THE HASHEMITE KINGDOM OF JORDAN
MINISTRY OF WATER AND IRRIGATION
WATER AUTHORITY

FY 1992-4-JORDAN

FINAL REPORT

SURVEY OF EXISTING AS-SAMRA WASTEWATER STABILIZATION POND SYSTEM

UPGRADING AND EXPANSION OF THE WASTEWATER STABILIZATION POND SYSTEM AT AS-SAMRA

March 1992

ENGINEERING-SCIENCE, INC.
PASADENA , CALIFORNIA , USA

In Association with

C.E.C.

مركز الاستشارات الهندسية
CONSULTING ENGINEERING CENTER
P.O.Box 8180-Telex 23469 CENTER JO-Amman-Jordan

BEST AVAILABLE COPY

ES
ENGINEERING - SCIENCE, INC.

مركز الاستشارات الهندسية
c.e.c. Consulting Engineering Center

FY 1992 - 4 Jordan

Ref. : 195/115
Date : 25/3/1992

The Secretary General
Water Authority of Jordan
Amman,
Jordan

Attn: Eng. Mutazz Bulibeisi

Project : Upgrading and Expansion of the Wastewater Stabilization Pond System at As-Samra

Subject : Survey Report
WAJ WA/7/2 dated 27/1/92

Dear Sir,

As requested by your letter of WA/7/2 dated 27/1/92, we have completed the redraft of the Survey of Existing As-Samra Wastewater Stabilization Pond System Report and are pleased to submit the final draft for your approval.

We have included all your previous comments (letter WA/7/2) which are located within the report as follows:-

Comment 1. (a) 1st* -	Section 2, Paragraphs: 2.1.1 and 2.1.2; Section 3, Paragraphs 3.1.2; and Section 4, Paragraphs 4.6 and 4.7.3
Comment 1. (a) 2nd* -	Section 2, Paragraph 2.2
Comment 1. (a) 3rd* -	Section 4, Paragraphs 4.2 and 4.8.7
Comment 1. (a) 4th* -	Section 5
Comment 1. (b) 1st* -	Section 4, Paragraph 4.7.8
Comment 1. (b) 2nd* -	Section 4, Paragraphs 4.7.5 and 4.7.6
Comment 1. (b) 3rd* -	Section 4, Paragraph 4.7.8
Comment 1. (c) 1st* -	Section 1, Paragraph 1.1 and Section 4
Comment 1. (c) 2nd* -	Section 4, Paragraph 4.7.8
Comment 1. (c) 3rd* -	Section 4, Paragraphs 4.7.4, etc.
Comment 1. (d) -	Section 4, Paragraphs 4.7.4, 4.7.2, etc.
Comment 1. (e) -	Section 6
Comment 1. (f) 1st* -	Section 7 (1)
Comment 1. (f) 2nd* -	Section 7 (1)
Comment 1. (f) 3rd* -	Section 7 (1)
Comment 2. 1st* -	Section 4, Paragraph 4.7.7

تلفون ٦٦١٢٥١/٦٦٢٨٢٧ - ص.ب ٨١٨٠ عمّان - الأردن - تلكس ٢٣٤٦٩ سنترجو - فاكس ٩٦٢-٦-٦٦٢٨٢٧

TEL. 661251/662827 - P.O.Box 8180 - AMMAN - JORDAN - TELEX 23469 CENTER JO - FAX 962-6-662827

C.E.C.

Comment 2. 2nd*	-	Section 5
Comment 2. 3rd*	-	Section 6
Comment 2. 4th*	-	Section 8

(1) To be discussed further in the Environment Assessment

We would be pleased to meet with you to discuss further the contents of the Survey Report. This submittal concludes the contractual requirements of the scope of work, Section 3.1.2.

Very Truly Yours,

Richard Deussen
Project Manager

C : USAID/Amman
C : File
RD/rj

TABLE OF CONTENTS

SECTION 1 INTRODUCTION 1-1

1.1 General 1-1
1.2 System Description 1-2

SECTION 2 SURVEY OF AGTP HEADWORKS AND SEWER/SIPHON SYSTEM 2-1

2.1 AGTP Headworks 2-1

2.1.1 Design Review 2-1
2.1.2 Mode of Operation 2-3
2.1.3 Performance 2-5
2.1.4 Condition 2-9

2.2 Sewer/Siphon System 2-9

2.2.1 Design Review 2-9
2.2.2 Mode of Operation 2-10
2.2.3 Performance 2-12
2.2.4 Condition 2-13

SECTION 3 SURVEY OF PUMP STATIONS 3-1

3.1 Zarqa Pump Station 3-1

3.1.1 Description 3-1
3.1.2 Design Review 3-1
3.1.3 Mode of Operation 3-2
3.1.4 Performance 3-3
3.1.5 Condition 3-3

3.2 Hashimiyeh Pump Station 3-4

3.2.1 Description 3-4
3.2.2 Design Review 3-4
3.2.3 Mode of Operation and Performance 3-4
3.2.4 Condition 3-5

3

SECTION 4 SURVEY OF EXISTING WASTEWATER STABILIZATION PONDS 4-1

4.1 Background 4-1
4.2 Description 4-2
4.3 Effluent Discharge 4-3
4.4 Discharge Criteria 4-3
4.5 Design Concept 4-4
4.6 Design Review 4-6
4.7 Performance 4-7

4.7.1 Flow and Organic Loads 4-7
4.7.2 Conceptual Changes Not Included in the Design 4-8
4.7.3 Performance Versus Design 4-10
4.7.4 Interpretation of Sampling and Testing Data 4-11
4.7.5 Recirculation Option 4-13
4.7.6 Parallel Option 4-14
4.7.7 Sludge and Scum Removal 4-14
4.7.8 Short Circuiting 4-16
4.7.9 Odor 4-18

4.8 Condition of WSP Components 4-19

4.8.1 Operational Water System 4-19
4.8.2 Metal Fixtures 4-20
4.8.3 Corrosion 4-20
4.8.4 Slide Gates 4-20
4.8.5 Telemetry 4-20
4.8.6 Laboratory Facilities 4-20
4.8.7 Chlorination Facility 4-21

4.9 WSP Operations Resources 4-22

4.9.1 WSP Site Personnel 4-22
4.9.2 Vehicle Inventory 4-22
4.9.3 Spare Parts 4-22
4.9.4 Operating Budget 4-23

SECTION 5 SURVEY OF IDLED AGTP 5-1

5.1 Introduction 5-1
5.2 Condition Assessment 5-2
5.3 Conclusions 5-3

BEST AVAILABLE COPY

SECTION 6 WASTEWATER EFFLUENT REUSE 6-1

6.1 Wastewater Reuse in Jordan 6-1

6.1.1 KTR Water Use for Irrigation in Jordan Valley 6-1
6.1.2 Direct Uses of As-Samra WSP Effluent 6-3

6.2 Wastewater Reuse Studies in Jordan 6-4
6.3 Wastewater Quality Requirements and Guidelines for Reuse 6-5

6.3.1 Jordanian Environmental Health Regulations.. 6-5
6.3.2 World Health Organization and Other Guidelines 6-6

6.4 Future Water Reuse Opportunities 6-11
6.5 Recommendations for Water Reuse 6-13

SECTION 7 ENVIRONMENTAL REVIEW OF THE WASTEWATER STABILIZATION POND SYSTEM AT AS-SAMRA 7-1

7.1 Introduction and Summary 7-1

7.1.1 Format and Content 7-1
7.2.1 System/Facilities Description 7-1

7.2 Key Environmental Issues 7-2

7.2.1 Project Region 7-2
7.2.2 Environmental Resources Affected 7-2
7.2.3 Other Environmentally Important Facilities.. 7-3
7.2.4 Overview of Environmental Issues and Concerns for As-Samra WSP System 7-4

7.3 Sector Reviews 7-4

7.3.1 Air Quality 7-4
7.3.2 Surface Water Resources 7-5
7.3.3 Groundwater Resources 7-7
7.3.4 Biotic Resources 7-8
7.3.5 Cultural Resources 7-9
7.3.6 Public Health 7-9
7.3.7 Land Uses and Resources 7-11
7.3.8 Resource Conservation 7-12

BEST AVAILABLE COPY

5

SECTION 8 CONCLUSIONS AND RECOMMENDATIONS 8-1

8.1 General 8-1
8.2 Ain Ghazal Headworks and Sewer/Siphon System 8-1
8.3 Pump Stations 8-3
8.4 Wastewater Stabilization Ponds 8-3
8.5 Idled Ain Ghazal Treatment Plant 8-5
8.6 Wastewater Effluent Reuse 8-5
8.7 Environmental Review 8-6

APPENDIX A

Effluent Monitoring Program for WSP A-1

APPENDIX B

Recommended Additional Spare Parts B-1

APPENDIX C

Laboratory Equipment and Materials C-1
Recommended Additional Equipment and Materials C-2

APPENDIX D

WSP Operating Data D-1

6

SECTION 1

INTRODUCTION

1.1 GENERAL

This report is submitted as a part of the consulting services assignment for the Technical and Economic Feasibility Study and Final Design of Upgrading and Expansion of the Wastewater Stabilization Pond (WSP) System at As-Samra. The pond system was commissioned in 1985 with a design capacity of 68,000 cu m/d average daily dry-weather flow. Current average daily flows are about 100,000 cu m/d.

The Terms of Reference for the consulting services require this report - Survey of Existing As-Samra Wastewater Stabilization Pond System - to be a brief report of the findings after only two months of work and to cover the followings aspects of the existing WSP system:

(a) A review of the design of the entire system, including the headworks at Ain Ghazal Treatment Plant (AGTP), pumping stations, transmission lines, ponds and disinfection arrangements;

(b) A review of the mode of operation;

(c) A review of the operating results;

(d) An assessment of the performance of the different processes in the system and of the effect on performance of such factors as season, temperature and the chemical and biological characteristics of the wastewater, including the effect of septage that is being added at the AGTP headworks and the Zarqa Pumping Station; and

(e) An Assessment of the experience with use of King Talal Reservoir (KTR) water containing treated effluent on irrigated agriculture in the Jordan Valley.

(f) A review of the environmental effects of the system from the AGTP to the KTR.

The findings of this Survey Report provide information which will guide future development of the project. It also provides suggestions on measures which could be implemented quickly which will improve operations and effluent quality. **However, it must be understood that the entire WSP system (except for the sewer/siphon, and the Zarqa and Hashimiyeh Pump Stations) is already about 50 percent overloaded both hydraulically and organically.** The ponds were hydraulically overloaded within two years after commissioning and overloaded organically upon commissioning because of the higher (850 mg/l BOD_5) loading rate than the rate used for design (526 mg/l BOD_5). **Therefore, in general , the information obtained in this survey regarding possible errors in design, lack of operational control, poor performance or poor operating results will have no effect on selection of an alternative expansion system. It will also be difficult to use these findings to suggest changes in the mode of operation or design to improve the performance as the existing data were obtained from an overloaded system. The findings can, however, be used to avoid the same problems in the design and operation of the expansion.**

The initial design objective of providing treatment during the expansion of the AGTP was changed drastically during construction of the WSP to accommodating flow from Zarqa and Hashimiyeh and treating raw sewage from Amman (and abandoning AGTP). Therefore, the WSP could not even accommodate this major increase in hydraulic and organic loads from the population in 1985. The rapid increase in population since commissioning and sludge transfer from other plants have further overloaded the facility.

The findings of the survey are presented in the text of this report. The major findings and the measures that could be implemented quickly to improve operations and possibly effluent quality are summarized hereinafter. Information on [illegible] aspects of the system are covered in a separate volume of this report.

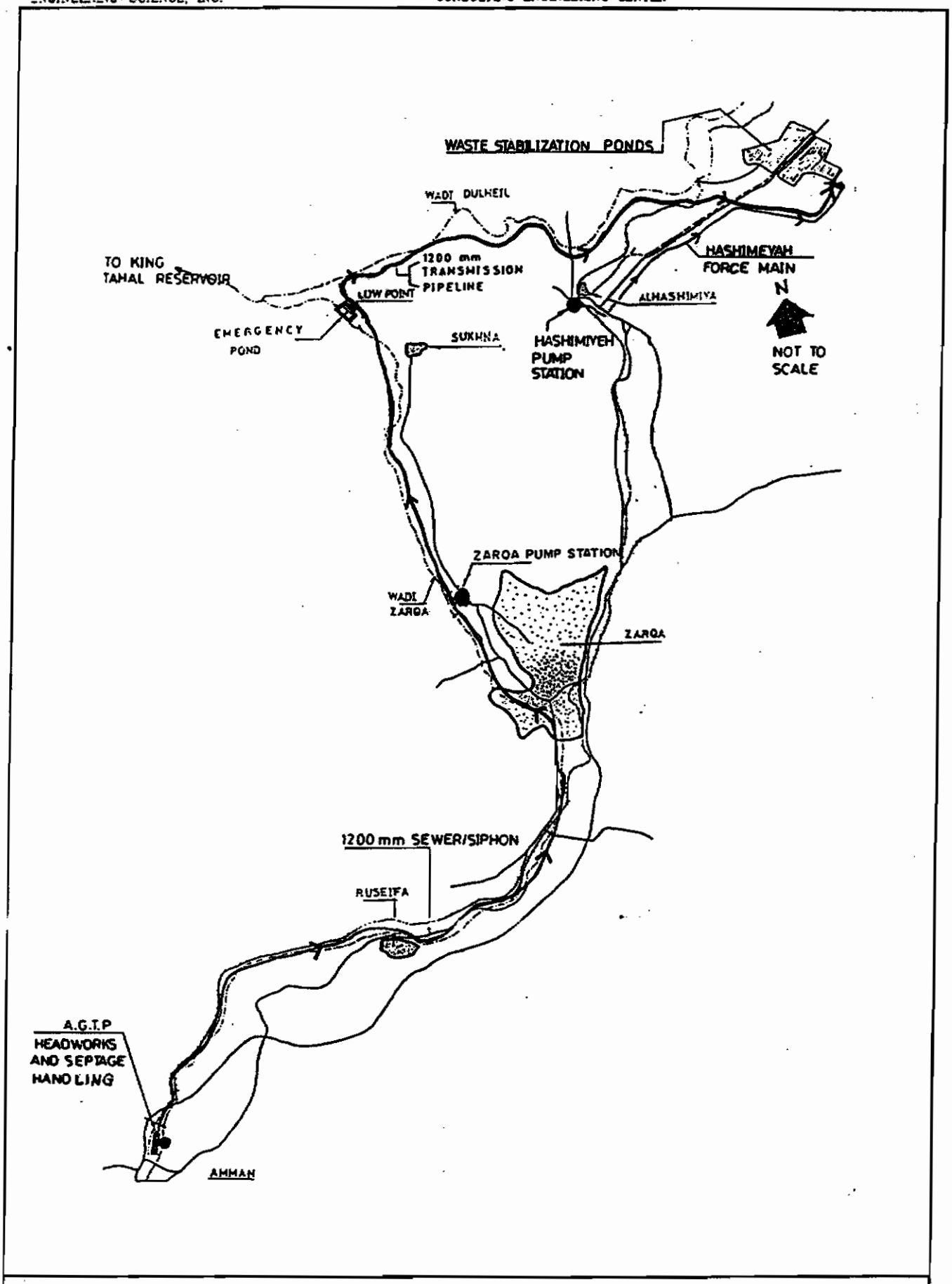
1.2 SYSTEM DESCRIPTION

The existing WSP system, as defined in the Terms of Reference, is shown on the Figure 1.1. It is comprised of:

1. Headworks and septage handling facilities at Ain Ghazal Treatment Plant (AGTP) site.

BEST AVAILABLE COPY

8



PROJECT LOCATION MAP

WASTEWATER STABILIZATION POND SYSTEM AT AS-SAMRA PROJECT

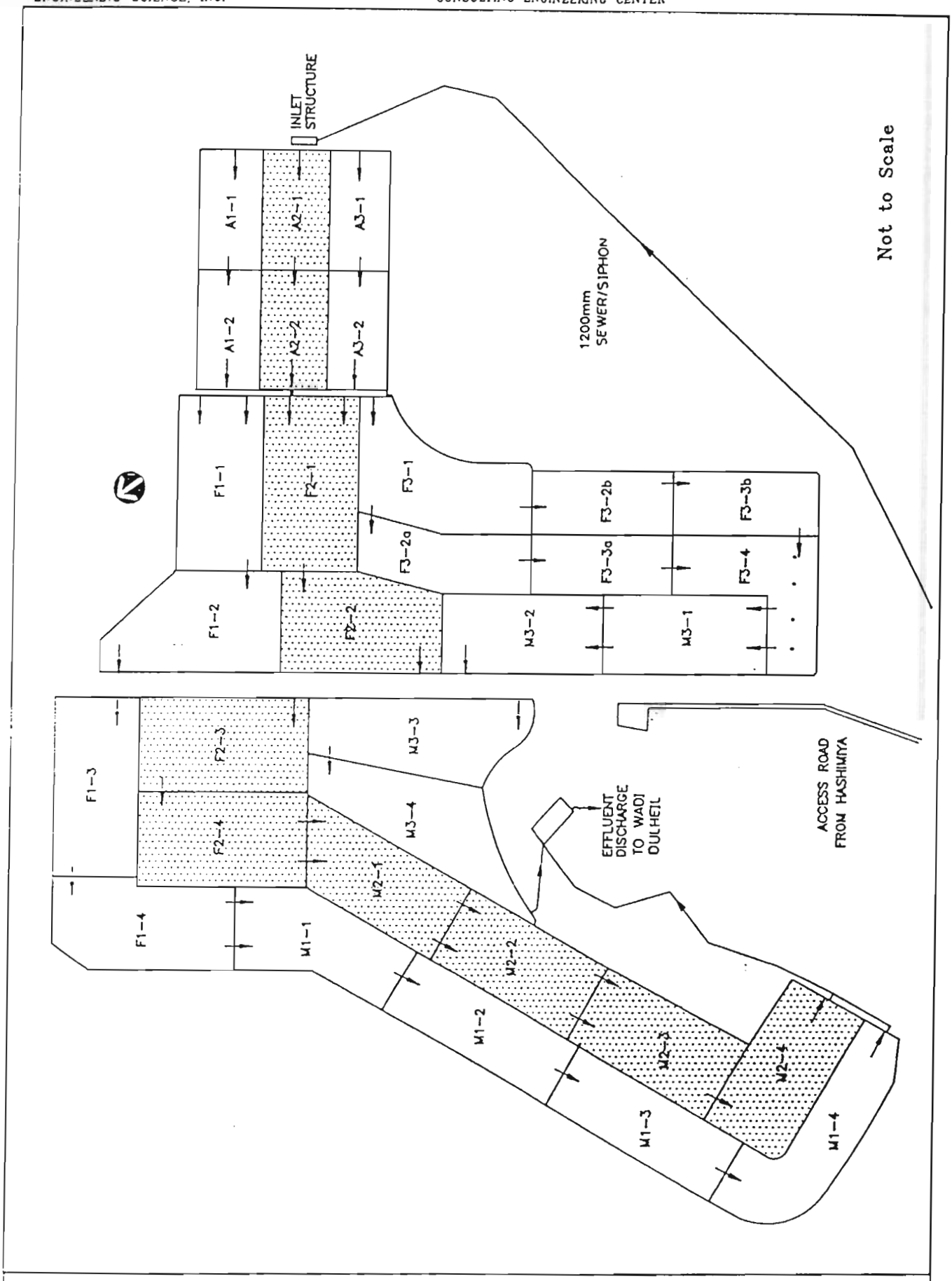
2. 39 km long and 1200 mm diameter sewer/siphon from AGTP to the wastewater stabilization pond (WSP) system near Khirbet As-Samra (village).

3. Pump station at Zarqa, which discharges sewage from Ruseifa and parts of Zarqa into the sewer/siphon. The pump station incorporates preliminary treatment processes and septage handling facilities.

4. Wastewater stabilization ponds near Khirbet As-Samra is comprised of three "trains" of anaerobic, facultative and maturation ponds, followed by chlorination facilities for disinfection. Layout of the waste stabilization ponds at As-Samra is shown in Figure 1.2.

5. Pump station at Hashimiyeh which discharges sewage from Hashimiyeh and other communities to the wastewater stabilization ponds headworks.

For completeness, the scope of the report has been broadened somewhat to include the major effluent disposal system which is the Wadi Dhuleil/Seil Zarqa watercourse into which the treated effluent is discharged, the King Talal Reservoir and irrigation of agriculture along Wadi Dhuleil and in the Jordan Valley.



AS-SAMRA WASTE STABILIZATION PONDS
GENERAL ARRANGEMENT

WASTEWATER STABILIZATION POND SYSTEM AT AS-SAMRA PROJECT

SECTION 2

SURVEY OF AGTP HEADWORKS AND SEWER SIPHON SYSTEM

2.1 AGTP HEADWORKS

2.1.1 Design Review

The AGTP headworks facilities were designed to collect and pretreat sewage and septage prior to entry into the sewer/siphon system. Designed for a maximum peak wet-weather flow of approximately 148,000 cu m/d, the collection system also receives stormwater in addition to sanitary sewage. Upstream flows in excess of 170,000 cu m/d are diverted to Wadi Ain Ghazal (which flows to Wadi Zarqa) by an overflow weir located in Manhole MH2, just outside the southwestern boundary of AGTP. The 1200 mm RCP sewer from MH2 to the headworks was designed to accommodate 200,000 cu m/d flowing 75 percent fall.

Because of the long length (39 km) and inverted siphon design of the sewer outfall piping, the low-lying portions of the outfall sewer/siphon connecting the AGTP headworks facility and the As-Samra WSP are particularly vulnerable to the accumulation of trash and solid materials. Reduced flow capacity, the creation of anaerobic conditions resulting in aggravated treatability and pipeline corrosion and unnecessary and difficult maintenance along the remote outfall pipeline route were all significant factors that dictated the need for the AGTP headworks facilities. Because of these recognized potential problems, the AGTP headworks facilities were specifically designed to remove trash from and minimize settlement of fine solid materials within the sewer/siphon system.

As designed, the AGTP headworks generally consist of a screening and grit removal facility for influent sewage and a collection, screening and grit removal facility for septage delivered to the site by tanker trucks.

BEST AVAILABLE COPY

12

Influent sewage arriving at AGTP was designed to be treated by mechanically raked bar screens to remove large solids and trash from the sewage, comminutors to reduce the size of solids not removed at the screens and aerated grit chambers to remove grit.

Mechanically raked bar screens with clear space openings of 25 mm and comminutors were designed to be duplicated in two parallel trains, each designed for a peak flow capacity of 74,000 cu m/d. A bypass channel with a mechanically raked bar screen and hand operated sluice gates has been provided for standby operations, but was not fitted with a comminutor. The screens are controlled by differential headloss as well as automatic default timers. At the peak design flow of 148,000 cu m/day the design freeboard of the screening channels is 400mm.

Grit removal facilities are similarly configured as two parallel trains of aerated tanks with manually operated sluice gates to access a bypass channel. The tanks are designed for spiral flow to achieve the design hydraulic detention time and are fitted with fixed coarse bubble diffusers. The tank sidewalls have not been constructed with "Y" walls which are generally considered to help direct air and liquid flow create the desired "rolling" effect. Grit is collected and lifted by air pumps to a storage basin. It is then pumped to a grit washer and cyclone. The grit tanks were also provided with a rotating scum removal pipe.

The AGTP also includes facilities to handle septage collected from septic tanks in areas of Amman which are not connected to the sewer system. Trucks discharge their contents to a channel which conveys septage to screening and grit removal facilities before joining the preliminary treated influent sewage and discharge to the sewer/siphon. Because of the malodorous nature of septage, these facilities are housed inside buildings from which foul air is drawn and passed through a wet scrubbing system for odor removal. The septage screening facilities include manually raked bar screens and an aerated grit removal chamber.

The septage treatment facilities include parallel manually raked bar screens that feed a single aerated grit removal tank. Aeration and grit removal equipment is similar to that in the sewage

BEST AVAILABLE COPY

13

treatment facility. No bypass channel has been provided for the septage screening or grit removal facilities.

The septage handing facilities were designed to receive up to 5,000 cu m/d of septage and flushing water (screened sewage effluent pumped from downstream of the preliminary treatment facilities). This screened effluent is used as a transport/dilution water to move septage through the septage treatment system.

The facility currently receives over 400 tankers of septage per day. With an average tanker capacity of 9 cu m, the total septage volume being received is somewhat over 3,600 cu m/d. Additional septage flows can be diverted, after screening and grit removal, to a septage holding tank which contains approximately 1,100 cu m volume.

The original design concept was to screen and degrit all sewage flow and then to divert a portion (40,000 cu m/d) to the existing AGTP treatment plant for treatment. The AGTP facilities for flow monitoring therefore consist of two flumes mounted in series immediately prior to the sewer/siphon. The system was originally designed to allow flow from the headworks to be measured at the first flume and the treatment plant flows to be combined and the total flow measured at the second flume.

A review of the design drawings indicates that the flumes were to be constructed as Parshall flumes. However the dimensions shown downstream of the throat do not conform in profile exactly to standard Parshall flumes.

2.1.2 Mode Of Operation

The current mode of operation has deteriorated from the original design because of facility overloading, poor equipment operation and related problems aggravated by the inability to maintain process equipment. The screening, comminution and grit removal facilities are all typically operating in the standby or bypass modes due to inoperative equipment. As a result, the primary objective of the headworks, which is to prevent the transport of solids to the sewer/siphon

14

system, is marginally effective under optimum operating conditions with the equipment available. Evidence of substantial solids bypassing has been verified by the observation of large volumes of unscreened solids that are removed at a trash rack immediately preceding the entrance to the sewer/siphon system. The nearby slaughterhouse often discharges offal directly to the headworks, overloading the screens and contributing large BOD5 loads to the system.

