IRN- 46596
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FINAL MASTER PLAN REPORT AND ENGINEERING DESIGN AND ECONOMIC ANALYSIS REPORT FOR WASTEWATER DISPOSAL FOR GREATER AMMAN AREA

VOLUME I
CHAPTERS 1-9

PREPARED FOR

NATIONAL PLANNING COUNCIL
THE HASHEMITE KINGDOM OF JORDAN

FEBRUARY 1982

JMM/DMJM
-A JOINT VENTURE-

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February 5, 1982

His Excellency The President
Dr. Hanna Odeh
National Planning Council
Box 555, Amman, Jordan

Re: Final Master Plan Report and Engineering Design and Economic Analysis Report for Wastewater Disposal for Greater Amman

Dear Dr. Odeh:

Pursuant to the agreement of May 17, 1980 between the National Planning Council and James M. Montgomery, Consulting Engineers, Inc., and DMJM International, a Joint Venture in association with Consulting Engineering Center, we are pleased to submit the Final Master Plan Report and Engineering Design and Economic Analysis Report for Wastewater Disposal for Greater Amman.

The subject report has been divided into two volumes. Volume I comprises Chapters 1-9, inclusive, and Volume II comprises Chapters 10-12, inclusive, plus the Appendices.

We express appreciation to the staff of NPC and the staffs of the many other governmental agencies for the cooperation extended us during the conduct of this important study.

Respectfully submitted,

Charles H. Lawrance,
Project Manager

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CHAPTER 1

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter summarizes the contents of all other chapters of this report and describes briefly the contents of the several appendices. Conclusions and recommendations for the report are then presented.

CHAPTER 2 - INTRODUCTION

The scope of work of this Master Plan Study for Wastewater Disposal for Greater Amman Area is described. The Study Area (Greater Amman Area) is defined as lying within a 30 kilometer radius of the center of Amman. The planning period is to year 2000. The work is to be coordinated with a recent planning study by another consultant for the Zarqa-Ruseifa area and its Industrial Wastes Study is to be used.

CHAPTER 3 - PRESENT AND FUTURE SOCIO-ECONOMIC CONDITIONS

Data from various governmental agencies are analyzed. These involve employment, income, land use, building restrictions and populations. Governmental plans and policies are reviewed along with actual status of land development. A declining growth rate is projected for the Study Area. The initial rate is for 1979-1990 at 4.46 percent annual increase. The subsequent rate is for 1991-2000 at 3.8 percent annual increase. The overall rate, beginning with the November 1979 census and extending to the horizon planning year 2000, is 4.13 percent per year. The Study Area populations at 1990 and 2000 are thus projected.

Saturation populations are then projected for the Cities of Amman, Wadi es Sir, Suweileh, Madaba, Sahab, and Na'ur from town plans, zoning, aerial photographs supplemented by field reconnaissance, and calculations of housing units and population densities. Based upon trends, the saturation population of Amman is projected to be realized within the period 1990-2000, but saturation for the other cities is projected to occur well beyond the horizon year 2000.

Amman's saturation population and the populations of Government-planned new communities (Abu Nasair, Sahab/Airport City and Airport City - Jiza) are deducted from the Study Area totals. The remaining populations are distributed among the remaining cities, towns, villages, and refugee camps. This is done in the light of Government policies, socio-economic data, established trends, and professional judgment. The resulting population projections, plus 1979 census data, stated in thousands, are as follows:

Community	1979	1990	2000
Amman	649	1,020	1,305
Zarqa	216	295	421
Suburban Ring (around Amman)	16	74	250
Ruseifa	50	91	125
Wadi es Sir	25	39	62
Suweileh	21	31	44
Salt	33	47	66
Madaba	29	41	58
Musherfeh	12	16	23
Na'ur	5	7	10
Abu Nasair	0	40	100
Sahab/Airport City	0	60	120
Airport City - Jiza	0	15	25
Baqa'a Camp	45	45	45
Schneller Camp	24	24	24
Towns & Villages	148	212	309
Study Area Total	1,273	2,057	2,987

Populations of Amman, Wadi es Sir, Madaba, Suweileh, Sahab, and Na'ur are then disaggregated by sub-areas for these years to provide data from which wastewater production values may subsequently be developed.

CHAPTER 4 - PUBLIC HEALTH CONSIDERATIONS

Public health statistics are presented, discussed, and interpreted. The data relate to Jordan in general and the Study Area in particular. Emphasis is placed on infant mortality, principal waterborne diseases, pathogenic organisms found in sewage, maximum acceptable levels for trace elements in drinking water, and hospitalization morbidity and mortality statistics according to major groups of illness. Special attention is paid to public health aspects of refugee camps.

An assessment is made of the aspects of water quality and health. It is concluded that the bacteriological quality of the public water supply of Amman, townships, and villages from source to consumers' premises is unsatisfactory at all points.

Provisions of wastewater collection, treatment, and proper disposal facilities for the various communities within the Greater Amman Area is expected to improve the health and well-being of the communities concerned and to protect the environment. However, attainment of these goals is expected only on a long term basis. The greatest benefit to be derived is that related to the control of waterborne diseases. This will be particularly true of the protection of children of school age from such disastrous and frequently fatal diseases as gastroenteritis.

Extreme care should be exercised in the selection of the most appropriate methodology for treatment, disposal and/or reuse of liquid waste. Reuse of reclaimed effluent for drinking and other domestic purposes appears premature for technical reasons and lack of public acceptance.

CHAPTER 5 - PRESENT AND FUTURE WASTE LOADS

Available data on water and wastewater quantities and wastewater qualities are analyzed. Water delivery data are projected as a means of aiding the wastewater projections. The unit values are expressed in liters per capita per day (lcd) as indicated below:

Area	1980	1990	2000
Amman (AWSA)*	85	95	110
Suburban Ring (of Amman)	95	105	115
Zarqa	67	90	110
Ruseifa	80	100	114
New Cities and Wadi es Sir	75	85	95
Other	50	70	80

* Amman Water and Sewerage Authority

These values reflect overall community water consumption (after distribution losses) including residential, commercial, municipal, and most industrial uses. With few exceptions, industrial water consumption is not a major factor.

The projections are then made of per capita waste loads for the various communities in the Study Area. These are slightly lower than water delivery values and are also expressed in liters per capita per day (lcd), as follows:

Area	1980	1990	2000
Amman (AWSA)	75	85	95
Suburban Ring (of Amman)	85	95	105
Zarqa	63	72	80
Ruseifa	50	63	71
New Cities and Wadi es Sir	65	75	85
Other	50	60	70

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The municipal wastewater flows being experienced in the AWSA system are unusually strong. This is due to the combination of average per capita organic contributions and unusually small per capita flow values. As time goes on and per capita flow contributions increase somewhat, the strength of the wastewater will decline somewhat, but it will probably remain quite high.

The per capita wastewater production values are later used in conjunction with projected populations to project wasteloads.

In the foregoing figures, the AWSA data are derived following analysis of operating data on the existing system. The effects of the municipal slaughterhouse and septage dumping are specifically taken into account. The per capita flow values represent overall annual averages from all effects, including existing industrial discharges and infiltration of groundwater into sewers but not inflow of stormwater during high intensity storms. The values indicated for new cities, Wadi es Sir, and "other" take the AWSA experience into account, as well as that of Salt and King Hussein Medical Center, each of which has an existing wastewater system. In contrast, the values listed for Zarqa and Ruseifa have special industrial effects included as well as both groundwater infiltration and stormwater inflow to the sewer system being proposed for this area. The values were developed by the special consultant who studied the area, and these values are considered and accepted in this report.

For the AWSA wastewater collection system additions and for other collection system work in facilities proposed in this report, a specific allowance is made for moderate groundwater infiltration effects. In special cases only, allowance is also made for specific industrial discharges from future industrially developed lands. It is considered unreasonable use of the sanitary sewer system to permit stormwater inflows from roof drains and the like, and no provision is made in the report to accommodate such occasional flows.

Average daily per capita waste contributions of Biochemical Oxygen Demand (BOD) and suspended Solids (SS) are used in this report. They are 60 grams per capita per day in each case. Superimposed on organic loadings computed from these values are specific loadings originating in "wet" industries, such as the municipal slaughterhouse, and discharges of septage. So-called "wet" industries are those which discharge significant quantities of wastewater and/or pollutants to sewer systems or elsewhere. Industrial organic loadings are used in conjunction with non-industrial wastewater quantities in sizing of wastewater treatment facilities.

Data are presented in the report indicating various types of organic and inorganic loadings to be anticipated from "wet" industries according to the types of process and amount of production. Review of available data and confirmatory field checking have revealed very little "wet" industry in the AWSA and other areas (aside from the special consultant considered Zarqa-Ruseifa area). Much relocation of existing industry and establishment of new industries (including some "wet" industries) are anticipated for Sahab Industrial City, where a specific wastewater treatment plant is being provided.

CHAPTER 6 - APPRAISAL OF EXISTING WASTEWATER FACILITIES

Within the Greater Amman Area there are three municipal type wastewater systems. These were appraised for present and future adequacy. The Army installations were not appraised because data were not available, for security reasons. If appropriate in the future, particularly in connection with design of projects, specific provision could be made to accommodate certain Army installations. Adequacy of existing cesspool systems for residences and other buildings in various urban areas is also considered. Each municipal type wastewater system comprises facilities for collection and treatment of the wastewater and for managing the sludge solids produced by the treatment.

The AWSA system is by far the most extensive of all. Assuming continued growth in Amman, the wastewater flows to AGTP will soon exceed its capacity. If the service area is extended to areas westerly of Amman, considerably more capacity than is available or has been contemplated will be required.

If the service area of AWSA is to be extended westerly of Amman, the increased flows in the primary network will exceed the available capacity of some of the trunk sewers. Hydraulic analysis shows that it will be necessary to reinforce such trunk sewers by constructing parallel sewers to relieve the surcharge. The amount of such reinforcement needed will depend upon whether or not an upstream treatment plant is implemented and operated to divert much of the inflow from westerly areas. Less reinforcement will be required with plant implementation and vice versa.

The AWSA collection system operates almost completely by gravity. Generally steep terrain makes this possible. It also provides for generally high flow velocities. This encourages aeration of the high strength wastewater and apparently discourages substantial generation of sulfides in the sewer system. High sulfide concentrations could result in sulfuric acid corrosion of the concrete sewer pipes in critical areas, greatly reducing their expected lives.

The AWSA collection system includes two pumping stations to bring flow into the primary network of trunk sewers where gravity flow is not possible because of intervening hills.

The University of Jordan and vicinity contribute flow to the primary network in the Sports City area by means of the University Pumping Station and force main. The pumping station is currently in operable condition although there are some deficiencies. The pumping station and force main would be adequate hydraulically for several years but the lower reaches of the gravity trunk sewer into which the flow is discharged become overloaded from this and other contributions. Gravity flow from the University area is possible by a more circuitous route via a developing but as yet unsewered area. Diversion of the pumped flow to a new gravity sewer would relieve the overload in the trunk sewer now receiving the pumped flow.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In the East Marka area, the Amman Airport and immediate vicinity contribute wastewater to the Ain Ghazal Treatment Plant (AGTP) via the East Marka Pumping Station. This is a new facility with little operating experience.

No sewer overloads are created by its operation. Gravity sewer discharge to AGTP would not be feasible from this area, but it could contribute by gravity to a downstream treatment plant. The pumping station is in operable condition although there are some deficiences. The capacity is adequate for the entire planning period.

The AGTP has been in operation since 1969. It incorporates the activated sludge process and anaerobic digestion of raw and waste activated sludge. Flows to the plant have gradually been increasing and within a very few years should reach its nominal capacity of about 30,00 cubic meters per day (cu m/da). They are presently about 21,000 cu m/da, for a tributary population of about 280,000 persons.

The plant performance has been adversely affected by the discharges of the municipal slaughterhouse and septage tank trunks directly upstream of the plant headworks. In addition to the unusually high strength wastewater and the superimposed industrial and septage loadings, some of the plant units have limitations which also reduce overall plant performance. Screenings and grit removal are unsatisfactory, diffused aeration facilities in the aeration tanks are subject to frequent clogging and do not produce sufficient mixing for the necessary suspension of wastewater and activated sludge (bacterial culture used to stabilize the wastewater). Control of the activated sludge progress is made difficult by limitations in suspended solids removed from the biological treatment system. Secondary sedimentation facilities are shallow and limited in their ability to clarify the aeration tank effluent prior to chlorination and discharge to the Seil Amman. Chlorination facilities have less than desirable efficiency and reliability.

The sludge processing facilities are soon to be enlarged under a recently awarded contract. This will correct a well recognized undersizing of current digestion capacity and will make the total digestion capacity equivalent to about 45,000 persons' contributions. This will be adequate for the next several years but not until 1990.

Sludge drying beds at AGTP were never intended to handle the entire flow of digested sludge. Their area will be even more limited when the new digesters and mechanical dewatering facilities are constructed, using some of the current drying bed space. Except for occasional emergency use, the remaining drying beds will be completely supplanted by three belt presses for sludge dewatering. These will be adequate for the next few years but will need to be reinforced by a fourth belt press before 1990.

The AGTP electrical facilities are generally adequate for present loads and for accommodating the new digesters. However, there are certain safety shortcomings involving use of live fuses in electrical switchboards without disconnects or circuit breakers. Substitution of circuit breakers would improve

both personnel safety and operating reliability.

The Municipality of Salt's sewer system is being adapted from an old Turkish system to a modern, piped system from which stormwater is being excluded. Slopes are steep due to the hilly terrain, making for relatively high flow velocities and sewer capacities.

Salt has an extended aeration treatment plant with open drying beds for secondary sludge from the aeration tank. The plant's rated capacity is 3,510 cu m/da, corresponding to a tributary population of about 50,000 persons. The current connected population is estimated at about 14,000 persons and the future connected population may be as high as 66,000 persons by year 2000, if all dwellings were connected.

The Salt treatment plant is adequate for the present and is underloaded. Effluent is discharged to Wadi es Salt, thence to Wadi Shu'eib. There are certain improvements that could be made to the plant to improve electrical efficiency and process reliability. Eventually, some enlargements will be required, but not before year 1990. Sludge is aerobically digested in the process and residues are dewatered on open drying beds.

The King Hussein Medical Center (KHMC) has its own gravity collection system for wastewater and an extended aeration treatment plant. The capacity of this plant (450 cu m/da) is exceeded by present wastewater flows (800 cu m/da). It is planned to replace the existing plant in the relatively near future with a 1,500 cu m/da capacity extended aeration plant. This should be adequate both for the current loads and those to be experienced from the expanded KHMC. Some of the effluent is presently used for irrigation of local landscaped areas. The remainder discharges down Wadi es Sir. Aerobically digested sludge residues from the process are dried in open beds.

Wastewater flows not presently being accommodated by AGTP, Salt Treatment Plant or KHMC Treatment Plant are discharged into cesspools. It is estimated that about 59,000 cu m/da of septage were being generated in the Study Area in 1979, as compared with about 21,000 cu m/da being treated in AGTP and KHMC TP. Much of the discharge came from unsewered areas within Amman itself.

Inasmuch as a relatively large concentration of population is located over a limited portion of the underlying groundwater aquifers, the relative impact of septage discharges from Amman in particular and the larger population centers clustered near Amman is considered high. In contrast, smaller outlying population centers are usually widely separated. They have less generalized impact upon the underlying groundwater basin than do the larger urban centers such as Amman.

Cesspool installations are commonly used in the Greater Amman Area, and these operate with varying degrees of success, depending upon loadings vis-a-vis capacity, soil conditions, and maintenance. In many instances, maintenance (pumpout) costs may be appreciable. A special Community Sanitation Reconnaissance during this study produced general information on these aspects.

Smaller builidng lots tend to have less space in which to locate both buildings and cesspools than do larger lots, sometimes tending to make cesspool disposal somewhat more difficult in smaller lots.

If no unprogrammed sewerage facilities were to be built in the Greater Amman Area, the continuing growth would result in substantial quantities of septage still discharging to the underground via cesspools. The corresponding numbers for 1990 and year 2000 are 45,000 and early 57,000 cu m/da, respectively. In areas where subsurface disposal conditions are poor or marginal, there are prospects for increasing failures of cesspool systems or, alternatively, increased pumpout costs.

CHAPTER 7 - CONSERVATION AND MANAGEMENT OF RESOURCES

Major Jordanian institutions managing water affairs are the Natural Resources Authority (NRA), the Water Supply Corporation (WSC), the Jordan Valley Authority (JVA), and the Amman Water and Sewerage Authority (AWSA). All except NRA also have management authority over sewerage systems within their jurisdictions. Consideration is being given to creation of a National Water and Sewerage Authority.

Jordan, including the Greater Amman Area, is already seriously water-deficient. This condition will worsen as growth and development continue. At present the sole source of supply within the Study Area is groundwater drawn from wells and springs.

The local groundwater is already being overdrawn under current demands. Local groundwater mining will continue unabated until imported supplemental supplies, from Azraq Wellfield, Qastal Wellfield and the East Ghor Canal (fed by the Yarmouk River) arrive at Amman and vicinity. There will still be a need for additional imported supply. Among the alternative sources being considered are the Euphrates River in Iraq, and the King Talal Reservoir.

King Talal Reservoir lies within the Study Area and impounds flow from the Seil Zarqa, including effluent discharged from the AGTP. King Talal water is currently used for irrigation in the Jordan Valley. If some of the reservoir yield were to be recycled to Amman for municipal water supply supplement, water quality considerations would become of much greater concern than they are at present. Recycling would also increase the reservoir yield. Mineral salts concentrations would tend to rise but would level off before reaching unacceptable limits.

King Talal Reservoir will soon receive increasing flows of wastewater treatment plant effluent from the AGTP, the soon-to-be-completed Jarash Treatment Plant, and the programmed Zarqa-Ruseifa Treatment Plant. A Baqa'a Valley Treatment Plant would also contribute effluent to King Talal Reservoir via Wadi Rumeimin.

Wadis originating within the Study Area supply two other reservoirs, both located within the Jordan Valley. The Kafrein Reservoir, on Wadi el Kafrein, is used for irrigation supply. Potential treatment plants serving lower Wadi es Sir and Na'ur

would discharge effluent feeding this reservoir. Shu'eib Reservoir, on Wadi Shu'eib, is used for groundwater recharge. The Salt Treatment Plant effluent discharges into the Wadi Shu'eib main tributary, but apparently the effluent does not reach the Shu'eib Reservoir as surface flow normally. A treatment plant serving Fuheis and Mahis would contribute effluent to this wadi system.

Water pollution control legislation in Jordan is not yet comprehensive. Current legislation is not always adequately applied. The Government is considering recommendations for strengthening water pollution control laws and their means of implementation.

Water pollution monitoring is carried out by NRA for groundwater conditions and by the Royal Scientific Society (RSS) for surface waters. Monitoring results generally show increasing degradation of both surface waters and groundwaters. This is due to discharges of wastewaters and effluents. Most surface water sampling has involved the Seil Zarqa and, more recently, King Talal Reservoir. Seil Zarqa flow, including contributions from AGTP, is used for agricultural irrigation on certain riparian lands en route to King Talal Reservoir. This flow does not have the benefit of any reservoir dilution or retention prior to use. It is doubtful if normally applicable bacteriological standards for irrigation use can be met by the present flow or by the flow anticipated in the future influenced by the discharge of effluent from an expanded and upgraded AGTP.

With respect to potential drinking water application, there would be anticipated difficulties with meeting standards for virus, coliform bacteria, and nitrates, as a minimum.

Due to the serious water shortages in the Study Area, possibilities of planned reuse of treatment plant effluent are discussed. Indirect recycling already occurs and planned recycling via King Talal Reservoir is being considered. Groundwater recharge with reclaimed effluent should be considered on a case by case basis. Direct domestic recycling is unacceptable because of health hazards. Agricultural irrigation appears to be the most feasible of various alternatives for effluent reuse because water quality requirements are generally the least stringent.

JVA is interested in capturing the maximum quantity of treatment plant effluent discharged into the wadis draining into the Jordan Valley so that the irrigation supply there may be augmented. Analysis of design criteria used in planning the East Ghor Canal, South Zone, indicates a likely seasonal variation in irrigation demand in the Jordan Valley varying between a winter low of about 44 percent of average annual demand to a summer high of about 133 percent of average annual. To meet such a demand variation requires regulatory storage, even for essentially uniform sources of future supply from wastewater treatment plants in the plateau area. The existing regulatory storage on Seil Zarqa, Wadi Shu'eib and Wadi el Kafrein would assist in this function, as would flexibility of diversion into the East Ghor Canal. To maximize conservation of effluent runoff to the Jordan Valley and to minimize wet year losses by reservoir spills would require additional storage.

A recent engineering report to JVA indicates a feasibility of enlarging King Talal Reservoir from 44 million cubic meters (MCM) of live storage to about 64 MCM capacity. Projected annual effluent flow from AGTP for year 2000 is about 80 percent of the existing capacity of King Talal Reservoir and 55 percent of a possible enlarged capacity.

Land resources in Jordan in many instances have suffered from overgrazing, wind and water erosion, and deforestation. Recovery of forestlands is more feasible in the northern highlands than in the southern, due to greater rainfall. Under carefully developed programs, use of digested sludges and even treatment plant effluent might be helpful in restoration of forest lands and even agricultural lands.

Jordan is energy deficient. There are relatively limited prospects for hydroelectrical power developments in Jordan. Wastewater systems should minimize energy demands wherever feasible. Wastewater treatment plants located at the higher plateau elevations would have potential energy advantages over those located at lower elevations from the standpoint of potential future deliveries of reclaimed effluent to possible reuse points on the plateau.

CHAPTER 8 - WASTEWATER COLLECTION, TREATMENT AND DISPOSAL ALTERNATIVES

Interim effluent quality standards are proposed for the upgraded AGTP and other secondary treatment plants which will discharge their effluent into the wadis of the Study Area. Such interim standards recognize the impracticality of fully achieving bacteriological quality suitable for irrigation with such secondary effluents but at least of improving upon the present quality experienced with AGTP effluent. Tertiary treatment, involving effluent filtration, would be necessary to meet the irrigation standards. For reasons of cost, it is not possible to include this treatment in the initial program for wastewater treatment. It is included as a long range objective as is denitrification.

The development of alternatives assumes that industrial wastes control measures will be fully implemented by 1990. This will provide time for affected industries to make their necessary internal improvements and for official agency control programs to be developed and implemented. However, extremely hazardous waste discharges, such as mercury wastes, should be discontinued immediately.

Initial development of alternatives considers the sub-basins of the three major watersheds of the Greater Amman Area. The sub-basins of the largest watershed within the Study Area, that of the Jordan River, are designated as the Seil Zarqa, the Northwestern, the Western, and the Southwestern. The Dead Sea Basin has the next largest watershed within the Study Area and has Southern Sub-basins. The Azraq watershed is barely within the Study Area, has no significant population, and is not of relevance to this Master Plan.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Sub-basins are formed by topography, which tends to limit the possibilities for linking of communities in adjacent sub-basins into common wastewater systems, except under unusual circumstances. Sub-basins also determine the routes which treatment plant effluents will normally take.

Amman, Zarqa, Ruseifa, and several other urban areas lie within the Seil Zarqa Sub-basin. Within the future AWSA system there are a number of wastewater collection alternatives that are considered and resolved. The analyses involve possibilities for connecting peripheral areas westerly of Amman to the AWSA network, either by gravity or by pumping. The findings are:

- A special analysis will be required subsequently in the report to determine whether or not an upstream treatment plant in southern Wadi es Sir, the Upper Wadi Abdoun Treatment Plant (UWATP) should be built in order to facilitate upper plateau reuse of reclaimed water and to minimize the need for AWSA primary network enlargements and downstream treatment plant capacity requirements, assuming the inclusion of developed and developing areas westerly of Amman into the AWSA system. If the UWATP is to be implemented, its site should be at a high elevation, on or near the watershed divide between the Seil Zarqa Sub-basin and the Western Sub-basin.

- The portions of Suweileh that drain to the north contain the bulk of the population of that community, including most of the urban poor and the majority of cesspool installations having operational difficulties. Sewers should be provided for north-draining Suweileh. If a Baqa'a Camp sewer system and treatment plant were not soon to be implemented, wastewater from north-draining Suweileh should be pumped across the watershed divide separating the Northwestern Sub-basin (Baqa'a Valley) and the Seil Zarqa Sub-basin. The flow would then be conveyed southerly in a new gravity trunk sewer to serve this area. Although such a pumping alternative is somewhat more costly than gravity sewerage to a potential Baqa'a Valley Treatment Plant, the advantages of the pumping alternative outweigh this cost disadvantage, unless Baqa'a Valley Treatment Plants soon to be implemented.

- There should be a new gravity trunk sewer running southerly from the University of Jordan area to a possible UWATP or else to the AWSA primary network. Inasmuch as this area and downstream areas are already fairly well developed and continue to grow, the sewer should be scheduled for fairly early implementation. Without an early Baqa'a Valley Treatment Plant project, the sewer would also serve north-draining Suweileh, at least for several years. It would be economical to abandon the University Pumping Station that now pumps wastewater from the University area across an intervening hill into the AWSA system and to discharge instead by gravity into the new trunk sewer. Because of the cost advantage and other benefits this alternative is recommended.

- King Hussein Medical Center (KHMC) will proceed with its local treatment plant project on the premises and operate in this manner until such time as a gravity sewer can be constructed to connect it to UWATP. During the interim, great care should be exercised in the operation of the new plant to ensure protection of public health and the environment. The new gravity trunk sewer will serve south-draining Suweileh and intermediate points southerly of KHMC as well as KHMC.

- The portion of the Municipality of Wadi es Sir which lies within the Western Sub-basin should not be included in the trunk sewer system that will feed the UWATP or, if UWATP is not implemented, the AWSA primary network. The costs for including lower Wadi es Sir in this trunk sewer system are hardly any less than those for providing a local Lower Wadi es Sir Treatment Plant that would serve the area by gravity. However, the disadvantages in the extensive pumping that would be required to include lower Wadi es Sir in the AWSA system are so great that this prospect should be eliminated and a local Lower Wadi es Sir Treatment Plant planned for.

- The Marj al Hammam area is developing rapidly and will require sewer service at a fairly early date. It would be somewhat more economical for wastewater from this area to be conveyed by gravity into the AWSA primary network by a new trunk sewer than for the flow to be pumped either to a possible UWATP or to a future Na'ur Treatment Plant. Gravity flow to AWSA would normally be recommended except for the additional capacity required thereby such as in the primary network and, particularly, at AFTP. Thus, pumping to UWATP appears advantageous.

At Ain Ghazal Treatment Plant (AGTP) basic treatment alternatives for the future expanded and upgraded plant are activated sludge with mechanical aeration (TA1) and roughing filters followed by activated sludge (TA2). (TA1) uses more energy than TA2 and but costs less to construct. It requires less space than the latter, so a larger capacity plant could be sited with the former than the latter in the same space. However, bth TA1 and TA2 are quite close in total cost when energy aspects, including energy recovery, are taken into account, and thus TA2 is recommended.

Anaerobic digestion of sludge solids at AGTP is more advantageous than aerobic digestion or thermal treatment, which were also considered. The primary advantages are in energy savings, but there is also an advantage in familiarity to operating personnel and relative simplicity of the process. Dewatering of digested sludge is best performed mechanically at AGTP by means of belt presses. They are the least energy consuming of all practical alternatives for sludge dewatering, and they cost no more than the next most favorable method, vacuum filters.

It would be energy-conservative and economical for digester gas engine generators to be installed at AGTP and operate on the combustible gases produced from anaerobic digestion of sludge solids. The electricity thus produced would be

used to help power the mechanical aeration equipment and other electrical equipment. The waste heat from the engines would be used to heat the incoming sludges to the digesters.

The AGTP, when enlarged to the maximum capability of the site, will be inadequate to receive all the future projected wastewter flow, even with implementation of an upstream plant. It will be necessary eventually for there to be a downstream plant adjoining the Seil Amman at Kharbet er Ruseifa. This will not be needed until after 1990, and its required capacity will reflect whether or not the upstream plant at the extension of Wadi Abdoun is implemented. The recommended treatment for Kharbet er Ruseifa Treatment Plant (KRTP) and for Upper Wadi Abdoun Treatment Plant (UWATP) if built, would be roughing filters followed by mechanical aeration activated sludge. Anaerobic sludge digestion would be recommended for KRTP, but UWATP would not process sludge, for reasons of simplicity and making the plant more acceptable in a new industrial area. Instead, process sludges would be discharged into the AWSA primary network and would be recovered and processed at AGTP and KRTP.

The trickling filter plant proposed under a separate study for the Zarqa- Ruseifa area should be implemented. Sludge drying beds should be used initially, as proposed, for dewatering of digested sludge. The plant will require enlargement in the future, somewhat earlier than contemplated by the previous study, because of the recommended inclusion, as soon as possible, of the East Marka area and Schneller Camp. When plant enlargements are made, there will no longer be sufficient space for sludge drying beds, and belt presses for mechanical dewatering should be provided.

Downstream of the Zarqa-Ruseifa Treatment Plant, a small treatment plant should be provided for the community of Sukhneh. A similar plant should be provided for Hashimiya across the ridge to the east. It would be uneconomical to provide a single plant for the two communities. Each community's plant should be of the facultative lagoon type and should be so sized as to cause the treated water to evaporate, thereby totally containing the effluent. Land availability and reasonably low costs favor this type of treatment, which is quite simple to operate and uses no external power. No significant sludge production would occur, but some accumulation in the lagoons might become noticeable after many years of operation.

For the Northwestern Sub-basin, a single treatment plant in Baqa'a Valley is proposed and would accommodate, by a gravity collection system, Baqa'a Camp, the small valley communities of Safut and Ain al Basha, and the hillside portion of Suweileh that drains to the north. The flows would be too great to permit consideration of lagoon type treatment or even of the simplified modification of activated sludge treatment known as extended aeration. Instead, conventional activated sludge treatment with separate anaerobic digestion and dewatering on open drying beds should be provided. Plant layout would anticipate future connection of Abu Nusair.

In the Western Sub-basin, analysis of alternatives shows that that it will be economical to link the communities of Fuheis and Mahis in a common system contributing to a single treatment plant. Pumping of wastewater from Mahis to Fuheis will be required. It will not be economical to include other communities. Extended aeration treatment will be appropriate for the plant. There is insufficient land available for lagoon treatment. Sludge drying beds will be used to dewater the modest quantities of sludge produced by this process.

The existing Salt Treatment Plant should continue in operation. Sometime between 1990 and year 2000, it is anticipated that the plant will require enlargement of about 1,000 cu m/day.

In the Southwestern Sub-basin, Lower Wadi es Sir should be provided with a separate treatment plant. It would not be economical to include the small communities of El Bassa and Um Nuwwara in this wastewater system. Space limitations preclude the use of lagoon type treatment for Lower Wadi es Sir Treatment Plant; thus the compact and effective extended aeration type plant is recommended. Sludge drying beds would be provided.

The Municipality of Na'ur is also in the Southwestern Sub-basin but is too far removed from Lower Wadi es Sir to be joined with it in a wastewater system. Na'ur should have its own treatment plant of the extended aeration type, the site limitations favoring this method.

In the Southern Sub-basin, the terrain is less steep and the land for treatment plants relatively inexpensive in comparison with many other plateau areas. Also the communities to be served are not very large. These factors favor the use of facultative lagoon treatment plants. Analysis shows that there should be two such plants in the Southern Sub-basin: one serving the Municipality of Sahab by itself; and a community plant to which Abu Alanda, Khirbet es Suq, and Juweideh would contribute via a common collection system involving certain pumping stations. The flow would be totally contained. Moderate accumulations of sludge in the lagoons would take place after many years of operation.

Within the Greater Amman Area, no direct effluent reuse applications have been identified, save for the modest landscape irrigation at KHMC. Future applications are still quite indefinite and will take at least several years to develop. In the meantime, however, incidental, indirect reuse will continue and expand by diversions from receiving wadis and irrigation deliveries from the storage reservoirs in Jordan. Irrigation appears to be the most promising future type of reuse application. This may eventually include plateau areas as well as the Jordan Valley and riparian areas along wadis.

Sludge use has not yet developed on any organized scale in the Greater Amman Area. Research in applying AGTP digested sludge to experimental agricultural lands in the Jordan Valley is continuing. Interest is already fairly high in the possibilities of using digested sludges in trial programs for wastershed reforestation. If successful, these could be expanded greatly and with increased benefit. The applications could probably eventually be extended to agricultural

applications, but this would first require deliberate development of a carefully controlled program over a period of several years. In the meantime, disposal of digested sludges to approved landfills will have to be practiced. This will include all wastewater treatment plants within the Greater Amman Area.

There are two approved landfill areas: one at Muwaqqar and the other east of Sahab near Zumlet al Alya. A third, but less suitable, possibility may exist at Yajuz, some 20 km northwest of Amman. Complete protection of the underlying groundwater against leaching of pollutants is a requisite of these landfill sites. It will be necessary for the sewage treatment plant digested sludges to be transported to these sites, particularly those near Muwaqqar and Sahab for disposal. This must be done until such time as land could be committed for sludge use so as to enhance the environment or dedicated for disposal but in a manner not damaging to the environment.

The most flexible and economical means of conveying digested sludge to the approved landfill area near Muwaqqar is in a dewatered state via truck. This holds true for all treatment plants and would also be true for the site northwest of Amman, if found acceptable. A comparison of wet transport of sludge via pumping and pipeline from AGTP, of wet transport of sludge via tank truck from AGTP, and dry-trucked transport from AGTP showed clearly the relative economics of dry-trucked transport.

CHAPTER 9 - MASTER PLAN

Wastewater and sludge management alternatives that were found to be viable in the initial screening of Chapter 8 are subjected to engineering, cost, and environmental analysis. Alternatives are then ranked on a regional basis according to priorities for implementation under a Master Plan program.

As a result of case by case investigations of local conditions, the following percentages of potential populations to be connected to sewers in the future are used in the Master Plan development:

	1990 Connected to Sewers		2000 Connected to Sewers	
Community	Percent	Population	Percent	Population
Amman	79	805,000	96	1,253,000
Suburban Ring (of Amman)	59	44,000	96	240.000
Zarqa-Ruseifa	65	250,000	72	391,000
Salt	90	42,000	98	65,000
Suweileh*	56	17,100	98	42,600
Wadi es Sir**	92	35,300	98	60,300
Baqa'a Valley***	94	63,200	95	73,400
Fuheis/Mahis	52	6,700	53	9,500

Na'ur	57	4,000	69	6,900
Sahab	65	11,000	67	16,100
Sukhneh	60	3,600	70	5,600
Hashimiya	50	3,000	60	4,800

	1990 Connected to Sewers		2000 Connected to Sewers	
Community	Percent	Population	Percent	Population
Abu Alanda/ Khirbet es Suq/ Juweidah	73	11,000	73	15,300

* Suweileh straddles the watershed divide between the Northwest Sub-basin (draining to Baqa'a Valley) and the Seil Zarqa Sub-basin (draining) through Amman and Zarqa, thence to King Talal Reservoir. Total sewered population is shown. The north draining portion of Suweileh is also shown in the Baqa'a Valley numbers.

** Wadi es Sir straddles the watershed divide between the Seil Zarqa sub-basin and the Western Sub-basin draining to Kafrein Reservoir. Total sewered population is shown.

*** Includes Baqa'a Refugee Camp, portion of Suweileh, and the small communities of Safut and Ain al Basha.

Basic wastewater collection alternatives for AWSA are designated CA1 and CA2. Under both alternatives, it is assumed that wastewater flows from Amman, the University of Jordan and vicinity will be augmented by future contributions from Suweileh, upper Wadi es Sir, and portions of the Suburban Ring and that the flows originating westerly of Amman will mostly be directed into the AWSA primary network in the upper reaches of Wadi Abdoun. Alternative CA1 assumes the contruction of the Upper Wadi Abdoun Treatment Plant (UWATP) and diversion to it of as much of the peripheral wastewater contributions as possible. (The jurisdiction over UWATP could be by AWSA or other appropriate governmental agency). Alternative CA2 assumes no construction of UWATP.

The required capacities of the AWSA plants, depending upon whether or not UWATP is provided are shown below in 1,000 cu m/da.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Treatment Plant	1990 CA1	1990 CA2	2000 CA1	2000 CA2
AGTP	60	75	75	75
UWATP	8	-	20	-
KRTP	(7) *	-	56	76

* Would not actually be built; rather flow build-up would be curtailed, if necessary (by limiting new sewers/connections) to avoid premature need for KRTP.

In addition to having differing effects upon the treatment plant capacities required, CA1 and CA2 have differing effects upon the trunk sewer relief requirements for the existing AWSA primary network. Under CA1, the trunk sewer relief requirements for handling year 2000 flows are less than for CA2 in terms of pipe sizes and lengths.

The proposed treatment facilities at AGTP, UWATP, and KRTP would incorporate roughing filters and activated sludge as the basic process and would produce an effluent substantially better than that presently possible from the existing AGTP. However, the bacteriological quality of the effluent would fall somewhat short of normally used standards for irrigation unless effluent filtration were to be included. It is not presently justified to undergo the additional cost of effluent filters in the initial program. Therefore, they are deferred indefinitely but kept as a long range objective in connection with the improvement of water quality, pending additional study and evaluation.

Similarly, it is not presently warranted to include denitrification facilities because of the questionable benefits in relation to the considerable expense. Denitrification is also deferred indefinitely, pending additional study and demonstration of need in connection with improvement of groundwater quality.

Effluent quality standards to be met by the various treatment plants discharging effluent to wadis are as follows:

Item	By 1990	By 2000
Secondary Treatment Effluent Quality		
Suspended Solids (SS), mg/l	50	30
Biochemical Oxygen Demand, (BOD_5), mg/l	50	30
Coliform Organisms, MPN/100 ml	20,000	2,000
Tertiary Treatment Effluent Quality		
SS mg/l	-	5
BOD_5, mg/l	-	10
Coliforms, MPN/100 ml	-	2.2
Nitrate, mg/l	-	45

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The treatment alternatives for the AWSA plants are designated as TA2 (roughing filters-activated sludge), TA3 (future filtration and denitrification added) and TA4 (no additional treatment beyond that now programmed). These same classifications of treatment alternatives are also used for the Baqa'a Valley Treatment Plant, while comparable classifications are used for the smaller treatment plants serving outlying communities and incorporating the activated sludge process. For the latter, the third treatment alternative signifies no-project.

Activated sludge plants already exist at Ain Ghazal, KHMC, and Salt. This process has fairly high operational and maintenance requirements in comparison with some of the simpler processes. Activated sludge plants are being proposed for three outlying areas in spite of this aspect, because the process has high performance capabilities but has only minimal site requirements. Limitations on available sites and substantial land costs are contributing reasons to the selection of the activated sludge process. Due to the need for maintaining good plant performance, it will be necessary for AWSA and other operating agencies to recruit and retain competent operating and maintenance personnel, even if this means higher labor costs than are customary.

Effluent from AGTP and KRTP will be discharged into the Seil Amman. It is assumed that flows from Seil Amman/Zarqa will continue to be diverted for riparian irrigation. Effluent from UWATP, under Alternative CA1, will have considerable flexibility as to its disposition. In addition to being divertable by gravity either to Seil Zarqa Sub-basin (King Talal Dam) or Southwestern Sub-basin (Kafrein Dam), the effluent could be pumped to the Southern Sub-basin if desired. This is due to the high elevation and strategic watershed divide location of UWATP. Effluent could also be available from an advantageous position for future reuse on the plateau when demand for this develops.

Both the AGTP and KRTP will employ anaerobic sludge digestion and digested sludge dewatering by belt presses. UWATP will not process sludge, for reasons of making the plant more acceptable in a developed area. Instead, the raw and waste activated sludges from UWATP will be discharged to the AWSA primary network via a separate sludge line, and the sludges will be recovered and processed at the AGTP and KRTP. Total sludge production would be the same under both alternatives CA1 and CA2.

Dewatered digested sludge will be hauled by truck to a new landfill near Muwaqqar where local subsurface conditions eliminate any hazard to the groundwater. Programs will be developed leading to future beneficial use of the sludge for reforestation and, eventually, for agriculture, both under carefully controlled conditions.

Out of considerations of disposition of plant effluent and digested sludge as well as integrity of system facilities and safety of operating personnel, it will be necessary to exclude harmful industrial wastes from the sewer system tributary to the AWSA treatment plant and other plants. This will require the establishment

and enforcement of effective industrial wastes control ordinances and programs. On-site measures, such as recycling and pretreatment, may be necessary in some cases.

Hard detergents have not proven a problem in the case of the three operating treatment plants in the Study Area. Unless some unforeseen circumstance arises, they will not prove a problem in the future plants.

The Baqa'a Valley Treatment plant and three other outlying plants that are being proposed are as follows:

Communities Served	Location Sub-basin	Capacity 1,000 cu m/da 1990	2000	Effluent to
Baqa'a Valley	Northwestern	2.80	3.70	Wadi Rumeimin
Fuheis/Mahis	Western	0.45	0.70	Wadi Shu'eib
Lower Wadi es Sir	Western	1.20	1.90	Wadi el Kafrein
Na'ur	Southwestern	0.24	0.48	Wadi el Kafrein

These plants and the areas which they serve reflect the only viable collection alternatives from the initial screening. Pumping of flow from Mahis to Fuheis is required. Otherwise, all systems operate fully by gravity.

The largest plant (Baqa'a Valley) would employ roughing filters followed by conventional activated sludge with separate (anaerobic) digestion. The three other plants would use the extended aeration modification of activated sludge, whereby sludge is digested and reduced in volume during the aeration process. In all four plants, dewatering of sludge would be on open drying beds with disposal to approved landfills. Eventually, beneficial use of the sludge would be developed.

In four other outlying areas to be sewered, the flows are sufficiently small, terrain relatively flat, and land costs representative of rural areas, so that facultative lagoons are the favored alternatives for treatment. This process relies upon solar energy for algal growth and oxygen production. While the treatment is not as effective as activated sludge, the energy costs are negligible and operation and maintenance requirements are much less than for activated sludge. It is proposed to make the lagoons sufficiently large as to contain the treated wastewater totally, thus preventing the discharge of any effluent to surface waters. Green belt irrigation may be practiced under controlled conditions to ensure compliance with public health considerations. The total containment lagoon installations are:

Communities Served	Location Sub-Basin	Capacity 1,000 cu m/da 1990	2000
Sukhneh	Seil Zarqa	0.25	0.45
Hashimiya	Seil Zarqa	0.21	0.39
Sahab	Southern	0.66	1.30
Abu Alanda/Khurbet es Suq/Juweideh	Southern	0.66	1.10

The Sukhneh and Hashimiya collection and treatment systems would operate completely by gravity. Both the Sahab collection system and that of Abu Alanda/Khirbet es Suq/Juweideh would involve some pumping in addition to gravity flow.

The total containment lagoons would not produce sludge regularly, but after many years there could be some bottom accumulation requiring removal. Treated wastewater would normally evaporate, but consideration would be given during design to the possibilities of controlled landscape irrigation with some of the flow. The lagoons would be designed to prevent leakage to the underlying groundwater.

For Zarqa-Ruseifa area, Seil Zarqa Sub-basin, a tricking filter plant is already programmed and is included in the Master Plan. Effluent quality should generally be equivalent to that of the activated sludge plants in this Master Plan, particularly if polymer addition is practiced when needed. Effluent will discharge to the Seil Zarqa. Anaerobically digested sludge will be dewatered for an interim period on open drying beds. When flows increase sufficiently, the 24,200 cu m/da capacity first stage plant will be enlarged to 41,200 cu m/da, at which time sludge drying beds will be supplanted by belt presses for mechanical sludge dewatering. Sludge disposal and use will be similar to that for the AWSA plants.

Cost analyses of the various wastewater alternatives or systems being proposed are summarized as follows, the data being presented on a per capita basis in JD/capita:

Area Served	1990 Invest.	1990 Ann. Cost	2000 Invest.	2000 Ann. Cost
Amman & Vicinity Alt. CA1	47	8.0	32	7.5
Sukhneh	119	14.5	29	12.9
Hashimiya	158	19.3	34	16.1
Baqa'a Valley, incl. north-draining Suweileh	68	9.2	12	10.0

Fuheis/Mahis	133	20.1	10	17.6
Lower Wadi es Sir	117	15.1	24	14.5
Na'ur	113	17.9	25	15.0
Sahab	99	11.7	17	10.0
Abu Alanda/Khirbet es Suq/Juweideh	126	14.9	2	11.0

The various alternatives showed annual unit expenditures of energy expressed on the basis of kwh/capita/yr, as follows:

Area Served	1990	2000
Amman and Vicinity	15.1	16.0
Sukhneh	Negl.	Negl.
Hashimiya	Negl.	Negl.
Baqa'a et al	18.0	23.4
Fuheis/Mahis	62.7	64.2
Lower Wadi es Sir	20.3	30.7
Na'ur	55.0	52.2
Sahab	0.4	0.6
Abu Alanda et al	1.3	1.0

An environmental ranking of alternatives was made according to the effects upon water resources, public health, agricultural and silvicultural resources, and energy resources. These had been identified in the project's environmental scoping conference as the major environmental concerns to be addressed in the project. Lesser factors that were also identified and included in the rankings were: archaeological and historical resources, terrestrial biota, aquatic biota, land use, and construction impacts.

The environmental rankings were used to select among local alternatives for collection, treatment, sludge dewatering, effluent use/disposal, sludge transportation, and sludge use/disposal. On this basis, Collection Alternative CA1 (involving construction of UWATP) was selected over Alternative CA2.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Regional priority ranking of local projects was undertaken on those local projects selected from the environmental rankings. Ranking factors were applied for both 1980-1990 and 1991-2000 periods. The ranking factors used were:

- Per capital annual cost
- Per capita total investment
- Per capita annual energy consumption
- Relative benefit on removing cesspool discharges from the underground
- Income levels benefitted
- Project flexibility
- Competing community needs
- Other environmental considerations (than those above)

As a result of the regional rankings, the following priorities were established:

Rank	Area Served	Wastewater Projects to be Implemented 1980 to 1990	1991 to 2000
1	Amman & Vicinity	Upgrade & enlarge AGTP Construct UWATP Reinforce AWSA trunks Construct new trunk from University of Jordan area southerly to UWATP. Connect KHMC to UWATP. Provide sewers for north-draining Suweileh, gravity flow to Baqa'a Valley TP. Pump flow from Marj al Hammam to UWATP. Construct new trunk to Zarqa-Ruseifa network to serve Schneller Camp and housing project (if Schneller is to be served).	Enlarge AGTP to ultimate Enlarge UWATP Reinforce AWSA trunks. Complete new trunk from south-draining Suweileh to UWATP. Construct KRTP. Provide sewers from East Marka to Zarqa-Ruseifa network. Sewer Schneller Camp and Airport housing (if not already accomplished).

Rank	Area Served	Wastewater Projects to be Implemented 1980 to 1990	1991 to 2000
3	Baqa'a Valley	Sewer Baqa'a Camp Construct trunk sewer and treatment plant for the Camp, north-draining Suweileh, Safut, and Ain Al Basha.	Enlarge Treatment Plant. Provide for future connection of Abu Nusair.
4	Abu Alanda/ Khirbet es Suq/	Construct trunk sewers and treatment plant Construct 2 pump stations and force mains	Enlarge treatment plant
5	Lower Wadi es Sir	Construct trunk sewers and treatment plant	Enlarge treatment plant
6	Sukhneh	----	Construct trunk sewers and treatment plant
7	Hashimiya	----	Construct trunk sewers and treatment plant
8	Na'ur	----	Construct trunk sewers and treatment plant
9	Fuheis/Mahis	----	Construct pump station and force main Construct trunk sewers and treatment plant.

For communities who, because of priority rankings for sewerage improvements may not receive such improvements for several years, certain interim measures should be taken for improvement of local wastewater sanitation conditions. Physical arrangements may range from construction of on-site community subsurface treatment-disposal systems to construction of off-site facilities (usually lagoons) supplied by septage tank truck and/or small diameter pipelines. Local cesspools requiring pumping out fairly frequently to prevent overflows could be scheduled for such operations on a regular basis through the auspices of an on-site wastewater management district or equivalent. Many variations are possible, and selection of the best arrangement for a specific community requires study of all the factors pertaining to that community. Costs need not be excessive provided all arrangments are carefully planned and implemented.

CHAPTER 10 - PRELIMINARY DESIGN AND COST ESTIMATES

Preliminary design criteria and data are presented for those wastewater facilities in the Greater Amman Area programmed for implementation during the Phase I Investment Program and occupying the highest priorities according to the Master Plan for Wastewater Disposal. Treatment facilities in this program include the improvements and enlargements at Ain Ghazal Treatment Plant (AGTP) as well as the initial construction stage for the Upper Wadi Abdoun Treatment Plant (UWATP). Collection facilities comprise initial reinforcement of the primary sewer network of Amman Water and Sewerage Authority (AWSA), a new gravity trunk sewer draining University of Jordan (U of J) and vicinity, a gravity sewer connection of KHMC to UWATP, a new pumping station and force main/gravity trunk sewer connecting the Marj al Hamam area to UWATP, and secondary network facilities in newly sewered areas.

The work at AGTP will necessitate utilization of the 2.5 hectare parcel of vacant land between the municipal slaughterhouse and the Administration Building and parking area at AGTP. This land is owned by the Municipality of Amman, and a small portion of its includes the dump manhole used by both municipal and private septage tank trucks. The parcel of vacant land together with the existing AGTP site will comprise some 7.0 hectares. This will be adequate not only for 60,000 m^3/day capacity AGTP secondary facility required for the Phase I Investment Program and 75,000 m^3/day secondary capacity required during 1990-2000, but also for the sludge processing facilities commensurate with these capacities. In addition, a portion of the combined site, on the northeast side, will be withheld from development, pending potential future requirements for effluent filtration.

The work at AGTP will be so designed and programmed as to eliminate existing deficiencies and augment and upgrade treatment capacity while maintaining continuity of service. Such a program will involve orderly staging of individual construction items as follows:

- New influent sewer and headworks including influent pumping station, mechanically raked barscreens, aerated grit removal and provision for polymer addition to primary influent. These will not be placed into service until the new treatment facilities in the currently vacant site (southern plant site) are completed.

- New facilities for storing and metering septage into the AGTP to smooth out shock loadings. These will involve discharge direct to the anaerobic digesters. There will also be aeration of the slaughterhouse wastes prior to treatment with the main process units. These facilities need not wait for construction of the new southern plant site treatment works.

- New primary sedimentation facilities, roughing filters, intermediate clarifiers, and mechanically aerated activated sludge facilities including secondary clarifiers, and chlorination facilities, all located in the southern plant site and having a nominal treatment capacity of 30,000 m^3/day, expandable to 45,000 m^3/day.

- Activation of the new influent sewer, common headworks, and southern plant site treatment facilities, once these have been completed and approved for service.

- Upgrading and expansion of the northern site facilities by selective improvements to the existing primary and secondary facilities and by introduction of roughing filters and intermediate clarifiers between the primary and secondary facilities, including sludge collection facilities. These improvements will make the capacity of the northern site facilities 30,000 m^3/day.

- Concurrent with the additions and conversions described above, three anaerobic digesters of 6,500 cubic meters capacity each and located in the northern plant site. A control building for these digesters would be included.

- Concurrent with the digester construction, conversion of the existing gravity sludge thickeners to dissolved air flotation type thickeners, for waste activated sludge processing prior to anaerobic digestion.

- Concurrent with the final digester construction, provision of a new belt press for digester sludge dewatering, to be located in the building currently being provided for sludge dewatering under a separate contract.

- Two gas engine generator units with appurtenances and housing on the northern plant sites, for cogeneration of power and heating of sludge being fed to the anaerobic digesters.

The work at AGTP described above will bring its sludged processing capabilities up to the point of accomodating 60,000 m^3/day of normal influent plus the return sludges from UWATP (which will not process sludge).

The estimated construction costs for the above-described improvements, stated in terms of late 1980 price levels are:

	JD 1,000	
Local	Foreign	Total
4,795	7,068	11,863

The foregoing costs are construction costs. Implementation costs are estimated to add 50 percent.

Selected design criteria upon which the recommended Phase I Investment Program AGTP improvements have been made are presented in Chapter 10. Belt press-dewatered sludge will be trucked to the Muwaqqar landfill. Five trucks will be required during 1982-83, and this will increase to nine trucks by 1990.

The AGTP will continue use of 220/380 volt electric power. Certain improvements in safety features will be made during the expansion. There will be limited instrumentation provided to facilitate process control by the operators. However, most controls will not be automatic and will rely upon the plant operators. Limited standby power will be provided sufficient for operating influent pumps and certain other loads during a posssible power outage.

The Upper Wadi Abdoun Treatment Plant (UWATP) will have an initial nominal capacity of 8,000 m^3/day, adequate for 1990 and anticipating a second stage capacity of 22,000 m^3/day, adequate for 2000. Plant features and design parameters are generally comparable to the new facilities proposed for AGTP; however, no sludge processing will be incorporated at UWATP. Rather, the raw and waste activated sludges will be discharged into the AWSA primary network via a connecting sewer. They will then be captured and processed at AGTP,

The UWATP Phase I Investment Program construction cost is estimated to be JD 0.71 million local, JD 0.63 million foreign, and JD 1.97 million total. Project cost would be 150 percent of these values.

The proposed collection system work for the Phase I Investment Program involves gravity sewers exclusively except for a pumping station and force main to connect Marj al Hamam to UWATP. KHMC will be connected to UWATP by gravity, and a new gravity trunk sewer will serve U of J and vicinity. Relief trunk sewers in the AWSA primary network will be sized to provide total trunk sewer capacities for the actual peak flows of 2000.

The estimated construction costs of the primary collection system improvements for the Phase I Investment Program, expressed in terms of late 1980 price levels, are as follows:

Collection System Element	Local	JD 1,000 Foreign	Total
AWSA Primary Network Relief	193	1.4	194.4
New Trunk, U of J and Vicinity to UWATP	561	5	566
Sludge Line, UWATP to AWSA Primary Network	57	53	110
KHMC to UWATP, Gravity Trunk Connection	209	2	211
Marj al Hamam Pumping Station	20	24	44
Marj al Haman Force Main	72	63	135
Marj al Hamam, Gravity Connection to UWATP	60	1	61
Primary Network Summary	1,172	149.4	1,321.4

The project costs comprise both construction costs and implementation costs and are taken as 150 percent of construction costs. Lateral sewer costs (secondary network) are shown in Chapter 12.

The implementation schedule for the various improvements is:

Item	Design	Construct
AGTP Phase IA	1982	1983-84
AGTP Phase IB	1982-83	1983-84
UWATP, including Sludge Line	1982-83	1983-85
Marj al Hamam Trunk (Gravity)	1982-83	1983-84
U of J to UWATP Trunk	1982-83	1983-84
AWSA Trunk Relief	1982-83	1982-85
KHMC Trunk	1982-83	1983-84
Force Main and Pumping Sta.	1982-83	1983-84

Lateral sewer construction would be coordinated with the foregoing.

CHAPTER 11 - PROJECT IMPLEMENTATION PLAN

The Master Plan for Wastewater Disposal in the Greater Amman Area involves major improvements and expansions in the AWSA wastewater collection and treatment system as well as new facilities for areas immediately westerly of AWSA, for Zarqa-Ruesifa, and for eight other communities or combinations of communities. The priorities established in the Master Plan favor early construction of the facilities for AWSA and immediate vicinity. Zarqa-Ruseifa facilities are already programmed. The eight other outlying area systems should follow as soon as funds are available and according to priorities.

AWSA already possesses ample legal authority to operate within its service area and, if necessary, outside its jurisdiction. The Water Supply Corporation (WSC) has authority to operate both waterworks and sewerage systems within Greater Amman outside of the AWSA area. WSC does not yet operate any sewerage systems in Greater Amman Area but is expected to do so within a few years. In the interim, AWSA is operating both the AGTP and King Hussein Medical Center Treatment Plant (KHMCTP). AWSA could also operate other facilities and might very well construct and operate the facilities westerly of AWSA, including the UWATP, tributary system, and Marj al Hamam collection system.

A National Water and Sewerage Authority is a possibility under consideration by the Government. If implemented, both AWSA and WSC might become departments within this Authority. Jordan Valley Authority (JVA) might do so also. Such an Authority could serve not only to plan, coordinate and operate facilities but also to establish uniform high standards of system operation, maintenance, and performance throughout Jordan.

There is a need for broadening, coordinating, and developing the legal basis for the protection of the public health and the environment in Jordan. There are also needs for increased public understanding of the importance of public health and environmental protection, particularly as regards wastes and wastewater disposal. Positive aspects, such as wastewater reclamation/reuse and beneficial use of digested sludges will require long term educational efforts for public acceptance.

Assuming that design and construction are adequate, the success of wastewater collection, treatment, and disposal facilities in meeting their objectives is highly dependent upon the quality of operation and maintenance provided. This is particularly true of treatment facilities where an understanding of the technical complexities of process control is very important, especially in the highest positions of responsibility but also including those in hour-to-hour charge of plant operation.

Competence in wastewater treatment plant operation is obtained by a combination of education, training and experience. Qualifications thus gained increase the wage-earning potential of technical and managerial staff persons in the open market. Thus, adequate remuneration and other incentives are essential if key experienced personnel are to be retained in service at treatment plants. This is a problem of which AWSA is aware. Current funding potentials and resulting personnel policies do not always permit recruiting and retention of the caliber of operators that might be desirable, particularly in the light of the wages offered by private industry in the Gulf States. Nevertheless, this problem must somehow be overcome for the treatment plant of the future to function adequately and reliably.

In addition to reducing staff turnover and maintaining an adequate number of plant personnel, the organization of such personnel according to responsibilities and lines of authority may be a factor in promoting good operation and maintenance. The present AGTP table of organization lists one management level staff, five supervisory level staff, 22 line staff, and 70 laborers for a total of 98 persons. The maintenance aspects are well covered, but experienced operators at the supervisory and line staff levels are not included. A proposed table of organization would include the same numbers of staff at each level and total but would establish three supervisory levels of authority corresponding to operations, maintenance, and laboratory, respectively, and would have specific positions of operations personnel and operators instead of having these functions filled by mechanics, welders, and electricians. Such an arrangement would not reduce the proper maintenance of the equipment but would lead to improvement of plant performance, particularly where trained operators were to be provided and limitations of plant and equipment corrected.

Some equipment and treatment unit limitations exist at AGTP, but these are programmed for correction in the Phase I Investment Program. However, it will also be important that improvements are made in the availability of spare parts if the future facilities are to function adequately. Currently at AGTP, certain specialized replacement parts must either be purchased locally at exorbitant prices or else ordered from the original equipment supplier with a 6 to 12 month wait for delivery.

An operator training program for AWSA personnel is to be implemented, and a training director has already been assigned and commenced program development. There will be a need for training of operation and maintenance personnel for AGTP, KHMCTP, UWATP, Salt TP, Zarqa-Ruseifa TP, and others within the Greater Amman Area. This will also be true for other areas in Jordan. A national

training center, if undertaken, would have several advantages, including efficiency, broadening the base of participation, and providing an increased variety of treatment plants and processes with which trainees could become familiar.

Total staff personnel needed for wastewater treatment plants in the Greater Amman Area for 1990 conditions are estimated as follows:

Plant*	Total Personnel**	
AGTP	109	(includes allowance for KHMCTP)
UWATP	12	
Salt	5	
Sahab	1	
Baqa'a Valley	6	
Abu Alanda	1	
Lower Wadi es Sir	4	
Sukhneh	1	
Hashimiya	1	
Na'ur	1	
Fuheis/Mahis	2	
TOTAL	143	

* Zarqa-Ruseifa TP has been studied by another consultant.

** At least two staff levels of responsibility are needed even in the plants showing only one person total, i.e. two levels, half-time.

CHAPTER 12 - FINANCING ANALYSIS AND REVENUE PROGRAM

Construction cost data for proposed facilities for the AWSA system expanded westerly and for eight independent systems within the Greater Amman Area are projected for future conditions in 1990, assuming annual inflation of 10 percent compounded. This inflation rate is assumed to apply equally to local costs and foreign components. The cost breakdown is made to indicate financing requirements from potential sources. Capitalized interest during construction is included as an added expense. The costs shown herein are calculated at 150 percent of construction costs.

Total Phase I Investment Program costs for house connection, lateral sewers, trunk sewers, pumping stations, force mains, and treatment plants are summarized below. The basic numbers are expressed in late 1980 price levels. Numbers in parentheses ( ) represent the aggregate costs corresponding at the various years of expenditures, including and illustrating the effects of inflation.

System	Local Costs	In 1,000 JD Foreign Components	Total Costs
Expanded AWSA (including AGTP, UWATP, service to KHMC, University of Jordan and vicinity, and Marj al Hamam)	19,259 (29,609)	13,125 (18,936)	32,384 (48,545)
Baqa'a Valley (including service to north-draining Suweileh, Baqa'a Camp, Safut and Ain Al Basha)	5,092 (8,055)	1,431 (1,110)	6,523 (9,165)
Fuheis/Mahis	905 (1,268)	142 (196)	1,042 (1,464)
Lower Wadi es Sir	3,451 (4,819)	294 (414)	3,745 (5,233)
Na'ur	476 (665)	52 (72)	528 (737)
Sahab	1,379 (1,925)	57 (82)	1,436 (2,007)
Sukhneh	551 (770)	28 (39)	579 (809)
Hashimiya	575 (805)	27 (38)	602 (843)
Abu Alanda/Khirbet es Suq/Juweideh	2,289 (3,196)	66 (90)	2,352 (3,286)
Total All Nine Systems	33,974	15,222	49,196
Capitalized Interest During Construction			(4,527)
Total Capital Requirement in 1,000 JD			(76,616)

Operation and maintenance costs for the nine separate systems are also projected. Debt principal repayment is included instead of depreciation expense due to the newness of the eight independent systems and to provide uniformity of comparisons among projects. Basic operation and maintenance costs are assumed to escalate uniformly at 10 percent annually, compounded. However, energy components are particularly sensitive to inflationary pressures and are thus assumed to escalate at 14 percent annually, compounded. Unit rates for energy in 1980 are 35 fils per kwh; outside of AWSA they are 39 fils per kwh.

Annual operation and maintenance (O & M) costs for the nine separate systems for representative years during the Phase I Investment Program are projected as follows. The data include the effects of inflation.

System	1984	In 1,000 JD 1987	1990
Expanded AWSA	2,608	3,704	5,384
Baqa'a Valley	152	315	448
Fuheis/Mahis	38	80	116
Lower Wadi es Sir	29	77	113
Na'ur	24	56	83
Sahab	16	31	41
Sukhneh	8	28	38
Hashimiya	12	50	68
Abu Alanda et al	19	38	50
Total, All Nine Sysems	2,906	4,379	6,341

Assumptions are made as to the growth of service connections for each system, according to local circumstances. In each case, uniform annual increases in active service connections from the time of system activation to 1990 are assumed. The active service connections form the basis of projected wastewater flows and variable (flow-related) operating costs. The growth of service connections is a measure of a significant revenue source, that of connection fees. These are direct contributions to capital cost by each new system user and are not offset by any costs incurred by the utility for physical connection.

Connection fees are estimated on the basis of cost escalation, historical practices, and the ability to pay. Connection fees actually are imposed upon non-residential system users as as well as upon new residences. For simplicity, the connections and resulting fees are expressed and calculated in terms of population or dwelling units. It is assumed that about 10 percent of the connected users will be classified other than single-family users. It is estimated that the standard single-family residential unit would pay a connection charge at least 10 percent lower than the average fees presented in the analyses.

Connection fees for AWSA have historically been slightly under JD 100 per connection. Therefore, for AWSA expanded system, connection fees were assumed to escalate from a value of JD 125 per connection in 1981 to JD 280 in 1990, the escalation rate being 10 percent per year, compounded. AWSA has existing tax revenue which yields significant income.

In contrast, the eight independent systems have no immediate prospect of revenue generation from sewerage taxes. Therefore, the connection fees for these systems must be correspondingly higher than those for AWSA. It is assumed that the initial fee of JD 240 per connection of 1984 will escalate to JD 420 in 1990.

The basic, on-going charge for sewer service is the water consumption surcharge. This method of revenue billing is generally fair and equitable, relatively simple to administer, and easy for customers to understand. This is used for both the expanded AWSA system and the eight independent systems.

For the expanded AWSA system, the projections of per household water consumption extend from a historical basis of about 300 m^3/yr. in recent years, assumed to continue for 1981-82. For 1983-85, it is assumed that the average annual water use will be 300 m^3 per capita, while for 1986 through 1990 the figure is taken as 360 m^3 per capita. The surcharge rate for expanded AWSA system is projected to increase progressively from 65 fil per m^3 at the end of 1981 to 210 fils per m^3 in 1990.

For the eight independent systems, actual water consumption data were not available. In the absence of such data, it was assumed that the per capita water consumption, upon which the sewerage surcharge would be imposed, would be 1.5 times the projected per capita wastewater production. The escalating surcahrge rates for the eight independent systems are developed based on historical rates elsewhere, recommended rated by the World Bank (IBRD) and inflationary escalation calculated to be within the user's ability to pay. The surcharge rates were set lower than those of expanded AWSA system, due to the significantly higher connection fees of the eight independent systems. Surcharges commenced at time of system activation (mid-1984) at 80 fils per m^3 and increased progressively to 145 fils per m^3 in 1990.

Experience has indicated that there will be delinquencies by system users in the payment of their sewerage service payments via water consumption surcharges. Accordingly, the revenues from this source have been discounted by two (2) percent for the AWSA system and five (5) percent for the independent systems to recognize uncollectible accounts or bad debt write-offs. With a uniformly applied collection enforcement program, uncollectible accounts should be maintained under two (2) percent of the total billings.

Projected revenues for the AWSA expanded system include water surcharges, connection fees, sewerage tax revenues, and other income, shown below for three representative years of the Phase I Investment Program. It should be noted that tax revenues will be significant due to continuing new construction, in spite of the 20-year limit of taxation on properties in Amman. However, there is a need for receiving tax revenue income or in lieu tax income from the growing areas served by AWSA outside Amman Municipality so that inequities will be corrected. Expanded AWSA's projected revenues are:

	In 1,000 JD		
Revenue Source	1984	1987	1990
Water Surcharges at 98 percent	607	1,640	3,114
Connection Fees	690	449	577
Sewerage Tax Revenue	1,042	1,099	1,463
Other Income (including septage fees)	140	186	249
Total Income	2,479	3,374	5,403

When the anticipated AWSA revenues are compared with operating costs, including certain depreciation expenses and costs for normal improvements and replacements, it is found that a deficit exists even before capital obligations are considered. These capital obligations comprise interest charges on previous loans and debt servicing on the capital improvements on the Phase I Investment Program (10 percent interest 25 year loan), including capitalized interest during construction. The corresponding values for the expanded AWSA system for representative years in the program are as follows:

Item	In 1,000 JD 1984	1987	1990
Total Income	2,479	3,374	5,403
Total Operating Costs	2,608	4,404	6,284
Difference	(129)	(1,030)	(881)
Interest - Previous Loans	230	230	230
Debt Service, New Loans @ 10%	213	4,983	5,445
Net Operating Surplus	(572)	(6,243)	(6,556)

* A deficit is denoted by parentheses ().

In contrast to the expanded AWSA system, it was immediately apparent that the eight independent systems would lack sufficient revenue to be able to meet operating expenses as well as full debt service. Therefore, it was assumed that these systems would be responsible for meeting limited debt service requirements, based on the escalated projected costs plus interest during construction as follows:

System	Total Capital Cost, 1,000 JD	Responsibility of System Percent	1,000 JD
Baqa'a Valley	9,895	15	1,484
Fuheis/Mahis	1,585	0	0
Lower Wadi es Sir	5,663	10	566
Na'ur	798	0	0
Sahab	2,172	30	652
Sukhneh	876	20	175
Hashimiya	912	10	91
Abu Alanda et al	3,557	20	711

The balance of total revenues and total expenditures, including discounted capital obligations, for the eight independent systems, shows the following data of surpluses or deficits () for representative years of the Phase I Investment Program:

System	1984	In 1,000 JD 1987	1990
Baqa'a Valley	294	(77)	(1,213)
Fuheis/Mahis	66	69	(127)
Lower Wadi es Sir	109	44	(204)
Na'ur	27	(16)	(175)
Sahab	117	98	(52)
Sukhneh	45	24	(69)
Hashimiya	34	(26)	(182)
Abu Alanda et al	127	92	(99)

In the foregoing analyses, the surplus tend to run out and deficits accumulate as time goes on and the early benefits of service connection fees are overtaken by mounting operating costs.

Sensitivity analyses were made to explore the effects of major adjustments in revenue sources for the extended AWSA system upon the ability of the system to meet debt service requirements as well as operating expenses. It was found that no single major revenue adjustment would meet revenue requirements if financing of the proposed facilities involves 10 percent interest rate. The closest single method was that of doubling the proposed water consumption surcharge, but this still fell short. The additional revenue raised by this device averaged some JD 1.45 million per year but was only 43 percent of the average debt service required during the period 1982-90. Doubling the tax rate was less productive for revenue generation and doubling the connection fees was even less productive than tax increases.

Doubling the AWSA water consumption surcharge would yield JD 3.11 million additional revenue in the year 1990, but this was still 57 percent of the debt service of some JD 5.44 million that year, based upon the 10 percent interest rate and 25-year repayment. Dropping the interest rate to 3-1/2 percent, however, if combined with the 100 percent water surcharge increase, would almost make the project financially self-supporting.

A comparable sensitivity analysis was run for the eight independent systems to determine the increased revenues that might be realized if water consumption surcharges and connection fees were both doubled. It was found that the combined effects of these increases would generate additional revenues corresponding to a low of 17 percent of average annual debt service without discount (for Lower Wadi es Sir) to a high of 42 percent of average annual debt service without discount for Sahab. Thus, even with these drastic measures for increasing the major revenue sources, there was no possibility of generating sufficient income for anything approaching full debt service.

Financing alternatives considered for improving financial feasibility are as follows:

- Taxation - This could be applicable to AWSA, but may not be practicable in view of an increase already experienced during recent years. It does not appear a likely possibility for the eight independent systems due to difficulties in establishment of taxing areas matching the proposed areas of benefit from the sewerage projects and in administering the corresponding taxing mechanisms.

- Special assessment districts - This device entails establishment of special improvement districts to finance allocated portions of the wastewater collection system via allotted costs to individual properties in the area of benefit, according to the assessment formula. The existing administrative structures in the Greater Amman Area do not currently encourage such financing methods, due to their complexities of administration. However, further study may be warranted.

- Inproved tariff structures - A more productive and equitable tariff structure than the water consumption surcharge could be developed whereby a service charge could cover fixed costs and a consumption rate, based on user classification, could cover the variable costs. This would require a complete tariff study.

- Subsidy of capital costs - This possibility should be considered by the Government and potential financing agencies in view of the potential benefits to the public health, welfare, environment and standard of living that would accrue from the proposed improvements.

An ability-to-pay analysis was conducted on the expanded AWSA system and eight independent systems, using 1985 conditions as the basis of the test and considering average low income groups household income. It was assumed initially that not more than five (5) percent spendable income should be required for both water and sewerage service, with a 2-1/2 percent limit on each type of service. The total sewerage charges included both the monthly water consumption surcharges and the amortized sewer connection fees (over a five-year period). It was found that these two charges correspond to spendable income ranging from a low of 2.7 percent in the expended AWSA system to a high of 3.8 percent in the Baqa'a Valley system. this slightly exceeds the arbitrarily chosen ceiling of 2-1/2 percent for sewerage. However, the one-time sewer connection charge represented more than half the total monthly cost and would vanish after five years, thus improving ability of low income household groups to pay for the facilities under the arrangements previously described.

Considerations of institutional arrangements result in the recommendation that AWSA own and operate the expanded AWSA system and levy charges for all those who use it.

A similar recommendation is made for WSC with respect to the eight independent systems.

APPENDIX A - ABBREVIATIONS

This includes a list of Abbreviations of Technical terms and a list of Proper Names of Institutions, Agencies, and Facilities.

APPENDIX B - SOCIO-ECONOMICS

This Appendix presents the methodology used for projecting saturation populations for Amman, Wadi es Sir, Suweileh, Madaba, Sahab, and Na'ur. This involves determinations of zones areas for residence and current states of development followed by calculations for saturation development according to zone.

APPENDIX C - ENVIRONMENTAL CONSIDERATIONS

This appendix comprises the NPC invitation of selected agencies to the environmental scoping meeting, the minutes of the scoping meeting, the environmental scoping statement, and the letter from the Department of Antiquities concerning proposed treatment plant sites within the Greater Amman Area.

APPENDIX D - INDUSTRIAL WASTE DATA

Appendix D1 presents general data and information on industrial wastewater composition and loadings, both for raw wastewater and pre-treated wastewater, of the type that may be encountered in the Greater Amman Area. Summary information on two industrial wastes ordinances in use in the Los Angeles, California area is also presented.

Appendix D2 presents tabular Rules and Regulations Governing Disposal of Industrial Wastes to the Sanitary Sewer and Storm Drain Systems of the City of Los Angeles, California.

Appendix D3 is a listing of some typical industries in the Greater Amman Area together with identification of selected industries that were visited by a brief consultant survey during the Master Plan study. Field information for two large water consumer/wastewater producer industries is included.

APPENDIX E - SANITARY SEWERS INFORMATION

A brief description on the theory and practical experience in hydrogen sulfide production in sanitary sewers is presented. This is followed by a description of the field inspections and flow gagings conducted in the AWSA sanitary network on September 17 and 19, 1980 and on Octobe 12 and 13, 1980. The findings are presented together with conclusions that the steep terrain of Amman makes for relatively high sewer flow velocities with satisfactory aeration of the flowing wastewater. Concrete sewer pipe has apparently performed well in the AWSA

sanitary network and should be acceptable for future conditions there and elsewhere.

Results of flow gaging via "Velocity Stick" are also presented for those selected manholes which were in the collection system which were accessible and appropriate for such gaging. Also included are gagings on certain contiguous manholes, which enabled calculation of an appropriate value of "n" used as the friction coefficient in the Manning Formula. University Pumping Station power consumption data are converted to average flow in 1979 in order to expand the available sewer flow information.

APPENDIX F - COMMUNITY SANITATION RECONNAISSANCE

The results are presented of a limited community sanitation reconnaissance which was undertaken in the summer and fall of 1980 within the Greater Amman Area. The purpose was to obtain general information on sanitation conditions relating to water supply and, particularly, to sewage disposal. Twenty-nine unsewered communities were visited, including once refugee camp, and available information was obtained on subsurface sewage disposal conditions and future outlook. The results, which are indicative but not rigorous, are presented in a series of tabulations according to size groupings of communities. A summary tabulation is also presented.

A general impression to be gained is that within the majority of communities visited, some problem with subsurface sewage disposal is already experienced, and the outlook is increasingly unfavorable. The reconnaissance results assisted identifying potential cesspool disposal problem areas and in setting priorities for wastewater collection and treatment.

APPENDIX G - SPECIAL CONDITIONS AT AIN CHAZAL TREATMENT PLANT

Appendix G1 is a letter report which assesses the structural feasibility at AGTP of converting the double deck secondary sedimentation tanks to single deck tanks by eliminating the middle slab. These modifications have been proposed in order to improve the solids removal efficiency of the tanks. The report presents two feasible means of structural modifications that will permit any tank to be filled while adjacent tanks are empty. These involve reinforcing the walls and their cantilever strength or, alternatively, providing transverse horizontal struts between the existing walls at regular intervals. The partially removed horizontal slab could be used to accomplish this.

Appendix G2 presents two engineering drawings showing existing electrical conditions at AGTP.

APPENDIX H - WATER QUALITY DATA

Apendix H1 is reserved for summary data to be supplied, when available, by the Royal Scientific Society, on their laboratory analyses of various water samples collected in the Seil Zarqa and King Talal Reservoir during 1980.

Appendix H2 presents discussions of water reclamation potentials for the Greater Amman Area for landscape irrigation, recreational impoundment, agricultural irrigation, body contact recreation and spray irrigation, and industrial applications. Criteria of the California State Department of Health on these potential applications are also presented. These include required treatment and allowable coliform densities (MPN/100 ml). Also included are minimum quality of reclaimed water to be attained for agricultural use. Finally, there is a discussion and presentation of water quality criteria for irrigation waters, with emphasis upon the mineral makeup of the water, the types of crops being irrigated, the soil types, and the manner of irrigation.

Appendix H3 reproduces the State of California Department of Health's "Wastewater Reclamation Criteria," California Administrative Code, Title 22, Division 4, Environmental Health. These include various regulations governing facilities, monitoring, and controls for water reclamation projects to assure reliability in the production of reclaimed water in order to ensure that its use does not impose undue risks to health. These are in addition to regulations that establish acceptable levels of constituents of reclaimed water.

APPENDIX I - DESIGN CRITERIA

Engineering design criteria are presented for wastewater collection system elements that have been used in the preparation of the Master Plan. These include wastewater flow rates and facilities criteria for gravity sewers, pumping stations, and force mains.

APENDIX J - COST ESTIMATING

Background information and adopted criteria are presented for estimating costs of various elements of the wastewater collection and treatment disposal facilities considered in this Master Plan and Feasibility Report. This includes pressure pipeline costs that would be applicable not only for wastewater force mains but also for transmission of liquid sludge or reclaimed effluent to points of disposal or use. Cost curves for sewers, pumping stations, and treatment plants are presented, along with expanations.

APPENDIX K - CHARACTERISTICS OF WASTEWATER SLUDGES

Digested sludge characteristics for AGTP and Salt TP are indicated. These appear normal, although they are based on very limited sampling. For illustrative purposes, analytical data are shown for various inland and coastal treatment plants in two major sewerage networks. Both micronutrients and macronutrients are likely to be present in digested sludge. Items of potential concern are toxic materials. These are most likely to originate from industrial sources.

APPENDIX L - COMPARISON OF ACTIVATED SLUDGE WITH ROUGHING FILTERS - ACTIVATED SLUDGE

This appendix recounts the detailed technical and cost comparisons that were

made by JMM/DMJM between the two basic secondary treatment alternatives for AGTP: TA1 (conventional activated sludge) and TA2 (roughing filters followed by activated sludge). Experiences from the professional literature are cited as are personal experiences of the consultant. The facets of capital cost, space requirements, energy demands, operational familiarity, and power recovery potential are all important considerations. The advantages of one alternative over the other trend to vary among these various facets. The selection is made for TA2, based upon a balance of considerations.

APPENDIX M - PHOTOGRAPHS

Several photographs and sequences of photographs are shown as an aid in documenting the investigations of the Consultant. These include the AWSA collection system, the AGTP and several of its elements and operations, the Seil Amman, the Seil Zarqa, King Talal Reservoir, Salt Treatment Plant, and Wadi Salt.

CONCLUSIONS AND RECOMMENDATIONS

As a result of the appraisals and analyses set forth in this Master Plan Report for Wastewater Disposal for Greater Amman Area, the following conclusions and recommendations are made:

1. The quality of groundwaters and surface waters within the influence of discharges of pollutants of the urbanized portions of the Greater Amman Area is suffering from degradation due to these discharges. Adverse impacts are less severe outside the heavily populated areas. Unless steps are taken to remedy the discharges of pollutants, including major septage contributions, groundwater quality in vulnerable areas will become increasingly substandard for drinking water supply and may eventually require expensive treatment in order to be acceptable for such use.

2. Discharges of pollutants to the Seil Zarqa are degrading that stream and having adverse impacts upon the King Talal Reservoir downstream. There is an obvious need for control and reduction of these pollutant discharges. This is due to public health aspects and the great reliance which must be placed upon the integrity of the very limited water resources available to the Greater Amman Area.

3. Initial emphasis on water pollution abatement should be placed upon the heavily urbanized areas because these are having the greatest adverse impact upon the environment, produce the greatest public health hazards, and are generally the most cost-effective to be remedied. Attention must then be directed to other urban areas for they, too, contribute to environmental degradation and public health jeopardy.

4. Reduction of pollutant discharges to the groundwaters and surface waters must be accomplished by means of public wastewater facilities

for collection, treatment, and disposal in such a manner that discharges of septage underground will be greatly reduced and municipal treatment will be at sufficient level to permit discharge of effluent to the various wadis within the Study Area. Such discharge to watercourses will be necessary in most cases. Exceptions involve small to moderate systems located in relatively flat terrain where land costs will not preclude the use of lagoon type treatment, so sized as to preclude the need of any discharge.

5. Although provision of sewer systems removes pollutants from the underground, it does add some residual pollutants to surface waters, via the treatment plant effluent, that were not there previously. However, the overall effect is beneficial to the environment and to the public health, provided the wastewater systems are designed, constructed, and operated properly.

6. The first priority of pollution abatement should be given to Amman, the immediately surrounding areas, and the Zarqa-Ruseifa area. The Zarqa-Ruseifa area is already programmed to be provided with public wastewater facilities. Amman Minicipality is already provided with a basic primary network of trunk sewers and a fairly extensive secondary network of lateral sewers that is currently underutilized due to a less-than-anticipated rate of connection of buildings to these sewers. The surrounding areas are yet to be sewered, but sewers will be needed for portions of these in the relatively near future and for other protions before the end of the planning period, year 2000.

7. Areas adjoining Amman which should be sewered initially include north-draining Suweileh, Jubeiha, University of Jordan and vicinity, Umm es Summaq, and upper Wadi es Sir. Wastewater flows from these areas should be made tributary to a new treatment plant in the upper reaches of Wadi Abdoun. Flow from north-draining Suweileh will require pumping accross a watershed divide. Flow from University of Jordan and vicinity will be diverted to a new gravity trunk sewer and will no longer have a pumped via the University Pumping Station. There will be no need to construct pumping stations west of the Sixth Circle, Jabal Amman, as originally planned by AWSA.

8. Another area adjoining Amman which should be sewered initially includes Marj al Hamam. This area should contribute by a new gravity trunk sewer to the AWSA primary network as currently being extended up the Wadi Abdoun. It will not be cost-effective to pump Marj al Hamam flow to Upper Wadi Abdoun Treatment Plant.

9. A housing project area east of the Amman Airport runway could be considered for initial phase sewering, provided Schneller Camp were also to be sewered. If the Schneller Camp sewerage project were to be deferred until after 1990, this would also defer sewer service to the

housing project. Sewering the housing project, and East Marka, would be by a trunk sewer connecting to the Zarqa-Ruseifa primary network. It is possible that such connection be made by gravity. However, natural gravity drainage is currently blocked by an obstruction, and pumping might be required to circumvent this.

10. The trunk sewer to serve south-draining Suweileh as far as King Hussein Medical Center, and vicinity should be deferred until after 1990, at which time there will be sufficient development to warrant this project. In the meantime, a new KHMC treatment plant is presently programmed for construction to accommodate both the existing load and additional load soon to be imposed from expanded clinic, hospital, and staff facilities. The new KHMC treatment plant will supplant the existing one. However, as soon as KHMC can be connected to Upper Wadi Abdoun Treatment Plant (UWATP) the KHMC treatment plant should be retired.

11. It will be necessary for the wastewater treatment capacity of AWSA to be increased greatly to accommodate the additional wastewater flows anticipated both from Amman and from surrounding areas. This would be true even if there were to be no inclusion of surrounding areas in the wastewater system.

12. The AGTP was designed to handle the flow contributions of 300,000 persons and a flow of 60,000 cu m/da. However, the wastewater from Amman is much more concentrated than had been anticipated, and discharges of septage and industrial wastes from municipal slaughterhouse make it difficult to produce a satisfactory effluent for discharge into the Seil Amman, even at present flow levels. In addition, there are certain limitations in some of the treatment units that require a downgrading of the plant's capacity to a level not much more than that which is presently being experienced for tributary population (about 280,000 persons) and flow levels (about 21,000 cu m/da). This means that major expansion is required immediately in order to accommodate increased flows from new sewers currently under construction, new sewers programmed for the AWSA network, and new sewers that should be constructed in adjoining areas.

13. AWSA's AGTP should be upgraded and expanded under a program that will increase its capacity ot 60,000 cu m/da by 1990 and 75,000 cu m/da by year 2000. This will be necessary to accommodate the projected flows of wastewater from Amman and adjoining areas and will represent the maximum reasonable utilization of the existing AGTP site and of the currently vacant municipal land between the municipal slaughterhouse and the Administration Building of AGTP.

14. An Upper Wadi Abdoun Treatment Plant should be built near the watershed divide between the Seil Zarqa Sub-basin and the Southwestern Sub-basin, having an initial capacity of 8,000 cu m/da for 1990 flows and an enlarged capacity of 20,000 cu m/day for year 2000 flows. The UWATP should intercept and treat flows from upper Wadi es Sir and northerly. This will be more economical and less disruptive in AWSA trunk sewer reinforcement than allowing these peripheral flows to pass through the AWSA system to Ain Ghazal and beyond. Downstream of AGTP, there should be a Kharbet er Ruseifa Treatment Plant, constructed ater 1990 and having a total capacity of 56,000 cu m/da.

15. The type of treatment to be employed at AGTP should continue to be the activated sludge process, except that mechanical aeration should be employed instead of diffused air aeration, for new units and roughing filters should be introduced ahead of all activated sludge units due to the exceptionally strong wastewater. Roughing filters activated sludge should also be used at UWATP and KRTP. Anaerobic sludge digestion should continue at AGTP and should be included at KRTP. No sludge processing should be included at UWATP, sludges from which will be recovered and processed at AGTP and KRTP.

16. Effluent disposal should continue to Seil Amman/Seil Zarqa for AGTP and this should also be planned for KRTP, it being impractical to dispose of the effluent elsewhere. In order to provide for increased public health protection via public access to Seil Zarqa and agricultural irrigation practiced with flow diversions, effluent filters should be planned for these treatment plants and be implemented as soon as funds are available and careful study shows that the benefits of this will exceed the costs. Effluent filters should also be planned for all Study Area treatment plants discharging to wadis or supplying water for irrigation or other beneficial use. The planning anticipates plant space allocation for these additional facilities in future years and also for denitrification, should this become necessary.

17. No significant demand for reclaimed effluent has yet been identified, so that it is not possible to program facilities for reuse. Effluent reuse may eventually become significant but will require careful controls for the protection of the public health. The UWATP will be strategically located for reclaimed water service to upper plateau areas and also for flexibility of effluent discharge to alternative sub-basins.

18. Belt press dewatering of digested sludge should be implemented and eventually expanded for AGTP because this is the most efficient and cost effective of the mechanical dewatering alternatives. Open drying bed dewatering is impractical at AGTP because of space limitations. Belt press dewatering should be incorporated at the future KRTP and should eventually replace the open drying beds at the programmed Zarqa-Ruseifa TP.

19. It will be most economical and flexible for dewatered sludges from AGTP, KRTP and other treatment plants to be trucked to disposal sites. Tank trunk transport or pipeline conveyance of liquid sludge is more costly and less flexible.

20. Throughout the Greater Amman Area, programs should be developed for beneficial use of digested sludge for reforestation and, eventually, for agricultural application. Such programs must be carefully controlled for reasons of protection of the public health and the environment.

21. The second priority for pollution abatement should be given to the less heavily populated areas by means of individual systems serving single communities or groups of communities, none of which is presently served or programmed to be served. The priority rankings for these systems should be as previously described for Sahab, Baqa'a Valley, Abu Alanda etal, Lower Wadi es Sir, Sukhneh, Hashimiya, Na'ur, and Fuheis/Mahis.

22. The type of wastewater treatment to be provided for the systems of the outlying areas should be:

Treatment	System
Roughing Filter/Activated Sludge	Baqa'a Valley
Activated Sludge (Extended Aeration)	Lower Wadi es Sir, Na'ur, Fuheis/ Mahis
Facultative Lagoon (Designed for Total Containment of Flow)	Sahab, Abu Alanda/Khirbet es Suq/Juweideh, Sukneh, and Hashimiya

23. Effluent disposal for four of the outlying plants should be to the adjacent wadis, from which most flow will be recovered for riparian irrigation or in the JVA reservoirs in the Jordan Valley. Effluent filters should eventually be provided for these plants. Digested sludge dewatering should be via open drying beds, with disposal initially to approved landfills.

24. It will be necessary for effective programs to be developed for the control of industrial wastes discharges. It does not presently appear necessary to restrict the use of hard detergents.

25. It will be necessary for baseline data to be developed and extended in a program of environmental monitoring, with major emphasis upon water quality, so that the effects of the Master Plan program implementation upon the environment may be assessed on a long range and continuing basis.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

26. As a result of the studies and analyses of this Master Plan report, it is recommended that the following be accomplished (in which the costs are stated in terms of late 1980 price levels):

    A. Arrange for and implement a wastewater facilities program for AWSA and adjacent areas which will:

        a. Expand and upgrade the Ain Ghazal Treatment Plant (AGTP) as described herein, this work to have the highest priority. The Phase I Investment Program estimated project cost for this work is JD 17,795,000.

        b. Construct reinforcements to certain trunk sewers in the AWSA primary network. The estimated Phase I project cost is JD 291,000.

        c. Provide trunk sewer service to various areas westerly of Amman, including pumping the north-draining portions of Suweileh. The estimated Phase I project cost is JD 1,043,000.

        d. Provide an Upper Wadi Abdoun Treatment Plant (UWATP) to intercept and treat those flows which originate westerly of Amman and north of southern Wadi es Sir and which would normally be tributary to Seil Zarqa Sub-basin via Amman; also flows from north-draining Suweileh, which is naturally tributary to Baqa'a Valley. Discharge effluent from UWATP either to Seil Zarqa Sub-basin or Southwestern Sub-basin as may be found most appropriate. The estimated Phase I project cost is JD 2,955,000.

    B. Arrange for and implement wastewater facilities for outlying areas according to the following priorities, areas and estimated Phase I investment program project costs:

        a. Sahab - JD 671,000

        b. Baqa'a Valley (if Baqa'a Camp is sewered) - JD 3,194,000. If not, the project should be deferred until after 1990.

        c. Abu Alanda/Khirbet es Suq/Juweideh - JD 1,386,000

        d. Lower Wadi es Sir - JD 905,000

27. If sufficient funds are not available to implement all of the above mentioned projects, implement first those projects for which funds are available according to the priority indicated by their order of listing. Defer the remaining projects for the Phase II Investment Program. Re-evaluate the unimplemented projects from time to time to ensure the continued validity of their priorities.

CHAPTER 2

INTRODUCTION

BACKGROUND

The Greater Amman Area is defined, for the purpose of this Master Plan, as the area within 30 kilometers radius from the center of Amman. Figures 2-1 and 2-2 are a location map and Study Area map, respectively, depicting the relative geographical location and extent of the Study Area covered in this Master Plan. The "Study Area" and "Greater Amman Area" are used here interchangeably.

Amman, the capital of the Hashemite Kingdom of Jordan, has experienced rapid growth in the past two decades, transforming it into a major metropolis bordered by growing suburbs and outlying communities. Amman's existing wastewater facilities, under the jurisdiction of the Amman Water and Sewerage Authority (AWSA), do not extend much beyond the borders of Amman Municipality. AWSA's existing sewerage network is essentially a gravity system draining to Ain Ghazal Treatment Plant (AGTP) and eventually to Seil Amman. Much of the growth in the outlying areas in the west and south is outside the drainage basin of Seil Amman. These new areas, which are currently unsewered but reliant upon cesspools for wastewater disposal, might be made tributary to the Ain Ghazal Treatment Plant by construction of sewage pumping stations. Conversely, they could be permitted to drain naturally, via new treatment plant(s) directly to other wadi(s) that discharge to the Jordan Valley.

It is evident that the Amman wastewater facilities, particularly the major trunk lines and treatment plant, will require careful appraisal and planning as to their future role in the overall wastewater plan for this Study Area. The best overall solution for Amman and neighboring communities' wastewater disposal problems requires a regional master plan study, taking into account engineering, economic and environmental concerns.

It is worth noting that sewerage facilities for Zarqa and Ruseifa were covered in a separate study and construction is expected to commence in 1981. Madaba, also within the Study Area, will be covered under a separate study.

AUTHORIZATION

On 17 May, 1980, the National Planning Council of the Government of the Hashemite Kingdom of Jordan (NPC) entered into an Agreement for Professional Services with James M. Montgomery, Consulting Engineers, Inc., and DMJM International, a Joint Venture, in association with the Consulting Engineering Center. NPC desired to obtain a Master Plan for Wastewater Disposal for the Greater Amman Area and to expand and upgrade the existing wastewater treatment plant in the City of Amman and/or to plan, design and construct new wastewater plants.

Accordingly, NPC arranged the Consultant's duties in three successive Stages, viz:

- Stage I involved a study and preparation of a Master Plan for wastewater disposal within the Greater Amman Area.

- Stage II comprised preparation of final design drawings and specifications, including tender documents of work to be constructed, services as required for prequalification of tenderers, and contract negotiations and award.

- Stage III was to provide services as required for supervision of construction of the Project.

MASTER PLAN OBJECTIVES

The general objective was to establish an integrated framework with an adequate system of wastewater disposal for the Greater Amman Area. Specific objectives included the following:

1. Conduct a study and prepare a Master Plan for Wastewater Disposal for the Greater Amman Area up to the year 2000, identifying the area within Amman and vicinity which can be economically tied to the Ain Ghazal Treatment Plant or new plants(s).

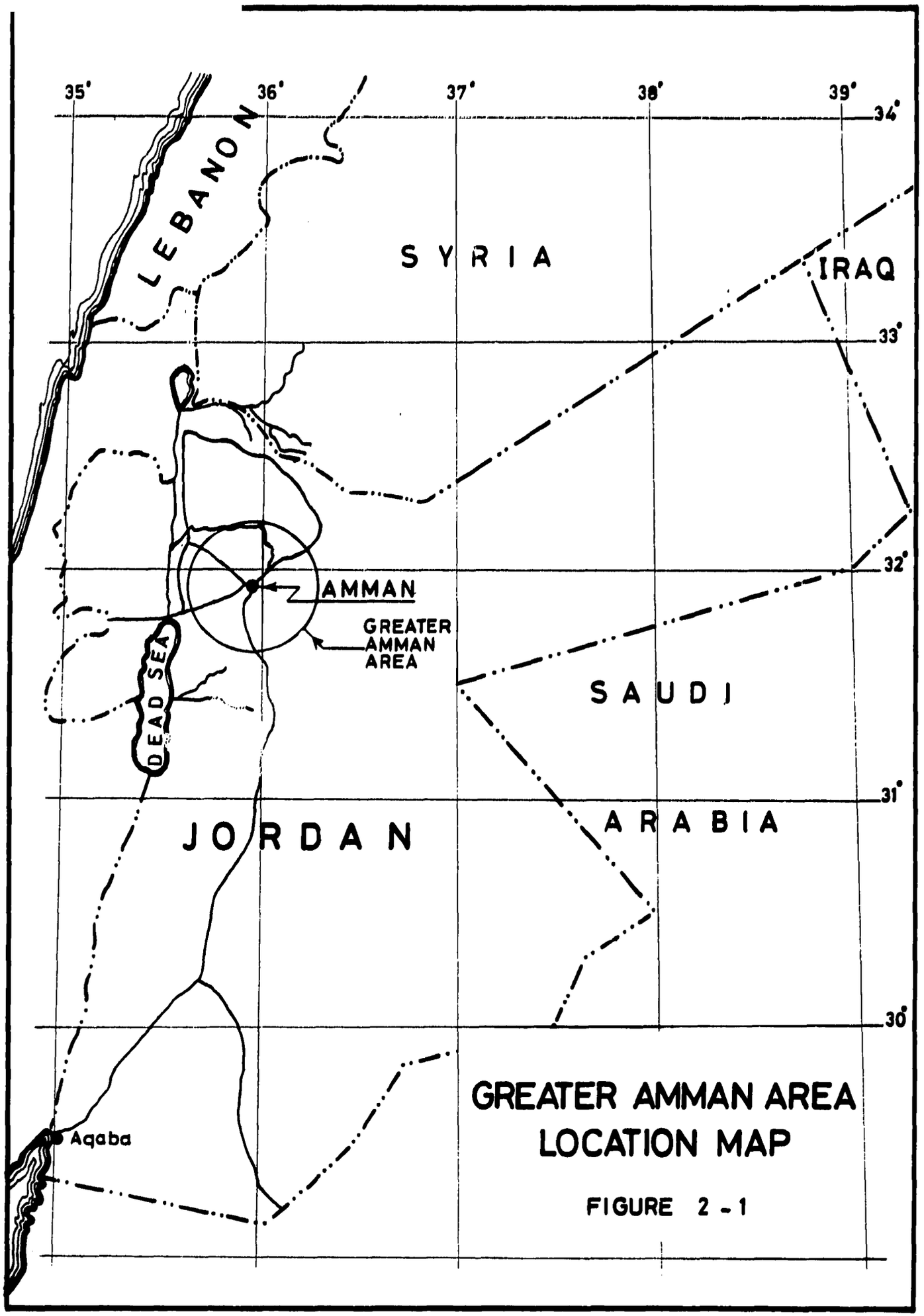
2. Identify the areas of the Greater Amman that should be connected to new treatment plants, recommend locations for such plants and the timing of plant and sewerage network construction, determine areas to be served by the various plants, establish priorities, and estimate costs.

3. Prepare a technical and economic feasibility study of the Phase I Investment Program to reflect the least capital and operations cost solution for disposal of wastewater flows for the Greater Amman Area up to the year 2000. Said study might include expansion and upgrading of the existing Ain Ghazal Treatment Plant and/or construction of one or more plants elsewhere.

4. Based on a preliminary study of the existing sewer trunk lines in Amman, investigate their adequacy to carry additional flows compatible with the size of the recommended expanded and upgraded Ain Ghazal Treatment Plant.

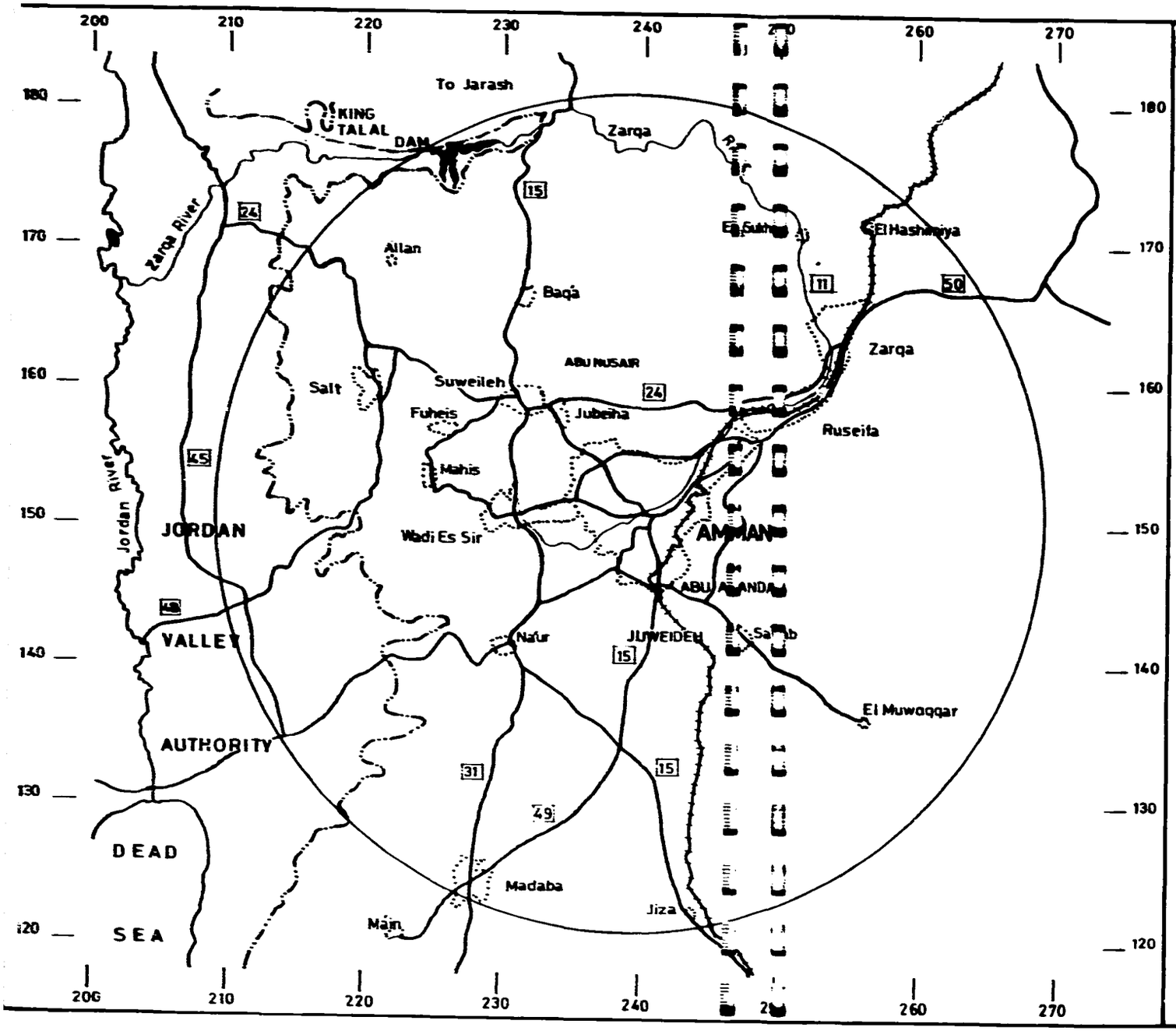
5. Develop detailed, flexible, investment programs for Ain Ghazal Treatment Plant expansion and upgrading and/or construction of new plant(s), with the first implementation phase to be established in detail to provide for needs up to year 1990. Said programs must be easily advanced or postponed to meet the actual growth requirements of the city.

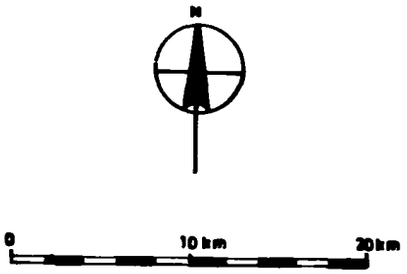
6. Plan further construction phases to cater for needs up to year 2000.



GREATER AMMAN AREA
LOCATION MAP

FIGURE 2 - 1





STUDY AREA

FIGURE 2 - 2

7. Suggest the percentage of population to be connected to and served by the sewerage system under each project implementation phase.

8. Recommend uses or disposal of treated wastewater and sludge under each project implementation phase.

9. Recommend minimum quality to be attained for treated wastewater under each project implementation phase, with special reference to environmental protection of the cities, surrounding areas, and downstream watershed areas.

10. Compare alternative wastewater treatment facilities and effluent and sludge disposal and/or use arrangements, both as to costs, benefits, operation and maintenance, and technical aspects.

11. Appraise generally present and future conditions regarding waterborne diseases and health aspects vis-a-vis sewerage facilities.

12. Recommend goals and objectives for improvement to be expected from the completion of various implementation phases of the project.

13. Examine and assess environmental problems that may arise or existing problems that may be aggravated by Ain Ghazal Treatment Plant expansion with particular emphasis on sludge treatment and disposal.

14. Assess wastewater characteristics and treatment requirements over the life of the Project, based on flows and effluent qualities for various areas to be served.

15. Recommend limiting controls on admission of industrial wastewater and hard detergents to the general sewerage system.

16. Investigate and evaluate industrial wastewater discharges to the Ain Ghazal Treatment Plant, determining which discharges would be deleterious to the plant process and recommending necessary pretreatment for compatibility.

17. For Zarqa/Ruseifa area, utilize the industrial wastes study performed separately by another consultant.

18. Identify problem areas in the Ain Ghazal Treatment Plant and evaluate the existing process.

19. Investigate and recommend measures concerning the use of methane gas from digesters for power supply, based upon economic and technical considerations.

20. Investigate and recommend measures on the disposal of liquid or dried sludge.

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21. Estimate detailed capital costs of construction under Implementation Phase I of wastewater treatment, including specified bases of present-day prices and future escalated prices for the construction period.

22. Provide recommendations as to sewerage taxes, rates, and other relevant charges for operating and maintaining the treatment plants.

23. Review and appraise the existing planned organizational structure of the operation and maintenance divisions of the agencies concerned with the project.

24. Prepare a training program for operation and maintenance personnel.

Following completion of the Master Plan and Feasibility Studies, the objectives would be to perform the final design, render prequalification and precontract services, and provide engineering services during construction of the Ain Ghazal Treatment Plant expansion and upgrading and/or new plant(s).

STRUCTURE OF STUDY AND REPORT

The work reported upon herein represents the integrated efforts of a multi-disciplined team of professionals. Although primarily an engineering investigation, the work also required the participation of a Socio-Economist, Environmental Analyst, Public Health Consultant, Financial Analyst, and Operation and Maintenance Training Specialist. The first chapter of this report represents a Summary, Conclusions and Recommendations for both the Master Plan for Wastewater and Sludge Disposal and the Implementation Phase I Program, Sewage Treatment Plant Expansion and Upgrading and/or Construction of New Plants. The next eight chapters develop and present the Master Plan for Wastewater and Sludge Disposal.

The final three chapters present the Preliminary Design and Cost Estimate, Environmental Assessment, Project Implementation Plan, and Financing Plan and Revenue Program. Appendices are also included.

The Draft Master Plan Report and Engineering Design, and Economic Analysis Report was reviewed by AWSA, NPC, the Ministry of Municipalities, Rural Affairs and the Environment (MMRAE) as well as other concerned governmental agencies. Refer to Appendix A for list of abbreviations of technical and proper names. The revisions resulting from the reviews by these key governmental agencies have been incorporated in this Final Master Plan document.

CHAPTER 3

PRESENT AND FUTURE SOCIO-ECONOMIC CONDITIONS

INTRODUCTION

This feasibility study was conducted to determine the sewage system requirements for the Greater Amman Area during the period 1980 through 2000. Although population growth is a major consideration in determining such requirements, it is by no means the only criterion. Human requirements of a sewage system are based on several factors including cultural traditions, personal attitudes toward usage of sewage facilities and personal hygiene, and financial aspects of currently used and proposed facilities. These considerations are important for several major aspects of project planning. The products of the socio-economic analysis will serve the following objectives with regard to the determination of sewage system requirements of the Study Area:

- Consider potential future economic conditions as input for the projection of future land use and population growth.
- Project future land use and population growth distribution as input for the projection of water use and sewage flows generated.
- Identify areas characterized by predominantly low-income population as a factor for determining project phasing and maximizing benefits to the general public.
- Determine income distribution of planning area residents as input for the "ability to pay" analysis, and as input for the cost/benefit analysis of the proposed project.
- Determine attitudes toward water use that are likely to affect future levels of consumption, as additional input for the projection of sewage flows.

The products of the socio-economic analysis, as listed above, can be grouped into two major categories leading ultimately to input for the cost/benefit analysis and facilities sizing.

The cost/benefit analysis of the proposed project is an important consideration as it has the most direct bearing in setting priorities and phasing of wastewater disposal improvements within the Study Area, (i.e., whether or not sewage improvements should be implemented in a given area). If those improvements are desired upon consideration, the analysis will help to determine what level of improvements is best.

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The cost/benefit analysis will weigh the potential (and likely) benefits of the proposed sewage system improvements against the expected short and long-term project costs and the foregone uses of capital devoted to this project. Expected and desired benefits to the public from improvement of sewerage facilities are improvement of health conditions of the general public including low-income groups, and improvement of local environments. The physical access to the present water and sewerage system within the Study Area is an important consideration for assessing the cost/benefit of the recommended improvements and therefore is included in the analysis.

The facilities sizing depends on the expected use of the proposed facilities measured primarily by volume of wastewater generated, which in turn, is dependent upon future land use and projected population distribution. In addition, the volume of wastewater is also dependent upon social and economic factors such as the attitudes of the people using the facilities towards personal hygiene, and the use of water, as well as their ability and willingness to pay for system improvements.

PRESENT AND FUTURE ECONOMIC CONDITIONS

Projections of future economic conditions within the Study Area are required to be used as input to both the land use and social analysis of this project. The connection to the projection of land use is necessary as a check on land use plans, to verify their validity, and to estimate the timing of open-scheduled plans for development of given areas. The social element related to the forecast of regional economic activity is manifested in future employment opportunities, which will, in turn play a role in the determination of population distribution, and to a certain extent, the levels of household income of populations in the various portions of the Study Area.

The scope of this study does not allow for a detailed in-depth forecast of future economic conditions in the Study Area. The major purposes of this brief review of recent trends, present conditions and the generalized qualitative forecasts is to ensure that development plans for residential, commercial and industrially zoned areas are consistent with the forecasted economic activities for those types of development.

For the purposes of the economic analysis, the Study Area will be equated with the Balqa-Amman Region, which is a planning division of the Hashemite Kingdom of Jordan. It is the division that most nearly approximates the Study Area. The only differences between the two are the exclusion from the Study Area of the Jordan Valley Authority jurisdiction on the western boundary of the Region, and the environs on Ma' in the extreme southwest. As more than 95 percent of the population of the Balqa-Amman Region reside and work within the Study Area, [1,2], the two geographic designations can be discussed interchangeably. Economic data often appear in a third regional division related to the Study Area, the Amman Governorate. This is an administrative unit which is similar to the study area in total population and other socio-economic parameters. Its geographic difference from the Study Area is its inclusion of sparsely inhabited desert areas to the east, and the exclusion of the Balqa area (greater Salt area) in the northwest.

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The Amman Governorate can also be used to represent the Study Area, as its 1979 population was 93 percent of the Study Area total.

RECENT TRENDS

The economy of the Balqa-Amman Region has been characterized in recent years by a continuing shift in relative importance from the agricultural sector to the industrial and services sectors. The construction industry, tourism and remittances from Jordanian workers abroad have also been major components of the Region's economy. Other indications of recent economic trends in the Region are the rapid increases in land and construction costs which are rising faster than incomes in the Region, especially in the Municipality of Amman and its suburbs.

The Gross National Product of Jordan (GNP) has increased from JD 187 million in 1970 to an estimated JD 853 million in 1979. Much of the accelerated growth during that period occurred between 1975 and 1979 when GNP is estimated to have increased by JD 510 million. This trend of economic expansion has been paralleled in the Balqa-Amman Region[3]. That expansion was reflected by high rates of growth in construction and industrial sectors.

The Region represents the vast majority of industrial activity within the East Bank. The 1974 Industrial Survey indicates that the Balqa-Amman Region contained 76 percent of the Nation's industrial establishments; 87 percent of its industrial employees, and 98 percent of the employees within firms of more than five employees. It is estimated that the Region's position of dominance in industry has not changed.[1]

Manufacturing's contribution to Gross Domestic Product tripled during the period 1968 and 1976[4], and industrial sector employment in the Balqa-Amman Region more than tripled from approximately 8,000 in 1959 to approximately 25,000 by 1976[5]. Most of the industrial sector employment is concentrated in the Zarqa and Ruseifa area, with much of the remainder in Marka. Although figures are not available, it is likely that this trend of rapid expansion continued (though at a slower rate) during the period 1977 to 1980. On the other hand, agricultural land in cultivation in the Region, declined 10 percent during the period 1975 to 1978, from 990,000 to 890,000 dunums. [6,7] It is likely that this trend has continued into 1980, as agricultural land in the suburban areas around Amman has continued to be developed for urban uses.

It is likely that regional employment trends will continue to parallel the shift from agricultural to non-agricultural activities of the regional economy. The East Bank experienced a significant shift in its employment structure between 1961, when agricultural employment accounted for 35 percent of the workforce, and 1975 when it accounted for only 18 percent. [8] The same trend was occurring in the Balqa-Amman Region.

An indication of the urban employment structure in the Study Area in 1975 and 1976 is presented in Table 3-1. In 1975, the Amman Governorate contained approximately 71 percent of the total urban employment in the manufacturing sector (87 percent), finance (90 percent), and utilities (84 percent). Employment

TABLE 3-1

STRUCTURE OF URBAN EMPLOYMENT

IN THE MUNICIPALITY OF AMMAN AND AMMAN GOVERNORATE

Sector	East Bank 1975		Amman Governorate 1975			Municipality of Amman 1976	
	Employees	Percent of Total	Employees	Percent Total	Percent of East Bank Total	Employees	Percent of Total
Mining	2,683	2.1	1,289	1.4	48.0	3,486	4.2
Manufacturing	19,583	15.3	16,986	18.8	86.7	10,099	12.1
Utilities	2,107	1.6	1,761	1.9	83.6	1,071	1.2
Construction	8,427	6.6	6,636	7.3	78.7	4,373	5.2
Commerce	25,157	19.6	18,151	20.0	72.2	4,616	5.5
Transportation	13,916	10.9	8,747	9.7	62.9	4,035	4.8
Finance	3,147	2.5	2,822	3.1	89.7	3,391	4.1
Public Administration[a] and Community Service	53,212	41.5	34,151	37.7	64.2	52,648	62.9
TOTAL	128,232	100.0	90,543	100.0	70.6	83,719	100.0

[a]Including military personnel

Source: Department of Statistics, Labor Force Census 1975, and Employment Survey for Establishments Engaging More than Five Persons, December, 1976

in those sectors is concentrated in Greater Amman, and if the Balqa Region were added to these figures to approximate more closely Study Area totals, their shares of national totals would be even more striking. The employment sectors which were less concentrated in the Amman Governorate were mining which accounted for only 48 percent of the national total; and transportation and public administration with 63 and 64 percent, respectively. [8]

The relative importance of the individual employment sectors within the study area is highlighted by comparing the percentage of the total urban workforces in Amman Governorate and the Municipality of Amman to total employment in both of those jurisdictions. In the Amman Governorate in 1975, public administration (including military personnel) accounted for approximately 38 percent of total employment, while commerce and manufacturing were also important, with 20 and 19 percent, respectively. [8,9]

Urban employment figures for the Municipality of Amman, were not available for 1975, but were available for 1976. Although the employment composition could be expected to have been changed somewhat between 1975 and 1976, the changes would be small enough to allow a comparison between 1976 ratios for the Municipality, and 1975 ratios for the Amman Governorate. Public administration accounted for 63 percent of total employment, while manufacturing accounted for only 12 percent, as compared with 38 and 19 percent, respectively, for the Amman Governorate. An even larger difference existed between the commerce sector totals for the two areas, as the Municipality of Amman had only about 6 percent of its workforce engaged in commerce. These differences may be accounted for by the fact that retail trade is required in outlying districts and suburbs to service residential areas, while an extremely large percentage of government offices and public service agencies are located within the Municipality of Amman. The relatively lower importance of manufacturing in the Municipality may also be due to the importance of public administration in that city. The total of manufacturing employment in the Municipality represented a high percentage of total manufacturing employment in the Amman Governorate. [8,9]

FUTURE CONDITIONS

Future economic and industrial development in the Study Area can be projected only in general terms, based on current plans and development in progress. The 1981-1985 National Five-Year Plan[11] is currently being formulated. It will contain a program for industrial and commercial development which will outline various generalized goals in terms of types and sizes of industries to be encouraged to locate at various industrial estates and Free Trade Zones. [11,12,13] In addition, it will outline plans for some specific projects. Unfortunately, the Five-Year Plan was not available at the time of this analysis.

A discussion of future industrial expansion, therefore, must be based on existing plans for the Sahab Industrial City and Free Trade Zones near Hashimiya and the Queen Alia Airport (Jiza), as well as the large industrially zoned areas in Zarqa, Ruseifa and in the south and east of Amman. A list of recommended priority industrial projects is currently being considered by a special interministerial committee preparing the Five-Year Plan.[11] That list includes categories of industries which may be encouraged to be developed at the Sahab Industrial City and/or the industrial sites in the Free Trade Zones. The list includes the following

major types of industries: textiles, furniture and other wood products, manufacturing, pharmaceuticals, electronics, plastics manufacturing, machinery, metal fabrication and food packaging and processing operations. Most of these industries are expected to be low to moderate water users, and less labor intensive than much of the older industries in the Study Area.

The Feasibility study of the Amman Industrial Estate and Free Trade Zone[12] Projected the Kingdom's mining and manufacturing sectors to grow at a rate of 9.6 percent from 1981-85 and 11 percent from 1986-1990. This growth was used as the basis for a projection of 51,000 increase in industrial and mining employment for the whole Kingdom by 1990. This additional employment would require an increase within the Study Area of 2530 dunums of light and medium industries in the Sahab area, 980 in the Zarqa-Ruseifa and 510 dunums in Salt.

The Sahab Industrial Estate will occupy 2,530 dunums, consisting of light and medium industries. Employment in the Estate is expected to reach 6,700 by the end of 1982, 2,600 of whom would be working for industries relocated from Amman. By 1990, the Industrial Estate is projected to have a total workforce of 25,000.[12]

The Free Trade Zones at Hashimiya and Queen Alia Airport will be smaller than the Sahab Industrial area, and will combine commercial and industrial activities. The Hashimiya project is planned for 1,200 net dunums of commercial and 650 net dunums of industrial land. Industries are to be light and medium, including a large "Food Town" which is to occupy 100 dunums of food processing plants. The Queen Alia Airport is planned for 1,000 dunums. Priority industries considered for this development are warehousing, transportation and assembly related industries, packaging of consumer goods, electronics and air shipment related items. Aircraft industry support and maintenance industries have also been considered.[13]

Industrial development in the existing general industrial zones south and east of Amman is expected to be similar to that already existing there (e.g., mainly small industries including wood and metal working, light machinery, printing operations, some food processing and other light industries).[1]

The Amman Urban Region Planning Group (AURPG) projected a need for 2,785 additional dunums of industrial land by the year 2000, to accomodate a projected increase in industrial sector employment between 1978 and 2000.

The projection is related to the national policy with regard to economic planning which has two major goals relating to employment and industrial growth:[1]

1. The provision of jobs for future increases in the workforce in conjunction with a continued shift of relative importance within the economy from the agricultural sector to manufacturing.

2. Introduction of industries that are capital intensive to make individual labor more productive in order to better adapt to the current shortage of local labor and high wage rates, and take advantage of Jordan's highly educated workforce (relative to neighboring countries).

To those ends, an ambitious labor training program is planned. It is divided into three categories. The first is academic education, which is provided by the Ministry of Education. The Ministry of Labor is responsible for the Vocational Training Corporation (VTC), which provides apprenticeships to young workers starting at the age of 15. The Ministry of Labor also conducts refresher courses for skilled workers. These programs will be directed toward expanding the skills of the nation's labor force to meet the future demands for planned capital intensive industrial development. To meet demand for the near future, the VTC is currently building four new centers within the Study Area, in Amman, Zarqa and Sahab.[14]

The industrial estates and Free Trade Zones represent the formal industrial sector, which is made up of large planned developments. Most of the existing industry within the Study Area is in the informal sector. The AURPG Plan for the period 1981 to 1985, has as its goal, 60 percent of total regional industrial employment in the formal sector.[1] This means that a very large percentage of regional industrial growth will occur within the industrial estates and Free Trade Zones, with a large portion of remaining development in the large industrial zones of Marj el Hamam, Rajib, and East Zarqa (Amman Ring) Road.

PRESENT AND FUTURE LAND USE

Projections of future land use conditions are required so as to provide impacts for the projection of future population of the Study Area and its urban communities, as well as inputs for the projection of future commercial and industrial wastewater flows. The analysis is used to determine the areas available for future residential development, and the areas which are planned for industrial development. The development of residential land during the study period is determined in part by economic factors such as the demand for industrial, commercial, residential and institutional land, and also by approved plans for development of designated sites. The bulk of the information available for the analysis is the current (1980) Regional Plan for the Balqa-Amman Region, and the current town plans of Amman and the Study Areas other major municipalities. The Planning and Building Code, 1979[15] is the current zoning law in effect for the municipalities and other larger urban centers of the Study Area (with the exception of official UNRWA Refugee Camps[16]). These regulations combined with the regional and town plans, are likely to shape urban development in the Study Area betwen 1980 and 2000.

CURRENT ZONING PLANNING AND BUILDING REGULATIONS

The Planning and Building Code of 1979 changed the previous Planning and Building Regulations by adding some new residential classifications. The new code is presented in Table 3-2. The changes were highlighted by the addition of "popular" zones for residential and commercial plots, and the introduction of zone of both larger and smaller minimum plot area. Maximum building ratios were raised for residential and commercial property.

For residential property, a new green zone was made for each of the old residential Zones A through D. The zones provided minimum plot areas of 2000 square meters for Zones A and B, 1200 for Zone C and 800 for Zone D. In

TABLE 3-2

MUNICIPALITIES
PLANNING AND BUILDING CODE, 1979[a]

Zone	Minimum Plot Area (m^2)	Maximum Building Ratio (%)	Maximum Height (m)	Maximum Floors[b]
Residential				
Green Zone "A"	2000	36		
Green Zone "B"	2000	42		
Green Zone "C"	1200	48		
Green Zone "D"	800	52		
A-Residential	1000	36		3
B-Residential	750	42		3
C-Residential	500	48		3
D-Residential	300	52		3
Popular	150	-		3
Commercial				
Central	150	85	72	
Normal "A"	600	70	72	
Normal "B"	600	70	72	
Normal "C"	400	70	72	
Normal "D"	200	70	72	
Normal "Popular"	100	70	72	
Industrial				
Heavy Industrial	2000	50	24 300% of plot	
Light Industrial	1000	50	24 300% of plot	

[a] Applies to all cities in the Kingdom

[b] Note that commercial and high rise structures can exceed these maximum limitations.

addition, the old Zones A through D were also retained. The new "popular" zone has a minimum plot area of 150 square meters, one-half the size of the smallest previous zone size.

Commercial zoning now includes a "popular" zone with a minimum plot size of 100 square meters. Four zones that correspond to the residential A through D are now in effect allowing a range of 200-600 square meters for minimum plot size, each allowing a 70 percent maximum building ratio. Industrial zoning allows 50 percent maximum building ratio, and 100 and 2000 square meters minimum plot area for light and heavy industry, respectively.

EXISTING CONDITIONS AND RECENT TRENDS

For the purpose of the land use analysis, the Balqa-Amman Region will again be equated with the Study Area, as it differs from the area only in the extreme southwest where the environs of Ma'in fall outside the 30 kilometer circle, and along the western boundary, where the Jordan Valley Authority jurisdiction both inside and outside the circle is not within the scope of this study.

Land use in the Study Area is characterized by the following general geographic configuration:

1. a corridor of urban uses stretching from the Zarqa/Ruseifa/Hashemiya area in the northeast, through Amman in the center of the Study Area, and into the outlying suburbs of Wadi es Sir, Jubeiha and Suweileh immediately west and northwest of Amman, with smaller centers of urban uses around the outlying cities of Salt, Madaba, Sahab, Na'ur, Fuheis, Mahis, and Baqa'a Camp;

2. large industrial areas in Zarqa, Ruseifa and the Marka area in Amman, small industrial areas in southeastern and southern Amman, western Madaba, Hashemiya, eastern Wadi es Sir and Salt;

3. mixed low density urban and agricultural uses in the areas surrounding the dense urban areas (e.g. north and west of the Greater Amman Area and surrounding Madaba and Salt;

4. desert grazing and pastoral land in the extreme eastern portion of the Study Area;

5. agricultural uses in the greater portions of the south, north and northwest of the Study Area;

6. special uses, including Jordan University, Queen Alia Airport, and various military installtions and camps.

Development of the Study Area is reflected in the historical growth of Amman, whose major development occurred after 1946. During the period 1946-1953 growth in Amman concentrated along the Salt Road to the northwest and the Wadi es Sir Road to the west. Population density was approximately 25.0 persons per dunum in 1953, about 3 percent greater than 1946. The level of density increase was kept small despite a large increase in population, because of a similar increase in land development.

