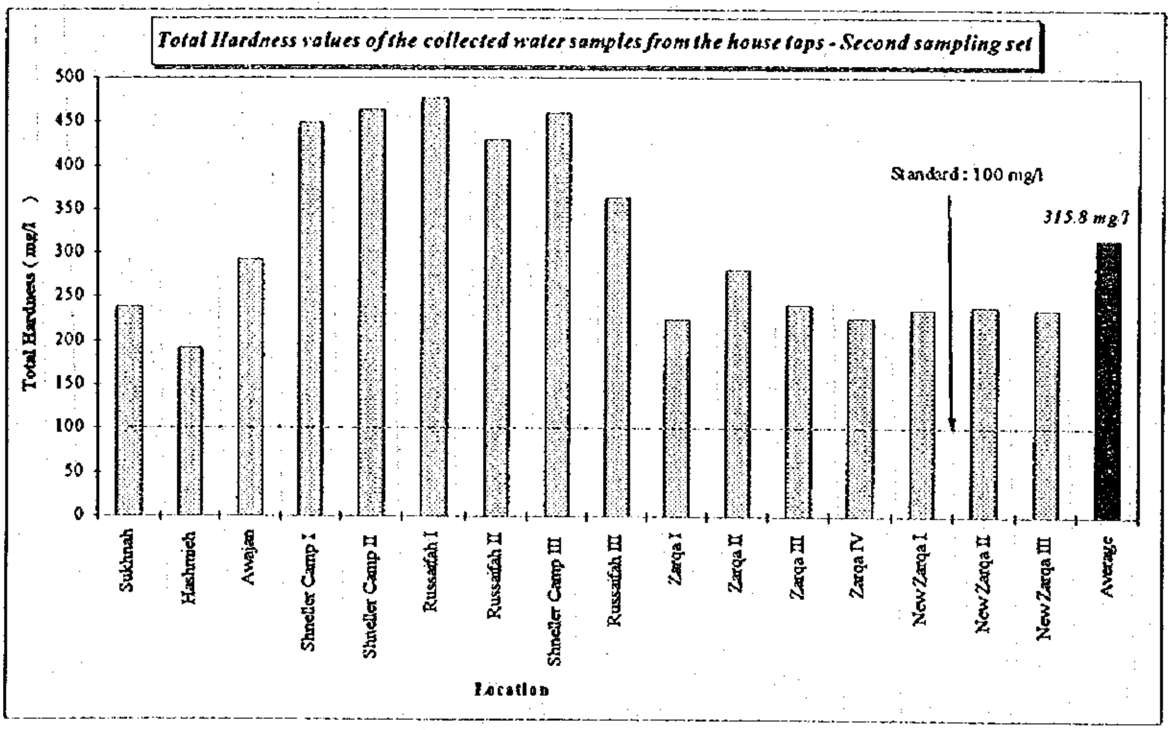


Figure 13: House taps Total Hardness values representation



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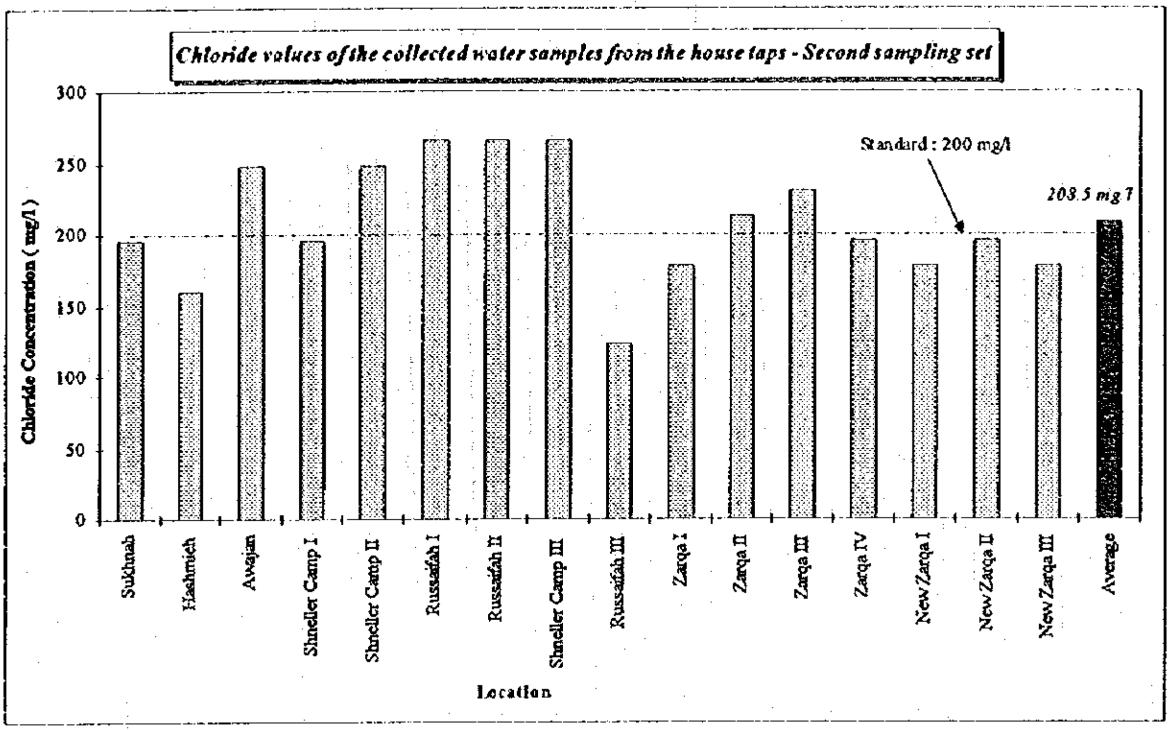

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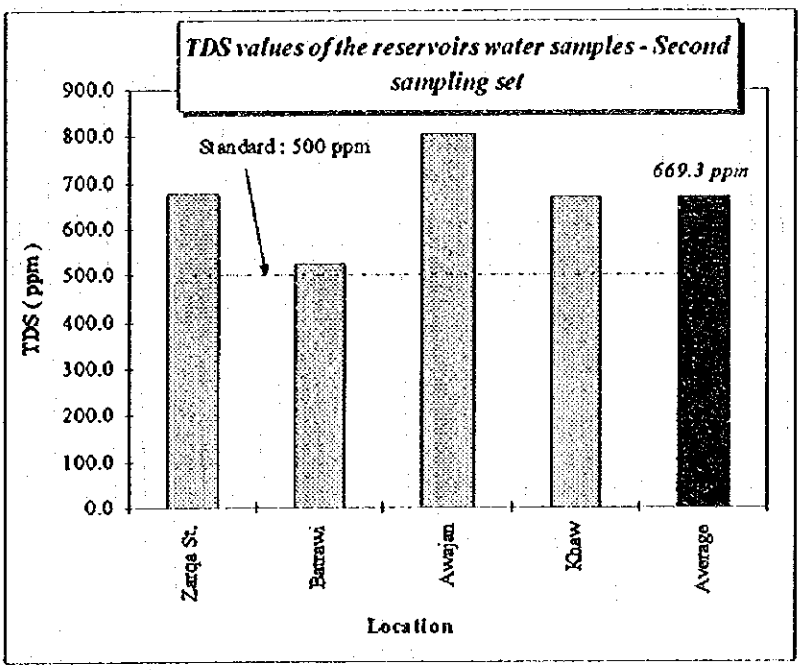

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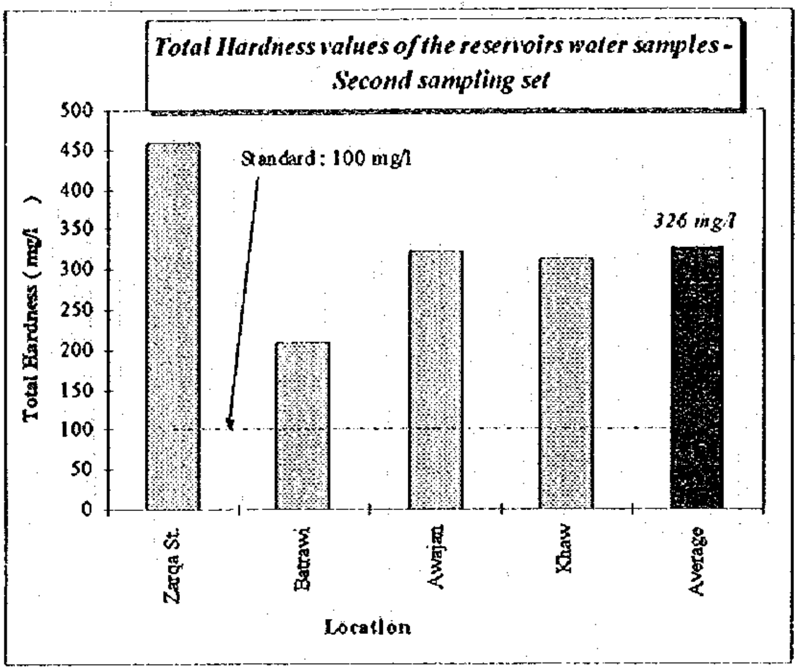
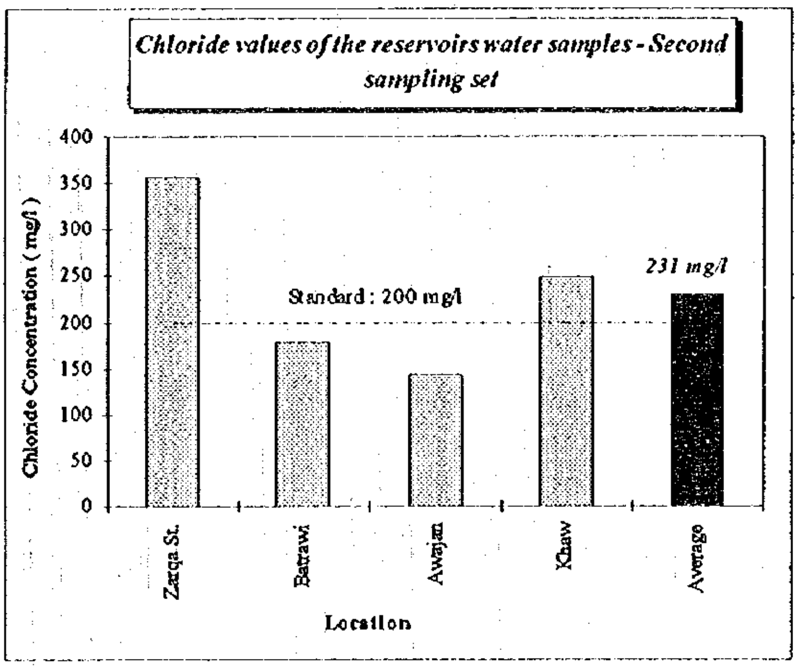


Figure 17: Reservoirs Chloride ion concentration values representation



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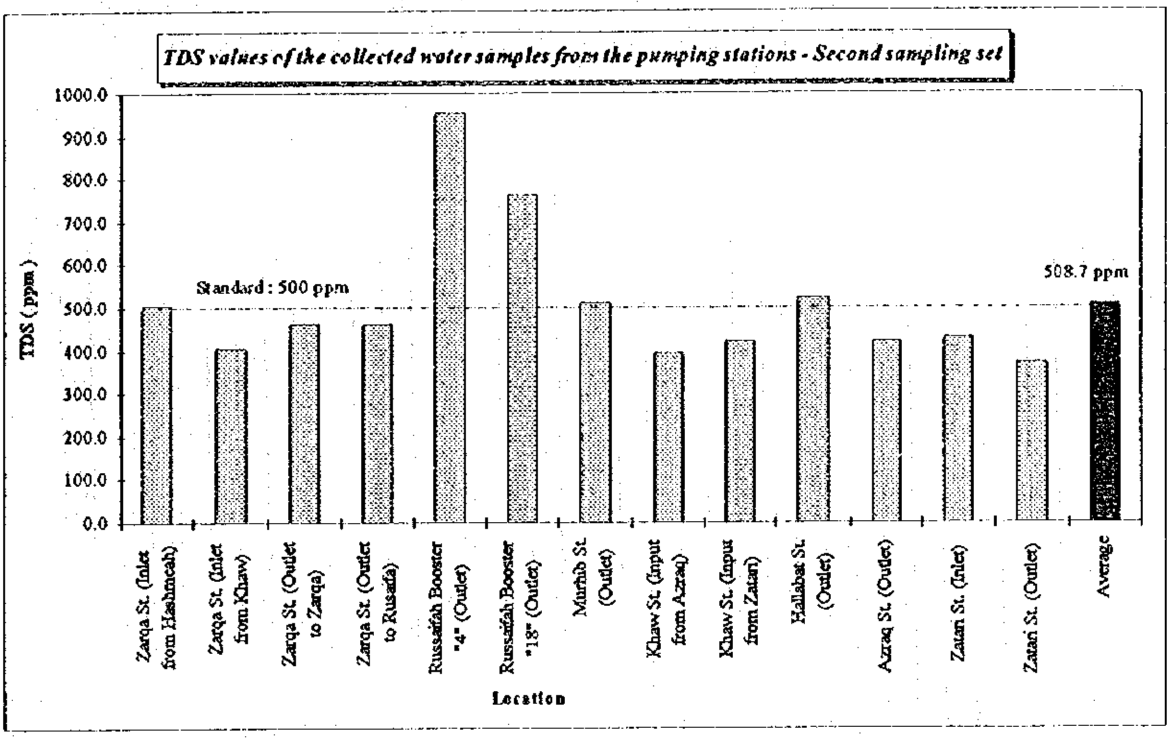