The mechanical screens have been reported to be susceptible to jamming. The maintenance and operation documents indicate that large articles can be pushed down by the rake operation and become trapped and accumulate at the base of the screen. This condition appears to occur regularly and results in frequent and long period of manual cleaning. The operating conditions appear to warrant mechanical screens capable of higher hydraulic/solids loadings and large solids removal capability. Current screen designs are available to address these specific shortcomings.

The original design provided for comminutors to be installed after each of the mechanical screens. It has been reported that these units were physically removed shortly after the facility was completed due to frequent jamming and excessive maintenance requirements. With the comminutors removed, all stringy and coarse solids that pass through the screens now pass directly to the grit removal tanks and have the capability to overload and plug the grit removal system and to be swept into the sewer/siphon system. As with the screen design, it appears that heavier duty units capable of more rugged operating conditions are required to insure more dependable performance and operation.

The grit removal system is not operated as designed. Air diffusers appear to be broken or plugged. It has been reported that the blowers have never been disassembled for inspection or maintenance. Blower operation cannot be verified since discharge pressure gauges were not working and no flow meters were installed. Air lift pumps are reported to clog frequently, probably due to the bypassing of large solids from the screening facility. The condition of other in-tank equipment could not otherwise be verified since no recent

15

tank dewaterings have been performed. Flotables are not removed as designed and are instead sent to the WSP.

The submersible pump which was designed to deliver transport water for the septage facility is completely plugged with grit and other solids carried over the weir. Transport water is not used to move septage through the pretreatment system.

The aerated grit system in the septage handling process requires continuous maintenance and breaks down frequently. Repairs and cleaning are often delayed or postponed because of high hydrogen sulfide (H_2S) conditions. Measurements of H_2S in the building verified this and also confirmed high H_2S at the exhaust stack of the odor control system indicating that the system is not operating properly. It appears that the system may be overloaded, however without operational monitoring instrumentation or chemical usage data no definitive conclusions can be made.

Flow measurement is monitored only in flume no.2; flume no. 1 is not used and the measuring equipment is not available. Noticeable quantities of H_2S can be sensed at the turbulent discharge zones of the flumes.

2.1.3 Performance

The present average daily flow of 100,000 cu m/d exceeds the design basis of 68,000 cu m/d by 47 percent. Even though this flow quantity is less than the peak hydraulic design of 148,000 cu m/d, sustained high hydraulic loadings, not to mention the additional current peak daily loadings have created unmanageable operating conditions with the existing equipment.

Based on typical design loading criteria for screens of 20 cu m of trash and 15 cu m of grit per million cubic meters of wastewater volume, the current average flows of 100,000 cu m/d generate an estimated 2 cubic meters of trash and 1.5 cu m of grit per day. These volumes are clearly less than the actual solids production and do not take into account the untreated slaughterhouse flows which are not pretreated.

BEST AVAILABLE COPY

16

Conservatively extrapolated (on the assumption that the facilities are operating correctly 50 percent of the time and not including current reported peak flows of up to 170,00 cu m/d), the present average daily flows of 100,000 cu m/d will transport enough solids to the sewer/siphon system to fill 1.7 meters of length per day or 0.6 kilometers per year.

While constricted pipeline velocities should be self-limiting to complete clogging of the sewer/siphon, it should be obvious that the inefficiencies, and as observed, lack of operation of the AGTP headworks facilities pose a major threat to the long term operation of the sewer/siphon system.

The mechanical screens are unreliable under the present service conditions. While the reported jamming conditions can be remedied without damage to the equipment, it appears that the present high service flows and large volumes of trash to be removed exceed the design capability of the existing screens.

To insure a high capture rate and prevent blinding, typical through screen velocities of 0.6-1.2 m/sec are commonly used for design. A hydraulic analysis of the existing screens based on data from the design hydraulic profile indicates that at the designed peak flow of 148,000 cu m/d designed screen velocities were expected to be 1.4 m/sec.

Higher average and peak flows aggravated by higher than average trash and solids loadings would generate higher velocities through screen openings. This appears to confirm observations and reports of the high frequency of clogging and jamming of the screens and solids bypassing downstream.

The existing screens can be kept in service, but have and will continue to demand unnecessarily high service attention because of their inability to effectively handle large amounts of trash. While this may be acceptable as a short term operational strategy, it is not consistent with the low maintenance design envisioned for the expanded works. Based on their service history,

17

mechanical screens designed for heavier duty service and capable of removing large solids are needed.

The comminutors were similarly under-designed for the actual service conditions. Unlike the screens, failure of the shredding mechanism of the comminutors creates an unacceptable headloss upon blockage that results in facility flooding. Since they could not be manually cleaned, the only solution available was complete removal. This remedy eliminated a needed unit treatment process and aggravated downstream solids loadings.

As a minimum measure, heavier duty and larger capacity comminution equipment is needed. As an improvement to be included with an expansion, a fine screen system should be evaluated to remove, rather than "shred and pass on" , fine solids to the sewer/siphon system.

The aerated grit removal facility is in disrepair and appears to be operating consistently in the bypass mode. Trash and solids passed on by the lack of comminution and high solids accumulations as the results of higher than designed hydraulic loadings have aggravated operation by clogging diffusers, grit collection hoppers and air lift grit removal piping. Poor air supply and distribution prevents the designed hydraulic motion from forming within the designed tank geometry to allow solids to drop out and also reduces detention time. This has been verified with observations of solids "wash out" over the effluent weirs.

It has also been confirmed on several occasions that more flow was being bypassed through the facility than was being treated in the grit tanks. The condition of the mechanical equipment and piping in the grit removal tanks is not known, however from observations of irregular surface turbulence, it is expected that the diffusers are either clogged or broken.

The condition of the air supply compressors is also not known. Operations staff indicated that the blowers have never been disassembled for inspection of maintenance. Discharge air pressure gauges do not appear to be functional. It should be assumed that major rehabilitation of all mechanical system is needed.

18

Aerated grit removal can be a highly efficient unit process. It is by design a system that needs to be "tuned" and monitored to operate properly. Balanced air flow to diffusers, proportioning of hydraulic flows and monitoring of waste flows are critical to maintaining good operations under design conditions. With the aggravated hydraulic and solids loadings even marginal performance may be unattainable.

The septage handling facilities do not appear to be overloaded based on observations and current data. Because septage is delivered by tanker trucks, maximum solids sizes are limited by tanker truck suction and discharge nozzles. As a result screening loadings are typically lighter than raw influent sewage flows. The manual screens in the septage building appear to be adequate based on observations of present operations and the lack of reported flooding. Close inspection of all facilities could not be made however, because of the dangerous H_2S conditions that exist.

The odor (H_2S) control system is not working. Although the fans appear to be operating, the lack of odor reduction is obvious. A review of design fan calculations indicates that adequate air changes appears to have been assumed. Packed tower surface areas, duct and louvre sizing and design reaction rates could not be verified. Lack of instrumentation or operating data prevented confirmation of operating performance. Reports of sodium hypochlorite supply and current usage indicate that dose rates are inadequate. The design documents indicate a daily consumption rate of 280 kg/d. Detailed records of operating data taken in strict compliance with the design and operation instructions will be required to determine the adequacy of the existing equipment systems.

It is strongly recommended that any and all measures required to reactivate the odor control system and reduce H_2S concentrations in the septage handling facilities be initiated as soon as possible to eliminate potential safety hazards.

19

2.1.4 Condition

Structures at the AGTP appear to be in acceptable condition. No major concrete or structural steel construction showed obvious signs of weakening, failure or significant corrosion damage. All equipment is in need of major maintenance and repair. Based on the observations made herein, it would appear that major equipment upgrades should also be considered for long term operations.

2.2 SEWER SIPHON SYSTEM

2.2.1 Design Review

The sewer/siphon system is a 38.6 km long, 1200 mm diameter pipeline designed to operate as an inverted siphon and convey up to 148,000 cu m/d of sewage to the WSP at As-Samra without flows, from Zarqa being pumped into the pipeline. A short length of 1200 mm diameter gravity sewer connects the upstream end of the sewer/siphon and the downstream end of the grit removal facilities. The sewer and siphon pipeline system begins at AGTP and is routed down Wadi Ain Ghazal and Wadi Zarqa past a low-point 25.8 km from AGTP, near Sukhna, and up Wadi Dhuleil to discharge at the As-Samra wastewater stabilization ponds (WSP). At a point 20.4 km from AGTP, the Zarqa Pump Station discharges into the sewer/siphon. The pipeline slopes downward from AGTP a vertical distance of 213 m to the low-point and then slopes upward to WSP a vertical distance of 112 m. The elevation difference of 101 m provides the hydraulic driving force to move sewage from AGTP to WSP. Air and vacuum valves, manways and blow-offs were installed at many locations along the pipeline.

At the low-point in the pipeline, an emergency storage pond has been constructed to drain the contents of the sewer/siphon in case of an emergency and to allow pipeline maintenance. It has not been used since the pipeline was placed in operation.

The sewer portion of the line, at the northern end of AGTP contains two Parshall flumes installed in series , one upstream of a connection from AGTP,

20

to measure flows from the headworks, and another downstream to measure combined flows. Since AGTP was abandoned, the first flume is no longer used.

Downstream of the flume is a launching station to send a cleaning device through the pipeline and the pipeline was constructed in a tunnel where it crosses the Zarqa - Amman Highway.

The sewer/siphon pipeline is constructed of cement-mortar lined and coated steel pipe with welded joints. Cathodic protection was also provided. The cement-mortar lining was specified to be 12.7 mm thick except for the first 12 km (upstream end) of the sewer/siphon pipeline. In this length, over which the pipeline was not initially expected to flow-full, a 25 mm thick sacrificial calcareous lining was installed. A cathodic protection system using anodes and test stations was installed to prevent electrolytic corrosion.

Construction of the pipeline involved numerous underground crossings and paralleling of Wadies Zarqa and Dhuliel. At all of these locations concrete encasement and bank erosion protection measures were installed. A field investigation located four reaches where additional protection is required. That work is presently being performed by WAJ.

Although designed as a 1200 mm pipeline, a 1228 mm line was installed, which can actually carry a flow of 191,350 cu m/d without Zarqa flows. The pipeline is completely buried the entire distance except at three locations where it crosses Wadi Dulheil on a bridge.

2.2.2 Mode of Operation

The transmission pipeline presently operates as a gravity sewer downstream of AGTP under average flow conditions (100,000 cu m/d) for about 9 km where it changes to a pressure pipeline (inverted siphon). The location of this transition from a gravity sewer to a pressurized siphon changes as the flow through the pipeline changes; as the flow increases the transition moves closer to AGTP.

The pipeline is operating as designed except that the design hydraulic flow (68,000 cu m/d) is exceeded daily. WAJ operators travel along the

21

pipeline to observe that erosion, excavation or filling of the ground over the sewer/siphon is not occurring and that storms have not damaged or exposed the pipeline. WAJ also checks the air and vacuum valves, blow-offs and cathodic protection facilities to insure that they are working and do not need repairs.

Under normal conditions , the present mode of operation is leave the valves at the low point and the blow-off valves along the pipeline closed. The valves at the low point are to be opened only in case of emergency, to drain the contents of the pipeline to the emergency storage pond. However , the blow-off valves along the pipeline should be opened frequently (once per month) to determine if the pipeline contains solids and should be cleaned. With the headworks being overloaded, this is especially important . Because the screens are overloaded and prone to solids bypassing, the comminutors removed and the grit system (both for septage and sewage) are not working as designed (because of overloading and inadequate maintenance), a major portion of the solids are being sent to the transmission pipeline. Over last six years, the TSS at AGTP averages 185 mg/l more than the influent to the WSP. This is an indication that solids are settling in the pipeline. They will accumulate at the low point and restrict the capacity of the pipeline, unless removed.

There are only two ways to clean the pipeline, either using the drain valves at the low point or using the swab provided to clear the line. Draining to the storage point to clean the pipeline is not recommended except in case of emergency . The cleaning device should be sent through the sewer/siphon once each year under normal conditions to remove settled material and slime. Under the present overloaded conditions, it should be cleaned more frequently.

Only one (flume no.2) of the sonic devices which measure flow at the Diversion Structure No.2 Parshall flumes is working, which is satisfactory since AGTP is not in operation. At the end of the flume structure , there is a wide-spaced screen which was designed as a safety device to prevent anyone who accidentally fell into the upstream open structure from entering the sewer/siphon. Because the upstream screens are not operating

22

and the comminutors were removed, this wide-spaced screen must be cleaned frequently. To do so, the operators have taken down a section of the fence. This is extremely dangerous for children and a gate with a lock should be installed immediately to prevent a potential accident.

Measurements of the calcareous aggregate lining in the sewer sections have not been made. However, based upon measurements of hydrogen sulfide, it is expected that a substantial portion of the lining has been sacrificed during the years of operation. Once a parallel pipeline has been installed, inspection and repairs or relining of the existing main should be performed, prior to placing it back into service.

The cathodic protection stations were reviewed in the field and were not fully operational nor maintained. No anodes have been replaced over the past five years.

A field review of the sewer/siphon route indicated that work had been performed at various locations to repair flood damage. This will be a continuous maintenance requirement. The sewer/siphon bridges appear to be in satisfactory condition.

2.2.3 Performance

The stormwater overflow upstream of the AGTP headworks has been modified to allow peak flows of up to 170,000 cu m/d to the sewer/siphon. The sewer/siphon can accommodate this flow if the Zarqa flows are not pumped into the pipeline. The design calculations estimated that the sewer/siphon will be able to transport peak flows at rates of up to 220,0000 cu m/d to the WSP system, with 72,000 cu m/d originating from Zarqa Pump Station, and 148,000 cu m/d originating from AGTP. The design calculations were based on a Hazen-Williams pipeline roughness coefficient of 120 which agrees with field monitoring and calculations conducted during this survey.

With no discharge from Zarqa Pump Station, the maximum possible throughput from AGTP would be 191,350 cu m/d. With 72,000 cu m/d discharge from Zarqa Pump Station, the maximum permissible concurrent peak inflow at AGTP would only be around 148,000 cu m/d. Thus, with Zarqa Pump Station upgraded to 72,000 cu m/d capacity and the

23

stormwater overflow at AGTP modified to pass up to 170,000 cu m/day to the sewer/siphon, it will be necessary to control the output of Zarqa Pump Station to avoid overspilling at AGTP during wet-weather conditions.

Both of these flows from AGTP were based on the pipe being full at structure MH14, the pipeline cleaning device launching station. If the pipeline was surcharged to one meter below the top of the Second Diversion Structure (which would submerge the Parshall flume) the flow from AGTP would be slightly greater.

2.2.3 Condition

The sewer/siphon system appears to be in good condition. It functions as designed and there have been no reports of problems in its operation.

The cathodic protection system consists of four cathodic protection stations along the pipeline each supplying a current of 40 Amps. The current is being impressed on the pipeline using silicon/iron " chrome " anodes installed in a horizontal ground bed.

A site survey of the cathodic protection stations revealed the following:

- The Transformer / Rectifier Stations No. 1, 2 & 3 are working properly.
- The Transformer /Rectifier Station No.4 is out of order (apparently for more than one year) due to unavailability of the necessary fuses and some electrical parts. The cover to the Transformer unit is missing.
- The silica gel in the Transformer/ Rectifier units should be replaced at all stations.
- No monitoring has been performed to check the operation of the cathodic protection systems. Periodic monitoring of the protective potentials along the pipeline through the test points must be performed as described in the operation and maintenance manual.

24

SECTION 3

SURVEY OF PUMP STATIONS

3.1 ZARQA PUMP STATION

3.1.1 Description

The decision to convey sewage from Ruseifa and Zarqa to Khirbet AS-Samra for treatment was taken in 1984/1985, during construction of the wastewater stabilization pond system. An earlier plan to construct separate sewage treatment facilities for Zarqa was abandoned.

Zarqa Pump Station is located alongside the sewer/siphon pipeline, about 20.4 km from AGTP.

3.1.2 Design Review

The Zarqa Pump Station (ZPS) was designed to provide pretreatment (screen and degrit) and pump 72,000 cu m/d of raw sewage. Since the hydraulic requirements at the time of construction were less than 20,000 cu m/d, the installed pumping capacities were set at 28,000 cu m/d with 100 percent redundancy for emergency back up. This was to be accomplished with the installation of two additional pumps of similar size for future expansion. The screening and degritting facilities were designed to accommodate flows up to 72,000 cu m/d.

Unit process equipment includes: manually raked trash screens, mechanically raked bar screens, aerated grit removal and comminution.

Two parallel manually raked trash screens/racks precede two parallel mechanically raked bar screens. Each of the four manual and mechanical screen channels can be hydraulically isolated with manually operated sluice gates. No flow through bypass channel is provided, however, a bypass to overflow to the wadi is located between the manual and mechanical screens. Existing site hydraulics require the screening channel invert elevations to be quite deep which makes manual raking quite difficult. Influent flow monitoring is located between screening and grit removal facilities.

BEST AVAILABLE COPY

Grit removal is accomplished with two parallel, spiral flow aerated grit tanks. The tanks are fitted with air diffusers, air lift pumps for grit removal and vortex type grit separator/washers and bucket elevators.

In contrast to the design at AGTP, the Zarqa Pump Station has comminution located downstream of the aerated grit removal tanks rather than upstream and directly following screening. Although the effluent flow requirements are somewhat different (i.e. pump protection at Zarqa compared to pipeline clogging at AGTP) the reduced solids loading and apparent (assuming maintenance performed is equivalent) improved operability of the comminutors appears to be significant.

The pump station has a wet-well/dry-well configuration with the pumps installed in a dry-well adjacent to the wet-well. They are connected by drive shafts to motors located at ground level to prevent flooding. The pumps are of a single-stage, high-head centrifugal type.

Two pumps (one duty and one standby) were installed for the Stage 1 duty. Each pump is capable initially of discharging 14,000 cu m/d at a head of 123 m. For Stage 2 duty a third and a fourth pump are to be installed.

The discharge from Zarqa Pump Station is interrelated with flow in the sewer/siphon pipeline. Under constant pump operating conditions the actual discharge to the sewer will vary, in response to varying inflow at AGTP.

3.1.3 Mode of Operation

The current mode of operation appears to be following the design operation. No problem was reported regarding the difficulty of deep manual raking even though some bypassing is occurring. Large trash removal is being performed effectively. Mechanical screening was similarly observed to be a reliable operation with all equipment in good working order and well maintained. It has been reported that the facility is sometimes bypassed during high storm flows. This could not be confirmed, but if true, could account for the apparent lack of aggressive loading conditions experienced and observed at AGTP.

Aerated grit removal and comminution appears to be operating reliably. Inspections of dewatered grit tanks verified all in tank piping to be in good operating condition with grit hoppers free from overloading. Vortex separators and bucket conveyors were in operating condition and well lubricated.

Since the pump station was designed and constructed by the same firm who designed and built the AGTP headworks, it is apparent the major difference is the severe overloading experienced at AGTP and better operation by WAJ staff at Zarqa Pump Station.

3.1.4 Performance

The original installed capacity of this station is now being exceeded, reducing the effective emergency standby by requiring the standby pump to be used for a period of time each day. To correct this situation, WAJ is installing two additional pumps as originally designed.

Construction for this upgrading in pumping capacity began in September 1990 and is scheduled to be completed in early 1992.

With the completion of this upgrade, the Zarqa Pump Station will have an effective capacity of 72,000 cu m/d with any one of the four installed pumps out of service. This station by itself is capable of delivering over 100 percent of the WSP's original design capacity (68,000 cu m/d).

Upgrade of the Pump Station includes an additional 1000 KVA generator for emergency power and one additional telemetry panel, for monitoring purposes at the Control Building.

Both the screening and degritting operations appear to be operating correctly and efficiently.

3.1.5 Condition

Twenty full-time employees operate and maintain the Zarqa Pump Station on a 24-hour basis. The structures and equipment appear well maintained and in satisfactory operating condition. However, septage is no longer accepted at ZPS and tanker trucks are diverted to the AGTP.

BEST AVAILABLE COPY

3.2 HASHIMIYEH PUMP STATION

3.2.1 Description

Hashimiyeh Pump Station serves the community of Hashimiyeh and parts of Zarqa. The pump station discharges sewage to the wastewater stabilization pond system at Khirbet As-Samra through a 600 mm diameter ductile-iron force main, approximately 6 km long. The point of discharge is the WSP headworks structure, upstream of the flow measuring flume.

3.2.2 Design Review

The pump station has three centrifugal pumps installed, each with a capacity of 10,000 cu m/d, providing 20,000 cu m/d capacity from two duty pumps. There is provision for installing two additional pumps for future capacity increases. The pumps are installed in a dry-well adjacent to the wet-well and driven by electric motors at ground level. Each pump also has an alternate diesel engine drive for use in case of power failure through a right angle gear.

Mechanically-raked bar screens are provided upstream of the wet-well. They are designed to handle the ultimate station capacity of 40,000 cu m/d.

The sewage inflow is measured at a measuring flume and the station discharge is also measured.

3.2.3 Mode of Operation and Performance

The installed capacity of this station is more than adequate for the flows now being experienced. Each of the three pumps installed is equipped with an emergency diesel-drive unit in case of power failure. The station is currently recording, through its totalizer, an average flow of 3,500 cu m/d.

The screening and grit removal systems appear to be operating as designed.

The instrumentation is not working as designed. All pump operation is manually controlled even though automatic controls are installed.

It was observed that the parshall flume was submerged. This is because the sewage was being maintained at a high level in the wet well. This causes the flow to backup and submerge the measuring flume. This is thought to be caused by manual operation of the pumping equipment. The influent to the station is therefore not accurate.

A check of the set points on the automatic pump control system could not verify the reason for manual operation. These automatic controls need to be repaired and allowed to control the pumps.

3.2.4 Condition

Fourteen full time employees operate and maintain the Hashimiyeh Pump Station on a 24-hour basis.

The structures and equipment appear well maintained and in satisfactory operating condition. The electric drive motor for Pump No. 3 is being rewound. A diesel drive unit is available for operation of this unit, if required. Odors at the station are minimal.

SECTION 4

SURVEY OF EXISTING WASTEWATER STABILIZATION PONDS

4.1 BACKGROUND

The ponds were overloaded organically upon commissioning. The influent BOD averaged about 850 mg/l versus the 526mg/l design value during the first year of operation. By mid 1987, the influent flow exceeded the design value of 68,000 cu m/d. Since the ponds were initially filled with raw sewage, it is extremely doubtful whether they ever reached equilibrium during the period before they were hydraulically overloaded. Therefore, it was not possible, even initially, for the Wastewater Stabilization Ponds (WSP) at As-Samra to meet the objectives of the design criteria.

Although the overloaded WSP has not met the design criteria, the WSP effluent meets the public health objectives of nematode and fecal coliform (during summer) controls and the water quality criteria for filtered BODs. These objectives, however, can only be achieved when operating all three trains and disinfecting effluent with chlorine.

The health effects of treated sewage have been well-recognized and are monitored by the Ministry of Health. As part of the design criteria for the WSP, limits for nematode eggs and fecal coliform were required which equaled or exceeded those values commonly applied to wastewater effluent used for irrigation and cultivation throughout the world.

Because the general public health of the Amman - Zarqa area is good to excellent, the influent levels of nematode eggs are significantly lower than in areas where nematode infestation is more prominent. Because of these low influent levels and more than 10 days settlement time in the WSP, the nematode limit is consistenly met or exceeded.

During winter seasons and when chlorine is unavailable for disinfection (1990-91), the WSP effluent can not meet the effluent limits of < 100 MPN/100 ml for fecal coliform and during 1990-91 averaged 4,000 MPN/100 ml. During these periods, the users of effluent for irrigation between WSP and KTR are exposed to public health risk. Public health is endangered by the use of poorly treated wastewater for irrigation due to direct contact of irrigators with the effluent and indirect contact with equipment and soils. Commonly harvested crops may also be washed during harvesting with effluent and disease organisms may be transferred to the consumer.

4.2 DESCRIPTION

The major components of the As-Samra Waste Stabilization Pond System are three trains of anaerobic, facultative and maturation ponds preceded by headworks which include flow measurement and flow division facilities. The ponds are followed by an effluent chlorination facility and also include an administration complex and a laboratory.

The ponds were designed to treat an average daily dry-weather sewage inflow of 68,000 cu m/d and a peak hydraulic inflow of 148,000 cu m/d during wet-weather conditions.

Each of the three trains includes two anaerobic ponds, four facultative ponds (except in Train 3 where ponds F3-2 and F3-3 are separated into two sub-units each) and four maturation ponds. All ten to twelve separate ponds in each train are designed to be operated in series, i.e. with flow passing from one pond to the next. The layout of the existing ponds is shown in Figure 1.2.

There is provision for the four (or six) facultative ponds in each train to be used as two separate parallel trains of two (or three) ponds.

It was also possible to pump from the following ponds back to the distribution box:

- The first maturation pond in Train 1.
- The last facultative pond in Train 2.
- The second maturation pond in Train 2.

An option was also included to allow flow to bypass two of the four (or six) facultative ponds in each train.

WSP effluent from the three trains are combined, metered, and disinfected prior to discharge into Wadi Dhuleil. A controlled continuous dosage of 25 mg/l of chorine at 68,000 cu m/d is provided. This maximum dosage rate decreases with an increase in flow to a minimum of 8 mg/l.