Expansion during the period 1953-1962 followed the previous patterns of Salt and Wadi es Sir Roads, and also included infilling of areas between Central Amman and the Western Sectors: Jabals Amman, Lweibdeh and Hussein. Low-income, high density settlements arose at the entrances of the Amman-Zarqa corridor. Both population and urbanized area increased by 9 percent during the period 1962-1972 marked a future expansion of Jabal Amman and Jabal Hussein, with the Amman-Zarqa corridor experiencing additional in-filling. Overall densities remained relatively low, but several pockets of high density developed. The City currently occupies approximately 43,000 dunums.[1] The Table below presents urbanized land, and population density of the Municipality of Amman for the period 1946-1979:

Period Year	Population Persons	Built Area (Dunums)	Density (Persons/Dunums)
1946	56,000	2500	22.4
1953	115,000	4600	25.0
1962	255,000	10000	25.5
1972	550,000	21000	26.2
1979	649,000	38000	15.6

Source: Amman Urban Region Planning Group, Planned Development in the Balqa-Amman Region 1981-1985, Department of Statistics, 1979 Census.

Recent development in the municipalities closest to Amman such as Wadi es Sir and Suweileh has been characterized by urban sprawl. These areas contain many relatively isolated high rise structures occupying over 40 percent of their total plot areas. Yet, they are often surrounded by agricultural land still in production.

In 1978, the Study Area contained approximately 75 percent of the Kingdom's urbanized land, or slightly less than 600,000 dunums. Amman Municipality contained almost two thirds of the latter figure, or 38,000 dunums. Between 1973 and 1979 the Region experienced urbanization of land at the rate of 4.0 square kilometers per year, while the Municipality of Amman urbanized 2.5 square kilometers per year.[1]

Table 3-3 presents industrial land use totals for the Balqa-Amman Region in 1978 by location. The Region totalled 32,462 dunums of land zoned for industrial uses, of which 11,197 dunums (35 percent) were developed. The Amman-Zarqa corridor contained approximately 93 percent of the developed industrial land in the Region, with 10,389 of 11, 197 dunums. The East Zarqa Road area formed the bulk of the latter total, with 8,500 dunums. Marj el Hamam and Rajib also substantial sites, each had 600 dunums.[1]

Undeveloped industrially-zoned land was distributed more widely throughout the Region. Although much of it (8500 dunums) was concentrated in East Zarqa (Amman Ring) Road, Amman, Rajib, Marj el Hamam, several proposed new industrial areas had significant totals. Sahab and Jiza (Queen Alia International Airport area) were proposed for sites of large industrial parks or estates.[1]

TABLE 3-3

INDUSTRIAL LAND USE IN THE STUDY AREA 1978
(dunums)

Location	Zones for Industrial Use	Developed	Potential Development
Ruseifa	52	39	13
As Salt	420	84	336
Wadi es Sir	440	44	396
Suweileh	100	30	70
Ain el Basha	490	50	440
Amman[a]	4,050	1,850	2,200
Ragib	3,000	600	2,400
East Zarqa Road	17,000	8,500	8,500
Marj al Hamam	1,500	600	900
Sahab[b]	2,000	0	2,000
Jiza[b]	1,000	0	1,000
Royal Scientific Society[b]	1,000	0	1,000
Madaba[b]	1,000	0	1,000
Hashimiya[b]	1,000	0	1,000
TOTAL	32,462	11,197	21,265

[a]Total not consistent with industrial land use total for Amman Municipality by Sector.

[b]Proposed new industrial zones.

Source: AURPG Planned Development in Balqa-Amman Region 1981-1985, 1979.

In 1979, approximately 105,000 dunums of land were occupied by public uses. Approximately half of this total (49 percent) was designated public forests. Major transportation facilities including airports and railroad land formed nearly 23 percent; and publicly-owned industrial estates represented about 20 percent. The other public uses including civic centers, schools, health care centers, parks and public housing projects were small by comparison.[17] Table 3-4 represents public land use by type for the Balqa-Amman Region in 1979.

TABLE 3-4

PUBLIC LAND USE IN THE BALQA-AMMAN REGION 1979[a]
(Dunums)

Land Use	1979 Estimated Total	Percent of Total
Public Service (Civil Centers, Public Buildings)	1,199	1.1
Schools	1,322	1.3
Major transportation	23,880	22.8
Industrial Estates	20,815	19.8
Health Care Centers	1,206	1.1
Urban Parks	1,304	1.3
Regional Parks	3,620	3.4
Forests	51,600	49.2
Public Housing	N.A	N.A
TOTAL	104,946[1]	100.0

[a] Not including public housing NHC planned projects in Amman, Abu Nsair, Sahab and Jiza.

Source: AURPG Planned Development in Balqa-Amman Region 1981-1985, 1979.

Agriculture occupies a significant share of the Region's land use. According to the latest agricultural census,[18] in 1975, 2,973,000 dunums of land were designated for agricultural use in the Balqa-Amman Region. This amount was roughly one-third of the total for the Nation (East Bank). Approximately one-third of the Region's agricultural land (990,000 dunums) was under cultivation. Virtually all of this land was planted with rain-fed crops, as only 0.5 percent was irrigated.

Conditions in the Study Area in 1980 are believed to be of similar magnitudes, as JVA development lies outside its boundaries. Much of the cultivated area was devoted to cereal crops in 1975; with winter cereals occupying 705,000 dunums, and summer cereals 11,000 dunums. The two represented approximately 72 percent of the total planted area in the Region. Vegetable crops occupied 124,000

dunums (13 percent), and tree crops 149,000 dunums (15 percent). The remaining agricultural dunums not in cultivation were utilized for livestock production. The major emphasis in that area was the raising of sheep and goats.

Municipality of Amman

Land use data for the Municiaplity of Amman for existing conditions are only available for the nine sectors of the city. The sectors are divided into 45 units used for census information. Figure 3-1 delineates the boundaries of the sectors and units of the Municipality of Amman. Units will be used later in this analysis to provide a more detailed breakdown of land use for the projection of future conditions.

The City Center is comprised mainly of commercial uses, and industrial land is concentrated in the Ain Ghazal area in the northeast, in the Al Rayhan and El Wahdat areas in the southeast, and in the Al Marj area in the extreme south. The remaining commercial land uses in the city are found along the major arterial streets, and as individual plots in residential neighborhoods. A large percentage of the city's government buildings are concentrated on Jabal Amman and Jabal Hussein. The higher density residential uses exist mainly in the eastern and southeastern portions of the city in Ain Ghazal, Al Nasr, Jabal Jofeh, Jabal Nuzha and the eastern portion of Jabal Amman. Lower density residential development predominates in the western third of the city, forming the major protion of land use in the Abdali and Zahran sectors. Open space occupies large areas in the north portion of the city in the vicinity of Al Rewaq, portions of the Al Nasr area in the southeast, and portions of the Shemeisani, Um Othaynah and Abdoun areas of the western and southwestern sectors of the city.[1]

Table 3-5 presents land use in the Municipality of Amman in 1978 for each of the city's sectors in dunums. As shown, approximately 52 percent of the city's land was developed by 1978. The Abdali sector was the least developed, with only 29 percent, while the City Center is completely developed. The Abdali and Zahran sectors are the fastest growing sectors in the city. In 1978, they contained 99 percent of the city's low density residential land (zones A and B) with 11,373 dunums. This represented a 225 percent increase over their total of 5,053 acres in 1972. In 1978, they contained 15,810 dunums of residential land of all types, which comprised approximately 47 percent of all residential land in the city. Residential urban sprawl development has remained the major form of development in these two sectors into 1980, and is expected to continue in the near future.[1]

Industrial land is concentrated in Ain Ghazal, whose 1,937 dunums, in 1978, represented 78 percent of the city's total. That figure represented a 213 percent increase over the sector's 1972 total of 909 dunums, which at that time included all of the city's industrial land.

Approximately 70 perent of the city's 3,712 dunums of special areas are concentrated in the City Center, Basman and Ain Ghazal. The City Center contains Basman and Raghadan Palaces, parks on Jabal Al Qala'a and the Roman Theatre. Abdali contains the Sport City, and various parks; Yarmouk contains Government Hospital grounds, and Ain Ghazal includes the City's airport.

TABLE 3-5

LAND USE IN THE MUNICIPALITY OF AMMAN IN 1978

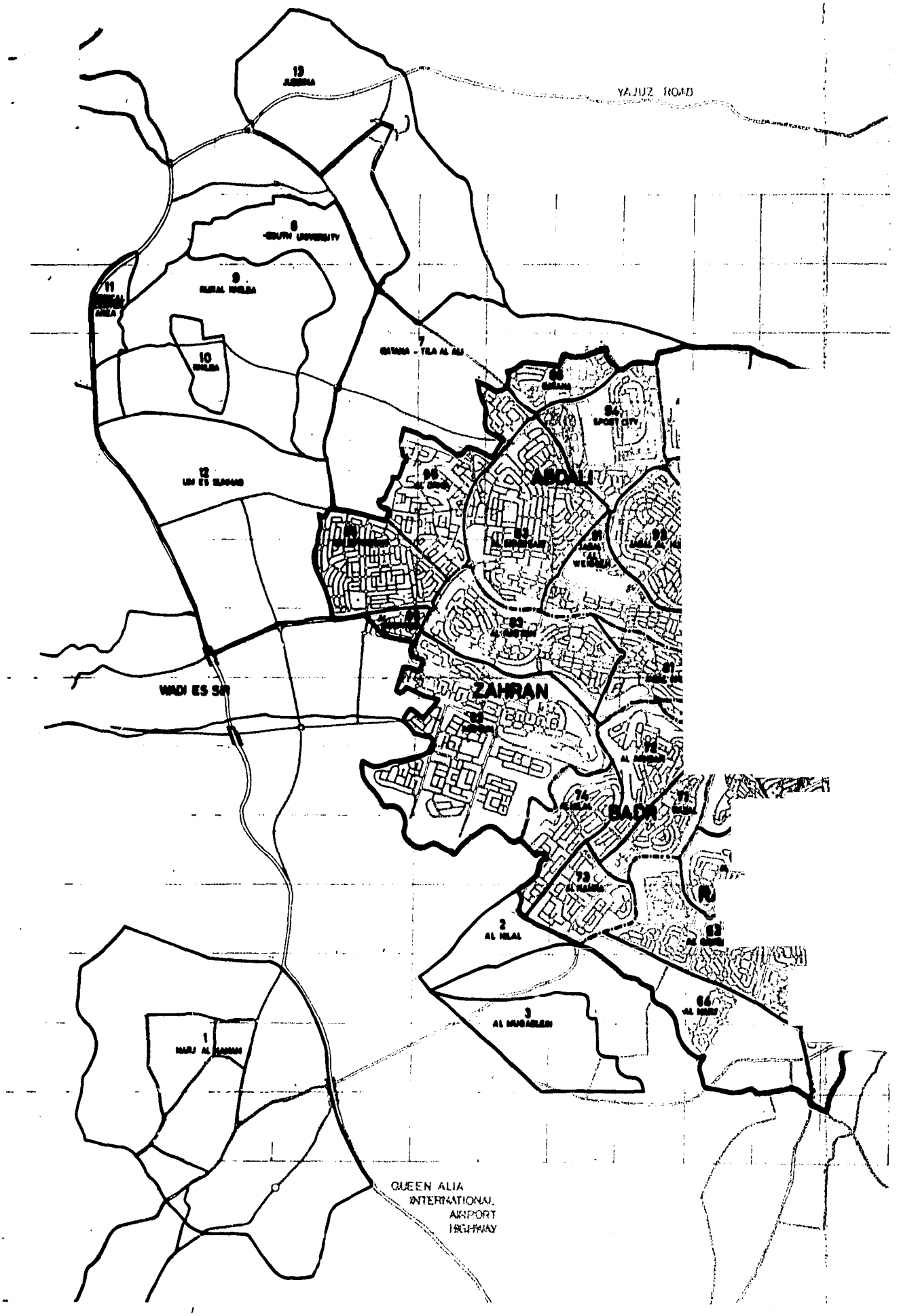
BY SECTOR (dunums)

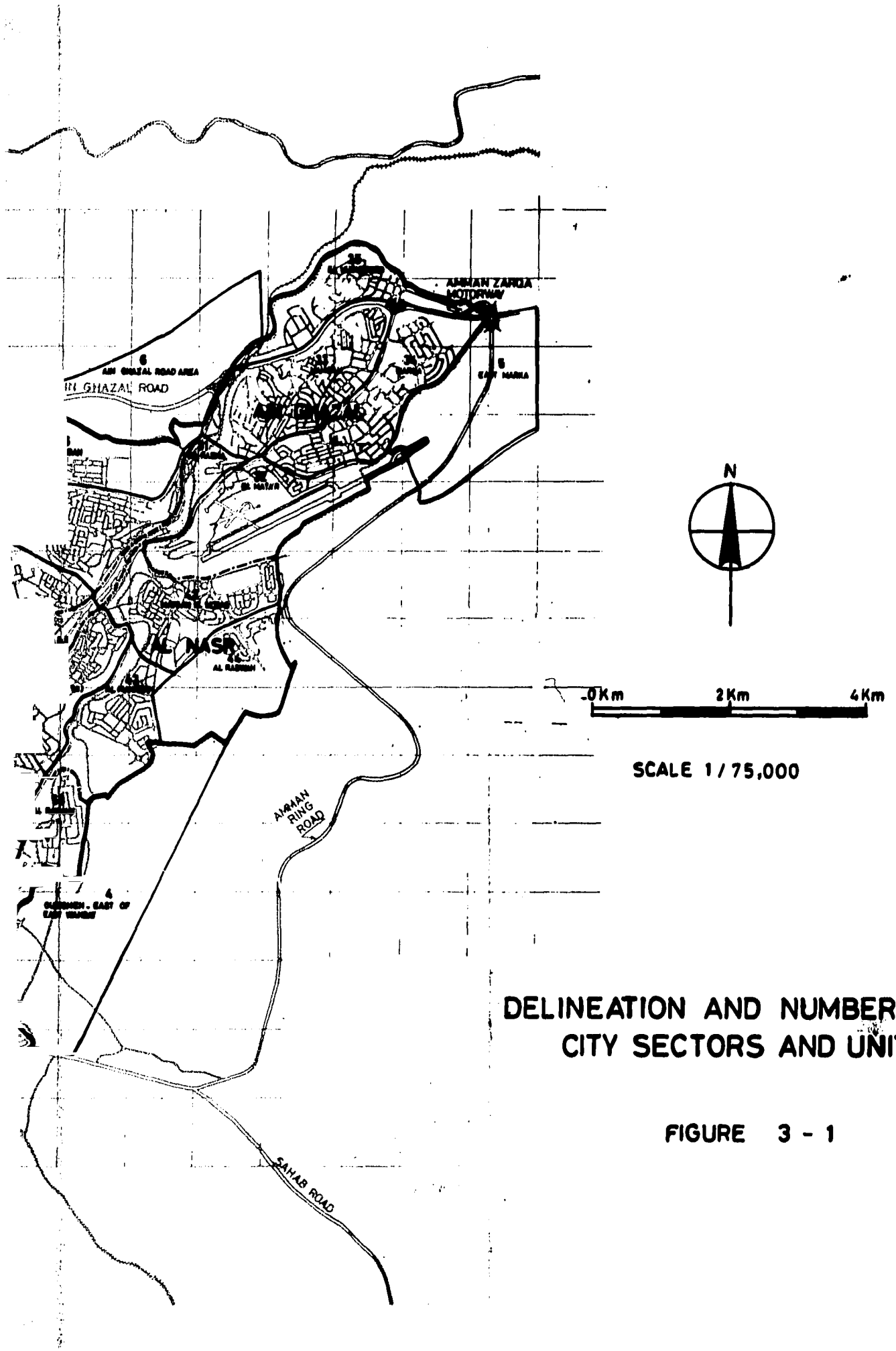
Land Use/Sector	City Center	Basman	Ain Ghazal	Al Nasr	Yarmouk	Ras Al-Ain	Badr	Zahran	Abdali	Total
Residential	983	4,326	1,568	3,739	2,392	2,040	2,485	6,376	9,434	33,343
A Lowest Density	-	-	-	-	-	-	-	3,575	3,027	6,602
B Low Density	-	-	-	-	-	-	93	1,067	3,704	4,864
C High Density	289	1,068	626	491	142	492	468	1,734	2,703	8,013
Highest Density	694	3,258	942	3,248	2,250	1,548	1,924	-	-	13,864
Commercial (C.B.D.)[a]	400	-	-	-	-	-	-	-	-	400
Industrial	-	40	1,937	-	431	-	75	-	-	2,483
Special Areas[b]	948	701	937	-	158	210	-	-	358	3,312
Unplanned	-	622	473	28	158	-	47	57	-	1,385
Non-built	0	8,991	7,469	4,826	2,658	7,243	3,092	7,092	4,041	45,412
Total	2,331	14,680	12,384	8,593	5,797	9,493	5,699	13,525	13,833	86,335
Percent developed	100.0	38.8	39.7	43.8	54.1	23.7	45.7	70.8		47.4

[a]The Central Business District is the only area of the City that contains a contiguous commercially zoned area of significant size. All other commercially zoned land within the City is scattered throughout the large residentially zoned areas.

[b]Including parks, recreation complexes, cemeteries, palace grounds, gardens and other planned open space.

Source: AMRPC Planned Development in Balqa - Amman Region 1981-1985, 1979.


YAJUZ ROAD
19
8
9
11
10
7
12
54
SPORT CITY
ABDALI
ZAHRAN
WADI ES SIR
BADR
2
AL HILAL
3
AL MUGABLEIN
1
QUEEN ALIA
INTERNATIONAL
AIRPORT
HIGHWAY



DELINEATION AND NUMBERING OF CITY SECTORS AND UNITS

FIGURE 3 - 1

Other Major Cities Within the Study Area

The Municipalities of Zarqa, Ruseifa, Madaba, Salt, Musherfeh, Suweileh, Wadi es Sir and Sahab are centers of population within the Study Area large enough to require individual attention. Zarqa, Ruseifa and Musherfeh were not included in this detailed analysis, as they were covered in detail in a separate study. Salt was not included because its town plan is in the process of being revised and other data concerning land use in that municipality could not be assembled without undue time and effort. For the purposes of this study, Salt was assumed to have similar proportions of the various urban land uses to the Municipalities of similar size (e.g., Madaba). Detailed information on current land use in the above-mentioned cities is not readily available. The town plans for these municipalities generally reflect existing conditions in the older inner-city areas, and areas of future planned development in the outer portions, will be discussed in the Projected Future Land Use Section with follows.

PROJECTED FUTURE LAND USE

The basis used in this analysis for determining future land use for the Study Area was the Balqa-Amman Region General Plan, and the town plans of the Municipalities of Amman, Wadi es Sir, Suweileh, Madaba, Sahab, and Na'ur. Figure 3-2 shows planned land uses for the Balqa-Amman Region and the study area.

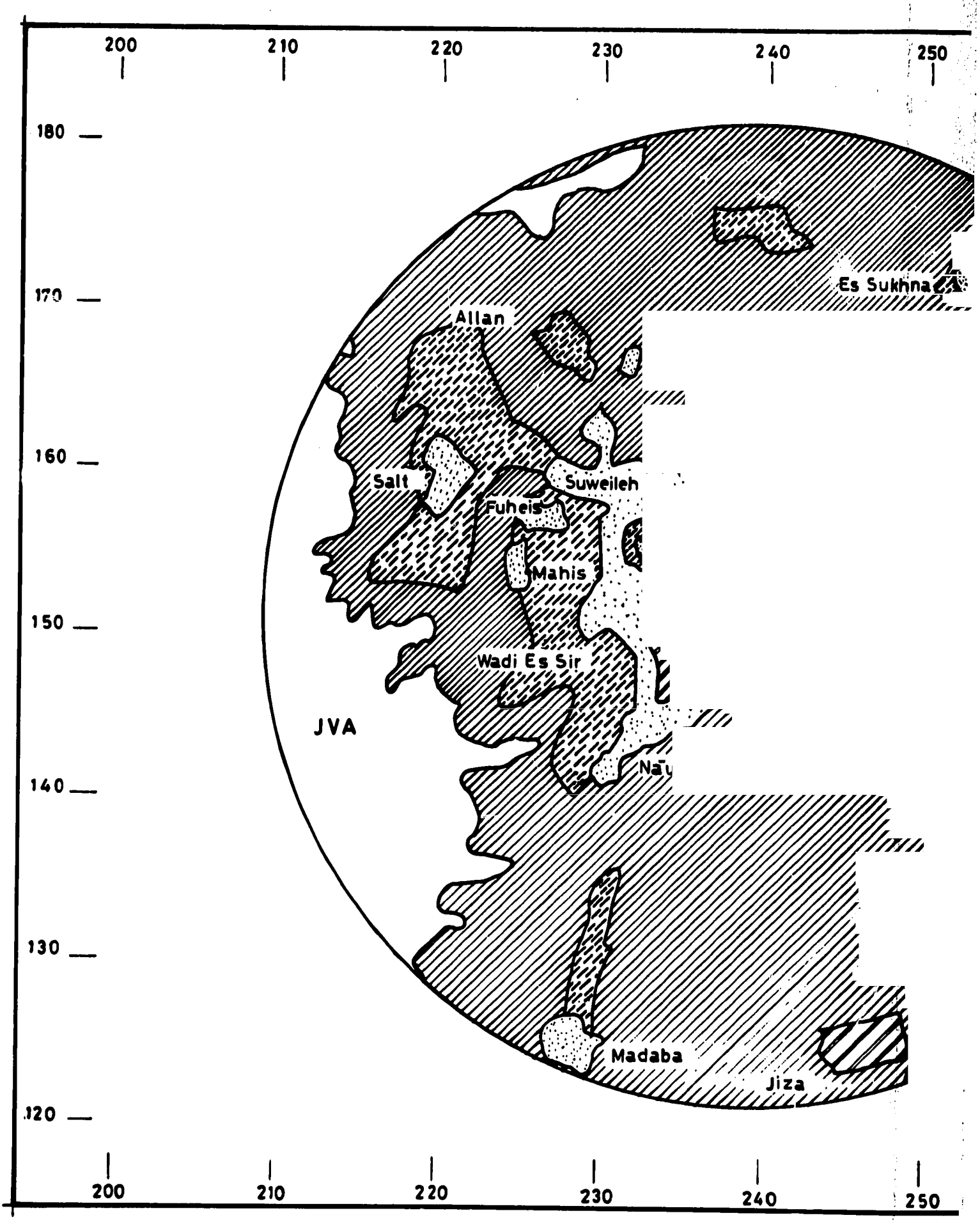
General changes in land use projected to occur, during the study period (1980-2000) are based on the planned land uses as shown on Figure 3-2 and discussed earlier. Expected changes include a significant expansion of urban land uses outward in a circle surrounding Amman, with much of the growth occurring in the western, northern and southern suburban areas, reaching Wadi es sir, Tila al Ali, Marj al Hamam and Suweileh.[7] A large proportion of the suburban area adjacent to Amman was grouped together for the purpose of this analysis into a single unit hereafter designated as the "Amman Suburban Ring." This area does not include Wadi es Sir and Suweileh because they were analyzed independently in great detail. Fig. 3-1, Amman and Suburban Ring Population Sub-areas, delineates the boundaries of the Suburban Ring, and its divisions, as well as the administrative divisions of the Municipality of Amman known as units. Growth of less magnitude, but of regional significance, is projected for the southern and eastern suburbs of Queismeh, Al Muqablein, the area east of East Wahdat, and East Marqa, all of which are also in the Suburban Ring.[17]

A significant development of residential land is projected to occur within the Study Area between 1979 and 2000, mainly in the outer areas of the larger municipalities and their surrounding suburbs. The suburban growth is, and will be, a reaction to high land costs in the inner portions of the cities combined with the need to be within commuting distance of centers of employment. Thus middle and upper middle income households can have a larger home in the suburbs for equivalent cost in the city. A significant portion of the outer areas of the Municipality of Amman (especially in the western and northwestern units) is currently undeveloped because of extremely high land costs which were bid up partly due to speculation. The nearby suburbs to the west and northwest have been filling in instead, because of relatively lower land costs.[1] This trend is

expected to continue for the next several years; but the outer areas of Amman are also expected to fill in slowly, and experience accelerated growth as the supply of undeveloped land within reasonable commuting distance of the employment centers of Amman diminishes. Table 3-6 presents total projected residential land developed during the two study periods (1979 to 1990, and 1991 to 2000). These projections were based on matching residentially zoned areas on town plans to aerial photographs, and determining saturation residential development. Then population projections based on net birth and death rate trends and net migration were used to determine the proportion of total saturation development that would be developed by the years 1990 and 2000 (see Appendix D for a detailed explanation of the methodology used in the saturation development analysis). As can be seen from Table 3-6, residential land use in the larger municipalities of the Study Area would increase by approximately 19,000 dunums between 1979 and 1990, and by approximately 19,700 dunums between 1991 and 2000. The Municipality of Amman would increase by approximately 7,000 dunums by 1990, and 6,200 dunums between 1991 and 2000, representing 21 and 15 percent increase respectively over the existing residential area of 33,343 dunums. See Tables B-9 through B-15 in Appendix B for detailed projections of residential land development by zone type for units of the Municipality of Amman, and for population sub-areas of Wadi es Sir, Madaba, Suweileh, Sahab, and Na'ur.

Commercial land within the Study Area is planned for significant expansion only in a few specified areas such as the undeveloped portion of the large government building zone in the west end of Jabal Weibdeh (adjacent to Shmeisani) in Amman. Other large areas planned for commercial development include the free trade zones at Jiza and east of Hashimiya. Remaining commercial development within the Study Area is expected to occur in strips on major streets, and scattered throughout residentially zoned areas.[1]

Industrial land use in the Study Area is expected to expand significantly between 1980 and 2000. The proposed Sahab Industrial City south of the city is planned for 2,530 dunums, 2,000 of which would contain industrial uses.[12] Other large industrially zoned areas which are expected to be developed by the year 2000 include 1,000 dunums near the Queen Alia Airport complex at Jiza;[1] approximately 1,000 dunums at Madaba; and another 1,000 at Hashimiya, in conjunction with the Zarqa/Hashimiya Free Trade Zone.[13] Refer to Table 3-3 for a list of industrial land potential development by area. Three major areas of new industrial development are planned for Amman and its immediate environs. They are located to the south and east of the city; south of Badr and Yarmouk sectors, east of the industrial area of Al Manarah, and east of Um al Heiran south of Abu Alanda. Industrially zoned areas in Wadi es Sir, Salt, Suweileh and Ain al Basha are also expected to expand significantly. The al Muqablein and Marj al Hamam areas are also planned for extensive industrial growth. Other important industrial development is planned for the existing Zarqa and Ruseifa industrial areas. Large commercial centers are planned to supplement industrial development in the Free Trade Zones planned for Zarqa/Hashimiya and the Queen Alia Airport complex.[17] Regional Agricultural Areas, of farms greater than 50 dunums in size, are planned for much of the north central and south central portions of the Study Area. The Baqa'a Valley is planned to remain mainly agricultural, with urban expansion only in Safut and a limited area northwest of Ain al Basha. The areas surrounding Allan, west of Fuheis and Mahis, and between Na'ur and Madaba are planned to remain important agricultural areas between 1980 and 2000.[17]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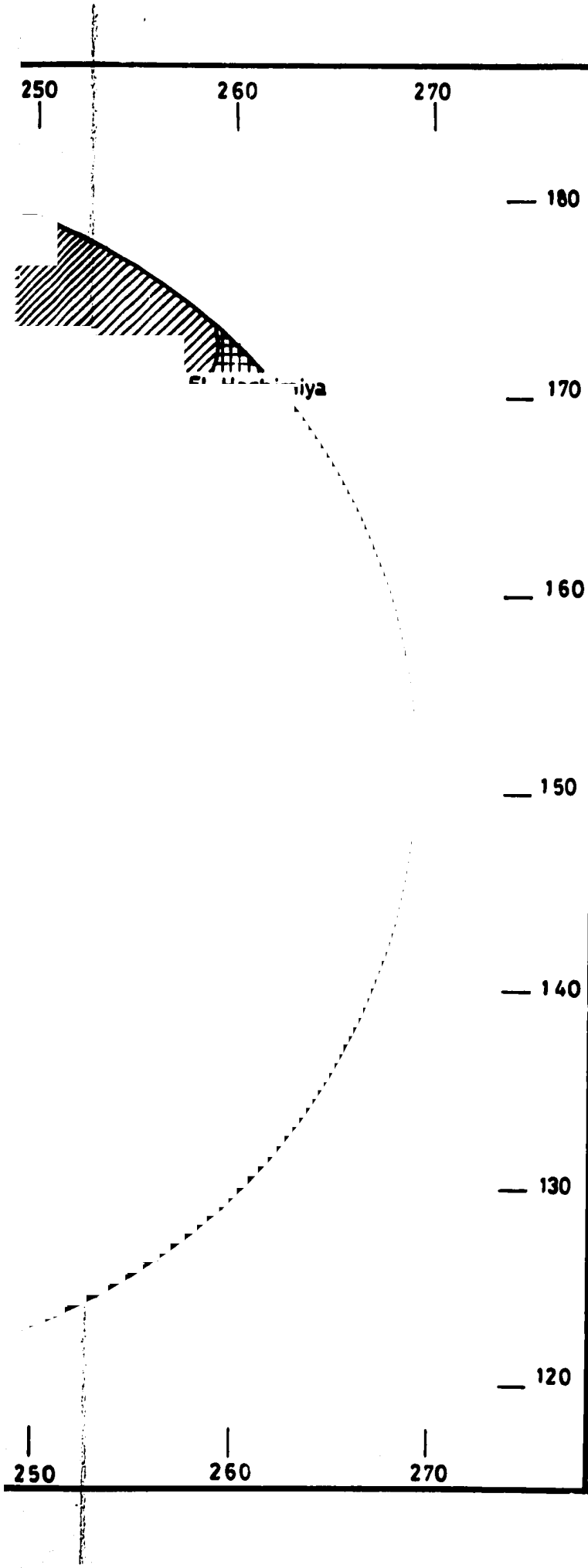

LEGEND

- URBAN USES
- MIXED LOW DENSITY URBAN AND AGRICULTURAL USES
- INDUSTRIAL
- SPECIAL USES
- AGRICULTURAL USES
- PASTORAL USES
- JORDAN VALLEY AUTHORITY

GREATER AMMAN AREA

REGIONAL LAND USE PLAN 1980 - 2000

FIGURE 3 - 2

TABLE 3-6

PROJECTED RESIDENTIAL LAND DEVELOPMENT
LARGE MUNICIPALITIES AND SUBURBS 1979 to 2000[a]
(Dunums)

	1979-1990 Increase	1991-2000 Increase
Amman	7,000	6,200
"Suburban Ring"	3,100	2,900
Wadi es Sir	600	600
Suweileh	400	400
Madaba	400	400
Sahab	300	300
Na'ur	[illegible]	100
Zarqa[b]	2,300	3,600
Ruseifa[b]	1,200	1,000
Salt[b]	400	500
Abu Nusair[c]	1,100	1,700
Sahab Airport City[c]	1,700	1,700
Airport City (Jiza)[c]	400	300
	19,000	19,700

[a]Based on Saturation analysis and growth projections outlined in following population subsection.

[b]Assuming 350 persons per hectare average density

[c]Totals for the new cities of Abu Nusair, Sahab/Airport City and Airport City (Jiza) for 1990 and 2000 are uncertain at this point in the planning phase.

Source: National Housing Corporation, Town Plans of Municipalities listed above, Feasibility Study Zarqa-Ruseifa Water Distribution Sewerage and Stormwater Systems Draft 1980, Malcolm Pirnie, Inc., Jouzy & Partners.

Other important land uses in the Study Area include a large number of military reserve areas; and special development areas such as the Queen Alia Airport site, Jordan University and the Wadi Abdoun catchment area, which cannot be used for residential or other urban uses.[17]

The geographic distribution of projected residential development outlined above forms the basis for the projection of population growth in the Study Area to 1990 and 2000. The projected development of industrial land use will provide input for the determination of water use factors for the individual drainage sub-areas, to project future sewage flows which will, in turn, be used as input in the sizing of sewer lines and/or treatment plant capacities.

PRESENT AND FUTURE POPULATION

Population projections for the various portions of the Study Area are required as a major input in the projection of the residential component of future water use, and thus sewage flows. The projection of future total population of the Study Area and the geographical distribution of that population within its boundaries requires the inputs of two major analyses. The first is the assessment of recent trends, and the subsequent formation of projected factors for future population increases. The second analysis is the projection of saturation population developed from the projection of future land use conditions. With those two inputs, the future populations of the Study Area's municipalities and other major urban communities can be projected, and disagregated into smaller units. The small units can then be matched to drainage areas within those cities and suburban areas to be used in the projection of water use and sewage flows.

RECENT TRENDS AND EXISTING CONDITIONS

The national census of population and housing, conducted in November 1979, reported the combined population of the Amman and Balqa Governorates as 1,339,132, a 5.5 percent rate of annual increase over the 512,675 total for these areas in 1961. The population of the Municipality of Amman was listed at 648,587, also an annual increase of 5.5 percent over the 1961 total of 246,475.[2,19] The only significant difference between the Study Area and the Balqa-Amman Region are the exclusions from the Study Area of Ma'in area in the extreme southwest of the Amman subregions, and the Jordan Valley communities between the Dead Sea and the Zarqa River. The Study Area contained an estimated population of 1,273,000, approximately 95 percent of the total population of the Balqa and Amman Governorates in 1979. Much of the growth in the East Bank between 1961 and 1979 was concentrated in the Study Area, and much of the latter area's growth was concentrated within its urban core (e.g. the Amman, Ruseifa, Zarqa corridor). This phenomenon is illustrated in the following table:

Area	Population 1961	Population 1979	Increase	Annual Growth Percent	Percent of Total East Bank Growth
Balqa and Amman Governorates	512,675	1,339,132	826,457	5.5	62
Municipality of Amman	246,475	648,587	402,112	5.5	30
Amman, Zarqa and Ruseifa	348,055	913,896	565,841	5.5	42
Remainder of East Bank	552,721	1,238,377	685,656	4.6	58
Total East Bank	900,776	2,152,273	1,251,497	4.9	100

Source: Department of Statustics, 1961 Census, 1979 Census (Preliminary Data)

The Balqa and Amman Governorates (approximating the Study Area) received approximately 62 percent of the total growth of the East Bank between 1961 and 1979, while the Municipality of Amman, alone, accounted for 30 percent. Amman, Zarqa and Ruseifa accounted for 42 percent of the East Bank's total growth while growing at a rate of 5.5 percent annually, while the remainder of the East Bank grew only 4.6 percent per year.

Between 1961 and 1979, the population of the East Bank increased at an average annual rate of 4.9 percent. At present, the crude birth rate is estimated to be between 45 and 50 births per 1,000 and the crude death rate is estimated to be between 9 and 12 deaths per 1000, for a natural growth rate of between 3.3 and 3.6 percent.[2,20] The influx of refugees from the West Bank and Gaza Strip during the hostilities of 1967 and 1973, and the conflict in Lebanon in 1975 have contributed significantly to the growth of the population of the East Bank.[1]

Other factors which affected the rate of growth during that period were the out-migration of Jordanian workers to the oil-producing Gulf countries, and the in-migration of workers from developing nations. The urban population of the East Bank, and the Study Area in particular, has grown at a faster rate than that of rural areas, because of the immigration of rural population, in addition to the immigration of refugees.[1]

The Municipality of Amman contained 51 percent of total Study Area population in 1979 Zarqa, with its 215,687 people, and Ruseifa with 49,622 combined to form another 21 percent. The combined total of all urban communities above 10,000 population in the Study Area was 1,115,000, representing 88 percent of the study area's population.

Table 3-7 shows population and household size for the larger municipalities, villages and refugee camps in the Study Area in 1979. The communities with populations above 3000 averaged 6.7 persons per household, ranging from 6.1 in Wadi es Sir and Na'ur to 8.6 in Suweileh. Amman was slightly below the regional average, with 6.5 persons per household. Zarqa, the other large population center in the Study Area, had an average household size of 6.9.

Municipality of Amman

Amman has experienced the same characteristics as that of the Greater Amman area. The rapid growth of the Municipality since the end of World War II has been exemplified in the Table below:

Year	Population	Built Area (Dunums)	Density in Built Areas (Persons/dunums)	Annual Growth Rate
1946	56,000	2,500	22.4	10.8
1953	115,000	4,600	25.0	9.3
1962	255,000	10,000	25.5	8.0
1972	550,000	21,000	26.2	2.4
1979	649,000	38,000	15.6	

Source: Amman Urban Region Planning Group, Department of Statistics 1979 Census

The most rapid growth occurred between 1946 and 1972, with an approximately equal growth in built area. Between 1972 and 1979, however, the amount of built area exceeded the gain in population, actually producing a significant reduction in population density. This trend is expected to continue. In 1979, the population density of the city was 15.6 persons per dunum of built area.

Table 3-8 presents population and household size of the nine sectors of the Municipality of Amman in 1979. The sectors varied greatly in total population and population density, but differences were much less pronounced in family size (Refer to Fig. 3-1 for delineation of the sectors and census units of the Municipality of Amman). Population of the sectors ranged from 36,000 in the Central City to 137,000 in Basman, with Yarmouk, Al Nasr and Abdali also containing relatively large totals. Ain Ghazal, Badr, and the currently developing Zahran sector contained relatively low populations, ranging from 37,000 to 45,000 people. Household size varied from 5.3 persons per household in Zahran, to 7.0 in Yarmouk. Zahran and Abdali, the fastest growing sectors in the municipality, had relatively low family sizes of 5.3 and 5.7 persons per household, respectively, while the remaining sectors ranged between 6.4 and 6.9 persons per household. Household size information for units of the city will not be available.

TABLE 3-7

POPULATION AND HOUSEHOLD SIZE OF STUDY AREA
MUNICIPALITIES, VILLAGES AND REFUGEE CAMPS, 1979
(above 3,000 persons)

Municipality/ Village	Population	Households	Persons Per Household
Amman	648,587	99,198	6.5
Zarqa	215,687	31,151	5.9
Ruseifa	49,622	6,868	7.2
Baqa'a	45,291	6,667	6.8
Salt	32,866	4,833	6.8
Madaba	28,509	3,989	7.1
Wadi es Sir	24,497	3,994	6.1
Schneller Camp	24,229	3,055	7.9
Suweileh	21,442	2,482	8.6
Musherfeh	12,052	1,729	7.0
Sahab	11,908	1,582	7.5
Queismeh[a]	8,500	NA	NA
Fuheis	5,215	902	5.8
Na'ur	5,199	846	6.1
Taibeh/Qaisiya	4,894	694	7.0
Dhuleil	4,801	663	7.2
Sukhneh	4,387	622	7.1
Abu Alanda	4,202	589	7.1
Hashimiya	4,179	536	7.8
Talbiya Camp	3,949	584	6.8
Mahis	3,892	482	8.1
Khirbet Suq	3,568	509	7.0
Ain el Basha	3,141	428	7.3
Juweideh	3,014	429	7.0

[a] Estimated from 1978 total (not available in 1979 Census Preliminary Data)

Source: 1979 Census Preliminary Estimates, Department of Statistics, Amman Urban Region Planning Group, 1978 Population Estimates.

TABLE 3-8

POPULATION AND HOUSEHOLD SIZE OF AMMAN
BY SECTOR 1979

Sector	Population	Households	Population Per Household
Central City	36,416	5,689	6.4
Basman	137,154	20,087	6.8
Ain Ghazal	36,914	5,747	6.4
Al Nasr	89,733	13,370	6.7
Yarmouk	120,877	17,147	7.0
Ras el Ain	64,327	9,260	6.9
Badr	45,235	6,812	6.6
Zahran	39,331	7,371	5.3
Abdali	78,600	13,715	5.7
Total City	648,587	99,198	6.5

Source: 1979 Census, Department of Statistics

PRESENT AND FUTURE SOCIO-ECONOMIC CONDITIONS

Table 3-9 lists population and population density (per dunum of built and non-built area) of the 46 units of Amman in 1979. Population of the units ranged from 75,000 in Jabal Al Nuzha to less than 1000 in three different units; with Al Hashemi, Jabal Al Taj, Al Ashrafiyeh, Al Awdah and Al Nadif also containing relatively large totals. The industrial units in Ain Ghazal, and many units in Zahran, Abdali and Badr Sectors contained relatively low totals.

The areas in the extreme west and southwest with relatively low populations include Abdoun, Sweifieh, Radwan, Um Othaynah, al Shmeisani, Sports City, Al Dahia and Qatana. The populations of these areas were each below 10,000; and the population densities of all but one were below 3 persons per dunum. The city mean density for all areas (built and non-built) was 7.5 persons per dunum. These density figures reflect three factors:

- The amount of built-up area
- Crowding
- Family size

The use of the factor "population per built-up area" has more meaning, because it eliminates one of the variables in the parameter. However, amount of built-up area w not available for units of the municipality of Amman. Density based on built and non-built areas can be used for comparison if the areas compared all are completely built-up, or approach the state. A good example of such a comparison would be Jabal Hussein vs. Jabal Nuzha has a density of 33.3 persons per dunum, while Jabal Hussein has a density of 15.1 persons per dunum.

The highest population densities were located in the older eastern and southern portions of the Municipality, including al Ashrafiyeh, Jabal al Nuzha, al Nadif, Jabal al Taj, and Al Awdah, ranging from approximately 24 to 33 persons per dunum. Other areas, such as Central City, Al-Hashemi, Maydan al Sebaq, al Rayhan, Nazal, al Akhdar, Jabal Hussein and Jabal Amman (eastern portion) had densities ranging from 14.4 to 17.5 persons per dunum. The remainder of the units had densities of 7 or less persons per dunum.

Other Major Cities Within the Study Area

No data are currently available for the populations of units or population sub-areas of the other cities in the Study Area. The 1979 Census information which will be tabulated by mid-1981, may provide such information. Estimates of 1979 populations of population sub-areas of Wadi es Sir, Madaba, Suweileh, Sahab and Na'ur were made strictly for use in the projection of saturation, 1990 and 2000 populations of segments of those cities; and as such, appear in the population projections section of this chapter.

Seasonal Variation

For the purpose of providing input for the determination of maximum daily waste flows, an attempt was made to quantify the net changes in population that might

TABLE 3-9

MUNICIPALITY OF AMMAN POPULATION AND POPULATION DENSITY BY UNIT IN 1979

Unit		1979 Population	Area (Dunum)	Density Population/Dunum
11-19	Central City	36,416	2,331	15.6
21	Jabal al Nusha	75,274	2,261	33.3
22	Al Kusour	10,486	1,729	6.1
23	Al Hashemi	40,974	2,593	15.8
24	Al Jorm	4,979	2,733	1.8
25	Al Rewaq	7,490	1,579	4.7
26	Raghadan	3,414	3,779	0.9
31	Al Rasha	5,819	931	6.3
32	Al Mata'r	2,995	3,130	1.0
33	Hamzah	18,218	3,451	5.3
34	Marka	9,192	2,891	3.2
35	Al Musherfeh	784	1,981	0.4
41	Jabal al Taj	47,389	1,842	25.7
42	Maydan al Sebaq	33,601	2,194	15.3
43	Al Manarah	6,057	1,888	3.2
44	Al Rabwah	2,922	2,669	1.1
51	Al Ashrafiyeh	47,480	1,492	31.8
52	Al Awdah	53,400	2,234	23.9
53	Al Rayhan	15,714	1,057	14.8
54	Um al Heiran	1,755	1,015	1.7
61	Al Nadif	40,969	1,273	32.2
62	Al Zohour	11,183	2,040	5.5
63	Al Rawdah	8,270	3,171	2.6
64	Al Marj	3,905	3,009	1.3

Unit		1979 Population	Area (Dunum)	Density Population/Dunum
71	Nasal	17,930	1,026	17.5
72	Al Akbar	27,297	1,882	14.5
73	Al Hamra	143	1,319	0.1
74	Al Hilal	2,135	1,482	1.4
81	Jabal Amman	26,133	1,820	14.4
82	Abdoun	3,672	6,424	0.6
83	Al Radwan	6,120	2,899	2.1
85	Al Sweifiyeh	261	329	0.8
86	Um Othaynah	3,145	2,053	1.5
91	Jabal al Weibdeh	15,355	2,146	7.2
92	Jabal al Hussein	36,538	2,421	15.1
93	Al Shmeisani	9,577	3,546	2.7
94	Sport City	1,423	2,762	0.5
95	Al Dahia	3,975	2,030	2.0
96	Qatana	4,464	928	4.8
Total City		646,778	86,335	7.5

Source: Department of Statistics, 1979 Census, Consultant Estimates.

affect the parameters used in the sizing of sewer lines, and sewage treatment facilities. The summer months were given most consideration in this analysis, as the highest rates of per capita water consumption generally occur during those months.

The major seasonal movements of population do, in fact, occur during the summer months, marked by the following phenomena:

- The return home of Jordanian workers from Saudi Arabia and the other Gulf States
- An influx of tourists and vacationers from other Arab Countries
- An influx of tourists from non-Arab Countries
- The exodus of Jordan University Students who reside in or near the University area, to their former homes scattered throughout Jordan and abroad
- Movement of farmers and farm laborers from the Jordan Valley to Villages and towns in the Plateau

During most of the year the number of Jordanians leaving the Country exceeds the number arriving. However, starting in June, the number of arrivals exceeds departures. The table below shows arrivals and departures of Jordanians in 1979 (in thousands) during the months from June to September, when the accumulation of these visitors is at its greatest:

Month	Arrivals	Departures	Differences	Accumulation
June	91.1	61.3	29.8	
July	99.1	71.6	27.5	57.3
August	91.4	78.5	12.9	70.2
September	62.3	157.9	(95.6)	(25.4)

Source: Department of Statistics, "Arrivals and Departures by Nationality." 1980

Steady arrivals of large numbers of Jordanians began in June, and lasted through August, with more than 90,000 arriving per month. In September, arrivals dropped to just over 60,000; but departure, which had ranged between 60,000 and 80,000 during June through August, more than doubled to 158,000. The latter is believed to represent for the most part, the return of Jordanian expatriates to Saudi Arabia and the other Gulf States where they work and live for most of the year. That assumption is given credence by the implied accumulation of Jordanian visitors in July and August totalling 57,000 and 70,000, respectively; and additionally in view of the fact that more than 250,000 Jordanians work in other Arab Countries. The latest information, from 1976, indicates that approximately 300,000 Jordanians worked in other Arab Countries. It is not unreasonable to

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assume that as many as 70,000, or approximately one-fourth of the Jordanian workers in the Gulf States come home to Jordan for a vacation during the hot summer months. A disaggregation of the accumulation of net Jordanian arrivals and departures into short and long visits (i.e., visits of expatriate Jordanian workers vs. short trips of permanent residents) cannot be accomplished given existing data. However, a new program which will provide identification cards for Jordanians working abroad will allow such information to be compiled. For the purposes of this analysis, it was assumed that the large accumulations of 57,000 and 70,000 during July and August represent expatriate workers, and that arrivals and departures of Jordanians on short trips cancel each other.

The expatriate workers and their families will stay in various parts of the country. However, due to its primary position in the Kingdom in terms of populations, services, economic activity, and as the only place for obtaining permits to enter the West Bank, it was assumed that the Greater Amman area would receive the vast majority of the Jordanian expatriates. The others would generally return to their former places of residence.

The number of tourists from the Arab Countries has increased dramatically in recent years; from 159,000 in 1972 to 431,000 in 1975, and 1,075,000 in 1979. A comparison of the monthly figures from 1972 to 1979 shows a significant increase in arrivals in May, steady high levels of arrivals through August, with a slight decrease in September. Departures, on the other hand, remain significantly lower than arrivals during these months so that an accumulation of visitors from other Arab Countries takes place.[22] The table below representing monthly arrivals and departures (in thousands) for the high season of 1979 illustrates that point:

Month	Arrivals	Departures	Differences	Accumulation
May	76.1	63.9	12.2	
June	81.7	61.3	20.4	32.6
July	93.7	71.6	22.1	54.7
August	97.7	78.5	19.4	74.1
September	89.6	157.9	(68.3)	5.8

The accumulation of Arab visitors from the period May to September, reaches a peak in August with 74,000; but is substantial also in July and June, with 55,000 and 33,000, respectively. It can be assumed that the high levels of Arab visitors remaining in Jordan during these peak summer months, spend relatively long periods, often from one to two months. It is reasonable to assume that most of these visitors stay in the Greater Amman Area, for the same reasons cited earlier. Comments from officials of some Municipalities and suburbs in the west and northwest suburban areas of Amman confirmed that assumption (see Appendix F Community Sanitation Reconnaisance Survey for detailed information). The cities of Suweileh, Jubeiha, Fuheis, and suburb of Safut were among the respondees.

Approximately half of the Arab Visitors to Jordan are from Syria, while the majority of the remainder come from Lebanon, Egypt and Saudi Arabia.

The numbers of visitors (tourists) from non-Arab Countries during the period 1975 to 1979, fluctuated between 200,000 and 300,000 per year. There has been no significant increase in recent years. A comparison of monthly arrivals and departures shows no discrepancy. Therefore, it can be concluded that these visits are of short duration. It is assumed that the vast majority of these visitors stay in hotels in Greater Amman, and subsequently in other parts of the Kingdom. It must be concluded that the contribution of non-Arab tourists to seasonal variation in population is insignificant.

The contribution of Jordan University students to seasonal variations in Jubeiha, Al Rashid and the general University area was assessed and found to be insignificant. Based on total enrollment of 9000 students, it was estimated that approximately 2000 foreign and male students could be living near campus, 1000 female students live on campus while the remaining 6000 students commute to their homes in the municipality of Amman and its proximity.[23] The effect will be even less significant when it is considered that the students living on or near campus are away for the summer holiday when the influx of Arab visitors is at its peak.

Seasonal variations in populations of other cities and villages within the Study Area do occur, but they are not significant in terms of sewage system planning. According to local officials the cities of Madaba and Na'ur, and villages of Jureina, Um el Basatine and Er Rawda experience population increases in summer in the form of vacationers and farmers and farm workers from the Jordan Valley. The three villages also experience increases in the late winter and early spring, as additional farmers and farm workers arrive. The large decrease occurs in autumn. The Baqa'a Refugee Camp and cities such as Zarqa, Ruseifa, Sukhneh and other around the Study Area reported large increases in summer due to the return of workers from the Gulf States, confirming the previous analysis of Jordanian arrivals and departures. (See Appendix F Community Sanitation Reconnaisance Survey for detailed information).

POPULATION PROJECTIONS

Previous Studies

The major source for most recently-produced population projections for the Amman Region has been the AURPG. In their 1979 report Planned Development in the Balqa-Amman Region 1981-1985, several models of future population of the Region were outlined. The following three models of National population growth were proposed and evaluated:

- Constant birth rate - of 51 per 1000 persons 1975-[illegible]
- Declining birth rate - declining to 46 per 1000 in 1985, [illegible] 26 by 2000
- Rapidly declining birth rate - 46 per 1000 population in 1985, and 26 per 1000 persons by the year 2000

The death rate applicable to all three models was assumed to decline slightly to a level of 9.8 per thousand per year in 1985, and 9.6 by 2000. In-migration was assumed to balance out-migration for the East Bank of the Kingdom. The following annual rates of increase were assumed in the three models:

	1975-1985	1985-2000
Constant	4.10	4.13
Declining	3.85	3.13
Rapidly Declining	3.85	2.63

Four distribution models were combined with the National Birth rate models to distribute population growth among the regions of the Kingdom. They represented high growth in Amman vs. other regions, medium growth and balance among the regions, a "de-Ammanization" model, and declining growth model with continued concentration in Amman. The fourth model was chosen to be used in combination with three subregional distribution models. It assumed a 5.0 percent annual increase for the Amman Region between 1975 and 1985, and a 3.8 percent increase for the period 1985 to 2000. The implied growth rate for the period 1979-2000 was calculated so that the annual rate of increase for the AURPG model could later be compared to the rate of increase chosen for this Study. The implied growth rate for 1979-2000 for the AURPG model was 4.03 percent.[24]

Other recent studies which included relevant population increase assumptions included two sewerage studies for AWSA, and a solid waste study for the Municipality of Amman. The 1979 solid waste management study for the Greater Amman Region[25] assumed a 3.2 to 4.0 percent annual increase for the Amman Region, representing a population of 2.6 to 3.2 million for the period 1979 to 2000.

A feasibility study completed in late 1977 for a water supply and sewage facilities system for AWSA[26] included population projections for the Amman Region based on the 1971 census. A range of annual increase from 5.0 to 3.2 percent was assumed for the period 1977 to 2000. The Municipality of Amman was projected to contain 1.1 million people by 1990, and 1.6 million by the year 2000.

Potential Saturation Population

The estimated saturation population of the urban centers within the Study Area can be used as one of the inputs in the sizing of sewerage facilities. It provides a gauge for determination of ultimate system requirements, which should be a major determinant of the sizing of sewer trunk lines, and the capacity of treatment plants if saturation levels are projected to be reached within the study period, or soon after. If saturation levels are not expected to be reached within five to ten years beyond the study period, they can still be used as an input in the determination of final system design sensitivity analysis, as an indication of the flexibility required by the system to meet future demands.

Saturation populations were estimated for the Municipality of Amman, the suburban area surrounding Amman, and the municipalities of Wadi es Sir, Suweileh, Madaba, Sahab and Na'ur. The Municipalities of Zarqa, Ruseifa and Musherefeh were not included because their saturation populations had been estimated recently in a separate study.[27] The estimates projected in that study were accepted for use in this study, as they were derived using the same method. The Municipality of Salt was not included, because its town plan is currently in the process of being revised. For the purposes of our study, we will assume that Salt will have a saturation population which is roughly similar to those of Madaba, Suweileh and the other large outlying municipalties in terms of their ratios of current population to saturation population. The Baqa'a and Schneller (Marka) Refugee Camps were assumed to have saturation populations equal to their current populations, as their residential areas are restricted to their current boundaries, and upward expansion of structures is prohibited. It is assumed that the excess populations of the refugee camps will move to other urban communities throughout the Study Area. Thus, all urban centers with populations above 10,000 were evaluated for potential saturation populations.

Na'ur was also evaluated although its population was only 5,200 in 1979, because the saturation populations of various subsections of that city were necessary for the projection of 1990 and 2000 populations for subsequent drainage and sewer line siting analysis.

The following method was used to project population saturation levels for the municipalities listed above:

Step 1 Map areas of particular zoning were measured through the use of a planimeter for each unit in the Municipality of Amman, and for the other cities as a whole.

Step 2 Aerial photographs from 1978, 1979 and 1980 were used to estimate the proportion of each zoned area that is currently undeveloped. Visual reconnaissance via automobile was used to supplement 1978 photographs.

Step 3 Zoning and building regulations from the 1979 Planning and Building Code regarding lot size, coverage and building height were applied to the areas of each zone to determine the maximum number of dwelling units for each zone.

Step 4 The projected number of units for each zone was multiplied by the 6.5 estimated number of persons per family (reflecting a slight decline from the current 6.7 average).

Step 5 Individual zones were grouped together into larger divisions of the municipalities based on contour lines and preceived small-scale drainage areas.

See Appendix B for a detailed description of the methodology used to project saturation populations.

Table 3-10 lists the saturation populations of the major municipalities within the Study Area (excluding Salt), and the suburban area surround Amman. The Municipality of Amman has a projected saturation of 1.3 million, or double its 1979 population of 649,000. Zarqa's projected 566,000, is 2.6 times as large as its 1979 total. Ruseifa (including Musherfeh) is projected for a capacity of 230,000, or 4.6 times as large as its 1979 population. The other areas with the large capacities for growth include Wadi es Sir, Madaba, Suweileh and the suburban area surrounding Amman. Saturation would increase the population of the latter by approximately 805,000. The outer areas of Amman Municipality, the suburban areas surrounding Amman, eastern Wadi es Sir, and the Ruseifa area, are expected to be the major growth areas within the Amman Region between 1980 and the year 2000. See Appendix B Tables B-3 through B-8 for breakdowns of projected saturation populations of the sub-areas of the Amman Suburban Ring and the cities of Wadi es Sir, Madaba, Suweileh, Sahab and Na'ur.

It must be noted that the saturation growth levels shown here are more a reflection of official development plans than the actual potential for growth. The overall average densities of these cities would be similar at saturation to current average densities. Differences would exist within the sub-areas or units of the cities due to planning goals as represented by the Planning and Building Code, 1979. The majority of land in the outer areas of the cities is zoned A and B for low-density development. However, currently built-up areas in city centers do not contain high-rise housing, which is allowed, and expected to be developed in some of the outlying and medium-distanced areas from city centers. These saturation projections took this into account, and used high-rise as a balance against the extensive A and B zoning for currently undeveloped areas. It would be possible, of course, to place more housing units on smaller plots in these areas, but the liberal high-rise assumption keeps the projection in line with what is realistic, without rejecting current plans.

The large difference among cities in growth required to reach saturation, such as only 101 and 162 percent growth for Amman and Zarqa, compared to 613 and 5,031 percent for Wadi es Sir and the Suburban Ring reflect the extent to which each municipality desired to plan outlying portions of their jurisdictions. The saturation levels for these particular plans are likely to be reached at highly separate intervals, most of which are likely to be after the year 2000.

These projections are valuable, however, because they provide a reasonable estimate of the ultimate populations that will occupy the land within the planning boundaries as assessed. It is also a gauge that can be used to test the validity of population projections for individual areas based on assumptions of birth rates, death rates and migration. For the cities of Amman and Zarqa, which will either reach saturation by 2000, or approach it, the saturation populations can be used as an important input for the sizing of sewage facilities.

Saturation levels for the units of the Municipality of Amman are presented in Table 3-11; the location and boundaries of those units are shown in Fig. 3-1. The units with the largest potential population increase are the following: Abdoun (89,000) and Shmeisani (31,000) in the west; Al Rawdah (65,000), Al Zuhour (35,000) and Al Akhdar (27,000) in the south; Al Rabwah (50,000) and Al Manarah (28,000) in the east; and Al Jorm (34,000) and Al Rewaq (29,000) in the north.

TABLE 3-10

ESTIMATED SATURATION POPULATION OF LARGE MUNICIPALITIES AND THE SUBURBAN AREA SURROUNDING AMMAN

(1,000)

Area[a]	Population 1979	Saturation Increase	Percent Increase	Total Saturation Population
Municipality of Amman	649	656	101	1,305
"Suburban Ring"[b]	16	805	5,031	821
Zarqa	216	350	162	566
Ruseifa[c]	50	180	360	230
Madaba	29	101	348	130
Wadi es Sir	25	147	613	171
Suweileh	21	58	276	79
Sahab	12	42	350	54
Na'ur	5	18	360	23

a The Municipality of Salt was not included in this analysis because its town plan is currently being amended.

b Including Jubeiha, Khilda, al Ali, Shmeisani al Gharbi, Umm es Summaq, Marj el Hamam, Al Muqablein, Queismeh, area east of Wahdat, East Marqa; South Jordan University, and the Ain Ghazal Road area west of Ain Ghazal.

c Including Musherfeh.

TABLE 3-11

PROJECTED SATURATION POPULATION
MUNICIPALITY OF AMMAN BY UNIT

Unit	Name	Saturation Increase (1000)	Saturation Population (1,000)
11-19	Central City	0	36
21	Jabal al Nuzha	7	82
22	Al Kusour	0	10
23	Al Hashemi	27	68
24	Al Jorm	34	39
25	Al Rewaq	29	37
26	Raghadan	17	21
31	Al Rasha	0	6
32	Al Matar	0	3
33	Hamzah	4	22
34	Marqa	2	12
35	Al Musherfeh	0	1
41	Jabal al Taj	0	47
42	Maydan al Sebaq	6	40
43	Al Manarah	28	34
44	Al Rabwah	50	53
51	Al Ashrafiyeh	0	47
52	Al Asdah	0	53
53	Al Rayhan	15	31
54	Um el Heiran	5	7
61	Al Nadif	0	41
62	Al Zohour	35	46
63	Al Rawdah	65	74
64	Al Marj	13	17
71	Nazal	20	37
72	Al Akhdar	27	55
73	Al Hamra	23	24
74	Al Hilal	21	23
71	Jabal Amman	4	30
82	Abdoun	89	93
83	Al Radwan	24	31
85	Al Swafiyeh	2	3
86	Um Othaynah	15	18
91	Jabal Weibdeh	6	21

Unit	Name	Saturation Increase (1000)	Saturation Population (1,000)
92	Jabal Hussein	7	44
93	Al Shmeisani	31	41
94	Sport City	16	18
95	Al Dahia	23	27
96	Qatana	10	14
Total City			1,305

Source: Consultant Analysis

These areas are all on the periphery of the city, adjacent to suburbs which also have large capacities for growth. The latter grouping is expected to have the fastest growth rate in the region during the study period.

The suburban area surrounding Amman is planned for urban uses (including residential), with major emphasis in the western suburbs. The suburbs adjacent to the southern and eastern boundaries of Amman are also planned for substantial growth. Only one limited area north of the Municipality is zoned for urban uses. Fig. 3-1 shows the "Suburban Ring" around Amman with its divisions for which saturation populations were estimated.

Projections for the Study Area 1979 to 2000

Using the growth models and saturation projections discussed earlier, the 1990 and 2000 populations of the entire Study Area and its individual large communities can be projected.

For the purpose of this study an annual growth rate of 4.13 was assumed for the Study Area for the period 1979 to 2000. The assumed growth rate for the period 1979 to 1990 was 4.46 percent, and 3.8 percent for the period 1991 to 2000. These assumptions parallel the projections of the AURPG Regional Model D, "declining growth rate and continued concentration in Amman" which has an implied 4.03 growth rate over the 1979-2000 period. The extra one-tenth percent was added because in-migration to the Study Area is not expected to decline as fast as it was in 1978 when the AURPG Study was made. The assumed growth rate is consistent with the current trend of a slight decline in birth rate and continued (though declining) migration from other parts of the Kingdom to Amman. The slight decline in birth rate is expected to result from an increasing level of education of the general population, combined with a significant increase in the participation of women in the workforce.[1] The planned new towns of Abu Nusair, Alia Airport city and the Sahab/Airport City were assumed to contain their planned populations for 1990 and 2000 as scheduled. To accommodate these plans, and retain the overall regional population rate of increase, the following steps were taken:

(1) The regional rate of increase was applied to 1979 population to project 1990 and 2000 regional totals.

(2) The projected new city totals for those years were subtracted from the Regional totals.

(3) The remaining populations were distributed among the three groups of communities listed above (Amman and suburbs, outlying large cities, small towns, villages and rural areas).

Application of the 4.46 annual percent increase for the period 1979 to 1990 to the existing Study Area population would result in an increase of 784,000, and a total population of 2,057,000 for that year. The area's 2000 population would be 2,987,000, an increase of 930,000 over the 1990 figure, assuming the 3.80 percent

increase for the period. That total would be 235 percent increase over 1979 population. The projected addition of 1.7 million is a large population to be absorbed by one urban area in a relatively short 21 year span.

The total populations of the new cities are projected to be approximately 115,000 by 1990, and 245,000 by the year 2000. A reduction of the projected population totals for those cities leaves increases of 669,000 to the year 1990, and 1,469,000 to 2000, to be distributed among the other cities, villages and rural areas, because the Radial Corridor Model did not take the proposed new cities into account. The growth rates of the remaining communities in this study 3.9 and 3.5 percent for the periods 1979-1990 and 1990-2000 respectively, will be lower than their respective rates projected by AURPG.

The "Radial Corridor" subregional distribution model suggested by AURPG was used as a guide for distribution of the increase within the Region. The model's growth projections are designated for subregions which closely match the urban areas of the larger cities in the Study Area. The growth rates in the AURPG Projection represented an overall study period of 1975 to 2000, as well as the interim periods 1975 to 1985, and 1985 to 2000. This model's implied growth rates for the period 1979 to 2000 were calculated so that the annual rate of increase would correspond to the study period in this analysis. The following table reflects these impled growth rates:

AURPG "RADIAL CORRIDOR MODEL"
(Adjusted from period 1975-1985)

	1979-1990	1990-2000	1979-2000
Amman Subregion	4.7	4.0	4.4
Zarqa, Ruseifa, Madaba Salt	3.7	3.2	3.5
Rural Communities	3.2	2.7	3.0

The AURPG Amman Subregion corresponds roughly to the total area of the municipality of Amman, Wadi es Sir, Suweileh and the "Suburban Ring."

It was assumed that the Municipality of Amman will grow at the rate of 4.2 percent per year between 1979 and 1990, and 3.9 percent between 1991 and 2000. These rates would increase Amman's population to 1,020,000 in 1990, and 1,510,000 in 2000. Assuming the City's saturation population total of 1,305,000 (as projected earlier in this analysis), saturation would be reached about 1996, or approximately, midway between 1990 and 2000. This of course refers only to the area within the Municipality's current (1980) boundaries. Alternatively, the "Suburban Ring" around Amman would be far from saturation, mainly because of its sparse density at the beginning of the study period. If the 4.2 and 3.9 percent annual increases were applied to its 1979 population of 16,400, the "Suburban Ring" area would only contain 26,000 people by 1990, and 38,000 by the year 2000.

This would not be a realistic growth rate for this area, as it is currently among the fastest growing areas in the Kingdom, and is expected to continue to be in the near future. Therefore, it was assumed that the excess of projected growth for the Municipality of Amman over the City's population at saturation would be located instead, within its "Suburban Ring." The 1990 and 2000 totals for the Suburban Ring were derived by applying the Amman Municipality 1990 and 2000 rates of increase to the areas 1979 total, and adding the excess population from Amman to the Suburban Ring totals. As saturation in Amman would not occur until approximately midway through the 1990-2000 period, and growth in the Suburban Ring would occur before Amman saturation, that period was assigned 75 percent of the excess while the remaining 25 percent of the excess will occur during 1979-1990. Wadi es Sir was assigned the high rate of growth assumed for Amman and its other suburbs for 1979 to 1990, and as its growth is expected to continue at a high rate, a 4.6 percent annual increase was assigned to the period 1990 to 2000. Zarqa and Ruseifa were assigned the growth rate used in the Zarqa-Ruseifa study,[27] as they were based on land use analysis. Zarqa and Ruseifa were assigned annual increases of 2.9 and 5.6 percent for the period 1979 to 1990, and 3.7 and 2.7 percent for 1991 to 2000, respectively. Madaba, Salt, Suweileh and Sahab were assumed to increase by 3.3 perent during the period 1979-1990, and 3.5 percent between 1990 and 2000. Sahab's growth is not expected to be as dramatic as that of the Amman Suburban area, as much of its growth would be diverted to the new Sahab/Airport City. Remaining growth was attributed to the small towns, villages and rural areas at the levels of 2.9 percent per year for 1979 to 1990, and 3.2 perent from 1991 to 2000. The low growth rates in the middle-size cities, villages and rural areas reflect the contined trend of migration of population from rural areas to the Greater Amman Area.

Table 3-12 presents population projections for 1990 and 2000, and saturation population for the major urban centers in the Study Area. Table 3-13 lists projected 1990 and 2000 populations for the remaining municipalities and villages with 1979 populations above 3000.

Figures 3-3 and 3-4 provide a geographic representation of population centers showing relative sizes for 1990 and 2000.

The National Housing Corporation (NHC), Jordan Urban Project, and the Jordan Cooperative Association have several housing projects planned for various sites in the Study Area within the next five years. The NPC projects, other than the Abu Nusair and Airport/Sahab City developments, are relatively small.[28]

The Jordan Urban Project developments scheduled for Wahdat and Wadi Haddada are planned for upgrading of substandard housing. The relatively large projects planned for East Marqa, North Ruseifa and Queismeh will contain 1200 and 1800, units, respectively. The substantial population increases projected for these areas within the Amman Suburban Ring and Ruseifa took into consideration the Jordan Urban Project Plans.[29]

The Jordan Cooperative Association represents many private housing cooperatives which have several housing developments planned for various sites throughout the Study Area. Most of these are relatively small compared to the growth projected for various sub-areas within the Study Area. The largest of these projects include

TABLE 3-12

PROJECTED POPULATIONS FOR MAJOR URBAN CENTERS 1990 AND 2000

(1,000)

Urban Center	Total 1979	Total 1990	Increase 1979-1990	Annual % Increase	Total 2000	Increase 1991-2000	Annual Increase	Saturation Population	Percent of Saturation reached by 2000
Study Area	1,273	2,057	784	4.5	2,987	930	3.8	-	-
Amman	649	1,020	371	4.2	1,305[a]	285	3.9[a]	1,305	100.0
Suburban Ring	16	74[b]	58	14.6	250[c]	176	12.9	821	30.0
Zarqa	216	295	79	2.9	421	126	3.7	566	74.0
Ruseifa	50	91	41	5.6	125	34	3.2	230	54.0
Baqa'a Camp[d]	45	45	0	0.0	45	0	0.0	45	100.0
Salt	33	47	14	3.3	66	19	3.5	-[e]	-
Madaba	29	41	12	3.3	58	17	3.5	130	45.0
Wadi es Sir	25	39	14	4.2	62	23	4.6	171	36.0
Schnellar Camp[d]	24	24	0	0.0	24	0	0.0	24	100.0
Suweileh	21	31	10	3.3	44	13	3.5	79	56.0
Sahab	12	17	5	3.3	24	7	3.5	54	
Mushorfeh	12	16	4	2.9	23	7	3.2	-[f]	-
Na'ur	5	7	2	2.9	10	3	3.2	23	43.0
New Cities[g]									
Abu Nusair	0	40	40	-	100	60	9.6	—	—
Sahab/Airport City	0	60	60	-	120	60	7.2	—	—
Airport City (Jiza)	0	15	15	-	[illegible]	10	5.3	—	—

[a] Saturation reached approximately by 1996. Excess growth is assigned to its adjacent "Suburban Ring."

[b] Includes 25 percent of excess above saturation population of Municipality of Amman.

[c] Includes 75 percent of excess above saturation population of Municipality of Amman.

[d] All refugee camps were assumed to be at saturation level because expansion upward on structures, and expansion of total housing area is restrict

[e] The Municipality of Salt was excluded from the saturation analysis because its town plan was in the process of being revised.

[f] Saturation analysis was not conducted separately for Musherfeh because it was included in the area of projected sautration of Buseifa, and is included in that city's total.

[g] National Housing Corporation Plan

Source: Department of Statistics, 1979 Census, Consultant Estimates.

TABLE 3-13

PROJECTED POPULATIONS OF MUNICIPALITIES, VILLAGES AND OTHER URBAN COMMUNITIES, YEARS 1990 AND 2000[a]

(1,000)

Community	Population 1979	Population 1990	Increase 1979-1990	Population 2000	Increase 1991-2000
Amman	649	1,020	371	1,305	285
Zarqa	216	295	79	421	126
Ruseifa	50	91	41	125	34
Baq'a Camp	45	45	0	45	0
Salt	33	47	14	66	19
Madaba	29	41	12	58	17
Wadi es Sir	25	39	14	62	23
Schneller Camp	24	24	0	24	0
Suweileh	21	31	10	44	13
Sahab	12	17	5	24	7
Musherfeh	12	16	4	23	7
Fuheis	5	7	2	10	3
Na'ur	5	7	2	10	3
Taibeh/Qaisiya	5	7	2	10	3
Duleil	5	7	2	10	3
Sukhneh	4	6	2	8	2
Abu Alanda	4	6	2	8	2
Hashimiya	4	6	2	8	2
Talbiya Camp[a]	4	4	0	4	0
Mahis	4	6	2	8	2
Khirbet Suq	4	5	1	7	2
Ain el Basha	3	4	1	6	2
Juweideh	3	4	1	6	2
Suburban Ring Around Amman[b]	16	74	58	250	176
Abu Nusair	0	40	40	100	60
Sahab/Airport City	0	60	60	120	60
Airport City (Jiza)	0	15	15	25	10
Remainder of Region	91	133	42	200	67
Total Region	1,273	2,057	784	2,987	930

a Refugee Camps were assumed to be at saturation because housing areas are restricted to current limits.

b Including Tila al Ali, Khilda, Al Muqablein, South University Area, Ain Ghazal Area, East Marka, East Wahdat, Shmeisani al Gharbi, Umm es Summaq, Jubeiha, Queismeh, and Marj el Hamam.

Source: Department of Statistics, 1979 Census, Consultant Estimates

the Alia Housing Project in Marj al Hamam, which is planned for approximately 400 units, 103 of which are planned to be developed within a year.

Marj al Hamam is planned for 178 additional units for 4 other cooperatives including one for Ministry of Agriculture employees. Other relatively large cooperatives include one at El Nuweijis for lawyers, with 106 units scheduled, a 190 unit cooperative at El Yaduda for pharmacists, and 300 units at Um es Summaq for Engineers.[30] Most of the other planned cooperatives are much smaller. None of these projects is large enough to warrant special treatment in the distribution of growth throughout region as are Abu Nusair, the Jiza Airport City, and the Airport/Sahab City, whose populations will be significant.

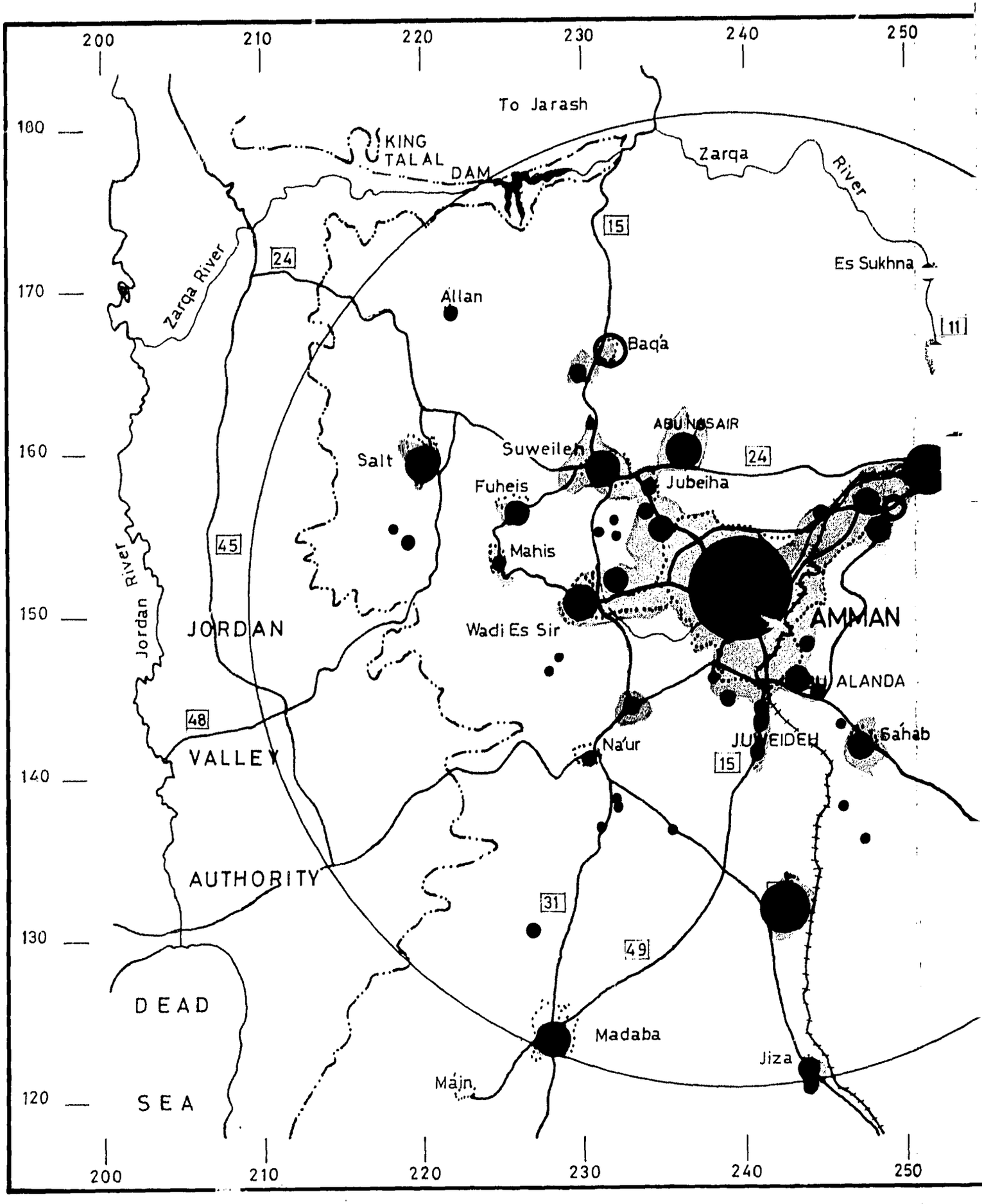
Military housing projects will be treated in the same manner as the other housing projects. The Military Housing Projects at Marj al Hamam and Um es Summaq, and future planned projects are not large enough to affect the population projections of a given area. The locations of the planned housing projects are within areas projected for significant growth according to this analysis. Therefore, the growth potential for these cooperatives is represented by a portion of the population increase projected for those areas.

Disaggregated Population Projections

The projected population increases for the Municipality of Amman, "Suburban Ring" around Amman, and several of the larger municipalities were disaggregated into subunits for the purpose of determining the spatial distribution of water demands and wastewater flows from particular drainage subareas. The basis for distribution of the projected city totals to subunits was the product of the saturation population analysis. The population increase for each subunit required to reach saturation was measured as a projection of the increase required to reach saturation for the entire city. That proportion was then assigned pro rata to the subunit as that proportion of the projected total city population for 1990 and 2000.

Municipality of Amman

Table 3-14 presents projected population and population density for the years 1990 and 2000 for the units of the Municipality of Amman. As indicated in the saturation population projections, the units of the city projected for the most growth in both study periods are Abdoun (Unit 82), Al Rawdah (Unit 63), Al Rabwah (Unit 44), Al Zohour (Unit 62), Al Jorm (Unit 24), Al Shmeisani (Unit 93) Al Rewaq (Unit 25), Al Manarah (Unit 43), Al Akhdar (Unit 72) and Al Hashemi (Unit 23). Each of the units listed above, represented more than four percent of the overall city increase. Abdoun would receive the largest increase, with approximately 51,000 during the first study period, and 38,000 during the second. Population density in that unit would increase from 0.6 persons per dunum in 1979, to 8.5 by 1990, and 14.5 in 2000. Al Rawdah would also change dramatically, with increases of 37 and 28 thousand during the first and second periods; and increasing density factors of 2.6 in 1979, 14.3 in 1990 and 23.2 in 2000. As stated in the saturation population analysis, the areas projected for the highest levels of growth are the far west, southwest, extreme south, eastern and north central portions of the City, generally adjacent to the city's boundaries. The central, older areas of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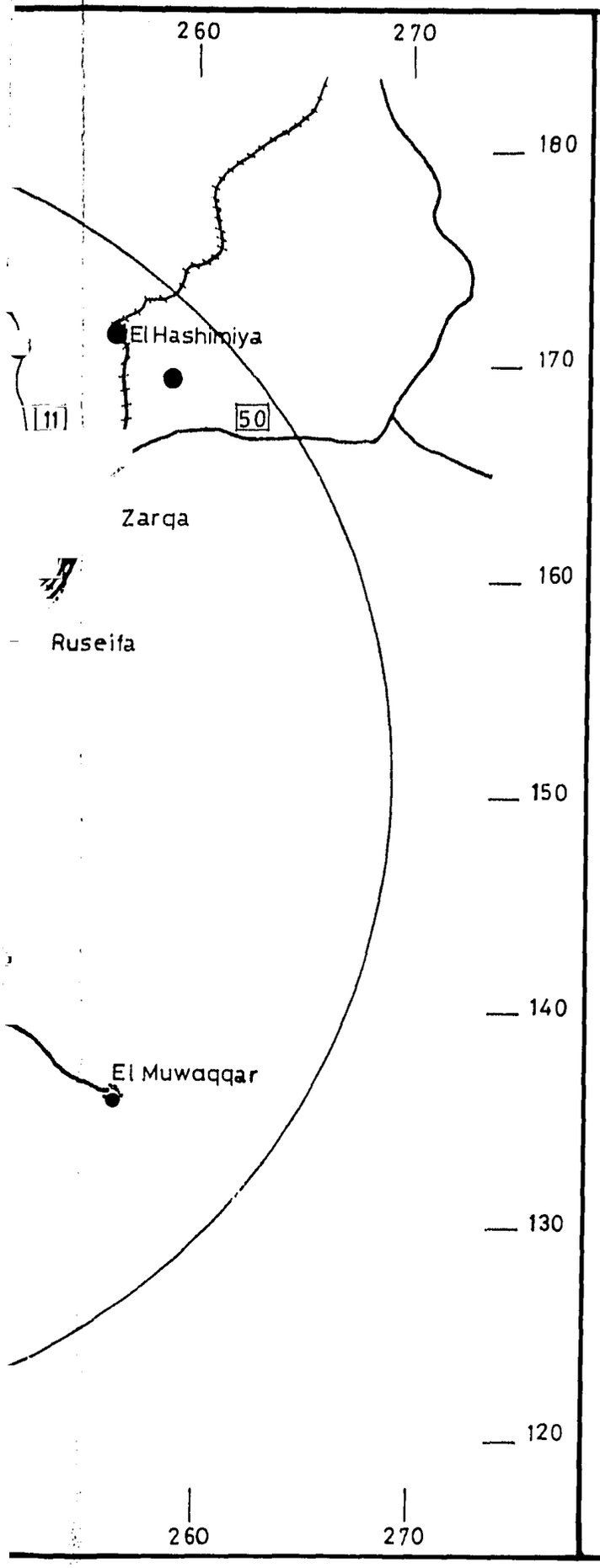


LEGEND

POPULATION CENTERS

- 1000 - 3000
- 3000 - 10000
- 10000 - 25000
- 25000 - 50000
- 50000 - 100000
- 100000 - 500000
- OVER 500000

REFUGEE CAMPS

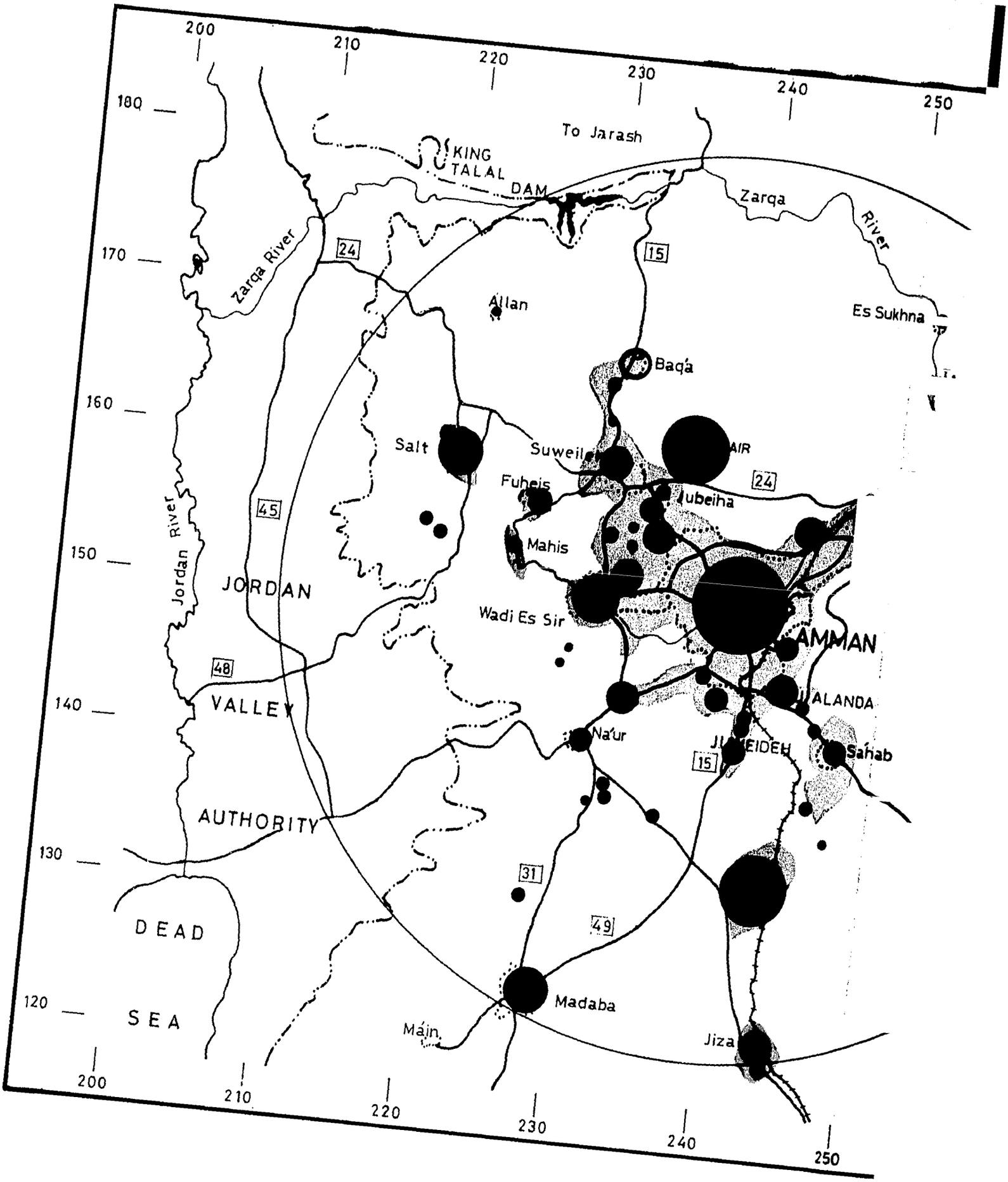
- 3000 - 10000
- 10000 - 25000
- 25000 - 50000

BUILT UP AREAS

GREATER AMMAN AREA

PROJECTED POPULATION DISTRIBUTION - 1990

FIGURE 3-3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To Jarash
KING
TALAL
DAM
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Suweil
AIR
Fuheis
Jubeiha
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Madaba
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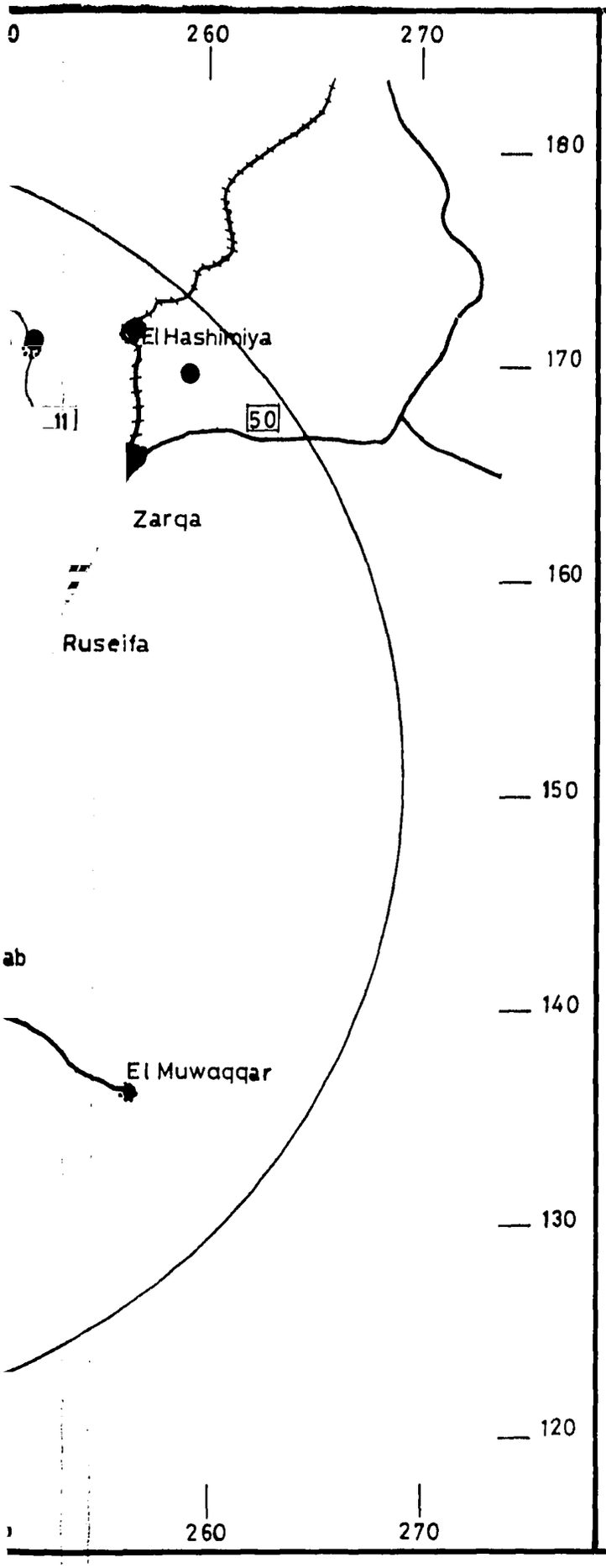


LEGEND

POPULATION CENTERS

- 1000 - 3000
- 3000 - 10000
- 10000 - 25000
- 25000 - 50000
- 50000 - 100000
- 100000 - 500000
- OVER 500000

REFUGEE CAMPS

- 3000 - 10000
- 10000 - 25000
- 25000 - 50000

BUILT UP AREAS

GREATER AMMAN AREA

PROJECTED POPULATION DISTRIBUTION — 2000

FIGURE 3-4

TABLE 3-14

POPULATION AND POPULATION DENSITY PROJECTIONS FOR MUNICIPALITY OF AMMAN BY CENSUS UNIT 1990 AND 2000[a]

Unit		Area (Dunums)	Population 1979	1979-1990 Increase[b]	Population 1990	Population Dunum 1990	1991-2000 Increase[b]	Population 2000	Population/ Dunum 2000	Saturation Increase[c]	Saturation% of Total
11-19	Central City	2,331	36,416	0	36,416	15.6	0	36,416	15.6	0	-
21	Jabal al Muzha	2,261	75,274	4,105	79,379	35.1	3,171	82,450	36.5	7,176	1.1
22	Al Kusour	1,729	10,486	0	10,486	6.1	0	10,486	6.1	0	-
23	Al Hashemi	2,593	40,974	15,302	56,276	21.7	11,283	67,559	26.1	26,585	4.1
24	Al Jorm	2,733	4,979	19,408	24,387	8.9	14,424	38,811	14.2	33,832	5.2
25	Al Rewaq	1,579	7,490	16,795	24,285	15.4	12,669	36,954	23.4	29,464	4.5
26	Raghadan	3,779	3,414	9,703	13,118	3.5	7,493	20,611	5.5	17,197	2.6
31	Al Rasha	931	5,819	0	5,819	6.3	0	5,819	6.3	0	0
32	Al Matar	3,130	2,995	0	2,995	1.0	0	2,995	1.0	0	0
33	Hamzah	3,451	18,218	2,239	20,457	5.9	1,687	22,144	6.4	3,926	0.6
34	Marka	2,891	9,192	1,493	10,685	3.7	899	11,584	4.0	2,392	0.4
35	Al Musherfeh	1,981	784	0	784	0.4	0	784	0.4	0	0
41	Jabal al Taj	1,842	47,389	0	47,389	25.7	0	47,389	25.7	0	0
42	Maydan al Sebaq	2,194	33,601	3,732	37,333	17.0	2,605	39,938	18.2	6,337	1.0
43	Al Manarah	1,888	6,057	16,049	22,106	11.7	11,946	34,052	18.0	27,995	4.3
44	Al Rabwah	2,669	2,922	28,365	31,287	11.7	21,730	53,017	19.9	50,095	7.6
51	Al Ashrafiyeh	1,492	47,480	0	47,480	31.8	0	47,480	31.8	0	0
52	Al Audah	2,234	53,400	0	53,400	23.9	0	53,400	23.9	0	0
53	Al Rayhan	1,057	15,714	8,584	24,298	23.0	6,204	30,502	28.9	14,788	2.3
54	Um el Heiran	1,015	1,755	2,986	4,741	4.7	2,312	7,053	7.0	5,298	0.8
61	Al Nadif	1,273	40,969	0	40,969	32.2	0	40,969	32.2	0	0
62	Al Zohour	2,040	11,183	19,780	30,964	15.2	15,065	46,029	22.6	34,846	5.3
63	Al Raudah	3,171	8,270	36,949	45,949	14.5	28,297	73,516	23.2	65,246	9.9

2)

TABLE 3-14 (Cont'd)

Unit		Area (Dunums)	Population 1979	1979-1990 Increase[b]	Population 1990	Population Dunum 1990	1990-2000 Increase[b]	Population 2000	Population/ Dunum 2000	Saturation Increase [c]	Saturation% of Total
64	Al Marj	3,004	3,905	7,464	11,369	3.8	5,373	16,742	5.6	12,837	2.0
71	Nazal	1,026	17,930	11,197	29,127	28.4	8,329	37,456	36.5	19,526	3.0
72	Al Akhdar	1,882	27,297	15,675	42,972	22.8	11,722	54,694	29.0	27,397	4.2
73	Al Hamra	1,319	143	13,436	13,579	10.3	9,964	23,543	17.9	23,400	3.6
74	Al Hilal	1,482	2,135	11,570	13,705	9.3	8,936	22,641	15.3	20,506	3.1
81	Jabal Amman	1,820	26,133	2,239	28,372	15.6	1,720	30,092	16.5	3,959	0.6
82	Abdoun	6,424	3,672	50,758	54,430	8.5	38,413	92,843	14.5	89,171	13.6
83	Al Radwan	2,899	6,120	13,809	19,929	6.9	10,588	30,515	10.5	24,395	8.7
85	Al Sueifiyeh	329	261	1,120	1,381	4.2	1,167	2,548	7.7	2,287	0.3
86	Umm Othaynah	2,053	3,145	8,584	11,729	5.7	6,639	18,368	9.0	15,223	2.3
91	Jabal Weibdeh	2,146	15,355	2,986	18,341	8.6	2,539	20,880	9.7	5,525	0.8
92	Jabal Hussein	2,421	36,538	4,104	40,643	16.8	3,220	43,863	18.1	7,325	1.1
93	Al Shmeisani	3,546	9,577	17,541	27,118	7.7	13,539	40,657	11.5	31,080	4.7
94	Sport City	1,423	2,762	9,331	12,093	8.5	5,678	17,771	12.5	16,348	2.5
95	Al Dahia	2,030	3,975	13,062	17,038	8.4	9,622	26,660	13.1	22,685	3.5
96	Qatana	928	4,464	5,598	10,062	10.8	3,996	14,058	15.2	9,594	1.5
Total City		86,335	646,778	373,222	1,020,000	11.8	283,123	1,303,213	15.1	656,435	100.0

[a] Numbers were not rounded off, they reflect original calculations. These numbers are not intended to imply a level of accuracy of more than three significant figures.

[b] Estimated by applying the ratio of Saturation increase for individual units to saturation increase of Total City prorate to the total estimated 1990 and 2000 population increases for the total city.

[c] Projected using 1979 planning and Building code, Amman Town Plan and 1978 aerial photographs, based on maximum development of currently undeveloped land.

Source: Department of Statistics, 1979 Census, Consultant Analysis

the city have, for the most part, already reached the saturation level; while the remaining areas will reach saturation during the period 1990 to 2000. The population density of the Municipality as a whole would increase from 7.5 persons per dunum in 1979 for total land area (developed and undeveloped), to 11.8 in 1990, and 15.1 in 2000. Densities for 1990 are projected to range from less than five persons per dunum in highly industrial portions of Ain Ghazal (Unit 32 and 35) and outlying areas such as Al Sweifiyeh, Al Marj, Raghadan, Um al Heiran; to over 20 persons per dunum in Jabal al Nuzha, Al Hashemi, Jabal al Taj, Al Ashrafiyeh, Al Awdah, Al Rayhan, Al Hadif, Nazal and Al Akhdar. The latter grouping represents much of the existing low income areas of the city. Population increases to the year 2000 would further increase densities of the non-saturated areas, with the most significant increases in the areas which were the most sparsely inhabited in 1990 (e.g., Abdoun, Al Hamra, Al Hilal, Al Rabwah, Al Manarah, Al Jorm, etc). Densities in the western portion of the city such as Shmeisani, Qatana, Sweifiyeh, Om Othaynah, Al Dahia and Sport City would also increase significantly, but for less density than the group of units listed above, due to lower planned densities.

Amman Suburban Ring

The "Suburban Ring" around Amman includes the following population sub-areas: south of the city (1) Marj al Hamam, (2) the area south of Al Hilal, (3) Al Muqablein - east of the city - (4) Queismeh/and the area east of East Wahdat, (5) East Marqa; north of the city - (6) the Ain Ghazal Road area immediately west of Ain Ghazal- northwest of the city - (7) Qatana/Tila al Ali, (8) area southwest of Jordan University, (9) rural area surrounding Khilda, (10) Khilda, (11) area east of King Hussein Medial Center, (12) Um es Summaq and (13) Jubeiha. The ring is completed by a portion of Wadi es Sir directly west of Abdoun and Sweifiyeh. Its population was disaggregated along with the remainder of Wadi es Sir. The areas listed above are shown on Fig.3-1.

Table 3-15 lists the disaggregated population projections for portions of the "Suburban Ring" sub-areas for 1990 and 2000. The sub-areas with the largest projected increases between 1979 and 1990, and 1991 and 2000, with the highest population in 1990 and 2000 are: Quesimeh/East Wahdat, East Marqa, Qatana/Tila al Ali and Um es Summaq- each with an annual increase greater than 10 percent, and in most cases, greater than 15 percent. These four sub-areas accounted for 63 percent of the growth in the "Suburban Ring" during the period increasing by 158,000. Areas within the "Suburban Ring" with smaller increases and lower population densities projected for 1990 and 2000 include Khilda, rural area surrounding Khilda, Jubeiha, the area south of Jordan University and east of the King Hussein Medical Center. Zoning in these areas prohibits dense development. The remaining sub-areas of the "Suburban Ring" are projected to experience high rates of growth but not as high as the eastern and western suburbs. Marj el Hamam, Al Muqablein, the Ain Ghazal Road area and Al Hilal would have a total population of 63,000 by the year 2000.

Other Cities

The 1990 and 2000 population projections for the Municipalities of Wadi es Sir, Madaba, Suweileh, Sahab and Na'ur were disaggregated into geographical subunits. The larger communities in the Study Area (those above 10,000 population) were

TABLE 3-15

AMMAN SUBURBAN RING AREA POPULATION PROJECTION

	Sub-area	1979 Estimate[a]	1990[b]	2000[c]	Saturation Population[d]
1.	Marj al Hamam	1,500	6,600	22,500	71,700
2.	Al Hilal	200	1,700	6,800	23,700
3.	Al Muqablein	800	3,600	12,500	41,200
4.	Queismeh-East of East Wahdat	8,500	20,500	51,400	125,200
5.	East Marqa	100	7,700	34,200	121,700
6.	Ain Ghazal Road	100	4,900	21,400	83,600
7.	Qatana-Tila al Ali	1,500	9,500	35,300	115,000
8.	South University	200	2,200	8,900	31,900
9.	Rural Khilda	100	600	2,400	5,200
10.	Khilda	200	800	2,600	8,300
11.	Medical Center Area	100	1,600	6,600	24,600
12.	Um es Summaq	1,500	9,900	37,400	127,200
13.	Jubeiha	1,600	3,500	7,900	19,100
Total		16,400	74,000	250,000	798,400

[a] Estimated from 1979 Census totals

[b] Projected by applying 4.2 percent annual increase to the existing population total, and adding to that figure, 25 percent of the Municipality of Amman excess of projected growth over its saturation population.

[c] Projected by applying 3.9 percent annual increase to 1990 population total, and adding to that figure, 75 percent of the Municipality of Amman excess of projected growth over its saturation population.

[d] Refer back to "Potential Saturation Population" subsection for a detailed description of methodology.

Source: Department of Statistics, 1979 Census; Consultant Analysis.

included with the following exceptions: Zarqa, Ruseifa, Salt and Musherfeh. Those cities were not included because they were studied in detail in the recent study.[27] Salt was not included because its town plan is currently being revised, and the new version would not have been available in time for this analysis.

The disaggregated population projections for sub-areas of the Municipalities of Wadi es Sir, Madaba, Suweileh, Sahab and Na'ur for 1990 and 2000 and saturation levels are listed on Table 3-16 through 3-20. Figures 3-5 through 3-9 show the boundaries of the sub-areas for the five municipalities. The 1979 populations for these sub-areas were not available from the census. Therefore they were estimated by apportioning the 1979 census figure for the total city to each sub-area by matching 1978-1980 aerial photographs to town planning maps.

During the periods 1979 through 1990, and 1991 through 2000, the bulk of the growth in Wadi es Sir is expected to occur in its eastern portion (new area). That portion of the city is called Bayader Wadi es Sir and is located both west and east of the Suweileh-Na'ur Road. It includes subareas 5 through 14 (see Figure 3-5). The Old City, or sub-areas 1 through 4, is projected to have a population of 14,200 by 1990, and 21,100 by 2000. These totals represent 41 and 110 percent increases above the 1979 total Old City population of 10,000. The other portions of the city are expected to grow at a much faster rate. The sub-areas with the largest projected populations in both 1990 and 2000 are 5 and 6, which would total 10,600 in 1990 and 17,500 in 2000. Sub-areas 8-12 would each have less than 2000 people by 1990, and less than 3,000 by the year 2000. Thus the areas with the highest concentrations of population, both in 1990 and 2000 are the Old City: Sub-areas 5, 6 and 7 (Bayader Wadi es Sir, both north and south of the Wadi es Sir-Amman Road), and the Sweifiyeh area (sub-areas 13 and 14) adjacent to Amman.

Major growth in Madaba between 1979 and 2000 is expected to occur in its western, northern and eastern outlying areas. The central and southern portions of the City, much nearer to saturation levels, would grow at the rate of 2.1 percent per year during the study period. The central and southern portions of the City, comparing sub-areas 1,2 and 3, are projected to grow from 21,400 in 1979 to 25,300 in 1990 and 30,600 in 2000. The bulk of Madaba's growth during the study period projected for the remaining sub-areas (4 through 7). They would increase from 7,100 in 1979, to 15,400 in 1990, and to 26,900 by the year 2000.

Projections for Suweileh show a pattern of development that differs from that of the other cities of the detailed analysis. Its growth is projected to be relatively uniform, spread among the City's sub-areas. Populations of the sub-areas would range from 1,100 to 6,700 in 2000. The sub-areas with the largest populations in 1979 (4, 6, 7 and 8) would continue to have the largest populations in the city in 1990 and 2000; with 17,500 in 1990 and 22,100 in the year 2000. These figures represented 40 and 51 percent of the city's total projected population in those years.

Sahab's growth to the year 2000 is expected to occur in a ring around the central part of the city. The central area (sub-area 1) is projected to increase by only about 500 people in the 20 year study period, while the peripheral sub-area (2 through 7) are expected to increase by 9.9 percent per year between 1979 and 1990, and 6.4 percent per year between 1991 and 2000.

TABLE 3-16

WADI ES SIR POPULATION PROJECTION

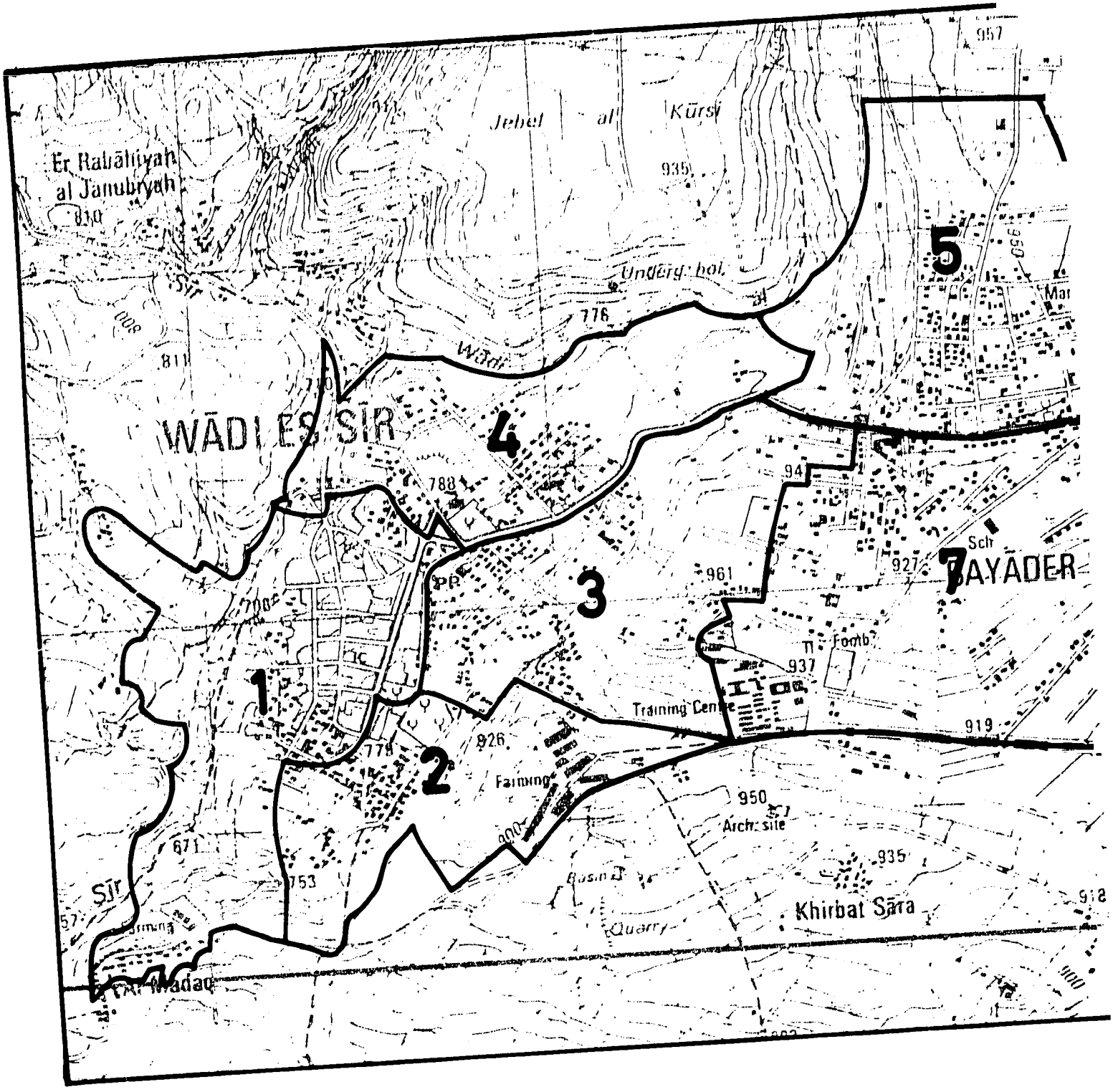
Sub-area	1979[a] Estimate	1990[b]	2000[c]	Saturation Population[d]
1	1,714	3,500	6,500	21,000
2	1,960	2,700	3,800	9,300
3	2,940	3,900	5,500	13,800
4	3,430	4,100	5,300	11,000
5	3,920	5,600	8,400	21,200
6	2,449	5,000	9,100	28,400
7	3,184	3,600	4,300	7,900
8	735	1,000	1,500	3,200
9	245	700	1,400	5,200
10	245	1,200	2,800	10,800
11	245	1,000	2,100	7,800
12	490	1,300	2,700	8,700
13	1,960	2,500	3,400	8,000
14	980	2,400	4,700	15,100
Total	24,497	38,500	61,500	171,400

[a] Estimated by matching land use plans to 1978 aerial photographs.

[b] Pro-rata distribution of projected City total based on sub-area share of saturation population.

[c] Refer back to "Potential Saturation Population" subsection for a detailed description of Methodology.

Source: Department of Statistics, 1979 Census, Consultant Analysis.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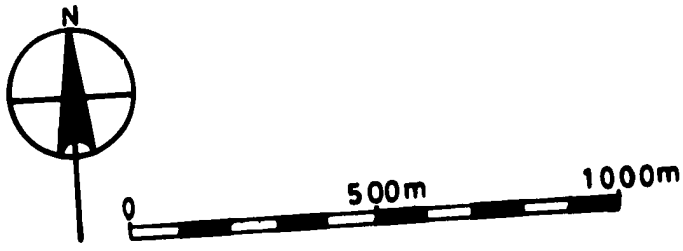
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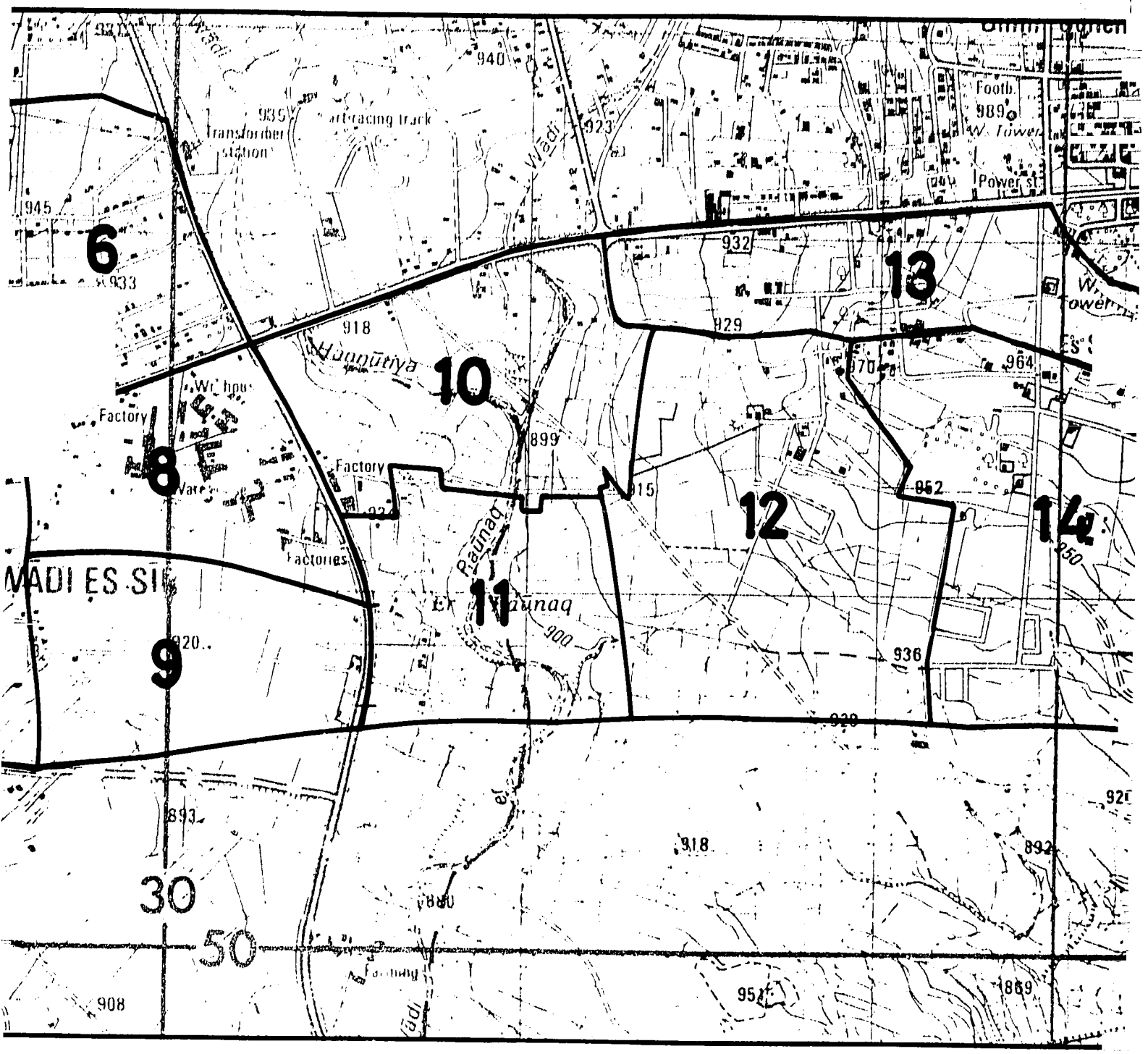
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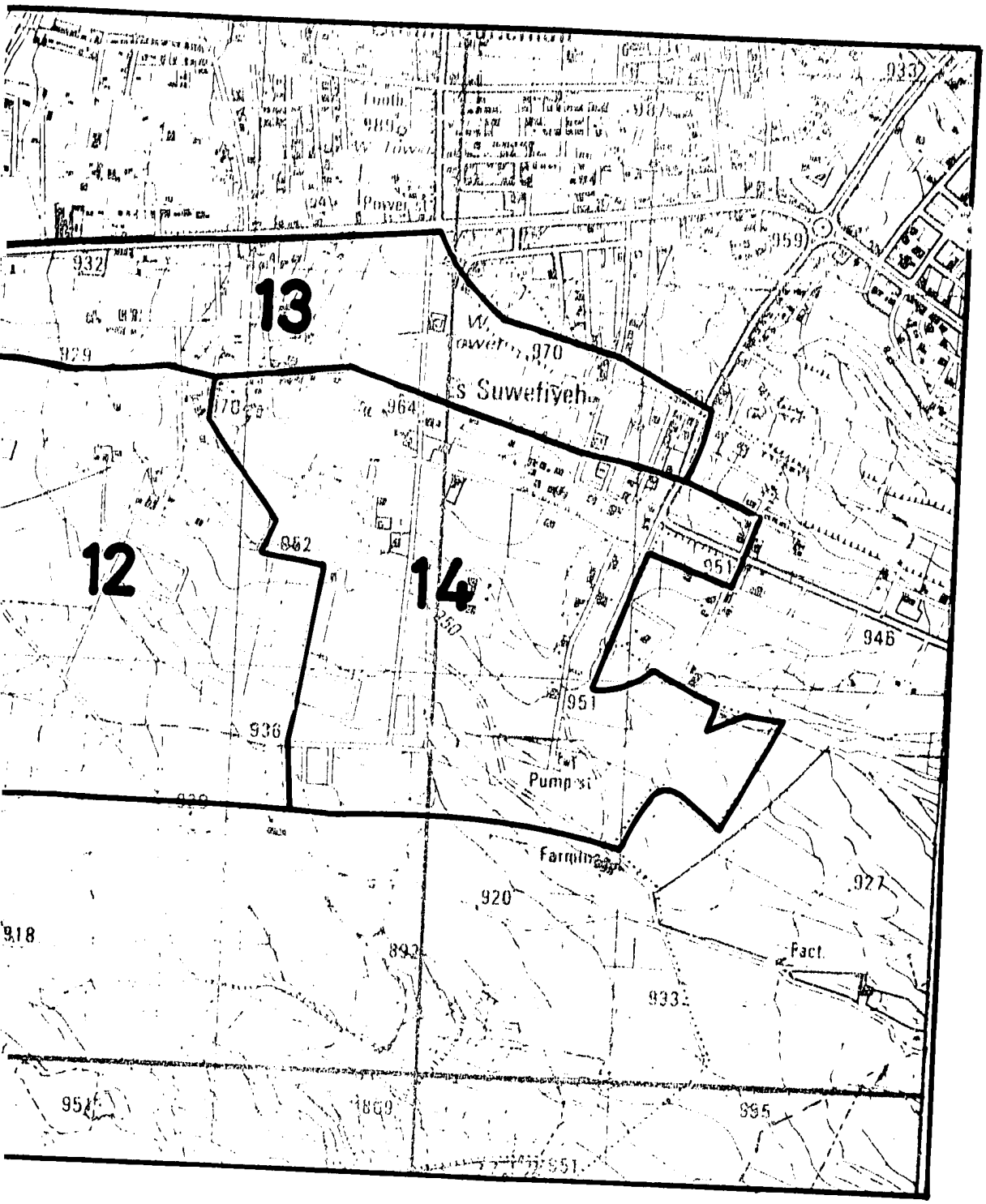


WADI ES SIR

POPULATION SUB - AREAS

FIGURE 3 - 5

TABLE 3-17

MADABA POPULATION PROJECTIONS[a]

Sub-area	1979 Estimate	1990 Total	2000 Total	Saturation Population
1	5,987	7,000	8,300	13,800
2	7,127	9,400	12,600	26,700
3	8,268	8,900	9,700	13,800
4	1,711	3,200	5,200	13,200
5	2,851	5,400	9,000	24,500
6	2,280	4,200	6,900	18,500
7	285	2,600	5,800	19,100
Total	28,509	40,700	57,500	129,600

[a] Refer to Table 3-16 for footnotes.

Source: Department of Statistics 1979 Census, Consultant Analysis.

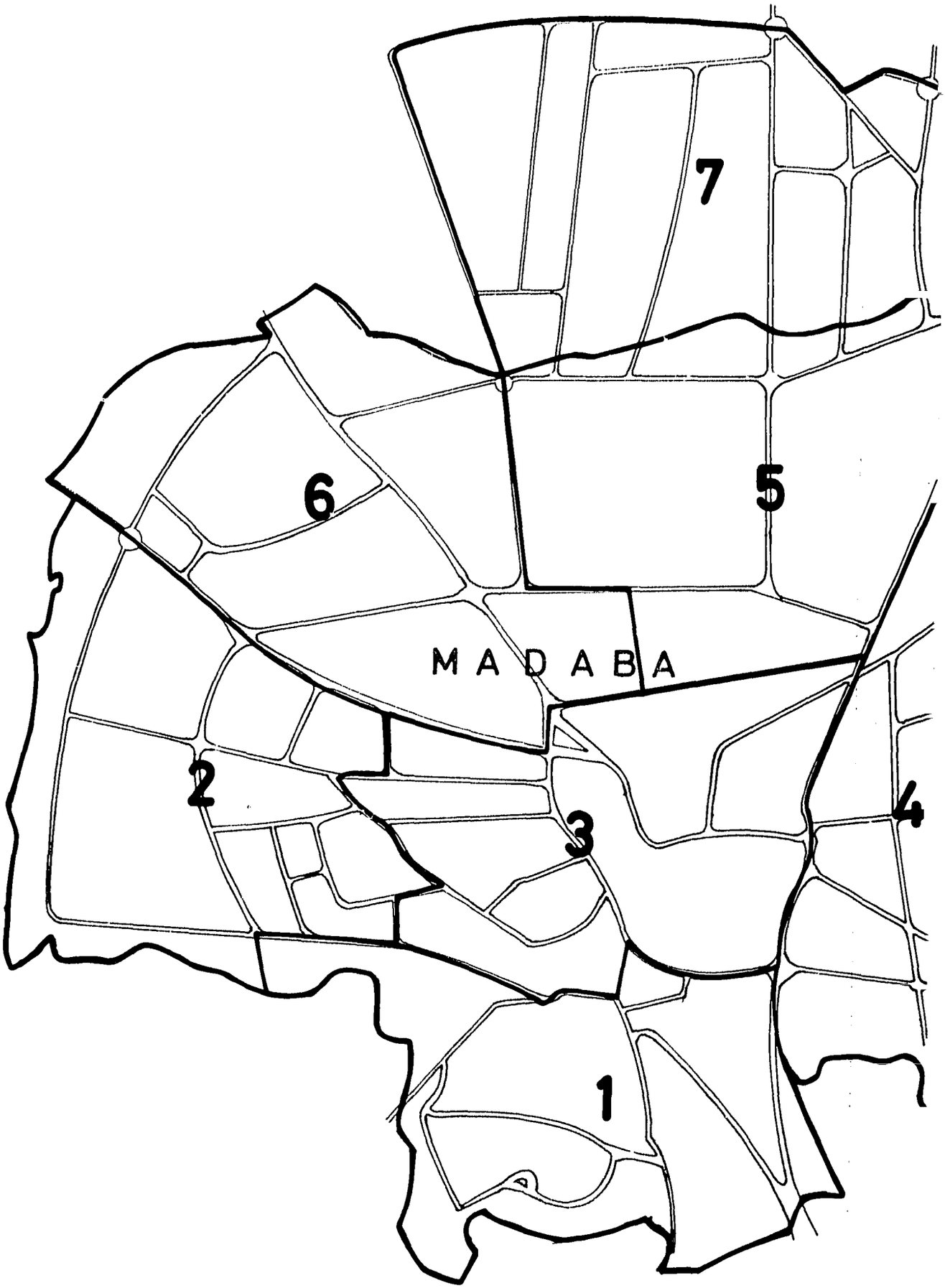
TABLE 3-18

SUWEILEH POPULATION PROJECTION[a]

Sub-area	1979 Estimate	1990 Total	2000 Total	Saturation Population
1	1,072	2,200	3,700	8,200
2	1,072	1,600	2,300	4,500
3	2,144	2,800	3,700	6,400
4	5,362	5,900	6,700	9,000
5	643	1,100	1,800	3,200
6	2,788	3,400	4,300	7,000
7	3,431	4,400	5,900	10,000
8	2,787	3,800	5,200	8,800
9	214	1,900	4,200	10,100
10	214	600	1,100	2,400
11	1,715	2,900	4,600	9,400
Total	21,442	30,600	43,500	79,000

[a] Refer to Table 3-16 for footnotes.