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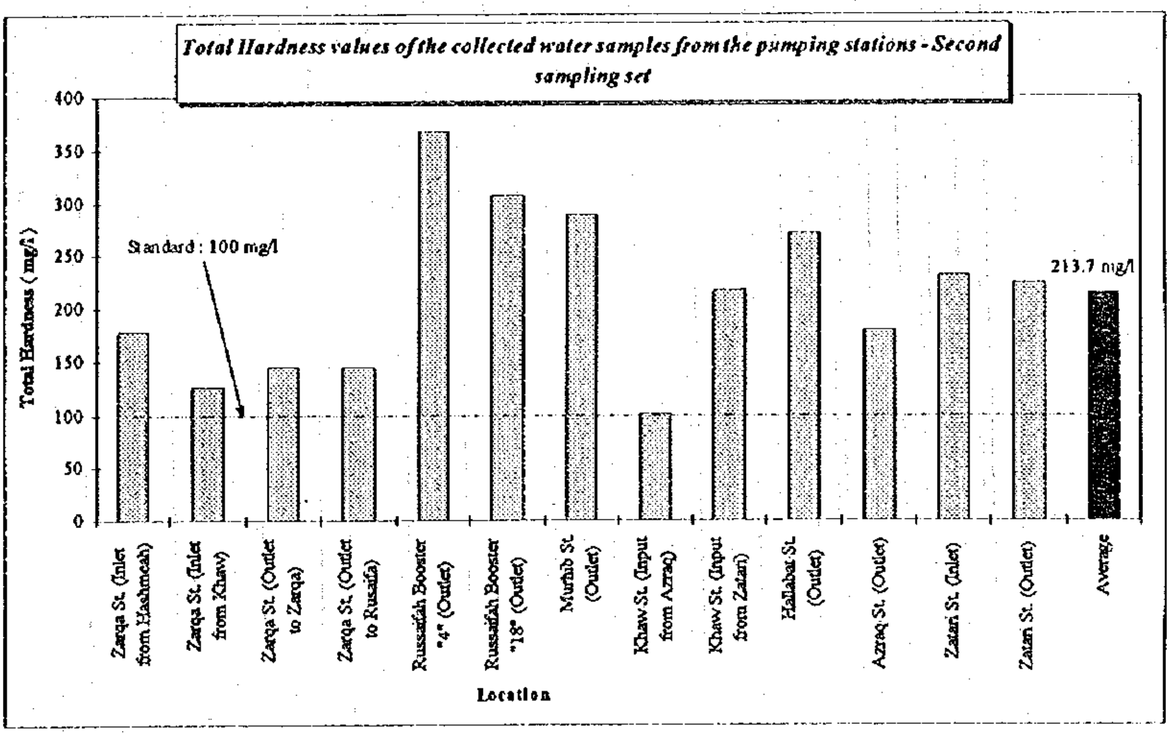
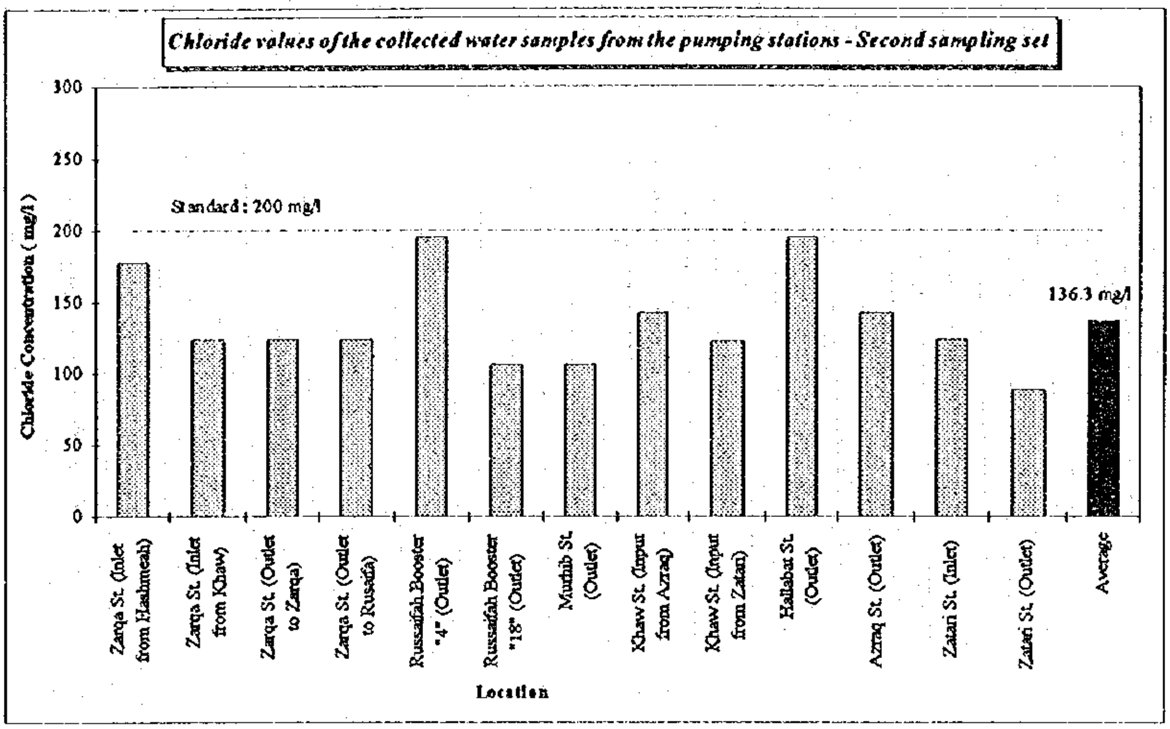


Figure 20: Boosters and pumping stations Chloride ion concentration values representation



Third campaign charts

Figure 21: House taps TDS values representation

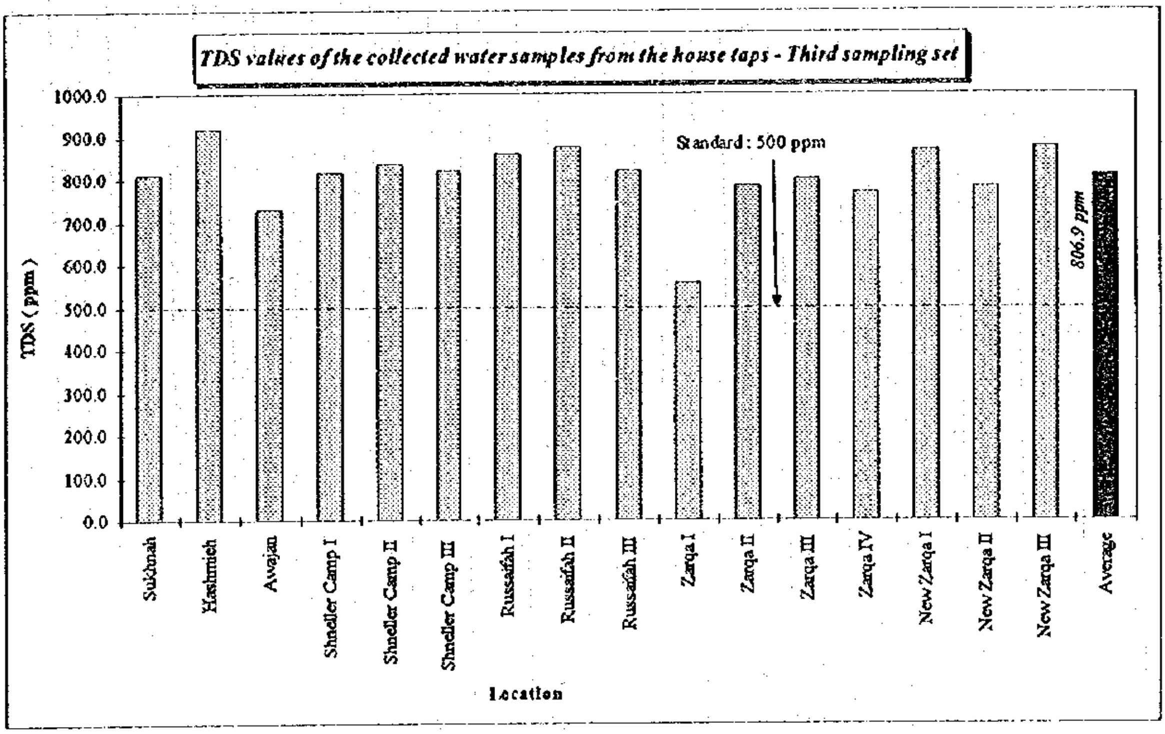
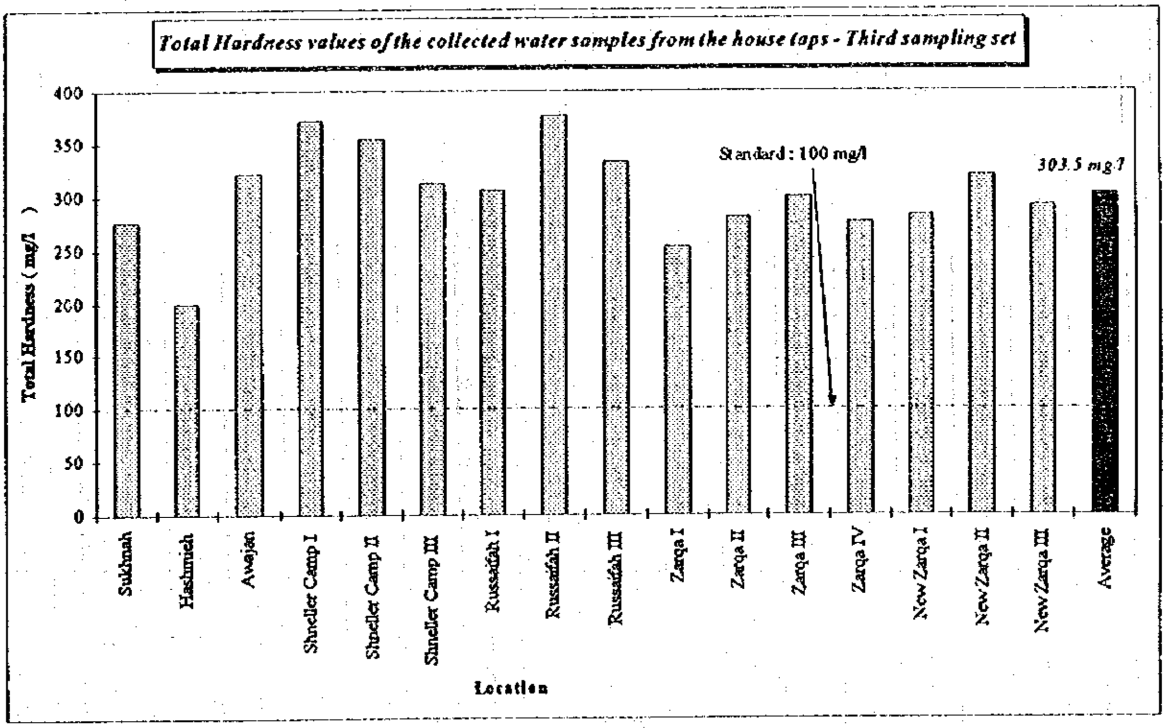