Disinfection consists of the storage of chlorine ton cylinders (two of which are placed on scales), the withdrawal of liquid chlorine to the evaporators (which convert liquid chlorine to gas), the establishment of chlorine dosage rates by two chlorinators based upon effluent flows, and the transfer of chlorine gas to two educators (located at the point of chlorination).

31

Only one point of chlorination was provided which is located upstream of the Parshall Flume prior to entering the chlorine contact basin. A submerged perforated pipe diffuses the chlorine solution into the effluent from the ponds.

The chlorine contact basin is a sloped side rectangular basin with internal baffles to create a serpentine mixing effect for about one hour at 68,000 cu m/d. Chlorinated effluent is discharged over a weir at the downstream end of the basin.

4.3 EFFLUENT DISCHARGE

The WSP facility discharges to the Wadi Dhuleil and over the past five years is the only significant perennial flow to the Wadi Dhuleil. The Wadi Dhuleil discharges to Seil Zarqa which ultimately discharges into the reservoir behind the King Talal Dam.

Many farms along Wadi Dhuleil use the effluent for irrigation of adjacent farmland (more than 15 sq km). However most of the effluent is discharged into King Talal Reservoir (KTR) and is ultimately used for agricultural irrigation in the Jordan Valley.

4.4 DISCHARGE CRITERIA

No regulatory agency has been established for the control or enforcement of effluent discharge criteria for the WSP, or at other municipal wastewater treatment facilities in Jordan. Effluent samples from the WSP are collected and analyzed by the Royal Scientific Society Environmental Research Center, Water and Soil Division (RSS), by the WSP Facility Laboratory, and by the WAJ Central Laboratory.

Effluent discharge limits are applied to industrial wastewater sources for discharge to waterways and sewers in accordance with Standard Specification No. 202. However, enforcement is minimal.

The sampling and testing program carried out by the RSS is summarized in Appendix A for the WSP.

The effluent discharge criteria stipulated for the WSP design were:

- Design average filtered BOD_5 (for 60 samples) - 20 mg/l
- Mean effluent filtered BOD_5 (for 60 samples) - <30 mg/l
- Max. fecal coliform, 80 % or more of the samples - <100 MPN/100 ml

4.5 DESIGN CONCEPT

The original concept for the WSP was to only provide immediate relief for the overloaded Ain Ghazal Treatment Plant (AGTP) during the expansion period of design and construction and the design was based upon the following flows and BOD_5 loadings:

	Flow cu m/d	BOD_5 kg/d
AGTP Treated Effluent	40,000	6,000
AGTP/Zarqa Septage	5,000	10,000
Waste Activated Sludge (WAS)	2,000	4,000
Raw Sewage	21,000	15,750
Total	68,000	35,750

After construction when flows were directed back to the AGTP, the WSP was to treat flows from the AGTP as shown above.

The concept was later modified to provide the only long-term sewage treatment facility, and the expansion plans for AGTP were abandoned.

Also, during construction of the WSP system, it was decided to abandon plans to construct the Zarqa Treatment Plant and the raw sewage flows were pumped directly into the sewer/siphon. Later, the Hashimiyeh area was sewered and the wastewater pumped to the WSP.

Peak factors used in design of the WSP were 1.6 peak daily dry-weather flows and 2.2 for wet-weather flows. A check against actual flows during the last five years verified these values.

4.6 DESIGN REVIEW

The design of the existing waste stabilization pond system followed conventional practice in most respects except for the number of the ponds.

The design minimized construction costs by adapting to the topographical features of the available land. To this extent, the multiple, series-connected pond system provides maximum opportunity to remove settlable pathogens, to compensate for short circuiting, if large ponds had been installed, and to accumulate sludge. The facility generally meets acceptable effluent quality criteria (i.e., fecal coliform, nematode eggs, and low to moderate dissolved salts and boron) for agricultural water reuse. However, the effluent does not meet the stated objectives of the initial design criteria.

The configuration of the ponds was dictated by the cost of construction which was established by the contractor at the time bids were submitted. Any charge in size or configuration would have required a charge order and an increase in price which WAJ could not agree to at the time.

The ponds were designed by a British firm, for the following influent characteristics established by WAJ:

Average Dry-Weather Flow	68,000 cu m/d
Average BOD_5 Load	35,750 kg/d
BOD5 of Raw Sewage	526 mg/l
Water Temperature	12.5° Centigrade

The following tabulation sets out the sequence of BOD_5 removal anticipated in the design for each train of the pond system, in winter. The design calculations acknowledge that for facultative operation in winter, pond BOD_5 loading should not exceed 200 kg/ha.d. To achieve this, ponds F1 through M1 were considered as a single unit. The anticipated performance in winter is summarized below.

34

POND	BOD REMOVAL (percent)	EFFLUENT BOD_5 (mg/l)	TOTAL EFFLUENT BOD_5 LOAD (kg/d)
Influent		526	35,750
Anaerobic A1	40	316	
Anaerobic A2	10	284	19,312
Facultative F1			
Facultative F2			
Facultative F3	81	54	3,669
Facultative F4			
Maturation M1			
Maturation M2	40	32	2,201
Maturation M3	40	29	1,321
Maturation M4	40	12	793

Pond performance in the warmer and sunnier summer months was expected to be much improved. It was calculated that only two trains would have to be operated to achieve the desired effluent quality and that ponds F3 through M2 would operate as facultative ponds and ponds M3 and M4 would be aerobic.

The design calculations at the design flow of 68,000 cu m/d and BOD_5 of 526 mg/l indicated that fecal coliform levels in the effluent at the WSP should be less that 129 MPN/100 ml in winter, with three pond trains operating, and less than 100 MPN/100 ml in summer with only two trains operating. The predicted effluent fecal coliform levels in winter and summer in a system using a single facultative pond of equivalent area would have been around 3,000/100 ml and 2,700/100 ml, respectively.

The effluent requirements for agricultural use involve only: <200 MPN/100 ml of fecal coliform, < 1 nematode egg/l, and acceptable total dissolved solids (<1400 mg/l) and boron (2mg/l). The existing facilities produce an effluent which generally meets both the nematode egg requirement and guidelines for total dissolved solids and boron.

Fecal coliform requirements can usually be met with chlorination.

Other WAJ criteria not directly related to agriculture (BOD_5 filtered; <30 mg/l) were commonly achieved during the summer with all three trains operating. However, the BOD_5 filtered levels can not be consistently achieved during the winter.

BEST AVAILABLE COPY

Pond depths are satisfactory. However, they are being impacted because of the increased levels of TSS in the influent not foreseen in the original design concept (Abandonment of AGTP, sludge transfer from other plants,etc.).

The major defects of the design included the lack of a more flexible physical arrangement or piping to allow parallel operation of facultative ponds, the lack of additional inlets/outlets to prevent short circuiting,more consideration given to removal of sludge accumulation, and better control of H_2S releases.

4.7 PERFORMANCE

The waste stabilization pond system was put into service in 1985, initially using two of the three trains. Since then the inflow to the ponds has steadily increased.

4.7.1 Flow and Organic Loads

The system was designed for an average daily dry-weather inflow of 68,000 cu m/d. The tabulation below indicates the annual average daily flow experienced in the years since commissioning as shown on Figure 4.1:

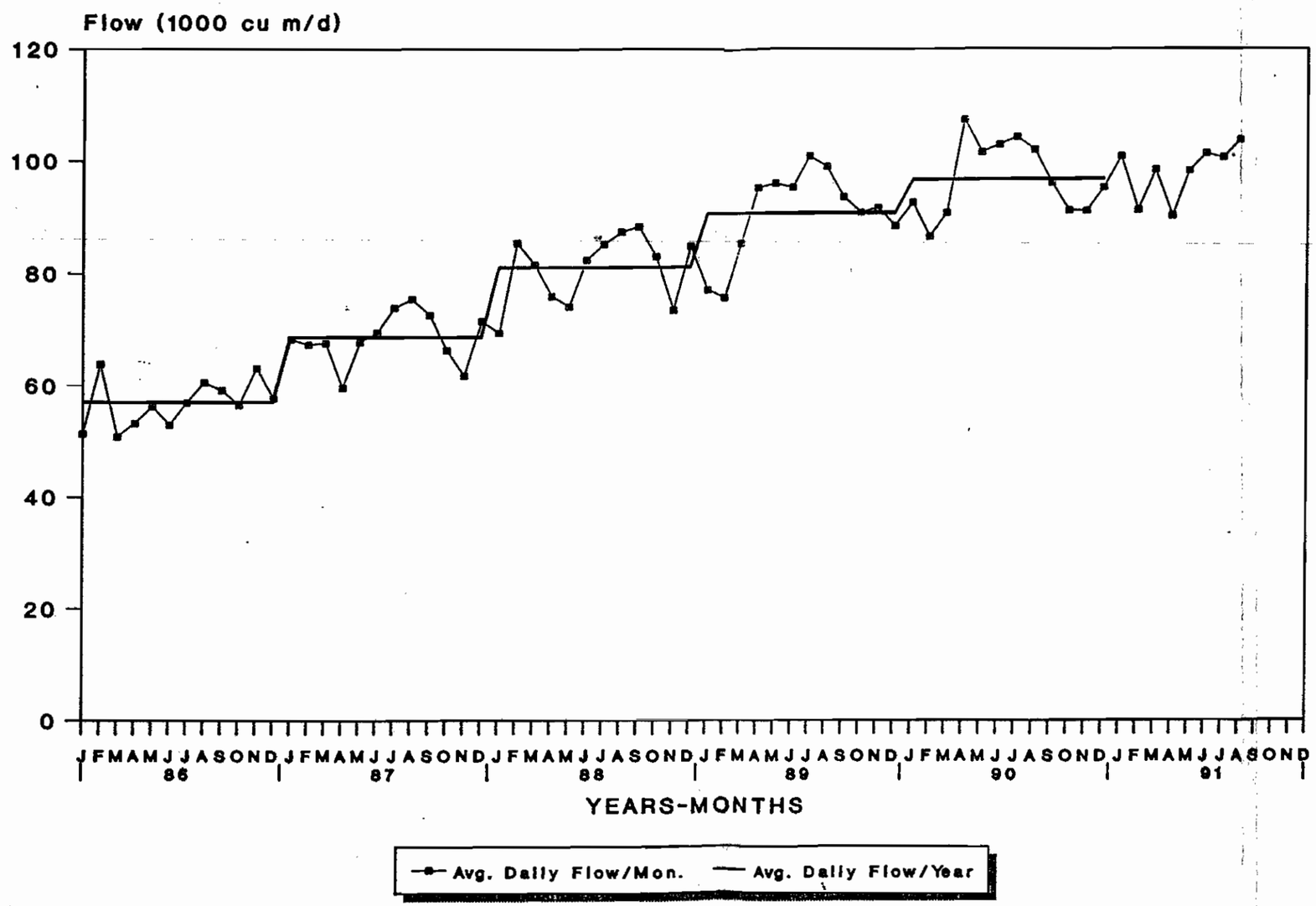
Year	Annual Average Daily Flow (cu m/d)
1986	58,000
1987	68,000
1988	80,000
1989	90,000
1990	96,000
1991	98,000 (incomplete)

The flow values shown were supplied by WAJ and were taken at the WSP.

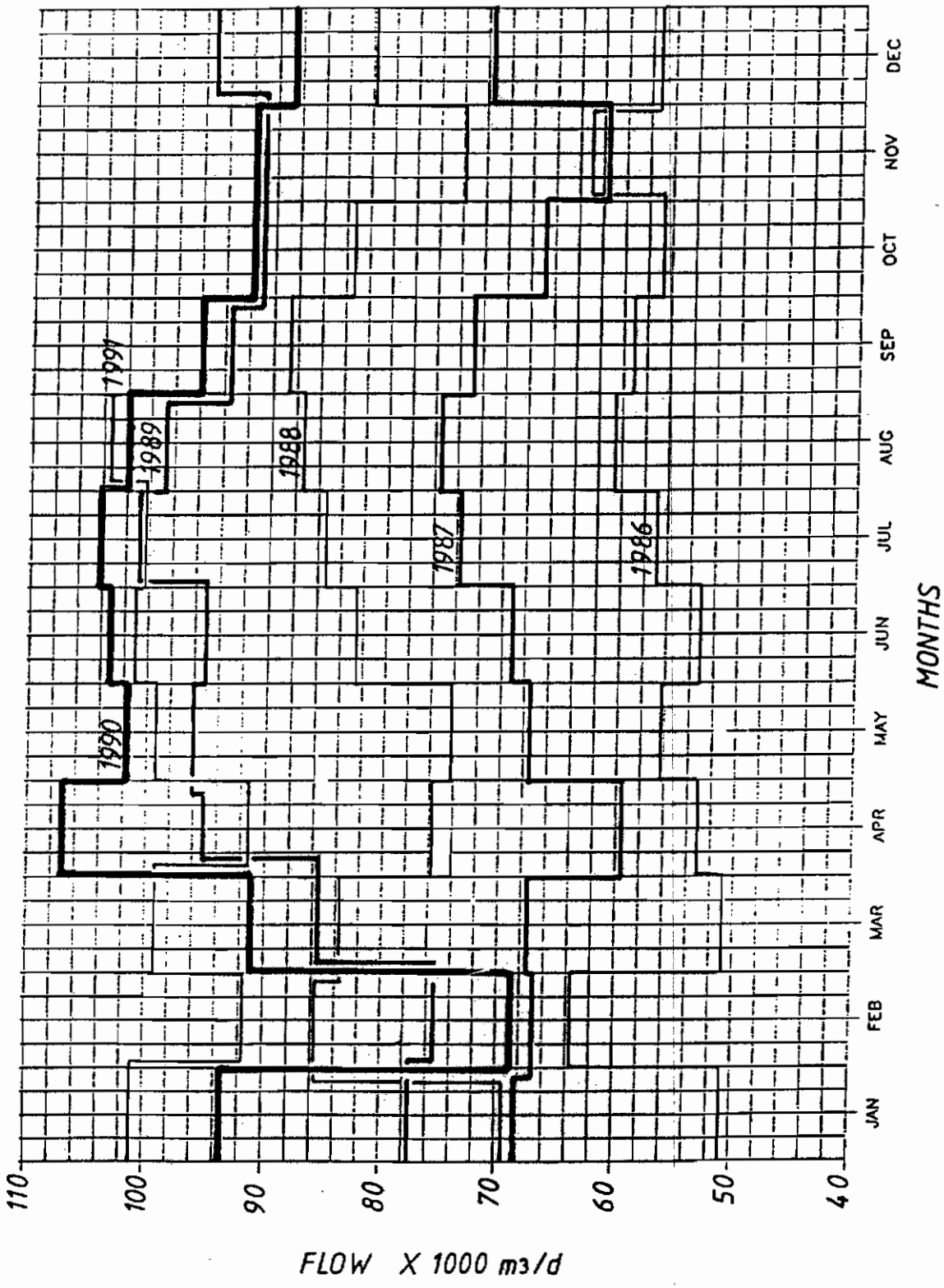
Thus, in hydraulic terms, the pond system began to receive flows in excess of design capacity within two years of commissioning. The highest monthly peak inflow recorded during wet weather has been around 170,350 cu m/d. Anything above this value was discharged at MH2 to the Wadi Zarqa.

Figure 4.2 shows monthly average flows.

36



Existing Average Daily Flow Variations At As - Samra WSP



MONTHLY AVERAGES FOR DAILY FLOW AT STABILIZATION PONDS AT AS-SAMRA

The design BOD_5 inflow for the wastewater stabilization pond system was 35,750 kg/d. The peak-month BOD_5 daily loads experienced in the years since commissioning are tabulated below :

Year	Peak Month BOD_5 (kg/d)	Yearly Average BOD_5 Load (kg/d)
1986	45,365	35,508
1987	61,427	50,509
1988	102,828	69,099
1989	79,962	66,874
1990	74,416	67,145
1991 (incomplete)	81,216	70,295

These figures have been computed from records of monthly inflow and periodic sampling of BOD_5 levels, averaged on a monthly and yearly basis. Yearly average figures are likely to be distorted by stormwater run-off. This is because the flow measurements during wet-weather are likely to have a greater impact on the statistics then the impact of BOD_5 measurements at times of high inflow.

Using the above 1986 values of 58,000 cu m/d and 35,508 kg/d, and assuming 50 percent reduction of BOD in the anaerobic ponds translate into an areal loading on the first facultative pond of 816 kg/d/ha. This value is extremely high and will overload the facultative ponds, provide poor organic removals and prevent aerobic conditions from developing. This demonstrates the overloading received by the WSP during the first year of operation.

4.7.2 Conceptual Changes Not Included in the Design

During construction of the WSP system, when WAJ decided to add flows from Zarqa and Hashimiyeh, it should be noted that both flow and BOD_5 loadings increased as follows, without a design change to the WSP.

	Flow (cu m/d)	Design (kg/d)
WSP Design	68,000	35,750
Zarqa	14,000	10,500
Hashimiyeh	5,000	3,750
Total	87,000	50,000

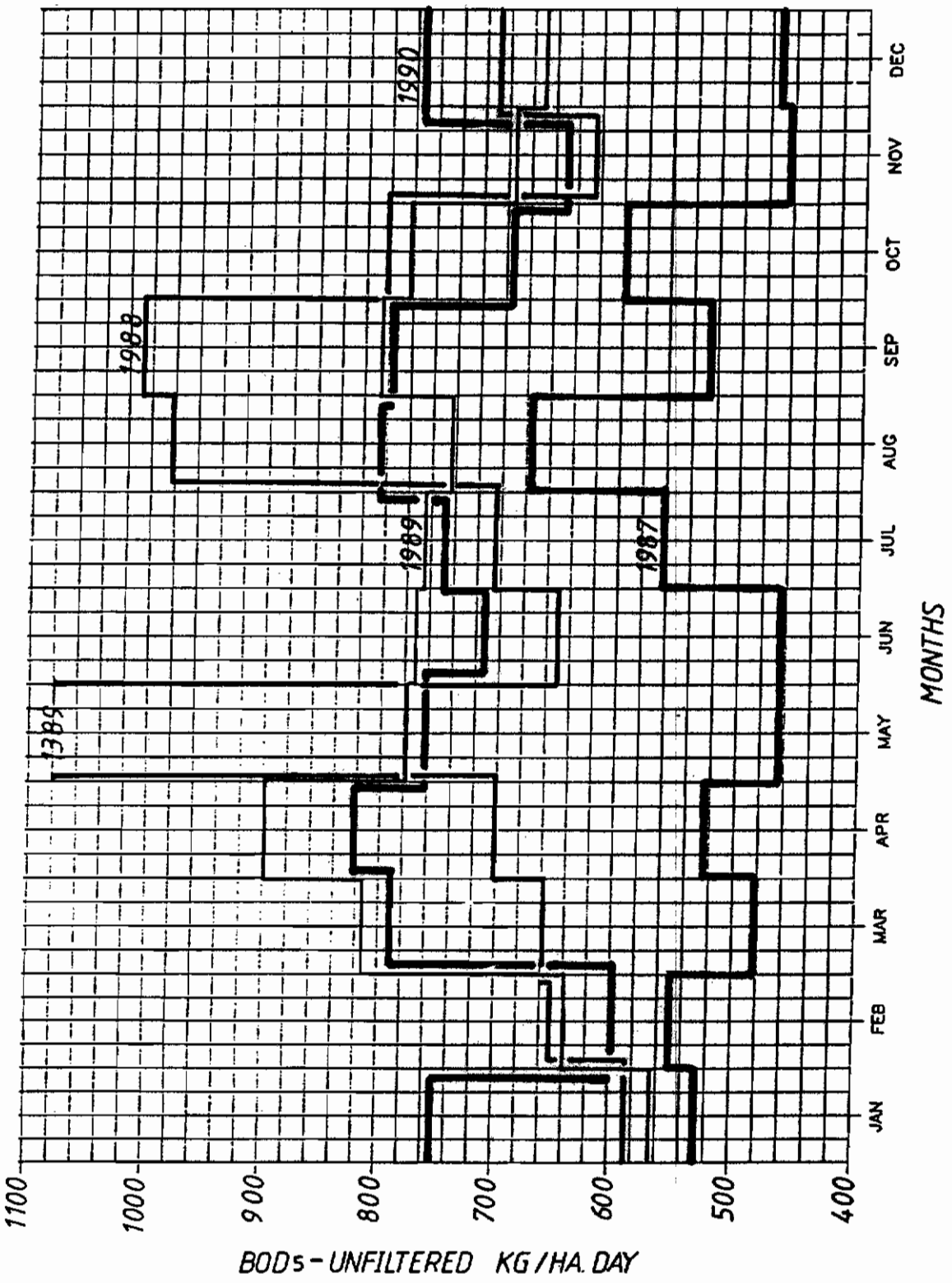
Because WAJ decided not to construct AGTP and therefore the AGTP secondary treated effluent and waste activated sludge became raw sewage, the actual BOD_5 loading became:

	Flow cu m/d	BOD_5 Total kg/d
AGTP	42,000	32,500
Septage	5,000	10,000
Raw Sewage from Amman	21,000	15,750
Zarqa	14,000	10,500
Hashimiyeh	5,000	3,750
	87,000	72,500

These changed conditions for flow and BOD were never used to change the original design criteria because construction was underway. The WSP was therefore destined to be overloaded even before construction was completed.

When compared against present average flows and BOD_5-total loadings of approximately 98,000 cu m/d and 70,000 kg/d, they are not too far removed from that anticipated as shown above. If the design for the WSP had been modified at that time, the ponds would not be substantially overloaded.

Figure 4.3 shows the monthly averages for BOD_5 loading rates over the past few years. The effects of water rationing are also shown by a decrease in the rising trend in 1990/1991.



MONTHLY AVERAGES FOR DAILY TOTAL BOD LOADS FOR ALL PONDS AT AS-SAMRA (1987-1990)

4.7.3 Performance Versus Design

WSP effluent met the design criteria for BOD_5 in filtered effluent samples and fecal coliforms with all three trains operating in summer followed with chlorination through much of 1986 and 1987. In 1988, by which time the plant was at least one hundred percent overloaded in terms of total BOD_5, the effluent failed to consistently meet the design criteria for filtered BOD_5.

The ponds were initially filled with raw sewage (it is preferable to use clear water, but this was obviously impractical in view of the quantities involved). Because raw sewage was used, it is believed the ponds did not reach a normal operating equilibrium before becoming overloaded.

Despite severe overloading of the pond system, the facility operators have managed to maintain a reasonably good treated effluent, suitable for irrigation use. However, for much of the year, almost the entire system is functioning in an anaerobic mode.

The plant operators, however, managed to maintain low fecal coliform levels in the effluent with chlorination until 1990, when chlorine for disinfection was no longer available. Once chlorine again became available (in 1991), the coliform levels were reduced.

Currently the WSP is 120 percent overloaded in terms of total BOD_5, and 42 percent overloaded hydraulically. The effluent levels being achieved are around 90 mg/l of BOD_5 in filtered samples and fecal coliform counts of around 200/100 ml (with disinfection). Although these values do not meet the design criteria for effluent, they may be considered good in view of the extent of overloading on the system. However, during the period when chlorine was not available for disinfection, fecal coliform levels were as high as 9,000,000/100 ml. This indicates that there is little reduction of fecal coliform in the treatment processes before disinfection and that most of the pond system is operating in an anaerobic mode (also reflected by high ammonia and detectible sulfide levels).

BEST AVAILABLE COPY

This anaerobic condition through all facultative and most maturation ponds is borne out by the types of algae and sulfur bacteria observed in the pond system during the summer, the low BOD removal, virtual absence of dissolved oxygen within the ponds, and the high levels of fecal coliform in effluent before chlorination.

Ammonia, total nitrogen and phosphorus are not reduced by the anaerobic WSP treatment although they decreased as the turbulent, aerated effluent moves downstream in Wadi Dhuleil and Seil Zarqa.

Ammonia appears to remain the same throughout the pond system because of inadequate nitrification in the anaerobic condition. Ammonia would be converted in fully aerobic maturation ponds.

Algae production through the pond system increased. However, because the system is overloaded and in an anaerobic mode, algae counts in the effluent are below that normally expected from waste stabilization ponds but do increase in the summer. The reddish brown color of the ponds and effluent results from anaerobic sulfur bacteria, not from brown algae.

To reduce the effects of ABS upon pond performance and to reduce foaming problems, the government should require that all detergents be biodegradable.

4.7.4 Interpretation of Sampling and Testing Data

The loading results from both the As-Samra WSP laboratory and the WAJ Central Laboratory are in close agreement with those from the RSS. This check on the quality of the testing results is important and should be continued. The frequency and methods of testing results is also important and should be continued. The frequency and methods of testing and parameters to be tested appear to be satisfactory. The testing results also appear to be adequate. However, the sampling methods should be improved by using an automatically prepared composite sampler. Grab samples, if performed, should be on the same day, at the same time, at the same point, and by the same person. All samples should be large enough to split 2 or 3 ways for testing by each agency.

BEST AVAILABLE COPY

Based on these test results and the data compiled in Appendix D, it is apparent that total BOD_5 removal and fecal coliform removal increases in summer (Figure 4.4).

Test results also indicate that the combined total BOD_5 removal in the anaerobic ponds is around 65 percent, which indicates far better performance than was anticipated in the design (46 percent). The very high suspended solids and BOD in current influent represent a significantly greater amount of settleable BOD than was used in the original BOD/TSS levels which reflect settling at AGTP or in the sewer/siphon. Because of the high organic load in the WSP influent and that of the anaerobic ponds, the surface loading on the facultative and maturation ponds greatly exceeds the design loading for both summer and winter, even when using the facultative ponds in parallel. The high flows and surface loading on the facultative and maturation ponds evidently prevents the treatment processes from operating in accordance with the intentions of the facultative and aerobic design and reduces the overall performance of the WSP system. Much of the pond system is functioning in an anaerobic mode, and only the last maturation pond shows any evidence of aerobic conditions during the summer.