Source: Department of Statistics, 1979 Census, Consultant Analysis.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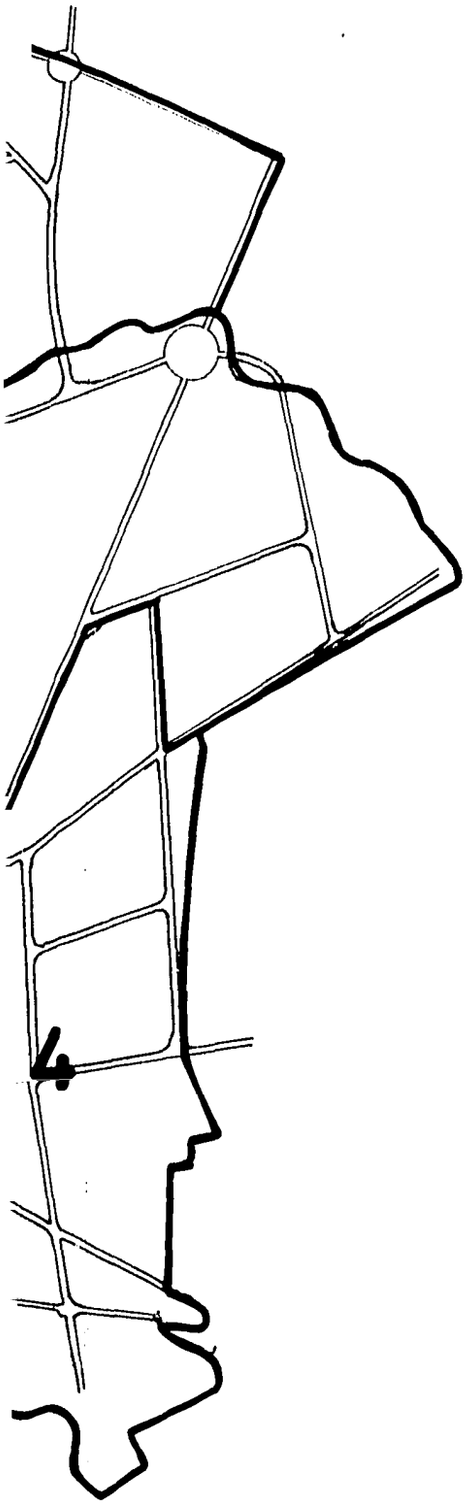
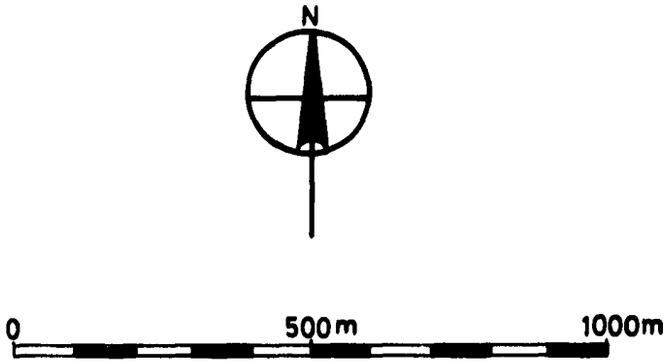
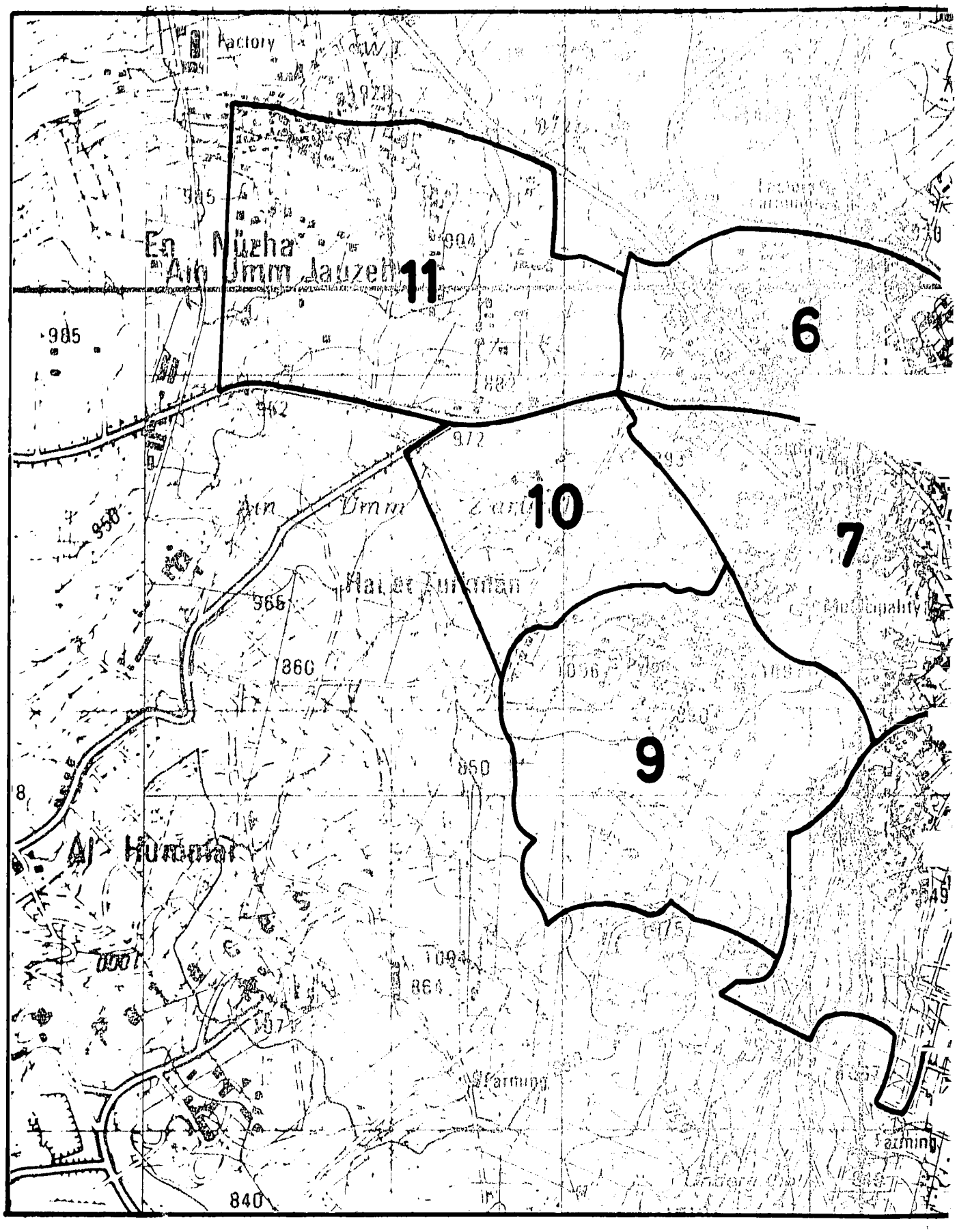




MADABA

POPULATION SUB - AREAS

FIGURE 3 - 6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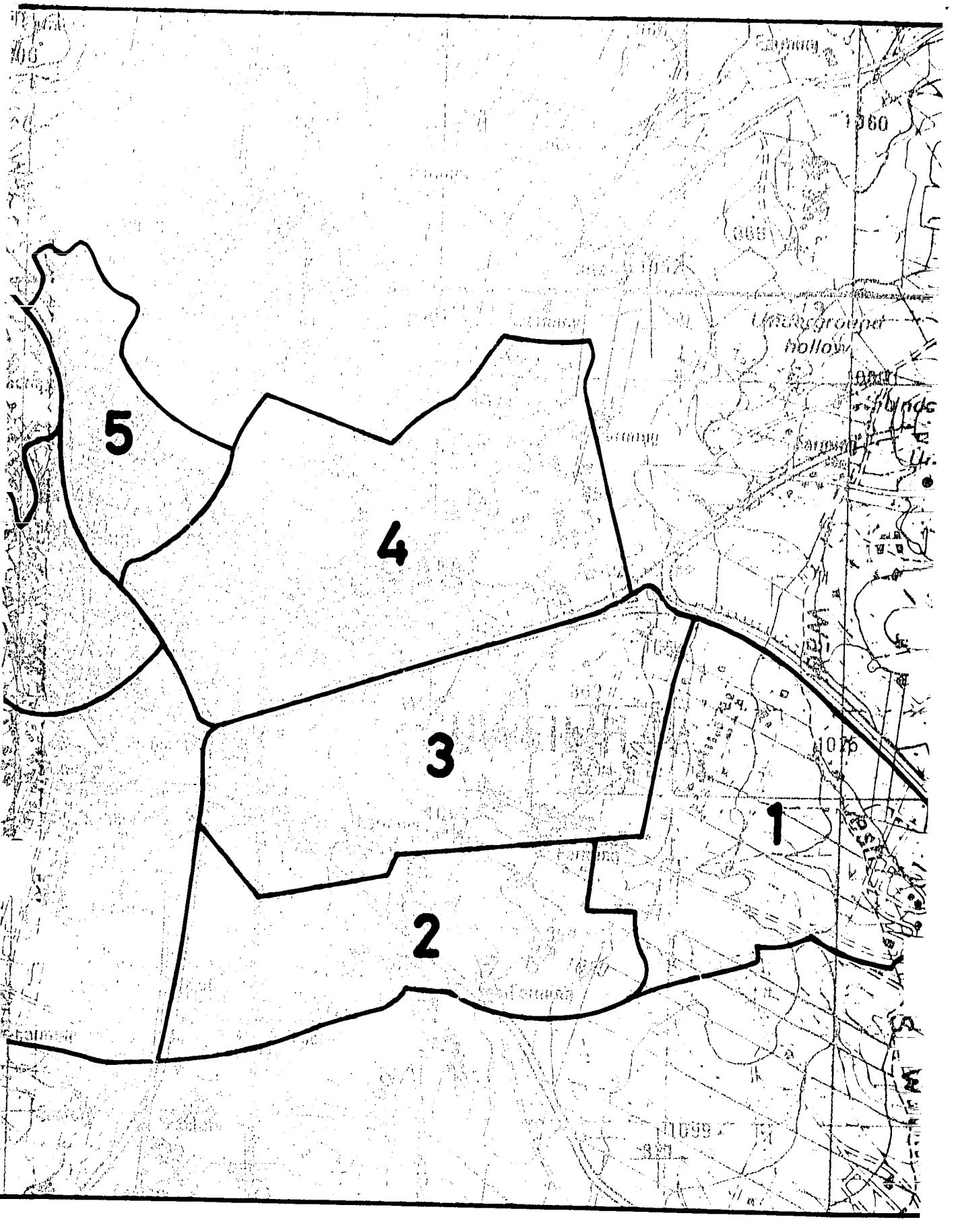

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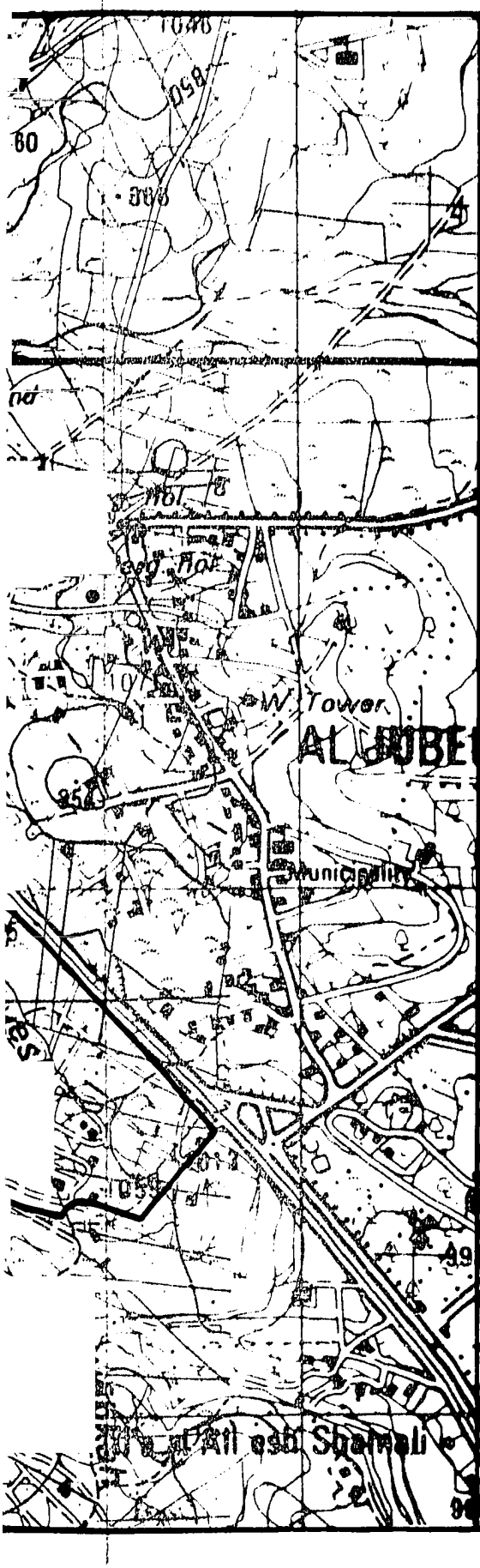
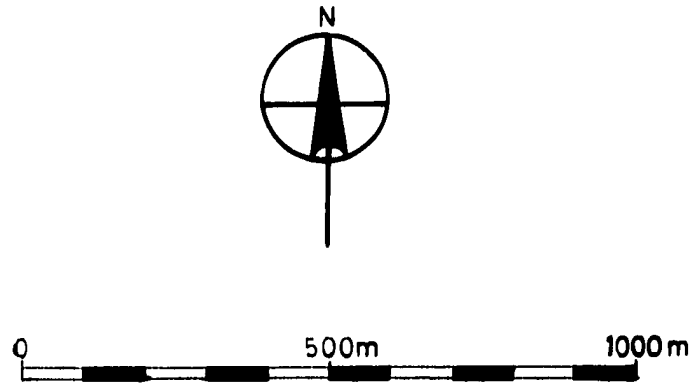




SUWEILEH

POPULATION SUB - AREAS

FIGURE 3 - 7

141b

TABLE 3-19

SAHAB POPULATION PROJECTIONS[a]

Sub-area	1979 Estimate	1990 Total	2000 Total	Saturation Population
1	6,192	6,200	6,300	6,700
2	834	1,100	1,500	3,000
3	953	1,500	2,300	5,500
4	119	1,600	3,500	11,800
5	119	1,500	3,300	11,200
6	1,548	2,100	2,900	6,200
7	2,143	3,000	4,200	9,300
Total	11,908	17,000	24,000	53,700

[a] Refer to Table 3-16 for footnotes.

Source: Department of Statistics, 1979 Census, Consultant Analysis.

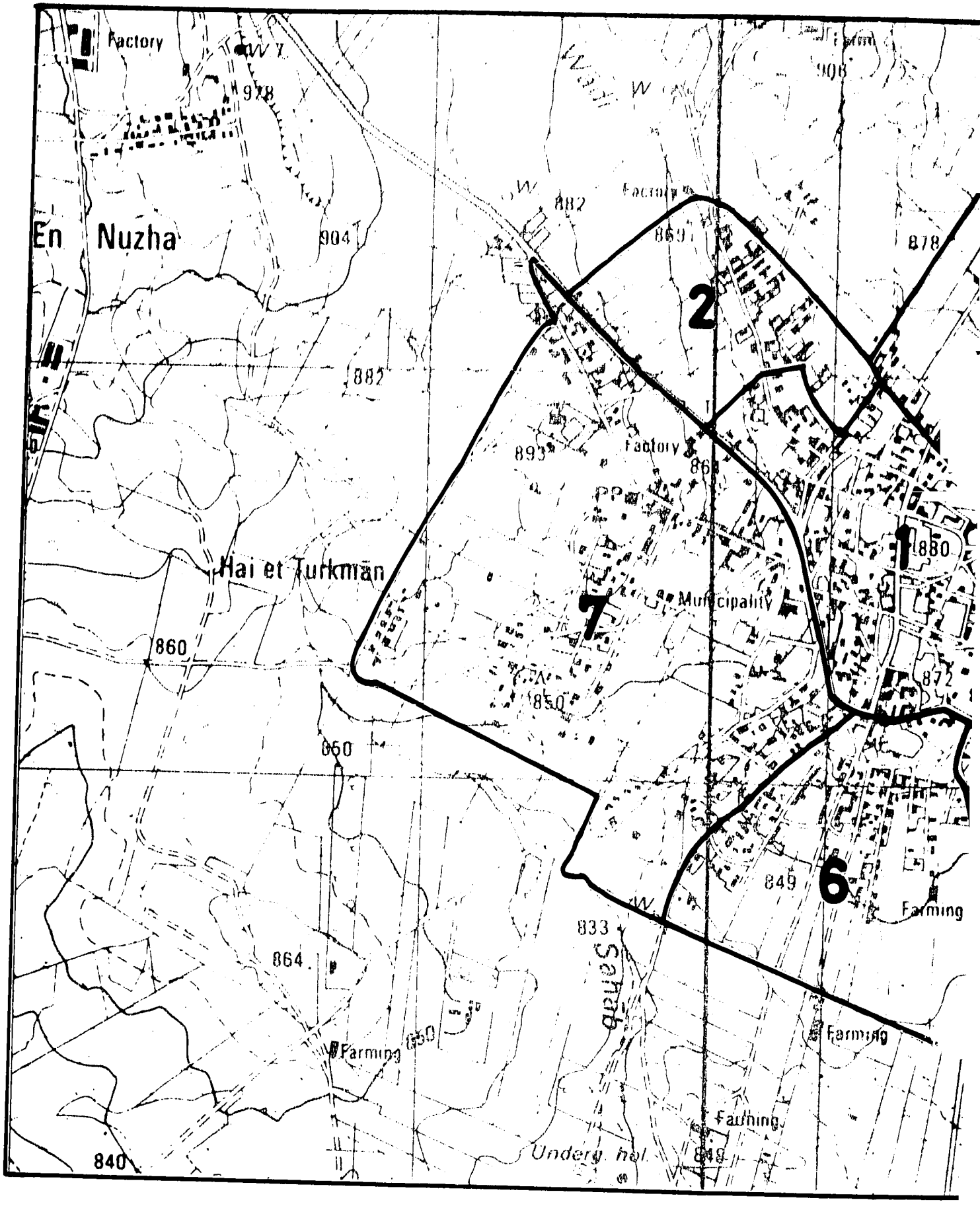
TABLE 3-20

NA'UR POPULATION PROJECTIONS[a]

Sub-area	1979 Estimate	1990 Total	2000 Total	Saturation Population
1	988	1,400	1,900	4,700
2	2,495	2,600	2,800	3,600
3	364	1,000	1,800	5,800
4	832	1,100	1,600	3,600
5	520	1,000	1,700	5,000
Total	5,199	7,100	9,800	22,700

[a] Refer to Table 3-16 for footnotes.

Source: Department of Statistics, 1979 Census, Consultant Analysis.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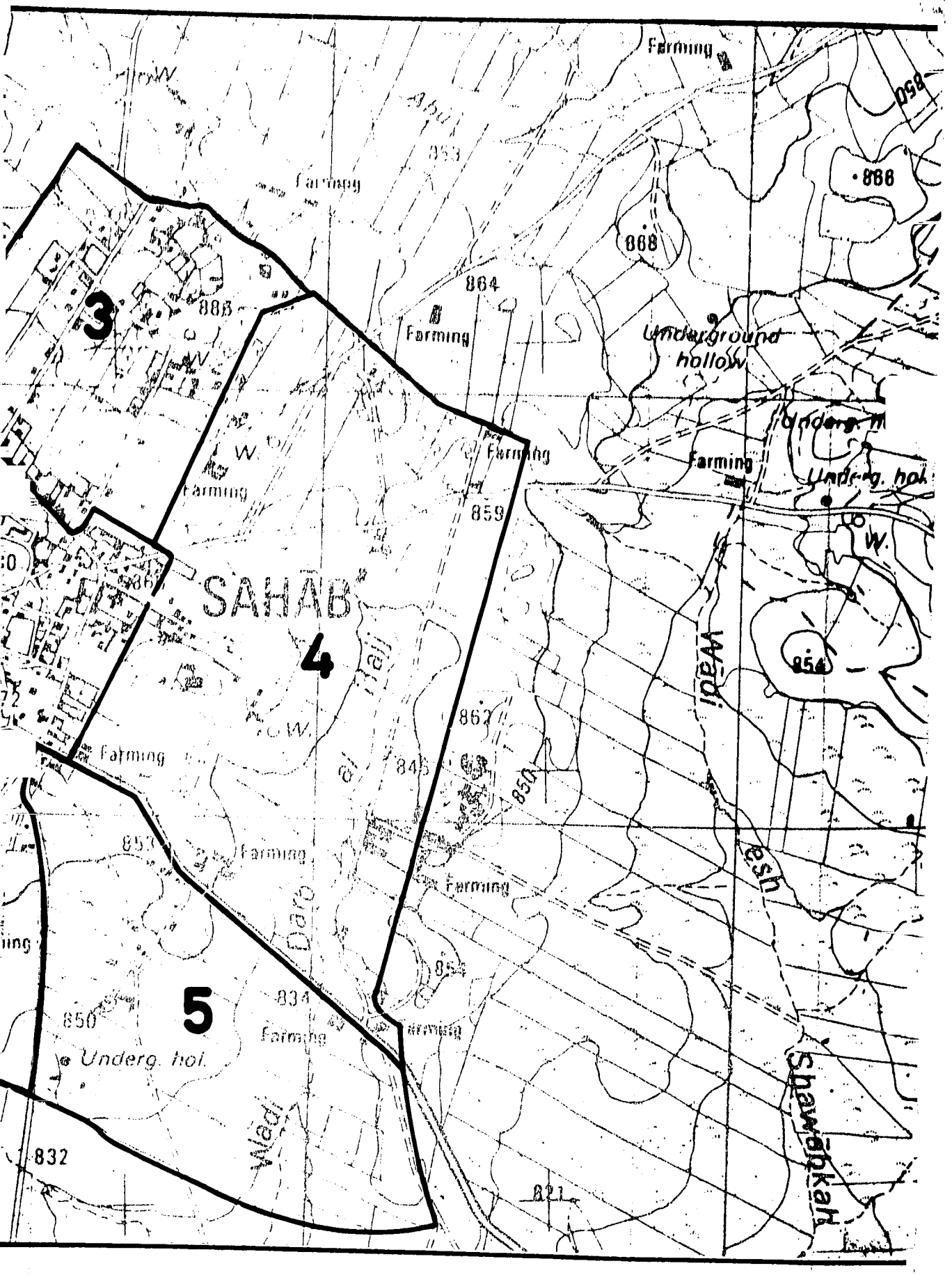
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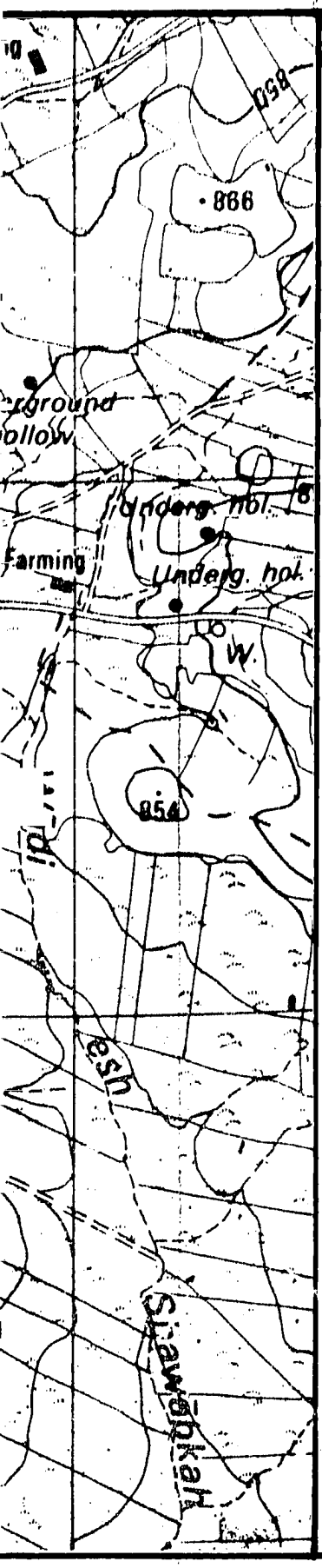

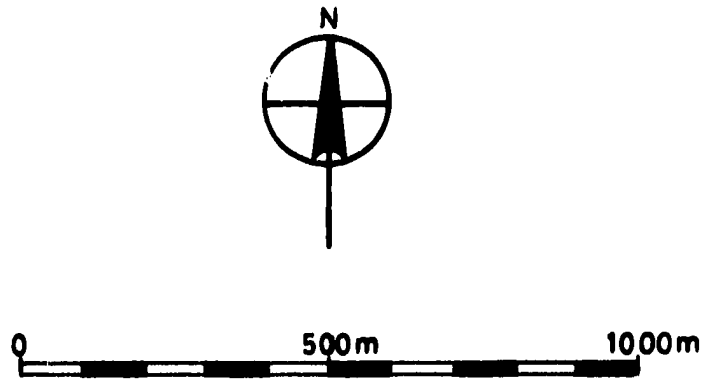

SAHAB

POPULATION SUB - AREAS

FIGURE 3 - 8

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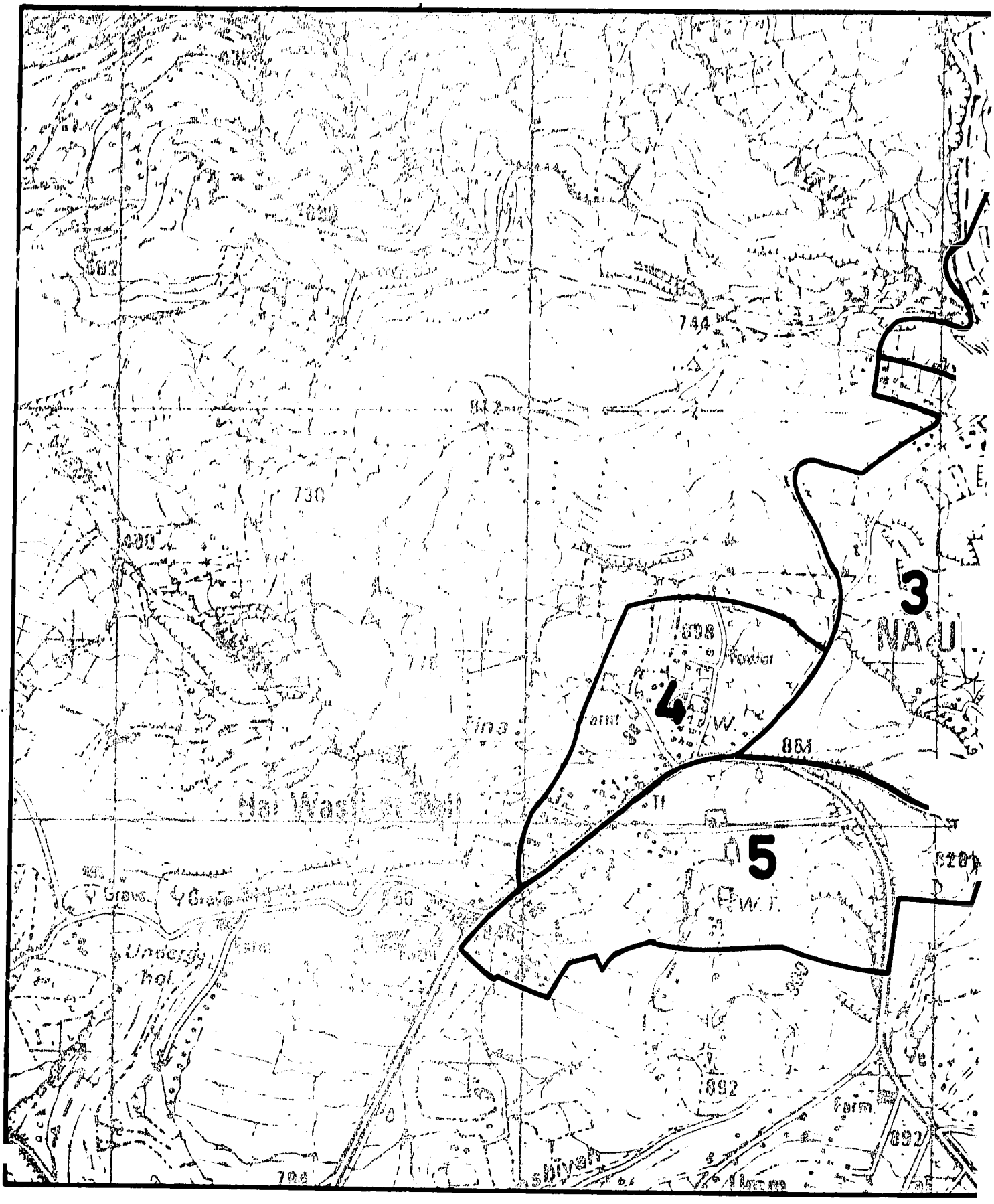
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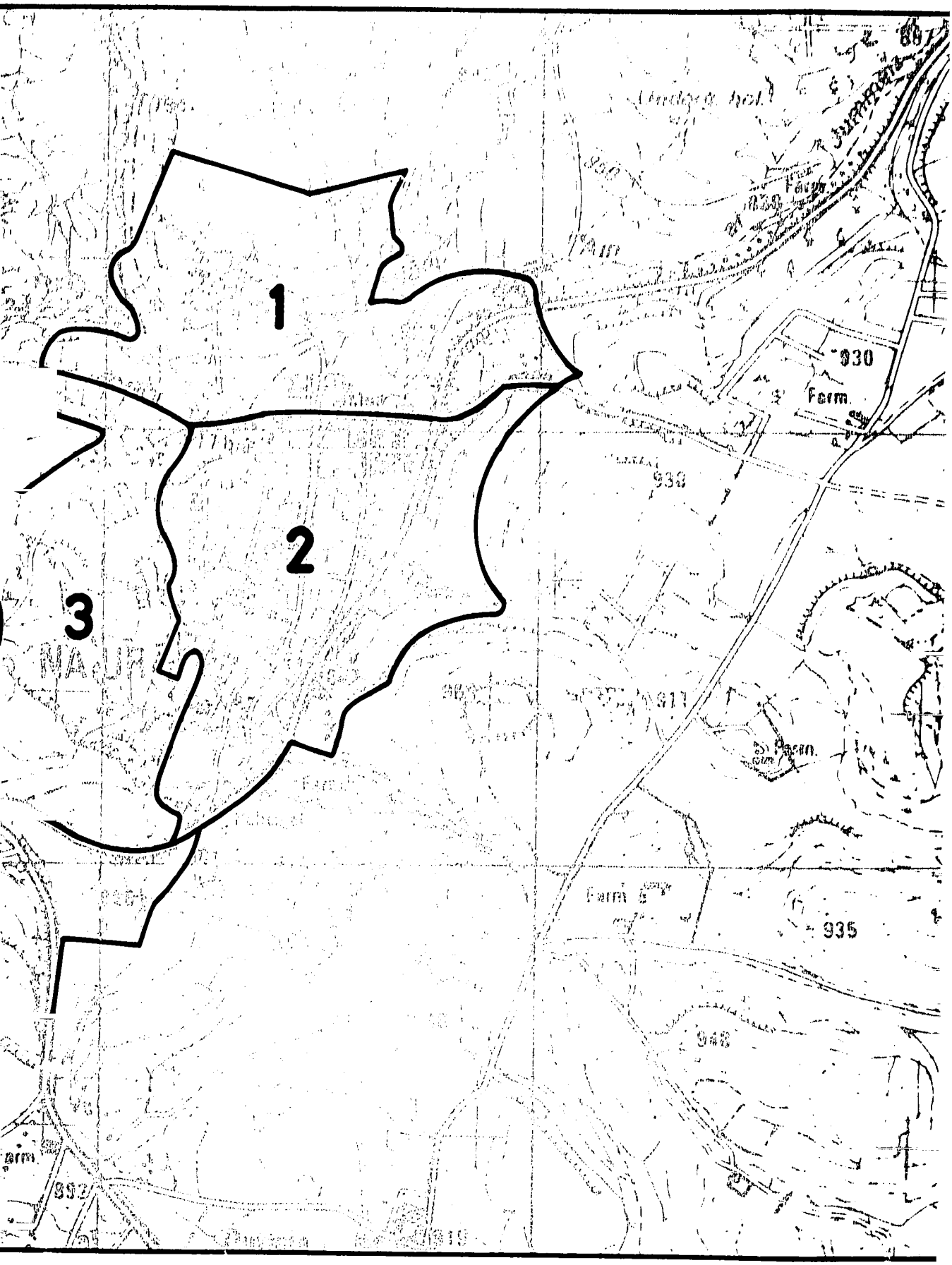

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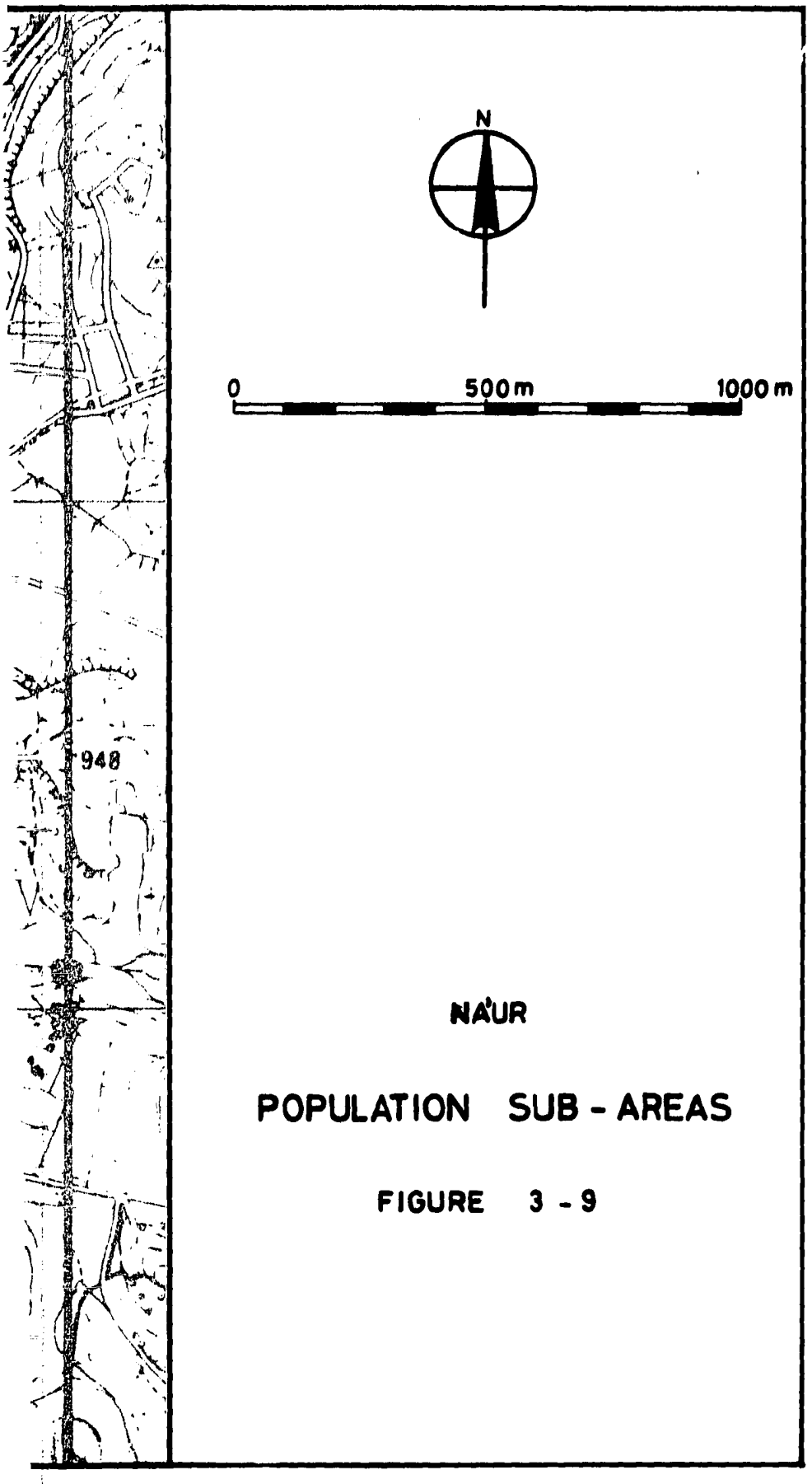

NA'UR

POPULATION SUB - AREAS

FIGURE 3 - 9

Na'ur also fits the major pattern of cities analyzed in detail in terms of projected growth, as its central area (sub-area 2) was projected to increase by only 300, or 0.6 percent per year to 2000. The remaining sub-areas (1, 3, 4, and 5) were projected to grow at the rate of 13.8 percent per year, and increase by 2,500 over the 21 year study period.

SOCIAL CONTEXT

The social aspects of this project will be analyzed to provide input for the assessment of project benefits and the projection of sewage flows. The potential benefits related to sewage system improvements are related to improvements to public health conditions and water quality, as well as a potential reduction in the cost of sanitation for some Study Area residents. Low-income groups will be given special consideration in terms of the potential for achieving greater equity in the levels of service provided and in spreading the costs of sanitation. In addition, the distribution of income throughout the Study Area will be considered to provide input to the ability to pay analysis. The social aspects which relate to the projection of sewage flows are those which affect the level of water use.

HOUSEHOLD INCOME

Information on income characteristics of individuals or households within the Study Area is extremely limited. Data related to household income are available from two sources: Studies on national and regional distributions of household income by percentile of income groups. The second source included data from spot surveys of small non-stratified samples in specific locations within the Municipality of Amman.

The first source of data is derived from studies completed by the Royal Scientific Society (RSS) in 1979,[31] and from the Jordan Urban Project Report in 1979.[32] The studies were based on the 1974 Income Distribution Survey conducted by the Department of Statistics. That survey yielded results on the size and sources of 1973 income of more than 15,000 households in urban and rural areas throughout the East Bank. The Amman Governorate was represented by 9,294 households, of which 8,339 were urban dwellers: The Balqa Governorate contributed 668 urban households. The urban dwellers represented the cities of Amman, Zarqa, Madaba and Salt in the Amman and Balqa Governorates.

The average comprehensive income (from all sources including transfers) of the individual earner in the urban sample in the RSS Study was JD 602 per year in 1973. The average annual income per earner in the Amman Governorate for the same year was JD 603. The following table presents preliminary estimates 1978 family urban income distribution from the Jordan Urban Project analysis, which represent escalation of the RSS 1973 income figures:

Percentile	Estimated 1978 Monthly Income (JD)
10th	50 or less
20th	70 or less
30th	81 or less
40th	92 or less
50th	102 or less
60th	116 or less
70th	138 or less

As shown in the above table, 50 percent of the population would have had monthly incomes of JD 102 and below, while the poorest 10 percent of the population would have had incomes of JD 50 and below.

The Jordan Urban Project study also estimated 1978 monthly household income by percentile for the Amman and Zarqa slums. The following table presents these figures:

Percentile	Estimated 1978 Monthly Income (JD)	
	Amman Slums	Zarqa Slums
20	44	42
40	56	62
60	74	78
80	112	116

Another source of estimated household income for non-specific geographic areas is the sample wage survey conducted by the Ministry of Labour in 1976.[8] This survey, when combined with data from the Employment Survey for Establishments Engaging More Than Five Persons conducted by the Department of Statistics in 1976 [9] provides an indication of the distribution of wages in the various sectors of the economy for employees working within the Municipality of Amman. Table 3-21 presents estimated average salaries of persons employed in Amman in 1976. These figures indicate that the average annual salary for wage earners was JD 816. This figure represents approximately 83 percent of the total workforce of the City (as that percentage of the workforce is estimated to receive salaries).[33] The higher average salaries were in the mining, electricity and utilities, and financial services sectors, ranging from an average of JD 1,210 to 1,305; while the lower salaries were concentrated in the public administration and transportation

TABLE 3-21

AVERAGE SALARY BY CATEGORY OF EMPLOYMENT

MUNICIPALITY OF AMMAN, 1976

Type of Employment	Number Employed[b]	Percent of Total	Average Annual Salary (JDs)[c]	% salaried in sector[d]
Mining	3,486	4.2	1,305	95.6
Manufacturing	10,099	12.1	846	67.9
Electricity	1,071	1.2	1,210	93.9
Construction	4,373	5.2	980	80.8
Commerce	4,616	5.5	818	32.4
Transport	4,035	4.8	700	75.9
Financial Services	3,391	4.1	1,299	85.0
Community Services, Public Administration[a]	52,648	62.9	740	91.2
TOTALS	83,719	100.0	816	83.4

[a]Including military personnel

[b]These percentages and numbers are taken from the Employment Survey for Establishments Engaging More than (5) Persons, Department of Statistics, December, 1976.

[c]Average annual salaries are derived from a sample survey conducted by the Ministry of Labor for the Kingdom of Jordan as a whole. All figures were upgraded by 25%, reflecting the World Bank estimated inflation factor for 1976 to 1977.

[d]These figures are extracted from the Multiple Purpose Household Survey, 1976.

Source: Department of Statistics, Ministry of Labor

sectors, ranging from JD 700 to 740. Manfacturing, construction and commerce had average salaries ranging from JD 818 to JD 980. The average wage of JD 816 per year represents JD 68 per month per worker, or JD 86.4 per month per household (assuming 1.27 workers per household).

The general data described previously were supplemented by spot surveys with extremely small sample sizes. These surveys were aimed at the identification of low-income areas within the large cities, and therefore represent households mainly from those areas presumed to have a larger proportion of low-income households than other areas within the Municipalities of Amman and Zarqa. Due to the small, non-scientifically chosen samples used in these surveys, they were not intended to provide estimates of household incomes in any geographic area or for any strata of the population, but were only intended to provide an indication of existing conditions for such population groups.

The following surveys provide indicative information as described above:

(1) Attitudinal Survey, April, 1979 - in conjunction with the Jordan Urban Project covering squatter settlements[a] in Jabal Jofeh, Wahdat, Wadi Abdoun, Wadi Haddadeh in Amman, and Jena'a in Zarqa;[32] (2) Socio-Economic Survey of Zarqa and Ruseifa-May, 1980 - in conjunction with Dr. Sari Nasir of University of Jordan;[27] (3) Amman Urban Region Planning Group (AURPG) Survey of Al Nuzha (Amman) Agugust, 1978,[34] (4) USAID Survey of Amman - selected low, middle and upper income areas, by Jabir S. Dajani, March 1978;[35] and (5) UNDP survey of slum and squatter settlements on Jabal Jofeh (Amman), July, 1977.[36]

The findings of the surveys listed above were as follows:

(1) Jordan Urban Project, April, 1979 (200 households)

- Aproximately three quarters of the households had monthly incomes below JD 100 in the sampled squatter areas of Amman and Zarqa.
- In the Amman squatter areas more than one-half of the households fell in the JD 40 and JD 80 income group, 45 percent in Jena'a (Zarqa).
- Approximately 16 percent of the households sampled in Jena'a had incomes below JD 40 per month.
- Wahdat had the lowest mean income, with more than 91 percent of sampled households reporting incomes below JD 80, and 73 percent below JD 60.
- Wadi Haddadah reported the highest incomes with 35 percent of households above JD 100, and only 53 percent below JD 80.

[a] Refers to settlements of occupants who reside on someone else's property without permission of the owner.

(2) Zarqa - Ruseifa Survey, May, 1980 (26 households)

- The households designated as being in the low-income group had a mean monthly income of JD 100 in Zarqa and 83 in Ruseifa.
- The middle income families sampled had a mean monthly income of JD 292 in Zarqa and 250 in Ruseifa.
- The upper income families sampled had a mean monthly income of over JD 417 in Zarqa and over 375 in Ruseifa.

(3) AURPG - Al Nuzha Survey, August, 1978 (30 households)

- The mean monthly income for all households was JD 93.
- The average salary per wage earner was JD 815 per year, or JD 68 per month.

(4) USAID - Dajani Survey of Amman Neighborhoods, March, 1978 (61 households)

- The mean monthly income of 29 households in low-income areas was JD 141.

  (Note: 42 percent of the total income of the 29 households was contributed by 4 households with a total of 18 salaried workers).
- Disregarding the 4 households with more than 2 workers, monthly mean income would be JD 95 for low-income households.
- The mean monthly income for 13 households surveyed in Jabal Amman was JD 376.
- The mean monthly income of 10 households in Jabal Hussein was JD 310, for 6 households in Jabal Weibdeh - JD 260, and for 3 households in Sheisani - JD 287.

(5) UNDP - Jabal Jofeh Survey, July, 1977 (140 households)

- Aproximately one-fifth (19 percent) of the households had monthly incomes below JD 40.
- Approximately 78 percent of the households had monthly incomes below JD 90.

The results of the surveys outlined above can be compared if JD values are escalated to a common denominator such as 1980 values. This can be done by assuming that the growth in household income paralleled growth in Gross Domestic Product and Gross National Product. Both economic indicators should be taken into account to ensure the inclusion of income earned by Jordanians abroad, and to provide a factor for exclusion of income earned by non-Jordanians.

For this reason an average of the annual change in both indicators was used to inflate pre-1980 values. Between 1977 and 1978, and 1979, Jordan's GNP increased by 14.5 percent and 19.5 percent, respectively. During both periods, GDP increased by 20.8 percent. Between 1971 and 1978 the ratio of the annual percent increase in Jordanian per capita income to the annual increase in both GNP and GDP remained constant at approximately 7 to 10 percent. Therefore acceleration factors used were 70 percent of the average of the annual percent increases in GNP and GDP from 1977 to 1979.

Acceleration factors used were 12.4 percent for 1977 to 1978, and 14.1 percent for 1978 to 1979. As no GNP and GDP estimates exist for the first half of 1980, a 14.0 percent acceleration factor was assumed. Table 3-22 compares data for the RSS national survey and the spot surveys of various low, middle and upper income areas, escalated to JD 1980. As can be seen from this table two major categories of measurement can be used to compare low-income areas in the five studies: mean household income, and the level of income below which 75 percent of the households surveyed for all. It is evident that, in most cases, the areas identified as "low income areas" have mean household incomes which are significantly less than the surveyed middle and upper income areas.

The middle and upper income areas surveyed averaged JD 371 per month. There is a great discrepancy in the level at which 75 percent of households are below. The "low-income" areas range from JD 68 to 137 in that category, while Jabal Amman has a figure of JD 705. According to AURPG, in 1978 the average household income of low-income households was JD 78, as the low income group ranged from JD 60 to JD 96. When inflated to 1980 JD this average would be JD 100.

Jarir Dajani, in his 1978 study for USAID, drew the poverty line at JD 83 per month for an average family of 6.7 members. When inflated to 1980 JD, the poverty line would be JD 106. The mean household incomes for low-income areas resulting from the small spot surveys were similar in magnitude to the Jordan Urban Project extrapolations of 1974 Income Survey data. If those estimates for 1978 are inflated to 1980 for comparison, the mean household income in the Amman slums would be JD 83 per month.

The AURPG estimated the poverty line in Jordan in 1979 to be between JD 600 and JD 1,000, or the 40th percentile of households (e.g., the 40 percent of the population with the lowest household income). That assessment agrees with the analysis of Dajani, and the Jordan Urban Project, which set the upper limit of low-income groups at the 40th percentile.

It is clear that the low-income households throughout the Greater Amman Area, including outlying cities have monthly incomes in the general range of JD 100 based on 1980 figures.

IDENTIFICATION OF LOW-INCOME AREAS

The lack of good geographically distributed personal or household income data has necessitated the use of indicative characteristics of the population or their environment to infer the general income level of particular neighborhoods. Low-

TABLE 3-22

INCOME SURVEY DATA COMPARISON

(JD 1980 per month)

	Mean Household Income	88-92% of Households Below	73-77% of Households Below	50% of Households Below	23-27% of Households Below
Jordan Urban Project					
Amman Squatter Areas					
Wadi Hadadah	—	182	114	—	—
Wahdat	—	228	137	91	—
Jabal Jofeh	—	91	68	—	—
Wadi Abdoun	—	182	114	—	—
Jena'a	—	182	114	—	—
Zarqa - Ruseifa Study		182	114	—	46
Zarqa Low Income	100	—	—	—	—
Zarqa Middle Income	292	—	—	—	—
Zarqa High Income	417+	—	—	—	—
Ruseifa Low Income	83	—	—	—	—
Ruseifa Middle Income	250	—	—	—	—
Ruseifa High Income	375+	—	—	—	—
AHRPC - Jabal Nuzha	119	—	—	—	—
USAID Study		—	—	—	—
Amman Low Income Areas					
Ashrafiyah	122[c]	—	135	125	64
Wahdat	147	—	—	—	—
Nazzal	261	—	—	—	—
Jabal Amman	148	—	—	—	—
	482	1575	705	512	192

TABLE 3-22

INCOME SURVEY DATA COMPARISON (Cont'd)

	Mean Household Income	88-92% of Households Below	73-77% of Households Below	50% of Households Below	23-27% of Households Below
USAID Study (cont'd)					
Jabal Hussein	310	780	—	—	—
Jabal Weibdeh	260	—	—	—	—
Shmeisani	287	—	—	—	—
UNDP Study					
Jabal Jofeh	—	—	90 (1977)	—	—

Source: United Nations Development Program, United States Agency for International Development, Amman Urban Region Planning Group, Malcolm Pirnie-Jousy, Jordan Urban Project, Central Bank of Jordan Monthly Statistical Bulletin, Royal Scientific Society.

Low-income areas within most of the other large municipalities in the Study Area cannot be identified, as the lower-income households are scattered among the middle and higher income households in those cities. This same phenomenon occurs with respect to the distribution of various levels of education within all cities. Interview with officials of Salt, Safut, Fuheis, Sukhneh, Hashimiya, Na'ur, Ain al Basha and Mahis supported that finding. These conditions also exist in many parts of the Municipality of Amman. Wide variations in income and lifestyle can exist side by side generally due to the following reasons:

- Clans or tribes of people who share the same backgrounds often reside next to each other.

- Skilled and unskilled workers who obtain high incomes send money home to their families in Jordan, who remain at their previous residences.

- The increasing demand for land near Amman and its suburbs resulted in high land costs, which in turn, has resulted in high rents. This, in turn, has led to fixed rent of occupied units leading to a reluctance to change residences, and overcrowding of existing units.

- Extreme variations in rents has resulted in conditions in which a 3-bedroom unit in a desirable area is renting for a small amount more than a one-room unit with one faucet in an older run-down area.[35]

Therefore, land price, value and condition of housing cannot be used to accurately identify household incomes. As indicated above, the level of education cannot be used either, as no recent data exists for individual households, and as is the case with incomes, people with differing education levels live adjacent to each other.

The use of family size as an indication of different levels of income would be somewhat useful if neighborhoods were relatively homogeneous, (i.e., with a predominance of one level of household size over all others). However, as indicated by the data from the 1979 census and presented in Table 3-7, household size does not vary enough from city to city, to form any conclusions about differences in income or education levels. All of the cities of the Study Area with more than 3,000 population ranged from 5.8 to 8.6 persons per household, with all but one city being over 6.0. Most cities were between 6.8 and 7.5.

Comparable data for the nine sectors of the Municipality of Amman indicate some differences among the sectors. The Zahran and Abdali Sectors, which include Jabal Amman, Shmeisani, Abdoun, Sport City and other areas which might be expected to be inhabited by a preponderance of households with relatively high incomes, had household sizes of 5.3 and 5.7 persons per household, respectively. Household size for all other sectors ranged from 6.4 to 7.0 with a mean of 6.79. Mean household size for Zahran and Abdali was 5.59. Average household size for Zahran and Abdali was 18 percent lower; and these areas were determined in other studies[26,37] (using other criteria) to contain an insignificant amount of low-income households. Therefore, it may be concluded that household size can be used, in some cases, as an indication of relative income differences. Unfortunately, household size breakdowns for the units of the Municipality of Amman are not available. The sectors are too large, and too diverse to be used for identification of the income level of individual neighborhoods. Breakdowns are also unavailable for segments of the other cities within the Study Area.

Upon completion of the tabulation of census data scheduled for mid-1981, the information required for such an analysis may become available.

Population density is another factor that is generally related to household incomes. Data necessary for the determination of population densities of segments of the larger urban communities is not available, except for the Municipality of Amman. Table 3-9 shows population densities per dunum of all land use types for each unit within the Municipality of Amman. Ideally, population per dunum of residential, or even built-up land should be used, as total land includes undeveloped land, which varies greatly among the units in the city. However, because built-up land totals for 1979 are not available for the units of Amman, the densities based on total area must be used. A review of 1979 density figures for the city's units shows that there is some correlation between low-income households and density, despite the limitations of this method of analysis. The highest densities were in the following units: Jabal Nuzha, Al Nadif, Ashrafiyeh, Jabal Taj, and Al Awdah. All of these units had densities of over 20 persons per dunum. Each of the above-mentioned was estimated to have at least 20 percent of its housholds in the low-income group. All of the areas estimated to contain at least 20 percent low-income households were in units of over 20 persons per dunum, except Nazal and the Ain Ghazal or Marka units (31 through 35). These exceptions are easily explained. Nazal's density was 17.5, which was the next highest density among units. Its density was diluted by a large portion of open space within its boundaries. The Ain Ghazal units contain large areas of industrial land which tend to distort any possible identification with the population density on residential land. Alternatively, none of the areas with small percentages of low-income households had densities of more than 15.1; and only two of the eight higher income areas had densities over 7.2. The above family size and population density analyses indicate that low-income families are more likely to be found in crowded areas, (i.e., areas with higher population densities and more people per household). Despite the fact that no studies of income levels in the other cities of the Study Area were undertaken, and population density and household size figures do not exist for sub-areas or neighborhoods of these cities, some identifiable areas of relatively low-income households exist. Discussions with officials of some of the outlying municipalities revealed the following information: The old portion of Suweileh (both east and west of the Jarash Road north of the Salt Road), the old city of Wadi es Sir, and the central city of Madaba have concentrations of relatively low-income households. In the case of Madaba, the relative difference between incomes of the outer city and central city are not of the same magnitude as those in Amman. However, the difference in incomes between the low-income and middle and upper income groups in the cities outside the suburban fringes of Amman generally are not great enough to warrant further consideration.

The use of estimates of income of low-income households as a gauge to determine abaility to pay for sewage system connection fees and annual fees for system maintenance may not be necessary. This conclusion cannot be made until further evidence is acquired. However, preliminary data seems to indicate that low-income households may be able to pay the costs of connection to sewer systems, and that they are willing to do so. In a recent test to determine the effectiveness of Article 23 of AWSA Law No. 48 for 1977, two sectors of recent AWSA sewer system connections were screened for number of connections and promptness of complying with the ordinance.[38] The ordinance states that the owners of

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TABLE 3-23

ESTIMATED LOW INCOME POPULATIONS IN AMMAN, 1976
(Percentage by Unit or Neighborhood)

Unit Number(s)	Unit(s) or Neighborhood[a]	Percentage of Low-Income Population VBB Study	IBRD Study
11	Jabal Qala'a	15	20
12-19	Central City	17	—
21,24,25	Jabal Nuzha	25	25
21	Wadi Hadadah	58	—
22	Al Kussour	28	—
23,26	Al Hashemi	20	—
31	Mahatta	20	20
31-35	Marka (Ain Ghazal)	20	20
41	Jabal Taj	15	20
42-44	Jabal Nasr	27	30
51	Jabal Jofeh[a]	30	20
51-53	Ashrafiya-Wahdat	30	30
61	Nadif	25	25
62	Shalieh[a]	40	25
63,64	Zohour	25	—
71,74	Nazzal	25	25
81,83,85,86	Jabal Amman	2	2
82	Abdoun	0	0
91	Jabal Weibdeh	0	0
92	Jabal Hussein	5	—
93	Shmeisani	0	0
94	Arjan (Sport City)	0	—
95	Shamsani (Dahia)	0	0
96	Sport City (Qatana)	0	—

[a]Estimates were made for portions of Municipality administrative units - these are designated as neighborhoods. Estimates for City subareas included one or more units as listed. Neighborhoods are listed under number of the Unit they are located within.

SOURCE: International Bank for Reconstruction and Development (IBRD)"Amman water and Sewerage Project III", March, 1978.

VBB-FAWZI and Associates, "Feasibility Study for the Amman Water and Sewerage Project", November, 1977.

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income areas within the Municipality of Amman have been identified in previous studies through the use of various criteria. Among them are: cost of land, type, condition and/or value of housing, population density, and possession of luxury goods. These criteria were used to analyze data from census and other national surveys, and supported in particular cases by physical reconnaissance and inspection.

Four recent major studies attempted to classify neighborhoods (mainly in Amman Municipality and Zarqa) into income groupings, or to identify the portion of urban poor in each neighborhood. The first of these studies was conducted in conjunction with the 1977 feasibility study for the Amman Water and Sewerage Project.[26] This study estimated the number of urban poor in various neighborhoods of the Municipality of Amman in 1976, and for projected population in 1980. The 1980 projections did not vary more than two percent in their ratios of urban poor to total population. The second study was conducted by the International bank for Reconstruction and Development in conjunction with their study of "Amman Water and Sewerage Project, III" in 1978.[37] This analysis also estimated the urban poor in Amman neighborhoods. These estimates did not contradict any of the findings of the first study. The third study was conducted in conjunction with the solid waste management feasibility study for the Greater Amman Region.[25] That analysis identified areas within the Municipality of Amman as to percentages of high, medium and low-income groups based on (a) 1971 census data on housing type and conditions, (b) information from Municipality District Directors on the type of housing predominant in their district, and (c) on data from the 1976 Multi-purpose Household Survey related to the possession of luxury goods. The fourth study was a socio-economic study conducted in conjunction with the Zarqa-Ruseifa water and sewerage system feasibility study in 1980.[27] This analysis combined a Delphi Panel with physical inspection of housing to determine low-income areas in Zarqa and Ruseifa.

Table 3-23 presents the findings of the two studies concerning Amman Municipality, by showing the percent of urban poor estimated for each neighborhood. As indicated in the table, the areas within Amman Municipality with the highest proportion of low-income households are Wadi Haddadah, Jabal Jofeh, Shalieh, Al Ashrafiyah, Wahdat, Al Kussour, Jabal Nuzha, Jabal Nasr, Al Zohour, Nadif and Nazzal. All of the above areas are estimated to have at least 25 percent of their households in the low-income group. In addition, the areas of Al Hashemi, Mahatta, Marqa, Jabal Qala'a, Central City and Jabal Taj are estimated to contain low-income households ranging from 15 to 20 percent of their total populations. The solid waste study indicated that all of these areas were composed entirely of low-income families.

The findings of the Zarqa - Ruseifa socio-economic study determined that low-income households were concentrated in the following areas: (1) Schneller (Marka) Refugee camp - (2) Jabal Al Shamali in northeast Ruseifa north of the Hussein Industrial City, as well as the area south of the Zarqa River to the south of the Zarqa River to the south of the Industrial City - (3) Awjan al Janubi, and central Awjan al Gharbi, both west of the River; (4) Hai ez Zawahreh west of the River in southwestern Zarqa; and (5) most of northeastern Zarqa.

properties shall pay fees to AWSA and complete their sewer connections according to AWSA standards within three months from the date of publication of the areas to be connected. If the owner fails to connect he will be charged cost plus 20 percent, and any legal fine pertaining to such action. In addition 9 percent interest will be charged for the period beyond the due date.

The two areas from which connection data were collected are Shmeisani and Jabal Nuzha. These areas were chosen because of their extreme differences in income status of their average households; the former being one of the highest-income areas in the City, and the latter being one of the lowest. Shmeisani was scheduled for 70 connections. At the end of the three month period plus one month of extension, 55 connections, or 78.6 percent were made. During the same period 258 of 280 scheduled connections were made in Jabal Nuzha, for 92 percent compliance. Although the sample sizes in this case were not large, compared to the total AWSA service population, and samples from additional areas should be taken to confirm this trend, this comparison indicates that low-income households in Amman (and possibly throughout the project area) may be able to raise the money to pay for connection to the sewer system. The reasons for desiring connection are likely to be the fear of the law, avoidance of inevitable penalties, and lower annual costs for service than current frequent pumpout costs in certain areas.

Additional checks of data for connections in low and high-income areas have been requested, and that information may be added to this analysis at a later date. Regardless of the ability to pay analysis requirement for income data, identification of low-income areas in Amman and the other portions of the Study Area is necessary for the evaluation of the potential benefits of proposed sewage system improvements.

SOCIAL ASPECTS OF WATER USE

The social aspects of water use is a measure of availability of water-related services, hygiene practice, and public health awareness among the different income levels within the Study Area. It provides an input for assessing the extent of potential benefits once the sewerage improvements are implemented, and the variations in water consumption and related wastewater generated.

Current water use of low-income areas has been estimated for some of the slum areas of Amman, as well as for low-income households in general. The AURPG Al Nuzha survey in 1978, found that the mean water consumption of the 30 household sample was 24.5 liters per capita per day (lpcd).[34] The AURPG suggested standard for "absolute minimum" requirements was 60 lpcd.

Jabir Dajani's 1978 study determined that the average consumption for the AWSA system was 40 to 50 lpcd, for water delivered by tanker and supplied through the municipal pipe system. A survey of 64 households, taken in conjunction with that study produced the following results: Average consumption for low to lower middle income groups was estimated to be 30 to 70 lpcd; and the range for the "poorest of the poor" (from 2 to 4 percent of the population) was estimated to be 15 to 30 lpcd; while middle income households were estimated to average 70 to 110 lpcd, with upper income groups averaging 110 to 300 lpcd.[35] Although the

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survey sample was small and not chosen scientifically, its results reflected such universally accepted differences between low and high-income areas that they can be considered indicative.

The "Water Use Strategy for North Jordan," Study 39 estimated 1975 per capita domestic consumption for Amman to be 80 lpcd, 65 lpcd for other communities with more than 15,000 people, 55 lpcd for communities with between 9,000 and 15,000 people, and 45 lpcd for communities below 3,000 people. Households with no pipeline connections were estimated to consume as low as 15 lpcd, while a housing project for upper-income professionals was metered, and found to consume 175 lpcd.

These findings suggest that the per capita water use of low-income households may range from 15 to about 50 lpcd. The lower estimates for the less urbanized smaller communities indicates that the type of service, types of plumbing and hygienic practices may all be highly significant factors. These figures reflect, in many cases, limited supplies and intermittent deliveries, as well as the use of plumbing facilities and types of water-using appliances that may change with connections to a sewer system. Recent water consumption data for the AWSA system for the first two quarters of 1980 seems to confirm the income-related findings of the studies listed above;[40] the data show that lower-income households use substantially lower volumes of water per capita. A comparison of the total system per capita consumption of the lower and upper-income areas of Amman, identified earlier in this analysis, showed significant differences. The upper-income areas of Shmeisani-West Jabal Weibdeh (AWSA Meter District No. 13), West Shmeisani (12) and West Jabal Amman (16) had per capita total system rates of 149, 102 and 86 lpcd, respectively. Conversely, the low-income areas of Nadif (District 22), Akhdar-Nazzal (21), Jabal Jofeh (27, 28), Jabal Nuzha-Wadi Haddadah-Jabal Qala'a (5 through 8), and Al Awdah-Ashrafiyeh-Wahdat (24 through 26) each averaged below 25 lpcd, and were the only areas to do so. These system averages include also commercial and industrial uses which distort the effect of the residential component. In addition, water tanker deliveries which account for a small portion of total system use, are not accounted for in these totals. Yet, despite these two limitations of the data, the differences are great enough to serve as an indication that low-income households consume significantly lower volumes of water per capita than do upper-income households.

Potential future increases in these rates of consumption would be subject to the following factors:

- Increases in the connections to municipal water distribution systems and provision of a continuous flow in those systems.
- Increased household incomes.
- Increased awareness of the necessity of water use for personal hygiene.
- Introduction of indoor plumbing and water using facilities and appliances.

The first factor applies to the general population, while the last three factors apply mainly to low-income households.

PRESENT AND FUTURE SOCIO-ECONOMIC CONDITIONS

Within the Muncipality of Amman, all areas are planned for eventual connection to the AWSA collection system. This is expected to occur early in the study period. The Water Supply Corporation has indicated that service to small towns and villages in the Study Area is planned. These increases in supply can be expected to result in increased consumption, independent of the effects of any of the other factors. Connections to the water systems would likely increase consumption. Similarly the effect of installation of sewers could result in indirect increases in water use, by encouraging the use of indoor plumbing, flush toilets and water-using appliances. At present, many of the outlying villages and portions of the larger outlying municipalities have outdoor sanitation facilities and no indoor plumbing.

Increased real income levels would also result in more demand for water, as it is currently estimated by AURPG and others, that many people in the Greater Amman Area consume below subsistence levels of water. Carrying of water before use and lack of hot water are two reasons for lower water use among low-income groups. The cost of electricity is a deterrent to the use of hot water heaters. Residents in these areas have cesspools which often require pumping out, which can cost from JD 6 to JD 15 per pumpout. These figures reflect charges of from JD 2 to JD 3 for each truck, and 3 to 5 trucks per pumpout. Houses with very low incomes will often consume less water to cut down the frequency of pumpouts and reduce costs.

An increase in awareness of the public (especially low-income and rural populations) of the role of water in personal hygiene would also help to increase consumption. However, surveys in Zarqa and Ruseifa and other areas with low average incomes indicate that monetary constraints were more significant than cultural differences or lack of awareness of hygiene and health benefits of increased cleanliness.

A last major point is the relationship of projects proposed for this study to the improvement of public health due to increased water use and installation of sewers and/or increased, or more efficient sewage treatment. The AWSA water system and sewage system is already planned to cover the entire area of the Municipality of Amman. Therefore, only changes in sewage treatment for the Municipality's residents would be related to this study. The problem of cesspool seepage into groundwater and intrusion of polluted groundwater into the water pipe systems during times of intermittent service and/or low pressure and volume is confined to some of the outer portions of the Study Area. Municipalities and villages which are hilly and have hard soil, and water sources of wells which are drained from the cesspool areas experiencing frequent overflows, could have their potential for public health problems reduced through installment of a sewer system. That system could reduce pollution of groundwater which might result in less likelihood of occasional epidemics of enteric diseases, thus allowing the full benefits to public health of implementation of sewage system improvements.[36]

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CHAPTER 3

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CHAPTER 4

PUBLIC HEALTH CONSIDERATIONS

A. THE PROBLEM AND RELATIONSHIP TO MASTER PLAN

There are a number of conditions that are related, directly or indirectly, to the health and well-being of the population in a given area. They are recognized to be of sufficient importance to deserve special attention in planning programs and projects intended to introduce improvements in public health through changes in the existing environmental conditions. The major ones include those mentioned hereunder without due regard to the order of importance and priority.

1. Programs directed at the assessment and gradual improvement of the environmental and sanitary conditions that have an impact on public health, with particular reference to water, food, atmosphere, and wastes.

2. Demographic and socio-economic conditions, especially trends in population growth and urbanization, as well as poverty—stricken areas and slums characterized by crowdedness, poor housing conditions, limited education, and ill-health.

3. Current and future development plans, particularly those relating to industrialization as they have a direct impact on the health of workers, and on the surrounding environment.

4. Public health and medical care programs, and their supporting health facilities.

5. Interest, initiative and capabilities of the governmental agencies concerned with public health in planning and implementation of programs, with particular reference to availability and allocation of funds, and to manpower development.

6. Public awareness, recognition of needs, attitudes towards changes in environmental and ecological conditions, as well as the current and future health education programs aimed at improvement in the knowledge and appreciation of these matters.

Once these conditions and trends have been defined and evaluated, then it would be possible to assess the level of health of the communities in question, and to predict in an acceptable manner the state of affairs brought about through the implementation of an environmental engineering program such as the one being planned for Greater Amman.

With these considerations in view, an attempt is made to present and discuss in this Chapter an account of the health status pertaining to the Greater Amman area in relation to the impact of improvement in the wastewater disposal systems. Deficiency in the available information, statistical data, and epidemiological

studies is a readily recognizable limiting factor in providing what can be described as an absolutely valid and factual description of the current situation and practices, let alone prediction of future conditions and impacts. Nevertheless, some reliance on information relevant to experiences, practices, and policies elsewhere would be useful under the circumstances. Sound judgement based on scientific knowledge is also warranted. But, in order to avoid unnecessary repetition of some of the interrelated information, this Chapter will be restricted to the public health aspects of domestic water supplies and wastewater disposal systems, unless otherwise dictated by the need to highlight certain outstanding matters.

B. PAST WORK BY OTHERS

Studies in the field of public health in Jordan are so scarce that an investigator is faced at the outset with the difficulty of finding documented information and reports. This then entails, at least in part, gathering first hand information through field visits, surveys, and interviews to bridge the gaps in the scattered information. Some of the reasons for such a shortcoming refer to the limited research facilities, research workers, and available funds in Jordan.

It is only recently that a few public health-oriented researchers of the University of Jordan and the Royal Scientific Society have become engaged in investigations in this field. This is a commendable start, and should be further encouraged and supported by both the private and public sectors, as the outcome would be essential for the provision of baseline information, identification of outstanding problems and solutions, and determination of trends and future impacts.

For purposes of convenience, some of the available reports relevant to the topic under discussion in this Chapter are mentioned and briefly discussed in what follows.

1. Khoury, S.A. and Abd Al-Wali, M.T., "Continuous Water Supply and Diarrheal Disease in Jordan: A Preliminary Study" University of Jordan, Unpublished, memograph, 8 pages, undated.

The purpose of this study was to provide a preliminary assessment of the relationship between continuous and intermittent supply of drinking water and the incidence of enteric diseases from May 1 to Nov. 30, 1979. The two towns selected for this study were Karak with a continuous water flow, and Salt having an intermittent flow. From the data obtained from the health centers in both towns it was concluded that the continuity of flow of drinking water in Karak may have contributed to a lower incidence of diarrheal disease as compared to that obtained in Salt.

These findings are not surprising in view of the possibility of admission into the water distribution system of microbiological and chemical pollutants by virtue of the negative pressure developed during non-flow periods. This is a common occurrence in Jordan and other water-short regions of the world. But, what is of equal importance is the observation that the number of diarrheal cases in both Karak (428 cases, or 3567/100,000 population and Salt (768 cases, or

2327/100,000 population) are appreciably high. The inference is that other communities in Jordan such as Amman with intermittent water supplies are likewise apt to suffer from water-borne diarrheal diseases. However, an interrupted flow is only one of the possible influencing factors.

2. Khoury, S.A., Qubain, S. And Shehabi, A., "The Water Contamination of Salt 1976: An Epidemiological Study of Disease Outbreaks." Jordan Med. J., 12: 34-43 (1977).

Contamination of groundwater from an old well used as one of the municipal water supply sources on or about December 23, 1975, resulted in a water-borne outbreak of gastrointestinal diseases from January through May, 1976, involving much more than the 4152 patients who had attended public clinics in Salt with gastrointestinal symptoms. Four different diseases were identified: (a) gastro-enteritis caused by Shigella Boydii; (b) Guillian - Barre syndrome, 20 confirmed cases; (c) typhoid fever caused by Salmonella typhi, 124 confirmed cases; (d) infectious hepatitis A, 90 confirmed cases. It was also shown in this study that the most susceptible age group for the gastro-enteritis cases was 1-14 years (80.0%), and for the typhoid cases was 5-14 years (69.2%).

3. Westinghouse Health Systems, "National Health Planning in Jordan, Phase Two: Health Policy Strategy." Columbia, Md., 1977.

In this rather extensive report a number of topics dealing with various aspects of health in Jordan are presented and discussed. An attempt is made to concentrate on information derived from demographic, mortality, morbidity, and health facilities utilization data in an effort to evaluate the health conditions, but suffers from the usual deficiency in, and unreliability of, the available statistical information.

Some of the important findings are briefly mentioned hereunder:

(a) Age distribution shows that among all deaths in 1974, about 28% are infants below 1 year, and that about 43% of all reported deaths are of children below the age of 15 years who represent about 51% of the population. Therefore, children in general, and especially in the pre-school years, are in the greatest need of health care.

(b) Classification of deaths by cause shows that enteritis, pneumonia, heart conditions other than ischemic heart disease, and accidents are the four leading known causes of death. Available data from other years supported this conclusion.

As motor vehicle accidents account for half of the deaths due to accidents, it is suggested that this important health problem be addressed in a comprehensive and effective manner.

(c) Classified by age and cause, mortality data shows enteritis and respiratory diseases are the major killers of children under 5 years, while accidents emerge as the leading killer in school-age children 5-14 years.

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(d) Morbidity data shows that from 1970 to 1975 enteric diseases (typhoid fever, dysentery, and infectious hepatitis) were the fourth most important group of illness. These diseases are closely related to the degree of water contamination and personal hygiene practices.

(e) Hospital admission statistics for 1975 show that diseases of the digestive system are the leading group, accounting for about 18% of all admissions, followed by diseases of the respiratory and the genito-urinary systems. It is concluded that these diseases form the major causes for seeking medical care.

(f) Study of the utilization of health services shows that the highest rate of hospitalization was in the south (Karak: 78/1000 and Ma'an: 51/1000), and the lowest rate in Balqa (30/1000). This is attributed, among other reasons, to the lack of effective health care services responding to the basic health needs of the population. This pattern results either in misuse of hospitals as providers of basic care, or in a need for care for unnecessarily advanced cases.

(g) Maternal and child health services cover only about 20% of all pregnancies with at least one prenatal visit. The other 80% of pregnant women do not even receive this visit before delivery. Postnatal coverage is even lower at 6%.

(h) Consideration is also given to the status of water supply and sewage disposal systems, and some of the major problems are briefly described.

4. Halcrow Fox and Associates, Jouzy and Partners, "Jordan Urban Project. Interim Sector Report No. 11. Health in the Amman -Zarqa Slum Areas." Feb. 1979.

This report and the studies on which it was based were undertaken from 5 to 26 February 1979. It does not dwell greatly on the conventional indices of ill-health such as morbidity and mortality statistics because these are known to be under-reported. The findings and recommendations are summarized hereunder.

(a) The urban slum health problems in the study area are such that improved water and excreta disposal are considered to be the most desirable services to be provided.

(b) Improvement in the health status of the target population would best be achieved by the expansion of the existing primary health care services.

(c) Training of practicing physicians, nurses and other health workers on community health care is also suggested, together with improvement in the public health education program.

C. EXISTING HEALTH CONDITIONS

1. Useful and Pertinent Considerations

In the absence of readily available, valid, and quantifiable indicators of ill-health arising from poor sanitary conditions and practices, mortality and morbidity statistics may serve the desired purpose of assessing the situation. Viewed in the light of additional information obtained through field surveys to determine the influencing environmental and other factors, the validity of the data would thus be enhanced.

Gastrointestinal diseases transmitted through water are generally recognized to reflect, to some degree at least, the prevailing sanitary conditions. The control of these diseases in the highly developed countries through the institution of effective measures for the provision of safe water, the proper disposal of human wastes, and promotion of personal hygiene is known to be an irrefutable accomplishment. In contrast, the developing countries continue to suffer from the consequence of gastrointenstinal disease, especially among children, on account of the unsatisfactory sanitary conditions that prevail. To illustrate this point, reference is made to mortality and morbidity figures quoted by Rifka (1980) from WHO sources that pertain to the Eastern Mediterranean Region where the infant mortality rates are high (Table 4-1).

Of the 11 million children born in the region in 1976, about 20% will die before the age of 5; 40% of these deaths are caused by gastrointestinal infections. 20% by respiratory infections, 5% by immunizable diseases, and 2.5% by malaria. Khan (1980), in an endeavour to promote primary health care programs, quotes a well known statement by WHO to the effect that about 90% of all deaths among children could be avoided by the provision of safe water and sanitation. This is in line with the Water Decade (1981 - 1990) recently declared by the UN. Oral rehydration thereapy programs, strongly advocated by WHO, is yet another promising approach that is gaining wide acceptance in many parts of the world (see, for instance, WHO 1976, 1979, and 1980). This involves oral administration of salt-sugar solutions to abolish death and disability caused by watery diarrhea.

The access of fecal matter originating from man and warm-blooded animals to drinking water supplies would lead to the transmission of water-borne diseases, of which the principal ones are given in Table 4-2. A well documented account of waterborne pathogens is given by Geldreich (1972), who also discusses the transport into surface and groundwaters of these pathogens derived from humans and farm animals by raw and treated sewage, and by storm-water. The same reference points out that the occurrence and magnitude of these pathogens in raw sewage would reflect the prevalence of disease at the moment. An obvious conclusion is that pathogens in raw sewage in developing countries, where gastrointestinal diseases are endemic, and particularly during outbreaks of disease, are much more concentrated than in raw sewage obtaining in developed countries.

Table 4-1. Infant Mortality Rates * in the Eastern Mediterranean Region

Country	Estimated Population 1977 (000's)	Rate (per 1,000 live births)
Afghanistan	20,340	182
Bahrain	270	64
Cyprus	690	33
Democratic Republic of Yemen	1,800	190
Djibouti	230	52
Egypt	38,740	100
Iran	34,160	139
Iraq	11,910	86
Jordan	2,080	89
Kuwait	1,130	43
Lebanon	3,060	65
Libya	2,570	73
Oman	820	138
Pakistan	75,280	124
Qatar	200	42
Saudi Arabia	9,520	152
Somalia	3,350	177
Sudan	16,530	140
Syria	7,840	93
Tunisia	6,070	120
United Arab Emirates	760	138
Yemen Arab Republic	7,080	152
TOTAL	244,430	

* Estimated from latest data available to WHO /EMRO, July 1978.

From Rifka, G. Conventional Health Care Systems and Meeting the Essential Needs of Underserved Population Groups in Developing Countries. In : American University of Beirut. Human Resources for Primary Health Care in the Middle East. AUB, Beirut (1980). Page 11.

Table 4-2. Principal Waterborne Diseases [a]

	Disease	Agent	Source	Common Vehicle [b]
BACTERIA	Cholera	Vibrio cholerae	Patients & carriers : feces, vomitus	Primary cases : water; secondary cases: direct contact, raw or improperly cooked foods, and flies
BACTERIA	Typhoid fever	Salmonella typhi	Patients & carriers : feces, urine	Water, food, and flies
BACTERIA	Paratyphoid	Salmonella : paratyphi schottmuelleri hirschfeldii	Patients & carriers : feces, urine	Water : few outbreaks; more commonly food, flies and direct contact
BACTERIA	Bascillary dysentery	Shigella : dysenteriae flexneri boydii sonnei	Patients & carriers : feces	Water, food, flies and direct contact
BACTERIA	Gastroenteritis	Unkown	Probably man and animals: feces	Water and food (latter more common)
VIRUSES	Infectious hepatitis	Recently isolated virus	Patients: feces, urine and nasal discharges	Water, food, and direct contact

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Table 4-2. continued

PROTOZOA	Amoebic	Entamoeba	Patients & carriers (and probably rats): feces	Water, food, flies and direct contact
HELMINTHS	Schistosomiasis (Bilharzia)	Schistosoma : heomatobium mansoni japonicum	Patients : urine or feces	Domestic, recreational or agricultural water
	Ascariasis (intestinal round worm)	Ascaris lumbricoidis	Infested persons : ova in feces	Water and food
MISCEL-LANEOUS	Diarrhoeal diseases	Shigella, Salmonella, E. coli, G. lamblia Viruses	Patients : feces	Water, food, and flies

a. Sources : (1) Benenson, A.S. Control of Communicable Diseases in Man. 11th ed. APHA, Washington, D C (1970).

(2) WHO. Guide to Simple Sanitary Measures for the Control of Enteric Diseases. WHO, Geneva (1974); p 11.

b. Food: raw vegetables, milk, milk products, or shellfish.

Hoadley and Goyal (1976) have enumerated the wide variety of parasites, pathogenic bacteria, and viruses occuring in sewage, and rightly indicate that the sanitary character of sewage varies from community to community depending upon urbanization, population density, and sanitary habits. Table 4-3 shows the pathogenic organisms commonly found in sewage as adapted from Mara (1978).

According to Geldreich (1972), sewage treatment processes will reduce the pathogen content of raw sewage, the degree of reduction being governed by the type of process and other factors. While marked reductions can be achieved by secondary sewage treatment, yet complete removal is not practicable. The trickling filter process, for instance, has been found to achieve the following percentage reductions of specific pathogens: S. paratyphi B, 84-99%; M. tuberculosis 66%; enteric viruses, 40-60%; tapeworm ova, 18-70%; E. histolytica cysts, 88-99%; total coliform, 82-97%. For the activated sludge process, the percentage reduction of such pathogenic bacteria as Salmonella and Shigella generally ranges from 85 to 95%, with 98% reduction for such viruses as Polio virus type I and Coxsackie A9 virus.

Sludge digestion has resulted in 25-92.4% reduction of S. typhi. The conclusion derived from these facts is that the treated effluents constitute a potential health hazard through polluted waters and vegetables contaminated by application of wastewaters to land, unless additional appropriate treatment is applied. Problems of land application of wastewater are highlighted by Lee (1976). Similar constraints apply to the use of reclaimed wastewater for the recharge of groundwater and other purposes (Sanks and Asano, 1976).

Bitton (1978) focuses attention on the more than 100 types of enteric viruses that are expected in feces and infect the gastrointestinal tract and other parts of the human body, and discusses the question of virus survival during wastewater treatment and spray irrigation for the application of wastewater on land. Survival in the aquatic environment, soils, sediments, and food (vegetables) are also discussed. His conclusion is that neither current sewage treatment nor water treatment processes satisfy the right of the public to virus-free water.

Both municipal sewage and sludge can contribute macro- and micro-chemical pollutants to contaminate water and soil. Higgins and Burns (1975) noted that nitrate leached from fertilizers or human and domestic animal sewage could contaminate drinking water supplies, or may accumulate in some plants (notably spinach, squash, beets and carrots) when grown on soil high in nitrate content. In such cases, there is the risk of methemoglobenemia among infants below one year of age.

With the increasing amounts of sewage sludge applied to land there is the potential for human health problems arising from metal contaminants in sludge. Among the various toxic trace metals (Cd, Cr, Se, Hg, and Pb), cadmium seems to be the metal of most concern to human health with applying muncipal sludge to land (Pharen et al, 1979). Wastewater treatment

Table 4-3. Pathogenic Organisms Commonly Found in Sewage *

Organism	Disease	Remarks
Virus	Poliomyelitis Hepatitis	Exact mode of transmission not yet known. Found in effluents from biological sewage purification plants
Vibrio cholerae **	Cholera	Transmitted by sewage and polluted water
Salmonella typhi **	Typhoid fever	Common in sewage and effluents in times of epidemics
Salmonella paratyphi **	Paratyphoid fever	Common in sewage and effluents in times of epidemics
Salmonella spp. **	Food poisoning	Common in sewage and effluents
Shigella spp. **	Bacillary dysentery	Polluted waters main source of infection
Bacillus anthracis **	Anthrax	Found in sewage. Spores resistant to treatment
Brucella spp. **	Brucellosis-Malta fever in man. Contagious abortion in sheep, goats and cattle	Normally transmitted by infected milk or by contact. Sewage also suspected
Mycobacterium tuberculosis **	Tuberculosis	Isolated from sewage and polluted streams. Possible mode of transmission. Care with sewage and sludge from sanatoria
Leptospira iceterohaemorrhagiae **	Leptospirosis (Weil's disease)	Carried by sewer rats

Table 4-3. continued

Organism	Disease	Remarks
Entamoeba histolytica **	Dysentery	Spread by contaminated waters and sludge used as fertilizer. Common in hot climates
Schistosoma spp.	Schistosomiasis	Probably killed by efficient sewage purification
Taenia spp.	Tapeworms	Eggs very resistant, present in sewage sludge and sewage effluents. Danger to cattle on sewage-irrigated land or land manured with sludge
Ascaris spp. Enterobius spp.	Nematode worms	Danger to man from sewage effluents and dried sludge used as fertilizer

* Source: Mara, D. Sewage Treatment in Hot Climates. John Wiley & Sons, New York (1978). Page 12.

** These organisms are bacteria.

technology for the removal of trace metals and other types of contaminants is adequately covered by Patterson (1978), but it is beyond the scope of this report to enter into the details.

The discharge of raw or treated wastewater of domestic or industrial origin into the environment (water or soil) is likely to lead ultimately to the accumulation of toxic trace elements. These are generally not included in routine chemical analysis of water for lack of analytical facilities, or because of mere lack of appreciation of their significance as to their potential health effects. In view of their importance with reference to drinking water, attention is drawn to the need for compliance with the limits set by the WHO International Standards for Drinking Water Standards (WHO 1971), and to the National Interim Primary Drinking Water Regulations by the US Environmental Protection Agency (EPA 1976). The maximum acceptable levels for trace elements in drinking water as set by WHO and EPA are given in Table 4-4. Exceeding these values forms the basis for rejecting water supplies intended for drinking purposes. It should also be noted that removal of trace elements in water requires a complex and rather costly technology that may be beyond the present capabilities of most communities in developing countries (EPA 1976). Therefore, prevention of contamination of water resources intended for domestic use is highly desirable wherever the required measures are feasible.

Public acceptance of water reclamation and re-use for domestic purposes may be a major obstacle to any project involving such a system. Knowing that the whole concept is still new to most people, it would be advisable to solicit the views and attitudes of the public to renovated water projects as suggested by Kasperson (1977), although such an approach may seem to be an unusual practice that is not sufficiently warranted.

The adverse health effects of some metals present in water supplies in excess should not be the only consideration, but judgement should also be based on their possible beneficial effects when their concentration in natural water is low, or is decreased by treatment (e.g., softening or demineralization). This has been stressed in a recent publication by WHO (1979). For instance, the high calcium content in hard water has been shown by a number of studies to be inversely associated with cardiovascular mortality, and with mortality in general.

The evidence for a similar relationship in the case of magnesium requires further studies and epidemiological support. An excessive sodium intake through food and water, on the other hand, has been shown to increase blood pressure, whereas normal concentrations of sodium in drinking water do not constitute a hazard to health. Softened drinking water containing an excess of sodium ions obtained through cation exchange has aroused concern. Studies in the West Bank of Jordan and in Nigeria suggest that trivalent chromium enhances the utilization of glucose in infants with protein-calorie malnutrition. In the Jordanian study, trivalent chromium deficiency and imparied glucose metabolism among infants from the hill regions of the West bank were attributed to the low chromium content in drinking water (0.5 ppb

Table 4-4. Maximum Acceptable Levels for Trace Elements in Drinking Water

Element	Maximum Acceptable Levels (mg/l)	
	WHO (1971) [a]	EPA (1976) [b]
Arsenic	0.05	0.05
Barium	--	1.00
Cadmium	0.01	0.01
Chromium (Cr^{+6})	--	0.05
Lead	0.1	0.05
Mercury	0.001	0.002
Selenium	0.01	0.01
Silver	--	0.05

a. WHO. International Drinking Water Standards. WHO, Geneva (1971).

b. Environmental Protection Agency. National Interim Primary Drinking Water Regulations. EPA, Publication 570/9-76-003, U.S. GPO, Washington, D.C. (1976).

of Cr; mostly rain water), in contrast to the normal group of infants from the Jordan Valley where the drinking water from springs contained an average of 1.6 ppb of Cr. (Hopkins et al., 1968). However, these findings were not confirmed in a similar study in Cairo (Carter et al., 1968). It is possible to conclude from all of these observations that: (a) where the mineral content of the diet alone may be deficient, water could be an important source of certain essential substances, especially calcium and magnesium; (b) drinking water with low mineral content (demineralized, desalinated, or rain water) should be cautiously accepted, and preferably only after a carefuly study has been made of the local inhabitants; (c) the possible harmful effects to high risk groups (such as persons on restricted sodium diets, people living in hot climates whose fluid intake may be very high, and those whose drinking water has a very high content of natural sodium) should be carefully considered in the light of available information.

2. Water-Borne Diseases

With a few exceptions, water-borne diseases appear to be endemic in Jordan where the occurrence of frequent outbreaks generally goes unnoticed, and accurate information about them is either scarce or lacking. This, however, does not necessarily apply in the case of such a 'scaring' disease as cholera when imported cases trigger an outbreak, partly because of the interest of WHO in the spread and control of this much dreaded disease.

In the discussion that follows, no attempt is made to distinguish between water and food-borne diseases as this is not practicable in view of the common connection between the two routes of transmission. In any case, this would not be necessary in view of the nature of the project under consideration which is intended ultimately to reduce diseases transmitted by both water and food.

Moreover, because of deficient reporting of communicable diseases, resort to morbidity and mortality statistics in hospitals is a more reliable alternative. The available sources of information for 1977 are limited to 25 hospitals as is indicated in "Morbidity Statistics in Hospitals, 1977" published by the Department of Statistics. Accordingly, the data provided hereunder is based on this reference, unless otherwise stated. But it should be indicated at the outset that the recorded data do not correctly reflect disease prevalence among the general population primarily because only a fraction of the sick people are hospitalized, with the majority being cared for at home, or at health care centers. Nevertheless, the data could still serve as a useful indicator.

Attention is focused on children below 15 years of age as this constitutes the group most vulnerable to gastrointestinal diseases transmitted by both contaminated water and food. In fact, 23.7% of all the patients hospitalized in the 25 hospitals for any cause belong to this age group, which also comprises 40.9% of all hospitalized males, and 13.6% of all hospitalized females. The last two figures are believed to be accounted for, at least in part, by the preferential care given by parents to their male offspring.

PUBLIC HEALTH CONSIDERATIONS

Several important inferences can be derived by consideration of the data provided in Table 4-5 as is briefly indicated below:

(a) The age group most vulnerable to water and food-borne diseases consists of infants below the age of one year (1006 out of 5399 cases hospitalized, or 18.6%), followed by pre-school children 1-4 years of age (552 out of 7416 cases, or 7.4%).

There were a total of 2916 cases suffering from the six diseases listed out of 97,766 patients hospitalized for all illnesses, or 3.0%. Patients 15 or more years old (909 cases) form only 1.2% of the 74,601 hospitalized cases in the same age group. Evidently then, it is the infants and pre-school children that need the greatest attention with respect to public health and medical intervention.

(b) Gastroenteritis and other diarrheal diseases form the bulk of the diseases under consideration with a total of 2270 cases, followed by the salmonella group of infections with a total of 372 cases. The other four diseases appear to be of a lesser magnitude and importance. When age distribution is considered with respect to these two illnesses, it becomes clearly evident that children from 0 to 4 years are predominant. These facts are supported by the findings of Khoury et al (1977) during an investigation of an outbreak in 1976 in the town of Salt. Their data shows that the number of cases with gastroenteritis (4152 cases) exceeded those with typhoid (130 cases), or infectious hepatitis (21 cases). Accordingly, it can be inferred that of the six diseases considered, gastroenteritis is the most prevalent among the Jordanian population.

From the standpoint of occupation, patients with low income occupations were appreciably more than those of the medium and high income categories (Table 6). The difference probably stems from better living conditions, nutritional status, and personal hygiene. The category of unemployed involving children, students and housewives with a total of 2623 out of 2916 cases, or 90.0%, by far exceeds that of the employed cases. This is obviously on account of the inclusion of the large group of children below the age of 15 years.

Two important facts can be deduced from the data given in Table 4-7 which shows the distribution of patients by group of illness and governorate (place of residence):

(a) The overall morbidity rate for the six diseases is 137.1 per 100,000 population, with the highest figure (106.7 per 100,000) assigned to gastroenteritis and other diarrheal diseases.

Table 4-5. Patients Hospitalized by Major Group of Illness and Age During 1977 [a,b]

Age (yrs)	A	B	C	D	E	F	Total (A-F)	Patients hospitalized for all illnesses
<1	14	11	981	0	0	0	1006	5399
1-4	34	10	502	1	0	5	552	7416
5-9	47	3	156	3	1	6	216	5535
10-14	87	7	129	8	0	2	233	4815
15-49	179	63	363	38	24	48	715	60,652
50 +	9	35	133	2	1	6	186	13,082
Not stated	2	0	6	0	0	0	8	867
Total	372	129	2270	52	26	67	2916	97,766

a. Adapted from Department of Statistics. Morbidity Statistics in Hospitals, 1977. Amman, September 1978.

b. A- typhoid, paratyphoid fever and other salmonella infections; B- bacillary dysentery and amoebiasis; C- enteritis and other diarrhoeal diseases; D- infectious hepatitis; E- malaria; F- helminthiases

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Table 4-6. Patients Hospitalized by Major Group of Illness and Occupation During 1977 [a]

Illness[b]	High income occupations	Medium income occupations	Low income occupations	Unemployed (children, students, housewives)	Total
A	19	17	37	299	372
B	4	5	22	98	129
C	18	26	95	2131	2270
D	4	3	4	41	52
E	7	3	7	9	26
F	1	4	17	45	67
Total	53	58	182	2623	2916

a. Adapted from Department of Statistics. Morbidity Statistics in Hospitals, 1977. Amman, September 1978.

b. A- typhoid, paratyphoid & other salmonella infections; B- bacillary dysentery and amoebiasis; C- enteritis and other diarrhoeal diseases- D- infectious hepatitis- E- malaria; F- helminthiasis.

Table 4-7. Patients Hospitalized by Major Group of Illness and Place (Governorate) of Residence During 1977 [a,b]

Illness[c]	Amman	Balqa	Irbid	Karak	M'aan	Outside Jordan	Total
A	211 (17.3)	9 (6.5)	112 (18.7)	34 (29.9)	5 (9.0)	1	372 (17.5)
B	26 (2.1)	5 (3.6)	56 (9.3)	38 (33.4)	4 (7.2)	0	129 (6.1)
C	706 (57.9)	44 (31.9)	715 (119.2)	723 (635.6)	69 (124.3)	13	2270 (106.7)
D	40 (3.3)	0 (0)	10 (1.7)	1 (0.9)	1 (1.8)	0	52 (2.4)
E	15 (1.2)	0 (0)	5 (0.8)	3 (2.6)	3 (5.4)	0	26 (1.2)
F	45 (3.7)	0 (0)	12 (2.0)	8 (7.0)	0 (0)	2	67 (3.2)
Total (A-F)	1043 (85.6)	58 (42.0)	910 (152.0)	807 (709.4)	82 (147.7)	16	2916 (137.1)

a. Adapted from Department of Statistics. Morbidity Statistics in Hospitals, 1977. Amman, September 1978.

b. Figures within brackets represent morbidity rates /10^5 population.

c. A- typhoid, partyphoid & other salmonella infections; B- bacillary dysentery and amoebiasis; C- enteritis and other diarrhoeal diseases; D- infectious hepatitis; E- malaria; F- helminthiases.

(b) The more rural communities in Irbid, Karak and Ma'an show significantly higher morbidity rates than those for Amman and Balqa governorates. The overall values per 100,000 population are 233.8 for Irbid, Karak and Ma'an, and 81.1 for Amman and Balqa. This may be explained on the basis of difference in socio-economic levels, educational status, hygienic practices, relative safety of water and food, available sanitary facilities, and provision of primary health care services.

The data for deaths occurring in hospitals among patients suffering from water- and food-borne diseases (Table 4-8) indicate that gastroenteritis and other diarrheal diseases occupy the foremost position, with 85 deaths out of a total of 90 (or 94.4%). This suggests that this group of illness has a greater mortality rate compared to the remaining illness groups, and is therefore of greater importance from the standpoint of public health. That children of pre-school age (0-4 years) pay the highest toll is clearly illustrated by figures for the death rates per 1000 patients : 7.0 for infants below one year, and 2.7 for children 1-4 years of age. In contrast, the data in Table 4-9 suggest an inverse relationship between age and length of stay in hospitals only with regard to patients with gastroenteritis and other diarrheal diseases. There do not appear to be regular trends in the cases of the other groups of diseases.

Typhoid fever, probably mostly water-borne, is known to be endemic in Jordan as is the case in most of the developing countries. Sporadic outbreaks are not infrequent, but they usually go unnoticed. Barring the shortcomings of excessive under-reporting of this and other communicable disease, it is inferred from Table 4-10 that, during the period extending from 1971 to 1978, a peak in the number of cases occurred in 1974. There are no indications that the situation is improving significantly if the figures are assumed to be somewhat valid.

Nevertheless, an annual mean value of 235 reported cases of typhoid is certainly not a negligible issue, especially when the incidence of other diseases transported through water and food is considered.

Malaria, a water-related disease, shows a definite increase in trend from 1970 to 1978 (Table 4-11). Out of the 360 identified malaria cases in 1977 (Table 4-11) only 26 cases have been hospitalized (Table 5), thus suggesting that the vast majority of cases are ambulatory. What is of prime importance is the fact that, according to the Ministry of Health, all the positive cases were imported. This is substantiated by the tremendous increase in recent years in the number of expatriates from such countries as Egypt and Indonesia where the prevalence of malaria is quite notable. The influx of an expatriate working force tends to offset the efforts by the Ministry of Health and municipalities to contain, if not to irradicate, the disease. Besides, the continuing application of large quantities of insecticides to control adult mosquitoes and larvae constitutes a

Table 4-8. Hospital Deaths and Patients by Age and Cause of Death During 1977 [a,b]

Age (yrs)	A	B	C	D	E	F	Total (A-F)	Hospital patients	Deaths /100 patients
<1	1	0	69	0	0	0	70	1006	7.0
1-4	1	1	12	0	1	0	15	552	2.7
5-9	0	0	2	0	0	0	2	216	0.9
10-14	0	0	0	0	0	0	0	233	0
15-49	0	0	1	1	0	0	2	715	0.3
50 +	0	0	1	0	0	0	1	194	0.5
Not stated	0	0	0	0	0	0	0	8	0
Total	2	1	85	1	1	0	90	2924	3.1

a. Adapted from Department of Statistics. Morbidity Statistics in Hospitals, 1977. Amman, September 1978.

b. A- typhoid, paratyphoid & other salmonella infections; B- bacillary dysentery and amoebiasis; C- enteritis and other diarrhoeal diseases; D- infectious hepatitis; E- malaria; F- helminthiasis.

Table 4-9. Patients Hospitalized by Major Group of Illness and Length of Stay During 1977 [a,b]

Stay (days)	A	B	C	D	E	F	Total (A-F)
1-2	73	56	1302	9	8	13	1461
3-4	91	40	512	4	8	11	666
5-6	60	16	216	10	1	10	313
7-14	126	14	178	20	8	25	371
15 +	22	3	62	9	1	8	105
Total	372	129	2270	52	26	67	2916

a. Adapted from Department of Statistics. Morbidity Statistics in Hospitals, 1977. Amman September 1978.

b. A- tyhoid, paratyphoid and other salmonella infections; B- bacillary dysenteryand amoebiasis; C- enteritis and other diarrheal diseases; D- infectious hepatitis; E- malaria; F- helminthiasis.

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Table 4-10. Typhoid Cases Reported In Jordan by Year (1971-1978) [a]

Year	Cases reported
1971	100
1972	62
1973	258
1974	430
1975	230
1976	315
1977	188
1978	294
Mean	235

a. Source : Ministry of Health.
Annual Statistical Report for 1978.

Table 4-11: Blood Specimens Examined for Malaria in Jordan (1970 - 1978)[a]

Year	Specimens examined	Positive cases[b] No.	o/oo
1970	121406	86	0.71
1971	140937	80	0.57
1972	166620	196	1.18
1973	163342	240	1.47
1974	128647	218	1.69
1975	136545	261	1.91
1976	111971	255	2.28
1977	112809	360	3.19
1978	93082	400	4.30
Mean	130595	232.9	1.78

a. Source : Ministry of Health. Annual Statistical Report for 1978.

b. All of the positive cases were imported.

potential health hazard in that the insecticide residues may ultimately be transported by runoff water into the groundwater aquifers. Apart from the large quantities of agricultural pesticides applied annually, about 15 tons of 75% DDT have been used in 1978 according to the Ministry of Health (1978).

Schistosomiasis (Bilharzia), another water related disease, does not at present constitute a significant public health problem. But, the threat is beginning to emerge and is destined to continue to grow unless checked by appropriate preventive measures. E. Saliba of the University of Jordan (personal communication) has recently demonstrated through a preliminary investigation that the intermediary host (Bulinus snails) have been found in the Zarqa River and in the King Talal reservoir. As with malaria, expatriates from regions where schistosomiasis is endemic, would help to complete the development cycle of the parasite, and consequently the spread of the disease. One of the important side issues arising from such a situation is that the King Talal reservoir, a very attractive and scenic area, might have to be placed out of bounds for recreational usage and contact sports.

3. Refugee Camps: Public Health Aspects

Since some of the Palestine refugee camps in Jordan are located within the city limits, their public health impact on the neighboring non-refugee communities cannot be overlooked. For this reason, a brief account of the health and sanitary conditions is presented to help in appreciating the consequences of the close relationship between the two kinds of communities. The information is obtained from two UNRWA documents (1979 and 1980) and applies to the conditions prevailing in 1978 and 1980.

(a) There are a total of 10 refugee camps, 4 of which were established prior to 1956, and 6 established in 1968 to accommodate refugees from the West Bank and Gaza in consequence of the Arab-Israeli War. The total population of the camp residents is estimated at 170,847 in June 1978, and 227,000 in November 1979. These refugees are eligible for full UNRWA health services, for which the Agency has allocated about two million dollars in 1980 for the basic sanitation services. The number of professional and semi-professional personnel, including laborers, employed in the health services by UNRWA is 869 for 1978, and this includes 342 laborers in the sanitation service, 40 physicians, 32 traditional midwives, one sanitation officer, and others.

The basic sanitation services provided by the Agency in cooperation with the Government of Jordan comprise mainly the provision of potable water, latrine facilities, disposal of refuse and wastewater, stormwater drainage, and control of rodent and insect vectors of disease.

At present UNRWA provides the camps with chlorinated drinking water at a rate of 12 liters per capita, excluding that received directly from the municipal water supply by some refugees through indoor taps or water tankers at their own expense. So far, 6,458

private water connections to municipal water supply systems have been provided, mainly at Jabal el-Hussein, Amman New, Zarqa and Irbid Camps.

The camp population served in this manner is estimated at about 29%, while 71% of the inhabitants are served by public water points with about 5 taps per water point.

The original temporary latrines have gradually been substituted by more hygienic public toilets connected to septic tanks and percolation pits for the disposal of effluents. These toilets provide 5 seats per 100 refugees. This system, however, presented some difficulties with respect to the privacy-oriented social structure of the refugee communities and unsatisfactory maintenance. Consequently, a family latrine construction program was initiated in 1972, thus providing at present almost 97% of the camp population in Jordan with 22,099 private family latrines. Moreover, the Government has provided sewerage networks at Jabal el-Hussein and Amman New camps which are linked to the Amman sewerage system. Pending similar sewerage schemes, Zarqa and Irbid camps have been provided with surface drainage systems for the disposal of wastewater effluents and stormwater. These drainage systems are linked to the natural water courses, and are supposed to be used only for the disposal of wastewater of non-fecal origin, e.g., from taps, kitchen, and facilties for washing and bathing. The effluents from latrines, constituting less than 10% of the total wastewater produced, is supposed to be discharged into the percolation pits provided. This would require modification of the internal drainage systems at the household level to avoid overloading the percolation pits and consequent overflooding. However, experience has shown that these arrangements have not worked out to expectations because of non-compliance, negligence, or the desire to save the cost of emptying the percolation pits by commercial or municipal tankers. As a result, pollution of the soil within the camps and the natural water courses continues to pose a potential public health problem.

There is some cooperation between UNRWA and the municipalities concerned regarding insect and rodent control, and refuse collection and disposal.

To acquire an insight into the prevalence of water-borne diseases among the camp population reference is made to Table 4-12 which provides data for 1978 as reported in the UNRWA Annual Report of the Director of Health.

An outstanding observation relates to the extremely high incidence of diarrheal diseases entailing a total of 37,494 cases in 1978, with a case rate of 6,051 per 100,000 population. The case rate of 4,285 per 100,000 population for children below the age of 3 years signifies that this age group is the most vulnerable. Although the

Table 4-12. Reported Cases of Notifiable Water - Borne Diseases Among Palestine Refugees in Jordan (East Bank) and in all UNRWA Fields During 1978[a]

Diseases	East Bank No	East Bank Rate /10^5 Population	All UNRWA Fields No	All UNRWA Fields Rate /10^5 Population
Bilharziasis	0	0	1	0.1
Diarrheal diseases	0-3yr: 26549	4285	0-3yr: 76157	5015
	>3yr: 10945	1766	>3yr: 33780	2224
	total: 37494	6051	total:109937	7239
Dysentery (bac. & am.)	916	148	4796	316
Enteric fevers	0	0	71	4.7
Infectious hepatitis	144	23.2	790	52.0
Malaria	1	0.2	2	0.1
Poliomyelitis	19	3.1	34	2.2
Others[b]	12504	2018	57093	3760

a. Adapted from UNRWA Annual Report of the Director of Health, 1978. UNRWA, Vienna, June 1979.

b. Notifiable diseases not transmitted by water.

corresponding data for the general population in Jordan is not available for comparison; yet it would not be surprising to find the figures for the camp population to be appreciably higher. This is on account of the inferior sanitary practices and environmental conditions that prevail in the refugee camps.

The data given in Table 4-13 for the incidence rates for three important communicable diseases transmitted through water and food indicate that the trend has been more or less constant and is expected to continue to be so in the future unless drastic and effective measures are instituted. The impact of the adverse conditions on the health of the general public cannot be overlooked.

4. Water Quality and Health

Some aspects of water quality and pollution will be discussed in Chapters 5 and 7. In this section, however, it would be necessary to highlight the practices leading to the deterioration in the chemical and bacteriological quality of the drinking water supplies and the public implications. Accordingly, the following facts are presented as background information that would help to appreciate the subsequent discussion. For further details reference is made to the Malcolm Pirnie report (1980).

(a) The communities located within the Amman-Zarqa Basin obtain water supplies for domestic, industrial and agricultural usage from groundwater sources through private and public wells. A much smaller quantity of water used for irrigation purposes is derived from the natural water courses, primarily the Zarqa River.

(b) Excessive abstraction of the groundwater in recent years has led to an appreciable lowering in the water-table. This is an indication that natural recharge, especially during years of drought, is not commensurate with the high rate of abstraction. In fact, recharge with wastewater from domestic, industrial and agricultural sources has helped to supplement the deficiency in natural recharge.

(c) Both groundwaters and surface waters are continuously being polluted from various sources, especially with domestic wastewater. By virtue of the process of recycling of the wastewater, with only partial discharge into the King Talal reservoir through the Zarqa River, the accumulation of inorganic and organic contaminants in the groundwater has aroused great concern. The same applies to the waters of the King Talal reservoir. Because of the acute shortage of water, and the limited alternative supplies, the communities in the Greater Amman area will have to continue utilizing the polluted groundwater, and to risk the consequent effects on health.

(d) So far, emphasis has been almost solely placed on the microbiological pollutants and their health effects and on the need to disinfect all drinking water supplies by chlorination. Very little attention has been given to the potential health hazards due to the

Table 4-13. Incidence Rates Per 100,000 Population for Three Communicable Diseases in All UNRWA Refuge Camps (1968 - 1978)

Year	Diarrheal Diseases	Infectious Hepatitis	Enteric Fevers
1968	6460	64	18
1969	6144	53	14
1970	5493	79	9
1971	5340	74	10
1972	5537	71	11
1973	5476	51	10
1974	5713	61	10
1975	5592	42	5
1976	5436	76	4
1977	5585	42	9
1978	5015	52	5

Source : UNRWA. Annual Report of the Director of Health, 1978. UNRWA Headquarters, Vienna (June 1979).

presence of excessive amounts of chemical contaminants. In fact, the routine water examinations are almost limited to bacterial indices of pollution. Water examination for chemical constitutents, particularly trace elements, has not been practiced to an extent that would provide adequate data and information. In effect, there seems to be a lack of comprehensive studies on water quality, as well as epidemiological investigations, with the exception of a few sporadic attempts.

(f) The relationship between municipal water supplies and the yielded wastewater dictates consideration of the two entities in preparing a master plan for wastewater treatment and disposal, particularly where the wastewater is to be recycled as the case is bound to be in the Greater Amman Area.

In light of this information, an attempt is made to evaluate the conditions with respect to the quality of water and the potential risks to consumers.

There are a number of conclusions that can be derived from the data presented in Table 4-14 regarding the bacteriological quality of municipal water supplies. Firstly, the water supplies are bacteriologically unsatisfactory at all points from source to the consumer's premises. Secondly, the Amman water supply is relatively less polluted when compared to those provided to other communities. Thirdly, there is an increasing trend in the chances of pollution from Amman to townships to villages. This is verified and supported to a certain extent by the geographic distribution of hospitalized patients suffering from water - and food-borne diseases as shown in Table 4-7. Plausible explanations for this situation include inferior sanitary conditions and less importance attached to water supplies and waste disposal in rural and semi-rural areas as compared to the capital city. A similar trend is again illustrated by the data in Table 4-15 which covers the period extending from 1971 to 1978. The latter further suggests that the situation has not changed in the past decade. Table 4-16 supplements Table 4-15.

The data presented in Table 4-17 showing the percentage distribution by month of bacteriologically unacceptable water samples in 1978 would be useful to identify seasonal variations and trends, and to correlate the findings with peak occurrences of disease outbreaks. The percentage of unacceptable samples for townships shows peak values in November and December, with the lowest values in January and February. The data for villages, on the other hand, show a peak in January with a decreasing trend towards the end of the year. In any case, the peaks seem to occur during the rainy season, a situation that supports the belief that drinking water supplies (mainly from groundwater sources) are more subject to pollution from human and animal fecal sources during the rainy season when pollutants could be transported into ground - and surface waters by surface runoff. Allowing a few weeks for the

Table 4-14. Percentage Distribution of Bacteriologically Unsatisfactory Water Samples by Community and Sampling Location (1978)[a]

Communities	Water Sources	Storage Reservoirs Public	Storage Reservoirs Private	Distribution Systems	All Locations
Amman	4.3	--	14.3	4.2	5.6
Townships	27.6	21.6	31.1	19.9	21.8
Villages	43.5	57.1	63.2	38.3	43.6
Mean	30.1	25.4	33.1	20.4	23.4

a. Source: Ministry of Health. Annual Statistical Report for 1978.

Table 4-15. Water Samples Examined Bacteriologically by Town (1971 - 1978)[a]

Town	Water Samples Examined		
	No.	NA[b]	o/o
Amman	2924	254	8.7
Zarqa	2098	492	23.4
Irbid	912	180	19.7
Salt	989	185	18.7
Total	6923	1111	16.0

a. Adapted from Ministry of Health. Annual Statistical Report for 1978.

b. NA - not acceptable.

Table 4-16. Water Samples Examined Bacteriologically by Town and Year (1972 - 78)[a]

Year	1972		1973		1974		1975		1976		1977		1978	
Towns	No.[b]	NA[c] (%)	No.	NA (%)	No.	NA (%)	No.	NA (%)	No.	NA (%)	No.	NA (%)	No.	NA (%)
Amman	444	7.2	469	8.3	626	12.9	377	8.5	410	8.5	39	2.5	48	4.4
Zerqa	231	10	172	12.2	161	42.8	187	21.3	387	27.9	383	20.3	510	29
Rusaifa	--	--	--	--	--	--	139	28.8	168	19	135	31.1	105	23.8
Salt	86	22.1	74	31.1	128	36.7	102	40.2	282	5.6	129	6.9	122	18.8
Madaba	93	35.5	146	26.7	144	29.4	108	12.9	147	16.3	113	10.6	96	12.5
Others	281	42.7	403	42.9	332	22.0	271	17.3	756	15.7	747	15.4	935	16.6
Total	1135	20.0	1264	23.3	1391	22.4	1184	18.1	2150	15.5	1546	16.6	1816	20.1

a. Adapted from Ministry of Health. Annual Statistical Report for 1978.

b. No. - Number of samples examined.

c. NA - Not acceptable.

Table 4-17. Water Samples Collected from Sources, Reservoirs, and Distribution Network and Percentage of Bacteriologically Unacceptable Ones by Month (1978) [a]

Month	Townships		Villages		Total	
	Samples	% NA[b]	Samples	% NA[b]	Samples	% NA[b]
J	244	15.2	45	64.4	289	22.8
F	207	12.1	27	55.6	234	17.1
M	251	21.1	14	50.0	265	22.6
A	224	17.9	36	52.8	260	22.7
M	179	20.7	26	50.0	205	24.4
J	202	21.3	29	41.4	231	23.8
J	237	20.2	31	35.5	268	20.0
A	217	18.4	23	21.7	240	18.8
S	179	25.7	9	11.1	188	25.0
O	208	18.8	22	36.4	230	20.4
N	112	34.8	7	14.3	119	33.6
D	190	31.1	6	16.7	196	30.6
Total	2450	20.6	275	44.4	2725	23.0

a. Adapted from Ministry of Health. Annual Statistical Report for 1978.

b. % NA - Percentage of unacceptable samples.

incubation periods, then the appearance of water-borne diseases would tend to show peaks sometime during the dry season.

This is illustrated to a certain degree by the graphical data provided by the Ministry of Health for reported typhoid cases for 1976-78. The peaks occur as follows: February and September, 1976; July and September, 1977; and July and September, 1978. However, it should be remembered that there are other influencing factors that may modify the trends.

Consideration of the Zarqa River water quality from the standpoint of chemical pollution would enhance the understanding of one of the main routes of such pollutants from their original source to the groundwater aquifers, and to King Talal reservoir. This is on account of the fact that Zarqa River serves as the main medium of transport of wastewater of domestic and industrial origin as is described in Chapters 5 and 7. A certain amount of the pollutants it carries may reach the groundwater aquifers through seepage, while the remaining constituents would be translocated to the King Talal reservoir. The data presented in Table 4-18, recalculated from analytical results reported by Stanley Consultants, Inc. (1978), may serve the purpose of illustrating the contribution of Ain Ghazal Sewage Treatment Plant in terms of organic and inorganic contaminants. The values also project the effects of discharged wastes by such other riverine towns as Ruseifa and Zarqa, as well as the numerous small industries located along with the water course. Some of the important findings with respect to the pollutional contributions by waste discharges are recorded hereunder:

(a) There is an increase in the organic content of the river water as reflected by the appreciable increase in the value for COD from 104 to 601 mg/l.

(b) The salt content downstream from the point of discharge is also increased as indicated by the values for conductance and TDS. This is reflected by increases in the soluble salts of Ca, Mg, Na, K, SO_4, and NH_4.

(c) Both iron and manganese concentrations are much higher than the 'maximum permissible levels' stipulated in the WHO International Drinking Water Standards (1971), which are 1.0 mg/l for total iron as Fe, and 0.5 mg/l for manganese as Mn.

Copper also exceeds the 'highest desirable level' of 0.05 mg/l set by WHO but is less than the 1.5 mg/l 'maximum permissible level.' The nitrate concentration upstream is higher than that downstream, but in no case is it excessive.

(d) The concentration of each of the three potentially toxic trace metals (Cd, Cr^{+6}, and Pb) exceeds the corresponding maximum acceptable level as shown in Table 5, but the state of oxidation for

Table 4-18. Zarqa River water Quality with Reference to Amman Sewage Treatment Plant (January-February, 1977)[a]

Constituent[b]	Upstream (Abdoun)	Plant effluent	Downstream (Plant to New Jarash Bridge)	Mean (river water)
Conductance	390	1950	512	495
TDS	250	1219	526	487
Calcium (Ca)	37.6	67.4	57.3	54.5
Magnesium (Mg)	3.2	26.2	84.4	72.8
Sodium (Na)	27.6	190.0	86.0	77.7
Potassium (K)	8.8	47.0	17.4	16.2
Sulfate (SO_4)	21.2	74.9	42.1	39.1
Bicarbonate (HCO_3)	110.4	643.6	250.7	230.6
pH	7.55	7.58	7.50	7.51
Nitrate (NO_3)	20.2	26.6	10.3	11.7
Silica (SiO_3)	10.1	26.3	12.6	12.2
Ammonium (NH_4)	3.8	36.8	7.2	6.7
COD	104	652	601	530
Zinc (Zn)	0.4	0.66	0.82	0.76
Cadmium (Cd)	0.025	0.015	0.022	0.022
Iron (Fe)	0.010	0.005	4.373	3.750
Chromium (Cr)	0.125	0.060	0.068	0.076
Copper (Cu)	0.075	0.035	0.075	0.075
Manganese (Mn)	1.115	0.365	1.186	1.176
Aluminum (Al)	0.02	0.00	3.34	2.86
Fluoride (F)	0.005	0.005	2.181	1.870
Lead (Pb)	0.065	0.150	0.112	0.105

a. Adapted from Stanley Consultants, Inc. Environmental Assessment on Water and Sewerage Project. July 21,1978
b. Units in terms of mg/l, except for conductance (μmhos/cm) and pH.

Cr is not given in Table 4-18. Assuming that the analytical results are valid, then these contaminants would pose quite a serious health problem. It would be interesting to know their concentrations in groundwater. Fluoride, another potentially toxic element, is found in higher concentrations downstream where the level reached is 2.181 mg/l at the New Jarash bridge, and the mean river water value is 1.870 mg/l. The increase in level does not appear to be due to the Ain Ghazal Sewage Treatment Plant effluent. Nevertheless, this is another case which requires great caution as such concentrations in drinking water might lead to dental and skeletal fluorosis. One of the possible sources of fluoride could be the Ruseifa phosphate mines, for rock phosphate is known to be rich in fluoride. In this connection, it is suggested that a study be undertaken to determine the actual contribution of these mines in terms of fluoride and radioactive substances to the Zarqa River water, and consequently to the groundwater in the neighborhood. This is desirable in view of the fact that phosphate mines could also serve as a source of radioactive elements (see, for example, Shain et al - 1979).

5. Comments and Recommendations

The primary aim of the project is to plan for the provision of the communities within the Greater Amman area with facilities for the collection, treatment and proper disposal of wastewater in such a manner as to promote the health and well-being of the communities concerned, and to protect the environment from further deterioration. It is not expected to attain these goals except on a long term basis.

The plan must take into account the comments and suggestions given below which pertain to policies, decisions and actions needed to ultimately achieve the set goals, and also hint at the anticipated outcomes.

(a) The wastewater systems, when completed, are expected to yield beneficial returns in terms of the health and welfare of the communities served. That this is apt to be one of the achievements can be inferred from the numerous experiences in the developed regions of the world, as well as in some developing countries. But, the greatest benefit to be derived is that related to the control of water-borne diseases, and consequently the protection of children, particularly those of school age, from such disastrous and frequently fatal diseases as gastroenteritis. It should be pointed out, however, that the degree of progress in terms of public health and the human environment cannot be substantial and tangible when considered on a short term basis. Nor would it be reasonable to expect that the disposal of wastewater, if taken by itself, would ultimately lead to the eradication of diseases of fecal origin as there are a number of other factors involved in the spread of these communicable diseases. Not least in this respect are food and personal hygiene, prevalence of domestic insects and rodents, and the condition of refuse collection and disposal. Sanitation is obviously an essential counterpart for achieving a more complete success.

(b) Effective protection of water resources from inadvertent or improper disposal of domestic, industrial, or agricultural wastes would depend to a great extent on the method and degree of treatment of such wastes, as well as on the appropriateness of the final disposal, or reclamation, system adopted.

Extreme care should, therefore, be exercised in the selection of the most appropriate methodology for treatment, disposal and/or reuse of liquid wastes.

The constraints described earlier regarding the potential adverse consequences of treatment and disposal of wastewaters on human health and on the environment should be kept in focus at all times. Admittedly, the availability of adequate funds is one of the decisive factors in the process of planning, setting priorities, and selecting appropriate technologies. Nevertheless, promotion of public health and protection of the environment should be given precedence wherever possible, knowing that maintenance of the health of a community and its environment are costly, but very worthwhile, investments.

(c) On account of the well recognized fact that the Greater Amman area is already suffering from an acute shortage of water supplies for all usages, water conservation measures, as well as renovation and reuse of wastewaters, deserve special consideration in the planning stage. Water conservation measures, needed even if water is to be renovated and reused, should not be too difficult to implement right from the start with the aid of an intensive public education program through the local mass media. What requires a greater depth of thought and sound, scientifically-based judgment in the light of the present and predicted future conditions is the decision to reuse renovated wastewater, and identification of the purpose of usage. Reuse for drinking and other domestic purposes seems to be premature, and perhaps even undesirable at least at this stage. There are several reasons for this view, the foremost of which is the fact that the technology required for tertiary treatment to assure a high degree of purity is relatively costly and complex, and would entail a high standard of professional knowledge and experience not presently available in Jordan. Perhaps even of greater importance is the possibility of rejection by the public on religious and social grounds. In addition, the long term effects on health of drinking renovated wastewater are not yet fully understood. Therefore, more realistic and less costly alternative uses need to be considered.

(d) Other highly desirable measures that would supplement the project under consideration, and at the same time enhance its effectiveness, include: (i) expansion and strengthening of the existing primary health care program, particularly in the rural areas; (ii) placing emphasis on manpower development to cover the great shortage of

qualified personnel at all levels; and (iii) planningand implementing an effective health education program to assure the dissemination of essential public health information.

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CHAPTER 5

PRESENT AND FUTURE WASTE LOADS

This chapter discusses available data, summarizes projections made by various authorities for future conditions pertaining to waste loads, and develops the analyses and projections for same. Consideration is given both to volumetric quantities of wastewater and sludge and quality characteristics thereof. This is done within the context of publicly owned treatment works, including industrial wastes contributions and privately owned treatment works for separate treatment of industrial wastes, where applicable.

WASTEWATER QUANTITIES

Present and future wastewater quantities are important from the standpoint of water resources and facilities for wastewater conveyance, treatment and disposal. Wastewater quantities are directly related to water consumption by a community and by industries. For the former, it is customary to relate water consumption to population; for the latter, it is normal to consider processes individually and according to type of process and quantity of raw materials processed.

WATER AND WASTEWATER PER CAPITA VALUES

Table 5-1 summarizes certain water supply and wastewater per capita values that have been used by various authorities and/or considered in certain engineering projects. The tabulation is subdivided according to water consumption and wastewater production for the various major cities in the Kingdom. Distinction between water production and water deliveries is necessary because of the significant differences between these categories, largely attributable to pipe network leakage, reservoir overflows, metering inaccuracies, and illicit connections. On the other hand, in a water-short area such as Greater Amman, where there is relatively little urban area devoted to gardens and grassed areas requiring irrigation, differences between water consumption and wastewater production tend to be relatively minor. Such differences would be due to car washing and other uses of water "outside" the dwelling not resulting in flows to public sewers or to private cesspool systems.

Before considering the individual areas and their respective per capita values for water deliveries and wastewater production, some general explanation is required of local circumstances in the Greater Amman area currently experienced and/or foreseen for the future. Logically, data to support generalizations and conclusions concerning water supply and wastewater must necessarily come from those large agencies having the most experience in these matters, notably the Amman Water and Sewerage Authority (AWSA), and the Water Supply Corporation (WSC).

TABLE 5-1

SUMMARY OF WATER CONSUMPTION AND WASTEWATER PER CAPITA FLOWS (LITER/CAPITA.DAY)

	AMMAN			IRBID		ZARQA		RUSEIFA	SALT	JERASH	OTHER[b]
Reference[a]	1	2	3	3	4	3	5	5	6	7	8
Water Consumption											
1975	40	-	110	90	70	95	-	-	-	-	43
1980	50	-	-	-	75	-	-	-	-	-	45
1990	70	-	-	-	85	-	-	-	-	-	60
2000	94	-	150	125	95	130	110	114	-	-	80
Wastewater Production											
1975	74	-	-	-	-	-	-	-	60	-	-
1980	57	50	-	-	-	-	-	-	65	65	-
1985	-	-	-	-	64	-	66	56	-	-	-
1990	71	76	-	-	68	-	72	63	75	75	-
2000	-	104	-	-	76	-	80	71	85	85	-

[a] For references See General References for Chapter 5

[b] Target for Balqa-Amman region

PRESENT AND FUTURE WASTE LOADS

According to the WSC, a wholesale and retail supplier of water to municipalities and villages, it has been estimated that as high as 40 percent of the water delivered to some municipalities is subsequently lost by leakage.[9] Similarly, AWSA conducted a comprehensive study on unaccounted-for water during 1975-76 and determined that only 52 percent of the water produced was being registered through consumer's water meters.[9] AWSA did estimate that although only 52 percent of the water produced was being charged for, probably 76 percent of the water produced was actually being delivered, the 24 percentage points of difference being ascribed to inaccurate meter registration. It was noted that lack of trained and experienced mechanics for meter testing, repair, and installation is largely responsible for these meter inaccuracies.

The discontinuity of supply and nature of the water distribution systems are other factors to be taken into account when interpreting past and current water production/consumption and wastewater production experience and projecting future values for these. Water supply shortages for both AWSA and WSC have necessitated intermittent deliveries of water to various sections of Amman and to various municipalities or villages, respectively. For example, within Amman, various sections of the distribution system were receiving water only two days per week during 1980 under a system of rationing.[10] Such intermittent service tends to constrain consumption where building storage tanks have limited capacity. Thus, elimination of rationing would be expected to result in some increased deliveries (greater satisfaction of water demand then presently possible).

Roof tanks are almost universally used for storage of water on consumer premises. The tanks are filled by pressure from the street main and/or on-site pumping from low level tanks. Float valves are common for shut-off purposes. There are five pressure zones within the Municipality, corresponding to various elevation ranges. Within any pressure zone, the lower elevations are normally first to have their roof tanks replenished and the higher elevations the last. Float valves on roof tanks or ground storage tanks throttle the flow considerably during the final stages of valve closing, sometimes to rates below the ability of the service meter to detect. This is one source of meter inaccuracy.

When water shortages are sufficiently eliminated to preclude the necessity of rationing and intermittent service to various distribution zones, it is possible that some roof tanks may be capable of being bypassed, for the pressure from the distribution system mains may be sufficient at all times. In most cases, however, the roof tanks will continue in service, primarily as a pressure supplement during times of peak demand. Distribution system pipes are not sized for the high flow rates corresponding to fire demands in some countries. Virtually exclusive use of masonry and reinforced concrete building construction in lieu of wood construction greatly reduces fire hazard and permits such limited pipe network capability. Distribution system networks are generally sized for meeting moderate peak demands superimposed on moderate average demands. The AWSA network has been fortified and improved considerably so that multiple connections branching from a single water main tap are no longer a serious factor in constraining pressure and water consumption.

PRESENT AND FUTURE WASTE LOADS

In connection with satisfaction of water demand, AWSA water resources planning is currently based on the following developments.[10]

Timing	Source of Firm Supply	Supply Inventory* MCM	Status of Rationing**
Mid-1980	Various local wells	15	Service to various districts, 2 days/wk
Late 1980	Add Azraq Well Field	Up to 25	Most rationing eliminated
Late 1981	Add WSC Connection from Qastal Wells	35 - 34	No more rationing
1985-1990	Add Major JVA supply, probably Maqarin Dam	40 - 65	None

* Present wells have been able to supply anywhere in the range of 12-18 MCM during the past 4 years, but this includes the effects of groundwater basin mining. For 1985 condition, 40 MCM would represent lack of mining whereas 65 MCM would involve basin mining. MCM- Million Cubic Meters per year.

