Chapter 3 Wastewater Effluent

CHAPTER 3
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3.1 Existing Wastewater Treatment

General explanation relating wastewater sector in Jordan is given in Annex 3.1. The existing treatment plants in Jordan are described in detail including applied treatment process, capacities and efficiencies in Annex 3.1.1. Detailed facts and findings of the individual plants as presented in the Annex 3.1.1 are summarized and evaluated in the following paragraphs.

3.1.1 Description of Existing Plants

Table 3.1.1-1 summarizes some basic data on the existing treatment plants.

The first treatment plant was constructed in 1981 in Salt. The plant in Wadi Arab was completed recently and started operation in May 1999. Wadi Hassan and Wadi Mousa Treatment Plant will start operation early 2001. Several plants were expanded or upgraded (e.g. Baqa, Jerash, Salt) since they were put in operation.

In total 17 public wastewater treatment plants are in operation (July 2000). Figure 3.1.1-1 shows the location of these plants within the 12 Governorates of Jordan. 6 treatment plants (including the biggest one in As Samra for Greater Amman) rely on extensive treatment technology using anaerobic pond, facultative pond and maturation pond system. At one plant (Wadi Essir) artificial aeration is provided in aerated ponds instead of the facultative (non-aerated) ponds. Intensive treatment technology is applied in 10 plants. These plants are based on activated sludge or trickling filter method or a combination of both.

The coverage of population living within the service areas ranges between about 45 and 95 %. The average of 82 % is relatively high due to 90 % coverage of As Samra Treatment Plant serving Greater Amman, where 70 % of the total population of towns with sewerage systems is living.

With respect to the hydraulic design capacity the treatment plants of As Samra, Karak, Ma'an, Madaba, Mafraq and Ramtha are overloaded by up to 145 % (As Samra). The plants Aqaba and Kufranja have more or less reached their design capacity. The degree of use of the remaining plants is between 25 (Wadi Essir) and 70 %.

The Wastewater Treatment Plant Wadi Hassan (Governorate Irbid) is presently under construction and will be completed most probably early 2001 (location see Figure 3.1.1-1). The plant will treat the wastewater of the villages An Nuayyima, Shatana and Kitm collecting sewage of up to 22,000 people according to the design. Applied treatment process will be extended aeration with tertiary treatment by maturation ponds.

The sewerage scheme and treatment plant of Wadi Mousa is located close to the ancient Nabataean city of Petra in the southern part of Jordan (see Figure 3.1.1-1) and will be completed early 2001. The communities of Wadi Mousa, Taiba, B'doul and Beida will be connected to the proposed scheme. Treatment process relies on activated sludge.

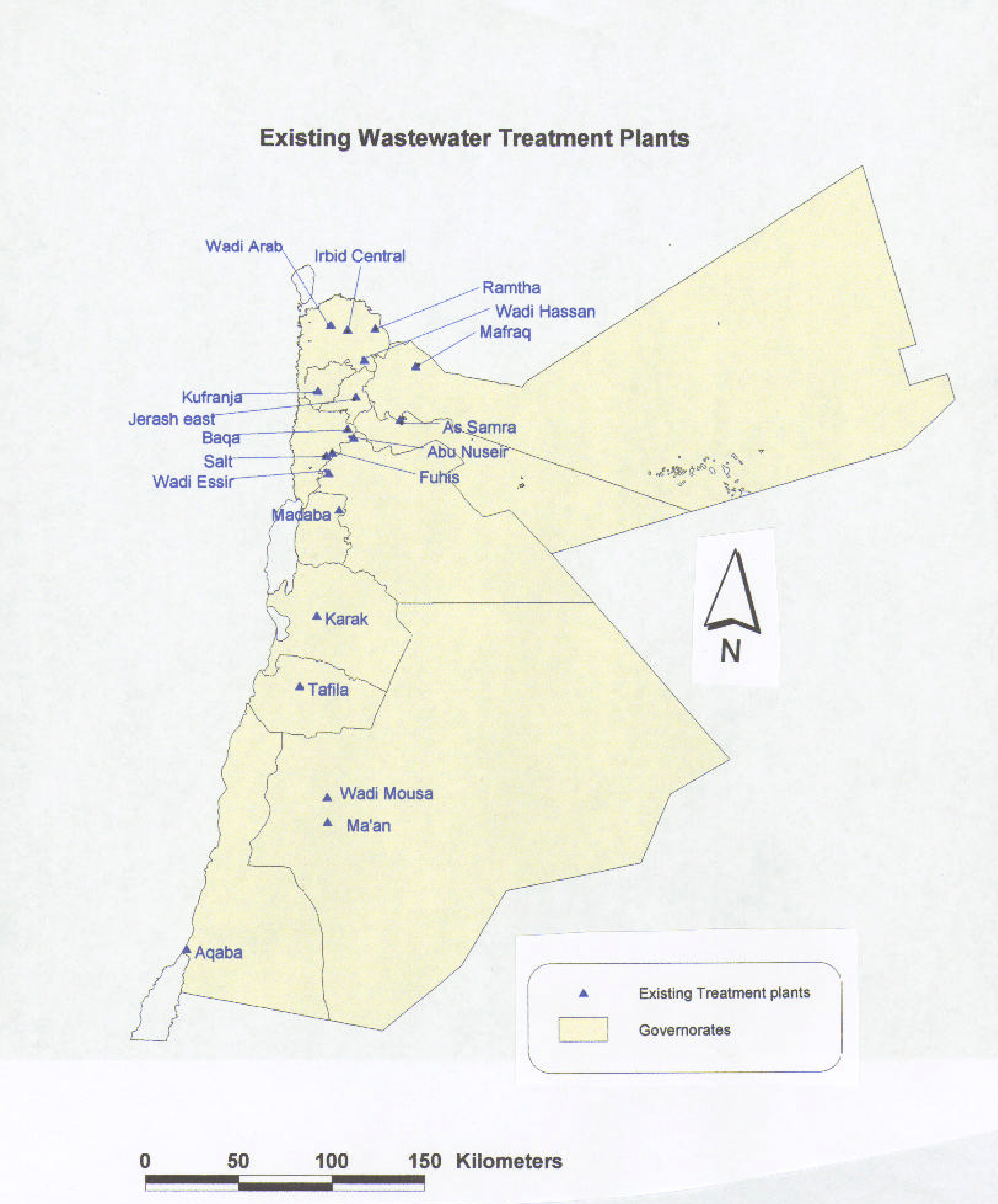


Figure 3.1.1-1 Location of existing treatment plants

Table 3.1.1-1 Basic data of existing treatment plants (status 1999)

	Treatment Plant	Governorate	In operation since	Type of treatment	Population in sewered zone 1994	Population in sewered zone 1999	Population served 3) 1999	Coverage %	Design capacity (m3/d)	Inflow in 1999 (m3/d)	Inflow in 1999 (mio m3/a)	Degree of use (%)
1	Abu Nuseir	Amman	1988	AS+RBC	18,800	22,400	13,800	62	4,000	1,411	0.515	35
2	Aqaba	Aqaba	1987	WSP	61,700	74,000	47,600	64	9,000	8,774	3.203	97
3	As-Samra	Amman	1985	WSP	1,818,000	2,170,000	1,951,000	90	68,000	166,844	60.898	245
4	Baqa	Balqa	1988(ext.99)	TF + MP 2)	146,000	174,000	164,000	94	15,000	10,284	3.754	69
5	Fuhis	Balqa	1996	EA + MP	18,100	21,600	10,600	49	2,400	1,019	0.372	42
6	Irbid (Central)	Irbid	1987	TF + AS 1)	76,800	92,000	46,480	51	11,000	4,612	1.683	42
7	Jerash (East)	Jerash	1983(ext.90)	EA + MP	42,800	51,000	27,600	54	3,500	1,603	0.585	46
8	Karak	Karak	1988	TF + MP	18,600	22,200	12,900	58	800	1,627	0.594	203
9	Kufranja	Ajlun	1989	TF + MP	44,800	53,500	35,500	66	1,800	1,734	0.633	96
10	Ma'an	Ma'an	1989	WSP	22,800	27,200	14,700	54	1,600	1,738	0.634	109
11	Madaba	Madaba	1989	WSP	55,200	65,900	51,000	77	2,000	3,609	1.317	180
12	Mafraq	Mafraq	1988	WSP	32,200	38,400	16,800	44	1,800	1,933	0.706	107
13	Ramtha	Irbid	1988	WSP	49,600	59,200	39,900	67	1,900	2,174	0.794	114
14	Salt	Balqa	1981(ext.94)	EA + MP	56,300	67,200	41,200	61	7,700	3,166	1.156	41
15	Tafielah	Tafielah	1989	TF + MP	20,900	24,900	12,300	49	1,600	851	0.311	53
16	Wadi Arab	Irbid	1999	EA 1)	143,000	171,000	86,320	50	21,000	5,993	2.187	29
17	Wadi Essir	Amman	1996	AP	8,800	11,000	8,700	79	4,000	914	0.334	23
	Total				2,634,400	3,145,500	2,580,400	82	157,100	218,286	80	

Remarks:
1) The treatment plants Irbid and Wadi Arab serve the town of Irbid. Before 1999 Irbid's sewage was treated by the Irbid Plant only.
2) The capacity of Baqa Treatment Plant was 1999 extended from 6,000 to 15,000 m3/d.
3) Population served is determined on the basis of influent load at the treatment plants taking into account a specific load of 65 g BOD5/c/d.

WSP	Wastewater stabilization ponds	RBC	Rotating biological contactor
AS	Acivated sludge process	TF	Trickling filter
EA	Extended aeration	MP	Maturation pond
AP	Aerated ponds		

3.1.2 Wastewater Quantity

Table 3.1.2-1 shows the annual influent to the treatment plants since 1987. During the last 10 years the influent of the treatment plants has increased by 100 % due to increased coverage of service and due to the new construction and expansion of sewerage systems and plants. Presently, about 218,000 m^3/d or 80 MCM/a of wastewater are treated. The produced wastewater quantity is strongly dominated by the discharges to As Samra Treatment Plant of Greater Amman, where more than 75 % of the sewage is generated.

Tables 1 to 3 in Annex 3.1.2 show the monthly influent to the treatment plants of the years 1997, 1998 and 1999. Generally, the peak month flows to the treatment plants appear during the summer months, when the water consumption is highest (as expected). However, some peak flows are observed in wintertime depending on treatment plant and year. The winter peaks are in particular due to the storm water and groundwater entering the sewerage system during rainy season as well as due to the suppressed water demand during summer, because potable water is not available in sufficient quantities.

Table 3.1.2-2 shows the peak month flow factors as found by the analysis of monthly discharges to the treatment plants during the last three years. The factors range between 1.1 and 1.25. A certain tendency for the order of magnitude of the factors may be observed as follows:

Population of city	Peak month flow factor
P < 30,000	1.25
30,000 < P < 100,000	1.15 – 1.2
P >100.000	1.1

In most of the treatment plants the effluent from the treatment plant is not measured, because there is no metering device available or existing device is not operational or simply not used. In conventional treatment plants relying on intensive treatment process (such as activated sludge or trickling filters) losses caused by evaporation and underground infiltration may be low and are in particular due to sludge elimination and drying. For plants applying extensive treatment methods these losses may be quite high. The losses are roughly estimated using the following percentages (related to the inflow):

Treatment process	Evaporation/infiltration losses (%)
Wastewater stabilization ponds	25
Aerated ponds	20
Activated sludge/trickling filter and maturation ponds	10
Activated sludge/trickling filter	5

Table 3.1.2-1 Annual influent to treatment plants

(in m3/d)

	Plant	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	Abu Nuseir		1,360	1,311	1,325	1,316	1,431	1,514	1,532	1,497	1,463	1,486	1,499	1,411
2	Aqaba	2,820	2,984	4,100	4,118	3,885	4,202	4,925	5,488	6,014	6,666	7,341	8,219	8,774
3	As-Samra	63,386	82,568	90,816	96,216	97,833	128,049	124,263	129,177	143,441	148,795	156,746	168,857	166,855
4	Baqa		1,254	3,014	4,204	4,998	4,770	5,170	5,214	6,920	6,891	7,301	8,783	10,284
5	Fuhis											410	847	1,019
6	Irbid (Central)	1,442	1,573	3,148	5,066	6,175	6,543	6,777	7,238	7,620	8,149	9,287	8,474	4,612
7	Jerash	1,017	1,041	1,242	1,316	1,510	1,349	1,387	1,354	1,450	1,524	1,555	1,808	1,603
8	Karak		296	496	582	718	705	827	1,071	1,165	1,266	1,164	1,122	1,146
9	Kufranja				544	516	888	790	690	730	1,517	1,649	2,240	1,734
10	Ma'an				577	902	1,174	1,260	1,350	1,530	1,672	1,802	1,923	1,738
11	Madaba				778	1,234	1,750	2,070	2,077	2,440	2,693	3,309	3,219	3,609
12	Mafraq		782	950	1,091	1,395	1,340	1,377	1,317	1,290	2,379	2,638	2,297	1,933
13	Ramtha			472	553	672	1,107	1,218	1,247	1,431	1,414	1,675	1,617	2,174
14	Salt	3,136	3,592	3,580	3,625	3,332	3,916	3,851	3,761	3,870	4,053	4,077	3,825	3,166
15	Tafielah			199	345	537	625	754	936	1,013	966	747	862	851
16	Wadi Arab													5,993
17	Wadi Essir											856	847	914
	Total m3/d	71,801	95,450	109,328	120,340	125,023	157,849	156,183	162,452	180,411	189,448	202,043	216,439	217,816
	Total mio.m3/a	26	35	40	44	46	58	57	59	66	69	74	79	80

Table 3.1.2-2 Monthly Peak Flow Factors of Influent to Treatment Plants

	Plant	Peak month factor
1	Abu Nuseir	1.10
2	Aqaba	1.15
3	As-Samra	1.10
4	Baqa	1.10
5	Fuhis	1.20
6	Irbid (Central)	1.10
7	Jerash	1.20
8	Karak	1.15
9	Kufranja	1.20
10	Ma'an	1.25
11	Madaba	1.10
12	Mafraq	1.25
13	Ramtha	1.25
14	Salt	1.20
15	Tafielah	1.25
16	Wadi Arab	1.10
17	Wadi Essir	1.20

3.1.3 Wastewater Quality

3.1.3.1 Domestic Wastewater

Tables 1 to 3 of Annex 3.1.3.1 contain water quality data of raw sewage (influent) and treated sewage (effluent) for 17 existing treatment plants for 1997, 1998 and 1999.

Generally, the quality of wastewater is strongly influenced by the low values of per capita water consumption. This influences particularly the salinity and the content of organic matter – the BOD_5-load – leading to high contents of both parameters in raw sewage e.g. up to 1,500 mg BOD_5/l. High values of BOD_5-concentration (often underestimated at the design stage) leads in some cases to biological overloading of the treatment plants, even if these are operated below the hydraulic design capacity. Concerning the salinity, the observed effects are similar and even more important for the plant's effluent, if the wastewater is treated by a pond system of high evaporation rates.

The average salinity (measured as total dissolved solids, TDS) of municipal drinking water is some 580 mg/l. The TDS in the effluent of the treatment plants ranges between 700 and 1,200 mg/l (effluent of As Samra pond system).

Because, generally, there are almost no significant sources of pollution in the existing collection networks others than domestic wastewater, such as industries, the content of toxic or other harmful constituents is not of importance. According to information got from the personnel responsible for wastewater collection and treatment, in most of the towns having a sewerage system and a treatment plant no important water polluting industries are connected to the sewerage system. It is estimated that about 10 % of the organic load is produced by industrial activities, whereby this value is related with the Greater Amman area, particularly.

Paragraph 3.1.5 contains a more detailed evaluation of treatment efficiencies and a discussion of the influences of effluent quality on the receiving water.

3.1.3.2 Industrial Wastewater

Annex 3.1.3.2 contains water quality data of industrial effluent of some important factories between 1995 and 2000.

Most of the industries are located within the Amman-Zarqa River Basin. In Mafraq area some agricultural/dairy factories exist. Detergent and soap factories are in Irbid and Salt area. In Ramtha area a factory for veterinary medicine and another for beverages are located.

Some of the industries operate only during season of harvest such as vegetables processing factories.

Most of the presented industrial effluents exceed in one or more water quality parameters the concentration limits as set by other countries to discharge in public sewer systems. However, in Jordan related standard concerns only the concentrations of COD and some heavy metals. If the allowable COD content of 1,500 mg/l is exceeded, the factory has to pay additional fees.

As far as the content of heavy metals is concerned the concentrations vary for some parameters considerably. The tannery shows a high concentration of chrome (as expected). Only in five cases the limit concentrations according to the "Instructions for the Commercial and Industrial Wastewater - Disposal through the Sewer Network" of WAJ are exceeded. However, extraordinary high concentrations and loads are not found.

According to the information got from the factories, the industrial wastewater is discharged into public sewers, used for gardening or dumped by vacuum trucks. None of these manners of disposal is acceptable from the environmental point of view. MOWI is advised to initiate a comprehensive regulation for the discharge of industrial wastewater into the public sewer. Generally, the industrial effluents are not appropriate to be used for gardening with respect to the Jordanian Standard JS 202/1991.

3.1.4 Cost of Wastewater Treatment

Table 3.1.4-1 shows the cost of wastewater treatment for the years 1997, 1998 and 1999. The presented costs consider expenses for operation and maintenance only. During this period the total cost increased from 1.9 to 2.2 mio. JD/a or by 5 and 9 % respectively.

Specific treatment costs are related to influent wastewater quantity. Lowest specific costs are reported for the treatment plants of As Samra and Aqaba (As Samra: 0.010 JD/m³ in 1999), while highest costs are found for Tafielah, Wadi Essir and Fuhis (Fuhis: 0.260 JD/m³ in 1998). Generally, the presented results show degressive specific cost, i.e. the costs per cubic meter of treated wastewater decreases with increasing total quantity of treated wastewater.

Cost for operation and maintenance are significantly lower for the treatment by wastewater stabilization ponds in comparison to the conventional treatment systems (extended aeration, trickling filters, activated sludge etc.). In average the specific cost for wastewater treatment by pond system is in the order of 0.075 and for conventional systems it equals to 0.150 JD/m³. This fact should be taken into account for the planning of future new wastewater treatment plants, in particular, if the capacities of the plants are low and land for the pond system is available.