Facultative pond operation requires a rigorous surface load requirement. Dissolved oxygen (D.O.) is required throughout the full diurnal cycle. Present loadings experienced in the WSP series - connected ponds are prohibiting the development of a continuous D.O. throughout the diurnal cycle. Sludge solids carryover is resulting in excess turbidity which is inhibiting sunlight penetration needed for algal photosynthesis and growth and thus the generation of oxygen. Sludge carryover is a result of short-circuiting, organic overloading, and high flows.

There is a kinetic relationship between bacteriological decomposition during the various seasons of the year. However, based on existing data and influent characteristics, the facultative ponds are similar between winter and summer operation. Due to the size of the ponds, the mean annual temperature existing in the lower depths of the ponds, operational capabilities, and overloaded conditions, it is not surprising that

BEST AVAILABLE COPY

marked seasonal differences in the pond effluent is presently observed. This holds for BOD, TSS, COD and fecal coliform.

Wind velocity and direction can materially impact short-circuiting potential, solids carryover, and reduction in both hydraulic detention and sludge retention times. However, no data is presently available relating these characteristics to quality.

The effect of septage and excess sludge from other plants has a material impact or organic loading, sludge storage, odors, sludge carryover, organic feedback, aerobicity, and both hydraulic detention and sludge retention times.

Design of the facility expansion will incorporate expected septage contributions and additional sludge transferred from other facilities.

4.7.5 Recirculation Option

The objective of the recirculation process is to return oxygen - rich water to ponds that are under stress (i.e. - low D.O. concentrations) or to reduce odors. However, if there is not an abundance of algae then recirculation is not an efficient or effective means of solving the problem.

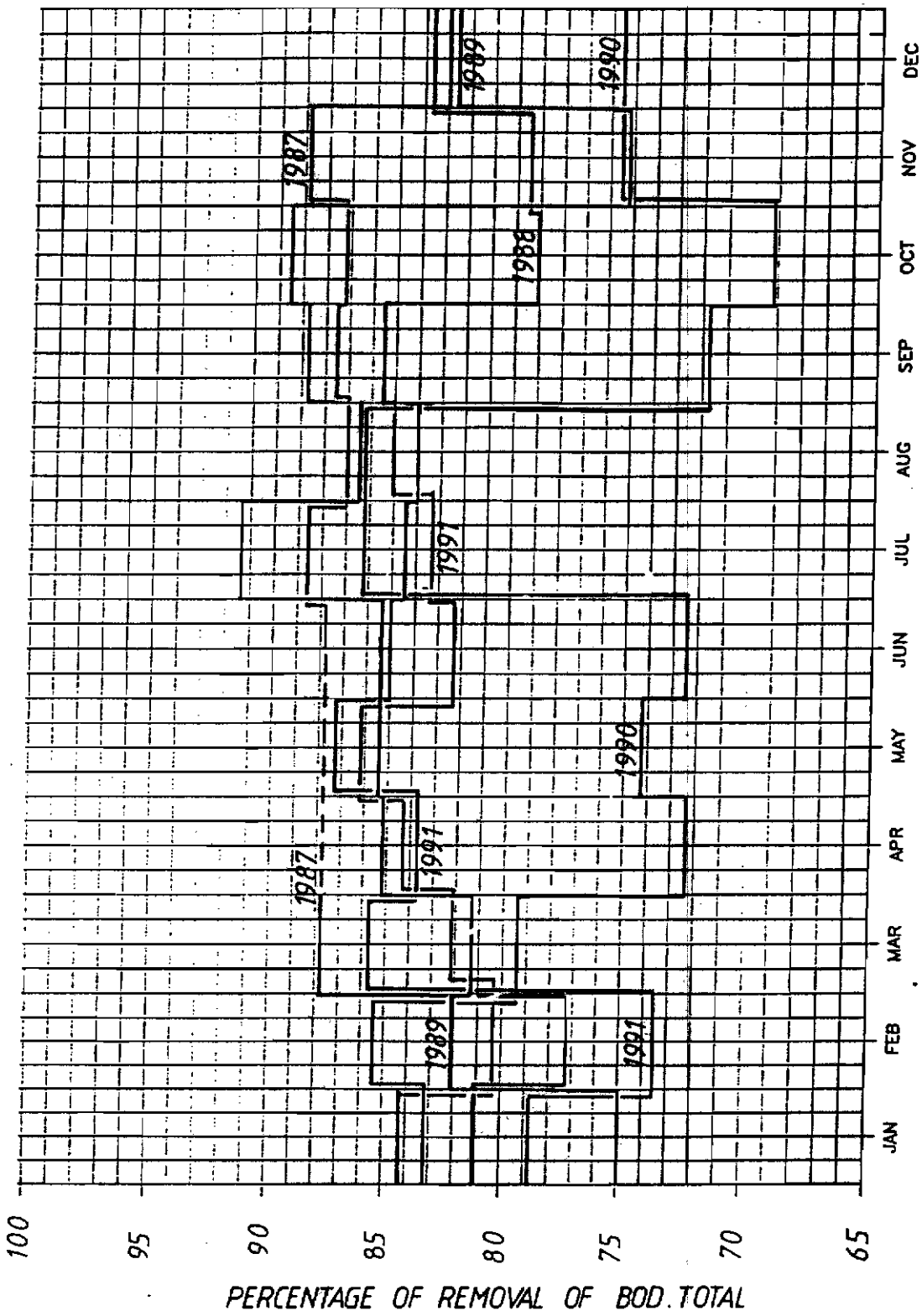
Recirculating water will also dilute the incoming organic load.

The recirculation concept is still valid, however the short-circuiting and overloading conditions (hydraulic and organic) must be remedied first before it can be effective.

Presently, the facultative ponds do not operate as facultative ponds because of the severe overloaded conditions. Neither the surface load nor the detention times will allow sufficient algal population to develop to maintain a dominant dissolved oxygen (D.O.) content, even if suspended sludge solids and short circuiting problems were not present.

The WSP operations personnel tried to operate the recirculation system in 1988 but only continuously for about one month. The procedure was abandoned

45



MONTHLY AVERAGES FOR DAILY REMOVAL OF BOD (UNFILTERED) BY ALL PONDS AT AS-SAMRA.

partly by operational difficulties but mainly because funds were unavailable to purchase diesel fuel to operate the pumps. Operational difficulties included the fact that recycle flows cannot be directed to any single train of ponds because of the configuration of the facultative ponds inlet distribution box, where the recycle flow is discharged. Upon the recycle flow entering the distribution box it is mixed with effluent from all the anaerobic ponds which overflows the weirs to all three facultative trains. Therefore, only one-third of the recycle flows reaches any one train. Recirculation in any expansion should have greater flexibility and not be restricted to only one location.

4.7.6 Parallel Option

Use of the parallel option for the facultative ponds was tried once for a few months by WAJ operations personnel during the winter of the first year of operation. This option did not improve the quality to any great extent (probably because the process had not reached equilibrium) and further use of the option was abandoned. The parallel option should have been continued. It would have improved the facultative effluent quality because the influent load to the facultative ponds would have been decreased. Expansion of the facilities should include provisions for parallel operations.

4.7.7 Sludge and Scum Removal

Much of the suspended solids content of the WSP influent has settled in the anaerobic ponds. It was the intent of the design that the accumulated sludge be removed periodically. The operation and maintenance manual suggests that sludge should be removed from each pond once it has accumulated to a depth of one meter. Measurements of sludge depth in early 1989 in pond A2-1 showed the depth to be 2.75 m halfway down the pond and 0.5 m at the inlet and outlet ends of the pond. The average depth was 1.8 m. At an average rate of 0.6 m/year, the present depth of sludge would be around 3.0 m (the pond is 5.0 m deep). Although we would recommend removing sludge once the depth reaches

BEST AVAILABLE COPY

2.0 m, it appears the 2.0 m depth has now been exceeded in the first anaerobic pond in each train and should be desludged.

With sludge removed, the overall hydraulic detention and sludge retention time in the system will be increased, sludge will not be swept into subsequent ponds during wet-weather flows, and organic loading on the facultative ponds will also be reduced. Thus, the average final effluent quality should improve slightly, particularly during storm conditions.

Maintenance of anaerobic ponds should also include removal of floating scum blankets on the surface of the ponds. The scum blankets provide a breeding habitat for insects, increase water-loss through evapotranspiration, flow over the pond discharge weirs and accumulate as bottom sludge in the following pond during peak flows and impede important operational activities, such as sludge depth monitoring. Although a dry-crusted scum blanket helps to reduce evaporation, the disadvantages including wetted surface and vegetation outweigh this advantage. Scum may be easily removed by spraying water on the surface and sinking the material.

The option to remove sludge is to use pumps placed on floating platforms (barges). This would allow the ponds to remain in service, or at least to retain a liquid cover over the sludge, minimizing the release of H_2S to the atmosphere. If the anaerobic pond is to be retained in use, the flow rate to that train should also be reduced; this can be accomplished by restricting the flows at the WSP headworks.

By restricting the width of the weir in the facultative ponds inlet distribution box and reducing flows to a facultative/maturation train would allow an algal bloom to be created in the last maturation pond of that train. After approximately two weeks, the liquid in this pond should have a high oxygen concentration. Recirculation of this high oxygenated water and algae should then be pumped back to the anaerobic pond being desludged, sprayed over the surface of the pond to create an aerobic layer on the surface. The aerobic layer will then help to oxidize H_2S gases released from the desludging operation.

BEST AVAILABLE COPY

At present, the first and second facultative ponds in each train are assuming the role of anaerobic ponds because of the high organic solids content in their influent. Because of the high solids concentration, sunlight penetration is minimal. Without the aid of algae, the ponds cannot produce adequate oxygen to overcome the biological oxygen demand. This is borne out by the development of reddish brown sulfur bacteria in the third and fourth facultative ponds in each train. These bacteria are found in liquids with high sulfur content and/or in oxygen deficient liquids. They reproduce rapidly, effectively blocking sunlight from penetrating more than a few millimeters into the liquid, which in turn eliminates the proprogation of the algae growth and effectively maintains an anaerobic state in the facultative and maturation ponds.

4.7.8 Short Circuiting

Observations of high wet-weather flows, reviews of physical designs, and float dispersion tests of the As-Samra Ponds indicate that the full physical volume of all ponds is not being efficiently used and that short-circuiting occurs. Poor circulation and mixing within the ponds adversely reduces treatment of the organic and hydraulic loads on the system. During recent wet-weather winter flows, persistent and significant transport of suspended anaerobic sludge materials through the entire pond system and into the effluent indicated that short circuiting was occurring and that accumulated sludge had been resuspended and carried throughout all ponds and into the effluent.

Distribution of wastewater influent to each train is entirely governed by the design of the distribution channel and manually operated sluice gates between the channel and downstream chambers. During dry weather flows, the distribution of influent flow appears satisfactory. During wet-weather flows, distribution of flow was highly disproportionate with the majority passing through the central distribution chamber and thence to Train 2 (Pond A2-1). Train 2 distribution chamber sewage level had risen to within one meter of the top of the chamber while the other two sewage levels (Trains 1 and 3) were below the crown of

BEST AVAILABLE COPY

the inlet distributor pipe. Partial closure of the sluice gates would relieve the high flow to Train 2 and distribute the flow evenly to all trains.

The ponds are generally rectangular with L/W ratios of 1.8 for anaerobic and 1.9 to 3+ for both facultative and maturation ponds. Such ratios are generally lower than normal (3+ being more typical). Lower ratios generally depend more on external factors (i.e., wind) to assure proper mixing and consistent flow through the ponds. The additional facultative ponds in Train 3 improves mixing and proper circulation through the longer, higher pond ratios.

Physical distribution of wastewater influent to and from each pond is largely governed by the number and location of the distribution channels and the configuration of the channel. All influent distributors (except for the initial A1,2,3-1) are flat-bottomed ramp-type channels which deliver flat flows of less than 10 cm across the 2+ m wide channels. Most outlets are designed to only allow discharge from the surface layer. The combination of surface inflow and outflows do not promote any significant hydraulic mixing and requires that all mixing be induced by surface winds. Of the total 32 ponds , 19 ponds have only single inlets and outlets or single outlets and would be expected to be more prone to short-circuiting than ponds with multiple inlets/outlets.

While the design allowed a total of 40+ days for passage through each train based on 68,000 cu m/d, this detention time had been reduced to less than 30 days during present average dry weather flows and about 15 days during peak wet-weather flows.

As the velocities of flow increase due to increased flow and reduction in detention times, the physical aspects of ratios, right-angle turns, and number and location of inlets/outlet tend to increase the potential for short circuiting.

On March 12 and 13, 1992, float studies were conducted using 4 cm partially submerged floats. Almost 300 floats were released at the inlet of Pond F2-2 and were observed for four hours and then on the following day. Southerly winds carried the floats directly across the pond in

BEST AVAILABLE COPY

less than two hours. Within three hours, more than one-third of the floats had been carried over the outlet of the pond and more than 50 percent crossed the outlet in four hours. Those floats remaining in the pond had been trapped in the rock shore protection and could no longer move.

About 80 small floats were also released along the southerly wall of the inlet of Pond A2-2 and were observed for three hours. The floats travelled to the mid point of the pond and had spread to the shoreline along the southerly side of the pond. From that point, the floats continued along the entire length of the pond in less than four hours.

These observations were made when usually high wet-weather flow was passing through Train 2 and when strong winds were parallel with normal flow directions through the anaerobic and facultative ponds. The observations indicated that short-circuiting does occur when winds are calm or parallel to pond flows. The single point discharges of virtually sheet flows to the pond surface layer do not promote mixing of surface and bottom layers and maximum dispersion of the influent to all areas and depths of the ponds.

4.7.9 Odor

A major concern of nearby communities, and of WAJ, is the odor originating from the wastewater stabilization pond system. Even though the ponds are located at about 4 - 6 km from the nearest communities and despite there being other major odor producing developments in the area (the oil refinery and thermal power station), numerous complaints regarding odors originating from the ponds have been received.

Odors were reported by residents of nearby communities to reach their maximum between 2:00 am and 8:00 am. This is normally a period of low ambient temperatures and cooling of the lower atmosphere. As a result an inversion very often occurs, causing the more dense odor-bearing air to remain, or concentrate, close to the ground.

Hydrogen sulfide (H_2S) levels in the influent at the headworks have been recorded as high as 45 mg/l in June 1986. The monthly average during the

BEST AVAILABLE COPY

51

last five years has averaged around 12 ppm (free gas) in the air space above the sewer/siphon discharge at the headworks.

On 22 October 1991, members of the project team conducted a survey of airborne H_2S levels throughout the WSP. The survey was performed using an Industrial Scientific Hydrogen Sulfide Monitor.

Very high levels of H_2S were found to be released at the headworks; levels were especially high at the point where the sewer/siphon discharges and at the flow diversion structure, where there is high turbulence. Measurements as high as 173 ppm were measured.

Hydrogen sulfide (H_2S) was also measured near the surface of the anaerobic ponds at 12 to 14 ppm.

Measurements of up to 2 ppm were recorded on the first two facultative ponds. No H_2S was detected above the last two facultative ponds, nor above any of the maturation ponds.

High levels of H_2S were measured at the inlet structures to the first facultative pond (F2-1) and at the inlet to the third facultative pond (F2-3). These readings were because of turbulence at the pond inlets.

Hydrogen sulfide is not the only odor generated by the pond system, there are also mercaptans and other compounds, but it is the only gas which can be readily measured.

4.8 CONDITION OF WSP COMPONENTS

4.8.1 Operational Water System

The original design did not provide water supply facilities around the project site. If the operations staff wish to wash-down structures and equipment around the site this must be be done using a tanker. It is suggested that a water distribution system be provided in the expansion for hosing-down the structures and also for sinking scum layers on pond surfaces.

BEST AVAILABLE COPY

4.8.2 **Metal Fixtures**

Metalwork around the site, including safety rails and the sewer/siphon cleaning swab retrieval apparatus should be cleaned and painted.

4.8.3 **Corrosion**

There is some evidence of concrete corrosion at the headworks, due to hydrogen sulfide in the incoming sewage. This does not need immediate attention, but should be monitored. The metal gaging staff, electrical boxes, and flow meter housing at the headworks should be replaced.

4.8.4 **Slide Gates**

The exposed screw-threads on the gate operators are normally provided with clear plastic covers to exclude dust and debris. Some covers are missing and should be replaced.

Consideration should be given in the expansion to motorizing those large penstocks at the headworks which are crucial to facility operation.

4.8.5 **Telemetry**

Flows into the WSP inlet are measured and recorded at a measurement flume at the headworks. Data were originally transmitted by a cable-based telemetry system to the monitoring panel in the Administration Building. This telemetry system has apparently never been effective, probably due to signal loss over the considerable length of cable. This should be corrected during the expansion.

4.8.6 **Laboratory Facilities**

The equipment in the WSP Laboratory was supplied through the construction contract for the most part. This equipment is still in satisfactory condition.

4.8.7 Chlorination Facility

The existing chlorination facilities appear to be generally in good condition. The system is designed as two parallel trains of equipment sized to operate in a duty/standby mode. Included in each train is an evaporator and chlorinator, located in an area adjacent to the administration building. Chlorine ejectors/injectors, powered by booster pumps , are located adjacent to the influent channel of the chlorine contact basin and feed diffusers mounted in the influent channel flow.

The only reported problems include insufficient chlorine gas production from the evaporators and clogging of the strainer feeding the chlorine booster pumps, which sometimes resulted in pump shut down. It has been reported that the heat exchanger units in the chlorine evaporators have not been serviced and that it is understood that inefficient heat transfer from the heating coils to the water bath in the evaporator will limit chlorine gas production. Maintenance and operational monitoring of the evaporators will need to be performed to determine if chlorine gas production is limited by the design capacity. Similarly, more detailed operational monitoring needs to be documented to determine if the existing duplex stainers are inadequate or need more frequent maintenance than is now provided. As an improvement/alternative, an automatic, self-cleaning type basket strainer could be designed to replace the existing strainers.

The chlorine contact basin is in good condition. The effluent sampler has been reported to be disconnected and modifications including lowering and opening of the effluent weir have been made to accommodate the higher current flowrates.

BEST AVAILABLE COPY

4.9 WSP OPERATIONS RESOURCES

4.9.1 WSP Site Personnel

There are a total of nine full-time personnel currently assigned to the WSP, including:

- Plant Superintendent
- Laboratory Technicians (2)
- Maintenance Technician
- Electrical Technician
- Technical Laborers (2)
- Non-Technical Laborers (2)

The current staffing level for WSP appears to be adequate for its current needs. The technical skills and abilities of the staff are also assessed to be more than adequate.

4.9.2 Vehicle Inventory

The facility is equipped with three double cab pick-up trucks for general maintenance and operations use. A 26-passenger bus is also assigned to the WSP and is used primarily for tours of the facility. Each vehicle appears to be in good condition. No additional vehicles are required at this time.

4.9.3 Spare Parts

The spare parts available at the WSP site have been surveyed and the inventory is listed below. Recommendations for additional chlorination equipment spare parts are shown in Appendix B. Additional lengths of pipe, one valve of each size and pump impellers and bearings should also be in stock.

BEST AVAILABLE COPY

SPARE PARTS CURRENTLY AVAILABLE AT AS-SAMRA WSP

CHLORINATION EQUIPMENT	QUANTITY
Isolation Valve	1
Pressure Gauge	2
Rupture Disc	4
Spring	1
Flow Meter	1
Flow Meter Float	1
Seal (orifice)	1
Cascade	1

4.9.4 Operating Budget

Operating budgets are prepared by the WAJ Central Operations Department. Specific budget requests and justifications are provided by the WSP operating staff for spare parts and new equipment.

Funding has decreased significantly since 1989, and there has been inadequate provision for spare parts and replacement equipment.

All budgetary obligations are allocated from the WAJ General Fund and all revenues generated return to the General Fund.

Funds for all chemicals, supplies, glassware and consumables for the WSP laboratory are supplied from the WAJ Central Laboratory budget, rather than from the Central Operations Department budget. A list of available and recommended laboratory equipment and chemicals for the WSP laboratory are in Appendix C.

BEST AVAILABLE COPY

SECTION 5

SURVEY OF IDLE AGTP

5.1 INTRODUCTION

This evaluation was made to determine the possibility of reactivating the existing facilities at AGTP as either a full secondary treatment plant or as a primary treatment plant only.

In either case, the present headworks facilities at AGTP would be used and treated effluent would still be transported to the As-Samra WSP through the sewer/siphon pipeline.

A detailed evaluation of the AGTP facilities is available in the "Final Master Plan Report and Engineering Design and Economic Analysis Report for wastewater Disposal for Greater Amman Area", prepared in 1982. A significant conclusion of this evaluation was that the actual treatment capacity of the facility was considered to be 30,000 cu m/d, because the high-strength of the raw sewage reduced the effectiveness of the activated sludge process. Other plant short-comings included frequent clogging of air diffusers in the activated sludge process, and inefficiencies in the final settling and chlorination system.

Conversion of the idle AGTP to a full secondary treatment facility (activated sludge) would allow 30,000 cu m/d of raw sewage to be diverted to the plant. Effluent would be returned to the sewer/siphon because the storage time necessary to remove nematode eggs is not adequate. Thus reducing the size of the future pipeline to carry flows to As-Samra would not be possible. BOD_5 loading to the ponds however, would be reduced by 15 percent.

It would be possible to use the idle AGTP as a 60,000 cu m/d primary treatment plant. The advantage, compared to reactivation as a full secondary plant, is that the large aeration blowers would not be required. Operating costs would be much reduced compared to operating a full activated sludge plant. Conversion of the secondary clarifiers to primary clarifiers has been evaluated. The digesters and belt filter presses are adequate to accommodate a loading of about 36,000 kg/d. The amount of primary sludge produced in a converted 60,000 cu m/d primary facility is estimated to be about 30,000 kg/d. As such, the digesters and the belt filter presses appear to be adequate to accommodate that

BEST AVAILABLE COPY

rate. The resultant BOD_5 loading for the year 2005 at As-Samra would be reduced by about 15 percent by this conversion.

Since primary treatment would not eliminate concerns regarding removal of nematode eggs, primary effluent flows would be returned to the As-Samra WSP through the sewer/siphon pipeline.

5.2 CONDITION ASSESSMENT

A detailed startup and check-out of each piece of equipment is beyond the scope of this assessment. Those items which must be repaired or replaced in returning AGTP to full operation as a primary treatment or as an activated sludge plant are listed below.

Pre-Aeration Facilities

- Replace air diffusers.

Primary Clarifiers

- Replace chain and flight mechanisms.
- Repair safety rails.

Aeration Basins

- Replace air diffusers.
- Repair safety rails.

Secondary Clarifiers

- Remove intermediate concrete slab to improve settling efficiency, if structurally acceptable.
- Replace chain and flight mechanisms.

Solids Stabilization Facilities

- Desludge both primary and Secondary Digesters.
- Inspect digester gas and mixing systems.

Solids Handing Facilities

- o Replace hoses on hydraulic system.
- o Replace filter belts.
- o Replace conveyor belts.

While this is an extensive and costly list of items to be repaired or replaced, it is not all-inclusive. The condition of some crucial equipment components cannot be ascertained until they are started and/or dismantled for inspection.

The condition of all switchgear and electrical connections must also be verified.

5.3 CONCLUSIONS

It would appear that reactivation of the idle AGTP activated sludge plant would be feasible. The cost to reactivate may be prohibitive, however. In addition, although reactivating the AGTP would reduce the present BOD_5 loading by 30 percent, the remaining amount would still exceed the design organic loading for WSP.

SECTION 6

WASTEWATER EFFLUENT REUSE

6.1 WASTEWATER REUSE IN JORDAN

Water reclamation and reuse has been recognized in Jordan as an important alternative source of water for non-potable purposes, particularly for agricultural irrigation[1]. Fourteen treatment plants in various parts of Jordan produce effluent, most of which is used successfully for agriculture. Reuse of effluent for agricultural irrigation is widely considered to be an important supplement to the Country's existing water resources.

The As-Samra Wastewater Stabilization Ponds effluent comprises the largest source of treated effluent (about 85% of total wastewater flow)[2]. Effluent from As-Samra Wastewater Stabilization Ponds (WSP) is currently suitable for irrigation of most crops, although marginally so for a few sensitive crops because of boron, TDS, and chloride concentrations. If practiced within the regulatory context and with proper irrigation management, its use will not harm the public health, the crops or the soils. Nearly all (80%) of the As-Samra effluent is presently used in agriculture, most of it in the Jordan Valley, after mixing with stormwater runoff in the King Talal Reservoir (KTR); some effluent recharges local groundwater or evaporates.

6.1.1 KTR Water Use for Irrigation in the Jordan Valley.

Since late 1985, the As-Samra WSP effluent has contributed a significant proportion of the water in KTR, ranging from about 80 percent in dry years to 18 percent in years with high precipitation. Outflow from KTR is used to irrigate some 6000 hectares of agricultural lands in the D-29 zone of the Jordan Valley. Comparing produce quality and yield from this zone with quality and yield from

---

1. Al-Salem, Saqer, Potential for Wastewater Reuse in Jordan, Regional Seminar on Wastewater Reclamation and Reuse 11- 16 December 1988.

2. Al Salem, Saqer, Wastewater Treatment and Reuse in Jordan, Regional Seminar on Reuse of Treated Effluent, Amman, Jordan, July 23-27, 1989.