** There has been rationing for at least the past 10 years.

Water Demands

With the arrival of imported water to Amman, it is anticipated that the consuming public will expect improved water service and will tend to consume more water as building storage tanks are replenished more rapidly than previously and the need for obtaining supplemental water from tank trucks or other sources diminishes. This same trend is anticipated outside Amman, where the WSC's program for extension of supply from Qastal Well Field and Bani Hasan progresses.

On the other hand, the long-range outlook for per capita water demand growth appears moderate. Political uncertainties and/or high costs involved in some of the supplemental supply projects vis-a-vis growing populations and the needs of agriculture and industry, are thought to require a continued national policy emphasizing wise and frugal use of water.

Accordingly, for the purposes of this Master Plan for Wastewater Disposal the following per capita water demand figures for delivered water are assumed for normal urban uses, including domestic, municipal, commercial, and some industrial (but not major industrial) demands:

PRESENT AND FUTURE WASTE LOADS

Demand for Delivered Water for Planning Areas
Values are in Liters per Capita per day (lcd)

Year	Amman	Suburban Ring	Zarqa-Ruseifa*	New Cities**	Other
1980	85	95	67/80	75	50
1990	95	105	90/100	85	70
2000	110	115	110/114	95	80

* Includes industrial deliveries.

** The new planned cities of Abu Nusair, Sahab/Airport City and Jiza.

Wastewater Production within AWSA

Total wastewater production tributary to the AWSA sewer network is processed at the Ain Ghazal Treatment Plant (AGTP) where it flows through one of two proportional (Sutro) weirs located between the barminutors and preaeration tanks. For the purposes of this report, it is considered that the influent flow data developed from stage recording charts at the weirs is reasonably accurate, except for isolated wet weather episodes of plant by-passing.

Ain Ghazal Treatment Plant began operation in 1969, and the wastewater flows entering the plant grew steadily as more and more sanitary sewers were constructed within the embryo network and connections made thereto. This process is still continuing. New connections are constantly being added as new sewers become available for service. The tributary population is steadily rising as is the influent flow to AGTP together with its organic load. The two refugee camps within Amman have been included within the sanitary network. Residential areas of various population densities have been connected, and additional areas are in the process of being connected or are programmed for service within the next decade.

The dynamic nature of these proceedings makes it difficult to derive suitable per capita values for use in future wastewater projections, particularly in the light of incomplete data. Nevertheless, it is important that existing data be examined and the most made of them.

To assess the present average daily wastewater flows and the ratio of peak hourly to average daily flows, available flow charts of the AGTP were examined. Flow charts prior to 1977 were not available. The available charts were thought to be of limited reliability mostly due to the infrequency of calibrating the flow measurement equipment. Spot checks of the height of water level above the Sutro weir and the chart reading which reads the same, did not correspond. However, the average daily flows for 1978 and 1979 through Feburary 1980 were estimated to be around 14,000 m^3/day and 16,000 m^3/day, respectively. The

present flow is estimated at 21,000 m^3/day. The sudden rise in the flow could be attributed to activation of new connections to the AWSA network.

Figure 5-1 shows a typical diurnal flow variation of AGTP. The flow shows an instantaneous peak of 180 percent of the average daily flow and an extended peak of 140 percent of the average daily flow from 8 AM to 5PM. The extended peak showed some variation from day-to-day operation but otherwise was a typical occurrence. A discussion of the design flow peaking factors as related to population being served is included in Appendix I.

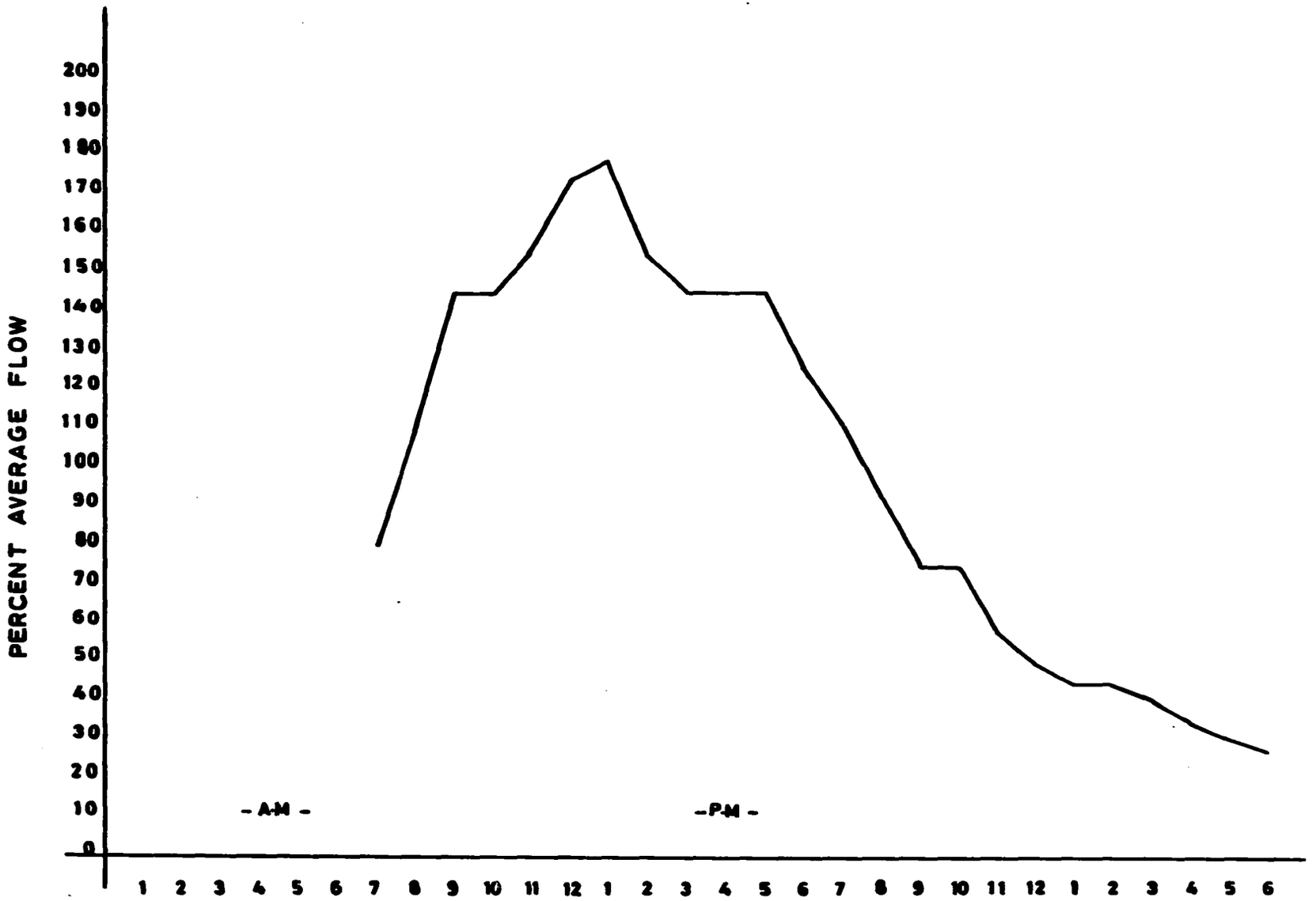
Data concerning the year to year growth in sewer connections have been furnished by AWSA and are included in Table 5-2. The values indicated for such connections reflect authorized connections. It is suspected that there may be as many as 1,000 illegal connections to the network, but these are not included in Table 5-2 as they do not influence the analysis.

Table 5-2 is intended to summarize the essential elements of information, within the constraints of data availability, used to consider per capital wastewater flow in the AWSA system based on organic loadings. As an approximation, it has been assumed that the persons connected to the system during any one year would be represented by the number of connections existing at the mid-point of that year, taken as an average straight line value. Flows are based upon a review of the influent weir recording charts. Overall organic loadings consider AGTP Analysis Journals data.

Because of the overriding influence of the wastewater discharges from the municipal slaughterhouse and the dumping of septage from Amman and surrounding areas, an attempt has been made to separate these effects from the overall organic burden entering the AGTP. This would then leave the "normal" contributions of municipal wastewater and other industrial wastes. Such an approach was deemed reasonable, particularly inasmuch as the municipal slaughterhouse discharges have been by far the most significant of all industrial discharges into the AWSA system, and those other industries which do discharge to the network are apparently not characterized by large volumes and/or strengths of wastewater.

One difficulty in deducting the slaughterhouse and septage impacts from the plant influent has been the fragmentary nature of the data. Another problem has been the somewhat variable levels of these operations from year to year (and even from day to day).

For example, as Amman has grown in recent years there has also been growth in population in neighboring areas. The traditional method of residential and other wastewater disposal has, until recently, been via subsurface sewage disposal system, primarily cesspools. The success of such disposal has been checked (see also Chapter 6), and there has apparently been a steadily growing operation of relieving active or incipient cesspool overflow conditions by removal of their contents by vacuum tank truck in many areas. The tank truck septage is removed from the premises and disposed of elsewhere. Despite the continuing extension of



AIN GHAZAL TREATMENT PLANT
TYPICAL DIURNAL FLOW VARIATION

FIGURE 5-1

TABLE 5-2

CONSIDERATION OF PER CAPITA WASTEWATER FLOW IN AWSA SYSTEM BASED ON ORGANIC LOADINGS

Item	1973	1974	1975	1976	1977	1978	1979	1980
House Connections[a]								
Added in year	1,108	1,144	2,368	1,495	2,154	2,652	2,250	1,460±
Cum., end of yr	2,478	3,622	5,990	7,485	9,639	12,291	14,541	16,000±
Cum., mid-yr	1,924	3,050	4,806	6,738	8,562	10,965	13,416	15,000
Round off	1,900	3,100	4,800	6,700	8,600	11,000	13,500	15,000
AGTP Typical Inf.[b]								
Flow $10^3 m^3$/da	—	—	—	11	11	14	16	21
BOD_5	910	800	1,010	1,110	1,170	1,280	1,160	910
1,000 Kg/da BOD_5	—	—	—	—	15.2	17.9	18.6	19.1
Slaughterhouse Operation[c]								
Typical Daily Kill								
Sheep	—	—	—	—	—	—	900	700
Cows	—	—	—	—	—	—	7	5
Chicken	—	—	—	—	—	—	12,000	15,000
Volume, m^3/da	—	—	115	115	—	400	—	—
BOD_5, mg/l	—	—	6,400	6,400	—	6,400	—	—
BOD_5, 1000 kg/da	—	—	0.7	0.7	0.9	0.7*	0.5*	0.6 (calc.)
Septage Loadings[d]								
Volume, m^3/da	—	—	—	—	400	900	—	610 (Plant Pers. Info)
BOD_5, mg/l	—	—	2,000	—	—	—	—	—
BOD_5, 1,000 kg/da	—	—	—	—	0.8	1.8	1.5*	1.2

TABLE 5-2 (Cont'd)

Item	1973	1974	1975	1976	1977	1978	1979	1980
Slaughterhouse + Septage								
1,000, BOD_5 kg/da	—	—	—	—	1.7	2.5	2.0	1.8
BOD_5, 1000 kg/da [e]								
Total Wastewater Load	—	—	—	—	15.2	17.9	18.6	19.1
Municipal & Other Ind'l	—	—	—	—	13.5	15.4	16.6	17.3
Theoretical population 1,000 @ 0.06 kg/c/da	—	—	—	—	225	257	277	288
Theoretical Conditions[f]								
Unit Wastewater flow, lcd	—	—	—	—	58	54	58	73
Persons/House connection	—	—	—	—	26	23	21	19
Assumed "Average" Conditions[g]								
Connected population, 1000	40	65	100	140	180	210	250	280
Persons/House Connection	21	21	21	21	21	19	19	19
Unit Wastewater, lcd	—	—	—	79	72	67	64	75
Normal BOD_5, 1,000 kg/da	2.4	3.9	6.0	8.4	10.8	12.6	15.0	16.8
Slaughterhouse/Septage BOD_5, 1000 kg/da	—	—	—	—	2±	2±	2±	2±

sewer service within Amman by AWSA, there appears to be a growing use of the septage dumping manhole on the outfall sewer immediately upstream of the AGTP headworks by as many as 80 different tankers. Some of this is attributable to growth within Amman itself, but a significant portion is doubtless due to contributions from neighboring areas where septage also is generated and where no reasonable disposal sites may exist.

The slaughterhouse operations appear to be growing, and it is understood that plans are being made for major expansions of the capacity for processing chickens, and possibly other animals. The analysis presented in Table 5-2 makes certain simplifying assumptions and approximations with respect to this source of wastewater. As in the case of the septage, the municipal slaughterhouse wastewater is relatively small in volume but high in strength. These contributions are made to a municipal wastewater that is already unusually strong, due to the relatively low quantities of wastewater bearing generally "standard" quantities of human organic wastes on a per capita basis.

The analysis presented in Table 5-2 must, of course, be considered as illustrative due to the nature of the data. The values presented under assumed "average conditions" appear to reconcile fairly well with values derived from other studies as well as being generally consistent among themselves. Therefore, the AWSA per capita wastewater flow for 1980 is taken to be 75 lcd.

Water and Wastewater Data for Salt

The Municipality of Salt has operated a wastewater treatment plant since April 1980, and the flow data derived from this operation have helped indicate the likely per capita contributions. Table 5-3 presents a consideration of current water and wastewater data for the Municipality of Salt. The data were incomplete and somewhat inconsistent. However, an attempt was made to obtain a reasonable reconciliation of those data available in order to appraise present conditions and allow for future conditions.

Water and Wastewater Data for Zarqa and Ruseifa

Sewerage facilities, among other utilities, were studied in detail in a recent study in early 1980.[5] Per capita water and wastewater data from their study have been previously included in the summary of Table 5-1. Inasmuch as there appears to be no reason to substitute other figures, their current and projected data are accepted for purpose of this Master Plan study. It may be noted that the combined domestic and commercial/industrial per capita wastewater flows are less than those being experienced by and projected for AWSA by a significant margin. This is attributed to the somewhat greater proportion of low-income persons residing in Zarqa-Ruseifa than in Amman and the much greater proportion of governmental facilities in the Capital City than in Zarqa-Ruseifa. The daily influx of workers in Amman from suburban areas is believed to be a significant factor in explaining the relatively high per capita figure in Amman. Also, Amman has proportionately more commerce than do the surrounding communities.

TABLE 5-3

CONSIDERATION OF CURRENT WATER/WASTEWATER DATA FOR SALT

Item	Description	Value
Water Production[a]		3,632 m^3/day
Water Deliveries[b]		1,500 m^3/day
Wastewater Flow[c]	Weekday 26 m^3/hr	620 m^3/day
	Weekend 18 m^3/hr	430 m^3/day
Per Capita Values		
Water Production[a]	3,632 m^3/day/133,000 pop'n	110 lcd
Water Deliveries[b]	1,500 m^3/day/33,000 pop'n	45 lcd
Wastewater Flow[c]		
Weekday	620 m^3/day/14,000 pop'n	44 lcd
Weekend	430 m^3/day/14,000 pop'n	31 lcd
Design by SCAN PLAN	BOD_5 @	0.06 kg/c/day
1975	9500 persons, 570 m^3/d-1000 mg/L	60 lcd
1980	11070 persons, 720 m^3/d-923 mg/L	65 lcd
1990	15400 persons, 1155 m^3/d-800 mg/L	75 lcd
2000	20500 persons, 1740 m^3/d-706 mg/L	85 lcd

[a]Water production information for Mr. Abu Anzeh, (Salt Municipality Engineer).

[b]According to Mr. Abu Anzeh only about 40 percent of the Water production is accounted for, this via metered connections. The unaccounted for 60 percent includes unmetered deliveries to Civil Defence, Fire Department, public lavatories, public gardens and public parks.. It is assumed herein that this might amount to roughly 10 to 20 percent of the production and that the remaining 50 to 40 percent of unaccounted for water is due to pipeline leakage, illicit unmetered connections, and meter underregistration.

[c]The Municipality Engineer estimates that no more than about 43 percent of the residents are connected to the sewer system, say 14,000 persons maximum. The connected population might even be substantially less. The remainder are either connected to an ancient Roman or Turkish sewer (discharge location not identified) or else discharge to cesspools. The average plant influent BOD_5 concentration is not yet well established because only recently has flow-proportional sampling been undertaken. Thus, the grab sample analyses made to date may not be representative. However, assuming 1,000 BOD_5 mg/l is typical the per capita BOD_5 contribution would be indicated as about $620 \times 10^6 / 14 \times 10^3 = 0.044$ kg/c/day, probably 75 percent of the expected. The data are too indefinite to warrant drawing conclusions for the present.

PRESENT AND FUTURE WASTE LOADS

SEASONAL EFFECTS

Seasonal effects in wastewater flow are experienced and involved in the following factors:

- Seasonal variations in population tributary to wastewater systems.
- Seasonal variations in the production of wastewater.
- Wet weather infiltration/inflow effects.

These have been considered in this Master Plan study, but it has been difficult to quantify the effects, as explained below.

Seasonal Population Variations

Chapter 3 addressed seasonal population variations. It concluded that there was a significant influx of workers from Saudi Arabia and other Gulf States during the hot, summer months, these workers being then on home leave. A range of 50,000 to 70,000 such workers during July and August was assumed. On the other hand arrivals and departures of Jordanians on short trips (vacations or business) were though to cancel each other. The cited range of workers was for all of Jordan, but it may be presumed that the majority, perhaps 70 to 80 percent affected the Greater Amman Area. (The data did not specify localities).

In addition to expatriate workers returning home, there appears to be a seasonal influx of tourists from other Middle East areas. It was assumed that most of the visitors would stay in the Greater Amman Area during the one or two months of a typical visit. The accumulation of (Arab) visitors reaches a peak in August with 74,000 currently. The communities of Suweileh, Jubeiha, Fuheis, and Safut were noted as being recipients of much of the influx.

University of Jordan students did not contribute significantly to seasonal variations, and there was some canceling effect of students leaving the area on summer vacation at the same time that expatriate workers were returning to Amman and vicinity along with foreign tourists.

It was concluded in Chapter 3 that the Amman area was particularly affected by seasonal population variations. The data do not warrant precise evaluation of these effects. However, an indication of possible impact may be obtained by simple parametric analysis,[12] viz:

- For the area tributary to AGTP, the 1980 average population has been about 650,000 persons, of which about 280,000 persons (43 percent) are believed to have been connected with the AWSA sanitary network. Thus, if the seasonal influx of returning workers located within the Greater Amman Area were 75 percent of the total for Jordan, and if the proportion of that number (say 45,000) tributary to AGTP were 40 percent, the seasonal influx from this source would be 18,000/280,000 equals about 6 percent increase

over base.

- If the seasonal influx of tourists from Arab countries involves 74,000 persons and of this total, half were in the AWSA area and 40 percent of the half were tributary to the AGTP as transients, the increase over the base would be 15,000/280,000 equals about 5 percent. Other assumptions would yield other percentages.

- If the combined influx of expatriate workers and tourists amounted to somewhere in the range of 5 to 15 percent over base for the AGTP (say 8 percent) this should have been reflected in the loadings experienced at the AGTP. Unfortunately, the changing status of sewer connections being added to the network makes it difficult to discern such effects. Even so, there is no reason to suppose that seasonal effects of some measure were not experienced.

- The percentages of seasonal increase over base load at AGTP should diminish somewhat as sewer connections are extended, for the influx of seasonal visitors is not a function of the sewered population but rather of the total population of Amman in all likelihood.

- Where local concentrations of seasonal population are experienced, such as in Suweileh, Jubeiha, etc., the effects would be more pronounced than in the case of a larger system such as AWSA's. This could be of particular concern in the case of local treatment facilities. Local sewer capabilities would not be affected significantly, as the sewers are normally sized for peak conditions based on saturation for lateral sewers and on growth several years into the future for trunk sewers, the peaking factors being quite conservative.

- As Amman Municipality continues to grow, there appears to be no reason to anticipate that the proportion of seasonal visitors to that community, such as it may actually be, should increase. Thus, the effects upon wastewater flow being generated within Amman itself should probably remain at a relatively low level (suggested above as possibly in the range of 5 to 15 percent of base) in which case there would be no significant effect upon either network design or treatment plant design for the purposes of this Master Plan.

- For outlying areas, it may be more important to make certain specific allowances for such variations, but the available data do not justify estimates of effects to be anticipated.

Seasonal Variations in Production of Wastewater

Some industrial operations involve seasonal activities. Canning, for example may entail seasonal activity. This could be a factor to be considered in agricultural produce areas such as Baqa'a Valley, where there is agricultural food processing activity. In most areas, however, it is not believed significant.

Among some population groups there may tend to be a mild seasonal variation in the production of wastewater related to personal bathing and laundering of clothes. During hot weather, some persons bathe more frequently that during cold weather. Also, there may be more soiling of clothing during summer than winter. However, it is not believed that these are very significant factors that require special provision in Master Plan arrangements. It is expected that there may be some exfiltration of wastewater from the AWSA sanitary sewer network, particularly during dry months of the year when the effects of the rainy season have subsided. This cannot be quantified at present. It could tend to cancel the increased wastewater flow during the summer.

Wet Weather Infiltration/Inflow

Groundwater infiltration in some measure is experienced in most sanitary sewer systems, particularly those having sewer joints that are not tight and where the subsoil becomes saturated. In the case of the AWSA network, rubber gasket joints in reinforced concrete pipe sewers are standard construction. The design does not include grooved spigots or bells to accomodate the gaskets, and some leakage may be expected. The soils occasionally may become saturated from water pipeline leakage, wet weather infiltration of rainfall/runoff, and (in isolated reaches) underground movement of cesspool septage.

AWSA construction personnel engaged in the construction of new sanitary sewer lines have routinely been involved in dry trench construction. Although most construction is during the dry weather, this would be indicative of a rather limited infiltration tendency for the sanitary sewers. Probably, the frequency and duration of infiltration are related primarily to periods of wet weather. For this purpose, a rate of infiltration of 10 cubic meters per day per kilometer of 200 mm diameter sewer pipe is assumed in the sizing of the collection system.

The inflow may be via building roof drains, yard drains, and other supposedly illegal connections. It is also understood that manhole covers are sometimes removed during times of street flooding in certain downtown areas as a means of aiding surface drainage. Within the AWSA system, the flows within the major trunk sewers (primary network) grow very large during heavy rainstorms and require that the AGTP by by-passed in order to avoid a hydraulic overload. Such conditions are almost characteristic of so-called "combined" systems, those which deliberately convey both sanitary sewage and storm runoff. In the case of AWSA's network, this is basically a condition of illegal use of the system for storm drainage. However, this problem is expected to be diminished with implementation of the new stormwater drainage project being undertaken by AWSA.

Inflow conditions within the outlying reaches of AWSA's network are not though to present serious problems. The conservative nature of the design peaking factors to be employed in sewer sizing makes it unnecessary to consider inflow matters for outlying parts of the network. In the downstream parts of the network, conditions from transitory inflow are more serious. In effect, a wet-weather peak flow is much higher than a dry weather peak flow. Even so, this is basically a

matter of public policy regarding the use (or misuse) of the sanitary sewer network, and it should be considered in this context. In any event, the frequency and duration of inflow are not sufficient to affect the overall planning for wastewater quantities to be handled at treatment plants as wastes loads.

INDUSTRIAL WASTEWATER QUANTITIES

It was possible to obtain only limited data on existing and projected wastewater quantities within the Study Area. This limitation is not considered critical, for reasons discussed below.

Sources of Data

The sources of data on industrial activities, particularly those data of relevance to this Wastewater Disposal Master Plan Report, included the following:

Areas Considered	Nature of Information
Zarqa and Ruseifa	Present and future water use and wastewater production in several significant industries. Also present and future waste loads, employment, and industrial wastes management alternatives [5]
Jordan and certain locations within	Production of major industries and progress in expansion of selected industries[13,14]
Amman Industrial Estate and Free Trade Zone (at Sahab); also discussions of Free Trade Zones of Irbid-Ramtha and Aqaba	Types of industries to be developed, projections of industrial estate water demand, likelihood of many industries in and around Amman relocating to the Sahab Estate, probably pre-treatment requirements[15]
Amman Vicinity	Names and nature of industries, together with product value estimates[16]
Hashemite Kingdom of Jordan	1979 Industrial Survey (jointly with Department of Statistics) primarily for economic study purposes. Some water use information included in the data (results not yet processed)[17]

PRESENT AND FUTURE WASTE LOADS

Zarqa - Ruseifa

The most comprehensive evalution of industrial water use and wastewater flow has been undertaken in a recent study titled "Industrial Effluents Treatment Report for Zarqa-Ruseifa."[5] In this document, data was presented for 14 industries in Ruseifa, 3 in Awjan al Janubi, 14 in Awjan esh Sharqi, and 8 in Awjan al Gharbi.

The industries ranged from very low water-using activities such as Transjordan Mineral Research Co., and Jordan Fiberglass Co., (producing 0.2 and 0.3 m^3/da wastewater, respectively) to fairly high water use such as Phosphate Mill, Jordan Paper & Cardboard, and Jordan Iron & Steel Co., (producing 1,696.0, 1,937.0, and 1,275.0 m^3/da wastewater, respectively). The major water users/wastewater dischargers included, in addition to the above mentioned, a soap factory, a soft drink bottling plant, a dairy, a worsted mill, a blanket factory, a tile company, two breweries, and a distillery. Of the total of 39 industries considered, the average water use was 211.1 m^3/da and the average wastewater production was 193.8 m^3/da or 91.7 percent of the water use.

In the Zarqa-Ruseifa area, the average water consumption was 5.42 m^3/day per industry, and the corresponding wastewater production averaged 4.97 m^3/day. These are relatively small values and indicate that from the standpoint of volumes of wastewater, the types of industries currently operating in the Study Area are only of nominal significance except where they may discharge to relatively small municipal wastewater systems. In the latter instance, particular attention should be paid to the industrial wastewater quantity.

Industrial Development Bank

The nature of major industries in Jordan is indicated in Table 5-4 taken from a recent Industrial Development Bank Report.[14] The majority of these industries are located within the Greater Amman Area. The Industrial Development Bank's Annual Reports for 1977 and 1978[14] note certain activities of interest such as Ministry of Trade and Industry licenses issued, viz:

Item	1976	1977	1978
Number of licenses issued for industrial projects	203	129	110
Total investment in new industries licensed, JD million	16	23	35
Total investment per license, JD million	0.079	0.178	0.318

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TABLE 5-4

PRODUCTION OF MAJOR INDUSTRIES IN JORDAN[a]

PRODUCTS	UNIT	1976	1977	1978	% of CHANGE 77-78[d]
Phosphate	000's tons	1781	1769.3	2328.7	31.6
Cement	000's tons	586.4	537.6	552.9	2.8
Petroleum Products[b]	000's tons	1145.5	1145.3	1396.6	21.9
Sole Leather, Wool & Hair	tons	162.3	345.5	197.8	(42.7)
Upper Leather	000's ft.	2910.1	2873.9	2826	(1.7)
Powder Soap and Detergent	tons	5027	6026.7	7090.9	17.6
Liquid Batteries	000's Unit	47	51.3	44.4	(13.5)
Cigarettes	tons	2407	2700	2851.6	5.6
Paper	tons	5360	5228	4621.1	(11.6)
Iron	tons	42449	77605	65290	(15.9)
Electricity[c]	Mill-KWH	323.7	401.3	489.7	22
Textile	000's yards	915.8	869.8	1140.8	31.1
Fodder	tons	50933	63182	51841	(18)
Pharmaceutical Products					
Liquid Products	000's lt.	440.1	485.2	496.7	2.3
Ointments, Tablets & Others	tons	99.6	137.3	142.8	4
Industrial Production index	1966-100	219.3	242.9	266.7	9.8

[a]Data from Monthly Statistical Bulletin, Central Bank of Jordan, as published in Industrial Development Bank's Fourteenth Annaul Report & Balance Sheet, 1978.[17]

[b]This figure includes The Arab Chemical Detergents Industries Co., Ltd., production.

[c]Figures represent the amount of electricity generated in Amman area only.

[d]There was a slight increase in the overall index for industrial production from 1977 to 1978, despite some products categories showing declines.

Clearly, the Government policy of encouraging and planning for healthy industrial growth is reflected in the above data. The total investment per license has increased dramatically in the three-year period. Some of this is due to inflation, presumably, but the major factor is probably the increasing size and complexity of the average industry being licensed. It was noted in the 1977 report[13] that brisk activity in the industrial sector was favorably affected by the virtual stoppage of land speculation and decrease in real estate investment.

The data in Table 5-4 represent the entire country, but essentially all of the types of industries shown lie within the Greater Amman Area. Table 5-5 is a summary of the typical industries and present and future industrial development by location in the Study Area. It is evident that the main industrial activities within the Municipality of Amman is located in Marqa, while the future development is planned for the new industrial cities. As will be discussed subsequently, a number of the existing industries in Amman and vicinity are relocating their operations to these planned industrial cities.

The foregoing information is somewhat general but assists in indicating the nature of the continuing industrial development. It is noted that only a few of the industries cited are so-called "wet-industries" (those that consume relatively large amounts of water and, correspondingly, produce large volumes of industrial wastewater).

Industrial Estates and Free Trade Zones

The Master Plan and Preliminary Engineering Report, prepared for NPC and the Industrial Development Bank, contained certain planning information on the Sahab Industrial Estate and the Free Trade Zones at Sahab, Aqaba, and Irbid-Ramtha.[15] The study reported that of 129 licensees (medium-sized industries) by the Ministry of Industry and Trade in 1977, by June, 1978, nearly 45 percent were still looking for factory sites and accommodations for their planned projects. At the same time, nearly 30 percent of the 340 small enterprise license holders were prepared to move into an industrial estate. It was speculated that if this same rate of site-looking development were to continue for two more years, Sahab Industrial Estate would soon have a large waiting list of some 240 factories desiring to locate there.

As regards the Sahab Free Trade Zone, it was indicated that there would be some 240 factories coming into operation during Phase I of the Development of the Amman Industrial Estate (at Sahab). Ultimately, over 700 factories would be located there. The planning includes segregation of food and pharmaceutical industries, electronic and electrical industries, and printing industries from the so-called "noxious industries," woodworking industries, and metal industries. "Noxious industries" were considered to be those that would give rise to air, water, and noise pollution, and solid waste problems, and extensive control measures were recommended for these industries. The areas allocated to various industry types were as follows:

TABLE 5-5

SUMMARY OF INDUSTRIAL DEVELOPMENT
IN THE STUDY AREA

Area	Type of Industry and Present Developments (dunums)	1980 - 2000 Additional Potential Development (dunums)
Municipality of Amman		
Marqa, Queismeh-Wahdat	Light industries, workshops, biscuits, sesame, trico, paints, detergents, painting, shoes, plastic, gases (1850) Mostly in Marqa	2200
Outside Amman		
Marj el Hamam and Na'ur Road	Plastic, pharmaceutical, juice, biscuits, metal, goodunums. (600)	900
Na'ur	Pharmaceutical (84)	
Ain el Basha, and Baqa'a area	Plastic, juice, detergents, building materials (50)	440
Salt	Pharmaceutical (84)	336
Abu Alanda and Rajib	Paint, pipes, juice, textile (600)	2400
Sahab	Industrial City (0)	2000
Jiza	Industrial City (0)	1000
Hashimiya	Industrial City (0)	1000
Wadi es Sir	Drugs, potato chips, ice cream (44)	356
Suweileh	Furniture, workshops (30)	70

PRESENT AND FUTURE WASTE LOADS

Industry Type	Area, hectares	Remarks
"Noxious and Pollution"	15.09	20-25 special industries
Medium	26.14	About 30 factories
Light:		
Electronic & Electrical	11.32	About 12 factories
Food & Pharmaceutical	9.75	About 17 installations
Printing	7.29	
Woodworking	0.11	Very small factories
	9.38	Larger woodworking, including electric sub-station area about 15-20 factories
Metal Fabrication	19.70	
Small Industries (Sub-Zone)		Many small, low-capital industries from Amman, Zarqa, Na'ur, Suweileh, and Abu Alanda (engaged in furniture making and repairs, motor workshops, vehicle painting, light metal fabrication, garment making etc.) would be relocated here.

Within the above-listed industries, the study listed several candidate industries. Some potential water-using, wastewater-producing industries appeared to include:

- Irrigation system and equipment (small pumps, sprinklers, and control mechanisms). However, if this were merely a systems assembly plant there would probably not be much water use.
- Electroforming and plating
- High quality locks.
- Metal fabrication for equipment for refinery, chemical plants and mining industry (particularly if pickling, plating, and other finishing processes were included).
- Washing machines (unless these were merely assembly plants).
- Plastics industries (but limited amounts if, as suggested, the industries were of the secondary type)

- Glucose manufacturing
- Poultry processing and freezing
- Animal feed
- Aircraft service
- Polyvinyl chloride manufacture
- Army rations, including canned food

The study states that Phase I development would accommodate a working population of 7,000 to 10,000, that the wastewater flow was assumed to average 545 lcd, this being approximately equal to the water consumption. Thus, those "wet" industries that are present are anticipated to have considerable impact on the wastewater volumes. The study notes that a wastewater treatment plant would be provided to treat the wastewater generated.

Supplemental information from the Trade Zone Corporation indicated that this governmental agency operates for the development of tax-exempt areas for commercial and industrial projects and has two current projects within the Greater Amman Area.[20] These are located in the Zarqa-Hashimiya area and Queen Alia Airport Complex, respectively.

The Zarqa-Hashimiya's industrial sector will comprise 640 dunums of industrial space and some 104 factories, the nature of which has only been suggested but not finalized. Priority industries being considered are slaughterhouse, meatpacking, freezing, printing, publishing, educational equipment, metal and metal transforming, electrical, electronics, plastics, food and pharmaceutical, non-metallic minerals, woodworking, toys, textiles, garments, travel goods, ship and aircraft service, chemicals, and "defense." The timing of this development is indicated to be about 1989 for completion. A local sewer system and wastewater treatment plant are planned for this development. The commercial sector of this Free Trade Zone will involve warehouses, automobile showrooms, commercial outlets, and administrative center.

It is planned that the priority industries within the Queen Alia Airport Complex will be generally similar to those in the Zarqa-Hashimiya Free Trade Zone's industrial sector, although the former's extent will be only about 83 percent of the latter in terms of space. Much of the Queen Alia site will be devoted to warehousing, transportation and assembly, packaging of consumer goods, electronics, and air shipment of related items. There has been some consideration given to aircraft industry support and maintenance, also.

Amman Chamber of Industry

The Amman Chamber of Industry has compiled general information on hundreds of industries of various sizes in Amman and vicinity. Information includes name,

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capital, production, site, address, "machineries," and official representative. No physical data were included. Major categories (mostly manufacturing) of industries include pharmaceutical, veterinary, medical (laboratories), dairy products, fodder, preserved food, confectionaries, wheat flour (mills), soft drinks, ice cream, fertilizer, tanneries, poultry farms, batteries, paint, soap, pesticides.

A listing of some typical industries in the Greater Amman Area is included in Appendix D. The listing affirms the variety, locations and the small size of these industries. The major industries in the Municipality of Amman are located in Marqa. Small workshops and other small factories can be found throughout the Municipality and especially in Wahdat, Queismeh area. Outside the Municipality of Amman, industries can be found in Marj el Hamam, Ain el Basha and Abu Alanda-Ragib area.

In view of the limitations on available data concerning existing industries within the Greater Amman area, a limited reconnaissance was conducted of some selected industries. The objective was to gather information concerning activities, water usage, wastewater production and other relevant information of interest to the Master Plan. It was concluded that only some of the small industries in the Marqa area are served by AWSA while the majority of industries use sub-surface disposal systems. Except for a few large water consuming industries identified in Appendix D, the water consumption rates reported were in the range of 3 to 5 m^3/day while the wastewater generation, mainly domestic, were between 1 to 2 m^3/day.

Dar Al-Handasa/NPC Industrial Programming Study

Dar Al-Handasa, under NPC contract and with NPC and Department of Statistics collaboration, conducted an industrial survey covering the entire Hashemite Kingdom of Jordan. The objective of this survey and the related industrial programming study was to develop an industrial program for incorporation in the 1980-85 Five-Year Plan. The entire project is scheduled for completion by mid-1981. Heavy emphasis was placed upon economics and only minor emphasis on physical factors bearing upon wastewater production.[18]

For example, the questionnaire that was circulated did include a subsector element pertaining to utilities and infrastructure, and its also included questions about the water supply. The questions were primarily related to the adequacy and cost of the supply such as might influence the economics of the plant's operation and possible interests in relocation. The questionnaire solicited information as to water rates, shortages, water price, discounts, total portion of utilities bill represented by water, prospects for increases in consumption, extent to which water supply might be a constraint on expansion, and percentage of total production costs represented by water supply. Such information might, of course, be of some interest to the Master Plan for Wastewater Disposal, provided it were in the proper form. Unfortunately, the data was not scheduled to be compiled until the end of 1980 and then only according to industrial sector and, possibly, region.

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PRESENT AND FUTURE WASTE LOADS

SUMMARY OF INDUSTRIAL ACTIVITY AND WASTEWATER DISCHARGES

With the exception of the Zarqa-Ruseifa study work,[7] so-called "wet industries" are not a major factor in the Study Area at present, nor will they apparently be so in the future. The only existing sewer system involved with industrial wastes appears to be the AWSA system, but the industrial wastewater contributions are apparently nominal. The organic waste load contributions of the municipal slaughterhouse are major, as indicated earlier, but the volumetric contributions (in relation to the total flow) are minor.

Many of the industries within the Study Area are contemplating a shift to the Amman Industrial Estate at Sahab. Industries are to be attracted to this and other Industrial Estates and Free Trade Zones. Inasmuch as these areas are new, controls will be exerted over industrial waste discharges. Also the Government will encourage that industrial water supply be used judiciously and wastage avoided because of general water shortages. Steps are already being taken by the consultants involved to account for the industrial wastewater flow in centralized collection and treatment facilities.

Many water-using industries are located apart from municipal and sewerage water systems and currently have private supply sources as well as local disposal facilities. The petroleum refinery and cement plant are examples of this. They can be dealt with as point source discharge users in later considerations.

This matter of industrial wastewater quantities should be reexamined in future years as the Industrial Estates and Free Trade Zones become better established. A general discussion on industrial wastewater composition and loadings is included in Appendix D.

Summary of Per Capita Wastewater Flows

In consideration of the foregoing, the following per capita wastewater flows are adopted in this Master Plan report for the areas designated, such values including all residential, municipal (governmental), commercial, and industrial contributions except as otherwise noted:

	Per Capita Wastewater, liters/capita/day		
Area	1980	1990	2000
Amman (AWSA)	75	85	95
Suburban Ring	85	95	105
Zarqa	63	72	80
Ruseifa	50	63	71
New Cities	65	75	85
Other	50	60	70

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PRESENT AND FUTURE WASTE LOADS

For the purpose of this Master Plan report, it was felt reasonable to allow for a modest annual increase in future per capita wastewater flows from residents, businesses, and moderate industries within the AWSA sanitary network. As previously mentioned, it is anticipated that some relief of water shortages will occur imminently, and while there will still be a need for the public to use water wisely and avoid wastes, there is reason to expect some increases in water consumption and wastewater production.

DISAGGREGATION OF WATER AND WASTEWATER QUANTITIES

The foregoing per capita values for various population areas are combined with the population projections for 1990 and 2000 presented previously in Chapter 3 to provide a general disaggregation of wastewater quantities according to network drainage areas as presented subsequently in Chapter 8. Table 5-6 presents the basic disaggregation of water and wastewater quantities.

NON-INDUSTRIAL WASTEWATER COMPOSITION AND LOADINGS

In the United States, typical unit loadings where food waste is not ground up and added to the sewer are 80 g/c/d of BOD_5 and 90 g/c/d of suspended solids. This occurs with average wastewater contribution in the range of 380 l/c/d. By comparison the 60 g/c/d numbers developed for the AWSA system seem reasonable as they represent a water consumption less than one-quarter of that in the United States and a lower average standard of living.

NON-INDUSTRIAL WASTEWATER COMPOSITION

As presented in Table 5-2, it appears that unit waste loadings of 60 g/c/d BOD_5 are appropriate for the Ain Ghazal Treatment Plant and the AWSA system. This value gives results that agree with the number of house connections and estimated wastewater production per capita. The most recent evaluation of suspended solids concentrations and loadings at the plant indicates that a loading of 60 g/c/d also is appropriate.

The plant records of lab tests performed were reviewed for the period December 1978 to July 1980. The tests most relevant to this study were the suspended solids of BOD_5 of the raw sewage, primary effluent, and final effluent. These tests are performed on a bi-weekly basis.

Samples are manually collected at two hour intervals and proportioned to the flow by the laboratory technician to get a twenty-four hour composite sample. These samples are analyzed in the Ain Ghazal Treatment Plant laboratory. The results of these tests are presented in Figures 5-2 and 5-3. There are large variations in the concentration of both suspended solids and BOD_5. No trends are apparent. The means and standard deviations of these parameters are presented below:

TABLE 5-6

DISAGGREGATION OF WATER AND WASTEWATER QUANTITIES BY POPULATION AREAS[a]

Population Area	Projected 1990 Condition					Projected 2000 Condition				
	Pop'n 1,000	Water Deliveries lcd	Water Deliveries $10^3 m^3/da$	Wastewater Prod'n lcd	Wastewater Prod'n $10^3 m^3/da$	Pop'n 1,000	Water Deliveries lcd	Water Deliveries $10^3 m^3/da$	Wastewater Prod'n lcd	Wastewater Prod'n $10^3 m^3/da$
Amman	1,020	95	96.9	85	86.7	1,305	110	144	95	124
Zarqa[b]	295	90	26.6	72	21.2	421	110	46.3	80	33.7
Ruseifa[b]	91	100	9.1	63	5.7	125	114	14.3	71	8.9
Baq'a Camp	45	70	3.2	60	2.7	45	80	3.6	70	3.2
Salt	47	70	3.3	60	2.8	66	80	5.3	70	4.6
Madaba	41	70	2.9	60	2.5	58	80	4.6	70	4.1
Wadi es Sir	39	85	3.3	75	2.9	62	95	5.9	85	5.3
Schnellar Camp	24	70	1.7	60	1.4	24	80	1.9	70	1.7
Suweileh	31	70	2.2	60	1.9	44	80	3.5	70	3.1
Suburban Ring[c]	74	105	7.8	95	7.0	250	115	28.8	105	26.2
Abu Nusair	40	85	3.4	75	3.0	100	95	9.5	85	8.5
Sahab/A'pt City	60	85	5.1	75	4.5	120	95	11.4	85	10.2
Airport City	15	85	1.3	75	1.1	25	95	2.4	85	2.1
Sahab	17	70	1.2	60	1.0	24	80	1.9	70	1.7
Musherfeh	16	70	1.1	60	1.0	23	80	1.8	70	1.6
Fuheis	7	70	0.5	60	0.4	10	80	0.8	70	0.7
Na'ur	7	70	0.5	60	0.4	10	80	0.8	70	0.7
Taibeh/Qaisiya	7	70	0.5	60	0.4	10	80	0.8	70	0.7
Duleil	7	70	0.5	60	0.4	10	80	0.8	70	0.7
Sukneh	6	70	0.4	60	0.4	8	80	0.6	70	0.6
Abu Alanda	6	70	0.4	60	0.4	8	80	0.6	70	0.7
Hashimiya	6	70	0.4	60	0.4	8	80	0.6	70	0.6
Mahis	6	70	0.4	60	0.4	8	80	0.6	70	0.6
Khirbet Suq	5	70	0.4	60	0.3	7	80	0.6	70	0.5
Total			170		149			292		245

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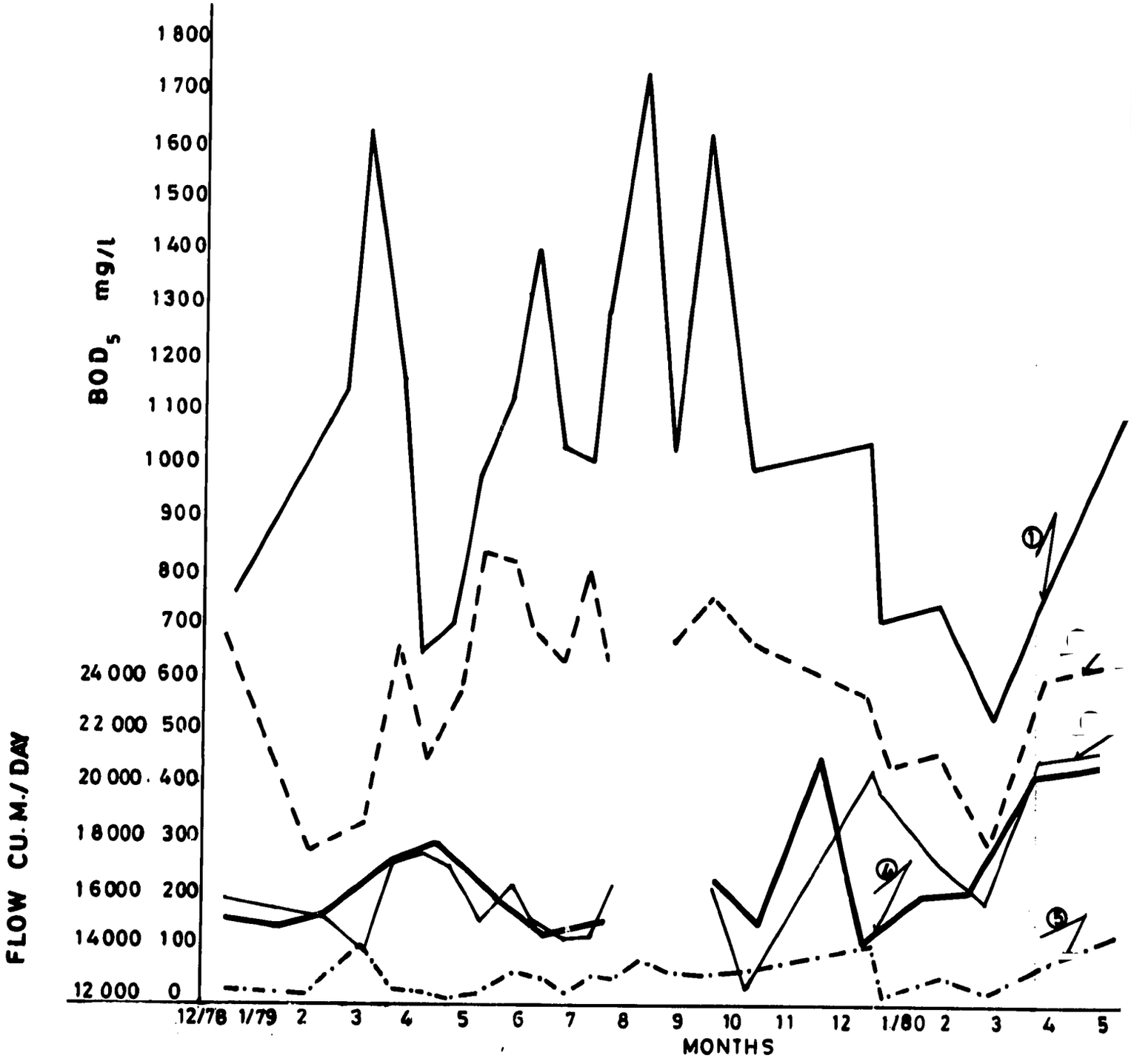
TABLE 5-6 (cont'd)

[a]Population data are taken from Table 3-13. These were developed in consideration of town plans were available. Disaggregation according to drainage areas within Amman and the Greater Amman area are covered in Chapters 6 and 8 respectively. This also includes considerations of the Amman Suburban Ring.

[b]Includes large contribution of industrial wastewater per MPI/Jouzy report.[5]

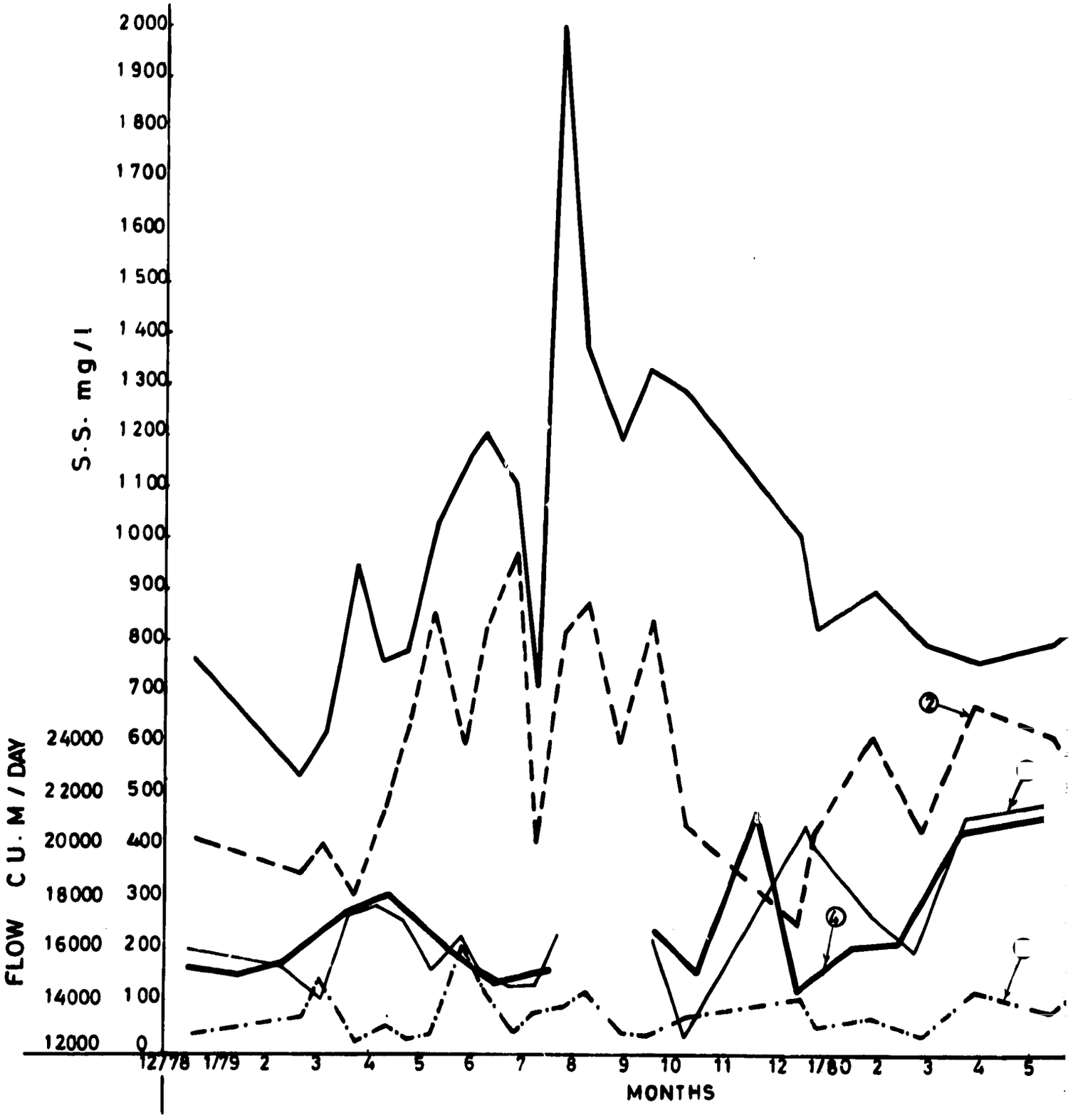
[c]Special recognition was given to the above average income levels anticipated for the Suburban Ring and the correspondignly higher-than-average water consumption and wastewater production. There are variations in these factors within the Suburban Ring, some areas being higher than others. The factors shown are overall averages.


BOD5 mg/l
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
FLOW CU.M./DAY
24000
22000
20000
18000
16000
14000
12000
12/78 1/79 2 3 4 5 6 7 8 9 10 11 12 1/80 2 3 4 5
MONTHS
1
4
5

① RAW WASTE WATER
② PRIMARY EFFLUENT
③ FLOW ON SAMPLE DAYS
④ AVERAGE MONTHLY FLOW
⑤ FINAL EFFLUENT

AIN GHAZAL TREATMENT PLANT
AVG. BOD_5 MONTHLY VALUES

FIGURE 5 - 2


S.S. mg/l
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
FLOW C U. M / DAY
24000
22000
20000
18000
16000
14000
12000
12/78
1/79
2
3
4
5
6
7
8
9
10
11
12
1/80
2
3
4
5
MONTHS

① RAW WASTE WATER
② PRIMARY EFFLUENT
③ FLOW ON SAMPLE DAYS
④ AVERAGE MONTHLY FLOW
⑤ FINAL EFFLUENT

AIN GHAZAL TREATMENT PLANT
AVG. S.S. MONTHLY VALUES

FIGURE 5 - 3

PRESENT AND FUTURE WASTE LOADS

	BOD_5		Suspended Solids	
	Mean (mg/l)	Standard Deviation (mg/l)	Mean (mg/l)	Standard Deviation (mg/l)
Raw Wastewater	1072	320	1015	325
Primary Effluent	657	226	590	201
Secondary Effluent	55	30	78	48

It is anticipated that the concentration of the wastewater constituents will decrease with time as the available water supply increases i.e., the mass loading of these constituents will remain the same while being diluted by increased water consumption.

NON-INDUSTRIAL WASTEWATER LOADINGS

The only long-term data available on loadings are found at AGTP as this was the only municipal treatment plant in the Kingdom until very recently. The AWSA values are used for estimates in other communities as it is presumed that the unit mass loadings of waste produced will remain the same despite varying unit wastewater production. This gives rise to varying raw wastewater quality concentrations dependent on the amount of water consumed per capita.

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CHAPTER 6

APPRAISAL OF EXISTING WASTEWATER FACILITIES

Prior to development of alternative wastewater management systems, the existing wastewater facilities must be examined to assess their capabilities to handle present and future loadings during this study period. Optimization of existing operations through upgrading and expanding of the existing facilities should be attempted prior to recommendations of new ones. The appraisal of the existing wastewater facilities will be discussed in this Chapter and serve as an input for the management facilities covered in Chapter 8.

At present, the major collection/treatment system within the Greater Amman Area is the Amman Water and Sewerage Authority "AWSA" System serving the Municipality of Amman. Salt is the other city within the Study Area which has its own sewerage facilities. King Hussein Medical Center is also served by a sewage treatment facility. Barring a few package treatment facilities utilized mostly on a temporary basis for public installations and housing developments, the aforementioned facilities are the only ones operated within the Study Area. The remainder of the Study Area is served by septic tank systems.

The following is an assessment of the collection/treatment facilities cited above.

AWSA SYSTEM

The construction of the AWSA first stage wastewater collection system was started in 1963 and completed in 1968. The work executed during this period comprised the construction of the Ain Ghazal Sewage Treatment Plant and the main trunk sewers. The second stage started right after the first stage was completed and included the expansion of the existing collection system to cover the central part of the city and the three main Jebels, namely Jebel Amman, Jebel Webdeh and Jebel Hussein. The work under the second construction stage included also a trunk line, serving the University of Jordan area and tying same to the AGTP. A detailed description of the wastewater collection facilities may be found in various studies prepared by AWSA.[1,2]

AWSA WASTEWATER COLLECTION SYSTEM

The AWSA collection system consists of over 230 km of lateral sewers and 18 km of trunk sewers, virtually all flowing by gravity to the AGTP. The exceptions are the University of Jordan area for which the wastewater generated is pumped over an intervening hill to a main sewer, and the Amman Airport area which is not in the AGTP drainage area and must therefore pump its wastewater back to the plant.

Although it is estimated that only about 43 percent of the population is connected to the collection system, 75 percent of the Municipality of Amman area is in a position to be served by the AWSA collection system by virtue of the presence of sanitary sewers in the streets. (Many potential contributors have not yet connected.) The collection system is currently being further expanded under Contracts 1S, 4WS, 5WS and 6WS to serve various areas of the Municipality.

APPRAISAL OF EXISTING WASTEWATER FACILITIES

The scope of work for this Master Plan includes an evaluation of the existing AWSA system. Of major importance are the two main trunk sewers and their capacities to handle the future flows generated from the Municipality of Amman and surrounding area. The two trunk lines are:

- The main trunk line running through the center of the city and discharging into the AGTP. It consists of approximately 10.4 km of sewers ranging in size from 200 mm to 1200 mm, and

- The University of Jordan trunk sewer which is approximately 7.2 kilometers long and consists of sewer pipe with diameters of 200, 300 and 400 mm. These trunk sewers are shown in Figure 6-1.

In evaluating a wastewater collection system, two important aspects must be considered: the physical condition of the system; and its hydraulic "carrying" capacity. The physical condition of the system must be determined through a field survey while the hydraulic adequacy can be determined through the use of projected wastewater flow rates, sewer profiles and hydraulic calculations.

Physical Survey

The physical survey of a collection system is performed to determine the general flow characteristics of the sewers, i.e., whether flowing partially full, full, or surcharged; groundwater levels, infiltration/inflow and the physical condition of the sewers. In the Greater Amman Area, the groundwater table is too far below the sewers' level to cause any infiltration problems during the dry season. On the contrary, ex-filtration is expected to occur through cracks, loose joints and manhole walls.

It was beyond the scope of work to make a detailed investigation into physical conditions in the AWSA network, but it was intended that at least a cursory investigation be undertaken for two basic purposes:

- To aid in the assessment of the key trunk sewers in conveying additional flow (especially from areas outside Amman) to the Ain Ghazal Treatment Plant.

- To yield general information as to the suitability of the local concrete sewer pipe for sanitary sewer application in Amman and elsewhere in the Greater Amman Area, both at present and under future conditions.

Unfortunately, difficulties in opening street manholes, lack of safety and monitoring equipment for entry into manholes, and inability to inspect manholes in the public right-of-way, combined to make network inspection difficult. Thus, the investigation was of a qualitative and subjective nature, based upon visual observations from street level in a limited number of manholes. Despite this limitation, the following seemed to be representative observations:

- Velocities were uniformly high even at off-peak flows.

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- There was no obvious presence of hydrogen sulfide in the atmosphere, not even at the manhole several hundred meters downstream from the discharge of the University Pumping Station force main.

- Interior surfaces of the concrete manholes did not appear to have sustained much deterioration, nor did the manhole rungs suffer from sulfide/sulfuric acid attack.

- No evidence could be seen from above of deterioration of the concrete sewer conduits. Flow surfaces, where visible, appeared to be smooth and undamaged.

- Detailed discussions of corrosion considerations due to hydrogen sulfide and flow gaging of the the AWSA are presented in Appendix E.

Hydraulic Capacity

Hydraulic analysis of a wastewater collection system relates projected wastewater flow rates to the carrying capacity of the receiving sewers and trunk lines based on their sizes and slopes. Sewers determined not to have the carrying capacity must be paralleled or part of the flow diverted elsewhere. In most cases, the former corrective measure is more feasible.

To determine the projected wastewater flow rates, the City of Amman and the portions of the Suburban Ring that are in the Seil Zarqa drainage have been divided into ten drainage subareas, as shown in Figure 6-1. This was done to simplify the analysis of the existing system and to allow the projected growth that will occur within the immediate vicinity of Amman to be incorporated more readily into the analysis. The projected wastewater flows for the years 1900 and 2000 were determined and are presented in Table 6-1, which also provides data on population projections, average daily wastewater flows, peaking factors, infiltration and total peak wastewater flows for each subarea. The population projections and wastewater flows are calculated using information presented in Chapters 3 and 5.

The domestic flows for subarea A were determined by multiplying the projected 1990 population by an average flow of 100 liters per capita per day (lcd) and the projected 2000 population by an average flow of 120 lcd. The domestic flows for subareas B through J were determined by multiplying the projected 1990 populations by an average flow of 85 lcd and the projected 2000 populations by an average flow of 95 lcd. The average per capita contributions in subarea A are expected to be higher than those for the other subareas because the residents in subarea A are in the higher income brackets and this type of residential area typically exhibits higher per capita wastewater flow contributions.

The peaking factors for the cumulative flows were obtained from the graph in Figure I-1, Appendix I. The factors in the graph which relate to population served, are then applied to the average daily flow generated to obtain the peak hourly flows. The peaking factors used in Table 6-1 range between 1.8 to 2 which was felt to be a good representation of the peaking conditions for the size drainage areas being analyzed.

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TABLE 6-1

DOMESTIC, COMMERCIAL AND INDUSTRIAL WASTEWATER FLOWS

AMMAN DRAINAGE AREA

Drainage Sub-Area	Tributary Population (1000)		Average Daily Wastewater Flow (l/sec)		Cumulative Average Daily Wastewater Flow (l/sec)		Peak Wastewater Flow[a] (l/sec)		Infiltration and Industrial Flow (l/sec)		Total Wastewater Flow (l/sec)	
	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000
A	127.4	256.1	135	326	135	326	270	587	20	20	299	607
B	83.4	121.7	82	144	217	470	412	846	31	31	443	877
C	382.8	493.7	377	541	594	1,011	1,069	1,820	84	84	1,153	1,904
D	183.0	221.2	179	241	773	1,252	1,391	2,254	109	109	1,500	2,363
E	222.0	285.3	218	302	991	1,554	1,784	2,797	180[b]	180[b]	1,964	2,977
F	68.9	100.2	68	110	1,059	1,664	1,906	2,995	189	189	2,095	3,184
G	49.2	70.7	49	78	1,108	1,742	1,994	3,136	196	196	2,190	3,332
H	17.0	49.7	15	49	1,123	1,791	2,021	3,224	200	200	2,221	3,424
I	11.8	12.7	12	14	1,135	1,805	2,043	3,249	202	202	2,245	3,451
J[c]	52.0	66.4	44	58	44	58	88	116	6	8	50	66

[a] Peaking factors of 2.0 and 1.9 were used for A and B's 1990 flow, respectively, and 1.8 peaking factor used for the remaining flows.

[b] Includes 40 liters per second of concentrated industrial flow.

[c] Area J is tributary to Zarqa-Ruseifa System. Population and flow figures include Schneller Camp.

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The infiltration rate was determined by using the rate of 10 cubic meters per day per kilometer of 200 millimeter (mm) diameter sewer pipe, (about 500 gallons per day per inch diameter per mile of sewer pipe). The total infiltration flow in the proposed network upstream from Wadi Abdoun amounted to 14 percent of the projected 1990 dry weather flow. The 14 percent figure was also applied to the projected dry weather flows in the existing AWSA system since the lengths and sizes of the various lines in the Amman Area are not available. No change in the filtration rates is expected between 1990 and 2000. An additional allowance for industrial flow of 40 liters per second has been added to the flows in subarea E.

The points on the trunk sewer delineated by letters in Figure 6-1 represent the locations to which all of the wastewater in each subarea drains. The existing AWSA trunk sewer begins at a point upstream of Point B and terminates at AGTP located between points G and H. The reach of trunk sewer in each subarea was subjected to hydraulic analysis to determine its maximum capacity using the Manning formula for open channel flow. The Manning roughness coefficient, "n", was assumed to be 0.013, which is the value that is generally accepted for reinforced concrete sewer pipe. A field test was performed as part of this Master Plan to verify the value of "n" for selected sections of the AWSA system. A discussion of the field test is presented in Appendix E, and the results indicate that an "n" of 0.013 is a fair approximation of the actual field conditions.

In order to determine the adequacy of the existing trunk system, the projected peak flow rates for the years 1990 and 2000 were compared to the capacity of the systems under flowing full conditions. No surcharging was allowed. The comparison was carried out for two separate conditions: (1) where all of the wastewater in the drainage subareas flows by gravity to the AGTP; and (2) where a portion of the wastewtaer from subarea A is diverted to a new treatment plant being considered at Wadi Abdoun, hereinafter called the Upper Wadi Abdoun Treatment Plant (UWATP). The comparison is summarized in Table 6-2 and is described below for the reach of trunk sewer in each subarea.

TABLE 6-2

AWSA TRUNK SEWER CAPACITIES

Trunk Sewer Reach Point to Point		Projected Wastewater Flows (l/sec) Without UWATP		With UWATP		Capacity Rating[a]
		1990	2000	1990	2000	
A	B	443	877	197	367	317
B	C	1,153	1,904	907	1,394	1,300
C	D	1,780	2,363	1,475	1,853	1,300
D	E	1,823	2,690	1,577	2,316	1,700
E	F	2,098	3,200	1,852	2,710	2,140
F	G	2,217	3,426	1,971	2,917	2,140
G	AGTP	2,237	3,483	1,990	2,973	2,500

[a] Rating for a trunk reach is based on the minimum capacity of the trunk within that reach. Units are l/sec.

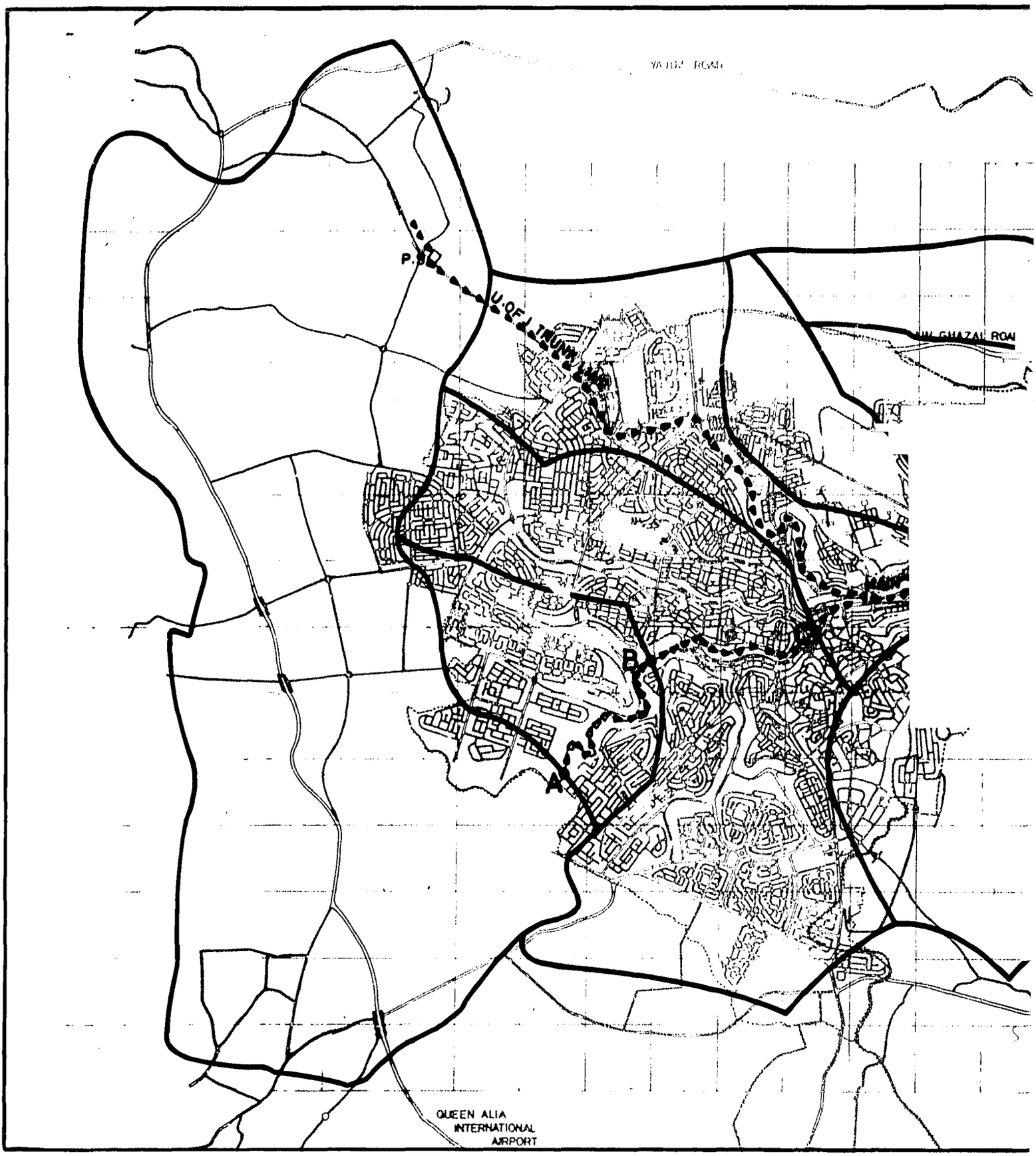
Subarea A. A sewage collection system does not exist in this subarea; however, it is in the planning stage and will be sized to accommodate the year 2000 projected contributary population. AWSA has undertaken a design of two sewage pumping stations to pump wastewater from a portion of this area (near the 7th and 6th Circles, Jabal Amman) across the divide near the 6th circle and into an existing trunk sewer. The pumping operation would be necessary rather than gravity sewerage to the AWSA primary network, because currently, there is insufficient development along the gravity route to be warrant its construction. However, the UWATP, if built, could receive flow by gravity from these and other developed upstream areas, thus eliminating the need for the proposed sewage pumping stations.

Subarea B. The existing trunk sewer begins in this subarea and has a maximum capacity of 317 liters per second. The trunk appears to have adequate capacity for the 1980 wastewater flows. The data in Table 6-2 indicate that the projected wastewater flow will exceed the capacity of the existing trunk sewer before 1990 if the UWATP is not built, and between 1990 and 2000 if the UWATP is built. To provide adequate capacity in this subarea, the existing trunk sewer will need to be paralleled with the following lengths of sewer pipe before year 2000:

Pipe Diameter (mm)	Pipe Length (m) Without UWATP	With UWATP
1000	0	0
900	0	0
800	186	0
700	110	0
600	550	0
500	0	0
400	0	186
300	0	110

The required additional sewer pipes represent the recommended size sewers needed to provide the additional carrying capacity when constructed at slopes similar to those being paralleled. While some of the suggested sizes may be changed during the course of actual design, the lengths and sizes shown are indicative of the extent of relief required and provide a good basis for cost estimating purposes. For programming and budgeting purposes an additional cost allowance will be made in subsequent chapters.

Subarea C. The trunk sewer in this subarea has a maximum capacity of 1,300 liters per second and appears to have adequate capacity for both projected 1990 flows, but does not have adequate capacity for either of the projected 2000 flows. The sewer pipe listed below should provide sufficient additional capacity to accommodate the year 2000.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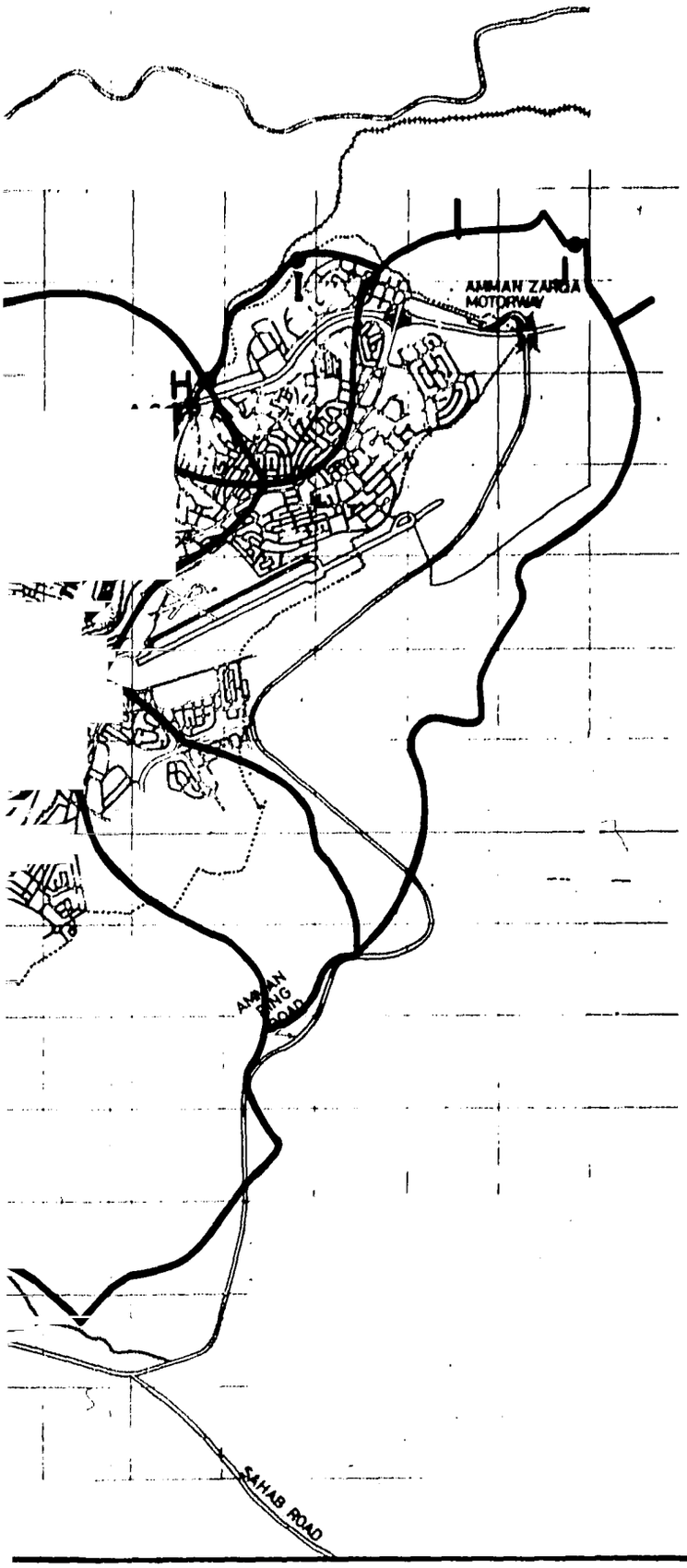

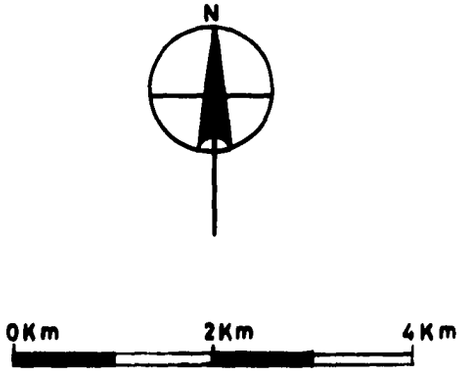

SCALE 1 / 75,000

DRAINAGE SUBAREAS TO AWSA MAIN TRUNK LINE

FIGURE 6 - 1

Pipe Diameter (mm)	Pipe Length (m) Without UWATP	With UWATP
1000	109	0
900	44	0
800	310	109
700	217	68
600	315	104
500	476	346
400	58	0
300	0	0

Subarea D. The trunk sewer in this subarea has a maximum capacity of 1,300 liters per second and appears to have adequate capacity for the existing wastewater flows. According to the hydraulic analysis, the wastewater flows should exceed the trunk's capacity between 1985 and 1990 if the UWATP is not built. If the UWATP is built, the flows are expected to exceed the capacity of the trunk sewer between 1990 and 2000. The sewer pipe listed below should provide sufficient additional capacity to accommodate the year 2000 flows.

Pipe Diameter (mm)	Pipe Length (m) Without UWATP	With UWATP
1000	624	0
900	728	394
800	382	230
700	301	757
600	112	332
500	45	241
400	25	83
300	0	54

University of Jordan Trunk Sewer

The University of Jordan trunk sewer is also located in subarea D. The University is located in subarea A, but wastewater from the University flows by gravity to a pump station that pumps the wastewater over an intervening hill and into subarea D. This trunk sewer currently is surcharged during peak flow periods, and AWSA plans to parallel the trunk to alleviate the surcharging. Information concerning the lengths and sizes of the proposed parallel lines was not available at the time this report was written. However, an hydraulic analysis of the existing trunk sewer was carried out as part of this Master Plan and the results of the analysis were combined with population projections and estimated per-capita wastewater flow rates for the area to approximate the sizes and lengths of sewer pipe that would be required to alleviate the surcharging. Because the area around the University is growing rapidly, a collection system to which the University could connect will be required by 1990. The pump station and force main may then be abandoned and the flow would no longer be carried by the trunk in subarea D. Instead it will flow by gravity to UWATP through a new interceptor as will be discussed in Chapter 8.

Pipe Diameter (mm)	Pipe Length (m) Without UWATP	With UWATP
1000	0	0
900	0	0
800	88	88
700	0	0
600	60	0
500	317	204
400	1,134	328
300	3,371	1,376
200	1,290	1,907

Subareas E, F and G. The data in Table 6-2 indicate that the maximum capacity of the trunk sewer in subarea E is 2,140 liters per second. The capacity of the trunk sewer in subarea E will be exceeded by 1990 regardless of whether or not the UWATP is built.

It was determined that the capacity of the trunk sewer in subarea F is 2,140 liters per second and that this capacity will be exceeded between 1990 and 2000 whether or not UWATP is built.

The estimated capacity of the trunk sewer in subarea G is 3,000 liters per second according to the hydraulic calculations of this study. This suggests that the trunk sewer's capacity will be exceeded by 1990 if UWATP is not built and between 1990

and 2000 if UWATP is built.

The data developed for this study were used to determine the sizes and lengths of sewer pipe that would be required to parallel the existing trunk sewer and provide adequate capacity through the study period. This information is presented in the following table for subareas E, F and G.

Pipe Diameter (mm)	Pipe Length (m) Without UWATP	With UWATP
1000	875	0
900	0	0
800	324	766
700	87	114
600	632	324
500	955	111
400	0	0
300	0	0

Subarea H. A short section of the existing trunk sewer is located in this subarea terminating at AGTP. The capacity of the trunk is calculated to be 2,500 liters per second and the flow is expected to be higher between 1990 and 2000 under both conditions in Table 6-2. The invert elevation of the trunk is approximately three meters lower than the influent weir wall at the AGTP. This causes flow to back up in the trunk line for a distance of aproximately 700 meters. Solids are also trapped upstream of the headworks which must be cleaned manually. The weir wall was provided as such to act as a trap to keep rocks from entering the plant at high velocities. However, this objective may be accomplished through other more efficient means without causing the flow to back up in the trunk system. This problem will be eliminated as part of the AGTP improvements, which is discussed in detail in Chapters 8 and 9. The sizes and lengths of sewer pipe that will be needed to provide adequate capacity in this trunk reach are listed below:

Pipe Diameter (mm)	Pipe Length (m) Without UWATP	With UWATP
1000	0	0
900	0	0
800	0	0
700	116	114

45

(Continued)

Pipe Diameter (mm)	Pipe Length (m) Without UWATP	With UWATP
600	0	0
500	0	0
400	0	0
300	0	0

Summary

Neither the main trunk sewer nor the University of Jordan trunk sewer will be able to accommodate the projected wastewater flows through the study period. The construction of UWATP will reduce significantly the amount of paralleling that must be done to provide sufficient capacity in the trunk sewers through the study period. The fact remains, however, that some of the trunk segments must be paralleled to eliminate the possibility of surcharging under peak design wastewater flow rates. The total lengths of sewer pipe that are required to accomplish this are summarized in the following table.

Pipe Diameter (mm)	Pipe Length (m) Without UWATP	With UWATP
1000	1,608	0
900	772	394
800	1,290	1,193
700	831	1,053
600	1,669	760
500	1,793	902
400	1,217	597
300	3,371	1,540
200	1,290	1,907

A discussion of the steps that must be taken and the costs involved in bringing the existing trunk sewer up to capacity are presented in Chapters 8 and 9.

University of Jordan Pumping Station

The University pumping station, built in 1970, pumps the wastewater collected from the University of Jordan, University Hospital and the University housing project through 200 m of 200 mm dia. force main to the AWSA collection system

where it flows by gravity to the AGTP. The pumping station is provided with three 29 hp, Flygt submersible pumps, each rated at 1500 l/min at 28 m total dynamic head (TDH). The current flow to the station is estimated at 800 m^3/day. However, during peak wet weather flows, two pumps are needed to handle the flows, the third pump being a standby. The pumps were rebuilt in 1977 and are pulled for inspection and repair every three months. The action of the pumps is controlled by floats in the wet well.

The station contains a standby generator that was used originally to operate the station before electricity was available. The generator, rated at 45 kw, is capable of operating only one pump and is insufficient to handle peak wet weather flows during power failures.

The pump station has not experienced serious mechanical problems, but the following deficiencies or potential problems were found to exist.

- The influent screening is inadequate allowing debris to pass through which can clog and damage the pumps.
- The influent flow meter is broken and accurate flow information is not available.
- The location of the station is such that it floods during heavy rainstorms. During flooded conditions, the combined storm water and sewage overflows into the street or adjacent wadi.
- The pump failure and high level alarms are local alarms. Alarms are not transmitted to the AGTP, or someplace elsewhere even when an immediate response is imperative.
- During prolonged power outages, the generator is insufficient to operate the station.
- The standby generator is manually operated and does not come on automatically. An undetected power failure could leave the station without power for up to 16 hours on weekdays or longer on holidays or days off.
- The general housekeeping at the facility is poor and some odors and sulfide corrosion are evident.

The East Marqa Pumping Station

The East Marqa pumping station, built in 1979, pumps the wastewater collected from the civil airport, Royal Air Force Base, the AWSA gravity collection system and surrounding Marqa area through 1200 m of 250 mm force main. The station is provided with two sets of two-stage pumps, each set with a capacity of 360 m^3/hr. The current flow to the station is low compared to its rated capacity. The station can accommodate a third set of two-stage pumps for future flows. The pump station is still under the control of the contractor due to items that

have not been corrected to meet specifications.

The station has sufficient capacity for the projected growth in the surrounding area. Inspection of the pump station disclosed the following deficiencies or potential problems:

- The pump seals are not sufficient for the pumping head, this resulting in leaking or blown seals.
- The pump casing was faulty on one of the lower submersible pumps.
- The float controls have been defective and sometimes fail due to excessive grease accumulation.
- The influent screening is inadequate and allows the passage of large solids.
- Prolonged power outages may cause a sewage overflow to the adjacent drainage area.
- Standby power is not available for emergency situations.
- The pump failure and high level alarms are local alarms. Alarms are not transmitted to the AGTP.
- The operations and maintenance staff at AGTP have not received recommended spare parts and maintenance literature on the equipment.

AIN GHAZAL TREATMENT PLANT

The Ain Ghazal Treatment Plant (AGTP) has been in operation since 1969. Since then, the wastewater flow has increased from 2400 m^3/day to 21,000 m^3/day at the present time. The AGTP was designed as a conventional activated sludge plant. Solids handling is provided using anaerobic digestion followed by sludge drying beds for dewatering. The wastewater treatment portion of the plant was designed using the following design parameters:

Population	300,000	
Per Capita Sewage Flow	200	lcd
Average Total Daily Sewage Flow	60,000	m^3/day
Average Hourly Flow, Average Day	2,500	m^3/hr
Maximum Hourly Flow, Average Day	4,200	m^3/hr
Per Capita BOD	60	gcd

The anaerobic digesters were designed for a population equivalent of 150,000 based on a unit volume of 40 liters per person. The digester volume is 6,000 cu m.

Because of the low water consumption per capita, about 75 lcd, the sewage generated is unusually strong averaging about 900 mg/l and 1000 mg/l BOD_5 and suspended solids respectively. At present flows of 21,000 m^3/day, it appears that

APPRAISAL OF EXISTING WASTEWATER FACILITIES

AGTP is rapidly reaching its design capacity.

The AGTP treatment units are shown in Figure 6-2 and include the following:

- Pretreatment which includes barminutors and grit removal units
- Primary sedimentation
- Secondary treatment using the activated sludge process
- Final sedimentation
- Chlorination prior to effluent discharge
- Sludge handling facilities which consist of sludge thickening, anaerobic digestion and sand drying beds

Assessment of the treatment units and upgrading measures required are included below:

Pretreatment Units

The pretreatment units include the inlet works, barminutors and the grit removal tanks. The inlet works are located at the south end of the maintenance building. Flow enters the plant by gravity and flows over a concrete wall (approximately 3 m above the invert elevation), thence through two barminutors. The weir wall which was provided to prevent large debris from damaging the barminutors, acts as a trap for such debris which must be removed manually on a daily basis. A particularly objectionable part of this operation is the organic matter caught along with the debris and mainly those originating from the slaughterhouse operation immediately south of the plant.

In general, the barminutors do not provide the service they were intended for. Barminutors are generally adequate for light duty applications only. Comminutors and mechanically-cleaned bar screens are more rugged and suitable for the flow and amount of screenings reaching the AGTP.

From the barminutors the wastewater flows to the sutro weirs where it is monitored both automatically and manually for flow measurement purposes. Due to limited dry weather flows entering the plant, only one sutro weir is in use at the present time. To remove the grit and preaerate the wastewater, two grit units are used in parallel. Each unit has three separate chambers 2.3 m wide x 20 m long. The settled grit is conveyed along a sump in the first chamber only by means of a horizontal screw conveyor which carries the grit to one corner from which it is removed by air lift pumps. Settled grit in the other two chambers does not have a provision made for its removal.

Grit removal has been a continuous problem due to frequent breakdowns of the screw conveyors. Because of such breakdowns, manual grit removal is practiced. Following grit accumulation in the units for a period of time, the units are alternately dewatered and drained allowing the grit to dry before it is hauled out manually. Such inefficient operation allows grit to reach the primary sedimentation tanks and ultimately end up in the digesters. Grit accumulation in the digesters reduces the volume available for organic sludge digestion and increases the frequency of needed digester cleanups.

To alleviate the problems associated with the pretreatment units, the entire inlet works and grit removal system need to be replaced. The present weir wall will have to be removed thus eliminating the dam and effect accumulation of debris in the inlet works. The trunk sewer will be free flowing, thus allowing for high cleaning velocities at all times and reducing the potential of sulfide generation. In order to provide the hydraulic head necessary to push the future flows through the plant (up to 96,000 m^3/day vs. present flows of 21,000 m^3/day), a low lift pump station would be required. The pump station would also provide the head required for the distribution of future flows between the existing plant and the new expansion proposed on the south side.

The pumps would be of the Archimedes screw type. Such pumps are used for similar conditions throughout Europe and the United States. They provide a number of advantages compared to variable speed centrifugal non-clog pumps which are the alternative equipment for this application. Screw pumps may be used to pump raw sewage prior to any screening. This eliminates the necessity of providing screening. This eliminates the necessity of providing screening facilities well below grade. The elimination of piping manifolds and valving is another major advantage. Generally, concrete channels at both ends of the screw pumps are all that is required. Since at AGTP flows of more than 80,000 m^3/day are being considered, large diameter piping and valves would be a major expense. Normal automatic controls are not required for the operation of screw pumps. A screw pump turns at a constant speed and would pump any influent flow up to its maximum capacity. For flows beyond that, the wastewater level rises in the inlet channel starting a new pump.

To replace the existing barminutors, two choices are available: automatically cleaned bar screens, and comminutors. The bar screens remove altogether the large material from the sewage, mostly rags, which ultimately gets trucked away to a landfill. Using comminutors, such large material is shredded and returned to the sewage flow where it settled in the primary sedimentation tanks. The choice between screening and comminution will be determined during the design phase.

Grit removal facilities would be required to replace the existing units. The geometry and detention time would be such that maximum grit removal efficiency is achieved. The grit would be collected in hoppers and pumped by recessed impeller mixed flow pumps to grit separation-dewatering units. The separation and dewatering of the grit would be performed by cyclone separators followed by screw classifiers. Dewatered grit would be disposed of by trucking to a landfill. Such a grit removal system would eliminate the problem of operating a submerged mechanical grit removal device such as presently is in use.

Primary Sedimentation

There are six primary sedimentation tanks, each 42 m long, 5 m wide and 1.5 m deep. The design parameters are:

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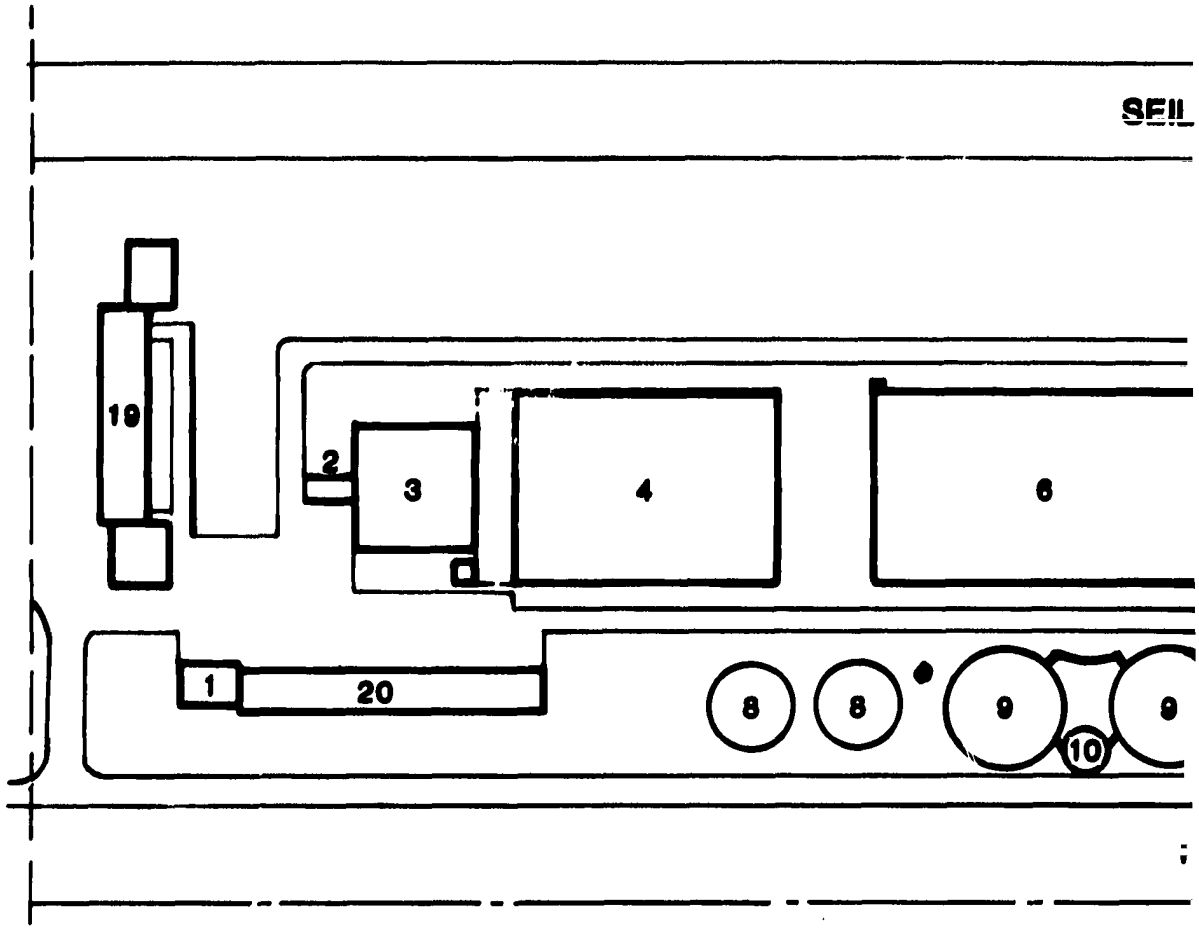
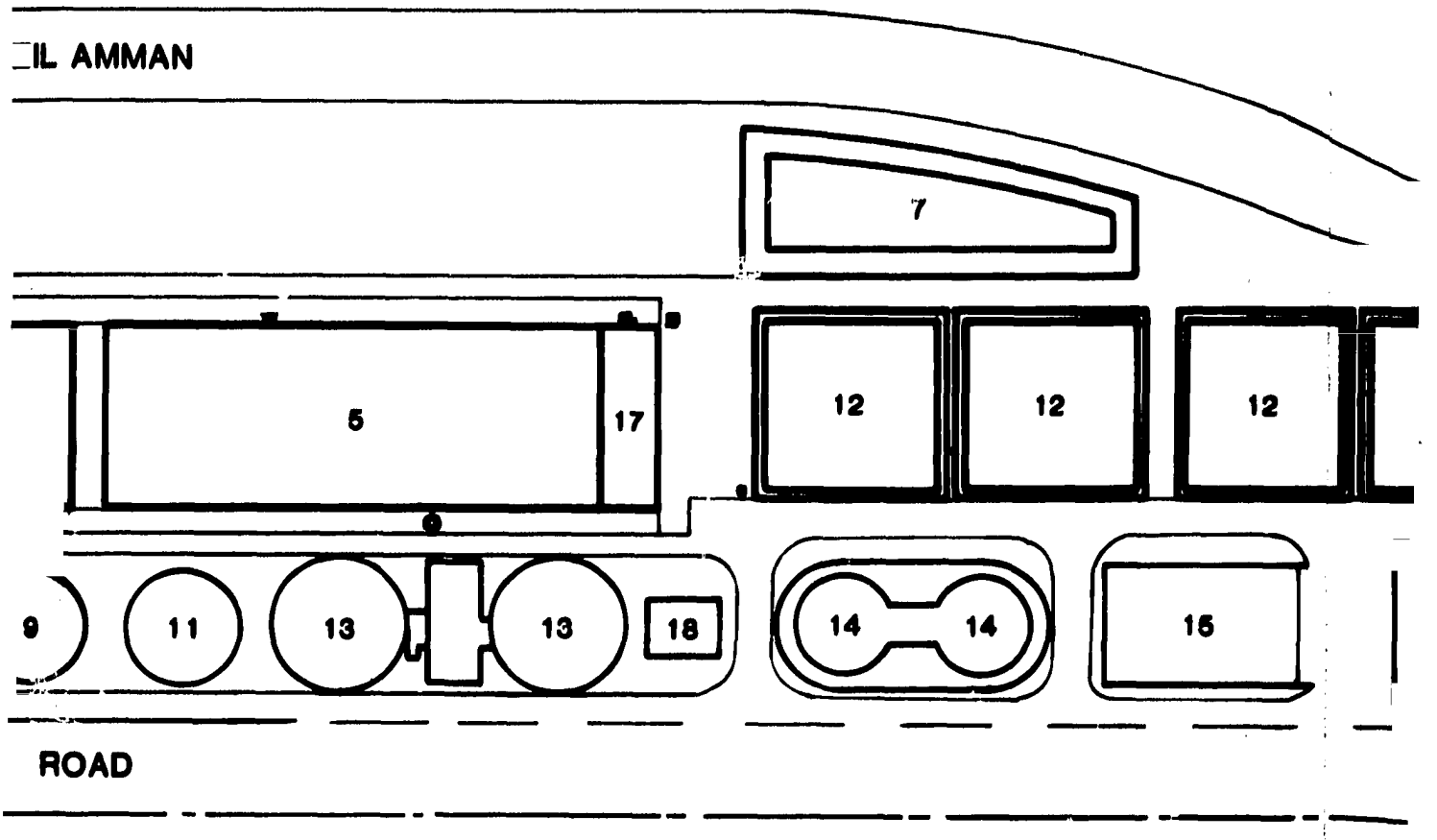


LEGEND

1 = HEADWORKS
2 = FLOW MEASUREMENT
3 = PREARATION
4 = PRIMARY SEDIMENTATION
5 = ACTIVATED SLUDGE AERATION
6 = SECONDARY CLARIFICATION (2-ST
7 = CHLORINE CONTACT (OPEN LAGO
8 = SLUDGE THICKENER
9 = INITIAL DIGESTER
10 = DIGESTED SLUDGE HOLDING TANK
11 = SLUDGE GAS HOLDER
12 = SLUDGE DRYING BED
13 = NEW DIGESTER (UNDER CONSTR.)
14 = NEW DIGESTED SLUDGE HOLDING
15 = NEW BELT PRESS BLDG. (UNDER C
16 = NEW DEWATERED SLUDGE STOCKP
17 = AERATION BLOWERS
18 = ELECTRICAL SUBSTATION
19 = CONTROL/ADMINISTRATION/LABOR
20 = CHLORINATION /MAINTENANCE



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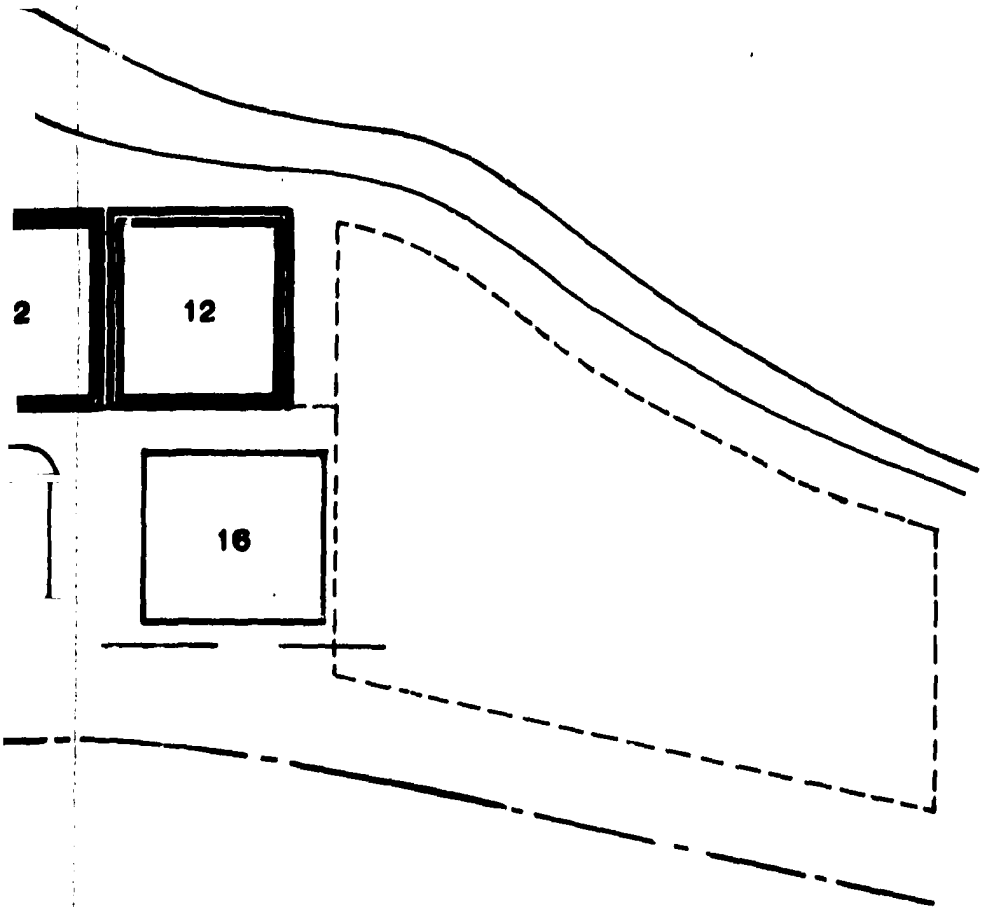

AIN GHAZAL
TREATMENT PLANT
EXISTING FACILITIES
FIGURE 6-2

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Average overflow rate	=	48 $m^3/m^2/day$
Detention time	=	0.9 hr.

On this basis, the primary sedimentation tanks are nominally rated for a flow of 60,000 m^3/day

Conventional design parameters used in the United States are:

	Range	Typical
Average overflow rate	32-48 $m^3/m^2/d$	—
Peak overflow rate	80-120 $m^3/m^2/d$	100
Detention time	1.5 - 2.5 hr	2.0 hr
Tank depth	3.0 - 5.0 m	3.6 m
Tank length	15 - 90 m	25-40 m
Tank width	3 - 24 m	6-10 m

The major difference between the existing tanks and conventional practice is the shallow depth. Where a conventional tank is normally at least 3.0 m in depth, the existing tanks are only 1.5 m deep.

Although it is generally agreed that the surface area and overflow rate are the major design parameters of sedimentation tanks, the depth and cross-sectional area are equally important. The depth must be adequate to allow for an undisturbed settled sludge zone at the bottom while the cross-sectional area must be large enough so that excessive horizontal velocities may not occur. Otherwise, the settled sludge is disturbed, allowing the suspended solids to go over the weirs, substantially reducing removal efficiencies.

Because of the high BOD and solids loading at the Ain Ghazal plant, improved primary sedimentation tanks could mean a substantial reduction in BOD loadings to the activated sludge process and subsequently savings in electrical requirement.

To meet the demands of the present flows only four out of six sedimentation tanks are operated. The current total daily flows vary between 18,000 and 22,000 cubic meters per day. At these flows, the operating parameters are:

Average overflow rates	21.6 to 26.4 $m^3/m^2/d$
Peak overflow rates	35 to 43 $m^3/m^2/d$
Detention time	2.0 to 1.6 hr

Within these parameters suspended solids removals reported average about 40% (December 1978 to June 1980). Typical variations in primary effluent solids may be seen in Figure 5-3. Normally, suspended solids removals are expected to be in the range of 50 to 60%. It appears that the tanks are not providing the necessary removals and will provide substantially less at 60,000 cubic meters per day. Operating experience and plant records indicate the hydraulic capacity of these tanks is not more than 30,000 m^3/day. Higher flows will require the construction

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of additional sedimentation tanks.

Secondary Treatment

Secondary treatment at AGTP is by the activated sludge process using diffused air aeration. The system was originally designed to provide treatment for 60,000 m^3/day of sewage flow based on a detention time of four hours. However, such short detention time is inadequate by any standards to treat the present organic load, due to the high strength waste of the AWSA system (900 mg/l BOD_5 and 1000 mg/l suspended solids). The design hydraulic detention time, (without recycle) should, as a minimum, be 8 hours so that reasonable reduction of the organic load may be achieved. The use of 8 hours would automatically reduce the hydraulic capacity of the aeration tanks by half, to 30,000 m^3/day.

Air to the activated sludge process is provided by six air blowers or compressors with a seventh compressor as a standby. Assessment of the available aeration capacity shows that the six compressors can provide 23,250 cfm at 8 psi. Assuming a 6 percent transfer efficiency for the dacron sock diffusers (as no data are available of field transfer efficiency), the system appears able to provide 680 kg/hr of oxygen, enough to handle an organic load of 11,500 kg/day of BOD_5. Present organic load to the aeration tanks of 13,700 kg/day (based on 650 mg/l BOD_5 and 21,000 m^3/day flow) exceeds the aeration capacity of the existing system. During site visits to the plant and through communications with the plant personnel, it was evident that the sock diffusers system clogged quite frequently and was a major maintenance problem. Mixing in the tanks, which is essential for the proper operation of the activated sludge process is also hampered by the clogging of the sock diffusers. The appearance of the mixed liquor was not the normal brown color; instead it appeared blackish, a sign of improper mixing and deficiency in oxygen. The lab analyses show a D.O. of 1 to 2 mg/l. A minimum D.). of 2.0 mg/l should be maintained.

A review of the kinetics of a conventional activated sludge treating the AWSA high strength waste shows that a mixed liquor suspended solids (MLSS) concentration of at least 3,000 mg/l will be required in order to oxidize the available substrate. The use of MLSS concentrations of this order may be beyond the mixing capabilities of the present diffused aeration system, although certain upstream improvements and aeration basin improvements could aid basin performance. In comparison with diffused air aeration, surface aerators generally have higher oxygen transfer, infrequent breakdowns, lower maintenance requirement, and improved mixing, and are often favored to keep the solids in suspension and provide the oxygen required. If adopted, this will require structural modifications of the existing aeration basins since mechanical aeration is not suited for long narrow basins.

The return activated sludge (RAS) and waste activated sludge (WAS) systems are two essential control operations in conjunction with the activated sludge process. The RAS flow which is normally expressed in percent of flow and ranges between 25 to 100 percent, determines the concentration of MLSS in the tanks, and the food to microorganisms ratio F:M. The WAS flow controls the sludge age or the sludge mean cell residence time.

The existing RAS and WAS are presently controlled by a V-notch weir, placed at the north end of the final sedimentation tanks. The settled sludge is removed from the tank hoppers by air lift pumps and discharged into an individual weir box for each tank. Two V-notch weirs are present in each box and can be manually adjusted by a hand wheel. One controls the discharge to a waste sludge sump and the other to a return sludge sump.

The present system does not accurately control and measure the RAS and WAS flows. A more positive control should be provided such as a centrifugal pump arrangement. Positive suction for RAS removal and accurate control of return activated sludge can be maintained by such a system.

Final Sedimentation

The existing final sedimentation tanks are of the two level type design. There are six tanks each 5 m wide by 51 m long by 1.5 m deep. The total surface area and volume are 3100 m^2 and 4600 m^3 respectively. The operating parameters for the design flow of 60,000 m^3/day are:

Average overflow rate	=	19.2 m^3/m^2/day
Detention time	=	1.84 hours

Typical design criteria for final sedimentation tanks are as follows:

Average overflow rate	16-32 m^3/m^2/day
Peak overflow rate	40-48 m^3/m^2/day
Average solids loading	3.0 - 6.0 kg/m^2 hour
Depth	3.5 - 5 meters

The difference between the above design parameters and those used in the AGTP plant design is the clarifiers' depth, 1.5 m vs. recommended depth of 3.5 m minimum. The state of the art shows the depth is a critical parameter in the design of the final sedimentation tanks. Unlike the primary sedimentation tanks where raw sewage solids are rather discrete particles, the activated sludge solids are light, fluffy particles, that are difficult to settle. The law of gravity is not the only factor that plays a role in activated sludge solids settlement. Flocculation, inter-particle forces, and solids loading (MLSS concentration) are other major factors that affect solids capture and removal. A well clarified effluent must be maintained to achieve the full benefit of treatment. Any solids losses over the weirs due to poor operation of the sedimentation tanks undermines the effort and expenses spent upstream of the sedimentation tanks to treat the wastewater.

To improve the efficiency of the final sedimentation tanks, the middle slab must be removed to give the tanks a depth of 3.0 meters. An assessment of the structural modifications necessary to deepen the tanks may be found in Appendix G. Submerged tube settlers, inserted below the surface, could also improve settling.

Chlorination

The existing chlorination facilities consist of three chlorinators and related appurtenances located in the maintenance buildings. The chlorine dosage is manually controlled and set at a constant rate irrespective of the daily fluctuations in the flow, i.e., not flow paced. This results in overdosing at times (chlorine wastage) or underdosing (improper disinfection). Presently the dosage is about 50 kg/day. Chlorine residual is generally below 1 mg/l.

In order to have effective disinfection, chlorine should be flow-proportioned so that the right dosage is continuously applied. The chlorine residual should be also monitored and used as a feedback to double check and control the dosage. Proper contact and contact duration of the effluent with chlorine are important factors also in disinfection. Careful attention must be given to the design of the chlorine contact tank so that short-circuiting will not occur. It is desirable to retain a minimum of 80 to 90 percent of the flow in the chlorine contact basin for the specified contact time - minimum of 15 minutes at peak hourly flow. In order to accomplish that, plug flow conditions must be maintained using narrow and long basins. Baffle walls are constructed in the chlorine tanks to provide the necessary geometry required.

The existing chlorine contact tank is a lagoon 16 m wide at the flow inlet, tapering to 4.5 m at the outlet point. The volume is 1250 m^3/day which provides 30 minutes detention time at 60,000 m^3/day, average daily flow. Although the theoretical contact time is adequate, short circuiting is inevitable due to the geometry of the basin and lack of baffling.

Sludge Handling Facilities

At present, the primary sludge is collected in the sedimentation tank hoppers and pumped directly to the anaerobic digesters. The waste activated sludge is pumped to the gravity sludge thickeners from which it is conveyed by gravity to the primary sludge pumps.

There is no direct flow measurement of the quantities of sludge pumped to the digesters. Instead, the operators record the number of hours the sludge pumps operate each day. The sludge pumps are triplex plunger pumps with variable capacities of 18, 24, 36 and 54 cubic meters per hour depending on the pump speed. The current feed rate is 24 m^3/hr. The operator adjusts the amount of sludge pumping based on experience and sampling the level of sludge in the sedimentation basin hopper with a dipper. Recent data on the quantities and characteristics of the sludge pumped to the digesters are presented in Tables 6-3 and 6-4.

These figures indicate an average demand of 423 KW during May-June of 1980, 692 KW during June-July (800 KVA at an assumed power factor of 0.865).

Existing electrical distribution and single line diagram are shown in Figures G2-1 and G2-2 in Appendix G.

SALT SYSTEM

COLLECTION SYSTEM

The city of Salt has had a sewage collection network dating back to the Turkish rule. It comprised stone slab type conduits after the style used by the Romans centuries before. In 1948, a program had begun to convert the home connections to pipe type construction, but the sewers still discharged into the wadi nearby.

In 1977 a major sewerage project was begun in Salt. The network program was for the elimination of the old stone conduits in favor of sewer pipes. The collection system has been divided into three areas. The first area will be completed in late 1980. Meanwhile, a major percentage of dwelling units and other buildings are connected to the treatment plant, even if it is via the old stone conduits. When the network program is completed, about 2100 house connections will have pipe facilities throughout, serving a population of over 30,000 people. The program of conversion should be complete in early 1981. The conversion also is systematically eliminating storm water connections such as roof drains.

SALT WASTEWATER TREATMENT PLANT

The existing Salt treatment plant was placed into operation in early 1980. The plant was designed to serve an equivalent population of 50,000 people. The design criteria for the plant are presented below:

	FLOW		BOD_5	
Stage	Avg. (m^3/day)	Peak (m^3/hr)	Avg. (kg/day)	Peak (kg/hr)
I	2,442	184	2,664 (1090 mg/l)	200.6
II	3,510	263	3,240 (923 mg/l)	242.7

The average daily flow reaching the plant so far has been about 630 cu m/day. The wastewater is mainly domestic in nature except for the industrial waste generated at the pharmaceutical factory in Salt and the wasted oil and grease discharged in the collection system from gas stations and garages.

Since the plant only started in April 1980, limited data are available on the plant's performance. A 24-hr composite sample showed the influent and effluent BOD_5 to be 435 mg/l and 15 mg/l respetively, a 97% removal. It should be noted that the plant is being operated at approximately one-quarter of its design capacity. The plant has been reliable. The main problem has been the peak storm flows which have to be bypassed to the wadi during wet weather conditions. It is anticipated that this problem will be improved when the new collection systems is completely constructed by 1981.

The treatment units of the Salt plant are:

- bar screen
- twin horizontal flow grit chambers
- extended aeration activated sludge
- secondary clarification
- chlorination
- gravity sludge thickening
- sludge drying beds

The flow enters the plant by a gravity sewer. Flow first passes through an automatically backraked bar screen actuated by a float. The screening material is collected manually on a daily basis and disposed of on site as the volume of material is small.

The flow next passes through twin horizontal grit chambers. These chambers have a rectangular section and are provided with manually removable grit trays. The water surface elevation is controlled by downstream Sutro weirs. The two grit chambers are alternated on a daily basis. The collected grit is disposed of on the plant site.

There is no primary sedimentation. The screened and degritted wastewater goes directly to earthen embankment aeration basins. The design parameters for this and the remaining wastewater treatment process are presented in Table 6-6. The aerators have two speeds and are currently run 45 minutes of the hour at low speed and the remaining fifteen minutes at high speed.

The flow next proceeds to a single peripheral feed circular clarifier. Sludge is drawn off the clarifier by gravity and conveyed to twin screw pumps which are located by the aeration basin. These pumps are used to return the sludge to the clarifiers and to proportion sludge wasting.

The secondary effluent passes through a serpentine, three-pass chlorine contact chamber. The water level is controlled by a V-notch weir. The chlorine is in the

form of calcium hypochlorite. The plant operators periodically make up a batch of the concentrated chemical and pump it at a constant rate to the chlorine contact chamber. The chlorine dose is not flow-proportional. It is estimated that the dose is 5 to 7 mg/l.

The plant is provided with an emergency power generation facility with a capacity of 420 kw. The current electrical load is 380 kva (approximately 300 KW); therefore, it is possible to run the entire plant during a power failure.

TABLE 6-6

DESIGN PARAMETERS FOR WASTEWATER TREATMENT PROCESSES AT SALT

Aeration Basin	
Dimensions	59 m x 39 m x 4.5 m
Volume	8400 cu m
Type	Earthen embankment
Number aerators	6
Size	30/45 kw
Type	2 speed
Sedimentation Tank	
Number	1
Diameter	17.0 m
Sidewater Depth	2.5 m
Area	227 sq m
Volume	567 cu m
Chlorine Contact Tank	
Dimensions	6.70 x 10 ± x 2.60 m
Detention Time at 3,510 m^3/day	70 min.
Type	3 pass, serpentine

Based on the units dimensions cited in Table 6-6 the operating parameters for present and design flows are as follows.

	Present Flow (630 m^3/day)	Stage I Design Flow (2442 mg^3/day)
Aeration Tank		
Detention time, hr	320 (13.3 days)	83 (3.43 days)

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	Present Flow (630 m^3/day)	Stage I Design Flow (2442 mg^3/day)
Secondary Clarifier		
Detention time, hr	21.9	5.7
Surface loading, m^3/m^2/day	2.8	10.8

It is obvious that the plant is oversized for the present and expected near future flows. The detention time in the aeration tanks is 13.3 days under present flow conditions and 3.43 days under Stage I flows. Electrical consumption in the aeration tanks could be cut down by almost 90 percent and 62 percent for the two flow conditions had the tanks been sized for a one day detention time. Under the present flow conditions, a savings of over JD 3,500 a month can be attained from the reduction of electrical consumption.

The secondary clarifier is also oversized, however, the oversizing of the tank is not as critical as the fact that there is only one tank. A malfunction or a breakdown of the equipment in the tank would result in a complete shutdown of the plant.

To improve on the present c[illegible] the following is required, taking into consideration minimizing the cost of [illegible]vation.

- Run the aerators at low speed at all time.
- A partition wall dividing the aeration basin into 1/3 - 2/3 the size should be constructed. The 1/3 portion will be used for now and until the flow is high enough to justify using the larger portion of the basin.
- Construct a new sedimentation tank about 12 meters in diameter. The present larger tank will be used as a backup in case of a breakdown.

Sludge Management

The waste sludge produced in th extended aeration process is pumped to a gravity thickener. The thickened sludge is pumped then to the drying beds while the supernatant flows by gravity to the aeration basin. The dimensions of the sludge handling units are given below:

Gravity Sludge Thickener

Diameter	5 m
Sidewater depth	4 m
Cone depth	3.5 m
Area	19.6 sq m

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Sludge Drying Beds

Dimensions (overall)	70 m x 37 m
Number	20
Area (total)	2550 sq m

The recommended loading rates for gravity thickeners are in the range of 60 to 100 kg/m^2 day. On this basis the capacity of the Salt gravity thickener is estimated to be around 1600 kg/day. The estimated sludge quantities for the years 1990 and 2000 are presented below:

Mean cell retention time = 15 days

Year	Sludge Production	Sludge Production 3% solids	Sludge Production 4% solids	Sludge Drying Beds Required Area 3% solids	Sludge Drying Beds Required Area 4% solids
1990	1151 kg/day	38 cu m/day	28 cu m/day	2660 sq m	1960 sq m
2000	1427 kg/day	48 cu m/day	36 cu m/day	3360 sq	2520 sq m
		Mean cell retention time = 30 days			
1990	781 kg/day	26 cu m/day	19.5 cu m/day	1820 sq m	1365 sq m
2000	969 kg/day	32 cu m/day	24 cu m/day	2240 sq m	1680 sq m

From above it appears that the sludge thickener has the capacity to meet the future requirements; however, due to the nature of the waste activated sludge which tend to float rather than settle, a flotation thickener would have better removal efficiencies.

Similar analysis shows that the existing sludge drying beds are adequate to handle future loads.

The plant effluent is discharged to the wadi nearby. It flows for about four kilometers partly through irrigation land before it disappears entirely into the ground. The effluent, although chlorinated, poses a public health hazard. The effluent should either be piped past the inhabited area to minimize public contact or be treated to a higher quality and chlorinated to render it safe in case of contact with the public.

Electrical Facilities

The plant receives electrical service at 220/380V, 3-phase, 4-wire, 50 hertz from a transformer which is owned and operated by Jordan Electricity Company, Ltd. A standby diesel-engine/generator unit by Cummins/DCA Fermont Division, rated at 420 KW, 1500 RPM, 220/380V, is at the plant to provide standby power for the entire load. Starting of the unit, power transfer/retransfer, and stopping is fully

automtic upon power failure. The main switchboard and motor control center is switch and fuse type, however, in contrast to the switchboards at Ain Ghazal, the switches and fuses are dead front. This provides safe conditions for disconnecting circuits and replacing of fuses. The switchboard is a product of BS TEKNIK (Bruun & Sorenson A/S Industrial Division) Denmark.

The electrical system at the plant has a capacity of 525 KVA. Present total connected load is approximately 330KW or 380 KVA (@ assumed P.F. of 0.87). On September 27, 1980, during the testing of the standby engine-generator the following readings at the instrument panel were observed:

Output Voltage	:	380V
Current	:	ØR 240A ØS 220A ØT 300A
Frequency	:	50 Hz

These figures indicate a plant demand load of 166 KVA. All major equipment was running during the test including the 6 aerators at high speed. Therefore the electrical load for the plant can be practically doubled in the future without overloading.

The outdoor underground distribution system consists of multiconductor cables (4 cond. 3 Ø+grnd. for power) installed in a trench with a sand bed, a concrete or brick tile layer over the sand, and earthfill above.

The plant electrical equipment controls allow basically unmanned automatic operation except for a few points where manual override is required. No on-line instrumentation is installed. A portable D.O. unit (Kent EIL No. 1520) is used to test D.O. in the aeration tank once every two or three days. If the D.O. level in the tank is low the plant operator switches the aerators to continuous high speed operation.

KING HUSSEIN MEDICAL CENTER SYSTEM

The King Hussein Medical Center, KHMC, is currently served by its own collection system and sewage treatment plant. The present load to the plant is from a 560 bed hospital facility plus 1600 staff, out-patients, a nursing college and the housing area for the medical staff.

The five-year plan for KHMC will see completion of two centers presently under construction: (a) rehabilitation center and (b) cardiac center. Originally it was planned that each would have its own sewage treatment plant, but it was then decided to have a single plant for the entire complex. The new plant will be on stream by the end of 1981 in order to accommodate the new facilities which it will serve.

KHMC TREATMENT PLANT

The existing plant is fed by two outfall sewers from the hospital and housing area which meet at the headworks. The headwork comprises a manually cleaned bar screen and an in-line grinder (out of action) followed by a Parshall flume (whose flow meter was also out of action). Secondary treatment of the wastewater uses activated sludge process followed by chlorination. The dimensions of the existing treatment units, the design criteria and operating parameters are presented in Table 6-7.

The plant was designed to be an extended aeration plant but with almost doubling the flow treated, the plant is operated now as a conventional activated sludge. Although the effluent should be equally of high quality, the sludge in the conventional activated sludge mode does not get digested and stabilized, resulting in potential odor problems. The secondary clarifiers are underloaded as can be seen from Table 6-7. The hydraulic surface loading rate falls within the recommended range of 8-16 $m^3/^2$/day. The high detention time, 5.1 hours, in the clarifiers coupled with inadequate sludge removal could very well be the reason for the high suspended solids in the effluent.

The sludge is applied to the drying beds for a depth of about 2 feet. Underdrainage is pumped back to the plant headworks. Dried sludge is scraped up and stockpiled.

The chlorinated effluent flows to a concrete storage tank whence some of the flow is used for irrigation of green areas in the vicinity of the KHMC. Most of the effluent overflows to the wadi below leading to Wadi es Sir. Residents of the town have complained that their water supply is being contaminated by the plant effluent. The installation of the new treatment plant, although it may improve the effluent quality, will not alleviate the potential for groundwater contamination. The effluent will have to be diverted away from Wadi es Sir area entirely or piped past the groundwater aquifer. The performance specifications for the new plant are:

PERFORMANCE SPECIFICATION FOR KHMC PROPOSED TREATMENT PLANT

Average Design Flow	1500 m^3/day
Peak Flow	150 m^3/hr
BOD Loading	400 kg/day (111 mg/l)
Effluent BOD	20 mg/l (82% removal)
Suspended Solids	6 mg/l (95% removal)

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TABLE 6-7

DESIGN CRITERIA

KHMC SEWAGE TREATMENT PLANT

Design Flow	450 cu m/day
Present Flow	800 cu m/day
Influent BOD_5	100 - 300 mg/l
Effluent BOD_5	20 - 40 mg/l
Aeration Basins	
Number	2
Dimensions (each)	7.3 x 7.3 x 3.6 m
Sidewater Depth	2.8 m
Volume (total)	300 cu m
Detention time	
At Design Flows	16 hr.
At Present Flows	9 hr.
Aerators	
Number	2
Size	5 hp
Secondary Clarifiers	
Number	2
Dimensions	5.5 x 5.5 x 3.6 m
Sidewater Depth	2.8 m
Surface Area (total)	60.5 sq m
Surface Loading	13 m^3/sw m/day
Detention time (at present flow)	5.1 hr
Chlorination	
Chlorine contact tank	1
Feeding rate	30 mg/l
Sludge Drying Beds	
Number	4
Dimensions (total)	6.0 x 7.8 m

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The plant is operated by AWSA personnel under a special contract.

ARMY INSTALLATIONS

The Royal Jordanian Army maintains many camps, barracks, and other military installations throughout the Greater Amman Area. While some of these are located within Amman and are provided with sewerage service, most are located in rural or otherwise unsewered areas and have their own sewage disposal systems.

Because these Army installations represent a potential concentration of population, an attempt was made to determine the specifics of population, location, and existing and planned sewage disposal facilities in order to accomodate such systems into the Master Plan, as appropriate. It was thought that as the Greater Amman Area develops and grows, there would be some cases where it would be logical for such military installations to join with the municipal systems for wastewater disposal.

For security reasons, the information was not readily available. Accordingly, it was not possible to include specific provisions for such installations in the Master Plan. However, during the design phase, provisions for wastewater disposal of military bases may be incorporated if warranted.

EXISTING CESSPOOL SYSTEMS

As discussed earlier, the Municipality of Amman, the Municipality of Salt, and the King Hussein Medical Center are the only entities that operate wastewater plants within the Study Area.

At present, both AWSA and Salt serve only 40 percent of their constituent populations, while KHMC is entirely served but is relatively small in comparison with many communities. Zarqa, the second largest municipality in the Study Area is unsewered, although plans will soon be drawn for sewerage facilities for both Zarqa and Ruseifa, including the intervening industrial area. For the time being, however, the great bulk of the Study Area's wastewater is being discharged into the underground via cesspool systems.

MAGNITUDE AND AREAL DISTRIBUTION OF SEPTAGE DISCHARGES

Cesspool installation contributions to the underground from major communities have been estimated for current conditions, and the approximate values are presented in Table 6-8. These discharges are of great concern because of potential impacts upon the underlying groundwater.

The relative potential impact of septage discharges from the several major communities upon the underlying groundwater basins is illustrated in Figure 6-3. The proposed groundwater protection area is indicated in order to show the relationship of the various communities to groundwater areas potentially vulnerable to pollution from wastes discharges. No attempt is made to differentiate between recharge areas of differing aquifers. Rather, all areas

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TABLE 6-8

APPROXIMATION OF CURRENT MAJOR CESSPOOL DISCHARGES INTO THE UNDERGROUND[a]

Population Area	Pop'n[b] 1,000	Wastewater Prod'n[c] lcd	MCM/yr	Septage Undergr'd[d] MCM/yr	Relative Area, km^2[e]	Relative Load	Areal Septage m/yr[f]
Amman (Total)	649	75	18	—	120		—
Amman (Unsew'd)	400	75	11	11	120		0.090
Zarqa	216	63	5	5	450		0.011
Ruseifa	50	50	0.9	0.9	200		0.005
Schneller Camp	24	50	0.4	0.4	120		0.004
Suburban Ring	16	75	0.4	0.4	120	(Same as Amman)	0.003
Suweileh	21	65	0.5	0.5	70		0.007
Wadi es Sir	25	65	0.6	0.6	140		0.004
Baqa'a Camp	45	50	0.8	0.8	340		0.002
Na'ur	5	50	0.9	0.9	210		0.0004
Sahab	12	50	0.2	0.2	170		0.001
Salt (before sewers)	33	50	0.6	0.6	180		0.003

[a] Avg. 1979 conditions are assumed. All septage numbers are approximate and rounded off. All wastewater values are related to population centers even though some industrial locations may be located apart from such centers.

