Chapter 2 Wadi Zarqa Treatment Plant Construction

Chapter 3 National Water Control System

Chapter 4 Municipal Water Network Rehabilitation

CHAPTER 2

WADI ZARQA TREATMENT PLANT

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2.1 Project Area

The present report covers the Pre-Feasibility Study for the **Construction of Wadi Zarqa Treatment Plant**. The study updates and summarizes the results and findings of the "Master Plan and Feasibility Study" for the rehabilitation, expansion and development of existing wastewater systems in Amman-Zarqa River basin area prepared for the Ministry of Water and Irrigation, Jordan by HARZA Consulting Engineers in Association with Metcalf & Eddy International, CC Johnson & Malhotra, P.C. and Jouzy & Partners in 1997. However, while the Master Plan of HARZA considers the Cities of Amman, Russeifa, Zarqa, Hashimiyya and Sukhna, the present Pre-Feasibility Study is limited to the last for mentioned urban centers.

2.1.1 Project Area Boundaries

The boundaries of the project area correspond to the service areas of the future Wastewater Treatment Plant Wadi Zarqa. These areas comprise a minor part of the Amman Governorate (Tariq and Marka) and a major part of Zarqa Governorate. They are in particular the following:

- Tariq and Marka (belonging to Amman Municipality)
- Zarqa,
- Russeifa,
- Hashimiyya and
- Sukhna

The boundaries of the project area are the drainage area of the planned Wadi Zarqa Treatment Plant (as defined in the HARZA Study of 1997) rather than the administrative boundaries of Amman, Zarqa and the other Municipalities. More details on the long-term development of the sewerage systems within the Wadi Zarqa Basin are given in Section 2.5.2. Figure 2.1.1-1 shows the project boundaries of Wadi Zarqa Project Area.

2.1.2 Geography

Amman is the seat of the national government, the Royal Court, and much of the business, commercial, financial, and cultural activity of Jordan. Together the Amman and Zarqa Governorates accounted for 52 % of the national population in 1994. Little industry is located in the Amman municipality, but the Zarqa Governorate has a modest level of industry including a thermal power plant, an oil refinery, and small textile, chemical and food industries.

Wadi Zarqa drains most of present day Amman, although the city is growing into adjacent basins. Wadi Zarqa flows northeasterly as it leaves the urban area, but at its confluence with Wadi Dhuleil, near Sukhna, it turns west to flow, via King Talal Reservoir (KTR), into the Jordan Valley where it joins the Jordan River at elevation – 350 m, about 20 km north of the Dead Sea.

The study area includes municipalities in the Zarqa Governorate that are northeast of Amman and downstream along the Wadi Zarqa. The municipalities of Russeifa, Zarqa and the Hashimiyya are sewered; the most downstream municipality, Sukhna, is not yet sewered. The Zarqa-Russeifa area contains many of the industries in the Amman urban area.

The Kingdom is divided administratively into Governorates for which statistical data are reported. Boundaries of Governorates and other administrative divisions are adjusted from time to time. The project study area serves communities, which are in the Amman (Marka and Tariq only) and the Zarqa Governorates. Municipalities of the Zarqa Governorate in the study area are Zarqa, Russeifa, Hashimiyya, and Sukhna (see Figure 2.1.1-1).

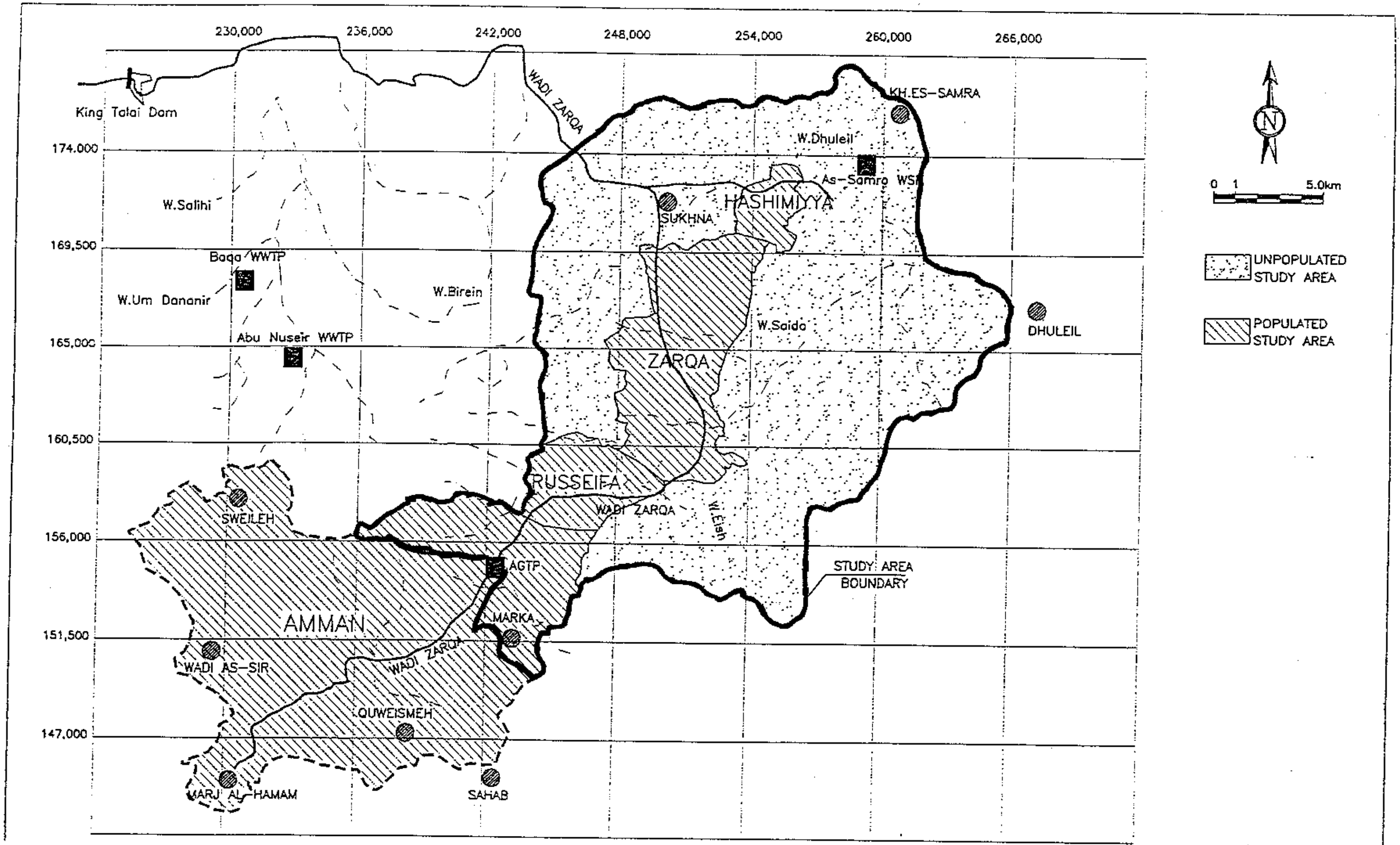

Figure 2.1.1-1 Boundaries of Project Area

2.1.3 Climate

A Mediterranean climate dominates in the study area with local variations due to large topographic differences and the rain shadow created to the east when moist air from the northwest and west crosses the deep Jordan Valley and raises some 1,500 m to the crest of the highlands. Summers are hot and dry and winters are cool with occasional rain and frost. The temperature increases towards the southeastern part (Eastern Desert) and decreases towards the western parts. However, temperatures rise to the west of the highlands as the land elevation falls steeply into the Jordan Valley.

A seasonal low pressure through over the Arabian Gulf, Iraq, Syria and Cyprus during summer causes westerly winds to enter Jordan from the Mediterranean. Autumn is associated with a change in the pressure system as the seasonal trough extending from Cyprus to Iraq begins to migrate southeast. Mediterranean depressions start developing with continental air from the Asiatic Steppes and warmer, moist air from the Mediterranean causing a decrease in temperature and the commencement of the seasonal frontal rains.

Most rainfall occurs during the winter and spring starting in November and possible extending to April. Usually the maximum amount of rain is during January. The mean temperature of the plateau of Amman during January is about 8 °C compared to about 14 °C in the Jordan Valley. The amount and the period of rainfall are highly variable, and they fluctuate widely from year-to-year. Within the study area, humidity and precipitation decrease rapidly moving from the Amman plateau towards the eastern deserts. The mean annual precipitation is highest in the highlands, between 200 and 400 mm. The rain intensity is extremely variable and is closely related to winter depressions approaching the area from the west and northwest.

Amman has a temperate climate of warm, dry summers, with temperatures generally no more than 38 °C, and cool winters during which most of the annual 300 to 500 mm of precipitation falls. Temperatures in winter generally remain above freezing, but snow disrupts traffic in the hills streets about one to three times per year.

Flooding of streets and wadis is experienced during any significant rainfall because the steep slopes concentrate runoff very rapidly.

Mean daily temperatures vary from about 18 to 24 °C in the summer (May to October) to about 3.5 to 18 °C in winter (November to April).

In the Zarqa Valley conditions are drier, and slightly warmer at lower elevations of the valley. In the vicinity of As Samra northeast of Amman, precipitation averages about 150 mm annually, and seldom exceeds 250 mm. KTR in the Zarqa Valley north of Amman averages about 300 mm of annual precipitation with maximum rainfall around 450 mm.

2.1.4 Surface Water

The following sections summarize the finding presented in the Harza Study.

(1) Flow in Wadi Zarqa

Average annual flow in the Zarqa River above KTR averaged 65.8 MCM (2.09 m^3/s) for the period 1953 to 1980 and varied between 17.6 and 164.4 MCM. By 1980, these flows included an estimated wastewater return component, which has grown to 10 MCM. Assuming that wastewater in the period had doubled, thereby averaging 7.5 MCM over the 1953 to 1980 period. Natural flow in the Zarqa River would have been about 58 MCM/year.

In addition to natural flows, the total flow of the Zarqa River into KTR includes large wastewater return flows from As Samra plus smaller flows from Jerash, Abu Nuseir and Baqa. These effluent flows are increasing annually, so that the mean annual flow to KTR in 1995 totals 105 MCM/year from 58 MCM/year of natural flow and 47 MCM/year of wastewater effluent.

(2) Water Quality of Wadi Dhuleil and Wadi Zarqa

Treated wastewater discharged from As Samra Wastewater Treatment Plant to Wadi Dhuleil flows downstream to join the Wadi Zarqa near Sukhna. Treated wastewater has become an ever-increasing percentage of Wadi Zarqa flows since the construction of the As Samra Plant. In 1995, treated wastewater constituted about 55 % of the total inflow to King Talal Reservoir (KTR).

The water quality in Wadi Dhuleil, and the Wadi Zarqa has been monitored by the Royal Scientific Society (RSS) since 1986. The parameters analyzed included pH, electric conductivity (EC), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), boron (B), total coliform bacteria counts and total fecal coliform counts (TCC and TFCC), detergents (MBAS) and other parameters.

Harza conducted a water quality assessment of Wadi Dhuleil and the Zarqa River using monitoring data for the five-year period from 1990 to 1991. This assessment indicated the significant reductions in BOD_5 and ammonia occur between the As Samra Plant and KTR. The turbulent stream functions like an efficient biological reactor, resulting in nearly a 70 % BOD_5 reduction in 18 hours flow time between As Samra and KTR. About 12 % of the effluent ammonia is oxidized to nitrate. Analysis of data also showed that concentrations of nutrients, such as nitrogen and phosphorous, are not appreciable affected.

According to Harza the average salinity (measured as TDS) in the plant's effluent was 1,218 mg/l during the period from January 1990 to December 1994, and the maximum monthly salinity was 2,300 mg/l in August 1993. (The second highest monthly salinity was 1,490 mg/l.) For the same period, average salinity was 1,236 mg/l in the inflow to KTR and 1,137 mg/l at the outlet of the reservoir. Variation in the salinity downstream of As Samra Plant is mainly due to evaporation and fluctuation in annual runoff. The lower salinity reported by WAJ in the small effluents from treatment plants at Baqa, Jerash and Abu Nuseir averaged 1,153 mg/l with a total effluent flow of 3.2 MCM/year (1995).

(3) King Talal Reservoir (KTR)

King Talal Reservoir (KTR), which impounds the Wadi Zarqa, was originally constructed in the 1970's and has been raised to its current height of 108 m in 1986. It is located on the Wadi Zarqa about 40 km upstream its confluence with the Jordan River. King Talal Dam (KTD) comprises a rock fill dam, a gated spillway, and a power generating station KTR is about 6 km long, 0.2 km wide, with a full (reservoir surface elevation 180 m MSL) surface area of about 2.8 km². The reservoir has a flushing time of about one year, depending on the Wadi Zarqa flows and reservoir levels. Storage is decreasing due to sedimentation. Estimated storage in 1994 was 75 MCM. Since the primary objective of KTR is to support irrigated agriculture in the Jordan Valley, its storage volume fluctuates according to irrigation demand and annual fluctuations in runoff.

KTR has been designated as an irrigation water source in contrast to its original designation as a potable water supply. This is consistent with the recognition that many substances, objectionable for potable water sources are discharged into the tributaries of KTR from point and non-point sources.

(4) Zarqa River Downstream From KTR to the King Abdullah Canal (KAC)

The water released from KTR flows downstream the Wadi Zarqa. Abstractions for irrigation are made at Thahab Weir, approximately 11.5 km downstream from KTR. The remaining flow continues downstream to Hwarat Weir, where it is diverted through a pipeline to Abu Zeighan Canal, which conveys water to the King Abdullah Canal (KAC) south of Zarqa River (KAC-s). The KAC is the main irrigation supply for the Jordan Valley. It diverts relatively high quality water from the Yarmouk River in the north. At present, much of the water diverted from the Yarmouk is abstracted from the KAC north of the Wadi Zarqa (KAC-n) for irrigation, industrial use and by a water supply project that conveys water from the KAC-n near Deir Alla to the Zai Water Treatment Plant, which serves Amman.

Monitoring conducted by the Royal Scientific Society (RSS) indicated that the total fecal coliform bacteria count (TFCC) in the KAC at time exceeded the permissible limits set by Jordanian Standard 893/1995 (1,000 MPN/100 ml) both before mixing of KAC water with KTR water and in other locations along the KAC after the mixing had taken place. High bacteria counts typically began to occur during the month of June during 1991, 1992, 1993, and 1994. Consequently, RSS has recommended that the Jordan Valley Authority reconsider the use of water from KAC for unrestricted irrigation, as it might have adverse effects on the health of farmers and consumers.

2.1.5 Geology and Groundwater Resources

The outcropping rocks in the study area mainly consist of basalt, limestone, clay, and chalk. Soil cover is generally thin, although local topography has led to accumulation of wind-blow soils in numerous places. Valleys are generally filled with alluvial deposits of gravel, boulders, and pebbles. Terraces along the Zarqa River are apparent.

Proposed site for treatment plant construction is in the valley of the Wadi Zarqa. Geological conditions, which will need to be considered, are the seismic hazard, the potential instability of the recently deposited semi-consolidated soils in the valleys, instability of bedrock formations inter-bedded with marls and clays, and flooding.

The Amman-Zarqa well field extends from Amman, northwards along Wadi Amman-Zarqa to about 30 km northeast of Amman, and at least 560 wells were productive in the area in 1997 (200 in 1982). The Amman-Zarqa basin has an estimated safe yield of about 8.8 MCM/yr. However there is a severe overdraft estimated at 87 MCM/yr in year 1993, mainly from meeting the irrigation requirements.

Groundwater in Amman-Zarqa Basin occurs in three aquifer systems:

- The Upper Aquifer System
- The Middle Aquifer System
- The Lower Aquifer System

Two sub-basins are distinguished due to the occurrence of the lava flow: the Wadi Dhuleil Basin, where the Basalt is covering most of the area, and the Zarqa Basin, where basalt does not occur.

2.1.6 Land Use of Project Cities

Zarqa Governorate is served by a number of municipalities that decide for the land uses and issue licenses for different uses, and also plan and serve the land uses of all lands within the municipalities borders. According to Harza Study (August 1996) the land use is designated according to four categories or zones of residential use, ranging from Zone A (the largest lot sizes) to Zone D (the smallest lot sizes). There are also commercial, industrial, public and agricultural classifications. Greater Amman Municipality, where the same functions are followed, serves Tariq and Marka, being part of Greater Amman. Figure 2.1.6-1 and Figure 2.1.6-2 show the land use for Amman and Zarqa areas.

Additionally, Marka has a very specific and dominant land use (as shown in Figure 2.1.6-1) of mostly residential areas and more specifically class D and popular residents. Russeifa is similar to Marka in terms of the land use, where most of it is class D and popular residents. Figure 2.1-3 shows a brief of the land use for Zarqa area including Russeifa and Hashimiya as residential areas of different classes, where most of them range from popular to commercial, industrial, public gardens, private use, oil refinery, and finally areas that are not zoned.

According to the National Soil Map and Land Use Project for Jordan, the land use for Hashimiya, and Zarqa can be determined separately although most of the uses are common between them. The land use ranges from urban and associated non-agricultural land (built-up areas, quarries and mines), to non-vegetated and sparsely vegetated land (basalt, bare rocks), to open field crops and fallow lands (rain-fed areas with a very low intensity of < 35 % cropping), and finally to ancient villages and archeological sites.

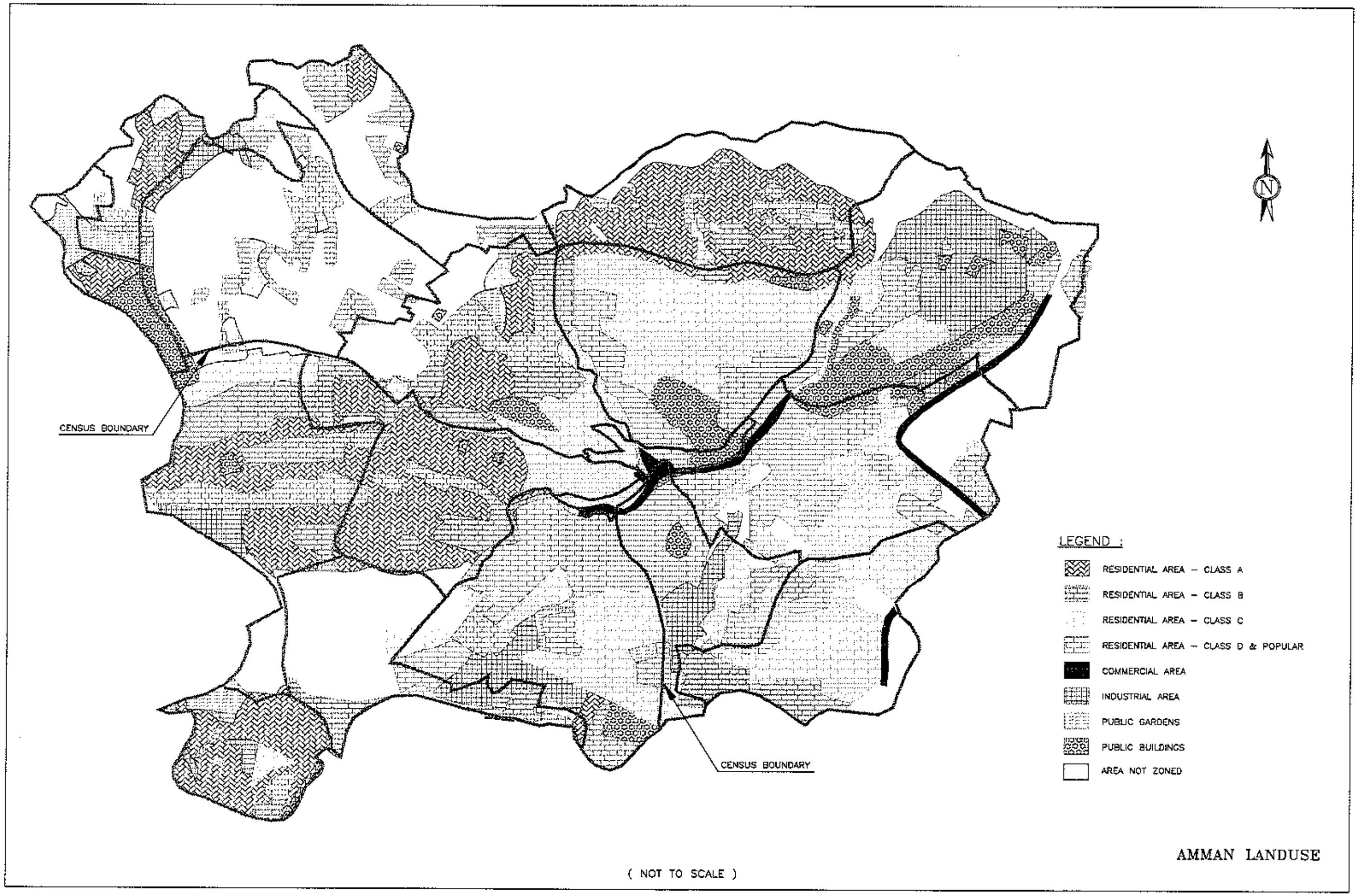

Figure 2.1.6-1 Land Use in Amman Area

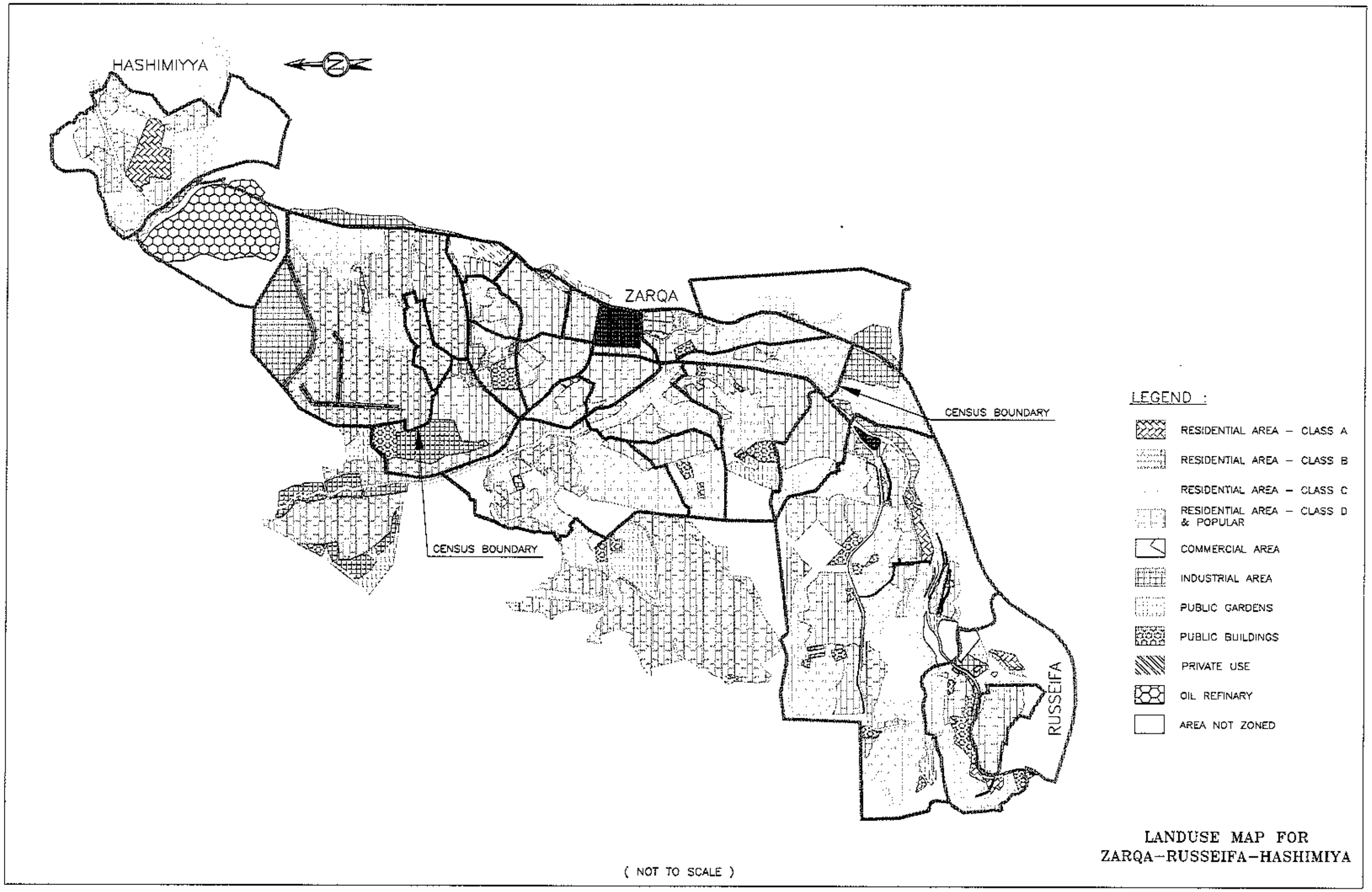

Figure 2.1.6-2 Land Use in Zarqa Area

2.2 Existing System of Sewerage, Sewage Treatment and Disposal

2.2.1 General Layout

The existing sewerage system in the Amman-Zarqa River Basin area (discharging wastewater to the As Samra Treatment Plant) includes three adjacent, but distinct sewerage systems (see Figure 2.2.1-1):

Amman (in Zarqa basin)
About 65 % of the wastewater discharged to As Samra Treatment Plant is collected by this sewerage system and discharged via Ain Ghazal Pre-Treatment Plant (AGTP) to the plant. The sewerage system covers the Municipality of Amman, Jubeiha, Tela'a Al Ali, Khilda, Umm El Soumaq, Marj El Hammam, Abu Alanda, Quweismeh, parts of Wadi Essir and parts of Sweileh. Sewage is discharged by a siphon (DN 1200, 38 km) to As Samra. Total length of the trunk mains network tributary to Ain Ghazal is approximately 270 km.