BEST AVAILABLE COPY

other Jordan Valley zones using other sources of water (e.g., Yarmouk River) has shown no significant

difference over the past several years[3] Farmers rely on leaching by additional irrigation and rainfall to periodically remove excess salts from the root zone.

A recent World Bank publication reviews water reuse practices around the world, including some of the most primitive instances where raw sewage has been used to irrigate vegetables[4].

It concludes that with treatment capable of achieving <1000 coliform per 100 mL and <1 intestinal nematode eggs per litre, reuse of wastewater effluent for irrigation of most crops is safe for the public health. Other field studies[5], using more advanced treatment schemes, have resulted in similar conclusions regarding safety and appropriateness of uses of reclaimed water. The Jordanian Ministry of Health monitors water quality and conducts epidemiological surveillance in the area. No public health problems have been reported or observed in connection with use of the undiluted treated effluent nor the more diluted KTR water.

In 1990, an infestation of white flies damaged the tomato crop in Jordan Valley severely; squash and some other crops were also affected to a lesser extent. The problem has been attributed to a number of factors including climatic anomalies. The wide distribution of the white fly infestation in Jordan Valley has removed use of KTR water as a prime suspect. However, a thorough pathological analysis might indicate additive effects of stress from the high-boron, high-TDS irrigation water

---

3. Personal communication with Mr. Mohammad Taher Hambali, Consultant to Jordan Valley Authority, September 29, 1991, Amman Jordan.

4. Integrated Resource Recovery; No. 6, World Bank Technical Paper, 1986

5. For example: Sheikh, B. et al, "Monterey Wastewater Reclamation Study for Agriculture", Research Journal WPCF, May June 1990.

BEST AVAILABLE COPY

contributing to the severity of the virus attack associated with white fly infestations. Field observations in portions of Jordan Valley[6] failed to reveal significant effects attributable to water quality differences between the use of treated effluent via KTR and other irrigation sources. Other studies have been conducted of the relationships of KTR water and the white fly infestation and the tomato crop failure and no direct connection hasbeenfound, although stress may have lessened the resistance to drought and other more influential factors directly related to the infestation[7].

6.1.2 Direct Uses of As-Samra WSP Effluent

Immediately downstream from the As-Samra Stabilization Ponds, a number of farmers pump treated effluent flowing in Wadi Dhuleil and Seil Zarqa for irrigation of various crops. Some farmers use the effluent for raw-eaten vegetables, such as carrots, spinach, cabbage and lettuce. This use of the effluent for irrigation of "uncooked" vegetables is currently unauthorized. The Ministry of Agriculture provides quidance and control to discourage use of the effluent by local farmers for irrigation of raw-eaten food crops. Continuation and expansion of irrigated farming in accordance with environmental health regulations is deemed to be beneficial for the farming community as well as for the quality of water in the streams and KTR, downstream. For the immediate future, enforcement of the existing crop restrictions would help ensure protection of the public and farmers health.

Use of effluent upstream of the KTR has two major advantages: 1) beneficial utilization of the water resource and the rich nutrient content of the effluent, and 2) reduction of nutrient KTR contributes to its eutrophication which reduces nutrients available for Jordan Valley agriculture.

---

6. Field trip, October 6, 1991, to Jordan Valley farms irrigated with Yarmouk River water and those irrigated with King Talal Reservoir water, where citrus, tomatoes, eqqplant and various other produce is grown.

7. Report by British Embassy on pollution of KTR water.

BEST AVAILABLE COPY

6.2 WASTEWATER REUSE STUDIES IN JORDAN

Past and ongoing wastewater reuse test plots[8] in Jordan have amply demonstrated the technical feasibility and safety of using reclaimed water for irrigation of an unlimited variety of crops with different types of irrigation systems. Future research and

demonstration projects -if deemed necessary -should concentrate on epidemiological effects of using reclaimed water for irrigation of various food crops. Such studies can provide the essential technical support needed for establishing public policy with regard to water reuse at the appropriate safety levels which the Society can afford. The As-Samra Wastewater Stabilization Ponds provide an excellent opportunity for prospective epidemiological studies because of the availability of reclaimed water at a number of treatment levels, including effluent from the anaerobic ponds, facultative ponds, maturation ponds, chlorination basins, and possibly, the rock filters. Another unique opportunity is provided by the natural infiltration of the effluent in the groundwater basin underlying Wadi Dhuleil and Wadi Zarqa. Migration and attenuation of pollutants, particularly organic compounds and viruses, should be traced at various distances perpendicular to the channels in the groundwater, at various depths. Information from these studies (if obtained in a quality-assured, rigorous, scientific manner) would be highly valuable, not only for Jordan, but for all others planning groundwater recharge projects using reclaimed water.

---

8. Test plots have been set up at the King Hussein Medical Center, at the Queen Alia International Airport, and at the As-Samra Treatment Plant, growing various vegetable crops with effluent under different irrigation regimes. These projects have been sponsored by the University of Jordan and by the United Nations FAO, respectively. The results are predictably positive and affirmative with regard to the applicability, safety and general reliability of using reclaimed water, even with less-than-adequate treatment, for irrigation of these crops. No negative results have been observed or reported where the treatment level has been up to standards.

BEST AVAILABLE COPY

6.3 WASTEWATER QUALITY REQUIREMENTS AND GUIDELINES FOR REUSE

6.3.1 Jordanian Environmental Health Regulations[9]

The Government of Jordan, Department of Environmental Health regulates water reuse in accordance with the "Martial Act of 1989, Articles 1, 2A, and 2B" issued September 25, 1989. These

regulations prohibit discharge of raw wastewater to rivers, or irrigation of any crops with untreated wastewater, or primary effluent and strongly restricts use of secondary effluents and commingled waters.

1. For irrigation of food crops which are normally cooked before consumption, fodder, orchards and forests, reclaimed water shall contain <1000 fecal coliform per 100 ml and <1 intestinal nematode eggs per liter during the irrigation season.

2. Effluent not meeting the above conditions can only be used for irrigation when:

   a. Srinklers irrigation method is not used,
   b. fruit is not picked from the ground, and
   c. irrigation is discontinued at least two weeks before harvest.

3. Effluent used for irrigation of public greenbelt, fields/parks or gardens must contain <200 fecal coliform per 100ml and <1 intestinal nematode eggs per liter.

4. Land adjacent to streams carrying effluent or commingled water may be used for cultivation of food crops normally cooked before eating, fodder, trees, or forests.

Ministries of Agriculture, Public Health, and Water and Irrigation are charged with implementing this Act and define stream types and "adjacent lands"; they decreed that Wadi Dhuleil from Wadi

---

9. Source: Mr. Mohammad Khandagh, Ministry of Environmental Health, personal communication on September 30, 1991, Amman, Jordan.

BEST AVAILABLE COPY

As-Samra to its confluence with Seil Zarqa (about 10 kilometers downstream, west of Sukhaneh) is a treated effluent stream. Crops may be those that are cooked before consumption, fodder, or trees. From the confluence to KTR, the Seil Zarqa is declared "commingled with effluent", and crops to be cultivated may be those cooked before consumption, fodder or trees. King Talal Reservoir (KTR) is declared a "surface water", suitable for unrestricted irrigation.

The Department of Environmental Health has monitored water quality in the various bodies of water currently used for irrigation in Seil Zarqa and in the Jordan Valley, including those carrying a large percentage of effluent. Over the past five years of monitoring for pathogenic organisms such as Shigella, Salmonella, Cholera and for nematode eggs, none have been detected in the irrigation waters. Compliance of the As- Samra WSP effluent with these regulations and the WHO Guidelinces, particularly during the summer irrigation season, was reported at a recent WHO Regional Seminar[10].

6.3.2 World Health Organization and Other Guidelines

Tentative guidelines issued by the World Health Organization (WHO) for use of reclaimed water are shown in Table 6-1. These **guidelines** are advisory. The Government of Jordan specifically adopted these Guidelines prior to adoption of its own regulations, summarized above.

Severity of affluent, humid regions' effluent reuse standards should not be viewed as appropriate under Jordan's arid conditions. Many experts familiar with world-wide water reuse experience support the less stringent requirements (such as those in WHO Guidelines) as equally protective of the public health under nearly all conditions.

---

10. Al Salem, S. and H. M. Al Tarazi, Compliance of Different Wastewater Treatment Systems with WHO Guidelines for Use in Unrestricted Irrigation, Regional Seminar on Reuse of Treated Effluents, Amman, Jordan 23-27 July, 1989.

BEST AVAILABLE COPY

TABLE 6.1

WORLD HEALTH ORGANIZATION GUIDELINES FOR RECOMMENDED MICROBIOLOGICAL QUALITY OF TREATED WASTEWATER EFFLUENT IN AGRICULTURAL IRRIGATION

Category	Reuse conditions	Exposed group	Intestinal nematodes[a] (arithmetic mean no. of eggs per litre[c])	Faecal coliforms (geometric mean no. per 100 ml[c])	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[e]	Workers, consumers, public	≤1	≤1000[d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[f]	Workers	≤1	No standard recommended	Retention in stabilization ponds for 8–10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

[a] In specific cases, local epidemiological, sociocultural and environmental factors should be taken into account, and the guidelines modified accordingly.

[b] *Ascaris* and *Trichuris* species and hookworms.

[c] During the irrigation period.

[d] A more stringent guideline (≤200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.

[e] In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

BEST AVAILABLE COPY

Water quality requirements for agriculture are given in FAO Manual 29[11] covering a wide range of parameters. These requirements are intended to protect the crop yield and quality and the long-term productivity of the soil. The requirements are equally applicable to irrigation with various sources of water, including reclaimed water. Some of the more pertinent parameters are summarized in Table 6-2 and 6-3. Currently, effluent from the As-Samra Stabilization Ponds meets most of these requirements. The problematic parameters include:

Total Dissolved Solids. Total dissolved solids (TDS) in the As-Samra Treatment Plant effluent is rather high, ranging from 800 to 1,400 mg/l. However, with proper management of the leaching fraction, farmers can obtain normal yields from most crops. Significant yield reductions can be expected if TDS remains consistently above 1,000 mg/l and proper irrigation management efforts are not undertaken. In "normal" precipitation years, rainwater is very effective in removing salts below the root zone, even if the farmer has not allowed for a "leaching fraction" (additional irrigation water). Drip irrigation systems are particularly effective in keeping the salts outside the root zone, if properly designed and maintained.

Nutrients. Levels of nutrients (N,P,K, and micronutrients) in the As-Samra Treatment Plant effluent are fairly high. The nutrient load applied to the soil can approach or exceed the fertilizer requirements of most crops grown in Jordan, simply from the undiluted reclaimed water source used for irrigation. Farmers should be alerted to the presence of high concentration of nutrients and advised to cut back on fertilizer application accordingly. Excess fertilizer application can pollute surface and groundwaters. Also, it can lead to reduced yield of fruits, nuts, cotton, sugarbeet and other non-vegetative farm products.

---

11. United Nations Food and Agriculture Organization, Water Quality for Agriculture, Manual No. 29, 1978.

TABLE 6_2

Guidelines for interpretations of water quality for irrigation[1]

Potential irrigation problems	*Units*	*Degree of restriction on use*		
		None	*Slight to moderate*	*Severe*
Salinity (affects crop water availability)[2]				
EC_w	ds/m	<0.7	0.7–3.0	>3.0
(or)				
TDS	mg/l	<450	450–2000	>2000
Infiltration (affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)[3]				
SAR = 0–3 and EC_w =		>0.7	0.7–0.2	<0.2
= 3–6 =		>1.2	1.2–0.3	<0.3
= 6–12 =		>1.9	1.9–0.5	<0.5
= 12–20 =		>2.9	2.9–1.3	<1.3
= 20–40 =		>5.0	5.0–2.9	<2.9
Specific ion toxicity (affects sensitive crops)				
Sodium (Na)[4]				
surface irrigation	SAR	<3	3–9	>9
sprinkler irrigation	me/l	<3	>3	
Chloride (Cl)[4]				
surface irrigation	me/l	<4	4–10	>10
sprinkler irrigation	me/l	<3	>3	
Boron (B)	mg/l	<0.7	0.7–3.0	>3.0
Trace elements				
Miscellaneous effects (affects susceptible crops)				
Nitrogen (NO_3–N)[5]	mg/l	<5	5–30	>30
Bicarbonate (HCO_3) (overhead sprinkling only)	me/l	<1.5	1.5–8.5	>8.5
pH		Normal range 6.5–8.4		

[1] Adapted from University of California Committee of Consultants 1974.

[2] EC_w means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at 25°C (ds/m) or in units millimhos per centimetre (mmhos/cm). Both are equivalent. TDS means total dissolved solids, reported in milligrams per litre (mg/l).

[3] SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. As a given SAR, infiltration rate increases as water salinity increases. Evaluate the potential infiltration problem by SAR.

[4] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; use the values shown. Most annual crops are not sensitive; overhead sprinkler irrigation and low humidity (<30%), sodium and chloride may be absorbed through the leaves of sensitive crops.

[5] NO_3–N means nitrate nitrogen reported in terms of elemental nitrogen (NH_4–N and organ should be included when wastewater is being used).

TDS, total dissolved solids; SAR sodium adsorption ratio

TABLE 6_3

INFLUENCE OF WATER QUALITY ON THE POTENTIAL FOR CLOGGING PROBLEMS IN LOCALIZED (DRIP) IRRIGATION SYSTEMS

Potential Problem	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Physical				
Suspended solids	mg/L	<50	50 - 100	>100
Chemical				
pH		<7.0	7.0 - 8.0	>8.0
Dissolved solids	mg/L	<500	500 - 2000	>2000
Manganese	mg/L	<0.1	0.1 - 1.5	>1.5
Iron	mg/L	<0.1	0.1 - 1.5	>1.5
Hydrogen sulfide	mg/L	<0.5	0.5 - 2.0	>2.0
Biological				
Bacterial populations	maximum number/mL	<10 000	10 000-50 000	>50 000

BEST AVAILABLE COPY

TABLE 6.4

RELATIVE BORON TOLERANCE OF AGRICULTURAL CROPS[1,2]

Very Sensitive (<0.5 mg/l)

Lemon	*Citrus limon*
Blackberry	*Rubus spp.*

Sensitive (0.5 - 0.75 mg/l)

Avocado	*Persea americana*
Grapefruit	*Citrus X paradisi*
Orange	*Citrus sinensis*
Apricot	*Prunus armeniaca*
Peach	*Prunus persica*
Cherry	*Prunus cerus*
Plum	*Prunus domestica*
Persimmon	*Diospyros kaki*
Fig, kadota	*Ficus carica*
Grape	*Vitis vinifera*
Walnut	*Juglans regia*
Pecan	*Carya illinoiensis*
Cowpea	*Vigna unguiculata*
Onion	*Allium cepa*

Sensitive (0.75 - 1.0 mg/l)

Garlic	*Allium sativum*
Sweet potato	*Ipomoea batatas*
Wheat	*Triticum aestivum*
Barley	*Hordeum vulgare*
Sunflower	*Helianthus annuus*
Bean, mung	*Vigna radiata*
Sesame	*Sesamum indicum*
Lupine	*Lupinus hartwegii*
Strawberry	*Fragaria spp.*
Artichoke, Jerusalem	*Helianthus tuberosus*
Bean, kidney	*Phaseolus vulgaris*
Bean, lima	*Phaseolus lunatus*
Groundnut/Peanut	*Arachis hypogaea*

Moderately Sensitive (1.0 - 2.0 mg/l)

Pepper, red	*Capsicum annuum*
Pea	*Pisum sativa*
Carrot	*Daucus carota*
Radish	*Raphanus sativus*
Potato	*Solanum tuberosum*
Cucumber	*Cucumis sativus*

Moderately Tolerant (2.0 - 4.0 mg/l)

Lettuce	*Lactuca sativa*
Cabbage	*Brassica oleracea capitata*
Celery	*Apium graveolens*
Turnip	*Brassica rapa*
Bluegrass, Kentucky	*Poa pratensis*
Oats	*Avena sativa*
Maize	*Zea mays*
Artichoke	*Cynara scolymus*
Tobacco	*Nicotiana tabacum*
Mustard	*Brassica juncea*
Clover, sweet	*Melilotus indica*
Squash	*Cucurbita pepo*
Muskmelon	*Cucumis melo*

Tolerant (4.0 - 6.0 mg/l)

Sorghum	*Sorghum bicolor*
Tomato	*Lycopersicon lycopersicum*
Alfalfa	*Medicago sativa*
Vetch, purple	*Vicia benghalensis*
Parsley	*Petroselinum crispum*
Beet, red	*Beta vulgaris*
Sugarbeet	*Beta vulgaris*

Very Tolerant (6.0 - 15.0 mg/l)

Cotton	*Gossypium hirsutum*
Asparagus	*Asparagus officinalis*

[1] Data taken from Maas (1984).

[2] Maximum concentrations tolerated in soil-water without yield or vegetative growth reductions. Boron tolerances vary depending upon climate, soil conditions and crop varieties. Maximum concentrations in the irrigation water are approximately equal to these values or slightly less.

BEST AVAILABLE COPY

Boron The most critical element in the As-Samra WSP effluent is boron, whose concentration has been increasing rather dramatically in recent years, as shown on Figure 6-1[12]. Boron concentrations in 1986 were acceptable for **all** crops.

Boron in the effluent has increased more than five-fold since then. Boron levels in the effluent are now (October 1991) harmful to many crops. Table 6-4 lists the relative tolerance of various agricultural crops to specific ranges of concentrations of this element in soil and water. A comparison of this Table with Figure 6-1 dramatizes the fast rate at which the choice of tolerant plants is declining. The leveling-off in the last two years may be illusory, due to incomplete data for 1991. The Directorate of Soil and Land Reclamation reported a 1991 boron concentration of 1.6mg/l in May 1990 in the influent[13].

If the general trend shown in Figure 6-1 continues, the undiluted effluent will be harmful to the majority of crops now grown in

Jordan Valley in the very near future. Only the most tolerant crops, such as cotton, asparagus, sugarbeet, parsley, tomato, etc. will then be able to be cultivated using this effluent, even after dilution with other sources of water.

---

12. Sources: Royal Scientific Society, Report of the Quality of Effluent from the As-Samra Wastewater Treatment Plant and the Waters of Zarqa River, (from February 1989 to February 1990), April 1990. The 1990 average was estimated from calculation of partial monthly monitoring data. The 1991 projection was based on monthly data through August 1991 and the previous year's trend for the remainder of the year. Montly data for 1990 and 1991 were provided to the project team by WAJ.

13. Directorate of Soil and Land Reclamation, Hashemite Government of Jordan, Effect of Boron Levels in the As-Samra Treatment Plant Effluent on Agriculture in the Jordan Valley, May 1990.

In normal and wet years, dilution of the effluent will help reduce boron concentration by the time the reclaimed water reaches the farm. Nonetheless, it would be sound public policy to limit introduction of boron to the wastewater stream through removal of boron compounds from detergent formulations and limitation of industrial discharges containing boron compounds. Data obtained from the Zarqa pumping station[14] indicate that high concentrations of boron originate from Zarqa.

The Ministry of Commerce and Industry has initiated a ban on the use of boron compounds in detergent formulations. The ban is expected to manifest its effects over several years' time, if vigorously enforced. Fortunately, there are alternative harmless chemicals that can be substituted in detergent formulations at no extra cost to the manufacturer or the consumer. The importance of limiting boron in the wastewater stream cannot be over-emphasized, because of the economic importance of protecting the nations's food crops.

Chloride. Chloride levels in the effluent are relatively high and potentially harmful for woody species of plants. At these high levels, spray irrigation can also result in chloride damage to plant leaves. For most crops, however, the existing levels do not pose an immediate, serious problem, particularly if surface irrigation is employed. Discharges of brine by industries, water softening devices and other sources of chlorides should be controlled to reduce chloride levels in the effluent. A ban on the future sale and installation of self-regenerating (automatic) home water softeners may be necessary if such devices are being used. Centralized regeneration facilities for other water softeners, and commercial water softeners should be controlled to prevent discharge of brine to the wastewater system. Alternative disposal systems, such as evaporative lagoons, or transport to other basins should be employed.

---

14. Royal Scientific Soceity, Report of the Quality of Effluent from the As-Samra Wastewater Treatment Plant and the Waters of the Zarqa River, April 1990.

71

TABLE 6.5

RECOMMENDED MAXIMUM CONCENTRATIONS OF TRACE ELEMENTS IN IRRIGATON WATER[1]

Element	*Recommended maximum concentration*[2] *(mg/l)*	*Remarks*
Al (aluminium)	5.0	Can cause non-productivity in acid soils (pH<5.5), but more alkaline soils at pH>7.0 will precipitate the ion and eliminate any toxicity.
As (arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Be (beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd (cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co (cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr (chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu (copper)	0.20	Toxic to a number of plants at 0.1–1.0 mg/l in nutrient solutions.
F (fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe (iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li (lithium)	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Mn (manganese)	0.20	Toxic to a number of crops at a few tenths to a few mg/l, but usually only in acid soils.
Mo (molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni (nickel)	0.20	Toxic to a number of plants at 0.5–1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Pd (lead)	5.0	Can inhibit plant cell growth at very high concentrations.
Se (selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations.
Sn (tin) Ti (titanium) W (tungsten)	—	Effectively excluded by plants; specific tolerance unknown.
V (vanadium)	0.10	Toxic to many plants at relatively low concentrations.
Zn (zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH>6.0 and in fine textured or organic soils.

[1] Adapted from National Academy of Sciences (1972) and Pratt (1972).

[2] The maximum concentration is based on a water application rate which is consistent with good irrigation practices (10 000 m³/ha per year). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10 000 m³/ha per year. The values given are for water used on a continuous basis at one site.

BEST AVAILABLE COPY

Table 6.6

Heavy Metals In The Kheibat As-Samra Treatment Plant

Sampling Date: December 25, 1988

Parameter	Zarqa Influent	Plant Influent	Plant Effluent
Aluminum	0.12	0.04	0.01
Arsenic	0.0025	0.0002	0.0002
Cadmium	0.002	<0.002	<0.002
Cobalt	<0.01	<0.01	<0.01
Chromium	<0.005	<0.005	<0.005
Copper	0.005	0.005	0.015
Mercury	0.0001	0.0001	0.0001
Lead	<0.02	<0.02	<0.02
Zinc	0.078	0.023	0.023

Source: Royal Scientific Society, Report of Study of As-Samra Wastewater Treatment Plant (from 1/1/1986 to 31/12/1988), June 1989, Page 174.

BEST AVAILABLE COPY

Trace Elements. Recommended maximum concentrations of trace elements in irrigation water are given in Table 6-5. A comparision of these limits with data from the 1989 report of the Royal Scientific Society[15] indicates that concentrations of trace elements in the effluent pose no problems for irrigated agriculture. Many trace elements are necessary for plant growth as micronutrients, in very small concentrations. Many of the trace elements are at concentrations below levels of detection, as shown in Table 6-6. Industrial source control and appropriate treatment of the wastewater should maintain trace element concentrations below levels shown in Table 6-5.

Trace metals in King Talal Reservoir have come from a variety of sources in the Zarqa basin leading to the reservoir. No direct and statistically reliable sampling of the KTR sediments has been conducted.

Review of the geological character of the Zarqa basin draining to KTR, shows no significant natual sources of heavy metals. The major sources of significant trace (heavy) metals are the industrial sources within Amman and Zarqa and the general runoff carrying settlable particulates from non-point sources (e.g., organic leads in gasoline, tire catalysts and engine metals in oils and lubricant leakage). Because of seasonal rainfalls, the early flushing rains of each winter could carry heavy metals to KTR along with inorganic clays and silts which will be deposited within the sediment of the reservoir.