[b] From 1979 census data.

[c] For all areas, per capita wastewater production numbers (lcd) are from Chapter 5 data. Annual discharges are computed from per capita flows and 1979 populations. Discharges of industrial wastes are assumed included in the wastewater production. Watson-Hauksley-ERL[3] estimated the annual cesspool recharge of the shallow aquifer underlying the Amman-Zarqa Basin as 28 MCM/yr.

[d] A relatively small amount of septage is disposed of via tankers to AGTP and other dumping points. For example the AGTP septage dumping is estimated in Table 5-2 as 610 m^3/da or 0.22 MCM/yr and by Watson-Hauksley-ERL[3] as 525 m^3/da or 0.2 MCM/yr. The septage surface dumping elsewhere is unknown but is probably less than the AGTP value. Therefore, no specific adjustment of the figures to recognize sewer or surface dumping is made.

[e] Relative area is estimated as the area of influence of the population area over the aquifer or recharge area below based on Thiess Polygons and including only the Study Area and proposed groundwater protection area.

[f] Annual quantity of septage underground divided by relative area. A theoretical, "apparent" number used, in this illustration, to give a rough comparison of the potential impacts of the various population areas. Hydrogeologic complexities are ignored in this illustration.

of groundwater recharge or overlying groundwater are treated impartially.

In Table 6-8, the so-called "Relative Area" of each major community is taken as the Theiss Polygon-determined territory in which the community is centered, the areas being confined within the Greater Amman Area (30-km radius) and the proposed groundwater protection area. When the annual septage discharge of the community is divided by the "relative area" an annual downward movement of septage is determined. This is a theoretical, apparent value which assumes that the entire relative area is uniformly affected by the septage rather than just the immediate area underlying the various cesspools of the community. Despite the artificial nature of this parameter, it does form a ready basis for roughly comparing the potential septage impact of the various communities on the groundwater. As expected, the largest urban areas not only have the greatest output of septage but often have limited "relative areas" because they tend to be clustered. Thus, the large unsewered urban areas normally have the greatest impact, as expected.

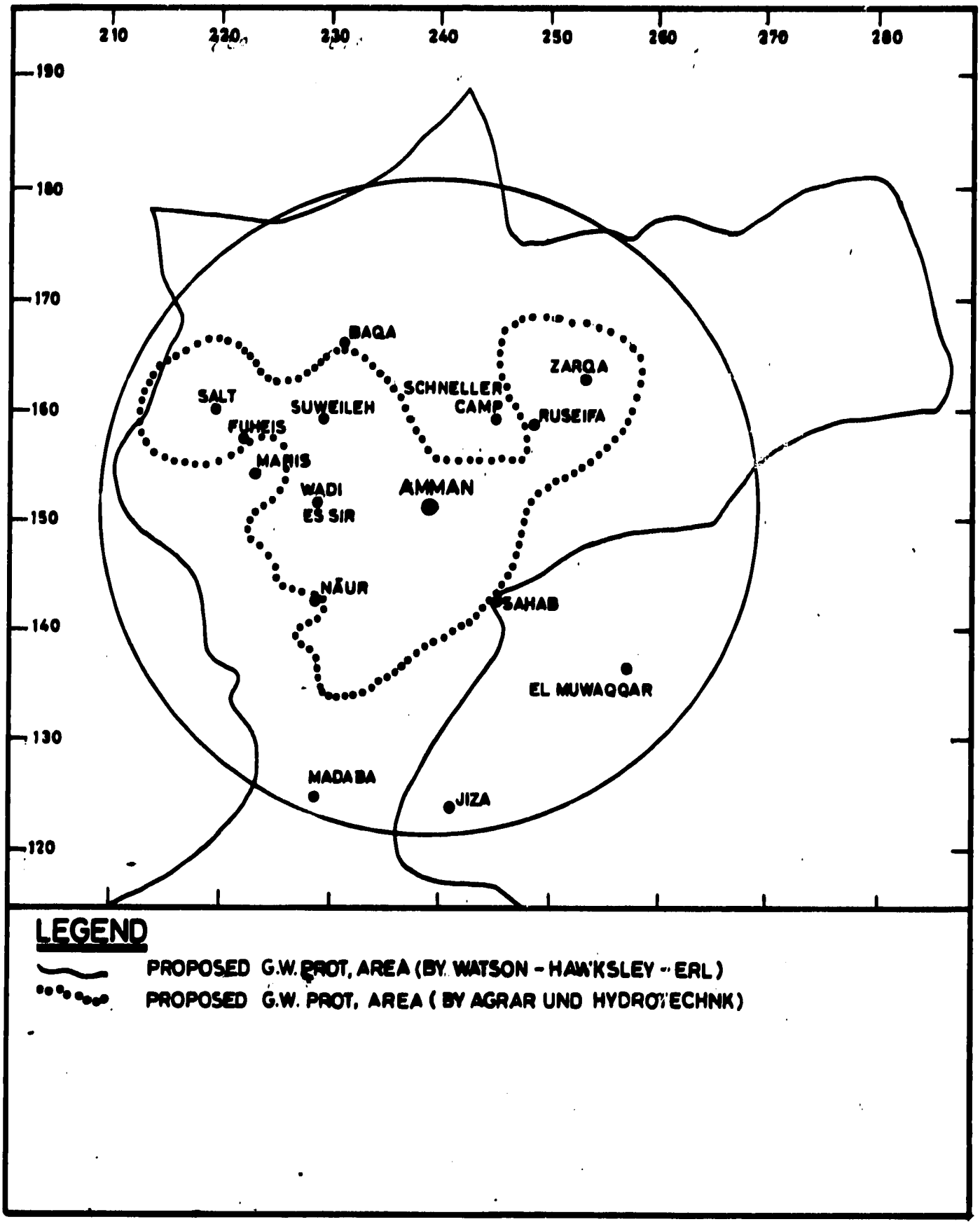
OPERATIONAL DIFFICULTIES WITH CESSPOOL INSTALLATIONS

Cesspool installations have experienced operational difficulties in many communities of the Greater Amman Area. In order to obtain some current assessment of these and other conditions in the area, a special Community Sanitation Reconnaissance was conducted for 29 municipalities, towns, villages, and refugee camps within the area (Appendix F). This reconnaissance was rather subjective, depending upon the judgment of the interviewer and the local respresentative interviewed, but the results appear to be realistic in the light of general knowledge of the area as well as observations made by the field personnel when determining possible routings for future sanitary sewers.

The Community Sanitation Reconnaissance is summarized in Appendix F. This summarizes data relevant to subsurface sewage disposal conditions. Despite their subjective nature the data serve to indicate the general magnitude of the problem of on-site sewage disposal within many of the unsewered communities of the Study Area. The general impression of the data is that the problem of subsurface sewage disposal is already manifested in the majority of the communities to at least a moderate extent and that in many cases, the outlook is increasingly unfavorable. A substantial population is already affected. The problem is in the form of cesspools which already overflow or else require inordinately frequent pumpouts to prevent such conditions. Obviously, there are associated social and health aspects of the problem, and these are dealt with in Chapters 3 and 4, respectively.

ENGINEERING CONSIDERATIONS OF SUBSURFACE SEWAGE DISPOSAL

Cesspools have been customarily employed for subsurface disposal of sanitary waste in Jordan. The success or failure of this practice varies from area to area, even from building lot to building lot, depending upon the adequacy of the facilities vis-a-vis the loads they receive and, particularly, upon the absorptive capacity of the substrata. Table F-1 in Appendix F provides certain general information as to the incidence of subsurface sewage disposal difficulties within



MAJOR POPULATION CENTERS IN RELATION TO PROPOSED GROUNDWATER PROTECTION AREA

FIGURE 6 - 3

the various municipalities of the Greater Amman Area. Steep slopes, rocky or otherwise nonporous soils, and crowding of houses one upon another, all make for frequent cesspool pumpouts or overflows.

The physical facilities typically used for residential (and other) subsurface sewage disposal are depicted in Figure 6-4. They consist of a vented sewer pipe inlet to an extremely small septic tank or simply a "trap," a run of connecting sewer, and a shallow, open bottom, rectangular shaft with rubble concrete walls, perforated on one or more sides and surrounded by native soil. This information also includes typical dimensions for three general size categories and estimated late 1980 construction cost estimates for same. As might be expected, it is more common for the larger installations to be found on the premises of the more affluent and the smaller installations on the properties of lower income persons.

These same economic factors also favor the higher income groups residing in larger buildings located on larger building lots than occupied by the lower income group. Zoning regulations of Amman Municipality are the standard elsewhere as well. They are used throughout other municipalities and even villages of Jordan and are administered by the ministry of Municipal and Rural Affairs and the Environment. Smaller lots would be expected to entail increased frequency of septage pumping or overflowing, for the unit loadings of the installations are likely to be greater than for those on larger lots.

However, disposal difficulties may be more influenced by subsurface soil conditions. Even so, it is expected that costs for cesspool maintenance are disproportionately higher for very small lots and installations than for larger lots and installations. For that reason, certain additional consideration is given to cesspool installations on different size building lots.

For example, it may be noted that for the largest lots considered (Zone A), cesspools may be located closer to a property line than may the building itself, while in the smallest lots (Zone D) the reverse is true. Due to high land costs and needs for housing, it apparently is common to utilize the available lot to the utmost, particularly in the lower (smaller lot) zone. This frequently results in cesspools being in fairly close proximity to the building in such zones. There are currently no standards for construction for such installations; the only controls extant are the minimum separation distances from property lines. The combination of limited funds and small building lots often results in a clustering of undersized cesspool installations in certain residential areas, with little opportunity to enlarge them or alternate the leaching facilities with standby ones. The consequence is a need for frequent pumpouts, particularly where soil conditions are unfavorable for seepage. The smaller lots (Zone C) allow for relatively little latitude in locating and constructing subsurface disposal systems. Zone D conditions are even more restrictive.

FUTURE OUTLOOK FOR CESSPOOL SYSTEMS

Although the investigation did not cover the matter of cesspool installations and their future outlook in great detail, some general observations appear warranted:

- Some cesspool installations, operating in favorable soils conditions, may function many years and require only infrequent pumpout. Other installations will require more frequent pumpout, and for some the frequency will increase with the passage of time. It is possible also that some installations will fail completely after a relatively short time, and correction of the conditions will be difficult, virtually impossible in isolated cases.

- Sewering of some areas may be found to be the best solution from several standpoints, including public health, general sanitation, and (depending upon subsidies) even economic.

- Because of groundwater pollution, there should be an emphasis on sewering the urban areas of concentrated population. Private subsurface sewage disposal is normally practiced for an interim period until such time as urban infill makes sewering economic or until other conditions require sewering.

- Within AWSA, it appears likely that there will continue to be a substantial unsewered population for several years. By 1990 there will probably still be about 20 percent of the population of Amman unconnected to sanitary sewers and thus practicing subsurface disposal. This could be as many as 214,000 persons still served by cesspool installations as compared to a 1980 estimate of unsewered population of about 400,000 persons in Amman alone. If sewers are not extended beyond Amman, there would be several hundred thousand persons contributing to septage discharges to the underground from these areas.

If there were to be no additional sewerage facilities in the Greater Amman Area beyond those already programmed for AWSA, Salt, and Zarqa/Ruseifa, the septage production and cesspool loadings would be approximately as shown in Table 6-9.

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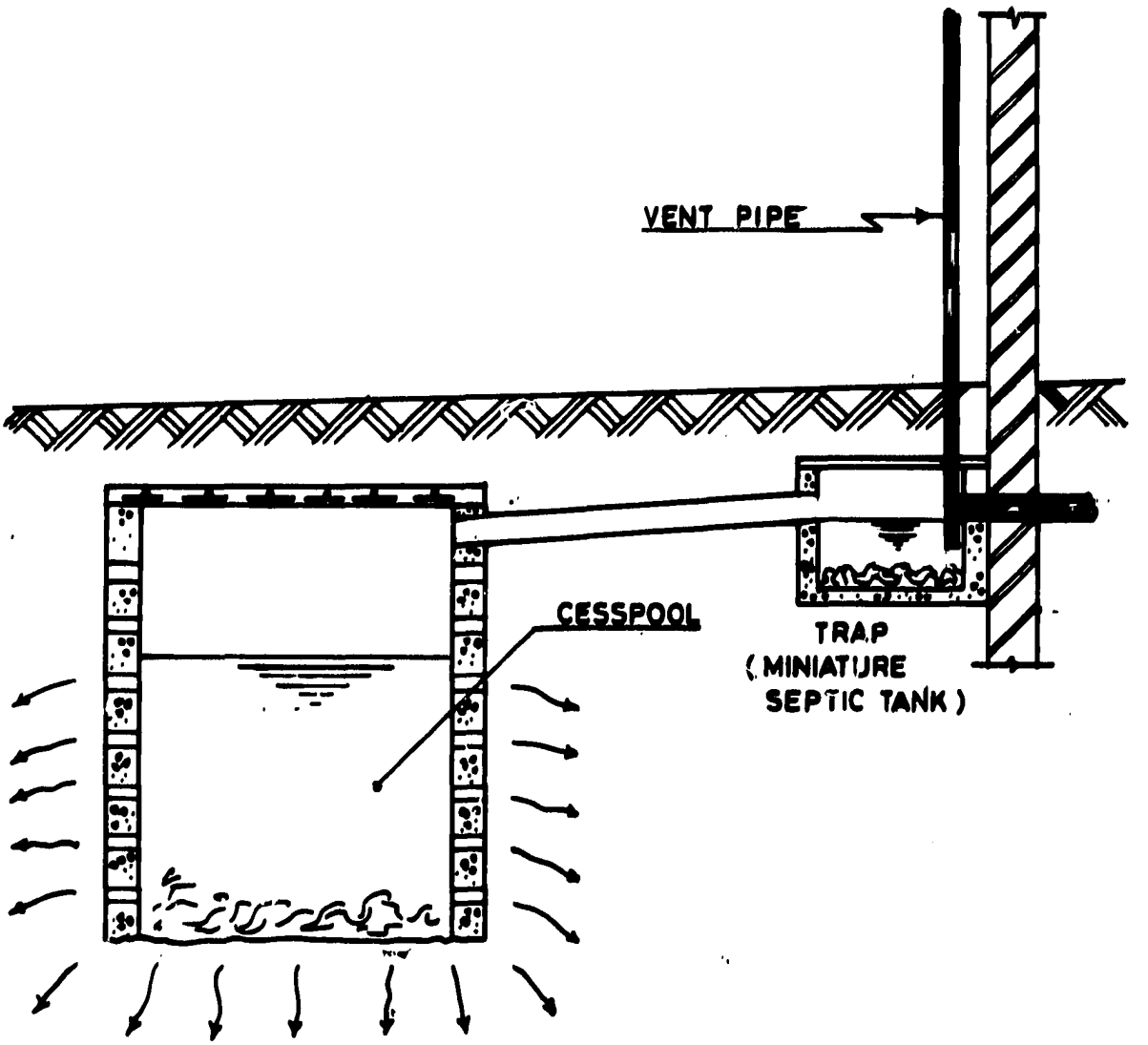

SCHEMATIC PROFILE-NO SCALE

ITEM	SMALL	AVERAGE	LARGE
L x W x D (METERS)			
TRAP	0.4 x 0.4 x 0.5	1 x 1 x 0.6	2 x 2 x 1
CESSPOOL	3 x 2 x 3	3 x 3 x 3	6 x 4 x 3
CONSTRUCTION COST, JD, 1980	370	500	1,150

PROFILE DATA ON RESIDENTIAL SUBSURFACE SEWAGE DISPOSAL SYSTEMS

FIGURE 6 - 4

TABLE 6-9

PROJECTED SEPTAGE PRODUCTION FROM MAJOR COMMUNITIES IF NO UNPROGRAMMED SEWERAGE FACILITIES WERE TO BE BUILT[a]

Population Area[b]	1990 Pop'n 1,000	1990 Septage lcd	1990 Prod'n MCM/yr	2000 Pop'n 1,000	2000 Septage lcd	2000 Prod'n MCM/yr
Amman (Total)	1,020	85	-	1,305	95	-
Amman (Unsewered)	214	85	6.64	196	95	1.81
Zarqa (Total)	295	72	-	421	80	-
Zarqa (Unsewered)	103	72	2.71	118	80	3.44
Ruseifa (Total)	91	63	-	125	71	-
Ruseifa (Unsewered)	32	63	0.73	35	71	0.91
Schneller Camp	24	60	0.53	24	70	0.61
Suburban Ring	92	75	2.52	285	85	8.84
Suweileh	31	60	0.68	44	70	1.12
Wadi es Sir	39	75	1.07	62	85	1.92
Baqa'a Camp	45	60	0.99	45	70	1.15
Na'ur	7	60	0.15	10	70	0.26
Sahab	17	60	0.37	24	70	0.61
Salt (Total)	47	60	-	66	70	-
Salt (Unsewered)	5	60	0.10	1	70	0.03

a Basic populations and per capita wastewater production in liters per capita per day (lcd) are from Table 5-6.

b It is assumed for the purposes of this illustration that the percentages of populations sewered in the future will be:

Municipality	1990	2000
Amman	79	96
Zarqa	65	72
Ruseifa	65	72
Salt	90	98

LIST OF REFERENCES

CHAPTER 6. APPRAISAL OF EXISTING WASTEWATER FACILITIES

1. VBB, "Feasibility Study and Master Plan for Amman Water and Sewage Works, Final Report, July 1972.

2. VBB-Fawzi & Associates, "Feasibility Study for Amman Water Supply and Sewerage Facilities," Final Report November 1977.

3. Watson Hawksley - ERL in association with Middle East Engineering Services, "Solid Waste Management and Disposal System for the Greater Amman Region, Feasibility Study, Interim Report," June 1979.

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CHAPTER 7

CONSERVATION AND MANAGEMENT OF RESOURCES

Development of the wastewater disposal master plan must consider relevant aspects of various natural resources of the Greater Amman Area, particularly water resources. Accordingly, this chapter discusses current arrangements for water resources management, water resources inventories and development plans, water pollution control arrangements, and water quality conditions. Water reclamation and reuse regulations, criteria, and potentials are discussed relative to possible applications within the Greater Amman Area. Treatment plant effluent discharges into wadis leading to the Jordan Valley are considered with respect to seasonal irrigation demand in the Jordan Valley and for possible influence upon the Master Plan for Wastewater Disposal. Brief summary information is presented on land resources and upon energy with respect to the Master Plan. This then helps set the stage for the Environmental Assessment presented in Chapter 9.

WATER RESOURCES

It is a well established fact that Jordan, including the Greater Amman Area, is water-deficient. This matter is of direct relevance to this Master Plan for Wastewater Disposal, for the manner in which the wastewater treatment plant effluents are disposed of and/or reused has a bearing upon the quantity, quality and ready availability of water for the various localities within the Area.

CURRENT ARRANGEMENTS FOR WATER RESOURCES MANAGEMENT

During Jordan's National Water Symposium, (March 1978) several important papers were presented which bore upon the conservation and management of resources. Among these was a review of present legislation and institutions involved in the water affairs in Jordan, with special stress on the major deficiencies and constraints of each.[1] It was pointed out that the water affairs on the regional and/or national level in Jordan were managed by four major institutions:

(1) The Natural Resources Authority (NRA)
(2) The Water Supply Corporation (WSC)
(3) The Jordan Valley Authority (JVA)
(4) The Amman Water and Sewerage Authority (AWSA)

Table 7-1 summarizes briefly the roles of these four key agencies in water resources management, including wastewater (sewage) matters, as described in the paper.[1]

It was noted that none of the four agencies listed in Table 7-1 was legally in charge of formulating and processing national water policy nor in overall control

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TABLE 7-1

SUMMARY OF FUNCTIONS OF MAJOR AGENCIES IN WATER RESOURCES MANAGEMENT[a]

Item	NRA	WRC	JVA	AMSA
Area of responsibility	Above 300m, MSL	Entire Kingdom, but does not actually operate within AMSA	Up to 300 m, MSL (includes Jordan Valley)	Amman Municipality
Water Resources Studies	Hydrological and hydrogeological data collection	Water needs of cities, villages, tribes, Bedouins groups and other civil and military installations	Hydrological, hydrogeological, geological	Establish local water basin boundaries. Determine future water needs of AMSA's population
Planning	Irrigation projects in the Plateau and Desert. Earth dams for irrigation and groundwater recharge in Plateau	Water supply policies for promotion of health and the environment (subject to Cabinet approval.) In cooperation with Ministry of Health, plan for distribution of potable supply	Domestic and irrigation projects, hydropower stations, wells, pumping stations, reservoirs, transmission and distribution systems	Facilities required for service to its population
Management	License and control private water wells, water rigs, and rig operators	Facilities management	Settle water rights disputes. Direct construction of private wells	Facilities management. Protect supply from pollution. Limit and restrict water use. Protect the Water Basin and Recharge Areas (with approval of MRAE and NRA)
Facilities	Drill exploratory and production wells for public use. Design, construct, operate, and maintain planned projects	Design, construct, operate, and maintain pumping transmission and (wholesale) distribution works, including tank trucks	Design, construct, operate and maintain planned projects	Design, construct, operate, and maintain planned facilities
Drainage		Plan and implement facilities for drainage, including flood water	Plan and implement facilities for both surface and subsurface drainage	Plan and implement facilities for surface water drainage, including storm water

TABLE 7-1 (Cont'd)

Item	NRA	WSC	JVA	AWSA
Sewage Facilities	---	Plan, design, construct, operate and maintain collection, treatment, and disposal works. (at present King Hussein Medical Center facilities are operated by AWSA under an agreement)	---	Plan, design, construct, operate and maintain collection, treatment and disposal works. (At present Ain Ghazal Treatment Plant is sole AWSA plant.)

[a]Information primarily derived from Himry, Y. F., "Present Water Legislation and Institutional Framework in Jordan," a paper presented at Jordan's National Water Symposium, 19-22 March, 1978, Amman, Jordan (Reference 1.)

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of the national water resources and data acquisition required for policy formulation and administration. The paper observed that there was a lack of a central coordinating agency for water policies, data acquisition, and water resources and that the four agencies were generally independent of each other.[1] It was felt that this situation would become more difficult as the current trend was to force development plans into regional packages in Amman, Irbid, Aqaba and other regions along the same line as was being implemented in the Jordan Valley. Thus, without a national approach, there would be conflicting interests and possibly conflicting decisions might be made without the decision makers having the means to define priorities and allocate water resources properly.

The paper recounted Governmental recognition of the situation by inclusion of a national water master plan and a water resources policy as one of the major objectives of the 1976-80 Five Year Plan for Economic and Social Development. The paper noted the completion by Agrar and Hydrotechnik of a National Water Master Plan[2] and presentation of an earlier paper which summarized the works of this major planning effort.[3] The Nimry paper[1] advocated establishment of a water board capable of processing and formulating the water budget and policy for the Kingdom and having means to conduct water studies and investigation. It also favored a "Water Act" which would supersede every other law in matters relating to the allocation and control of water resources and would require that any party, public or private, obtain a license or permit from such water board prior to constructing dams, drilling wells, or utilizing water resources where such might impact the water balance of the country. Other recommendations included maintenance of water meters and consumption records and prohibition of any public agency licensing any new industrial, urban, or agricultural product that requires water in any part of the country without the approval of the board.

It is understood that consideration has been given to the recommendations regarding a National Water and Sewerage Authority and a committee comprising representatives from AWSA, WSC, NRA, JVA, and MMRAE (Ministry of Municipalities, Rural Affairs, and the Environment) has proposed legislation to establish such a National Authority. Within this Authority, the individual major governmental agencies could become departments. The proposal is presently under consideration in the Prime Minister's Office.

WATER RESOURCES INVENTORIES AND DEVELOPMENT PLANS

The water resources inventories and development plans of Jordan in general and North Jordan in particular have been reported upon extensively by others and will not be described herein other than as brief summaries to provide a context for the Master Plan for Wastewater Disposal. [2,3,4,5,6,7,8,9]

Comparison of Supply and Demand

Table 7-2 presents a capsule summary of water resources relevant to the Greater Amman Area. A rough comparison of the yields of the already developed resources listed to the projected water demands for the Area (Table 5-6) indicates the serious nature of the water deficits and the heavy reliance being placed upon

TABLE 7-2

CAPSULE SUMMARY OF WATER RESOURCES RELEVANT TO GREATER AMMAN AREA[a]

Name and Nature of Resource	Location of Resource	Perennial Annual[b] Yield, MCM/yr.	Status of Development	Remarks[c]
Amman-Zarqa Well Field (groundwater)	Underlies Amman, Zarqa and vicinity	25[5]	Heavily used. In 1978 thought to be 30 MCM/yr for municipal (and industrial) supply and 9 MCM/yr for irrigation.[5] Return flows available for reuse as well as extractions equal to annual recharge	Excess production being achieved by mining the deeper (of two) aquifers.[5] Intention is to import water to the area, thereby relieving the annual overdraft.
Qastal Well Field (groundwater)	20 km S. of Amman	5,[5] 7[7]	Used in part to supply Madaba and local villages via WSC	Pipeline being extended to Amman, first deliveries in 1981-82. Present use is less than annual recharge.[8]
Wadi Dhuleil Well Field (groundwater)	40 km NE of Amman	20[5] 9[7] (incl. Sukhneh Spring)	Heavily used for local agriculture plus some municipal use	Much of the yield of Dhuleil "mound" is taken by several high producing wells
Baqa'a Basin (groundwater)	15 km NW of Amman	2,[5] 1[7]	Used by local agriculture, also by local urban areas	Inadequate for area if full-scale irrigation develops.[7]
Azraq Well Field (groundwater)	85 km easterly of Amman	10 - 20[5] 12[7]	Already supplies Azraq & Irbid. Will also be tapped for supply to Amman	Land surrounding Azraq is partly suitable for irrigation.[8] Azraq pipeline to Amman due for completion in late 1980.

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TABLE 7-2 (Cont'd)

Name and Nature of Resource	Location of Resource	Perennial Annual[b] Yield, MCM/yr.	Status of Development	Remarks
King Talal Reservoir (Zarqa River or Seil Zarqa)	30 km NNW of Amman	48[7] for Irrig. 12[7] for Urban, based on current recycling	Live storage is 48 MCM Guaranteed base flow is 18 MCM/yr and mean annual base flow in excess of guaranteed is 15 MCM/yr Direct runoff is 4 MCM/yr[c]	With greater water to Amman and hence, recycling the yield of King Talal would increase.[7] Consideration being given to enlargement of reservoir by raising King Talal Dam. Pipeline studies have already been conducted from King Talal Reservoir to Amman.
East Ghor Main Canal (Yarmouk River plus Seil Zarqa)	About 20 km westerly of Amman	02 MCM/yr	KCMC has been active many years; southerly extension is under construction. Pipeline system to Amman is proposed (via Salt and Suweileh)[7]	In conjunction with direct pipeline from Maqarin Dam will entail diversion or release of 120 MCM/yr from Maqarin, and a net depletion of 60 MCM/yr from the Jordan Valley Irrigation Project.[6]
Maqarin Dam (Yarmouk River)	82 km N of Amman	32 MCM/yr	Proposed. Maqarin Dam not yet constructed.	Differing pipeline alignments studied.[5,6] Recommended route is Irbid-Mafraq-Zarqa.[7] Total Maqarin diversion/release is 120 MCM/yr. 60 MCM/yr net depletions presume return flows of about 50%.[7]
Euphrates River	Iraq	Project still in conceptual stages	Project still in conceptual stages	JVA plans to commission feasibility of study on importation of Euphrates River water to Amman
Wadi Abdoun Reservoir (Wadi Abdoun) (Prince Ali Dam)	- km of Central Amman	3 MCM/yr avg (zero yield in dry years)[7] 1.1 - 1.6 MCM/yr avg., depending upon drawoff rate.[9]	Proposed by NRA. Site below confluence of 3 wadis is favored[8]	Apparently not a high priority because of limited yield. Some small depletion of King Talal Res. yield. Also Wadi Abdoun could aid in groundwater recharge. Could be used as parkland after reservoir bottom seals.[9] Not economical for flood control. Queen Alia Freeway, already under construction, would be partially inundated if the reservoir were to be built.
Kafrein Reservoir	Jordan Valley on Wadi el Kafrein	Not known[5]	Live storage is 4.8 MCM[5]	Used for irrigation.
Sh'Ueib Reservoir	Jordan Valley on Wadi Sh'Ueib	--	Live storage is 4.4 MCM[5]	Used for groundwater recharge.

[a] The major existing or potential supply sources are listed. The data are derived from the references notes. See groundwater discussion.

[b] Yields from groundwater resources are not necessarily additive to surface water resources, inasmuch as groundwater extractions influence yields from surface flows. MCM/yr denotes million cubic meters per year. This is equivalent to 2,747 m^3/da, average rate.

[c] Water rights considerations are not included in this tabulation or in the text. They are of some significance in King Talal Reservoir's yield because of claims of upstream riparian water users. International water rights to the Yarmouk River and Euphrates River may be of great significance in determining yields to Jordan and even project feasibility. It should be noted that great reliance is placed by JVA and its consultants upon recycled sewage treatment plant effluent via the Zeil Zarqa.

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importation of water to the Amman Area (and Zarqa Area) and upon recycling of sewage effluent into the system. This problem has been commented upon widely by various authorities. For example, a recent study projected that by 1987 the water demand in the Amman-Zarqa District would be more than three times the 1977 production and five times the safe yield of sources then used.[5] The study has also compared the estimated domestic and industrial water demand and agricultural water requirements projections for 2002 for four North Jordan Districts (comprising a considerably larger area than Greater Amman Area) with water available to meet these requirements.[5,10] The year 2002 data were as follows:

Item	Value, MCM/yr
Domestic and Industrial (M&I)* Water Demand	289
Agricultural (Ag)* Water Requirements	632
Total Projected Requirement	921 (for all four North Jordan Districts)
* M&I denotes urban, Ag denotes agricultural	
Exploitable Groundwater Resources (Excluding Mining Potential)	74
Estimated Surface Water Resources	683
Total Potential Water Resources	757

It was estimated that if adequate surface storage were provided, it would be possible to utilize about 550 MCM/yr of the 683 MCM/yr of surface resources listed (about 80 percent), the balance being wasted as flood flows.[10]

Regarding recycling and reuse, it has been reported that returns from domestic use normally exceeded 50 percent of supplied water, but returns from industry and agriculture were much less and so were considered negligible in assessments of resources.[5] Some indirect reuse of wastewater has been already occurring, either via groundwater recharge from cesspools or impoundment of surface water at King Talal Reservoir. In general some indirect reuse of wastewater effluent in public water supply occurs with increasing frequency in the heavily populated areas of the world.[10] Nevertheless, direct reuse of reclaimed effluent for potable supplies is ruled out based on the fact that the quality considerations for agricultural reuse of water are less rigorous than those for domestic use.

Of other surface water development potentials, two were within the Greater Amman Area: Zarqa (at Deir Alla) for 67 MCM/yr and Salt-Madaba for 68 MCM/yr. These developments appear to be indefinite and are not considered herein.[5]

Groundwater

Despite certain data limitations, groundwater resources of Jordan have received a major consideration in various studies in recent years.[2,5,7] Table 7-3 presents a

TABLE 7-3

SUMMARY OF PRINCIPAL GROUNDWATER RESOURCES[a] SUITABLE FOR CONSIDERATION AS A SUPPLY

Surface Water Catchment Area[b]	National Water Master Plan[2] Estimates: Available Groundwater MCM/yr	National Water Master Plan[2] Estimates: Stored Groundwater MCM	Water Use Strategy[5] Estimates: Favorable Wellfield Area	Water Use Strategy[5] Estimates: Exploitable Groundwater Resources MCM/yr
Yarmouk	15	600	Sama Sdoud	5 - 10
Azraq*	20	1680	El Azraq[d]	10 - 20
N E Desert	10	50	N E Desert	5
W. Dhuleil*[c]	15	540	Dhuleil	18 - 21
Upper Zarqa*	25	720	Amman-Zarqa	20
Jerash*	17	440	Baqa'a	2.5
Ajlun	18	1700	Small local supplies	
Salt-Madaba*	25	1900	Small local supplies	
Mujib	25	1160	(Qastal	5
			(Qatrana	1.5
			(Siwaqa	1.5
			(Sultani	3.6

(Footnotes)

[a]Stored groundwater is within 150 m of ground surface. Estimates of groundwater resource are associated with the named individual favorable areas and are based on "safe yield." Values quoted include present abstraction. The exploitation of any of these resources is likely to reduce surface baseflow.[5]

[b]Defined in Reference 5, Volume 2. Asterisk denotes at least a portion is within Greater Amman Area.

[c]The estimates made in the present study exceed those of Agrar und Hydrotechnik 1977. Discussed in Reference 5.

[d]Up to 14 MCM/yr could be taken from springflow.

summary of principal groundwater resources suitable for considerations as supply based on two of these studies. Figure 7-1 presents the Amman-Zarqa basin, which is in the Greater Amman-Zarqa basin, and also in the Greater Amman Area.

Groundwater is a very significant portion of the total water resources. Its protection for continued usefulness is most important. Although detailed consideration of the aquifers is beyond the scope of this report, it is of interest to consider generally the recharge of the aquifers and movement of groundwater as they may influence wastewater management alternatives.

Figure 7-2 presents a map of the Greater Amman Area showing approximated groundwater movement and recharge areas.[11] The illustration also considers the Wadi Mujib Groundwater Flowmap for the Amman-Wadi es Sir System[5] and the Water Resources Study Geological Map.[7] It will be noted that considerable recharge area coincides with the urbanized portions of the Study Area for the various aquifers. This is of great concern as regards the discharge of relatively large quantities of cesspool effluent into the underground, most of it of potential impact upon underlying aquifers. In this connection, it would be desirable to reduce recycling of cesspool effluent in the future for the Amman-Zarqa Groundwater Basin and finally eliminate such cycling completely. Presumably, wet year rainfall penetration capture might be enhanced somewhat if there was less septage in the ground. In view of the high proportion of non-consumptive pumpage for domestic, irrigation and industrial purposes in the Upper Zarqa Area, the potential capacity of the upper aquifer could be considerably increased by better management which would include minimizing waste recycling and artificial recharge.[5]

In the Upper Amman Zarqa Area, recharge to the lower aquifer is mainly at the outcrop area northwest of Amman by direct rainfall infiltration.[5] Natural recharge to the upper aquifer takes place by direct infiltration of rainfall in the outcrop areas and to a greater extent by indirect streamflow infiltration through the alluvial deposits.[5] Artificial recharge is via sewage effluent, cesspools, leakage from the water distribution network and return irrigation water.[7]

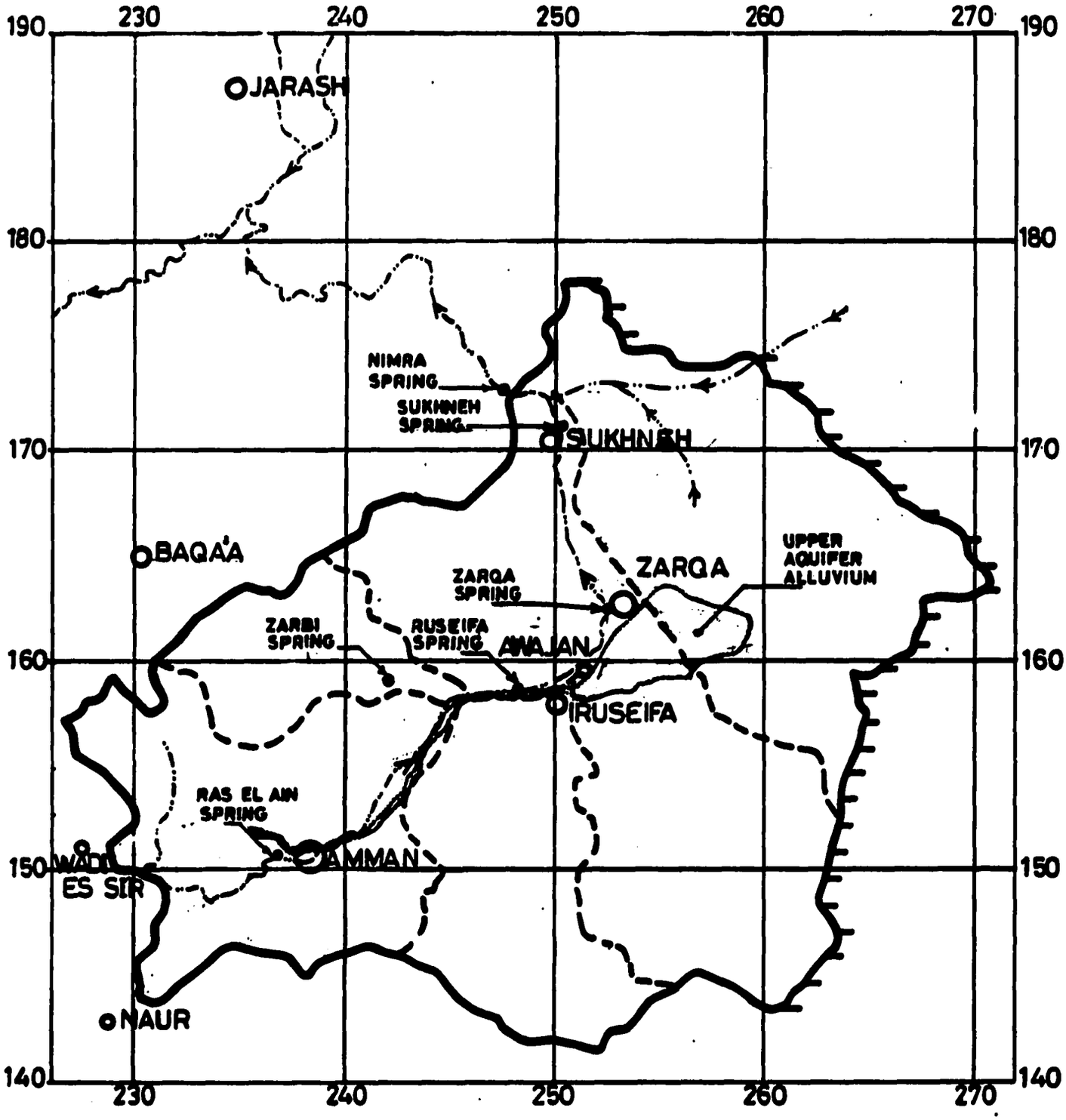
In Baqa'a Area, recharge of the two aquifers (Kurnub and Zarqa) is accomplished by direct infiltration, runoff, and springflow discharging from the Na'ur formation.[5] Baqa'a Valley is an important agricultural area and irrigation returns are a recharge factor.

In the Amman-Wadi es Sir aquifer system in the Wadi Mujib Basin (southerly of Amman) recharge occurs directly by rainfall and indirectly by concentrated surface runoff, return irrigation flow, surface reservoirs, and transfers from other aquifer systems.

CURRENT ARRANGEMENTS FOR WATER POLLUTION CONTROL

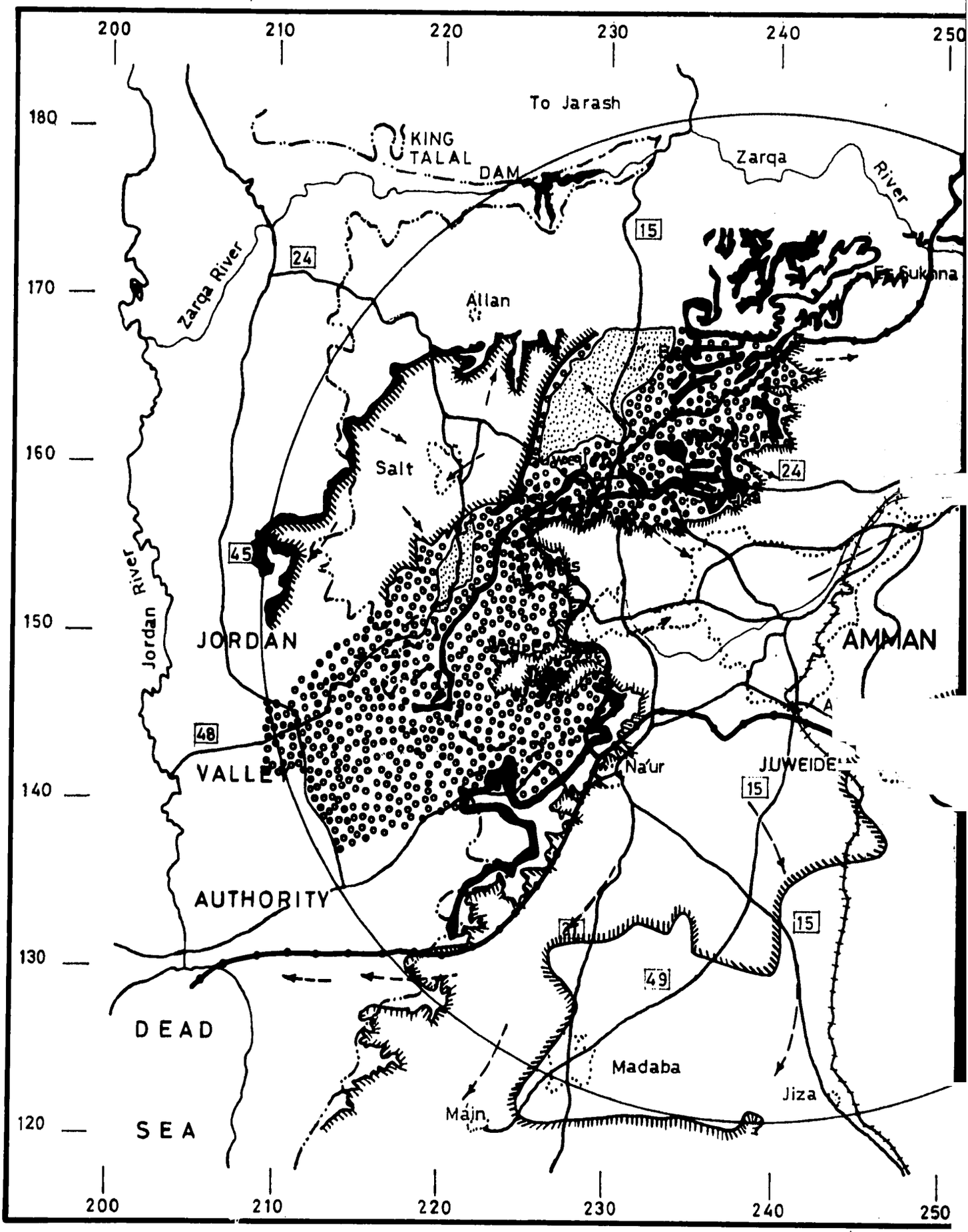
Another important paper presented at Jordan's National Water Symposium considered the current status of potable water pollution in Jordan.[4] The authors stated that Jordan lacked a comprehensive legislation on water pollution and that provisions on pollution were scattered among different laws. Such provisions have contained at least two basic principles: restricted zoning for catchment areas and

1 - UPPER AQUIFER INCLUDES ALLUVIUM, B 1/2 AND A7 FORMATIONS.
2 - LOWER AQUIFER IS A4 FORMATION.



AMMAN-ZARQA GROUNDWATER BASIN

FIGURE 7 - 1


200
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240
250
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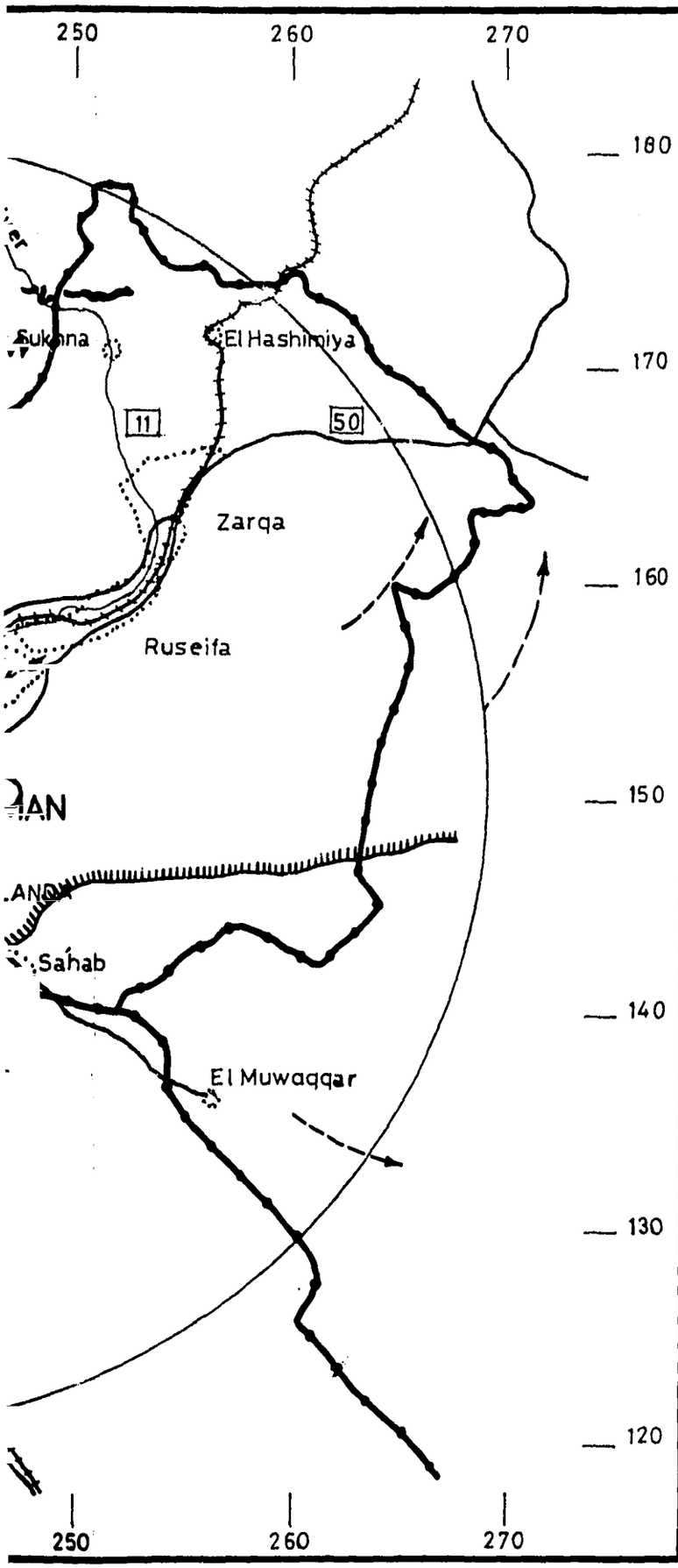
120
To Jarash
KING
TALAL
DAM
Zarqa
River
Zarqa River
24
15
Allan
Salt
45
Jordan
River
JORDAN
VALLEY
AUTHORITY
48
AMMAN
Na'ur
JUWEIDEH
15
21
49
DEAD
SEA
Madaba
Jiza
Mâjn

- 15



LEGEND

- UPPER AQUIFER POTENTIAL RECHARGE
- LOWER AQUIFER POTENTIAL RECHARGE
- LIMESTONE AQUIFER RECHARGE
- USABLE SANDSTONE RECHARGE
- GROUNDWATER BASIN BOUNDARY
- GROUNDWATER MOVEMENT

APPROXIMATE GROUNDWATER MOVEMENT AND RECHARGE GREATER AMMAN AREA

FIGURE 7 - 2

control of waste discharge into waterbodies and sewers. It noted that present laws on pollution control were not fully implemented, possibly from inadequacies in the law or by lack of competent personnel to carry out the required duties.[4] In a brief summary of existing anti-pollution legislation, the following provisions were noted:

Title	Provisions
Natural Resources Authority Law No. 12-1968	Defines pollution as changing the physical, chemical and biological characteristics of water to such an extent that may limit its use; prohibits any person from introducing into the waters any polluting material without a permit specifying the kind of polluting material and required protective measures.
Amman Water and Sewerage Authority Temporary Law No. 48-1977	Includes protection of water from "pollution" as one of the aims of AWSA and gives AWSA the power to establish restricted zones for protection of watershed areas.
Water Supply Corporation Law No. 56-1973	Defines "water purification" as the removal of all harmful substances so that drinking water is up to the WHO standards; allows WSC to retain the power to claim protection zones for water works, including the power to acquire land and property.
Public Health Law No. 21-1971	Defines drinking water as water "free from all physical, chemical or bacterial pollution;" gives the Ministry of Health the power to examine water, forbid the distribution of unsafe water, and approve new water systems; requires all sewerage systems to conform to the health regulations.
Public Sewerage Law Temporary Law No. 12-1977	Covers all municipalities except City of Amman; provides legal ground for municipalities to install and operate sewerage systems and collect revenues; requires that industrial wastes conform to established standards for acceptance of discharge into the public system.

The paper stated that in Jordan, legislation on pollution is inadequate and that many sections in the present law have not been implemented. In the absence of nationally accepted standards or instructions from government agencies,

consulting engineering firms usually derive their own parameters for effluent quality, but these may not always meet local environmental protection needs or objectives.

The paper recommended centralizing responsibility for all water supply and pollution control activities under a single organization which could be part of an agency to control water planning and management. It recommended establishment of a national authority to deal with sewerage works and a water quality unit in which programs could be conducted on problems of national significance. It also recommended improved data collection, evaluation, and information dissemination on water pollution control activities, measures, and conditions. It advocated application of basic water sanitation principles, more and better operated and maintained sewage treatment plants, training programs for both professional and non-professional personnel, improved watershed management practices (particularly agricultural practices), and encouragement of industrial in-plant controls for reduction of effluent loads.[4]

Regarding industrial pollution, the Ministry of Health has peremptory power to stop the dumping of hazardous wastes into the environment — e.g., watercourses -- as long as it has evidence to support is contention that the discharges are, in fact, hazardous to health.[12] The Minister of Health has discretionary power to shut down any industry he finds is threatening the public health by a hazardous practice.

At the present time, the various recommendations pertaining to strengthened pollution control laws and means of implementation are under consideration by the Government.

MONITORING OF WATER POLLUTION

The principal activities in monitoring water pollution within the Greater Amman Area have been those of the Natural Resources Authority (NRA) and the Royal Scientific Society (RSS). Water pollution, under its broadest definition, is not confined to point source discharges. It also includes non-point source discharges such as from mining, agricultural practices in application of pesticides, fertilizers, and even irrigation water.

For example, NRA Water Laboratory data show mineralization and quality changes of groundwater in the Wadi Dhuleil Region as a result of agricultural development. An average increase in Total Dissolved Solids (TDS) of 291 percent during the periods embraced by 1971-1977 was noted in the six wells studied.[4] Although the water quality was still acceptable for irrigation of many types of crops, the trends were alarming. Generally comparable data were also presented for well water mineralization in the El-Jafr Region. Data were also presented from NRA analyses of groundwater quality showing the effects of urban type pollution.

The RSS has been active in sampling of surface waters, notably the Seil Zarqa and King Talal Reservoir (see Appendix H). In addition, the RSS has sampled many industrial wastewaters. The picture provided is one of increasing adverse impacts of urban wastewaters upon the surface waters.

CONSERVATION AND MANAGEMENT OF RESOURCES

WATER QUALITY CONDITIONS

The NRA, RSS, and AWSA laboratories have performed most of the analyses of water quality within the Greater Amman Area. Compilations are somewhat limited, but additional data are gradually being compiled. The native waters tend to be of a calcium magnesium bicarbonate nature, but the effects of human activities are being felt. The principle is illustrated in Figure 7-3 which displays a schematic diagram of water supply and wastewater disposal within the largest of all the drainages in the Study Area, the Seil Zarqa Drainage. The schematic is intended to indicate the aspects and issues of resources and conservation and management which must be recognized in the development of the wastewater disposal master plan. These are interrelated and include:

- Surface water quality and quantity
- Groundwater quality and quantity
- Disposal of wastewater and beneficial uses of treatment plant effluent
- Public health concerns
- Geographical relationships (Plateau, Wadis, Baqa'a and Jordan Valleys)
- Costs of water and wastewater management, as may be influenced by horizontal and vertical distances involved in potential facilities

Surface Water

Table 7-4 presents a summary of 1970-73 river sampling data from the Zarqa River (Seil Zarqa) as reported in a recent consultant report.[5] More recent and comprehensive analyses were presented in certain feasibility studies for AWSA,[13] data from which are abstracted in Table 7-5. The impacts of Ain Ghazal Treatment Plant (AGTP) effluent and other effluents are implied. The effluent from AGTP already flows via the Seil Zarqa directly into King Talal Reservoir. En route it is in communication with the upper aquifer of the Amman-Zarqa Groundwater Basin and it is also used both as a direct and indirect source of irrigation supply to the many riparian farms between Marka and the confluence of Seil Zarqa and Wadi edh Dhuleil downstream of Sukhneh. During dry weather, the AGTP effluent is the major if not the sole source of Seil Zarqa flow. Within the next several months, this flow will be augmented by effluent discharges from the new wastewater treatment plant of the Municipality of Jarash. Within a few years, the effluent of the proposed wastewater treatment plant of Zarqa and Ruseifa will add measurably to the flow. Thus, a significant portion of King Talal Reservoir's impoundment will represent municipal treatment plant effluent, the remainder being flood and freshet runoff plus some spring-fed flow.

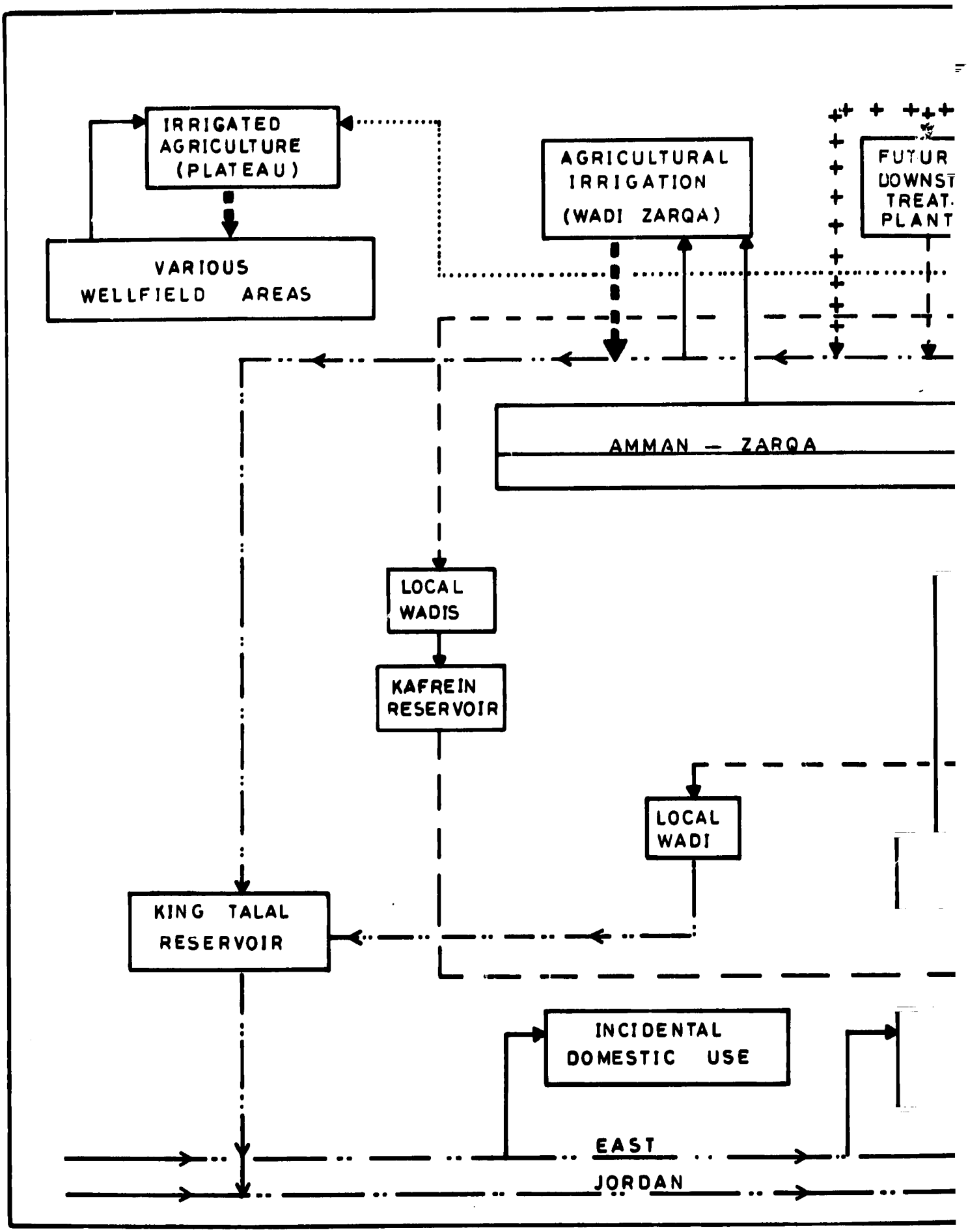
Pollution of the Seil Zarqa has been a matter of great concern to many authorities, not only from the standpoint of riparian use of the water flowing towards King Talal Reservoir but also because the reservoir water has been proposed for use as a supplemental source of drinking water for Amman.[4,6] King

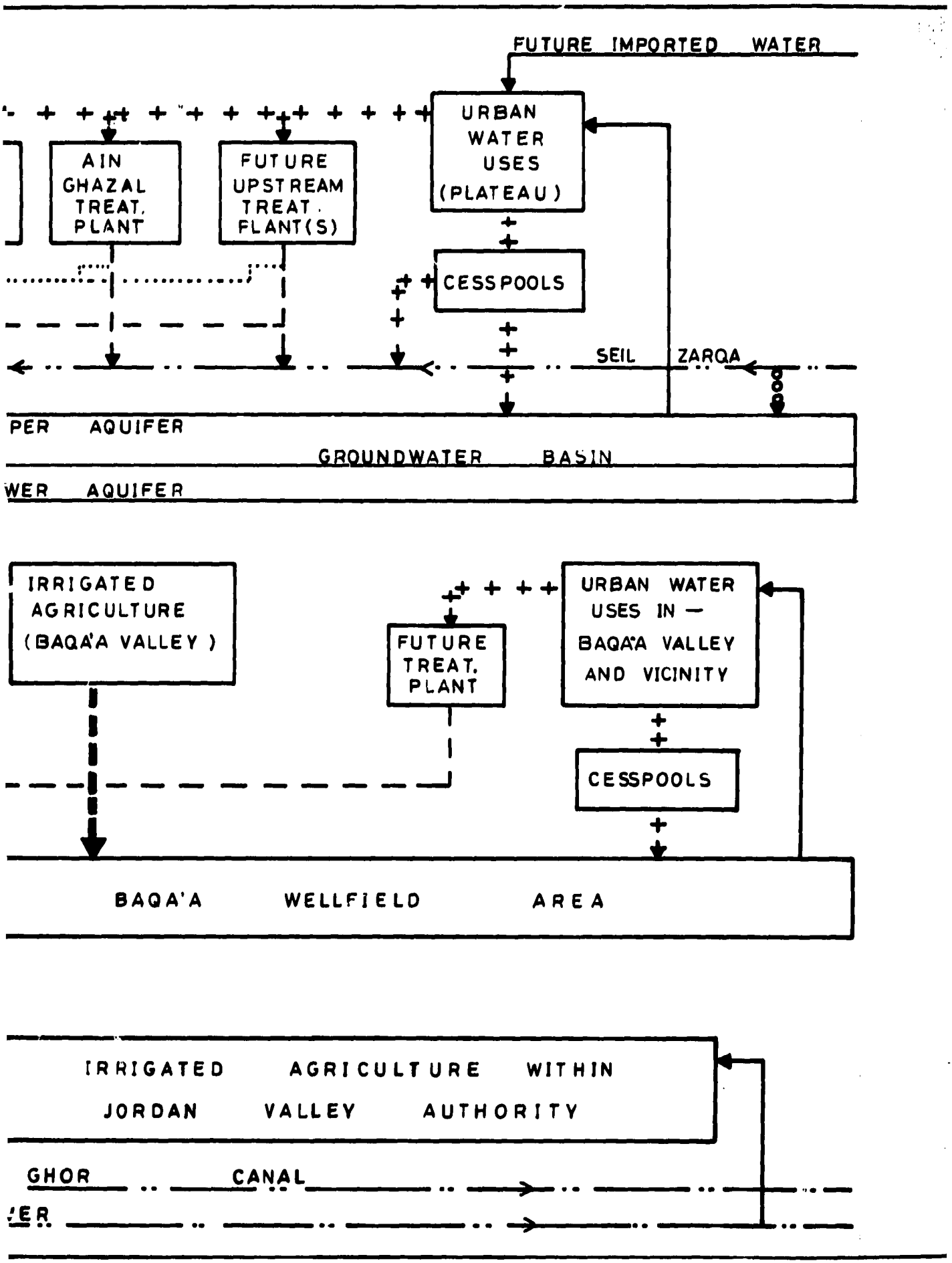
TABLE 7-4

SURFACE WATER QUALITY - ZARQA RIVER, 1970-73

Location	Date	Mean Daily Discharge (m^3/sec.)	Specific Conductance (umhos/cm)	Total Dissolved Solids (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	Sodium Adsorption Ratio	Boron (ppm)	pH
Zarqa River at Deir Alla	27 Dec 71	1.26	-	730	160	250	1.95	-	7.6
Zarqa River at Jarash	12 Mar 73	1.12	1 080	691	145	223	1.87	-	7.8
Zarqa River at New Jerash Bridge	2 Oct 70	0.92	1 300	832	205	223	2.53	-	-
	2 Dec 70	1.52	1 150	736	157	194	1.75	-	-
	13 May 71	0.44	1 020	653	123	187	2.50	-	-
	9 Jun 71	0.32	1 120	717	148	204	1.88	-	-

Source: Unpublished records from Jordan Natural Resources Authority.


IRRIGATED AGRICULTURE (PLATEAU)
VARIOUS WELLFIELD AREAS
AGRICULTURAL IRRIGATION (WADI ZARQA)
FUTUR DOWNST TREAT. PLANT
AMMAN — ZARQA
LOCAL WADIS
KAFREIN RESERVOIR
LOCAL WADI
KING TALAL RESERVOIR
INCIDENTAL DOMESTIC USE
EAST
JORDAN


FUTURE IMPORTED WATER
URBAN WATER USES (PLATEAU)
AIN GHAZAL TREAT. PLANT
FUTURE UPSTREAM TREAT. PLANT(S)
CESSPOOLS
SEIL
ZARQA
PER AQUIFER
GROUNDWATER BASIN
WER AQUIFER
IRRIGATED AGRICULTURE (BAQA'A VALLEY)
FUTURE TREAT. PLANT
URBAN WATER USES IN — BAQA'A VALLEY AND VICINITY
CESSPOOLS
BAQA'A WELLFIELD AREA
IRRIGATED AGRICULTURE WITHIN JORDAN VALLEY AUTHORITY
GHOR CANAL
ER

LEGEND

————	PIPED WATER SYSTEM
+ + + +	WASTEWATER
— — — —	TREATMENT PLANT EFFLUENT
.....	RECLAIMED EFFLUENT
▬ ▬ ▬ ▬	IRRIGATION RETURNS
—··→··—	RIVER, WADI, OR CANAL
oooooooooo	BASIN RECHARGE

NOTES

1. IMPORTED WATER IS SCHEDULED (FOR AMMAN) FROM:
   - AZRAQ WELL FIELD
   - QASTAL WELL FIELD (WSC)
   - OTHER, POSSIBLY KING TALAL RESERVOIR EAST GHOR CANAL OR IRAQ (EUPHRATES RIVER)

2. OPTIMUM MANAGEMENT OF WATER SUPPLY AND WASTEWATER DISPOSAL IS COMPLICATED BY POPULATION GROWTH, CONTINUING WATER SHORTAGES, PUBLIC HEALTH CONCERNS AND LIMITATIONS OF ENERGY AND FUNDS.

SCHEMATIC DIAGRAM
WATER SUPPLY AND
WASTEWATER DISPOSAL
SEIL ZARQA DRAINAGE

FIGURE 7-3

290b

TABLE 7-5

SURFACE WATER QUALITY - ZARQA RIVER, 1977[a]

Results are stated in mg/l

Constituent and Location of Sample	January 1977	February 1977
Abdoun		
TDS	250	250
Chloride	42.6	33.4
Sulfate	19.2	23.1
Nitrate	27.9	11.5
COD	41.8	186.2
AGTP Effluent		
TDS	1,246	1,190
Chloride	236.8	209.5
Sulfate	89.3	60.5
Nitrate	52.3	0.8
COD	158.0	1,146.6
Downstream of AGTP		
TDS	448	416
Chloride	81.7	67.4
Sulfate	38.4	25.0
Nitrate	25.0	3.7
COD	1,325.7	803.6
Before Phosphorus Mines, Ruseifeh		
TDS	403	346
Chloride	78.8	54.0
Sulfate	33.6	11.5
Nitrate	[illegible]	8.8
COD	958.9	607.6

TABLE 7-5 (Cont'd)

Constituent and Location of Sample	January 1977	February 1977
Ruseifah		
TDS	317	640
Chloride	51.5	113.6
Sulfate	24.0	45.6
Nitrate	21.3	1.8
COD	526.6	803.6
Awajun Bridge		
TDS	333	832
Chloride	58.2	158.7
Sulfate	24.0	40.3
Nitrate	19.2	0
COD	533.9	1,313.2
Zarqa Bridge (Zarqa)		
TDS	326	768
Chloride	58.6	142.4
Sulfate	38.4	52.8
Nitrate	18.3	1.8
COD	134.4	1,528.8
New Jarash Bridge		
TDS	928	557
Chloride	221.9	111.8
Sulfate	151.7	77.8
Nitrate	13.3	17.3
COD	70.8	176.4

[a] Results are taken from Table 5, Zarqa River Quality, Environmental Assessment on Amman Water and Sewerage Project.[13] The results are purported to reflect stream conditions during high flow periods, but after the first half of the rainy season.

Talal Dam was constructed by the Jordan Valley Authority (JVA) as a major impoundment for irrigation water within the Jordan Valley. Releases from King Talal Dam are already supplying irrigation works of the JVA, as intended. The East Ghor Canal, the backbone distribution facility of the JVA, is fed primarily by the Yarmouk River but it also is fed by King Talal Dam. The East Ghor Canal water is used by a few inhabitants in the Jordan Valley, presumably for domestic purposes.[4]

In connection with a study and report and immediate improvements and expansion of sludge facilities for the AGTP, the Seil Amman was sampled about 400 m downstream of the AGTP's effluent discharge on September 9, 1977. The flow represented essentially undiluted AGTP effluent.

The Royal Scientific Society (RSS) commenced a three-year project of sampling King Talal Reservoir in July 1980, including both surface and depth samples with both in situ and laboratory analyses of various quality parameters. Preliminary results of this work are summarized in Appendix H. Earlier, RSS conducted a six-month program of sampling on the Seil Amman, Seil Ruseifa, Seil Zarqa, and King Talal Reservoir, the results of which are also summarized in Appendix H. The program results to date reflect the conditions in both the river system and reservoir that would be expected in light of the pollutants burden which they bear. The reservoir, however, does have some assimilative capacity, particularly following the large impoundments of the 1979-80 rainy season occasioned by heavy flood runoff. Also, there is some attenuation of certain pollutants in the flowing river system. Nevertheless, the concerns over pollution are real and well-founded. The RSS will soon expand its stream sampling program to include various tributary wadis to the Seil Zarqa, the intent being to provide background information prior to the activation of the Jarash Wastewater Treatment Plant as well as general quality information on the overall river system.

Groundwater

The groundwater basin underlying the most heavily populated areas of the Greater Amman Area is known as the Amman-Zarqa Basin, as previously depicted in Figure 7-1, which is adapted from the Water Resources Study of 1976.[2] The Basin contains an unconfined upper aquifer of complex geological formation and a confined lower aquifer which is largely homogeneous and nearly of uniformly thick rock formation. The potential recharge of the upper aquifer is in the order of 20 MCM, half of which is experienced in areas downstream of Amman. As a result of a hydrogeological model study, it was concluded that the extraction of 13 MCM within Amman from the upper aquifer could continue only as long as the current recharge of the aquifer by cesspool seepage and water distribution network leakage continued. It was noted that the upper aquifer quality was strongly affected by human activity and that nitrate concentrations frequently exceeded recommend WHO maximum permissible levels.

It was reported that the lower aquifer is potentially rechargeable in the order of 5 MCM, about half of which should be extractable within Amman.[2] Wells penetrating the lower aquifer were also affected by human pollution. It was

concluded that either the lower wells draw from both aquifers, upper and lower, or a leakage of water from the upper to the lower aquifer takes place in the wells. Human pollution of the aquifer(s) is characterized by high nitrates, but it also may involve increased mineralization and bacterial density increases. A comparison of 1966 conditions with 1973 conditions of 14 selected wells in the metropolitan area of the Amman-Zarqa Basin showed total dissolved solids (TDS) increases ranging from 2 to 129 percent and averaging 66 percent.[4] Increased chloride levels in these same wells ranged from 36 to 624 percent and averaged 195 percent. This reference also showed an example of an industrial well in the Awajan area which had been uncontaminated in 1957 but showed signs of slight contamination by 1965 (based on mineralization) and gross contamination by 1973.[4] The reference also cited Shehabi[5] as determining that 20 out of 46 wells in the Amman-Zarqa area, when sampled during July and August 1975, exhibited coliform organisms, indicating pollution. The sampling and bacteriological analyses were made upon raw water. Chlorination is being relied upon heavily for reduction of coliform densities to acceptable levels in drinking water supplied by such wells.

Increased nitrates and salts are not the only manifestations of groundwater pollution by municipal and industrial activities. Oil pollution of AWSA Well No. A9 and bacterial pollution of Wells No. A8 and A28 have been observed.[7]

It is evident that indirect recycling of wastewater effluent already takes place and much more will be experienced in the future with the continued population growth and the advent of imported water.

DRINKING WATER QUALITY CRITERIA AND CONSIDERATIONS

Table 7-6 presents drinking water criteria which might affect public health proposals by various authorities. Comparison of proposed quality criteria of these authorities shows a marked similarity, for the most part, for the quality constituents or parameters. It is also of interest to note that, except for the constituents arsenic, cyanide, and organic matter (CCE), those constituents common to all three United States standards, beginning in 1962 and ending in 1975, have remained unchanged during this time period.

The proposed quality criteria originate in various industrialized nations; hence, the attention paid to various heavy metals, organic matter, and pesticides. These are apt to occur in greater concentrations in the water resources of industrialized nations than of non-industrial nations. In Jordan's case, they must be borne in mind inasmuch as some industry already exists and more is programmed.

Pesticides are potential problems in waters draining from agricultural areas, and Jordan may be no exception. Nitrate nitrogen is also a factor in agricultural drainage, particularly where chemical fertilizers are employed.

Of immediate concern to the Greater Amman Area are the Table 7-6 parameters of nitrate nitrogen, coliform organisms, E. Coli, and virus. Another constituent not included is residue upon evaporation, also known as Total Dissolved Solids (TDS). Apparently no agreement has been reached on acceptable limits of TDS as

TABLE 7-6

DRINKING WATER QUALITY CRITERIA WHICH MAY AFFECT PUBLIC HEALTH-PROPOSALS BY VARIOUS AUTHORITIES[a]

All concentration in μg/l unless otherwise stated

Constituent	Quality criteria proposed by									
					WHO					
	USPHS (1962)	Japan (1968)	UK (1969)	USSR (1970)	European (1970)	International (1971)	SABS (1971)	NAS (1972)	Australia (1973)	EPA (1975)
Arsenic	10	50		50	50	50	50	100	50	50
Barium	1,000			4,000	1,000	-	-	1,000	1,000	1,000
Cadmium	10			10	10	10	50	10	10	10
Chromium	50	50		100	50	-	50	50	50	50
Copper	1,000	10,000		100	50	50	1,000	1,000	10,000	-
Cyanide	10	10		100	50	50	10	200	10	-
Lead	50	100		100	100	100	50	50	50	50
Mercury	-	1		5	-	1	-	2	-	2
Phenolic compounds	1	5		1	1	1	1	1	4	-
Selenium	10	-		1	10	10	-	10	10	10
Silver	50	-		-	-	-	-	-	50	50
Zinc	5,000	1,000		1,000	5,000	5,000	5,000.	5,000	5,000	-
Organic matter (CCE)[b], %	200	-		-	200 to 500	-	-	300	700	-
Pesticides										
Total chlorinated hydrocarbons	-	-		-	-	-	-	1,066	-	1,092
Total organophosphorus and carbamates	-	-		-	-	-	-	100	-	-
Total chlorophenoxyls	-	-		-	-	-	-	52	-	110
Nitrate nitrogen, mg/l	10	10		10	<11.5	10	10	10	10	10
Fluoride, mg/l	0.6 to 1.7	0.8		1.5	0.7 to 1.7	0.6 to 1.7	1.0 to 1.5	1.4 to 2.4	1.5	1.4 to 2.4

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TABLE 7-6 (Cont'd)

Coliforms, per 100 ml	<1[c]	0	<10	-	-	0	<10	-	0	<1
E.Coli 1, per 100 ml	-	0	0	-	-	0	0	-	0	-
Total plate count, per ml	-		-	-	-	-	<100	-		-
Virus, per liter	-		-	-	-	1[d]	-	-		-

[a] Taken from AWWA Research Foundation, "Water Reuse Highlights, A Summary Volume of Wastewater Reclamation and Reuse Information," Denver, Colorado, January 1978.[7] Also in National Institute for Water Research, "Manual for Water Renovation and Reclamation," Pretoria, South Africa, 1978.[8]

[b] CCE carbon chloroform extractables.

[c] Less than 10% of samples should be positive in any one month.

[d] One Plaque forming unit on testing 10-liter samples.

far as public health is concerned, although various authorities promulgate objectives for this parameter. These may be based upon aesthetic and physical considerations as well as health considerations. For example, the State of California Department of Health has set a standard of 500 mg/l TDS in drinking water for many years pursuant to administration of the Pure Water Law and issuance of domestic water permits. However, many of the natural fresh waters of California contain more than this 500 mg/l TDS level. The Department recognizes this condition and, where no supplies are available to meet the 500 mg/l TDS standard, will accept up to 1,000 mg/l TDS.

Nitrate Concerns

The criteria of Table 7-6 are goals which should be striven for. With respect to nitrates, it is noted that a typical per capita contribution of total nitrogen in municipal wastewater in the Western United States is about 0.02 kg/capita/day. Based upon a per capita wastewater flow of, say, 75 lcd, this would correspond to $0.02 \times 10^6/75$ equals 267 mg/l total nitrogen. However, measurement of both ammonia nitrogen and nitrate nitrogen on raw sewage and effluent at AGTP during seven successive days in September 1977, showed that the average ammonia nitrogen of the influent was 123 mg/l and of the effluent was 109 mg/l, there being relatively little variation in the levels from day to day.[9] The nitrate nitrogen showed somewhat greater variation, but the levels in influent and effluent were both low, averaging 0.20 and 0.60, respectively. These data indicate that the per capita contribution of nitrogen may be significantly less than that experienced in the Western United States.

All but one of the proposed (maximum allowable) nitrate nitrogen concentrations in Table 7-6 are 10 mg/l. This corresponds to 45 mg/l nitrate concentration. The reasoning behind this standard has been the possible implications of methemoglobinemia in infants who consume water having concentrations in excess of this value. High nitrate concentration are not thought to be of health significance to humans other than infants (see discussion under Chaper 4). It should be noted that once nitrogen compounds such as ammonia become oxidized to nitrate in natural waters, it is generally impractical as well as uneconomical to reduce the nitrate concentration other than by blending with low nitrate water, where necessary. This dictates handling the nitrate problem in wastewater treatment plants before effluents are released, assuming that such is determined essential.

Salinity Considerations

Dissolved mineral salts are added to water in the process of converting it to wastewater from domestic, municipal, commercial, and industrial uses. The TDS of such a wastewater is usually significantly greater than the freshwater from which it is derived. During 1973-75, the average TDS of deep aquifer-derived groundwater from the Amman-Zarqa Basin within the urbanized area ranged between 318 and 409 mg/l.[4] At the same time (1974), the TDS in the municipal water supply for Amman obtained from the wells at Ras El-in, Ain Ghazal, and Wadi es Sir was 467, 550, and 367 mg/l, respectively.[4]

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The TDS of the AGTP effluent has been measured at various times. The salinity (TDS) of AGTP effluent was reported to range between about 1,000 to 1,200 mg/l between August 1975 and May 1976.[2] The Natural Resources Authority (NRA) determined the TDS of the AGTP effluent as being 1,352 and 1,239 in samples taken in 1976 and 1977, respectively,[4] and 1,210 mg/l TDS in the effluent on October 6, 1977.[9] It is apparent that recent TDS effluent concentrations have been in the range of 1,200 to 1,300 mg/l, and probably the increment of TDS due to various uses is in the order of 700 to 800 mg/l, although this has not been specifically investigated.

As water is imported into Amman from the Azraq well field and, possibly, the East Ghor Canal or Euphrates River, there will be an additional salt burden imposed upon the local water resources of the Greater Amman Area. However, unless widespread irrigation were to be undertaken on the plateau — an event not foreseen, at least for the near future — the bulk of the new salt will flow into King Talal Reservoir as part of the increased quantities of wastewater treatment plant effluent. If King Talal Reservoir supply is used as a future supplemental supply for Amman, there will be a recycling of some of these salts, but most of the salt will find its way into the Jordan Valley with a major portion probably reaching the Dead Sea.

The entire issue of salinity is very complex, and the assessment of quality effects resulting from wastewater disposal arrangements can be addressed only in a limited degree herein. Much will depend upon the actual quantity and quality values involved in water importation, groundwater extraction, recycling, and disposal, all as related to various localities, basins, and drainages. Preliminary work has indicated that a major problem may not necessarily exist with respect to TDS and recycling from King Talal Reservoir.[5] Therefore, for the purposes of this Master Plan, it is recommended that future investigations of salinity effects for the various elements of the water resources be undertaken pursuant to major developments for water supply, preferably as environmental assessments but at least as monitoring and control measures after the fact.

WASTEWATER RECLAMATION AND REUSE

At the present time, there is no planned wastewater reclamation and reuse within the Greater Amman Area. However, there is already indirect recycling of wastewater treatment plant effluents from the AWSA and Salt plants via the Seil Zarqa and Wadi Shu'eib, respectively, principally for irrigation. Because of the current lack of standards for effluent discharges and receiving water quality, the conditions, particularly for the Seil Zarqa, do not conform to regulations and criteria developed by progressive governmental agencies elsewhere. In general, achievement of high water quality standards entails an appreciable cost, and this may not be entirely possible for Jordan for several years. Nevertheless, these should be long range objectives and balanced with other important objectives in ensuing Five Year Plans. If possible, they should even be short range objectives.

Water Reclamation Regulations, Criteria and Potentials

Water reclamation regulations and criteria have been developed in the United States and elsewhere for the various reuse applications of reclaimed wastewater that might be considered for the plateau and desert of the Greater Amman Area, viz:

- Landscape irrigation
- Recreational impoundments
- Agricultural irrigation
- Body-contract recreation and spray irrigation
- Industrial applications

Not included in the foregoing are groundwater recharge or drinking water use. The former is subject to consideration on a case-by-case basis. The latter is not considered a reasonable practice because of potential hazards to the public health.

Although none of the five applications listed above appears to be a good prospect for the near future, there may be long range prospects. Therefore, a brief discussion of each is included below and in a greater detail in Appendix H. The primary criteria listed are those of the California State Department of Health.

Landscape Irrigation: Because of the critical shortages of water in Jordan, it is doubtful that much priority can be given to developing large-scale irrigation works. Furthermore, it is not always economical to substitute reclaimed water for potable water for irrigation. Landscape irrigation is viable, however, in certain cases as a means of effluent disposal.

Recreational Impoundments: There are no recreational impoundments within the Greater Amman Area. Reuse of reclaimed water for this purpose implies a high degree of treatment to alleviate two potential problems: eutrophication and public health.

Agricultural Irrigation: Of all the potential reuse methods, agricultural irrigation seems to be the most feasible. Irrigation of fruit trees where the reclaimed effluent does not come in contact with the crop does not impose a requirement for a high quality effluent.

Body Contact Recreation: Due to the complexity and high cost of treatment required to produce an effluent quality suitable for body-contact recration, the reuse of this reclaimed effluent for this purpose is not likely to be of early application in Jordan.

Industrial Application: Barring refining and mining operations, there are no obvious industrial reuse applications evident in the Greater Amman Area. The major "wet industries" are not many. Industries for the most part utilize drinking quality water. It would require a market survey and special feasibility studies to determine if such possibilities may exist in select industries in the Greater Amman Area.

Current Agriculture in Greater Amman Area. Table 7-7 presents a summary of groundwater-irrigated agricultural areas within or adjacent to the Greater Amman Area. The data are from the Department of Statistics.[14] The implication is that some of this area might some day become irrigated with reclaimed effluent, given favorable considerations, including economics. It is suspected, however, that agricultural irrigation with reclaimed water — other than riparian irrigation in the Seil Zarqa and, indirectly, in the Jordan Valley — will be several years in developing. The Ministry of Agriculture was contacted in this regard,[15] but no encouragement was obtained. Nevertheless, this possibility should be kept in mind. The chief interest, however, is on the current riparian agricultural use of AGTP effluent from the Seil Zarqa. Of immediate concern is the matter of pathogenic microorganisms as it is of potential hazard to workers engaged in irrigation operations, others exposed to the AGTP effluent, and persons who consume crops (sometimes raw) which were irrigated with the effluent.

Pathogenic Microorganisms: Gedeon, Shalbak and Shehabi have reported upon bacterial pollution of water in Jordan, citing inadequate means of sewage disposal, obsolete methods employed in the management of solid wastes, and, above all, the new industrial growth in high population density areas such as Zarqa.[4] They cite data indicating difficulties with bacteriological quality in drinking water systems in Jordan and refer to recent outbreaks of acute diarrheal disease, typhoid fever, and cholera (see also Chapter 4). They note that in assessing the degree and seriousness of a state of pollution, it is not essential to isolate and identify all the organisms in the water which could cause a particular disease. It is, however, important to search for biological indicators of pollution. These have been displayed in Table 7-6.

Effluent Disinfection: The chief concern of the current discussion is the impact of AGTP effluent upon bacterial and viral pollution of the Seil Amman. Currently, certain limitations in the facilities and operations of the AGTP — many of which are outside the control of the plant operators — combine to make reliable disinfection of the plant effluent impossible. As previously noted, Binnie & Partners observed an average ammonia nitrogen content of the plant effluent of 109 mg/l in the seven days of sampling in early September 1977.[9] The effluent suspended solids averaged 115 mg/l during this period. Review of plant operating records (Analysis Journals) indicates that the above values are representative. They show essentially impossible conditions for disinfection of the effluent, because of the combined effects of harborage of the microorganisms within the numerous suspended solids particles and the loss of much of the disinfecting power of the chlorine solution by combination with the ammonia content to form the less efficacious chloramines.

TABLE 7-7

SUMMARY OF GROUNDWATER-IRRIGATED AGRICULTURE IN 1979

WITHIN AND NEAR GREATER AMMAN AREA[a]

Area	FIELD CROPS		VEGETABLES		FRUIT TREES	
	Prod'n (tons)	Area (dunums)	Prod'n (tons)	Area (dunums)	Prod'n (tons)	Area (dunums)
Duleil	1,100	1,040	15,000	8,700	390	1,950
Zarqa	10	10	4,700	2,800	24	370
Sukhneh	--	--	2,800	1,500	310	410
Al Ghores	20	100	51,700	28,300	5,160	2,420
Al Qastal	--	--	12,100	5,900	280	560
Subtotal, Greater Amman & Immed. vicinity	1,140	1,150	87,100	47,200	6,164	5,710
Other	5,960	7,150	18,600	9,600	436	--
Total East Bank	7,100	8,300	105,700	56,800	6,600	--

[a]Data from Survey of Agricultural Land Irrigated by Artesian Wells.[14]

When the AGTP is expanded and upgraded, the facilities should be capable of producing improved suspended solids levels in the effluent, probably averaging about 50 mg/l. This would represent nearly 95 percent reduction in the suspended solids entering the plant. Because of the unusually high strength of the raw wastewater, it would be unrealistic to contemplate much greater reductions in the suspended solids loadings on a reliable basis, although there may be times when effluent quality is better than this average, particularly in the period before the loadings build up to the plant's capacity.

If the activated sludge plant effluent were to be filtered, the suspended solids in the effluent could be reduced to negligible concentrations and the effluent made amenable to disinfection by chlorination. As in the case of potential denitrification, however, a consideration must be made of the potential benefits with respect to the probable costs of filtration.

Although the AGTP is probably a major contributor to the Seil Zarqa of microorganisms and/or substances favoring the proliferation of microorganisms, it is not the only contributor. There are currently overflows of septage, storm runoff from urban areas, and raw sewage and industrial wastes discharges.[10] It would be questionable to require filtration for AGTP effluent unless all the point source wastes could also be provided requisite treatment. Moreover, it is worth remembering that the Seil Zarqa has been used for crop irrigation by riparian farmers for many years, even prior to activation of AGTP. Crops grown include vegetables consumed raw (Chapter 4). Superficially at least, there is no well-established connection between this specific practice of irrigating these crops with an inadequately disinfected treatment plant effluent and the outbreak of disease from human consumption of these crops.

There are about four kilometers of river channel between the point of AGTP effluent discharge and the first widening of the wadi and development of irrigated agriculture. During this and subsequent river reaches, it would be expected that natural action of predators, sunlight and sedimentation would reduce the bacterial densities. Some of the riparian agriculture draws raw surface water directly from the Seil Zarqa, while in other cases, infiltration galleries or wells may be employed. The well water would probably be filtered by the soil and be fairly free of bacteria, depending upon physical conditions. The raw surface water would not have this advantage. The further downstream the flow proceeds, the greater would be the attenuation of bacterial pollution due to AGTP. The flow actually proceeds nearly 30 kilometers along the wadi from Ain Ghazal before the Seil narrows, precluding additional riparian agriculture.

Appendix H-3 presents a summary of Wastewater Reclamation Criteria, excerpted from the California Administrative Code, Title 22, Division 4, Environmental Health 1975).[16] This represents the most current standard in use in the United States, and it is fairly widely accepted elsewhere. Table H2-4 presented previously, summarizes the California Title 22 standard and standards from South Africa and West Germany. It is noted that in order to irrigate crops by spray (sprinkler) irrigation in California, the wastewater must first be adequately oxidized, coagulated, clarified, filtered, and disinfected. The median number of

coliform organisms at some location in the process must not exceed 2.2 per 100 ml, among other requirements. Surface irrigation does not require filtration but the bacteriological requirements are nearly as strict as for spray irrigation.

As previously noted, there is probably no way that the AGTP could produce an effluent that would meet the spray irrigation standard or even the surface irrigation standard save for the inclusion of filtration in the process stream. This step is very costly, however, probably involving an additional JD 1.5 to 1.7 million of construction funds alone for a 600,000 population equivalent at AGTP. The site could be downstream of AGTP, connected by a gravity pipeline therefrom. In view of the current and past conditions as presently understood by JMM/DMJM, it would appear inappropriate to recommend incorporation of effluent filtration at the outset. Rather, it seems proper to recommend providing for future filtration at some location downstream from the AGTP and at a time when careful monitoring and study of water quality conditions indicate the true need and benefit of such filtration. In the interim, filtration of the effluent of AGTP and other plants discharging into the Seil Zarqa should be considered a future goal, as a minimum. Without effluent filtration, the aspect of disinfection of AGTP effluent (and other effluents) assumes major importance.

Disinfection by chlorination is now being recognized as a potential detriment in some instances as well as an admitted detriment. Impacts of effluent chlorination upon fisheries and in creating carcinogenic compounds are becoming of concern in Canada and other areas even though the protection of the public health by chlorine disinfection is invaluable.[17] In Jordan's case, the latter is believed paramount for the foreseeable future.

WHO Standards

The World Health Organization (WHO) suggests treatment processes to meet given health criteria for reuse as presented in Table 7-8.

TABLE 7-8

SUGGESTED TREATMENT PROCESSES TO MEET THE GIVEN HEALTH CRITERIA FOR WASTEWATER RE-USE

(From WHO Bul. No. 517)

	Irrigation			Recreation		Industrial re-use	Municipal re-use	
	Crops not for direct human consumption	Crops eaten cooked fish culture	Crops eaten raw	Contact: No contact	Contact	Non potable		Potable
Health criteria (see below for explanation of symbols)	A+F	B+F or D+F	D+F	B	D+G	C or D	C	E
Primary treatment	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Secondary treatment		xxx	xxx	xxx	xxx	xxx	xxx	xxx
Sand infiltration or equivalent polishing methods		x	x		xxx	x	xxx	xx
Nitrification						x		xxx
Dentrification								xx
Chemical clarification						x		xx
Carbon absorption								xx
Ion exchange or other means of removing ions						x		xx
Disinfection		x	xxx	x	xxx	x	xxx	xxxo

Health criteria:

A Freedom from gross solids; significant removal of parasite eggs.
B As A plus significant removal of bacteria.
C As B plus more effective removal of bacteria, plus some removal of viruses.
D Not more than 100 coliform organisms per 100 ml in 80% of samples.
E No faecal coliform organisms in 100 ml, plus no virus particles in 1000. ml, plus no toxic effects on man, and other drinking-water criteria.
F No chemicals that lead to undesirable residues in crops or fish.
G No chemicals that lead to irritation of mucous membranes and skin.

In order to meet the given health criteria, processes marked xxx will be essential. In addition, one or more processes marked xx will also be essential, and further processes marked x may sometimes be required.

o Free chlorine after 1 hour.

REGULATION OF WASTEWATER TREATMENT PLANT EFFLUENT FLOW

The Terms of Reference for this Master Plan for Wastewater Disposal require inter alia consideration of several relevant factors, among which are:

> "The storage capacity of reservoirs on the wadis leading to the Jordan Valley, particularly the King Talal Reservoir, and the relationship of return sewage flows and timing of irrigation requirements of the Jordan Valley Authority."

It is understood that the basic concern is that whereas the flow of municipal wastewater treatment plant effluent is known to occur on a more or less uniform basis from day to day and season to season, the irrigation demands of farmlands within the Jordan Valley occur seasonally, depending both upon the cropping patterns and climatic conditions. Were it not for this factor, the present and future effluents flowing down the various wadis leading to the Jordan Valley could be diverted more or less constantly to irrigation works on a dependable basis comparable to a base flow. The concern is that as more and more water is imported to the urban developments within Greater Amman Area and more wastewater treatment plant effluent is discharged into the various wadis, the chances of a portion of this flow being lost to the Dead Sea through flood runoff increases. In view of the precious character of Jordan's water resources, this aspect requires some consideration as part of the Master Plan for Wastewater Disposal.

WASTEWATER FLOWS ACCORDING TO DRAINAGE WADIS

Figure 7-4 depicts the drainage areas in the Study Area draining to the Jordan Valley and the location of the reservoirs. As can be seen, the major portion of the Study Area drains into Seil Zarqa and King Talal Dam catchment basin. Table 7-9 indicates the projected wastewater effluent production within the Greater Amman Area which drain towards the various wadis. Included within Table 7-9 are hydrological data indicating the magnitude and frequency of runoff in various wadis, where such data are available. Hydrologic data were largely derived from the National Water Master Plan of Jordan.[2]

SEASONAL DEMAND PATTERNS IN JORDAN VALLEY

Studies of the agricultural irrigation requirements within the JVA area have indicated both spring and fall crops and the reports have noted two differing opinions as to the extent of long term developments.[6] The "conservative" opinion is that the area irrigated will increase only slightly, while the "progressive" opinion is that the privately irrigated area will approximately double by the year 2000. Some of the water required for this additional area will result from increased efficiency, but overall, water requirements will increase significantly.[6] For the "conservative" estimates, the Jordan Valley cropping pattern was assumed as 67 percent vegetables, 22 percent fruit, and 39 percent field crops. (The

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TABLE 7-9

WASTEWATER EFFLUENT AND NATURAL RUNOFF IN WADIS DRAINING TO JORDAN VALLEY[a]

Item	Wadi Abdoun, etc., to Seil Zarqa		Wadi Dananir to Wadi Rumeimin		Wadi es Salt to Wadi Shu'eib		Wadi es Sir & Wadi Na'ur to Wadi Deir Abu Es Suwan	
Regulatory storage,[b] Name and capacity MCM	King Talal Reservoir (Live) 48[8]		King Talal Reservoir (Live) 48[8]		Shu'eib Dam (Live) 4.4[5], 2.3		Kafrein Dam (Wadi el Kafrein) (Live) 4.8[5]	
Tributary Community and[c] Potential Tributary Wastewater 1990 - 1000 m^3/day (2000 - 1000 m^3/day)	Suweileh (more if pump)	- 0.6 -(1.0)	Suweileh	- 1.3 -(2.1)	Salt	- 2.8 -(4.6)	Wadi es Sir	- 1.1 -(1.8)
	Wadi es Sir	- 1.8 (3.5)	Baqa'a Camp	- 2.7 -(3.2)	Fuheis/ Mahis	- 0.8 -(1.3)	Na'ur	- 0.4 -(0.7)
	Amman Municipal	-86.7 (124)	Total	- 4.0 -(5.3)	Total	- 3.6 -(5.9)	Total	- 1.5 -(2.5)
	Suburbs of Amman	- 7.0 (26.3)	MCM/yr 1990 2000	- 1.5 -(1.9)	MCM/yr 1990 2000	- 1.3 -(2.2)	MCM/yr 1990 2000	- 0.5 -(0.9)
	Schneller Camp	- 1.4 -(1.7)						
	Ruseifa	- 5.7 -(8.9)						
	Zarqa	-21.2 (33.7)						
	Sukhneh	- 0.4 (0.6)						
	Hashimiya	- 0.4 (0.6)						
	Total	-125 (198)						
	MCM/yr 1990 2000	45.7 73.1						

TABLE 7-9 (Cont'd)

	Wadi Abdoun, etc., to Seil Zarqa			Wadi Dansnir to Wadi Rumeinin			Wadi es Salt to Wadi Shu'eib			Wadi es Sir & Wadi Ma'ur to Wadi Deir Abu es Suwwan		
	Base	Storm	Total	Base[e]	Storm[e]	Total[e]	Base	Storm	Total	Base	Storm	Total
Natural Annual Runoff, MCM[d]												
Dry Year (16-year return)	41			13.6	4.0	17.6	5.6	0.4	6.0	8.4	0.1	8.5
Long Term Average			97	16.7	9.1	25.8	8.0	1.8	9.8	12.0	1.6	13.6
Wet Year (15-year return)	82			19.8	16.3	36.1	10.4	4.1	14.5	15.6	3.5	19.1

[a]The purpose of this table is to provide a general comparison of the essentially uniform flow of wastewater treatment plant effluent anticipated from future plants whose discharges will reach the Jordan Valley and the variable natural flows in these receiving wadis. The stream flow information for the wadis shown, except for Seil Zarqa, were considered incomplete and were not considered in The National Water Master Plan.[2]

[b]King Talal Dam is operated as an irrigation storage reservoir, with releases made to meet demands of East Ghor Canal not otherwise fulfilled by headworks diversions from the Yarmouk River. Water rights released are nominal from King Talal Dam.
Shu'eib Reservoir is a JVA installation which is used for irrigation in the Jordan Valley

Kafrein Reservoir is also a JVA installation. It is used for groundwater recharge in the Jordan Valley.

[c]Basic data are taken from Table 5-6 as subsequently broken down by collection systems.

[d]Most of the natural annual runoff data are taken from Map SW-8N of Volume III of "The National Water Master Plan of Jordan."[2] Data for Seil Zarqa and King Talal Reservoir are from VBB Water Resources Study[8] and Water Use Strategy, North Jordan.[6] Net yield of King Talal Reservoir is 53 MCM/yr.[6]

[e]Data for Wadi Dansnir to Wadi Rumeinin are not only for these wadis (which drain Baqa'a Valley to King Talal Reservoir) but are for the drainage unit AL2 which <u>includes</u> these wadis but gets much of its flow from other tributaries as well.

percentages total more than 100 percent, indicating some double-cropping). For the "progressive" estimates, a vegetable intensive cropping pattern for the Jordan Valley was assumed which reflected 87 percent vegetables, 22 percent fruit, and 13 percent field crops.[6]

Table 7-10 presents a summary of average seasonal irrigation requirements for both the North Zone and South Zone of the Jordan Valley. The data were derived from a study of the Jordan Valley Irrigation Project - Stage II, Irrigation Network.[18] The magnitude of the seasonal variations in demand can be seen to vary from about 44 percent in winter to about 133 percent of average in summer. The East Ghor Canal and apurtenant irrigation works were required to accommodate such variations as these and were so designed. The regulatory storage on the supply source(s) is to be used to satisfy these varying demands via regulated releases. The principal storage presently is King Talal Reservoir, but the Maqarin Dam, when built, would provide major regulatory capacity, making it somewhat easier for the entire system of storages and diversions to operate and maximize the catchment of flood runoff.

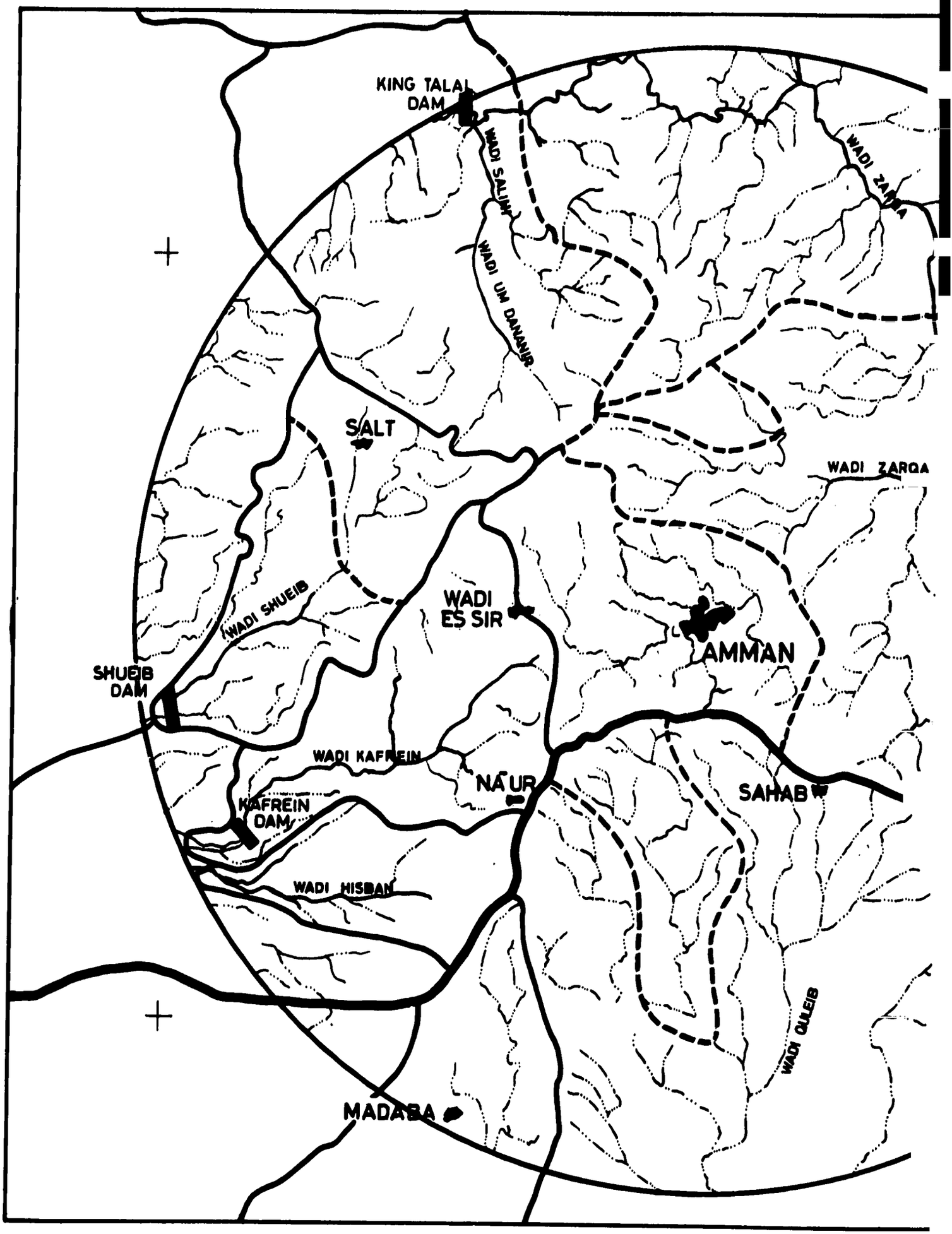
JORDAN VALLEY IRRIGATION DEMAND

According to Frantz[3] the projected annual water demand in the Jordan Valley is about 360 MCM, primarily for irrigation purposes. This compared with a projected M&I water demand in the greater Amman-Zarqa area of about 100 MCM/yr. From Table 5-6 presented earlier, the year 2000 projections for water deliveries and wastewater production for those communities located within the Amman-Zarqa conurbation were taken to be 292,000 m^3/day and 245,000 m^3/day, respectively. In terms of annual flows these would correspond to 106 MCM water deliveries and 89 MCM wastewater. It is implied that the depletions (consumptive use via evapotranspiration) would be about 16 MCM/yr or 18 percent of the M&I applied water. The great bulk of the urban water would return to the hydrologic cycle, primarily as wastewater treatment plant effluent, depending upon the extent to which the urban area becomes sewered. With full sewerage of this urban area the effluent runoff would be about 25 percent of the projected irrigation demand in the Jordan Valley.

RETURNS TO THE JORDAN VALLEY

JVA has indicated their reliance upon very substantial wastewater returns from the urban areas within the territory bounded by Wadi Walla to the south, JVA boundary to the west, Yarmouk River to the north, and vicinity of the Hejaz Railroad to the east.[19] This territory embraces the Greater Amman Area, being somewhat larger than it and including the urban developments of Jarash and Irbid as well as those of Greater Amman Area. The great bulk of the M&I use, however, will be in Greater Amman and as indicated above, the depletions from such would not be expected to be extensive.

JVA's criteria for maximum depletions within the territory east of JVA is apparently up to 60 MCM/yr[19] increased slightly from the earlier estimate prepared by the JVA for use in the studies of ultimate development of the Jordan


KING TALAL DAM
WADI SALIM
WADI UM DANANIR
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SALT
WADI ZARQA
WADI SHUEIB
WADI ES SIR
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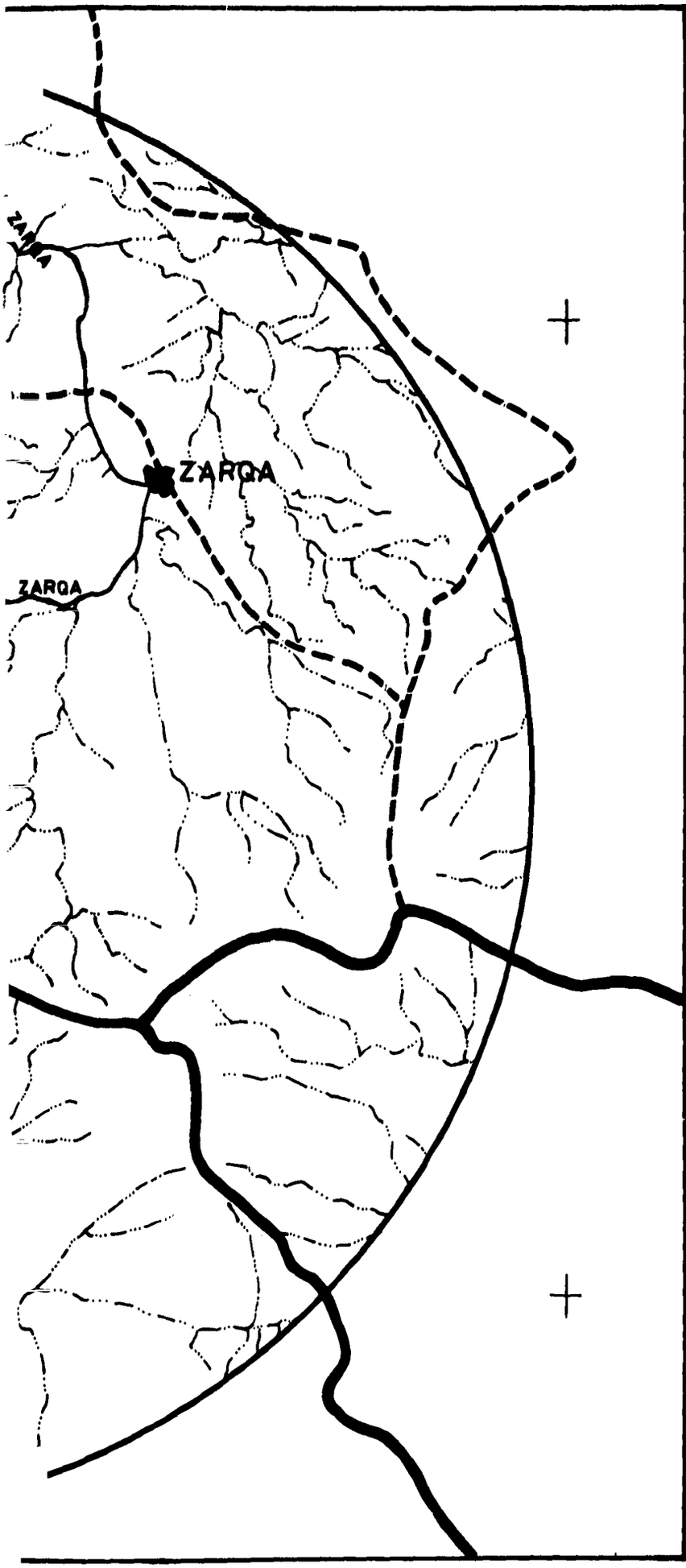
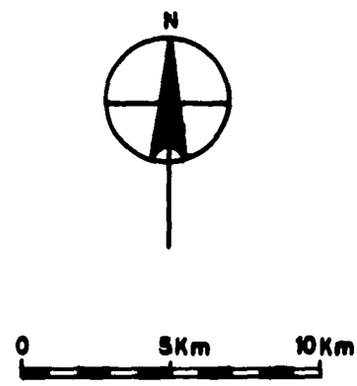
WADI KAFREIN
NA'UR
SAHAB
KAFREIN DAM
WADI HISBAN
WADI QUEIB
MADABA





SCALE 1/250,000

DRAINAGE AREAS AND LOCATION OF RESERVOIRS IN THE GREATER AMMAN AREA

FIGURE 7 - 4

TABLE 7-10

SUMMARY OF AVERAGE SEASONAL IRRIGATION REQUIREMENTS

WITHIN THE JORDAN VALLEY[a]

Monthly requirements are expressed as percentages of annual requirements

Crop Group and JVA Zone[b]	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
I - North	5.0	3.8	5.8	9.8	10.4	10.7	14.5	13.6	10.6	8.6	5.1	4.1	100.0
I - South	4.5	4.7	7.3	7.6	8.9	10.1	13.5	12.6	9.8	8.7	7.0	5.3	100.0
II - North	0.9	4.7	5.2	10.5	13.8	14.0	4.5	9.5	11.7	15.7	6.9	2.6	100.0
II - South	1.2	4.9	6.7	7.9	12.8	13.8	4.6	9.4	11.8	12.3	9.8	4.8	100.0
III - North	1.2	2.9	4.3	8.3	12.4	13.2	10.7	13.4	12.8	11.7	6.8	3.3	100.0
III - South	1.8	2.9	4.2	8.3	11.3	13.1	10.6	13.4	12.8	11.6	6.7	3.3	100.0
IV - North	-	-	-	-	-	-	-	-	-	-	-	-	-
IV - South	4.0	4.3	6.9	8.2	10.2	8.1	10.2	12.1	11.0	11.5	8.0	5.5	100.0
V - North	-	-	-	-	-	-	-	-	-	-	-	-	-
V - South	5.2	5.6	7.3	11.4	11.8	8.6	4.8	7.9	10.5	11.2	9.5	6.2	100.0
Avg - N	1.7	3.9	5.2	9.6	11.9	12.6	9.8	12.1	11.6	12.1	6.2	3.3	100.0
Avg - S[c]	3.7	4.6	6.7	8.8	10.9	10.0	8.7	10.9	11.0	11.1	8.3	5.3	100.0

[a]Data are computed from Table 1.1 "Farm Irrigation Requirements of Possible on-Farm Cropping Patterns Within Equitable Water Allocation," from Jordan Valley Irrigation Project - Stage II Irrigation Network, Rationale and Verification of Design Concepts."[12] Monthly requirements assumed 75 percent irrigation efficiency. Average values shown are weighted according to total monthly irrigation requirement.

[b]North Zone is shown only for comparative purposes. South Zone is affected by wadis draining from Greater Amman Area. "Crop Group" arbitrarily is organized to separate pages in which Table 1.1 appears. Thus Crop Group I comprises wheat/barley, berseems, maize, sorghum, 3 types of tomatoes, and 2 types of eggplant. Crop Group II comprises 2 types each of peppers, squash/cucumbers, cabbage/cauliflower, and beans and one type each of melons and potatoes. Crop Group III comprises one type each of potato, onion/garlic, other vegetables, bananas, citrus, and other fruits. Crop Group IV comprises pepper, citrus, 3 types of tomatoes, melons, squash, 2 types of cucumbers, wheat/barley, onions/garlic, bananas, citrus, corn, berseem, beans, and 2 types of potato. Crop Group V comprises 2 types each of cabbage/cauliflower, beans and eggplant, and one type each of other vegetables, citrus, squash, melons and wheat/barley.

[c]Inasmuch as an average monthly rate would be roughly 8.33 percent of the total annual consumption, it can be seen that the seasonal variation (South Zone) ranges between about 3.7/8.33 equals 44.4 percent of average in the lowest winter month to about 11.0/8.33 equals 133 percent of average during the highest summer months of irrigation.

Valley Irrigation Project of 57 MCM/yr.[6,19] It was reported that the return flows from Irbid will percolate into the groundwater to be used again or will flow into a tributary to the Yarmouk River where it will be available for reuse. The return flow from the northern area will return to the Wadi Araba, where it could be stored in the proposed Wadi Araba Dam, or else returned directly to the Yarmouk River.[6]

Return flows from the Amman-Zarqa area will either enter the groundwater system or the Zarqa River system from which latter it would be released from King Talal Reservoir on a regulated basis.[6] For both Amman-Zarqa and Irbid areas, it is estimated qualitatively that about 60 percent of the supply would become return flow, but this would increase if greater portions of the areas became sewered. Thus, for 80 percent sewering of Amman and 60 percent sewering of Irbid, the return flows would increase to about 65 percent.[6] It is noted that the data cited from Table 5-6 imply a 100 percent sewering of the urban area, hence a major return to the Jordan Valley, presumably via Seil Zarqa. JVA is generally more interested in surface water returns than in the less positive returns via groundwater.[19]

SIGNIFICANCE OF WADI STORAGE

JVA has indicated that due to the uniform flow nature of return wastewater effluents from the urban areas, these contributions to the Jordan Valley would be generally comparable to natural base flows in the wadis and thus would not be particularly in need of regulatory storage. Furthermore, riparian vegetation in these wadis is not extensive, and consumptive losses in transit to the Jordan Valley would be relatively insignificant.[19] Thus, it appears that any remaining concern may be over possible losses of urban effluent as a result of flood flows and the limitations of existing wadi storage in storing both the effluent-augmented natural base flows and storm runoff for optimum use in meeting JVA irrigation demands.

A detailed examination of the hydrological experience and flow impoundment and regulation capabilities of existing wadi storage or potential augmented storage is beyond the scope of this Master Plan for Wastewater Disposal. Dam project feasibility is determined only upon comprehensive studies of all relevant physical, environmental and economic factors. It is likely that additional storage could be constructed in the various wadis (including Wadi Zarqa or Seil Zarqa) which are already or will in the future be the recipients of urban wastewater effluents from the Greater Amman Area. It is understood that final studies are nearing completion for an enlargement of King Talal Reservoir by raising of King Talal Dam.[20] It is known that the annual stream flow in the hydrologic areas involving Salt, Amman, and Wadi es Sir ranges between 50 and 80 mm and in the areas involving Na'ur and Baqa'a ranges between 80 and 120 mm.[2] There are doubtless a number of potential damsites on certain of the wadis but it remains to be demonstrated that they could form significant impoundments to aid in conserving effluent as well as flood waters. However, the King Talal Reservoir appears to be a real possibility.[21] By raising the dam about 9.5 m, the storage could be increased from about 44 MCM to about 64 MCM. Adequate storage is, of course,

the key to water conservation. Without adequate storage there is greatly impaired potential for capture of both natural and man-made runoff.

SIGNIFICANCE TO MASTER PLAN

Table 7-10 indicated a seasonal variation in the irrigation demand in the Southern Zone of the Jordan Valley ranging between a low of about 44 percent of annual average to and a high of about 133 percent of annual average. Of course, the low demand period coincides with the heaviest periods of rainfall (December through March, normally) and the highest demand period parallels the normally rainless months. To the extent that storage already in existence on the various wadis draining from the plateau of the Greater Amman Area can regulate the uniform effluent outflow vis-a-vis the irrigation demand while still functioning adequately to capture intended runoff, there should be little, if any, concern about the impacts of such effluent outflow upon the JVA system. However, it is recognized that the smaller wadis have limited storage capacity, such as Shu'eib and Kafrein Dams. Storm runoff, particularly in wet years, would have a fairly good opportunity of washing some or most of the impounded effluent out of the system and into the Jordan River and Dead Sea (refer to Table 7-9).

In the case of King Talal Reservoir, the stakes are even higher because the bulk of the effluent will be flowing down the Seil Zarqa and into the reservoir.

As an extreme illustration, assume that King Talal Reservoir alone were called upon to regulate flow for the total irrigation demand within the Jordan Valley, taken as 360 MCM/yr (averaging 30 MCM/mo), and the variation were to range between a seasonal low of about 13 MCM/mo and a seasonal high of about 40 MCM/mo under a demand pattern generally as indicated in Table 7-10. Then for a uniform flow to King Talal Reservoir, and ignoring surface evaporation, the required irrigation regulatory storage would be about 40 MCM or 80 percent of the live capacity of the existing reservoir. Of course, there is actually considerable diversion flexibility using the existing Yarmouk River headworks and much more to be provided when Maqarin Dam in constructed. However, there is no question that additional regulatory capacity in King Talal Reservoir could prove beneficial.

The question arises as to whether there would be merit in causing some of the wastewater treatment plant effluent to be diverted from one wadi to another, such as by sewering arrangements for contiguous communities located in adjacent drainages. In Chapter 9, under the section entitled "Cost Analysis of AWSA Facilities", an analysis is presented on a possibility for southerly diversion of UWATP effluent. Such effluent would normally drain to the Seil Zarqa drainage but, because of the location of UWATP on the watershed divide, the flow could be diverted with little or no pumping to the Wadi Kafrein. If desired, the flow could be pumped across the watershed divide into either the headwaters of Wadi el Oastal or Wadi Hisban. The potential benefits in such a pumped diversion (such as by riparian agriculture) would have to be weighed against the facilities costs (including pumping energy) to determine the best course of action. In general, such arrangements would not normally be considered as valid alternatives, out of

considerations of pumping energy requirements where they are substantial.

The UWATP potential diversion of effluent might be an exception. Normally, diversion of either raw wastewater or treatment plant effluent to an adjoining watershed would not prove attractive. It is questionable if even comprehensive operational studies of the various reservoir systems would be able to demonstrate advantages in such arrangements even if sufficient hydrologic data were available to permit such studies. The Vice President of JVA has indicated there would be no advantage of such a diversion to JVA.[19] Of course, there could presumably be a reduced water quality impact upon King Talal Reservoir, and this might be beneficial. Therefore, future planning should remain alert to possibilities for improved salvage of effluent for beneficial use and improvement of water quality.

It is recognized that there will be urban wastewater contributions to the Seil Zarqa not only from the Greater Amman Area but also from the new treatment plant at Jarash. Some perspective on this is given by the following tabulation which compares year 2000 anticipated effluent flows from various wastewater treatment plants to the reservoir live storage on affected wadis.

Treatment Plant	Effluent MCM/yr	Annual Effluent Flow as Percent of Reservoir Storage			
		KTR (Now)	KTR (Enl.)	Kafrein	Shu'eib
Ain ghazal	35.0	80	55	---	---
Upper Wadi Abdoun	6.2	17	12	129	---
Kharb.-Rus.	13.2	32	22	---	---
Zarqa-Rus.	12.0	27	19	---	---
Jarash	0.3	1	1-	---	---
Salt	1.7	--	--	---	38
KHMC	0.5	1+	1-	11+	---

It is concluded that additional storage would be beneficial in capturing effluent runoff but that detailed operational study would be necessary for optimization. It could be beneficial to divert flows from Upper Wadi Abdoun Treatment Plant to Wadi es Sir thence to Wadi Deir Abu es Suwwan and Kafrein Reservoir. It would be possible to divert UWATP effluent southerly to the Dead Sea watershed, although pumping would be required to traverse the watershed divide.

LAND RESOURCES

One source of information, among others, on land resources in Jordan is the Draft Environmental Report on Jordan by the Science and Technology Division, Library of Congress.[22] Reference is made to this document within the context of the need for enhancement of the productivity of many of the lands of Jordan, including the Study Area. To this end, the following excerpts from this Draft Environmental Report are of interest to this Master Plan Report with respect to potential applications of digested sludges and, possibly, reclaimed effluent:

- Within Jordan, the Forest Department controls about 131,500 ha designated as forest land, but the actual forested area has been estimated to be much smaller: only about 36,000 ha as of 1964.

- Both the main forest areas in the northern highlands and the southern highlands are degraded, but rainfall conditions in the north make forest regeneration in this area more feasible than in the south.

- Reasons for deforestation have varied from time to time, although overgrazing, clearing of land for agriculture, and exploitation of forest for fuel have been persistent problems.

- The effects of deforestation are many: soil erosion resulting from the loss of vegetative cover; loss of valuable timber resources; and damage to watershed areas.

- Jordan is, for the most part, underlain by calcareous rock representing many ages and types. In the north central part of the country there are, however, large areas of basalt laval flows while scattered volcanic intrusions occur along the western escarpment.

- Red Mediterranean soils are typical of areas with greater than 275 mm rainfall; although usually derived from calcareous rocks, such soils are also occasionally derived from basalt and sandstone. Most of the good agricultural soils of the Jordanian plateau belong to this group, which, when deep, serve as excellent cropland.

- Yellow Mediterranean soils are found in some parts of the highlands and in the Rift Valley. Where water is available, they are suitable for irrigation.

- Yellow soils, typical of the arid climate, are extremely calcareous, varying in origin from weathered limestone and chalk to colluvial loess. These soils which typically support steppe vegetation have suffered badly from degradation of many kinds: uprooting of shrubs for fuels; excessive ploughing; trampling; overgrazing; and wind and water erosion.

Factors such as the foregoing should be taken into consideration when developing programs for beneficial use of digested sludge and, possibly, irrigation with reclaimed effluent. It will require a number of years of effort before such programs can be developed, probably including pilot plant or demonstration plant applications as one of the stages.

ENERGY RESOURCES

According to the 1978 Annual Report of the Industrial Development Bank[23] generated power in Jordan increased by 20 percent to 714 million kwh. On the other hand, consumption of electricity increased by 15.3 percent to 599 million kwh, 27 percent of which was for industrial use, 36 percent for domestic use, and the balance for commercial, water pumping and other uses. The Library of Congress Draft Environmental Report on Jordan[22] noted that hydroelectric power that was not highly developed by hydroelectric powerplants is planned for the Maqarin Dam (20 MW) as well as for King Talal Dam (2 MW). A few small-scale hydro-power developments might be possible on Wadi Jurum.

The point of the foregoing is that energy resources in Jordan should be considered as precious and wastewater disposal developments should seek to minimize energy consumption, particularly if reasonable alternatives exist. This also holds true for the possibilities of beneficial reuse of effluent on the plateau.

For example, there are roughly 200 m vertical difference between a potential Upper Wadi Abdoun Treatment (or Reclamation) Plant site and the existing Ain Ghazal Treatment Plant. Making reclaimed effluent available at such an upper plant, if feasible on other accounts, would have a particular elevation advantage over availability at AGTP. Considering both static lift and pipeline friction losses, a general advantage of roughly one kwh per m^3 would be held by the upper plant location. This could be important in reuse developments.

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CHAPTER 8

WASTEWATER COLLECTION, TREATMENT AND DISPOSAL ALTERNATIVES

This chapter integrates information and criteria from the previous chapters into the development of wastewater collection, treatment and disposal/reuse alternatives that will meet the needs of the Greater Amman Area. Water quality standards and objectives are developed, following which effluent requirements for treatment and disposal alternatives are established. Communities, or groups of communities, that can reasonably be served by public facilities are selected, and specific wastewater collection, treatment and disposal alternatives are devised for them to accommodate the projected wastewater flows and meet water quality standards and objectives. The alternatives are then analyzed and the most viable alternative is selected based primarily on cost and environmental considerations. The alternatives thus selected are subsequently analyzed in Chapter 9, ranked in an environmental assessment, and given a regional priority ranking for future Master Plan implementation.

WATER QUALITY STANDARDS AND OBJECTIVES

Water is an extremely scarce and valuable commodity in the Greater Amman Area and throughout The Hashemite Kingdom of Jordan. It is a resource that must be protected, preserved and upgraded whenever possible. The main purpose of this Master Plan for Wastewater Disposal is to develop a program for wastewater disposal facilities and wastewater management that will enhance the public health and simultaneously aid in conserving water and upgrading water quality.

As a first step, water quality standards and objectives must be developed and used as a baseline for establishing effluent requirements for proposed wastewater treatment and disposal facilities.

Water quality conditons and water quality criteria have been presented in Chapter 7. In addition, Appendix H-3 has presented water quality criteria and regulations governing the use of treated effluent for irrigation water, industrial water, and recreational impoundments. These criteria are of interest in determining both the desirable and achievable types of wastewater treatment facilities that should be included in this Master Plan. They also indicate the effluent quality to be expected from differing degrees of wastewater treatment as well as the qualities of water of wastewater origin that are required for differing types of use. Table 8-1 summarizes this information.