Figure 22: House taps Total Hardness values representation



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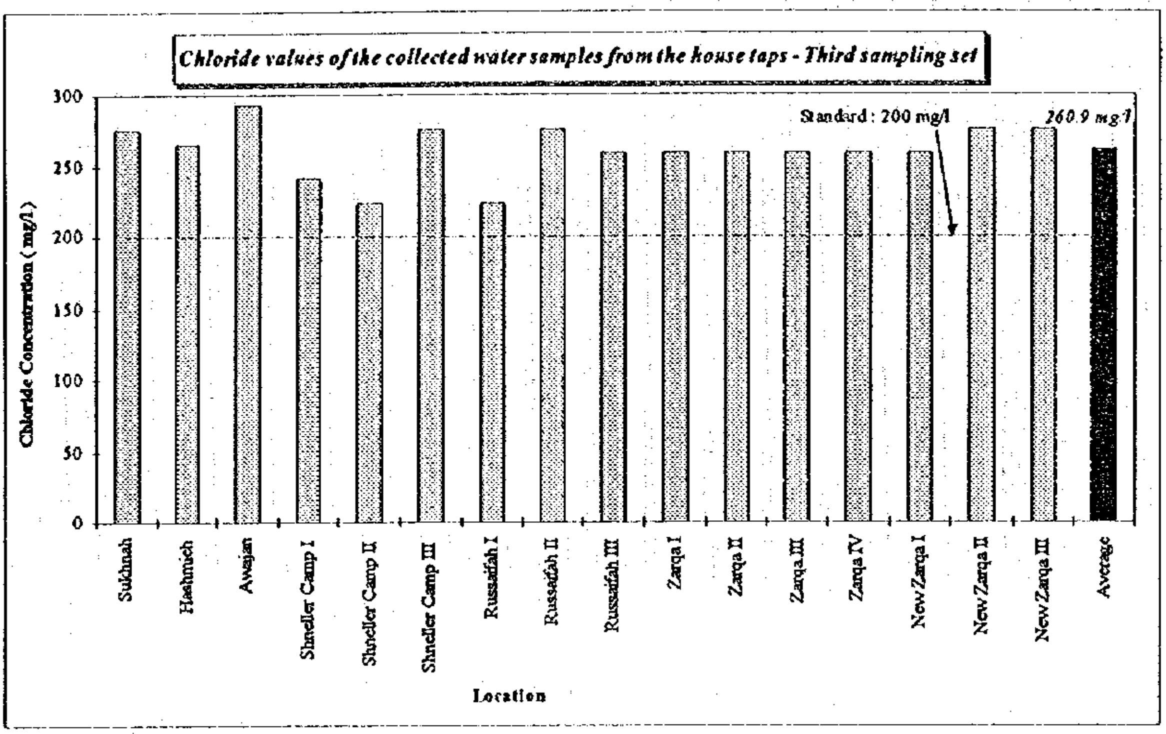
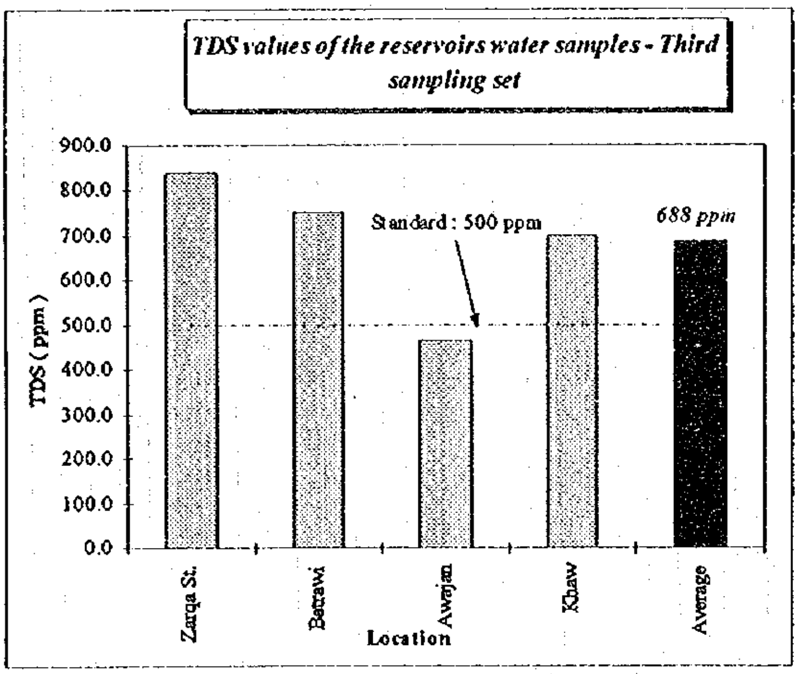


Figure 24: Reservoirs TDS values representation



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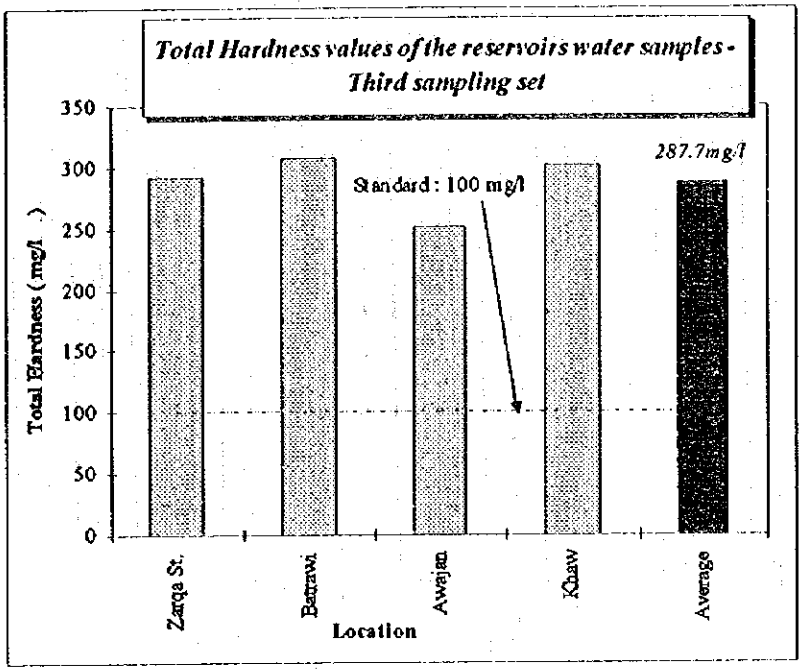

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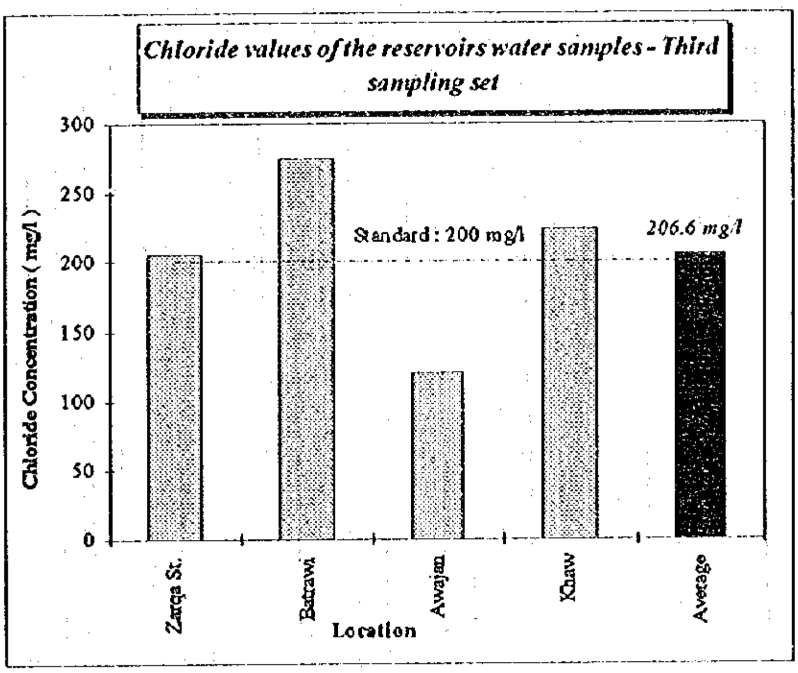

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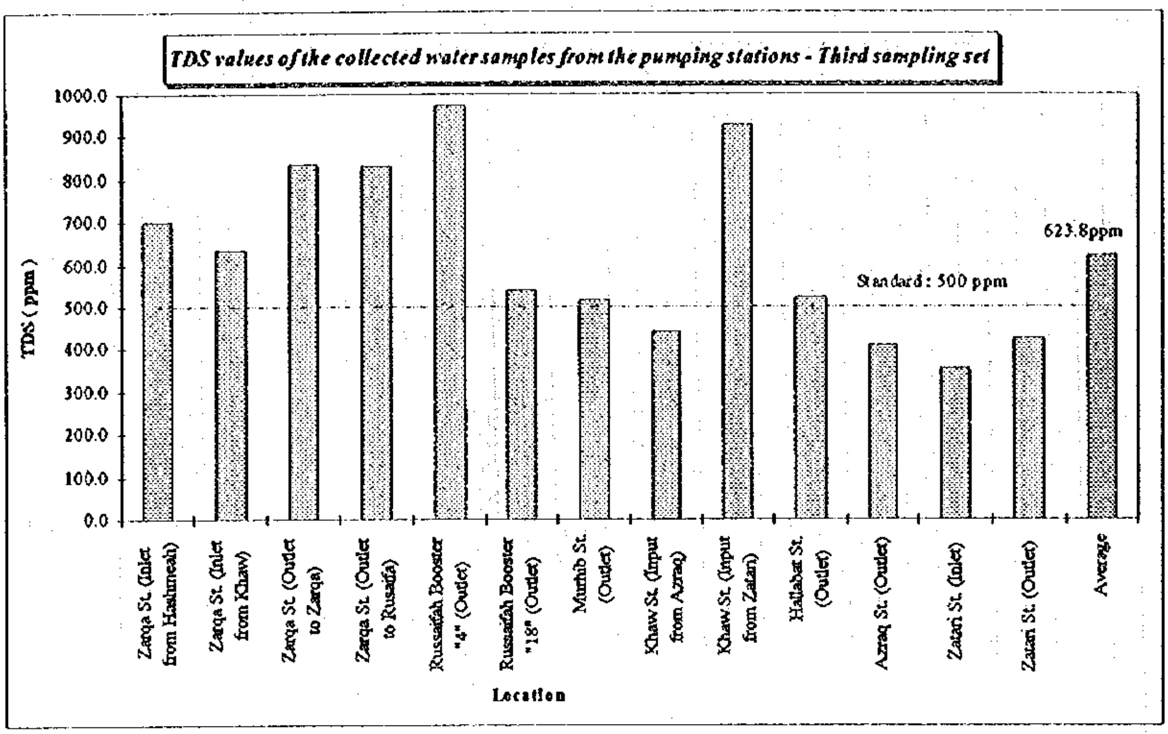

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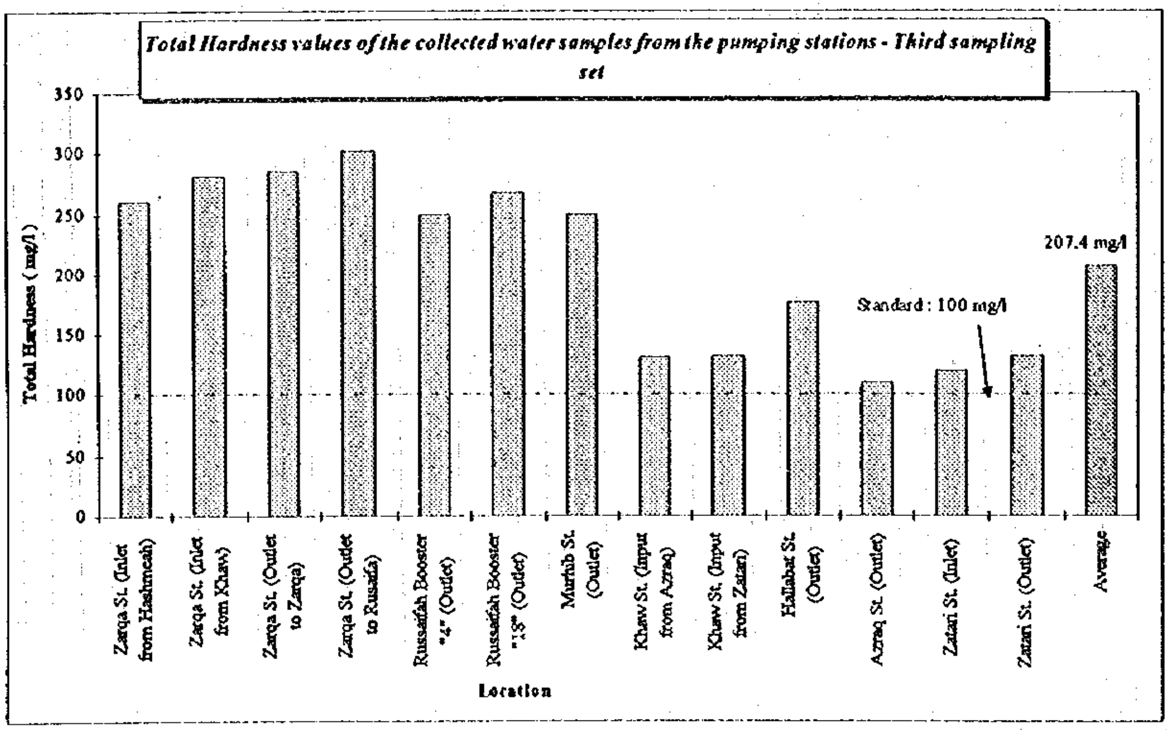

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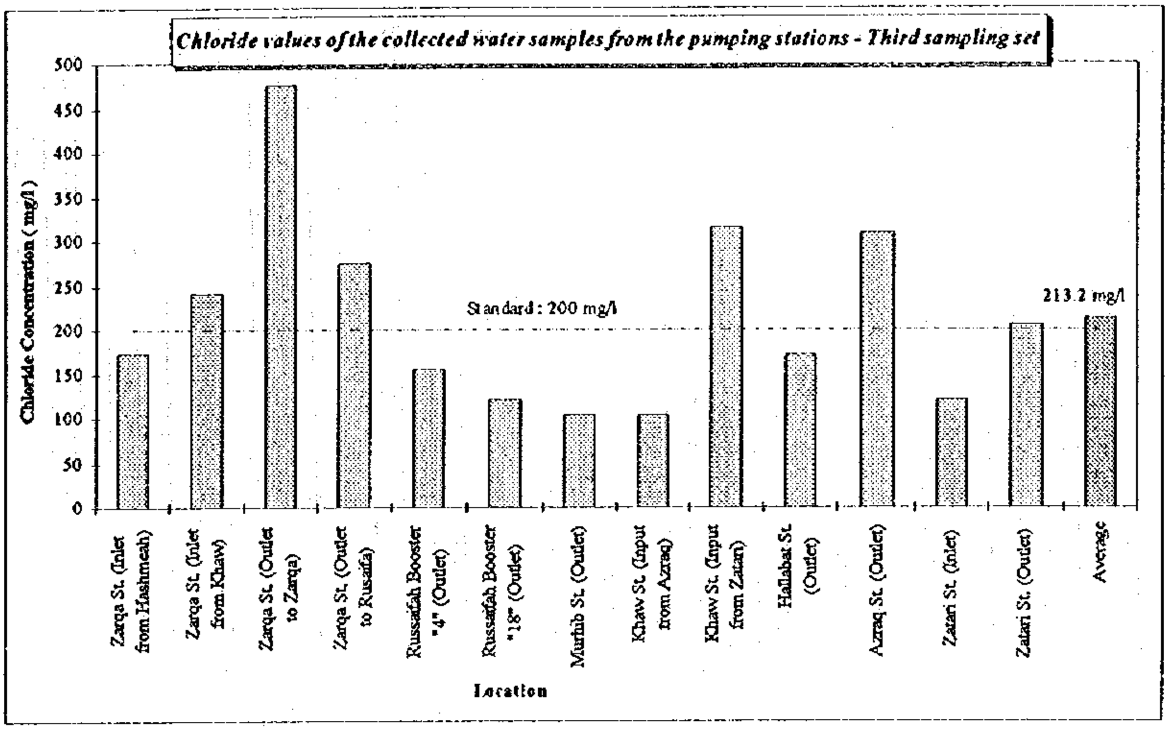