Heavy metals reaching the WSP system will be settled in large part in the sludge of the WSP. RSS data from 1987-90 indicated low levels of various significant metals in both the influent to the WSP and its effluent (no data is available on WSP sludge), as indicated below:

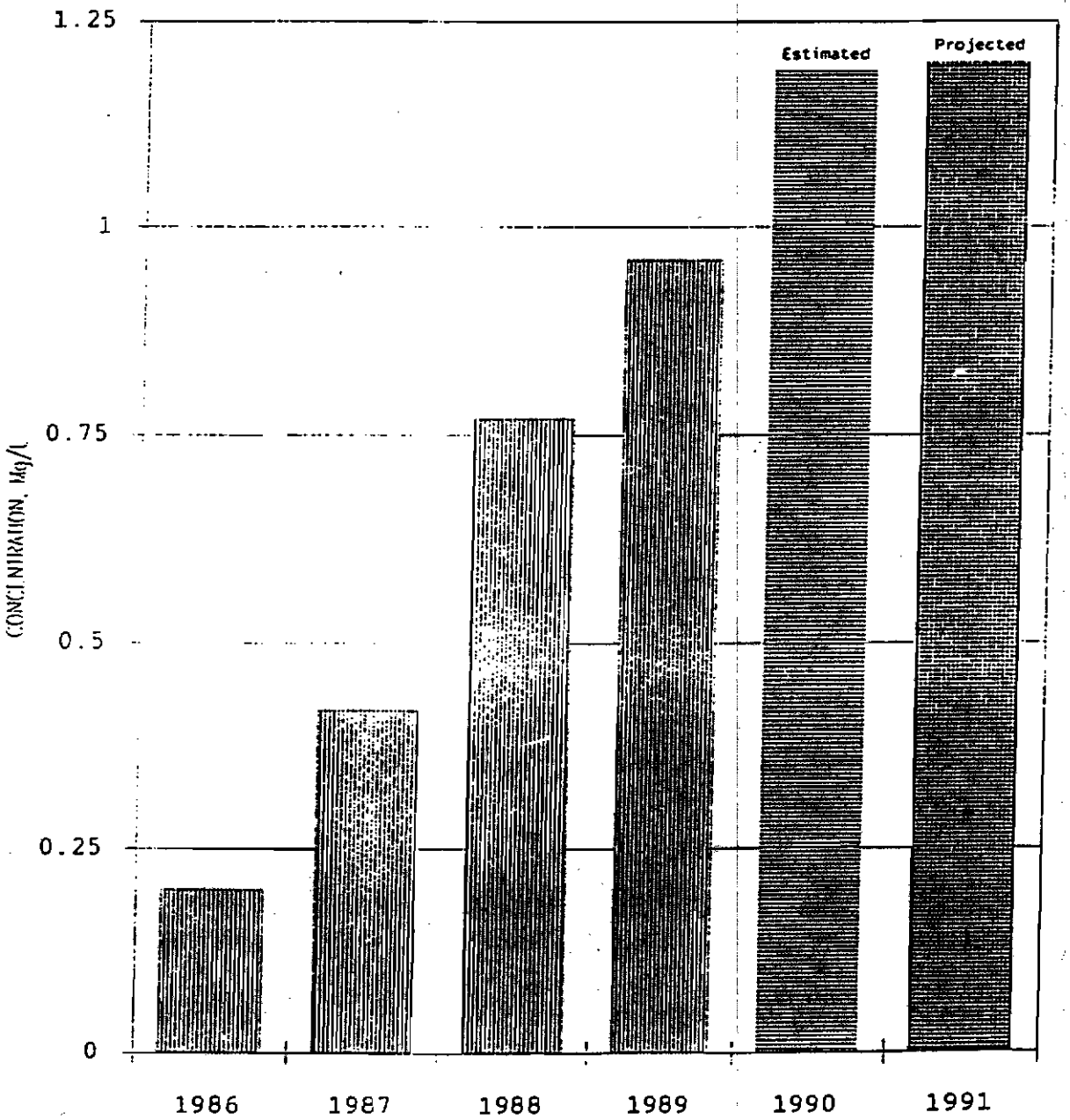
---

15. Royal Scientific Society, Report of Study of the As-Samra Wastewater Treatment Plant for Natural Purification and Its Effluent, (from 1/12/1986 to 29/11/1987), February 1988.

BEST AVAILABLE COPY

FIGURE 6_)

AVERAGE ANNUAL BORON CONCENTRATION IN AS-SAMRA WSP EFFLUENT



BEST AVAILABLE COPY

T5

Metal	WSP Influent* 1987	1988	1990	WSP Effluent* 1987	1988	1990
Cd	<2	<2	<5	<2	<2	<5
Cr	20	<5	<51	<10	<5	<10
Cu	50	5	<41	20	15	<10-30
Pb	60	<20	<21	40	<20	=/<20
Hg	.4	.1	<.5	.2	.1	<.5
As	2	.2	<13	.4	.2	<5
Zn	200	23	-	200	23	-

* All values in micrograms per litre (ug/l).

Point sources of metals for the WSP system generally are industries, and these generally discharge to the system through the Zarqa Pump Station. Levels of metals (and ABS) in the sewage from Zarqa Pump Station are generally higher (2-10 times) than those from AGTP.

6.4 FUTURE WATER REUSE OPPORTUNITIES

The remote location of the As-Samra Wastewater Stabilization Ponds limits future uses of reclaimed water to primarily agricultural irrigation. As Jordan becomes more industrialized, as Amman and Zarqa expands, and as available water supplies becomes even more limited, industrial and municipal water users will look increasingly toward reclaimed water to meet their demands. For nearly all municipal and industrial water uses, further treatment of the effluent (e.g., filtration, partial demineralization, TOC removal and disinfection) will be required, with substantial additional costs.
Urban uses may become possible if satellite treatment plants are built close to reuse locations. Such plants have the potential of relieving hydraulic and organic load on the

BEST AVAILABLE COPY

existing wastewater treatment plants and making reclaimed water available for local use. Successful use of reclaimed water on-site occurs in Cyprus[16],[17] where major tourist hotels treat their own wastewater and reuse it for landscape irrigation and toilet flushing[18].

Some uses of reclaimed water in or near Amman may include the following:

- Toilet flushing and air conditioning in industrial and institutional buildings;
- Industrial cooling, processing, boiler feed;
- Dust control, construction uses, concrete mix;
- Street and drain cleaning, sweeping, removal of residue;
- Fire fighting;
- Irrigation of parks, playgrounds, landscaping, nurseries;
- Irrigation of golf courses, highway and airport landscaping;
- Recreational lakes, decorative fountains, reflection pools;
- Plant nurseries, fish hatcheries, agriculture;
- Groundwater recharge, surface spreading or direct injection, indirect irrigation and potable off-peak storage and reuse.

By the time such additional uses gain acceptance in Jordan, worldwide experience will have developed the most economical approaches to treatment, conveyance and distribution of the

---

16. Stylianou, Y., Findings of Cyprus Experience in the Field of Waste Water Reuse, FAO Regional Seminar on the Treatment and Use of Sewage Effluent for Irrigation, Amman, Jordan, September 1988.

17. Papadopoulos, I., Quality Appraisal of Treated Effluent for Irrigation, FAO Regional Seminar on the Treatment and Use of Sewage Effluent for Irrigation, Amman, Jordan, September 1988.

18. Tebaii, Larbi, Personal Communication, September 25, 1991, Playa d'Aro, Spain.

77

reclaimed water. The cumulative impact of such successful water reclamation may persuade the responsible public health authorities world wide to relax some regulations. The following trends are expected to result in relaxation of some water reclamation regulations at the local, regional, national and international levels, particularly for the less direct human uses:

- Increasing populations exerting pressure on limited water sources;
- Increasing costs of developing the next incremental source(s) of water;
- Global weather pattern changes likely to lead to warming, desertification, and reduced water supply;
- Improvements and efficiencies in wastewater treatment technologies leading to reduced costs of water reclamation processes while at the same time improving pollutant control.

World Health Organization guidelines for water reuse are under review and are expected to be modified somewhat to encourage greater local variations. However, they will probably remain essentially unchanged in terms of coliform and nematode numerical numerical guidelines. The Jordanian Environmental Health Standards will require periodic revisions to reflect future needs of the country and its ability to provide more advanced treatment. Agricultural water quality requirements are expected to remain unchanged as far as soil and plant sensitivities to various parameters are concerned.

6.5 RECOMMENDATIONS FOR WATER REUSE

The following are tentative recommendations pending further evaluation and discussion:

1. Effluent from the As-Samra Stabilization Ponds be reused as close to the point of discharge as possible;
2. GOJ and WAJ aggressively enforce its ban on boron (and phosphates) in detergent formulations;
3. GOJ and WAJ control or eliminate industrial discharges of boron from Zarqa, brines, water softener fluids, and trace pollutants;

BEST AVAILABLE COPY

4. The Jordan Valley Authority, the Ministry of Agriculture and the Miniutry of Water and Irrigation agree on a policy regarding expanded local agricultural irrigation in Wadi Dhuleil and Zarqa, to reduce pollutant input to KTR;

5. GOJ/WAJ enforce crop irrigation restrictions imposed in the Martial Act of 1989 and provide educational programs for local farmers to protect the public health, to prevent over-fertilization, and reduce groundwater degradation;

6. Control sale, installation and regeneration of water softeners in Amman and Zarqa, review water softener discharges and controls, and enact and enforce polices.

BEST AVAILABLE COPY

SECTION 7

ENVIRONMENTAL REVIEW OF THE

WASTEWATER STABILIZATION POND SYSTEM AT AS-SAMRA

7.1 INTRODUCTION AND SUMMARY

7.1.1 Format and Content

As required by the Scope of Consulting Services, Section 3.1.2. (f), the following environmental review identifies environmental effects resulting from the major existing As-Samra system facilities and their direct products including: 1) a 38.6Km sewer/siphon system from AGTP through Zarqa to As-Samra, 2) the existing stabilization ponds at As-Samra, and 3) the pond effluent as it passes through Wadi Dhuleil, Seil Zarqa, and into King Talal Reservoir.

The emphasis of this section will be on the performance of the existing system including the effects of discharged effluent and the disposal of sludge removed from the WSP. In this review, no mitigation or compensation measures are proposed for any adverse effects . Also, since no alternatives are available for discussion at this time, the review does not compare the existing effects with those from alternatives. Such measures and comparisions will form a vital part of the evaluation of proposed projects which will be included during the remainder of the stage I development.

References to other sections of the Survey of Existing As-Samra Wastewater Stabilization Pond System are made in the review and this review should be considered as a part of the Survey.

7.1.2 System/Facilities Description

The existing Wastewater Stabilization Pond System at As-Samra includes a conveyance-treatment-discharge system which has operated since 1985. The conveyance facilities (a 1200 mm diameter sewer/siphon) has operated successfully with flows of up to 170,000 cu m/d. The Zarqa Pumping

BEST AVAILABLE COPY

Station pumps into the siphon and is presently being upgraded. The As-Samra Stabilization Ponds are described in other sections of the Survey Report.

Overloaded operating conditions (both flow and BOD_5 loading) reduce dissolved oxygen and increase ammonia and nitrates in the effluent. Other potentially detrimental chemical constituents (e.g., dissolved solids, boron, phosphorus, etc.) in the influent sewage are not affected significantly, or may be increased by up to 10 percent, through the treatment process because of evaporation. Most inorganic compounds cannot be efficiently removed or decreased by the waste stabilization pond treatment process.

7.2 KEY ENVIRONMENTAL ISSUES

7.2.1 Project Region

The Project-affected environment encompasses a very large triangular region from Amman northeasterly to Khirbet As-Samra, westerly to King Talal Reservoir and the Jordan Valley, and southeasterly to Amman. The Jordan Valley irrigation water supply comes largely from wastewater produced by most of Amman and Zarqa which flows by sewer/siphon to the ponds at As-Samra. Treatment Pond effluent then flows back to the Jordan Valley via Wadi Dhuleil, Seil Zarqa, King Talal Reservoir and related irrigation works. The WSP system therefore indirectly affects the irrigation supply of the Jordan Valley.

7.2.2 Environmental Resources Affected

The As-Samra System WSP has the potential to affect several significant environmental resources of the Project Region:

- Groundwater tables and aquifers.
- Surface runoff.
- King Talal Reservoir.
- Public Health

BEST AVAILABLE COPY

- Air quality in the Hashimiyeh and Zarqa area.
- Cultivated lands around ponds, along wadis, and in the Jordan Valley.
- Riparian habitats along Wadi Dhuleil and Seil Zarqa.

7.2.3 Other Environmentally Important Facilities

Within the WSP System Project Area, there are several other sources of air and wastewater discharges, which also affect the environment and may interact with emissions from the WSP system. Major and most direct non-Project effects arise in the Zarqa urban area which extracts large amounts of groundwater and which has numerous sources of untreated or minimally treated wastewater disposal either to the Wadi Zarqa, Wadi Sa'id, or to other wadis and their underlying aquifers. The Jordanian Petroleum Company's refinery in Zarqa uses 5000 cu m/d of water from the local water table and discharges treated wastewater. The refinery is an air pollutant source which can reach ground levels in the surrounding ridges (including Hashimiyeh and Zarqa). The Al Hussein Power Station at Zarqa (oil - fueled gas turbines, 4000 MW) also uses large supplies of water from local sources, generates high dissolved solids and discharges treated wastewater. It also releases large amounts of sulfur dioxide in air emissions. Industry and numerous military bases in the area also use local groundwater sources, provide only basic wastewater treatment, and discharge to Wadi Said/Sayeh.

Numerous villages along Wadi Dhuleil, Wadi Zarqa, and Seil Zarqa exist and appear to be expanding as new roads (e.g., Zarqa-Jerash road) provide improved access. These villages generate wastewater and agricultural runoff which enter local wadis and eventually into the groundwater basins, including Wadi Dhuleil and Wadi Said/Sayeh.

The area also contains numerous industrial manufacturers including soap manufacturers in Ruseifa and canning operations in Zarqa, Most of whom have little, if any, wastewater treatment.

BEST AVAILABLE COPY

7.2.4 Overview of Environmental Issues and Concerns for As-Samra WSP System

Several major environmental issues and concerns have arisen regarding the WSP system and particularly effects resulting from the present over-loaded condition of the stabilization ponds. These are briefly listed:

- Emission of hydrogen sulfide and other odorous gases.
- Eutrophication of streams and reservoirs.
- Evaporation of a water resource.
- Groundwater quality decline through effluent seepage.
- Public health through irrigation of agriculture with treated effluent and proliferation of insect vectors.
- Biotic habitat improvements.

7.3 SECTOR REVIEWS

The following sector review discusses the above overview concerns and issues and briefly describes the reported and probable significant adverse effects because of the WSP system from Ain Ghazal through the As-Samra Ponds, and thence to King Talal Reservoir. Odors and surface water quality impacts have been identified as significant adverse impacts both locally within the Project Area and within the larger Project Region. These effects arise at least in part from overloading of the waste stabilization ponds.

7.3.1 Air Quality

Odors are currently generated by the release of hydrogen sulfide and other odorous gases at the As-Samra headworks, at the anaerobic ponds, and at the cascading interconnections between ponds. Hydrogen sulfide release from the headworks where the sewer/siphon discharges occur is because of the long detention time in the sewer/siphon, non-use of previously planned aeration at AGTP, and and turbulent flow conditions at the headworks.

BEST AVAILABLE COPY

Odors from the interconnection structures between ponds are a result of turbulent water conditions. The anaerobic ponds discharge odors from normal biological activity.

Odors appear to peak during early morning hours or near-calm conditions and generally reflect the release of hydrogen sulfide at the headworks, the release of hydrogen sulfide and other gases from the overloaded anaerobic and facultative ponds, and the odors from decaying algae and other odorous materials in the wadi channels and along the pond edges. These odors generally occur within five kilometers of the stabilization ponds.

The high plateau location of the As-Samra treatment ponds allows down slope gentle winds to carry these emissions to downwind residential areas. The plateau location also allows for dispersion over a large area when lower elevation stratification occurs. Valley locations may also be subject to such winds or cool night/ morning stagnation at the Ain Ghazal headworks, the Zarqa Pumping Station and the Hashimiyeh pumping station, although to a lesser degree.

Wind directions and dispersion are not adaquately documented to demonstrate the relationships between odorous gases from the ponds and from other facilities, for example from stack and fugitive emissions from the refinery, or from stack emissions of the Power Station.

Exposure of anaerobic sludge during desludging operations will form a significant source of air pollutants. Air drying will generate odors released from the surface, while mechanical pumping of sludge and mechanical agitation during loading will again release hydrogen sulfide and other gases.

7.3.2 Surface Water Resources

The ponds produce an effluent with relatively high BOD and suspended solids. The BOD is greater than 100 mg/1. These high levels of BOD and suspended solids are due more to organics and solids rather than algae which naturally occur in properly operating ponds. Ammonia levels are greater than

BEST AVAILABLE COPY

50 mg/1. Effluent water quality is unsuitable for fisheries but is suitable for irrigation of many crops. Some effluent is used directly for local irrigation along Wadi As-Samra, Wadi Dhuleil, and Wadi Zarqa. The effluent from As-Samra WSP contributes about 20 percent of the annual runoff during a normal runoff year into KTR. Recently, because of drought conditions, the flow from the WSP system has reached 85 percent of the total annual runoff. Flows into the KTR are first used for power generation and then for irrigation in the Jordan Valley.

Before the WSP system was constructed, stream flows (and some local village drainage) were close to untreated sewage. Base flows were estimated at 0.6 cu m/sec, both at Ain Ghazal-Wadi Zarqa and at Jerash Bridge-Seil Zaraq. With treatment at As-Samra and Jerash, improved water quality and increased flow has encouraged greater recreational use of accessible banks of the Seil Zarqa.

Effluent discharges represent the only year-round source of irrigation water along Seil Zaraq, especially during the recent dry years, and these support significan riparian vegetation and crops .

The existing treatment ponds, open channel flow, channel infiltration, and natural riparian vegetation, allow for evapotranspiration of up to 20 percent of the total flows. King Talal Reservoir itself loses 20,000 cu m/d to evaporation. Total evaporative and riparian transpiration losses between Ain Ghazal and the Jordan Valley are significant.

In the arid to semi-arid environment, water forms a vital and development-limiting resource both by its availability and in its quality. Existing effluent, forms a very large portion of the annual flow to the King Talal Reservoir and provides more than 100,000 cu m/d of water suitable for riparian biota and agricultural irrigation. Effluent phosphates, nitrates, and ammonia also provide important resources which if removed from the wastewater would require increased use of fertilizers. Irrigation of land close to the pond system, rather than downstream of KTR would both conserve water and make better use of the fertilizing content of the effluent. It would also reduce the total addition of salts to the Jordan

BEST AVAILABLE COPY

Valley. Local drainage systems would have to be improved however and groundwater resources properly managed.

7.3.3 Groundwater Water Resources

Locally, groundwater is affected directly from both a minor amount of pond seepage and by channel recharge of effluent along Wadi Dhuleil/Seil Zarqa and indirectly from downstream uses of effluent for irrigation. Some groundwater effects also arise from other nearby local uses of effluent and discharges of wastewaters.

The most significant groundwater quality changes occur from the direct discharge of effluent to Wadi Dhuleil and eventually to Seil Zarqa. Review of the available and reported information and assessment of groundwater conditions in the area indicate the following general water quality relationships:

- Recharge of groundwater basins by rainfall and runoff will be reduced by the ever increasing demand for water.
- Increasing groundwater uses accelerate infiltration rates for perennial wastewater sources (including As-Samra pond seepage), reduces the dilution effect of rainfall, and thereby increases the pollution of the groundwater basins.
- Greater domestic and industrial wastewater discharges and irrigation drainage generates lower quality surface water for recharge.
- Leachate water from irrigation will recharge the depleted groundwater table with increasingly degraded water quality.
- Depleted groundwater basins in Zarqa are recharged with wastewater discharge which flows underground or rises to the surface to replenish downstream water tables, further degrading these basins.

BEST AVAILABLE COPY

- Recharge of depleted groundwater basins with wastewater will result in increased levels of dissolved solids, nitrogen, phosporus, and ammonia remaining in the basins.

Without the wastewater ponds and effluent discharge, significantly less (virtually no) irrigation and groundwater recharge would occur along Wadi As-Samra and most of lower Wadi Dhuleil (below As-Samra). Furthermore, some degradation of the shallow groundwater table would still occur because of other discharges in the local area.

7.3.4 Biotic Resources

Effluent from the ponds supports an extensive upland habitat around the ponds and riparian habitats along Wadi Dhuleil, Seil Zarqa and around the King Talal Reservoir.

Effluent nutrients have been suspected to encourage eutrophication in the reservoir, which inhibits aquatic biota. However, The reservoir was reported as eutrophic during its earliest operations and would be eutrophic with or without the As-Samra efflent. This assessment is based upon several reports (Thames, 1988) and our own evaluations.

Vegetation and avian wildlife surrounding the existing stabilization ponds are of high value in the relatively barren desert habitat. Natural desert and steppe vegetation is affected by the present cultivation of effluent-irrigated olive groves. Irrigation and olive trees increase the wildlife habitat diversity compared to the overgrazed areas outside the protective fence line. Treatment ponds and the surrounding orchards support a community of reptiles, birds, and small mammals and their related food-species of plants, insects, and other invertebrates. Even the effluent-maintained stream below the ponds supports riparian and upland vegetation (watered indirectly from irrigation runoff) along the wadis and Seil Zarqa.

Aquatic biota within the Wadi Zarqa and Wadi Dhuleil, Seil Zarqa, and KTR are not large in numbers or diversity and are not expected to

BEST AVAILABLE COPY

include any unique species. Before the effluent discharge from As-Samra, the biota were reported to be characteristic of sewage polluted streams.

The KTR is a long, narrow, winding and deep reservoir and has very limited natural mixing and aeration; This enhances the potential for eutrophication. The upstream basin receives drainage and sewage from several different villages, Baqa, Jerash, and As-Samra. Development in the basins will intensify irrigation and other non-point discharges which will increasingly release nutrients to the downstream channels and the KTR. Fertilizer usage in the basins, treated effluent from other urban centers, and treated effluent from the As-Samra ponds will yield suficient nutrients to encourage eutrophication in the KTR during even normal rain years.

7.3.5 Cultural Resources

Many prehistoric and historic antiquities are known within the Project area and along wadi floodplains and terraces. Numerous historic ruins are recorded on topographic maps, and surveys have identified many historic and prehistoric remains, sites, structures, and villages. The Ain Ghazal (less than 500 meters west of the existing treatment plant site) and Khirbet As-Samra sites represent important locations requiring complete protection. The many significant archaeological resources reflect the important regional transportation corridor of Wadi Zarqa-Wadi Dhuleil-Wadi Sayeh/Sa'ida-Seil Zarqa which form the natural physiographic corridor for travel between the Jordan Valley and the eastern deserts.

7.3.6 Public Health

Effluent water quality is unsuitable (due to high BOD, ammonia, phosphates, etc) for most urban or industrial water supply needs but is suitable for irrigation of many feed, grain, and cooked vegetable crops. Fecal coliform levels in the effluent are within acceptable limits (after chlorination); parasite larvae and egg levels are reported as undetected. Although existing regulations restrict some beneficial uses of the effluent in the wadi channels above the King Talal Reservoir (KTR), pumped or well-fed irrigation systems using effluent occur along the entire

length of Wadi Dhuleil and Seil Zarqa. Water-related recreation exists wherever access, vegetation, and land are suitable. No adverse public health effects have been reported with regard to current recreational or irrigation uses of the treated effluent.

Bacteriological quality of effluent along Wadi Dhuleil generally meets discharge requirements when chlorinated, and reported increases in fecal coliform downstream of the ponds are most probably due to local discharge of untreated wastewater, cesspool effluent or seepage, and runoff from various livestock sources along the wadis.

Effluent recharges the alluvial groundwater table along Wadi Dhuleil and Seil Zarqa and has probably participated in degrading local well water supplies and increased the potential for adverse health effects. However, a piped potable water supply is available in the area. Effluent irrigation has increased crop yields for the area, generated higher cash returns, and has probably raised the standards of living for many farmers. These improvements may compensate for poorer quality or loss of local water supplies for potable purposes.

Increasing salts (above 1,500 mg/l), nitrogen, BOD, and even fecal coliform bacteria can be attributed to increasing surface applications of the effluent without sufficient leaching controls, to livestock, and to local wastewater production. Local degradation of water supplies and associated public health concerns are only indirectly realted to the WSP effluent and its quality.

Snails suitable for vectors/intermediate hosts for schistosomiasis are reported in KTR and along Seil Zarqa. Public health departments and other agencies have conducted health monitoring, inspection, and educational programs in order to prevent development of any infestations. If infestations did occur, related diseases could potentially have significant adverse effects on public health. The performance of stabilization ponds is sufficient to remove parasitic eggs and larvae from the effluent, and thus the effluent would not contribute directly to risks. However, the effluent does support the riparian and stream vegetation which shelter snails and other

BEST AVAILABLE COPY

intermediate hosts/vectors; thus the effluent and the biotic benefits indirectly contribute to potential health risks.

Increased vegetation and open water surfaces in the As-Samra ponds area and along Wadi Dhuleil and Seil Zarqa provide habitats for insects, including mosquitoes and flies. Infectious disease associations of these vectors increases the risk of vector-borne disease in areas along Wadi Dhuleil and Seil Zarqa.

The overflow of raw sewage at Ain Ghazal Treatment Plant during wet weather conditions creates adverse environmental impact along Wadi Zarqa and Seil Zarqa, particularly for communities who are now accustomed to "safe" conditions at most times.

7.3.7 Land Uses and Resources

Land uses within and adjacent to the Project area vary from residential and commercial uses, to irrigated agriculture, deserts and reforested desert lands. The Ain Ghazal Treatment Plant has been abandoned but the site and capital improvements have been retained in a mixed urban area of residential and industrial uses. The sewer/siphon passes through low density rural and cultivated areas.

The stabilization ponds are located in a desert area and have minimal adverse effect on other beneficial land uses. With protection from over-grazing, vegetation at the WSP site has improved while the effluent provides for increased irrigation above the KTR and in the Jordan Valley.

Odors and groundwater effects are considered by local residents as having reduced the value of land in the vicinity of the ponds and lower Wadi Dhuleil. However, the availability of effluent for irrigation has increased crop yields and the value of cultivated lands in the area. The fertilizer value of ammonia and nitrates in the effluent reduces the need for fertilizers and thus the cost of raising crops.

BEST AVAILABLE COPY

No sludge has been removed from the As-Samra Stabilization Ponds and therefore no sludge disposal has occurred. Required desludging of the anaerobic ponds and disposal of such sludge will possibly have significant environmental effects.

7.3.8 Resource Conservation

Resource (e.g., water and nutrients) and energy losses arise in different degrees during operation of all wastewater treatment systems. In Jordan, water is one of the most important resources. The As-Samra ponds lose significant amounts of water by evaporation during the summer and minimal amounts through seepage.

The downstream Wadi Dhuleil-Seil Zarq flows and storage in the King Talal Reservoir, may lose more water to evaporation, riparian transpiration, and percolation than do the ponds themselves .

Nutrients in the treated effluent represent important resources. Large amounts of nitrate fertilizer are imported to Jordan and applied on irrigated crops. The WSP effluent is rich in these nutrients and generally can be expected to produce crops equivalvent to those cultivated using artifical, imported fertilizers.