Within the Greater Amman Area, the only deliberate reuse of wastewtaer treatment plant effluent that has come to light during this study is the limited landscape irrigation that is practiced locally at King Hussein Medical Center (KHMC). However, a much greater indirect use takes place downstream of AGTP in the form of riparian irrigation of agricultural lands using surface flow from the Seil Zarqa, which is mostly AGTP effluent. In addition, the effluents from KHMC, AGTP, and Salt TP are all being used indirectly and unintentially for

TABLE 8-1

COMPARISON OF WATER QUALITY PARAMETERS FOR VARIOUS WATER USES[a]

Water Use	Maximum Value of Constituent mg/l					Allowable Coliforms
	TDS	Nitrate	Chloride	Sulfate	PO4	MPN/100 ml
Drinking[c]	500	45	250	250	-	Less than 1
Use, Reclaimed from Wastewater						
Agricultural Irrigation						
Food Crops	750	Note 1	Note 2	Note 3	Note 1	2.2
Fodder	Varies	Note 1	Note 2	Note 3	Note 1	---
Landscape Irrigation						
Golf Courses, cemetaries & general landscaping	750	Note 1	Note 2	Note 3	Note 1	23
Parks, playgrounds & schoolyards	Varies	Note 1	Note 2	Note 3	Note 1	2.2
Recreational Impoundments						
Non-restricted	--	Note 1	Note 2	Note 3	Note 1	2.2
Restricted	--	Note 1	Note 2	Note 3	Note 1	2.2
Landscape, non-contact	--	Note 1	Note 2	Note 3	Note 1	23
Industrial	Criteria vary with the specific application					

a For additional details, see Chapter 7.

b According to the University of California Cooperative Extension Guidelines for Interpretation of Quality of Water for Irrigation (Table H2-5) no salinity problems occur when the electrical conductivity (EC) does not exceed 750 umhos/cm. This would correspond to a TDS concentration of perhaps 450 to 550 mg/l TDS, depending upon salinity makeup. However, it is entirely possible to use irrigation water successfully with electrical conductivity of 1,000 to 1,500 umhos/cm even more, although the likelihood of problems developing increases with the conductivity, particularly where sodium and chloride contents are significant. For example, Colorado River water with TDS content of 750 mg/l and EC in excess of

TABLE 8-1 (Cont'd)

b continued

has been widely used for irrigation in Southern California with fairly good success. It is desirable, though not mandatory for irrigation waters to be lower in conductivity than 750 umhos/cm, certainly lower than 750 mg/l TDS where possible. The National Academy of Sciences and National Academy of Engineering "Water Quality Criteria, 1972" cite tolerance of crop plants to salt, from which the following examples are taken:

High Salt Tolerance	Medium Salt Tolerance	Low Salt Tolerance
Beets, asparagus	Tomato, cauliflower, cucumber, squash	Radish, green beans, celery
Sugar beets, cotton	Wheat, oats, sunflower	Field beans
Date palm	Fig, olive, grape	Strawberry, citrus, apple pear, apricot
Salt grass, Bermuda grass, barley	Several clovers, rye wheat, brome,	White Dutch clover Red and Ladino clovers

c

Nitrate standard is generally used by various authorities. TDS, chloride, and sulfate standards are those of California Department of Health for drinking water permits. If no water of this quality is available, water supply is acceptable with up to double these values listed.

Notes:

1. Nitrate is a plant nutrient and is normally advantageous in irrigation water. For recreational impoundments, high concentrations of nitrogen are sometimes of concern (because of eutrophication possibilities) but phosphorus is frequently controlling.
2. Chloride is a monovalent ion and contributes substantially to EC when present in large concentrations. Also there may be some specific ion toxicity potentials (Table H2-5.)
3. Sulfate is not as much a problem as chloride normally in irrigation waters but should not be present in very high concentrations.

groundwater recharge. It is likely that similar effects will be experienced in future years from new wastewater treatment plants as well. There will undoubtedly be incidental human contact with the effluent, as is now the case. Therefore the best possible attempts must be made to obtain treatment plant effluent quality that will reduce the hazards to the public health.

The following tabulation briefly compares certain water quality standards with candidate treatment facilities within the Study Area:

Beneficial Use	Key Water Quality Standards	Candidate Treatment	Acceptability of Treatment
Agricultural irrigation	Coliform organisms (2.2 MPN per 100 ml)	Primary	Extremely limited. Effluent not suitable for discharge into a wadi. Therefore eliminated from further consideration.
		Secondary	Much less limited in application than primary but may have difficulty in meeting coliform criteria.
		Filtered Secondary (Tertiary)	Good, will comply with standards but is relatively expensive.
Groundwater recharge	Considered case by case but often coliforms and virus are limiting. Nitrate could also be a limitation. Drinking water standard is 45 mg/l NO_3.	Secondary	May suffice for microorganisms but not for nitrates.
		Tertiary	Acceptable for microorganisms but not for nitrates.
		Tertiary plus dentirification	More acceptable
		Advanced	Most acceptable, but too costly for consideration

From the foregoing comparisons, it is clear that the minimum level of wastewater treatment to be considered where effluent discharge to a wadi will be experienced is secondary. It would be desirable for there to be filtration of secondary effluent for reduction of microorganisms and denitrification as well. However, both steps are expensive and presently difficult to justify. Accordingly, interim effluent quality standards are established which will be achievable by well operated secondary treatment platns, viz:

Parameter	Discharge Requirement
BOD^5	50 mg/l
SS	50 mg/l
Coliform Organisms	MPN 2000/100 ml
pH	6.5 to 8.5

The long range goal is to meet water quality standards for irrigation, and possibly landscape impoundments, without restrictin by providing effluent filtration as mininum. This will have to be deferred until funds are available. Another long range goal, probably of less urgency, is denitrification.

The first step is to provide adequate secondary treatment as the minimum standard of treatment for all plants which will discharge effluent to a wadi.

INDUSTRIAL WASTES CONTROLS

At the present time, the newer industries of the Greater Amman Area are already required to provide internal measures to contain discharges of pollutants to the surface or groundwaters. However, the older industries were mostly established during times when little consideration was given to the consequences of pollutant discharges. As a result, instituting internal measures to contain or pretreat their wastes would be difficult and costly for many of the older industries. Requiring these industries to revamp their operations and internal facilities could prove to be economically burdensome to many of them, perhaps to the point of forcing some of them out of business. In as much as this would be contrary to the Government's goal of attaining fully employment and a healthy economy, a compromise might be sought with the goals of environmental protection, at least in hardship cases. Thus for an interim period, the true hardship cases might be given staged upgrading requirements extending over a period of several years. However, by 1990 at the latest, there sould be full compliance with industrial wastes discharge requirements by all industries. Hazardous discharges such as of mercury wastes would be corrected as soon as practicable by internal measures or by plant shutdown.

The analyses in this Master Plan are based on the assumption that full compliance with recommended industrial wastes ordinances will be accomplished by 1990.

Therefore, no special provisions will be made in the Master Plan for water quality standards and objectives to accommodate industrial wastes discharges.

DRAINAGE BASINS OF GREATER AMMAN AREA

The Greater Amman Area is divided into three major watersheds: the Jordan River Basin; the Dead Sea Basin; and the Azraq Basin. As has been shown in Figure 7-4, the Jordan River Basin encompasses the majority of the Study Area, while the Dead Sea Basin drains the southern part of the Study Area and the Azraq Basin drains a small portion in the southeast. Each basin can be divided into a myriad of smaller basins, but for convenience, the major basins have been divided into the following sub-basins:

Major Basin	Sub-Basins
Jordan River	Seil Zarqa Northwestern Western Southwestern
Dead Sea	Southern
Azraq	Not applicable

In order to avoid spending undue time and effort analyzing projects that would have little or no impact on the Study Area, only those communities with an existing population of 3,000 or greater were considered. The 3,000 cut-off point was chosen because communities of less than 3,000 often have no water distribution systems, which has a major impact on the generation of wastewater, and because these small communities comprise less than 8 percent of the existing Study Area population. Communities of less than 3,000 will be considered, however, if they are within easy access to new collection and treatment facilities that are being analyzed for larger communities.

ALTERNATIVES FOR SEIL ZARQA SUB-BASIN

Seil Zarqa Sub-Basin is the major sub-basin in the Greater Amman Area. It also involves the AWSA system which is by far the largest system of all Jordan. Certain programmed work is already underway for this system. The programmed work and alternatives for additional work are presented in the following discussions.

AWSA Program of Sewer Extensions

Table 5-2, previously presented, included certain historic data on the annual buildup of sewer connections to the AWSA sanitary sewer network. AWSA intends to complete its sanitary network and connections thereto by about 1990, although delays have set the program back by perhaps one or two years. Nevertheless, various active sewer construction projects in this continuing program are resulting

in the additon of 2,000 to 2,500 new connections yearly, corresponding to as much as 40,000 or 50,000 persons per year. AWSA's goal is to extend sewers throughout the Municipality of Amman. However, until such time as the Master Plan for Wastewater Disposal recommends which areas external to Amman can also be taken into the network, AWSA is being forced to restrict its network expansion plans basically to Amman Municipality. Accordingly, only the sewering of Amman can be assumed as a baseline for future planning.

AWSA Program for AGTP Improvements

AWSA's Ain Ghazal Treatment Plant (AGTP) was nominally designed to accommodate a population equivalent of 300,000 persons.[1] However, the sludge processing facilities were not up to such a population level. The AWSA has undertaken a design that will expand the sludge processing facilities and will upgrade other processes within the plant to meet the needs of the immediate future. The basic plant capacity will not be enlarged, but the anaerobic digestion capacity and sludge dewatering facilities capacity will be increased to a population equivalent of 450,000. A construction contract for this work has recently been signed. Additional work needed for upgrading the plant is yet to be established as part of this Master Plan. Only the existing plant and immediate improvements and sludge expansion may be taken as baseline conditions.

AWSA Collection System Alternatives

Nearly the entire sewer network of AWSA operates by gravity. The logical alternative would be to extend sewers within Amman Municipality and beyond Amman, if feasible, to take advantage of the considerable gravity potential that exists betwen the unsewered areas and the AGTP. In addition to Amman territory, unsewered neighboring areas lie primarily to the northwest, west, southwest, south, and southeast of Amman. Alternatives for accommodating these other areas are presented in the following discussions.

The first consideration is that of a possible upstream treatment plant in the upper reaches of Wadi Abdoun that might intercept wastewater flows from much of the area westerly of Amman and provide local treatment. The effluent would then be discharged into a nearby wadi, but could also be available for reuse. The general location of this potential plant, south of Wadi es Sir, has been designated as the Upper Wadi Abdoun Treatment Plant (UWATP). Whether or not this plant is implemented may effect slightly the sewering costs of the areas westerly of Amman as explained subsequently.

Upper Wadi Abdoun Alternatives

Field investigations have identified three possible plant sites in the Upper Wadi Abdoun Area. The first of these sites is located near where the Wadi Mutba at Musa comes very close to the Na'ur Road. (The Wadi Mutba at Musa is an upper portion of the Wadi Abdoun). Because of a geographical peculiarity, the sewage tributary area lying betwen Wadi es Sir and the western city limit of Amman can drain to the next catchment area which is drained by the Wadi esh Shita. This

would convey the wastewater effluent completely out of the AWSA drainage area. A treatment plant can be construced on either the eastern or western side of the Na'ur Road and still take advantage of this situation. Investigations of the area have shown that more development has occurred and should continue to occur on the eastern side of the Na'ur Road. To minimize possible conflicts with the residents in the area, the wastewater treatment plant should be sited on the west side of the Na'ur Road where less development is expected to occur. This is known as Alt. Site 1. It is the basic site shown on Figure 8-1.

The second site is immediately to the south by the edge of the Wadi Deir Chubar near an abandoned quarry site (Alt. Site 2). It would handle the drainage from the same region as the first site. The natural drainage from this site is down the Wadi Abdoun and through the city of Amman. Effluent could also be pumped back from this site across the Na'ur Road to the Wadi esh Shita.

The third site is at the junction of the Wadi Deir Ghubar and Wadi Jahara. It would take flow from Marj el Hamam and the surrounding areas and as such can treat more flow. The flows which can be treated at each site and total AWSA flows, presuming 100 percent connections, are presented below:

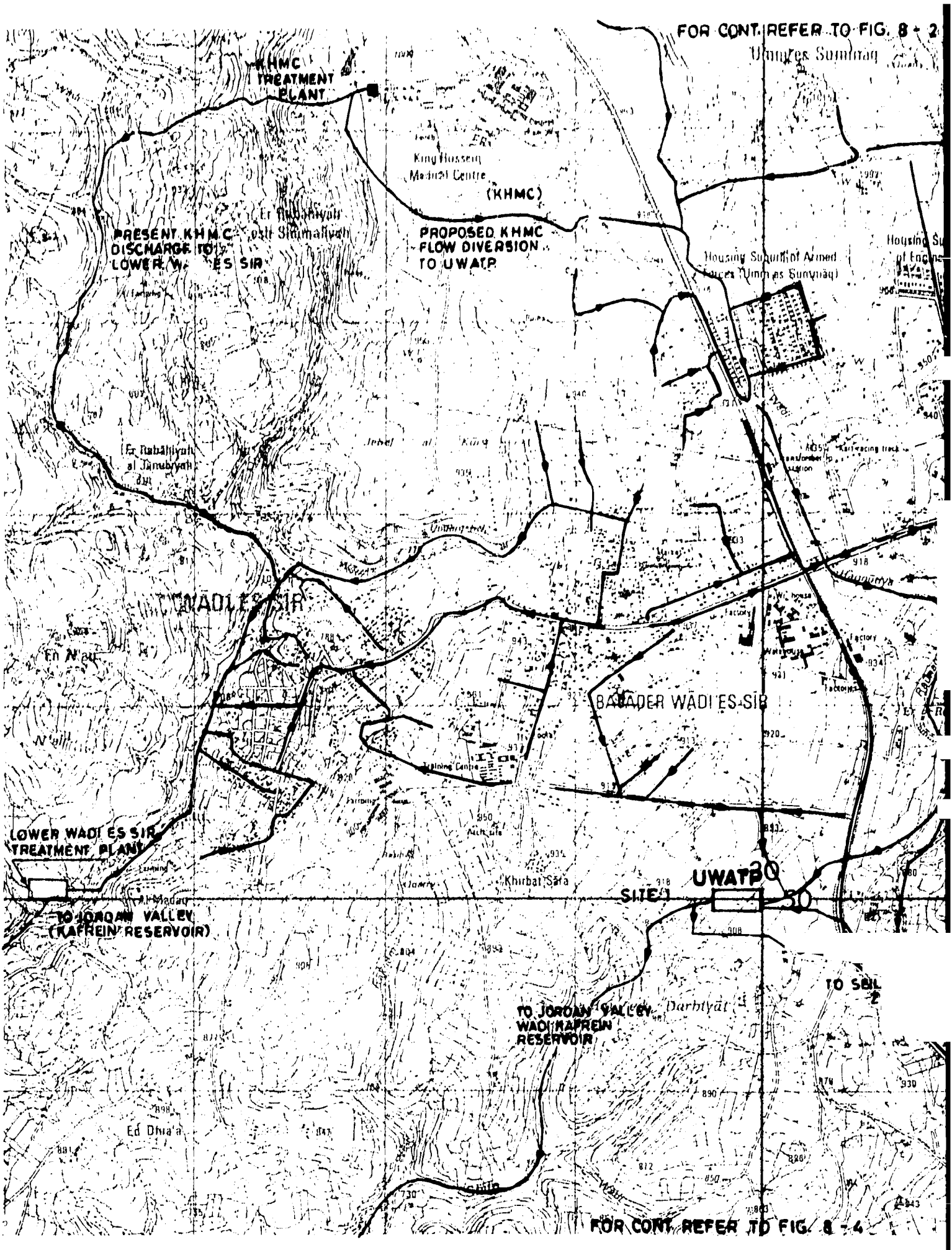
	Wastewater Flow (m^3/day)	
Site	1990	2000
1	8,600	21,200
2	8,600	21,200
3	11,400	28,200

Site 3 is located approximately 60 meters in elevation below Site 2, and is referred to as Alt. Site 3. Pumping back to a different drainage area would involve more than to meters of lift and two and one-half kilometers of pipeline. Therefore, the choice of site 3 appears to preclude an economic means of removing the sewage flow from the Amman drainage area.

Site 1 appears to be the best location for the UWATP for the following reasons:

- Wastewater can drain by gravity to the western sub-basin, thus reducing the impact of effluent on the King Talal Reservoir.
- Agriculture in the Western Sub-Basin would be provided with a new and relatively reliable source of irrigation water.
- A potential source of wastewater would be eliminated from the AWSA network, thus reducing future capacity requirements in the downstream treatment facilities.

All of these facts argue for constructing a separate UNWATP at Site 1. Another important reason why the UWATP should be built there, is that it will substanially reduce the lengths of existing trunk sewers that must be paralleled in Amman, as previously discussed in Chapter 6. This will not only save substantial trunk sewer


FOR CONT. REFER TO FIG. 8 - 2
KHMC TREATMENT PLANT
King Hussein Medical Centre
(KHMC)
PRESENT KHMC DISCHARGE TO LOWER WADI ES SIR
PROPOSED KHMC FLOW DIVERSION TO UWATP
Housing Suburb of Armed Forces (Umm as Summaq)
WADI ES SIR
BADADER WADI ES SIR
LOWER WADI ES SIR TREATMENT PLANT
TO JORDAN VALLEY (KAFREIN RESERVOIR)
UWATP SITE
TO JORDAN VALLEY WADI KAFREIN RESERVOIR
TO SEIL
Khirbat Sara
Ed Dhra'a
FOR CONT. REFER TO FIG. 8 - 4

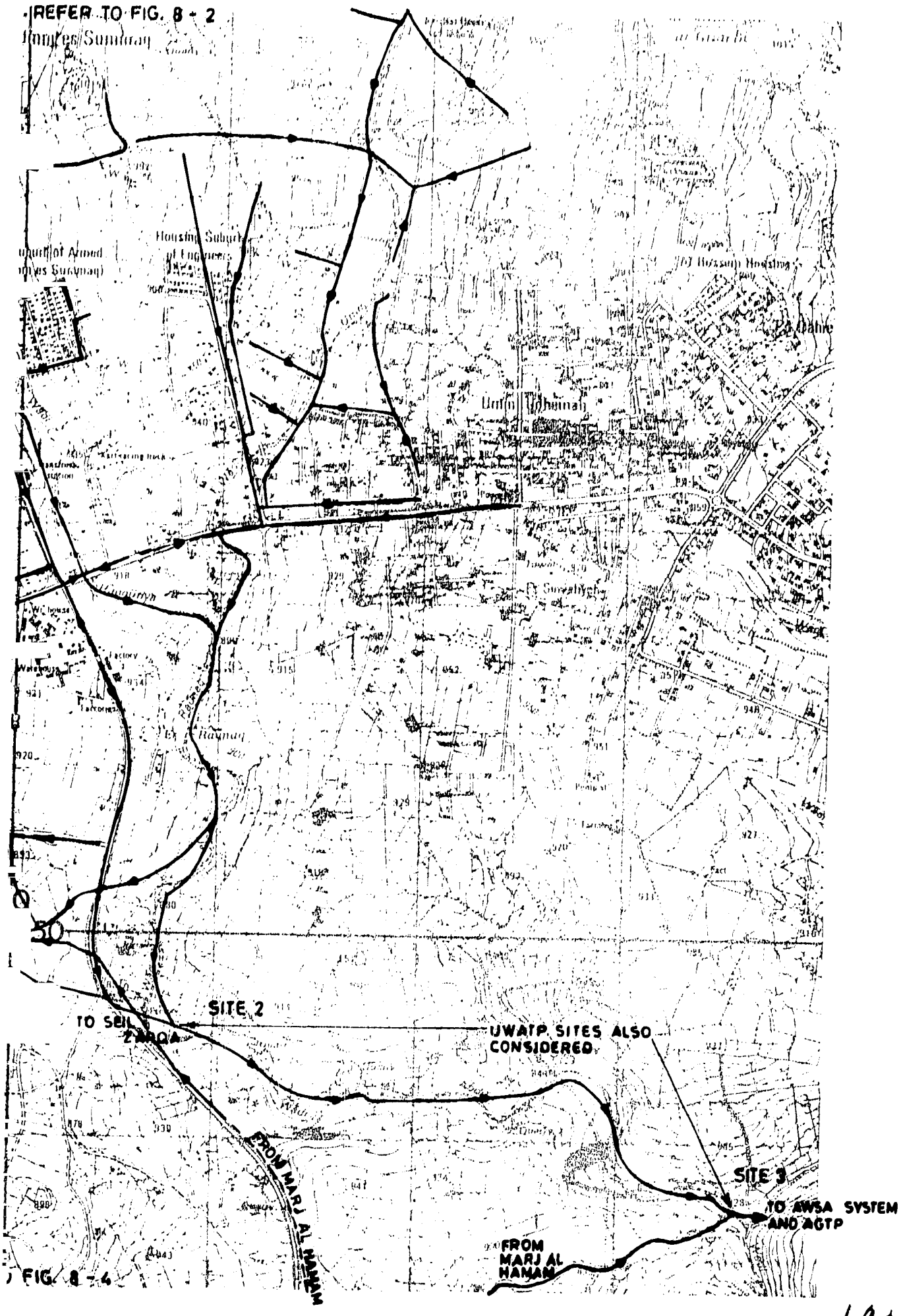
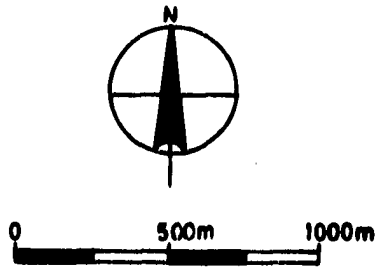

REFER TO FIG. 8 - 2
SITE 2
TO SEIL ZARQA
UWATP SITES ALSO CONSIDERED
FROM MARJ AL HAMAM
SITE 3
TO AWSA SYSTEM AND AGTP
FROM MARJ AL HAMAM

FIG. 8 - 4



LEGEND

——— PROPOSED SEWERS

NOTES :-

COLLECTION / DISPOSAL ALT. FOR WESTERN SUBURBAN RING :-

ALT. CA1 - CONSTRUCT UWATP
GRAVITY DISPOSAL JORDAN VALLEY
(a) VIA KAFREIN DAM. DISPOSAL BY PUMPING POSSIBLE TO DEAD SEA BASIN

ALT. CA2 - NO UWATP. - FLOW TO AGTP.

COLLECTION / TREATMENT ALT. FOR KHMC :-

ALT. 1 - PRESENT CONDITIONS - TREATMENT AT KHMC
DISPOSAL TO WADI ES SIR

ALT. 2 - DIVERSION OF FLOW / TREATMENT AT UWATP.

ALTERNATIVES FOR KHMC, UWATP, AND LOWER WADI ES SIR

FIGURE 8 - 1

relief costs, but also will reduce the impact that the construction will have on traffic congestion in downtown Amman. Based on the previous discussion, constructing a new treatment plant at Site 1 appears to be the best alternative for the upper Wadi Abdoun area.

If UWATP is to be implemented, Site 1 is preferred. However, it has not yet been demonstrated that implementation of UWATP is preferable to not implementing it. Therefore, in subsequent analyses, more detailed consideration is given to the basic alternatives concerning UWATP.

- Collection Alternative CA1 for AWSA involves the implementation of UWATP (Figure 8-1). It entails diversions of tributary flows and reductions of downstream capacity requirements in AWSA primary network relief sewers as well as in overall treatment facilities. It reduces somewhat the total runs of gravity sewers from certain tributary areas westerly of Amman and, hence, slightly lowers the sewering costs to these areas. It makes available for potential reuse, reclaimed water at an advantageous elevation on the plateau, and it provides flexibility in the disposition of effluent as to sub-basin receiving it.

- Collection Alternative CA2 for AWSA involves no implementation of UWATP. Therefore tributary flows from westerly areas will have somewhat longer sewer runs to reach the AWSA network than for CA1. There will be greater AWSA trunk relief requirements in the existing primary network and greater downstream treatment capacity requirements than for CA1. Reuse potential advantages and effluent discharge flexibility will be lost.

North-Draining Suweileh Alternatives

The most densely populated portions of Suweileh are in the central area, which is where the greatest concentration of poor people live and where difficulties with cesspool disposal appear to be greatest. The drainage is towards Baqa'a Valley and King Talal Reservoir. The nearest major population center in this Northwest sub-basin is Baqa'a Refugee Camp, located several kilometers to the north of Suweileh and easterly of a west-central valley location for a treatment plant that could serve them both. Baqa'a Camp lacks adequate water distribution at present, and this feature could have a higher priority than public sewerage.

Suweileh embraces a watershed divide separating the Seil Zarqa sub-basin, the northwest sub-basin, and the western sub-basin. Septage discharges and overflows that occur in the central Suweileh area could be relieved by pumping wastewater flow from north-draining Suweileh to the Seil Zarqa sub-basin. The pumped wastewater would be directed either into a gravity trunk sewer that would likely be constructed in a fairly early stage to serve Al Jubeihah, the University of Jordan, and downstream developments, or alternatively into a gravity trunk sewer that would serve south-draining Suweileh, the King Hussein Medical Center area

(KHMC), and portions of Umm es Summaq. The latter trunk sewer probably will not be needed for several years because the area it will serve is undergoing a relatively slow rate of development.

Preliminary engineering comparisons were made of two alternatives (Nos. 1 and 2) for disposing of wastewater from north-draining Suweileh into the two alternative trunk sewer systems that would be tributary either to an Upper Wadi Abdoun Treatment Plant (UWATP) or to the AWSA network leading to AGTP. The year 2000 populations were assumed to be 100 percent connected for purposes of the comparison. Also considered was the gravity alternative (No. 3) of public sewerage for north-draining Suweileh into Baqa'a Valley in conjunction with Baqa'a Valley, Ain al Basha, and Safut using the same assumption of 100 percent connections in the year 2000. These alternatives are shown on Figures 8-2 and 8-3 respectively.

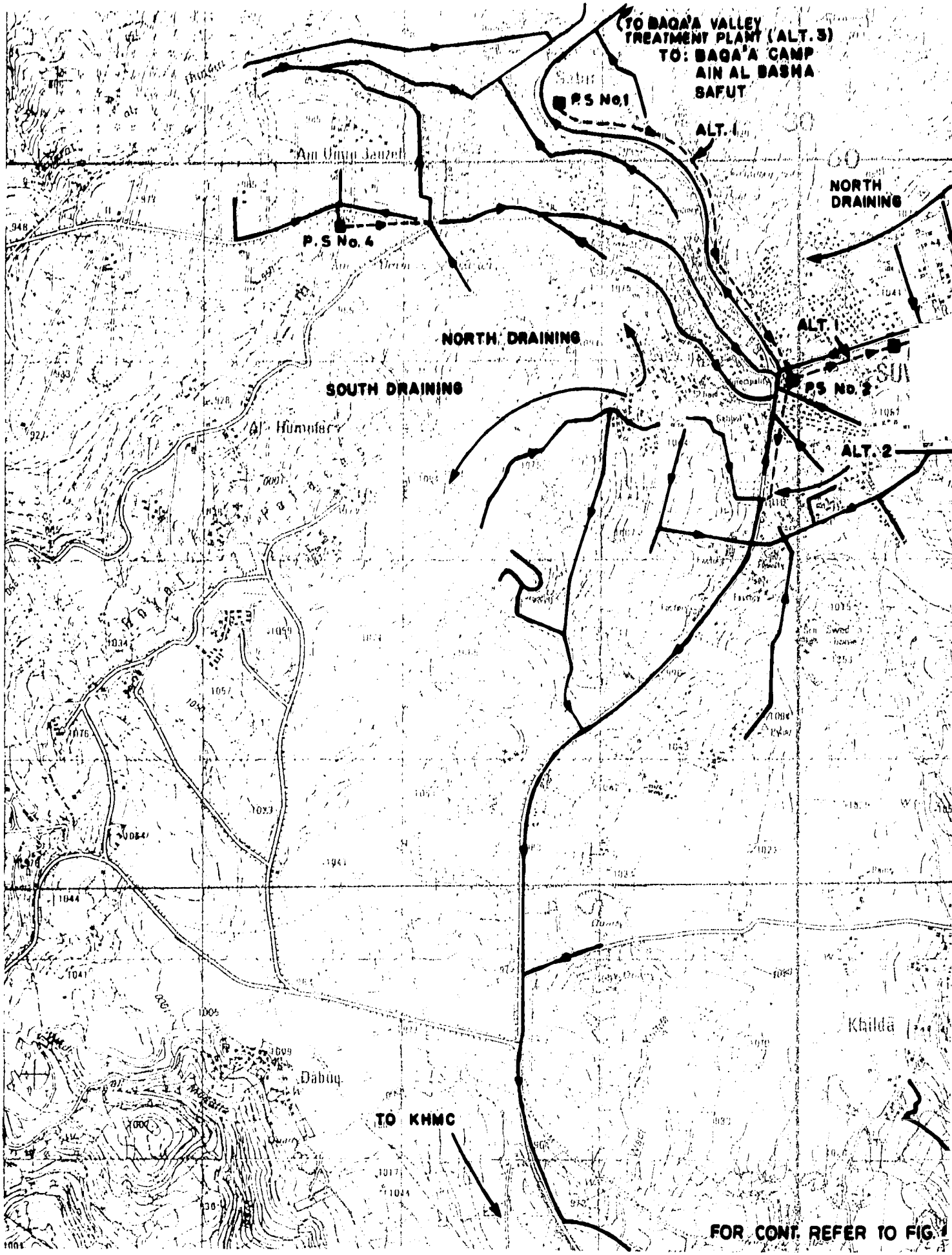
For Alternative 1, wastewater from north-draining Suweileh would be pumped out of the Suweileh area and the Northwest sub-basin and into the gravity trunk sewer serving the University of Jordan and downstream areas. This would require three pumping stations rated at a total of 85 kw, and would involve an estimated capital outlay of JD 308,000 for the pump stations and force mains plus an incremental capital outlay of JD 92,000 for increased gravity trunk sewer capacity to the UWATP. The annual power and O&M costs would total JD 28,000.

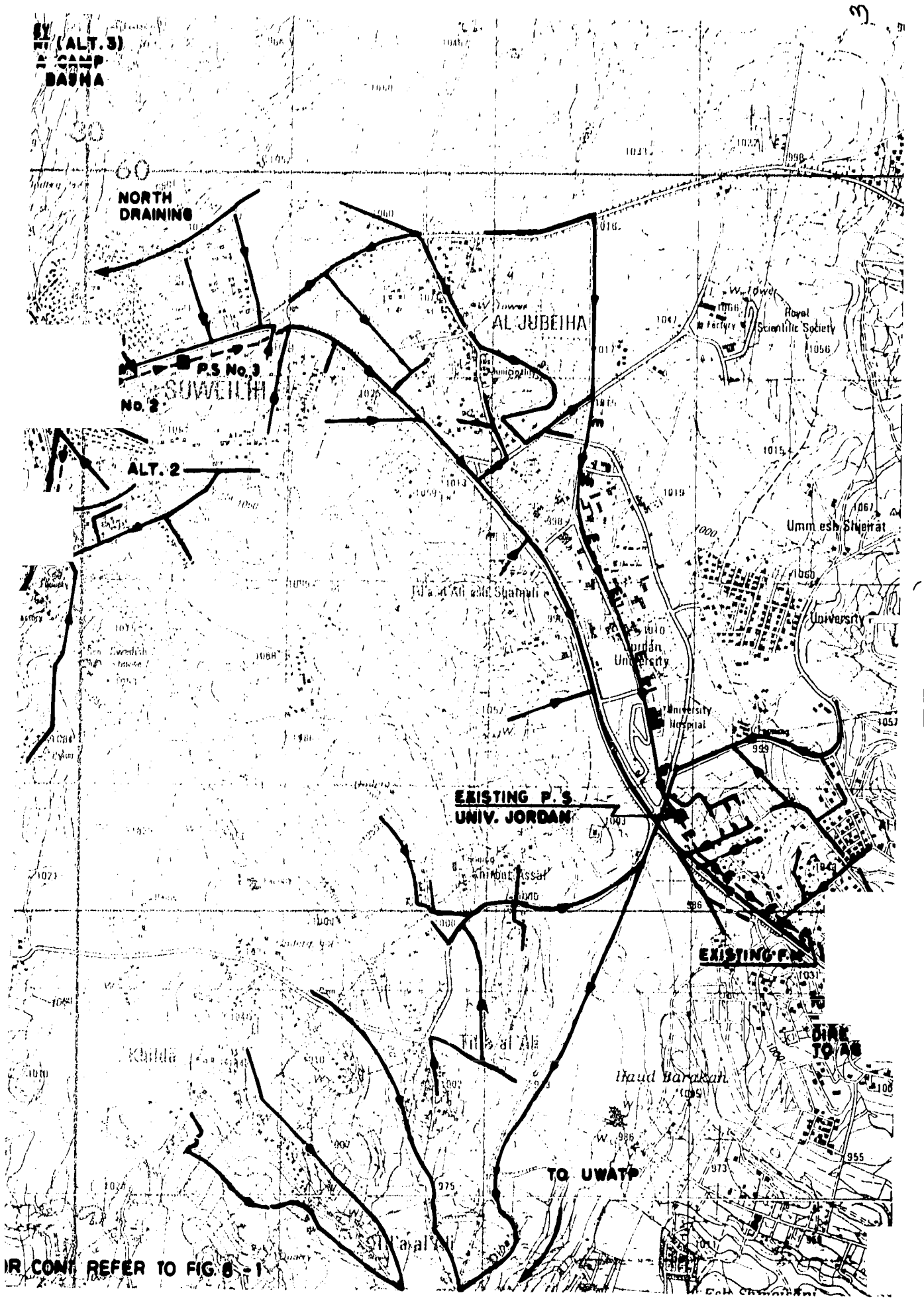
For Alternative 2, flow from the same area would be pumped to the gravity trunk sewer serving south-draining Suweileh, the KHMC and the downstream developments in this area. This would require two pump stations rated at a total of 55 kw, and would involve an estimated total capital outlay of JD 232,000 for the pump stations and force mains plus an incremental capital outlay of JD 35,000 for increased gravity trunk sewer capacity to the UWATP. The annual power and O&M costs would total JD 18,000.

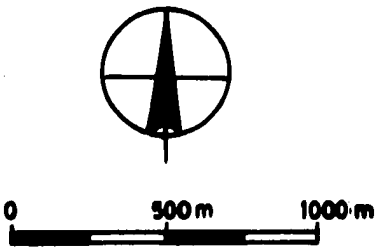
Alternative 3 would not require any pump stations and force mains, but would require that a gravity trunk sewer be constructed from Suweileh to the proposed treatment facility in the Baqa'a Valley. The estimated construction cost for extending a gravity trunk sewer from Safut, which is the next population center downstream from Suweileh, to north-draining Suweileh is JD 102,000.

These cost data are summarized in the following table:

Item	Alt. 1	Alt. 2	Alt. 3
Construction Costs			
Pump Station and Force Main	308,000	232,000	0
Gravity Sewer	92,000	35,000	102,000


(TO BAQA'A VALLEY
TREATMENT PLANT (ALT. 3)
TO: BAQA'A CAMP
AIN AL BASHA
SAFUT
P.S No.1
ALT. 1
NORTH
DRAINING
P.S No. 4
NORTH DRAINING
SOUTH DRAINING
ALT. 1
P.S No. 2
ALT. 2
Khilda
Dabuq
TO KHMC
FOR CONT. REFER TO FIG. 1


(ALT. 3)
BASHA
NORTH
DRAINING
AL JUBEIHA
P.S No. 3
No. 2
SUWEILIH
ALT. 2
Royal
Scientific Society
Umm esh Sherrat
University
Jordan
University
University
Hospital
EXISTING P.S.
UNIV. JORDAN
EXISTING P.S.
DIRE
TO AB
Khilda
Haud Barakah
TO UWATP
OR CONT. REFER TO FIG. 8 - 1



LEGEND

PROPOSED SEWERS

PROPOSED P.S AND FORCE MAIN

EXISTING SEWERS

EXISTING FORCE MAIN

NOTES :-

COLLECTION ALT. FOR SUWEILEH :-

ALT. 1 - PUMP FLOW VIA P.S 1, 2 AND 3 VIA U of J AREA TO UWATP.

ALT. 2 - PUMP FLOW VIA P.S 1 AND 2 TO UWATP VIA KHMC.

ALT. 3 - FLOW BY GRAVITY TO BAQA'A VALLEY TREATMENT PLANT

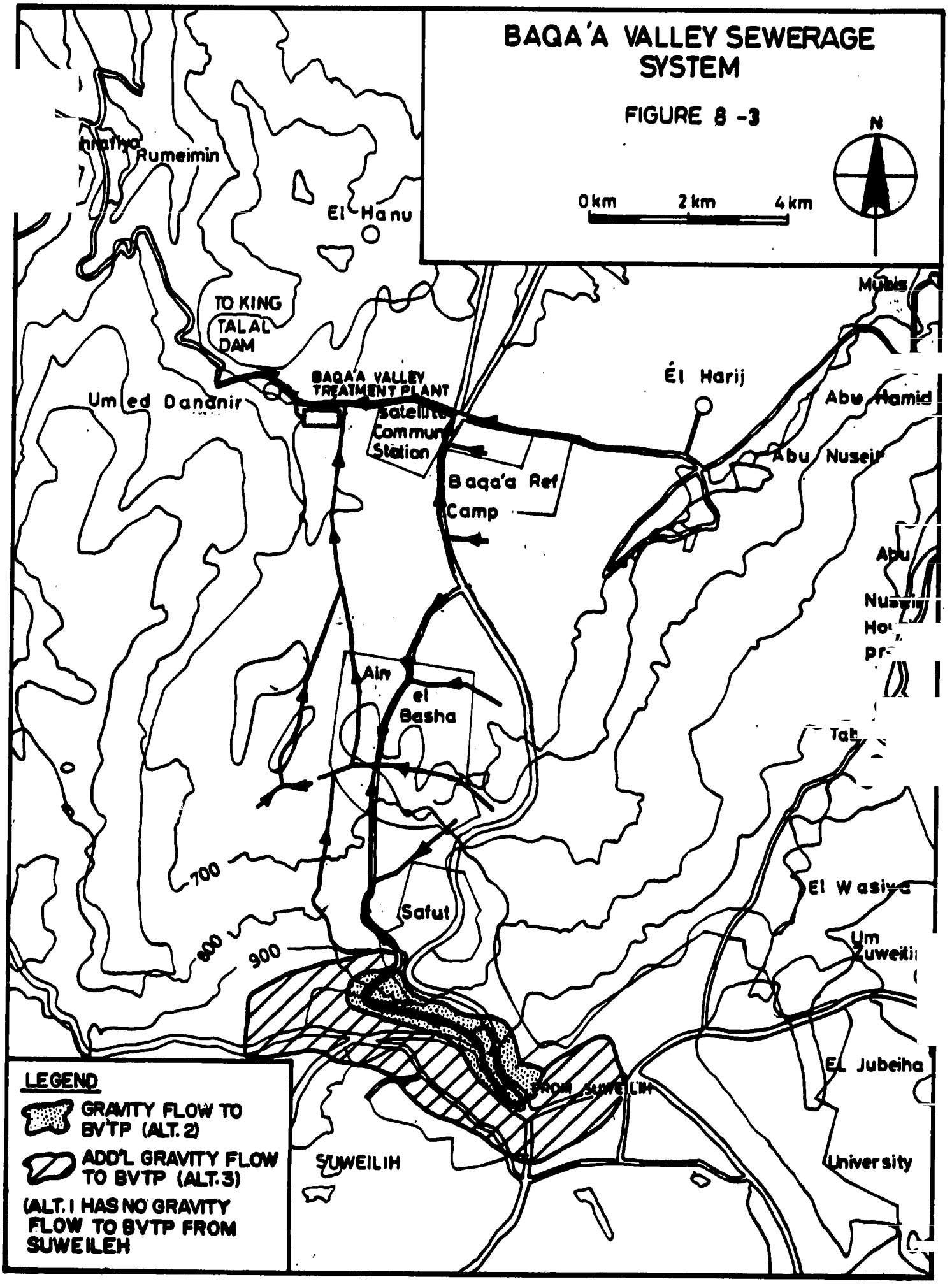
COLLECTION ALT. FOR U of J

ALT. 1 - CONTINUE PUMPING TO AWSA SYSTEM

ALT. 2 - P.S TO BE ABANDONED. FLOW BY GRAVITY TO UWATP.

ALTERNATIVES FOR SUWEILEH AND UNIVERSITY OF JORDAN

FIGURE 8 - 2


BAQA'A VALLEY SEWERAGE SYSTEM
FIGURE 8 -3
N
0 km
2 km
4 km
Rumeimin
El Hanu
TO KING TALAL DAM
BAQA'A VALLEY TREATMENT PLANT
Satellite Community Station
Um ed Dananir
El Harij
Abu Hamid
Abu Nusein
Baqa'a Ref Camp
Ain el Basha
Safut
700
800
900
El Wasiya
Um Zuweili
El Jubeiha
FROM SUWEILIH
SUWEILIH
University
LEGEND
GRAVITY FLOW TO BVTP (ALT. 2)
ADD'L GRAVITY FLOW TO BVTP (ALT. 3)
(ALT. 1 HAS NO GRAVITY FLOW TO BVTP FROM SUWEILEH

WASTEWATER COLLECTION, TREATMENT AND DISPOSAL ALTERNATIVES

Item	Alt. 1	Alt. 2	Alt. 3
Total Construction Cost	400,000	267,000	102,000
Implementation Cost	200,000	133,500	51,000
Total Project Cost	600,000	400,500	153,000
Equivalent Annual Capital Cost*	70,500	47,100	18,000
Annual O&M Cost	17,100	11,100	800
Annual Power Cost**	11,200	6,800	0
Total Annual Cost	98,800	65,000	18,800

* Assumes 10 percent interest and 20 year life
** For year 2000, pumps in Alts. 1 and 2 would operate slightly over 9 and 7 hr/days/respectively.

The annual power costs shown for Alts. 1 and 2 do not yet include a differential inflation allowance for energy of 4 percent per annum. When this is applied, the total annual costs for Alts. 1 and 2 rise to about JD 112,000 and 73,000, respectively.

There is considerable flexibility in Alt. 1. The University of Jordan area is already developed and therefore a candidate for early sewering. In contrast, the south-draining Suweileh area and downstream is less developed and not likely to be sewered in the near future. Alt. 1 could be used initially to provide relief to septage discharges and cesspool maintenance problems for north draining Suweileh by pumping the wastewater to the easterly trunk sewer. Eventually, the westerly trunk sewer by construction of a new force main and continued use of the intermediate level and lower level pumping stations. Inasmuch as the uppermost pumping station and force main would no longer be needed, they would be retired and a savings in energy affected. This would amount to nearly JD 10,000 annually and would more than make up for the added capital costs of the new force main.

Under either Alt. 1 or Alt. 2, it would be possible to discontinue pumping completely and to discharge by gravity to a Baqa'a Valley Treatment Plant, whenever it became implemented.

Despite the good flexibility of Alt. 1 and the lesser flexibility of Alt. 2, they are both more costly than Alt. 3. Thus, from a purely cost comparison standpoint, Alt. 3 should be selected. However, there are offsetting considerations that must be taken into acccount, viz:

- The Baqa'a Valley Treatment Plant, if implemented, would discharge effluent into the Wadi Rumeimin system leading to King Talal Reservoir.

There would be significant public exposure en route as well as impacts upon the reservoir. It would be relatively costly to mitigate these impacts by additional treatment beyond secondary.

- In contrast, implementation of either Alt. 1 or Alt. 2 would have the inherent capability of eliminating the impact on King Talal Reservoir from north-draining Suweileh by diversion of UWATP effluent to the Western sub-basin (or even by pumping it across the watershed divide and into the Southern sub-basin). Impact upon Kafrein Reservoir would resumably be less critical than corresponding impact on King Talal Reservoir.

- From the standpoint of priorities, the Baqa'a Refugee camp, the other major participant in the Baqa'a Valley TP, appears to have a greater need for adequate water distribution facilities than for public sewerage. Accordingly, it may be several years before a sewerage project serving this Camp may develop. By waiting for the Camp's participation, north-draining Suweileh could lose several years of time in which groundwater pollution and cesspool maintenance problems would continue unabated. If north-draining Suweileh were to undertake a Baqa'a Valley TP project on its own, the costs thereof allocable to north-draining Suweileh would rise because there would be no sharing of common facilities and because of economy of scale lost.

- The unit cost for pumping wastewater from north-draining Suweileh are not prohibitive. In terms of the population likely to be served (25,000 persons) they would be about JD 4.4/capita/yr or perhaps JD 26/household/yr. This would not include the cost of treatment. These would be added to the costs displayed for any alternative.

- As a matter of public policy, the costs for pumping wastewater from north-draining Suweileh could be spread over a large number of participants in the wastewater system rather than being allocated solely to the area from which the pumpage originated.

- The costs of treatment would be less under Alts. 1 and 2 than under Alt. 3 because of economy of scale and efficiency factors favoring the larger plant.

- By virtue of its participation in either or both gravity trunk sewers to UWATP, the capacity-allocated costs to other participants would be reduced. This would facilitiate their participation and concurrent reduction in groundwater pollution and cesspool maintenance problems.

Despite the fact that Alt. 1 is not the least cost solution for north-draining Suweileh, it is believed that the regional economics and environmental considerations more than compensate for this factor and that Alt. 1 should be implemented, provided Baqa'a Valley Treatment Plant is not implemented fairly soon. In the long run, Alt. 3 is the permanent solution. It should be noted that

this could also include the new, planned town of Abu Musair which is to have its own wastewater treatment plant initially but could evenutally contribute flow by gravity to Baqa'a Valley Treatment Plant.

University of Jordan Alternatives

The University of Jordan has been connected to the AWSA network since it activation some 11 years ago. At that time there was relatively little development westerly of the Third circle, Jabal Amman or what is now called Sport City. A pumping station and force main were constructed to convey the University's flow over the summit of an intervening hill between the University and Sport City area.

Now that the territory southerly of the University has developed significantly and such areas are logical candidates to be considered for inclusion in the AWSA network in future years, gravity trunk sewers will soon be constructed in the vicinity of the University of Jordan.

The basic choice is between continuing to contribute to the AWSA network via the University pumping station and force main (Alternative 1) or to retire these facilities and contribute to the new gravity trunk sewer (Alternative 2), which is shown in Figure 8-2. The choice between these alternatives is based on the costs of pumping energy and pumping station operation and maintenance versus the allocated capital cost of a new gravity sewer serving the University and adjoining area.

In 1979, about 57,400 kwh of pumping energy were consumed to pump the flow from the University of Jordan over the ridge and into the gravity collection network of AWSA, according to AWSA records. At a unit cost of 39 fils/kwh, this amounts to some JD 2,240/yr at present for energy alone for the same flows. However, with four percent allowance for annual energy inflation, this would become JD 4,900/yr by year 2000. Increasing flows would make this year 2000 pumping energy cost about JD 10,000. University pumping station operation and maintenance (other than energy) would be expected to make the year 2000 costs of pumping about JD 16,000 per year. Assuming a cost of money at 10 percent and a financing period of 20 years, a new investment in a gravity sewer for this area could be as much as JD 136,000 total capital outlay to be equivalent to the anticipated pumping cost.

The gravity sewer distance from the University of Jordan to AGTP point is about 17 km. However, if the "UWATP" were to be provided to handle this flow, the run of gravity sewer would be shortened by some 8 km. This would reduce the gravity sewer costs considerable and the allocated costs to the University and vicinity.

The capacity required by the University in a gravity sewer would approach that of two pumps running simultaneously in the current University pumping station, which is about 900 imperial gallons per minute or 68.3 l/sec, peak discharge. Allocating the costs of this peak flow capacity in the 9 km of gravity sewer on a reach by reach basis results in a total construction cost to the University and

vicinity between about JD 85,000 and 90,000. The equivalent project cost would be between about JD 128,000 and 135,000, depending upon whether or not pumped flow from north-draining Suweileh were included and helped share the cost.

The University and vicinity already have trunk sewer and treatment plant capacity in the AWSA system and would not be required to pay a connection fee for the gravity trunk sewer. Thus, the gravity sewer alternative appears to be only slightly less costly than continuing to pump flow towards Sports City. However, two other factors make the gravity sewer alternative much more attractive:

- Major repairs and improvements will be needed at the University Pumping Station within the next several years.
- By diverting the pumped flow from the AWSA primary network at its present discharge point will reduce the project cost of a relief sewer in the Shmeisani Area by some JD 125,000.

In addition to costs savings, there would be other considerations in energy savings and facilitating the sewering of already developed or developing areas westerly of the AWSA network.

In view of the foregoing, it is concluded that the University Pumping Station should be retired and gravity trunk sewer service provided for the University and vicinity, including to developed areas contiguous to the new sewer. The timing of this work is addressed in Chapter 9.

King Hussein Medical Center Alternatives

The King Hussein Medical Center (KHMC) has its own wastewater treatment plant which is designed for 450 m^3/day flow but is currently receiving some 800 m^3/day. A new treatment plant has been designed and will be constructed within the next year to supplant the present plant and also accommodate the additional loads to be experienced when the additional facilities (Rehabilitation Center, Cardiac Center, etc) are activated. The new plant will be designed to handle an average flow of 1,500 m^3/day, and a peak flow of 41.7 l/sec.

The basic consideration is whether to continue discharging effluent from the treatment platn into the Wadi Ein el Batiya which ultimately flows through the Municipality of Wadi es sir (Alternative 1), or to retire the new plant and divert the raw wastewater into a new gravity trunk sewer that will be constructed to serve Suweileh, KHMC area and portions of Wadi es Sir (Alternative 2). The new trunk sewer will discharge to either UWATP or the AWSA sewer network. In any analysis, the new treatment plant at KHMC can be assumed to be a sunk cost, for it will be several years before the trunk sewer is built. The timing of such a project is addressed in Chapter 9.

WASTEWATER COLLECTION, TREATMENT AND DISPOSAL ALTERNATIVES

For this analysis, the alternatives to be analyzed are:

- Continue to operate the KHMC Treatment Plant
- Connect to the new gravity trunk sewer and abandon the KHMC Treatment Plant.

By continuing to operate the new KHMC treatment plant and not connecting to the new gravity trunk sewer, the KHMC could avoid having to pay for a portion of the sewer construction cost, the sewer connection fee, and its share of the operation and maintenance costs of either the AGTP or the new UWATP. By connecting to the new gravity trunk sewer, the KHMC would pay for the above mentioned costs, but would save on the operation and maintenance costs of the abandoned KHMC facility.

In its simplest terms, the differential costs of energy for treatment at KHMC versus either the AGTP or the UWATP could be weighed against the gravity trunk sewer connection costs (not including other capacity charges).

For the volumes and strengths of wastewater contemplated at KHMC, the hourly average power use would be 29 kw for the KHMC and 7 kw for either the AGTP or the UWATP. The differential energy saving by diverting to the trunk sewer would therefore be 22 kw or 193,000 kw/yr, which is equivalent to approximately JD 7,500 at the 39 fils/kwh rate (applicable both to KHMC and UWATP). However, if this is escalated at 4 percent per annum, the annual cost by year 2000 would be over JD 16,000.

To divert flow from KHMC to the AWSA system would require about 2 km of gravity connection within KHMC plus 5 km of shared trunk sewer leading to UWATP. KHMC would supposedly be responsible for the entire cost of the local connection but a capacity-allocated cost of the shared trunk sewer. The total allocated project cost would be about JD 179,000. This is equivalent to an annual capital cost of JD 21,000, assuming 20 year repayment and 10 percent interest. The sewer alternative thus appears to be about 31 percent more costly than the local treatment alternative.

However, there are other important considerations that should also be weighed as follows:

- KHMC might be expected to buy capacity in the UWATP, and this would be an additional cost. However, due to economy of scale, this capacity would be cheaper than the local capacity of the new plant to be constructed at KHMC imminently:

- It will probably be at least a decade before growth in the southern area of Suweileh, Hussein Medical Center area, and areas between KHMC and Wadi es Sir is sufficient to justify a new trunk sewer to serve these areas. Assuming a value of 10 years use of the new KHMC TP and normal 20 year life for illustrative purposes, the KHMC TP would have 50 percent salvage value at the end of 10 years. However, from a present worth

standpoint, using 10 percent interest rate and 20 year repayment period, there would be very little economic value left for the plant. In other words, in 10 years (or more) the investment in the new plant would have been well justified economically even if the plant were then to be retired in favor of gravity diversion of raw wastewater towards UWATP.

- The operation and maintenance costs for wastewater treatment, other than power, would be less on a unit flow basis for UWATP than for KHMC TP due to economy of scale. In the long run, these differences could become significant.

- By eventually joining in an external sewerage system, KHMC would be facilitating other areas being connected to this sytem, by reason of sharing sewer capacity costs, thereby aiding in reducing discharges of septage underground and improving groundwater quality. These areas are already in the Seil Zarqa sub-basin whereas KHMC is in the Western sub-basin.

- The current discharge of effluent from the existing KHMC TP reportedly is having adverse effects upon groundwater supplies in Wadi es Sir. Provision of the new treatment plant should greatly reduce this problem because the plant will then have adequate capacity and will presumably also be operated by AWSA personnel, as is the case with the present plant. Eventually, however, nitrate concerns may become significant, thereby warranting retirement of the plant.

- Extensive experience in wastewater management in large metropolitan areas such as Los Angeles County has shown that it is desirable to eliminate small treatment plants in favor of a select number of larger and more efficient plants. This improves overall efficiency and water quality control. Inland water reclamation plants of suitable design may play a constructive role in this arrangement.

As a result of the foregoing, it is concluded that the new KHMC TP should be used during the period 1981-91 and possibly a few years longer. It should then be retired in favor of gravity sewer flow to UWATP in a system that would also include ajoining areas both to the north and south. During the interim period of local plant operation, careful plant operation and effluent monitoring would be required to ensure that adverse conditions downstream of the discharge do not develop. Following the interim period, consideration could be given to retention of some of the local plant capacity for water reclamation purposes, based upon a careful elevation of all relevant factors. The specific timing of the connection of KHMC to the Seil Amman drainage sewer system may be influenced by future sewerage developments in the AWSA system and vicinity as they actually unfold.

Lower Wadi es Sir Alternatives

The Municipality of Wadi es Sir straddles the watershed divide between the Seil Zarqa sub-basin and the southwestern sub-basin. The projected year 2000 population of that portion lying within the southwestern sub-basin, designated herein as lower Wadi es Sir, is 23,000 persons. The average daily wastewater production is about 1,900 cu m/da. A comparison is made between the alternatives of providing a local treatment plant for lower Wadi es Sir and pumping the wastewater across the watershed divide and into the AWSA system.

The lower Wadi es Sir ground elevation ranges between about 700 m and 950 m, mean sea level. If a local collection system were to convey the entire flow to a single collection point, the static lift for inter-basin transfer would be 250 m. When coupled with force main friction of over 10 m and other losses, a total pumping lift of about 290 m would be entailed. This is excessive for sewage pumping units. Probably at least eight pumping stations in series would be needed.

It would be desirable, at extra cost, to so arrange the gravity collection system sewers as to limit the total amount of pumping needed for the flows originating in the upper part of the collection system. This would be accomplished by concentrating the maximum amount of wastewater at as high elevation as reasonably possible. The flows originating in the lower parts would, of course, have to be lifted the full amount. Considering these facts and allowing for additonal losses incurred in the local pumping stations, it is estimated that the average lift for the overall wastewater flow would be about 170 m. The average energy consumption would be about 78 kw for the pumping.

In a simplified comparison of alternatives for Lower Wadi es Sir, the capital and power costs of a local outfall sewer and treatment plant would be compared with the capital and power costs of the pumping stations and force mains plus the cost of buying capacity in the AWSA system. The following tabulation presents this simplified comparison, the energy costs being escalated at four percent per year for 20 years:

Item	Local Treatment Plant Lower Wadi es Sir	Pump Wastewater Across Divide
Project Cost		
Local Treatment Plant	1,110	---
Local Outfall Sewer/Int'r	150	135
Pumping Stations	---	360
Force Mains	---	93
Present Worth, AWSA		
Capacity Buy-in*	---	390

Total Present Worth	1,260	978
Equivalent Annual Capital Cost	148	115
Annual O & M Costs		
Energy	60	51
Other	11	39
Total Annual Costs, Simplified Comparison	219	205

* Assumes 2,600 connections at 150 JD/connection.

The above comparison indicates that the least cost solution would be for pumping the lower Wadi es Sir wastewater across the watershed divide and into the Seil Zarqa sub-basin for connection to the AWSA system, presumably the UWATP. Despite this apparent economic advantage, it is recommended that the local treatment plant alternative be selected for the following reasons:

- The two alternatives are fairly close in total annual cost under the assumptions used. This means that other relevant factors should be particularly important in making the selection.

- Pumping wastewater uphill through a long series of successive pumping stations is to be avoided wherever possible for various reasons, including operation and maintenance. If these are not effective, reliability may suffer and overflows result. (This is less of a factor with limited stations, as in north-draining Suweileh).

- Although the energy consumption for treating the wastewater at AGTP or UWATP would be less than at lower Wadi es sir TP, this would be less than offset by the high energy costs of pumping the flow over the watershed divide.

- From the environmental standpoint, there would be no apparent advantage in transferring effluent from one portion of the Western sub-basin to another, as would occur if the flow were to be treated at UWATP instead of at lower Wadi es Sir TP. There would be no advantage at all in transferring the flow to the Seil Zarqa sub-basin.

The foregoing considerations are taken as ample justification to recommend implementation of the Lower Wadi es Sir TP instead of pumping the wastewater across the watershed divide into the AWSA system.

Marj al Hamam Alternatives

Marj al Hamam lies southwesterly of Amman within the Seil Zarqa sub-basin but is a relatively short distance from the divide that separates the Seil Zarqa and the southwestern sub-basins. The projected year 2000 populations of Marj al Hamam is 25,700 persons as compared with the 1979 census population of only 1,500. Obviously, growth of great significance is not only anticipated but is already occurring.

The three possible wastewater collection alternatives that appear feasible for Marj al Hamam are presented below and shown on Figure 8-4.

- Alternative 1 - Gravity flow to AWSA network.
- Alternative 2 - Pump wastewater to Upper Wadi Abdoun Treatment Plant.
- Alternative 3 - Pump wastewtaer to Na'ur.

As in the previous discussions of alternatives for other areas, the differences in the three alternatives for Marj al Hamam have to do with disposing of the raw wastewater after it has been collected in the community's proposed wastewater collection system.

Alternative 1 would utilize the AWSA network for ultimate disposal. The collected wastewater would flow by gravity from Marj al Hamam to the AWSA network via a gravity trunk sewer approximately 4.5 kilometers long constructed expecially for that purpose. The trunk would connect to another gravity trunk sewer that would be carrying either raw wastewater from the area above Wadi Abdoun or sludge from the UWATP. The project cost of the Marj al Hamam trunk sewer is estimated to be JD 229,500 and the estimted annual O&M costs are JD 1,100.

Alternative 2 would pump raw wastewater from Marj al Hamam to the proposed UWATP. This would require a 45 kw pump station and approximately 3.7 kilometers of 200 mm force main. Estimated project costs for the pump station and force main total JD 221,400, while the estimated annual power and O&M costs would total JD 13,000.

Alternative 3 proposes to pump raw wastewater to Na'ur for treatment and disposal. This would necessitate constructing a 40 kw pump station and approximately 2.3 kilometers of 200 mm force main. Estimated total project cost for the pump station and force main is JD 156,000, and the estimated annual power and O&M costs would total JD 12,100.

A cost summary of the three alternatives is presented in the following table:

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WASTEWATER COLLECTION, TREATMENT AND DISPOSAL ALTERNATIVES

Item	Alt. 1	Alt. 2	Alt. 3
Construction Costs			
Pump Station and Force Main	0	147,600	104,400
Gravity Sewer	153,000	0	0
Total Construction Cost	153,000	147,600	104,400
Implementation Cost	76,500	73,800	52,200
Total Project Cost	229,500	221,400	156,600
Equivalent Annual Project Cost	27,000	31,500	21,200
Annual O&M Cost	1,100	6,000	6,000
Annual Power Cost*	0	7,000	6,100
Total Annual Cost	28,100	44,500	33,300

* For Alts. 1 and 2 the pumps would be active nearly 11 hr/day in year 2000.

The cost comparison clearly favors Alternative 1, but other factors should be considered. First and foremost is the availability of a wastewater treatment facility. For Alternative 1, wastewater from Marj al Hamam would be treated at the AGTP, which is already in operation. All that would be required would be to connect to the AWSA network with a gravity trunk sewer from the community and from the Wadi Abdoun area. This appears to be a very likely prospect because the area above Wadi Abdoun is undergoing rapid growth and will need to be served by a wastewater collection system in the near future. Alternatives 2 and 3 would rely on treatment facilities that are not even in the planning stage at this time.

Instituting Alternatives 2 and 3 would result in the removal of a source of wastewater from the Seil Zarqa sub-basin and thus from the King Talal Reservoir. This would have a modest impact because the projected wastewater flow from Marj al Hamam is a small portion of the flow that eventually finds its way to the Reservoir. Alternatives 2 and 3 would both reduce the flow to the AGTP or to a downstream facility.

Based on the previous discussion, Alternative 1 appears to be the best choice for Marj al Hamam, both in terms of cost and in terms of the benefits to the Greater Amman Area. Therefore it is recommended for selection unless other factors intervene.

Ain Ghazal Treatment Plant Alternatives

The earlier discussions in this chapter have set forth interim water quality criteria that should be achieved to protect public health. Any proposed methods of treatment must meet at least four criteria to attain this goal, via:

- To provide a high quality secondary effluent
- To minimize energy consumption and, thus, future costs, because the future prices of both electricity and fossil fuels will probably accelerate rapidly
- To reserve space at the plant site for potential future increases in the level of treatment
- To provide a system which is relatively simple to operate and maintain

If some of these goals may be mutually exclusive, an optimum balance of these factors should be sought.

The conditions at the AGTP have been discussed in some detail in Chapter 6. The assessment of the treatment plant has led to a basic project to optimize the current operations at the plant, and is summarized in the following tabulation:

- Abandon the existing headworks
- Revise the existing inlet sewer to achieve a free flow into the treatment plant
- Provide low head influent pumping using Archimedean screw pumps
- Provide new screening of the raw sewage with comminutors
- Provide new grit removal facilities
- Convert the existing final sedimentation tanks to primary sedimentation tanks by deleting the intermediate slabs
- Abandon the existing primary sedimentation tanks
- Construct new secondary sedimentation tanks
- Convert the existing gravity thickeners to dissolved air flotation thickeners
- Provide additional aeration capacity for the aeration tanks to meet the high organic loads
- Provide standby power for influent pumping

As indicated earlier, two anaerobic digesters and dewatering facilities are already programmed to be built in the near future and may be taken as "existing" for Master Plan purposes. Long-range plans by AWSA have included expanding the AGTP to accommodate increased loadings when appropriate. Chapter 5 has

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provided the projections of such loadings. The following discussions consider alterantives for modifying and expanding the individual treatment units.

Pretreatment: The existing pre-treatment units comprising the barminutors and grit chambers will be abandoned due to their inferior performance and the poor condition of the mechancial equipment. Proposed new pretreatment units are presented in Table 8-2.

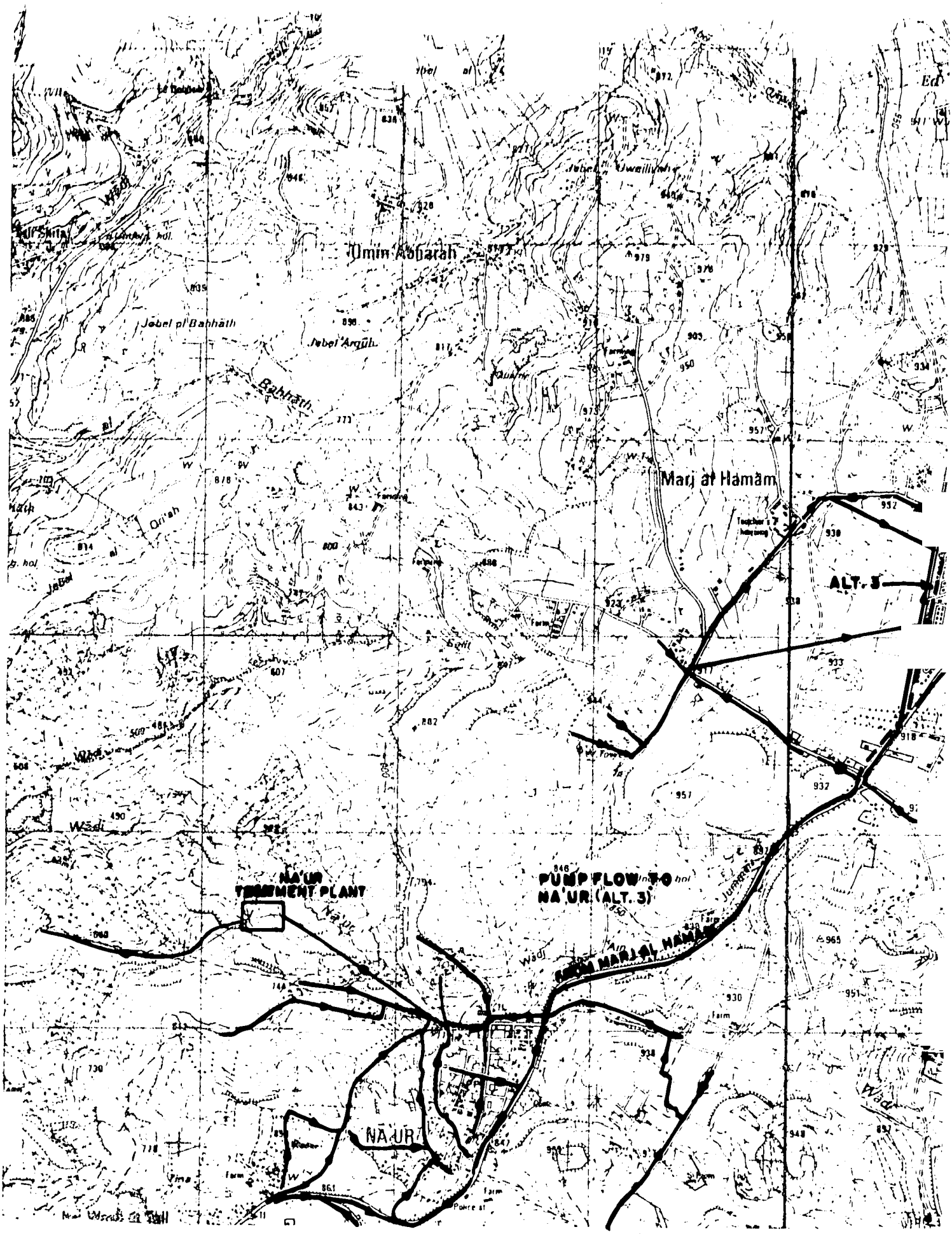
Primary Treatment: The capacity of the existing secondary sedimentation tanks when converted to primary tanks will equal 60,000 m^3/da. This will accommodate almost all of the proposed treatment plant expansion on the present site. The existing primary tanks may be used to provide an additional capacity of up to 30,000 m^3/da. The actual capacity rating will depend upon the biological treatment alternative chosen and the corresponding loading to these upstream units.

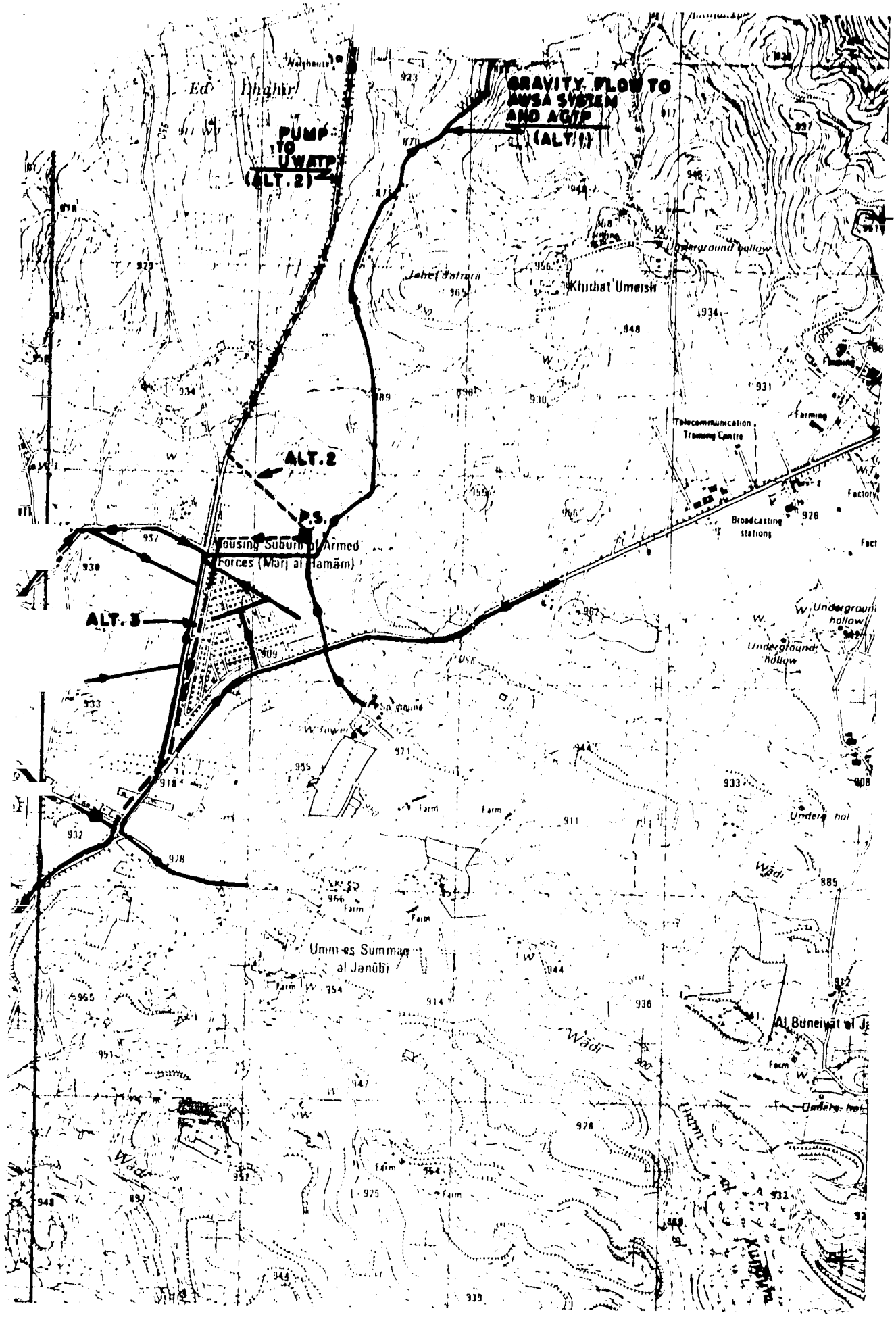
Polymer addition should be investigated as a means of enhancing settling and thus increasing the efficiency of the primary sedimentation tanks. Any polymer system requires testing to determine the proper polymer and dosage rates. Typical polymer doses elsewhere have been approximately 0.3 mg/l which would result in a polymer consumption of three kilograms per 10,000 cu m/day.

When polymer of the correct type and dose is added to primary influent, there may be substantially increased removals of suspended solids. This decreases the suspended solids content of the influent to the biological treatment systems are usually more effective in removing dissolved and colloidal BOD than suspended BOD. There can also be a removal of a certain amount of BOD in the primary sedimentation process attributable to the polymer addition. Although this may not be commensurate with the suspended solids removal, it is still beneficial to the biological treatment system.

For example, at the Joint Water Pollution Control Plant of the Los Angeles County Sanitation Districts, in Carson, California, primary influent polymer addition increased the suspended solids removal from a normal value of about 65 percent to an improved value of about 78 percent.[2] Inasmuch as the plant influent SS was about 500 mg/l, this meant an additional 65 mg/l suspended solids removed ahead ahead of downstream treatment. The primary treatment BOD removal enhancement was in the order of 20 mg/l. The prospects for such an operation, if applied at AGTP, would appear favorable and might show an overall economy in aeration power saved, even when considering the costs of the imported polymer and its operating facilities.

The design parameters for the modifications to the primary treatment works are presented in Table 8-2.


Umm Abbarah
Jebel al Bahhath
Jebel Arqūb
Bahhath
Marj al Hamām
ALT. 3
NA'UR
TREATMENT PLANT
PUMP FLOW TO
NA'UR (ALT. 3)
NA'UR


GRAVITY FLOW TO
AWSA SYSTEM
AND AGTP
(ALT. 1)
PUMP
TO
UWATP
(ALT. 2)
ALT. 2
P.S.
ALT. 3
Housing Suburb of Armed
Forces (Marj al Hamām)
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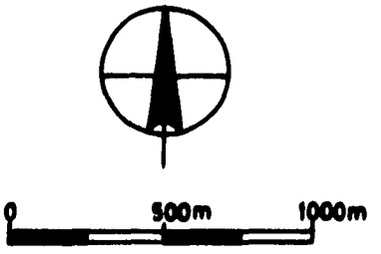

LEGEND

——— PROPOSED SEWERS

■—·—·— PROPOSED P.S AND FORCE MAIN.
APPLIES TO ALTS. 2 & 3
(VIA DIFFERING FORCE MAIN
ROUTES AND DESTINATIONS)

NOTES :-

COLLECTION / TREATMENT ALT. FOR MARJ EL HAMAM

ALT. 1 FLOW BY GRAVITY TO AWSA SYSTEM AND AGTP.

ALT. 2 PUMP TO UWATP

ALT. 3 PUMP TO NA'UR TREATMENT PLANT

ALTERNATIVES FOR MARJ AL HAMAM AND NA'UR

FIGURE 8 - 4

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TABLE 8-2

DESIGN CRITERIA FOR
MODIFICATIONS TO PRIMARY TREATMENT WORKS[a]

Influent Pumping	
Average Flow, Year 2000	96,000 m^3/day
Peak Flow	173,000 m^3/day
Number Pumps Archimedes Screw (incl. 2 standby)	10
Capacity Each Pump	21,500 m^3/day
Lift	6 m
Power	30 kw
Comminutors	
Number	2
Capacity	69,800 m^3/day for peak hydraulic
Power	3.75 kw
Parshall Flumes	
Number	2
Capacity each	200,000 m^3/day
Throat Width	122 cm
Grit Chambers (Aerated)	
Average Flow	96,000 m^3/day
Peak Flow	173,000 m^3/day
Detention Time (Peak Flow)	5 mins.
Tank Volume (Total of Two)	600 m^3
Depth	5 m
Width	7.5 m
Length (Total of Two)	16 m
Air Requirement	11 m^3/min
Grit Processing Units	
Centrifugal Separators (2)	1.1 m^3/min each
Grit Washer/Classifier (2)	1.1 m^3/min
Recessed Impeller Pump Units (3)	1.1 m^3/min each

TABLE 8-2 (Continued)

Primary Sedimentation Tanks

Existing Primary Tanks[b]

Number	6
Overflow Rate (30,000 cu m/d)	24 $m^3/m^2/day$
Detention Time	1.5 hr
Width	5 m
Length	42 m
Depth	1.5 m

Primary Tanks Converted from Final Sedimentation Tanks

Number	6
Overflow Rate (60,000 cu m/d)	40 $m^3/m^2/day$
Detention Time	2 hr
Width[c]	5.0 m
Length	51 m
Depth	3.0 m

[a] Number and sizes of equipment will be evaluated during the design phase.

[b] The existing primary sedimentation tanks may or may not be included in the future system depending on the treatment alternative chosen.

[c] Width may decrease due to the structural modification required.

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Biological Treatment: Different biological treatment alternatives were considered for upgrading the AGTP. Comparison of these options was made assuming a raw sewage BOD_5 of 900 mg/l and 900 mg/l of SS. These assumptions were deemed quite conservative but realistic for planning purposes. After primary treatment, the estiamted BOD concentration of the effluent reaching the biological system is assumed to be 585 mg/l. The alternative systems were sized on this basis.

For the purposes of this comparison, the entire existing plant and the site lying between the municipal slaughterhouse and the treatment plant were assumed to be utilized. This provided a realistic assessment of the relative use of land for all alternatives. The land lying to the north of the existing site is reserved for future development of effluent filtration or possibly other forms of tertiary treatment depending on long-term assessment of effluent quality needs. A discussion of possible future effluent criteria affecting such choices may be found in Chapter 5. Staging of treatment plant expansion is not considered in detail in this chapter; rather, a selection is made for the most viable future process for the treatment plant. The recommended construction staging is addressed in Chapter 10.

Two basic biological treatment alternatives were considered as part of this Master Plan:

- Conventional Activated Sludge
- Roughing Filters Followed by Conventional Activated Sludge

A third alternative, the pure oxygen activated sludge process (commonly known as UNOX), was also considered but was dropped during the initial screening. UNOX has been developed as a viable form of secondary treatment in the past decade. It can produce high quality effluents when dealing with strong wastes, and is slightly less land intensive than conventional activated sludge. Thus, if UNOX were to be employed at the AGTP site, a slightly higher capacity plant would be possible than for conventional activated sludge. However, UNOX is an energy intensive process which involves the generation of pure oxygen plus the necessary mixing in the (covered) aeration basins. This system is also considered a high technology process because it requires a cryogenic system to produce pure oxygen. Such a cryogenic system must be completely renovated every five years. During this down time either a duplicate system must already be available to provide the necessary oxygen or liquid oxygen must be purchased and brought on-site.

The several disadvantages of pure oxygen activated sludge were judged to outweigh the advantages offered by the process. Accordingly, the pure oxygen system was eliminated from further consideration. The two surviving alternatives are discussed in detail in the following sections.

Treatment Alternative (TA1) - Conventional Activated Sludge

The conventional activated sludge process is presently used at the AGTP. It is probably the most frequently used secondary treatment process in major municipal treatment plants and normally provides the highest quality effluent that can be attained short of tertiary treatment. Effluent quality of 30 mg/l for both BOD_5 and suspended solids can be readily achieved when treating normal strength domestic sewage (200 mg/l BOD_5), and frequently, an even better effluent quality can be achieved. However, primary sedimentation and activated sludge treatment of much stronger wastes similar to the Study Area's (in the order of 900 mg/l BOD_5) are not likely to produce such high quality effluent. As discussed earlier, it is felt that an AGTP effluent quality of 50 mg/l for both BOD_5 and suspended solids may be achieved under well designed and operated secondary treatment activated sludge facilities following primary sedimentation.

The unusual strength of the Study Area's wastewater requires certain design and operational considerations that are not required for a normal strength wastewater. The projected primary effluent's strength is more than double the raw wastewater strength of many municipal waterwaters. This requires a high suspended solids concentration in the aeration tanks in order to effectively treat the wastewater. As implied by the design parameter, food to micro-organisms (F:M) ratio, when the food (BOD) increases the biomass concentration (MLSS) should be increased accordingly, particularly [illegible] the F:M ratio is to be maintained within a limited, acceptable range. [illegible] order to achieve the desired BOD removals from high strength aeration tank [illegible]ent detention times must be increased above the normal. This factor, coupled with the extended peak flows experienced at AGTP (1.4 times the average daily flow to 6 to 8 hours), require high detention times in the range of 18 hours.

In order to maintain the high solids concentration in suspension and to provide the oxygen required for biomass uptake, proper mixing and efficient oxygen transfer are essential. Mechanical surface aeration can meet such requirements; however, certain limitations are imposed by the size of the aerator on the geometry of the basins. The dimensions of the basin must be generally proportional to the aerator size in order for the basin content to be completely mixed and to minimize oxygen transfer losses due to flow surging and vortexing. Aerator suppliers provide recommended minimum and maximum size basins for efficient operation of a given horsepower. In the case of high strength wastewater, the basin dimensions may actually be governed by the size of the aerator rather than by the process kinetics.

Proper facilities for monitoring and control of the activated sludge process are also essential. A substantial flow of return activated sludge (RAS) is required to maintain the needed mixed liquor suspended solids (MLSS) concentration in the aeration basins. Flexibility of providing RAS in the range of 25 to 100 percent of the design (throughput) flow should be provided. This can be best accomplished through the use of variable speed centrifugal pumps. In addition to varying the RAS rate, the variable speed pumps provide a positive means of withdrawing sludge from the secondary clarifiers. The RAS flow and density should be

measured and the measurements indicated and recorded.

Excess activated sludge is wasted as required to maintain a predetermined mean cell residence time (MCRT). This diversion of waste activated sludge (WAS) may be accomplished by either wasting MLSS from the aeration tanks or by wasting a portion of the RAS flow. Like the RAS, controls such as indicators, recorders and totalizers are required to monitor and record the amount of activated sludge wasted.

In addition to providing new aeration basins, the existing aeration tanks will be modified for surface aeration application. This will increase the efficiency of the existing tanks substantially. The existing compressors (blowers) will be used to provide additional mixing and oxygenation capacity during their remaining useful life. An evaluation of the existing compressors and the extent they can be used will be made during the design stage.

Due to their limited capability, the most efficient way to utilize the modified existing tanks would be for the existing tanks to handle a constant flow while the new tanks would be designed to accommodate the extended peak flows experienced at AGTP. This may be difficult to accomplish though due to the complexity of flow distribution between the existing and new units.

The converted existing aeration tanks plus the new ones on the existing developed site would provide a total capacity of 53,000 cu m/day. The Southern site (undeveloped municipal land between the AGTP and slaughterhouse) could be developed for 37,000 cu m/day. The new plant in the Southern Site would act almost as an independent treatment plant and would be constructed initially so that the operation of the AGTP would not be interrupted during existing units modification. The design parameters for Treatment Alternative TA1 are summarized in in Table 8-3. Figures 8-5 and 8-6 show the proposed units and layout of the facilities in both the existing site and to be developed Southern site.

Treatment Alternative (TA2) - Roughing Filters Followed by Activated Sludge

The combination roughing filter - activated sludge mode is generally used to handle high strength wastewater as when a plant receives a substantial amount of industrial wastewater. As a result, this type of treatment technique is felt to be applicable to the relatively strong wastes encountered at AGTP. A layout for a 75,000 cubic meter per day plant is presented in Figures 8-7 and 8-8. The existing primary sedimentation tanks will be used as part of this alternative and all flow from the primaries will be directed to the roughing filters on the southern plant site. As in Alternative TA1, the site is developed to is maximum capacity to compare adequately the relative land use of the two alternatives.

The particular advantages of using a roughing filter treating a strong waste is the resiliency of the process. Experience has shown that even when major variations in waste concentration and quantity occur, the roughing filter requires only minior operational adjustments to maintain a consistent efficient quality. From this standpoint, roughing filters provide a more reliable process than does the activated

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TABLE 8-3

DESIGN CRITERIA FOR TREATMENT ALTERNATIVE TA1

Existing Plant Site	
Existing Aeration Tanks	
Design Avg. Daily Flow	17,300 m^3/day
Number basins	8
Length x Width	15 m x 26 m
Sidewater Depth	4.3
Detention Time Average	18 hr
Mean Cell Retention Time	6 days
MLVSS	2,250
MLSS	3,000
BOD_5 Applied, Average	10,120 kg/day
F/M, Average	0.34
Oxygen Required, Average	14,200 kg/day
Connected Aeration Capacity	600 kw
New Aeration Tanks	
Design Average Daily Flow	41,700 m^3/day
Extended Peak Flow	63,700 m^3/day
Number basins	9
Length x Width	23.8 x 23.8 m
Sidewater Depth	6.0 m
Average	18
Extended Peak	11.8
Peak	10.0
Mean Cell Residence Time	6 days
MLVSS	2,250 mg/l
MLSS	3,000 mg/l
BOD_5 Applied	24,410 kg/day
F/M 0.34	
Oxygen Required	34,170 kg/day
Connected Aeration Capacity	1,450 kw
Secondary Clarifiers	
Design Avg. Daily Flow (small/large)	59,000 m^3/day
Number	3
Diameter	33.5 m/40.0 m
Sidewater Depth (all)	3.8 m
Surface Area (each, small/large)	881 sq. m/1.256 sq. in
Surface Loading	
Average	15 m^3/m^2/day
Extended Peak	20 m^3/m^2/day
Peak	26 m^3/m^2/day

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TABLE 8-3 (Continued)

Detention Time	
Average	6.0 hr
Extended Peak	4.6 hr
Peak	3.5 hr
Southern Plant Site	
Design Avg. Daily Flow	37,000 cu m/day
Primary Sedimentation	
Number	5
Avg. Overflow Rate	40 m^3/m^2/day
Detention Time	2.1 hr
Width	5 m
Length	37.5 m
Depth	3.5 m
Aeration Tanks	
Number	8
Length x Width	23.8 x 23.8
Sidewater Depth	6.0 m
Detention Time	
Average	18
Extended Peak	13.1
Peak	9.5
Mean Cell Retention Time	6.0 days
MLVSS	2,250
MLSS	3,000
BOD_5 Applied	21,600 kg/day
F/M	0.34
Oxygen Required	30,300 kg/day
Connected Aeration Capacity	1,040 kw
Secondary Clarifiers	
Number	2
Diameter	40 m
Sidewater Depth	3.8 m
Surface Area (each)	1,256 sq m
Surface Loading	
Average	14.7 m^3/m^2/day
Extended Peak	20.6 m^3/m^2/day
Peak	26.5 m^3/m^2/day
Detention Time	
Average	6.2 hr
Extended Peak	4.3 hr
Peak	3.4 hr

Treatment Alternative (TA2) - Roughing Filters Followed by Activated Sludge

The combination of roughing filters (initial trickling filters) followed by activated sludge for treatment of primary effluent of unusually high strength (BOD) is sometimes used in municipal treatment works if exceptionally strong industrial wastes cause very high BOD concentrations in plant influent. The AGTP influent of the future will have a high BOD concentration. Although this is primarily because of the low per capita water consumption and not because of excessive industrial wastes, the roughing filters-activated sludge arrangement is still a very logical candidate for the future AGTP facilities. The roughing filters, sometimes known as oxidation towers, would reduce the BOD of the primary effluent to an intermediate strength, facilitating the final BOD reduction to the required effluent levels by the activated sludge. The sizes of the activated sludge units would thus be reduced from those otherwise required.

Among the advantages of trickling filters in wastewater treatment are the following:

- Relatively simple operation and maintenance requirements (however, see ensuing discussion concerning odor control).
- Resilience and reliability in accommodating fluctuating hydraulic and particularly organic loads (shock loads) while still effecting substantial removals of pollutants and yielding generally favorable effluents for subsequent activated sludge treatment.
- Relatively low energy requirements vis-a-vis the activated sludge process.

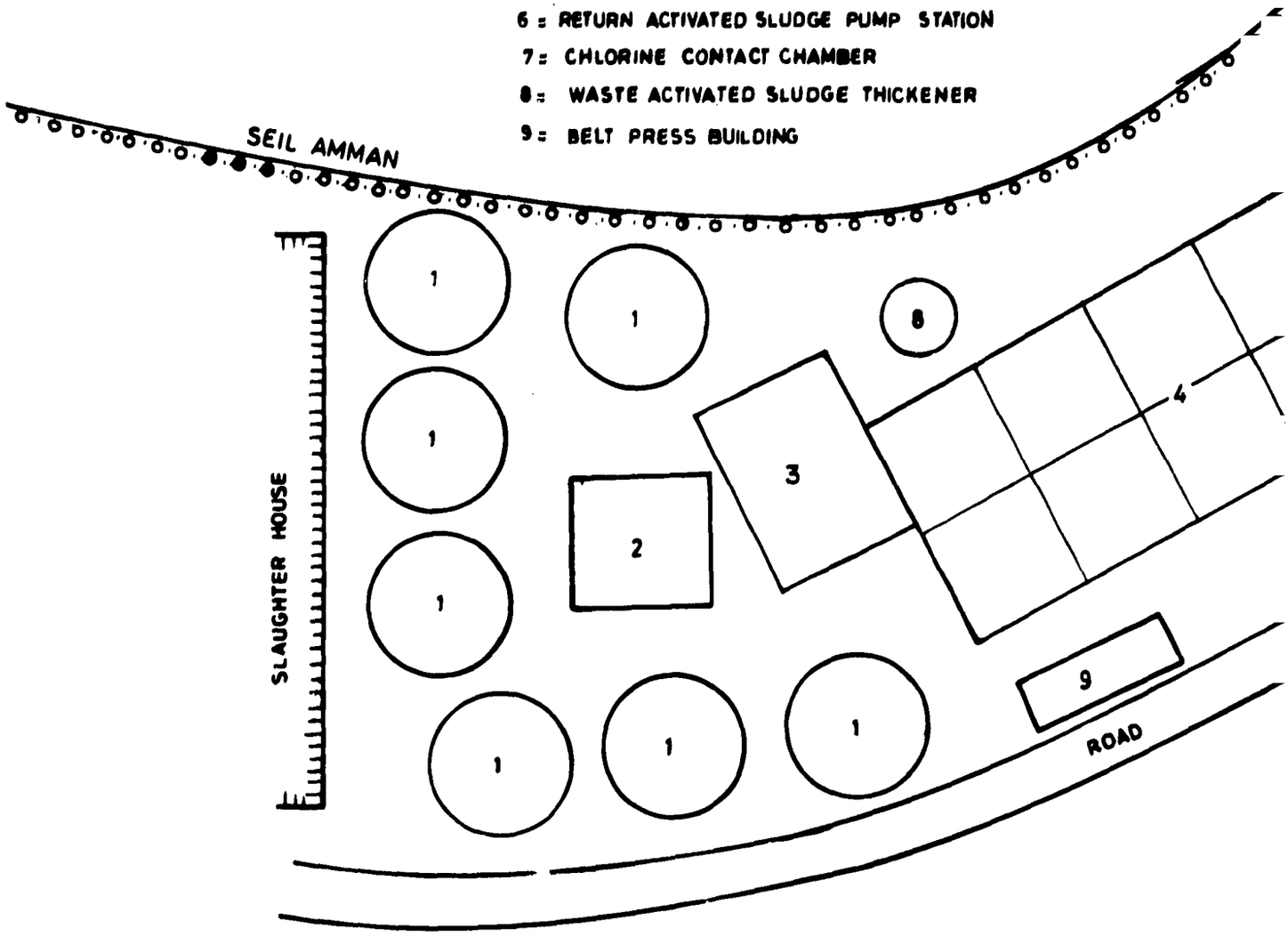
Despite unquestionable advantages, there are also certain disadvantages to trickling filters, including the following:

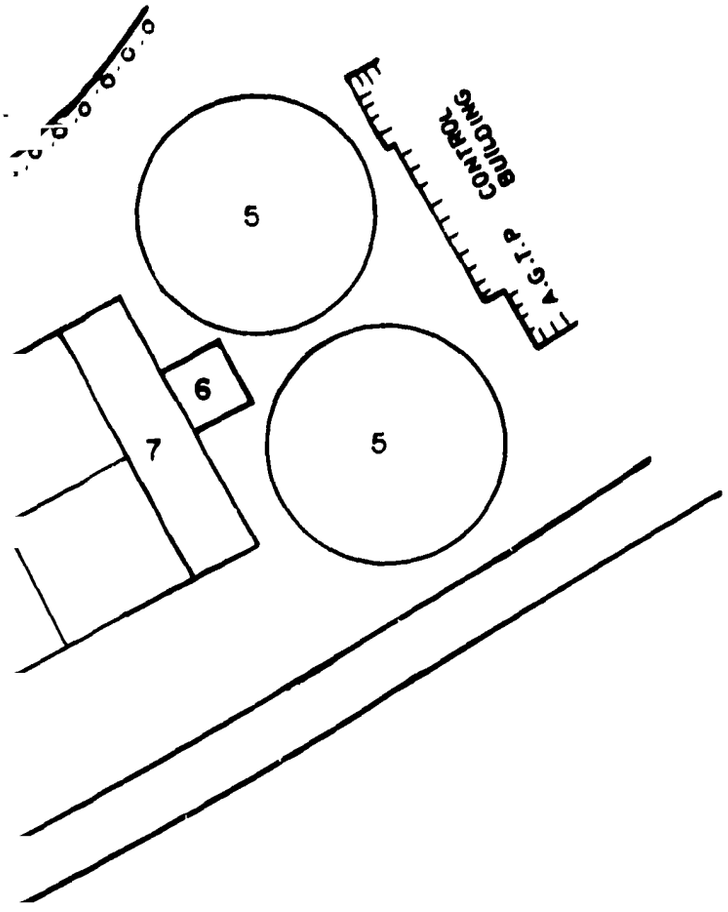
- Greater space requirements than activated sludge
- Greater capital cost requirements than activated sludge
- Greater vulnerability to low temperature fall-off in efficiency of operation than activated sludge.

In order to develop a realistic comparison between TA1 and TA2 for the future AGTP facilities, it was necessary to investigate the probable requirements of needed facilities for these respective alternatives to the extent that the maximum facilities possible could be installed at the existing AGTP developed site and at the immediately adjoining site to the south. Such a basis of comparison was deemed appropriate because of the early need for greatly increased AGTP capacity, the immediate availability of limited space for development at and immediately adjacent to the current plant site, and the eventual requirement for obtaining a downstream plant site and constructing a downstream outfall sewer and treatment facilities. It would probably be economical to minimize the future capacity and site requirements for these

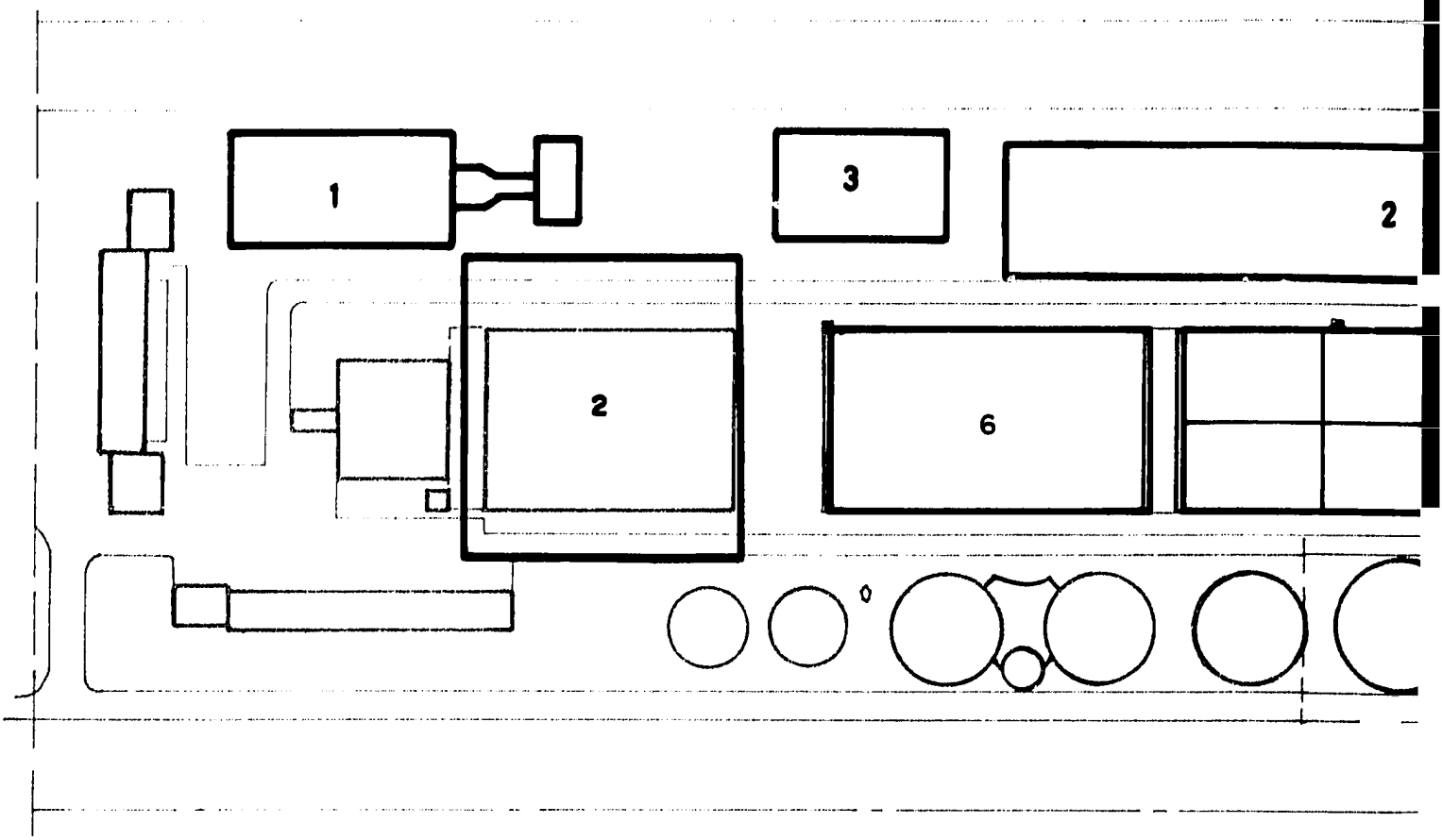
LEGEND :–

1 : ANAEROBIC DIGESTER
2 : DIGESTER CONTROL BUILDING
3 : PRIMARY SEDIMENTATION TANKS
4 : AERATION TANKS
5 : SECONDARY CLARIFIERS
6 : RETURN ACTIVATED SLUDGE PUMP STATION
7 : CHLORINE CONTACT CHAMBER
8 : WASTE ACTIVATED SLUDGE THICKENER
9 : BELT PRESS BUILDING





AIN GHAZAL TREATMENT PLANT
SOUTHERN SITE
TREATMENT ALTERNATIVE TA 1



LEGEND:
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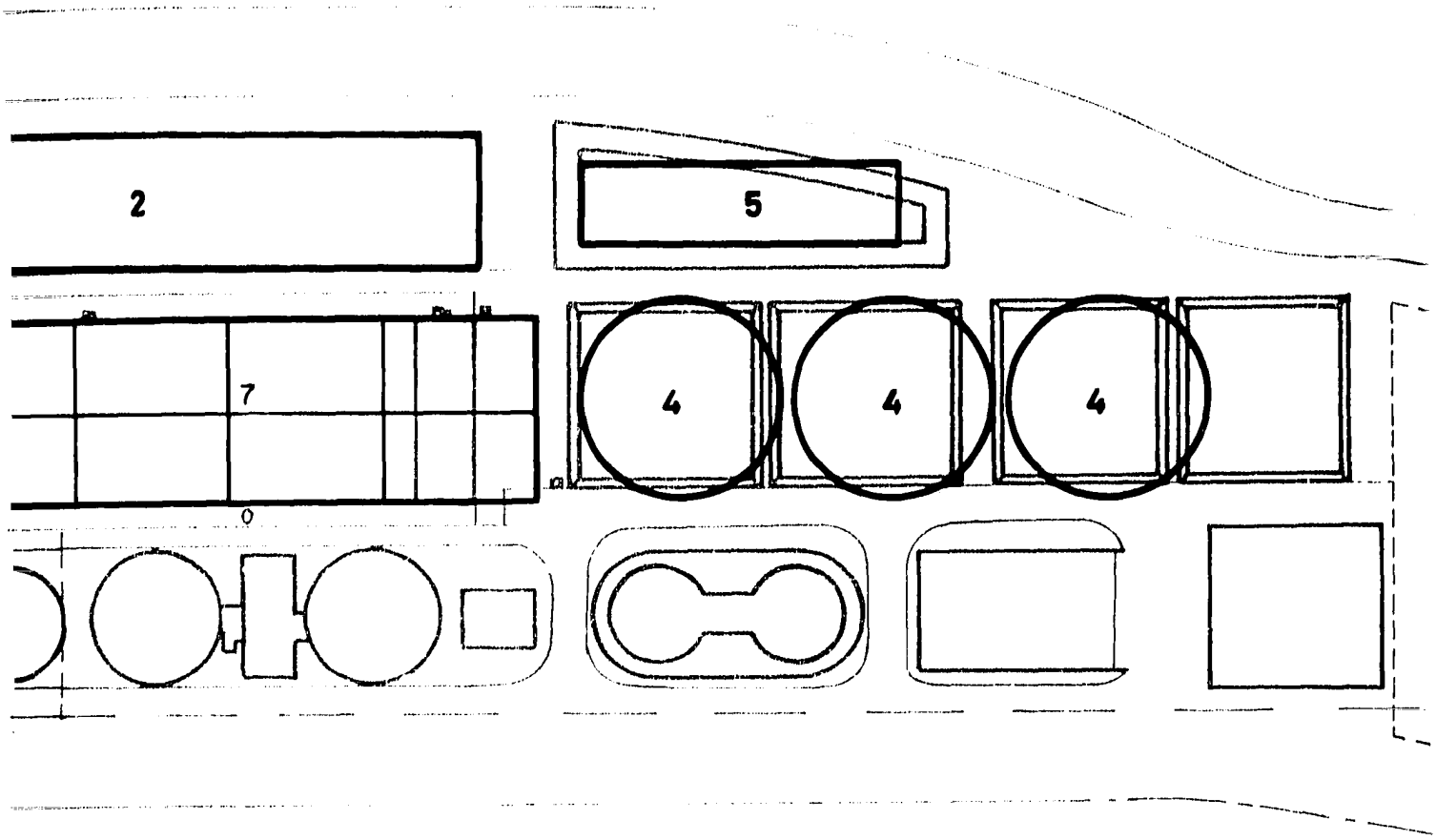

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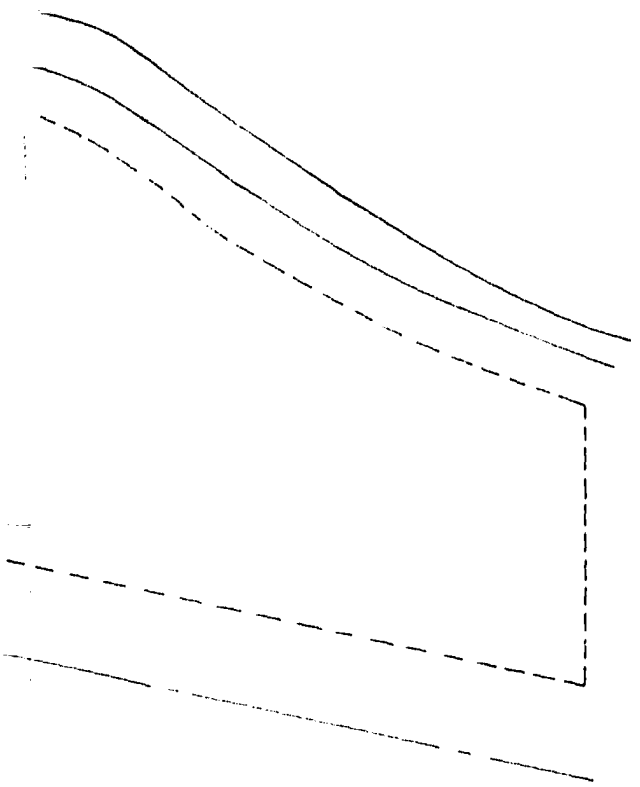
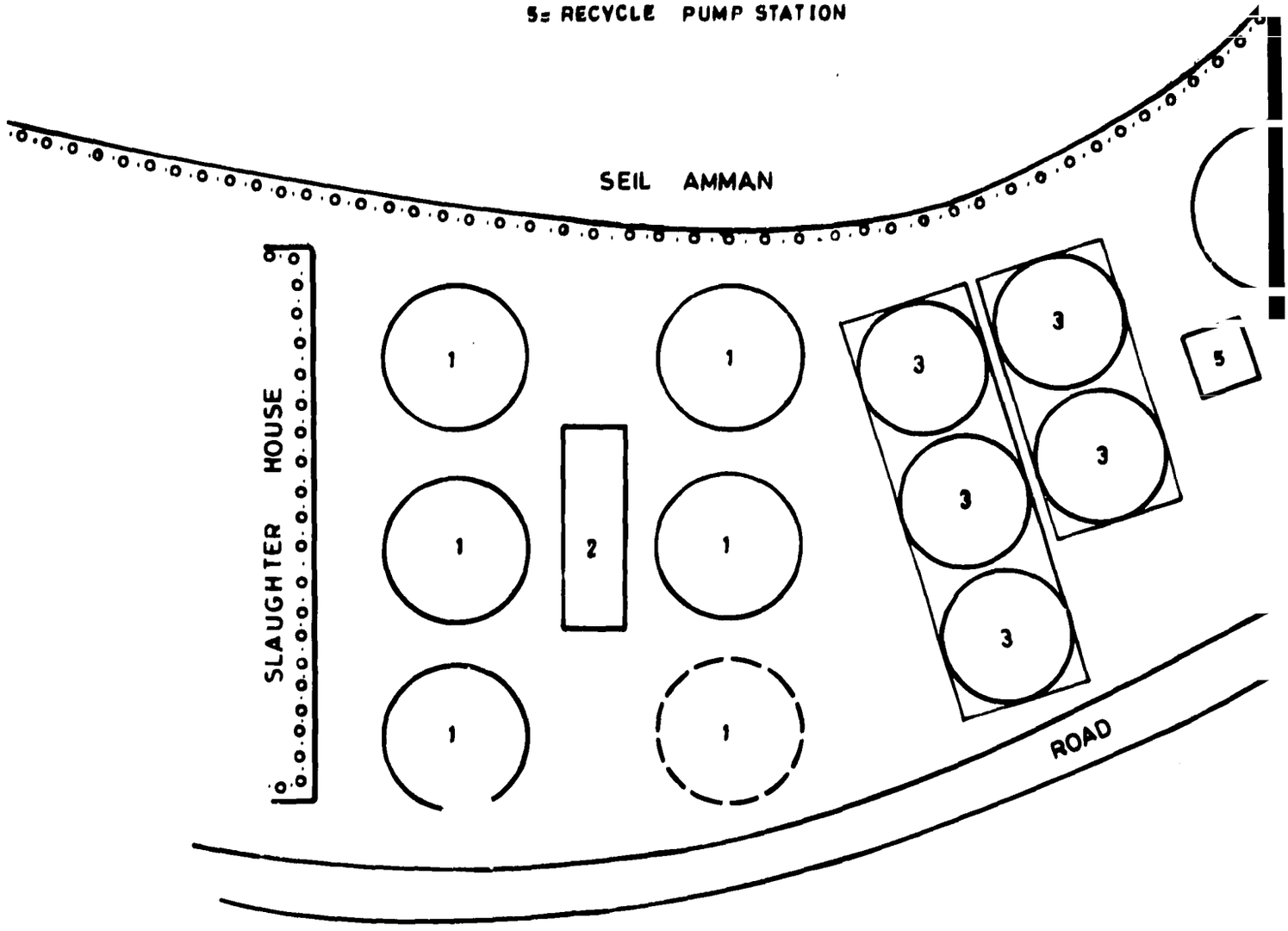
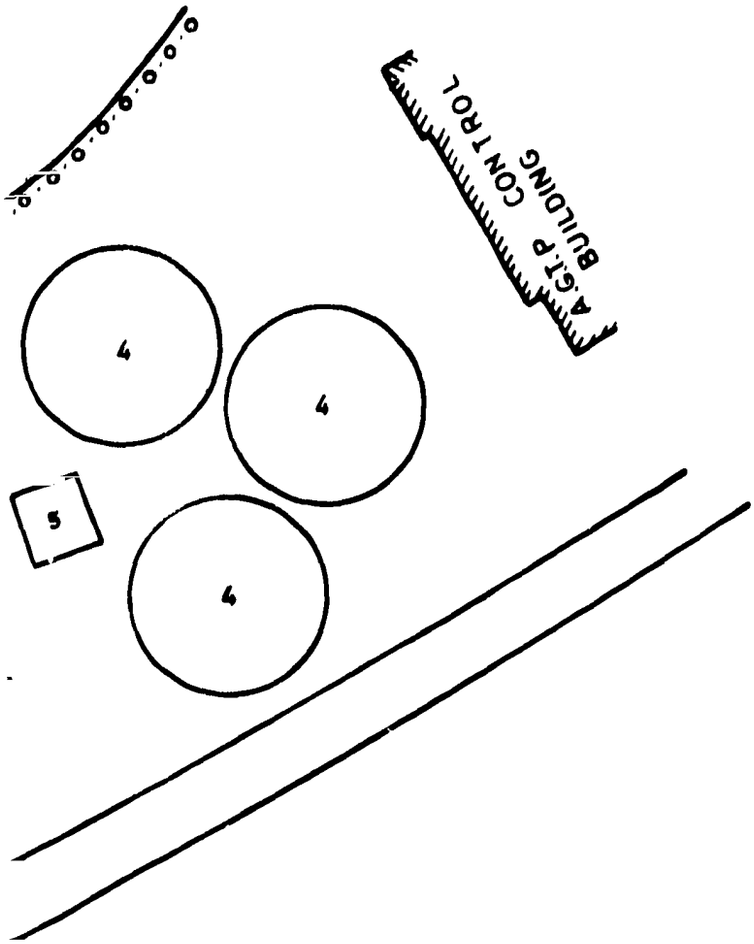


AIN GHAZAL TREATMENT PLANT
NORTHERN SITE
TREATMENT ALTERNATIVE TA 1

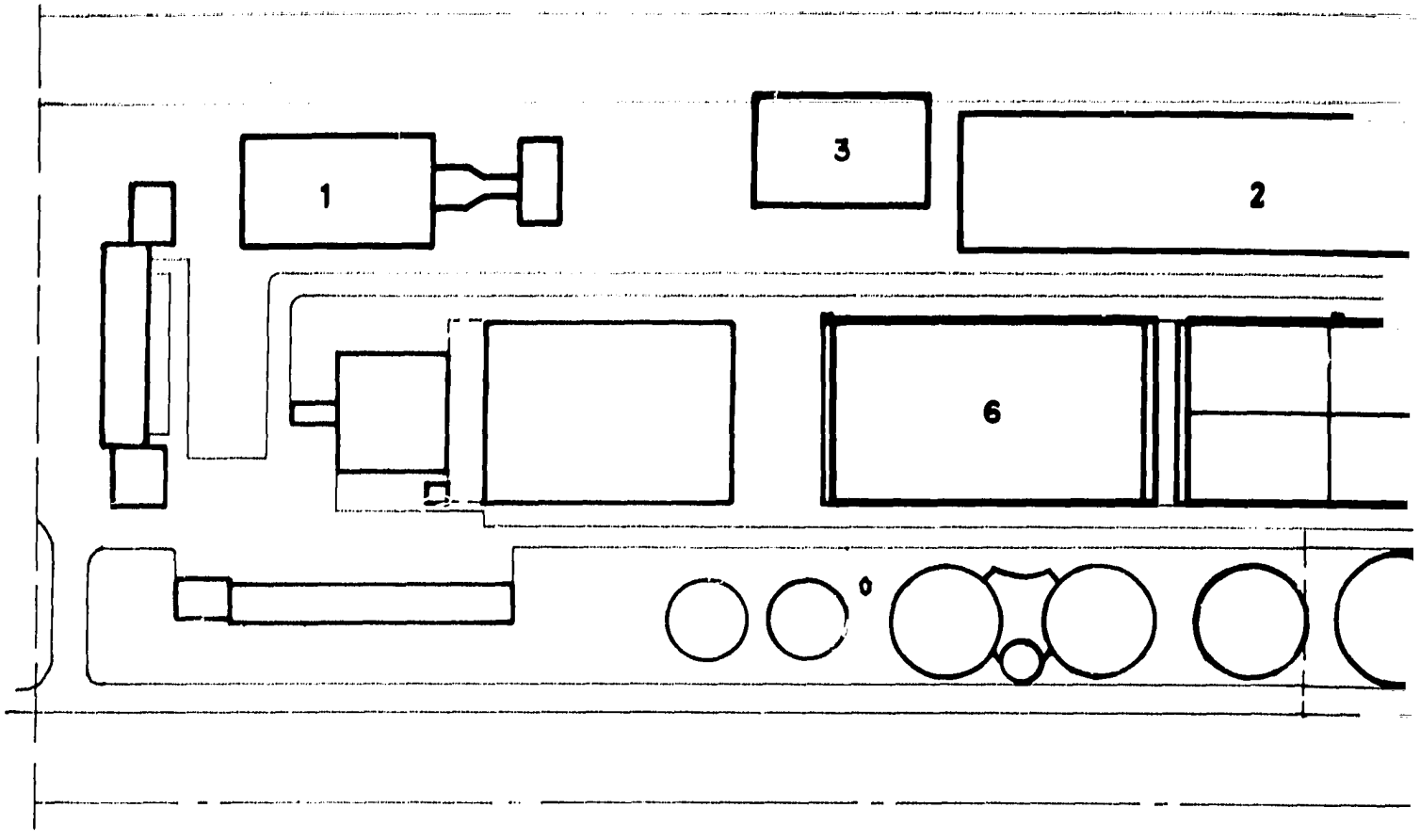
FIGURE 8 - 6

LEGEND : 1 = ANAEROBIC DIGESTER
2 = DIGESTER CONTROL BUILDING
3 = ROUGHING FILTERS
4 = INTERMEDIATE CLARIFIERS
5 = RECYCLE PUMP STATION





AIN GHAZAL TREATMENT PLANT
SOUTHERN SITE
TREATMENT ALTERNATIVE TA 2



LEGEND:

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2= NEW AE
3= ENGINE (
4= SECOND
5= CHLORIN
6 = PRIMAR
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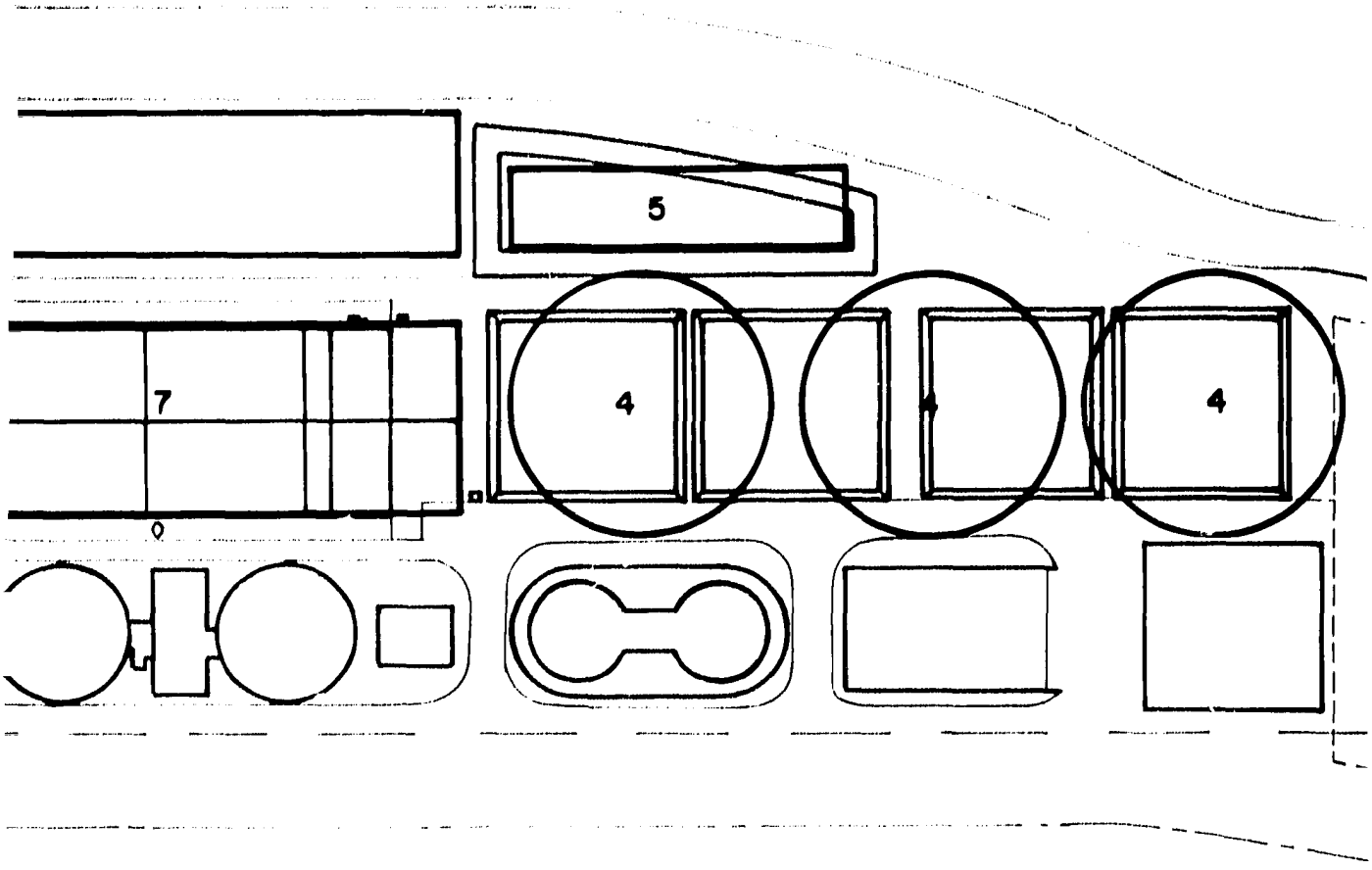

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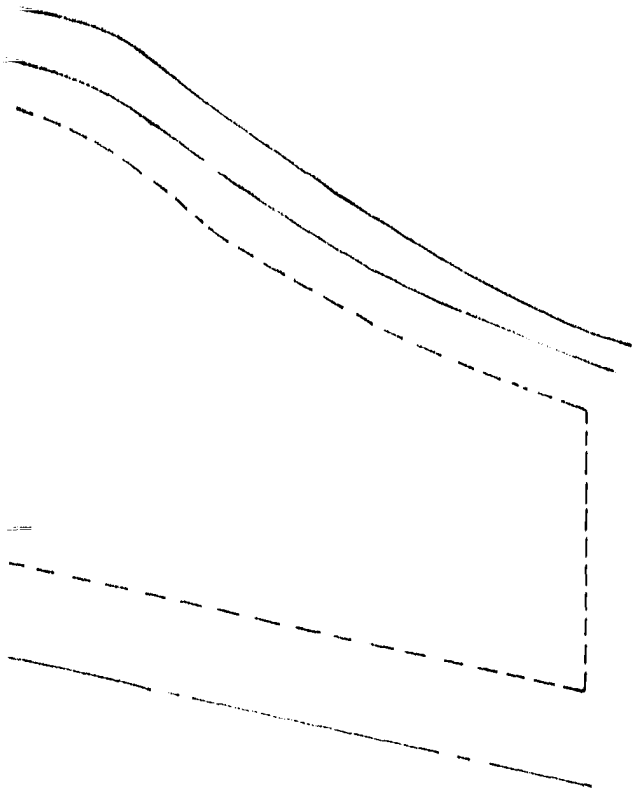

AIN GHAZAL TREATMENT PLANT
NORTHERN SITE
TREATMENT ALTERNATIVE TA 2

FIGURE 8 - 8

downstream facilities that would be needed to take surplus flows when the AGTP capacity reaches its ultimate capacity. By providing maximum development at the AGTP, this purpose would be accomplished. It would also delay the future date by which such downstream facilities would be required.

The sizing of facilities for alternative TA2 as well as the comparison of TA1 and TA2 as to specific facilities, performance, costs, and various ramifications involves considerable detail. This is presented in Appendix L of this report.

Table 8-4 presents the design criteria for Treatment Alternative TA2. Figures 8-7 and 8-8 show the proposed units and layout of the facilities in both the existing site and the Southern site to be developed.

Comparative Costs for Alternatives TA1 and TA2

Information derived in Appendix L summarizes comparative costs of biological (secondary) treatment for the AGTP under Alternative TA1 and TA2 and is presented in Table 8-5.

Recommended Alternative

JMM/DMJM's analyses (Appendix L) have indicated that either TA1 or TA2 would be acceptable and that the cost comparisons between these alternatives are quite close, particularly when the roughing filters (oxidation towers) of TA2 are not provided with special ventilation and odor control systems and when power recovery systems are provided and if future energy costs escalate rapidly. NPC is understood to favor power recovery for the plant and to be very concerned about the future prospects for energy cost escalation. Also, NPC does not feel it likely that special odor control facilities for oxidation towers need be considered under the circumstances. Also, the use of TA2 alternative, suitably modified in actual design, can be made to adapt to the existing facilities and layout at AGTP with advantage. Thus, NPC believes that TA2 is preferable to TA1. Following a weighing of all factors concerned, JMM/DMJM concurs with this appraisal and recommends Alternative TA2.

Tertiary Treatment Alternatives. Because the influent concentration of both BOD_5 and SS of the AGTP are so much higher than those generally found in a normal strength domestic sewage, some type of tertiary treatment will be required to achieve the water quality objectives listed in Table 8-1. The most common forms of tertiary treatment are effluent filtration and nitrification/denitrification.

Effluent filtration removes residual suspended solids and BOD_5 from an effluent. This aids the disinfection process by eliminating extraneous solids that impart a high chlorine demand, simultaneously reducing the amount of chlorine that is needed and increasing the efficiency of the disinfection process. It also enhances the quality of the receiving stream by removing a source of oxygen demand from the effluent.

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TABLE 8-4

DESIGN CRITERIA FOR TREATMENT ALTERNATIVE TA2

Roughing Filters	
Design Avg. Daily Flow	75,000 m^3/day
Number	5
Diameter	25 m
Media Depth	5.8 m
Area (Each)	491 m^2
Media Volume (Each)	2,857
Surface loading (without recycle)	
Average	31 m^3/m^2/day
Instantaneous Peak	56 m^3/m^2/day
BOD loading	
Average	43,900 kg/day
BOD Removal	
Average	50%
Winter	42%
Recirculation Ratio	2:1
Intermediate Clarifiers	
Number	3
Diameter	31.7 m
Sidewater Depth	3.8 m
Surface Area (Each)	788 m^2
Surface loading	
Average	32 m^3/m^2/day
Peak	57 m^3/m^2/day
Detention Time	
Average	2.5 hr
Peak (Conservative Basis)	1.4 hr
Existing Aeration Tanks (converted)	
Design Avg. Daily Flow	30,000 m^3/day
Number	8
Length x Width (Each)	26 x 15 m
Sidewater Depth	4.3 m
Detention Time	
Average	10.7 hr
Mean Cell Retention Time	— days

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TABLE 8-4
(Continued)

	Average Temp.	Winter Temp.
MLVSS (Average)	2,250 mg/l	2,680 mg/l
MLSS (average)	2,820 mg/l	3,350 mg/l
BOD_5 Applied Avg.	8,780 kg/day	10,185 kg/day
F/M Average	0.29	0.28
Oxygen Required	12,400 kg/day	14,300 kg/day
Connected Aeration Capacity		
Existing:		
kw	990	
m^3/min.	680	
Oxygen available	720 kg/hr	
New Aeration Tanks		
Design Avg. Daily Flow		45,000 m^3/day
Number		6
Length x Width		22.5 x 22.5 m
Sidewater Depth		6.0 m
Detention Time		
Average		9.7 hr
Extended Peak		7.3 hr
Peak		5.4 hr
Mean Cell Retention Time		— day

	Average Temp.	Winter Temp.
MLVSS (Average)	2,250 mg/l	2,680 mg/l
MLSS (average)	2,820 mg/l	3,350 mg/l
BOD_5	13,170 kg/day	15,280 kg/day
F/M Average	0.32	0.31
Oxygen Required	18,600 kg/day	21,570 kg/day
Connected Aeration Capacity		1,015 kw
Secondary Clarifiers		
Number		3
Diameter		44 m
Sidewater Depth		4.0 m
Surface Area (each)		1,520 sq. m
Surface Loading		
Average		16.4 m^3/m^2/day
Extended Peak		23.5 m^3/m^2/day
Peak		29.4 m^3/m^2/day
Detention Time (Conservative Basis)		
Average		5.8 hr
Extended Peak		4.2 hr
Peak		3.3 hr

TABLE 8-5

SUMMARY COST COMPARISON BETWEEN SECONDARY TREATMENT ALTERNATIVES TA1 AND TA2
(See Appendix L for Additional Detail)

Item	TA1 Activated Sludge Alone	TA2 Roughing Filters plus Activated Sludge[1]
Total Construction Cost, JD 1,000	7,160	7,150
Implementation Cost, JD 1,000	3,580	3,575
Total Project Cost	10,740	10,735
Annual Capital Cost, JD 1,000	1,262	1,261
Unit Capital Cost, JD/1,000 m^3	1,262/35.0 MCM/yr = 36,100	1,261/27.4 MCM/yr = 46,700
Average Annual kwh, millions	25.9	20.3
Annual Energy Cost for Biological Treatment Alone JD 1,000 [2]	907	711
Total Annual Cost, JD 1,000 [3]	2,169	1,972
Total Unit Cost, JD/1,000 m^3	62,000	72,000

[1] System does not include ventilation system or odor control facilities for the roughing filters (oxidation towers). The need for same is uncertain. If they were found necessary, the capital costs could rise by over 30 percent for TA2. Power costs would increase by perhaps 18 percent.

[2] Does not include sludge processing, power recovery or energy escalation from current 35 fils/kwh rate at AGTP. With 4 percent annual energy escalation, year 2000 costs would be 1,987 and 1,557, respectively (in JD 1,000). This works in favor of TA2.