Table 3.1.4-1 Cost of Wastewater Treatment (operation and maintenance only)

	Treatment Plant	Annual cost (JD/a)			Cost (JD/m^3)		
		1997	1998	1999	1997	1998	1999
1	Abu Nuseir	88.784	79.940	86.387	0,164	0,146	0,168
2	Aqaba	41.900	50.100	50.900	0,016	0,017	0,016
3	As-Samra	592.850	706.550	629.620	0,010	0,011	0,010
4	Baqa	211.250	193.250	220.250	0,079	0,060	0,059
5	Fuhis	35.544	80.437	82.110	0,238	0,260	0,221
6	Irbid (Central)	332.000	289.000	202.390	0,098	0,093	0,120
7	Jerash	68.855	80.255	88.830	0,121	0,122	0,152
8	Karak	79.165	58.656	67.579	0,186	0,143	0,162
9	Kufranja	60.358	68.708	82.850	0,100	0,084	0,131
10	Ma'an	29.189	31.865	46.350	0,044	0,045	0,073
11	Madaba	50.621	53.812	56.792	0,042	0,046	0,043
12	Mafraq	36.208	41.992	68.396	0,038	0,050	0,097
13	Ramtha	61.160	35.827	46.665	0,100	0,061	0,059
14	Salt	147.001	144.209	150.403	0,099	0,104	0,130
15	Tafielah	57.505	67.463	74.368	0,211	0,214	0,239
16	Wadi Arab	-	-	202.736	-	-	0,093
17	Wadi Essir	60.088	71.728	72.327	0,192	0,240	0,217
Total		1.952.478	2.053.792	2.228.953	-	-	-
Annual increase %		-	5	9	-	-	-

Table 3.1.4-2 Cost distribution of wastewater treatment in 1999 (including cost for pumping)

	Treatment Plant	Type of treatment	Salary JD	Electricity JD	Telephone JD	Water JD	Spare parts JD	Chemicals and chlorine JD	Sludge disposal JD	Laboratory matters JD	RSS tests JD	Fuel and oil JD	Pesticides JD	Others JD
1	Abu Nuseir	AS+RBC	49,320	26,890	250	385	600	2,340	4,520	200	0	1,067	0	815
2	Aqaba	WSP	57,000	27,500	500	4,500	16,000	2,090	0	400	0	1,200	4,200	1,200
3	As-Samra	WSP	258,720	678,100	1,970	19,400	203,000	5,800	6,600	0	50,000	20,660	10,500	7,720
4	Baqa	TF + MP	97,000	66,000	750	650	21,500	5,000	42,000	2,500	0	10,900	2,500	2,150
5	Fuhis	EA + MP	69,000	21,800	350	300	1,700	2,400	2,200	150	0	2,050	235	100
6	Irbid	TF + AS	113,000	37,500	1,200	1,000	4,790	12,000	23,700	1,200	0	5,000	1,000	2,000
7	Jerash	EA + MP	49,000	23,557	200	500	7,500	3,537	2,596	200	0	740	300	700
8	Karak	TF + MP	45,000	2,237	592	100	4,000	9,400	250	2,500	0	2,450	300	750
9	Kufranja	TF + MP	51,320	13,200	280	120	10,430	0	0	0	0	3,200	1,100	3,200
10	Ma'an	WSP	37,385	1,080	0	200	5,630	0	0	0	0	1,430	480	145
11	Madaba	WSP	33,898	8,174	483	377	6,500	420	110	720	0	2,475	1,385	2,250
12	Mafraq	WSP	51,328	7,518	0	600	8,000	250	0	0	0	250	250	200
13	Ramtha	WSP	26,896	6,587	255	220	8,000	0	0	0	0	3,132	75	1,500
14	Salt	EA + MP	38,000	71,203	400	400	17,800	5,100	14,500	0	1,000	1,100	500	400
15	Tafielah	TF + MP	48,978	9,124	260	743	5,000	120	0	150	0	1,175	130	8,988
16	Wadi Arab	EA	89,600	78,800	0	1,600	0	5,400	4,368	12,000	0	2,968	0	8,000
17	Wadi Essir	AP	53,242	10,769	0	110	1,380	1,386	0	885	0	2,915	1,340	300
	Total		1,168,687	1,090,039	7,490	31,205	321,830	55,243	100,844	20,905	51,000	62,712	24,295	40,418
	%		39	37	0	1	11	2	3	1	2	2	1	1

Table 3.1.4-2 presents the cost distribution for wastewater treatment (including cost for pumping, if pump stations exist) in 1999. It shows clearly that staff and electric power costs with a share of 39 and 37 % respectively dominate the cost for operation and maintenance.

3.1.5 Present Condition of Treatment

The following assessment of the efficiency of existing wastewater treatment plants and environmental impacts is based on the water quality data as published by WAJ in the annual Sewerage Sector Operation Reports of 1997, 1998 and 1999. However, it has to be mentioned that results of water quality analysis done by other institutions differ from the WAJ's data. In general, data on wastewater quality measured by other institutions (Ministry of Health, Royal Scientific Society, compare Section 2.4 also) give a worse picture of the treatment plants' efficiency as it is using WAJ's data.

3.1.5.1 Assessment of Wastewater and Sludge Treatment

The results of the assessment of the treatment plant are summarized in Table3.1.5-1.

Generally, the efficiency of BOD_5-elimination of the treatment plants is satisfactory in comparison to experiences gained in other countries with similar treatment facilities (as shown in the following table).

Efficiencies of Treatment Processes (according to experiences):

Treatment process	Reduction in %			
	BOD_5	Suspended matter	Helminth eggs	Bacteria
Physical (pretreatment)	25 - 35	55 - 65	10 - 99	0 -50
Extended aeration	85 - 95	85 - 95	10 - 99	90 - 99
Activated sludge (medium load)	85 - 95	85 - 95	10 - 99	10 - 99
Trickling filter (low load)	80 - 90	70 - 90	10 - 99	10 - 99
Ponds (anaerobic, facultative, maturation)	95 - 98	95 - 98	99 - 99,9	99,9-99,99

According to Table 3-6 the expected elimination of BOD_5 is not reached in 4 treatment pants only (Aqaba, Ma'an, Madaba and Mafraq). All 4 plants are stabilization pond systems. However, in this context it has to be mentioned that the effluent BOD_5 of the pond system plants is to a certain extend influenced by the organic matter of algae grown particularly in the maturation ponds.

As far as sludge management is concerned in most of the cases applied treatment and disposal methods are unsatisfactory. The conventional treatment plants of Abu Nuseir and Baqa do not dispose of any sludge treatment facilities. Sludge of both plants is transported by tankers to Ain Ghazal pretreatment plant and discharged in the raw sewage to As Samra, the treatment plant of Greater Amman. Only a portion of the sludge of Fuhis and Salt is dried, while another portion is also brought in liquid stage to

Ain Ghazal. In some other treatment plants sludge is dried in summer only (but not all the quantities produced in winter) and disposed either in solid or liquid stage at the solid waste dumping grounds.

This practice of sludge disposal may have serious harm to the natural environment. In particular this is true for the disposal of liquid, non-stabilized sludge on dumping grounds of Al Akeder, Jorf Darawesh and Lagoun. The fresh sludge disposed in liquid form at the dumping grounds may infiltrate into the groundwater table and pollute considerably the local water resources used for drinking purposes. Additionally, disposed sludge may be transported by surface water during rainy season away from the dumping ground. The recent environmental accident at the Al Akeder dumping ground (in May 2000) has shown that such a risk for significant environmental pollution is rather high.

Generally, every treatment plant should dispose of adequate sludge drying facilities. Taking into account the local conditions it seems that sludge drying beds are the most appropriate facility. Most of the plant's operators complain that the space of the drying beds are not sufficient, in particular during rainy season in winter time. Additional storage capacity for liquid sludge and additional drying beds could be the solution.

In general, the anaerobic ponds have to be desludged more often as this was the case up to now. All the anaerobic ponds were desludged only once in ten years. It is reported of a pond, where the usable water layer was reduced to 50 cm only, when it was desludged for the first time. The sludge layer in the ponds has to be monitored continuously and the pond desludged when the sludge layer is more than 0.5 m. About 40 l/c/a can be assumed as average annual sludge production. The sludge quantity accumulated at the pond's ground may be roughly estimated using this figure.

None of the wastewater stabilization ponds dispose of a sludge treatment facility such as drying beds. When the anaerobic pond was desludged, in most of the cases some ditches were excavated. After filling them with sludge they were covered by earth.

As a summary it has to be said that the sludge treatment and disposal is the weakest part in all of the wastewater treatment plants. Plant related solutions have to be elaborated and implemented to improve the existing situation.

Table 3.1.5-1 Assessment of wastewater and sludge treatment (status 1999)

	Treatment Plant	Type of treatment	Degree of use 1) (%)	Assessment of hydr. use	Efficiency (BOD-elim.) (%)	Expected efficiency 2) (%)	Assessment of efficiency	Sludge treatment 3)	Sludge disposal 3)	Assessment of sludge treatm. and disposal
1	Abu Nuseir	AS+RBC	35		97	90 - 95	acceptable	no	As Samra T.P.	unsatisfactory
2	Aqaba	WSP	97	at design cap.	69	80 - 90	too low	no	excav.ditches	unsatisfactory
3	As-Samra	WSP	245	overloaded	84	80 - 90	acceptable	no	?	unsatisfactory
4	Baqa	TF + MP	69		92	90 - 95	acceptable	no	As Samra T.P.	unsatisfactory
5	Fuhis	EA + MP	42		98	90 - 98	acceptable	thick.,part.dried	A.S.T.P. or d.g.	unsatisfactory
6	Irbid	TF + AS	42		96	95 - 98	acceptable	thick.,part.dried	d. g. Al Akeder	unsatisfactory
7	Jerash	EA + MP	46		97	90 - 98	acceptable	thick.,part.dried	d. g. Al Akeder	unsatisfactory
8	Karak	TF + MP	203	overloaded	94	90 - 95	acceptable	partly dried	d. g. Lagoun	unsatisfactory
9	Kufranja	TF + MP	96	at design cap.	95	90 - 95	acceptable	partly dried	dump. ground	unsatisfactory
10	Ma'an	WSP	109	overloaded	79	80 - 90	too low	no	excav.ditches	unsatisfactory
11	Madaba	WSP	180	overloaded	69	80 - 90	too low	no	excav.ditches	unsatisfactory
12	Mafraq	WSP	107	overloaded	65	80 - 90	too low	no	excav.ditches	unsatisfactory
13	Ramtha	WSP	114	overloaded	80	80 - 90	acceptable	no	d. g. Al Akeder	unsatisfactory
14	Salt	EA + MP	41		99	90 - 98	acceptable	thick.,part.dried	A.S.T.P. or d.g.	unsatisfactory
15	Tafielah	TF + MP	53		96	90 - 95	acceptable	partly dried	d.g.JorfDarawesh	unsatisfactory
16	Wadi Arab	EA	29		99	85 - 95	acceptable	dried	d. g. Al Akeder	acceptable
17	Wadi Essir	AP	23		92	80 - 90	acceptable	n.a.	n.a.	n.a.

1) Related to the hydraulic design capacity
2) According to general experience depending on the applied treatment process.
3) As Samra T.P. — Liquid sludge is transported by tankers to Ain Ghazal and discharged into raw sewage of Greater Amman.
excav.ditches — In case of desludging of anaerobic ponds sludge is filled in excavated ditches and covered by earth.
A.S.T.P. or d.g. — Liquid sludge is transported by tankers to Ain Ghazal and discharged into raw sewage of Greater Amman and dried sludge is disposed at solid waste dumping ground.
d.g. — Liquid or partly dried sludge is disposed at solid waste dumping grounds of Al Akeder, Lagoun or Jorf Darawesh.
thick.,part.dried — Sludge is thickened and partly dried depending on summer/winter.
partly dried — Sludge is partly dried depending on summer/winter.

WSP — Wastewater stabilization ponds
AS — Acivated sludge process
EA — Extended aeration
RBC — Rotating biological contactor
TF — Trickling filter
MP — Maturation pond
AP — Aerated ponds

3.1.5.2 Negative Environmental Impact

Table 3.1.5-2 shows the most important environmental impacts of wastewater treatment plants' effluent.

All treatment plants would hydrographically discharge into wadis as natural receiving water. 7 of the wadis mouth into a reservoir (King Talal, Shua'ab and Kafrein Reservoir) used for irrigation water storage. The discharge of treated wastewater into the King Talal Reservoir is of particular importance insofar as the Wadi Zarqa with the effluent of As Samra Treatment Plant (about 45 MCM/a) flows into this Reservoir. The high flow rates together with the high amounts of nutrients lead to eutrophication of the impounded water. Therefore, tertiary treatment including nitrogen and phosphorus removal is proposed for the planned new treatment plant in As Samra and Wadi Zarqa.

According to the Jordanian Standard JS 893/1995 (see Annex 3.1) the maximum BOD_5-content of treatments plants' effluent into wadis and catchment areas should not exceed 50 mg/l. Based on this water quality requirement the environmental impact of the plants' effluent were assessed. Table 3.1.5-2 shows that 9 of the 17 treatment plants do not fulfill the requirements of the standards. For 6 of the plants the BOD_5-concentration of the effluent exceeds even 100 mg/l.

Particular protection of water resources downstream of the wastewater plants of Aqaba, Irbid and Wadi Arab, Karak, Madaba, Mafraq as well as Ramtha have to be respected. For all of these plants, it is not allowed to discharge any treated wastewater into the natural (hydrographic) receiving water. Therefore, the effluent of treatment plants of Aqaba, Madaba, Mafraq as well as Ramtha is either evaporated or infiltrated into the underground inside the plant's area or reused for agricultural irrigation inside or close to the plant's site.

The natural receiving water of the plants of Karak, Irbid and Wadi Arab are flowing through an area, where wells and springs are located used for drinking water extraction. Consequently, any risk for contamination of these resources by treated wastewater has to be avoided and direct discharge of effluent to these wadis is not allowed. Conveyor pipes conduct the treated wastewater to a section downstream of the sensitive areas.

With respect to the Aqaba Plant, the Gulf of Aqaba is an aquatic environment rich of coral reefs and unique with respect to the faun and flora and, therefore, calls for special protection. In addition, it is an important tourist resource area insofar as it is used for bathing and diving.

The natural receiving water of the Madaba treatment Plant's effluent is the Wadi Al Habis a tributary of Wadi Walah. Resources (several springs) along Wadi Walah would be polluted by the poorly treated wastewater of the Madaba plant. It was decided to avoid the discharge of the effluent into the Wadi Al Habis.

Emission of treatment facilities leading to bad smell in their environments is reported for several plants. Most of these plants are wastewater stabilization pond systems, where the major source is the anaerobic pond. For four of these plants (Aqaba, As

Samra, Ramtha and Madaba) there are plans for the conversion of plant to conventional treatment systems based on activated sludge process, which will most probably solve the odor problem. The locations of the other concerned plants are, in general, far enough distant from the settlements so that no molestations of built-up areas exist except of the plant in Irbid. This plant is relatively close to settled area of town of Irbid. There are no plans for rehabilitation of the Treatment Plant Irbid Central. It is even proposed to abandon this plant after its general lifetime is reached (about 2020). All wastewater would then be discharged to Wadi Arab Treatment Plant.

The former extreme odor emission of the treatment plant of Baqa will not anymore exist, when the ongoing construction measures will be completed.

Table 3.1.5-2 Environmental impacts of the treatment plants (status 1999)

	Treatment Plant	Natural receiving water (NRW)	Particular protection measures (not allowing effluent discharge into natural receiving water)	Concentration of BOD_5 at the effluent mg/l	Water quality requirements 1) (acc.to JS 893/1995)	Odor problems
1	Abu Nuseir	Wadi Bereen to King Talal Reservoir		17	respected	not particularly
2	Aqaba	hydrographically Wadi Araba	no discharge into the Gulf of Aqaba, because it is bathing water	111	not respected	in some months, no complaints
3	As-Samra	Wadi Dhuleil to Wadi Zarqa to King Talal Reservoir		118	not respected	yes
4	Baqa	Wadi Rumman to King Talal Reservoir		80	not respected	not part.(after compl.of measures)
5	Fuhis	Wadi Shua'ab to Shua'ab Reservoir		11	respected	not particularly
6	Irbid	hydrographically Wadi Arab (30 km pipe to Jordan Valley)	no discharge into NRW, because of wells downstream	51	not respected	yes (particularly in summer)
7	Jerash	Wadi Jerash to Wadi Zarqa to King Talal Reservoir		33	respected	not particularly
8	Karak	Wadi Karak (8 km downstream of the plant by a pipe)	no discharge into NRW, because of springs downstream	46	respected	not particularly
9	Kufranja	Wadi Kufranja to Jordan Valley		65	not respected	yes (particularly in summer)
10	Ma'an	Wadi Al Hamam		118	not respected	minor (particularly in summer)
11	Madaba	hydrographically Wadi Al Habis	no discharge into NRW, because of hot springs downstream	282	not respected	extremly (particularly in summer)
12	Mafraq	hydrographically Wadi Ghadeer to Wadi Senhan	no discharge into NRW, because of wells of Mafraq downstream	197	not respected	extremly (particularly in summer)
13	Ramtha	hydrographically Wadi Shomar to Yarmouk River	no discharge into NRW, because Yarmouk is resource of pot.water	239	not respected	yes (particularly in summer)
14	Salt	Wadi Shua'ab to Shua'ab Reservoir		11	respected	not particularly
15	Tafielah	Wadi Al Gheir		35	respected	not particularly
16	Wadi Arab	hydrographically Wadi Arab (15 km pipe to Jordan Valley)	no discharge into NRW, because of wells downstream	10	respected	not particularly
17	Wadi Essir	Wadi Essir/Wadi El Bukhath to Kafrein Reservoir		50	respected	not particularly

1) The max BOD_5-content of treatment plant's effluent into wadis and catchment areas should not exceed 50 mg/l.
2) NRW = natural receiving water

3.1.5.3 Assessment of Operation and Maintenance of Treatment Systems

Staff requirements for existing treatment plants are estimated in Table 3.1.5-3 based on German experience (ATV-Work Paper FA 2.12). Generally, staff number depends on the specific available treatment facilities and on the capacity of the plant considered as connected population equivalents. The number of staff is estimated for each plant taking into account the particular condition of each treatment plant on a monthly working hour basis. Working hours per year and employee is assumed as 1,500. The so determined required number of staff is increased additionally by 100 % with respect to the specific difficult local working conditions.

As Table 3.1.5-4 indicates most of the treatment plants are overstaffed if compared with estimated staff requirements (see Table 3.1.5-3). In particular the number of employees of the plants in Abu Nuseir, Fuhis, Karak, Tafielah and Wadi Arab exceeds by far the estimated staff requirement. Only in As Samra, Aqaba and Madaba the staff employed at the treatment plant is of a reasonable number.

The number of employees working for operation and maintenance of the collection network are assessed in Table 3.1.5-4. In general, a reasonable number of employees per 1,000 house connections is between 2 and 4.

The number of complaints concerning wastewater collection is registered in most of the towns having a sewerage system. To make this information comparable between the various towns, the number of complaints was related to the total sewer length of each sewerage system. Table 3.1.5-4 shows the results: The highest rates of complaints were found for the towns of Aqaba, Baqa, Ma'an and Salt. The reasons for this may be the bad condition of the sewerage system and/or the insufficient operation and maintenance activities.

In general, the electrical power cuts at the treatment plants do not expose a particular problem. For the wastewater stabilization ponds (where in most cases a generator set is not available) electrical power is of minor importance for the treatment only. The conventional treatment plants rely on electric power (e.g. for sludge recycling pumps and aerators) dispose of generators, which are switched on in cases of power cuts. The responsible staff at none of the treatment plants considered unreliable electric power supply as a problem.

To operate and maintain adequately a treatment plant an operation manual for the specific treatment process and the arrangement of the facilities is required. In addition, a proper management of a plant is based on a clear structure for the organization of regular preventive as well as corrective maintenance. This includes a clear work order system and the recording of executed maintenance tasks beside of the monitoring of process parameters (e.g. influent discharge, water quality parameters). However, a comprehensive well-organized operation and maintenance structure is established in a few treatment plants only. In the long run improvements in organization of daily work would improve treatment efficiency, reduce operation cost and extend lifetime of facilities and equipment.

Special attention shall be drawn to the operation of wastewater stabilization pond systems. In some of these plants it is not allowed to discharge treated effluent into the natural receiving water due to specific protection measures of water resources (see Table 3.1.5-2). Forced by these conditions the operators of some of these pond systems operate to a certain extend the ponds as wastewater holding tanks to store water in times of low water demand for irrigation. Ponds are partly emptied, when the high quantities of irrigation water is needed. In these cases desired conditions of biocoenose in the ponds may be not developed. This is of particular significance for the facultative ponds, where different layers of aerobic and anaerobic conditions should be established and kept. More appropriate solutions should be found to fulfill the requirement not to discharge effluent into the natural receiving water.

Specific problems and deficiencies at the treatment plants are reported by the responsible personal during the site visits in March/April 2000. They are summarized in Table 3.1.5-4. Measures to solve these problems are already undertaken (e.g. construction of new treatment plants in Aqaba, As Samra and Madaba). Others have to be urgently to be solved (such as the overloading of the plant in Karak, the non-operational wastewater distributors of the trickling filters in Irbid, the blockage of the trickling filters in Kufranja) to avoid further harm to the environment by too low treatment efficiencies and/or further damages to the technical facilities.

3.1.6 Present Status of Planning of Wastewater Treatment Plants

As already mentioned 6 of the 17 existing treatment plants are overloaded with respect to the hydraulic design capacity. For 4 of these overloaded plants specific plans exists for the new construction of a treatment plant or expansion of the existing one: The Ministry of Water and Irrigation intends to construct a new treatment plant in As Samra for an average daily capacity of 267,000 m^3. A new design for the treatment plant of Madaba and Ramtha was prepared and construction work is tendered in 2000. A Feasibility Study on the expansion of the Karak's treatment plant and sewerage system will be prepared in 2001.

In addition, for Aqaba a Feasibility Study on the new construction of a treatment plant and network extension is completed in May 2000. The feasibility of the expansion of Kufranja's treatment plant and sewerage system will be studied in 2001.