Some resource recycling or conservation occurs by local farmers irrigating with effluent.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 GENERAL

This section summarizes the conclusions and recommendations resulting from the studies carried out in preparing the final Comprehensive Survey Report for the Upgrading and Expansion of Wastewater Stabilization Pond System at As-Samra.

8.2 AIN GHAZAL HEADWORKS AND SEWER/SIPHON SYSTEM

The existing headworks facilities at Ain Ghazal are currently accommodating hydraulic loads greater than their design capacity, in terms of both dry-weather and wet-weather flows.

Many mechanical, electric, and instrument-control equipment at the headworks are in need of maintenance, repair, and replacement.

The septage facilities are adequate to accommodate present and future flows to 5,000 cu m/d.

The odor facilities are not operating as designed and new or upgraded equipment should be provided with the expansion. A safety hazard (High H_2S levels) at the septage degritting structure prevents adequate maintenance and operation. This must be corrected immediately by repairing or replacing exhaust fans to meet the air changes required and if the odor control system is working , supply the chemicals in the amount required to eliminate odors.

Trash and solids are delivered to the sewer/siphon pipeline instead of being removed because of the higher than design flow rates and inoperative equipment. This should be corrected immediately by closing the sluice gates to the aerated grit tanks to approximate the design flow (68,000 cu m/d) while bypassing the remaining flow. The existing equipment must be repaired or replaced to allow operation as originally designed. Placing the grit facilities into operation will also allow the scum removal pipe to function as designed. Manual screens with smaller openings should also be installed downstream of the existing mechanical screens to remove additional trash and solids and replace the intended function of the comminutor. These items (placing grit system in operation and installing

92

smaller screens) will reduce the solids loading on the sewer/siphon and the WSP and will also reduce scouring effects within the pipeline.

An expansion of the headwork will be required to serve the projected year 2005 flows. As part of the long-term scheme, the existing facilities should be upgraded by installation of more suitable screens, grit removal facilities and modifications to the odor control facilities.

The sewer/siphon has operated satisfactorily since commissioning. Urgent maintenance attention to the cathodic protection system and replacement of anodes, if required, is essential. Maintenance personnel must also remain vigilant in inspecting the pipeline alignment for potential problems such as wadi bank erosion and any problems corrected promptly.

The blow-offs along the pipeline should be opened briefly to determine if the pipeline is filling with solids. If the pipeline is not filled with solids beyond a minor amount at the low-point, the swab should be sent through the line to remove slime and the minor amounts of solids. If the pipeline is restricted at the low point, the expansion should contain provisions for cleaning the pipeline after a new parallel pipeline (required to deliver future flows to the WSP) has been installed and placed into operation.

Once the parallel pipeline has been installed, the calcareous lining should be inspected by television and repairs made, if required. This work can be included in the work for the expansion.

One improvement which should be corrected immediately is the installation of a chained and locked gate at the entrance to the siphon to prevent anyone from entering and falling into the open diversion structure.

An operations plan should also be prepared and the operations personnel trained to respond to major emergencies that might occur at the headworks or to the pipeline. These include flooding, fire,breaks, toxic releases,valves sticking in the open or closed position, and the cleaning device being stuck in the sewer/siphon. Natural disasters or negligence by third

BEST AVAILABLE COPY

parties might occur which could cause these emergencies. The plan should also include responses to emergencies at the pump stations and the WSP.

8.3 PUMP STATIONS

The Zarqa (once expanded) and Hashimiyeh Pump Stations are in satisfactory operating condition and require only routine maintenance and repair/replacement activities to be carried out. The instrumentation equipment at Hashimiyeh should be repaired or replaced to allow automatic pump operation.

An expansion of the Zarqa Pump Station will be required to accommodate the year 2005 flows.

8.4 WASTEWATER STABILIZATION PONDS

The existing wastewater stabilization ponds (WSP) are severely overloaded and became so shortly after commissioning. Contributory to the overloading were the decisions taken during construction to (1) abandon all use of the AGTP and (2) convey all wastewater from Zarqa and Hashimiyeh for treatment at the WSP. The design criteria adopted for the WSP included the assumption that a number of facultative ponds operated in series would act in a mode similar to that of a single large facultative pond, disregarding the high organic loading on the first ponds of each series.

The WSP operators have some flexibility available in operation of the facultative ponds. They may (1) operate the facultative ponds in either three parallel trains with four (or five) ponds in series or as six parallel trains with two (or three) ponds in series, and (2) recirculate effluent from the maturation ponds to the inlet distributor of the first facultative ponds.

Because of the severe hydraulic and organic overloading, it is impossible to make minor improvements or operational changes which would allow the pond processes to approach typical modes of operation for this type of facility or improve effluent quality or to significantly affect performance.

However, operation of the facultative ponds in six parallel trains does not require substantial investment and is recommended. The latter may be done at no cost and will reduce organic loadings on the initial facultative ponds (F1-1, F2-1, and F3-1). Any improvement in effluent quality will be minimal,

BEST AVAILABLE COPY

however. Operation of the recirculation facilities is costly and would be of little benefit under present conditions.

The anaerobic ponds must be desludged periodically. Although these ponds are performing better than their original design assumptions, the O & M manual criteria for desludging (on the basis of sludge accumulation depths) has been exceeded. Sludge removal will increase the retention time in the WSP system, avoid transfer of sludge to downstream ponds during peak wet-weather flows, and should thus enhance performance. In order to avoid the adverse effects of removing one pond from service, it is recommended that additional anaerobic ponds (similar to A1) be constructed as a short-term upgrading measure for use during the desludging operation. These ponds can be into the expansion. Scum blankets on the anaerobic ponds should also be removed during desludging. A sludge dredge with the necessary appurtenances should be acquired to pump sludge from the anaerobic ponds. It may be possible to use the existing sludge facilities at AGTP to thicken and dry the sludge prior to disposal.

Odors from the WSP have led to complaints from nearby communities. Surveys have established that much of the odor is generated at the WSP headworks structure. It is recommended that the existing inlet be covered or sealed and vented through an odor scrubbing system as part of the immediate upgrading measures and expanded and improved during the later expansion program.

Additional inlets and outlets to reduce short circuiting should be installed during the expansion.

Additional chlorination capacity should also be provided immediately to meet the present disinfection requirements. The equipment can be incorporated into the next expansion.

One immediate improvement which would improve the effluent quality substantially is the addition of oxygen into the treatment process. Floating aerators located in the second anaerobic pond could be installed using diesel engine generators for the power requirements. However, prior to making such a large

BEST AVAILABLE COPY

if this is true, why is the option of providing more ponds 4 X as costly?

investment in capital equipment, the recommended alternative treatment system to accommodate 2005 flows needs to be evaluated in the conceptual report.

8.5 IDLED AIN GHAZAL TREATMENT PLANT

It would be technically feasible to reactivate AGTP as an activated sludge treatment facility or to modify it to serve as a primary treatment facility. In either case, the effluent quality would be unsuitable for discharge to Wadi Zarqa and the treated effluent would be returned to the sewer/siphon for further treatment at the WSP.

The potential benefits from reactivating AGTP does not justify the capital costs involved and the subsequent high O & M costs.

The AGTP facilities can be used for stormwater retention prior to return to the sewer/siphon. This would avoid these high flows which disrupt the normal treatment process at WSP.

The existing sludge facilities at AGTP, including thickeners, digesters, belt presses and accessories, should be evaluated to determine if it would be economical to use them during desludging of the anaerobic ponds, for treatment of septage, for further treatment of sludges from other treatment plants of a combination of these sludge operations.

8.6 WASTEWATER EFFLUENT REUSE

Water reclamation and reuse for agricultural irrigation is considered an important supplement to Jordan's other water resources. Most of the treated effluent from the WSP is used for irrigation in the Jordan Valley, after storage in KTR. Effluent from the WSP is currently suitable for irrigation of most crops, although marginally so for a few crops which are sensitive to boron, total dissolved solids (TDS), and chlorides. If used within the existing regulatory requirements and with proper irrigation management, the effluent should not harm the public health, crops, or soils. The effluent meets most of the irrigation water quality advisory guidelines issued by the World Health Organization. Those parameters which might be considered problems include: TDS (which can be alleviated by proper irrigation management), nutrients (which reduces the need for fertilizer applications), boron (which must be reduced by control of detergent

BEST AVAILABLE COPY

96

formulations and industrial discharges), and chlorides (which can only be reduced by controlling industrial discharges).

There should be no major concern with continued use of treated effluent from the WSP for agricultural irrigation, provided adequate disinfection of the treated effluent is continued. It is recommended that:

- The ban on boron and resistant phosphates in detergent formulations be aggressively enforced.
- Industrial discharges of boron from Zarqa, brines, and trace elements be controlled.
- Crop irrigation restrictions placed by existing legislation be enforced, and
- Educational programs for farmers related to public health protection and irrigation management be provided.

8.7 ENVIRONMENTAL REVIEW

The existing overloaded condition at the WSP has the potential to affect several environmental resources in the region. These concerns include the impacts upon:

- groundwater tables and aquifers
- surface waters
- King Talal Reservoir
- air quality in the Hashimiyeh and Zarqa areas
- loss of water resources to evaporation
- public health

Comparisons of influent and effluent flows at the WSP and evaporation rates indicate that limited seepage from the ponds does takes place. There is also assumed to be some loss of effluent water into the underlying alluvial and bedrock along the channels of Wadi Dhuleil and Seil Zarqa.

Before construction of the WSP, dry-weather stream flow in the Seil Zarqa was comprised exclusively of treated effluent from the AGTP and Jerash and of untreated wastewater from other sources. The quality of effluent from the WSP is an improvement on previous surface water quality.

BEST AVAILABLE COPY

Treated effluent from the WSP is a large part of the annual inflow to KTR, ranging from 20 percent during normal years to over 80 percent during dry years. In addition, KTR receives a number of discharges of industrial wastewaters from the Zarqa basin and surface water runoff from the phosphate mining areas within its catchment, which has a major impact on the water quality at KTR.

Odors arising from the WSP are a presistant source of complaints from nearby communities, some more than 5.0 km from the WSP. Surveys have indicated that most odor is released from the WSP headworks. Early action should be taken to enclose the headworks and exhaust the gases through a scrubbing system.

The large surface area of the WSP inevitably leads to evaporation. It is estimated that 10,000 - 15,000 cu m/d (average through the year) of water is lost to evaporation. Evaporative losses at the WSP can only be lessened by reducing the evporative surface area of the treatment facility and using treatment processes which are more costly to operate.

No adverse public health effects with regard to irrigation use of the effluent from WSP has been reported, and none would be expected. The Jordanian Ministry of Health monitors water quality and conducts epidemioloigcal surveys in the area. Effluent from the WSP is chlorinated and its quality is monitored and controlled. There are likely to be greater health risks associated with uncontrolled local discharges of untreated waterwater, cesspool effluent or seepage, and runoff from livestock areas. To ensure that polluted groundwater is not used for domestic service, piped water supplies should be available to all dwellings.

BEST AVAILABLE COPY

98

APPENDIX A

EFFLUENT MONITORING PROGRAM FOR WSP AT AS-SAMRA BY THE ROYAL SCIENTIFIC SOCIETY

PARAMETER			MONITORING FREQUENCY	SAMPLE TYPE
Flow		cu m/d	* Continuous	Meter
Total Solids	TS	mg/l	* 2/month	Grab
Total Volatile Solids	TV	mg/l	* 2/month	Grab
Total Filterable Solids	TFS	mg/l	* 2/month	Grab
Total Suspended Solids	TSS	mg/l	* 2/month	Grab
Total Volatile Suspended Solids	TVSS	mg/l	* 2/month	Grab
Total Filterable Suspended Solids	TFSS	mg/l	* 2/month	Grab
Chemical Oxygen Demand	COD	mg/l	* 2/month	Grab
Total Biological Oxygen Demand	BOD5	mg/l	* 2/month	Grab
Biological Oxygen Demand-Filtered	BOFD	mg/l	2/month	Grab
Sulfate	SO4	mg/l	2/month	Grab
Ammonia, Nitrogen	NH4-N	mg/l	2/month	Grab
Nitrate, Nitrogen	NO3-N	mg/l	2/month	Grab
Total Coliform Count	TCC	100 ml	2/month	Grab
Total Fecal Coliform Count	TFCC	100 ml	2/month	Grab

* Sample analyses are undertaken at both the WAJ Control Laboratory and the WSP Laboratory. All Samples for WSP Laboratory analyses are composite samples. All other samples are as indicated.

Additional analysis are provided on a once per month basis by the RSS and WAJ Central Laboratories. They include the following:

Total Dissolved Solids	TDS	Electrical Conductivity	EC
Sodium Adsorption Ratio	SAR	Boron	B
Alkalinity	ALK	Bicarbonate	HCO3
Total Nitrogen	T-N	Fats, Oils, and Grease	FOG
Total Phosphorus	T-P	Phosphate	PO4
Hydrogen Sulfide	H2S	Chlorine Residual	CL2
Methylene Blue Active Substance	MBAS	Alkylbenzene Sulfurnate	ABS

Parasites NEMATODES (eggs)
ASCARIS
HOOK WORMS
TRICHURIS

Algae Identification ALGAL I.D.

Analyses of heavy metals are reported monthly.

BEST AVAILABLE COPY

APPENDIX B

RECOMMENDED ADDITIONAL SPARE PARTS FOR CHLORINATION EQUIPMENT

ITEM DESCRIPTION	PART NO.
Gasket N-Notch	
Shaft Seal	P3450B
Window	P36983
Nuts, Washers	P36802, PC5875B,P37015
O-Ring	P28509
Pipe Plug	P21488B
Elbow	P39235B
Diaphragm Assembly	U17357
Seal Gasket, Seals, Gaskets	P34506B, P83510, P80830, P8734, P37541, P36988, P36984, P36982
Spring Stop	P36967
Springs	P38604, P36966, P36698, P26482, P37003
Stem	P83721
Stem Bottom	P42394
Vacuum Gauge	U82500
Adaptor	P39238
1" Chlorine Stop Valve Assembly	U80668
Valve	U83172
Alarm Box	U81021
Grommet	P30760B
Anode	P30764B
Immersion Heater 4K 220 Volt	U80462
Plug	P38591
Clamping Plate	P37001B
Sleeve Clamping	P36931
O-Ring	P44120
Stud	P36834B
Ball & Seat Assembly	U80723
Throat Exit Assembly	U18250B

BEST AVAILABLE COPY

APPENDIX C - 1

LABORATORY EQUIPMENT AND MATERIALS

CURRENTLY AVAILABLE AT THE AS-SAMRA WSP LABORATORY

1. EQUIPMENT

Electronic Balance
Electronic Analytical Balance
Water Bath
Combustion Furnace
Hot Plate
Hot Plate (Stirring)
Incubators
- High Performance
- Low Temperature

Microscope
Test Tube Mixer
Iso Temp Oven (for sterilizing)
Iso Temp Oven (for drying)
Pressure / Vacuum Pump
Dissolved Oxygen Meter
pH Meter
Thermometer
COD Reactors
Fluorometer
Laboratory Centrifuge
Desiccators
Automatic Samplers

2. GLASSWARE

Crucibles (50 ml)
Burettes with Reservoirs (5 ml)
Burettes with Reservoirs (10 ml)
Conical Flask (Erlenmeyer - 200 ml)
Pipettes (10 ml)
Graduated Cylinders (100 ml)

3. CHEMICALS & MATERIALS

Potassium Di-Hydrogen Phosphate
Di-Potassium Hydrogen Phosphate
Di-Potassium Hydrogen Phosphate Heptanydrates
Ammonium chloride
Sulfuric Acid
Sodium Iodide
Salicylic Acid
Ferric Chloride

4. CONSUMABLE CHEMICALS AND MATERIALS ROUTINELY PROVIDED

Iodine
Starch
Ethanol
Lauryl Triptose Broth
E. coli Nutrient Broth
Glass Mcrofiber Filter

BEST AVAILABLE COPY

APPENDIX C - 2

RECOMMENDED ADDITIONAL EQUIPMENT AND MATERIALS

FOR AS-SAMRA WSP LABORATORY

1. EQUIPMENT

Dissolved Oxygen Meters (additional)
pH Meters (Additional)
Sludge Detector Devices
Oxidation-Reduction Potentiometers
Electrical Conductivity Meters

2. GLASSWARE

Beakers (250 ml, 500 ml, 1000 ml)
Weighing Bottles
Brushes for Beakers, Tubes, Graduated Cylinders
Automatic Burettes
Crucibles (25 ml & 50 ml)
Graduated Cylinders (50 ml & 100 ml)
Petri Dishes
Conical Flasks (Erlenmeyer - 50 ml, 250 ml)
General Purpose Filtering Funnels
Volumetric Flash with Ground Glass Stoppers
Test Tubes with covers
Loops

3. CHEMICALS & MATERIALS

Manganese Sulphate
Sodium Hydroxide
Sodium Azide
Sodium Thiosulfate
Potassium Dichromate
Magnesium Sulphate
Calcium Chloride
Silver Sulphate
Mercuric Sulphate
Ferrous Ammonium Sulphate
1.10 Phenatholine Monohydrate
Ferrous Sulphte
Zinc Acetate
Silica Gel
Aluminum Chloride
Ringer Solution Tables

BEST AVAILABLE COPY

APPENDIX D

WSP LABORATORY DATA-Six (6) Year Summary

ENGINEERING - SCIENCE, INC.

Facility:
As Samra

Sheet 2

DATE	FLOW M-3 INFL	FLOW M-3 EFF	PLANT INFLUENT AGTP BOD	WSP BOD	AGTP TSS	WSP TSS	PH	PLANT EFFLUENT PH	DO MG/L	% BOD REM	Kg BOD DISC.	S.S. MG/L	% S.S. REM	Kg S.S. DISC.	FECAL COUNT	TOTAL RET.	CL-2 RES.
										****	****		****	****		****	
1986	56,813	48,198	766	625	909	751	6.90	7.80	5.9						54	49.7	0.58
1987	68,348	56,282	968	739	917	729	7.20	7.90	7.0	85.4%	6,634	180	80.5%	9,308	853	41.3	0.00
1988	80,629	67,191	980	857	658	584	7.10	8.20	6.2	83.1%	9,511	220	65.4%	14,814	16,793	35.0	0.00
1989	90,738	72,871		737		617	6.90	8.10	5.8	84.2%	8,463	171	71.6%	12,430	48	31.2	0.00
1990	95,241	82,332	715	705	826	620	7.10	8.10	5.3	77.8%	12,761				90,025	29.3	0.00
1991	98,041	83,457	988	717	883	622	7.20	8.10	5.6	83.1%	10,019				144,371	27.4	0.00
PERMIT								6 - 9				30			100		
STD DEV.																	
AVERAGE	81,635	68,388	883	730	838	654			6.0	82.7%	9,477	190	72.5%	12,184	42,024	35.6	0.10
MINIMUM	56,813	48,198		625		584	6.90	7.80	5.3						48		0.00
MAXIMUM	98,041	83,457	988	857	917	751	7.20	8.20	7.0	85.4%	12,761		80.5%	14,814	144,371	49.7	0.58
TOTAL	489,810	410,331															
DESIGN AVG	68,000	68,000		526		421	6.00	6.00	1.0	95.0%	1,788	21	95.0%	1,431		41.3	
DESIGN MAX	100,000	100,000		789		631	9.00	9.00	2.0	90.0%	7,890	63	90.0%	6,312		28.1	
Quarter 1	68,597	5,538	905	740	828	688	7.07	7.97	6.4	84.2%	8,072	200	73.0%	12,061	5,900	42.0	0.19
Quarter 2	94,673	7,458	852	719	854	620	7.07	8.10	5.6	81.7%	10,414	171	71.6%	12,430	78,148	29.3	0.00
Quarter 3																	
Quarter 4																	

BEST AVAILABLE COPY

1986 Monthly Data Summary

ENGINEERING - SCIENCE, INC.

Facility:
As Samra

Sheet 2

DATE 1986	FLOW M-3 INFL	FLOW M-3 EFF	PLANT INFLUENT AGTP BOD	PLANT INFLUENT WSP BOD	PLANT INFLUENT AGTP TSS	PLANT INFLUENT WSP TSS	PLANT INFLUENT PH	PLANT EFFLUENT PH	DO MG/L	BOD MG/L	% BOD REM	Kg BOD DISC.	S.S. MG/L	% S.S. REM	Kg S.S. DISC.	FECAL COUNT	TOTAL RET.	CL-2 RES.
JAN.	51,260	44,751	786	534	713	546	6.90	7.80	7.7		****	****		****	****		****	
FEB.	63,745	57,424	725	572	609	476	7.10	7.40	7.5								54.8	
MAR.	50,762	41,280	757	773	875	879	7.60	8.00	5.9							93	44.0	
APR.	53,192	41,280	878	792	1280	844	7.50	7.70	6.2							3	55.3	0.50
MAY	56,263	48,000	747	603	930	870	7.40	8.20	4.2							11	52.8	0.50
JUN.	52,900	45,000	774	630	991	867	7.30	8.00	4.9							4	49.9	0.50
JUL.	56,930	46,850	658	570	709	706	7.20	7.60	4.6							2	53.1	0.50
AUG.	60,500	48,067	753	750	988	810	7.30	7.70	5.1							2	49.3	0.75
SEP.	59,112	48,890	762	590	854	846	7.10	7.60	4.5							3	46.4	0.70
OCT.	56,484	50,235	815	545	977	713	7.20	8.10	5.9							5	47.5	
NOV.	63,010	55,695	798	608	1063	750	7.20	7.70	7.3							60	49.7	
DEC.	57,600	50,905	741	535	913	707	7.00	7.30	6.4							200	44.6	
																270	48.7	
PERMIT								6 - 9		30			30			100		
STD DEV	4,105	4,770	51	89	171	125	0.19	0.26	1.2							87		
AVERAGE	56,813	48,198	766	625	909	751			5.9							54	49.7	0.58
MINIMUM	50,762	41,280	658	534	609	476	6.90	7.30	4.2								44.0	0.50
MAXIMUM	63,745	57,424	878	792	1,280	879	7.60	8.20	7.7							270	55.3	0.75
TOTAL	681,758	578,377																
DESIGN AVG	68,000	68,000		526		421	6.00	6.00	1.0	26	95.0%	1,788	21	95.0%	1,431		41.3	
DESIGN MAX	100,000	100,000		789		631	9.00	9.00	2.0	79	90.0%	7,890	63	90.0%	6,312		28.1	
Quarterly Avg.																		
Quarter 1	55,256	47,818	756	626	732	634	7.20	7.73	7.0							48	51.4	0.50
Quarter 2	54,118	44,760	800	675	1,067	860	7.40	7.97	5.1							6	51.9	0.50
Quarter 3	58,847	47,936	724	637	850	787	7.20	7.63	4.7							3	47.7	0.73
Quarter 4	59,031	52,278	785	563	984	723	7.13	7.70	6.5							177	47.7	

BEST AVAILABLE COPY

1987 Monthly Data Summary

ENGINEERING - SCIENCE, INC.

Facility:
As Samra

Sheet 2

DATE 1987	FLOW M-3 INFL	FLOW M-3 EFF	PLANT INFLUENT AGTP BOD	PLANT INFLUENT WSP BOD	PLANT INFLUENT AGTP TSS	PLANT INFLUENT WSP TSS	PLANT INFLUENT PH	PLANT EFFLUENT PH	DO MG/L	BOD MG/L	% BOD REM	Kg BOD DISC.	S.S. MG/L	% S.S. REM	Kg S.S. DISC.	FECAL COUNT	TOTAL RET.	CL-2 RES.
JAN.	68,150	63,626	852	723	793	755	7.00	7.40	5.7	135	81.3%	8,590	89	88.8%	5,631	40	41.2	0.00
FEB.	67,166	53,592	898	784	722	702	7.20	7.70	5.7	178	77.3%	9,539	118	83.7%	6,324	2,000	41.8	0.00
MAR.	67,420		779	690	695	700	7.50	7.10	4.3	85	87.7%		115	83.5%		900	41.6	0.00
APR.	59,490		853	836	848	874	7.10	7.90	6.3				169	80.1%		1,000	47.2	0.00
MAY	67,590		952	644	1353	736	7.10	8.20	6.3				207	84.7%		3,000	41.5	0.00
JUN.	69,345		868	631	966	703	6.80	7.90	6.7				222	77.0%		20	40.5	0.00
JUL.	73,780		926	682	1189	714	7.30	8.30	8.5	79	88.5%		268	77.5%		20	38.1	0.00
AUG.	75,370	55,470	1065	815	937	720	7.00	8.00	8.6	106	87.0%	5,861	178	81.3%	9,744	9	37.3	0.00
SEP.	72,560	60,103	1125	663	1000	715	7.00	8.00	9.0	83	87.6%	4,958	205	79.5%	12,341	450	38.7	0.00
OCT.	66,180	48,880	1298	838	881	765	7.00	7.90	8.0	108	87.2%	5,263	224	74.6%	10,933	400	42.4	0.00
NOV.	61,660	51,836	977	825	828	693	7.10	8.10	9.0	90	89.1%	4,665	203	75.5%	10,505	400	45.5	0.00
DEC.	71,460	60,470	1022	736	797	670	7.10	8.00	6.0	125	83.0%	7,559	160	79.9%	9,675	2,000	39.3	0.00
PERMIT								6 - 9		30			30			100		
STD DEV.	4,453	4,907	137	75	184	50	0.17	0.32	1.5		37.1%	3,543		4.0%	4,905	940	2.8	
AVERAGE	68,348	56,282	968	739	917	729			7.0	110	85.4%	6,634	180	80.5%	9,308	853	41.3	0.00
MINIMUM	59,490	48,880	779	631	695	670	6.80	7.10	4.3				89	74.6%		9	37.3	0.00
MAXIMUM	75,370	63,626	1,298	838	1,353	874	7.50	8.30	9.0	178	89.1%	9,539		88.8%	12,341	3,000	47.2	0.00
TOTAL	820,171	393,977																
DESIGN AVG	68,000	68,000		526		421	6.00	6.00	1.0	26	95.0%	1,788	21	95.0%	1,431		41.3	
DESIGN MAX	100,000	100,000		789		631	9.00	9.00	2.0	79	90.0%	7,890	63	90.0%	6,312		28.1	
Quarterly Avg.																		
Quarter 1	67,579	58,609	843	732	737	719	7.23	7.40	5.2	133	82.1%	9,064	107	85.3%	5,977	980	41.5	0.00
Quarter 2	65,475		891	704	1,056	771	7.00	8.00	6.4				199	80.6%		1,340	43.1	0.00
Quarter 3	73,903	57,787	1,039	720	1,042	716	7.10	8.10	8.7	89	87.7%	5,410	216	79.4%	11,043	160	38.0	0.00
Quarter 4	66,433	53,729	1,099	800	835	709	7.07	8.00	7.7	108	86.4%	5,829	195	78.7%	10,371	933	42.4	0.00

BEST AVAILABLE COPY

100

1988 Monthly Data Summary

ENGINEERING - SCIENCE, INC.