[3] Power recovey if added to both TA1 and TA2, would harness sludge gas amounting to 4.20/35.0 = 0.12 m^3 per m^3 wastewater for TA1 and 0.14 m^3 per m^3 wastewater for TA2, thus favoring TA2. For this comparison, non-energy O&M costs are assumed approximately equal for TA1 and TA2 and are therefore omitted.

The primary reason for utilizing nitrification/denitrification in a treatment facility is to remove another source of oxygen demand from the receiving stream. Nitrogen, in domestic waste is found primarily in the form of ammonia, and little reduction of ammonia occurs in a normal secondary treatment facility. As a result, ammonia is discharged to the receiving stream where it exerts an oxygen demand by consuming oxygen as it converts from ammonia to nitrite and ultimately to nitrate. The concentrations of ammonia in the effluent from a treatment plant like Ain Ghazal can exert such a high oxygen demand in the receiving stream that virtually all of the oxygen is depleted. When this occurs, anaerobic conditions may occur. The following discussion describes the two tertiary treatment processes for consideration at the AGTP.

Effluent Filtration. Effluent filtration, if added to the process stream, would comprise in-line alum coagulation and dual media or sand filtration, followed by disinfection. The nominal filtration rate would be 0.20 m^3/m^2/minute, and for a 75,000 m^3/day AGTP, the gross area requirements would be about 1,600 m^2. Inasmuch as effluent filtration facilities probably will not be constructed in the near future, the full design criteria have not been developed for this Master Plan. The effluent filtration would reduce turbidity to about 1-5 JTU, thereby permitting chlorination to reduce the MPN coliform densitites to the desired 2.2/100 ml.

Nitrification/Denitrification. Nitrification/denitrification, if added to the process stream, would comprise biological nitrification in the activated sludge aeration tanks followed by either anaerobic denitrification or ammonia stripping. In the latter case, the ammonia would be stripped as a gas by line-treated effluent when passed through a cooling tower. For an 96,000 m^3/day AGTP, the gross area requirements for ammonia stripping would be about 5600 m^2. Either method would reduce the effluent nitrate level to below 45 mg/l, if implemented. Although nitrification/denitrification would be desirable at the AGTP, it is not essential to the overall performance. As a result, full design criteria have not been developed for this Master Plan.

Sludge Processing Alternatives. During the process of wastewater treatment, large quantities of primary and waste activated sludge are produced. Primary sludge is composed of heavier organic and inorganic solids that settle out of the raw wastewater in the primary sedimentation tanks, and can ususally be readily digested under the proper conditions. Waste activated sludge settles out in the secondary clarifiers and is composed of bacterial cell mass produced in the activated sludge process. Like primary sludge, waste activated sludge is readily digested given the proper conditions.

Both of these sludges accumulate continuously in their respective clarifiers and must ultimately be removed from the process stream. The steps that are taken to process the sludges are sludge thickening followed by sludge stabilization followed by sludge dewatering. The dewatered sludge is either landfilled or spread on the ground as a soil conditioner. The following sections present sludge processing alternatives for use at the Ain Ghazal Treatment Plant.

Sludge Thickening. The primary sludge must be thickened to a minimum concentration of 5 percent before it can be fed to the anaerobic digesters. In many plants this has been accomplished by control of the sludge quantities in the hoppers of the primary sedimentation tanks. The hoppers at AGTP appear to be adequate for this type of operation. Such an operation requires operator attention and daily testing of sludge concentrations.

The assessment of existing conditions at Ain Ghazal suggests that the waste activated sludge thickening be done with dissolved air flotation thickeners. Such thickeners have been found to work well with activated sludges, producing 90 percent solids recovery and 4 to 6 percent solids in the float. The design parameters for dissolved air flotation thickeners are presented below:

Parameter	Design Figure
Solids Loading Rate	88 kg/m^2 day
Air to Solids Ratio	0.03 kg air/kg solids
Polymer Dose	5 kg/metric ton
Solids Capture	90 percent
Type of pressurization	recycle flow

The two converted thickeners would each be able to treat 10,800 kg/day of waste for a total of 21,600 kg/day, for TA1. An estimated 34,600 kg/day of waste activated sludge will ultimately require thickening, which is a short-fall of 13,000 kg/day. Therefore, this alternative will require an additional air flotation thickener with an area of 150 square meters.

Sludge Stabilization. Sludge must be stablized prior to disposal to eliminate a substantial amount of its pathogens and to reduce the organic matter in the sludge flow. Three general methods of sludge stablization have been used in most treatment plant installations. These are: aerobic sludge digestion; thermal treatment of the sludge, including wet air oxidation; and anaerobic sludge digestion.

Aerobic Digestion. Aerobic sludge digestion has enjoyed a time of popularity for a period to time due to its ease of operation. Fifteen to twenty days of detention time are provided in a basin where the sludge is aerated. Typical volatile solids reductions average forty percent. Relatively little control of the process is required and a number of treatment plants have such systems. The major disadvantage of such a system is that it requires a great deal of energy to provide aeration and mixing. For a 60,000 cubmic meter per day plant at Ain ghazal, approximately ten million kwh/yr of electricity would be required.[3] This is equivalent to JD 300,000/yr at current electrical rates. Because of this excessive energy requirement, aerobic digestion has been eliminated from further consideration in this Master Plan.

Thermal Treatment. Thermal treatment has been developed by several manufacturers as a method of stabilizing sludge. A study was performed for the United States Environmental Protection Agency (EPA) entitled "Effects of Thermal Treatment of Sludge on Municipal Wastewater Treatment Costs"[4] which investigated various installations throughout the United States. A portion of the conclusions and recommendations contained in the study is summarized below:

- Pilot plant operation before design is desirable.
- The auxiliary units for which backup should be provided include sludge feed pumps, grinders, air compressors, high pressure pumps, boiler waterfeed pumps, and boilers.
- Grit removal from the slude is essential.
- The treated sludge storage tank should be equipped with decanting facilities.
- Digestion before heat treatment is not desirable.
- Operating temperature should be kept as low as possible consistent with adequate sludge conditioning.
- The lead operator for the thermal treatment system should have a good mechanical aptitude and be able to do frequent, routine preventive maintenance.
- The need to remove scale from heat exchangers is the most frequent reason for routine shutdowns of thermal treatment systems.
- High chloride wastewaters (i.e., in coastal areas where seawater intrusion may occur) require the use of especially corrosion resistant materials in the thermal treatment system.
- Odor problems are common and adequate control facilities should be used. The methods most commonly used for control of odors are high temperature incineration, adsorption on activated carbon, and chemical scrubbing.
- The BOD load imposed on the wastewater treatment plant by recycle of the liquors from the thermal treatment system can constitute 20 percent of the total influent BOD load. The recycle liquors usually impart a color to the final effluent and may significantly degrade the effluent quality if the wastewater treatment plant does not have adequate capacity to treat the recycle loads.

The advantages of thermal treatment systems include the following:

- Condition sludges so that they dewater more readily and more completely than when conditioned by other means. This provides a reduction in dewatering costs.
- Can provide pasteurization of the sludge rendering it free of pathogenic organisms.
- Can provide oxidation of sludges without the preliminary dewatering required for incineration and with substantially reduced air pollution potential.
- Can provide reduction of sludges containing toxic materials which would render biological stabilization processes ineffective.

The disadvantages of thermal treatment systems are that they:

- Involve greater mechanical complexity than most systems that municipal treatment plant operators are familiar with. Operators are often reluctant to work on or around the high temperature-pressure equipment.
- Require substantial operator attention and frequent maintenance. Many of the systems visited reported substantial downtime due to maintenance problems.
- Produce odorous off-gas that must be collected and deodorized before release.
- Transform insoluble organic substances in the sludge into soluble materials which appear in a high strength cooking liquor. Recycle of this liquor to the wastewater treatment plant can degrade effluent quality if the plant does not have adequate capacity to handle the recycle load. Recycled liquor many also result in refractory organics appearing in the effluent causing color and increased COD levels.

A thermal treatment system for Ain Ghazal would require a system sized for approximately 2,000 cubic meters per day. Based on the EPA study of this, operation and maintenance labor would be 26,400 man hours per year. Fuel and power requirements are presented in the following table.

System	Fuel Requirements (10^6 BTU/yr)	Primary Elect. Requirements (10^6 kwh/yr)	Bldg. & Site Elect. Req. (10^6 kwh/hr)
Thermal Conditioning	1.6	1.5	3
Thermal Conditioning with Air Addition	0.9	2.8	3

At current prices of 35 fils/kwh and 15 fils/liter of diesel fuel, typical energy costs are estimated for these processes as follows:

System	Fuel Cost (10^5 JD/yr)[a]	Electrical Cost (10^5 JD/yr)
Thermal Conditioning	1.51	1.58
Thermal Conditioning with Air Additive	0.85	2.03

[a] Cost of operation and maintenance labor at 110 JD/man-months is 17,870 JD/yr.

The thermal treatment systems offer a number of disadvantages. Notably, they require skilled and frequent maintenance. They are an energy intensive system and as such will increase in operating costs as time goes on. The EPA is reluctant to fund these processes because of chronic operational problems. For these reasons, thermal treatment will be deleted from further consideration in this Master Plan.

Anaerobic Digestion. The system of sludge stabilization currently in use at the AGTP is anaerobic digestion. The existing anaerobic digesters have a total volume of 6,000 cubic meters. In the near future, an additional 12,000 cubic meters of capacity will be constructed, which will raise the total digestion capacity to 18,000 cubic meters. Parameters that are generally used for sizing anaerobic digesters are as follows:

Parameter	Design Figure
Detention Time	20 days
Solids Loading Rate	1.6 kg VSS/m^3.d
Volatile Solids Reduction	45 to 55%
Gas Production	0.94 m^3/kg VSS reduced
Heat Value of Gas	6.21 kwh/m^3
Operating Temperature	30°C

Assuming that the total volume of the existing digesters is 18,000 cubic meters, the maximum allowable loading rate to the existing digesters would be 28,800 kg volatile solids per day, using the design figures presented above. Typical domestic sludge contains approximately 80 percent volatile solids, which means that the maximum weight of sludge solids that could be treated in the existing digesters is 36,000 kg/day. The estimated sludge production rate for Treatment Alternative TA1 in the year 2000 is 90,200 kg/day, which is 54,800 kg/day above the estimated capacity of the existing digesters. Based on this analysis, additional sludge stabilization facilities will be needed at the AGTP by the year 2000.

The logical choice for the additional facilities is anaerobic digestion, for the following reasons. First, the Ain Ghazal personnel have been operating anaerobic digesters for some years and thus have a great deal of experience with this process. Second, mechanical problems mentioned in Chapter 6 can be solved by proper design of the digestion facilities and new grit removal facilities. Third, toxic industrial wastes will not represent a significant portion of the wastewater flow in the future, so the anaerobic digesters should not be susceptible to upset. Fourth, anaerobic digesters produce more energy, in the form of digester gas, than they consume. This energy can be recovered as electrical energy and used to heat the digesters, which is a substantial advantage as compared to other alternatives. Finally, the process is not complex. The operator is introducing sludge to a tank where it is heated and mixed. A natural fermentation process occurs which produces methane gas and carbon dioxide as the principle by-products.

The proper operation of an anaerobic digester requries that the sludge be properly thickened and gradually fed to the digester in small increments. This implies proper operation of raw sludge pumping and thickening and the waste activated sludge thickening. Proper design of digestion facilities will provide adequate heating and mixing. both draft tubes and gas injection at the bottom of the digester have been used for mixing with success. For heating, heat exchangers similar to the existing ones appear appropriate, though in some cases direct steam injection has been used with great success. These matters would be determined during the detailed design phase.

Engine generators can be used to recover a portion of the energy in the digester gas by producing electricity. A schematic of such a system is presented in Appendix K. Approximately thirty percent of the net fuel value of the gas can be recovered as electrical output from the generators. Waste heat from the engine generator can also be recovered by recycling the engine cooling water and engine exhause through heat exchangers to heat digested sludge. Fifty-five percent of the net fuel value can be recovered in this fashion. The total potential recovery is therefore eighty-five percent.[5] At a total sludge production rate of 90,200 kg/day in the year 2000,the estimated gas produced would be 33,900 m^3/day which would power an engine generator rated at 2600 kw. This would reduce substantially the amount of power which would have to be furnished from outside the plant. At the current price of 35 fils/kwh this recovered energy is worth JD 800,000/yr for TA1 in the year 2000. The costs of implementing such a process are discussed in more detail in Chapter 9. Obviously it should be included as part of the next plant exapnsion if that is economically feasible. If necessary, it could be built after the expansion if funding is limited.

Sludge Dewatering. Up to the present time, the only form of dewatering practiced at Ain Ghazal has been the use of open sand drying beds. Their use has been limited because the dried sludge must be removed manually. More than eighty percent of the sludge is trucked in liquid form to the municipal landfill. As stated previously the existing plant site is limited in size and will be utilized completely when the plant is upgraded. As a result, the land needed for continued use of sludge drying beds will not be available and an alternative method of sludge dewatering must be employed. Potential dewatering methods are described in the following sections.

Belt Presses. Belt presses use horizontally mounted continuous belts to convey and dewater the stabilized sludge. Under an exisiting project, three of these units will be installed at the AGTP in the near future, and another will be added when needed. Total capacity is expected to be 54,000 kg/day of digested sludge which is equivalent to 82,000 kg/day of undigested primary and waste activated sludge. The belt press has the advantage of being simpler to maintain than the other alternatives described in this section. However, the belt wears out and must be replaced eventually, but this is a relatively simple operation. Experienced employees of belt press manufacturers can change a belt on one of the machines within two hours, but replacement of a belt by plant personnel, who do it infrequently, probably would require one full shift.

Centrifuges. The centrifuge that is most often used for dewatering sludge is the solid bowl type. This centrifuge has a rotating bowl into which sludge is fed and separates into a dense cake containing the solids and a dilute stream called the centrate. The centrate contains fine, low-density solids and is generally recycled through the treatment plant. The sludge cake is discharged by a screw feeder into a hopper or conveyer. Centrifuges are characteristically a high-maintenance item. The edges of the screw feeder are protected by a material called hardface which is gradually worn away by grit in the sludge and must be replaced. To accomplish this, the centrifuge must be shut down and the screw feeder removed and taken to a welding shop for replacement of the hardface. This process can easily take several weeks. In addition, centrifuges consume a relatively large amount of energy since the operation of a centrifuge necessitates the bowl to rotate at a very high speed. The feeder also rotates but at a lower speed than the bowl.

Filter Presses. Filter presses dewater sludge by forcing the water from the sludge under high pressure. This is accomplished by conveying sludge on cloth filters fitted between two plates. The plates are pressed together for one to three hours, and the water escapes through the filter cloth and plate outlet ports, leaving the dewatered sludge behind on the cloth. Plate and frame filter presses require periodic replacement of the filter cloth on each plate. This is a lengthy operation because such presses can have as many as 95 plates. Filter presses have more extensive support equipment than any other system. They also require sludge to be conditioned with lime and ferric chloride. A lime system, in particular, is expensive because lime doses from 10 to 25 percent of the sludge weight are typical. Systems must be provided to acid wash the press to clean it.

The total system becomes very complicated and expensive, being typically twice the cost of the other systems under discussion.

Vacuum Filters. A vacuum filter is composed of a cylindrical drum over which is stretched a filter medium which can be a cloth of natural or synthetic fibers, coil springs, or a wire-mesh fabric. The drum is partially submerged and rotates slowly in a bath of sludge. The interior or the drum is subjected to a vacuum, the sludge is pulled against the fabric, the water is pulled through and the solids are left behind. The solids are removed from the fabric surface by a scraper that deposits them in a hopper or on a conveyer for disposal. The vacuum filter is most comparable to a belt press in that the major form of maintenance is the replacement of the filter cloth. Generally vacuum filters do not perform as well as belt presses.

Energy Consumption of Alternatives. Typical values for the energy consumption of dewatering processes are presented below:

Process	Energy Consumption (kwh/1000 kg dry sludge)
Centifuge	200-400
Filter Press	100-200
Vacuum Filter	40-60
Belt Filter Press[a]	10-20

[a] From recent belt press evaluations in Chino, California

Selection of Alternative. To summarize the mechanical dewatering options, the cost comparison between the use of vacuum filters or centrifuges is very close both in terms of capital cost and cost per kg of sludge processed. Filter presses cost approximately twice either of these in both capital cost and cost per kg of sludge processed. The cost of a belt press installation is comparable to that of a vacuum filter or a centifuge with all other criteria being equal but the relative ease of maintaining the belt press makes it the preferred choice.

Treatment Alternatives for the New Plants

A new treatment plant, whether constructed at or near the Upper Wadi Abdoun site or the Khirbet er Ruseifa site, would be located in an urban area where the cost of the land is substantial and the terrain does not favor land-intensive type processes. In view of the significant flows that would have to be accommodated at these alternative locations, the activated sludge process appears to be the most appropriate selection for treatment. Effluent standards would be similar to those for AGTP. Further consideration of treatment alternatives for the new treatment plants is not necessary. A process description and cost estimates for each alternative are presented below.

Upper Wadi Abdoun Treatment Plant

A treatment plant site has been identified in the Upper Wadi Abdoun area which will provide substantial hydraulic relief to the sewers in Amman. This has already been discussed in the portion of this chapter dealing with the AWSA collection system. Presuming 100 percent connections, the flows to this plant are estimated at 8,600 m^3/day in 1990 and 21,200 m^3/day in 2000.

The area around the proposed Upper Wadi Abdoun Treatment Plant (UWATP) is expected to be extensively developed by the year 2000. As a result, real potential exists for complaints due to odors from the treatment plant. Most odors from wastewater treatment plants arise from sludge digestion and dewatering. To minimize this problem, the sludge produced at the UWATP will be returned to the sewer where it will be conveyed to the AGTP, settled in the primary sedimentation tanks and further treated in the AGTP solids processing facilities. This concept has been used by both Los Angeles County Sanitation Districts and the City of Los Angeles. This will require additional digestion and solids processing facilities at the AGTP.

The size of the UWATP in the year 2000 makes conventional activated sludge the viable treatment alternative. The cost of such a plant without solids processing facilities are presented below:

Item	Cost (JD)
Construction Cost	6,050,000
Implementation Cost	3,025,000
Total Project Cost	9,075,000
Equivalent Annual Project Cost	1,066,000
Annual Operation & Maintenance Cost	138,000
Annual Power Cost	403,200
Total Annual Cost	1,607,200

The anticipated sludge production for the plant is presented below:

	Sludge Production		
Year	Dry Weight (kg/day)	Wet Volume (m^3/day)	Dry Volume (m^3/day)
1990	8,100	202	45
2000	19,900	498	100

The additional digestion capacity required at the AGTP to handle these solids is 5,100 m^3 in 1990 and 12,400 m^3 in 2000. This can be accommodated in the southern plant site. The dewatering facilities would have to be expanded by a

minimum of one belt press by the year 2000. A new dewatering building should be constructed on the southern plant site at the AGTP and then two belt presses be provided, one acting as standby. This would have to be done between 1990 and 2000. The cost incurred at the AGTP which may be assigned to the UWATP in the year 2000 are as follows:

Item	Cost (JD)
Construction Cost	1,720,000
Implementaton Cost	860,000
Total Project Cost	2,580,000
Equivalent Annual Project Cost	303,150
Annual Operation & Maintenance Cost	162,000
Annual Power Cost	156,800
Total Annual Cost	621,950

The disposal of the sludge is discussed in the Sludge Management Alternative section.

Khirbet er Ruseifa Treatment Plant

Even with Upper Wadi Abdoun Treatment Plant, the year 2000 flows in the AWSA system cannot be handled at the UWATP or AGTP sites. This requires building a treatment plant downstream of the AGTP near Khirbet er Ruseifa.

The potential AWSA system flow, presuming 100 percent connections and the flow treated at each treatment plant site are presented below:

	Wastewater Flow (m^3/day)			
	With UWATP		Without UWATP	
Item	1990	2000	1990	2000
AGTP	96,000	96,000	96,000	96,000
UWATP	9,000	22,500	--	--
KRTP	--	58,000	9,000	80,500
Total	105,000	176,500	105,000	176,500

A new treatment plant site will apparently have to be developed to accommodate the flows between 1990 and 2000, and construction would begin sometime about 1991. If, in fact, connections in the AWSA system proceed at a lower rate than is projected in this section, the construction could be deferred.

In any case, AWSA should make plans to purchase this land in the near future. The KRTP will require approximately 120 dunums, presuming that mechanical dewatering of sludge would be used. The land in the area is estimated to be worth

JD 15/m^2, so the cost of the site would be JD 1,800,000. The site is approximately 100 meters wide at its narrowest point, and lies within the Seil Zarqa flood plain. The proposed treatment plant site will therefore require flood protection. At the AGTP, flood protection was provided by constructing a flood control channel. Instead, earthen wall embankments may be used at the upstream and downstream edge of the KRTP site while a concrete bulkhead should be used parallel to the flow. This is something that should be carefully evaluated during the plant design phase.

With reference to the discussion of the AGTP, a new treatment plant using conventional activated sludge with anaerobic digestion and belt press dewatering is proposed. The estimated cost of such a plant at the year 2000 alternative flows is presented below:

Item	With UWATP Cost (JD)	Without UWATP Cost (JD)
Construction Cost	19,500,000	26,000,000
Implementation Cost	9,750,000	13,000,000
Total Project Cost	29,250,000	39,000,000
Equivalent Annual Project Cost	3,440,000	4,580,000
Annual Operation & Maint. Cost	740,000	1,000,000
Annual Power Cost	738,000	1,080,000
Total Annual Cost	4,918,000	6,660,000

The quantities of sludge produced in the year 2000 by these alternatives is presented below:

Item	With UWATP	Without UWATP
Dry Weight (kg/day)	54,500	79,430
Wet Volume (m^3/day)	1,090	1,590
Dry Volume (m^3/day)	270	400

The disposal of sludge is discussed in the Sludge Management Alternatives section.

Zarqa-Ruseifa

A draft feasibility study has already been submitted for the Zarqa-Ruseifa (Z-R) region.[6] The study has been reviewed as part of this Master Plan Scope of Work and its findings related to population and wastewater flows were accepted.

The Scope of Work in the Z-R Study did not cover the Schneller Camp, Marka area and East Marka, Figure 8-9. East Marka which was considered earlier in the Suburban Ring is projected to have an industrial zone and low to medium income housing projects. Two Marka housing projects have been completed and a new one is scheduled to be completed about 1984. The total population of the housing projects is estimated to be about 20,000 by or prior to 1990.

Both the Schneller Camp and the Marka area can be taken into the Z-R system by providing appropriate trunk sewer extentions and enlargements plus a pump station near the Schneller Camp. This would be necessary to clear a drainage obstacle near the phosphate mining area. Water impoundment behind the obstacle is due to natural drainage, industrial waste flow from the phosphaste mining operations and the two major wet industries in the area, see Appendix D3, and a possible leachate from the Schneller Camp subsurface disposal system.

The potential additional tibutary flow to the Z-R system is as follows:

	1979		1990		2000	
	Pop'n	Flow m^3/day	Pop'n	Flow m^3/day	Pop'n	Flow m^3/day
Al Matar and Marka Area[a]	12,000	900	14,000	1,190	15,000	1,425
East Marka	-	-	20,000	1,700	34,000[b]	3,230
Schneller Camp	24,000	1,200	24,000	1,440	24,000	1,680
	36,000	2,100	58,000	4,330	73,000	6,335

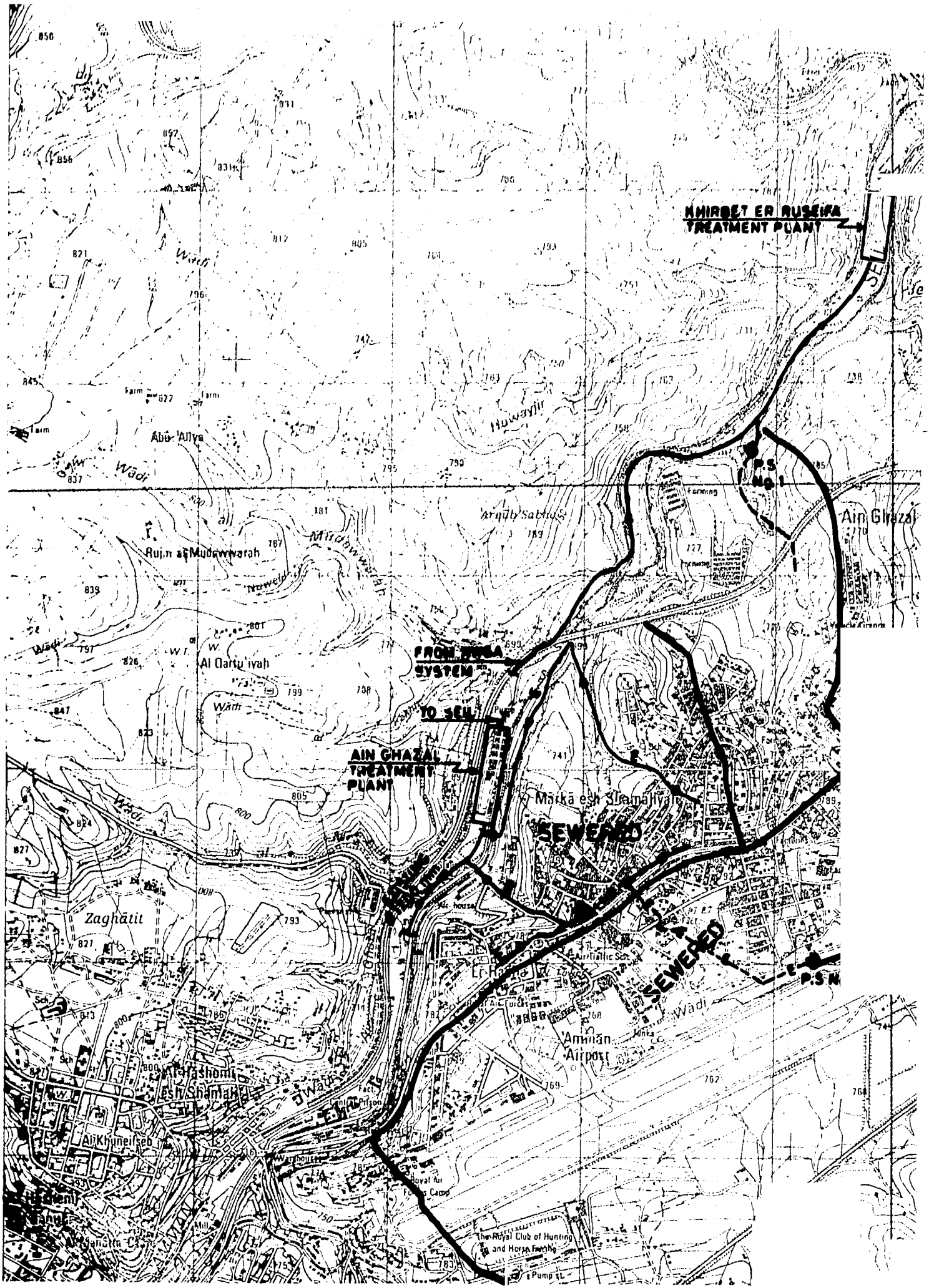
[a] Assuming P.S. No. 4 is abandoned and P.S. No. 3 is not built. Refer to Figure 8-9

[b] Projected equivalent population including industrial contribution. Industrial development has not occured yet in this area.

The Z-R Study calls for Phase I plant capacity of 24,200 m^3/day to meet the needs up to the year 1990 and Phase II plant capacity of 41,200 m^3/day for the year 2000. The additional flows generating from Schneller Camp and the East Marka Area tabulated above constitute 18 percent and 15 percent increase over the Phase I and Phase II flows respectively. These are fairly substantial increases and provision should be made in the design of the Z-R treatment facilities to accommodate them.

Construction could be phased to include the Schneller Camp first into the Z-R system. The housing projects which will not reach their maximum occupancy before 1985 would be phased in next. The Al Matar area and a portion of Marka are served presently by the newly constructed pump station designated No. 4 and need not be connected to the Z-R system until 1990. At that time the pump station will be abondoned and the flow will be transmitted to Z-R system via pump station No. 2.

The previously planned pump stations No. 3 and No. 1 need not be built under the Phase I program. The wastewater from the area south of the Zarqa highway and tributary to pump station No. 1 can be collected and transmitted to AGTP by gravity or, if not possible, by a low lift pump station. Eventually this area will be served by KRTP, the downstream plant. The area north of the highway and tributary to the pump station is lightly populated and need not be served prior to 1990.


KHIRBET ER RUSEIFA
TREATMENT PLANT
P.S
No. 1
Ain Ghazal
FROM ZARQA
SYSTEM
TO SEU
AIN GHAZAL
TREATMENT
PLANT
SEWERED
SEWERED
P.S No.
Abu Allya
Wadi
Huwayjir
Arqub Sahiyah
Ruin aş Muqawwarah
Al Qartu'iyah
Zaghatit
Al Hashimi
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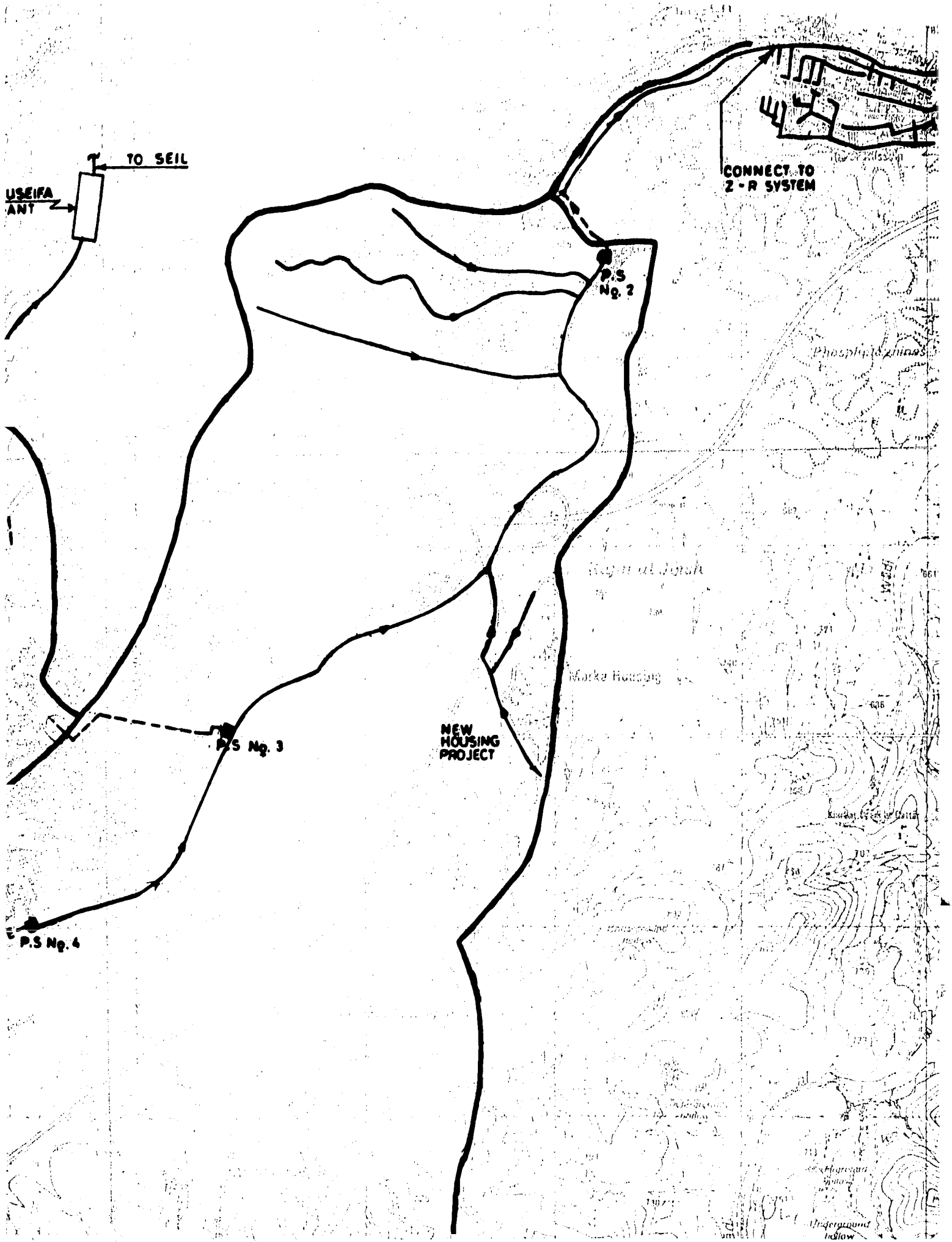
Al Khuneiseb
Amman
Airport
Marka esh Shamaliyah
The Royal Club of Hunting
and Horse Racing


TO SEIL
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Z - R SYSTEM
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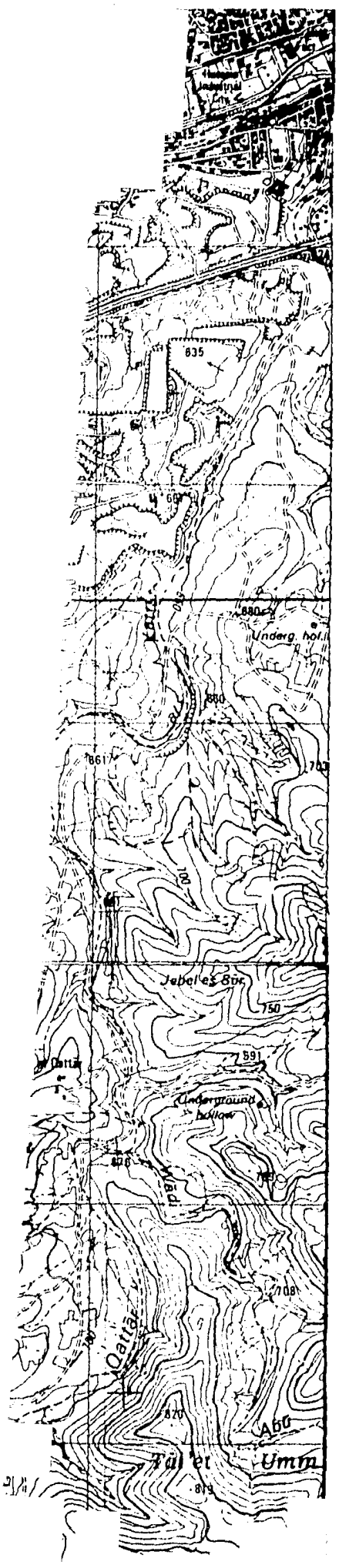
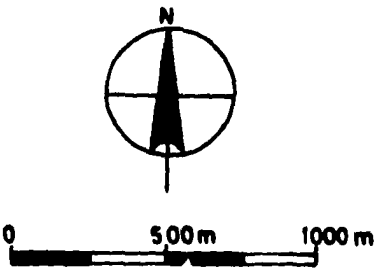
No. 2
P.S No. 3
NEW
HOUSING
PROJECT
P.S No. 4





LEGEND

- PROPOSED SEWERS
- PROPOSED P.S AND FORCE MIN.
- E E EXISTING SEWERS
- E-E. EXISTING FORCE MAIN
- DRAINAGE AREA BOUNDARY

NOTES :-

AREA TRIBUTARY TO P.S. No. 4

ALT.1 - CONTINUE PUMPING TO AGTP

ALT.2 - ABANDON P.S. No.4 - GRAVITY TO P.S. No. 2

AREA TRIBUTARY TO P.S. No. 3

ALT.1 - CONSTRUCT P.S. - PUMP TO AGTP

ALT.2 - GRAVITY TO P.S. No. 2

AREA TRIBUTARY TO P.S. No. 1

ALT.1 - CONSTRUCT P.S. - PUMP TO AGTP

ALT.2 - GRAVITY TO KRTP.

ALTERNATIVES FOR SCHNELLER CAMP AND MARKA AREA

FIGURE 8 - 9

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The housing projects and Schneller Camp with a total population of 44,000 by 1985 form a significant source of concentrated wastewater load that need to be addressed. In order to have a cost effective system, the camp and the housing projects should both be sewered. The housing project by itself would not be able to bear the cost of the trunk sewer and pumping station.

A cost summary of the trunk system and pump station is presented in the following table:

	Length (meters)	Diameter (mm)	Cost (JD)
Al Matar to Housing Projects	3,300	300	121,000
Housing Project to Schneller Camp	1,200	400	51,000
Schneller Camp to Pump Station No. 2	1,000	500	47,000
Pump Station and Force Main	400	300	145,000
Interceptor to Z-R System	1,500	500	70,000
Total Construction Cost			434,000
Project Implementation			217,000
Total Project Cost			651,000

The Z-R Study recommended a typical plastic media trickling filter plant followed by post aeration and chlorination. This appeared to be the most cost effective option as compared to stone media trickling filters and activated sludge. A BOD removal of 90% is shown across the system on the mass balance diagram presented in the Appendix to this Study. The percent removal indicated is certainly possible during average temperature conditions. However, there is some doubt as to whether such high removal could be achieved during cold weather conditions. Average temperature in this region can reach a low of 5°C to 8°C during January and occasionally drops below freezing. The months of December and February are also relatively cool. Under such cold weather conditions, the treatment efficiency of a trickling filter is greatly impaired. At an average ambient temperature of 7°C, the estimated BOD_5 removal efficiencies for the system could drop to a low of around 65 percent.

The Z-R Study estimates minimum BOD_5 removal efficiencies of 75 percent at 10°C, which is the typical winter wastewater temperature at the AGTP. However, when the sewage passes through a trickling filter with plastic media, a heat exchange effect takes place and the wastewater temperature drops further. Assuming that the BOD_5 of the primary effluent is 575 mg/l, the effluent from the trickling filter plant could be as high as 144 to 201 mg/l, using the above removal efficiencies. Some dilution of the flow may occur from stormwater flows during the wet winter season. The Z-R Study presents the following information on the average daily flows in the Seil Zarqa during the wet season:

Type of Year	Flow (m^3/day)
Wet Year	314,300
Average Year	227,700
Dry Year	168,000

The dilution effect of such flows is presented in Table 8-5.

TABLE 8-5

EFFLUENT DILUTION EFFECTS OF WET WEATHER FLOWS[a]

	Z-R Effluent Concentration at 144 mg/l Concentration after Dilution (mg/l)		Z-R Effluent Concentration at 201 mg/l Concentation After Dilution (mg/l)	
	1990	2000	1990	2000
Wet Year	10.2	16.7	14.0	23.0
Average Year	14.0	22.0	19.3	30.8
Dry Year	18.0	28.4	25.3	39.6

[a] The above figures assume zero BOD concentration in the river flow. BOD data are not available, however BOD concentrations vary depending on the tributary flows at any given time and the quality of such flows.

As can be seen from Table 8-5, wet weather flows can cause a substantial dilution of the high BOD concentrations in the plant effluent. However, the flows in the Zarqa River are rather irregular even during the wet seasons and could not be depended on to give the dilution effect required when the treatment plant removal efficiencies fall below the desirable level.

Since the proposed Z-R plant is at some distance from the Muwaqqar landfill site, the economics of sludge disposal require the trucking of sludge in a dewatered form rather than in a liquid form. Since the land is available for sludge drying beds, their use would be appropriate until such time when the site becomes limiting, and a shift to mechanical dewatering then would be justified. The Study's recommended use of anaerobic digestion for sludge stabilization appears to be cost effective.

Es Sukhneh and Hashimiya Alternatives

Es Sukhneh and Hashimiya are the only communities of any significance remaining undiscussed in the Seil Zarqa drainage. Es Sukhneh lies approximately six kilometers north and west of Zarqa while Hashimiya lies six kilometers north and east. The Community Sanitation Reconnaissance performed in August and September of 1980 indicated no existing problems with subsurface disposal of

waste, and none are anticipated in the near future. The populations and potential wastewater flows for these communities, presuming 100 percent connections, are presented below:

	1979		1990		2000	
	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)
Sukhneh	4,000	200	6,000	400	8,000	600
Hashimiya	4,000	200	6,000	400	8,000	600

A free trade zone is planned to the east of Hashimiya. This project is planned for 1200 net dunums of commercial and 650 net dunums of industrial land. Industries are to be light and medium including 100 dunums of food processing plants. At the present time, no development has been started in this area and no firm schedule for implementation of this plan has been established. Substantial contributions of wastewater may be anticipated particularly from the food processing plants. The best approach is to wait until such time as the plans become more definite and then consider constructing separate sewage treatment for this area or possibly providing a common treatment plant for Hashimiya and the Hashimiya Free Trade Zone. The only existing major industry is a petroleum refinery which uses approximately 100 m^3/day of water and has its own treatment plant.

Collection System Alternatives. Both Hashimiya and Sukhneh can be served with a gravity collection system in town without the need for any pump station. Once collected, Hashimiya's wastewater may be pumped to either the proposed Zarqa-Ruseifa sewer system or to Sukhneh. From Sukhneh, the combined flows of both Hashimiya and Sukhneh could be pumped to the Zarqa-Ruseifa Treatment Plant. Hashimiya is approximatedly 5 kilometers away from and 60 m lower than the proposed Zarqa-Ruseifa East Side Pumping Station, while Hashimiya is four and one-half kilometers away and 30 m lower than the high point between it and Sukhneh. Sukhneh is four and one-half kilometers and 25 m lower than the Zarqa-Ruseifa Treatment Plant. The costs of these various options are presented in Table 8-6.

The alternative of pumping Hashimiya to Sukhneh and then pumping the combined flow to the Zarqa-Ruseifa plant has a total annual cost of JD 73,300. Pumping Sukhneh directly to the treatment plant and Hashimiya to the Zarqa-Ruseifa East Side Pumping Station has a total annual cost of JD 70,000. Puming the flow from Hashimiya to the Zarqa-Ruseifa system will affect the sizing of the East Side Pumping Station and the operating costs. This pump station pumps over the divide in Zarqa which is an elevation change of 70 meters. The additional cost of pumping the flow through Zarqa makes the alternative of pumping flow from Hashimiya to Sukhneh more economical. However, the cost of pumping is high enough that the alternative that calls for constructing treatment plants at each community appears to be the most economical. The chosen alternative will depend to a large extent on the cost of individual treatment plants at Hashimiya and Sukhneh.

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TABLE 8-6

PUMPING ALTERNATIVES FOR SUKHNEH AND HASHIMIYA

	Pump Hashimiya to Sukhneh	Pump Combined Flow To Zarqa-Ruseifa Plant	Pump Hashimiya Zarqa-Ruseifa Collection	Pump Sukhneh to Zarqa-Ruseifa
Pump Station Construction Cost	40,000	56,000	60,000	40,000
Pipeline Construction Cost	111,800	132,500	124,200	117,800
Implementation Cost	75,900	94,300	92,100	78,900
Total Project Cost	227,700	282,800	276,300	236,700
Equivalent Annual Project Cost	26,800	33,200	32,500	27,800
Annual Operation & Maintenance Cost	4,000	5,500	4,000	4,000
Annual Power Cost	2,000	1,800	1,300	800
Total Annual Cost	32,800	40,500	37,800	32,600

Treatment Facilities Alternatives. Enough flat land is available near both Hashimiya and Sukhneh to make a total containment lagoon an attractive alternative. Since both these communities are located in a groundwater recharged area, a lined lagoon must be provided. This is particularly important at Sukhneh where there are some 47 springs. The lagoon system would require some 100 dunums of land for each community. The other treatment alternatives are conventional activated sludge and extended aeration. A cost comparison is presented in Table 8-7. Since both treatment plants are the same size, the costs apply to each community. The lagoons appear to be the most cost effective alternative.

The annual cost of pumping to the Zarqa-Ruseifa Treatment Plant is estimated to be JD 13,200. Treatment facilities for both communities would have a combined annual cost of JD 121,000. If either Hashimiya or Sukhneh were to use the Zarqa-Ruseifa Treatment Plant, the community would have to assume a portion of the debt and the operation and maintenance costs incurred by the communities of Zarqa and Ruseifa in building the plant. Based on the cost estimate presented in the Z-R Study, the capacity at the Zarqa-Ruseifa plant is estimated to cost JD 38 per cubic meter capacty per year, which is equivalent to JD 45,600/yr, for the communities of Sukhneh and Hashimiya. The total of pumping annual costs and treatment annual costs is JD 119,000/yr, and is approximated the same as the cost for building total containment lagoons at both communities. The actual cost effective choice will depend on the actual bid price and operating costs of the Zarqa-Ruseifa Plant. At the time of the plant's construction and initial operation, the possibilities for serving Hashimiya and Sukhneh must be reevaluated. For the time being, planning may be based on providing total containment lagoons.

Effluent Disposal. Presuming that total containment lagoons are built, no effluent will be discharged and no effect will be felt on the Seil Zarqa drainage.

Sludge Disposal. An estimated ten years' of sludge storage will be provided in the first lagoon by adding additional depth to the bottom. Because the sludge stored in the bottom of the lagoon undergoes a form of anaerobic digestion, the exact rate of sludge accumulationn is difficult to predict. When it is determined that sludge removal is necessary, the lagoon is taken out of service and drained. The bottom sludge is allowed to dry for a period of time before it is hauled away. The sludge would be in a fairly stabilized condition and may be spread on land as a fertilizer and soil conditioner. This issue is discussed in more detail in the Sludge Management Alternatives section.

ALTERNATIVES FOR THE NORTHWESTERN SUB-BASIN

The communities in this sub-basin drain northerly through wadi um Dananir and ultimately into King Talal Reservoir. Figure 7-4 depicts the drainage pattern and the major communities of this sub-basin namely northern sections of Suweileh, the Baqa'a Camp and Ain el Basha. The community of Safut, although it has a population of approximately 1,000, lies between Suweileh and Ain el Basha and as

TABLE 8-7

COST COMPARISON OF TREATMENT PLANT ALTERNATIVES
AT SUKHNEH AND HASHIMIYA

	Total Containment Lagoons	Extended Aeration	Conventional Activated Sludge
Construction Cost	250,000	170,000	240,000
Implementation Cost	125,000	85,000	120,000
Land Cost	100,000	2,000	2,000
Total Project Cost	475,000	257,000	362,000
Equivalent Annual Cost	55,800	30,200	42,500
Annual Operation and Maintenance Cost	4,700	10,000	10,000
Annual Power Cost	--	32,000	13,500
Total Annual Cost	60,500	72,200	66,000

such can be easily served. The smaller communities in this area which may require treatment plants in the long term are Allan, Um Juzeh and Er Rumeimin. These lie downhill from the major population centers at distance of four to eight kilometers and have populations of approximately one thousand or less. It is not judged feasible to plan to serve them at this time. The population and flows of the remaining communities, presuming 100 percent sewer connections, are presented below:

	1979		1990		2000	
	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)
Baqa'a Camp	45,000	2,250	45,000	2,700	45,000	3,200
Northern Suweileh	15,000	750	22,000	1,330	30,000	2,100
Ain el Basha	3,000	150	4,000	240	6,000	360
Safut	1,000	60	1,000	60	2,000	240
Total	64,000	3,210	72,000	4,330	83,000	5,900

In addition to these existing communities, a major city is to be built near the present town of Abu Nusair. Discussions with the engineers[7] who are planning this development revealed that construction of this city should begin in early 1981. The first phase is to consist of 2600 homes and a predicted population of 18,000. By 1990 the population is expected to be 40,000. However, this is dependent on the implementation of the first phase. The city will provide housing for low to middle income individuals.

The new city will have its own sewage treatment plant using the activated sludge process. The plant will be located northeasterly of the city and will be discharged into the sub-basin adjacent to the Baqa'a Valley. Ultimately flow will drain to King Talal Dam.

It was determined not practical or cost effective at present to pump the wastewater from Abu Nusair into a centralized treatment facility serving the Baqa'a Valley sub-basin. The new city is about 5 km west of the Baqa'a proposed treatment plant site.

Industrial activity of some magnitude is present in the Ain el Basha industrial area. Industries include manufacturing of brick, gypsum, marble, paper and cardboard boxes, and precast concrete elements. Food and poultry feed industries are also present. A survey of the industries in the area indicated that they are not "wet" industries and have insignificant amounts of industrial discharge. Future outlook of industrial planning and activities in the Greater Amman seem to indicate that the same trend will prevail in the future in this area.

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WASTEWATER COLLECTION, TREATMENT AND DISPOSAL ALTERNATIVES

Collection System Alternatives

In the previous discussion for the AWSA collection system, an evaluation of pumping the most densely populated area of northern Suweileh to the AWSA collection system was made. In this section, the collection system will be devised to collect the major communities by gravity and convey their flows to a common treatment plant site. The drainage from all these communities goes to the Wadi Um ed Dananir. A gravity trunk sewer layout is presented in Figure 8-3. The treatment plant site is located at the junction of the Rumeimin Road and the Wadi Um ed Dananir. A treatment plant constructed at this location can serve the four communities in this area and provide for future possible development of the existing open space. There should be at least 300 m separation from the plant and any urban developments or dwellings in order to guard against odors and other nuisances.

Treatment Facilities Alternatives

The treatment plant will be discharging to the Wadi Um ed Dananir. This is a sensitive area because the wadi is used for recreation by the public, particularly at a waterfall below Rumeimin. This means that high quality effluent must ultimately be provided. The requirements for discharge to such a sensitive area delete the low technology alternative of lagoons where a discharge may occur. Total containment lagoons would be required, and would have to be lined as there is continuity between the surface water and groundwater. The surface area of the total containment lagoons would have to be over 85 hectares to evaporate all of the wastewater. This much land would cost approximately JD 6.8 million in the Baqa'a Valley, which is excessively high.

As a result, total containment lagoons cannot be considered a viable alternative and will not be discussed further.

The high technology alternatives are: trickling filters; roughing filters followed by activated sludge; conventional activated sludge; and extended aeration.

Trickling filters will produce a high quality effluent under average conditions during the year, but the treatment efficiency is markedly affected by the cooler temperatures during the mild local winter. It is anticipated that during the months of December, January and February the treatment plant effluent BOD_5 would be in the range of 150 to 200 mg/l with comparable suspended solids. Since no large, continuous winter flows are anticipated in this wadi, the treatment plant effluent will still be almost the entire flow. Because of this, effluent of this quality is not acceptable.

The treatment process of roughing filters followed by activated sludge has already been found to be an uneconomical option in the analysis of the AGTP, and will not be considered further.

The remaining treatment plant options are conventional activated sludged and extended aeration. A comparison of their costs at year 2000 flows is presented below:

	Extended Aeration	Conventional Activated Sludge
Construction Cost	1,400,000	2,300,000
Implementation Cost	700,000	1,150,000
Total Project Cost	2,100,000	3,450,000
Equivalent Annual Project Cost	247,000	405,000
Annual O&M Cost	34,000	34,000
Annual Power Cost	300,000	130,000
Total Annual Cost	581,000	569,000

Conventional activated sludge appears to be the proper treatment alternative for this plant.

Effluent Disposal

The initial proposal for effluent disposal is to drain to the Wadi Um ed Dananir. The need for high quality effluent is readily apparent and has already been discussed. Potential use of the effluent is for irrigation purposes on the farms of the Baqa'a Valley. In 1990 there would be enough flow to irrigate 116 hectares, presuming 100% sewer connections. This will require effluent filtration as has already been discussed in this Chapter.

Sludge Disposal

The methods for disposing of sludge inclusive of the possibility of beneficial reuse are discussed in great detail in the Sludge Management Alternatives section as part of a regional plan. The quantities of sludge produced for the chosen alternative, presuming 100 percent connections, are presented below:

		Sludge Production	
Year	Dry Weight (kg/day)	Wet Volume (m^3/day	Dry Volume (m^3/day)
1990	4140	138	10.4
2000	5550	185	14

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ALTERNATIVES FOR THE WESTERN SUB-BASIN

The Western sub-basin contains the major communities of Salt, Fuheis and Mahis and other smaller communities such as Ira and Yarqa. This area drains to the Jordan River, as shown in Figure 7-4. Salt is already served by its own wastewater treatment plant. This plant has been evaluated in Chapter 6 and will be further evaluated in terms of future flows and loadings in a separate portion of this section. The centers of the communities of Fuheis and Mahis are located within 3 kilometers of each other, with the borders of the communities substantially closer. Yarqa is located approximately seven kilometers west of Mahis with one intervening wadi. Ira is located approximately nine kilometers west of Mahis with two intervening wadis. Both Yarqa and Ira are clearly too distant to be brought into a common wastewater treatment plant with either Fuheis or Mahis. As their populations are small, with Yarqa's current population at 2000 and Ira's population at 1000, they will be eliminated from further discussion. A treatment plant would be a very long range option for either of these communities.

Salt

At Salt, the major industrial contributor is the Arab Pharmaceutical Manufacturing Co., Ltd. The company manufactures a broad range of antibiotics, other drugs, and vitamins. All portions of the plant are directly connected to the city sewer with no allowance for pre-treatment of effluent. The average water consumption is 50 m^3/day. The flow is insignificant as compared to the capacity of the Salt Wastewater Treatment Plant. The contribution of rejected medicines does not appear to have any effect on the treatment plant as it is operating properly.

The populations and potential sewage flows for Salt are presented below:

	1979		1990		2000	
	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)
Salt	33,000	2,100	47,000	3,500	66,000	5,600

This table presumes 100 percent of the population is connected.

Salt is already provided with a treatment plant and a partially completed collection system. The city indicates that the collection system will be completed within the next few years. The treatment plant is an extended aeration plant which will require an additional secondary sedimentation tank as a reliability measure at the present and to meet the needs of the year 2000. The plant is adequate to meet the needs of the community up to the year 1990 and beyond. A detailed discussion of the Salt sewerage facilities is included in Chapter 6.

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Fuheis and Mahis

The principal industrial activity at Fuheis is a portland cement plant located within the town limits. Town residents have complained that the cement plant was polluting the town water supply with its discharges. This situation was recently corrected when the cement plant installed a wastewater treatment plant which completely recycles the effluent for use in its manufacturing.

The populations and potential sewage flows for the cities of Fuheis and Mahis are presented below:

	1979		1990		2000	
	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)
Fuheis	5,000	250	7,000	400	10,000	700
Mahis	4,000	200	6,000	400	8,000	600
Total	9,000	450	13,000	800	18,000	1,300

This table presumes 100 percent of the population is connected. The actual fraction of the population connected will be discussed in Chapter 9 for these communities.

Collection System Alternatives. Fuheis and Mahis are separated communities and each will have its own collection system, Figure 8-10. As part of the collection/treatment alternatives, a comparison will be made between providing one plant to serve both communities versus separate plants to serve each community. The former alternative would entail pumping from Mahis to Fuheis. As the basic collection system is the same for each community, the cost of pumping is an incremental cost addition to the joint treatment alternative. Since the static lift is about 50 meters, two pumping stations will be required. The force main would be 150 mm steel pipe. The costs are presented below:

	Pump Stations	Pipeline
Construction Cost	46,000	10,100
Implementation Cost	23,000	5,100
Total Project Cost	69,000	15,200
Equivalent Annual Project Cost	8,100	1,800
Annual Operation & Mainentance Cost	1,400	—
Annual Power Cost	5,400	—
Total Annual Cost	14,900	1,800

Note: It is presumed that the pipeline will be installed above ground. The operation and maintenance of the pipeline is included in the pump station operation and maintenance.

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The collection system alternatives will be further evaluated as part of the overall treatment alternatives.

Treatment Facilities Alternatives. Due to the continuity between the surface and the groundwater, a lined facultative lagoon will be necessary in this area. The effluent from a treatment plant at Fuheis or Mahis will discharge to a wadi where it is likely that the water will be used by the public. Such restrictions require either a total containment lagoon or a high quality effluent for which the process of extended aeration or conventional activated sludge are appropriate.

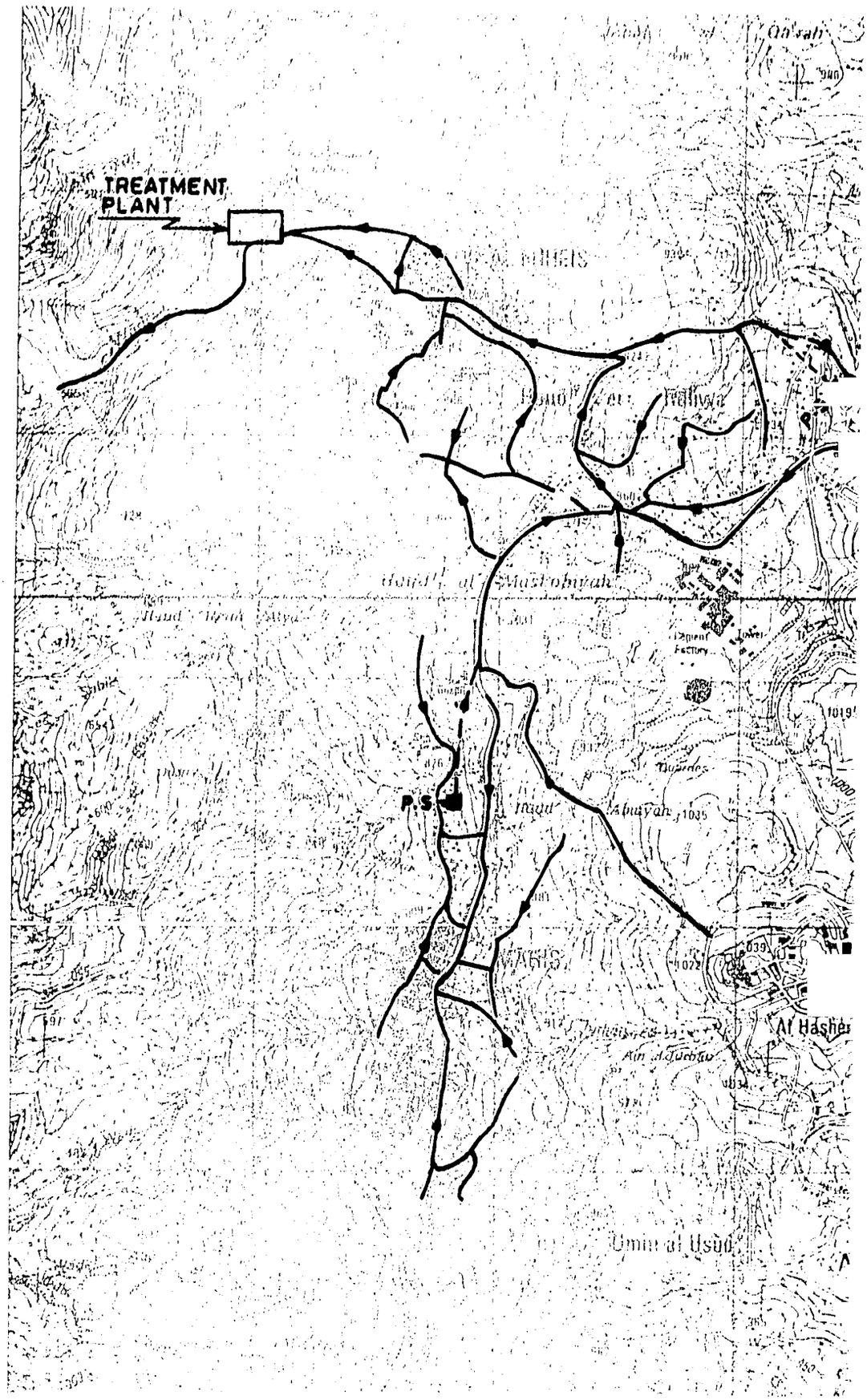
A total containment lagoon to serve both communities would require 200 dunums of area. This is too much land to use in an area where flat land is scarce. The treatment plant site cannot accommodate such a system. As a result, a total containment lagoon cannot be considered as a viable alternate and will not be analyzed further.

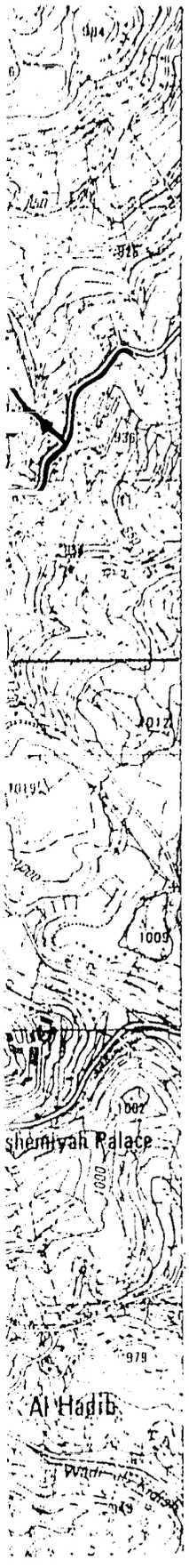
The following discussion involves the choice between extended aeration vs conventional activated sludge and between separate vs joint treatment facilities for the two communities.

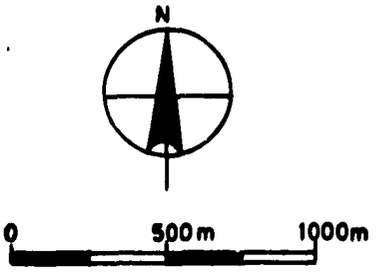
The cost of a treatment plant at Fuheis serving both communities at the year 2000 combined flow of 1400 m^3/day is presented in the following table:

	Extended Aeration	Conventional Activated Sludge
Construction Cost	380,000	540,000
Implementation Cost	190,000	270,000
Total Project Cost	570,000	810,000
Equivalent Annual Project Cost	67,000	95,200
Annual Operation and Maintenance Costs	10,800	10,800
Annual Power Cost	65,000	28,000
Total Annual Cost	142,800	134,000

The choice for a separate plant at Fuheis for the year 2000 flows again lies between extended aeration and conventional activated sludge. The costs are presented below:


TREATMENT PLANT
P.S.
Umm al Usud
Al Hashem





LEGEND

—— PROPOSED SEWERS

■ - - - PROPOSED P.S AND FORCE MAIN

ALTERNATIVES FOR FUHEIS AND MAHIS

FIGURE 8 - 10

	Extended Aeration	Conventional Activated Sludge
Construction Cost	250,000	310,000
Implementation Cost	125,000	155,000
Total Project Cost	375,000	465,000
Equivalent Annual Project Cost	44,000	54,600
Annual Operation & Maintenance Costs	10,300	10,300
Annual Power Cost	49,000	21,000
Total Annual Cost	103,300	85,900

Note: Power costs are escalated relative to other annual costs. Conventional activated sludge appears to be the economic choice.

For Mahis, at a year 2000 flow of 600 m^3/day, the choice still lies between conventional activated sludge and extended aeration. This is presented below:

	Extended Aeration	Conventional Activated Sludge
Construction Cost	170,000	240,000
Implementation Cost	85,000	120,000
Total Project Cost	255,000	360,000
Equivalent Annual Project Cost	29,960	42,300
Annual Operation & Maintenance Costs	10,000	10,000
Annual Power Cost	32,000	13,000
Total Annual Cost	71,960	65,300

The apparent cost effective choice at Mahis is conventional activated sludge. The combined annual cost of the two treatment plants is JD 151,200. This compares to a cost for one treatment plant and pumping system of JD 150,700. This difference in cost is insignificant.

Given a choice like this, one larger treatment facility has generally been found to produce a more uniform and high-quality effluent than two smaller facilities. Also, the administration of one plant, whether by the cities or an overall agency, is easier. Therefore, the recommended alternative is to treat wastewater from both communities at one treatment plant located at Fuheis. The cost comparison between extended aeration and conventional activated sludge is so close that the advantages of the former treatment process favors its adoption and recommendation.

Effluent Disposal. The effluent from the treatment plant at Fuheis will drain to the Wadi ez Zeitun which is an upper tributary of the Wadi Shu'eib. Opportunities exist for effluent reuse for agricultural purposes along the drainage. Substantial opportunities for public contact also exist in this water scarce area. Therefore, as in many other cases, effluent filtration will be required in the long term. This has already been discussed at some length in Chapters 7 and 8, and will not be repeated here.

Sludge Disposal. The methods for disposing of sludge, including possible beneficial reuse, are discussed in great detail in the Sludge Management Alternatives section as part of a regional plan. The quantities of sludge which will be produced for the chosen alternative, presuming 100 percent connections, are presented below:

	Sludge Production		
Year	Dry Weight (kg/day)	Wet Volume (m^3/day	Dry Volume (m^3/day)
1990	752	25	1.9
2000	1222	41	3.0

ALTERNATIVES FOR SOUTHWESTERN SUB-BASIN

The major communities lying within the Southwestern Sub-basin are the lower portion of Wadi es Sir and Na'ur. Communities with populations lying between 1,000 and 3,000 are Hisban, El Bassa, and Iraq al Amir. The Southwestern Sub-basin drains to the Jordan River by way of the Wadi Kafrein, Wadi Hisban and their tributaries, as shown on Figure 7-4.

Hisban is isolated from either major population centers, and does not have a water distribution system at the present time. Little growth is expected to take place in Hisban and will likely remain a small rural community. The field survey conducted in the course of this study covered Hisban and indicated that there is little potential for cesspool associated problems in this community.

El Bassa and Iraq al Amir lie relatively close to Wadi es Sir with El Bassa being four kilometers away and Iraq al Amir seven kilometers. Both communities lie downhill from lower Wadi es Sir along the Wadi. The present population of each community is estimated to be approximately 1000 persons, expected to grow to a population of 2000 by the year 2000. At the present time neither community is served by a water distribution system, and no immediate plans are in the works to provide such service to either town. Both communities are rather small farming communities and are anticipated to remain so throughout the Study Period. As a result, any sewage collection and treatment facilities are long-term possibilities.

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Na'ur

Na'ur is one of the larger communities in this sub-basin. Contributory populations and flows, presuming 100% connections, are:

	1979		1990		2000	
	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)
Na'ur	5,000	300	7,000	400	10,000	600

The town of Na'ur can be completely served by a gravity collection system. No pumping is required. As can be seen in Figure 8-4, the terrain is rather steep and drains northwesterly to Wadi Na'ur. The community is located far enough from other communities in the Study Area to warrant consideration of a joint treatment plant. A site option for the treatment plant was selected in a flat area in the proximity of town.

Treatment Facilities Alternatives. Na'ur is located in a groundwater recharge area, and is also located in an area where a substantial opportunity for public contact exists. These facts must be taken into account when considering treatment alternatives.

The low technology treatment alternative is a total containmednt lagoon facility in which evaporation from the lagoon would preclude any discharge from occurring.

Based on climatic data from the Amman Airport, the required lagoon area is estimated to be 89 dunums. Due to the continuity of the surface water and groundwater, the lagoon would have to be lined with an impervious liner. Field inspection of potential treatment plant sites did not reveal enough flat land for a lagoon site, as can be seen in Figure 8-4, so this alternative was deleted from further consideration. The remaining treatment alternatives considered were conventional activated sludge and extended aeration. A cost comparison is presented below:

	Extended Aeration	Conventional Activated Sludge
Construction Cost	195,000	320,000
Implementation Cost	97,500	160,000
Total Project Cost	292,500	480,000
Equivalent Annual Project Cost	34,370	56,400
Annual Operation & Maintenance Costs	10,200	10,200
Annual Power Cost	35,000	15,000
Total Annual Cost	79,570	81,600

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The cost appear to be the same for both treatment alternatives. However, considering the advantages of the extended aeration alternative in terms of less requirement for operation and maintenance, it was selected as the treatment process for the Na'ur treatment facilities.

Effluent Disposal. The effluent will drain to Wadi Na'ur which is an upper tributary of Wadi Kafrein. As elsewhere in the Study Area, the possibilities exist for the reuse of effluent for agricultural purposes along the Wadi. Public exposure to the effluent is a potential risk also. Therefore, effluent filtration will be required in the long term as has been discussed previously.

Sludge Disposal. The methods for disposing of sludge including the possibility of beneficial use are discussed in great detail in the Sludge Management Alternatives section as part of a regional plan.

The quantities of sludge which will be produced for the chosen alternative, presuming 100 percent connections, are presented below:

	Sludge Production		
Year	Dry Weight (kg/day)	Wet Volume (m^3/day	Dry Volume (m^3/day)
1990	376	30	0.75
2000	564	45	1.4

Lower Wadi es Sir

Collection System Alternatives. The collection system for lower Wadi es Sir may be found in Figure 8-1. As part of the AWSA collection system alternatives, the possibility of pumping lower Wadi es Sir to the AWSA system was evaluted and was found to be excessively expensive. The drainage pattern of lower Wadi es Sir allows the whole area to be served by a gravity collection system to be selected wastewater treatment site. The site is on a fairly flat land large enough to accommodate a conventional treatment plant.

Contributory populations and flows, assuming 100 percent connections, for lower Wadi es Sir, are presented below:

	1979		1990		2000	
	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)
Lower Wadi Es Sir	9,200	600	14,300	1,100	21,200	1,800

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Treatment Facilities Alternatives. The effluent from the treatment plant will drain to the Wadi es Sir where it may be used for irrigation. The effluent from such a plant will have to be of high quality ultimately, requiring effluent filtration to meet the effluent quality requirement for such uses. As in prior discussions of other communities, the alternatives are limited to a total containment lagoon, conventional activated sludge, or extended aeration.

A total containment lagoon will require an area of 27 ha by the year 2000. Such high requirement for relatively flat land can not be met, and the total containment lagoon alternative will not be considered further. The costs for the remaining options are presented below:

	Extended Aeration	Conventional Activated Sludge
Construction Cost	480,000	670,000
Implementation Cost	240,000	335,000
Total Project Cost	720,000	1,005,000
Equivalent Annual Project Cost	84,600	118,090
Annual Operation & Maintenance Cost	11,000	11,000
Annual Power Cost	80,000	34,000
Total Annual Cost	175,000	163,090

Once again the costs are essentially identical, i.e., within the normal range of accuracy of such estimates. Therefore, since the extended aeration process requires less skilled operator attention it is the recommended treatment system for lower Wadi es Sir.

Sludge Disposal. The methods for disposing of sludge, including the possibility of beneficial use, are discussed in great detail as part of a regional plan in the Sludge Managment Alternatives section. The quantities of sludge which will be produced for the chosen alternative, presuming 100 percent connections, are presented below.

		Sludge Management	
Year	Dry Weight (kg/day)	Wet Volume (m^3/day	Dry Volume (m^3/day)
1990	1030	20.7	2.6
2000	1690	34	4.2

ALTERNATIVES FOR SOUTHERN SUB-BASIN

The drainage in the Southern Sub-Basin goes through a series of wadis directly to the Dead Sea and as such has no effect on the King Talal Reservoir, as can be seen in Figures 8-11 and 8-12. The existing communities that will be studied in this area are Madaba, Sahab, Abu Alanda, Khirbet es Suq and Juweideh. Madaba is part of a separate report and is therefore outside the scope of this report.

A susbstantial amount of development is planned or underway in this sub-basin. This development is anticipated to result in major concentrations of populations where presently there are none. Under construction at this time are both the Queen Alia Airport and the Sahab Industrial City. Each of these facilities plans to install its own sewage treatment plant as part of the development. Consultations with the engineers at the Queen Alia Airport have revealed that a package treatment plant utilizing extended aeration will be provided to serve the airport.[8] Sludge drying beds are to be provided to dewater the sludge. The design parameters for the plant are:

Item	Design Figure
Flow	1890 m^3/day
BOD_5 Loading	758 kg/day
BOD_5 Removal	90 percent

The Sahab Industrial City will have a treatment plant that will be capable of treating a population equivalent of 10,000 people as part of the phase I project (1980-1982) and will be expanded in phase II (1983-1987) to serve an additional 10,000 people.

Construction of Queen Alia Airport and Sahab Industrial City is expected to create a new city between Sahab and the Queen Alia Airport known as the Sahab/Airport City. People working in the Sahab Industrial City and a portion of those working at the Queen Alia Airport will most likely live in this area. At the present time the area is sparsely populated and the new city must be completely constructed.

The Queen Alia Airport is expected to create a new population center known as Airport City which will absorb the present town of Jiza. At the present time Jiza is a small, scattered community with a population of only 700.

Since no development has as yet occurred at either Sahab/Airport City or Airport City, planning of wastewater collection and treatment should wait until development actually begins. Sahab/Airport City would have its own treatment plant while a plant located at Airport City would also be able to serve Jiza and Talbiya Camp. Ultimately, the treatment plant at the Queen Alia Airport could be abandoned and one centralized plant constructed for that area to treat wastewater from the airport and Airport City. Because wastewater collection and treatment facilities are included in the plans for Sahab/Airport City and Airport City, this study will only consider collection and treatment facilities for

the existing cities of Sahab, Abu Alanda, Khirbet es Suq and Juweideh.

Sahab

Sahab is a community of approximately 12,000 people located 10 kilometers southeast of Amman. Like all of the outlying communities, Sahab relies on septic tank systems for wastewater treatment and disposal, and the present conditions apparently favor this system. The Community Sanitation Reconnaissance, which was carried out in August and September of 1980 and is summarized in Appendix E, indicated that the soil conditions are not a limiting factor; cesspools overflow only infrequently; most of the cesspools are pumped out at a greater than annual frequency; and the cost of pumpout is in the range of 0 to 10 JD per year. In addition, the community is situated on the edge of the shallow aquifer recharge area, with the drainage apparently falling away from the aquifer and toward the Dead Sea. Thus, the septage has little or no impact on groundwater quality.

Sahab is felt to be a growth area because of its proximity to Amman and to the planned industrial city that is to be built directly adjacent to Sahab. The population of this community is projected to grow to 17,000 by 1990 and 24,000 by the year 2000 as the result of the activity that is occurring in the area. Although the new city of Sahab/Airport City is expected to absorb the major growth of the area during the Study Period, initial growth should occur in the present city of Sahab until the new city is constructed. The construction is not expected to be completed before the latter part of the 1980's. Because of this growth, the cesspool systems will become more and more inadequate and will ultimately have to be replaced by centralized wastwater collection and treatment facilities.

Collection System Alternatives. The topography of Sahab divides the community into two small drainage areas each draining to a separate wadi. Both wadis drain in a southerly direction and join together approximately 5 kilometers south of Sahab. Gravity collection systems would naturally have to follow the two drainages, with the easterly drainage collecting wastewater from approximately 65 percent of the residents and the westerly drainage collecting from the remaining 35 percent. Two alternative collection system configurations appear feasible for Sahab:

- Install gravity trunk sewer down each wadi to confluence.
- Pump wastewater from the smaller drainage to the larger one.

A plan of the two alternatives is shown on Figure 8-11. The difference between the two alternatives is that the gravity trunk sewer alternative would pick up the small community of Rujm es Shami (projected year 2000 population of 3,000) while the pumping alternative would add a pump station and approximately 1 kilometer of force main but would eliminate the need for approximately 4.5 kilometers of gravity trunk sewer in each wadi, for a total of 9 kilometers.

Using a year 2000 wastewater flow rate of 70 lcd, the average day design flow for Sahab is 1,680 cubic meters per day or 20 liters per second. Using a peaking

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factor of 2.75, the peak design flow is 55.0 liters per second. The easterly drainage would contribute 65 percent or 36.0 litres per second and the westerly drainage would contribute the remaining 19.0 litres per second. Assuming a minimum slope of 7 mm/m, the easterly gravity trunk sewer would need to be 300 mm in diameter and the westerly would be 200 mm. At a unit cost of JD 26 per meter for 200 mm pipe and JD 34 per meter for 300 mm pipe, the total construction cost of the gravity trunk sewers for the first alternative would be JD 270,000.

The puming alternative calls for a pump station that would be capable of pumping 19.0 litres per second against a total head of approximately 15 meters and through a 150 mm force main 1 kilometer in length. The size of the pump that would be needed to accomplish this would be 5 kw. Estimated construction costs for a pump station of this capacity is JD 15,000 and for the force main is JD 22,000 for a total construction cost of JD 37,000. Power and operation and maintenance costs must also be included because a pump station and force main generally require more attention than does a gravity sewer. These costs total approximately JD 8,000 per year which, at a capital recovery rate of 10 percent over 20 years, equals a present worth of JD 68,000. Thus, the total present worth of the pump station and force main is JD 105,000. Comparing this cost to that of the gravity trunk sewer, the pump station and force main alternative would save JD 165,000 and is clearly the better alternative for Sahab.

Treatment Facilities Alternatives. As the proposed treatment plant lies outside the groundwater recharge area and no continuity exists between the surface and the groundwater, unlined facultative lagoons can be used for wastewater treatment at Sahab. The land is very cheap at appoximately JD 1/m^2 and is relatively flat. Treatment would be accomplished using total containment lagoons with evaporation as a means for disposal so that there would be no effluent. Alternatives to a total containment lagoon would be either a conventional activated sludge plant or an extended aeration plant. It is clear that a total containment lagoon is the cost effective alternative.

Effluent Disposal. Total containment lagoons do not discharge any effluent. It is lost to evaporation and percolation. Some of the effluent could be used for green belt irrigation, as long as such practice does not become a public health hazard. Multi-cell ponds with a total retention time of 60 to 100 days can reduce fecal coliforms to levels obtained by conventional secondary treatment. To reduce the coliform concentration further, a high dose of chlorine would be required due to the presence of algae in the effluent. Upgrading the effluent quality by algae removal is possible through the use of filtration or air flotation thickeners. However, the use of such upgrading techniques defeats the cost effectiveness of the lagoons.

Sludge Disposal. The first lagoon in the plant would be designed with additional depth to allow for storing the solids that settle out in the raw sewage. The sludge stored in the bottom of the lagoon undergoes a form of anaerobic digestion. The rate of sludge accumulation is difficult to predict. Once the sludge has

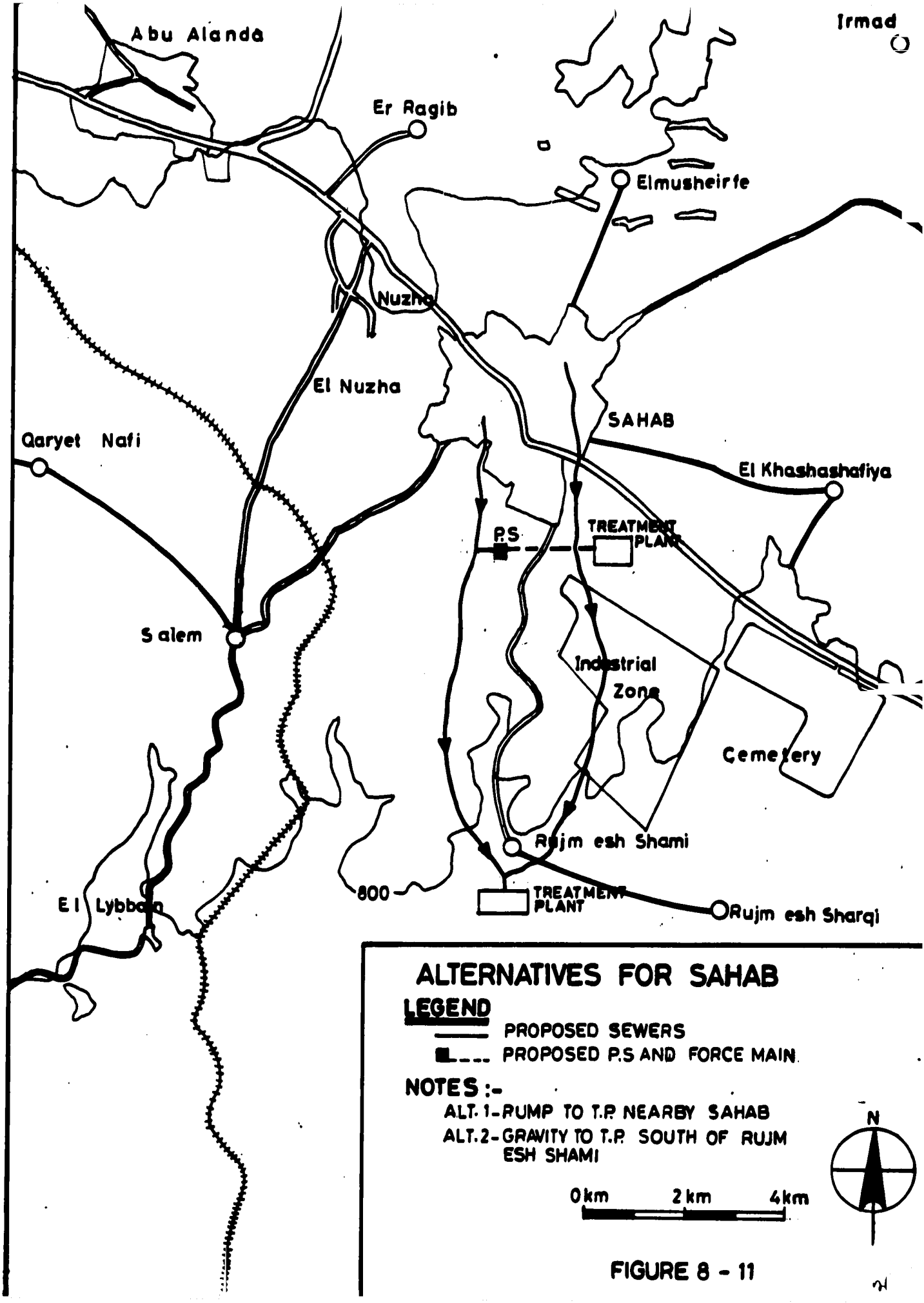
Abu Alanda
Irmad
Er Ragib
Elmusheirfe
Nuzha
El Nuzha
SAHAB
Qaryet Nafi
El Khashashafiya
P.S
TREATMENT PLANT
Salem
Industrial Zone
Cemetery
Rujm esh Shami
800
TREATMENT PLANT
Rujm esh Sharqi
El Lybban
ALTERNATIVES FOR SAHAB
LEGEND
PROPOSED SEWERS
PROPOSED P.S AND FORCE MAIN
NOTES :-
ALT. 1-PUMP TO T.P. NEARBY SAHAB
ALT. 2-GRAVITY TO T.P. SOUTH OF RUJM ESH SHAMI
0 km
2 km
4 km
N

FIGURE 8 - 11

TABLE 8-8

SAHAB TREATMENT ALTERNATIVES COMPARISON

	Unlined Lagoon	Extended Aeration	Conventional Activated Sludge
Construction Cost	230,000	450,000	650,000
Land Cost	400,000	6,000	6,000
Implementation Cost	115,000	225,000	325,000
Total Project Cost	745,000	681,000	981,000
Equivalent Annual Project Cost	87,540	80,000	115,300
Annual Operation and Maintenance Cost	5,000	11,000	11,000
Annual Power Cost	negligible	80,000	34,000
Total Annual Project Cost	92,540	171,000	160,300

accumulated to a predetermined level, the lagoon is drained out and the sludge is allowed to dry before it is hauled away for land application or to a landfill site.

Abu Alanda, Khirbet es Suq and Juweideh

These three communities are located within two kilometers of each other with Juweideh approximately 7 kilometers south of Amman (Figure 8-12). The population and potential wastewater flows for these communities, presuming 100 percent connections are:

	1979		1990		2000	
Community	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)	Pop'n	Flow (m^3/day)
Abu Alanda	4,000	200	6,000	360	8,000	560
Khirbet es Suq	4,000	200	5,000	300	7,000	490
Juweideh	3,000	150	4,000	240	6,000	420
Total	11,000	550	15,000	900	21,000	1,470

Collection System Alternatives. Juweideh and Khirbet es Suq share a common drainage to the Wadi el Marashida. All of Juweideh can be serve i with a gravity sewer collection system. All of the Khirbet es Suq except a small portion to the south can also be served by a gravity collection system. The borders of these communities overlap each other and can easily be served by one wastewater treatment plant. This is considered as the appropriate collection system as very little pumping is required.

Abu Alanda drains to the tributary of the Wadi al Qusin which is separate from the drainage of Juweideh and Khribet es Suq. One alternative would call for a gravity collection system and a separate treatment plant to serve Abu Alanda alone. A second alternative available for Abu Alanda is to pump the wastewater flow over a 10 meter lift and into an interceptor sewer draining to the Juweideh collection system. Because the cost of the collection system is common to the separate treatment plant alternative for Abu Alanda and pumping to the Juweideh system, a comparison may be made between the combined cost of the pump station, force main, and interceptor sewer, and incremental treatment cost at Juweideh and the cost of a separate treatment facility for Abu Alanda.

The costs of the pump station, force main and interceptor are presented below:

Item	Cost (JD)
Pump Station Construction Cost	10,000
Force Main Construction Cost	14,960
Interceptor Construction Cost	95,680
Total Construction Cost	120,640

Item	Cost (JD)
Implementation Cost	60,320
Total Project Cost	180,960
Equivalent Annual Project Cost	21,260
Annual Operation & Maintenance Cost	700
Annual Power Cost	820
Total Annual Cost	22,780

This cost must be compared to the cost of the separate treatment system which is discussed in the next section.

Treatment Alternatives. Two collection treatment alternatives were proposed in the previous section for the three communities: One calls for serving Abu Alanda independently from Khribet es Suq and Juweideh; and the other alternative calls for pumping the flow from Abu Alanda to Juweideh where the combined flow from the three communities would be treated at one treatment plant. The cost of two separate facilities will be compared with the cost of pumping Abu Alanda plus the cost of a central facility in order to develop the more cost effective alternative for this area.

Abu Alanda lies at the edge of but apparently within the groundwater recharge area surrounding Amman. Thus the treatment alternatives available are lined total containment lagoons, conventional activated sludge, and extended aeration activated sludge. Costs for these alternative systems are presented in Table 8-9. The cost effective treatment plant for Abu Alanda appears to be the total containment lagoons.

A treatment plant to serve the communities of Khirbet es Suq and Juweideh will be located outside the groundwater recharge area for Greater Amman, so the potential treatment alternatives are unlined total containment lagoons, extended aeration, and conventional activated sludge. The costs for these alternatives are presented in Table 8-10. Once again the total containment lagoon appears to be the cost effective alternative.

The final alternative treatment system to be considered is one that will serve all three communities. Because total containment lagoons have already been found to be the cost effective alternative for the separate facilities at Abu Alanda and at Khirbet es Suq and Juweideh, only this treatment alternative has been evaluated and the costs are presented in the following table:

TABLE 8-9

ABU ALANDA TREATMENT
ALTERNATIVES COMPARISON

Item	Total Containment Lagoon	Extended Aeration	Conventional Activated Sludge
Construction Cost	240,000	170,000	270,000
Implementation Cost	120,000	85,000	135,000
Total Project Cost	360,000	255,000	405,000
Equivalent Annual Project Cost	42,300	29,962	47,577
Annual Operation and Maintenance Cost	4,600	10,000	10,000
Annual Power Cost	—	28,980	12,600
Total Annual Cost	46,900	68,942	70,188

TABLE 8-10

KHIRBET ES SUQ
AND JUWEIDEH
TREATMENT ALTERNATIVES COMPARISON

Item	Total Containment Lagoon	Extended Aeration	Conventional Activated Sludge
Construction Cost	165,000	270,000	400,000
Implementation Cost	82,500	135,000	200,000
Total Project Cost	247,500	405,000	600,000
Equivalent Annual Project Cost	29,100	47,600	70,500
Annual Operation and Maintenance Cost	5,100	10,200	10,200
Annual Power Cost	—	46,000	19,800
Total Annual Cost	34,200	103,800	100,500

Item	Cost (JD)
Construction Cost	190,000
Implementation Cost	95,000
Total Project Cost	285,000
Equivalent Annual Project Cost	33,500
Annual Operation and Maintenance Cost	5,800
Annual Power Cost	--
Total Annual Cost	39,300

The comparison for treatment alternatives lies between separate facilities at Khirbet es Suq/Juweideh and Abu Alanda and a combined treatment plant for all three communities at Khirbet es Suq. Lined lagoons will be required at Abu Alanda while unlined lagoons can be constructed at Khirbet es Suq because of the differences in groundwater characteristics.

The total annual cost for separate plants at Khirbet es Suq/Juweideh and Abu Alanda is JD 81,100, while the total annual cost for a treatment plant serving all three communities, including the cost of the pump station, force main, and interceptor is JD 62,080. Therefore, the most cost effective alternative appears to be a central facility serving all three communities and utilizing unlined total containment lagoons.

Effluent Disposal. As with Sahab, the total containment lagoons will not produce any effluent because all of the wastewater will be lost through evaporation. Some of the lagoon wastewater could also be used to maintain a green belt around the treatment plant as long as the irrigation method was carefully controlled and managed to preclude human contact.

Sludge Disposal. As discussed earlier, sludge handling/disposal is not a daily operation with such a treatment system. The wastewater solids settle out in the first of the multicell lagoons system and undergoes anaerobic digestion. Sludge accumulation over the year is hauled away after the lagoon is drained out and the sludge is allowed to dry.

SLUDGE MANAGEMENT ALTERNATIVES

A comprehensive sludge management program is an integral part of any wastewater treatment plant operation. In the past, emphasis has been placed on the quality of the effluent that is discharged from a facility, while little or no consideration has been given to the treatment and disposal of sludges. This trend is gradually being reversed because of the increasing awareness that the bulk of the pathogens, heavy metals and other toxic substances that reach a treatment plant settle out in the sludge. Proper treatment and disposal of wastewater treatment plant sludges is therefore essential if the public health and environment is to be protected.

This section of the Master Plan outlines standards and objectives toward which sludge management programs in the Greater Amman Area should be directed, and presents discussions of management alternatives for each area studied in the previous sections of this Chapter. After thorough analysis, the best alternative for each area is selected for further consideration in Chapter 9.

STANDARDS AND OBJECTIVES

Throughout this discussion, reference will be made to the United States EPA document "Municipal Sludge Management: Environmental Factors"[9] and the State of California Department of Health document[10] pertaining to sludge disposal. Both of these documents are concerned with the health effects of sludge disposal and recommend procedures for dealing with them. The document from the State of California is one of the most stringent in controlling matters of environmental health, and is useful as a standard in determining how careful a government agency can choose to be.

The 1977 EPA requirements for Municipal Sludge Management set the minimum level of sludge stabilization to that achieved by anaerobic digestion. This concept was adopted in this Master Plan and used as the minimum standard of treatment to be considered since a substantial reduction in pathogens, odors and volatile solids is accomplished by this process or its equivalent. Beyond sludge stabilization, the choices in sludge processing are a function of easy handling, economics, and ultimate disposal.

Municipal wastewater sludges are rich in organic matter. When properly digested or otherwise stabilized under controlled conditions, the residual material can be of value as a soil conditioner and, in some respects, as a fertilizer. An obvious objective in sludge management, therefore, would be to maximize the beneficial use (sometimes referred to herein as "reuse") of the sludge to promote soil stabilization and enhance soil productivity. In so doing, it is implicit that the environment would have to be protected.

Digested sludge is in the form of a liquid suspension. Inasmuch as another obvious objective of sludge management would be to minimize costs of transporting the digested sludge from the points of production to the points of beneficial use and/or disposal, careful study must be given to the best means of such transportation and whether or not dewatering is preferable to liquid transport.

SLUDGE CHARACTERISTICS

Appendix K presents selected data and discussion on sludge characteristics. This includes information obtained on digested sludge from the Salt Treatment Plant and for the AGTP. The limited information available suggests that the characteristics are normal for municipal sludges and show no undue presence of industrial wastes materials so far. It would be helpful for more extended sampling and analyses to be undertaken in the future as a means of augmenting the existing information. It is important to have adequate data of this nature so that disposal

and beneficial use applications can be developed.

CURRENT PRACTICES IN SLUDGE MANAGEMENT

At present, the sludge produced at the AGTP is anaerobically digested. The digested sludge is dewatered to about 20 percent solids on open drying beds, before it is disposed of to a landfill. The AGTP dried sludge is used at times in the Jordan Valley for fertilizer and soil conditioner applications in selected areas such as citrus groves. The bulk of the digested sludge, normally at least 80 percent dry basis, is hauled by tanker truck to the Amman Municipality Dump for disposal.

For Salt, the bed-dried sludge is primarily stockpiled on the premises, but consideration is being given to the possibility of using it for nurseries and possibly for farm crops, pending Ministry of Health approval. The plant has been in operation less than one year.

For KHMC, the sludge is stockpiled and has not been used or disposed of as yet.

APPROACH TO SLUDGE MANAGEMENT

The paramount consideration in sludge management is the protection of the public health. Operations involved in digested sludge management are dewatering, further conditioning, transportation, disposal, and beneficial use. These considerations hold for all plants, regardless of size. However, because of the magnitudes of sludge involved in large plants, the concerns are often greater than for small plants in regards to such matters.

The main concern in sludge management programs is the possible release of harmful substances into the terrestrial and aquatic environment through improper sludge practices. As a minimum, public health protection requires the monitoring of sludge periodically (on at least a monthly basis) to determine the concentrations of heavy metals or other trace substances which may have harmful effects. Where sludge is to be applied to land at greater than agricultural rates, effects upon groundwater are a major consideration. A review of the existing information and investigation of groundwater conditions for proposed or existing sites is a necessity. Attention must be paid to the site geology and soil physical properties to avoid areas underlain by highly porous, fractured, or stratified formations. Where surface water runoff may enter or leave the disposal site, the amounts and ultimate disposal of runoff must be controlled by proper grading.

Where soils receive sludge for agricultural purposes, the soil must be treated for phosphorous, pH, potassium, and heavy metals. Crops vary in their reaction to sludge-conditioned soils. Most benefit from the nutrients and organic matter in the sludge, but some crops may take up certain trace elements which will limit the use of harvested materials particularly when they are part of the human food chain. Where the sludge can be used for forestation and reclamation projects, the soil fertility can be improved without significant risk to public health. These uses

still must meet the need for control of impacts on groundwater, surface water and air.

At the present time digested sludge can be applied directly to agricultural land in most of the United States. The State of California[10] has more stringent regulations which require that sludge be dewatered and composted (with the alternative of long-term storage or other techniques) to achieve additional bacterial, viral, and parasite reduction.

The extent of possible health hazards from the use of sludge on croplands is still not defined. Rather, it is a matter of ongoing study. Recommendations for study are developed under the subsequent discussion on various sludge management operations.

Sludge Dewatering

Normally, open drying beds equipped with underdrains are employed at small plants. The underdrainage is returned to the process stream for treatment. In cold, wet climates, the beds often must be enclosed in "greenhouses," but in Jordan, this would not be required. Open drying beds are not suitable for large plants because of the extensive land areas that are required. Large plants normally serve large urban areas, where land is likely to be costly and residential developments tend to crowd against the plant premises. Adoption of nuisance control measures becomes important and quite costly. Therefore, large plants generally employ mechanical dewatering to reduce the bulk of the sludge prior to transport to disposal or reuse areas.

For the purposes of environmental analysis Chapter 9, sludge dewatering alternatives are identified herein as follows:

- For Amman-Zarqa-Ruseifa, Alt. DA1 is Proposed Action (Short-term) comprising belt press dewatering at AGTP, drying beds at Zarqa-Ruseifa and at a downstream plant (Kharbet er Ruseifa) if built. Alt. DA2 is Proposed Action (Long-Term) comprising belt presses at all plants. Alt. DA3 is No-Project, same as Alt. DA1, except there would be no downstream plant.

- For all other treatment plant sites, Alt. DO1 is Proposed Action (sludge drying beds) and Alt. DO2 is No-Project, Continued Use of Cesspools.

Further Conditioning

Digested sludge is sometimes given additional conditioning in order to reduce pathogens and improve the usability of the product. Such conditioning may include composting with or without addition of other organic materials. Heat treatment is sometimes employed.

Sludge Transport

As indicated above, wet sludge is customarily removed from the digested sludge storage tank at AGTP by means of tanker trucks and is hauled to the Municipal Dump for disposal. Dried sludge cake is hauled by means of dump trucks to disposal/reuse Sites. Pumping wet sludge through a pipeline is another method used in some treatment plants for the transport of sludge to disposal/reuse sites. Usually such a practice is done where a long-range disposal/reuse site will be available on a long-range basis and the economics favor wet, pipeline transport over alternate methods. For example, the metropolitan San Diego Treatment Plant digested sludge has been piped through a long pipeline for nearly two decades to create artifical islands within a fine aquatic development in Mission Bay. The sludge mixed with marsh sediments forms a rich soil upon which the local grass, lawns trees, and shrubs thrive.

For the purposes of subsequent environmental analysis in Chapter 9, sludge transportation alternatives are identified as follows:

For AGTP:

- Alt. ST1 is Proposed Action and No-Project: Truck dewatered sludge. (A transition period could exist during which liquid and dewatered sludge could be trucked).
- Alt. ST2: Truck liquid sludge.
- Alt. ST3: Pump liquid sludge.

For All Other Plants:

- Alt. SO1 - Proposed Action: Truck dewatered sludge.
- Alt. SO2 - No-Project: Continued use of cesspools. (Surplus septage trucked to treatment plants).

Sludge Disposal

Until recently, disposal of treatment plant sludges has not received the proper attention and concern by regulatory authorities. However, concern is mounting at present for groundwater quality as a result of possible adverse effects attributable to dumping of sludge, particularly wet sludge, in landfills that do not have impervious layers. An example of this is the Municipality of Amman's dump site.

Previous studies have documented that the groundwater beneath the existing landfill is being degraded by the introduction of nitrates from the liquid sludge being dumped. Recommendations were for relocating the sludge dump site to other areas where the potential for groundwater degradation is minimized. The

recently completed solids waste study for Amman has identified several potential sites.

There are two basic methods of disposing of sludge: landfilling; and use as a soil conditioner or fertilizer. The latter is a long-rang plan for the Greater Amman Area.

POTENTIAL FOR USE

Sludge has been used for many years as a fertilizer and a soil conditioner. It does not compare favorably with commercial fertilizers when the comparison is based on nutrient content or ease of handling. It does, however, have exceptional soil conditioning characteristics which can greatly improve the physical properties of soil and thereby its fertility. This makes it especially valuable for the reclamation of marginal lands for recreation, agriculture, or forestation.

There are, however, significant potential drawbacks to such use of sludge:

- Depending on the degree of treatment, it can contain pathogenic bacteria or viral organisms that are potential health hazards.
- Depending on the sources of the sewage, and particularly on the amount and type of industrial wastes it includes, the sludge may contain heavy metals that can be taken up by crops or leach into groundwater.
- If the sludge is applied in excessive amounts, nutrients such as nitrogen and phosphorus can contaminate ground or surface waters.

These potential drawbacks are discussed below:

Pathogenic Organisms

Sludge can be used at three different levels of treatment:

- Raw sludge (primary treatment only, or raw sewage) - Raw sludge contains high levels of pathogenic organisms. While raw sludge is sometimes used in this condition, such use is potentially hazardous and will not be considered here.
- Digested sludge (or equivalent stabilizing process) - Digestion destroys most of the pathogens in sludge and makes it safe for use under controlled conditions. Some pathogens still remain, but these are largely screened out near the soil surface and do not leach through the soil. Opinions vary as to the amount of control that is necessary for safe use. Some sources recommend that crops be restricted to fruit trees and other crops which do not come in contact with the soil, unless sludge application is discontinued some time before harvest. These sources generally indicate that public access should be limited and buffer zones used. More recent

sources however, are uncertain about the need for such controls. The latest USEPA guidelines on land application of sludge state the need for controlled public access only where it is required by State regulations or where application rates are higher than those for normal agricultural use. In practice, in the United States, sludge that is not treated beyond digestion is generally used at controlled sites, and is not dispensed to the public for general use.

- Composted or pasteurized sludge - After digestion, sludge can be dewatered, either mechanically or in drying beds, and then composted or pasteurized. These processes destroy almost all the pathogenic organisms, so that the sludge can be used for any purpose without the risk of pathogenic contamination.

- Heat treatment of wet sludge following or in lieu of digestion. This may comprise wet air oxidation (Zimmerman Process) or heat treatment without the addition of air (Porteus Process). Although the sludge becomes completely sterilized and sludge dewaterability is improved, there are certain drawbacks such as the release of additional soluble BOD from the broken down sludge cells. Therefore, serious consideration is not given to the application of this process for the Greater Amman Area.

Heavy Metals and Nutrient Buildup

Sludges vary considerably in their content of heavy metals, and the effects of these metals can also vary greatly depending on soil type, type crop, soil pH, and other factors. Under proper conditions, heavy metals can accumulate in upper soil layers in amounts toxic to crops. There may also be potential for introduction of metals into the food chain in hazardous amounts. It is very important, therefore, to conduct tests of the sludge to determine proper loading rates for the soil type and crops being used.

Similar precautions must be exercised to prevent nutrient contamination. Excessive amounts of nitrogen can easily leach into groundwater, and phosphorus build up in upper soil layers gets washed away to surface waters. Sludge application rates must therefore be geared toward optimum use of these nutrients by crops, and particular care must be taken where high water tables, permeable soils, steep slopes, or adjacent surface waters create the potential for water contamination.

USE ALTERNATIVES

Beneficial use alternatives involve reforestation, land reclamation, and agricultural use.

Reforestation and Land Reclamation

Thousands of years of often demanding use of land have taken their toll on Jordan's soils. The loss of vegetation cover due to destruction of the forests and overgrazing by nomadic herds have left the soil unprotected and susceptible to damage from wind and water erosion and from the region's high temperatures. As a result, much of the country's soil has poor stucture and poor water-retention capability. Improvement of the soil through the use of amendments is necessary in many places to obtain maximum use of the soil resources.

Because of its high organic content, sludge has excellent use potential for reforestation projects, the slowing of desert encroachment, and reclamation of land for parks, green belts, or open space. The high pH of most Jordanian soils decreases the potential for plant uptake of heavy metals. Also the generally good weather is conducive for spreading or trenching operations.

The most significant drawback to such use is the potential for nitrate pollution of ground or surface waters. Since nitrate pollution of groundwater is already a significant problem in the study area, sludge reuse programs must be located and managed so as to preclude the leaching or runoff of nitrates to water sources. It should be noted that some of the outlying areas are outside the proposed groundwater protection areas and could be considered for potential disposal sites without concern for potential groundwater degradation. Among those are Jiza, El Muwaqqar, and southwestern Sahab.

Figure 6-3 shows areas where hydrologic continuity exists between surface and groundwaters. In these areas, sludge application rates should be matched to the nitrogen uptake of the vegetable covering, and groundwater should be monitored to insure that pollution is not occurring. Composted sludge is best for use in these areas, dewatered sludge next best, and liquid sludge least desirable, since higher water content increases the potential for nitrate leaching or runoff.

All of the city of Amman and its immediate surroundings are in areas where continuity to groundwater exists. The use of sludge in Amman for parks, green belts, and open space should therefore be carefully planned to insure proper application rates.

The use of sludge should probably be avoided in the immediate vicinity of the King Talal Reservoir. Slopes are steep in this area, and runoff of nitrates into the reservoir would cause further degradation of water supplies. If it is determined in the future that this water is to be used only for irrigation purposes then such restrictions may not be necessary. Addition of the nitrates to irrigation water would not be harmful, and might even be beneficial to crops.

Areas where land application of sludge is possible without the risk of groundwater pollution should be identified. This should be done in coordination with the Natural Resources Authority, the Ministry of Agriculture and other concerned governmental agencies.

Agricultural Use

The preceding comments on land reclamation also apply generally to agricultural use. In the case of agricultural use, however, control of heavy metals and pathogens must be considered more carefully. Until further information becomes available to indicate that sludges not treated beyond digestion can be used without restriction, attempts should be made to minimize public exposure and direct contact with fruits and vegetables crops eaten raw. Sludge should be analyzed and application rates carefully matched to the crops selected in order to prevent dangerous buildup or plant uptake of metals.

Sludge can be used for agricultural purposes in two ways: either to accomplish maximum crop production or to accomplish maximum sludge disposal, with crop production as an ancillary benefit. In the first case, the sludge is used on good agricultural lands and is spread on the soil, since trenching could damage the soil through excessive exposure. Application rates are low and are matched to crop uptake.

In the second case, land is purchased and dedicated to the disposal of sludge. Such land is generally of marginal agricultural capability. Trenching is used to achieve maximum disposal rates. Crops are grown only as an incidental benefit, and are selected for their tolerance to large amounts of sludge. Disposal on dedicated land should only be done in areas where there is not continuity between surface and groundwaters.

Aside from technical considerations, a program for agricultural use of sludge will probably be more difficult to establish than one for reforestation or land reclamation. Many farmers have long-established prejudices against the use of human wastes, and an educational program will be necessary to change these attitudes. Until this is accomplished, there will probably be little market for the use of sludge. The Agricultural Research and Extension Office[11] in Amman has attempted, so far with little success, to interest farmers in the use of digested and dried sludge now available at the AGTP.

DISPOSAL ALTERNATIVES

Landfilling is the simplest, most reliable, and safest method of disposing of sludge. However, it represents the waste of a potential resource since no benefit is derived from the sludge. Landfills for sludge disposal should be located only in areas where continuity does not exist between surface and groundwaters.

Landfilling

The solid waste management study[12] for the Greater Amman region has identified several potential sites where the geology is suitable for disposal of liquid sludge. This study picked two principal sites, one to the east of Muwaqqar and the other to the east of Sahab at Zumlet al Alya. The Muwaqqar site has a paved two-lane road to the town of Muwaqqar and thereafter would require construction of an

access road. There is no major road to the Zumlet al Alya site, so, even though it is closer to Amman, it would require substantially more road work to provide access. For the purpose of this analysis the Muwaqqar site will be considered the disposal point for sludge.

Incineration

The use of incineration is practiced where there is a major constraint on available sites for disposal of sludge. The sludge is dewatered and conveyed to the incinerator where organics are volatilized leaving an ash residue. The ash residue must then be trucked to a disposal site. Incineration in general is a complex process in terms of material handling and operation. A previous investigation[12] has concluded that the cost of incineration for solid waste disposal would be very high requiring a large expenditure of foreign exchange; that the operation of a sophisticated thermal treatment plant may pose problems in terms of management and maintenance requirements; and the overall net disposal costs are high compared to other alternatives. These same considerations apply to incineration of sludge. Sludge incineration even with waste heat recovery will be an overall energy consumer requiring substantial amounts of fuel for operation. As an example, an approximte energy budget for Alternative TA2 is tabulated below.

Item	TA2 Incineration Energy Requirements
Fuel:	
Start-up[a]	6.1×10^{7} B.T.U./yr.
Operation	4.5×10^{11} B.T.U./yr.
Electricity	1.8×10^{6} kwh/hr.
Total	4.5×10^{11} B.T.U./yr.
Recovered Heat	3.9×10^{11}
Net Heat	0.6×10^{11} B.T.U./yr.

[a] Assume 10 start-ups per year

Reference: Energy Conservation in Municipal Wastewater Treatment[3]

Since this is an initial estimate based on generalized numbers there may be more available energy savings than is apparent. Energy recovery of waste heat obviously must be practiced to make this alternative near viable. The operation of waste heat recovery system makes the incineration more complex and prone to problems. Due to the inherent problems with incineration, it is deleted from further consideration.

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Composting

The solid waste study for the Greater Amman area[12] examined the composting of solid waste as an alterntive to simple disposal at the landfill site in Muwaqqar. The conclusion was that composting would be more expensive than bulk handing and disposal of solid wastes. However, there appeared to be a net beneficial use for compost as a soil conditioner. The report recommended that a pilot windrow type composting plant be started at the Muwaqqar landfill site. It also recommended that the sludge not be mixed with the refuse because the typical refuse from the Greater Amman area has a high moisture content and the addition of this wet sludge would make mechanical handling and composting difficult. Therefore, the composting of wet digested sludge with other organic wastes is deleted as an alternative.

Dewatered sludge has been successfully composted by both windrow and static pile methods and this could be done at the landfill site. The dewatered sludge could also be composted with refuse without creating the materials handling problems caused by too wet a material.

TRANSPORTATION ALTERNATIVES

Since specific sites for sludge reuse are not known, transportation alternatives will be evaluated assuming disposal at the recommended Muwaqqar landfill site. Three alternative methods of transporting sludge have been presented previously and are discussed in this section.

Trucking of Wet Sludge

The route for trucking sludge from the AGTP would skirt the edge of Amman center and proceed southeast to Sahab and thence to Muwaqqar, which is a round trip of approximately 60 kilometers. At an average speed of 40 km/hr, one trip would require 1.5 hrs. Allowing a half hour for loading and unloading the trucks, one complete trip would take 2.5 hrs. At the present time, the plant truck drivers work six hours per day, six days per week. Operating options are to truck seven days per week and either extend the working hours to eight hours per day, or have two six-hour shifts per day. The effect of the choice of an operating regimen on the number of trucks required is presented below:

	Trucks Required	
Hour Operation	Seven-day Operation	Six-day Operation
6 hr/day	76 (6 standby)	89 (8 standby)
8 hr/day	58 (5 standby)	68 (6 standby)

Note: Truck capacity assumed to be 12 cubic meters.

A subalternative is to truck liquid sludges to a point where it could be used as a soil conditioner. Ordinarily, specialized trucks are used to inject sludge into the

ground in furrows to minmize odor and pest problems.

Trucking of Dewatered Sludge

The following discussion persumes that dewatered sludge will have a solids content of 20 percent which is normally attainable with a belt press. Sludge drying beds can produce drier solids, usually in the range of 40 percent, but this method of sludge drying is not practical at the AGTP because of the large land requirement. The principle economic difference in disposing of dewatered sludge as compared to liquid sludge is the greatly reduced volume of material to be transported. This minimizes the number of trucks involved in hauling, as shown below:

	Trucks Required	
Hour Operation	Seven-day Operation	Six-day Operation
6 hr/day	13	16
8 hr/day	11	13
12 hr/day	7	9

Note: In all cases one standby truck is provided.

Other advantages of trucking dewatered sludge are: it is easier to handle and apply to the soil at the disposal site since it can be carried in a dump truck or a pickup truck and spread with shovels or rakes; it can be used in conventional fertilizer spreading machinery; and it is less objectionable aesthetically than wet sludge and as such may be easier to market.

Sludge Pumping

Pumping sludge to agricultural or reforestation areas will not be considered in this Master Plan for the following reasons:

- Several years would be required to outline use programs, set guidelines and identify sites suitable for such use.

- A pumping option is rather inflexible and precludes expansion to other markets. Use would be confined to one area, and if for unforseen reasons the area needs to be relocated, the pumping system would have to be abandoned.

- The long-term adverse impacts of sludge use cannot be foreseen. Due to this potential risk, the application site may have to be abandoned before the design life of the pumping system ends, resulting in higher cost per unit sludge pumped.

- The sludge may have to be dewatered at the pipeline terminus prior to use. This requirement will eliminate the major advantage of this option namely the feasibility of transporting sludge without the need for

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dewatering.

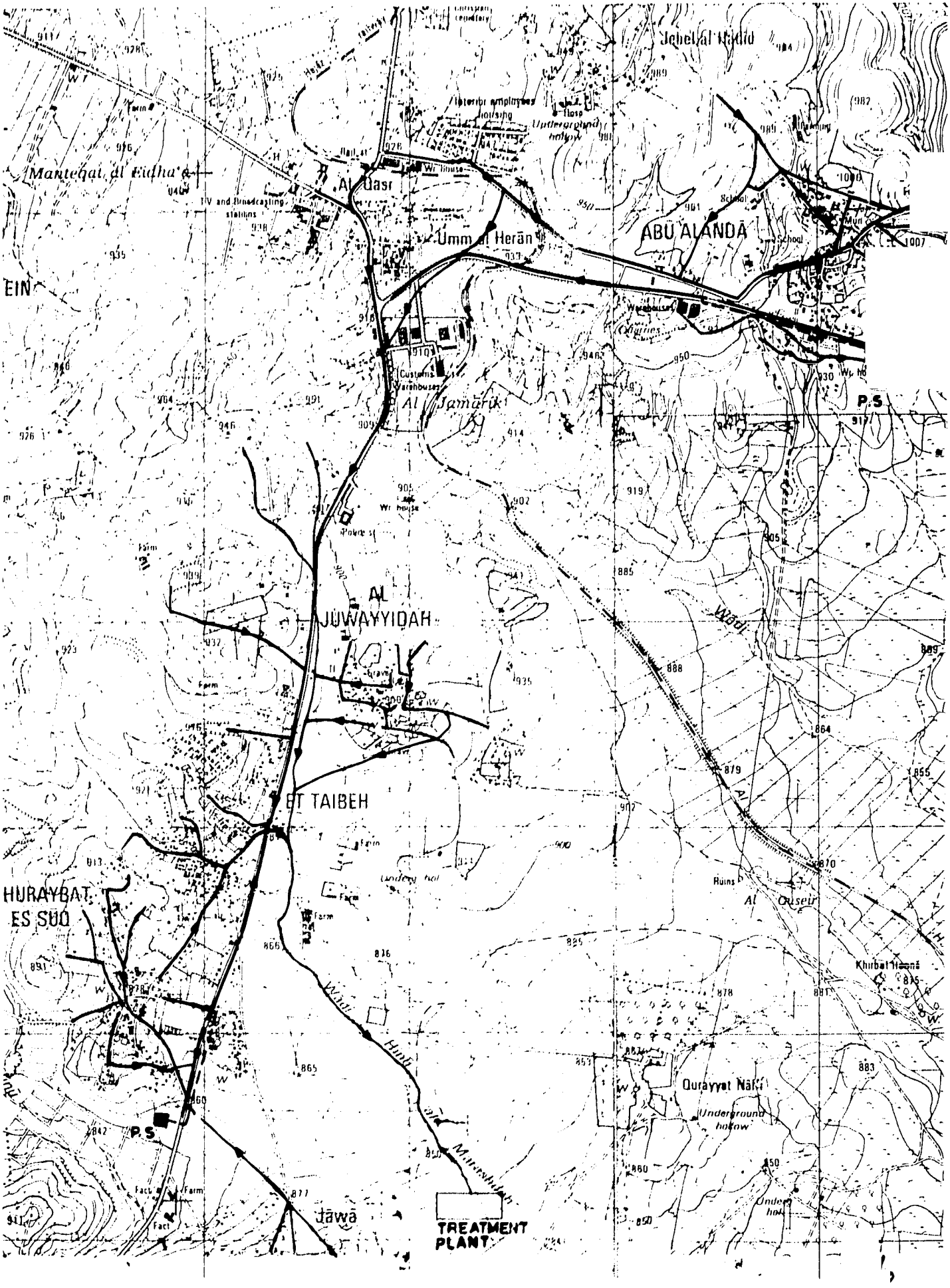
For these reasons, pumping sludge for reuse is not a viable alternative at the present and will not be discussed further. However, pumping sludge to a disposal area does appear to be a viable alternative worth considering. The disposal area is taken to be the Muwaqqar landfill site proposed by previous studies.[12] Sludge can be pumped to the site, stored in lagoons and trenched into the ground as the geology of the site favors such disposal method. The disadvantages of this option is the inflexibility element inherent in the alternative as stated earlier, and the high capital and operation and maintenance costs. The sludge will have to be pumped through a 30 km pipeline over hilly terrain which reaches a high point of 940 m at Abu Alanda, drops through Sahab to a low point of 800 m and rises again to 930 m at Muwaqqar.

RECOMMENDATIONS FOR SLUDGE MANAGEMENT

Use of sludge for agriculture, reforestation, and land reclamation is seen as a viable long-term objective. Before such a program can be implemented, however, the following preliminary steps must be taken:

- Testing - Sludges from Ain Ghazal, Salt, and perhaps other plants that are to be used must be analyzed to determine their content of nutrients, salts, metals and other characteristics. The information will be important for determining application rates, crops to be used, potential hazards, and other essential information. The sludges must be tested with a variety of crops, soils, and application rates to establish the best conditions and techniques for their use, and to determine potential problems that might result. Such a program is now being conducted by the Research and Extension Department of the Ministry of Agriculture. The tests have been in progress for a year, and useful results are expected in two to three years. Similar tests are needed for reforestation and reclamation use. Discussions have been held with personnel of the Forest Training Center, Department of Forestry, and it appears that there is a possibility for starting such tests in the near future.[13]

- Past Experience - Disposal of sludge has become a major concern of all large metropolitan areas in recent years. Many disposal and reuse programs have been initiated recently, and a great deal of information on techniques and related problems is being added to the body of knowledge on the subject. U.S. Environmental Protection Agency regulations will soon prohibit ocean dumping of sludge, and several large cities that have depended on this method have recently conducted extensive analyses of reuse and disposal options. The Los Angeles/Orange County Metropolitan Area Regional Wastewater Solids Management Program (LA/OMA) is one example of such efforts. This program has produced extensive technical data on reuse options and potential environmental hazards related to their use. Past experience should be investigated to obtain the most up-to-date information available on such topics as application rates and techniques;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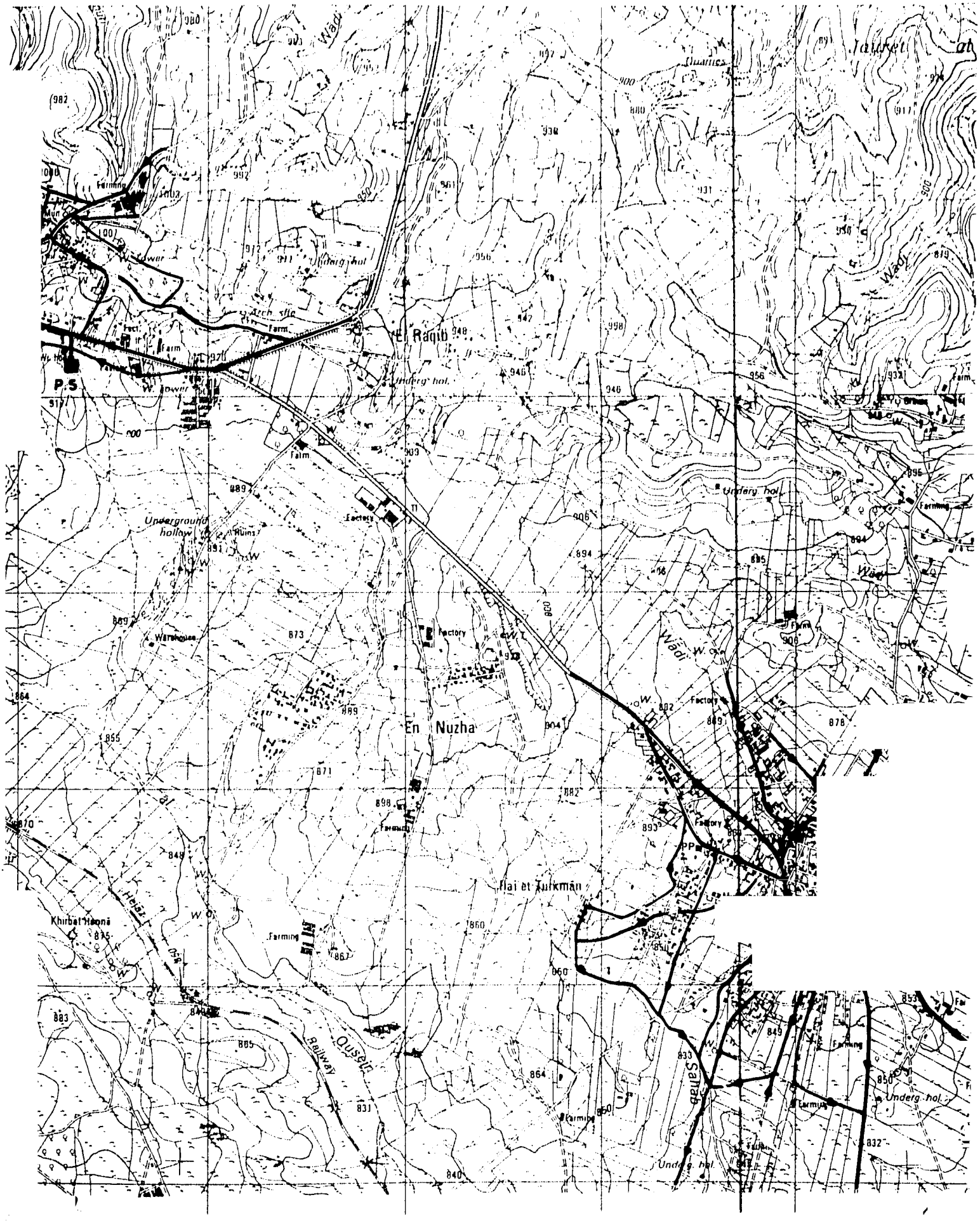
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En Nuzha
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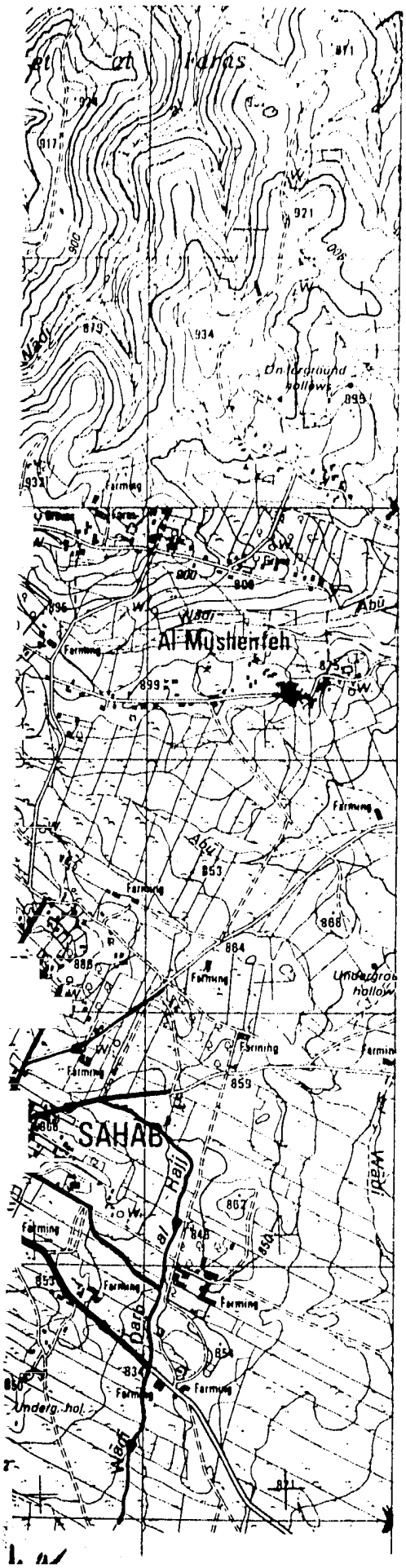

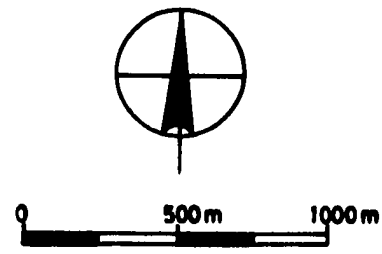

LEGEND

——— PROPOSED SEWERS

■ - - - PROPOSED P.S. AND FORCE MAIN

ALTERNATIVES FOR ABU ALANDA, KHIRBET ES SUQ AND JUWEIDEH

FIGURE 8 -12

pathogen, heavy metal, and nitrate hazards; and the long-term viability of reuse programs. Existing guidelines for land application of sludge should be reviewed in order to develop similar guidelines for a local program.

- Market Development - An analysis should be made of potential markets to determine realistically how much sludge might be used for agriculture, reforestation and reclamation projects in the first years of a reuse program, and where such markets might be located. Commitments must be obtained from agencies and organizations that would be users before the program can be implemented. Education would be an essential part of such a program, since people must acquaint themselves with the possible benefits of sludge use and overcome existing psychological barriers against its use.

- Coordination by implementing agencies - Implementation of a sludge reuse program should be a coordinated effort of AWSA, the Agricultural Research and Extension Department, the Department of Forestry, the Ministry of Health, and perhaps other agencies. Such coordination, perhaps in the form of a special project under the direction of a joint board composed of members of such agencies, could greatly reduce the time needed to establish a reuse program and do much to insure its effective operation. Such a concerted effort would insure that each agency is aware of other agencies needs and concerns, that information and data are freely distributed among the agencies, and that overlapping efforts are minimized. The distribution of data among agencies has been a problem in the past, and this significantly limits the effectiveness of money spent to gather such information.