Table 3.1.5-3 Estimation of staff requirements for treatment plants

	Population and equivalents				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
					Abu Nuseir	Aqaba	As-Samra	Baqa	Fuhis	Irbid (Central)	Jerash (East)	Karak	Kufranja	Ma'an	Madaba	Mafraq	Ramtha	Salt	Tafielah	Wadi Arab	Wadi Essir
	10-20,000	20-50,000	50-100,000	2,000,000	13,800	47,600	1,951,000	164,000	10,600	46,480	27,600	12,900	35,500	14,700	51,000	16,800	39,900	41,200	12,300	86,320	8,700
	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month	h/month
Lifting station at treatment plant	8	15	27																		
Screens	13	20	30	200	13	30	200	30	13	30	20	13	20	13	30	13	20	20	13	30	13
Grit chamber	9	15	22	150	9		150	22	9	22	15	9						15		22	
Primary settling tank	18	30	45		18			45		45		18	30						18	45	
Activated sludge bassin	17	22	26		17				17		22							22			
Trickling filter	9	15	25					25		25		18	15						9		
Secondary settling tank	15	25	42		15			42	15	42	25	15	25					25	15	42	
Chemical precipitation	18	23	28							28											
Digester	9	14	22		9					22		9	14						9		
Thickener	5	8	12		5			12	5	12	8	5	8					8		12	
Mechanical dewatering of sludge	40	70	120																		
Drying beds	70	120	250						70	250	120	70	120					120	70	250	
Electromechanical equipment	13	22	42		13	42		42	13	42	22	13	22		42	13	22	22	13	42	
Anaerobic pond	80	160	320	1,600			1,600							80	320	80	160				80
Facultative pond	50	100	200	1,000		200	1,000							50	200	50	100				50
Maturation	30	60	120	600		120	600	120	30		60	30		30	120	30	60	60	30		30
Administration	11	28	30		11	30	0	30	11	30	28	11	28	11	30	11	28	28	11	30	11
Operation building	15	25	40		15	40	0	40	15	40	25	15	25	15	40	15	25	25	15	40	15
Treatment plant site	15	25	40		15	40	0	40	15	40	25	15	25	15	40	15	25	25	15	40	15
Others	10	20	38		10	38	0	38	10	38	20	10	20	10	38	10	20	20	10	38	10
Monitoring, laboratory	60	100	160		60	160	0	160	60	160	100	60	100	60	160	60	100	100	60	160	60
Working hours per year					2,520	8,400	42,600	7,752	3,396	9,912	5,880	3,732	5,424	3,408	12,240	3,564	6,720	5,880	3,456	9,012	3,408
Required staff members 1)					2	6	28	5	2	7	4	3	4	2	8	2	5	4	2	6	2
Modified required staff members 2)					3	11	57	10	5	13	8	5	7	5	16	5	9	8	5	12	5

Remarks: 1) Working hours per staff member and year: 1,500 h/staff/a

2) Increase of staff numbers in percent regarding sp 100 %

Table 3.1.5-4 Assessment of operation and maintenance

	Treatment Plant	Type of treatment 1)	Employees sewerage syst. per 100 h.c. 2)	Employees at WWTP	Recomm. no. of empl. at WWTP 3)	No.of complaints per km sewer	Electric power cuts	Operation and maintenance organisation	Specific problems at the treatment plants
1	Abu Nuseir	AS+RBC	1.3	18	3	?	1 per year, no problem	?	floating sludge at sec.settling tanks
2	Aqaba	WSP	3.2	12	11	1.5	3 per year (for 1 h), no problem	basic	some scum in the facultative ponds
3	As-Samra	WSP	1.3	50	57	?	no problem	?	overloading of plant
4	Baqa	TF + MP	1.5	30	10	2.6	1 per month, no problem	?	no, when ongoing construction measures completed
5	Fuhis	EA + MP	4.7	22	5	1.3	several times per month, no problem	?	floating sludge at sec.settling tanks
6	Irbid	TF + AS	1.1	42	13	0.5	2 per year, generator available	yes	deficiencies in sludge treatment, TF out of operation
7	Jerash	EA + MP	7.1	22	8	0.8	1 per month (1-2 h), generator available	basic	too less drying beds
8	Karak	TF + MP	4.1	23	5	1.2	1 per month (0.5 h), generator available	basic	overload of the plant
9	Kufranja	TF + MP	4.0	21	7	0.6	1per week (2-5 h), generator available	basic	blockage of trickling filters
10	Ma'an	WSP	4.6	15	5	1.6	1 per month (1-2 h), no generator available	none	no laboratory available at plant
11	Madaba	WSP	2.4	10	16	0.6	no problem	?	biological overloading of plant
12	Mafraq	WSP	2.9	12	5	?	no problem	?	low treatment efficiency
13	Ramtha	WSP	2.7	14	9	0.1	no problem	no	high discharges in winter (up to 3 times design cap.)
14	Salt	EA + MP	2.7	21	8	1.8	3 -5 per month, no problem	?	no
15	Tafielah	TF + MP	4.9	20	5	0.4	2 per month (5 - 20 min.), generator available	basic	no
16	Wadi Arab	EA	1.1	61	12	0.5	1 per week (up to 3 h), no problem	yes	no
17	Wadi Essir	AP	1.3	13	5	?	no problem	yes	landslides within the treatment plant area

1) WSP Wastewater stabilisation ponds; AS Acivated sludge process; EA Extended aeration; RBC Rotating biological contactor; TF Trickling filter; AP Aerated ponds; MP Maturation pond

2) A reasonable number of employees per 1,000 house connections (h.c.) is 2 - 3

3) According to experience (see Table 3-8)

3.2 Present Reuse of Wastewater and Sludge

3.2.1 Wastewater Ruse

3.2.1.1 Irrigation Water Quantities

Table 3.2.1-1 shows the present requirement, resources and deficit of irrigation water in Jordan. Demand is subdivided in main regions – the Jordan Valley and the Up/Midlands. In 1999 total quantity of irrigation water was about 630 MCM/a (including reuse of treated effluent from treatment plants).

The average specific irrigation water demand is roughly 1,400 m³/a/donum in the Jordan Valley and 900 m³/a/donum in the Up/Midlands.

Table 3.2.1-1 Total Requirement, Resources and Deficit in Irrigation Water in Jordan, 1998 (MOWI/WB)

	Unit	Upland/ Midland	Jordan Valley	Total
Freshwater	MCM/a	303	253	556
Treated effluent	MCM/a	11	56	67
Total resources	MCM/a	314	309	623
Total requirement	MCM/a	371	460	831
Deficit	MCM/a	57	151	208

Table 3.2.1-2 gives an overview of the irrigation efficiency for surface, sprinkler and drip irrigation, which underlines the meaning, and necessity of an appropriate irrigation method in case of scarcity of water resources, as this is the case in Jordan. However, the table indicates that about 60 % of the irrigated areas rely on drip systems.

The irrigated areas are located more or less to 50 % in the Jordan Valley and in the Highlands.

Table 3.2.1-2 Present Irrigated Area and Overall Irrigation Efficiency in Jordan

(in donums, 1 donum = 0.1 ha)

Crop	Irrigated area			Total irrigated area (Jordan)	Jordan Valley	Highlands Disi Mudawara
	Surface	Sprinkler	Drip			
Efficiency (%)	42	68	70			
Vegetables	50,000	13,700	242,000	305,700		
Fruit trees	112,000	-	105,000	217,000		
Green houses	-	-	25,000	25,000		
Field crops		90,500	-	90,500		
Total	162,000	90,500	372,000	638,200	300,000	330,000

3.2.1.2 Present Reuse of Treated Wastewater

Table 3.2.1-3 shows the effluent quality of the existing wastewater treatment plants with regard to four parameters relevant in the view of the reuse of treated wastewater for irrigation purposes. However, it has to be mentioned that only a few data on fecal coliforms and helminth eggs are available and, therefore, the assessment on the suitability for agricultural irrigation is limited.

With respect to the quality criteria for treated domestic wastewater according to Jordanian Standard 893/1995 (compare with Annex 3.1) none of the effluent fulfills the standards for unrestricted use for irrigation. Generally, the limiting water quality parameter is the content of fecal coliform count. For some of treatment plants the effluent approaches the limit of 1,000 fecal coliforms for unrestricted use, but a stable microbiological water quality is not recognizable. For safety reasons a chlorination of the effluent should be provided, if used for unrestricted irrigation.

At present restricted irrigation by treated wastewater is practiced at agricultural land close to the treatment plants (inside or in the vicinity of the plant) and downstream of it along the wadis serving as receiving water for the effluents. About 15,700 donums of cereal, fodder, forest trees and fruits are irrigated. WAJ and the Ministry of Health control the reuse, if the irrigated land is inside of the treatment plant area, while the Ministry of Agriculture (MOA), Ministry of Health (MOH) and the General Corporation for Environmental Protection (GCEP) is responsible for the control outside of the treatment plant area.

Table 3.2.1-3 Effluent Quality and Suitability for Agricultural Irrigation (existing treatment plants)

	Treatment Plant	Effluent quality				Suitability for agricultural irrigation
		Fecal coliforms 1) (1/100ml)	Helminth eggs 1) (eggs/l)	BOD_5 2) (mg/l)	TDS 2) (mg/l)	
1	Abu Nuseir	< 1,000 (by chlorin.)	>1	17	823	restricted irrigation
2	Aqaba	4,700 up to 1 mio.	0	111	879	restricted irrigation
3	As Samra	140,000	0	118	1,258	restricted irrigation
4	Baqa	2,500	0	80	1,093	restricted irrigation
5	Fuhis	15,000	0	11	669	restricted irrigation
6	Irbid (Centr.)	2,000	>1	51	no inform.	restricted irrigation
7	Jerash (East)	No information	0	33	1,132	restricted irrigation
8	Karak	>1,600	0	46	896	restricted irrigation
9	Kufranja	No information	0	65	935	restricted irrigation
10	Ma'an	16 mio. in Oct.1999	0	118	945	restricted irrigation
11	Madaba	>15,000	0	282	1,439	restricted irrigation
12	Mafraq	>15,000	0	197	1,284	restricted irrigation
13	Ramtha	>15,000	0	239	1,546	restricted irrigation
14	Salt	>15,000	0	11	666	restricted irrigation
15	Tafielah	No information	0	35	798	restricted irrigation
16	Wadi Arab	1,000	0	10	no inform.	unrestricted irrig. after chlorin.
17	Wadi Essir	1,600	0	50	1,084	unrestricted irrig. after chlorin.

Remarks: 1) Data of 1999 or before, if not available for 1999
2) Data of 1999

About effluent is reused for unrestricted irrigation at 91,000 donums of agricultural land in the Jordan Valley after mixing with freshwater. Related areas are mostly in the Middle and Southern Valley. Out of this surface some 58,000 donums of vegetables are irrigated. Generally, the dilution takes place by part of effluent to 3 parts of freshwater. The Jordan Valley Authority (JVA) and the Ministry of Health supervise restricted irrigation commonly.

In total more than 100,000 donums are irrigated by treated effluent of the existing treatment plants (see Table 3.2.1-4).

Presently, total annual treated effluent quantity reused for irrigation is roughly estimated to 50 MCM/a, whereby this volume is applied by

- 15 MCM for restricted irrigation and
- 35 MCM for unrestricted irrigation.

Taking into account total applied irrigation water of 630 MCM/a, the reuse of treated effluent for irrigation purposes is in the order of 8 to 10 %.

Table 3.2.1-4 Areas Presently Irrigated by Treated Wastewater

(in donums, 1 donum = 0.1 ha)

Irrigation	Type of crop: Cereal and fodder 1)	Forest trees 2)	Fruits 3)	Vegetable 4)	Total	Supervision under
Restricted irrigation close to treatment plant	1,770	3,190	1,700	0	6,660	WAJ and MOH
Restricted irrigation down-stream of treatment plant	2,000	500	6,500		9,000	MOA, MOH and GCEP
Unrestricted irrigation after mixing with freshwater 5)	6,500	1,000	25,000	58,500	91,000	WAJ and MOH
Total	10,270	4,687	33,197	58,500	106,654	

1) Barley, sudan grass, alfalfa, maize (forage)
2) Acacia, cassorina, eucalyptus etc.
3) Olive, citrus, banana and others
4) various vegetables
5) Mixing in Jordan Valley

Area of restricted irrigation close to the treatment plants composed as shown in Table 3.2.1-5. The share of As Samra dominates with about 50 % of the irrigated areas.

Irrigated crops are fodder, olive trees and forests. Fodder is irrigated in particular in As Samra, Kufranja, Ma'an, Madaba, Mafraq and Ramtha. The largest areas of olive trees and forest irrigation are close to As Samra and Aqaba.

3.2.1.3 Limits of Irrigation Reuse: Soil Salinity

This problem may develop as a consequent of using saline water or applying excessive non-saline water without providing adequate artificial drainage if natural drainage is not sufficient to percolate excess water deep beneath the root system. In some cases, salinity may develop as a result of using non-saline water, if the volume of irrigation water was not sufficient to meet the leaching requirement of that area. As an example, the drip application of good quality irrigation water in arid areas may lead to salinity buildup due to the absence of natural leaching of the accumulating salts by rainwater.

Table 3.2.1-5 Areas and Type of Crops Irrigated On-site at the Treatment Plants (restricted irrigation)

(in donums, 1 donum = 0.1 ha)

	Plant	Fodder	Olives	Forests	Total
1	Abu Nuseir		5	2	7
2	Aqaba		50	1,500	1,550
3	As-Samra	300	1,500	1,500	3,300
4	Baqa			5	5
5	Fuhis		10	10	20
6	Irbid		2	5	7
7	Jerash			5	5
8	Karak		10	15	25
9	Kufranja	70	10	10	90
10	Ma'an	50	20	50	120
11	Madaba	600	10	20	630
12	Mafraq	250	30	15	295
13	Ramtha	500	5	15	520
14	Salt		10	5	15
15	Tafielah		15		15
16	Wadi Arab				
17	Wadi Essir		20	30	50
	Total	1,770	1,697	3,187	6,654

Salinity per se does no have an adverse affect on soil properties, particularly soil structure. In fact, increasing salinity of irrigation water maintains structural stability. Deterioration in soil structure may develop when utilizing non-saline irrigation water of relatively intermediate or high sodicity (SAR>10). In the Jordan areas of soil types other than the vertisols (formerly know as the red Mediterranean soils), deterioration in soil structure may take place even when employing irrigation waters of both low salinity and sodicity (SAR<5). It is for this reason, salinity and sodicity of irrigation waters are considered hand-in-hand in modern approaches. However, these two parameters represent one aspect of the criteria assessment process. Other factors affecting evaluation water quality criteria are:

1. Soil clay content and type: as clay content increases soil becomes more sensitive to the dispersive effect of irrigation water. In addition, the most labile soils are these rich in montmorillonite clay.
2. Soil content of easily weather able minerals like carbonate and gypsum: These soils tend to dissolve some salts of divalent cat ions leading to the enhancement of the subsurface structure against breakdown tendency.
3. Soil content of organic matter: Organic matter enhances stability of soil structure.
4. Soil content of oxides and hydroxides of Al and Fe: These components have a stabilizing effect too.

On the other hand, increasing soil salinity increases crop salt injury and, thus, reduces crop yield, if salinity exceeds a certain threshold level. Crop salt tolerance is evaluated by the threshold salinity below which no reduction of crop yield is observed. When soil salinity exceeds the threshold level, relative crop yield declines.

3.2.1.4 Other Reuse of Treated Wastewater

At present, no industrial reuse worth mentioning is known. Some factories may reuse part of the industrial water on a small scale and mainly for cooling purposes.

Generally, aquifer recharge is not common in Jordan due to restrictions given by existing regulations (see Annex Report), the high demand of irrigation water and the general water scarcity. However, aquifer recharge is practiced to a certain extend by the treated effluent of the Aqaba Wastewater Treatment Plant. It was decided to avoid any discharge into the Gulf to protect the aquatic environment and the quality of seawater. Therefore, the treated wastewater of the plant is partly evaporated and infiltrated at the plant site and partly reused for agricultural irrigation. It is estimated that out of the total inflow to the plant

- 25 % is evaporated in the facultative and maturation ponds
- 30 % is used for irrigation
- 35 % is evaporated and/or infiltrated in ponds

In several unsealed ponds (downstream of the maturation ponds) of a total surface of 200,000 m^2 the treated wastewater is evaporated and infiltrated into the groundwater. These ponds are mostly arranged in series so that the water quality is by far better than the one measured at the outlet of the maturation ponds.

3.2.2 Sludge Disposal

Presently, no treated sludge of the treatment plants of Jordan is reused in agriculture. Most of the sludge of the conventional plants is disposed on existing solid waste dumping grounds compare Table 3.1.5-1 in Section 3.1.5). However, utilization of treated sludge in the agriculture may have several advantages, which are discussed in the following paragraphs.

Using dewatered and dried sludge from the sewage treatment plant can compensate the deficit of nutrients in irrigated agriculture. In addition the sludge serves as a soil conditioner. Following basic design criteria can be adopted:

- Sludge production: 40 l/c/d
- Dosage of sludge on fields (about 1.7 t/ha/a): 3.0 m^3/ha/a
- Dosage of P_2O_5 (4 % of 1.7 t): 68 kg/ha/a

Benefits include the saving of expenditure for the use of chemical fertilizers of the same content of P_2O_5. A dosage of 136 kg/ha/a fertilizers corresponds roughly to 68 kg/ha/a of P_2O_5.

By settling processes of the treatment plant the helminth eggs are eliminated of the wastewater and accumulated in the sludge. The same is viable for other microorganisms such as pathogenic germs, but the survival time is higher. In order to reduce the hygiene risk coming from the helminth eggs to a supportable extend the sludge should be exposed to sunlight and dried for about 6 - 12 months in the sludge drying beds.

Heavy metals accumulate on solid phase. So raised heavy metal concentrations in sewage sludge can be anticipated. However, the risk of such an accumulation reaching dangerous contents is not very high: Table 3.2.2-1 shows heavy metal concentrations in As Samra sludge as measured by CDM International in 1993. A comparison of the detected concentrations (Table 3.2.2-1) with the maximum concentration of heavy metals in treated sludge to be reused for agricultural purposes according to Jordan Standards JS 1145/1996 (see Table3-1 in Annex 3.1) reveals that even all the maximum values of As Samra sludge are by a factor 3 lower than the permissible concentrations. Therefore, it can be concluded that generally the content of heavy metals in the sludge would not exclude its agricultural utilization assuming that industrial activities are concentrated in Amman and, thus, the concentrations in the sludge of other treatment plants are even lower.

Table 3.2.2-1 Heavy Metal Concentration in As Samra Sludge

(in mg/kg dry mass)

Element	Geometric average	Maximum value	Max. concentration (Jordan Standard)
Al	7,800	13,207	
Ag	1.49	23.5	
As	1.31	2.9	75
B	33.6	88.8	
Cd	3.65	8.1	85
Co	4.63	50.7	150
Cr	222	669	3,000
Cu	231	362	4,300
Fe	436	23,676	
Hg	2.49	5.3	57
Li	2.9	5.6	
Mn	127	175	
Mo	-	-	75
Ni	46.6	68.4	420
Pb	152	211	840
Se	1.46	6.3	100
Si	1.15	1,028	
Sn	0.19	0.6	
Ti	78.8	316	
V	22.1	141	
Zn	2,163	3,850	7,500

3.2.3 Acceptance by the Farmers of Treated Wastewater and Sludge Reuse

The joint venture of DAR, RRI and Sigma has studied in 1995 the acceptance by the farmers of treated wastewater and sludge reuse. In the following main results of this study are summarized.

3.2.3.1 Application of Treated Wastewater to Jordan Valley Farms

The study by questionnaires had the objective to evaluate farmers' opinions in the Northern Jordan Valley toward substituting their traditional good quality irrigation water by treated wastewater. Major features of the irrigated agriculture in the Northern Jordan Valley were found as outlined in the following.

Major results concerning Jordan Valley Agriculture

1. Crops
   Vegetables enjoyed the highest priority of the farmers (45 %) to be followed by orange orchards (38 %). Moreover, an additional 14 % of the surveyed farmers practiced the combined cultivation of these two crops.

2. Type of irrigation
   Surface irrigation was the most dominant system (43 %).

3. Farm size and ownership
   Among the interviewed farmers, there were only 10 % each who cultivated either more than 60 donums or less than 30 and 60 donums. The rest of the farmers (80 %) cultivated farms ranged in area between 30 and 60 donums. Moreover, 39 % of the farmers were landlords, 47 % were tenants and the rest (14 %) were partners with the landlords.

4. Education and experience of farmers
   The majority of the farmers (43 %) enjoyed high school education. Next to that group, there were 39 %, who competed only elementary education. The percentage of illiterate farmers was relatively low (12 %). On the other hand, most of these farmers (60 %) had long (>10 years) experience with agriculture. Only 12 % of the farmers had short term (<5 years) experience.