Russeifa-West Zarqa Sewer System
This area contributes by about 28 % of the sewage discharged to As Samra Plant. To this sewerage system belong the northeastern part of Amman (Tariq and Marka), the community of Russeifa and West-Zarqa. Flow collected by the Russeifa-West Zarqa system drains by gravity to the West Zarqa Pumping Station. This station pumps into the siphon to the As Samra Plant. Total length of trunk mains of this sub-system is about 50 km.

East Zarqa-Hashimiyya Sewer System
About 7 % of the wastewater treated in As Samra is collected in this system serving areas of East Zarqa and Hashimiyya. The network discharges the sewage by gravity to the Hashimiyya Pumping Station. The station pumps wastewater directly to As Samra via a DN 500 force main. Total length of trunk mains is about 30 km.

The existing collection system (separate system) in Zarqa/Russeifa area consists of main sewer trunk lines of diameters ranging from 300 to 1200 mm in addition to the collection network predominantly 200 mm in diameter. The area lies in one basin that drains naturally to Wadi Zarqa and eventually to King Talal Reservoir. Nevertheless, the existing configuration and services split the area into three major sub-systems (see above), where flow from each portion of the collection systems is discharged into the system terminating at As Samra Plant. Two of these systems are in the area of this study (Russeifa-West Zarqa and East Zarqa-Hashimiyya Sewer System). In addition to this the fourth system, which is planned to be in place in the near future, proposes to serve Sukhna area by pumping the collected wastewater to West Zarqa pumping station. Figure 2.2.1-1shows the area tributary to the proposed Wadi Zarqa Treatment Plant.

The features of these three systems are described in the following sections.

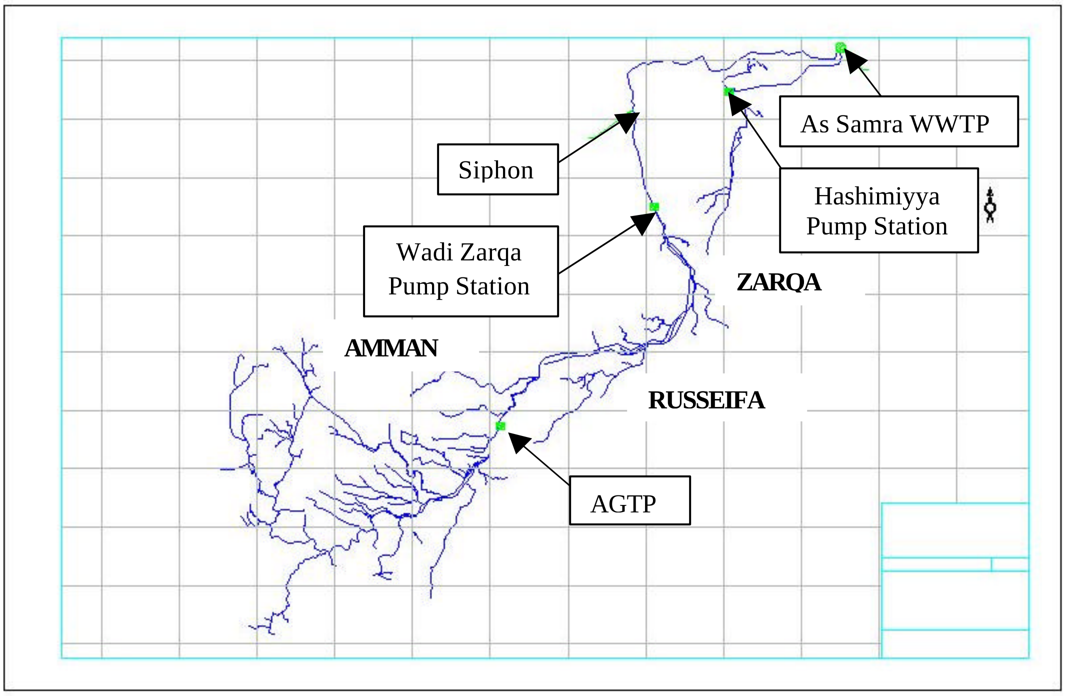

Figure 2.2.1-1 Existing Trunk Sewers and Conveyance System

The main components of the wastewater management system for Zarqa consists of:

- the collection system (which receives flows from the collector of Marka and Tariq systems of Amman, West Zarqa/ Russeifa and East Zarqa/ Hashimiyya),
- the conveyance system,
- the pumping stations, and
- the treatment facilities at As Samra site with the sludge disposal system.

The conveyance system components are:

- the siphon from AGTP to As Samra, the West Zarqa pumping station with the force main and
- the Hashimiyya pumping station with the force main.

2.2.2 Sewerage System

2.2.2.1 West Zarqa System

This system covers the area located northeast of Amman and consists mainly of Russeifa and West Zarqa, in addition to northeastern parts of Amman Tariq and Marka. The flow collected by this system drains by gravity to West Zarqa Pumping Station, where the wastewater flows are pumped into the existing siphon conveying the wastewater to As Samra Plant. The total amount of the wastewater generated from the areas served by this system accounts for 24 % of the total flow to As Samra Plant.

The trunk sewers in this system are 300 to 1000 mm in diameter, with a total length of approximately 65 kilometers.

(1) Collection Network in Marka and Tariq

Wastewater from part of Marka and Tariq is discharged by gravity to West Zarqa system as these parts are located and drain naturally beyond Ain Ghazal catchment area.

The collection system in this area is predominantly consisting of concrete pipes with diameters of 200 and 300 mm with main trunks in the Wadis of 400 and 500 mm. The collection system is relatively new, being in place for less than 15 years on average. Field investigations performed by Harza Team and LEMA (Consortium of Suez Lyonnaise des Eaux – Montgomery Watson Arabtech Jardaneh responsible for sewerage system) indicate that the sewers are in a good conditions due to the normal slopes employed except for some manholes in wadis where silts and debris are accumulated which necessitates frequent maintenance. Currently, the capacity of the sewers in this area can carry the estimated dry weather flows until the year 2005 without significant changes.

(2) Collection Network in Zarqa

The wastewater services in the area started in mid eighties. Parts of the Zarqa drain by gravity to the West, where as the rest drains to the east.

The collection system in this area predominantly consists of concrete pipes with diameters of 200 and 300 mm. Other hydraulic analyses of the capacity of the existing collection system, showed that most of these branches leading to the main trunk sewers have adequate capacity to convey dry weather flows. Although the collection system is relatively new, being in place for less than 15 years, field investigations performed by Harza Team indicated that some manholes in Wadis have accumulation of silts and debris necessitating frequent maintenance. This fact was also supported by the maintenance department in Zarqa Water Administration. Additionally, in flat areas, with low slopes, surcharging incidences during peak hours are witnessed. Currently, the capacity of the sewers in this area can carry the dry weather flows until the year 2005 without significant changes except for the main trunks where measures have to be taken in the near future.

(3) Collection Network in Russeifa

The collection system in Russeifa consists of laterals of 200 mm in diameter, with the main trunk passing through the area conveying the wastewater from Schneller Camp and parts of Greater Amman area. The collection system is in a good condition while the main trunks need an immediate expansion or enlargement to carry the wastewater generated from the tributary area.

Low slopes in some areas cause frequent blockages resulting in sewage overflows into Wadis. Currently, WAJ is in the process of tendering works to replace and reinforce some of these mains.

2.2.2.2 East Zarqa System

The developed area in East Zarqa and the town of Hashimiyya is served by this system. Flow is collected and conveyed by gravity to the Hashimiyya pumping station and pumped directly via a 600 mm diameter steel iron force main to As Samra Plant. The total amount of wastewater generated in the areas served by this system accounts for 20 % of the wastewater generated in the Zarqa/Russeifa area and only 6.2 % of the current flow to As Samra Plant. The trunk sewers in this system are 300 to 800 mm in diameter, with a total length of 30 kilometers.

(1) East Zarqa Collection System

The collection system at East Zarqa area was constructed in the eighties together with West Zarqa area and other systems. The same conditions faced in other areas were faced in this one, too. Some flat areas suffer from frequent blockages resulting in street overflows; this situation necessitates proper maintenance of the system especially the preventive maintenance.

(2) Hashimiyya Collection System

The town of Hashimiyya located to the northeast of Zarqa is served by a wastewater collection system where the wastewater is discharged by gravity to the lowest point of the town, where the East Zarqa area also terminates its wastewater at Hashimiyya pumping station. The main trunks conveying the wastewater from East Zarqa passes through Hashimiyya area. Low water consumption doesn't allow for self-cleansing velocities to be maintained which results in silts and debris accumulation in the network. Such situation enhances the hydrogen sulfide production, which reduces the life of the sewers. The BOD_5 concentration at Hashimiyya pumping station measured by WAJ laboratories indicates values higher than any waste in the country reaching 1,500 mg/l.

2.2.2.3 Sukhna Area

This area consists of the town of Sukhna and Sukhna Refugee Camp. Currently there are no wastewater collection systems. Wastewater disposal relies mainly on septic tanks and cesspits of private buildings. Presently, the Water Authority of Jordan, through the Ministry of Planning is preparing for consultancy services to serve this area by sewerage systems. According to existing Feasibility Studies of the area sewage of Sukhna will be pumped to the West Zarqa Pumping Station as a temporary measure until the year 2008. Later the three systems mentioned above will be served by a separate treatment plant (Wadi Zarqa Wastewater Treatment Plant) some 15 km downstream of Sukhna. By that time, the new plant at Wadi Zarqa will replace the two existing pumping stations and the new Sukhna pumping station, where the whole flows will be conveyed by gravity to the new plant.

The collection system and laterals are already designed and ready for tendering through the Ministry of Public Works and Housing, where the design of the main conveyor and the pumping station will be tendered by WAJ by June 2001. This project component will be financed under an Italian financial cooperation.

2.2.2.4 Summary on Physical Conditions of the Collection System

According to Harza Study of 1997, field visits, and interviews with employees of the Operation and Maintenance Department at Zarqa Governorate's Water Administration, and LEMA for Tariq and Marka area, the physical conditions of the collection systems are good. Very minor hydrogen sulfide damages are reported and are limited only to Zarqa area due to minimum slopes in some sections.

Although the existing sewer network and mainly the main trunks can handle the dry weather flows, silts and debris should be removed from some segments in order to accommodate the peak flows. However, most of the existing mains need to be enlarged to accommodate the future flows. Table 2.5.4-1 shows the lengths of segments to be enlarged in different years. The table also illustrates the diameters as well as the investment needed in different years split in 5-year intervals.

2.2.2.5 West Zarqa and Hashimiyya Pumping Stations

(1) West Zarqa Pumping Station

A. Description of Facilities

The West Zarqa pumping station is located beside Wadi Zarqa. It was built in 1985 and was originally designed to inject flows from Zarqa and Russeifa into the siphon for conveyance to As Samra. It comprises two pumps with a rated pumping capacity of 47,000 m^3/day. In 1991 two wet well pumps were added to the existing ones in order to increase the pumping capacity to the ultimate level, being around 72,000m^3/day.

The main facilities existing in the pumping station are:

Component	Description
Manually cleaned bar screens	Two 80 cm wide screens, 4 m long 5 cm screen openings.
Mechanically raked bar screens	Two 120 cm wide screens, 5 m long with 12 mm bar spacing.
Parshall flume	One flume without a level sensor.
Aerated grit removal channels	Two 2.5 m wide channels, 6 m long, 4 m deep.
Blowers	Four units, rated 115 m3/h at 6 psi.
Comminutors	Two units.
Wet wells	Original: One 8 m long, 3 m wide, 4.7 m deep. Added in 1991: Two 4 m long, 4 m wide, and 4.7 m deep.
Pumps	Four units rated 972 m^3/h at 120 m head at speed of 1,470 rpm.
Motors	Four 450 kW electric motors with variable speed drives.
Standby generators	Two 1,000-kVA generator- engine sets.
Discharge flow meter	One magnetic meter.
Attenuation Pond	10,000 m^3 capacity, polyethylene lined equipped with air diffusers and a compressor.

The flow from Tariq and Marka areas of Amman, Russeifa, and the western part of Zarqa enter the West Zarqa pumping station through a 1000mm diameter sewer line. The total inflow to the station, after passing the bar screens is recorded by a Parshall flume. Before entering the pumping station wet wells and after the flume, the wastewater passes through two aerated grit removal tanks. The wet wells are three with a total storage volume of 263 m^3. Then the flow is discharged through a 700mm diameter discharge header, which splits into two 700mm diameter. The discharge from the station is monitored by a magnetic flow meter.

In the year 2000, an aerated attenuation pond of a capacity of 10,000 m^3 was constructed to balance the excess flows in peak hours, where air is provided through air compressors to prevent odor generation while the wastewater is stored.

The pumping equipment at the West Zarqa pumping station is rated for a discharge head of 120 m with a normal operating head range of 90 – 110 m. Two by-pass pipes of 800 mm in diameter are also available to by-pass the peak winter flows (stormwater) to the adjacent wadi if needed.

B. Physical Condition of Facilities

Most of the time, in the West Zarqa pumping station only one pump is in operation. In order to match the peak flow, two pumps are operated for 4 – 5 hours a day. A third one is used to manage the peak flow during wintertime. The other equipment like the Parshall flume flow meter is not operational due to the lack of an appropriate level sensor. The bar screen is operated although it is subject to excessive accumulation of screenings at the bottom of the unit during the period of high flow. As for the grit removal facilities, although operable, their effectiveness is low due to frequent clogging. The quantities of removed grit averaged in the year 2000 at 10 m^3/day.

New electrical panels were installed to replace the old panels. In addition to the new electric generators capacity of 1000-kVA, a new small generator was installed to take care of the lighting.

C. Hydraulic Capacity of Facilities

The rated pumping capacity of the pumps at the West Zarqa pumping station is 70,000m^3/day at 120 m Total Dynamic Head (TDH), while the historic data indicate only 52,800 m^3/day as the maximum pumping rate. So, the actual capacity of the pumps under normal siphon operating conditions must be verified by conducting field tests of the existing pumping equipment.

D. Operation of West Zarqa Pumping Station

The discharge flow rate of the West Zarqa pumping station is controlled by the wastewater flow rates into the siphon at Ain Ghazal. The reason is that the elevation of the siphon inlet is higher that the elevation of the shutoff of the Zarqa pumping station (680 to 663 m). So the system operator at Ain Ghazal controls the discharge of the pumping station. That means there should be a continuous coordination between the two operators. The operator at the West Zarqa pumping station should direct the operator at Ain Ghazal of when to divert the water to the siphon and when to store the wastewater especially during

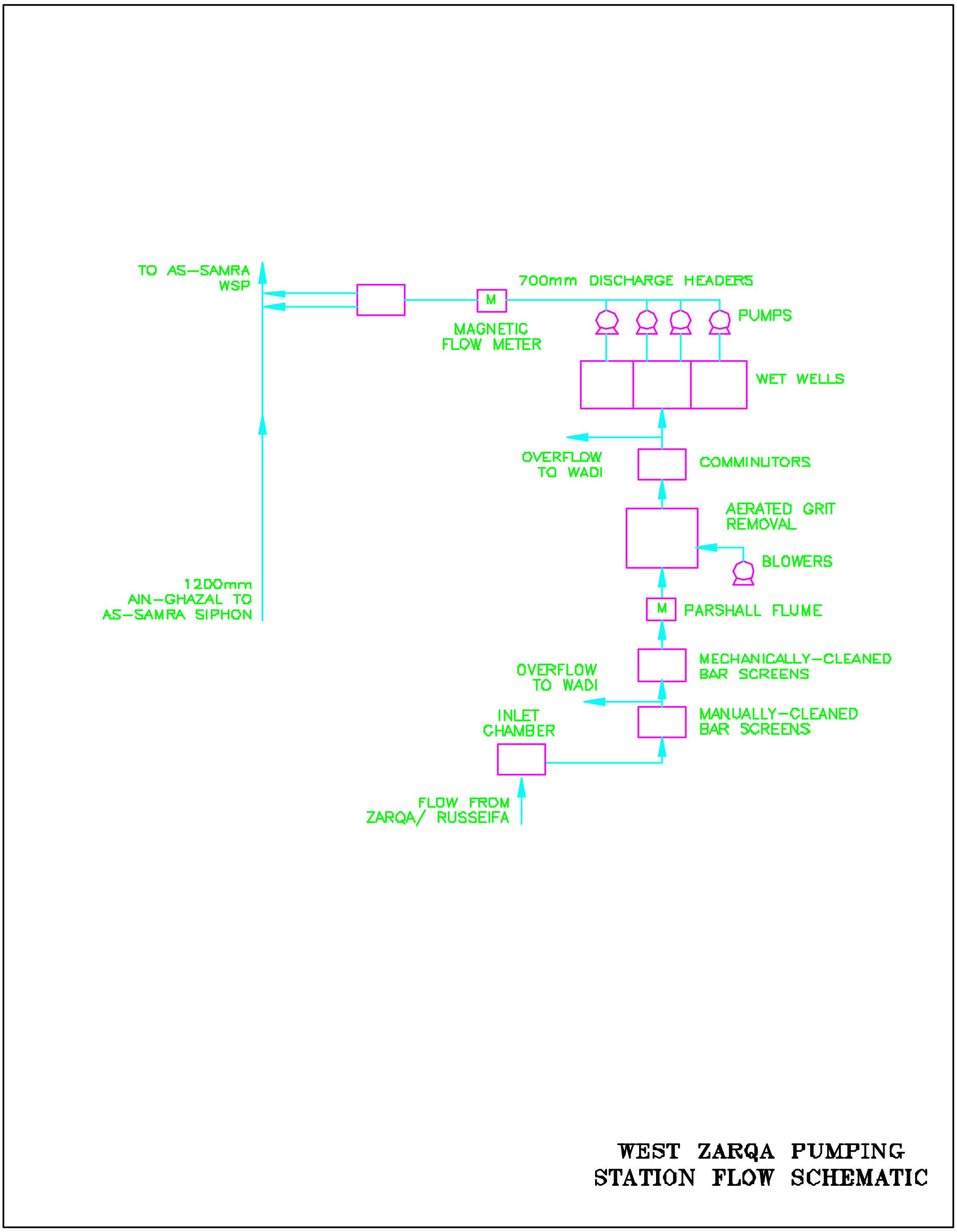

Figure 2.2.2-1: West Zarqa Pumping Station

the peak time. This mode of operation will be changed after operating the new 1500-mm new siphon. The flow from Ain Ghazal will then be conveyed to As Samra separately and the old siphon will be used only to pump the wastewater from Zarqa pumping station. Such an arrangement necessitates the installation of a surge tank to take care of the water hammer in case of energy failure at the station. This is indeed needed for the period until the new Wadi Zarqa Treatment Plant is constructed. After construction of the new plant this pumping station will be abandoned.

The facilities at the station are connected to a computerized system, which allows for their control and monitoring from the data room.

Figure 2.2.2-1 shows a schematic drawing with the main facilities at this pumping station.

(2) Hashimiyya Pumping Station and Force Main

A. Description of Facilities

The Hashimiyya pumping station was constructed in 1988. This pumping station and its force main conveys the wastewater from East Zarqa and Hashimiyya to the inlet of the As Samra wastewater treatment plant. The pumping station was constructed with a design capacity of 40,000 m^3/day. It is located 8 km north of Zarqa and 7 km west of As Samra wastewater treatment plant. There are three pumps with an installed capacity of 30,000 m^3/day and a firm capacity of 20,000 m^3/day. The design capacity of the pumping station is 50,000 m^3/day; a level that needed the installation of two more pumps to be reached. All pumps are operated by electric motors, but in case of emergency the pumps can be operated by a diesel engine.

The major equipment in use at the Hashimiyya pumping station is described below (see Figure 2.2.2-2):

Component	Description
Mechanically raked bar screens	Two 1 m wide rotary screens
Parshall Flume	One flume without sensor
Wet well	One well 9 m x 4 m, 3.5 m deep One well 11m x 4 m, 3.5 m deep
Pumps	Three horizontal pumps rated 420 m^3/h at 88 m head at a speed of 1,475 rpm Two vertical pumps KSB rated 4,000 m^3/h at 88 m head at speed 1,450 rpm
Diesel engines	Two manually operated units rated 283 kW at 1,500 rpm
Motors	Two 315 kW electric motors
Generator	New 1999 generator 1,450 kVA
Transformers	Two 500 kVA

The wastewater arriving at Hashimiyya pumping station enters the facilities through an 800 mm diameter trunk sewer that serves East Zarqa and Hashimiyya. The wastewater is then directed through a parallel set of mechanically raked bar screens to a Parshall

Flume and into the pumping station wet wells. There are two wet wells connected to a sluice gate. Three pumps draw from one wet well and the other two pumps draw from the other wet well. Then the wastewater is discharged via a 600-mm force main, which runs 7 km to As Samra Wastewater Treatment Plant. The flow is estimated from the pump run time and rated capacity because of the lack of operative flow meters.

The rated total discharge head for the pumps at the Hashimiyya pumping station is 88 m, while the pump curve data for the pumps indicate a normal operating range between 82 and 91 m of head. When the inflow to the Hashimiyya pumping station exceeds the capacity of the equipment, the excess flow can be diverted to Wadi Dhuleil through an 800 mm overflow pipe located upstream of the flow entrance to the pumping plant.