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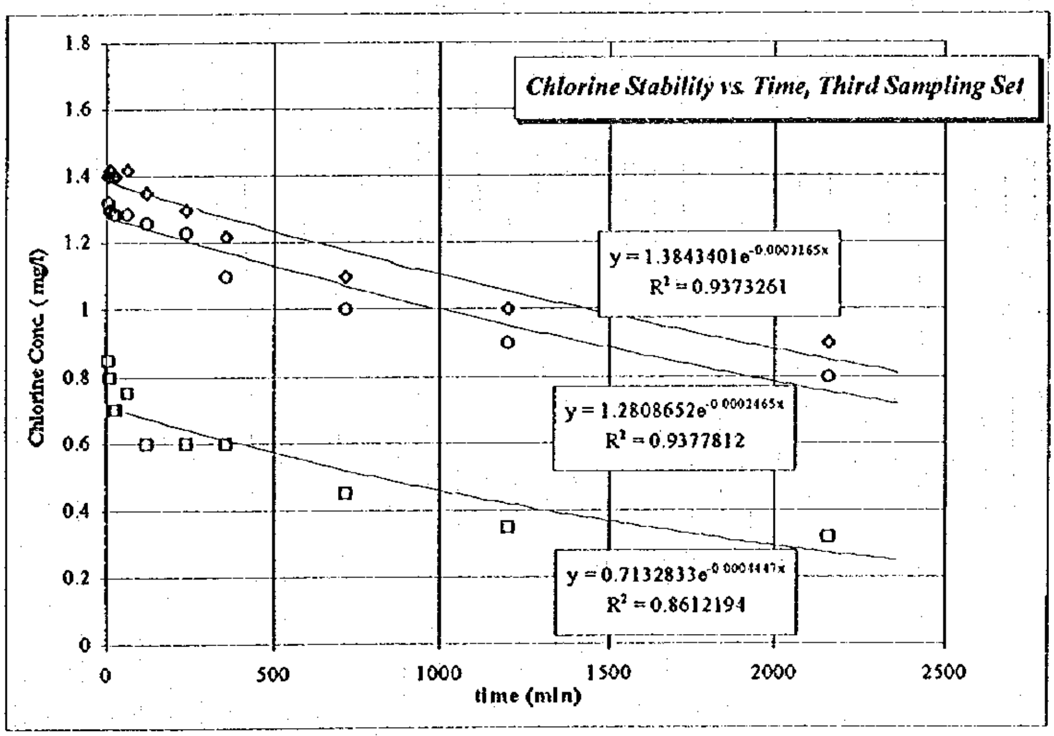

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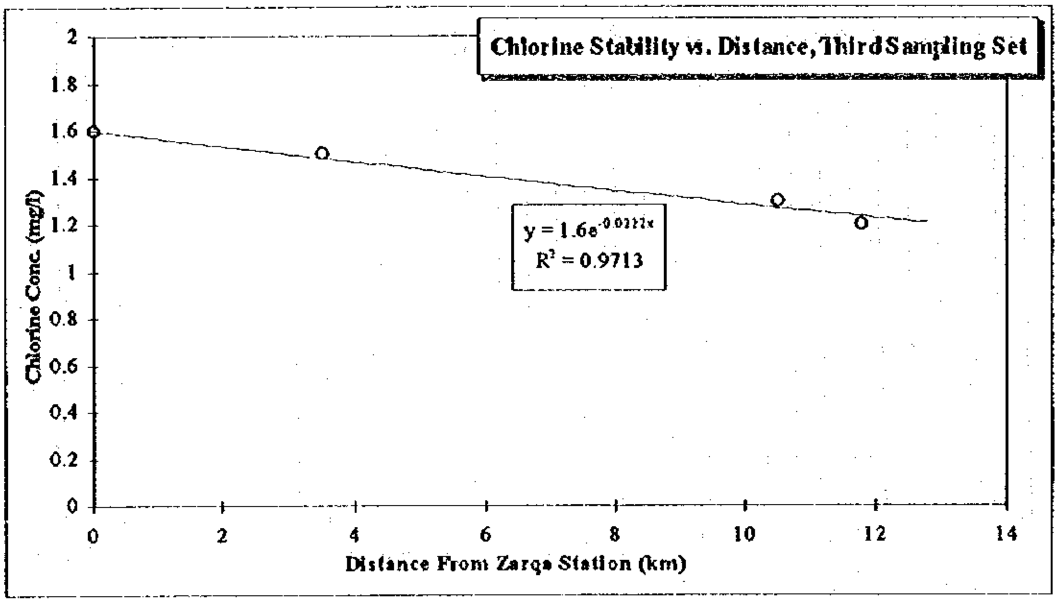
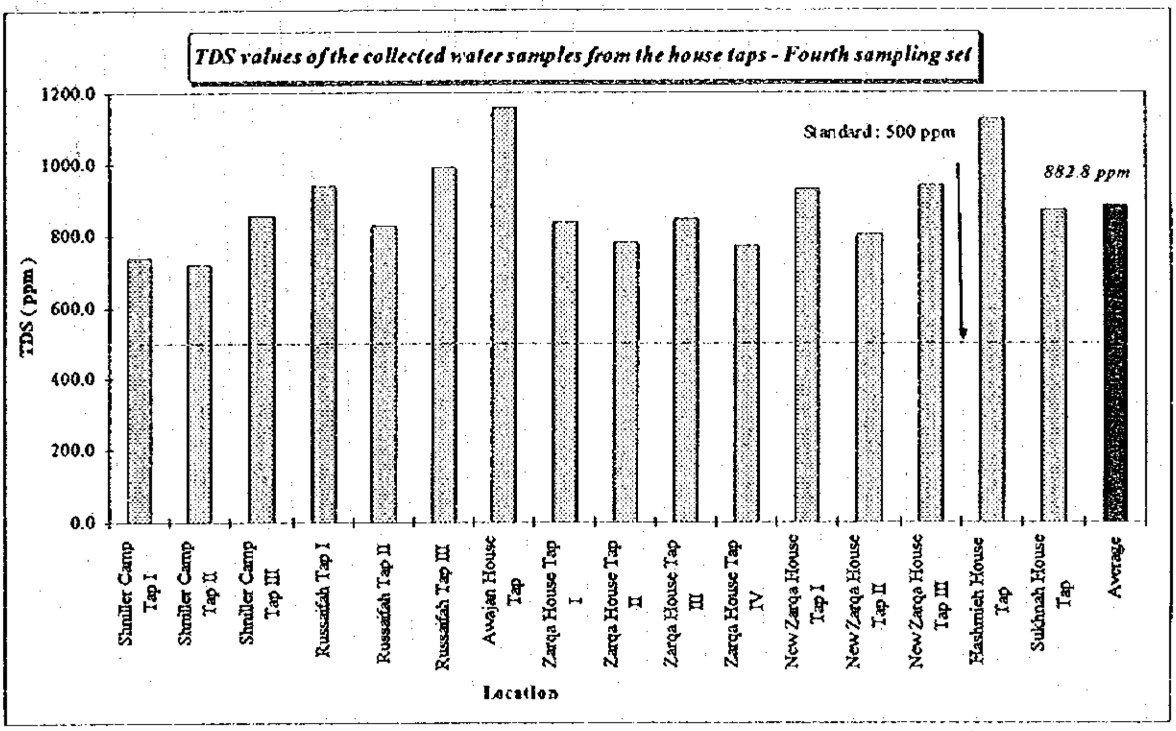


Fourth campaign charts

Figure 32: House taps TDS values representation



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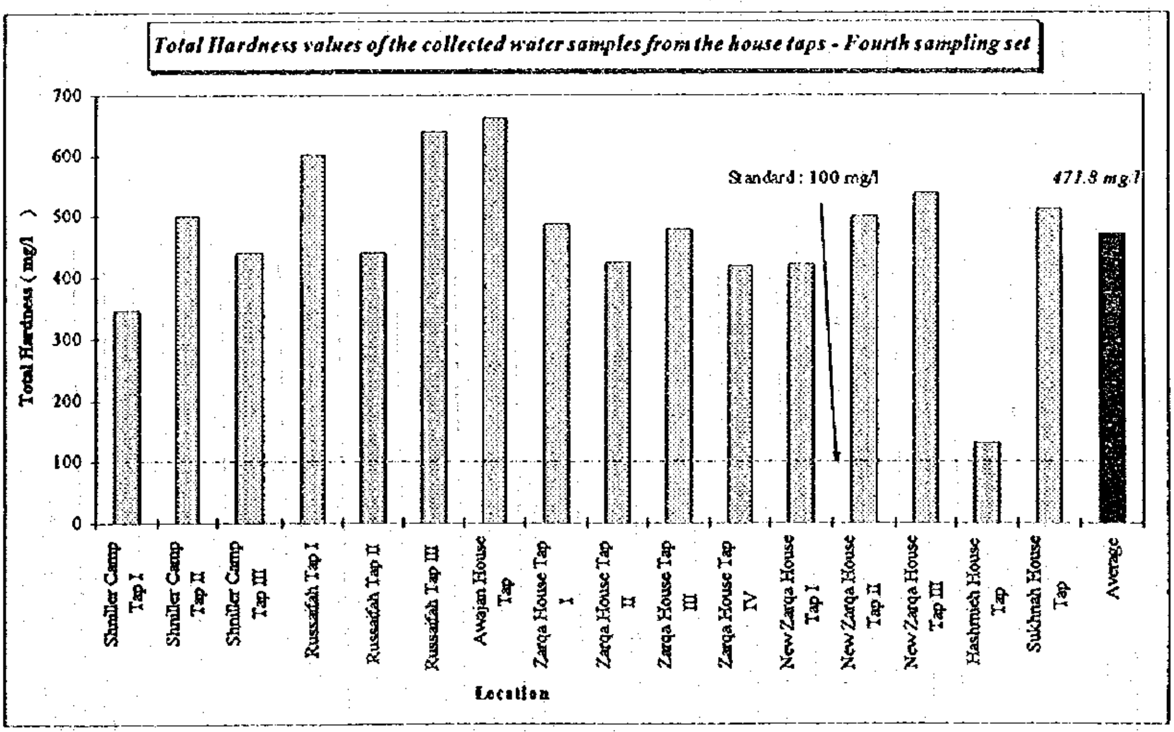