Farmers and Irrigation Water in the Jordan Valley

1. The majority of the farmers (73 %) believed that the price of irrigation water should be 5 Fils per m^3. Only 20 % agreed to double that price. A comparable percentage (71 %) of these farmers classified the cost of irrigation water as intermediate relative to the rest of items of agricultural expenditures.

2. Almost all of the farmers (96 %) believed in the occurrence of shortage in the supply of irrigation water. However, more than half (55 %) of these farmers wanted the government to provide more irrigation water by all means. **About one-third (29 %) of these farmers agreed on solving the problem by using**

treated wastewater although half of the whole sample (53 %) were not able to distinguish between irrigation waters based on quality criteria. Among the rest of the sample (47 %), who decided that there are certain differences in quality criteria, 16 % attributed such variation to unknown parameters, 14 % to salinity differences, and 10 % to pathogenity of the irrigation water.

3. The ambiguity of irrigation water quality criteria was best manifested be observing that 61 % of those, who decided that there is a difference in quality of irrigation waters, agreed also on that such differences can not be corrected by proper management of the water resources.

4. When a direct question was addressed to the farmers if they are willing **to use a treated wastewater in their own farms, 61 % agreed on using such water**. This result was much higher than the 29 % who assumed the use of treated wastewater as a solution to the problem of water shortage. Among the remainder (39 %) who did not agree on using treated wastewater, 35 % were absolutely certain in their negative response irrespective of the possibility of offering that water at a reduced price. 78 % did not prefer saline or treated wastewater over each other but rather decided that some quality criteria should be employed in doing so The acceptance of using treated wastewater was somewhat conservation since only 35 % of the farmers agreed on irrigation 100 % of their land holds.

5. Only 35 % of the farmers who agreed on using treated wastewater agreed also on changing their irrigation systems to suit the application of treated wastewater. Among those who rejected the former idea, 14 % and 16 % attributed their rejection to technical and financial difficulties, respectively. When the question was directed this time to the possibilities of changing cropping patterns as a result of using treated wastewater, only 26 % agreed on that alternate solution among whose 22 % wanted to grow vegetable crops. Switching farming system to orchards (especially oranges) or forage was totally unacceptable or not significant (6 %), respectively.

At the conclusion of this section, one may argue that farmer's opinion towards the treated wastewater might have been affected by certain personal considerations like educational level, land ownership, or farming experience. Table 3.2.3-1 shows almost no such an effect on farmers' decision to use such water. The table indicates that the ratio between farmers accepting and not accepting the utilization of the treated wastewater remained at or close to 2:1 except for the landlords where the ratio decreased to 1.4 and, thus, reflected the conservative human nature of protecting personal property from possible "potential hazards"

Table 3.2.3-1 Effect of Educational Level, Farming Experience and Land Ownership on Farmer's Opinion toward the Reuse of Treated Wastewater for Irrigation in North Jordan Valley

Parameter	Accepting	Not Accepting
Education Level:		
High School	14	7
Elementary School	12	7
Farming Experience:		
Long (more than 10 years)	22	12
Short (less than 5 years)	4	2
Land Ownership:		
Landlord	11	8
Tenant	15	8

3.2.3.2 Application of Treated Wastewater to Rain Fed Farms in the Highlands

For the rain fed farms in the highlands results can be summarized as follows:

1. Landholds were higher than the corresponding areas in the Jordan Valley. Here, 98 % of the farmers personally managed their farms.

2. Distribution of educational levels of the highland farmers was almost similar to that of their Jordan Valley colleagues.

3. Although 93 % of the farmers believed in the existence of water shortage, 68 % believed in the possibility of being supplied by irrigation water and 66 % agreed on that the reduced price of 5 Fils per m³ is a feasible price. Such an optimistic and unrealistic expectation may be explained by the eagerness of those farmers to upgrade the productivity of the their land (100 % want to continue cultivating their farms after being supplied by irrigation water).

4. 56 % of the farmers proposed to be supplied by additional fresh water as a solution to the water shortage. To the contrary, **34 % agreed on using treated wastewater** as a practical solution to that problem. This result was similar to the previously reported findings pertaining to the Jordan Valley farmers i.e. 55 % and 29 %, respectively. In fact, the percentage of farmers accepting the application of treated wastewater to their own rain fed farms (68 %) was similar to the percentage of the colleagues down in the Jordan Valley. In addition, those who rejected the application of treated wastewater to their farms (29 %) were almost adamant to their rejection irrespective of the attractive offers such as providing treated wastewater at a reduced price.

5. Among the farmers, who agreed on using treated wastewater, 59 % agreed on carrying major switch to their cropping patterns in harmony with the changing soil and water characteristics. 32 % of the farmers who accepted such a switch proposed cultivating crops of no hygienic risk (cereal and dodder crops and fruit trees).

6. A striking result was such that the majority of the farmers who agreed on using treated wastewater also agreed on irrigating 100 % of their land hold, probably due to their strong desire to increase their land productivity. This point, in fact, sheds light on the objectivity of these farmers towards utilization of the treated wastewater and whether had such a decision been affected by certain personal considerations.

Table 3.2.3-2 shows the effect of educational level, farming experience, and land ownership on the farmer's decision concerning using or not using treated wastewater. The table indicates that the ratio of farmers accepting using treated wastewater to those not accepting the utilization of that water was always greater than 1. This result reflects the preference of these farmers to use treated wastewater as an alternate solution to the conventional practice of rain fed – cultivation of their landholds. No specific effect was observed in respect to the three personal criteria listed in Table 3.2.3-2. However, the strongest inclination to the application of treated wastewater was observed among the farmers who completed their high school study. To the contrary, the farmers who had a relatively long experience in agriculture tended to respond in a conservative manner, probably because of their long-term tradition with the rain fed agriculture.

Table 3.2.3-2 Effect of Educational Level, Farming Experience and Land Ownership on Farmer's Opinion toward the Reuse of Treated Wastewater for Irrigation in Cultivated-cultivated Highland

Parameter	Accepting	Not Accepting
Education Level:		
High School	14	4
Elementary School	10	4
Farming Experience:		
Long (more than 10 years)	16	11
Short (less than 5 years)	9	0
Land Ownership:		
Landlord	27	12
Tenant	1	0

3.2.3.3 Application of Stabilized Sludge in the Jordan Valley

Application of stabilized sludge as organic fertilizer or soil conditioner is an attractive environmental solution substituting other disposing methods like incineration or landfill. Soils of Jordan are known of having poor organic matter content (usually less than 1 %) and weak structural stability. Therefore, obstacles facing application of stabilized sludge to such poor soils were investigated. The major findings of the study by questionnaires are summarized below:

1. 70 % of the farmers apply three or four types of chemical fertilizers. The majority of the farmers (86 %) classified their expenditure on the chemical fertilizers as "moderate" relative to the other items of the agricultural expenses. However, low percentage of the farmers used to apply excessive amount of farm manure (organic fertilizer).

2. Relatively poor awareness of the role of organic matter as a soil conditioner and as a source of nutrient was found. Only 31 % of the farmers had some ideas about stabilized sludge. Unfortunately, the ideas of most of these farmers were negative but not stemming from religious consideration like "Najasa". Because of that, about half of these farmers (43 %) were adamant to their rejection. Another 49 % of the farmers inclined to change their negative attitude, if they will be given certain "legal coverage" (by governmental regulations) to their practice. Finally, dry and ground was the most preferred form of stabilized sludge to the farmers who agreed on its application to their lands.

3. The distorted image of stabilized sludge in the minds of the farmers can be attributed, at least in part, to the poor extension services. Here, 61 % of the farmers classified such services as "poor" in comparison to 24 % who considered the services as "excellent and adequate".

In this context, farmers with considerable education (high school graduates) were more flexible than those of elementary education (Table 3.2.3-3) in conditionally accepting the application of stabilized sludge, if the government permits its application. Farming experience and land ownership had no apparent effect on the farmer's attitude toward the application of stabilized sludge.

Table 3.2.3-3 Effect of Educational Level, Farming Experience and Land Ownership on Farmer's Opinion toward the Utilization of Stabilized Sludge in North Jordan Valley

Parameter	Uncond. "Yes"	Cond. "Yes"	Absolutely "No"	"May be"
Education Level:				
High School	0	15	5	1
Elementary School	3	5	11	0
Farming Experience:				
Long (more than 10 years)	2	15	17	0
Short (less than 5 years)	0	3	2	1
Land Ownership:				
Landlord	2	10	7	0
Tenant	0	13	9	1

3.2.3.4 Application of Stabilized Sludge to Rain Fed Farms of the Highland

1. Table 3.2.3-4 shows only half of the farmers (49 %) used to add chemical fertilizers to their lands mainly in the form of nitrogen (N) like urea. This is mainly due to the fact that total rainfall and rainfall distribution and not soil fertility status are the major factors limiting crop yield. Although the application rates of chemical fertilizers to the cultivated-cultivated soils remained much lower than the rates employed in the irrigation agriculture (Jordan Valley), 44 % of the highland farmers classified the cost of these fertilizers as "high" contrary to their colleagues in the Jordan Valley. This, again, was probably due to dependence of such areas on amount and distribution of rainfall, which control soil response to fertilizer application and make the whole agricultural process

rather precarious and less profitable one. On the other hand, 66 % of the farmers apply farm manure to their lands but at rates much lower than in the Jordan Valley, most likely because of the former reason.

2. As their colleagues in the Jordan Valley, the majority of the highland farmers (80 %) were not familiar with the stabilized sludge. Only 17 % knew something about stabilized sludge (responded by "yes" to the question if they had a previous idea about stabilized sludge) but they held negative opinion about it. Among those who agreed on replacing farm manure by stabilized sludge, 54 % sought legal cover before deciding to apply the product to their lands. This figure was similar to the corresponding response (49 %) of the Jordan Valley farmers. Similar to the response of their colleagues in the Jordan Valley, dry and ground was the most preferred form of stabilized sludge to the highland farmers.

3. More strikingly, the percentages of the farmers who classified the extension services as "poor" and 'excellent and adequate" (63 and 27 %, respectively) were almost identical to those belonged to the Jordan Valley farmers.

Because of the traditional characteristics of the rain fed agriculture, there was no specific effect of educational or agricultural experience on the decision taken by those farmers. In general, the farmers tended to respond in a flexible manner to the possibility of applying stabilized sludge to their lands (by virtue of giving conditional acceptance subject to certain endorsement by the government). Only farmers with long agricultural experience (most likely old farmers too) were more negative in their response to that issue.

Table 3.2.3-4 Effect of Educational Level, Farming Experience and Land Ownership on Farmer's Opinion toward the Utilization of Stabilized Sludge in Cultivated-cultivated Highland

Parameter	Uncond. "Yes"	Cond. "Yes"	Absolutely "No"	"May be"
Education Level:				
High School	1	13	3	1
Elementary School	1	8	4	0
Farming Experience:				
Long (more than 10 years)	2	12	10	2
Short (less than 5 years)	0	6	1	1
Land Ownership:				
Landlord	1	22	12	3
Tenant	1	0	0	0

3.2.3.5 Summarizing Remarks

It can be summarized that about two third of the interviewed farmers would accept the reuse of treated wastewater for agricultural irrigation.

With respect to the utilization of stabilized sludge on agricultural land more hesitation of the farmers was found. This is in particular due to missing knowledge and awareness on its advantages. In this context it has also to be mentioned that the Jordan Standard JS 1145/1996 concerning the utilization of treated sludge came in force 1996, while the above-mentioned study was carried out in 1995. Therefore, meanwhile the missing "legal coverage" is given and related negative attitude of the farmers is not longer valid.

3.3 Recommendations for Improvement of Existing Wastewater Treatment and Disposal

3.3.1 Wastewater Treatment

The following statements are based on the observations made during the site visits to the treatment plants made in March 2000 as outlined in section 3.1. More detailed information of treatment plants is presented in Annex 3.1.1.

3.3.1.1 General

Non-operational treatment facilities should be repaired as soon as for two main reasons, i.e. to improve the treatment efficiency and to avoid further harm to the existing facilities. For example the trickling filters in Irbid Central Treatment Plant needs urgent repair to reach required treatment efficiency to fulfill the requirements set in the Jordanian Standard JS893/1995 for wastewater effluents.

Obviously, the *coverage (connection rate to the collection network) may be increased* by the construction of new house connections within the existing sewered areas to optimize the use of the existing collection network. Potential of increase seems possible in particular in that towns, where at the same time the sewer lengths per connected capita is high and coverage rates are low. This is in particular in the towns of Fuhis, Mafraq and Tafielah. For these towns (but also for the others) it should be studied whether and how the more houses may be connected to the already existing sewer network. It has to be mentioned that the degree of use (hydraulic) of the treatment plants of Fuhis and Mafraq are rather low 42 and 53 % respectively. Therefore, it is supposed to increase wastewater quantity collected, treated and finally available for reuse without major investments.

Presently, not the total effluent of treatment plants is reused for agricultural irrigation. A certain quantity is still discharged unused to the receiving water (wadis). In addition, the *local reuse of effluent should be improved and maximized* to avoid additional losses of effluent along the flow in the watercourses. Proposals will be made in section 3.4.2..

There are several treatment plants operating close or above their design capacity. Adequate measures are undertaken for all of these plants except of the *extension of overloaded plant of Ma'an*. Due to the fact that Ma'an Treatment Plant operates hydraulically at 10 % more than its design capacity, this plant calls for urgent upgrading/expansion.

3.3.1.2 Institutional

According to the policies and strategies as presented in Annex 3.1 the reuse of wastewater for irrigation purposes is one of the declared political objective. However, until now there is no clear attribution of the responsibility for implementation and operation of wastewater reuse facilities. Usually, the reuse facilities including irrigational infrastructure (if any) were implemented as part of the wastewater project under the responsibility of the Ministry of Water and Irrigation. On the other hand the Ministry of Agriculture is responsible for agricultural irrigation and irrigation water quality. It carries out research projects in field of wastewater reuse and its effect on crops. So, *existing overlapping and/or vacant responsibilities* in matter of wastewater reuse for irrigational purposes should be cleared away.

3.3.1.3 Design

All sewerage systems are designed as separate systems. Nevertheless, a certain quantity of stormwater (e.g. through uncovered manholes or wrong connections) penetrates into the sewage collection network. Therefore, every sewerage system should dispose of a *stormwater overflow structure* to divert the discharge exceeding the hydraulic capacity of the treatment plant. Several systems have not even one overflow.

The degree of use of a treatment plant should be between 50 and 100 %. For example the plant of Jerash is used by less than 50 % even the extended plant is in operation since 1990. In this case efforts should be undertaken to *increase the connection rate* of the houses to the sewerage network.

Adequate design criteria should be established for every project based on general experience. For example the depth of 5 m for a maturation pond (e.g. Jerash) is not adequate, if the pond shall serve for tertiary treatment.

The efficiency of several primary or secondary settling tanks is not satisfactory, because only a portion of the related overflow weirs is charged. *Vertically adjustable overflow weirs* would allow easily solving the problem. Triangular openings of fixed weirs have to be deepened to reach a regular charge of the settling tank (e.g. Jerash).

In case of wastewater stabilization ponds an overflow weir to stabilize the water level in the upstream pond should control the discharge from one pond to the next. Some of the pond systems dispose only of connection pipes close to the bottom, which allows a to broad range of water levels leading to miss-manipulations (e.g. Ramtha).

Ponds have to be designed in a manner that *dead zones of the water surface* are avoided. This criterion is important for the design of the pond's form and arrangement of the inlet and outlet structures (e.g. Jerash).

The recently prepared studies on wastewater treatment recommend all *sand filtration as tertiary treatment* in order to improve effluent's quality for agricultural reuse. Granular media filtration involves the passage of water through a bed of filter media with resulting deposition of solids. Eventually, the pressure drop across the bed becomes excessive or the ability of the bed to remove suspended solids is impaired. Cleaning is then necessary to restore operating head and effluent quality. The time in service between cleanings is termed the run length. Filter run lengths are between 8 and 48 hours. The head loss at which filtration is interrupted for cleaning is called the terminal head loss (about 1.8 to 4.5 m) and this is maximized by the judicious choice of media sizes.

Gravity filters operate either using the available head from the previous treatment unit, or by pumping to a split box after which the wastewater flows by gravity to the filter cells. Pressure filters utilize pumping to increase the available head. Normally filter systems include multiple filter compartments. This allows for the filtration system to continue operating while one compartment is being backwashed.

A filter unit generally consists of a containing vessel, the filter media, structures to support the media, distribution and collection devices for influent, effluent and backwash water flows, supplemental cleaning devices and necessary controls for flows, water levels and backwash sequencing. Backwash sequences can include air scour or surface wash steps. Backwash water can be stored separately or in chambers that are integral parts of the filter unit. Backwash water can be pumped through the unit or can be supplied through gravity head tanks.

Generally, filtration is applied to remove residual biological flocs in settled effluents from secondary treatment and removal of residual chemical-biological flocs after alum, iron or lime precipitation in tertiary or independent physical-chemical wastewater treatment. Efficiency of filtration is highly dependent on consistent pretreatment quality and flow modulations. Increasing solids loading will reduce run lengths.

As can be concluded from the facts outlined above sand filtration is a cost intensive, susceptible technology requiring qualified staff in comparison with polishing by maturation ponds as tertiary treatment step. In Jordan, where tertiary treatment is applied to improve effluent quality for reuse in agricultural irrigation, the following reasons do not favor the application of sand filtration:

1. Filter head loss may need pumping upstream or downstream of the filters.
2. Filter cleaning equipment (air blower and pumps for backwash water) requires energy
3. Initial investment and reinvestment cost (for electromechanical equipment) are high.
4. Operation and maintenance of filters is costly due to requirements of energy, spare parts for electromechanical equipment, additional staff etc..
5. Operation and maintenance of filters requires well trained staff
6. Growth of algae at surface of the filters could lead to difficulties for filter operation.
7. Filtration will reduce the content of suspended solids to 5 – 20 mg /l. However, elimination of microbiological pollutants (fecal coliform counts) will be limited and will be not enough to reach 1,000 fecal coliforms per 100 ml as required for unrestricted irrigation.
8. Backwash water (about 5 – 10 % of the through put) has to be either returned to the head of the plant increasing the hydraulic load accordingly or discharged in the receiving water leading to a loss of water for reuse.

Taking into account the presented specific conditions, water polishing by maturation ponds seems the preferable solution for tertiary wastewater treatment instead of sand filtration. However, if the Ministry of Water and Irrigation or the water Authority of Jordan insists to use sand filtration, it is recommended to apply at one treatment plant sand filtration (as pilot project) and gain some practical experience with the operation of sand filtration units rather than to implement such facilities in every new treatment plant.

3.3.1.4 Operation

Every type of treatment plant has a *specific mode of operation*. To each treatment plant belongs a manual, where the mode of operation is described. For example the staff of Tafielah and Ma'an reported that the treatment plant does not dispose of a comprehensive operation and maintenance manual for the treatment plant. However, about ten copies of the manual for Tafielah and Ma'an were found in the library of the Ministry (Volume 1 and 2 of each prepared by Arabtech Consultants in 1989). The specified instruction has to be followed. This is in particular true e.g. for the plants in Ramtha and Mafraq. At these plants the ponds are more or less operated as holding tanks.

In general, all inlets and outlets of ponds have to be used in order to get a regular charge of the entire water surface i.e. to *avoid dead zones of ponds*, which reduce their efficiency (e.g. Karak).

As it is outlined in detail in section 3.1.5.3 most of the *treatment plants are overstaffed*. According to Table 3.1.4-2 the share of staff cost for wastewater treatment amounts to some 40 % of the total cost for operation and maintenance. If the staff members would be reduced as indicated in Table 3.1.5-4 the cost for operation and maintenance could be reduced by 20 %.

3.3.2 Sludge Treatment

3.3.2.1 General Recommendations

The given possibilities for *reuse of treated sludge for agricultural purpose* taking into account the related Jordanian Standard JS 1145/96 should be used. As outlined in Section 3.2.2 sludge should be dried by in drying beds (treatment level 1). After such treatment sludge may be used as a conditioner for improving the Badia soil characteristics (Badia = desert region of Jordan).

An *institution for control of sludge reuse for agricultural purposes* has to be created or nominated. This institution shall supervise the application of treated sludge as set forth in the Jordanian Standard JS 1145/96. According to the text of this standard the use of treated sludge for agricultural purposes is controlled by related "official organizations". However, such organizations are not specified in the standard.