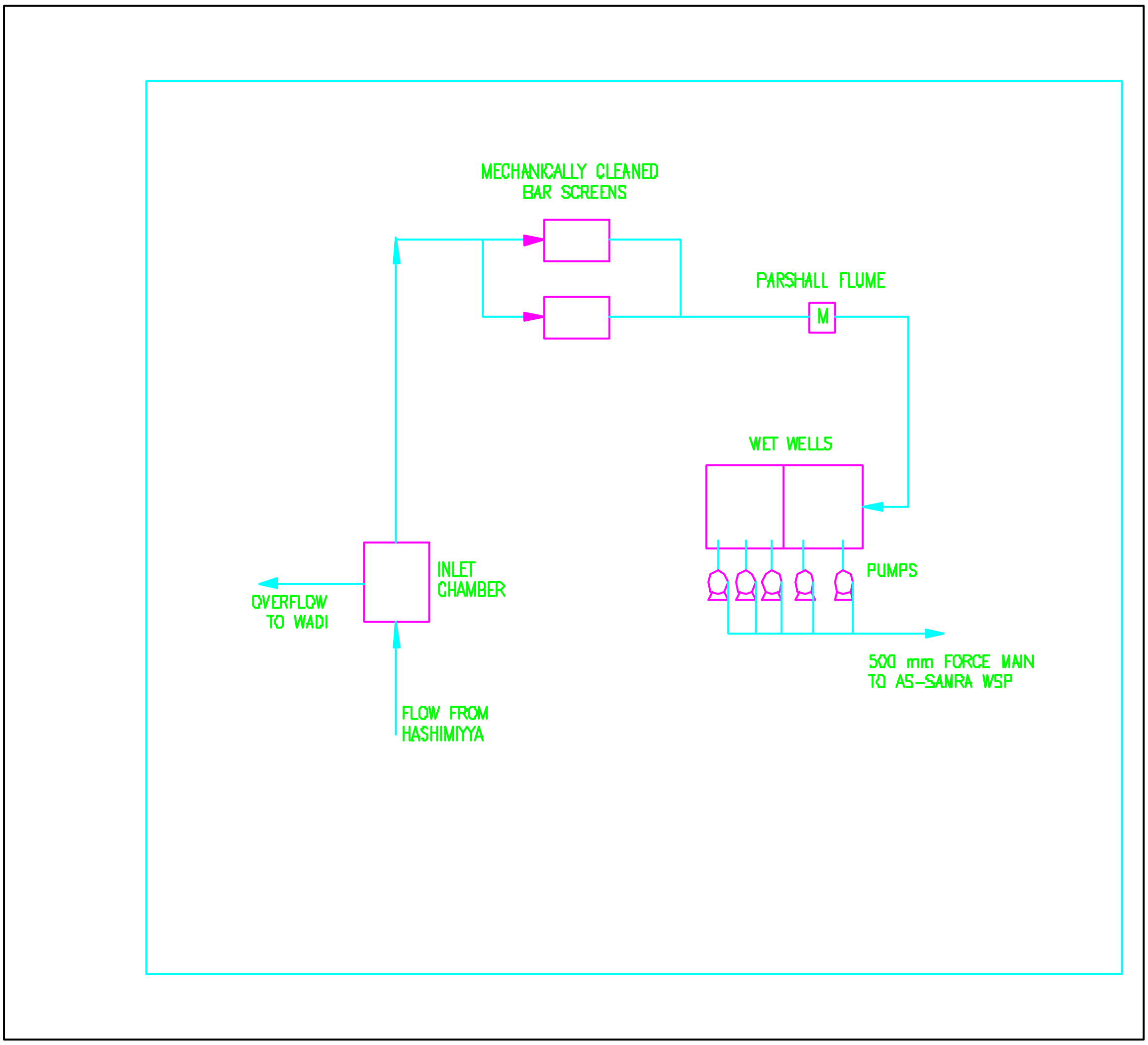

Figure 2.2.2-2: Hashimiyya Pumping Station

B. Physical Condition of Facilities

All the facilities at the Hashimiyya pumping station including the pumps are operative and in a good condition but are in need for maintenance. The only equipment, which is not operational, is the flow meter because of the lack of a flow depth sensor.

There is no grit removal facility at the station. Absence of such installation is believed to adversely affect the conditions of the force main by damaging the lining.

C. Hydraulic Capacity of Facilities

The firm pumping capacity at the Hashimiyya pumping station was approximately 20,000 m^3/day, which was also determined from the system head curve with two pumps operating. WAJ records indicated that the peak discharge rates at the station were around 31,000 m^3/day with three pumps operating.

The installation of the new pumps allowed for operating 4 pumps in parallel and increased the total peak pumping capacity by a marginal percentage; this is due to the limited force main capacity, which was believed to be reduced because of the friction losses.

Figure 2.2.2-2 is a schematic drawing showing the main facilities at this pumping station.

2.2.3 Industrial Wastewater

2.2.3.1 General

Most of the industries in Zarqa, Russeifa, and the areas draining naturally (by gravity) into Zarqa pumping stations are concentrated in Marka and Zarqa areas. While most industries use piped water for drinking and sanitary purposes, the majority of the industrial water supply (process water) is from private wells.

There are about 21 major industries in the Zarqa area that discharge their industrial effluent to the public sewers.

In terms of both flow and pollutant loading, industrial wastewater generation is rather small compared to the domestic wastewater and pollution load generation in the study area. Industrial discharges into the wastewater system from the 21 industries connected to the public sewers in Zarqa amounted to 4,553 m^3/day, or 8.7 % of the flow to East and West Zarqa pumping stations in the year 2000. Industrial discharges from Amman/Zarqa basin amounts to 3.4 % of the total flow into As Samra Wastewater Treatment Plant (WAJ estimate in 2000), whereas the Hussein Thermal Power Station, for instance, discharges 54 % of the total industrial flow.

Figure 2.2.3-1 shows the major industries in Amman and Zarqa areas.

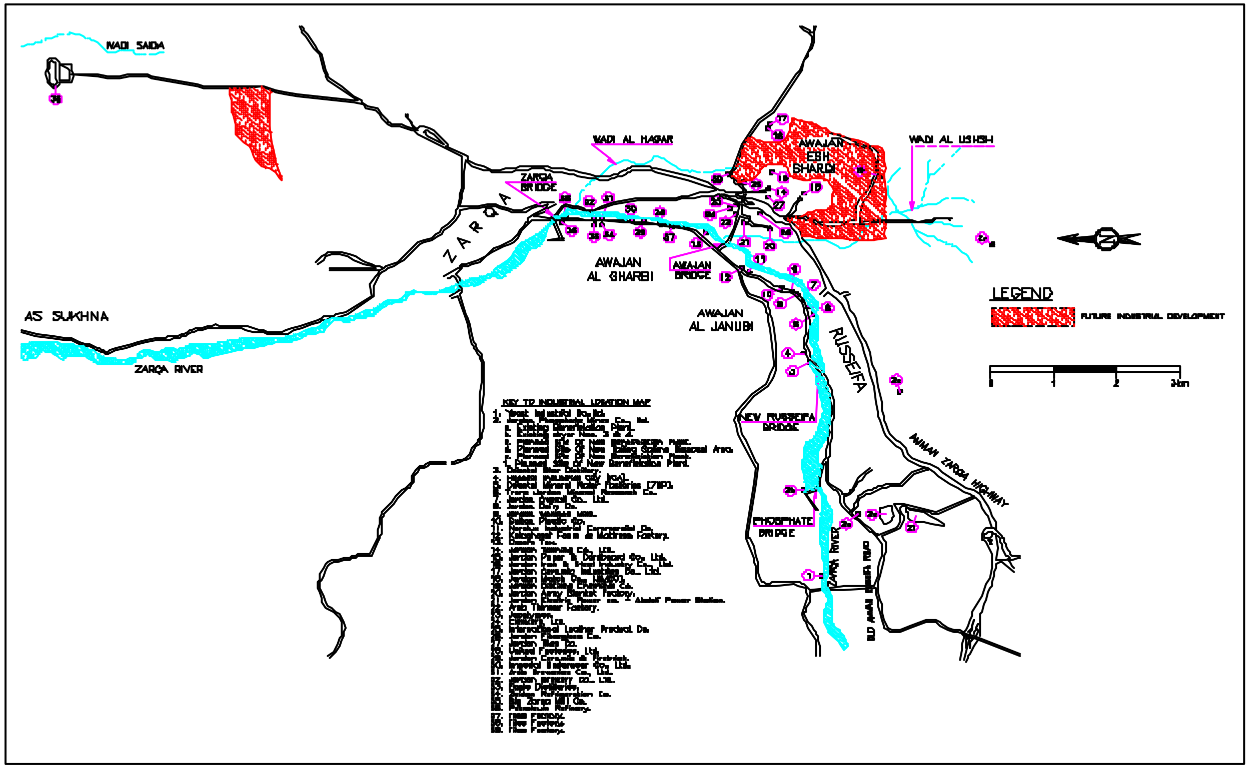

Figure 2.2.3-1 Industries in Zarqa

2.2.3.2 Monitoring, Control and Pre-Treatment Facilities

The Jordanian Effluent Standards (JS202/1991) taking into consideration the water supply used and the water body affected by the disposal, regulated industrial effluent discharges to waterways in 1991.

In order to guarantee a safe operation and use of the public wastewater collection and treatment systems, as well as a production of a final effluent suitable for reuse, regulations were issued by WAJ in 1988 for the discharge of the industrial wastewater into the public sewer system. These regulations were revised in 1998. Additionally, WAJ has implemented a Monitoring and Control Program whereby regular inspections and effluent sampling took place of industries connected to the public sewer system to ensure compliance with the standards (JS202/1991) and the 1998 regulations.

As a result, more than thirty industries in the Amman-Zarqa area were identified in 1991 as potentially hazardous to the environment and water resources. Since then, many of these industries have installed pre-treatment facilities for their effluents before they are discharged into the main sewer system.

2.2.3.3 Industrial Wastewater Discharges

WAJ's Monitoring Program stipulates that WAJ laboratories take monthly samples from the connected industries and estimate effluent flows. For some industries more than one sample is taken per month. Table 2.2.3-1 shows concentrations of organic and chemical constituents discharged by the connected industries (WAJ Report 2000). Loadings for these industries to be connected to the future Wadi Zarqa Treatment Plant are shown in the same table. Some industries eliminate their liquid effluent by evaporation, whereas others recycle the effluent and use the water. These industries are reported to have zero flows. Table 2.2.3.-2 shows a comparison between the loads of industries and the Zarqa pumping stations influent flows. The present (in 2000) industrial BOD_5 and COD contributions are estimated at around 1.0 % and 2.2 % respectively of the total at the stations.

Reports by WAJ and the RSS showed that the heavy metal loads from the industries are small. Supporting this fact is the analysis of As Samra sludge of the year 1993. A reasonable expectation would be for the future industrial discharges to remain a small proportion of the total flow, and the characteristics of the combined wastewater to be pre-dominantly domestic in nature. Such conditions will require WAJ to pursue their endeavors enforcing the regulations regarding the metals and toxic materials discharge.

A review of the industrial pre-treatment program indicated that it would be more cost effective for most industries, particularly food industries, to discharge directly into the sewers without pre-treatment. This is because their wastewater characteristics are compatible with the biological secondary process appropriate for domestic wastewater.

Table 2.2.3-1: Pollutant Loading from Industries Connected to the Public Sewers in the Zarqa Area

No.	Factory	Indust. type	Q (m^3/d)	BOD_5 (kg/d)	COD	TSS	TDS	NH_4-N	PO_4-P	ABS	B	Cu	Cr	Pb
1	Jordan Dairy Co.	Food	170	70.4	174	28.9	344.85	.006	2.4	-	-	-	-	-
2	Jordan Beer Comp.	Food	100	15.2	32.8	4.70	66.8	0.16	2.5	0.02	0.06	-	-	-
3	Arab Beer Comp.	Food	50	11.5	22.9	3.70	103	0.08	0.3	-	-	-	-	-
4	Eagle DistilleriesCo.	Food	150	140.8	1,282.6	59.93	478.5	16.24	.91	1.05	0.084	-	-	0.03
5	Mudieb Haddad & Sons. Co.	Food	15	7.02	13.0	3.87	21.3	0.17	0.32	0.04	-	-	-	-
6	Zedan IceCreamCo.	Food	25	11.7	21.6	6.45	33.0	0.28	0.53	0.06	-	-	-	-
7	Jabri Factory/Zarqa	Food	45	2.07	5.63	2.12	49.5	-	-	134	-	-	-	-
8	Rasha Juice Co.	Food	Zero	-	-	-	-	-	-	-	-	-	-	-
9	Sanabel Dairy Co.	Food	Zero	-	-	-	-	-	-	-	-	-	-	-
10	The Jordanian Worsted Mills Co.	Textile	300	107	384	43.8	334	2.39	5.52	1.39	0.20	-	0.01	-
11	Karemtex Co.	Textile	60	7.44	16.0	5.52	125	0.2	-	0.81	0.04	-	-	0.03
12	Imperial Co.	Textile	10	1.86	4.11	1.09	21.6	0.04	0.08	0.10	0.01	-	-	-
13	Jordan Tanning Co.	Textile	300	27	139.84	83.33	3,543	31.8	4.8	1.10	0.30	-	0.22	-
14	Blankets Factory	Textile	80	3.68	13.4	5.68	87.8	1.05	0.17	0.14	0.03	-	-	0.01
15	Jordan Spinning & Weaving	Textile	8.0	2.46	10.5	1.58	33.1	0.06	0.10	0.04	0.01	-	-	-
16	United Factories Co.	Chemical	10	43.0	113	10.0	47.6	1.92	0.22	-	-	-	-	-
17	Liquid Batteries Fact	Chemical	Discharge to zero in 1996			--	-	-	-	-	-	-	-	-
18	Al-Naja Soap Factory	Chemical	Zero	-	-	-	-	-	-	-	-	-	-	-
19	Industr, Commerce, Agric. Co.		110	35.95	89.55	26.51	238.7	0.61	0.62	-	0.68	-	-	-
20	Jordan Co. for Metal Coating	Metals	Zero	-	-	-	-	-	-	-	-	-	-	-
21	Hussein Thermal Power Station	Electricity	3,120	65.5	331	309	3,249	4.05	5.00	3.75	-	-	-	-
	Total		4,553	553	2,653	596	8,777	59.1	23.5	142.5	1,414	-	0.23	0.07

Table 2.2.3-2: Domestic and Industrial Wastewater Loading at Zarqa and Hashimiyya Pump Stations (2000)

Parameters	Zarqa Service Area		Load of Industries in Zarqa Area Connected to Public Sewers	
	(mg/l)	(kg/d)	(kg/d)	(% of total)
BOD_5	1,050	54,705	552	1.0
COD	2,310	120,351	2,654	2.2
TSS	950	49,495	596	1.2
TDS	1,200	62,500	8,777	14.0
NH_4-N	95	4,949	59.06	1.19
PO_4-P			23.47	-
ABS			142.5	-
B	0.7	36.5	1.414	3.87
Cr			0.23	-
Pb			0.07	-
Flow(m^3/day)	52,100		4,553 (8.7 % of Zarqa/Hash. P. Stations)	

In conclusion, the industrial loads in the area is quite low. Over the last years, observations revealed that these loads in comparison with the domestic loads are decreasing because the expansion of the industries in the area is not allowed and, in addition, the portion of the domestic wastewater increases.

Of major concern is the TDS accounting for 14 % of the total load. Conventional treatment of wastewater doesn't reduce the salinity of the wastewater. In addition, existing concentrations do not exceed the Jordanian Standards. Nevertheless, focus on this issue of TDS has to be continued and measures have to be taken to alleviate the effect of salinity on the effluent use. Salinity (expressed as Total Dissolved Solids (TDS) concentrations in mg/l) is an important parameter for wastewater reuse for agricultural irrigation.

In the sewage influent, salinity primarily originates from: water supply TDS, human beings metabolic activities contribution to the TDS, industrial TDS, and other domestic usages. Zarqa is supplied by drinking water from sources with relatively high salinity. For example, Russeifa wells had a TDS of 660 mg/l, and at Khaw pumping station, where mixing water from different sources takes place, the TDS is in the range of 650 mg/l.

2.2.4 Treatment Facilities

Wastewater of the cities of Amman, Zarqa, Russeifa and Hashimiyya is presently treated in the As Samra Wastewater Treatment Plant (see Figure 2.1.1-1). In addition, thickened sludge of the treatment plants in Abu Nuseir, Baqa, Fuhis, Salt and Wadi Essir is transported by tankers to Ain Ghazal pre-treatment plant and conveyed together with the raw wastewater of Amman to the As Samra plant.

The wastewater stabilization pond system (anaerobic, facultative and maturation ponds of in total 181 ha) of As Samra plant is currently only adequate to meet the basic wastewater needs of half a million people. The plant is totally overloaded by a wastewater flow, which is exceeds the design flow by about 150 %. It has no nitrogen removal capability. In addition, the existing treatment plant lacks basic facilities for sludge management. The sludge in the anaerobic ponds was removed only once in 15 years, which is by far too less. Figure 2.2.4-1 shows a schematic layout of the As Samra Treatment Plant. In Annex 2.2.4 some additional information on the sewerage and treatment system As Samra is summarized.

The exposed deficiencies of the treatment plant result in effluents of poor quality, only partially treated wastewater. Formerly existing odor problems have been reduced partially by measures of deodorization at the inlet structure. Nevertheless, significant improvements, both in terms of capacity and level of treatment, are required just to overcome the existing deficiencies at the site.

The effluent of the plant is discharged to the Wadi Dhuleil, which joins the Wadi Zarqa, the major tributary to the King Talal Reservoir. The quality (> 100 mg BOD_5/l) is quite unsatisfactory. Effluent does not meet the requirements according to the relevant Jordanian Standard 893/1995 for discharge to wadis and catchment areas.

One of the main tasks for operation and maintenance of a stabilization pond system is the regular desludging of the ponds, in particular the anaerobic ponds, which is obviously not done in As Samra in an adequate manner.

The Ministry of Water and Irrigation intends to construct new treatment facilities in As Samra applying the Build-Operate-Transfer (BOT) method. The project of As Samra includes design, construction and operation and maintenance of a new treatment plant with tertiary treatment capability for a projected average daily capacity of 267,000 m^3 per day as well as take-over, operation and maintenance of the existing ponds with a current average flow of 170,000 m^3. Additionally, the contract will comprise the takeover, operation and maintenance of the conveyor pipeline from Ain Ghazal to As Samra including the pretreatment facilities in Ain Ghazal. Tendering of the BOT-Project is presently under process (May 2001).

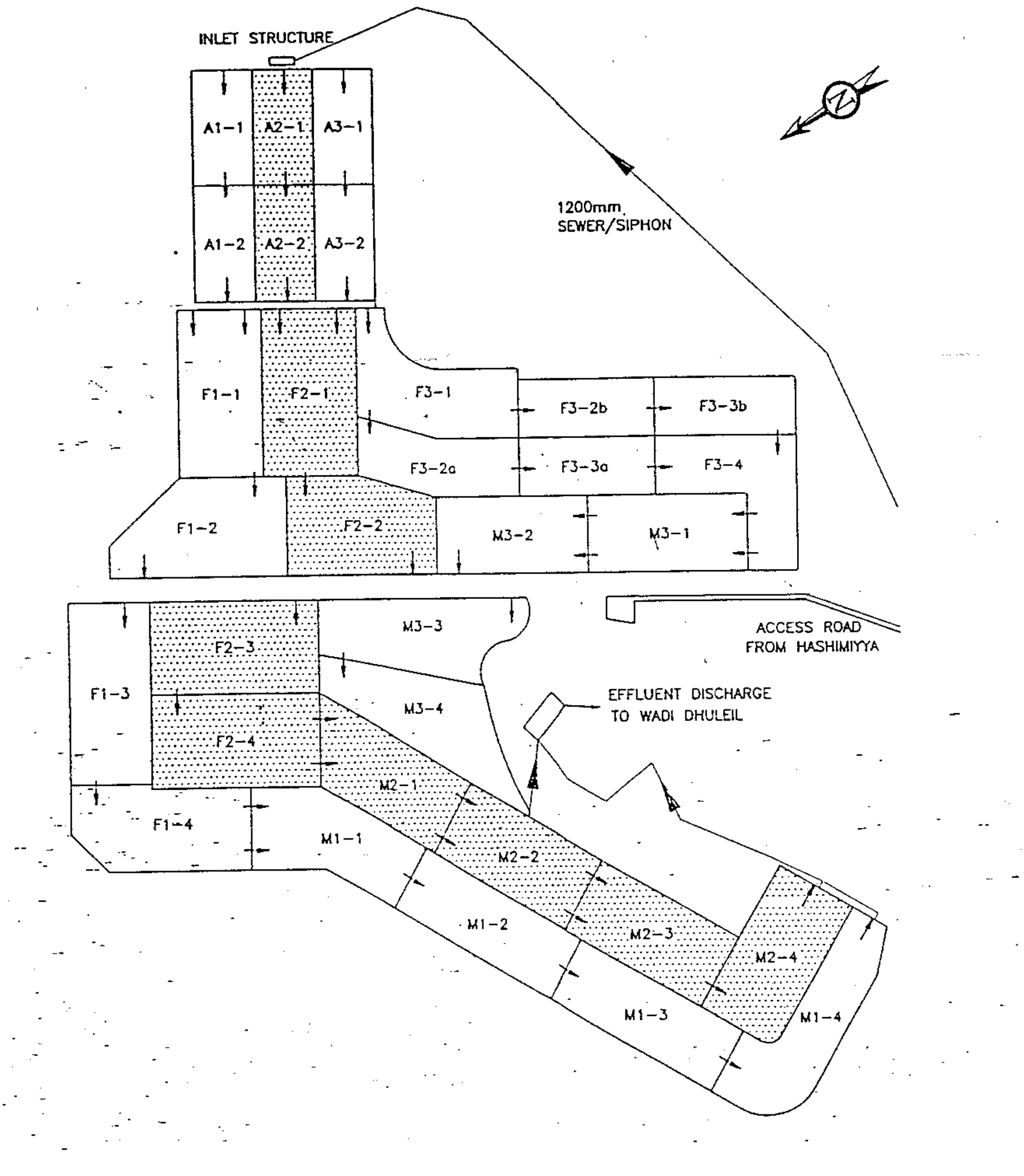

Figure 2.2.4-1 Schematic Layout of Existing As Samra Wastewater Treatment Plant

2.2.5 Effluent Disposal

Effluent of As Samra Treatment Plant is discharged to the Wadi Dhuleil, which joins the Wadi Zarqa, the major tributary to the King Talal Reservoir (KTR). Water of (KTR) is used for agricultural irrigation purposes in the Jordan Valley.

Presently, within the plant's area and downstream of it some 3,300 donums are irrigated by treated effluent of As Samra. This area is composed by 300 donums of fodder, 1,500 donums of olive trees and 1,500 donums of forests.

The effluent of the plant (> 100 mg BOD_5/l) is quite unsatisfactory. Effluent does not meet the requirements according to the relevant Jordanian Standard 893/1995 for discharge to wadis and catchment areas. Serious environmental negative impacts downstream of the treatment plant result of the remaining pollutional load of the treated wastewater (see section 2.1.4.2 also). The effluent can be reused for restricted irrigation only due to the high fecal coliform counts (> 100,000 per 100 ml).

2.2.6 Wastewater Quantities Generated in Project Cities

Table 2.2.6-1 below illustrates the wastewater generated from the tributary areas in cubic meters per day to the two existing systems and with an estimated figure for the proposed Sukhna area.

Table 2.2.6-1 Current Wastewater Generation

Tributary Area		Tributary Area (km^2)	Year 2000	
			m^3/d	MCM/a
West Zarqa System				
	Tariq and Marka		7,200	
	Russeifa		15,200	
	West Zarqa		19,100	
	Total for the System	71		(15.15)
East Zarqa System			10,598	
	East Zarqa and Hashimiyya			
	Total for the System			(3.87)
Sukhna (Estimation)		5	989	
Total				(19.39)

2.3 Design Criteria

2.3.1 Wastewater Collection

The design criteria for the wastewater collection system were primarily set for the purpose of eliminating surcharging and overflow within the sewer network and to provide reliable operation and maintenance procedures.

The system capacity should also be capable of conveying dry weather peak flows, which are growing with population and water use. Therefore, the system capacity should be ahead of the growth of the projected flow.

WAJ has published in 1995 *General Technical Specifications for Sewerage Works*. It specifies general and technical requirements, excavation and earthwork, backfilling, concrete and reinforced concrete, pipes and pipe laying, manholes as well as the outline for bill of quantities.

The design criteria used by WAJ and the Consultants may be summarized as follows:

- Design conditions: Peak dry weather flow.
- Peaking factor: 2.4
- Manning's coefficient: 0.015 for concrete pipes and 0.013 for steel and ductile pipes.
- Design flow to full capacity ratio, Q/Q_{max}: 0.8
- Design depth to full flow depth ratio, d/D: 0.68
- Maximum velocity: 4.5 m/s.
- Minimum velocity: 0.7 m/s.

These criteria assume properly maintained conditions, free of obstructions and without major structural damage.