Facility:
As Samra

Sheet 2

DATE 1988	FLOW M-3 INFL	FLOW M-3 EFF	PLANT INFLUENT AGTP BOD	WSP BOD	AGTP TSS	WSP TSS	PH	PLANT EFFLUENT PH	DO MG/L	% BOD REM	Kg BOD DISC.	S.S. MG/L	% S.S. REM	Kg S.S. DISC.	FECAL COUNT	TOTAL RET.	CL-2 RES.
										****	****		****	****		****	
JAN.	69,300	60,473	1,001	768	814	593	7.00	8.00	6.3	84.3%	7,277	193	76.3%	11,671	200,000	40.5	0.00
FEB.	85,423	79,255	901	677	651	560	7.00	7.80	5.0	80.5%	10,462	174	73.3%	13,764	90	32.9	0.00
MAR.	81,520	70,170	1,111	725	648	535	7.10	7.80	5.8	82.1%	9,099	175	73.0%	12,256	7	34.4	0.00
APR.	75,890	59,660	1,174	826	579	643	6.90	7.50	5.6	84.3%	7,716	193	66.7%	11,494	3	37.0	0.00
MAY	74,030	54,337	1,159	1,389	841	692	6.70	7.70	6.0	86.5%	10,161	203	75.8%	11,049	20	37.9	0.00
JUN.	82,370	62,160	786	706	492	543	7.10	8.00	7.0	82.4%	7,708	219	55.5%	13,613	100	34.1	0.00
JUL.	85,150	64,740	797	753	682	674	7.10	7.80	5.0	83.7%	7,963	203	70.2%	13,142	200	33.0	0.00
AUG.	87,323	66,883	1,032	1006	684	550	7.00	7.30	5.0	85.3%	9,876	232	66.0%	15,539	800	32.2	0.00
SEP.	88,280	71,820	978	1028	497	523	7.10	8.10	7.0	85.9%	10,414	270	45.7%	19,367	20	31.8	0.00
OCT.	82,980	70,100	1,158	860	785	495	7.20	8.00	7.0	79.2%	12,525	287	63.4%	20,119	100	33.8	0.00
NOV.	73,410	66,190	939	764	701	540	7.10	8.10	8.0	79.9%	10,171	278	60.3%	18,423	80	38.2	0.00
DEC.	81,873	80,501	725	778	518	663	7.20	8.00	7.0	82.8%	10,760	215	58.4%	17,335	100	34.3	0.00
PERMIT								6 - 9				30			100		
STD DEV.	5,803	7,422	149	192	114	64	0.13	0.24	0.9	2.3%	1,511		8.8%	3,106	55,239	2.6	
AVERAGE	80,629	67,191	980	857	658	584			6.2	83.1%	9,511	220	65.4%	14,814	16,793	35.0	0.00
MINIMUM	69,300	54,337	725	677	492	495	6.70	7.30	5.0	79.2%	7,277	174	45.7%	11,049	3	31.8	0.00
MAXIMUM	88,280	80,501	1,174	1,389	841	692	7.20	8.10	8.0	86.5%	12,525		76.3%	20,119	200,000	40.5	0.00
TOTAL	967,549	806,289															
DESIGN AVG	68,000	68,000		526		421	6.00	6.00	1.0	95.0%	1,788	21	95.0%	1,431		41.3	
DESIGN MAX	100,000	100,000		789		631	9.00	9.00	2.0	90.0%	7,890	63	90.0%	6,312		28.1	
Quarterly Avg.																	
Quarter 1	78,748	69,966	1,004	723	704	563	7.03	7.87	5.7	82.3%	8,946	180	74.2%	12,564	66,699	35.9	0.00
Quarter 2	77,430	58,719	1,040	974	637	626	6.90	7.73	6.2	84.4%	8,528	205	66.0%	12,052	41	36.3	0.00
Quarter 3	86,918	67,814	936	929	621	582	7.07	7.73	5.7	85.0%	9,418	235	60.7%	16,016	340	32.3	0.00
Quarter 4	79,421	72,264	941	801	668	566	7.17	8.03	7.3	80.6%	11,152	260	60.7%	18,625	93	35.5	0.00

BEST AVAILABLE COPY

1989 Monthly Data Summary

ENGINEERING - SCIENCE, INC.

Facility:
As Samra

Sheet 2

DATE 1989	FLOW M-3 INFL	FLOW M-3 EFF	PLANT INFLUENT AGTP BOD	WSP BOD	AGTP TSS	WSP TSS	PH	PLANT EFFLUENT PH	DO MG/L	BOD MG/L	% BOD REM	Kg BOD DISC.	S.S. MG/L	% S.S. REM	Kg S.S. DISC.	FECAL COUNT	TOTAL RET.	CL-2 RES.
JAN.	77,045	77,135		651		672	6.90	7.80	6.0	163	75.0%	12,573	91	86.5%	7,019		36.4	0.00
FEB.	75,700	70,080		760		605	7.20	7.90	7.0	135	82.2%	9,461	95	84.3%	6,658		37.1	0.00
MAR.	85,358	75,120		852		610	7.10	8.20	5.0	156	81.7%	11,719	105	82.8%	7,888	60	32.9	0.00
APR.	95,193	74,210		840		600	6.90	8.10	6.0	125	85.2%	9,252	198	66.9%	14,718	50	29.5	0.00
MAY	95,932	70,840		730		587	7.10	8.10	6.0	106	85.4%	7,533	207	64.8%	14,640	20	29.3	0.00
JUN.	95,260	68,630		730		580	7.20	8.10	7.0	107	85.4%	7,321	201	65.4%	13,772	20	29.5	0.00
JUL.	100,860	73,870		680		614	6.80	8.00	5.0	58	91.4%	4,309	156	74.6%	11,499		27.8	0.00
AUG.	99,000	72,717		680		650	7.30	8.10	5.0	91	86.6%	6,617	164	74.7%	11,950	200	28.4	0.00
SEP.	93,575	69,334		780		660	7.30	8.10	6.0	87	88.8%	6,055	202	69.3%	14,029	20	30.0	0.00
OCT.	90,820	70,040		785		800	7.20	8.30	5.0	83	89.4%	5,813	195	75.6%	13,681	20	30.9	0.00
NOV.	91,671	74,998		670		564	7.20	8.20	6.0	164	75.5%	12,300	222	60.6%	16,650	20	30.6	0.00
DEC.	88,440	77,473		680		462	7.30	8.00	6.0	111	83.7%	8,600	215	53.5%	16,657	20	31.7	0.00
PERMIT								6 - 9		30			30			100		
STD DEV.	7,609	2,918		65		76	0.16	0.13	0.7		4.8%	2,574		9.6%	3,367		2.8	
AVERAGE	90,738	72,871		737		617			5.8	116	84.2%	8,463	171	71.6%	12,430	48	31.2	0.00
MINIMUM	75,700	68,630		651		462	6.80	7.80	5.0	58	75.0%	4,309	91	53.5%	6,658	20	27.8	0.00
MAXIMUM	100,860	77,473		852		800	7.30	8.30	7.0	164	91.4%	12,573		86.5%	16,657	200	37.1	0.00
TOTAL	1,088,854	874,447																
DESIGN AVG	68,000	68,000		526		421	6.00	6.00	1.0	26	95.0%	1,788	21	95.0%	1,431		41.3	
DESIGN MAX	100,000	100,000		789		631	9.00	9.00	2.0	79	90.0%	7,890	63	90.0%	6,312		28.1	
Quarterly Avg.																		
Quarter 1	79,368	74,112		754		629	7.07	7.97	6.0	151	79.6%	11,251	97	84.5%	7,188	60	35.5	0.00
Quarter 2	95,462	71,227		767		589	7.07	8.10	6.3	113	85.3%	8,035	202	65.7%	14,377	30	29.4	0.00
Quarter 3	97,812	71,974		713		641	7.13	8.07	5.3	79	88.9%	5,660	174	72.9%	12,493	110	28.7	0.00
Quarter 4	90,310	74,170		712		609	7.23	8.17	5.7	119	82.9%	8,904	211	63.2%	15,662	20	31.1	0.00

BEST AVAILABLE COPY

113

1990 Monthly Data Summary

ENGINEERING - SCIENCE, INC.

Facility:
As Samra

Sheet 2

DATE 1990	FLOW M-3 INFL	FLOW M-3 EFF	PLANT INFLUENT AGTP BOD	WSP BOD	AGTP TSS	WSP TSS	PH	PLANT EFFLUENT PH	DO MG/L	BOD MG/L	% BOD REM	Kg BOD DISC.	S.S. MG/L	% S.S. REM	Kg S.S. DISC.	FECAL COUNT	TOTAL RET.	CL-2 RES.
											****	****		****	****		****	
JAN.	92,585	81,583	848	720	1000	697	7.20	7.60	5.0	120	83.3%	9,790				500,000	30.2	0.00
FEB.	68,520	76,192	500	790	649	638	7.00	7.80	5.0	112	85.8%	8,534				80,000	40.7	0.00
MAR.	90,710	79,815	738	780	617	557	6.90	7.80	6.0	160	79.5%	12,770				3,000	30.7	0.00
APR.	107,350	93,609	450	690	410	560	6.50	7.80	6.0	192	72.2%	17,973				200	25.9	0.00
MAY	101,490	82,020	684	680	2000	560	6.90	7.90	7.0	175	74.3%	14,354				50	27.3	0.00
JUN.	102,844	80,320	886	625	940	624	7.00	8.20	5.0	172	72.5%	13,815					26.8	0.00
JUL.	104,200	91,311	747	650	931	626	7.60	8.40	6.0	87	86.6%	7,944				20	26.4	0.00
AUG.	101,940	81,950		730	514	688	7.30	8.30	6.0	97	86.7%	7,949				1,000	26.9	0.00
SEP.	96,020	80,250	588	750	682	665	7.30	8.50	5.0	210	72.0%	16,853				3,000	28.5	0.00
OCT.	91,080	80,066	848	680	687	541	7.20	8.00	4.0	210	69.1%	16,814				3,000	30.0	0.00
NOV.	91,000	82,273		630		660	7.10	8.10	4.0	152	75.9%	12,505				100,000	29.9	0.00
DEC.	95,152	78,594	862	730	652	625	7.30	8.20	5.0	176	75.9%	13,833				300,000	28.5	0.00
PERMIT								6 - 9		30			30			100		
STD DEV.	9,773	4,832		52		52	0.27	0.27	0.8		6.1%	3,394					3.8	
AVERAGE	95,241	82,332	715	705	826	620			5.3	155	77.8%	12,761				90,025	29.3	0.00
MINIMUM	68,520	76,192	450	625	410	541	6.50	7.60	4.0	87	69.1%	7,944				20	25.9	0.00
MAXIMUM	107,350	93,609	886	790	2,000	697	7.60	8.50	7.0	210	86.7%	17,973				500,000	40.7	0.00
TOTAL	1,142,891	987,983																
DESIGN AVG	68,000	68,000		526		421	6.00	6.00	1.0	26	95.0%	1,788	21	95.0%	1,431		41.3	
DESIGN MAX	100,000	100,000		789		631	9.00	9.00	2.0	79	90.0%	7,890	63	90.0%	6,312		28.1	
Quarterly Avg.																		
Quarter 1	83,938	79,197	695	763	755	631	7.03	7.73	5.3	131	82.9%	10,365				194,333	33.9	0.00
Quarter 2	103,895	85,316	673	665	1,117	581	6.80	7.97	6.0	180	73.0%	15,380				125	26.7	0.00
Quarter 3	100,720	84,504	687	710	709	660	7.40	8.40	5.7	131	81.8%	10,915				1,340	27.3	0.00
Quarter 4	92,411	80,311	855	680	670	609	7.20	8.10	4.3	179	73.6%	14,384				134,333	29.5	0.00

BEST AVAILABLE COPY

1991 Monthly Data Summary

ENGINEERING - SCIENCE, INC.

Facility:
As Samra

Sheet 2

DATE 1991	FLOW M-3 INFL	FLOW M-3 EFF	PLANT INFLUENT AGTP BOD	PLANT INFLUENT WSP BOD	PLANT INFLUENT AGTP TSS	PLANT INFLUENT WSP TSS	PLANT INFLUENT PH	PLANT EFFLUENT PH	PLANT EFFLUENT DO MG/L	PLANT EFFLUENT BOD MG/L	PLANT EFFLUENT % BOD REM	PLANT EFFLUENT Kg BOD DISC.	PLANT EFFLUENT S.S. MG/L	PLANT EFFLUENT % S.S. REM	PLANT EFFLUENT Kg S.S. DISC.	PLANT EFFLUENT FECAL COUNT	PLANT EFFLUENT TOTAL RET.	PLANT EFFLUENT CL-2 RES.
											****	****		****	****		****	
JAN.	100,770	86,278	988	670	676	635	6.90	7.80	5.0	139	79.3%	11,993					26.8	0.00
FEB.	91,205	87,730	746	620	720	540	6.70	7.90	6.0	163	73.7%	14,300				900,000	29.6	0.00
MAR.	98,355	87,060	988	850	676	570	7.20	7.90	7.0	120	85.9%	10,447				50,000	27.3	0.00
APR.	90,240	78,592	1040	900	798	620	7.60	8.10	6.0	145	83.9%	11,398				20,000	29.7	0.00
MAY	98,230	80,780	1300	720	722	550	7.40	8.40	5.0	91	87.4%	7,351				40,000	27.2	0.00
JUN.	101,350	87,890	941	710	1200	635	7.20	8.50	6.0	103	85.5%	9,053				200	26.3	0.00
JUL.	100,535	77,845	888	650	782	690	7.60	8.70	5.0	99	84.8%	7,707				200	28.4	0.00
AUG.	103,643	81,480	1016	615	1492	735	7.20	8.10	5.0	97	84.2%	7,904				200	25.6	0.00
SEP.																		
OCT.																		
NOV.																		
DEC.																		
PERMIT								6 - 9		30			30			100		
STD DEV.																		
AVERAGE	98,041	83,457	988	717	883	622			5.6	120	83.1%	10,019				144,371	27.4	0.00
MINIMUM	90,240	77,845	746	615	676	540	6.70	7.80	5.0							200		0.00
MAXIMUM	103,643	87,890	1,300	900	1,492	735	7.60	8.70	7.0	163	87.4%	14,300				900,000	29.7	0.00
TOTAL	784,328	667,655																
DESIGN AVG	68,000	68,000		526		421	6.00	6.00	1.0	26	95.0%	1,788	21	95.0%	1,431		41.3	
DESIGN MAX	100,000	100,000		789		631	9.00	9.00	2.0	79	90.0%	7,890	63	90.0%	6,312		28.1	
Quarterly Avg.																		
Quarter 1	96,777	87,023	907	713	691	582	6.93	7.87	6.0	141	79.6%	12,247				475,000	27.9	0.00
Quarter 2	96,607	82,421	1,094	777	907	602	7.40	8.33	5.7	113	85.6%	9,266				20,067	27.7	0.00
Quarter 3	102,089	79,663	952	633	1,137	713	7.40	8.40	3.3	98	84.5%	7,805				200	26.0	0.00
Quarter 4																		

BEST AVAILABLE COPY

1990 - 1991 Quarterly Data Summary by pond/train

YEAR 1990

TRAIN #1

BOD5

DATE:	Inlet	A2	% REDUC.	F4	% REDUC.	M4	% REDUC.	Outlet	% OVERALL REDUC.
04/2	612	240	60.6%	204	15.0%	195	4.4%	165	73.0%
11/2	720	220	69.4%	144	34.5%	165	-14.6%	143	80.1%
18/2	570	240	57.9%	156	35.0%	142	9.0%	128	77.5%
25/2	600	280	53.3%	204	27.1%	150	26.5%	128	78.7%
05/8	570	240	57.9%	96	60.0%	60	37.5%	68	88.1%
12/8	660	240	83.6%	132	45.0%	87	34.1%	90	86.4%
19/8	690	240	85.2%	108	55.0%	105	2.8%	90	87.0%
26/8	440	300	31.8%	94	68.7%	100	-8.4%	98	77.7%
AVERAGE	608	250		142		126		114	
AVG. % RED.			57.5%		42.5%		11.7%		81.1%

119

YEAR 1990

TRAIN #2

BOD5

DATE:	Inlet	A2	% REDUC.	F4	% REDUC.	M4	% REDUC.	Outlet	% OVERALL REDUC.
06/2	810	260	67.9%	160	30.8%	143	20.6%	173	78.6%
13/2	480	240	50.0%	168	30.0%	90	46.4%	127	73.5%
20/2	650	180	72.3%	170	5.6%	75	55.9%	90	86.2%
07/8	675	190	71.9%	144	24.2%	90	37.5%	88	87.3%
14/8	720	280	61.1%	120	57.1%	98	18.3%	90	87.5%
21/8	660	220	66.7%	120	45.5%	83	30.8%	75	88.6%
28/8	510	200	60.8%	120	40.0%	120	0.0%	90	82.4%
AVERAGE	644	224		146		100		104	
AVG. % RED.			64.4%		33.3%		29.9%		83.4%

120

YEAR 1990

TRAIN #3

BOD5

DATE:	Inlet	A2	% REDUC.	F4	% REDUC.	M4	% REDUC.	Outlet	% OVERALL REDUC.
06/2		220		180	18.2%	158	12.2%	165	0.0%
13/2		180		156	13.3%	120	23.1%	127	0.0%
20/2		180		150	16.7%	83	44.7%	128	0.0%
07/8	675	220	67.4%	160	18.2%	105	41.7%	86	87.3%
14/8	720	300	58.3%	190	36.7%	98	48.4%	90	87.5%
21/8	660	180	72.7%	140	22.2%	83	40.7%	75	88.6%
28/8	510	240	52.9%	220	8.3%	128	41.6%	90	82.4%
AVERAGE	641	217		174		111		109	
AVG. % RED.			62.9%		19.1%		36.1%		49.4%

121

OVERALL PERFOMANCE FOR 1990

	Inlet	A2	REDUC.	F4	REDUC.	M4	REDUC.	Outlet	REDUC.
TRAIN #1	608	250	57.5%	142	42.5%	128	11.7%	114	81.3%
TRAIN #2	844	224	64.4%	146	33.3%	100	29.9%	104	83.8%
TRAIN #3	641	217	62.9%	174	19.1%	111	36.1%	109	83.0%
AVERAGE	631	230		154		112		109	
AVG. % RED.			61.6%		31.6%		25.9%		82.7%

BEST AVAILABLE COPY

YEAR 1991

TRAIN #1

BOD5

DATE:	Inlet	A2	% REDUC.	F4	% REDUC.	M4	% REDUC.	Outlet	% OVERALL REDUC.
05/2	757	320	57.7%	200	37.5%	147	26.5%	175	76.9%
12/2	760	278	63.7%	210	23.9%	139	33.8%	129	83.0%
19/2	850	257	60.5%	216	16.0%	135	37.5%	141	78.3%
26/2	760	252	66.8%	252	0.0%	173	31.3%	160	78.9%
02/4	680	360	45.5%	216	40.0%	113	47.7%	98	85.2%
09/4	680	218	88.2%	188	13.9%	112	39.8%	120	82.4%
16/4	680	324	50.9%	162	50.0%	138	14.8%	110	83.3%
23/4	880	215	68.4%	158	26.5%	118	25.3%	115	83.1%
06/8	800	100	87.5%	72	28.0%	182	-125.0%	66	91.8%
13/8	610	110	86.4%	90	18.2%	112	-24.4%	81	90.0%
20/8	600	180	70.0%	130	27.8%	36	72.3%	90	85.0%
27/8	744	110	85.2%	130	-18.2%	78	40.0%	90	87.9%
AVERAGE	713	227		169		122		115	
AVG. % RED.			87.6%		22.0%		18.3%		81.4%

123

YEAR 1991

TRAIN #2

BOD5

DATE:	Inlet	A2	% REDUC.	F4	% REDUC.	M4	% REDUC.	Outlet	% OVERALL REDUC.
05/2	800	384	52.0%	198	48.4%	157	20.7%	188	76.5%
12/2	980	324	66.9%	225	30.6%	143	36.4%	159	83.8%
19/2	720	288	60.0%	210	27.1%	161	23.3%	146	79.7%
26/2	800	264	67.0%	234	11.4%	185	29.5%	160	77.5%
02/4	855	165	80.7%	160	3.0%	99	38.1%	120	86.0%
09/4	630	275	56.3%	160	34.5%	138	23.3%	124	80.3%
16/4	780	360	53.6%	144	60.0%	120	16.7%	100	87.2%
23/4	670	289	56.9%	129	55.4%	120	7.0%	100	85.1%
06/6	640	200	68.8%	180	10.0%	102	43.3%	84	86.9%
13/6	780	190	75.6%	140	26.3%	83	55.0%	108	86.2%
20/6	640	130	79.7%	50	61.5%	57	-14.0%	54	91.6%
27/8	720	130	61.9%	100	23.1%	68	34.0%	86	90.8%
AVERAGE	751	250		163		116		119	
AVG. % RED.			66.6%		32.6%		26.1%		82.0%

YEAR 1991

TRAIN #3

BOD5

DATE:	Inlet	A2	% REDUC.	F4	% REDUC.	M4	% REDUC.	Outlet	% OVERALL REDUC.
05/2	800	360	55.0%	218	40.0%	157	27.3%	188	76.5%
12/2	980	280	71.4%	204	27.1%	148	28.4%	159	63.8%
19/2	720	264	63.3%	222	15.9%	185	25.7%	146	79.7%
26/2	800	336	58.0%	240	28.6%	180	25.0%	180	77.5%
02/4	855	210	75.4%	195	7.1%	141	27.7%	120	86.0%
09/4	630	280	55.6%	165	41.1%	152	7.9%	124	80.3%
16/4	780	225	71.2%	144	36.0%	101	29.9%	100	87.2%
23/4	670	228	66.0%	150	34.2%	120	20.0%	120	82.1%
06/8	640	230	64.1%	110	52.2%	89	37.3%	54	91.6%
13/8	780	180	76.9%	130	27.8%	90	30.8%	108	86.2%
20/8	640	144	77.5%	130	9.7%	108	16.9%	84	86.9%
27/8	720	1156	-60.8%	137	88.1%	78	43.1%	66	90.8%
AVERAGE	751	324		170		126		121	
AVG. % RED.			58.2%		34.0%		26.7%		81.6%

OVERALL PERFOMANCE FOR 1991

	Inlet	A2	REDUC.	F4	REDUC.	M4	REDUC.	Outlet	REDUC.
TRAIN #1	713	227	67.6%	169	22.0%	122	18.3%	115	83.9%
TRAIN #2	751	250	66.6%	163	32.6%	116	26.1%	119	84.1%
TRAIN #3	751	324	56.2%	170	34.0%	128	26.7%	121	83.9%
AVERAGE	739	267		167		121		118	
AVG. % RED.			63.5%		29.5%		23.7%		84.0%

EFFECTIVE POND SIZES AND RETENTION TIMES (At 68000 m^3/day)

Pond	Total Depth (m)	Effective Depth (m)	3 trains			2 trains		
			Area (ha)	Volume ($m^3 \times 10^5$)	Retention time (days)	Area (ha)	Volume ($m^3 \times 10^5$)	Retention time (days)
A1	5.0	3.0	9.5	2.85	4.2	6.3	1.90	2.8
A2	5.0	3.0	9.5	2.85	4.2	6.3	1.90	2.8
F1	2.25	1.5	21.75	3.26	4.8	14.5	2.17	3.2
F2	2.0	1.5	21.75	3.26	4.8	14.5	2.17	3.2
F3	1.5	1.5	21.75	3.26	4.8	14.5	2.17	3.2
F4	1.5	1.5	21.75	3.26	4.8	14.5	2.17	3.2
M1	1.25	1.25	18.75	2.34	3.4	12.5	1.56	2.3
M2	1.25	1.25	18.75	2.34	3.4	12.5	1.56	2.3
M3	1.25	1.25	18.75	2.34	3.4	12.5	1.56	2.3
M4	1.25	1.25	18.75	2.34	3.4	12.5	1.56	2.3
TOTAL			181	28.10	41.2	120.6	18.72	27.6