3.3.2.2 Specific Proposals for Existing Facilities

Construction of adequate facilities, where not available, has to be provided. This is particularly true for the sludge treatment facilities, which is in most of the treatment plants the weakest part. Sufficient drying beds (if no other sludge treatment process is foreseen) have to be provided for every plant following the existing standards in force. It is evident that the *capacity of the sludge drying beds* is in most of the treatment plants too small. According to the Jordanian Standard JS 1145/1996 at least 3 months are required for sludge drying and exposure to ultraviolet sunlight (supposed that daily temperature is more than 0°C for 2 months out of these 3 months).

As already said for the wastewater treatment facilities existing but presently *non-operational facilities shall be repaired*. For example the anaerobic digester in Irbid Central is out of operation. Sludge digestion and drying using the available drying beds would allow safe sludge treatment and either disposal at the dumping ground Al Akeder or reuse at agricultural land. In any case disposal of liquid, non-stabilized sludge (as it is practiced at present) is worst option and contents high risks for serious environmental pollution as the accident in Al Akeder has shown in May 2000.

The *use of existing sludge treatment facilities* is by far not optimal. In Fuhis and Irbid Central are sludge drying beds available, which are not used at its full capacity. Therefore, e.g. for Irbid the share of cost for sludge disposal is 12 % of the total cost for operation and maintenance (compare Table 3.1.4-2). A simple calculation shows that the transport cost may be reduced to one tenth, if the sludge is dewatered by drying beds from 5 % dry solid content to 50 %.

The presently applied *sludge disposal of the treatment plants of Abu Nuseir, Baqa, Fuhis and Salt* is not acceptable: Liquid sludge of these treatment plants is transported by tankers to Ain Ghazal and discharged into the wastewater flow from Amman to As Samra Treatment Plant. It means that the already eliminated pollutional load of these treatment plants is again mixed with the raw sewage of Amman. Again this sludge disposal practice result in tremendous cost: E.g. for Salt Treatment Plant the cost for sludge disposal has a share of 10 % operation and maintenance cost, while these percentage amounts even to 17 % for Baqa.

3.3.2.3 Improved Systems for Sludge Treatment

The majority of the treatment plant's operators complain about the insufficient sludge drying due to insufficient surface of drying beds and due to rainfall in winter time. Certainly, the *efficiency of sludge drying beds may be improved* by a modification of the design of the sludge drying beds.

1) Solar sludge drying

Solar sewage sludge drying has further developed the idea of the former simple sludge drying beds: In simple lightweight construction shelters (covered by transparent foil or glass) the evaporation rate can be increased significantly with solar energy alone. Such shelters have the following particular advantages:

- The rainwater is kept away from the drying beds.
- The evaporation rate will be significantly increased by the greenhouse effect of the shelters.
- The sludge could be turned regularly to bring the capillary tied water to the dry air and to improve, therefore, the evaporation rate.

Several plants in Germany applying this technique have shown reasonable results. It is reported that values of up to 90 % dry mass were received. It is recommended to start a pilot project on solar sludge drying using such shelters in one of the existing treatment plants.

2) Sludge reed beds

Research has been carried out about the treatment of sludge on beds planted with *phragmites* (reed plants). The root systems take up the water in the sludge as well as providing a drainage path for free water to escape more readily to under drains. It has been reported that dewatering occurs rather more rapidly than with conventional sludge beds, evapotranspiration being partly responsible for this improvement. The reeds continue to grow through the sludge layer as it builds up. Reed plants favor the aeration, the materialization and the production of the sludge. The resulting humus-like material can be dug out after several years and used as a soil conditioner.

The operation is similar to a sludge drying bed except that the sludge can be applied intermittently to the bed without the need to remove the sludge cake. Reed beds have to be provided with an impermeable layer and a drainage system comparable to the one required for conventional drying beds. Examples of sludge reed beds are found in Europe and North America

3.3.3 Wastewater Sector

In addition to the more technical recommendations the following recommendations concern the wastewater sector, i.e. sewage collection, treatment and reuse (with regard to WB, 1997 also):

1. Responsibilities for implementation and operation of wastewater reuse schemes (in particular, as far as local reuse close to the related treatment plant is concerned) have to be clearly attributed to one authority (see Section 3.3.1.2 also).
2. Disposal of sludge from wastewater treatment plants on solid waste disposal sites or in ponds close to these sites (in particular if they are not lined) is not a proper method. Sludge reuse in agriculture should be promoted.
3. Environmentally-safe reuse of
   - treated wastewater and
   - treated sludge

   from treatment plants should be actively promoted by a research and extension effort coordinated between WAJ, JVA and the Ministry of Agriculture, working with farmers' groups.

4. A wastewater treatment and reuse management strategy has to be formulated to guide a more commercial approach to the use of reclaimed water for irrigation and other purposes.
5. The proposed wastewater strategy shall be developed with full consideration of the environmental impacts of wastewater, and provide for expansion of the sewerage system where this can be economically and financially justified, taking into account the benefits of reuse and environmental improvement (see Section 3.3.1.1 also).
6. A strategic plan and priority investments be developed for the reclamation and reuse of wastewater.
7. Industries shall be actively encouraged by WAJ to pre-treat their wastewater respecting related effluent standards in force. Common treatment facilities shall be considered for groupings of small industries. These measures are not only important for the protection of workers and process stability of the communal treatment plants, but also to avoid that hazardous substances in the sludge will exclude its reuse in the agricultural.
8. Capacity and efficiency of wastewater treatment plants, especially Al-Samra, should be augmented to meet projected wastewater quantities of adequate quality for agricultural and/or industrial reuse.

3.4 Future Development

3.4.1 Planned Development of Wastewater Treatment

3.4.1.1 Existing and Proposed Treatment Plants

Various studies were prepared on behalf of the Ministry for Water and Irrigation and WAJ dealing with the expansion/rehabilitation of existing treatment plants and the construction of new ones (see Table 3.4.1-1, nos. 1 – 35). A further study was prepared on behalf of the Jordan Valley Authority for a tourist development project at the east coast of the Dead Sea. This project includes required infrastructure for wastewater collection, treatment and reuse (see Table 3.4.1-1, no. 36). Figure 3.4.1-1 shows the location of the existing and proposed treatment plants.

Table 3.4.1-1 summaries future wastewater treatment capacity in Jordan: At present for 9 of the 17 existing treatment plants specific planning work for rehabilitation, upgrading and expansion is under preparation. The plants of Wadi Hassan and Wadi Mousa will be completed early 2001. In addition the construction of 17 new plants is proposed during a period of 10 to 12 years. After completion of all planned measures the total number of treatment plants will increase to 36. In several of the newly planned treatment plants sand filtration is proposed as tertiary treatment instead of maturation ponds.

According to Table 3.4.1-1 installed treatment capacity of existing treatment pants (including the plants under construction) after completion of all upgrading and expansion measures will be increased to some 394,000 m^3/d, while this capacity of additional planned plants will be about 262,000 m^3/d leading to a total capacity of about 656,000 m^3/d.

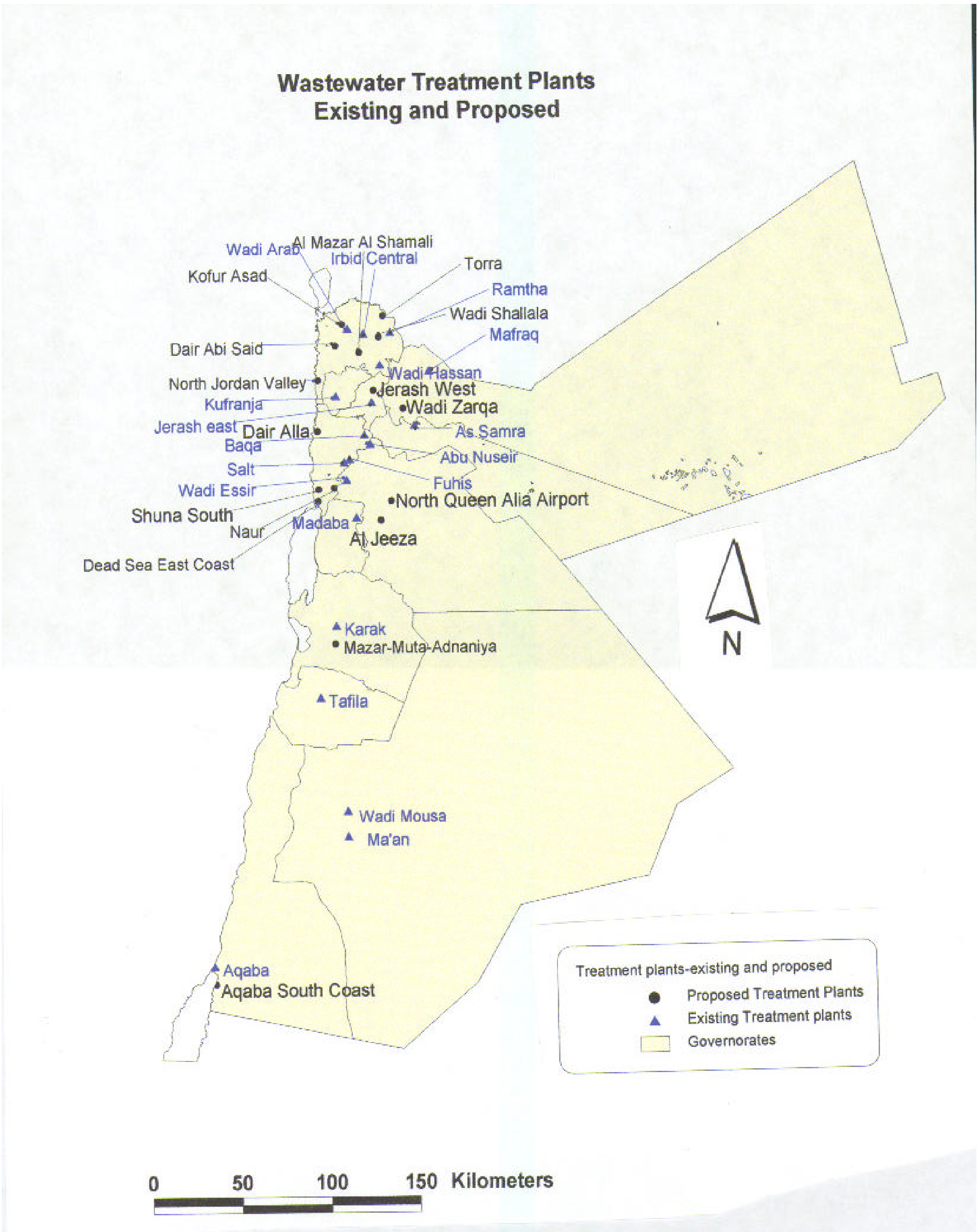


Figure 3.4.1-1 Location of Existing and Proposed Treatment Plants

Table 3.4.1-1 Existing and Planned Treatment Plants (status October 2000)

	Treatment Plant	Governorate	Future type treatment 1)	Status of planning (October 2000)	Planned year of completion next phase 3)	Existing/planned plant's capacity (m³/d)	Required plant's capacity in 2020 (m³/d) 2)
	Existing						
1	Abu Nuseir	Amman	AS+RBC	No particular planning	-	4.000	4.200
2	Aqaba	Aqaba	EA+MP	Final design in 2000	2003	24.000	43.000
3	As-Samra	Amman	AS	Tendering for BOT in 2000	2005	268.000	340.000
4	Baqa	Balqa	TF + MP	Upgrading/rehabilitation	2000	15.000	15.000
5	Fuhis	Balqa	EA + MP	No particular planning	-	2.400	3.300
6	Irbid (Central)	Irbid	TF + AS	No particular planning	-	11.000	12.000
7	Jerash (East)	Jerash	EA + MP	No particular planning	-	3.500	8.500
8	Karak	Karak	TF + MP	Feasibility study in 2001	2004	2.700	4.300
9	Kufranja	Ajlun	TF + MP	Feasibility study in 2001	2004	5.800	9.900
10	Ma'an	Ma'an	WSP	No particular planning	2005	2.000	5.100
11	Madaba	Madaba	EA + MP	Construction tendered 2000	2003	7.600	11.600
12	Mafraq	Mafraq	EA + MP	Feasibility study in 2000	2003	3.500	4.500
13	Ramtha	Irbid	EA + MP	Construction tendered 2000	2003	5.400	9.000
14	Salt	Balqa	EA + MP	No particular planning	-	7.700	11.700
15	Tafielah	Tafielah	TF + MP	No particular planning	-	1.600	3.500
16	Wadi Arab	Irbid	EA	No particular planning	-	21.000	35.800
17	Wadi Essir	Amman	AP	No particular planning	-	4.000	2.500
	Subtotal 1					***389.200***	***523.900***
	Under construction						
18	Wadi Hassan	Irbid	EA + MP	Start of operation in 2001	2001	1.600	2.500
19	Wadi Mousa	Ma'an	EA + MP	Start of operation in 2001	2001	3.400	4.800
	Subtotal 2					***5.000***	***7.300***
	Planned						
20	Al Jeeza	Amman	EA + MP	Final design in 1995	2005	7.200	8.800
21	Al Mazar Al Shamali	Irbid	EA + SF	Prefeasibility study in 1998	2010	4.500	4.500
22	Dair Abi Said	Irbid	EA + SF	Prefeasibility study in 1998	2013	4.900	4.900
23	Dair Alla	Balqa	EA + SF	Prefeasibility study in 1998	2005	8.900	10.400
24	Jerash West	Jerash	EA + SF	Prefeasibility study in 1998	2008	7.200	7.200
25	Kofur Asad	Irbid	EA + SF	Prefeasibility study in 1998	2007	11.900	11.900
26	Aqaba South Coast	Aqaba	EA + SF	Final design in 2000	2003	1.000	1.600
27	Naur	Amman	EA + MP	Feasibility study in 1995	2008	5.200	5.200
28	North Queen Alia Airport	Amman	EA + MP	Final design in 1995	2005	23.000	28.500
29	North Jordan Valley	Irbid	EA + SF	Final design in 2000	2003	8.000	9.400
30	Shuna South	Balqa	EA + SF	Prefeasibility study in 1998	2004	5.600	6.500
31	Torra	Irbid	EA + SF	Prefeasibility study in 1998	2012	5.600	5.600
32	Um Al Basateen	Amman	EA + MP	Final design 1995 (Al Jeeza)	2005	incl.Al Jeeza	incl.Al Jeeza
33	Wadi Shallala (Irbid East)	Irbid	EA + SF	Feasibility study in 1998	2005	15.000	18.000
34	Wadi Zarqa	Zarqa	AS	Feasibility study in 1997	2009	146.000	183.000
35	Mazar, Muta, Adnaniya	Karak	WSP	Feasib. study not available	2009	3.500	3.500
36	Dead Sea East Coast	Balqa	EA + MP	Prefeasibility study 1997	2005	4.350	8.470
	Subtotal 3					***261.850***	***317.470***
	TOTAL					**656.050**	**848.670**

1) WSP Wastewater stabilization ponds RBC Rotating biol. contactor EA Extended aeration
MP Maturation ponds (tertiary treatment) AP Aerated ponds SF Sand filtration (tert.treatm)
2) Acc. to Consultant's Study Report
3) For existing treatment plants: Rehabilitation, upgrading and extension measures.

3.4.1.2 Future Wastewater Quantity According to Consultants' Studies (Scenario 0)

Annex 3.4.1 contains a description of proposed measures for wastewater collection, treatment and disposal for all existing and planned systems including a schematic layout of the sewerage systems and the treatment plant. Future population (connected and non-connected to the sewerage system) in each project town is projected up to 2020. Population growth rates and per capita water consumption were considered as assumed by the Consultants having prepared the related study.

Estimations of wastewater collected have taken into account connection rates to the sewer network, losses of/inflow in the sewerage system and return flow factor following the Consultants' assumptions. However, quantities of collected wastewater for the year 2000 were adjusted to the actual wastewater flows to the treatment plants as measured in 1999 taking into consideration a slight increase between 1999 and 2000. Effluent quantities of the plants were estimated based on inflow and on a reduction caused by losses due to evaporation and/or infiltration in the underground within the treatment plants. Loss percentages were considered as presented in Section 3.1.2.

Annex 3.4.2 contains tables presenting the future development on the wastewater sector. Table 1(0) of Annex 3.4.2 presents in detail the population living within the service areas as well as the connected population between 2000 and 2020. Table 2(0) shows the wastewater inflow and effluent of the existing and planned treatment plants, while Table 3(0) gives an overview on produced wastewater quantities in the 12 Governorates of Jordan.

Based on the existing studies and reports on the planning of related sewerage systems as prepared by the various Consultants (see Table 3.4.1-1), development of connected population and wastewater quantities were estimated up to the target year (of the present study) 2020. Table 3.4.1-2 shows the overall development of total population living in the service area, connected population, total wastewater inflow and effluent of the treatment plants taking into account the assumptions as presented in the previous paragraph.

Table 3.4.1-2 Future Development of Wastewater Treatment
(Scenario 0 "Consultants' Study")

	Unit	2000	2005	2010	2015	2020
Total population of Jordan 1)	mio. inh	5.07	5.94	6.92	7.99	9.12
Total population (living in service area)	mio. inh	3.74	4.53	5.51	6.64	7.95
Connected population	mio. inh	2.51	3.79	5.10	6.28	7.56
Connected pop.related tot.Jord.population	%	49	64	74	79	83
Wastewater inflow to treatment plants	MCM/a	82	147	198	253	314
Wastewater effluent of treatment plants	MCM/a	64	138	186	237	295

1) Taking into account global growth rates acc. to World Bank 2000

3.4.1.3 Future Wastewater Quantity According to Various Other Scenarios

Three other scenarios were developed to estimate the future water demand for the various purposes, i.e. municipal, industrial and tourist purposes. For details of the assumed conditions and parameters it is referred to the related volume of the Study.

As far as the wastewater collection and treatment is concerned, future development is generally based on the Consultants' studies available for each sewerage system and wastewater treatment plant except of the water demand estimations. Losses of/inflow in the sewerage system, coverage rates and return factors were taken over from the Consultants' studies. Evaporation and/or infiltration losses within the treatment plants were assumed as presented in Section 3.1.2.

Collected wastewater (inflow to the treatment plants) for the year 2000 was adjusted to a certain extend using the flows to the treatment plants as metered in 1999 applying a certain allowance for increase between 1999 and 2000.

(1) Scenario 1

Scenario 1 follows the MOWI/World Bank assumptions with respect to population growth rates and specific water demands (both countrywide constant) as considered for the projections carried out in 2000. The following figures comprise municipal and tourist demand:

	Unit	2000	2005	2010	2015	2020
Growth rates	%	3.59	3.21	3.1	2.9	2.7
Specific water demand (freshwater)	l/c/d	103	104	129	136	133

Future development of total, connected and non-connected population as well as wastewater quantities are summarized in Table 3.4.1-3 with respect to the assumptions as outlined above. Detailed calculation is given in Tables 5(1) to 7(1) of Annex 3.4.2.

In comparison to the results according to the Consultant's Studies (Scenario 0) the present Scenario 1 shows lower figures for the connected population. Wastewater inflow and effluent of the treatment plants for 2020 would be about 25 % lower in case of Scenario 1.

Table 3.4.1-3Future Development of Wastewater Treatment (Scenario 1)

	Unit	2000	2005	2010	2015	2020
Total population of Jordan	mio. Inh	5.07	5.94	6.92	7.99	9.12
Total population (living in service area)	mio. Inh	3.73	4.38	5.07	5.85	6.68
Connected population	mio. Inh	2.47	3.63	4.65	5.49	6.29
Connected pop.related tot.Jord.population	%	49	61	67	69	69
Wastewater inflow to treatment plants	MCM/a	82	116	189	222	249
Wastewater effluent of treatment plants	MCM/a	64	108	177	208	233

(2) Scenario 2

For Scenario 2 the same growth rates as in Scenario 1 (MOWI/World Bank assumptions) were considered, while specific water demand (municipal and tourist demand) figures are increased for 2015 and 2020 (growth rate and specific demand is considered as countrywide constant):

	Unit	2000	2005	2010	2015	2020
Growth rates	%	3.59	3.21	3.1	2.9	2.7
Specific water demand (freshwater)	l/c/d	103	104	129	150	155

Table 3.4.1-4 presents the future development of connected and non-connected population and quantities of inflow of raw sewage to the treatment plants as well as of the treated effluent. For details it is referred to Tables 9(2) to 11(2) of Annex 3.4.2.

Due to increased specific water demands the wastewater inflow and effluent of treatment plants will be higher than in case of Scenario 2. Related quantities are about 22 % higher than in Scenario 1.