The Manning's coefficient of 0.015 used for concrete pipes is conservative due to the fact that sewer performance degrades the pipes conditions.

The sequence of the design starts with identifying the flows to be conveyed throughout the life of the pipes, which is thirty years. Then the pipe diameter is selected based on the above criteria, after which the velocities are checked against the minimum and maximum values. Any sewers with velocities more than 4.5 m/s will have drop manholes preferably less than 60 cm, and any ones with velocities less than the self cleansing velocity of 0.7 m/s will have to have either reduced pipe diameters, or a change in the materials to ensure a smooth inner surface.

The minimum cover depends on the location of the sewers where it is required to be not less than 1m otherwise it will have to be reinforced with concrete. If the depth exceeds 6 meters and depending on the bedding material reinforcement is also required.

2.3.2 Wastewater Generation and Strength

Estimations on future wastewater flows and loads are based on existing data within the Zarqa project area.

During the past years per capita water demand was suppressed due to shortage of developed water resources caused by the difficulty of obtaining new water supply sources and the growth of population. Municipal water is scarce and is supplied on an intermittent basis (2 to 3 days per week for 24 hours or less per day). In addition water consumption varies between different areas within the municipalities and between summer and winter.

JICA studied the water supply in Zarqa Governorate in 1995. The JICA analysis of WAJ data showed that water supplied by WAJ had increased from 97 l/c/d in 1989 to

113 l/c/d in 1994. Metered consumption was between 50 and 55 l/c/d, unaccounted water (UFW) had increased from 49 % in 1989 to 54 % in 1993. UFW is estimated to 15 – 30 % physical leakage and 20 – 30 % administrative losses.

In the HARZA-Study 85, 90 and 115 l/c/d for East Zarqa/Hashimiyya, West Zarqa/Russeifa and Amman was estimated as "adjusted consumption" i.e. water produced or supplied minus leakage in transmission and distribution for 1994. Water supply will be improved by the development of additional resources and extension of capacities of existing water production facilities. Therefore, an increase of 1 l/c/d per year is supposed. Table 2.3.2-1 shows assumptions on specific adjusted water demand until 2025, i.e. of HARZA for the project area East Zarqa/Hashimiyya, West Zarqa/Russeifa and Marka/Tariq (Amman) in comparison to the values adopted in the Master Plan Study of JICA/YEC of 2001. For the years 2015/20 water demand assumed by HARZA for the Cities of Zarqa, Russeifa, Hashimiyya and Sukhna are lower than the one adopted by MOWI/WB (Ministry for Water and Irrigation and World Bank), while the ones for Amman are higher. This seems justifiable considering that the demand of the Capital Amman will certainly be higher than the Jordanian average, while the demand in the other cities within the project area will be lower.

Table 2.3.2-1: Adjusted Specific Water Demand of Different Studies (2000/25)

	2000	2005	2010	2015	2020	2025
HARZA 1)	96	101	106	111	116	121
HARZA 2)	91	96	101	106	111	116
HARZA 3)	121	126	131	136	141	146
Scenario 1 4)	103	104	129	136	133	
Scenario 2 5)	103	104	129	150	155	

Values in l/c/d

1) HARZA Study: assumptions for West Zarqa/Russeifa
2) HARZA Study: assumptions for East Zarqa/Hasimiyya
3) HARZA Study: assumptions for Tariq/Marka (belonging to Amman)
4) Scenario 1: MOWI/WB assumptions for total Jordan (see JICA/YEC, Master Plan 2001)
5) Scenario 2: MOWI assumptions for total Jordan (see JICA/YEC, Master Plan 2001)

Evaluation of pumped wastewater quantities in the pumping stations at West Zarqa and Hashimiyya showed that percentage of adjusted consumption of returned to the sewerage as sewage is 87 % (return factor 0.87). It is assumed that the coverage (percentage of population connected to the sewerage) will be 100 % in the future.

Historical wastewater quality data compiled by WAJ have been used to estimate organic, solids and nutrient loadings rates. The high concentration of BOD_5, total suspended solids (TSS) and ammonia-nitrogen (NH_4-N) characterize the sewage as a high strength sewage, which is typical for area in which specific water supply is low. Per capita daily BOD_5-contribution for the resident population has been taken as 65 g/c/d, which is in line with the loadings of other comparable treatment plants in Jordan.

All basic assumptions for future wastewater flow and load are summarized in Table 2.3.2-2.

Table 2.3.2-2 Basic Assumptions on Wastewater Flows and Pollutional Load

Basic data:	Unit	1994	2000	2005	2010	2015	2020	2025
Spec.water demand								
West Zarqa/Russeifa, Sukhna	l/c/d	85	91	96	101	106	111	116
East Zarqa/Hasimiyya	l/c/d	90	96	101	106	111	116	121
Tariq/Marka	l/c/d	115	121	126	131	136	141	146
Increase of spec.water demand	l/c/d per a	1	1	1	1	1	1	1
Coverage (sewerage)	%	96	96	100	100	100	100	100
Return factor	-	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Losses/inflow	%	0	0	0	0	0	0	0
Specific pollutional load	$gBOD_5$/c/d	65	65	65	65	65	65	65

2.3.3 Wastewater Treatment

2.3.3.1 Effluent Criteria

The Standard on Treated Domestic Wastewater (Jordanian Standard JS 893/1995) defines the requirements of effluent discharge from treatment plants or reused for various types of irrigation, fisheries, discharge into natural receiving water (wadis and catchment areas) and artificial recharge of groundwater. Sampling frequency and method as well as standard methods for water analysis is specified.

Most important effluent criteria are summarized in Table 2.3.3-1 in case of discharge to wadis, irrigation of vegetables eaten cooked, fruit trees, forestation, fodder plants, which are expected as potential effluent paths of the treatment plant of Wadi Zarqa.

Table 2.3.3-1 Quality Criteria for Treated Domestic Wastewater According Jordanian Standard 893/1995 (summary)

Quality parameter	Vegetables eaten cooked	Fruit trees, forestation industrial crops and grains	Discharge to wadis and catchment areas	Fodder
BOD_5 (mg/l) 1)	150	150	50	250
TDS (mg/l)	2,000	2,000	2,000	2,000
TSS (mg/l)	200	200	50	2,000
NH_4-N (mg/l)	-	-	15	-
NO_3-N (mg/l)	50	50	25	50
Total-N (mg/l)	50	100	50	-
TFCC (1/100 ml) 2)	1,000	-	1,000	-
Nematodes (eggs/l) 3)	<1	-	<1	<1

1) BOD_5 for wastewater stabilization ponds is filtered samples, and non-filtered in other plants
2) Most Probable Number (MPN)
3) Mean Safaris, Enclostoma and Trycus

Percentage of samples, which does not meet the specified criteria, must not exceed 20 % of the number of samples collected and analyzed.

The standard pays special attention to the agricultural irrigation:

- Irrigation must not take place within two weeks before harvesting (fruit collection)
- Sprinkler irrigation is prohibited to use
- Irrigation of crops eaten raw by treated domestic wastewater is not allowed
- Closed pipes or lined canals must be used when conveying treated domestic wastewater through areas of high permeability, which might effect the groundwater aquifer or surface water used for drinking purposes
- Dilution of treated wastewater on-site with fresh water to meet the criteria is prohibited

In addition the standard states clearly that it is prohibited to recharge artificially groundwater aquifers used for drinking purposes by treated domestic wastewater.

With regard to the discharge of effluent of the proposed treatment plant into the Wadi Zarqa as well as taking into account effluent's reuse for agricultural irrigation the most significant parameter limits (maximum concentrations) applicable to the wastewater from the study area are 50 mg/l for BOD_5, 50 mg/l for TSS, 15 mg/l for ammonia (NH_4-N), 50 mg/l for total nitrogen (N), 1 egg/liter for nematode eggs and 1,000 fecal coliforms per 100 ml. The dominant characteristics of wastewater from the study area are those of domestic wastewater.

In the project area industrial discharges to public sewers have a share of about 6 % and, therefore, are of minor importance. The industrial wastewaters, if discharged into the sanitary sewer system or into natural water bodies, are controlled by regulations (*Standard on Industrial Wastewater*, i.e. JS 202/91 and *Regulation for Commercial and Industrial Wastewater to be Discharged into the Public Sewerage system*). If necessary, pretreatment is required before its discharge. As a result heavy metals and toxic substances are considered not to be problems.

2.3.3.2 Design of Treatment Process

(1) Mechanical Treatment

The purpose of preliminary treatment (screening and degritting) is to remove large objects as well as grit, in order to prevent damage to subsequent treatment and process equipment. Objects normally removed by this treatment step can be extremely harmful to pumps and can increase downtime due to pipe clogging and clarifier scraper mechanism failures (for details see e.g. EPA Manual).

A. Screening

There are two types of bar screens (or racks). The most commonly used and oldest technology, consists of hand-cleaned bar racks. These are generally used in smaller treatment plants. The second type of bar screen is mechanically cleaned and is commonly used in larger facilities.

Screens are commonly designed respecting

spacing of bars:	12 mm
bar size:	10 mm
maximum flow velocity:	1.0 m/s

B. Degritting

Grit is most commonly removed in chambers, which are capable of settling out high density solid materials, such as sand, gravel and cinders. There are two types of grit chambers: (1) horizontal flow and (2) aerated. In both types the settleables are collected at the bottom of the unit. The horizontal units are designed to maintain a relatively constant velocity by use of proportional weirs or flumes in order to prevent settling of organic solids, while simultaneously obtaining relatively complete removal of inorganic particles (grit).

The aerated type produces spiral action whereby the heavier particles remain at the bottom of the tank, while organic particles are maintained in suspension by rising air bubbles. One main advantage of aerated units is that the amount of air can be regulated to control the grit/organic solid separation, and less offensive odors are generated. The aeration process also facilitates cleaning of the grit. The grit removed from horizontal flow unit usually needs additional cleaning steps prior to disposal.

Basic design parameters for grit chambers are

detention time (for Q_{max}):	3 – 10 min
hydraulic surface loading:	0.5 - 1.5 m/h

D. Primary Treatment (Primary Clarifier)

Primary clarifiers are constructed in circular and rectangular shape. The following description considers a rectangular type.

Primary clarification involves a relatively long period of quiescence in basin (depth of 3 to 4.5 m) where most of the settleable solids in a pretreated wastewater fall out of suspension by gravity. The solids are mechanically transported along the bottom of the tank by a scraper mechanism and pumped as a sludge underflow.

The maximum length of rectangular tanks has been approximately 80 m, where widths of greater than 6 m are required; multiple bays with individual cleaning equipment may be employed, thus permitting tank widths up to 25 m or more. Influent channels and effluent channels should be located at opposite ends of the tank.

Sludge removal equipment usually consists of a pair of endless conveyor chains. Attached to the chains at about 3 m intervals are crosspieces of flights, extending the full width of the tank or bay. Linear conveyor speeds of 0.6 to 1.2 m/min are common. The settled solids are scraped to sludge hoppers in small tanks and to transverse troughs in large tanks. The troughs, in turn, are equipped with cross collectors, usually of the same type as the longitudinal collectors, which convey solids to one or more sludge hoppers. Screw conveyors have been used for the cross collectors.

Scum is usually collected at the effluent end of rectangular tanks by the flights returning at the liquid surface. The scum is moved by the flights to a point where it is trapped by baffles removal or it can also be moved along the surface by water sprays. The scum is then scraped manually up an inclined apron, or it can be removed hydraulically or mechanically, and for this process a number of means have been developed (rotating slotted pipe, transverse rotating helical wiper, chain and flight collectors, scum rakes). Figure 2.3.3-1 shows a schema with primary treatment including screen, grit chamber and primary clarifier as part of the activated sludge process.

Primary clarifiers are designed for

detention time:	2.5 h
hydraulic surface loading:	1.5 m/h

The following removal efficiencies are expected

BOD_5 removal:	30 %
Suspended solids removal:	50 %

(2) Biological Treatment (Secondary treatment by Activated Sludge)
For details see e.g. EPA Manual.

A. Activated Process (incl. Nitrification - Denitrification)

Activated sludge is a continuous flow, biological treatment process characterized by a suspension of aerobic microorganisms, maintained in a relatively homogeneous state by the mixing and turbulence induced by aeration. The microorganisms are used to oxidize soluble and colloidal organics to CO_2 and H_2O in the presence of molecular oxygen. The process is generally preceded by primary sedimentation (primary clarifier). The mixture of organisms and wastewater formed in the aeration basins, called mixed liquor, is transferred to gravity clarifiers for liquid solid separation.

The major portion of the microorganisms settling out in the clarifiers is recycled to the aeration basins to be mixed with incoming wastewater, while the excess, which constitutes the waste sludge, is sent to the sludge handling facilities. The rate and concentration of activated sludge returned to the aeration basins determines the mixed liquor suspended solids (MLSS) level developed and maintained in the basins. During the oxidation process, a certain amount of the organic material is synthesized into new cells, some of which then undergoes auto-oxidation (self-oxidation or endogenous respiration) in the aeration basins, the remainder forming net growth or excess sludge.

Activated sludge systems are classified as high rate, conventional or extended aeration (low rate) based on the organic loading. In the conventional activated sludge plant, the wastewater is commonly aerated for a period of four to eight hours (based on average daily flow). Either surface or submerged aeration systems can be employed to transfer oxygen from air to wastewater.

Activated sludge systems including nitrification/denitrification processes are designed for

volumetric BOD_5-loading:	600 kg BOD_5/1,000 m³/d
volumetric TKN-loading:	200 kg BOD_5/1,000 m³/d
biological sludge production:	0.7 kg TSS/kg BOD_5 removed
O_2 requirement:	1.5 kg O_2/kg BOD_5 removed
O_2 requirement for nitrification:	4.6 kg O_2/kg NH_3-N removed
O_2 produced by denitrification:	2.86 kg O_2/kg NO_3 reduced to N_2

Mechanical aeration methods consists of a surface-type mechanical entrainment aerators. The surface-type aerators entrain atmospheric air by producing a region of intense turbulence at the surface around their periphery. They are designed to pump large quantities of liquid, thus dispersing the entrained air and agitating and mixing the basin contents. Volatile compounds are driven off to a certain extent in the aeration process. Metals will also be partially removed, with accumulation in the sludge. Figure 2.3.3-1 presents a schema of treatment by activated sludge process.

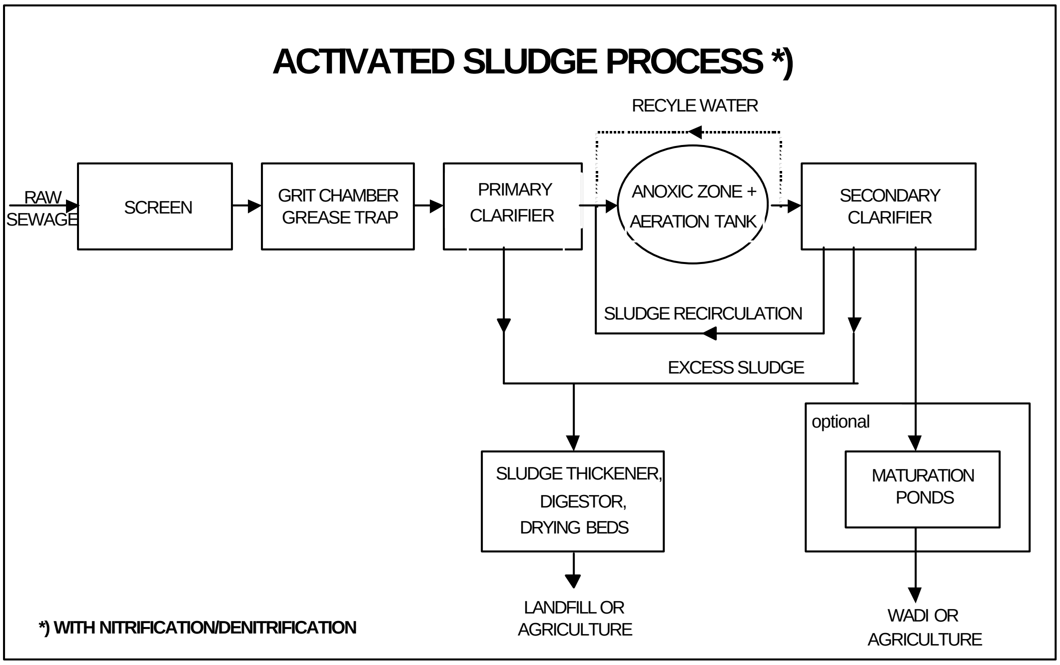

Figure 2.3.3-1 Schema of Treatment by Activated Sludge Process with Nitrification/Denitrification

B. Secondary Clarifier

The design of secondary clarifiers is similar to primary clarifiers except that the large volume of flocculants solids in the mixed liquor must be considered during the design of activated-sludge clarifiers and in sizing of sludge pumps. Further, the mixed liquor, on entering the tank, has a tendency to flow as a density current interfering with the separation of the solids and the thickening of the sludge. To cope successfully with these characteristics, factors that must be considered in the design of there tanks include: (1) type of tank to be used, (2) surface loading rate, (3) solids loading rate, (4) flow-through velocities, (5) weir placement and loading rates and (6) scum removal.

Flow through rectangular tanks enters at one end, passes a baffle arrangement and traverses the length of the tank to effluent weirs. The maximum length of rectangular tanks has been approximately 90 m with depths of 3.5 to 4.5 m. Where widths of greater than 6 m are required, multiple bays with individual cleaning equipment may be employed, thus permitting tank widths up to 25 m or more.

Sludge removal equipment usually consists of a pair of endless conveyor chains. Attached to the chains at 4 m intervals are crosspieces or flights, 15 to 20 cm deep, extending the full width of the tank or bay. Linear conveyor speeds of 5 to 10 cm/min are common. The settled solids are scraped to sludge hoppers in small tanks and to transverse troughs in large tanks. The troughs, in turn, are equipped with cross collectors, usually of the same type as the longitudinal collectors, which convey solids to one or more sludge hoppers. Screw conveyors have also been used for the cross collectors. Tanks may also be cleaned by a bridge-type mechanism, which travels up and down the tank on rails supported on the sidewalls. Scraper blades are suspended from the bridge and are lifted clear of the sludge on the return travel. For very long tanks, it is desirable to use two sets of chains and flights in tandem with a central hopper to receive the sludge. Tanks in which mechanisms that move the sludge toward the effluent end in the same direction as the density current have shown superior performance in some instances.

Scum is usually collected at the effluent end of rectangular tanks by the flights returning at the liquid surface. The scum is moved by the flights to a point where it is trapped by baffles before removal, or it can also be moved along the surface by water sprays. The scum is then scraped manually up an inclined apron, or it can be removed hydraulically or mechanically, and for this process a number of means have been developed (rotating transverse rotating helical wiper, chain and flight collectors, scum rakes).

Generally, secondary clarifiers are designed for

hydraulic surface loading:	1.7 – 2.7 m/h
depth:	3.5 – 4.5 m

(3) Sludge Treatment
For details see e.g. EPA Manual.

A. Sludge Thickening
Thickening of sludge consists of the removal of supernatant, thereby reducing the volume of sludge that requires disposal or further treatment. Gravity thickening takes advantage of the difference in specific gravity between the solids and water.

A gravity thickener normally consists of truss-type steel scraper arms mounted on a hollow pipe shaft keyed to a motorized hoist mechanism. A truss-type bridge is fastened to the tank walls or to steel or concrete columns. The bridge spans the tank and supports the entire mechanism. The thickener resembles a conventional circular clarifier with the exception of having a greater bottom slope. Sludge enters at the middle of the thickener and the solids settle into a blanket at the bottom. The concentrated sludge is very gently agitated by the moving rake dislodges gas bubbles and prevents bridging of the sludge solids. It also keeps the sludge moving toward the center well from which it is removed. Supernatant liquor passes over an effluent weir around the circumference of the thickener. It has been shown that in the operation of gravity thickeners it is desirable to keep a sufficiently high flow of fresh liquid entering the concentrator to prevent septic conditions and resulting odors from developing.

Gravity thickening is characterized by zone settling. The four basic settling zones in a thickener are:

- The clarification zone at the top containing the relatively clear supernatant.
- The hindered settling zone where the suspension moves downward at a constant rate and a layer of settled solids begins building from the bottom of the zone.
- The transition zone characterized by a decreasing solids settling rate.
- The compression zone where consolidation of sludge results solely from liquid being forced upward around the solids.

Generally, detention times of one to three days are usually used. Thickener are designed for the following conditions:

Sludge type	Solids surface loading kg/d/m²	Thickened sludge solids concentration (%)
Primary	100 to 150	8 to 10
Activated sludge	25 to 30	2.5 to 3
Trickling filter	40 to 50	7 to 9
Limed tertiary	300	12 to 15
Primary and activated	30 to 50	4 to 7
Primary and trickling filter	50 to 60	7 to 9
Limed primary	100 to 120	7 to 12

B. Anaerobic Sludge Digestion

A two vessel system of sludge stabilization, where the first tank is used for digestion and is equipped with one or more of the following: heater, sludge recirculation pumps, methane gas recirculation, mixers and scum breaking mechanisms. The second tank is used for storage and concentration of digested sludge and for formation of a supernatant. Anaerobic digestion results in the breakdown of the sludge into methane, carbon dioxide, unusable intermediate organics and a relatively small amount of cellular protoplasm. This process consists of two distinct simultaneous stages of conversion of organic material by acid forming bacteria and gasification of the organic acids by methane forming bacteria. The methane producing bacteria are very sensitive to conditions of their environment and require careful control of temperature, pH, excess concentrations of soluble salts, metal cations, oxidizing compounds and volatile acids. They also show an extreme substrate specificity. The process can be operated at various loading rates and is therefore not always clearly defined as either standard or high rate.

Digester requires periodic cleanout (from 1 to 2 years) due to buildup of sand and gravel on digester bottom.

The process is suitable for primary sludge or combinations of primary and secondary sludge. Digested sludge is reduced in volume and pathogenic organism content, is less odorous and easily dewatered and is suitable for ultimate disposal. Advantages over single stage digestion include increased gas production, a clearer supernatant liquor, necessity for heating a smaller primary tank thus economizing in heat and more complete digestion. Process also lends itself to modification changes, such as to high-rate digestion.

Basic design parameters are:

solids loading:	0.6 – 6 kg SS/m³/d
volumetric loading:	0.001 – 0.03 m³/c/d

C. Sludge Dewatering

Drying beds are used to dewater sludge both the drainage through the sludge mass and by evaporation from the surface exposed to the air. Collected filtrate is usually returned to the treatment plant. Drying beds usually consist of 0.1 to 0.25 m of sand, which is placed over 0.2 to 0.5 m of graded gravel or stone. Drying beds typically has an effective size of 0.3 to 1.2 mm and a uniformity coefficient of less than 5.0. Gravel is normally graded from 0.3 to 2.5 cm. Drying beds have under drains that are spaced from 2.5 to 6 m apart. Under drain piping is often vitrified clay laid with open joints, has a minimum diameter of 100 mm, and has a minimum slope of about 1 percent

The drying area is partitioned into individual beds, approximately 6 m wide by 6 to 30 m long, of a convenient size so that one or two beds will be filled by a normal withdrawal of sludge from the digesters. The interior partitions commonly consist of two or three creosoted planks, one on top of the other, to a height of 0.4 to 0.5 m, stretching between slots in pre-cast concrete posts. The outer boundaries may be of similar construction or earthen embankments for open beds, but concrete foundation walls are required if the beds are to be covered.

Piping to the sludge beds is generally made of cast iron and designed from a minimum velocity of 0.8 m/s. It is arranged to drain into the beds and provisions are made to flush the lines and to prevent freezing in cold climates. Distribution boxes are provided to divert sludge flow to the selected bed. Splash plates are used at the sludge inlets to distribute the sludge over the bed and to prevent erosion of the sand.

Sludge can be removed from the drying bed after it has drained and dried sufficiently to be spadable. Sludge removal is accomplished by manual shoveling into wheelbarrows or trucks or by a scraper or from-end loader. Provisions should be made for driving a truck onto or along the bed to facilitate loading. Mechanical devices can remove sludge of 20 to 30 percent solids while cakes of 30 to 40 percent generally require hand removal.