Figure 34: House taps Chloride ion concentration values representation

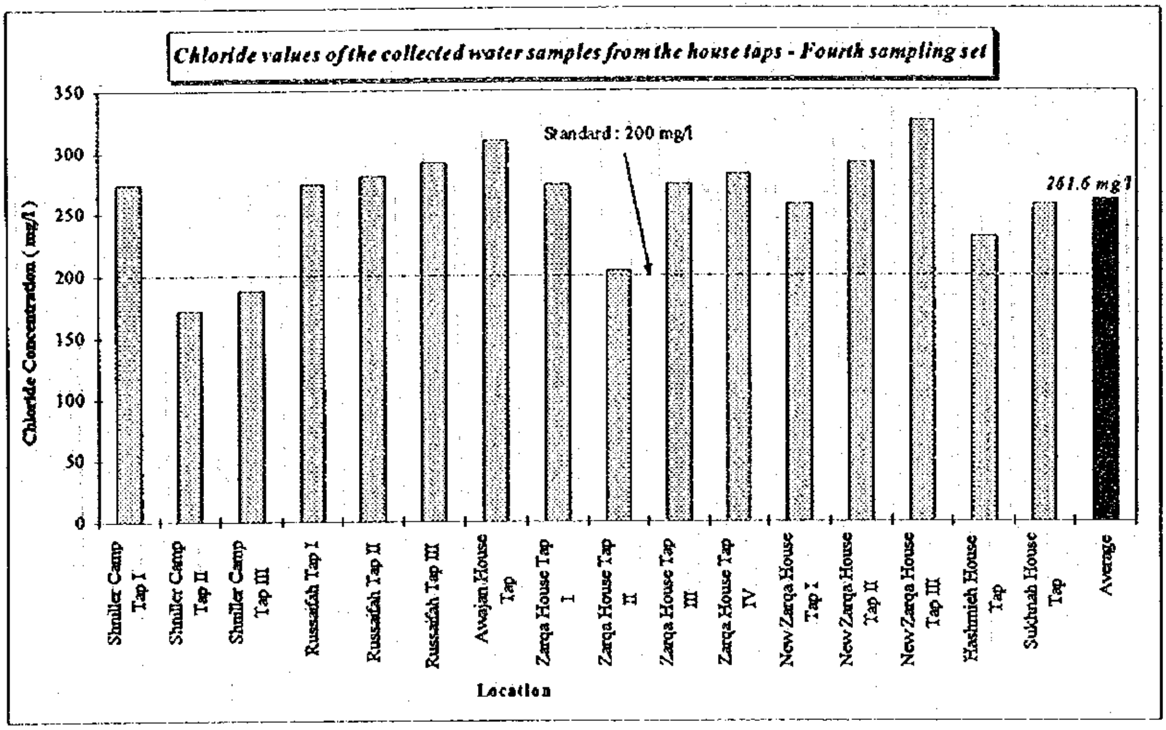


Figure 35: Reservoirs TDS values representation

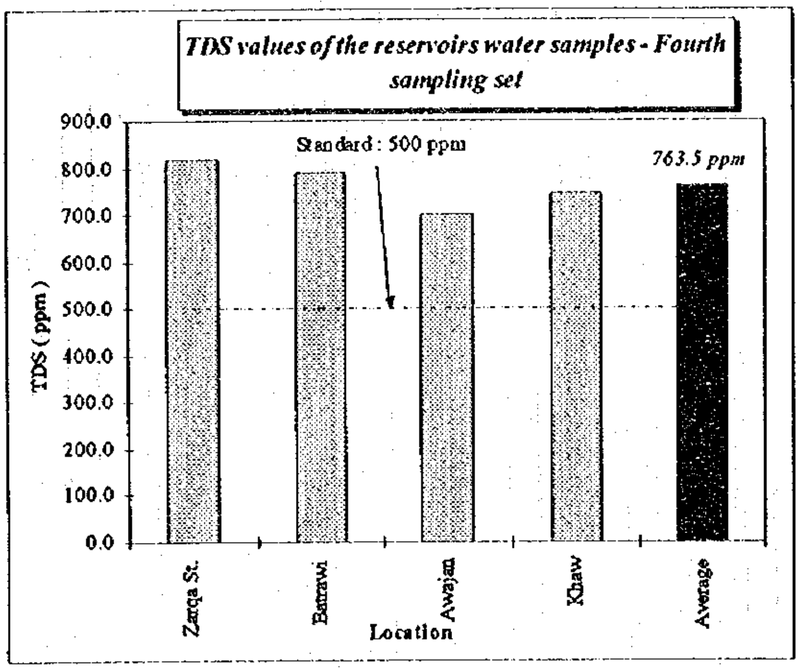


Figure 36: Reservoirs Total Hardness values representation

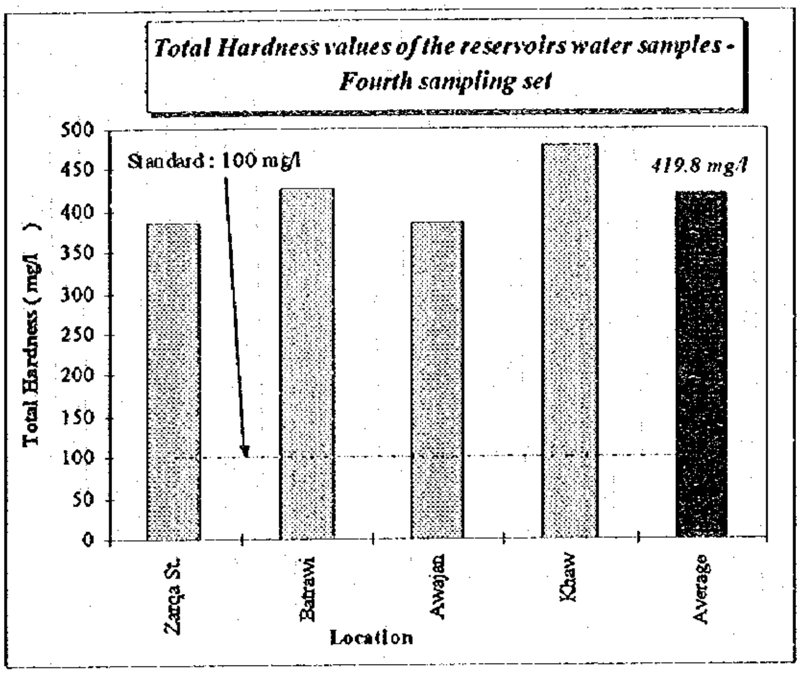


Figure 37: Reservoirs Chloride ion concentration values representation

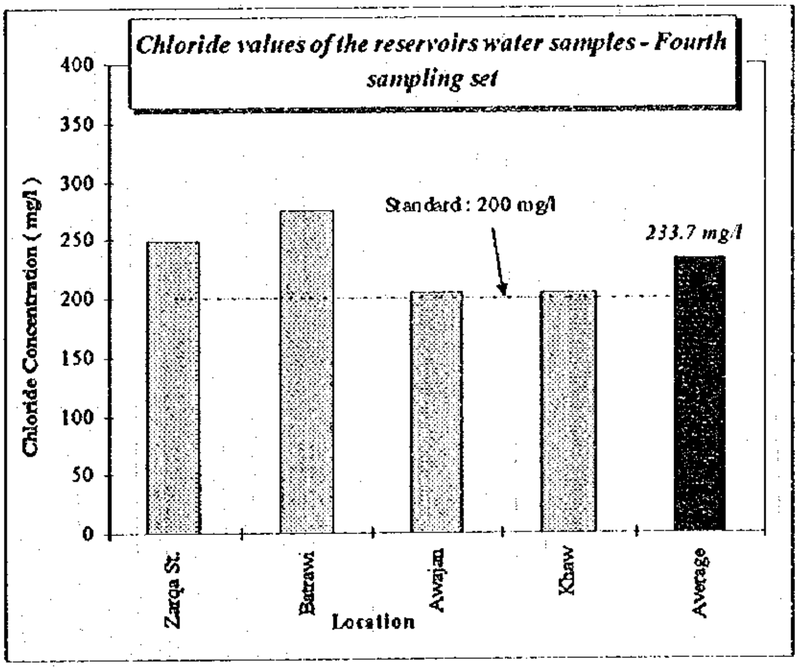


Figure 38: Boosters and pumping stations TDS values representation

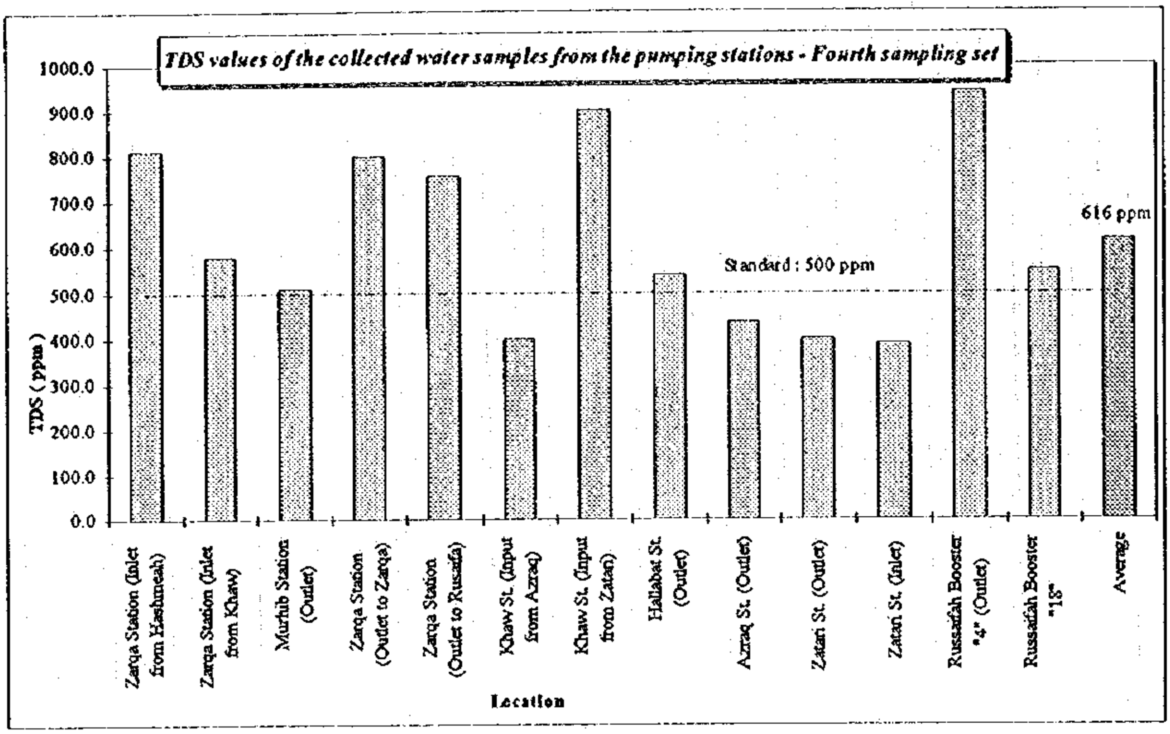


Figure 39: Boosters and pumping stations Total Hardness values representation

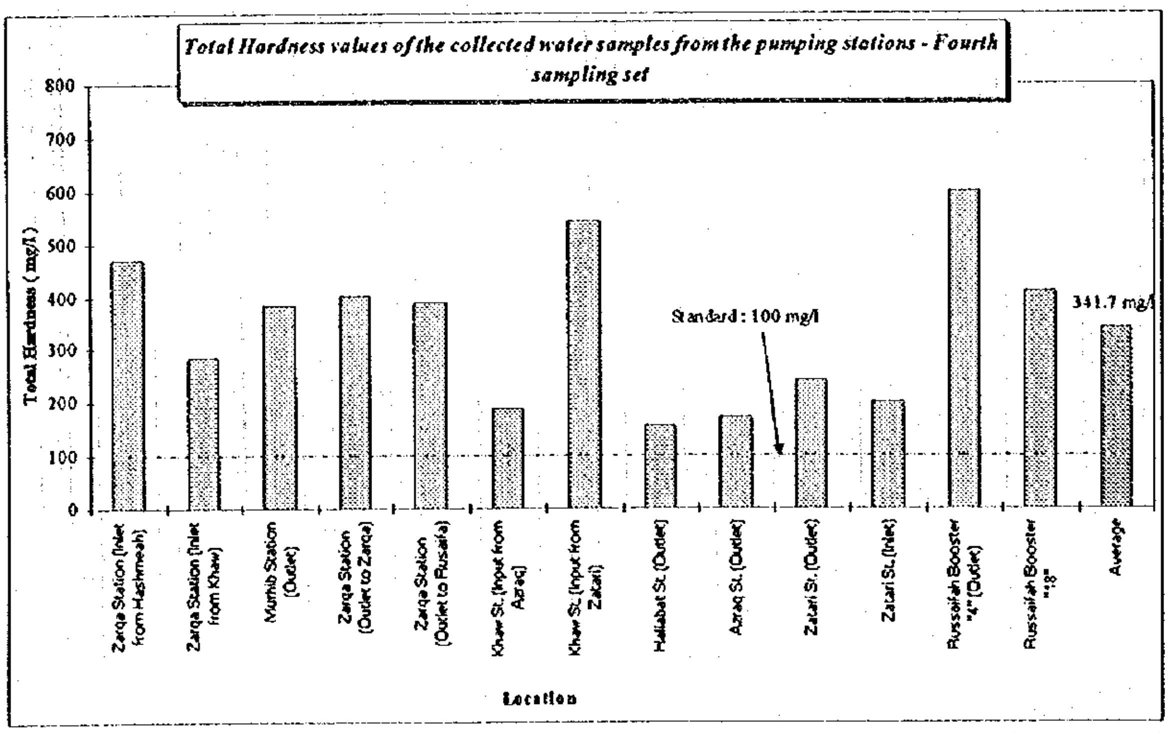
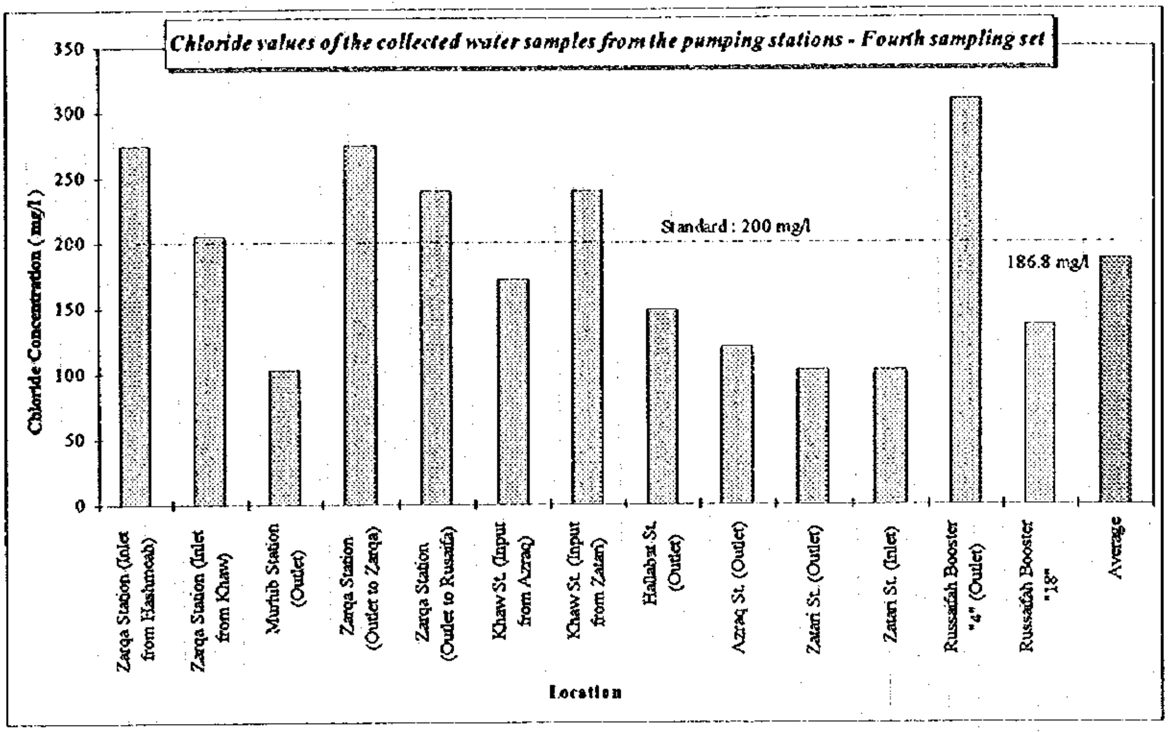


Figure 40: Boosters and pumping stations Chloride ion concentration values representation



J. POPULATION AND WATER DEMAND PROJECTION

Appendix J
- Population and Water Demand Forecast -

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1. POPULATION PROJECTION

Population projection in the Study Area is made on the basis of the analysis on the historical trend and future development potential in the following manner.