Table 3.4.1-4Future Development of Wastewater Treatment (Scenario 2)

	Unit	2000	2005	2010	2015	2020
Total population of Jordan	mio. inh	5.07	5.94	6.92	7.99	9.12
Total population (living in service area)	mio. inh	3.73	4.38	5.07	5.85	6.68
Connected population	mio. inh	2.47	3.63	4.65	5.49	6.29
Connected pop.related tot.Jord.population	%	49	61	67	69	69
Wastewater inflow to treatment plants	MCM/a	82	116	188	247	304
Wastewater effluent of treatment plants	MCM/a	64	108	177	232	285

(3) Scenario 3

Scenario 3 takes into account the growth rates as proposed by the Department of Statistics (DOS). Specific water demand figures (municipal and tourist demand) were kept as assumed in Scenario 2. Growth rates and specific demand is considered as countrywide constant:

	Unit	2000	2005	2010	2015	2020
Growth rates	%	3.4	2.52	2.5	2.3	2.0
Specific water demand (freshwater)	l/c/d	103	104	129	150	155

Table 3.4.1-5 summarizes the projection of total, connected and non-connected population as well as wastewater quantities taking into account above mentioned assumptions (for details see Tables 13(3) to 15(3) of Annex 3.4.2).

Because of lower growth rates in Scenario 3 consequently connected population and sewage flows (inflow and effluent) are lower as estimated for Scenario 2. Nevertheless, resulting figures of Scenario 3 are still higher than in case of Scenario 1. The difference (sewage flows) to Scenario 1 is in the order of 5 % for the year 2020.

Table 3.4.1-5Future Development of Wastewater Treatment (Scenario 3)

	Unit	2000	2005	2010	2015	2020
Total population of Jordan	mio. inh	5.02	5.69	6.44	7.21	7.97
Total population (living in service area)	mio. inh	3.69	4.18	4.64	5.20	5.74
Connected population	mio. inh	2.44	3.47	4.26	4.88	5.40
Connected pop.related tot.Jord.population	%	49	61	66	68	68
Wastewater inflow to treatment plants	MCM/a	81	111	173	220	262
Wastewater effluent of treatment plants	MCM/a	63	103	162	207	246

In comparison to the above-presented development of future wastewater quantities Table 3.4.1-6 shows the results of the projection prepared by World Bank in 1997, GTZ/JCE in 1995 and GTZ/CES in 1996.

It seems that the results of Scenarios 1 and 3 are comparable to those produced by GTZ/JCE/CES in 1995 and 1996, while quantities of wastewater effluent following the assumptions of Scenarios 0 and 2 are generally higher as the one estimated by GTZ/JCE/CES.

Table 3.4.1-6 Comparison of Various Projections of Wastewater Effluent (in MCM/a)

Reference	1994/95	2000	2005	2010	2015	2020	2040
World Bank 1997	58	87	114	141	170	200	
GTZ, JCE et al. 1995 1)	76	90	110	150	165	220	540
GTZ/CES 1996 2)	52	71		181			658

1) According to "Low Scenario"
2) According to "Sustainable Scenario"

3.4.2 Future Reuse of Treated Wastewater

3.4.2.1 General

The following sections deal with the spatial availability of the treated effluent of the treatment plants. They aim at the question to which extend the present freshwater used for irrigation at different locations in Jordan may be substituted by treated wastewater as stated in the strategy papers of the Jordanian Government. Generally it has to be said that from the technical and economical point of view in particular for small treatment plants it is not advisable to conduct the small effluent quantities to existing irrigation schemes located far from the plant's site. Investment and operation costs would be too high. In addition losses due to evaporation and infiltration would be high, if the effluent is transferred in wadis by open flow.

In 2000 World Bank estimated total requirement (demand) for agricultural irrigation as follows:

Target year	Upland	Jordan Valley	Total
2005	371	454	825
2010	371	509	880
2015	371	502	873
2020	371	496	867

3.4.2.2 Proposed Reuse Schemes

Proposed measures of wastewater reuse for each existing and proposed treatment plant are summarized in Annex 3.4.1. It contains also a schematic layout of the potential reuse areas including treatment plant site, if a local reuse (in the vicinity of the plant) is proposed.

Generally, large-scale effluent storage is not recommended in a first planning period in addition to the presently existing (such as e.g. King Talal Reservoir) due to following reasons:

1. Existing storage facilities will serve to store the effluent of high capacity treatment plants also in future (e.g. effluents of As Samra Treatment Plant in King Talal Reservoir).
2. A continuous low intensity application of water is preferred for the local reuse schemes. The effluent quantity of the treatment plant is more or less continuous with a slight peak during summer time, when irrigation water demand is high.
3. Costs providing large-scale storage facilities are high and would further increase the reuse cost of the treated wastewater. Such storage facilities would absorb a rather high amount of capital, which would not be available for other planned reuse projects.
4. High detention times in reservoirs of massive volumes could favor eutrophication processes and odor problems due to anaerobic processes in the

stored treated water. This again would call for additional wastewater treatment efforts of nutrient removal (phosphorus and nitrogen).

Table 3.4.2-1 summarizes the proposed reuse measures for final target year 2020 and the present status of planning. For some cases existing reuse concept will be kept (e.g. Jerash, Baqa i.e. the discharge of treated effluent via King Talal Dam to the Jordan Valley). Irrigation schemes for the effluents of Irbid and Wadi Arab has to be implemented in the Northern Jordan Valley, while the transmission pipe exists already. The existing reuse schemes of Madaba, Mafraq and Ramtha have to be rehabilitated, improved and/or extended.

The Consultants' studies of the planned new treatment plants contain all an option for reuse of treated wastewater in the agriculture. Related projects were taken into account in the present study and improved or modified, if required.

In most of the new planned treatment plants local reuse systems were selected in particular for the small treatment plants of low effluent quantities. However, most of the effluent quantity will be conducted to irrigation systems more or less far from the treatment plants site due to the fact that the treated wastewater of the big plants (e.g. As Samra, Zarqa, Irbid) is not reused close to the treatment facilities.

3.4.2.3 Effluent Reuse and Substitution of Freshwater for Irrigation

Tables 4(0), 8(1), 12(2) and 16(3) of Annex 3.4.2 show the effluent production (sites of treatment plants) and potential reuse of treated wastewater for the studied scenarios 0, 1, 2 and 3. The following paths of disposal or reuse are considered:

0) Not used (or only partly) used
1) Local reuse for irrigation (close to the treatment plant, in general less than 2 km)
   in the upland and
   in the Jordan Valley
2) Discharge via pipe along Wadi Arab to Jordan Valley
3) Reuse of effluent of As Samra
   in the upland for agricultural purposes and
   for industrial purposes
4) Discharge via King Talal Reservoir to Jordan Valley
5) Discharge via Wadi Kufranja to Jordan Valley
6) Discharge via Shua'ab Reservoir to Jordan Valley
7) Discharge via Kafrein Reservoir to Jordan Valley

Disposal paths mentioned under points 0 and 1 as well as the industrial reuse will not contribute to the substitution of freshwater presently used for irrigation purposes by treated wastewater. In some locations the place of wastewater generation and treatment is not necessarily identical with the place of reuse/disposal (compare points 2 to 7).

Category "local reuse" means that total effluent quantity will be reused close to the treatment plant's site with minor quantities discharged into the natural receiving water. Potential areas for agricultural irrigation will be generally in a distance less than 2 km from the related treatment plant. This form of reuse is practiced e.g. at Madaba, Mafraq and Ramtha presently. At additional sites this form of reuse is proposed, whereby new irrigation schemes including transmission facilities from the plant to the irrigable areas have to be implemented (see section 3.4.2.2). The effluent of all these treatment plants may not contribute to substitution of freshwater presently used for irrigation insofar as these irrigation areas have to be, in general, newly implemented.

According to the "Jordan Water Resource Policy Support" project presently implemented by ARD and financed by USAID it is proposed to reuse a portion of the effluent from the new wastewater treatment plant of As Samra for industrial purpose (in the area of Greater Amman, Zarqa and Russeifa including the existing and new thermal power plant)). This will reduce in the future the effluent quantity discharged to the Jordan Valley via Wadi Zarqa and King Talal Reservoir. Effluent reused in the industrial sector will reduce freshwater presently or in future used to cover industrial water demand. Figure 3.4.2-2 shows the location of reservoirs in the northern part of Jordan.

Following the proposed future reuse schemes as presented in Table 3.4.2-1, related quantities were determined. Principally, "five destinations or disposal paths" of treatment plant's effluent were distinguished:

① **Not (or only partly) used**

This "destination" means that most of the effluent quantities may not be reused, because e.g. appropriate agricultural areas for irrigation are not available in the vicinity of the plant. Only a minor portion of the effluents are reused e.g. within the treatment plant's area. Due to low quantity, big distance to potential reuse areas or required high power cost it is not economic to reuse these quantities. The effluent discharged into the receiving water will infiltrate and evaporate along the flow path and is therefore not available for substitution of freshwater presently used for irrigation.

② **Reuse in Upland/Midland**

－Reuse of effluent of As Samra in the Upland/Midland

Within the frame of the "Jordan Water Resource Policy Support" project it is studied to reuse a portion of the effluent of the new As Samra Treatment Plant for agricultural irrigation purposes in the Upland (northeast of the treatment plant). However, first results show that it is economically not feasible to implement such facilities.

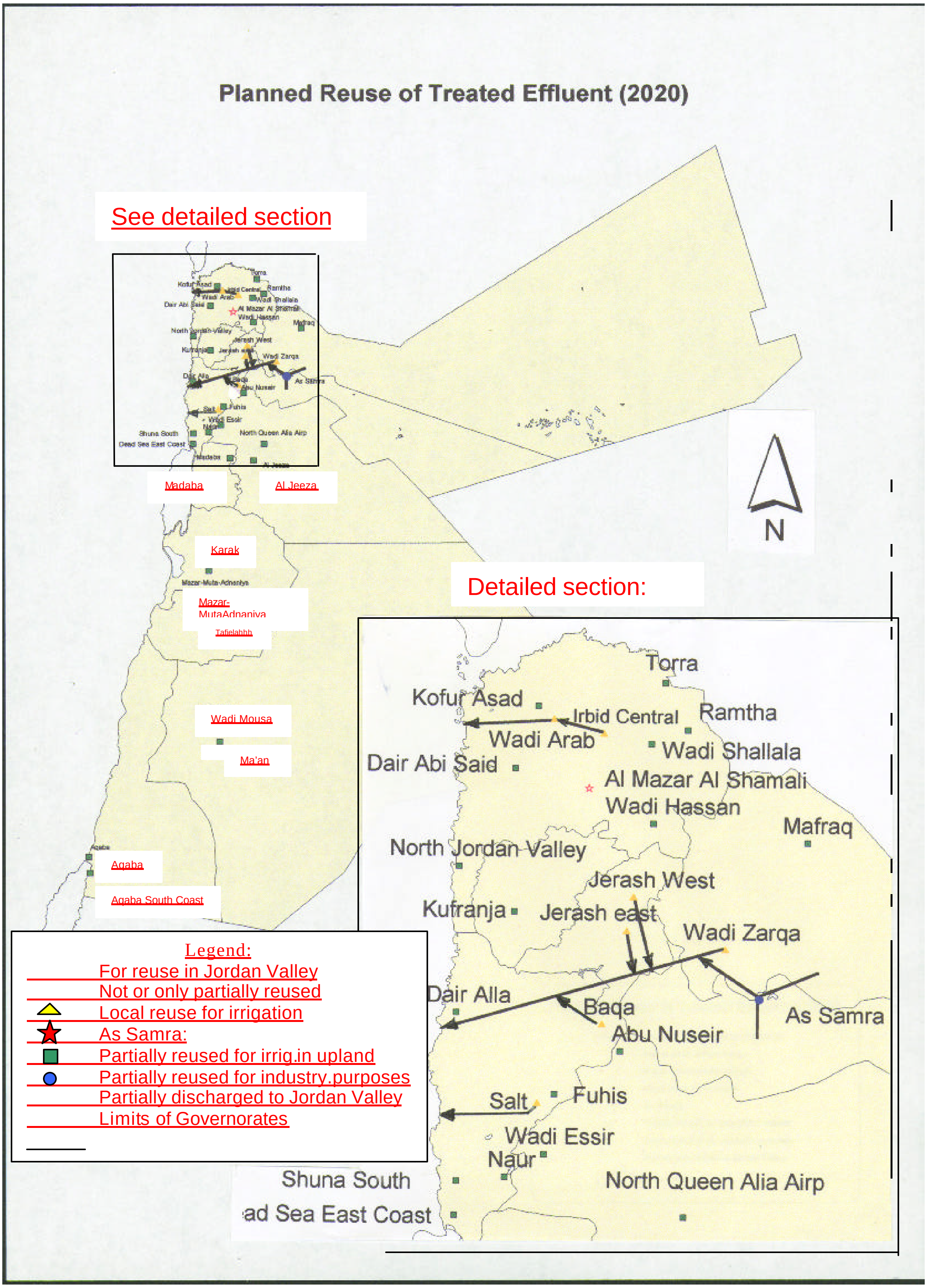
－ Local reuse in the Upland/Midland

It is proposed to reuse locally (in the vicinity of the plant) the effluent of several treatment plants in the uplands/midlands. In addition to the presently existing ones (e.g. at Madaba, Mafraq and Ramtha) additional plants will be provided with reuse facilities.

Table 3.4.2-1 Proposed Future Reuse Schemes (in 2020)

	Treatment Plant	Proposed future reuse scheme Status of planning	(July 2000)
	Existing		
1	Abu Nuseir	Local reuse	Proposal of JICA 2000
2	Aqaba	Local reuse	Proposal Montgom./AJ 2000
3	As-Samra	Industrial (upland) as well as Agricultural (upland and Jor.Valley)	Proposal USAID/ARD 2000
4	Baqa	Jordan Valley via King Talal Reservoir	Existing
5	Fuhis	Local reuse	Proposal GKW/CEC 1994
6	Irbid (Central)	Jordan Valley via pipe along Wadi Arab	Proposal of JICA 2000
7	Jerash (East)	Jordan Valley via King Talal Reservoir	Existing
8	Karak	Local reuse	Proposal of JICA 2000
9	Kufranja	Local reuse	Proposal of JICA 2000
10	Ma'an	Local reuse	Proposal of JICA 2000
11	Madaba	Local reuse	Existing/Proposal JICA 2000 for improv.
12	Mafraq	Local reuse	Existing/Proposal JICA 2000 for improv.
13	Ramtha	Local reuse	Existing/Proposal JICA 2000 for improv.
14	Salt	Jordan Valley via Shua'ab Reservoir	Existing
15	Tafielah	Local reuse	Proposal of JICA 2000
16	Wadi Arab	Jordan Valley via pipe along Wadi Arab	Proposal of JICA 2000
17	Wadi Essir	Local reuse	Proposal of JICA 2000
	Under construction		
18	Wadi Hassan	Local reuse	Proposal of JICA 2000
19	Wadi Mousa	Local reuse	Proposal CDM&ACE 1996/JICA 2000
	Planned		
20	Al Jeeza	Local reuse	Proposal Montgom.1995/JICA 2000
21	Al Mazar Al Shamali	Not or only partly used	Proposal TYPSA 1998
22	Dair Abi Said	Local reuse	Proposal TYPSA 1998/JICA 2000
23	Dair Alla	Local reuse	Proposal TYPSA 1998
24	Jerash West	Jordan Valley via King Talal Reservoir	Proposal TYPSA 1998
25	Kofur Asad	Local reuse	Proposal TYPSA 1998
26	Aqaba South Coast	Local reuse	Proposal Montgom./AJ 2000
27	Naur	Local reuse	Proposal MOTT/CEC 1996
28	North Queen Alia Airport	Local reuse	Proposal Montgom.1995/JICA 2000
29	North Jordan Valley	Local reuse	ProposalMetcalf&Eddy/JICA 2000
30	Shuna South	Local reuse	Proposal TYPSA 1998
31	Torra	Local reuse	Proposal CDM 1996
32	Um Al Basateen	Included in Al Jeeza	Proposal Montgom./AJ 1995
33	Wadi Shallala (Irbid East)	Local reuse	Proposal DAR 1998/JICA 2000
34	Wadi Zarqa	Jordan Valley via King Talal Reservoir	Proposal USAID/ARD 2000
35	Mazar, Muta, Adnaniya	Local reuse	Proposal of JICA
36	Dead Sea East Coast	Local reuse	Proposal SIGMA 1997

Figure 3.4.2-1 Location of Proposed Reuse Schemes (in 2020)



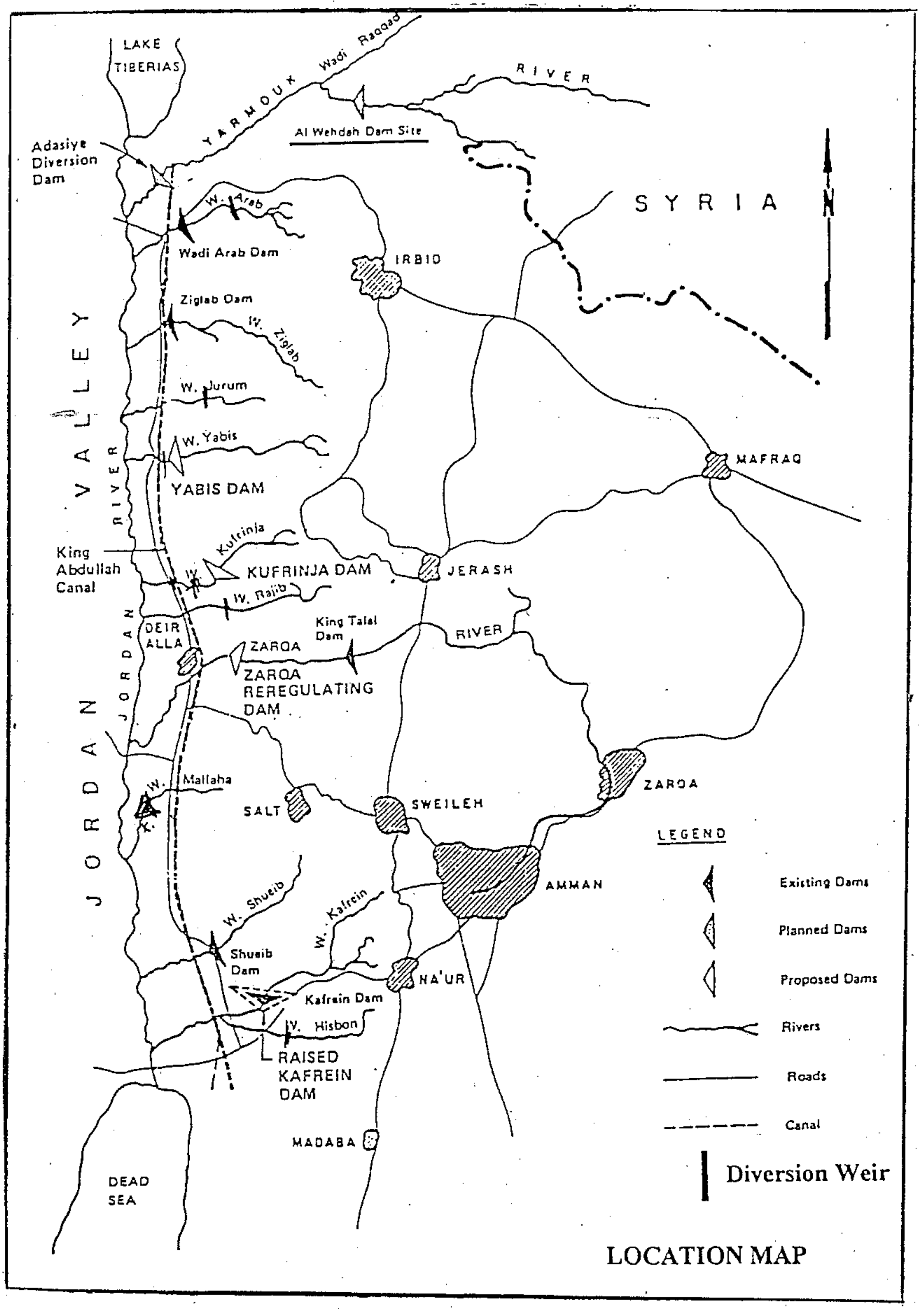


Figure 3.4.2-2 Location of Reservoirs in the Northern Part of Jordan

③ Reuse for industrial purposes

According to the "Jordan Water Resource Policy Support" project it is proposed to reuse a portion of the effluent from the new wastewater treatment plant of As Samra for industrial purpose. Major reusing industries will be in the area of Greater Amman, Zarqa and Russeifa. In addition the existing and new thermal power plant (proposed location close to As Samra) will use the effluent of As Samra Treatment Plant for cooling processes. In addition it is proposed that the industrial complexes in Irbid and Aqaba will reuse a certain amount treated effluent:

(in MCM/a)

	2000	2005	2010	2015	2020
Amman/Zarqa	0	15	15	15	20
Irbid	0	0	5	5	5
Aqaba	0	0	0	5	5
Total	0	15	20	25	30

④ Reuse in Jordan Valley for agricultural purposes

− Northern Jordan Valley

A pipe around the Wadi Arab Dam to the Jordan Valley discharges treated wastewater of Central Irbid and Wadi Arab Treatment Plants. In addition, effluent of the Kufranja Wastewater Treatment Plant is flowing presently through the Wadi Kufranja to the Jordan Valley. All related effluent of the mentioned plants is available for agricultural reuse in the Northern Jordan Valley and contribute therefore to the quantity disposable for substitution of freshwater presently used for irrigation.