Paved drying beds with limited drainage systems permit the use of mechanical equipment for cleaning. Field experience indicates that the use of paved drying beds results in shorted drying times as well as more economical operation when compared with conventional sand beds because, as indicated above, the use of mechanical equipment for cleaning permits the removal of sludge with a higher moisture content than in the case of hand cleaning paved beds have worked successfully with an aerobically digested sludge but are less desirable than sand beds fro aerobically digested activated sludge.

Vacuum assisted drying is a method used to accelerate dewatering by applying a vacuum to the underside of porous filter plates, which support the sludge. Preconditioning of the sludge with polymer is required and the dried sludge can be removed with front-end loader. Solids concentrations range from 8 to 23 % with relatively short cycle times from 1 to 3 days. However, additional processing may be necessary to achieve higher sludge solids concentrations.

D. Methane Recovery / Power Generation Facilities

Methane produced in the anaerobic sludge digester can be used for power generation. Per capita methane generation estimates vary from place to place. For local condition (based on 65 g BOD_5/c/d) it is estimated that approximately 13 m^3 methane/1,000 persons will be generated per day. Considering efficiency of conversion of methane to HP and other factors affecting generation of methane and power, it is estimated that approximately 2 HP/1,000 persons can be generated.

2.4 Demographic Development, Wastewater Flow and Pollution Load Projection

2.4.1 Demographic Development

Censuses of Jordan were conducted in 1952, 1961, 1979 and 1994. Results of these censuses are presented in Table 2.4.1-1. Analysis of the national censuses showed that the population growth rate had been affected greatly by immigration caused by regional conflicts. For example, the annual growth rate of Jordan between 1979 and 1994 was increased by 1 % on the average by the return of approximately 300,000 Jordanians from Kuwait and other Gulf nations during 1990 – 1991. Forecasts of immigration over the next 30 years are subject to great uncertainty. The HARZA team adopted the overall growth rate of 3.45 % after removing the effects of Kuwait returnees from the growth rate of 4.45 % as shown in Table 2.4.1-1 for 1979 – 1994 period, as its base national growth rate. It is assumed that the overall growth rate will decline by 0.1 % every 5 years to 2.8 % in 2025. Immigration has historically added to the growth rate. Additional immigration may continue to contribute 0.5 % to growth rate through the planning period.

Table 2.4.1-1 Population and Growth Rates According to Censuses

Area	1952	1961	1979	1994
Population of Jordan	586,000	901,000	2,133,000	4,096,000
Population of Amman			624,000	1,300,000
Population of Zarqa Municipality			300,000	609,000
Annual growth rates		4.9 %	4.9 %	4.45 %

Table 2.4.1-2 Growth Rates of Different Studies

	1994/2000	2000/05	2005/10	2010/15	2015/20	2020/25
HARZA 1)	4.2	4.1	4.0	3.9	3.8	3.7
Scenario 1 2)	3.4	2.52	2.5	2.3	2.0	2.0
Scenario 3 3)	3.59	3.21	3.1	2.9	2.7	2.5

1) HARZA Study: assumptions for present project area
2) Scenario 1: MOWI/WB assumptions for total Jordan (see JICA/YEC, Master Plan 2001)
3) Scenario 3: Department of Statistics (DOS) assumptions for total Jordan (see JICA/YEC, Master Plan 2001)

The share of national population in Zarqa Municipalities increased by 0.054 % per year. Thus, the growth rates are higher as the national ones. Therefore, resulting growth rates during the planning period until 2025 are estimated as shown in Table 2.4.1-2 (HARZA). In addition the table presents rates assumed by HARZA for the project area in comparison to the values of Scenarios 1 and 3 taken into account in the Master Plan Study of 2001 for the total Jordan. The growth rates adopted by HARZA for the Cities of Zarqa, Russeifa, Hashimiyya and Sukhna are about 1 % higher than the rates estimated by the Department of Statistics (DOS) for Jordan. These higher rates may be justified with the fact that there is still an ongoing migration from other regions of Jordan to the capital Amman and the neighboring Cities Zarqa, Russeifa, Hashimiyya and Sukhna.

According to the last census in 1994 the population in the project area was 67,000 in Tariq and Marka (belonging to the Amman Governorate), 332,667 in Zarqa, 196,743 in Russeifa, 17,685 in Hashimiyya and 9,764 in Sukhna (see Table 2.4.1-3). This is about 5 % of the population in Amman city and 91 % of the cities in the Zarqa Governorate.

Taking into account estimated growth rates and census figures of 1994 population as presented in Table 2.4.1-2, in 2025, about 2 mio. inhabitants will live within the service areas.

In the Table 2.4.1-3 population figures are broken down according to administrative areas (municipalities) as well as drainage areas allowing estimates on wastewater flows in different main sewage conveyors (see Section 2.5.3).

Table 2.4.1-3 Demographic Development in the Service Areas

	Unit	1994	2000	2005	2010	2015	2020	2025
Population								
Annual growth	%		4.2	4.1	4.0	3.9	3.8	3.7
Marka (belonging to Amman)	c	67,000	86,000	105,000	128,000	155,000	187,000	224,000
Zarqa Municipality	c	332,667	426,000	521,000	634,000	768,000	925,000	1,109,000
Russeifa Municipality	c	196,743	252,000	308,000	375,000	454,000	547,000	656,000
Hashimiyya Municipality	c	17,685	23,000	28,000	34,000	41,000	49,000	59,000
Sukhna Municipality	c	9,764	12,000	15,000	18,000	22,000	27,000	32,000
Total		623.859	799,000	977,000	1,189,000	1,440,000	1,735,000	2,080,000
Population in drainage areas I								
Tariq and Marka	c	67,000	86,000	105,000	128,000	155,000	187,000	224,000
Russeifa	c	196,743	252,000	308,000	375,000	454,000	547,000	656,000
West Zarqa	c	216,234	277,000	339,000	412,000	499,000	601,000	721,000
East Zarqa and Hashimiyya	c	134,118	172,000	210,000	255,000	309,000	372,000	446,000
Sukhna	c	9,764	12,000	15,000	18,000	22,000	27,000	32,000
Total		623.859	799,000	977,000	1,188,000	1,439,000	1,734,000	2,079,000
Population in drainage areas II								
West Zarqa Pump Station	c	479,977	615,000	752,000	915,000	1,108,000	1,335,000	1,601,000
Hashimiyya Pump Station	c	143,882	184,000	225,000	273,000	331,000	399,000	478,000
Total		623.859	799,000	977,000	1,188,000	1,439,000	1,734,000	2,079,000

2.4.2 Wastewater Flow and Load

Based on the assumptions presented in the previous sections (in particular sections 2.3.2 and 2.4.1) the total wastewater flow and load was calculated up to the year 2025. Production of industrial wastewater and pollutional load is considered as constant (equaling to the present values, see section 2.2.3) throughout the planning period. This can be justified by the fact that all new industries have to be established in the new industrial zone, which is part of the drainage area discharging to the As Samra Treatment Plant.

Results are summarized in Table 2.4.2-1. Annual wastewater production will increase from about 25 in 2000 to more than 80 MCM in the year 2025, i.e. an increase by a factor of 3 to 4. However, it has to be mentioned that these quantities depend strongly on the development of fresh water resources, because an increasing specific water consumption was taken into account assuming that the presently suppressed water demand will not exist anymore in future.

Pollutional load will increase in the same period by a factor of 2.7 or from 50 to 135 t BOD_5/d. This load may be considered as independent on the water consumption development.

Considering a water loss of 5 % within the proposed Wadi Zarqa Wastewater Treatment Plant the effluent will rise from about 30 MCM after the completion of the plant (in 2005) to almost 80 MCM in 2025.

Table 2.4.2-1 Projection of Wastewater Flows and Pollutional Load

	Unit	1994	2000	2005	2010	2015	2020	2025
Population	c	623,859	798,533	976,217	1,187,717	1,438,106	1,732,916	2,078,124
Connected (sewerage)	c	598,905	766,591	976,217	1,187,717	1,438,106	1,732,916	2,078,124
Not connected (sewerage)	c	24,954	31,941	0	0	0	0	0
Water demand (without physical losses)								
Tariq and Marka	m^3/d	7,705	10,377	13,210	16,710	21,005	26,241	32,585
Russeifa	m^3/d	16,723	22,916	29,555	37,831	48,074	60,662	76,023
West Zarqa	m^3/d	18,380	25,187	32,483	41,579	52,836	66,671	83,554
East Zarqa and Hashimiyya	m^3/d	12,071	16,480	21,197	27,066	34,318	43,215	54,058
Sukhna	m^3/d	830	1,137	1,467	1,877	2,386	3,011	3,773
Total	m^3/d	55,709	76,098	97,911	125,063	158,618	199,800	249,992
Wastewater production								
Tariq and Marka	m^3/d	6,435	8,667	11,493	14,538	18,274	22,830	28,349
Russeifa	m^3/d	13,967	19,140	25,713	32,913	41,824	52,776	66,140
West Zarqa	m^3/d	15,351	21,036	28,260	36,173	45,968	58,004	72,692
East Zarqa and Hashimiyya	m^3/d	10,081	13,764	18,441	23,547	29,856	37,597	47,030
Sukhna	m^3/d	693	950	1,276	1,633	2,076	2,619	3,282
Industrial wastewater	m^3/d		4,500	4,500	4,500	4,500	4,500	4,500
Total	m^3/d	46,528	68,057	89,683	113,305	142,498	178,326	221,993
	m^3/month	1,395,835	2,041,702	2,690,489	3,399,140	4,274,942	5,349,772	6,659,781
	MCM	17.0	24.8	32.7	41.4	52.0	65.1	81.0
Pollutional load								
Poll. load (dom.demand)	$kgBOD_5/d$	38,929	49,828	63,454	77,202	93,477	112,640	135,078
Poll. load (industries)	$kgBOD_5/d$		550	550	550	550	550	550
Total load	$kgBOD_5/d$	38,929	50,378	64,004	77,752	94,027	113,190	135,628
Concentration	$mgBOD_5/l$	837	740	714	686	660	635	611
Reuse of wastewater								
Inflow treatment plant	MCM			32.73	41.36	52.01	65.09	81.03
Losses in treatment plant	%			5.0	5.0	5.0	5.0	5.0
	MCM			1.64	2.07	2.60	3.25	4.05
Effluent of treatment plant	MCM			31.10	39.29	49.41	61.83	76.98

2.5 Preliminary Design of Facilities

2.5.1 Alternative Systems for Long Term Development

Harza has studied 10 system alternatives consisting combination of treatment plant sites, pumping stations and conveyance pipe lines to meet year 2025 needs for wastewater conveyance, treatment and disposal for the Amman – Zarqa Area. The alternative conveyance/treatment system projects were combinations of five potential treatment plants and the associated wastewater conveyance facilities

In addition, Harza has developed an alternative, which would continue to use the As Samra Wastewater Stabilization Ponds to its capacity with additional capacity supplied by an activated sludge plant. To allow comparison of sites, all the plants were evaluated using activated sludge as the secondary treatment process. WWTP sites studied were located at:

- The existing As Samra site;
- About 15 km downstream of the confluence of the Zarqa River and Wadi Dhuleil;
- Near an old phosphate mine at Russeifa;
- The Jordan Valley (downstream of King Talal Reservoir) near the confluence of the Zarqa River and the King Abdullah Canal; and
- At Sukhna, a small WWTP for the Sukhna area.

Studied alternatives are actually four basic wastewater system configurations i.e.

- Alternatives 1 and 10 feature use of the As-Samra site;
- Alternatives 2 and 3 have treatment plants on the Zarqa River and near Russeifa;
- Alternatives 6, 7 and 8 have plants at As Samra and on the Zarqa River; and
- Alternative 9 has treatment in Jordan Valley.

Components common to all alternatives include expansion of the AGTP pretreatment facility to remove grit and floating debris, expansion of the septage collection facility at Ain Ghazal, and addition of significant new conveyance and treatment capacity. The alternatives, which do not require pumping station, are 2, 6, 8 and 9.

Table 2.5.1-1 contains comparative construction costs, operation cost, land requirements and power requirements for all ten alternatives. Alternatives with the lowest construction costs have, as a common feature, the use of a new pipeline form AGTP to As Samra, which is completed with German aid.

Table 2.5.1-1 Summary of Costs, Power and Land Requirements of System Alternatives (acc. to Harza)

Alternative	Total Construction Cost[1)] (10^6 JD)	Annual O & M Cost (10^6 JD)	Land Requirement (ha)	Power Requirement (hp)
Alternative 1	265	18.0	190	39,100
Alternative 2	294	17.0	190	25,100
Alternative 3	300	17.6	190	28,600
Alternative 4	290	18.6	190	40,200
Alternative 5	291	18.1	190	37,600
Alternative 6	313	16.5	190	25,100
Alternative 7	258	16.5	190	29,400
Alternative 8	257	16.2	190	25,100
Alternative 9	389	16.8	190	24,100
Alternative 10	260	18.1	170	36,700

1) The above construction cost includes conveyance, pumping and treatment facilities; however it does not include the costs of engineering, nitrification/denitrification facilities and common element such as expansion of AGTP facilities, etc.

Costs for operation and maintenance for all system alternatives are similar. Land requirements for all alternatives are estimated to be about 190 hectares. Power requirements vary from about 24,000 hp for alternative 9 to about 40,000 hp for Alternative 4.

Harza's economic analysis shows similar costs of Alternatives 6, 7, and 8, however, which are lower than for the other Alternatives.

Ranking criteria (environmental impact/concern, reliability, construction cost, operating cost and odor) and the weighting factors of ranking alternatives were also developed. Finally, WAJ selected Alternative 8 as the preferred alternative, which has the lowest capital and operation costs. The alternative comprises 2 new plants, one at As Samra and another one at Wadi Zarqa.

A site about 15 km downstream of the confluence of Zarqa River and Wadi Dhuleil was identified as a potential site for the location of a new Wadi Zarqa Wastewater Treatment Plant. Cost of conveyance was based on a pipeline required to convey wastewaters to that location (see Figure 2.5.1-1).

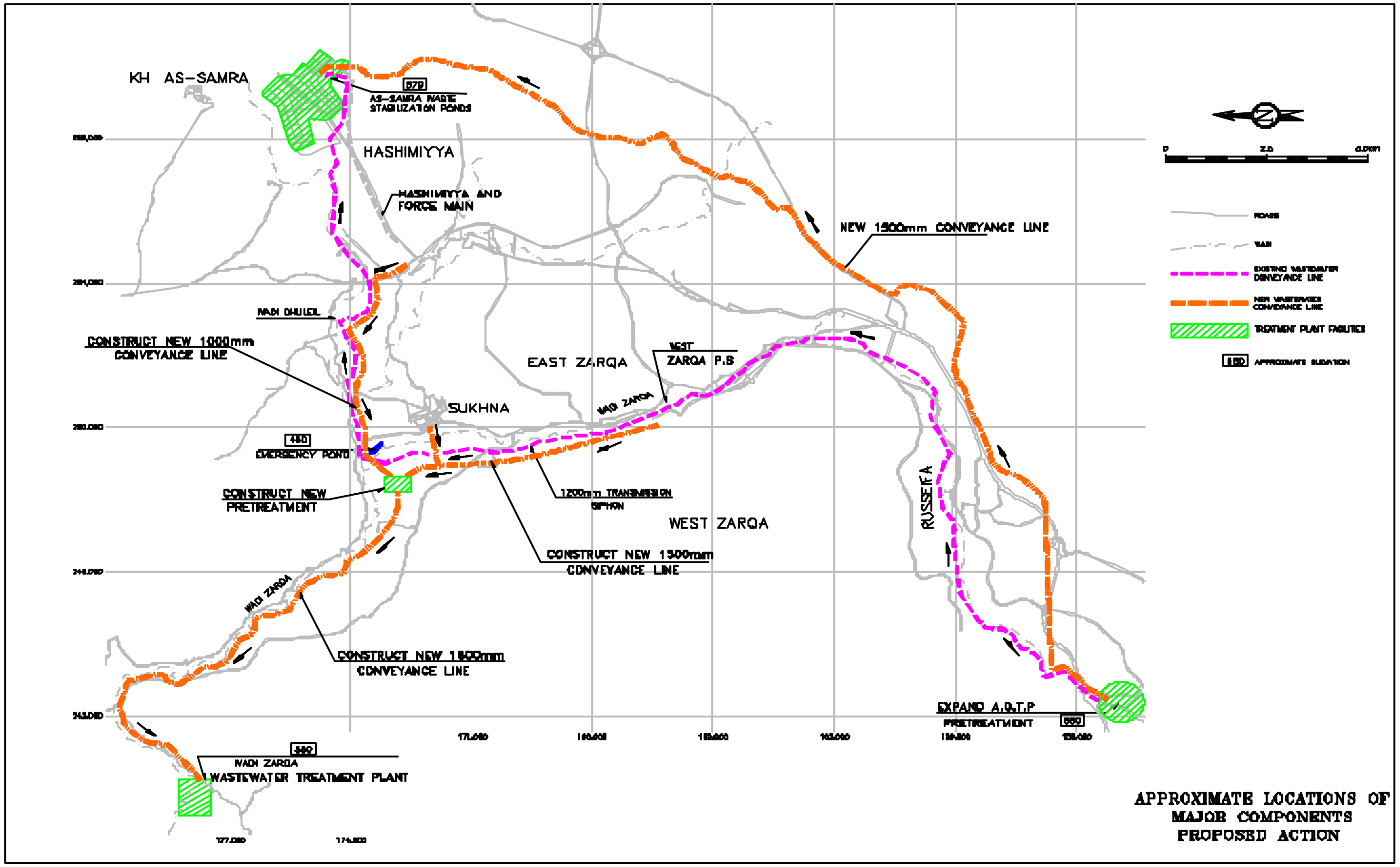

Figure 2.5.1-1 Location of As Samra and Wadi Zarqa Wastewater Treatment Plant and Conveyance Layout

2.5.2 Proposed Layout for Long Term Development

According to the HARZA's Study Report the long-term strategy for the Amman-Zarqa River Basin Area foresees the construction of two wastewater treatment plants:

- a As Samra Treatment Plant (a new plant at the present As Samra plant site) and
- a Wadi Zarqa Treatment Plant (a new plant along Wadi Zarqa downstream of Sukhna)

The basic concept of the long-term development for Amman-Zarqa River Basin Area is shown in the Figure 2.5.1-1.

Proposed As Samra Treatment Plant

This treatment plant will serve the majority of Amman area (belonging to Wadi Zarqa Basin except of town districts of Marka and Tariq). Collected sewage will be pretreated in Ain Ghazal pre-treatment facilities (AGTP) and then discharged by a new conveyor (DN 1500, 32 km, completed in 2001).

Proposed Wadi Zarqa Treatment Plant

The treatment plant will receive wastewater flows from the eastern portions of Amman (Tariq and Marka) as well as Zarqa, Russeifa and Hashimiyya via a new gravity conveyance system. The Wadi Zarqa system will also collect and treat wastewater from the presently unsewered Sukhna Municipality.

The proposed Wadi Zarqa Treatment Plant and conveyance consists of new facilities to be constructed in two phases, the first phase to serve the area until the year 2015 of a total population of 1.4 million with an estimated capacity of n2estimated capacity of 80 CM per year for the year 2025. Such facilities will serve Zarqa, Russeifa, Hashimiyya, S1khna and Tariq and Marka from the Greater Amman Area. The pumping stations of West and East Zarqa can be abandoned and the wastewater will be conveyed by gravity to a junction near the confluence of Wadi Zarqa and Wadi Dhuleil, thus eliminating the need for pumping.

At the confluence, new pretreatment works are foreseen to remove the grit and screenings in order to protect the conveyor downstream down to the treatment location some 15 km northwest of Wadi Zarqa. This is due to the fact that a portion of the conveyor will operate under pressure. If another route for the conveyor is selected, it might be possible to overcome the need for pretreatment requirements at the confluence and these facilities would then be at the treatment site as a part of the treatment process itself.

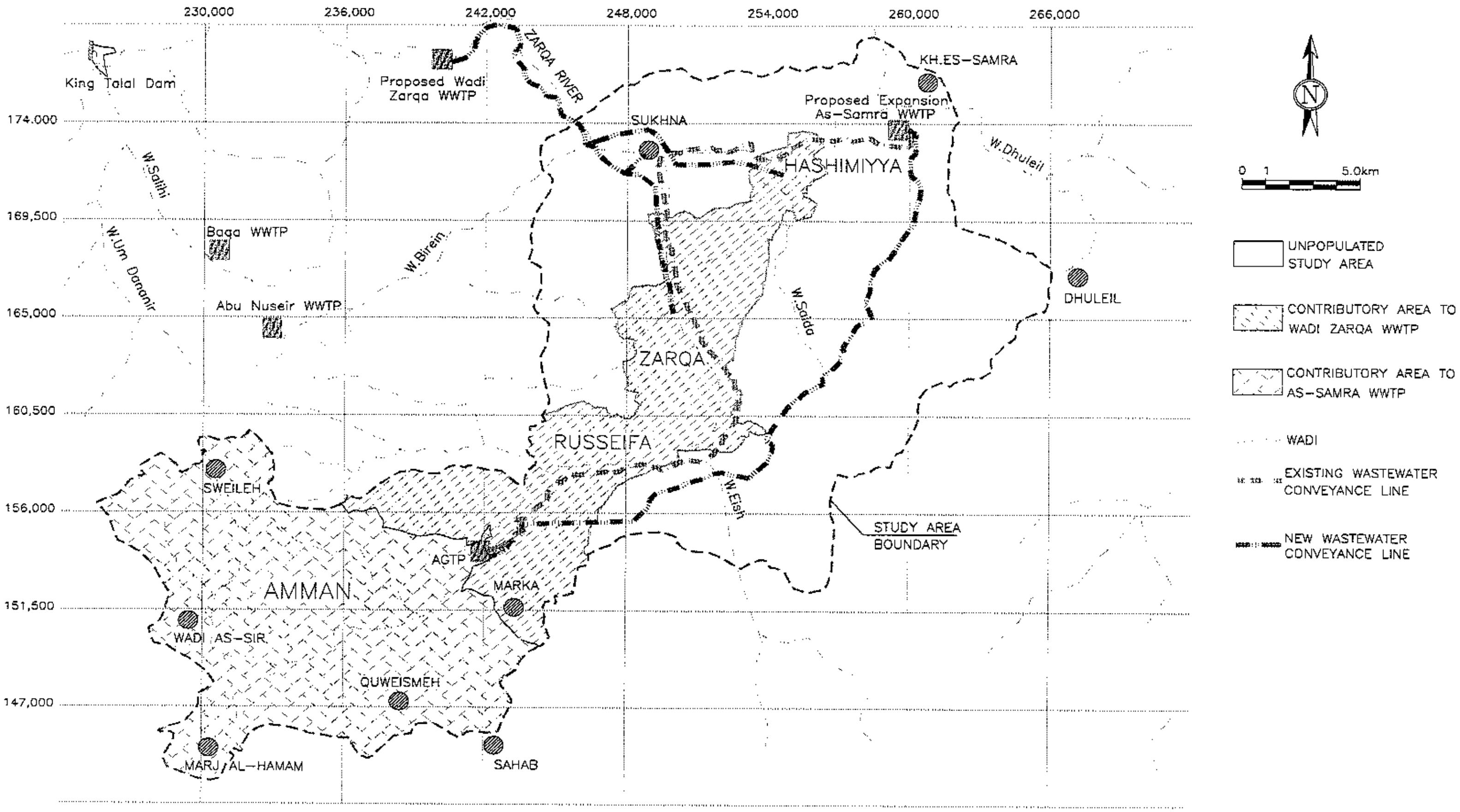

Figure 2.5.2-1 Future Wastewater System and Proposed Service Areas

2.5.3 Transmission System

(1) General

Under the proposed scheme for constructing a new wastewater treatment plant, which is intended to treat the wastewater generated from Zarqa, Russeifa, Marka, Tariq, Hashimiyya and the unsewered area of Sukhna, a new wastewater conveyor is proposed to collect the flows from the tributaries to the existing West Zarqa and Hashimiyya pumping stations and convey them by gravity to the treatment plant location some 15 km downstream of the confluence of Wadi Zarqa and Wadi Dhuleil. Such an arrangement will allow for the decommissioning of the existing two pumping stations which will allow As Samra plant to serve Amman Area for a longer period of time (until the year 2015) before the second stage is needed. This arrangement will also reduce the cost of pumping and the need to expand and rehabilitate the existing facilities involved in pumping.