1.1 Frame of Total Population Growth

The population of the Study Area increased at 3.9% p.a. during the period of 1979 - 1994. The population increase includes the considerable number of returnees from the Gulf countries, which is approximately estimated at around 60,000. Excluding this factor, natural population growth is estimated at 3.1% during this period.

Another indicative figure for future population projection of total population frame would be the planned population growth rate set up in "Economic and Social Development Plan of Jordan, 1993 - 1997. The projected figure is 3.2% p.a. during the plan period.

Based on these figures, total population growth of the Study Area is estimated, which will be used as the total population frame in the whole Study Area to be projected.

Period	Frame of Total Population Growth In The Study Area
1995 - 2000	3.2% p.a.
2000 - 2005	2.8% p.a.
2005 - 2015	2.4% p.a.

During 1995 - 2000, a little bit higher rate than the past trend is applied in due consideration of the socio - economic effect of the Peace Treaty. But, the high growth rate will go down after the year of 2000 as the household income increase and the living standard improve.

1.2 Population Projection for Sub - Areas

The population census conducted in 1994 contains the population data for 67 sub - areas in the Study Area. Based on the data population densities for the sub - areas are calculated and the sub - areas are grouped into G1, G2, G3 and G4 according to the densities as presented in Fig.-J.1.

Future population increase for each group is estimated in due consideration of the present population density and future potential development in the Study Area within the projected total population frame.

By applying the different growth rates, population of each sub-area is estimated as presented in Table J.1. (population distribution in each sub-area is summarized in Fig. J.2). Projected population in each municipality and in the Study Area will be 644,800 in 2000, 739,300 in 2005 and 938,500 in 2015 as presented below.

Projected Population in the Study Area

Municipality	*1994*	*1994 - 2000*	*2000*	*2000 - 2005*	*2005*	*2005 - 2015*	*2015*
Zarqa	344,524	2.8%	406,600	2.5%	460,000	2.3%	577,500
Sukna	9,764	4.4%	12,600	3.9%	15,300	3.0%	20,600
Hashemeyeh	13,038	4.7%	17,200	4.0%	20,900	3.2%	28,600
Rusaifa	131,130	4.0%	165,900	3.3%	195,200	2.6%	252,300
Schenuller	36,218	2.7%	42,500	2.4%	47,900	2.2%	59,500
Total	534,674	3.2%	644,800	2.8%	739,300	2.4%	938,500

Source: JICA Study Team

2. WATER DEMAND FORECAST

2.1 Methodology

Water consumption records of WAJ contain some incomplete data, caused from insufficiency of flow measuring instruments and slightly obsolete data-compilation practiced in WAJ Zarqa. Furthermore, the data do not necessarily reflect real water demand by consumers because of rationing.

As regards domestic water use, it is considered appropriate to set up goals of per capita water demand for the target year of 2015 based on available data and interpolate for the intermediate years, rather than applying historical trend of the unit water consumption for extrapolation. To this end, attention was paid to water consumption by customers in Zarqa municipality who currently enjoy the continuous water supply. Indepth analysis of WAJ water consumtion data revealed the average per capita consumption during summer season ranges between 75 and 80 lpcd. In winter season, this value drops to 70 lpcd. In consideration of the future change in living standard, a way of life, and the decrease of household size, another 10 -15 lpcd was

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1) Average household size will decrease to 6 - 8 members per household which is equivalent to 2 - 3 lpcd increase in unit water consumption,

2) Conventional pour-flush toilet will be dominantly used by the reseidents even if sewerage service coverage ratio increases,

3) Customers behaviour for laundering, washing and bathing will not change significantly in frequency from the present, and

4) Water use appliances such as washing machines will be disseminated as the standard of living rises in future, which is euqivalent to 13 lpcd increase. (= 200 litter/ 2 days/ 7persons)

Other water use categories including industry and governmental institutions consume only few percentage amount of water. The factory survey conducted by the Team also suggests that large scale factories located in the service area tend to rely on their private wells also for the future. On the other hand, midium and small scale factories who cannot afford to construct private wells, are depending on the WAJ water or water tanker. Therefore, it is supposed that the present water consumption of these categories will increase gradually with similar growth rates of the municipalities (population growth rate). Water consumption increments confirmed during the factory survey are then added to the above. Table - J.2 provides information on present and future water consumption by factories.

In estimating daily maximum water demand, a peak factor (Daily maximum/Daily average = 1.20), due to the seasonal and daily fluctuation was employed.

Fig.- J3 illustrates a flow chart applied for the water demand forecast. As discussed in the preceding paragraphs, water demand forecast was made for two major water use categories, ie., domestic and others.

2.2 Results of Forecast

Table - J2 presents results of water demand forecast for 2000, 2005, 2010 and 2015. The present demand is 97 mld while the supply is 70 mld. Water demand will increase significantly from 97 mld in 1994 to 145 mld in 2015. This increase stemmed from population growth and, improvement of the living standard might be slightly lower than the expected. In terms of water supply planning, the forecast was considered as positive and appropriate

It should be, however, noted that the above forecast dose not reflect any future change in regulatory measures to be probably undertaken by the government particularly concerning the industrial water usage. It simply supposes the present water consumption pattern will continue as well. Therefore, the above forecast should be reviewed if the circumstances be fundamentally changed.

2.3 WATER BALANCE

Water sources available within the study area are in shortage even at present. If any appropriate measures for new water resource development are not advanced by the agencies concerned, the water shortage in the area would become more serious than ever.

Relevant to the water shortage problem in the area, WAJ confirmed, expressing its preparedness in the meeting held on 15, June 1995 that any balance resulted from the above water demand forecast would be regulated by new water sources developed under the ongoing water resource development projects in Jordan. They are Disi Project, Brackish Water Development Project, Yamouk River Project, etc.

Tables

Table - J1 PROJECTED POPULATION IN SUB-AREAS

Unit	1994	2000	2005	2015
1	1,600	1,998	2,343	3,052
2	3,793	4,736	5,555	7,234
3	2,926	3,653	4,286	5,581
4	2,611	3,260	3,824	4,980
5	11,444	14,289	16,761	21,826
6	3,271	4,084	4,791	6,239
7	10,173	12,210	13,899	17,295
8	4,179	5,016	5,709	7,105
9	4,143	4,972	5,660	7,044
10	2,844	3,551	4,165	5,424
11	8,242	9,410	10,394	12,701
12	13,358	15,251	16,846	20,586
13	5,960	6,805	7,516	9,185
14	7,534	9,042	10,293	12,809
15	5,877	6,710	7,412	9,057
16	6,992	7,983	8,818	10,775
17	9,444	10,782	11,910	14,554
18	2,957	3,376	3,729	4,557
19	4,910	5,606	6,192	7,567
20	8,751	9,991	11,036	13,486
21	2,055	2,466	2,808	3,494
22	4,656	5,316	5,872	7,175
23	6,984	7,974	8,808	10,763
24	11,076	13,830	16,222	21,124
25	2,432	2,919	3,323	4,135
26	4,460	5,092	5,625	6,873
27	8,355	9,539	10,537	12,876
28	3,071	3,506	3,873	4,733
29	9,555	10,909	12,050	14,725
30	2,520	3,147	3,691	4,806
31	2,100	2,622	3,076	4,005
32	6,472	7,389	8,162	9,974
33	7,592	9,480	11,120	14,480
34	7,608	9,131	10,394	12,934
35	17,658	20,161	22,269	27,212
36	10,222	12,764	14,972	19,496
37	6,382	7,969	9,347	12,172
38	6,015	7,511	8,810	11,472
39	12,751	15,304	17,421	21,678
40	17,151	21,415	25,120	32,711
41	5,984	7,472	8,764	11,413
42	19,036	23,769	27,881	36,306
43	14,408	17,990	21,103	27,479
44	2,405	2,732	3,044	3,822
45	6,012	7,507	8,805	11,466
46	10,354	12,427	14,146	17,603
47	6,378	7,964	9,342	12,164
48	1,190	1,352	1,506	1,891
49	0	125	139	175
50	2,234	2,538	2,827	3,551
51	1,482	1,684	1,876	2,355
52	654	743	828	1,039
53	19,133	23,890	28,023	36,491
54	15,210	18,992	22,277	29,009
55	8,878	11,085	13,003	16,932
56	11,162	13,397	15,250	18,977
57	13,275	16,576	19,443	25,318
58	8,139	10,163	11,921	15,523
59	6,016	7,512	8,811	11,474
60	16,842	20,214	23,010	28,633
61	10,731	13,399	15,717	20,466
62	1,327	1,507	1,680	2,109
64	13,936	17,401	20,411	26,579
65	9,764	12,192	14,301	18,622
66	23,782	29,695	34,832	45,357
67	36,218	41,351	45,675	55,814
Total	534,674	644,844	739,256	938,460

Table - J2 PRESENT WATER CONSUMPTION AND WATER DEMAND INCREMENTS BY FACTORY

No.	Name of Factory	Water Consumption			Add. Demand
		Wells (m^3/day)	WAJ (m^3/day)	Tanker (m^3/day)	(m^3/day)
1	Jordan Petroleum Co.	6,000	0	0	0
2	Pepsi Cola Co.	3,100	0	0	0
3	Jordan Spinning &Weaving Co.	300	0	0	25
4	I.C.A. Co.	420 - 650	0	0	0
5	Subhi Jabri Co.	65	10	0	0
6	Hussein Thermal Power Station	2,000 - 3,000	0	0	1,000-1680
7	Jordan Paper and Cardboard Factories Co	800	12	0	0
8	Al-Hussein Iron Steel Industries Co.	350	20	0	0
9	Arab Iron & Steel Industries Co.	100 - 150	4	0	0
10	Jordan Dairy Co.	150 - 200	10 - 15	0	0
11	Jordan Worsted Mills Co.	160 - 200	3	0	0
12	Jordan Tanning Co.	200	5	0	0
13	Sulphochemicals Co.	150	0	0	0
14	Eagle Distilleries Co.	130	10	0	0
15	Jordan Pipes Co.	150 - 600	7	0	1
16	Tissue Paper Factory	240 - 350	8	0	100
17	Jordan for Mineral Explorant Co.	40	5	0	7
18	Yeast Industries Co.	550	2 - 3	0	0
19	Jimeco	25 - 50	0	1	20
20	Arab Brewery Co.	80	1	0	0
21	Jordanian Beer Co.	110	2	0	2
22	Jordan Ceramic Co.	-	0	100	0
23	Modhyb Hadad Co.	-	23	30	0
24	Duhlil Slughter House	-	300 - 400	0	0
25	Chemical Factory	-	0	10	35
26	Iron Steel Manufacture Co.	-	0	18	0
27	Rookwool Factory	-	15	0	0
28	Wear House Co.	-	0	40	0
29	Masoud Dairy	-	20	0	0
30	Zaidan Factory	-	35	6 -10	0
31	Al-sanabil Dairy	-	5	0	0
32	Alharithi	-	27	0	0
33	Jordan Polymers & Inter Chemicals Co.	-	3	20	0
34	Kareem Tix Center	-	5	30	0
35	Nora Lux Co.	-	10	100	0
36	Sweilem Press	100	0	0	0
37	United Factory	-	5	3 - 5	0
38	Jordan Tiles	12	8	0	0
39	Al-Aqsa Press	-	4	1 - 2	0
40	Alquidis Press	-	2	1	0
41	Brilliant Star for Textile	-	20	0	0
42	White Cement Factory	300	0	0	20
43	Jordan Food Processing Co.	20	13	0	60
	Total	15,552 - 17,507	594 - 700	360 - 367	1,270 - 1,950

Source: Quoted from Supporting Reports D-Factory Survey, WAJ Zarqa and JICA Study Team, January1995