− Southern Jordan Valley

Treated wastewater discharged in the Wadi Zarqa, Wadi Shua'ab and Wadi Kafrein will be available as irrigation water in the Southern Jordan Valley. Certainly, the flow through Wadi Zarqa and King Talal Reservoir originating of Greater Amman (in future only parts), Jerash, Baqa, dominates the other discharge quantities. This effluent will contribute to substitution of freshwater presently used for irrigation in the Southern Jordan Valley.

− Local reuse in the Jordan Valley

All irrigation facilities for local reuse of treated wastewater in the Jordan Valley have to be newly constructed. In total the effluent of 6 treatment plants (e.g. Kofur Asad, Shuna South, Dair Ala) will be locally reused in the future.

⑤ Reuse in Aqaba

Aqaba is considered separately because it does not belong to the categories 1 – 4. Two schemes are proposed for Aqaba: Wastewater of the Aqaba Treatment Plant will be reused for agricultural purposes north of the plant's location. Effluent of the Treatment Plant Aqaba South Coast will be reused for irrigation of green areas.

With the concept described above the quantities available for substitution of freshwater for irrigation purposes were determined. Table 3.4.2-2 summarizes the local availability of treated wastewater and related quantities for the considered scenarios.

In this context it has to be mentioned that wastewater quantities as presented in Table 3.4.2-2 are determined under purely quantitative aspects i.e. taking into account planned development of infrastructure with respect to sewerage and sewage treatment only. It has to be considered that the effluents of the treatment plants have to comply with quality standards to be reusable for agricultural irrigation and/or industrial purpose. Therefore, the treated effluent quantities as shown in Table 3.4.2-2 may not be available in total for substitution of freshwater in irrigation, if the quality of treated wastewater will not be acceptable with regard to related Jordanian Standard 893/1995.

Table 3.4.2-2 Major Areas of Treated Effluent's Reuse

	Available treated wastewater/effluent (MCM/a)				
	2000	2005	2010	2015	2020
Scenario 0 "Consultants' Study"					
1. Not (or only partly) used	4.8	0.0	1.2	1.3	1.6
2. For reuse in Upland/Midland for irrigation	2.2	19.5	27.4	36.2	44.3
3. For reuse for industrial purpose (AmmanZarqa)	0.0	15.0	15.0	15.0	20.0
4. For reuse to Jordan Valley (without Aqaba)	54.3	97.4	134.1	173.3	213.9
5. For reuse in Aqaba	2.4	5.7	8.2	11.6	14.8
Total	63.6	137.7	185.8	237.4	294.6
Losses (8%) during transmission/storage to Jord.Valley	4.2	6.7	9.0	11.6	14.4
Not available for substitution of freshwater in irrigation	11.2	53.1	71.6	90.1	112.1
Available for substitution of freshwater in irrigation	52.4	84.6	114.3	147.3	182.5

Scenario 1					
1. Not (or only partly) used	4.4	0	1.1	1.3	1.5
2. For reuse in Upland/Midland for irrigation	2.3	20.0	31.4	40.5	45.7
3. For reuse for industrial purpose (Amman/Zarqa)	0	15.0	15.0	15.0	20.0
4. For reuse to Jordan Valley (without Aqaba)	55.2	73.2	124.5	156.7	171.9
5. For reuse in Aqaba	1.9	4.0	5.0	6.0	6.8
Total	63.8	112.2	177.0	219.6	245.8
Losses (8%) during transmission/storage to Jord.Valley	4.3	4.9	8.1	10.1	11.1
Not available for substitution of freshwater in irrigation	10.9	49.6	72.2	88.7	102.3
Available for substitution of freshwater in irrigation	52.9	62.6	104.7	130.9	143.5

Table 3.4.2-2 Major Areas of Treated Effluent's Reuse (continued)

	Available treated wastewater/effluent (MCM/a)				
	2000	2005	2010	2015	2020
Scenario 2					
1. Not (or only partly) used	4.4	0	1.1	1.5	1.7
2. For reuse in Upland/Midland for irrigation	2.3	20.0	31.4	44.7	53.1
3. For reuse for industrial purpose (Amman/Zarqa)	0	15.0	15.0	15.0	20.0
4. For reuse to Jordan Valley (without Aqaba)	55.2	73.2	124.2	173.6	202.5
5. For reuse in Aqaba	1.9	4.0	5.0	6.6	7.7
Total	63.8	112.2	176.7	241.3	285.1
Losses (8%) during transmission/storage to Jord.Valley	4.3	4.9	8.1	11.3	13.2
Not available for substitution of freshwater in irrigation	10.9	49.6	72.2	96.1	115.7
Available for substitution of freshwater in irrigation	52.9	62.6	104.5	145.2	169.4
Scenario 3					
1. Not (or only partly) used	4.3	0	1.0	1.3	1.5
2. For reuse in Upland/Midland for irrigation	2.3	19.0	29.1	40.2	46.2
3. For reuse for industrial purpose (Amman/Zarqa)	0	15.0	15.0	15.0	20.0
4. For reuse to Jordan Valley (without Aqaba)	54.6	69.3	111.7	152.0	170.6
5. For reuse in Aqaba	1.9	3.8	4.7	5.9	6.7
Total	63.1	107.2	161.5	214.5	245.1
Losses (8%) during transmission/storage to Jord.Valley	4.2	4.6	7.2	9.8	10.9
Not available for substitution of freshwater in irrigation	10.8	48.1	67.9	87.9	103.0
Available for substitution of freshwater in irrigation	52.3	59.1	93.6	126.6	142.1

3.4.3 Implementation Schedule

Implementation before 2020 (see Table 3.4.3-1) of project measures as presented in sections 3.4.1 and 3.4.2 is proposed. Most of them will be even realized until 2010. The implementation schedule as described in the following is based on the "Investment Program 2000 – 2010" (updated in December 1999) by the Ministry of Water and Irrigation. Assumed implementation periods are based on the proposals made in the Consultants' Study Reports.

The biggest treatment plants serving Greater Amman are supposed to be completed in 2005 (As Samra) and 2009 (Wadi Zarqa).

In general the treatment plants are planned for a design capacity reached within 10 to 15 years after their completion. This requires an extension of the plants after this time period. Nevertheless, for the treatment plants of Abu Nuseir and Wadi Essir an extension would not be required until 2020 due to sufficient capacities of the existing facilities (if the development of collected wastewater quantities will develop as projected).

Construction work of the treatment plants of Wadi Hassan and Wadi Mousa will be completed early 2001.

Table 3.4.3-1 Implementation Schedule of Wastewater Projects

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Existing Treatment Plants																					
1 Abu Nuseir																					IIII
2 Aqaba		IIII	IIII	IIII							IIII	IIII									
3 As-Samra			IIII	IIII	IIII	IIII										IIII	IIII				
4 Baqa						IIII	IIII														
5 Fuhis															IIII	IIII					
6 Irbid (Central)																					
7 Jerash (East)										IIII	IIII										
8 Karak				IIII	IIII											IIII	IIII				
9 Kufranja				IIII	IIII											IIII	IIII				
10 Ma'an					IIII	IIII											IIII	IIII			
11 Madaba			IIII	IIII									IIII	IIII							
12 Mafraq				IIII	IIII									IIII	IIII						
13 Ramtha			IIII	IIII									IIII	IIII							
14 Salt										IIII	IIII										
15 Tafielah							IIII	IIII													
16 Wadi Arab											IIII	IIII									
17 Wadi Essir																					
18 Wadi Hassan	░░										IIII	IIII									
19 Wadi Mousa	░░										IIII	IIII									
Planned Treatment Plants																					
20 Al Jeeza				░░	░░	░░											IIII	IIII			
21 Al Mazar Al Shamali									░░	░░											
22 Dair Abi Said												░░	░░								
23 Dair Alla					░░	░░											IIII	IIII			
24 Jerash West							░░	░░	░░												
25 Kofur Asad						░░	░░	░░													
26 Aqaba South Coast		░░	░░									IIII	IIII								
27 Naur							░░	░░											IIII	IIII	
28 North Queen Alia Airport				░░	░░	░░											IIII	IIII			
29 North Jordan Valley			░░	░░												IIII	IIII				
30 Shuna South					░░	░░											IIII	IIII			
31 Torra												░░	░░								
32 Um Al Basateen																					
33 Wadi Shallala (Irbid East)				░░	░░	░░												IIII	IIII		
34 Wadi Zarqa							░░	░░	░░	░░											
35 Mazar, Muta, Adnaniya									░░	░░											
36 Dead Sea East Coast					░░	░░															

IIII Rehabilitation/extension measures for existing plants ░░ New constructions

3.4.4 Implementation Schedule for Proposed Wastewater Reuse Facilities

Wastewater effluent will be reused as shown in Table 3.4.4-1 below and the implementation schedule for the proposed wastewater reuse facilities is shown in Table 3.4.4-2.

Table 3.4.4-1 Wastewater Reuse Plan

No.	Treatment Plant	Gov.	Wastewater Effluent of WWTP (MCM/a)					Wastewater Reuse Category				
			2000	2005	2010	2015	2020	2000	2005	2010	2015	2020
Existing												
1	Abu Nuseir	AM	0.5	0.6	1.0	1.2	1.3	*4*	*2*	*2*	*2*	*2*
2	Aqaba	AQ	1.9	3.9	4.8	5.8	6.5	*1*	*5*	*5*	*5*	*5*
3	As-samra	AM	46.2	67.5	61.2	74.5	83.2	*4*	*3+4*	*3+4*	*3+4*	*3+4*
4	Baqa	BA	3.8	5.5	8.4	10.2	11.4	*4*	*4*	*4*	*4*	*4*
5	Fuhis	BA	0.3	0.6	0.9	1.1	1.2	*1*	*2*	*2*	*2*	*2*
6	Irbid (Central)	IR	1.4	2.4	4.2	4.2	4.2	*4*	*4*	*4*	*4*	*4*
7	Jerash (East)	JA	0.5	1.0	1.7	2.4	2.7	*4*	*4*	*4*	*4*	*4*
8	Karak	KA	0.4	0.6	0.9	1.2	1.3	*1*	*2*	*2*	*2*	*2*
9	Kufranja	AJ	0.8	1.3	2.2	2.8	3.1	*4*	*2*	*2*	*2*	*2*
10	Ma'an	MN	0.5	0.6	0.8	1.1	1.4	*1*	*2*	*2*	*2*	*2*
11	Madaba	MA	1.2	1.6	2.7	3.4	3.9	*2*	*2*	*2*	*2*	*2*
12	Mafraq	MF	0.5	0.7	1.0	1.2	1.4	*2*	*2*	*2*	*2*	*2*
13	Ramtha	IR	0.7	1.3	2.2	2.9	3.4	*2*	*2*	*2*	*2*	*2*
14	Salt	BA	1.2	2.0	2.9	3.5	4.0	*4*	*4*	*4*	*4*	*4*
15	Tafielah	TA	0.3	0.5	0.8	1.0	1.1	*1*	*2*	*2*	*2*	*2*
16	Wadi Arab	IR	2.5	4.1	7.9	10.4	12.2	*4*	*4*	*4*	*4*	*4*
17	Wadi Essir	AM	0.2	0.3	0.4	0.5	0.6	*4*	*2*	*2*	*2*	*2*
Under construction												
18	Wadi Hassan	IR	0.4	0.5	0.7	0.9	1.0	*1*	*2*	*2*	*2*	*2*
19	Wadi Mousa	MN	0.5	0.7	1.0	1.2	1.4	*1*	*2*	*2*	*2*	*2*
Planned												
20	Al Jeeza	AM	0	1.8	2.5	3.0	3.4	*1*	*2*	*2*	*2*	*2*
21	Al Mazar Al Shamali	IR	0	0	1.1	1.3	1.5	*1*	*1*	*1*	*1*	*1*
22	Dair Abi Said	IR	0	0	0	1.4	1.6	*1*	*1*	*1*	*4*	*4*
23	Dair Alla	BA	0	1.8	2.6	3.1	3.5	*1*	*4*	*4*	*4*	*4*
24	Jerash West	JA	0	0	1.3	1.9	2.4	*1*	*1*	*4*	*4*	*4*
25	Kofur Asad	IR	0	0	3.0	3.7	4.1	*1*	*1*	*4*	*4*	*4*
26	Aqaba South Coast	AQ	0	0.2	0.2	0.3	0.3	*1*	*5*	*5*	*5*	*5*
27	Naur	AM	0	0	0.8	1.0	1.1	*1*	*1*	*2*	*2*	*2*
28	North Queen Allia Airport	AM	0	5.7	8.1	9.9	10.9	*1*	*2*	*2*	*2*	*2*
29	North Jordan Valley	IR	0	2.3	3.6	4.3	4.7	*1*	*4*	*4*	*4*	*4*
30	Shuna South	BA	0	1.1	1.6	2.0	2.2	*1*	*4*	*4*	*4*	*4*
31	Torra	IR	0	0	0	1.6	1.8	*1*	*1*	*1*	*2*	*2*
32	Um Al Basateen	AM	(included in Al Jeeza)					(included in Al Jeeza)				
33	Wadi Shallala (Irbid East)	IR	0	3.3	4.8	5.8	6.5	*1*	*2*	*2*	*2*	*2*
34	Wadi Zarqa	ZA	0	0	40.3	49.0	54.7	*1*	*1*	*4*	*4*	*4*
35	Mazar, Muta, Adnaniya	KA	0	0	0.6	0.8	1.0	*1*	*1*	*2*	*2*	*2*
36	Dead Sea East Coast	BA	0	0.6	0.9	1.2	1.2	*1*	*4*	*4*	*4*	*4*
	Total		63.8	112.2	177.0	219.5	245.8					

Wastewater reuse category	2000	2005	2010	2015	2020
1 : Not (or only partly) used	4.4	0	1.1	1.3	1.5
2 : For reuse in Upland/Midland for irrigation	7.3	25.0	36.4	45.5	50.7
3 : For reuse for industrial purpose (Amman/Zarqa)	0	15.0	15.0	15.0	20.0
4 : For reuse to Jordan Valley (without Aqaba)	50.2	68.2	119.5	151.7	166.9
5 : For reuse in Aqaba	1.9	4.0	5.0	6.0	6.8
Total	63.8	112.2	177.0	219.6	245.8

No.	Treatment Plant	Gov.	Wastewater Reuse Facility: Pump Station	Wastewater Reuse Facility: Transmission Main	Wastewater Reuse Facility: Reservoir
Existing					
1	Abu Nuseir	AM		φ 300 x 600m (concr.)	8,000m³ x 1unit
2	Aqaba	AQ	Q=1,600m³/h, H=70m	φ 400 x 3,500m (DI)	60,000m³ x 1unit
				φ 500 x 9,500m (DI)	
				φ 600 x 5,500m (DI)	
3	As-samra	AM	(already reused)		
4	Baqa	BA	(already reused)		
5	Fuhis	BA		φ 300 x 200m (concr.)	
6	Irbid (Central)+Wadi Arab	IR		φ 700 x 4,000m (DI)	60,000m³ x 1unit
7	Jerash (East)	JA	(already reused)		
8	Karak	KA		φ 300 x 1,500m (concr.)	9,000m³ x 1unit
9	Kufranja	AJ		φ 400 x 2,000m (concr.)	20,000m³ x 1unit
10	Ma'an	MN	Q=160m³/h, H=15m	φ 300 x 200m (DI)	9,000m³ x 1unit
11	Madaba	MA	Q=435m³/h, H=15m	φ 400 x 200m (DI)	20,000m³ x 1unit
12	Mafraq	MF	Q=350m³/h, H=5m	φ 400 x 200m (DI)	10,000m³ x 1unit
13	Ramtha	IR	Q=335m³/h, H=5m	φ 400 x 500m (DI)	18,000m³ x 1unit
14	Salt	BA	(already reused)		
15	Tafielah	TA	Q=130m³/h, H=25m	φ 300 x 1,000m (DI)	7,000m³ x 1unit
16	Wadi Arab	IR	(included in Irbid Central)		
17	Wadi Essir	AM		φ 200 x 600m (concr.)	
Under construction					
18	Wadi Hassan	IR		φ 250 x 750m (DI)	5,000m³ x 1unit
19	Wadi Mousa	MN		φ 300 x 200m (DI)	9,000m³ x 1unit
Planned					
20	Al Jeeza	AM	Q=330m³/h, H=25m	φ 400 x 200m (DI)	18,000m³ x 1unit
21	Al Mazar Al Shamali	IR	(No reuse)		
22	Dair Abi Said	IR	Q=200m³/h, H=25m	φ 300 x 1,800m (DI)	10,000m³ x 1unit
23	Dair Alla	BA	Q=270m³/h, H=15m	φ 250 x 200m (DI)	15,000m³ x 1unit
				φ 300 x 3,000m (DI, FM)	
24	Jerash West	JA	(to be reused via KTR)		
25	Kofur Asad	IR		φ 400 x 1,500m (concr.)	20,000m³ x 1unit
26	Aqaba South Coast	AQ	Q=60m³/h, H=20m	φ 200 x 1,500m (DI)	5,000m³ x 1unit
27	Naur	AM		φ 300 x 500m (concr.)	10,000m³ x 1unit
28	North Queen Allia Airport	AM		φ 500 x 1,500m (concr.)	60,000m³ x 1unit
29	North Jordan Valley	IR	Q=450m³/h, H=115m	φ 500 x 1,100m (DI)	12,000m³ x 1unit
30	Shuna South	BA	Q=260m³/h, H=30m	φ 300 x 3,000m (DI)	12,000m³ x 1unit
31	Torra	IR	Q=220m³/h, H=25m	φ 300 x 1,000m (DI)	12,000m³ x 1unit
32	Um Al Basateen	AM	(included in Al Jeeza)		
33	Wadi Shallala (Irbid East)	IR	Q=670m³/h, H=20m	φ 300 x 700m (DI)	45,000m³ x 1unit
34	Wadi Zarqa	ZA	(to be reused via KTR)		
35	Mazar, Muta, Adnaniya	KA		φ 250 x 2,000m (concr.)	7,000m³ x 1unit
36	Dead Sea East Coast	BA	Q=140m³/h, H=40m	φ 300 x 2,000m (DI)	8,000m³ x 1unit

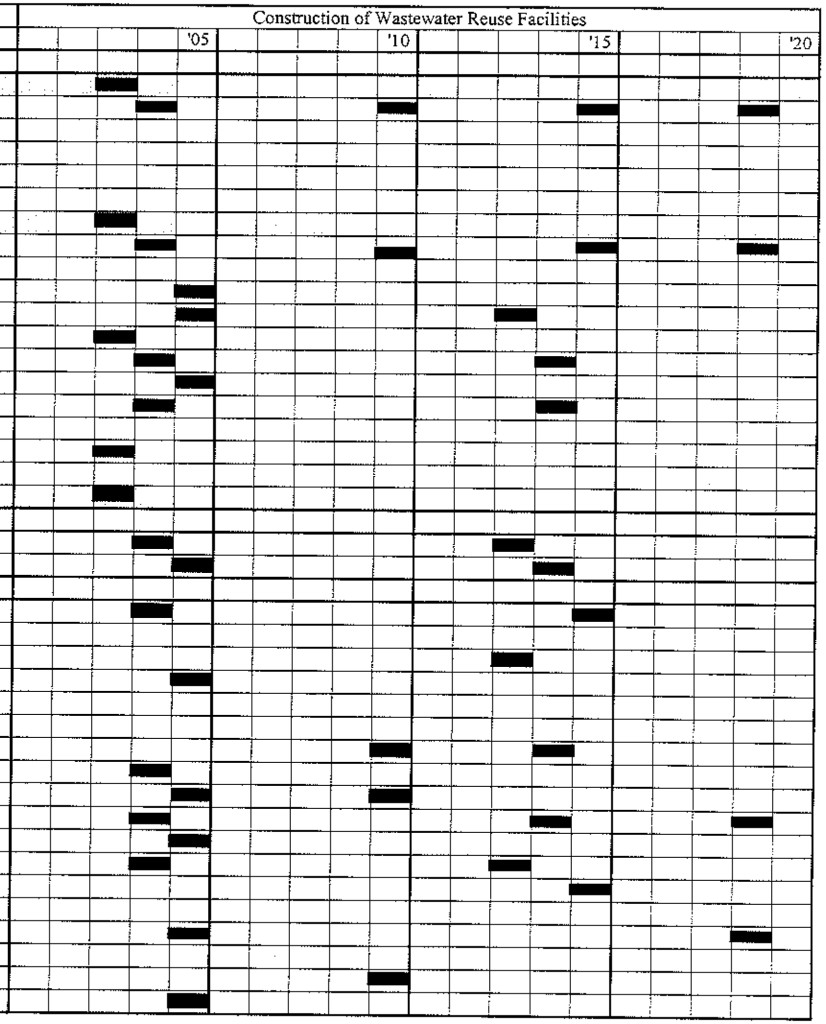


Fig. 3.4.4-1 Implementation Schedule for Proposed Wastewater Reuse Facilities

3.5 Consideration on Sector Policy

The Ministry of Water and Irrigation prepared a Water Strategy for Jordan. It was adopted by a joint session of the Board of Directors of both the Jordan Valley Authority (JVA) and the Water Authority of Jordan (WAJ). The strategy was approved by the Council of Ministers in 1997. Under the strategy, the Ministry and its two authorities formulate a series of policies.