The components of the new conveyor for the year 2025-2030 include the following (see Figure 2.5-1):

- New 8 km long, 1500 mm diameter gravity concrete pipeline between the existing West Zarqa pumping station and the confluence of the Wadis Zarqa and Dhuleil.
- New 7 km long, 1000 mm diameter gravity concrete pipeline from the existing Hashimiyya pumping station to the same point (the confluence).
- New 2 km long, 300 mm diameter gravity concrete pipeline from Sukhna lowest point to the same point (the confluence).
- New 15 km long, 1800 mm diameter gravity concrete pipeline from the confluence to the new proposed treatment site

The future conveyance lines needed are presented in Table 2.5.3-1 including required lengths and diameters.

Table 2.5.3-1 Conveyance System-Main Conveyor

Item	Diameter (mm)	Length (km)	Construction cost JD
New pipeline Between West Zarqa PS and the Confluence	1500	8.0	3
New Pipeline Between Hashimiyya PS and the Confluence	1000	7.0	1.4
New Pipeline from Sukhna to the Confluence	300	2.0	1
New Pipeline from the Confluence to the TP Site	1800	15.0	14.9
Total		32.0	20.3

(2) West Zarqa to the Confluence Pipeline

By constructing the proposed 8 km long pipeline of 1500 mm diameter gravity conveyor between West Zarqa pumping station and the confluence where the pre-treatment facilities near Sukhna is proposed, the pumping station will be eliminated. This new conveyor will convey all the wastewater from the areas presently tributary to the pumping station to the treatment site without pumping. The size of this conveyor provides adequate capacity for 350,000 m^3/day, which is equivalent to the peak dry weather flow projections of the year 2025.

The new gravity pipeline will run in parallel with the existing 1200 mm siphon from Ain Ghazal to As Samra between the existing pumping station and Sukhna. The conveyor will run under open channel conditions as the topography allows for such conditions to be followed. A long-term protection is needed during the detailed design and construction to protect the line against corrosion, damage, and erosion etc..

(3) Hashimiyya to the Confluence Pipeline

This gravity pipeline also eliminates the need for Hashimiyya pumping station. The proposed pipeline will be 7 km long, 100 mm in diameter gravity conveyance line running in parallel with the Wadi Dhuleil between Hashimiyya pumping station and the proposed pre-treatment facilities near Sukhna. This arrangement will allow all the wastewater tributary to the Hashimiyya pumping station to be conveyed to the treatment site without pumping. The size of this pipeline will be adequate to convey 100,000 m^3/day, which is equal to the projected 2025 year peak dry weather flow.

The flow in the pipeline will run under open channel conditions as the pipe follows the direction of the terrain, which allows the construction of the pipe without being under pressure.

(4) Sukhna to Wadi Zarqa Wastewater Treatment Plant

A single gravity pipeline is proposed to carry the total flow from the entire service area from the junction point near Sukhna to the new treatment site. The length of this pipeline will be approximately 15 km, with 1800 mm in diameter. This line will run parallel to Wadi Zarqa. The line will be adequate to convey the projected 2025 peak dry weather flow of 450,000 m^3/day from the confluence point down to the treatment site.

According to the terrain, it is expected that this portion of the line will run under pressure due to the need for avoiding erosion and damage if placed strictly near the Wadi. Such an arrangement will reduce the length of the pipeline and eventually the cost.

2.5.4 Sewerage System

The review of the record drawings of the sewerage system, the data on historical flow records, water usage, and the operation and maintenance procedures, indicate that the conditions of the collection and trunk sewers need major changes in order to expand the capacity to carry the current and future flows. A part of the capacity of the pipes, slopes and conditions of the sewers were also a factor that has been considered to establish the configuration and the investment needed for the collection and conveyance systems.

Table 2.5.4-1 summarizes the changes required in the systems in terms of diameters and lengths for the areas tributary to the new Zarqa Treatment Plant with the respective years. In the following sections details are given with regard to the various areas within the study area.

Table 2.5.4-1 Required Sewers for Rehabilitation/Extension (2005/25)

Diameter	2005	2010	2015	2020	2025
DN 400	370	35	1,250	4,359	7,428
DN 500	495	3,907	990	0	516
DN 600	0	0	1,697	350	2,952
DN 700	0	1,120	4,700	381	1,704
DN 800	0	1,223	0	0	0
DN 900	3,101	0	564	1,260	0
DN 1000	1,604	0	0	0	3,359
DN 1100	0	0	0	0	0
DN 1200	0	509	1,326	527	0
DN 1300	0	1,813	0	0	0
DN 1400	70	0	540	0	0
DN 1500	2,568	558	194	0	0
DN 1600	1,192	1,239	0	0	0
DN 1700	0	0	0	0	0
DN 1800	0	0	0	0	0
DN 1900	547	0	0	0	0
Total	**9,947**	**10,404**	**11,261**	**6,877**	**15,959**
Grand Total					**54,448**

(Lengths in meters)

(1) Extension/Rehabilitation Measures in Marka and Tariq

The general conditions of the system are good, except for some manholes in Wadis that suffer from silt and debris accumulation in addition to lost covers due to vandalism. The capacity of the system is sufficient to discharge the current dry weather flows. Major trunk lines are now at their capacity, therefore, key segments of the trunk lines have to be enlarged or reinforced. Table 1 of Annex 2.5.4 shows the requirements in terms of diameters, lengths, and time for the expansions required.

(2) Extension/Rehabilitation Measures in Zarqa

Due to the low slopes of major trunk lines in Zarqa, silts and debris accumulation is of a major concern, because of the reduction of the capacity of the pipes they cause. Hydrogen sulfide production turned out not to be a major problem. The hydraulic capacity is right at the edge of its limit in many segments, and can hardly meet the dry peak weather flows at present. Major main trunks need require capacity additions as indicated in Table 2 of Annex 2.5.4.

(3) Extension/Rehabilitation Measures in Russeifa

The physical conditions of the system in Russeifa are good in general. Nevertheless, capacity additions are required in many parts in order to convey the design dry peak weather flows, which are growing with population growth in the area. Measures have to be taken to enforce the capacity of the system as shown in Table 2 of Annex 2.5.4.

(4) Extension/Rehabilitation Measures in Hashimiyya

The collection system in Hashimiyya is in good condition; with a fairly good hydraulic capacity. However, expansion or enforcement of some segments of the main trunks (around 2 km length) is needed by the year 2020 and approximately 1 km by the year 2025. Table 2 of Annex 2.5.4. illustrates these needs in different years.

(5) Proposed Constructions in Sukhna

As it is said in section 2.2.2.3 Sukhna collection system and laterals is already designed and ready for tendering through the Ministry of Public Works and Housing. Design of the main conveyor and the pumping station will be tendered by WAJ by June 2001. Financing will be by the Italian cooperation.

2.5.5 Treatment Facilities

2.5.5.1 Alternative Treatment Processes

Harza has studied in detail alternatives for wastewater treatment technologies as follows:

- Preliminary treatment
  - Screening and
  - Grit removal)
- Primary treatment
  - Primary clarification with oil and grease scum removal by Skimming
  - Upflow Anaerobic Sludge Blanket (UASB)
- Secondary treatment
  - Activated sludge
  - Trickling filters
  - Aerated lagoon
- Helminth egg removal processes
  - Continuously backwashed sand filters
- Disinfection
  - Gas chlorination
- Sludge stabilization
  - Anaerobic digestion
  - Aerobic digestion
- Sludge drying
  - Gravity sludge drying beds
  - Vacuum assisted sludge drying beds

Above mentioned technologies were combined to form complete treatment process train alternatives, whereby all process trains included nitrification/denitrification to meet wadi effluent standards.

The following screening criteria were applied for optimal process identification:

- Technologies must provide a level of treatment capable of meeting the design and effluent criteria
- Technologies must have ability to operate under the conditions expected in Amman-Zarqa Study Area
- Technologies must operate without severe odor problems
- Technologies must provide maximum flexibility for future expansion and future quality improvements

The evaluation resulted in identification of the following technologies for incorporation into 4 process trains. They are:

- Biological treatment processes
  - Activated sludge
  - Extended aeration or aerated lagoons (modified)
  - Trickling filters
  - UASB (considered as intermediate treatment)
- Sludge dewatering
  - Gravity sludge drying beds
  - Vacuum assisted sludge drying beds
- Nematode egg removal
  - Maturation ponds
  - Sand filtration.

Harza has determined major unit sizes of components under each of the 4 process trains. Construction costs were developed based on vendor provided information for major equipment items and local unit costs for civil works items. Operation and maintenance costs are based on unit costs of chemicals, power, manpower applicable relative to operation and maintenance of facilities of this type and size.

Table 2.5.5-1 presents construction costs and costs for operation and maintenance as well as total annual cost for the 4 process alternatives respectively (cost basis 1997). Harza summarizes the evaluation as follows:

- As far as the **investment costs** are concerned, aerated lagoon (modified) process train is the cheapest to construct followed by UASB, and activated sludge. Trickling filter process train is estimated to cost the highest.
- On the basis of **operation and maintenance costs**, however, activated sludge is the cheapest. The higher operation and maintenance costs under trickling filter and UASB alternatives are attributable primarily to cost of methanol addition for denitrification where as the much higher cost of aerated lagoon alternative is attributable to very high energy requirements for sludge stabilization under aerobic conditions.

- On the basis of **total annual cost**, which includes operation and maintenance cost, and annual cost of amortization of the construction cost (at interest rate 8 %), activated sludge and UASB are very close to each other and cheaper than trickling filter and aerated lagoon alternatives.

Finally, Harza in cooperation with WAJ selected activated sludge process with nitrification/denitrification as the optimum process that could be considered for implementation.

Table 2.5.5-1 Cost Comparison of Alternative Treatment Processes (HARZA 1997)

	Unit	Activated sludge	Trickling filter	UASB	Aerated lagoon
Investment cost through year 2025	Mio.JD	130.4	152.3	117.8	116.0
Operation and maintenance cost	Mio. JD/a	8.62	10.21	9.53	12.66
Total annual costs 1)	Mio. JD/a	23.9	28.0	23.3	26.2
Total annual costs 2)	Mio. JD/a	21.9	25.7	21.5	24.5
Total annual costs 3)	Mio. JD/a	20.8	24.5	20.6	23.5

Remarks:1 US$ = 0.708 JD in 1997
All process alternatives including nitrification/denitrification
1) Amortization period: 15 years, Interest rate: 8 %
2) Amortization period: 20 years, Interest rate: 8 %
3) Amortization period: 25 years, Interest rate: 8 %

2.5.5.2 Description of Selected System (Activated Sludge Process)

Figure 2.5.5-1 schematically presents major unit components of the activated sludge process train according to Harza's Study. Raw wastewater, after screening and grit removal, will flow to primary clarifiers. These clarifiers will remove approximately 30 % BOD_5 and 50 % suspended solids (mostly organic). Primary clarifier effluent will flow to anoxic zone of the activated sludge aeration tank. In this single stage activated sludge nitrification/denitrification process BOD_5 will be removed to desired level and ammonia will be converted to nitrates in the aeration basin. The aeration basin with nitrified effluent (secondary effluent) will be recycled to anoxic zone (reactor) at the head end of the aeration tank and contacted (mixed) with primary settled wastewater. In this anoxic zone nitrate will be converted to nitrogen gas; however no appreciable BOD_5 will be removed from the primary settled wastewater. The net effluent (same rate as primary effluent) from the aeration tank will be subjected to secondary clarification. This effluent will meet BOD_5 ammonia, nitrate and total nitrogen criteria for wadi discharge. In this process train, sand filtration is also included to remove nematode eggs if required. The effluent will be chlorinated to reduce coliforms to permissible level and discharged to receiving stream.

Primary sludge will be pumped to anaerobic digester; waste activated (secondary clarifier bio sludge) will be thickened through (gravity on dissolved air) sludge thickeners and anaerobically digested. The anaerobically digested primary and secondary sludges will be dewatered by vacuum assisted sludge drying beds for Wadi Zarqa site (due to space limitation at Wadi Zarqa site). Dewatered sludge will be stored on site for approximately 2 to 3 years to accomplish inactivation of nematode eggs and pathogens. The sludge will be ultimately disposed off by land application.

Table 2.5.5-2 summarizes major units and dimensions of the proposed treatment system.

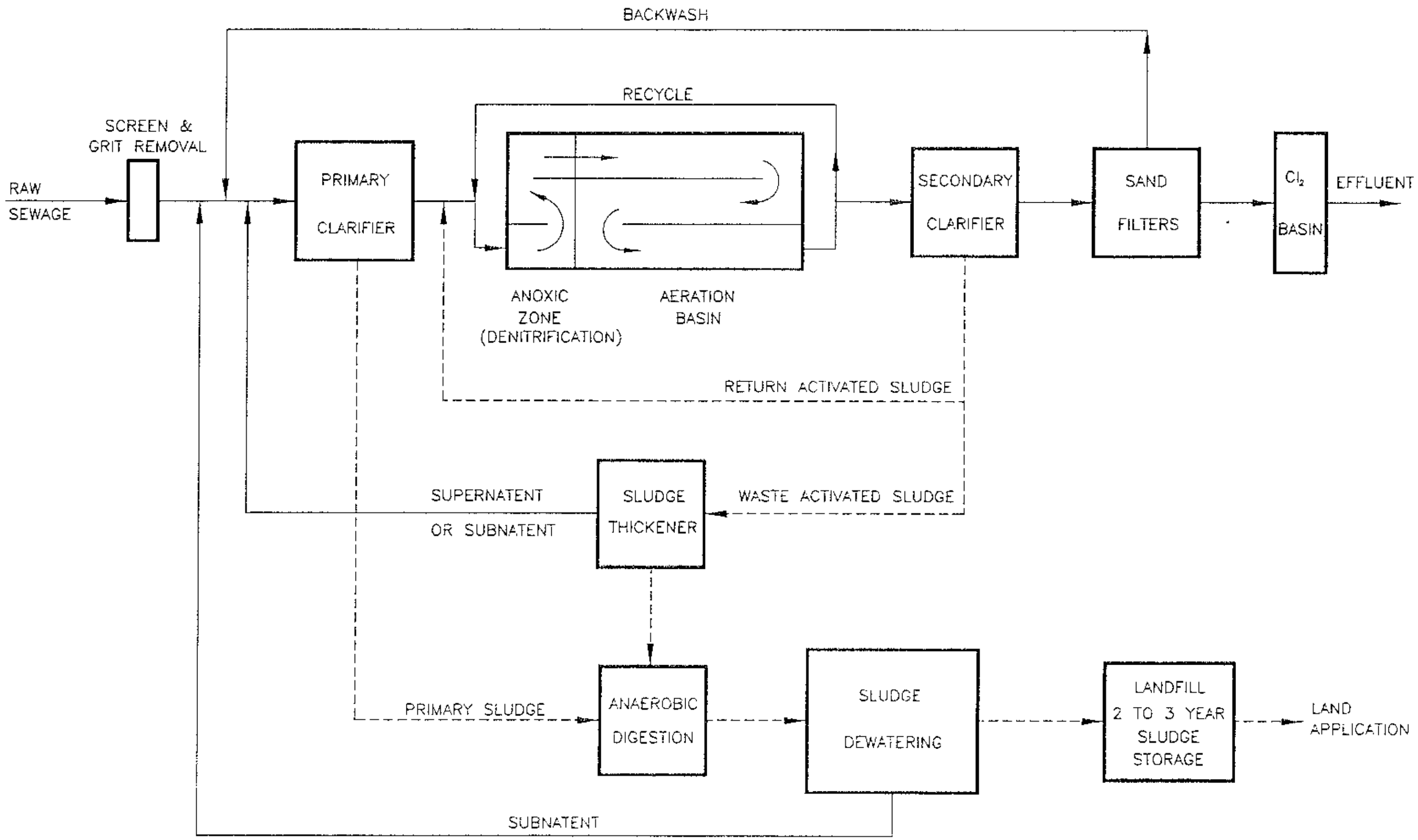

Figure 2.5.5-1 Scheme of Proposed Activated Sludge Process Train

Table 2.5.5-2 Major Unit Sizes of Proposed Process Trains Wadi Zarqa Treatment Plant (design year 2025)

Population million	2.08
Flow, m^3/day	226,000
Preliminary Treatment	
Bar Screens	
Number	3
Grit Chamber	
Number	4
Length, m	17.1
Width, m	4.6
Side Water Depth, m	3
Total Volume, m^3	944
Calculated Detention Time (h)	0.1
Primary Clarifiers	
Number	8
Diameter, m	38
Side Water Depth, m	3.7
Total Volume, m^3	33,600
Calculated Detention Time (h)	3.6
Aeration Basin	
Anoxic Zone for Denitrification	
Number	8
Length, m	16
Width, m	46
Side Water Depth, m	4.9
Total Volume m^3	28,900
Calculated Detention Time (h)	3.1
Aeration Zone for combined Oxidation/Nitrification	
Number	8
Length, m	84
Width, m	46
Side Water Depth, m	4.9
Total Volume, m^3	151,500
Calculated Detention Time (h)	16.1
Secondary Clarifier	
Number	8
Diameter, m	43
Side Water Depth, m	4.6
Total Volume, m^3	53,400
Calculated Detention Time (h)	5.7
Sand Filters	
Number of Basins	14
Number of Filters/Basin	12
Filter Unit Area, m^2	4.6
Basin Length, m	14
Basin Width, m	4.6
Chlorine Contract Tank	
Number	4
Length, m	46
Width, m	15.5
Side Water Depth, m	3.6
Total Volume, m^3	10,300
Calculated Detention Time (h)	1.1
Sludge Thickener	
Number	8
Diameter, m	21.5
Side Water Depth, m	4.5
Total Volume, m^3	13,100
Calculated Detention Time (day)	2.3

Anaerobic Digester	
Primary	
Number	8
Diameter, m	30.5
Side Water Depth, m	9.2
Total Volume, m^3	53,800
Calculated Detention Time (day)	24
Secondary	
Number	8
Diameter, m	24.5
Side Water Depth, m	9.2
Total Volume, m^3	34,700
Calculated detention time (days)	15
Vacuum Assisted Drying Beds	
Drying Area, Hectares	1

2.5.5.3 Site of Treatment Plant

The first Wastewater Master Plan of 1982, proposed the construction of a treatment plant located some 5 km downstream from the Wadi Zarqa/Wadi Dhuleil confluence. This site offered an area of about 50 - 55 hectares. This option was envisioned to be the best to construct a treatment plant to serve Zarqa, Russeifa, Hashimiyya and Sukhna areas by gravity. Due to the budget constraints, WAJ decided to construct the existing two pumping stations of West and East Zarqa and to defer the construction of any treatment plants in Zarqa area. Another site was identified later by Harza Team and then both sites were evaluated for their suitability to handle the installation for a longer period of time, taking into consideration the public acceptance and the environmental measures.

The new site located 10 km downstream of the first site offered more area than the first one. A total area of about 100 hectares was available for the second site. Although the construction of a longer conveyor of another 10 km is required for this site, it provides a location with more land for the layout of the treatment and solids handling facilities. It was also a site that included higher grounds less susceptible to flooding by high water flows. These factors were the reasons for the selection of this site.

The site was underdeveloped at the time of the survey in 1997 where primitive agricultural activities took place. Ground elevations in the level portion of the site range from 350 m to 385 m above sea level, with a steep drop near the Wadi. Under typical flow conditions the bank of the Wadi is at about 336 meters above sea level. Preliminary engineering design conducted by Harza Team revealed that this site is suitable for the development of the proposed treatment works. Additionally, the drainage direction from the whole site is towards the Wadi Zarqa, which eliminates the need for any kind of pumping.

The terrain and the main features of the treatment plant location are shown in Figure 2.5.5-2.

It is worth mentioning that the land needed for the plant at the selected location is privately owned and land acquisition is needed. The land now is agriculturally well developed. The lower part close to the Wadi bed is used to produce cerial crops, while the rest of the land is cultivated with olive, peach and apricot trees. The site is completely fenced and drip irrigation is also installed. It is believed that the water used to irrigate the trees is from the treated wastewater pumped from the Wadi. The land having been developed now, increased in value by at least twice its original value before any development.

The area available at this site is limited and does not allow for the use of drying beds as the means for sludge dewatering. Thus, mechanical or vacuum assisted drying beds for the second stage of the treatment are to be studied to cope with the land availability. Otherwise sludge has to be pumped to adjacent areas at elevated levels in order to be dried.

2.5.6 Effluent Disposal

In Section 10.2 of the Master Plan Study the water reuse plan for the Amman-Zarqa Basin and Jordan Valley as prepared by ARD in 2001 is summarized. The plan foresees to reuse a certain portion of treated effluent of the As Samra Wastewater Treatment Plant for agricultural irrigation in the uplands and industrial purposes. Generally, in the uplands the reuse of effluent (for agricultural irrigation and industrial purposes) from the As Samra WWTP has priority before the reuse of effluent from Wadi Zarqa WWTP due to the fact that As Samra WWTP is located in a higher elevation (As Samra: 600 m; Wadi Zarqa: 350 m). According to the results of ARD-Study, economic feasibility (high pumping cost) of some reuse options of effluent from As Samra WWTP are quite doubtful and, therefore, most probably the totality of effluent of As Samra WWTP will not be reused in the uplands. Therefore, it is not recommended to reuse the effluent of Wadi Zarqa WWTP on the upland region, which would cause even higher operation cost.

Therefore, effluent of the Wadi Zarqa Wastewater Treatment Plant will be discharged to the Wadi Zarqa adjacent to the plant. Finally the treated wastewater will flow into the King Talal Reservoir. From there water will flow to the Jordan Valley for ultimate reuse.

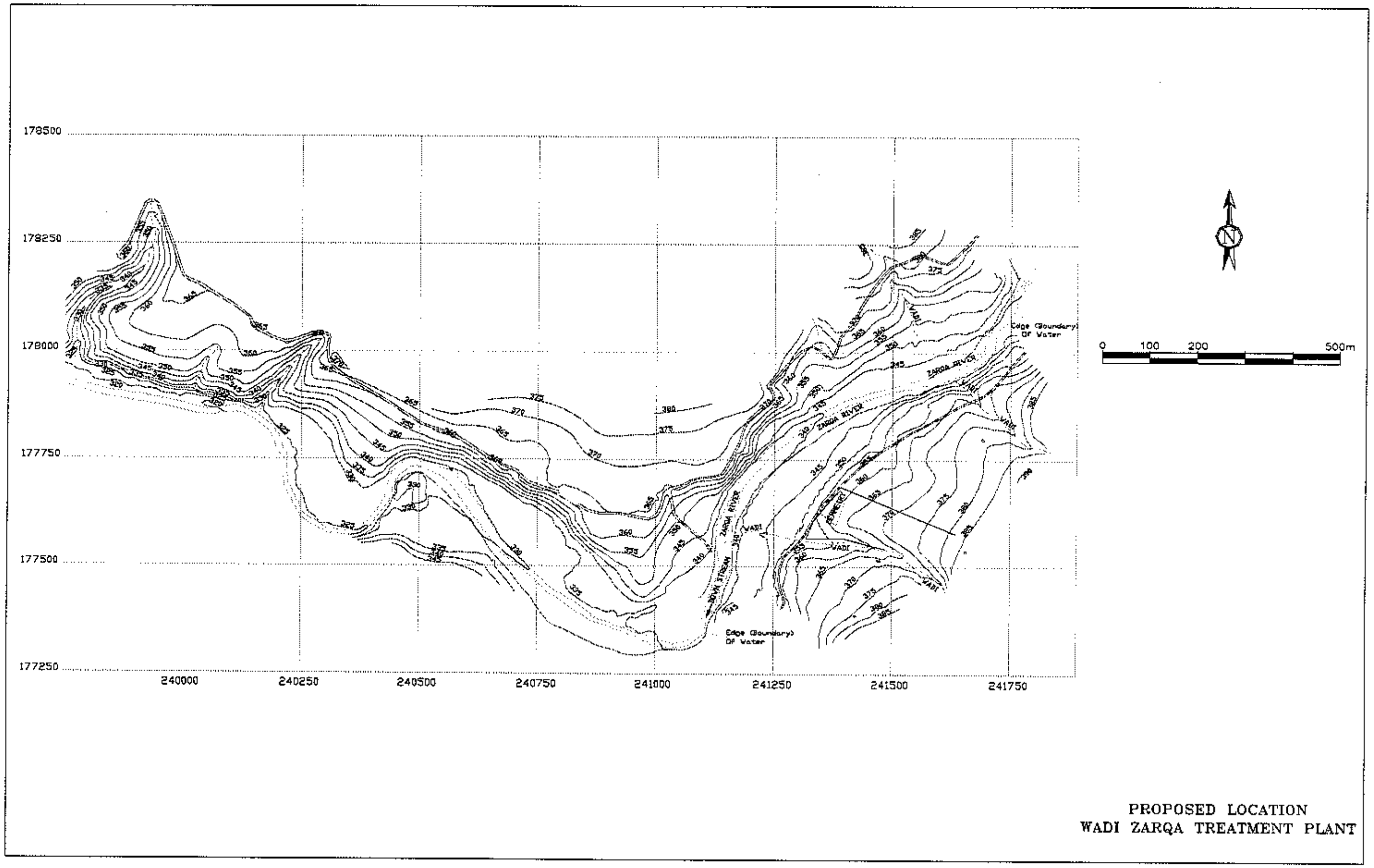

Figure 2.5.1-2 Terrain and Features of Wadi Zarqa Wastewater Treatment Plant

2.6 Operation and Maintenance Procedures

2.6.1 General

Referring 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.