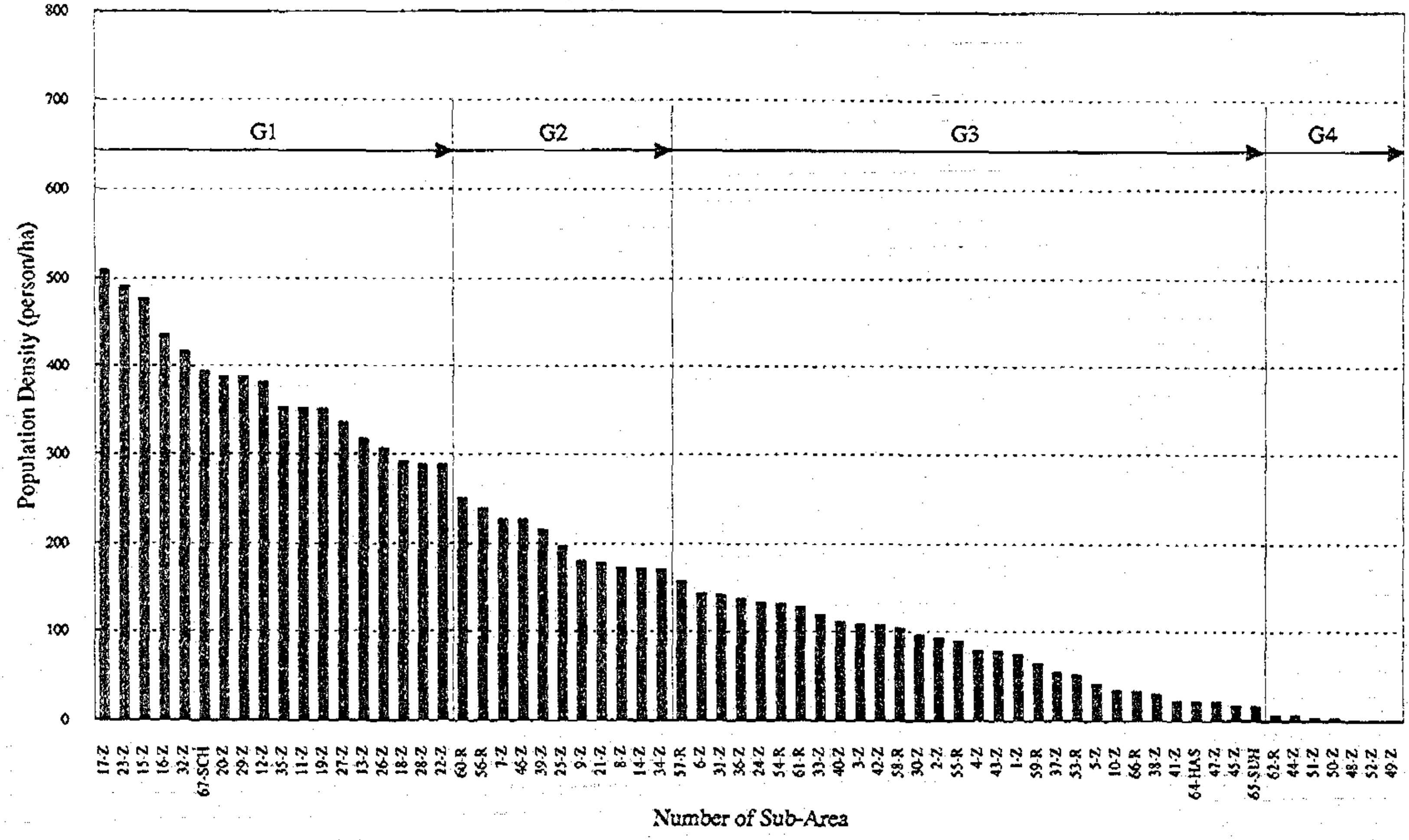
Note: 1) Amount of additional or incremental water demand by factories for WAJ water excluding those for groundwater from their wells.

Table - J.3 WATER DEMAND FORECAST

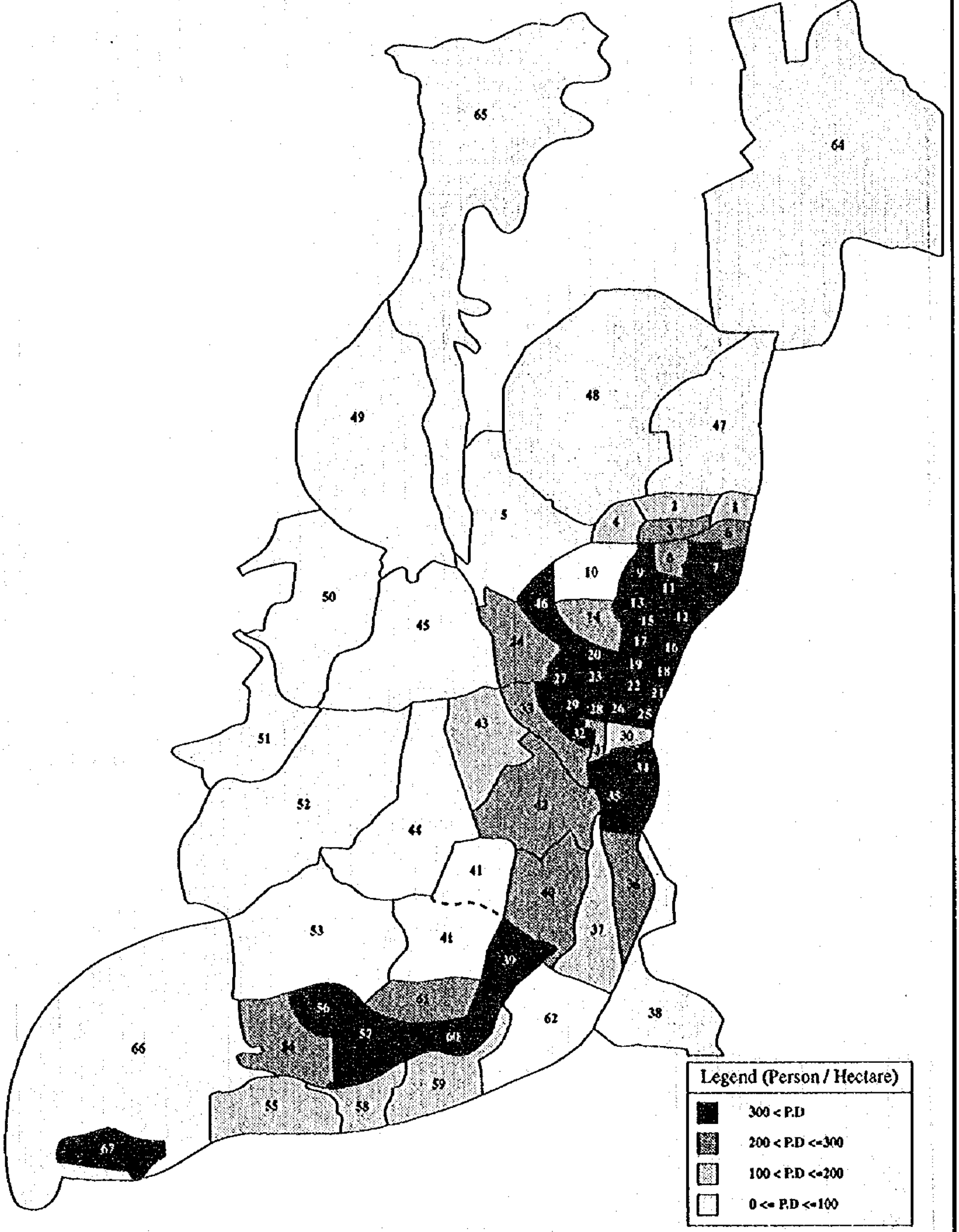
	Year				
	1994	2000	2005	2010	2015
1) Population *	534,674	644,800	739,200	832,300	938,500
2) Accounted-for-Water (m^3/day)	37,400	48,400	59,100	70,700	84,500
(lpcd)	70	75	80	85	90
3) Unaccounted-for Water (m^3/day)	43,900	44,700	42,800	39,800	36,200
(%)	54%	48%	42%	36%	30%
4) Average Water Demand (m^3/day)	81,000	93,000	102,000	111,000	121,000
(lpcd)	151	144	138	133	129
5) Peak Factor (Daily Max./Daily Ave.)	1.20	1.20	1.20	1.20	1.20
6) Maximum Water Demand (m^3/day)	97,000	112,000	122,000	133,000	145,000
(lpcd)	181	174	165	160	155
7) Annual Water Demand (MCM/year)	29.6	33.9	37.2	40.5	44.2

* Whole population is assumed to be served by the water supply system for the planning purpose. The current service ration is 99 %.

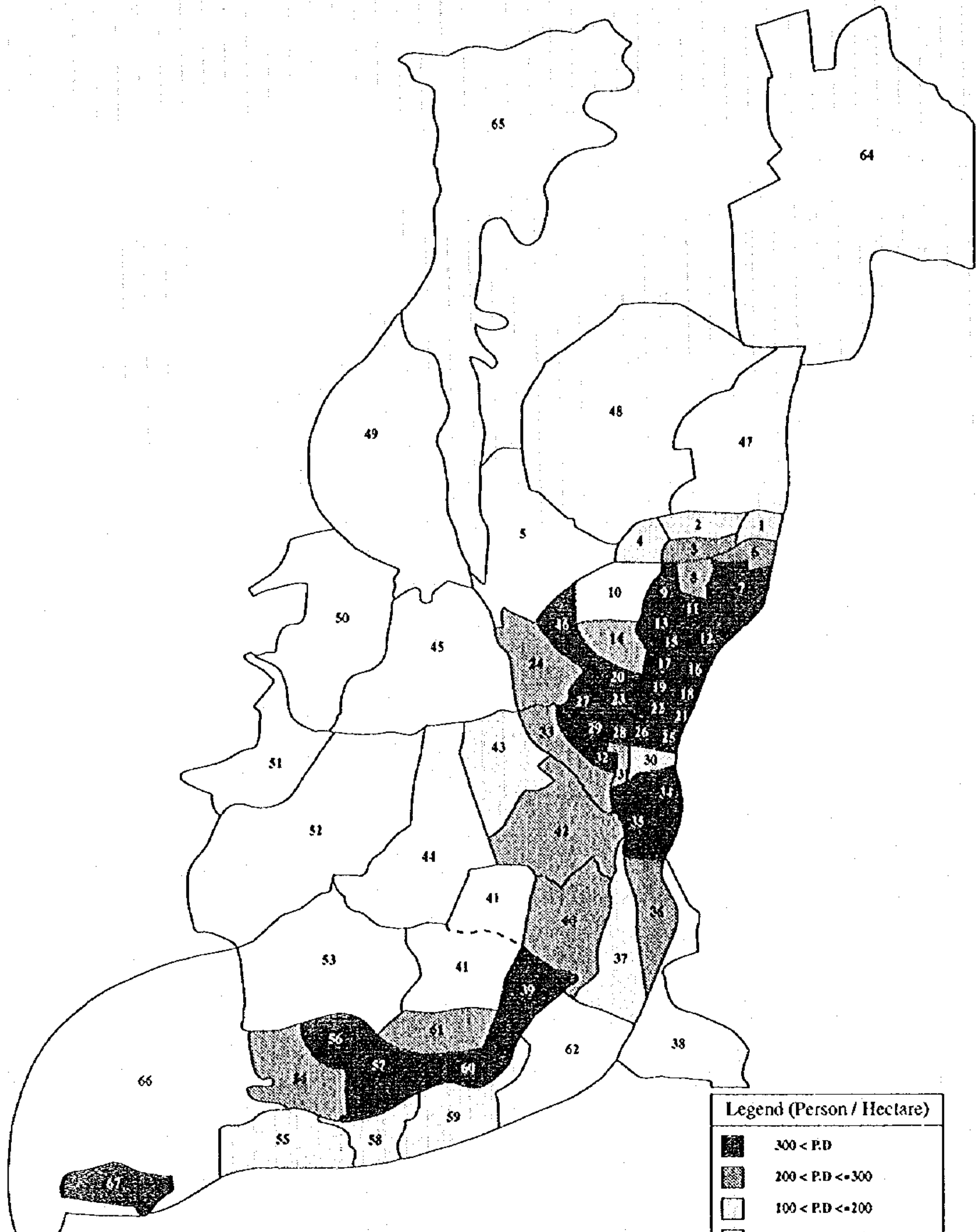
Figures



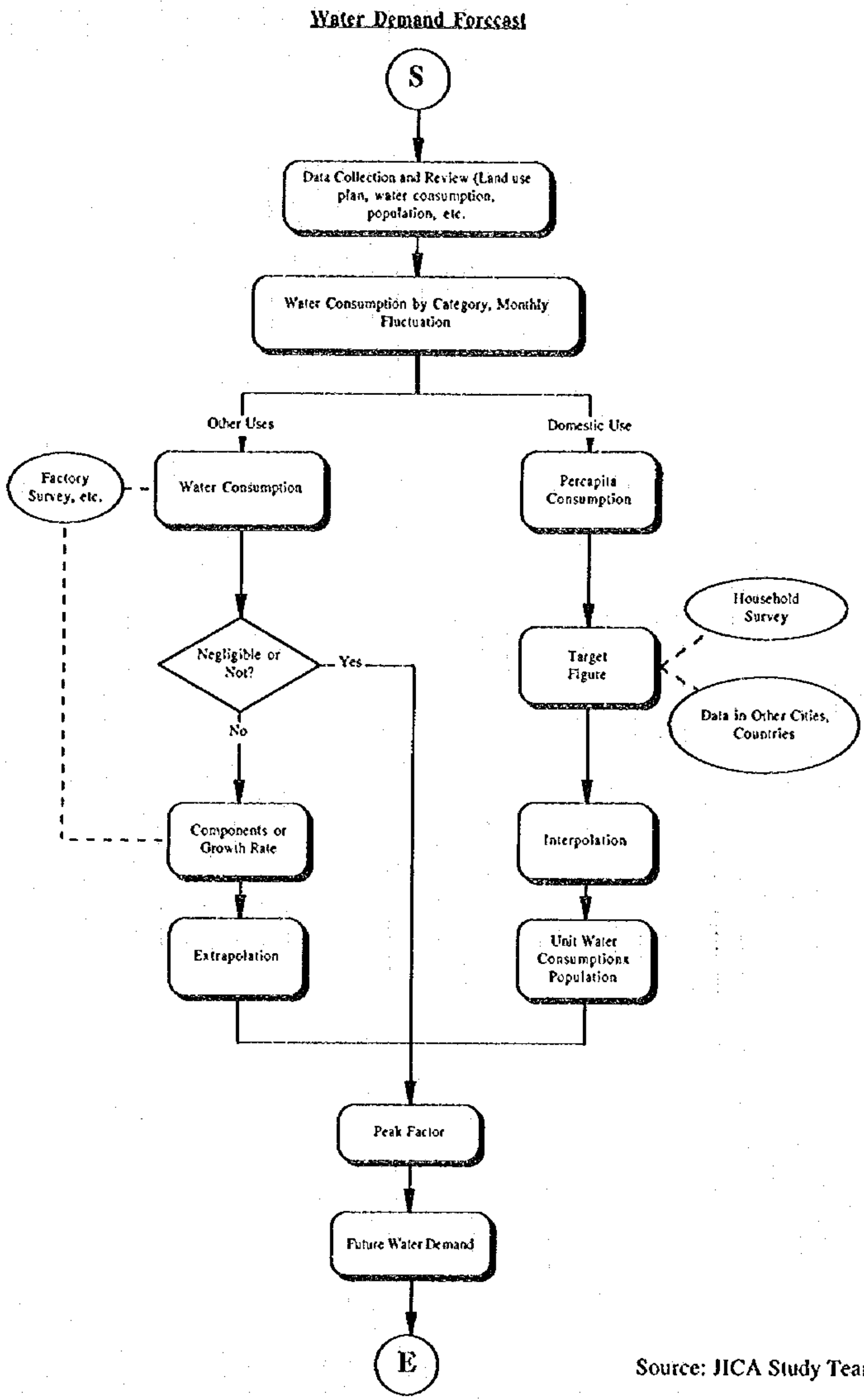
THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig. - J1 POPULATION DENSITY OF SUB-AREAS,1994
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig - J2
JAPAN INTERNATIONAL COOPERATION AGENCY	POPULATION DENSITY IN 2015



THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig - J2
JAPAN INTERNATIONAL COOPERATION AGENCY	POPULATION DENSITY IN 2015



Source: JICA Study Team

THE STUDY ON THE IMPROVEMENT OF THE WATER SUPPLY SYSTEM FOR THE ZARQA DISTRICT	Fig.- J3 Flow Chart for Water Demand Forecast
JAPAN INTERNATIONAL COOPERATION AGENCY	

K. HYDRAULIC NETWORK ANALYSIS

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APPENDIX K HYDRAULIC NETWORK ANALYSIS

1 Background of the Study

1.1 The Study Area

(1) Boundaries and Administrative Situation

Zarqa District is an industrial center located at about 20 km north east of the Capital Amman. The Zarqa Governorate has a population of 624,000 people according to the 1994 census while the population of the study area is 534,674. The study area included in the study were:

- Zarqa City
- Rusaifa City
- Schneller Refugee Camp
- Hashemiyah
- New Zarqa
- Sukhneh
- Awajan

The total area that was covered in the study is about 238 Sq.km.

(2) Topography

The study area can be divided into three topographic zones as follows.

- The Zarqa city which includes down town of Zarqa city and the wells and Awajan Area, the Zarqa Refugee Camp, Hai Ramzi etc., all area located at the east side of Zarqa River.
- The Rusaifa Area which covers all of Rusaifa and the Schneller Refugee Camp, this is characterized big valley surrounded by high hills on both sides of the valley and leads to the highest point in the study area.
- The Hashemiyah and Sukhneh area which are relatively flat and has very little change in the topography and landscaping of the area.

(3) Population

The Zarqa District has expanded considerably during the last 20 years and especially in 1992. The main features of the urban development have been the following:

- Rapid urbanization over the newly developed areas west of the city centre
- Predominantly high density area, for lower income households and the Refugee Camps in the center of the city.
- Lower density residential areas, for upper income households, to the West and North of the city.
- Gradual absorption of the rural area into a continuos urban area.

1.2 Water Supply System

(1) Water Resources

The water resources can be classified into 2 categories corresponding to the successive development stages.

a. Wells and Springs Inside the Study Area

These wells were the first resources used by Zarqa. Several wells were abandoned but the following wells are still in use.

- Hashemiyah 1, 2, 3, 5
- Awajan 21, 22, 23
- Zarqa 14
- Rusaifa 18
- Bassateen 1, 1A
- Shenmuler Camp 1, 2
- Deep Phosphate

b. Well Fields Out Side the Study Area

During the last ten years, two major systems have been developed to meet the increase of the water demand.

Azraq System, which collects water from three well fields located at:

- Azraq about 80 km East of Zarqa
- Za'attary and Khaldieh, Mafraq Governorate
- Hallabat

The water is pumped through 2-400mm dia transmission line from Khaw PS to Zarqa PS which is the major water works complex of the central distribution system.

Murhib System, which collects water from one well field located at Murhib the water is then pumped directly into the Awajan tank though a 300mm dia line.

In 1994 the total production has been 27.7 Million cubic meter with the following breakdown.

Local wells and springs	7.0 MCM (25% of total)
Azraq System	20.2 MCM (73% of total)
Murhib System	0.5 MCM (2% of total)

(2) Distribution Systems

The study area is supplied by three distribution systems.

a. Zarqa city System

It covers the Zarqa city, Ma'soum, Hai Ramzi, Al-Ghouriyeh and the other highly urbanized zones. This system relies upon several water works (reservoirs, pumping stations , wells).

b. Rusaifa System

It covers mainly the southern Zarqa city and Rusaifa city including the Schneller Refugee Camp. This system is pressurized by the Zarqa pumping station but it is also supplied by several wells on the way and is boosted several times in order to reach the high areas.

c. The Hashemiyah and Sukhneh Systems

It covers mainly the Hashemiyah and Sukhneh areas, this system is supplied by the Khaw Pumping Station then into two small pumps at Hashemiyah pump station which gives water to both areas.

2 Objectives of the Study

System layouts upgrading the existing records of the water distribution system in the Zarqa District were produced for the network analysis. The project area considered included all the facilities in the water system of the Zarqa District as of March 1995.

The objectives of the network analysis may be gathered under two logical headings:
- Studies of the present operating conditions of the water supply system.
- Study of their improvement.

(1) Study of the present operating conditions of the water supply system.

The analysis has to be directed towards the following items:

- The pressure, in order to identify the areas where it is abnormally high (resulting in operational problems such as pipe failures) or abnormally low (resulting in a poor service).
- The transfer of water from the water works to the various service area and the transfers between these areas, in order to provide an answer to this important question: " from where does the water come and where does it go?"
- The actual pumping conditions, in order to identify:
  - o The pumps which are unsuited to the hydraulic constraints of the networks.
  - o The boosters which are possibly useless
- The pumping costs in order to identify the possible savings.

Other objectives of the network analysis are directly related to the UFW and leakage control component:

- Choice of the pilot areas
- Determination of the necessary arrangements in these areas.

(2) Study of the operating conditions improvement.

After completion of the diagnostic phase, corrective measures have to be studied. They should be directed towards the following objectives.

- Improvement of the service quality
- Possible reduction of the pressure where it is to a high
- Reduction of the pumping costs
- Rationalization of the use of the available water

To achieve the above mentioned objectives, a computerized model of the water distribution system has to be built and extensively used.

To be fully reliable and representative of the actual water system, this model has to be calibrated, i.e. it has to be adjusted on the basis of actual field measurements.

A computerized model of the network can rapidly meet the following targets.

- Improvements of knowledge of the network operating conditions.
- Definition of immediate operational improvements
- Rationalization of network operation by identifying the operating modes that are best suited and the most economical.
- Identification and definition of measures to be taken in the event of operating anomalies.
- Improvement in the definition of the points within the network where monitoring is desirable.

3 Method of Approach and Facilities Used

3.1 General Considerations

Although mathematical models have been used for many years in studies of urban water distribution networks (with the first application dating back practically to the introduction of the first generation of electronic calculators in the 1960s) it is probably useful to give a brief summary of their basic design so as to make it quite clear exactly what is to be expected from them , and hence what both their limitations and possibilities are.

Section 3.2 in this chapter discusses in greater detail the various features of the program used (WATNET). A few basic principles must first be given.

a. Reduced to basics, a water distribution network consists of a set of pressurizing works (pumping stations, reservoirs), which are supplied from production points (springs, wells, treatment plants) and a network of water mains of varying diameter designed to convey the water to the user.

In order to ensure a reliable supply and to balance pressure as demand varies, the pipes are generally meshed. Flow distribution between the pipes will therefore depend on both the network structure and the demand. Variations may be quite considerable from one situation to another and, without relying on complex calculations, it quickly becomes difficult to determine this distribution.

b. This situation is often made more complicated by the fact that the networks have not necessarily been developed very coherently to meet the increase of the demand. This is the classic example of large cities like the Zarqa District where the built-up area tends to expand progressively further, gradually encompassing local structures and networks which had never designed to be integrated eventually into a more general system.

In order to operate these various facilities despite everything, the operator therefore generally has to adopt temporary, and often precautions, measures. These may involve, in particular, the use of certain valves in an attempt to balance flow transfers. However, in practice, these measures give rise to considerable complications in general operation of the network, making a simple analysis almost impossible.

c. While it is true to say that the first applications of computer assisted calculation of looped networks were strictly limited by the low capacity of the hardware available on the market at that time, this situation had under gone considerable development in recent years with the advent of mini and then micro computers. For an equivalent cost, the computation potential of these modern machines has increased exponentially and indeed continues to do so. This means that calculation programs and associated models which just a few years ago required heavy hardware facilities, today operate on a very light configurations of the personal computer (PC) type.

d. All the looped network flow computation programs currently available on the market, or at least those giving best performance, are built around the same basic principles:-

- To determine flow conditions in the network, these programs use the Hardy Cross iterative method, generally in its conventional form with balancing of flow rates in the various loops, and less commonly in its dual form with balancing of pressures in the vicinity of nodes. It is worth noting that the latter method, used by WATNET, gives the program certain advantages. These are described later on.

- By convention, the flow outputs simulating consumption are allocated to the network nodes (i.e the junction points of pipes represented in the model). Certain programs (including WATNET) provide the possibility of allocating these consumptions to the pipes themselves (assuming uniform distribution).

- To simulate network operation during a given period (a day for example), the programs break down this period into a succession of steady states. The calculation of these states is carried out automatically, taking into account the variations introduced in the network between the start and end of each elementary steady state (changes in reservoirs levels, shut-down or start-up of pumps, closing or opening of valves).

- They offer the possibility of simulating hydraulic operation of all special equipment usually encountered in a distribution network (pumps, control valves, check valves, etc.)

The mathematical model of a network thus actually consists of the three following components.

1. The computation program which controls inputs and outputs and makes all necessary calculations for processing and presenting results and also performs data coherency and conformity tests.
2. The hydraulic characteristics and topological description of the various component parts of the network (pipe diameter, length, and roughness, connections between the pipes and their elevations, volume, top and low water levels of reservoirs, pump characteristic curves, valve head loss characteristic, etc.).
3. Operational data relating to the water demand (consumption at the various nodes of the model, modulation during the day) and to the operating conditions considered for meeting demand, (operation of pumps and valves, initial reservoir levels).

The results that can be expected from the mathematical model will therefore depend on these same three components:

1. The computation program gives only a simplified view of the hydraulic phenomena governing flows in the network. Approximations involving allocating the consumption to the nodes and assimilating a long period to a succession of steady states are generally sufficient to obtain a satisfactory approach to real conditions. However, it is most important to remember that these approximations are only hypotheses and that it may therefore be necessary to call them into question and, in certain cases, modify the model accordingly. Moreover, one should also bear in mind that such a program is designed for the calculation

of steady pressurized flows. These are the normal operating conditions encountered in a water network, and the program cannot provide satisfactory results outside these operating conditions. In particular, the results should be treated with caution in cases where free surface flow conditions may occasionally be encountered (mainly as a result of insufficient supply).

2. The validity of the results supplied by the model will also largely depend on the quality of the data used to describe the network. Data of insufficient reliability, while not necessarily totally wrong, may dramatically modify the results obtained.

   It is thus essential to give considerable attention to describing actual conditions as faithfully as possible and always to bear in mind, when interpreting the results, all doubts that may remain concerning the net work (elevation of structures, connections between pipes, status of values, etc.).

3. Finally, the operating data adopted for the simulation is often one of the points, the most difficult to evaluate. This data includes, in the first place, the operating rules adopted (pump working periods, valve opening and closing maneuvers etc.) which are not always very well known, especially when, as it is the case for the Zarqa networks, the operating rules are empirical and an occasion circumstantial (valve opening or closing left to the application of local operators for example). However, the spatial distribution of the consumption is after one of the most delicate points to be determined and ultimately, one involving the greatest discussion. By its very nature, this consumption varies with time and in fact depends on a multitude of factors. The relative importance of these factors is generally difficult to appreciate owing to insufficient observation data. Rather than using the "consumption", the expression "output flow" should be used. This value includes not only what consumers are estimated to draw off, normally determined from subscribers' meters, but also all "parasite" flows (leaks before meters, non metered consumptions, reservoir overflows, etc).

   Information on such parasite flows is not generally very accurate or even non existent. Here again, the results must not be taken of face value and will have to be interpreted in relation to the most reliable aspects of the available data.

To summarize what has been discussed above, a mathematical model must above all be considered as an analytical tool. The considerable advantages that it provides can be broadly divided into two categories.

- It must be constructed according to a strict set of rules and cannot accept vague approximations in the description of system topological features. Its construction can thus be considered as a first step towards a better understanding of the network. Indeed this