3.5.1 Irrigation Water Policy

The *Policy Paper No. 2 "Irrigation Water Policy"* of February 1998 details the long-term objectives outlined in the Water Strategy of Jordan. It states water related issues of resource development: agricultural use, resource management, technology transfer, water quality, efficiency, cost recovery, management and other issues. In the following paragraphs such issues are summarized, which are of particular significance for the reuse of treated wastewater for agricultural irrigation.

Under the heading "Resource development and use" it is outlined that wastewater is a resource and cannot be treated as "waste". It shall be collected and treated to obtain a water quality that allow its reuse in irrigation unrestricted by health and public health considerations or unduly constrained by high salinity contents. After satisfying the local municipal and industrial needs from unallocated water resources, water resources shall be allocated to agricultural production including livestock. This means that in case of reuse of treated wastewater priority should be given to industrial use in comparison to agricultural use.

Advanced methods as drip irrigation, micro-sprinkler irrigation are favored over less efficient methods. Night application of irrigation water, especially in the dry season, shall be encouraged to reduce evaporation losses. Programs shall be prepared to raise the public and farmers' awareness of the availability of irrigation water, its rational and economic use and on the impacts of its quality.

Under the title "Irrigation water quality" it is said, where marginal quality water, such as treated wastewater effluent, is a source of irrigation water, care should be taken, to the maximum extend possible, to have the quality improved to standards that allow it to use for unrestricted irrigation. This can be achieved through blending with fresher water sources.

The water price shall at least cover the cost of operation and maintenance, and, subject to some other constraints, it should also recover part of the capital cost of the irrigation water project. The ultimate objective shall be full cost recovery subject to economic, social and political constraints. Part of the capital cost shall be recovered through the application of a one-time charge against irrigation rights. This is applied as a rate per unit area of the irrigated farm. The size of the portion thus recovered shall not be less than half the irrigation network development cost.

3.5.2 Wastewater Management Policy

The following paragraph summarizes present policy as stated in the *Policy Paper No. 4 "Management of Wastewater"* of June 1998.

The following key issues are presented in order to develop the Wastewater Management Policy:

1. Provision of adequate wastewater collection and treatment facilities for all the major cities in Jordan
2. Protection of the environment and public health in the areas affected by the proposed systems, especially, surface waters and groundwater.
3. Consideration of treated effluents as a source for irrigation reuse.
4. Improvement of the socio-economic conditions in the areas to be served by the proposed systems.

The policy focuses on the management of wastewater as a water resource and includes, amongst others, development, management, wastewater collection and treatment as well as the reuse of wastewater and sludge in the agriculture, pricing, selected priority issues, standards and regulations.

Wastewater shall be collected and treated in accordance with WHO and FAO Guideline as the basis for effluent quality requirements for reuse in irrigation. The use of treated wastewater in irrigation (unrestricted irrigation) shall be given the highest priority and shall be pursued with care.

Industrial wastewater shall be recycled as much as possible within the factories. Industries shall treat the remainder of wastewater to meet the standards/regulations set for the ultimate wastewater reuse for its disposal through the collection system and/or into receiving environment.

Sludge from treatment plants shall be used for power generation, if proven technically, economically and financially feasible. It shall be processed so it may be used as fertilizer and soil conditioner for agricultural purposes.

Generally, the "polluter pays" principle shall be applied. Wastewater charges, connection fees, sewerage taxes ant treatment fees shall cover at least the operation and maintenance costs. The ultimate aim is for full cost recovery. Treated effluent shall be priced and sold to end users at a price covering at least the operation and maintenance costs of delivery.

Through private sector participation, management of infrastructure and services shall be transferred from the public to the private sector, in order to improve performance and upgrade the level of services.

3.5.3 Water Utility Policy

According to the *Water Utility Policy of July 1997* the Government intends through private sector participation, to transfer infrastructure and services from the public to the private sector, in order to improve performance and ensure the delivery of services to the population. The private sector shall be involved through management contracts, concessions and other forms in water utilities. BOT/BOO models shall be applied for water and wastewater projects. Private sector activities shall be continually monitored and assessed. In accordance with formulated Water Utility Policy, WAJ has embarked on a course of increasing private sector participation for both capital investment and management of services

The Ministry will set municipal water and wastewater charges at a level, which will cover at least the cost of operation and maintenance. It will also move towards the recovery of all part of capital costs of water infrastructure. Until the financing is full, and the national savings reach levels capable of domestic financing of development projects, project financing will depend on concessionary loans, private borrowing and/or BOO and BOT arrangements.

Under point 6 of the Water Utility Policy paper it is said that the Ministry intends to raise the effluent quantity of wastewater treatment plants from 60 million in the year 1997 to a volume of 200 million m^3 per year in the year 2020. In light of this, the Ministry is developing a wastewater master plan, which will establish targets for providing wastewater collection systems and treatment facilities to not yet serviced areas throughout the country.

Privatization of Jordan's water sector has started with a water and wastewater management contract (supported by World Bank) for Greater Amman. Contract was awarded to LEMA, a consortium of Suez Lyonnaise des Eaux - Montgomery Watson Arabtech Jardaneh. The consortium has started work in 1999. The contract comprises retail water supply including wastewater collection for the Greater Amman area. It does not include pretreatment in Ain Ghazal, conveyance of wastewater to the plant in As Samra and its treatment by this plant. Implementation of the planned new wastewater treatment plant in As Samra is intended applying the BOT concept. The contract comprises wastewater treatment by the plants in Wadi Essir and Abu Nuseir. Additionally to these measures, WAJ is considering further management contracts as well as BOT schemes for desalination of brackish and sea water and for conveyance.

3.6 Preliminary Cost Estimation for Wastewater Reuse Facilities

3.6.1 Unit Costs

The adopted unit construction costs are established based on the following information and documents:

- Several previous Study Reports of MOWI
- Latest price list of the Ministry of Public Works and Housing, version 1999 (The Government Tenders Directorate Annual Report
- Quotation and consultation with local contractors and manufacturers
- Experience of the Consultant

Unit prices include all the costs for construction works including belongings and all indirect prices except owner's engineering cost and contingencies. The prices given in the previous study reports of MOWI mentioned above are converted to year 2000 prices considering the annual escalation ratio of 3 % per annum.

Table 3.6.1-1 shows basic construction cost for civil works taken into account for unit price estimation. Table 3.6.1-2 summarizes unit prices for the estimates of investment cost for reuse facilities. Both tables are based on prices of the year 2000.

Table 3.6.1-1 Basic Construction Cost for Civil Works

		Unit	Unit price (JD/unit)
Land acquisition			
North Jordan Valley		ha	16,000
Middle and South Jordan Valley		ha	12,000
Others		ha	8,000
Earth work			
Site leveling		m^2	2
Excavation	Common	m^3	3.5
	Rock	m^3	8.5
Backfill		m^3	2.5
Concrete			
Lean concrete		m^3	45
Mass concrete		m^3	70
Reinforced concrete		m^3	140
Anchor block		m^3	115
Steel			
Steel bar		t	520
Structural steel		t	1,570
Building			
High quality		m^2	350
Middle quality		m^2	200
Low quality		m^2	160
Road construction		m^2	9.5
Fence and gate		m	25

Table 3.6.1-2 Unit Prices for Reuse Facilities

Component	Unit	Unit cost (JD/unit)
Pump station		
Portion civil works	%	50
Portion electromechanical equipment	%	50
Capacity 50 - 100 m^3/h	JD/(m^3/h)	785
Capacity 100 - 250 m^3/h	JD/(m^3/h)	705
Capacity 250 - 500 m^3/h	JD/(m^3/h)	600
Capacity 500 - 750 m^3/h	JD/(m^3/h)	510
Capacity 750 - 1000 m^3/h	JD/(m^3/h)	485
Capacity 1000 - 1500 m^3/h	JD/(m^3/h)	420
Capacity 1500 - 2160 m^3/h	JD/(m^3/h)	355
Transmission main in ductile iron (DI)		
DN 100	m	49
DN 150	m	58
DN 200	m	67
DN 250	m	81
DN 300	m	95
DN 350	m	120
DN 400	m	135
DN 500	m	170
DN 600	m	205
Transmission main in concrete		
DN 150	m	34
DN 200	m	50
DN 250	m	60
Transmission main in reinforced concrete		
DN 300	m	70
DN 350	m	75
DN 400	m	81
DN 500	m	93
DN 600	m	107
DN 700	m	122
DN 800	m	138
DN 900	m	160
Reservoir 5,000 m^3	1	43,000
Reservoir 7,000 m^3	1	58,800
Reservoir 8,000 m^3	1	65,600
Reservoir 9,000 m^3	1	73,800
Reservoir 10,000 m^3	1	82,000
Reservoir 12,000 m^3	1	97,200
Reservoir 15,000 m^3	1	118,500
Reservoir 18,000 m^3	1	140,400
Reservoir 20,000 m^3	1	156,000
Reservoir 45,000 m^3	1	337,500
Reservoir 60,000 m^3	1	450,000

3.6.2 Estimation of Investment Cost

For preliminary estimates of investment costs it was distinguished between base construction cost, engineering cost and contingencies as described in the following.

3.6.2.1 Basic Design Assumptions for Base Construction Cost Estimation

Preliminary costs were estimated for all local reuse facilities for irrigation. However, estimates do not contain costs e.g. for the facilities as required for the industrial reuse of treated effluent of As Samra. Furthermore, no costs are considered for provision of additional storage volume (e.g. King Talal Reservoir) or additional transmission facilities in the Southern and Middle Jordan Valley. These costs will be estimated within the frame of the ongoing project "Water resource policy support" prepared by ARD/ USAID.

Investment cost estimates consider all required facilities between the wastewater treatment plants and the potential irrigation areas. This means that they comprise pumping facilities too (if required), but they do not include distribution facilities downstream of the storage reservoir or the transmission pipe. It is assumed that the users of the irrigation system will finance that distribution network.

Unit construction cost for pump stations is given in JD per m³/h of installed capacity (see Table 8-2). Unit prices decrease with increasing total capacity of pumping station. Investment cost for pumping facilities was calculated accordingly, whereby the portion of cost for each - electromechanical equipment and civil works - was estimated to 50 % of the total price.

For transmission of treated effluent from the treatment plants to potential reuse areas ductile iron pipes were proposed for pressure mains and concrete or reinforced concrete pipes in case of gravity flow. Reinforced concrete are selected for diameters DN 300 mm and bigger, while concrete will be used for diameters 250 mm and lower.

In general the reservoirs of treated effluent shall have a volume of about two days effluent quantity of the treatment plant. However, such an additional storage reservoir was not proposed in cases, where the treatment plant comprises maturation ponds and the treated effluent is discharged by gravity to the irrigation areas. It is assumed that the maturation ponds provide sufficient storage volume (e.g. Wadi Essir, Wadi Hassan) in these cases.

HDPE lined reservoirs are adopted as they satisfy the required function and have an enormous economical advantage. This type of reservoir is applied already in many irrigation systems of Jordan. It is assumed that the water depth will be 3.5 m with an additional freeboard of 0.5 m. The irrigation areas will be supplied by gravity flow from the reservoirs.

Base construction costs are calculated applying unit prices as outlined in Tables 3.6.1-1 and 3.6.1-2 and preliminary estimated quantities of works.

3.6.2.2 Costs for Engineering and Contingencies

Engineering costs include the cost for the engineering services such as surveys, planning, designs, site supervision etc.. The amount of these services is estimated as 15 % of the base construction cost according to the experience of the consultant.

Due to the limitation that the cost estimates at this stage of the project is based on a rough plan, allowance is taken into account for unpredictable variation in construction conditions and other unforeseen difficulties that may increase the final construction cost. The amount of these contingencies is estimated as 15 % of the base cost.

3.6.3 Estimation of Operation Cost

Two types of operation and maintenance costs have to be distinguished, i.e. fixed and variable costs. The fixed costs do not depend on the quantity of treated effluent to be reused (e.g. staff and maintenance cost). The variable costs are directly related to the effluent quantities to be reused and refer to such items as electrical power consumed for pumping.

3.6.3.1 Staff Cost

Following criteria are applied to estimate required staff for operation and maintenance of reuse facilities:

Criteria	Required staff
Effluent quantity of treatment plant $< 5{,}000\ m^3/d$	1
Effluent quantity of treatment plant $5{,}000 < m^3/d < 20{,}000$	2
Effluent quantity of treatment plant $20{,}000 < m^3/d < 50{,}000$	3
For each pump station	1

Estimates of personnel costs are based on current salaries paid including all overhead costs (e.g. allowances, contributions to pension fund etc.). Total annual costs are estimated to be 3,500 JD/a (basic salary) plus 5,300 JD/a (overhead cost), which results in a total of 8,800 JD/a.

3.6.3.2 Maintenance Cost

Operation and maintenance requirements are calculated as a percentage of the investment costs. This item includes the equipment (including all materials and small tools) required but does not include personnel cost, which is considered separately (see paragraph 3.6.3.1). The following percentages of the capital cost were considered for the annual maintenance cost:

0.5 % p.a.	for civil works
2.0 % p.a.	for mechanical and electrical equipment
0.5 % p.a.	for transmission mains including distribution network (if any)

These percentages are based on experience and are widely accepted as representative of typical conditions. Details of maintenance cost estimation are given in Annex 3.6

3.6.3.3 Power Cost

Electrical energy is consumed for pumping of treated effluent to the reuse areas, if required. Power consumption is calculated by:

$$E = \frac{gamma * Q_a * H_{av}}{k * eta_{glob}} = \frac{Q_a * H_{av}}{eta_{glob}} \mathbf{x}\ 2.725*10^{-3}\ [kWh/a]$$

where:	H_{av}	= pumping head at average flow	[m]
	Q_a	= annual discharge	[m^3/a]
	eta_{glob}	= global efficiency factor	[-]
	gamma	= gravity acceleration	[9.81 N/m^3]
	k	= conversion factor	[3,600 Nm/Wh]

Global efficiency factor is assumed as 70 %. Present average compound rate per kWh for agricultural sector is 0.023 JD. Annual maintenance cost estimation is shown in Annex 3.6.

3.6.4 Results of Preliminary Cost Estimates

Table 3.6.4-1 summarizes the results of preliminary estimates for capital, operation and maintenance costs as far as the local reuse facilities for irrigation is concerned. It includes also the common reuse facilities of the Treatment Plants Central Irbid and Wadi Arab. The treated effluents of Treatment Plants Irbid Central and Wadi Arab are discharged in a common transmission main (already existing) to the North Jordan Valley. Capital cost estimates do not consider the construction of this pipe, but the allowance is given for the operation and maintenance of this transmission main.

In Al Mazar Al Shamali no suitable areas for agricultural irrigation could be identified. Therefore, no reuse facilities were proposed.

The sewerage system and treatment plants for Dair Abi Said and Torra will be implemented after 2010. Therefore, no expenses for operation and maintenance are indicated in 2010.

Specific costs for investment as well as for operation and maintenance of proposed reuse systems differ in some cases considerably depending on the manner of effluent transfer to the irrigation areas, whether this is a gravity system or a pumped one. Cost for pumped systems are in general double related to gravity systems.

Annex 3.6 presents details of cost estimation for each town, where reuse systems for treated effluent from the treatment plants are planned.

Table 3.6.4-1 Summary of Preliminary Estimates for Capital, Operation and Maintenance Costs

Reuse facilities for effluent of treatment plant	Total investment cost (JD)	Specific 1) investment cost (JD/1000m³/a)	Annual (2010) operation costs (JD/a)	Annual (2020) operation costs (JD/a)	Specific (2010) operation cost (JD/m³)	Specific (2020) operation cost (JD/m³)	Remarks
			h59	n59	h61	n61	
Existing							
1 Abu Nuseir	143,000	98	9,239	9,350	0.012	0.006	
2 Aqaba	7,411,300	520	98,822	148,007	0.013	0.010	Pumped system
3 As-Samra							Reuse of treated effluent in Jordan Valley
4 Baqa							Reuse of treated effluent in Jordan Valley
5 Fuhis	19,240	18	0	8,874	0.000	0.008	
6 Irbid Central (Central/Wadi Arab together)	1,619,800	98	42,228	44,780	0.004	0.003	Same as Wadi Arab (common system)
7 Jerash (East)							Reuse of treated effluent in Jordan Valley
8 Karak	240,240	170	9,447	9,724	0.013	0.007	
9 Kufranja	455,000	132	18,475	19,350	0.009	0.006	
10 Maan	263,900	189	19,771	21,314	0.026	0.015	Pumped system
11 Madaba	558,740	146	21,830	35,525	0.014	0.009	Pumped system
12 Mafraq	387,010	250	19,750	21,175	0.022	0.014	Pumped system
13 Ramtha	511,485	174	20,103	31,021	0.012	0.011	Pumped system
14 Salt							Reuse of treated effluent in Jordan Valley
15 Tafielah	332,410	287	20,522	22,191	0.024	0.019	Pumped system
16 Wadi Arab (Centr.Irbid/W.Arab together)	1,619,800	98	42,228	44,780	0.004	0.003	Same as Irbid Central (common system)
17 Wadi Essir	42,900	53	0	8,965	0.000	0.011	
Under construction							
18 Wadi Hassan	85,800	103	0	9,130	0.000	0.011	
19 Wadi Mousa	115,180	72	9,206	9,243	0.011	0.006	
Planned							
20 Al Jeeza	500,630	174	22,927	36,391	0.015	0.013	Pumped system
21 Al Mazar Al Shamali							No reuse of effluent proposed
22 Dair Abi Said	527,280	307	0	24,529	0.000	0.014	Pumped system, implemented after 2010
23 Dair Alla	785,330	327	31,800	33,867	0.021	0.014	Pumped system
24 Jerash West							Reuse of treated effluent in Jordan Valley
25 Kofur Assad	391,950	95	18,962	19,108	0.006	0.005	
26 Aqaba South Coast	264,550	484	18,803	19,958	0.069	0.037	Pumped system
27 Naur	154,700	90	9,321	9,395	0.010	0.005	
28 North Queen Alia Airport	822,900	88	19,183	29,565	0.004	0.003	
29 North Jordan Valley	995,930	245	52,096	76,135	0.025	0.019	Pumped system
30 Shuna South	760,760	337	23,720	36,759	0.016	0.016	Pumped system
31 Torra	456,300	234	0	33,663	0.000	0.017	Pumped system, implemented after 2010
32 Um Al Basateen							Included in Al Jeeza
33 Wadi Shallala	967,070	163	35,952	43,305	0.011	0.007	Pumped system
34 Wadi Zarqa							Reuse of treated effluent in Jordan Valley
35 Mazar, Muta, Adnaniya	237,640	247	9,466	9,714	0.016	0.010	
36 Dead Sea East Coast	523,380	423	21,719	25,098	0.033	0.020	Pumped system

1) Related to treated effluent quantities of 2020

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