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. The contract comprises wastewater treatment by the plants in Wadi Essir and Abu Nuseir.

Implementation of the planned new wastewater treatment plant in As Samra is intended applying the BOT concept. In 2001 related contract was tendered, while start of implementation is expected for 2002.

Most probably the proposed Wadi Zarqa Wastewater Treatment Plant will be implemented and operated by BOT concept, too. Experiences made with the water and wastewater management contract for Greater Amman and also with the envisaged contract to be concluded for conveyance and treatment system As Samra shall be taken into account for an envisaged contract for Wadi Zarqa wastewater project.

2.6.2 Sewerage System

To achieve the goal of conveying the generated wastewater from the catchment area of the new wastewater treatment plant at Wadi Zarqa, without major immediate capital expenditure, certain operation and maintenance measures should be followed. This will allow for proper planning for any future expansion and will certainly guarantee savings in the capital investment.

Three main problems need to be addressed, these are:

- Some pipes contain silt and debris and root intrusions, which obstruct flow in the system.
- The system receives wet weather flows from roofs and area drains connected to the sanitary system.
- Some segments have insufficient capacity to handle the projected dry weather peak flows. The number of these segments increases progressively with the planned years.

The first two issues are subject to administrative and operation and maintenance procedures to be followed, while the third issue is pure financial depending on the planning for the future and the population growth as well as the availability of water to satisfy the demand.

The following measures have to be taken to bring the collection system to operation at its full design capacity:

The day-to-day operation and maintenance program followed by WAJ is purely responding to complaints from consumers, mainly when overflows or back flows into houses are reported. The equipment used is predominantly jetting machines. In addition to these activities, the following measures have to be taken to ensure proper operation of the collection network:

- Sewer System Maintenance: this includes a systematic program of sewer inspection and cleaning to be implemented using the manhole inspection and sewer televising skills. This should be a part of the on-going day-to-day operations maintained by WAJ. Manholes inspection should be a permanent and ongoing effort until an inventory is built; then a periodic inspection would serve the needs.
- Pipes and manholes containing silts and debris accumulation have to be cleaned regularly as a part of the on-going efforts, with special emphasis on the pipes with shallow grades.
- Root intrusions have to be removed which requires special equipment, presently not available at WAJ. Such equipment will be used for the removal of the grease build up that can not be removed by normal pipe jetting equipment.
- Manholes with missing covers and lost safety steps should be replaced/repaired and maintained throughout the operation and maintenance program.
- Property installation while connecting to the network should be carefully monitored to prevent protruding taps that form areas of silts and debris accumulation and hinders the cleaning procedures.

The collection system is designed to carry dry weather peak flows, but storm water is discharged into the system mainly through roof connections. Actions should be initiated to eliminate these violations. Law No. 18 prohibits the roof connections and any drains to be discharged into the sewers except for the wastewater. This law should be activated in close cooperation between WAJ and the municipalities through the enforcement of the building codes.

Hotels and restaurants should use oil traps or oil removal units to reduce and eliminate the grease accumulation in the sewers. This became a serious problem that reduces the cross sectional area of the pipes.

The above-mentioned measures would result in improving the current conditions of the sewers in several areas and reduce the incidences of overflows in the rainy weather.

2.6.3 Treatment Facilities

In particular startup but also operation and maintenance of a new wastewater treatment plant will present challenges to the personnel assigned those responsibilities. An important component of this process is the preparation of an operation and maintenance manual by the design engineering team. The manual should be in Arabic and English versions.

Adequate training is essential in order to understand and successfully apply the guidance in the operation and maintenance manual and to support the technical staff assigned these responsibilities. The individuals who will carry out the responsibilities must be identified and their existing skills evaluated. Comparison of skills to job requirements will guide the development of a training program focused on achieving successful operation of such a complex plant as proposed for Wadi Zarqa.

In the frame of on-the-job training experienced technicians shall guide counterparts who are new to the process or specific equipment that will be under their care. The manufacturer of specific equipment installed will be expected to instruct operators and technicians on its unique characteristics and requirements.

Operation and maintenance procedures in Phase I will require about 50 employees and in Phase II some 65 employees.

2.7 Preliminary Cost Estimates

2.7.1 Basic Assumptions and Unit Costs

All investment and operation costs are presented as constant prices 2001. Costs are based HARZA's estimates and are inflated by 3 % per annum for the years between 1997 and 2001 and finally rounded to a round number.

Cost estimation for sewer pipes, major electrical and mechanical equipment are based on prices obtained from suppliers and bids.

For construction cost following basic prices were assumed:

- Excavation: 8 JD/m³
- Backfill: 1.7 JD/m³
- Reinforced Concrete: 100 JD/m³

For operation and maintenance the following basic costs were assumed:

- Power: 0.023 JD/kWh
- Average Labor: 340 JD/month
- Chlorine: 0.45 JD/kg
- Methanol: 250 JD/ton (Duty free)
- Polyelectrolyte: 5.25 JD/kg
- Fuel: 0.3 JD/liter
- Average Maintenance: 3 % of construction cost/year

2.7.2 Investment Costs

Wadi Zarqa Treatment Plant and conveyance consist of new facilities to be constructed in two phases. The first phase (Phase I) is to serve the area until the year 2015 of a total population of 1.4 million with an estimated capacity of 52 MCM per year. The next stage is to serve a total population of 2.1 million with an estimated capacity of 81 MCM per year for the year 2025 (Phase II).

Table 2.7.2-1 shows the changes required for the rehabilitation and extension of the sewerage systems in terms of cost for the areas tributary to the new Wadi Zarqa Treatment Plant with the respective years. In addition the table summarizes the investment needed in five-year intervals (see section 2.5.4). In addition, Annex 2.7.2 summarizes the investment needed in five-year intervals based on the same figures, but broken down in different sewerage areas..

Table 2.7.2-1 Net Investment Cost for Sewerage System (2005/25)

Diameter	Cost in JD				
	2005	2010	2015	2020	2025
DN 400	25,900	2,450	87,486	305,116	519,981
DN 500	37,125	293,003	74,243	0	38,700
DN 600	0	0	144,245	29,784	250,912
DN 700	0	99,716	418,282	33,945	151,674
DN 800	0	119,834	0	0	0
DN 900	356,581	0	64,860	144,900	0
DN 1000	212,241	0	0	0	444,516
DN 1100	0	0	0	0	0
DN 1200	0	76,335	198,885	79,050	0
DN 1300	0	290,096	0	0	0
DN 1400	13,650	0	105,222	0	0
DN 1500	680,414	147,817	51,304	0	0
DN 1600	369,458	383,966	0	0	0
DN 1700	0	0	0	0	0
DN 1800	0	0	0	0	0
DN 1900	243,282	0	0	0	0
Total	1,938,650	1,413,217	1,144,527	592,795	1,405,782
Grand Total					**6,494,970**

Estimated construction costs for the treatment facilities selected (see section 2.5.5.2) by implementation Phase I (2015) are summarized in Table 2.7.2-2. Total cost for Phase I are found to be 95.1 million JD. Additional 28.6 million JD are required for expansion of the plant's capacity to about 250,000 m³/d for target year 2025.

Cost for land acquisition are presented as separate line item. 100,000 JD per hectare for non- farm land and 70,000 JD per hectare for farmland were taken as unit price. A total price of 7.88 million JD is estimated to acquire the 100 hectares.

Table 2.7.2-2 Net Cost for Treatment Plant

	Phase I (2015) in mill.JD			**Phase II (2025) in mill.JD[1)]**		
	Foreign	**Local**	**Total**	**Foreign**	**Local**	**Total**
Preliminary treatment (screens/grit chambers)	2.219	2.219	4.437	740	740	1.480
Primary treatment (primary clarifiers)	1.243	1.243	2.486	414	414	829
Biological treatment (aeration basins)	8.403	8.403	16.807	2.801	2.801	5.602
Secondary clarifiers	1.789	1.789	3.578	597	597	1.193
Filtration (backwash filters)	2.949	1.966	4.916	983	656	1.639
Disinfections	878	585	1.463	292	195	487
Sludge thickeners	559	839	1.398	186	279	466
Anaerobic digesters	5.828	5.828	11.656	1.943	1.943	3.886
Drying beds (Vaccum assisted)	4.154	6.231	10.384	1.384	2.077	3.461
Methane recovery/Power generation facilities	2.279	570	2.849	760	190	950
Buildings	198	793	992	0	0	0
Subtotal 1	**30.500**	**30.466**	**60.966**	**10.101**	**9.891**	**19.992**
Site work (10%)	1.219	4.877	6.097	400	1.599	1.999
Yard piping (8%)	3.414	1.463	4.877	1.120	480	1.599
Electrical equipment (15%)	9.145	0	9.145	2.999	0	2.999
Instrumentation (10%)	6.097	0	6.097	1.999	0	1.999
Subtotal 2 (WWTP without land cost)	**50.375**	**36.807**	**87.181**	**16.618**	**11.970**	**28.588**
Land acquisition (100 ha)	0	7.879	7.879	0	0	0
Subtotal 3 (WWTP with land cost)	**50.375**	**44.685**	**95.060**	**16.618**	**11.970**	**28.588**

1) Additional in 2025 in relation to the investments up to 2015

Total investment cost until 2015 for the Wadi Zarqa system is shown in Table 2.7.2-3.

Table 2.7.2-3 Total Investment Cost for Wadi Zarqa Sewerage and Treatment System

(Basis: JD2001)

COMPONENT	UNIT	QUAN-TITY	FOREIGN AMOUNT JD	LOCAL AMOUNT JD	TOTAL AMOUNT JD	PERCENT OF TOT. NET PRICES
SEWERAGE NETWORK						
Extension of existing sewerage system (2004)	l. sum	1	194,000	1,746,000	1,940,000	2.0%
Extension of existing sewerage system (2009)	l. sum	1	141,000	1,269,000	1,410,000	1.4%
SUB-TOTAL SEWERAGE NETWORK			335,000	3,015,000	3,350,000	3.4%
WASTEWATER TREATMENT PLANT (WWTP)						
Wastewater treatment plant (Phase 1, 2015)	l. sum	1	50,370,000	36,810,000	87,180,000	88.6%
Land acquisition	l. sum	1	0	7,880,000	7,880,000	8.0%
SUB-TOTAL WWWTP			50,370,000	44,690,000	95,060,000	96.6%
SUB-TOTAL (Sewerage and treatment plant)			**50,705,000**	**47,705,000**	**98,410,000**	
OTHER WORKS						
SUB-TOTAL (BASE COST FOR INFRASTRUCTURE)			**50,705,000**	**47,705,000**	**98,410,000**	**100.0%**
Administration costs (5 % of net invest. cost)		5	0	4,920,500	4,920,500	5.0%
Engineering costs (10 % of net invest. cost)		10	7,872,800	1,968,000	9,841,000	10.0%
SUB-TOTAL (INDIRECT COST)			7,872,000	6,888,700	14,761,500	15.0%
Physical contingencies (10 % of base cost infrastructure+indir.cost)		10	5,857,780	5,459,370	11,317,150	11.5%
TOTAL			**64,435,580**	**60,053,070**	**124,488,650**	126.5%

2.7.3 Operation and Maintenance Costs

Based on the unit prices and assumptions outlined in section 2.7.1 costs for operation and maintenance were estimated. Table 2.7.3-1 shows the estimated operation cost for the target year 2015. As far as the sewerage system is concerned presented costs are related with the new investment only (from 2005 on). Operating costs for the new Wadi Zarqa Wastewater Treatment Plant are dominated by energy cost required for the aeration in the biological reactors. Total annual costs for operation and maintenance amount to some 6.27 million JD in 2005 and about 7.37 million JD in 2015 to serve a population of 1.7 million connected to the sewerage system.

Table 2.7.3-1 Operation and Maintenance Cost

Component	Unit	Costs 2005	Costs 2015
Staff cost	JD/a	204,000	204,000
Maintenance cost (WWTP)	JD/a	3,140,000	3,140,000
Maintenance cost (sewerage)[1)]	JD/a	10,000	17,000
Consumables (chlorine, polyelectrolyte, methanol)	JD/a	1,140,000	1,810,000
Energy cost	JD/a	1,600,000	2,540,000
Miscellaneous (laboratory, fuel, etc.)	JD/a	171,000	171,000
Methane recovery/power generation	JD/a	(323,000)	(513,000)
Total cost:	**JD/a**	**6,265,000**	**7,369,000**

1) For new investments (up to 2015) only

2.8 Economic and Financial Analysis

2.8.1 Socio-Economic Conditions

(1) Population

<u>Population and its Growth in the Past</u>

Item	1979 Census	1994 Census	Inter-Censual Growth Rate/a
Jordan	2,149,177	4,139,458	4.5%
Zarqa Governorate	332,195	639,469	4.5%
Zarqa City*	216,065	350,849	3.3%

Source: Department of Statistics
Note: *=Includes the population of Beirain sub-district.

The 1994 population of Zarqa City and its localities was 350,849. It accounted for 55% of the governorate population. It grew during the inter-censual 15 years 1979 to 1994 at the average annual rate of 3.3%, which was more than one percent lower than both the governorate and national averages as shown in the above table.

(2) Employment

Employment

Item	Employment, 1997	Population, 1997	Employment/1,000 Population
Jordan	410,136	4,600,000	89
Amman Governorate	269,499	1,751,680	154
Jordan (excl. Amman Governorate)	140,637	2,848,320	49
Zarqa Governorate	33,927	710,700	48

Source: Statistical Yearbook of Jordan 1998, Department of Statistics

The employment includes that for all the establishments employing 5 persons or more, in both public and private sectors for all economic activities, with the exception of the agricultural sector, armed forces, public security and civil defense.

Employment per 1,000 population was 48 in the Zarqa Governorate in comparison with its outside Amman Governorate average of 49 in 1997. It shows that the economic activities of this governorate is on a par with the rest of the country excluding the Amman Governorate.

2.8.2 Economic and Financial Analysis

(1) Methodology

1) Financial Analysis

(a) Preparation of cost benefits streams

a) Project life for financial analysis was set at 30 years.

b) Preparation of cost streams
The estimated initial cost of the project was spread over the implementation period. Also, the annual recurrent cost for the operation and maintenance (O & M) of the facilities was entered annually after the implementation up to the end of the project life.

c) Preparation of influent stream
The quantity of influent to be transported from the users to the wastewater treatment plant was annually entered after the implementation of the project up to the end of the project life.

Then, the estimated administrative loss of water was annually subtracted from the quantity of water to be transported. This way, the quantity of water to be transported and billed was annually determined up to the end of the project life.

d) Estimation of the unit value of influent
The financial value of the unit quantity of influent was estimated based on the existing sewerage tariff and the future needs for raising it.

e) Preparation of benefits stream
From items c) and d) the benefits stream was worked out up to the end of the project life.

(b) Calculation of Financial Criteria and Financial Evaluation

a) The discount rate was assumed as 5%.

b) Using the cost benefits streams, FIRR, NPV and the unit wastewater price were calculated.

c) Based on the values of financial criteria, taking into consideration qualitative factors as well, the judgment on the financial feasibility of the project was passed.

2) Economic Analysis

(a) Preparation of cost benefits streams

a) Project life
(Same as in financial analysis)

b) Preparation of cost streams
The estimated initial cost was divided into foreign and local components. The standard conversion factor was applied to the local components, except land acquisition cost, which was annualized based on land rent.

The initial cost of the project was spread over the implementation period. Also, the annual recurrent cost for the operation and maintenance (O & M) of the facilities was entered annually after the implementation up to the end of the project life.

c) Preparation of influent stream
The quantity of influent to be transported from the users to the wastewater treatment plant was annually entered after the implementation of the project up to the end of the project life.

d) Estimation of unit value of influent
The economic value of the unit quantity of wastewater to be transported by the sewerage was estimated based on the affordability of a household to pay for the sewerage service and the wastewater discharge per household.

e) Preparation of benefits stream
From items c) and d) the benefits stream was worked out up to the end of the project life.

(b) Calculation of Economic Criteria and Economic Evaluation

a) The opportunity cost of capital was assumed as 10%.

b) Using the cost benefit streams, EIRR, NPV and the wastewater price were calculated.

c) Based on the values of economic criteria, taking into consideration qualitative factors as well, the judgment on the economic feasibility of the project was passed.

(2) Preconditions

1) Incremental Wastewater Inflow (Unit: m^3/year)

Year	2005	2010	2015
Incremental Wastewater Inflow	32,730,000	41,400,000	52,000,000

2) Investment Costs (Unit: JD)

Investment Costs	Local Components		Foreign Components	
124,488,650	48%	60,053,070	52%	64,435,580

3) Implementation Schedule

2001	2002	2003	2004	2005	2006

4) O & M Costs (Unit: JD)

Year	2005	2010	2015
O & M Costs	6,265,000	6,817,000	7,369,000

5) Sewerage Tariff (Unit: Fils/m^3)

2003	2004	2005	2006	2007	2008	2009	2010
147	173	205	242	285	336	397	468

Starting in 2004, the average sewerage tariff per m^3 of wastewater was assumed to be increased at the annual rate of 18% up to 2010.

6) Unit Benefits of Sewage : 368 Fils/m^3

(3) Results of Financial Analysis

FIRR	NPV (JD)	Unit Wastewater Price (Fils)
7.4%	42,775,788	363

Note: Discount Rate=5%

(4) Results of Economic Analysis

EIRR	NPV (JD)	Unit Wastewater Price (Fils)
6.5%	-30,053,706	464

Note: Discount Rate=10%

(5) Evaluation

This project is financially feasible with the FIRR of 7.4%, NPV of 42.8 million JD and the unit wastewater price of 363 fils per m^3. However, it is economically not feasible with the EIRR of 6.5%, NPV of –30.1 million JD and the unit wastewater price of 464 fils per m^3.

The project is financially feasible on conditions that the sewerage tariff be raised at the annual rate of 18% since 2004 up to 2010. As a result, the sewerage tariff will be 468 fils per m^3 in 2010. This value is beyond the assumed affordable limit of 368 fils per m^3. However, as the sewerage charge is paid together with the water charge, which is still substantially low compared with the affordability limit, the combined water and sewerage charges are calculated to be sufficiently affordable by the households. The EIRR of 6.5% is low measured by the OCC of 10%. However, the value can be said to be passable as a socially oriented project.

As a conclusion, the project is judged to be financially as well as economically worthwhile and suitable for implementation.

2.8.3 Preparation of Projected Financial Statements

(1) Preconditions

The projected financial statements, namely the income statement, the funds statement and the balance sheet were prepared.

In preparing projected financial statements, the following preconditions were set:

Item	Values, etc.
Financing resources	80% : External; 20%: Local
Financing terms	Repayment period: 30 years
	Grace period: 5 years
	Annual interest rate: 4%
Inflation rate	2%/a
Executing Entity	Public
Corporate Tax	0%

(2) Evaluation of Projected Financial Statements

The financial statements for the wadi Zarqa wastewater treatment plant extension project shown in Table 2.8.3-1 are summarized by the representative managerial indices as follows:

(Unit: %)

Project	Profit/ Revenues	Working Capital/ Revenues	Profit/ Liabilities and Capital
	Up to 2020	Up to 2020	Up to 2020
Wadi Zarqa WW Treatment	24.3	21.6	4.3

For the sake of comparison analysis, it can be stated that the standard level would be 10% for the profit to revenues ratio, 10% for the working capital to revenues ratio, and 5% for the profit to liabilities and capital ratio.

Regarding the profit to revenues ratio, the project has been found to be perfectly OK with the calculated value more than two times the standard level. With regard to the working capital to revenues ratio also, the project is solidly sustainable with the value more than twice the desired level.

With respect to the profit to liabilities and capital ratio, the project would not be up to the standard level. However, this point should not be overemphasized because this undertaking of social nature is essentially not profit-oriented and, therefore, the estimated value should be regarded as acceptable.

In conclusion, it can be stated that the project would be financially quite sustainable under the afore-mentioned preconditions, although it should be noted that it might face liquidity problem in the initial years, which must be overcome by either the fund on hand or by borrowings.

Table 2.8.3-1 Financial Statement of Wadi Zarqa Wastewater Treatment Project

unit : JD at Current Price

Item	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
(1) Income Statement																		
Revenues	0	0	0	8,001,329	10,204,732	13,013,370	16,593,108	21,155,171	22,142,015	23,174,893	24,255,953	25,387,442	26,571,712	26,571,712	26,571,712	26,571,712	26,571,712	26,571,712
O & M Cost	0	0	0	6,761,702	7,014,402	7,276,546	7,548,486	7,830,590	7,953,487	8,078,312	8,205,096	8,333,870	8,464,665	8,464,665	8,464,665	8,464,665	8,464,665	8,464,665
Depreciation	0	0	0	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660
Interest Payment	1,659,849	3,319,697	4,979,546	4,979,546	4,979,546	4,979,546	4,780,364	4,581,182	4,382,000	4,182,819	3,983,637	3,784,455	3,585,273	3,386,091	3,186,909	2,987,728	2,788,546	2,589,364
Expenditures	1,659,849	3,319,697	4,979,546	15,475,908	15,728,608	15,990,751	16,063,510	16,146,432	16,070,146	15,995,790	15,923,392	15,852,984	15,784,597	15,585,415	15,386,234	15,187,052	14,987,870	14,788,688
Profit Before Tax	-1,659,849	-3,319,697	-4,979,546	-7,474,579	-5,523,875	-2,977,381	529,598	5,008,739	6,071,868	7,179,103	8,332,561	9,534,457	10,787,115	10,986,297	11,185,478	11,384,660	11,583,842	11,783,024
Tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Profit After Tax	-1,659,849	-3,319,697	-4,979,546	-7,474,579	-5,523,875	-2,977,381	529,598	5,008,739	6,071,868	7,179,103	8,332,561	9,534,457	10,787,115	10,986,297	11,185,478	11,384,660	11,583,842	11,783,024
	(up to 2020)																	
Average Profit Before Tax to Revenues Ratio	24.3%																	
Average Profit After Tax to Revenues Ratio	24.3%																	
(2) Funds Statement																		
Profit After Tax	-1,659,849	-3,319,697	-4,979,546	-7,474,579	-5,523,875	-2,977,381	529,598	5,008,739	6,071,868	7,179,103	8,332,561	9,534,457	10,787,115	10,986,297	11,185,478	11,384,660	11,583,842	11,783,024
Loans+Budget	41,496,217	41,496,217	41,496,217	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Depreciation	0	0	0	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660	3,734,660
Sources	39,836,368	38,176,519	36,516,671	-3,739,919	-1,789,216	757,278	4,264,257	8,743,398	9,806,528	10,913,763	12,067,220	13,269,117	14,521,774	14,720,956	14,920,138	15,119,320	15,318,502	15,517,683
Capital Works	41,496,217	41,496,217	41,496,217	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Payment of Principal	0	0	0	0	0	4,979,546	4,979,546	4,979,546	4,979,546	4,979,546	4,979,546	4,979,546	4,979,546	4,979,546	4,979,546	4,979,546	4,979,546	4,979,546
Working Capital	-1,659,849	-3,319,697	-4,979,546	-3,739,919	-1,789,216	-4,222,268	-715,289	3,763,852	4,826,982	5,934,217	7,087,674	8,289,571	9,542,228	9,741,410	9,940,592	10,139,774	10,338,956	10,538,137
Applications	39,836,368	38,176,519	36,516,671	-3,739,919	-1,789,216	757,278	4,264,257	8,743,398	9,806,528	10,913,763	12,067,220	13,269,117	14,521,774	14,720,956	14,920,138	15,119,320	15,318,502	15,517,683
	(up to 2020)																	
Average Working Capital to Revenues Ratio	21.6%																	
(3) Balance Sheet																		
Liabilities	33,196,973	62,244,325	91,291,677	91,291,677	91,291,677	86,312,131	81,332,585	76,353,039	71,373,493	66,393,947	61,414,401	56,434,855	51,455,309	46,475,763	41,496,217	36,516,671	31,537,125	26,557,579
Capital	6,639,395	15,768,562	23,237,881	15,763,303	10,239,427	7,262,046	7,791,644	12,800,383	18,872,251	26,051,354	34,383,915	43,918,372	54,705,487	65,691,783	76,877,262	88,261,922	99,845,764	111,628,788
Liabilities and Capital	39,836,368	78,012,887	114,529,558	107,054,979	101,531,104	93,574,177	89,124,229	89,153,421	90,245,744	92,445,301	95,798,315	100,353,227	106,160,795	112,167,546	118,373,478	124,778,593	#########	138,186,367
Current Assets	-1,659,849	-4,979,546	-9,959,092	-13,699,011	-15,488,227	-19,710,495	-20,425,783	-16,661,931	-11,834,949	-5,900,733	1,186,941	9,476,512	19,018,740	28,760,150	38,700,742	48,840,516	59,179,472	69,717,609
Fixed Assets	41,496,217	82,992,433	124,488,650	120,753,991	117,019,331	113,284,672	109,550,012	105,815,353	102,080,693	98,346,034	94,611,374	90,876,715	87,142,055	83,407,396	79,672,736	75,938,077	72,203,417	68,468,758
Assets	39,836,368	78,012,887	114,529,558	107,054,979	101,531,104	93,574,177	89,124,229	89,153,421	90,245,744	92,445,301	95,798,315	100,353,227	106,160,795	112,167,546	118,373,478	124,778,593	#########	138,186,367
	(up to 2020)																	
Average Profit Before Tax to Liabilities and Capital Ratio	4.3%																	

2.9 Preliminary Implementation Plan

The construction of Wadi Zarqa Wastewater Treatment Plant will be implemented by 2003 after commencement of the construction of As Samra Wastewater Treatment Plant. The construction period is scheduled to be around four (4) years according to the existing plan as shown below:

Year	2001	2002	2003	2004	2005	2006	2007	2008
As Samra TP								
Wadi Zarqa TP								

2.10 IEE for the Wadi Zarqa Wastewater Treatment Plant

2.10.1 Project Components and Activities

Wadi Zarqa Wastewater Treatment Plant is part of the sewerage system in the Amman-Zarqa area. Its service area will cover Zarqa, Russeifa, Hashimiyya and the presently unsewered Sukhna as is shown in Fig. 2.10.1-1. Table 2.10.1-1 shows the main components of the Wadi Zarqa conveyance and treatment system. Their locations are also shown in Fig. 2.10.1-1.

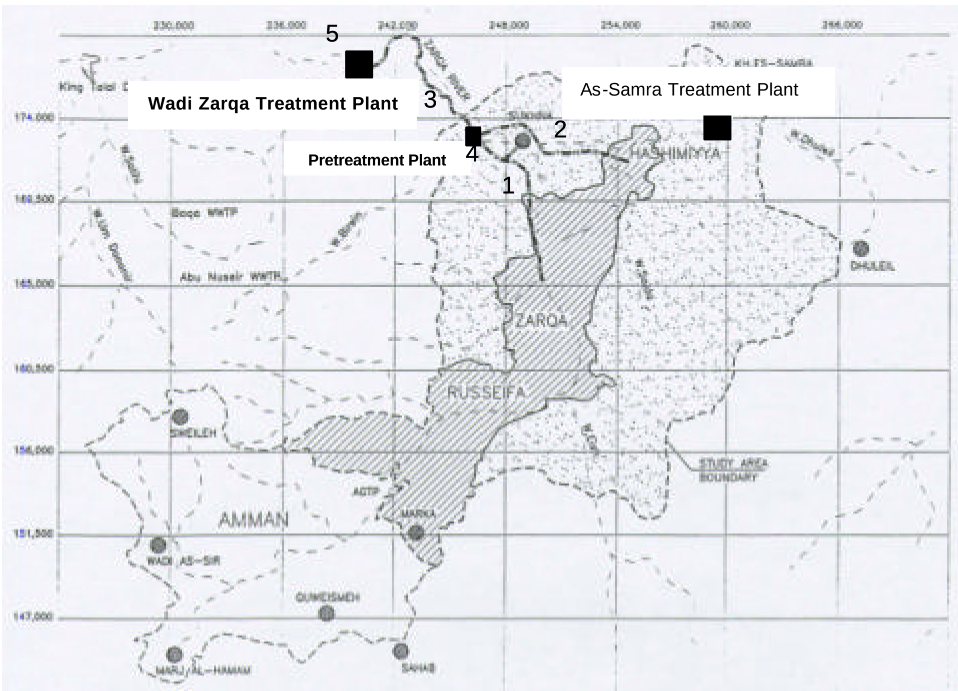

Fig. 2.10.1-1 Service Area of Wadi Zarqa WWTP

Table 2.10.1-1 Main Project Components

Project Components			Description
Conveyance Pipelines	**1**	West Zarqa Pumping Station – Sukha Pretreatment Plant	8 km long, 1500 mm diameter
	2	Hashimiyya Pumping Station – Sukha Pretreatment Plant	7 km long, 1000 mm diameter
	3	Sukha Pretreatment Plant – Wadi Zarqa WWTP	15 km long, 1800 mm diameter
Treatment Facilities	**4**	Sukhna Pretreatment Plant	Facilities: coarse screens, bar screens, aerated grit chambers; Capacity: 226,000 m^3/d
	5	Wadi Zarqa WWTP	Facilities: activated slude process with nitrification/denitrification; Capacity: 146,000 m^3/d (2015), 226,000 m^3/d (2025)

2.10.2 Environmental Examination Matrix

Using the main project activities shown in Table 2.10.1-1 and the environmental elements specified in the JICA guideline, an environmental examination matrix is obtained as below.

Table 2.10.2-1 Environmental Examination Matrix for the Wadi Zarqa WWTP

Environmental Elements / Project Activities		Social Environment									Natural Environment									Environmental Pollution						
		Resettlement	Economic Activity	Traffic & Living Facilities	Community Separation	Archaeological & Cultural Properties	Water Right / Right of Common	Public Health & Sanitation	Solid Waste	Risk of Disaster	Topography & Geography	Soil Erosion	Groundwater	Lake and Rivers	Coastal Area	Flora & Fauna	Meteorology	Landscape	Air Pollution	Water Pollution	Soil Pollution	Noise & Vibration	Ground Subsidence	Offensive Odor	Hazardous Substances
Construction Phase	Conveyance Pipelines			△		△						△		△		△				△					
	Pretreatment Plant					△			△			△		△		△				△					
	Wadi Zarqa WWTP		△			△			△			△		△		△				△					
Operation Phase	Conveyance Pipelines																								
	Pretreatment Plant																							△	
	Wadi Zarqa W WTP												△								△			△	

×: Significant Negative Impact △: Moderate Negative Impact Shade: No Negative Impact

2.10.3 Rational of Environmental Impacts Screening

2.10.3.1 Social Environmental Factors

(1) Resettlement

The construction of the Wadi Zarqa WWTP will need land acquisition of approximately 100 ha. The proposed site is located along the Wadi Zarqa about 15 km downstream of Sukhna. It is an area recently developed for farming. There are two small roads running parallel to the wadi and also a small cemetery in the vicinity. The village mostly near the site is As Sahara with a population about 70 people. However, all the village houses are at the left bank of the wadi, but the WWTP site will be at the right bank. Therefore, no houses will be affected by the plant construction and the problem of resettlement will not be involved at all.

Regarding the pretreatment plant at Sukhna, the proposed site is also near the wadi a little bit downstream of the confluence of the Wadi Dhuleil with the Wadi Zarqa. The site is presently undeveloped and therefore with no village houses in the vicinity.

For the construction of wastewater conveyance lines, access road and electric power transmission line, temporary use of land will be involved. The route of these lines will mainly be along the wadis, and no impacts on any village house are anticipated. However, they may have an impact on the King Talal Reservoir's capacity due to sediment transport to the reservoir.

(2) Economic Activity

During the study of HARZA before 1997, the WWTP site was almost undeveloped except for certain cultivated land near the wadi. Afterwards, the landlord speeded the development of the land in almost all the proposed plant area. The Study Team conducted site reconnaissance and noticed the remarkable change after the four years. By the existing road parallel to the wadi, the site is divided into the wadi side part and hill side part. At the wadi side, the land is mainly used for cultivation of potatoes, and at the hill side, there are newly planted trees of apricot and olive. The only undeveloped area is the steep rocky slope in between. Therefore, the construction of the WWTP will need an acquisition of all these cultivated lands. The current agricultural activity at this site will be stopped.

The construction of the pretreatment plant and the conveyance pipelines may also disturb directly or indirectly the agricultural and/or pastoral activities in the related area, but the extent may not be so great because most of the area is still undeveloped.

However, positive impacts are also anticipated because the implementation of the project will provide opportunity of employment during project construction and operation.

(3) Traffic and Living Facilities

The sites for the WWTP and pretreatment plant will be in the agricultural and pastoral area, and the route for the conveyance pipelines will be along the wadis. In the vicinities of these sites, there are not public buildings or facilities. There is one main road almost parallel with the Wadi Zarqa before and after the confluence of Wadi Duhleil near Sukhna, and across the wadi at two locations. The construction of the 1500mm and 1800mm conveyance pipelines may more or less affect the traffic condition of this road. There is another road parallel with the Wadi Zarqa at its right bank. This is the road to be improved for the access to the WWTP.

(4) Community Separation

Because the construction sites of the WWTP and pretreatment plant are in the undeveloped area and the route of the conveyance pipelines is along the existing wadis, the implementation of the project will not cause the problem of community separation.

(5) Archaeological and Cultural Properties

In and surrounding the project area, there exist many archaeological sites dated from Palaeolithic, Neolithic, Bronze ages to Roman and Islamic periods. It is because the Wadi Zarqa was a major communication route in the past between the Jordan Valley and the highlands to the east, and because of its semi-permanent flow of water, that much use was made of it over the millennia. According to the Harza study (1997), at least the known sites shown in Table 2.10.3-1 within the project area need to be paid particular attention.

Table 2.10.3-1 Known Archaeological Sites in the Project Area

Area	Site Name	JADIS Number	Age
Wadi Zarqa upstrem the confluence	Site 45	2516.016	Iron Age II
	Jreyyeh	2516.011	Early Bronze Age II
	Jebel Reheil	2517.022	Islamic Period
	Tell Es-Sukhna	2517.002	Roman and Byzantine Time
	Sukhna North	2517.027	Early Bronze Age II
Wadi Zarqa downstream the confluence	Wad'ah	2417.025	Roman and Byzantine Time
	Khirbet el-Wad'ah	2417.005	Islamic Period
	Bireh South	2417.044	Roman and Byzantine Time
	Tell Bireh	2417.021	Iron Age II

Note: JADIS – Jordan Antiquities Data Information System

In addition to those shown in Table 2.9.3-1, there are still many locations of archaeological significance. The Department of Antiquities has records of these sites in the JADIS database. Attention should be paid in the final decision of the route of the conveyance pipelines for an effective protection of these archaeological sites.

(6) Water Right and Right of Common

The implementation of the project will not relate to any problem regarding water right or right of common.

(7) Public Health and Sanitation

The objectives of the project are to improve the sanitary condition and to protect the environment in the service area. In this regard, the impacts will be positive regarding this item. The effluent from the WWTP will be discharged to the Wadi Zarqa where water finally flows to the King Talal Reservoir (KTR). Because the wadi is presently a carrier of the wastewater effluent from As Samra WWTP, discharge of the effluent from the new WWTP to it will not change its nature at all, and on the contrary, because of the more advanced wastewater treatment process (activated sludge and nitrification/ denitrification system) to be applied in the new WWTP than that presently applied in As Samra (pond system), the quality of the effluent will be much improved. Consequently, the sanitary condition in the Wadi Zarqa - KTR system will be improved. The KTR water is now being conveyed to the Jordan Rift Valley area through the lower part of the Wadi Zarqa for agricultural irrigation. In the future, the reuse scheme will be much expanded. With the improvement in the quality of the effluent from the new WWTP, as well as that from the As Samra WWTP through another project, the impacts of water quality on the public health directly through the water environment and indirectly through its reuse for the irrigation of crop field will definitely mitigated.

(8) Solid Waste

Solid wastes will be generated in the construction of the WWTP and the pretreatment plant, and also from the construction of conveyance pipelines. Most of the solid wastes are soils from excavation. In the case of conveyance pipelines, the soil will be used to fill up the excavated ditch to bury the pipes but some part of the soil will remain. Much excavated soil will be borne in the plant construction site. Hence a suitable place will need to be located as the disposal site. Because there will be no hazardous wastes generated during the construction work, significant impact on the environment is not anticipated in the solid waste disposal.

In the operation phase, sludge will be generated from the WWTP and also the pretreatment plant. The primary means of sludge disposal is expected to be use of digested, stabilized sludge for land application for agricultural, forestry and other uses. To assure that the sludge is safe for application, sufficient area will be provided in the WWTP sites for sludge storage for up to three years. The prolonged storage period is considered necessary to provide for removal, through natural mortality, of nematode eggs.

(9) Risk of Disaster

Considering the scale and contents of the project, there will not be any factor related to any risk of disaster.

2.10.3.2 Natural Environmental Factors

(1) Topography and Geography

The project sites are in the Zarqa River Valley area featured by the presence of the fault zone which is explained as the relative 20^o rotation of the block on both sides of the Wadi Zarqa. The site proposed for the new WWTP is at the right bank of the Wadi Zarqa approximately 15 km downstream of Sukhna. Ground elevations in the relatively level portions of the site range from about 350 m to 385 m above sea level. The elevations drop off steeply near the wadi where the bank elevation is about 336 m under typical flow conditions. Drainage from the entire site is toward the Wadi Zarqa. The construction of the treatment facilities will basically utilize the natural slop and therefore the topographic feature of that area will not be changed.

Because the conveyance pipelines will along the wadis, any impact on topography and geography is not anticipated either.

(2) Soil Erosion

Soil erosion may more or less happen during the construction phase due to excavation related to the construction of treatment facilities and conveyance pipelines. However, the impact will be short term and limited to the construction sites. In the operation phase, no impact is anticipated regarding this item.

(3) Groundwater

Regarding the impacts on groundwater, we have to consider different areas related to the project. The provision of improved sewerage facilities as a result of the project, will reduce localized contamination of the upper groundwater aquifer that currently results from cesspools. This result will be the most significant in the presently unsewered Sukhna area. Therefore, in the service area of the sewerage system the impacts would be positive.

Groundwater infiltration of the treated wastewater effluent into the river channel alluvium and B2/A7 aquifer along the Wadi Zarqa is a problem of concern. Generally speaking, implementation of the project will increase the quantity of the effluent discharged to the wadi, but not expand the affected area. With the activated sludge with nitrification/denitrification processes applied in the new Wadi Zarqa WWTP, the treated effluent will comply with the Jordanian Standards for discharge of treated wastewater effluent to wadis and rivers (JS 893). This water will be of substantially better quality with regard to nitrogen content and of slightly better quality relative to TDS than that currently flowing in the wadi – the effluent from As Samra stabilization pond system. Although infiltration may continue to occur, the impacts on groundwater quality may be lessened.

The impacts on groundwater when the effluent is reused for irrigation have also to be considered. An increase of irrigation area with the increase of available quantity of the effluent will result in an increase of the groundwater infiltration, but the impacts may be minor because of the better quality of the effluent as mentioned above.

(4) Lake and Rivers

The project sites will be near the Wadi Zarqa, and downstream the wadi there is the KTR. In the construction phase, excavation will result in soil erosion and stream siltation both related to the construction of treatment facilities and conveyance pipelines. This will increase the suspended solid in the wadi and even the reservoir. However, this impact will not be long term.

In the operation phase, the effluent from the WWTP will be continuously discharged into Wadi Zarqa and then flow to the KTR. From the viewpoint of water quality, the discharge will have no negative impacts on the wadi and the reservoir, because the effluent quality will definitely be better than the current flow in the wadi.

(5) Coastal Area

The project has not direct relation with coastal area.

(6) Flora and Fauna

The area surrounding Wadi Zarqa was formerly rich with aquatic flora and fauna due to the presence of large areas of permanent surface water. However, the flora and fauna have undergone a decline for many years because of the increasing pollution of water from domestic and agricultural sources. Representative species of the present flora community include common reed, cattail, oleander and sedges along the stream channel. The major fauna include certain species of reptiles, amphibians, aquatic vertebrates, macroinvertebrates. The diverse habitats of this area also attract a variety of migratory birds.

During the construction phase, the environment for these flora and fauna may more or less disturbed due to direct reasons such as cutting off vegetations for site preparation, and change, or indirect reasons such as any change in the stream during construction work. Such disturbance will not last for long term.

In the operation phase, no negative impacts are anticipated on flora and fauna. Contrarily, with more water flowing in the wadi and better water quality than it is currently as the result of the project, the environment can become more suitable for flora and fauna.

(7) Meteorology

The scale of the project is not large enough to cause any impact on local weather condition.

(8) Landscape

It is not anticipated that the completion of the new wastewater treatment plant and pretreatment plant will impair the landscape of the project area, because it is away from the populated area and with no scenery attractiveness. The construction sites of the conveyance pipelines will be completely recovered to their previous experience after completion, and will therefore have no impact on the landscape.

2.10.3.3 Environmental Pollution

(1) Air Pollution

The project will not cause air pollution. Offensive odor may be a problem which is discussed in item (6) below.

(2) Water Pollution

This item relates to the items of ‘Groundwater’ and ‘Lake and Rivers’ discussed in the former section. In the construction phase, increase of suspended solids in the wadi may happen as the result of excavation work near the wadi. As for groundwater, the impacts will be minor.

(3) Soil Pollution

Soil pollution may not happen as a direct result of the project construction. In the operation phase, the treated effluent will be discharged directly to the Wadi Zarqa and then flow to KTR where water is stored and then supplied to the Jordan Rift Valley area for irrigation. Use of the effluent for irrigation in the vicinity of the wadi upstream of KTR will also happen. Therefore the issue of concern is the effects of water quality on soil when the treated effluent is finally reused for irrigation.

(4) Noise and Vibration

Noise and vibration will occur during the construction work. However, because the construction sites for the WWTP, pretreatment plant and conveyance pipelines are away from the residential area, the impacts will be ignorable.

(5) Ground Subsidence

The project is in any sense unlikely to cause ground subsidence.

(6) Offensive Odor

The operation of wastewater treatment facilities may result in the emission of offensive smelling gases. Odors are predominantly generated as a result of the decomposition of organic matter containing sulfur, which results in the emission of hydrogen sulfide (H_2S) etc. Measures to mitigate offensive odor will be integrated with the treatment plant process to control anaerobic decomposition and H_2S generation. These measures will mitigate but not completely eliminate offensive odor.

However, because the location of the Wadi Zarqa WWTP is away from the residential area, the impacts of offensive odor will not be significant.

(7) Hazardous Substances

Hazardous substances will not be generated from the wastewater treatment process. As discussed in the former section for the item of 'Solid Waste', the stabilized sludge from the WWTP will have no hazardous effect when it is used for land application.

2.10.4 Consideration on Impacts Mitigation

As a result of the screening of the impacts on the environmental items from the project activities using the environmental examination matrix, no significant negative impact is anticipated but certain moderate negative impacts may possibly occur. The impacts from the project in the construction phase include the followings:

Economic activity (for the construction of the WWTP)
Traffic condition (for the construction of conveyance pipeline)
Archaeological properties
Solid wastes (for the construction of treatment facilities)
Soil erosion
River water
Flora & fauna

Water pollution

The impacts from the project in the operation phase include:

Groundwater (in the reuse of treated wastewater effluent)
Soil pollution (in the reuse of treated wastewater effluent)
Offensive odor (from treatment processes)

In the construction phase, the impacts on the archaeological properties can be completely erased by a careful study or investigation of the archaeological sites in the related area before the detailed engineering design. Regarding the other items, the impacts may not be completely erased but can be reduced to the minimum. For example, the construction site for the WWTP should be studied again before engineering design. There are currently undeveloped or less developed places near the proposed site. The feasibility of shifting the construction site to other locations should be considered. The impacts on the traffic condition of the main road from the construction of the conveyance pipeline can be reduced by well arrangement of the construction work. Solid wastes from the construction of the treatment facilities can be well managed by selecting a suitable disposal site. Soil erosion and impacts on river water can also be reduced by well arrangement of the excavation work.

In the operation phase, the envisaged impacts on groundwater and soil will be from the reuse of treated wastewater effluent for irrigation. These impacts can be mitigated by well management of the treatment process to make the treatment facilities function well and to obtain good quality effluent. The problem of offensive odor can also be controlled in the same way.

2.11 Project Evaluation

2.11.1 Economic and Financial Evaluation

Generally speaking, the wastewater treatment projects are financially as well as economically difficult to be feasible without drastically raising the sewerage tariff because of a higher investment cost compared with wastewater reuse and water supply projects.

The current average sewerage tariff of 147 fils per m^3 is too low to meet the cost of this kind of projects. It is therefore assumed at the outset that it be raised gradually every year, finally to 468 fils in 2010. In economic analysis, the unit benefits of sewage was determined to be 368 fils per m^3 based on households' affordability.

In performing financial analysis, the discount rate was set at 5% in anticipation of the provision of a kind of soft loans for the implementation of the project.

The summary of the economic and financial analysis of the project is as follows:

Economic/Financial Criteria

Project	FIRR (%)	Unit Wastewater Price	EIRR (%)
Wadi Zarqa Treatment	7.4	363	6.5

Note: Discount Rate: Financial=5%, Economic=10%

Managerial Indices (Unit: %)

Project	Profit/Revenues*	Working Capital/Revenues**	Profit/Liabilities and Capital***
Wadi Zarqa Treatment	24.3	21.6	4.3

Note: Standard Levels:*=10%, **=10%, ***=5%

As the above table shows, the project is financially feasible with a substantially higher FIRR than the discount rate, and with the unit wastewater price considerably lower than the set one. Although, the project has an EIRR lower than the OCC, this point should not be overemphasized because it is a socially oriented project. In terms of managerial indices, both profitability and liquidity are excellent, attesting to the high financial sustainability of the project.

In conclusion, the wadi Zarqa treatment plant construction project is financially as well as economically strongly recommended as a solid candidate for early implementation.

2.11.2 Environmental Evaluation

Although certain moderate negative impacts may possibily occour, no significant negative impacts are anticipated. Furthermore, Zarqa Treatment Plant will treat the great amount of sewage to be discharged from Great Amman area, and its completion will greatly contribute to the improvement of environmental condition in the area.