A full-scale sludge "reuse" program might take three to five years to establish for agricultural uses, and perhaps two to three years for reforestation and reclamation uses. In the interim period, sludge would be landfilled at the recommended Muwaqqar site. After the establishment of a reuse program, excess sludge for which there is no market would continue to be landfilled. The capability of landfilling all of the sludge must be maintained, even after establishment of a successful reuse program, as a back-up contingency.

For the purpose of subsequent environmental analysis in Chapter 9, sludge use/disposal alternatives are identified as follows for all site:

- Alt. SU1 is Proposed Action (Short term): Landfilling at proposed sites (Muwaqqar and east of Sahab at Zumlet al Alya).

- Alt. SU2 is Proposed Action (Long-term): Use for reforestation/reclamation projects.

- Alt. SU 3 is Proposed Action (Long-term): Use for agricultural projects.

- Alt. SU4 is No-Project: Landfilling of existing dump sites, small amounts

of agricultural use.

These alternative sludge management programs were analyzed and the most reasonable program was selected for existing and proposed wastewater treatment plants in the Greater Amman area.

Alternative Selection for the AGTP

Alternative TA1 has been selected as the most cost effective wastewater treatment alternative. The combined sludge production of both primary and waste activated sludge for this alternative is estimated to be 90,200 kg/day at the existing site saturation capacity of 96,000 m^3/day. Anaerobic digestion has been selected as the most desirable alternative for sludge stabilization. The additional digester capacity that will be required to treat this volume of sludge is 23,400 cubic meters. The construction cost of this added capacity is estimated to be JD 2,300,000. An additional dissolved air flotation thickener is required to thicken 12,000 kg/day of waste activated sludge. The estimated construction cost is JD 140,000.

As has been previously discussed, the three alternatives available for sludge transport are: trucking wet sludge; trucking dewatered sludge; and pumping wet sludge to the Muwaqqar landfill site. The numbers of trucks required for the trucking alternative were already presented.

The pumping alternative would require a 200 mm pipeline 30 km long and 7 pump stations. Sludge storage would be provided at the landfill site prior to disposal. Trucks would be required to haul the sludge from the pipeline terminus to the actual point of disposal at the landfill.

The comparison of these alternatives was made assuming that trenching would be the means of disposal at the landfill site. Table 8-11 presents the comparison between trucking wet sludge, trucking dry sludge, and pumping wet sludge to disposal. In summary, the total annual cost of trucking wet sludge is JD 1,161,300 of trucking dried sludge is JD 639,000/yr, and of pumping sludge is JD 1,712,700. The cost effective alternative appears to be the trucking of dewatered sludge.

Some generalizations can be made from these results. The relatively high cost of transporting large volumes of wet sludge to the site always makes trucking dewatered sludge more efficient. Pumping sludge is effected in the same way. A fundamental assumption is that the mechanical dewatering plant at Ain Ghazal Treatment Plant will be run continuously. If a decision were made to operate a dewatering facility only on a 40 hr/wk basis the capital cost of a dewatering facility for an equivalent capacity would approximately quadruple and would tip the economic scales in favor of wet trucking. Dewatering facilities must therefore be operated 24 hr/day at a large plant to make them cost effective.

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TABLE 8-11

SLUDGE DISPOSAL ALTERNATIVES
FOR THE AGTP

Item	Trucking Wet Sludge	Trucking Dewatered Sludge
No. trucks	58	11
Capital Cost	JD 1,160,000	JD 220,200
Annual Capital Cost	JD 188,200	JD 35,800
Annual Labor Cost	JD 94,400	JD 19,300
Annual Fuel Cost	JD 55,600	JD 9,200
Annual Maintenance Cost	JD 139,200	JD 2,500
Total Annual Trucking Cost	JD 477,900	JD 66,800
Disposal at Site		
Quantity[a]	2,000 m^3/day	440 m^3/day
Annual Cost	JD 735,800	JD 160,600
Total Annual Trucking & Disposal Cost		JD 227,400
Annual Dewatering Cost	JD 1,213,700	JD 416,560
Total Sludge Disposal Cost	JD 1,213,000	JD 643,960

[a] Type of Disposal assumed to be trenching.

SLUDGE PUMPING

	Capital Cost	Annual Cost
Pipeline	JD 1,125,000	JD 132,200
Pumping Stations	JD 570,000	JD 67,100
Power		JD 57,500
O & M Cost		JD 39,000
On-Site Sludge Storage Cost		JD 11,000
O & M Storage		JD 7,800
Transportation at site		JD 72,000
O & M Transportation at site		JD 108,100
Disposal at site		JD 1,218,000
Total Sludge Disposal Cost		JD 1,712,700

In the case of a smaller community, the choice for sludge disposal would be between sludge drying beds followed by trucking or trucking wet sludge (no dewatering). Where land is available for sludge drying beds, dewatering using this method would be recommended prior to trucking. Otherwise the sludge may be trucked wet rather than installing mechanical dewatering equipment which require an appreciable amount of operation and maintenance.

Alternative Selection for UWATP

Sludge produced at the UWATP will be processed at AGTP sludge handling facilities. The volumes of dewatered sludge produced are estimated to be:

Year	Volume of Dewatered Sludge (m^3day)
1990	45
2000	106

In order to transport the UWATP sludge volumes from the AGTP to the landfill site, an additional 4000 hours of trucking by two trucks would be needed in 1990, and 8200 hours by three trucks would be required by 2000. The costs of operating these trucks are presented below:

Item	1990	2000
Truck Capital Cost	JD40,000	JD60,000
Equivalent Annual Truck Cost	6,510	9,765
Annual Labor Cost	4,080	8,530
Annual O&M Cost	5,030	10,510
Annual Fuel Costs	1,370	2,870
Total Annual Cost	JD16,990	JD31,675

Alternative Selection for the KRTP

The proposed site for the KRTP lies just four kilometers farther from the Muwaqqar landfill than does the AGTP. Using the same arguments as those for the AGTP, the best method of sludge disposal at the KRTP would be to truck dewatered sludge to the landfill. The KRTP will not be needed until after 1990, but should be in operation before the year 2000. The volume of sludge that will be produced depends upon whether or not the UWATP is built. By the year 2000, the estimated quantity of dewatered sludge that will have to be landfilled is 270 cubic meters per day if the UWATP is built and 400 cubic meters per day if the UWATP is not built. The costs for trucking these to volumes to the landfill are presented in the following table:

Item	With UWATP (JD)	Without UWATP (JD)
Truck Capital Cost	160,000	260,000
Equivalent Annual Cost	26,000	42,300
Annual Labor Cost	24,000	35,500
Annual O&M Cost	29,400	43,700
Annual Fuel Cost	8,300	12,400
Total Annual Cost	87,700	133,900

Constructing the UWATP would save the KRTP JD 46,200 per year in annual costs.

Alternative Selection for Outlying Treatment Plants

The outlying treatment plants recommended for possible implementation by this study are located at Baqa'a Valley, Fuheis, Na'ur, Lower Wadi es Sir, Sahab, Sukhneh, Hashimiya and Khirbet es Suq. The distance of each of these treatment plants from the Muwaqqar landfill is presented below:

Site	Distance
Baqa'a	52 km
Fuheis	53 km
Na'ur	34 km
Lower Wadi es Sir	35 km
Sahab	16 km
Sukhneh	55 km
Hashimiya	55 km
Khirbet es Suq	25 km

The plants at Baqa'a, Fuhis, Na'ur, and Lower Wadi es Sir are activated sludge plants of either the conventional or extended aeration types. Since they are at greater distances from the Muwaqqar landfill site than the AGTP, trucking dewatered sludge is the apparent best alternative. The production of dewatered sludge at each of these plant sites is presented below:

Site	Dewatered Sludge Production (m^3/day)	
	1990	2000
Baqa'a	10.4	14
Fuheis	1.9	3.0
Na'ur	0.75	1.4
Lower Wadi es Sir	2.0	4.2

Note: Dewatered sludge assumed to be at 40 solids

The estimated hours of trucking required per year are as follows:

Site	Truck Operating Hours 1990	2000
Baqa'a	1150	1600
Fuheis	290	425
Na'ur	65	120
Lower Wadi es Sir	140	290

A normal work week for the trucking operation at each plant is assumed to be six hours per day six days per week. The best way to operate a system of this sort would be to lease sludge trucks from AWSA on a part time basis or to establish a new regional agency for this purpose. By 1990 only one truck would be necessary to serve all of these plants. An arrangement of this sort would certainly be the most economical. The typical costs of operating one truck for sludge disposal full time are presented below:

Item	Trucking Costs
Truck Capital Cost	JD20,000
Equivalent Annual Cost	JD 3,255
Annual Labor Cost	1,947
Annual O & M Cost	2,400
Fuel Costs	655
Total Annual Cost	JD 8,257

Fuel costs were estimated by averaging different hauling distances and idle times for the four plants. The equivalent annual cost is taken assuming a 10 year truck life and a 10% interest rate.

In the case of Sahab, Sukhneh, Hashimiya and Khirbet es Suq where total containment lagoons are to provide treatment/disposal of the wastewater, the sludge accumulated in the lagoons over years of operation is dried out on location and the stabilized sludge is used for soil conditioning and/or trucked to a landfill site.

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CHAPTER 9

MASTER PLAN

This chapter considers those wastewtaer and sludge management alternatives that were determined to be viable after the initial screening in Chapter 8 and subjects such alternatives to engineering and cost analyses in greater detail than was required in the initial screening. The alternatives are also subjected to environmental analysis and limited cost benefit analysis. The alternatives are then ranked according to regional priorities and a Master Plan is established, based upon the foregoing.

ENGINEERING ANALYSIS OF ALTERNATIVES

The basic factors to be established for the various alternatives are:

- Percentage of population to be connected to the facilities according to a time frame within the 1990-2000 planning period.
- Proposed facilities, nature, capacity, and staging, including flexibility.
- Effluent quality to be achieved according to a time frame within the planning period.
- Operational and maintenance aspects of proposed facilities.
- Energy requirements of the proposed facilities.
- Beneficial reuse potentials of the alternatives regarding treatment plant effluent and digested sludge.
- Requirements for limiting controls of industrial wastewater and hard detergents into sewer systems, together with industrial pretreatment requirements, as applicable.

The foregoing factors are examined according to alternatives for wastewater collection and treatment/disposal, and for sludge reuse/disposal, according to the various sub-areas of the Study Area and the agencies within them.

RATE OF CONNECTION OF POPULATION TO SEWER SYSTEMS

It is necessary to make initial assumptions as to the percentages of the population to be connected to and served by sewerage systems for the various project implementation phases. Then, based upon resulting analyses, adjustments can be made if warranted. The experiences of AWSA and Salt are particularly of interest in considering rates of connection of system users to a sewer system.

AWSA Experience

The AWSA system was recently projected to have a 1990 connected population of 925,000 out of a projected population of about 1.13 million. This corresponds to about 82 percent connected by 1990, ignoring any slight discrepancies between the extent of the AWSA system and the limits of Amman Municipality.[1]

Table 5-2, previously presented, included historic data on connections made to AWSA's sanitary network. It can be seen that in recent years there have been about 2,000 or more new sewer connections added annually. As an approximation, the percent population connected to the AWSA sanitary network is believed to have been roughly:

	Population in Thousands		
Year	Total	Connected	Percent Connected
1973	400	40	10
1974	440	65	15
1975	470	100	20
1976	500	140	28
1977	550	180	33
1978	600	210	35
1979	649	250	39
1980	700	280	40

In the last decade, Amman more than doubled in population and the sanitary network began to develop, first at a modest rate and then at an accelerated rate. Even so, the growth of the community has nearly equalled the apparent ability of AWSA to construct new network sewers and connect buildings to them. It is expected, however, that as more and more apartment buildings are constructed and become connected and as Amman approaches saturation population, the network will finally catch up on the population.

Projections for AWSA

Obviously, there are many possibilities for future connections to the AWSA network from which a judicious choice should be made for Master Plan purposes. These possibilities include variations in the average numbers of connections per year for the next decade and the average numbers of persons per new connection. The following tabulation indicates the range of possibilities that was considered in a sensitivity analysis approach:

Item	Scenario of Sewer Connections 1	2	3	4	5
Avg connections/yr	2,100	2,500	2,100	2,500	1,700
Avg persons/connection	19	19	25	25	40
New population connected in thousands	399	475	525	625	680
Total connected population in 1990 (1980 is 280,000)	679	755	805	905	960
Percent connected out of projected 1.02 mill. pop.	66.6	74.0	78.9	88.7	94.1
Basic flow, 10^3 m^3/day, at 85 lcd	57.7	64.2	68.4	76.9	81.6

In consideration of the sheer magnitude of sewer construction work to be accomplished as well as hisctorical trends, the third scenario appeared to be the most reasonable for Master Plan purposes and was therefore selected. The percent connected by 1990 is not much less than what has been projected, and it is understood that the program for network expansion is actually running perhaps two years behind schedule.

Figure 9-1 presents these alternative Scenarios of connected population and the extended trend line to year 2000 for Scenario 3 wastewater flows. Beyond 1990, the total potential flows are indicated not only from Amman but also from Suweileh, Wadi es Sir and the Suburban Ring.

The extended trend line for current AWSA (primarily Amman) indicates 119,000 cu m/day wastewater flow by year 2000 and corresponds to 96 percent connection of the projected population of 1.305 million. Flows from other areas are projected for 32,000 cu m/day.

Salt Experience and Projections

The Municipality of Salt completed basic construction of its new wastewater treatment plant in early 1980 and began operations, meanwhile continuing to connect dwellings and other buildings to the new sanitary network tributary to the new plant. No definitive information was available on the extent of the population connected to the system by the autumn of 1980, but estimates were as high as 43 percent with the understanding that the figure could be substantially lower. Assessments, connection fees, and service changes are sometimes sufficiently high to discourage some persons from connecting, even when the sewer becomes available for connection, so there is usually a lag experienced between sewer availability and completion of connection thereto. Lacking any substantial basis for projection, it has been assumed that for Salt, the percent

population connected would be about as follows:

Year	Connected to Sewers Percent	Population
1980	40	14,000
1985	85	34,000
1990	90	42,000
2000	98	65,000

It should be noted that due to the hilly nature of the terrain, most of the population is centralized. Also, the construction work necessary to connect the population to the new plant is not as great as that for AWSA.

Zarqa - Ruseifa Assumptions

The recent study for Zarqa-Ruseifa[2] made the following assumptions as to service areas and served population:

- Streets on which more than half of the developable lots have been built upon will be sewered during the initial phase, but small clusters of houses located at some distance from existing populations will not be sewered during the initial phase.

- Small sections of heavily developed areas which drain into undeveloped land and that would require an extensive amount of sewering within the undeveloped area will not be sewered during the initial phase.

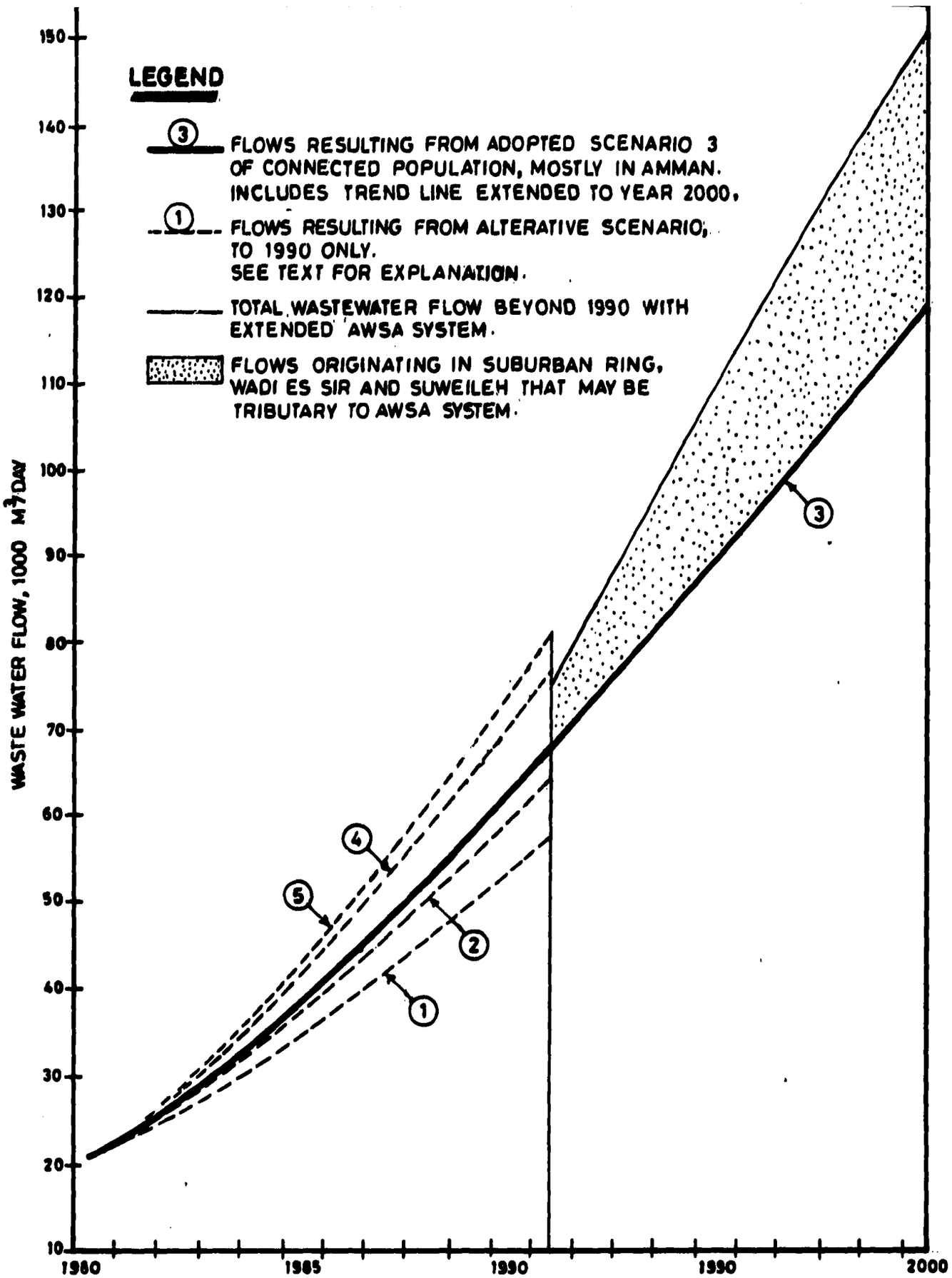
- No initial sewering would be attempted for large lots within agricultural areas along the Seil Zarqa although future provision for same would be made.

- Based upon the above criteria, the investment program contemplated service to 64.7 percent of the population by 1990, 71.6 percent of the population by 2000, and 82.9 percent of the population by 2020. Population served in 1990 and year 2000 are about 250,000 and 391,000, respectively.

The study's criteria and findings appear reasonable and will be adopted for the Zarqa-Ruseifa area for purposes of this Master Plan.

Criteria for Other Areas

General consideration has been given to the extent and nature of both existing and projected development for the various candidate areas for sewering outside of AWSA's immediate network, Salt, and Zarqa-Ruseifa. The criteria that have been



PROJECTED AWSA SYSTEM WASTEWATER FLOWS

FIGURE 9 - 1

employed are:

- If substantial concentrated unsewered populations already exist or will be in existence by the time a sewerage program can be organized, they should be included in the first phase investment program considerations, particularly if sewering can be accomplished on a cost-effective basis.
- Where only patches of development exist or are projected to exist and where there are large intervening areas of undeveloped land, such developments should be deferred from first phase investment program consideration and until such time as sufficient population density of the community has developed. This is determined on a subjective basis from consideration of present and future populations, population densities, and land development, including studies of recent aerial photographs.
- Due to the diversity of developments for the various localities, feasibility for sewering is determined on a case by case basis.

The percentages of total community populations connected to the sewer system for the "other areas" have been estimated and used herein as follows:

	1990 Conditions Connected to Sewer		2000 Conditions Connected to Sewer	
Sewered Community	Percent	Population	Percent	Population
Baqa'a Camp	---	---	---	---
North-Draining Suweileh	---	---	---	---
Safut	---	---	---	---
Ain al Basha	---	---	---	---
Subtotal Baqa'a Valley (overall)*	94	63,200	95	73,400
Lower Wadi es Sir	92	15,300	98	22,500
Fuheis	---	---	---	---
Mahis	---	---	---	---
Subtotal Fuheis/Mahis (overall)	52	6,700	53	9,500
Na'ur	57	4,000	69	6,900
Sahab	65	11,000	67	16,100
Sukhneh	60	3,600	70	5,600
Hashimiya	50	3,000	60	4,800
Abu Alanda	---	---	---	---
Khirbut es Suq	---	---	---	---
Juweideh	---	---	---	---
Subtotal Abu Alanda et al (overall)	73	11,000	73	15,000

* See subsequent discussion of special report on "Immediate Improvement Program for Baga'a Camp Wastewater Disposal."

(Continued)

Suburban Ring (of Amman	59	44,000	96	240,000
Upper Wadi es Sir	92	20,000	98	37,800
South-Draining Suweileh	---	---	98	17,600
Total	71 (wtd avg)	181,000	91 (wtd avg)	449,500

SEIL ZARQA SUB-BASIN

As noted in Chapter 8, there are distinct possibilities of flow transfers between adjacent sub-basins that could involve AWSA and westerly areas. It was determined economically feasible for north-draining Suweileh wastewater to be pumped from the Northwest sub-basin to the Seil Zarqa sub-basin but not for the lower Wadi es Sir wastewater to be pumped from the Western sub-basin. The subsequent analyses assume that these peripheral areas will be tributary to the AWSA system (see also discussion of Baqa'a Valley regarding North-draining Suweileh).

In addition, a topographic oddity came to light during the field work involving siting of the UWATP. It was found that the topographic divide separating the watersheds of Seil Zarqa and Wadi el Kafrein in southeastern Wadi es Sir is relatively flat so that by means of simple and inexpensive engineering works, gravity diversion of drainage from the upper reaches of the Seil Zarqa watershed descending from the Suweileh area may be diverted to the adjacent watershed of Wadi el Kafrein. This finding, independently made, was then found to have confirmed the earlier finding by NRA, made several years ago during the course of drainage studies.[3] Thus, being located very close to the watershed divide of Seil Zarqa and Wadi el Kafrein, the effluent from UWATP could be made to flow by gravity into either watershed as may be determined optimum from considerations of downstream uses and impacts. Without much additional cost, the plant facilities could incorporate the necessary flexibility to permit gravity diversion of effluent in either direction. This does not influence collection or treatment alternatives but only disposal/reuse alternatives.

It would also be possible for effluent from UWATP to be diverted to the south and across the watershed divide, but pumping would be required to accomplish this. There is an intervening summit between the site of the UWATP and the Dead Sea Basin, located along the highway to Marj al Hamam and entailing about 55 m of pumping lift. A force main of about 2.5 km would extend southerly from UWATP to this summit, upon which a storage tank or reservoir would be located for pump control and flow regulation purposes. A gravity pipeline would then run southerly and cross the divide at the selected point(s): to the headwaters of Wadi el Qastal (south of Marj el Hamam) or to the headwaters of Wadi Hisban (south of Na'ur). Pipeline length from the tank to the former point would be about 4.5 km and to the latter point about 8 km. If both delivery points were desired to be included for maximum flexibility, the total pipeline length would be about 11.2 km downstream of the tank.

Although there is no downstream storage on either Wadi el Qastal or Wadi Hisban, there should be a potential for some irrigation. The gradients are not as steep as that of Wadi el Kafrein and it is presumed that some of the lands along these wadis would be developable for irrigated agriculture.

The equivalent pumping lift, augmented by additional pipelines, could probably form the basis of irrigation supply southerly and southeasterly of Amman, but this aspect has not been studied in detail as no irrigation sites have yet been identified. As indicated earlier in Chapter 7, there is a distinct elevation advantage of UWATP over the downstream plants in potentials for supplying reclaimed water to future reuse applications on the plateau.

Facilities proposed within the Seil Zarqa sub-basin are those of AWSA and Zarqa-Ruseifa. Facilities for Es Sukhneh and Hashimiya are discussed subsequently. Future facilities for Hashimiya Free Trade Zone, would be specially provided for, once this development has been formalized. The nature and rate of industrial development will dictate the facilities needed and their timing.

AWSA Facilities

AWSA is unique in having extensive facilities already in operation and offering several possibilities for system extension. The staging of new facilities is influenced to some extent by needed enlargements as determined by the selected collection alternatives.

AGTP Staging

The staging of facilities under various alternatives must consider the amenability of the AGTP to upgrading and enlargement in a logical sequence.

AGTP has a design capacity of 60,000 m^3/day but does not achieve desired effluent quality results even at 21,000 m^3/day, thus requiring upgrading. The process selected in Chapter 8 was biological treatment of primary effluent by roughing filters followed by activated sludge. This process takes more room than conventional activated sludge, thus limiting the potential plant capacity. The area south of the existing facilities and north of the slaughterhouse could be developed for some 45,000 m^3/day of capacity, while available area on the present site could be developed into some 30,000 m^3/day of total plant capacity. This would include modifications to the existing plant. In effect, the ultimate plant capacity for the existing AGTP site (withholding limited area to the northeast of the blower building for possible future filtration and denitrification) is some 75,000 m^3/day. An initial staging would be for 60,000 m^3/day.

In enlarging the AGTP, it will obviously be necessary to construct certain new facilities first; then, once these have been activated and are performing satisfactorily, conversions can be made of the existing facilities Accordingly, the first stage of incremental capacity would be for 30,000 m^3/day, involving the area between the existing facilities and the slaughterhouse.

Collection System Alternatives

Figure 9-2 shows a possible arrangement for treating wastewater from Amman and portions of Suweileh, Wadi es Sir and the Suburban Ring. In this arrangment, the AGTP enlargement is supplemented by construction of the UWATP, deferring and minimizing subsequent construction of a Kharbet er Ruseifa Treatment Plant (KRTP). This is designated as collection system alternative CA1.

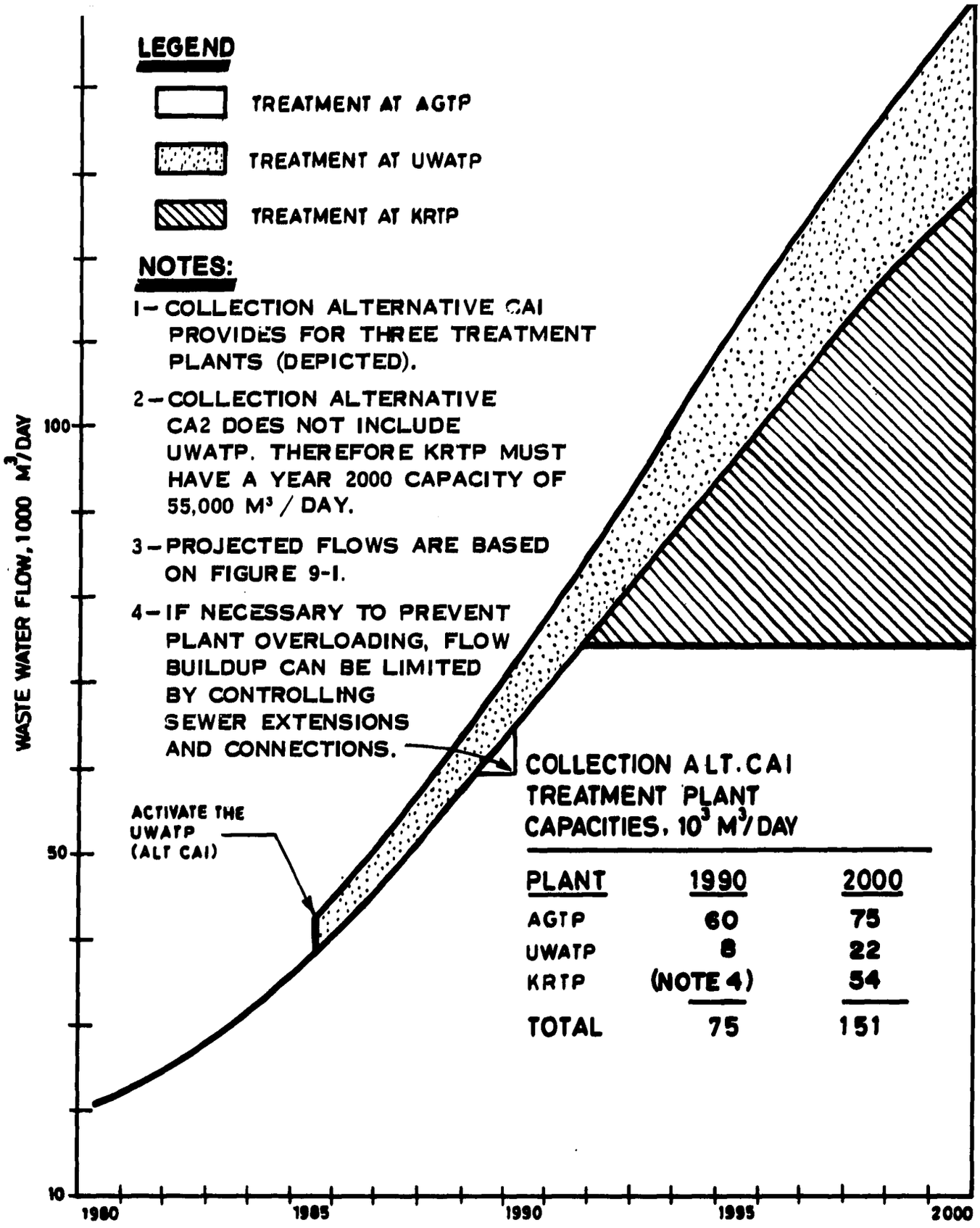
Under an alternative arrangement designated as collection system alternative CA2, there would be no UWATP at all and all flows would be directed to AGTP and a KRTP. This would require earlier construction and greater capacity of KRTP than for (CA1).

In brief, the staging of facilities for the respective treatment plants would be as follows:

Year and Plant	Plant Capacity, 1,000 m^3/day	
	Alternative CA1	Alternative CA2
1990		
AGTP	60.0	75.0
UWATP	8.0	---
KRTP	7.0*	---
2000		
AGTP	75.0	75.0
UWATP	21.0	---
KRTP	54.0	75.0

* Theoretically, KRTP would need to be built at this capacity by 1990, but as a practical matter, if it appeared that the combined capacities of AGTP and UWATP of 68.0 m^3/day might not suffice, then future connections to the system might be limited until these plants had been expanded.

The staging of trunk sewer enlargements (via paralleling of critical reaches of existing trunk sewers) would be as follows:



TREATMENT OF WASTEWATER FOR ALTERNATIVE CA1

FIGURE 9 - 2

	Trunk Sewer Lengths (m)			
	Needed by 1990		Add'l Needed by 2000	
	CA1	CA2	CA1	CA2
1000	0	1043	0	615
900	394	728	0	44
800	318	656	725	634
700	757	445	44	270
600	332	601	428	1183
500	283	362	733	1431
400	514	1137	83	83
300	581	1757	959	1614
200	0	0	1907	1290

Both Alternatives CA1 and CA2 would be reasonably flexible, but Alternative CA1 would appear somewhat more so in that it would provide the opportunity to defer trunk sewer relief projects and a second capacity enlargment at AGTP for a period of years, during which time direction of development, planning policies and percent of population served would be better defined. Also, experience could be gained, not only in operations at the enlarged AGTP and new UWATP but also in the effects of the discharge of their effluents upon the respective receiving wadis. UWATP could be diverted either to Seil Zarqa sub-basin or Wadi Na'ur. The experience gained in operation of these plants prior to the need for KRTP would be greater under CA1 than under CA2 and presumably would be more helpful in the establishment of KRTP. Also, if it should develop that the wastewater flows to be handled are greater or less than currently projected, suitable adjustments could be made in either case, but probably more so for CA1 than for CA2.

Treatment Alternatives and Effluent Quality

The Alternatives to be considered are basically related to effluent quality for the proposed plants (AGTP, UWATP, and KRTP). All plants would incorporate roughing filters followed by mechanical aeration activated sludge. There would be dissolved air flotation concentration of waste activated sludge, and anaerobic digestion of sludge at AGTP and KRTP. All plants would initially produce effluent meeting an average requirement of 50 mg/l Suspended Solids and 50 mg/l BOD, assuming satisfactory plant operation and maintenance. It would be unwarranted and too costly to provide filters until such time as the cost of effluent upgrading has been clearly justified. In the long run, however, effluent filters should be provided in order to permit reliable effluent disinfection. Denitrification is even less of a future prospect, but long range provision of this treatment step should also be included in the program, subject to need establishment on the basis of continuing study. The effluent quality and advanced treatment facilities for the treatment alternatives are the same for all three treatment plants and are as indicated in Table 9-1.

TABLE 9-1

TREATMENT ALTERNATIVES AND EFFLUENT QUALITY[a]

Item	LEVEL OF TREATMENT									
Type of Effluent	Secondary Effluent (Recommended Minimum)						Tertiary Effluent (If Required)			
Year Applicable	1990			2000			2000			
Quality Parameter	SS	BOD	Colif.	SS	BOD	Colif.	SS	BOD	Colif.	NO_3
Units	mg/l	mg/l	MPN/ 100 ml	mg/l	mg/l	MPN/ 100 ml	mg/l	mg/l	MPN/ 100 ml	mg/l
Values	50	50	20,000	30	30	2,000	5	10	2.2	45
Designation of Treatment Alternatives by Sub-basin										
Seil Zarqa										
AWSA Facilities										
AGTP		TA2			TA2			TA3		
UWATP		TA2			TA2			TA3		
KRTP					TA2			TA3		
Zarqa-Ruseifa	Separate Consultant Study - Effluent considerations generally similar to others depicted									
Sukneh		Not applicable[b]			Not applicable[b]			Not applicable[b]		
Hashimiya		Not applicable[b]			Not applicable[b]			Not applicable[b]		
Northwest										
Baqa'a Valley		TB1			TB1			TB2		
Western										
Fuheis/Mahis		TF1			TF1			TF2		
Lower Wadi es Sir		TW1			TW1			TW2		
Southwestern										
Na'ur		TN1			TN1			TN2		
Southern										
Sahab		Not applicable[b]			Not applicable[b]			Not applicable[b]		
Abu Alanda, et al		Not applicable[b]			Not applicable[b]			Not applicable[b]		

[a] See text for further description. Modest reduction in wastewater strength between 1990 and 2000 should aid in pollutant removals by the treatment processes. Tertiary effluent requirements, if realized, would be established on the basis of future experience with secondary effluent and additional study.

[b] Denotes total containment lagoons, no effluent discharge to watercourses (wadis).

Table 9-1 differentiates between secondary effluent quality in 1990 and 2000. The anticipated improvement in secondary effluent quality for the AWSA plants and other treatment plants is due primarily to moderate reductions in wastewater strength and resulting increases in overall removals of SS and BOD. Such removals should, in turn, enhance the effectiveness of chlorination and reduce coliform densities. Should these anticipated improvements in effluent quality not materialize, it would be possible to add polymer to aid secondary clarification. Removal of additional suspended solids by this measure should be particularly helpful in improving the effectiveness of disinfection by chlorination.

Operation and Maintenance Aspects

In order for the proposed treatment plants to perform their functions satisfactorily, it will be necessary for qualified operation and maintenance personnel to be hired and placed in responsible staff positions. Emphasis will have to be made on operational skills and training to a greater extent than has been possible up to now. The treatment works being proposed and the equipment involved are not much more sophisticated than that which is presently in operation at AGTP. Therefore, if sufficient monetary incentive is provided for qualified professional and subprofessional personnel, together with continuing training, the desired results should be achievable. Under the assumption that this will be the case, estimates for staffing are made for the various treatment alternatives for the three proposed plants as presented in Table 9-2. Certain other relevant requirements are also included.

Pumping stations are generally equivalent to treatment plants in requiring qualified operators and maintenance personnel, although process control is not a factor in pumping stations and this capability is not needed. The emphasis is on electromechanical capabilities for pumping stations. It is not normally necessary to have constant manning of pumping stations, provided that qualified operators are always on call via constantly monitored remote alarm systems. It is, however, important that pumping stations be maintained in failure-free condition. Trunk sewer and lateral sewer maintenance should become more oriented towards prevention of difficulties and less towards response to emergency conditions than has been possible in the past.

Energy Requirements of Proposed Facilities

Table 9-3 presents the estimated energy requirements for the various AWSA facilities of the respective collection and treatment/disposal alternatives.

Beneficial Use of Effluent and Digested Sludge

Alternative CA1 would provide for reclaimed water from the UWATP which would be available at relatively high elevation on the plateau for future reuse applications as they may develop. CA1 also provides for diversion of effluent to the Jordan Valley via Wadi el Kafrein instead of discharge to Seil Zarqa. However, there appears to be less riparian irrigation from the Wadi than from the Seil, so this may not be an advantage as far as indirect reuse is concerned. Reclaimed

TABLE 9-2

ESTIMATED STAFFING AND OTHER REQUIREMENTS

FOR AWSA WASTEWATER TREATMENT PLANTS

Item	AGTP (Has Digesters)	UWATP (No Digesters)	KRTP (Has Digesters)
Collection Alt. CA1			
1990 Condition			
Plant Cap., $10^3 m^3$/day	68	7.0	--
Staff Requirements			
Professionals	7	1	--
Line	35	7	--
Laborers	67	4	--
Treatment Plant Site Req'ts, dunums[a]	No add'l	30	57
2000 Condition			
Plant Cap., $10^3 m^3$/day	96	21.0	34
Staff Requirements			
Professionals	7	1	3
Line	46	12	23
Laborers	75	10	13
Treatment Plant Site Req'ts, dunums[a]	No add'l	30	57
Collection Alt. CA2			
1990 Condition			
Plant Cap., $10^3 m^3$/day	75	--	--
Staff Requirements			
Professionals	7	--	--
Line	43	--	--
Laborers	72	--	--
Treatment Plant Site Req'ts, dunums[a]	No add'l	--	83
2000 Condition			
Plant Cap., $10^3 m^3$/day	96	--	55
Staff Requirements			
Professionals	7	--	4
Line	46	--	27
Laborers	75	--	16
Treatment Plant Site Req'ts, dunums[a]	No add'l	--	83

[a] Typically, treatment plant sites should be acquired initially at size needed for year 2000 conditions.

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TABLE 9-3

ESTIMATED ENERGY REQUIREMENTS FOR AWSA FACILITIES
Annual requirements are in 10^6kwh[a]

Item	AGTP	UWATP	KRTP	Pump Sta.	Total
Collection Alt. CA1					
1985	20.0	0.8	--	0.2	21.0
1987	22.9	1.3	--	0.2	24.4
1990	28.6	3.1	--	0.2	31.9
1995	34.2	6.0	7.0	0.2	47.4
2000	40.0	8.9	14.3	0.2	63.4
Collection Alt. CA2					
1985	20.6	--	--	0.2	20.8
1987	24.2	--	--	0.2	24.4
1990	31.4	--	--	0.2	31.6
1995	40.0	--	7.1	0.2	47.3
2000	40.0	--	22.9	0.2	63.1

[a] See Table 9-6 which includes the effects of power recovery at both AGTP and KRTP, along with process selection of roughing filters - activated sludge.

effluent would also be available from the lower plants (AGTP and KRTP) under either CA1 or CA2. It is expected that the availability of reclaimed water would be much greater than the demand for same for many years.

Digested sludge would be readily available from either of the downstream plants (AGTP and KRTP), and the same amount of digested sludge from these two plants would be produced, regardless of collection alternative. Opportunities and economics for reuse (use) of the sludge would not be significantly influenced by selection of one collection alternative or another.

Controls of Industrial Wastewater and Hard Detergents

Future industrial wastes should be regulated to exclude excessive concentrations of harmful materials.

Inasmuch as most of the contributions will continue to be relatively easily accommodated in the wastewater system, industrial wastes discharge limitations should not be critical. A detailed discussion on future industrial loads is included in Chapter 7. None of the areas tributary to UWATP is zoned for industrial development.

Only relatively few, light industries may discharge to the UWATP, and their effect upon the plant operations should be insignificant. Nevertheless, it will be generally necessary that an effective industrial waste control program be developed.

So-called "hard" detergents frequently include two constituents that are sometimes troublesome when present in wastewater in sufficient concentrations. These are surfactants, of the type that incorporate alkyl benzene sulfonate (ABS), and phosphates.

ABS, when sufficiently concentrated may cause undesirable foaming in wastewater treatment plant aeration tanks. The ABS may carry through with the plant effluent and cause foaming in receiving streams where these are sufficiently turbulent. Phosphates are likely to carry through secondary treatment plants into receiving waters, increasing tendencies towards eutrophication of lakes and reservoirs into which these may flow.

Although there are apparently "hard" detergents in use in Amman and vicinity, these do not so far appear to have caused a significant problem either in the existing wastewater treatment plants or in the receiving waters into which the plant effluents flow. For example, with respect to foaming in aeration tanks at AGTP, KHMC, or Salt TP, there appears to have been only minor experience in such effects. This may be due to a relatively low per capita use of the detergents or other factors, but there has been relatively little foaming experienced either in aeration tanks or in effluent discharges to and in the receiving waters. Over a quarter of a century ago in the United States, ABS constituted such a foaming problem in wastewater treatment plants that it became necessary to have detergent manufacturers reduce the amounts of these foam-causing surfactants in

their products. This action, coupled with institution of froth sprays on aeration tanks (used to beat down forming foam), have kept the problem under control. Admittedly, U.S. per capita consumption of detergent may have been somewhat higher than is the case in Jordan. However, it appears correct to conclude tentatively that no limiting controls appear necessary on hard detergents in the AWSA system or in any of the other active systems, at least for the foreseeable future.

Inorganic phosphates in detergents (household cleaners and other cleaners) are present in the wastewater entering AGTP and in its effluent. The effects of the phosphate burden of AGTP upon King Talal Reservoir have been considered in a recent environmental assessment.[4] It was noted that the total phosphate burden at that time (1978) was about 168 kg/day (as phosphorus) but that King Talal Reservoir would become very highly eutrophic regardless of whether or not phosphorus removal were to be instituted at this and other wastewater discharges. It was considered that control measures to reduce phosphorus loading on the reservoir would be ineffective.

On the basis of an estimated connected population in 1978 or 210,000 persons the per capita contribution of phosphorus to the AGTP effluent would have been 168,000 g/day divided by 210,000 persons or 0.8 g/c/da. The removals in the AGTP itself might be roughly equal to this value. It would probably be safe to assume the per capita contributions in the wastewater itself were on the order of 1.6 g/c/da. This value is only about one-half of the values often encountered in the U.S. This tends to support the earlier observation that detergent uses in Jordan are probably significantly less than those in the U.S. In any event, "hard" detergents do not presently appear to be of potential concern to the present or future AGTP or to the future KRTP.

The UWATP effluent would probably be discharged to the Wadi Na'ur, thence to Kafrein Reservoir overlooking the Jordan Valley. Phosphorus in this flow would actually be beneficial for the irrigation uses supplied by the reservoir. Thus, "hard" detergents would not appear to be of concern to this treatment plant either.

Zarqa-Ruseifa Facilities

The recommended program for wastewtaer facilities for the Zarqa-Ruseifa area includes the following:[2]

For 1990 Service Level (Phase I)

- 26,000 house connections initially plus 7,970 subsequently
- 203 km of collection and subtank sewers initially plus 66 km of collection sewers subsequently
- 22 km of trunk sewers

- One pumping station and 3 km of force main
- A 24,200 m^3/day treatment plant using plastic-media trickling filters

For 2000 Service Level (Phase II)

- 20,300 additional house connections; total becomes 54,270
- 205 km of additional collection and subtrunk sewers; total of all sewers becomes 496 km (plus 3 km of force main)
- 17,000 m^3/day additional treatment plant capacity; total becomes 41,200 m^3/day

Inclusion of Schneller Camp and East Marqa

The Zarqa-Ruseifa trunk sewer system did not extend as far west as Schneller Camp or Jebel Faisal, both outside the Zarqa-Ruseifa planning area. However, they could be served by the proposed trunk sewer system, and the necessary extensions and enlargements for accommodating this peripheral flow as well as approximate costs for same were reported.[2] As has been discussed in Chapter 8, the Schneller Camp and housing projects alone could add up to about 44,000 by 1985. It was felt that the areas should be served in the Phase I Program, however a decision regarding this was deferred until it was determined whether Schneller Camp would be sewered or not. If not, then serving the housing projects would be more cost effective and economically feasible to be implemented after 1990, when the needs of the East Marka area become more profound. At any rate, provisions should be made in the on-going design for enlarging the Z-R trunk sewer system to serve the area's projected population, 73,000 by the year 2000. This should be carried out regardless whether the Schneller Camp and the housing projects are served in the Phase I Program or not. (Since the preparation of this Master Plan Report, a special study has been made for an immediate improvement program for Marka Camp — Schneller Camp — wastewater disposal.)

The additional flow from the Schneller Camp and East Marka area would require enlargement of the plant during the design phase or slightly earlier expansion in the future.

It was planned that the sewers not be extended to Musherifeh area, which borders Schneller Camp and Jebel Faisal until the 1990-2000. It was noted that the need for serving Jebel Faisal or Musherifeh were not as great as other areas.

Treatment Alternatives and Effluent Quality The trickling filter plant proposed by the consultants would generally produce a secondary type of effluent quality and later addition of tertiary facilities, if found justified, would upgrade the effluent quality. Effluent quality may vary with temperature as has been discussed in Chapter 8 and Appendix L.

Operational and Maintenance Aspects The trickling filter plant has relatively low operational requirements, and these have been reported upon previously.[2] Inclusion of Schneller Camp and East Marqa area in the system would not have much effect upon the system's O&M aspects.

Other Considerations There would be only moderate increases in energy consumption caused by including Schneller Camp and East Marqa in the Zarqa-Ruseifa System. Trickling filtration treatment is relatively low in energy requirements. The comments previously made under AWSA facilities regarding beneficial use of effluent and digested sludge and control of hard detergents are believed applicable to the Zarqa-Ruseifa system as well. Control of industrial wastewater will be particularly important for this system however, because of the presence of considerable industry. Effluent reuse potentials, such as for plateau irrigation to the east, might eventually develop. Sludge use potentials would be the same as for AGTP.

Sukhneh and Hasimiya Facilities

These two small communities in the lower populated part of the Seil Zarqa Drainage are in a position to have their septage discharges to the groundwater greatly reduced by providing sewers to the most developed areas and treating and disposing of the wastewater in facultative lagoons one system per community. The lagoons would be lined to prevent percolation and sized to evaporate the lagoon effluent. In effect, these would be total containment lagoons and would require no energy for operation. The effluent quality would not be of relevance because there would be no percolation to the underground or discharge to watercourse. Operation and maintenance requirements would be minimal. Hard detergents would not be a consideration. Industrial wastes from these rural communities should not be of significance. There would be no effluent or sludge use potentials. However, consideration might be given to controlled landscape irrigation of greenbelt areas. This would make some beneficial use of the water without complete loss by evaporation. This matter would be investigated during design.

Table 9-4 summarizes the lower Seil Zarqa wastewater facilities, including Zarqa-Ruseifa as well as Sukhneh and Hashimiya.

NORTHWEST SUB-BASIN

The proposed facilities within the Northwest sub-basin are those of the entity that would serve Baqa'a Valley, including Baqa'a Camp, Safut, Ain al Basha, and North-draining Suweileh. North-draining Suweileh would participate initially, via pumping in the Seil Zarqa sub-basin Alternatives CA1 and CA2. After a period of time, if it were determined warranted to proceed with Baqa'a Valley facilities, a decision would be made as to whether or not to include North-draining Suweileh in that system or to leave it on the Seil Zarqa System. (A recent separate report, superceding this Master Plan Report, has been made on immediate improvement program for Baqa'a Camp wastewater disposal.)

TABLE 9-4

SUMMARY OF LOWER SEIL ZARQA

WASTEWATER FACILITIES

Item	Zarqa-Ruseifa 1990	Zarqa-Ruseifa 2000	Sukhneh 1990	Sukhneh 2000	Hashimiya 1990	Hashimiya 2000
Plant Capacity, $10^3 m^3$/day	24.2	41.2	0.26	0.45	0.21	0.39
Staff Requirements						
Professionals	3	3	----	----	----	----
Line	19	19	0.5	0.5	0.5	0.5
Laborers	8	11	0.5	0.5	0.5	0.5
Treatment Plant Site Requirements, dunums	244	244	73	73	62	62
Average Flow, 10^3 m^3/day	19.2	32.9	0.26	0.45	0.21	0.39
Annual Energy, 10^6 kwh	1.34	2.06	Negl.	Negl.	Negl.	Negl.
Collection System[a]						
Trunk Sewers, km	22	22	1.0	1.0	2.0	2.0
Lateral Sewers	269	474	3.6	5.6	4.0	6.0
Force Mains km	3	3	--	--	--	--
Pumping Stations, No. of	1	1	--	--	--	--
Developed Area Served Dunums	--	--	--	--	--	--
Population Served (1,000's)	272.5	419.7	3.6	5.6	3.0	4.8
Persons Served/dunum	--	--				

[a] Trunk sewers are considered the major sewers (primary network.) Lateral sewers are the smaller sewers and may include sub-trunks, considered as the secondary network.

Collection System Alternatives

The terrain and available space dictate a gravity collection system and single treatment, the latter being located in the west-central Baqa'a Valley. It was previously determined impractical and uneconomic to include the small downstream community of Er Rumeimin in the system by pumping back flow from this Community to Baqa'a Valley or locating the plant downstream of it. Er Rumeimin is too small a population to be considered for public sewers in the program, although, eventually (post 2000) it might have its own plant.

The recommended collection system alternative for Baqa'a Valley is CB1, gravity sewers to a single treatment plant, this has been shown in Figure 8-3. The No-Project alternative is CB2.

Treatment Alternatives and Effluent Quality

The recommended project would incorporate the roughing filters followed by activated sludge process with anaerobic digestion of sludge. The plant site is located in sloping terrain near the exit of Wadi Rumeimin from the west central Baqa'a Valley. (See later comments pertaining to subsequent special study for Baqa'a Camp which resulted in an acceleration of the Baqa'a Valley Treatment Plant project, including a change in plant location.) Both terrain limitations - the site is within an agricultural area -and effluent requirements dictated a process having the potential to produce high quality effluent. Trickling filters, followed by polishing ponds would have used less energy but more space and would have cost more. The alternatives are: TB1 -activated sludge; TB2 -add effluent filtration and denitrification as a long-term objective; and TB3 - No Project. Effluent eventually will reach King Talal Reservoir.

The effluent quality anticipated for the alternatives TB1 and TB2 is as previously presented in Table 9-1.

Operational and Maintenance Aspects

The proposed collection system would require no pumping but would operate by gravity alone. The treatment process would require careful operation and maintenance, these being necessay if the desired effluent quality is to be produced reliably. Projected staffing requirements for Baqa'a Valley facilities and certain other relevant data are as follows:

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Item	By 1990	By 2000
Plant Capacity, $10^3 m^3$/day	2.8	3.7
Staff Requirements		
Professionals	---	---
Line	3	4
Laborers	3	4
Treatment Site Requirements, dunums	6	6
Average Flow, $10^3 m^3$/day	2.84	3.67
Annual Energy, 10^6 kwh*	1.08	1.45
Collection System		
Trunk Sewers, km	11.4	11.4
Lateral Sewers, km	65.5	73.5
Force Mains, km	---	---
Pumping Stations, number of	---	---
Developed Area Served, dunums		
Population Served (000's)	63.2	73.4
Persons Served/dunum		

* Energy values at mid-points of periods, i.e., 1987 and 1995 respectively.

Beneficial Use of Effluent and Digested Sludge

It is hoped that agricultural irrigation with reclaimed water from the Baqa'a Valley Treatment Plant would eventually become possible. The effluent would have to be pumped, but the pumping lifts would not appear prohibitive, as the potential irrigation areas are within Baqa'a Valley itself. Similarly, anaerobically digested sludge potential applications could be nearby for reforestation and, eventually, for agriculture applications.

Industrial Wastewater and Hard Detergents

A few agricultural food processing plants exist within Baqa'a Valley and more may develop in the future. Wastewaters from such plants should be required to be pretreated in order to avoid excess loadings, seasonal or otherwise, that could overload the municipal plant. Hard detergents are not anticipated to be a significant problem.

WESTERN SUB-BASIN

Included within these drainages are the municipal systems of Salt, Fuheis/Mahis, and Lower Wadi es Sir. The Salt system exists, and its evaluation was presented in Chapter 6. It was found to be essentially adequate for year 2000 conditions, with only relatively minor modifications being required. The other municipal systems are proposed.

Fuheis/Mahis Facilities

These two rural communities are partially contiguous, but most of the communities are separated by a hillside. In Chapter 8 analysis was presented which showed the most cost-effective collection alternative was for wastewater from Mahis to be pumped to a treatment plant near Fuheis which would serve both communities. This alternative, (CF1) is the only alternative now being considered, other than the No-Project alternative (CF2).

Treatment Alternatives and Effluent Quality The recommended alternative (TF1) for Fuheis and Mahis would incorporate extended aeration (a simplified modification of activated sludge). The long-range objective alternative (TF2) would eventually incorporate effluent filtration and denitrification. No-Project is alternative TF3.

Effluent quality anticipated for the alternatives TF1 and TF2 is as presented in Table 9-1.

Operation and Maintenance Aspects Extended aeration is relatively simple to operate, and the process digests most of the sludge solids. There would be one pumping station in the collection system requiring operation and maintenance. Projected operational and maintenance requirements and certain other relevant data for the Fuheis/Mahis facilities are as follows:

Item	By 1990	By 2000
Plant Capacity, $10^3 m^3$/day	0.45	0.70
Staff Requirements		
Professionals	---	---
Line	1	1
Laborers	1	1
Treatment Site Requirements, dunums	4	4
Average Flow, $10^3 m^3$/day	0.45	0.70
Annual Energy, 10^6 kwh*	0.42	0.61
Collection System		
Trunk Sewers, km	6.5	6.5
Lateral Sewers, km	7.4	12.0
Force Mains, km	0.7	0.7
Pumping Stations, number of	1	1
Developed Area Served, dunums		
Population Served (000's)	6.7	9.5
Persons Served/Dunum		

* Energy values are at mid-points of periods, i.e., 1987 and 1995, respectively.

Beneficial Use of Effluent and Digested Sludge Effluent from the Fuheis/Mahis plant would discharge down the Wadi ez Zeitum a tributary of Wadi Shu'eib upon which Shu'eib Dam and Reservoir are located. Inasmuch as releases from Shu'eib Dam are used for groundwater recharge in the Jordan Valley, there would be

indirect beneficial use of the effluent, even though the quality standards for drinking water would not initially be met. There would be modest sludge production from the extended aeration plant at most. It would probably not be a source of significant quantities of sludge either for disposal or beneficial use. Sludge could probably be used for tree nurseries, if appropriate.

Industrial Wastewter and Hard Detergents The local cement plant (Fuheis) operates its own industrial wastewater treatment facilities and would not discharge into the municipal system. Other industrial wastewater sources are anticipated to be significant. Hard detergents are not expected to represent a problem in the system.

Wadi es Sir

Lower Wadi es Sir lies within the Western Drainage, while Upper Wadi es Sir is within Seil Zarqa Drainage, being tributary by gravity to AWSA's proposed UWATP. It was shown in Chapter 8 that it would be uneconomical for Lower Wadi es Sir to be tributary, by pumping, to Seil Zarqa Drainage; therefore, the collection alternative is for a local plant for Lower Wadi es Sir. It was further shown in Chapter 8 that it would not be cost-effective for such local plant also to serve the small downstream communities of El Bassa and Iraq al Amin, and therefore, the recommended alternative (CW1) involves only Lower Wadi es Sir. The No-Project alternative is CW2.

Treatment Alternatives and Effluent Quality The recommended treatment alternative for Wadi es Sir is the extended aeration modification of activated sludge (TW1). The long-range objective alternative (TW2) would be to incorporate effluent filtration and denitrification. The No-Project alternative is TW3.

Effluent quality anticipated for the alternatives TW1 and TW2 is as presented in Table 9-1.

Operational and Maintenance Aspects The discussions previously presented for Fuheis/Mahis would be generally applicable to Wadi es Sir as well. Requirements for O&M and certain other relevant data for the Wadi es Sir facilities are as follows:

Item	By 1990	By 2000
Plant Capacity, $10^3 m^3$/day	1.2	1.9
Staff Requirements		
Professionals	---	---
Line	2	3
Laborers	2	3
Treatment Site Requirements, dunums	4	4
Average Flow, $10^3 m^3$/day	1.2	1.9
Annual Energy, 10^6 kwh	0.31	0.69
Collection System		
Trunk Sewers, km	5	5
Lateral Sewers, km	20	22
Force Mains, km	---	---
Pumping Stations, number of	---	---
Developed Area Served, dunums		
Population Served (OOO's)	15.3	22.5
Persons Served/Dunum		

Beneficial Use of Effluent and Digested Sludge Effluent would discharge down the Wadi es Sir a tributary of Wadi el Kafrein, upon which Kafrein Dam and Reservoir are located. Inasmuch as releases from Kafrein Dam are used for irrigation in the Jordan Valley, there would be indirect beneficial use of the effluent, even though the quality standards for drinking water would not initially be met. There would be modest sludge production from the extended aeration plant at most. It would probably not be a source of significant quantities of sludge either for disposal or beneficial use. Sludge could probably be used for tree nurseries, if appropriate.

Industrial Wastewater and Hard Detergents Industrial wastewater sources are anticipated to be insignificant. Hard detergents are not expected to represent a problem in the system

SOUTHWESTERN SUB-BASIN

The only system within the Southwestern sub-basin is that of the Municipality of Na'ur. It was determined in Chapter 8 that the only viable alternative for wastewater collection was for a local sewer system and treatment plant, this being designated as alternative CN1. No-Project was designated as alternative CN2.

Treatment Alternatives and Effluent Quality The recommended treatment alternative for Na'ur is the extended aeration modification of activated sludge (TN1). The long-range objective alternative (TN2) would be to incorporate effluent filtration and denitrification. The No-Project alternative is TN3. Effluent quality anticipated for the alternatives TN2 and TN3 is as presented in Table 9-1.

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Operational Maintenance Aspects The discussion previously presented for Fuheis/Mahis would be generally applicable to Na'ur as well. Requirements for O&M and certain other relevant data for the Na'ur facilities are as follows:

Item	By 1990	By 2000
Plant Capacity, $10^3 m^3$/day	0.24	0.48
Staff Requirements		
Professionals	---	---
Line	1	1
Laborers	1	1
Treatment Site Requirements, dunums	2	2
Average Flow, $10^3 m^3$/day	0.24	0.48
Annual Energy, 10^6 kwh	0.22	0.36
Collection System		
Trunk Sewers, km	3.3	3.3
Lateral Sewers, km	4.6	6.5
Force Mains, km	---	---
Pumping Stations, number of	---	---
Developed Area Served, dunums		
Population Served (OOO's)	4.0	6.9
Persons Served/Dunum		

*Energy values are mid-points of periods, i.e., 1987 and 1995, respectively.

Beneficial Use of Effluent and Digested Sludge Effluent from the Na'ur Plant would discharge down the Wadi Na'ur a tributary of Wadi el Kafrein, upon which Kafrein Dam and Reservoir are located. Thus, the comments previously made for Wadi es Sir/El Bassa/Iraq el Amin facilities would also apply to the Na'ur facilities as well.

Industrial Wastewater and Hard Detergents Industrial wastewater sources are anticipated to be insignificant. Hard detergents are not expected to represent a problem in the system.

SOUTHERN SUB-BASIN

There are two wastewater systems within the Southern sub-basin: that of Sahab and that of Abu Alanda/Khirbet es Suq/Juweideh. Collection system alternatives for each of these respective systems were found by analysis in Chapter 8 to be most cost-effective for joint community sewers and single treatment plant. The recommended collection system alternatives are CS1 and CAA1, respectively, while the respective No-Project alternatives would be CS2 and CAA2.

Treatment Alternatives and Effluent Quality

Both the Sahab and Abu Alanda/Khirbet es Suq/Judweideh systems are located in gently rolling terrain where it is practical to use total containment type, facultative lagoons for treatment/disposal. Inasmuch as disposal would be by

evaporation from the multicell lagoons, which would be lined to prevent seepage, effluent quality would not be a consideration. The lagoons would, however, be designed to operate without nuisance.

Operation, Maintenance, and Miscellaneous Aspects

Table 9-5 summarizes the facilities for the Southern sub-basin, those of Sahab and Abu Alanda/Khirbet es Suq/Juweideh, respectively. Sahab Industrial City is to be the center of the area's industrial activity, and will have a separate treatment plant, so Sahab et al's system would not be anticipated to be concerned with industrial wastewater discharges. The same would hold true for Abu Alanda, et al. Hard detergents are not anticipated to pose a problem for either system.

COST ANALYSIS OF ALTERNATIVES

The purpose of the cost anlysis is to provide a common basis for and comparison of the several alternatives according to cost under specified conditions. In order to do so certain assumptions are first made. The analysis then proceeds, and the resulting data are used in the ranking of alternatives.

ASSUMPTIONS

In order to compare the alternatives on a common basis, the following simplifying assumptions have been made:

- Except as noted in the case of certain AWSA projects, all construction work is to be provided in two stages:
  - First stage is to be activated in 1984 and sized for flow conditions projected for 1990.
  - Second stage is to be activated in 1990 and sized for flow conditions projected for 2000.
- Capital outlay (project cost expenditures) is to be incurred in lump sums for the two consecutive stages during 1983 and 1990, respectively.
- Construction costs are obtained from the cost curves displayed in Appendix J. Price levels are late 1980, for Jordan. (No separation of local and foreign cost components is required for screening purposes).
- Project costs are taken as 150 percent of construction costs. They include basic construction work and additional expenses for: contingencies, legal, engineering, surveying and laboratory work, and for inspection and contract administration.
- Interest rate is 10 percent.
- Project life (comparable to repayment period) is 20 years.

TABLE 9-5

SUMMARY OF WASTEWATER FACILITIES FOR SOUTHERN SUB-BASIN

Item	Sahab 1990	Sahab 2000	Abu Alanda/Khurbet es Suq/Juweideh 1990	Abu Alanda/Khurbet es Suq/Juweideh 2000
Plant Capacity, $10^3 m^3$/day	0.66	1.3	0.66	1.1
Staff Requirements				
Professionals	--	--	--	--
Line	0.5	0.5	0.5	0.5
Laborers	0.5	0.5	0.5	0.5
Treatment Site Requirements, dunums	87	147	190	190
Average Flow, $10^3 m^3$/day	0.66	1.3	0.66	1.1
Annual Energy, 10^6 kwh	0.004	0.010	0.014	0.016
Collection System				
Trunk Sewers, km	6	6	8	8
Lateral Sewers, km	12.8	14.8	17	17
Force Mains, km	1	1	1.2	1.2
Pumping Stations, number of	1	1	2	2
Developed Area Served, dunums	11.0	16.0	11	15.3
Population Served (000's)				
Persons Served/Dunums				

* Energy values are at mid-points of periods, i.t., 1987 and 1995, respectively.

- Depreciation is straight line basis.

- Salvage value for wastewater treatment plants, both first and second construction stages, is negligible at the end of the project (year 2000) and can reasonably be ignored.

- Pumping station life is 20 years. Salvage value at year 2000 may safely be ignored for the purpose of ranking alternatives.

- Sewer life is 40 years. Salvage value at year 2000 is considered where necessary, on a present worth basis. Same for force mains.

- No special recognition need be taken of general cost inflation in the studies. It is assumed that interest rate and inflation are essentially equal and therefore future costs are identical to present costs on a present worth basis.

- Operation and maintenance (O&M) costs for wastewater facilities, particularly treatment plants, are also pegged to late 1980 price levels. Future energy costs are taken to increase differentially over general inflation at four percent (4%) per annum, compounded over time, beginning in 1980. This specifically recognizes the major impact of energy costs on affecting general inflation.

- Except for certain AWSA installations, wastewater flows are assumed to increase uniformly from 1983 to 2000, and flow-associated O&M costs are also assumed to increase uniformly.

- Mid-stage O&M costs are taken as representative of each entire construction stage. Thus, representative O&M costs for 1987 are assumed for the first construction stage and those of 1995 for the second construction stage.

- All capital and O&M costs are converted to annual costs and related to numbers of persons served by the facilities, in order to provide a common basis for comparison.

COST ANALYSIS OF AWSA FACILITIES

It has been established previously that the AWSA facilities will require expansion at an early date, due to continuing growth and impending overload of the AGTP. The costs associated with these facilities are displayed in Table 9-6 together with an analysis of the data according to the population benefitted.

Special Considerations for AWSA Facilities

Unlike other projects being considered herein, AWSA's system involves an existing primary network, a fairly well developed secondary network, and an existing treatment plant. It also entails an existing population which is currently being

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TABLE 9-6

COST ANALYSIS OF AMSA FACILITIES FOR 1990 and 2000 CONDITIONS[a]

Item[b]	AGTP[c]	UWATP[d]	KRTP[e]	P.Stas.[f]	P.Mains[g]	Lat.Sewers[h]	Trunks[i]	Total System[j]
Collection Alt. CA1								
1990 Service Pop'n, 1,000	495	97	-	-	-	-	-	592
1990 Costs, 1,000 JD								
Construction	11,863	1,970	-	106	112	3,279	1,023	18,353
Project	17,795	2,955	-	159	168	4,919	1,534	27,530
Annual Capital	2,091	347	-	19	18	535	169	3,179
Annual Energy	361	91	-	10	-	-	-	462
Other Ann. O & M	950	92	-	17	1	16	5	1,081
Total Annual	3,042	530	-	46	19	551	174	4,722
Annual JD Per Capital	6.9	5.5	-	-	-	-	-	8.0
2000 Service Pop'n, 1,000	789	210	574	-	-	-	-	1,573
2000 Costs, 1,000 JD								
Construction	3,050	4,030	15,600	-	31	9,643	701	33,055
Project	4,575	6,045	23,400	-	47	14,465	1,052	49,584
Annual Capital	2,628	1,058	2,750	19	23	2,109	283	8,870
Annual Energy	291	250	325	11	-	-	-	877
Other Annual O & M	1,015	136	855	11	1	64	9	1,979
Total Annual	3,934	1,444	3,930	41	24	2,173	292	11,838
Annual JD Per Capita	5.0	6.9	6.8	-	-	-	-	7.5
Collection Alt. CA2								
1990 Service Pop'n, 1,000[a]	592	-	-	-	-	-	-	592
1990 Costs, 1,000 JD								
Construction	14,500	-	-	106	112	3,279	1,343	19,340
Project	21,750	-	-	159	168	4,919	2,014	29,010
Annual Capital	2,556	-	-	19	18	535	219	3,347
Annual Energy	444	-	-	10	-	-	-	454
Other Annual O & M	1,015	-	-	17	1	16	7	1,056
Total Annual	4,015	-	-	46	19	551	226	4,857
Annual JD Per Capita	6.8	-	-	-	-	-	-	8.2
2000 Service Pop'n, 1,000	781	-	792	-	-	-	-	1,573
2000 Costs, 1,000 JD								
Construction	380	-	19,600	-	31	9,643	749	30,403
Project	570	-	29,400	-	47	14,465	1,124	45,606
Annual Capital	2,623	-	3,455	19	23	2,109	341	8,570
Annual Energy	291	-	457	11	-	-	-	759
Other Annual O & M	1,015	-	1,203	11	1	64	11	2,305
Total Annual	3,929	-	5,115	41	24	2,173	352	11,634
Annual JD Per Capita	5.0	-	6.5	-	-	-	-	7.4

TABLE 9-6 (cont'd)

[a] For 1990 data, only the incremental populations to be served and incremental facilities are included. These are over and above the 1980 connected population, estimated at about 280,000 persons, and the existing primary and secondary sanitary network. However, all operating and maintenance costs for the total AGTP operation are included. See discussion.

[b] Collection Alternative CA1 involves construction of UWATP and diversion of most of the flow originating westerly of Amman, thereby reducing the need for construction of relief trunk sewers in the AWSA primary network as well as for additional capacity in both AGTP and KRTP. Collection Alternative CA2 does not include UWATP at all.

[c] AGTP does not require any additional plant site area. Under CA1, the plant capacity would be 60,000 cu m/da by 1990 and 75,000 cu m/da by year 2000. Under CA2, the AGTP capacity would be 75,000 cu m/da by 1990 as well as for year 2000.

[d] UWATP would be built under CA1 only and would involve 8,000 cu m/da initial capacity, adequate for 1990, and 22,000 cu m/da total capacity for the second stage, adequate for year 2000. The cost of land is included in the project cost.

[e] KRTP would be required under either CA1 or CA2 after 1990 in capacities of 54,000 and 76,000 cu m/da, respectively. Land cost is included in project cost.

[f] Pumping stations are for north-draining Suweileh. Initially three stations would be used, but following 1990, one of these would be retired and a new force main activated to direct the flow southerly into a new gravity trunk sewer draining southern Suweileh, KHMC and vicinity to UWATP. The total pumping via this arrangement would be less than by the initial arrangement.

[g] A new length of force main would be required after 1990 for north-draining Suweileh.

[h] Lateral sewers include those needed for the new populations to be served. Inasmuch as some surplus lateral sewer capacity already exists in the AWSA network, this item is less somewhat of a cost factor than for other projects elsewhere.

[i] Trunk sewers include relief trunks within AWSA's network as well as new ones for outside areas to be served for the first time. Under CA1 there is less need for trunk sewer relief than under CA2.

[j] Total costs of incremental facilities (but all O & M costs for AGTP) and total incremental population served are listed. Annual cost per capita is based on incremental costs and incremental population. Capital cost of currently programmed sludge facilities expansion is not included in the data, although O & M costs are included. To include the annual capital costs, add about JD 400,000 per year. The effects of doing this are not major. It can be seen that from the cost standpoint and within the level of accuracy of the estimates, CA1 and CA2 are essentially equal, and the selection may properly be made on other bases.

served. A much greater future population will be served, both within Amman and outside of Amman, and this will require greatly expanded treatment facilities, some sewer expansions within Amman, and new trunk and lateral sewers in areas surrounding Amman.

Consideration was given to two alternative methods of expressing costs and benefitted populations. These were for total costs/total populations and for incremental costs/incremental populations, respectively. As explained below, it was determined to be fairest to use the method of incremental costs/incremental populations.

To begin with, the current population served (1980) is estimated at about 280,000 persons as compared with an incremental population served of about 592,000 persons by 1990 and 1,573,000 persons by year 2000. Thus, the existing served population is about 32 percent of the total 1990 population and about 15 percent of the total year 2000 population. However, the existing investment in AGTP, primary network (trunk sewers), and secondary network (lateral sewers) is relatively small in comparison with the investment yet to be made for the Implementation Phase I and subsequent phases catering to the needs for year 2000. It was difficult to determine the exact current investment in utility plant corresponding to the current served population, but it is believed that this is in the order of JD 6 million. Of this, it is understood that over 80 percent is in the network and less than 20 percent in AGTP.

Most of the investment in network and AGTP was made many years ago when construction costs were much lower than they are now. Furthermore, the facilities probably have an average age of at least 10 years and are already partially written off. Ignoring this aspect, it might appear that the existing investment of, say, JD 6 million is less than 10 percent of the existing investment plus future investment for 1990 and year 2000 phases (Table 9-6, last column, showing about JD 77.1 million total project costs for these two phases, Alt. CA1, expressed in late 1980 prices). It can be concluded that the new investment is relatively large with respect to the new population to be served. This can be illustrated by the following comparison, which expresses capital investment in terms of benefitted population according to the alternatives of total values and incremental values, respectively, on the basis of year 2000 conditions:

Total	Total Cost/ Total Population	Incremental Cost/ Incremental Population
Total Investment, JD million		
Existing	6	---
Future	77.1	77.1
Total	83.1	77.1
Total Population Millions		
Existing	0.28	---
Future	1.57	1.57
Total	1.85	1.57
Ratio, Investment/ Population	44.9	49.1

By selecting the incremental cost/incremental population method for Phase I, in Table 9-6 and subsequent tabulations herein, the relative cost/benefit advantages of the existing AWSA system over new proposed systems tend to be minimized.

It is noted that the existing served population of about 280,000 persons is contributing a flow to the plant of about 21,000 cu m/da and that this is roughly equal to the effective capacity of the existing AGTP main process (see Chapters 6 and 8 for additional technical analyses). In other words, the additional population would require additional facilities anyway; thus, the incremental cost/incremental population method would appear particularly valid from this standpoint.

Table 9-6 does not include the investment costs of the recently tendered sludge facilities expansion at AGTP but it does include the O&M costs for the entire plant, including existing, new, and future sludge facilities, and this does reflect the impact of sludges discharged into the primary network from UWATP.

If the annual capital cost of these facilities were to be added to the totals, the total annual costs for the total system would rise by about JD 400,000 or approximately 8 percent for 1990, Alt. CA1, the most critical situation. Thus, the effects of including the programmed sludge facilities expansion in the analysis are not major.

Cost Analysis for Southerly Diversion of UWATP Effluent

A brief investigation was made into the possibilities of diverting up to about 7,000 cu m/da of UWATP effluent southerly across the watershed divide and into either the headwaters of Wadi el Qastal or Wadi Hisban. As indicated earlier, an effluent pumping station would be required. In addition to a storage tank on an intervening summit along the pipeline, there would probably be a need for some regulatory storage at the plant site itself. In this way, the diurnal variations of influent flow at UWATP could be accommodated and very little effluent lost. The

1.56

importance of such local storage would be diminished when the plant was enlarged and flows increased.

The preliminary figures for the pumping and transmission facilities are presented in Table 9-7.

TABLE 9-7

COST ANALYSIS FOR SOUTHERLY DIVERSION OF UWATP EFFLUENT VIA PUMPING

Item	Value	Remarks
Construction Cost, 1,000 JD		
Pumping Station	70	Sized for 180 percent of 7,000 cu m/da
Force Main	115	——
Storage	100	Plantsite plus summit tank or reservoir
Gravity Pipelines:		
(1) To Wadi el Qastal	207	Shorter run but greater diameter than (2)
(2) To Wadi Hisban	296	An alternate to (1)
Project Cost, 1,000 JD		
Pumping Station	105	Assumes 150 percent of construction cost
Force Main	173	
Storage	150	
Gravity Pipelines:		
(1) To Wadi el Qastal	311	Alternative to (2)
(2) To Wadi Hisban	444	Alternative to (1)
Annual Capital Cost, 1,000 JD		
Pumping Station	12.3	20-year life
Force Main	18.8	40-year life
Storage	16.3	40-year life
Gravity Pipelines:		
(1) To Wadi el Qastal	33.8	40-year life
(2) To Wadi Hisban	48.3	40-year life

Item	Value	Remarks
Annual O&M, 1,000 JD		
Pumping Station Energy	23.7	Not escalated
Other O&M		
Pumping Station	7.7	
Force Main	0.6	
Storage	2.4	
Gravity Pipelines:		
(1) To Wadi el Qastal	1.0	
(2) To Wadi Hisban	1.5	
Total System		
For (1) (Wadi el Qastal)	35.4	No energy escalation incl.
For (2) (Wadi Hisban)	35.9	No energy escalation incl.
Total Annual Cost		
For (1) (Wadi el Qastal)	116.6	
For (2) (Wadi Hisban)	131.6	
Total Unit Cost for 2.56 MCM/yr		For 7,000 cu m/da flow
For (1), Fils/cu m	45.5	
For (2), Fils/cu m	54.4	

If energy escalation, say to 1987 levels, were included, the total annual cost would rise by about 7,500 JD/yr. If the escalation were to 1995 levels, the total annual cost would rise by about 19,000 JD/yr. This would make the unit costs for (1) rise to about 48.5 and nearly 53 Fils/cu m for the respective escalations. For (2), the corresponding numbers would be about 57 and 62 Fils/cu m, respectively.

If added flexibility were desired by providing capabilities for diverson to both Wadi el Qastal and Wadi Hisban, the unit cost would rise by about 10 Fils/cu m from the previously cited figures. Thus, the range of unit costs for transmission of 7,000 cu m/da of effluent across the watershed divide to the south is roughly in the range of 50 to 70 Fils/cu m.

COST ANALYSIS OF SUKHNEH AND HASHIMIYA FACILITIES

Table 9-8 presents the costs analysis of Sukhneh and Hashimiya facilities.

COST ANALYSIS OF NORTHWEST SUB-BASIN FACILITIES

The wastewater facilities of the Northwest Drainage are those serving the Baqa'a Valley, and the cost analysis for them is as presented in Table 9-9.

TABLE 9-8

COST ANALYSIS FOR SUKHNEH AND HASHIMIYA FACILITIES

Item	Sukhneh 1990	Sukhneh 2000	Hashimiya 1990	Hashimiya 2000
Service Population 1,000	3.6	5.6	3.0	4.8
Construction Cost, 1,000 JD				
Lateral Sewers	106.8	59.5	129.0	59.5
Trunk Sewers	28.2	—	56.5	--
Treatment Plants	150.0	50.0	130.0	50.0
Total	285.0	109.5	315.5	109.5
Project Cost, 1,000 JD				
Lateral Sewers	160.2	89.3	193.5	89.3
Trunk Sewers	42.3	—	84.8	--
Treatment Plants	225.0	75.0	195.0	75.0
Total	427.5	164.3	473.3	164.3
Annual Capital Costs, 1,000 JD				
Lateral Sewers	17.4	27.1	21.1	30.8
Trunk Sewers	4.6	4.6	9.2	9.2
Treatment Plants	26.4	35.3	22.9	31.7
Total	48.4	67.0	53.2	71.7
Annual O & M Costs, 1,000 JD				
Collection System	0.7	1.0	0.9	1.2
Treatment Plant	3.6	4.3	3.9	4.4
Total System	4.0	5.3	4.8	5.6
Total Annual System Cost, 1,000 JD	52.4	72.3	58.0	77.3
Total Annual Cost, JD per capita	14.5	12.9	19.3	16.1

TABLE 9-9

COST ANALYSIS FOR BAQA'A VALLEY FACILITIES

Item	By 1990	By 2000
Service Population, 1,000	89.8	103.2
Construction Cost, 1,000 JD		
Lateral Sewers	1,943	237
Trunk Sewers	416	---
Treatment Plant	1,700	612
Total	4,059	849
Project cost, 1,000 JD		
Lateral Sewers	2,915*	356*
Trunk Sewers	624	---
Treatment Plant	2,550	918
Total	6,089	1,274
Annual Capital Cost, 1,000 JD		
Lateral Sewers	317	356
Trunk Sewers	68	68
Treatment Plant	300	407
Total	685	831
Annual O&M Cost, 1,000 JD		
Collection System	12	13
Treatment Plant		
Energy	63	94
Other	63	93
Total System	138	200
Total Annual Cost, 1,000 JD	823	1,031
Total Annual Cost, JD per Capita	9.2	10.0

* Including local sewers in Baqa'a Camp

COST ANALYSIS OF WESTERN SUB-BASIN FACILITIES

Table 9-10 presents the cost analysis of the wastewater facilities for the Western Drainages, those of Fuheis/Mahis and Lower Wadi es Sir, respectively.

COST ANALYSIS OF SOUTHWESTERN SUB-BASIN FACILITIES

The cost anlysis of the wastewater facilities for the Southwestern sub-basin, those of Na'ur is as presented in Table 9-11.

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TABLE 9-10

COST ANALYSIS FOR WESTERN SUB-BASIN FACILITIES

Item	Fuheis/Mahis 1990	Fuheis/Mahis 2000	Lower Wadi es Sir 1990	Lower Wadi es Sir 2000
Service Population, 1000	6.7	9.5	15.3	22.5
Construction Cost, 1,000 JD				
Lateral Sewers	220	----	593	59
Trunk Sewers	183	----	161	----
Force Mains	10	----	---	----
Pump Stations	46	----	---	----
Treatment Plant	135	65	440	300
Total	594	65	1,194	359
Project Cost, 1,000 JD				
Lateral Sewers	330	----	890	89
Trunk Sewers	275	----	242	----
Force Mains	15	----	----	----
Pump Stations	69	----	----	----
Treatment Plant	203	98	660	450
Total	892	98	1,792	539
Annual Capital Cost, 1,000 JD				
Lateral Sewers	35.9	35.9	96.8	106.5
Trunk Sewers	29.9	29.9	26.3	26.3
Force Mains	1.6	1.6	-----	-----
Pump Stations	8.1	8.1	-----	-----
Treatment Plant	23.9	35.4	77.6	130.5
Total	99.4	110.9	200.7	263.3
Annual O & M Cost, 1,000 JD				
Collection System				
Energy	1.3	2.4	-----	-----
Other	3.6	3.8	3.8	4.1
	4.9	6.2	3.8	4.1

TABLE 9-10 (Cont'd)

Item	Fuheis/Mahis 1990	Fuheis/Mahis 2000	Lower Wadi es Sir 1990	Lower Wadi es Sir 2000
Annual O & M, 1,000 JD				
Treatment Plant				
Energy	20.4	40.2	16.1	48.6
Other	10.0	10.2	10.5	11.0
Total	30.4	50.4	26.6	59.6
Total System	35.3	56.6	30.4	63.7
Total Annual Cost, 1,000 JD	134.7	167.5	231.1	327.0
Total Annual Cost, JD per Capita	20.1	17.6	15.1	14.5

TABLE 9-11

COST ANALYSIS FOR NA'UR WASTEWATER FACILITIES

Item	By 1990	By 2000
Service Population, 1,000	4.0	6.9
Construction Cost, 1,000 JD		
Lateral Sewers	137	56
Trunk Sewers	94	---
Treatment Plant	70	60
Total	301	116
Project Cost, 1,000 JD		
Lateral Sewers	206	84
Trunk Sewers	141	---
Treatment Plant	105	90
Total	452	174
Annual Capital Cost, 1,000 JD		
Lateral Sewers	22.4	31.6
Trunk Sewers	15.3	15.3
Treatment Plant	12.3	22.9
Total	50.0	69.8
Annual O&M Cost, 1,000 JD		
Collection System	1.2	1.4
Treatment Plant		
Energy	11.3	22.4
Other	9.2	9.8
Total	50.0	32.2
Total System	21.7	33.6
Total Annual Cost, 1,000 JD	71.7	103.4
Total Annual Cost, JD per Capita	17.9	15.0

COST ANALYSIS OF SOUTHERN SUB-BASIN FACILITIES

Table 9-12 presents the cost analysis of the wastewater facilities for the Southern Drainage, notably those of Sahab and of Abu Alanda/Khurbet es Suq/Juweideh, respectively.

ENVIRONMENTAL ASSESSMENT

An early determination of the possible environmental effects of a proposed project serves two purposes.

TABLE 9-12

COST ANALYSIS OF SOUTHERN SUB-BASIN FACILITIES

Item	Sahab 1990	Sahab 2000	Abu Alanda/Khurbet es Suq/Juweideh 1990	Abu Alanda/Khurbet es Suq/Juweideh 2000
Service Population 1,000	11.0	16.1	11.0	15.3
Construction Cost 1,000 JD				
Lateral Sewers	380	59	504	----
Trunk Sewers	169	----	226	----
Force Mains	22	----	26	----
Pump Stations	15	----	18	----
Treatment Plant	142	122	148	22
Total	728	181	922	22
Project Cost, 1,000 JD				
Lateral Sewers	570	89	756	----
Trunk Sewers	254	----	339	----
Force Mains	33	----	39	----
Pump Stations	23	----	27	----
Treatment Plant	360	183	222	33
Total	1,240	272	1,383	33
Annual Capital, 1,000 JD				
Lateral Sewers	62.0	71.7	82.3	82.3
Trunk Sewers	27.6	27.6	36.9	36.9
Force Mains	3.6	3.6	4.2	4.2
Pump Stations	2.7	2.7	3.2	3.2
Treatment Plant	42.3	63.8	26.1	30.0
Total	138.2	169.4	152.7	156.6
Annual O & M Cost, 1,000 JD				
Sewers and Force Mains	2.9	3.2	3.8	3.8
Pump Stations				
Energy	0.2	0.7	0.7	1.1
Other	0.1	0.1	1.4	1.4

TABLE 9-12 (Cont'd)

Item	Sahab 1990	Sahab 2000	Abu Alanda/Khurbet es Suq/Juweideh 1990	Abu Alanda/Khurbet es Suq/Juweideh 2000
Annual O & M Cost, 1,000 JD				
Treatment Plant				
Energy	----	----	----	----
Other	4.9	5.4	5.0	5.6
Total	4.9	5.4	5.0	5.6
Total System	8.1	9.4	10.9	11.9
Total Annual Cost, 1,000 JD	146	179	164	169
Total Annual Cost per Capita	13.3	11.1	14.9	11.0

- It provides information on environmental costs and benefits that is used in the selection of a preferred alternative from among the available project options.
- It allows identification of needed mitigation of adverse impacts when changes can most easily be incorporated into the project planning.

AFFECTED ENVIRONMENTS

The Study Area has been defined in Chapter 2 and the socio-economic conditions have been described in Chapter 3. Public health considerations have been discussed in Chapter 4. Reference is made to Chapter 5, 6, and 7 for amplifying information on environmental resources, for which a summary is presented herein.

Water Resources and Demands

The Study Area lies near the western edge of the Syrian Desert (Badiet esh Sham) and has a dry, arid climate. Average annual rainfall varies from a high of about 600 mm between Salt and Suweileh to a low of less than 100 mm at the eastern edge of the Study Area.[6] Most rain occurs from November through April, and almost none falls from June through September. Evaporation rates are significantly higher in the east than in the west.

The major surface water features in the Study Area are the Seil Zarqa, its tributaries, and the King Talal Reservoir. Two other wadis have regulatory storage in the Jordan Valley. These are the Wadi el Kafrein (Kafrein Reservoir) and Wadi Shu'eib (Shu'eib Reservoir).

The Seil Zarqa and the numerous lesser wadis in the area have low flows or are dry during the summer months. Surface water is generally unavailable in usable amounts during this period except for a number of local springs, water from the King Talal and Kafrein Reservoirs, and effluent from the area's sewage treatment plants (Ain Ghazal, Salt, and the King Hussein Medical Center).

Because of the intermittent availability of most surface waters, groundwater aquifers supply most of the Study Area's current water needs and essentially all of its non-agricultural needs. The area overlies all or part of six surface catchment basins and six roughly corresponding groundwater subdivisions (Figure 7-4).

Most groundwater used in the area is extracted from two aquifers underlying the Amman-Zarqa Basin and is used for domestic or industrial purposes in the Amman-Zarqa municipal area. A water resources consultant estimated that 40.6 MCM of water were extracted from these aquifers in 1976, which accounted for about 77 percent of the basin's total water needs.[5] About 69 percent of this extracted water was used for domestic or industrial purposes and the remainder for agriculture.

Studies indicate that these aquifers are being used near or above their maximum long-term potential. Although, the upper aquifer was somewhat underexploited,

the lower aquifer was being mined at the rate of about 5.4 MCM/yr in 1976[5] and was experiencing water level declines of about 10 meters per year.[4]

As an illustration of the potential for increased water shortages, annual water needs for the communities overlying the Amman-Zarqa Basin have been projected to increase from an estimated 62 MCM in 1990 to about 106 MCM in 2000 (data from Table 5-6). Since groundwater supplies will fall far short of these requirements, it will be necessary to import water from sources outside the basin. Projects currently under way will bring domestic water supplies to Amman from Azraq, a desert oasis about 85 kilometers from Amman, and from the Qastal area, about 25 kilometers south of Amman. Additional developments are also being made for bringing water to Amman from the East Ghor Canal for domestic use.

Agricultural and Silvicultural Resources

Chapter 7 has presented selected data pertaining to agriculture within the Greater Amman area. The greatest source of crops is the Jordan Valley, where the climate and availability of irrigation water permit multiple cropping of a wide variety of field crops and fruits in addition to livestock raising.

Crops are also grown in Baqa'a Valley, along some of the wadis, and in various plateau areas. Raising of sheep and goats is fairly widespread. Irrigated agriculture in plateau areas is relatively limited.

Agriculture remains an important part of the Jordan economy. Jordan's cultivable land has been called its principal natural resource.[6] Water is the chief limiting factor for agriculture in Jordan.[6] Within Amman Governorate, the nature of the topography is such that 60 to 65 percent of the total area could be used for agriculture or urban purposes. Much of the remaining 35 to 40 percent of the land has been designated as open grazing land and is utilized throughout the year.

Jordan was once the site of extensive forests, particularly west of the Syrian Desert. Over the years, however, these forests were nearly eliminated as a result of logging for construction of the Hejaz Railroad, for industrial fuels, for military purposes, and by assorted activities. Extensive grazing by livestock may have contributed to the diminished silvicultural resources.

There is now concern over the seeming advance westward of the Syrian Desert. There is also concern over the great erosion potentials of the many treeless expanses of watersheds leading to Jordan Valley reservoirs, such as King Talal, Shu'eib, and Kafrein. These concerns have prompted interest in reforestation in critical areas as a possible long-range program that might involve wastewater treatment plant sludge use as well as reclaimed effluent.

Forests today cover less than one percent of the total area of Jordan. The Forest Department controls about 131,500 hectares designated as forest land, but the actual forested area was thought to be only about 36,000 hectares as of 1964.[6]

The northern highlands (within Greater Amman Area) and the southern highlands (outside this area) are the two main areas of forest growth. Although both areas are degraded, rainfall conditions in the northern area make forest regeneration more feasible than for the south.

Energy Resources

Jordan does not possess fossil fuels naturally. A hydroelectric powerplant is planned for King Talal Reservoir, and other hydro developments may eventually occur. Most energy is imported at present. Quite naturally, there is considerable interest in the prospects of solar energy in view of the abundant sunshine in Jordan. Energy limitations require careful weighing of energy impacts in wastewater management alternatives.

Archeological and Historical Resources

Jordan is rich in arechaeological and historical resources. The land contains evidence of human habitation dating back as far as 100,000 years, and settlements have existed in the area for about 9,000 years. There are major archeological sites from the Neolithic Period, the Bronze Age, the Hellenistic Age, the Nabataean civilization, the Roman Period, the Byzantine Empire, early Islam, the Crusades, and the Turkish occupation.[6] The land and the people of the area have played a significant role in the development of modern civilization, and in the development of three of man's major religions. The cultural resources of the country provide evidence that is important not only to Jordan, but to the entire civilized world, in understanding its heritage and traditions.

Jordan contains some 800 known archaeological sites, and more are added to this list each year. Fewer than five percent of the known sites have undergone major excavations. The country recognizes the importance of these cultural resources, and is making efforts to protect them. Major threats to the sites include looting, especially for illegal sales to tourists, and losses to modern development.

Biotic Resources

Jordan's natural biotic regions are described in the Library of Congress Draft Environmental Report. The Study Area embraces part of three of these regions.

Centuries of human disturbances, however, including agricultuare, hunting, deforestation for lumber and fuel, grazing by domestic animals, and fire, have left only small remnant populations of these original biotic communities. Remaining plant and animal species are those adapted to introduced conditions, including extensive soil losses resulting from erosion and overgrazing, and reduced soil water-holding capacity. Large areas exist that are denuded of most vegetation, and areas where irrigation is practiced often contains weeds associated with agricultural crops. Efforts are being made to reforest parts of the country, and this may result in extensive biotic changes in some areas in the future if secondary vegetative species and new faunal communities become established following planting of trees and shrubs.

No recent compilations of faunal species exist for the Study Area. The sites recommended for wastewater treatment plants or plant expansion are all in disturbed areas and contain no significant natural communities. The sites have all been recently used for agriculture or grazing except for the Ain Ghazal expansion area, which has been heavily disturbed by activity associated with the treatment plant. All areas to be sewered have been heavily disturbed by previous urban development.

Riparian and aquatic associations in the wadis and streams that will receive effluent discharges reflect similar human disturbances, including changes caused by the construction of dams and previous discharges of effluent or other urban wastes. Little information exists on species surviving in these areas. Observation on the Zarqa River just upstream of King Talal Reservoir in 1979 indicated high levels of algal growth, no fish, and low diversity of aquatic insects.[6]

The King Talal Reservoir is presently in a highly eutrophic condition, partially as a result of wastewater discharges (industrial and domestic) and irrigation return flows.[4] Aquatic species are limited to those characteristic of such disturbed conditions, notably heavy phytoplankton blooms. No information is available on aquatic species in the Shu'eib and Kafrein Reservoirs.

Endangered Species

No endangered species of animals are known to inhabit the Study Area. Only one Jordanian animal appears on the U.S. Fish and Wildfire Service's list of Endangered and Threatened Wildlife and Plants. This is the Arabian Ostrich (Strithio Camelus Sryiacus).[6]

Soil Resources

Soil resources have been described in Chapter 7, briefly. Soil erosion has been identified as a severe problem in certain areas of Jordan.[6] This condition arises from overgrazing, deforestation, and improper land use, particularly improper farming methods. Soil erosion leads to reduced land productivity and siltation of reservoirs. In the catchment area for King Talal Reservoir, about 95 percent of the land is said to be affected by sheet erosion resulting from over-grazing, cultivation, and lumbering.

Air Resources

Air quality in the Greater Amman Area is generally good. Meteorological conditions favor good quality by dispersing or diluting possible pollutants.[6] This aspect is of interest in local areas with respect to potential wastewater treatment plant activities.

ENVIRONMENTAL ISSUES

Recently adopted USAID guidelines on environmental documentation[7] stress consideration of environmental effects of the project along with cost and other engineering matters. This discussion therefore emphasizes such considerations.

The new guidelines also provide a means for focusing the effort of the analysis on significant issues. In accordance with these guidelines, a scoping meeting was held during the initial stages of the project to focus the effort of this assessment on those areas of greatest potential environmental concern. These areas of concern were determined to be: water resources, public health, agricultural and silvicultural resources (with regard to the use of reclaimed effluent and sludge), and energy resources. Areas of lesser concern were identified as: archaeological and historical resources, biotic resources, land use and growth inducement, treatment plant odors, and construction impacts. The discussions in this chapter of existing conditions and potential impacts reflect in their level of detail the issues identified in the scoping meeting. Minutes of the scoping meeting and the approved Scoping Statement are contained in Appendix C.

PURPOSE AND NEED FOR PROJECT

The lack of adequate water supplies is one of the major problems facing planners in the Study Area. The region has grown rapidly in recent years as a result of past conflicts in the area and resulting influx of people. The Greater Amman Area now contains about 62 percent of East Bank's population. About 80 percent of this area's population is served by the AWSA municipal water system.[8] Water is allocated on an intermittent basis, however, and flow is provided to many neighborhoods only once or twice a week, even during relatively wet years. Elsewhere in the Study Area, the Water Supply Corporation supplies water to communities. Frequently, this is on an intermittent basis.

Amman's water supply is currently derived primarily from wells fed by the two aquifers that underlie the city. Other communities also rely on those aquifers as well. The quality of the water in these aquifers has been significantly affected by pollutants from the municipal area. This is particularly true of the areas downstream from Amman. Sources of this municipal pollution include leachate from cesspools, leachate from liquid sludge disposed of at the municipal refuse dump, effluent from the Ain Ghazal Plant that percolates through the Seil Zarqa riverbed, and industrial discharges.

Another source of water contamination is backsiphonage of cesspool leachate into water distribution pipes. Loss of pressure occurs in the pipes when flow is shut down during intermittent operation, sometimes causing leachate to be drawn from the soil into the water pipes.

Expansion of the Amman sewer system in recent years and recent construction of the Salt wastewater collection and treatment facilities have prevented some pollution of the aquifers that would otherwise have occurred in Amman and elsewhere. The basic purpose of the project being evaluated here is to continue reduction of pollutant discharges to the aquifer system through further expansion of the area's sewer system, through construction of new sewer systems and treatment plants, through upgrading and expansion of the Ain Ghazal Treatment Plant, and through improved handling and disposal of sewage sludges and industrial wastes. A corollary purpose is to upgrade surface water quality where it is currently adversely affected by effluent discharges.

Chapters 2 through 7 of this report contain a more detailed discussion of water quality problems in the Amman area and of project objectives.

PROJECT AND NO-PROJECT ALTERNATIVES

Development of a Master Plan for wastewater disposal involves consideration of a large number of optional approaches and techniques. These alternatives can be grouped into the following categories: wastewater collection, wastewater treatment, sludge dewatering, effluent use/disposal, and sludge use/disposal.

Since the most appropriate treatment system and disposal methods might vary from locality to locality within the Study Area, alternatives are grouped by drainage areas or sub-basins. Detailed descriptions of each alternative an discussion of options rejected for consideration as alternatives are included in Chapter 8. General locations of treatment plant sites and their corresponding service areas are indicated in Figure 9-3.

Wastewater Collection Alternatives

Chapter 8 contains descriptions and analyses of various collection alternatives, including the bases by which certain of these were rejected from further consideration. Engineering analyses of surviving alternatives appear earlier in this chapter. The wastewater collection alternatives to be considered herein are:

Amman/Zarqa-Ruseifa (Seil Zarqa Sub-Basin)

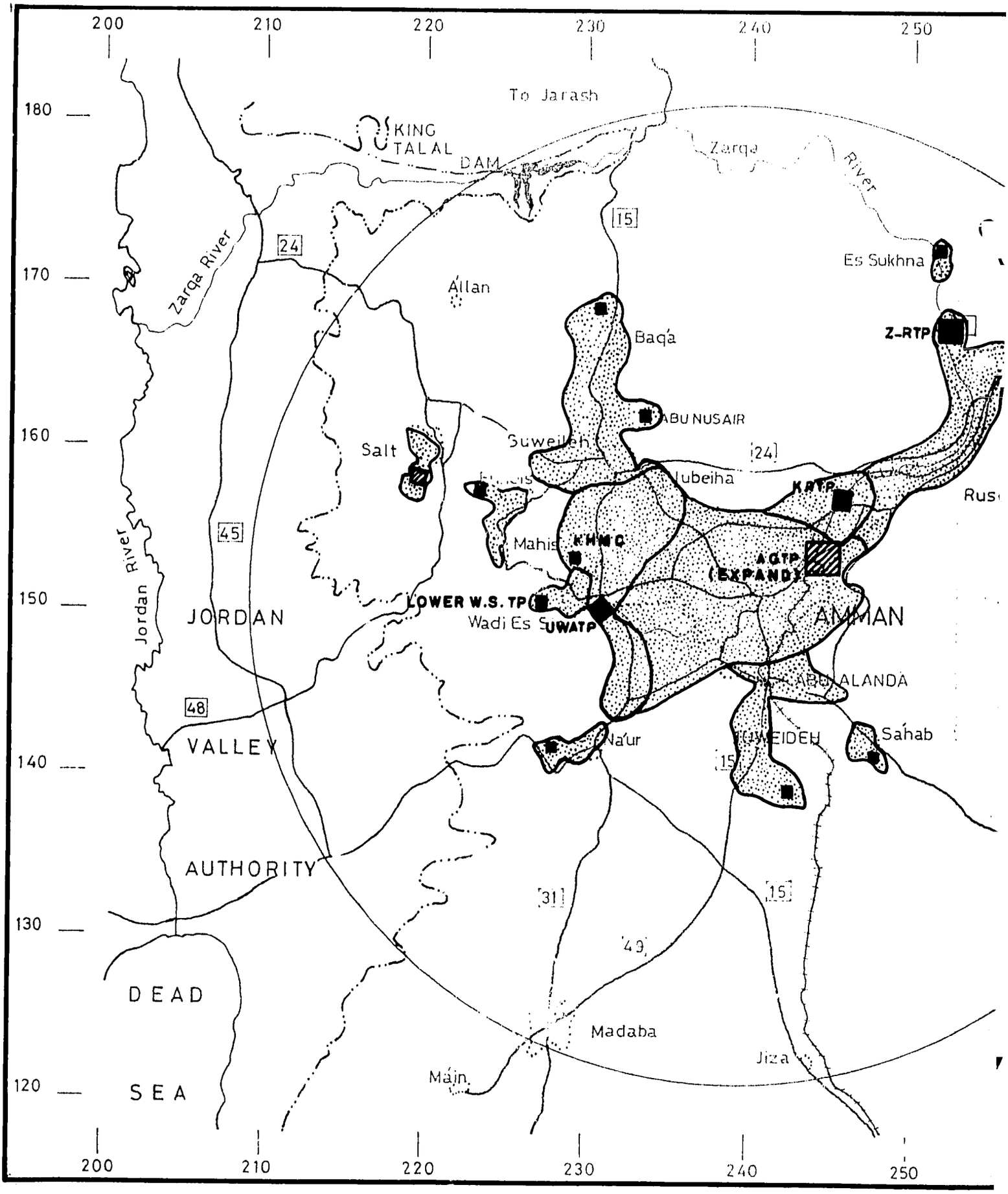
- Alternative CA1. Proposed action. Expanded sewer system with four treatment plants: AGTP, UWATP, KRTP and ZRTP.
- Alternative CA2. Expanded sewer system with three treatment plants: AGTP, KRTP, and ZRTP.
- Alternative CA3. No-Project. No sewer expansions beyond those now planned. Two plants: AGTP and ZRTP.

Sukhneh and Hashimiya (Seil Zarqa Sub-Basin)

- Alternative CAS1. Sewers for Sukhneh plus a treatment plant.
- Alternative CAS2. No-Project. Continued use of cesspools.
- Alternative CAH1. Sewers for Hashimiya plus a treatment plant.
- Alternative CAH2. No-Project. Continued use of cesspools.

Baqa'a Valley (Northwest Sub-Basin)

- Alternative CB1. Treatment plant and sewer system serving Baqa'a Valley.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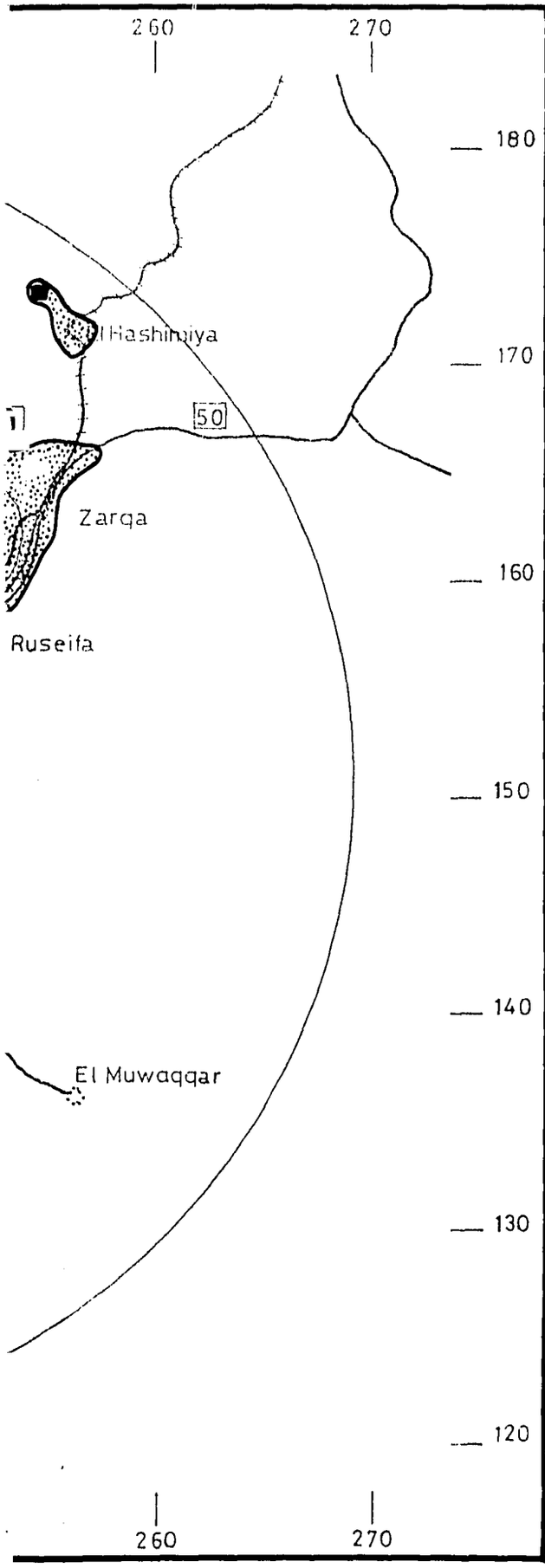

LEGEND

- EXISTING WASTEWATER TREATMENT PLANT
- PROPOSED WASTEWATER TREATMENT PLANT
- SERVICE AREA FOR TREATMENT PLANT

PROPOSED TREATMENT PLANTS AND SERVICE AREAS

FIGURE 9 - 3

- Alternative CB2. No-Project. Continued use of cesspools.

Fuheis/Mahis (Western Sub-Basin)

- Alternative CF1. Proposed Action. Sewer systems for Fuheis and Mahis. One treatment plant serving both communities.
- Alternative CF2. No-Project. Continued use of cesspools.

Lower Wadi es Sir (Western Sub-Basin)

- Alternative CW1. Proposed Action. Sewer system for lower Wadi es Sir. One plant.
- Alternative CW2. No-Project. Continued use of cesspools.

Na'ur (Southwest Sub-Basin)

- Alternative CN1. Proposed Action. Sewer system and treatment plant.
- Alternative CN2. No-Project. Continued use of cesspools.

Sahab (Southern Sub-Basin)

- Alternative CS1. Proposed Action. Sewer system for Sahab, One plant.
- Alternative CS2. No-Project. Continued use of cesspools.

Abu Alanda/Khirbet es Suq/Juweideh (Southern Sub-Basin)

- Alternative CAA1. Proposed Action. Sewer system for all three towns. One joint plant.
- Alternative CAA2. No Project. Continued use of cesspools.

<u>Wastewater Treatment Alternatives</u>

AWSA System

- Alternative TA2. Proposed Action for AGTP, UWATP and KRTP. Secondary treatment by roughing filters followed by the activated sludge process. Sludge digestion for AGTP and KRTP. Sludge from UWATP to be processed at AGTP and KRTP.
- Alternative TA3 (long-term). Add effluent filtration to all 3 plants.
- Alternative TA4. No-Project. Existing AGTP plus improvements now in progress.

Sukhneh

- Alternative TS1. Proposed Action. Wastewater treatment lagoons totally contained.

- Alternative TS2. No-Project. Continued use of cesspools.

  The treatment alternatives are also applicable to Hashimiya, Sahab and Abu Alanda et al.

Baqa'a Valley

- Alternative TB1. Proposed Action. Roughing filters followed by activated sludge treatment.

- Alternative TB2 (long-term). Add effluent filtration.

- Alternative TB3. No-Project. Continued use of cesspools.

  The treatment alternatives are also applicable to Fuheis/Mahis, Lower Wadi es Sir and Na'ur except that they are extended aeration plants with no provision for anaerobic sludge digestion.

Dewatering Alternatives

Amman/Zarqa-Ruseifa

- Alternative DA1. Proposed Action (short-term). Belt presses at Ain Ghazal, drying beds at Zarqa-Ruseifa and Khirbet er Ruseifa plant.

- Alternative DA2. Proposed Action (long-term). Belt presses at all three plants.

- Alternative DA3. No-Project. Same as Alternative DA1, except that there would be no downstream plant at Khirbet er Ruseifa.

All other Sites

- Alternative DO1. Proposed Action. Sludge drying beds.

- Alternative DO2. No-Project. Continued use of cesspools.

Effluent Use/Disposal Alternatives

- Alternative E1. Proposed Action. Aquifer recharge with improved quality water. Agriculture use from reservoir impoundments and/or groundwater aquifer. Indirect domestic use from groundwater aquifer.

- Alternative E2 (long term). Aquifer recharge with filtered effluent. Direct agriculture use. Indirect domestic use from groundwater aquifer.

- Alternative E3. No-Project. Continued aquifer recharge with substandard quality water. Effluent use is same as E1.

Sludge Use/Disposal Alternatives

All sites

- Alternative SU1. Proposed Action (short-term). Landfilling at proposed sites.

- Alternative SU2. Proposed Action (long-term). Use for reforestation/reclamation projects.

- Alternative SU3. Proposed Action (long-term). Use for agricultural projects.

- Alternative SU4. No-Project. Landfilling at existing dump site, small amount of agricultural use.

Sludge Transportation Alternatives

Ain Ghazal Treatment Plant

- Alternative ST1. Proposed Action and No-Project. Truck dewatered sludge (transition period would exist during which liquid and dewatered sludge would be trucked).

- Alternative ST2. Truck liquid sludge.

- Alternative ST3. Pump liquid sludge.

All other plants

- Alternative SO1. Proposed Action. Truck dewatered sludge.

- Alternative SO2. No-Project. Continued use of cesspools (surplus septage, trucked to treatment plants).

ENVIRONMENTAL CONSEQUENCES

Environmental consequences of most concern are those upon water resources, public health, and agricultural and silvicultural resources.

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WATER RESOURCES

There would be both positive and negative effects on water quantity as well as water quality as a result of project implementation. The effects may vary somewhat according to sub-basin. However, in all sub-basins there is the prospect that the provision of sanitary sewers and concurrent elimination of cesspools may stimulate an increase in water consumption. This could result from improved hygienic practices and from elimination of deliberate underutilization of domestic water supply in hopes of reducing frequencies of cesspool overflows/pumpouts. Availability of sanitary sewers could indirectly encourage development and use of indoor plumbing and water-using appliances.

Seil Zarqa Sub-Basin

The project alternatives for the Seil Zarqa Sub-Basin would decrease recharge of the upper aquifer by cesspool leachate. Cesspool effluent that would otherwise have filtered into the upper aquifer would instead be treated and discharged into the Seil Zarqa. Part of this water would percolate into the aquifers through the bed of the Seil Zarqa. The remaining would flow out of the Sub-Basin to King Talal Reservoir where it would be used for irrigation in the Jordan Valley, and/or would be lost to evaporation. Irrigation takes place along the Seil Zarqa also.

Cesspool effluent in 1976, was estimated to account for 18 MCM of recharge to the upper aquifer.[9] It was indicated that if this amount of recharge were discontinued (by sewering) and not replaced, that "a rapid long-term decline of the groundwater level would take place within Amman." However, since water would soon be imported to the Amman area in large amounts, the consultant estimated that the reduction in cesspool effluent recharge "will more or less be compensated by increased leakage from the water supply network." This estimate of water main leakage for the city of Amman only, however, (excluding the Zarqa-Ruseifa area) was 5 MCM by 1990. Tables 6-8 and 6-9 have previously indicated the magnitude of septage discharges underground, while Chapter 5 data have indicated water consumption projections.

There would be increased groundwater recharge by treated effluent in Seil Zarqa and other wadis. In 1976, about 4 MCM of treated effluent was recharged to the upper aquifer.[9] This was the entire amount discharged from the Ain Ghazal Treatment Plant except for losses to evaporation and irrigation use along the Seil Zarqa. More recently, however, AGTP effluent has been reaching King Talal Reservoir. Increased sewering, increased population, and increased water usage will result in increased flows of treated effluent from the AWSA system and in new discharges from the programmed Zarqa-Ruseifa plant. Data presented earlier in this Chapter have indicated the magnitudes of these and other effluent discharges. Within the Seil Zarqa, part of this increased flow will be lost to increased evaporation, part might be lost to increased agricultural use, and part will reach King Talal Reservoir. Recharge of the upper aquifer through the river bed will increase, however. Information is not available at this time to indicate what the infiltration rate would be under increased flow conditions, and it is therefore not possible to determine whether this amount, together with increased

leakage from the water system, would provide a balanced discharge/recharge condition for the aquifer. The net effect of the project considered by itself (without importation of water to Amman) would be a decrease in recharge of the Amman-Zarqa aquifers.

Alternative CA1 (with UWATP implemented) would facilitate effluent reuse in the upper plateau areas by virtue of its high location. Also, it would probably result in increased aquifer recharge via the streambed of the upper reaches of Wadi Abdoun with effluent discharged into the Seil Zarqa sub-basin.

Differences in total aquifer recharge between CA1 and CA2 cannot currently be assessed. Differences between these alternatives in evaporation losses are probably minor as regards Seil Zarqa discharge of effluent.

If UWATP effluent is used for irrigation in the plateau there would be a tradeoff between the beneficial uses gained thereby and the aquifer recharge lost. Some of the applied water would probably recharge the aquifer underlying the irrigated area; the remainder would be used consumptively. However, if UWATP effluent is discharged into the wadi system of Wadi el Kafrein, there could be aquifer recharge in that system as well as consumptive losses. There would be a corresponding reduction in the recharge potentials in Amman-Zarqa aquifer.

CA3, the No-Project Alternative, would result in the most recharge to the Amman-Zarqa aquifers (cesspool leachate) and in the least loss to the Study Area's water resources due to evaporation or evapotranspiration.

These tradeoffs as to the disposal/reuse of water resources must, however, include a consideration of the quality of water made available for each of the uses discussed. Beneficial uses of water cannot be claimed if the water quality is below permissible standards for the uses being considered. It is therefore necessary to consider collection and treatment alternatives jointly in order to determine the overall effect of any alternative on water resources.

Treatment Alternative TA2 would produce improved effluent quality, better than presently attainable, and hence would have better effect on water resources quality. Higher removal efficiencies of pollutants by the new plants and improved and expanded treatment at AGTP would reduce the net pollutant load into the groundwater aquifer. This is not, however, applicable to salt concentrations which are expected to be the same. Both salts and nitrate concentrations would be greater than recommended standards for groundwater recharge. The general improvement in water quality throughout the aquifer system might be accomplished at the expense of higher nitrates due to increased effluent flow through the river bed.

The No-Project Alternatives (CA3 and TA4) would provide for no approved direct use of wastewater. CA1 and CA2, together with TA2, would provide for acceptable irrigation use of the effluent from the King Talal Reservoir. Water reaching the reservoir would undergo further improvement during its storage in the reservoir, and would be diluted sufficiently by other impounded water to

achieve acceptable quality for irrigation. Direct agricultural use of the treated effluent would also undoubtedly occur along the Seil Zarqa, (but this cannot be considered an acceptable use since the effluent at that point would not be of sufficient quality for irrigation).

Alternative TA3 is a long-term step for effluent quality improvement. Addition of filtration would make the effluent suitable for direct irrigation. Addition of denitrification would improve effluent quality even more, making it more compatible with Drinking Water Standards as far as groundwater recharge is concerned. Thus, the implementation of TA3 would enhance the usefulness of effluent from any treatment plant. For UWATP (CA1), this could be particularly important because of its advantageous location with respect to probable points of reuse in the plateau.

For both CAS1 and CAH1, there would be a net depletion of the aquifer, for it is intended that the treatment plant effluent be evaporated from the lined total containment lagoons serving Sukhneh and Hashimiya respectively. This is of little consequence since their volumes would be rather insignificant especially when compared with those of AGTP, and UWATP. The treated wastewater would not be suitable for reuse. For the corresponding No-Project Alternatives, the status quo would remain concerning the aquifers quantity and quality.

Other Sub-Basins

Effects on water resources from the construction of sewage systems at Baqa'a Fuheis/Mahis, Lower Wadi es Sir, and Na'ur (Alternatives CB1, CF1, CW1, and CN1) would be similar to those described above for the AWSA facilities. Removal of cesspool leachate from the underground would improve groundwater quality. There would, however, be new flows of treatment plant effluent in the affected wadis. thse would carry that portion of the organic load and microorganisms not removed in the treatment process. There would be some effects experienced on the aquifers recharged by effluent flowing in these wadis. However, the overall effects upon groundwater quality would be beneficial.

Substitution of centralized sewage treatment and effluent disposal for individual cesspools will reduce the overall water resource quantities somewhat due to evaporation losses in wadis receiving the treatment plant effluent. It is possible that augmented streamflow in the wadis receiving the effluent will facilitate riparian irrigation, even before filtration is implemented. Without sufficient dilution and natural exposure to sunlight etc. the quality of the secondary effluent would fall short of that required for most agricultural irrigation applications.

At the plant sites for Baqa'a, Fuheis/Mahis, Lower Wadi es Sir, and Na'ur, the topography is such that there is not sufficient space for the use of wastewater treatment lagoons. Therefore, it is necessary to employ the more sophisticated and expensive secondary treatment process of roughing filters activated sludge (Baqa'a) or the extended aeration modification (for the other plants). This treatment produces a better quality effluent than does the lagoon treatment. This is of some significance because of public exposure, particularly in Wadi

Rumeimin downstream from the Baqa'a Plant, and groundwater quality impacts in general. The effluent from KHMC TP, which is currently substandard, is reportedly adversely affecting groundwater in the Upper Wadi es Sir area. Residents in the Wadi es Sir area would want reassurance that the proposed plant would produce satisfactory quality effluent.

The activated sludge plants for all of these outlying areas except Baqa'a Valley would be discharging effluent into wadis leading either to Kafrein Reservoir or Shu'eib Reservoir. The regulatory capacities of these reservoirs would assist in conserving the effluent for beneficial use and addition to the total water inventory.

For Sahab, Abu Alanda/Khirbet es Suq/Juweideh, Sukhneh and Hashimiya, sufficient land is available for facultative lagoons. Under the lagoons alternatives, treated wastewater would be disposed of by evaporation and/or percolation. This would not provide for use of the effluent. Since the water would not be of sufficient quality for recharge, degradation of groundwater supplies would probably result at each of these locations except possibly Sahab and Abu Alanda et al. Site specific investigation would be required to determine whether there would be any possibility of groundwater contamination at Sahab and Abu Alanda et al.

In each case except Sahab, the No-Project Alternative would result in continued leaching of cesspool effluent to groundwater supplies, with gradually increased deterioration of groundwater quality as populations grow (Alternatives CB2, CF2, CW2, CN2). At Sahab (Alternative CS2) the No-Project option would have no known adverse effects on water resources (benefits of sewering in this area would be related to economic and public health conditions).

As in the AWSA system the addition of filtration to effluent treatment would greatly increase the potential water resources benefits of the effluent. Due to better disinfection and resulting safer effluent to handle, filtration would allow direct use of the effluent for agriculture and other potential uses. However, this is a long-term objective due to the high cost involved.

Effects of Dewatering Alternatives

All liquid collected from sludge drying operations, whether belt presses or drying beds, would be returned to the treatment plant as a sidestream. There would be no percolation to groundwaters from either process, and therefore no direct effect on groundwater quality or quantity.

Effects of Effluent Use/Disposal Alternatives

Use of effluent of acceptable quality for irrigation purposes (Alternative E1) would probably result in small additional amounts of nitrate and salt loading in

waters underlying areas of irrigation use, since the treated effluent would probably be higher in nitrates and salts than waters would otherwise be used. Careful matching of application rates and crop requirements would minimize this impact.

There would be no effect on groundwater quality from indirect use of effluent via groundwater basins for domestic purposes..

The No-Project Alternative (E3) would result in continued degradation of groundwater supplies by cesspool leachate.

Specific impacts of the reuse alternatives can be determined only through a detailed quantitative comparison of the economic costs of the use of effluent versus the use of other available water supplies for irrigation or domestic purposes in various potential reuse area.

Effects of Sludge Use/Disposal Alternatives

Assuming the use of proper procedures to prevent runoff into nearby surface waters, the landfilling of sludge at proposed sites (Alternative SU1) would have no effect on water resources, since there is no continuity between surface and groundwater in the areas of the proposed landfill sites.

Continued landfilling of sludge at existing dump sites (No-Project Alternative SU4) would result in continued degradation of the quality of water underlying the dump sites, since all existing dump sites are in areas where continuity exists between surface and groundwaters.

The use of sludge for reforestation, land reclamation, or agriculture (Alternatives SU2, SU3) has the potential for degradation of ground and surface waters, depending on slope, soil type, hydrologic characteristics, application rate and technique, and characteristics of the sludge used in any given situation (see Chapter 8). The most significant concerns involve the potential for buildup of nitrates, heavy metals or pathogens. Such contamination could occur either through the leaching of liquid into groundwater supplies or through runoff into surface water.

Effects of Sludge Transporation Alternatives

Transportation of sludge in liquid form, either by pipeline or truck (Alternatives ST2, ST3) would result in greater possibility for contamination of ground or surface waters after delivery than transportation in dewatered form (Alternative ST1). There would be more potential for leachate and runoff from facilities for the use, disposal, or drying of liquid sludge than from facilities for dewatered sludge.

The No-Project Alternatives for the outlying areas (SO2) would mean the transportation of septage to sewage treatment facilities or to open area and designated disposal sites. This is the only transportation alternative available.

Disposal of septage to treatment facilities eliminates the possibility of direct contamination of groundwater by septage, however, it constitutes an additional organic load that has to be provided for.

Mitigation of Water Resources Impacts

It should be noted that the proposed project is itself a mitigation of an adverse impact on water resources, that is, the pollution of groundwater supplies by cesspool leachate. Implementation of the project alternatives would, however, cause other negative effects, some of which could be partially or competely mitigated.

Alternatives CA1 and CA2 would result in decreased recharge of the Amman-Zarqa aquifers. This could be mitigated by reducing extraction from the aquifers until a balanced condition resulted. Imported water would be required to make up for the reduction in groundwater extraction.

Pollution of groundwater along the Seil Zarqa by treated effluent (Alternatives CA1 or CA2 in combination with TA1 could be eliminated by piping the effluent to the northern edge of the recharge area of the Amman-Zarqa aquifers. However, this would further reduce recharge of the aquifers by both natural runoff and effluents and would require an even greater reliance on imported water to maintain a balanced water level in the aquifers.

The use of effluent or sludge for agriculture, reforestation, or land reclamation must be done only with strict safeguards to prevent contamination of water supplies. Application rates and methods of application must be carefully determined after consideration of soil types, slopes, hydrogeology and content of the effluent and sludge in order to prevent leaching or runoff of contaminants into water supplies. Particular care must be taken in the use of effluent or sludge on slopes in the vicinity of reservoirs, since runoff could result in degradation of reservoir water supplies.

PUBLIC HEALTH

Impacts of the Master Plan for Wastewater Disposal upon the public health in the Study Area would likely be experienced on a long-term basis. The improvement in public health will be particularly felt in the communities for which facilities for the collection, treatment, and proper disposal of wastewater will be implemented. The greatest benefit anticipated is related to the control of water-borne diseases and the protection of the public, particularly children of school age, from such diseases. These benefits are, of course, also attributable to improved water supply and general sanitation, which are not specifically part of this Master Plan. Refugee camps seem particularly in need of these improvements. (See comments elsewhere concerning immediate improvements for Baqa'a and Schneller Camps.)

In addition to public health benefits cited above, there could be still potentially adverse impacts which require mitigation measures.

The treatment of wastewater is not expected to yield virus-safe effluent, so there could be some public health exposure to virus-borne diseases. Filtration, if implemented on treatment plant effluent, could greatly enhance the effectiveness of disinfection and reduction of both bacteria and viruses. Normal secondary treatment does not reduce pathogenic bacteria or viruses to a safe level, so there is still some potential health hazard through application of secondary effluent for irrigation of root crops and other vegetables. Thus irrigation with chlorinated secondary effluent should be undertaken only with the additional safeguards of natural dilution, sun exposure during storage or stream flow and/or percolation and recovery as groundwater. Monitoring of effluent discharge and groundwater should be carefully conducted to anticipate potential adverse public health impacts.

Without nitrification-denitrification of treatment plant effluent, the contributions of nitrate to the groundwater resources, would continue to build up. The adverse effects of high nitrate in water supply could be mitigated by blending of low-nitrate waters with high-nitrate waters in public water systems prior to distribution.

Both municipal sewage and sludge can contribute macro- and micro-chemical pollutants to water and soil, depending upon actual conditions. If digested sludges from wastewater treatment plants are applied to land, there is a potential for human health problems arising from metal contaminants in the sludge. Of the most toxic trace metals thus released to the soils, cadmium seems to be of the most concern to human health. Although heavy metals contamination is not expected in the Study Area, these problems may be mitigated by controlled handling and application of sewage sludges, including careful monitoring.

As industrialization proceeds in the Greater Amman, Area, the potential for toxic industrial emissions into the aqueous environment increases. These may involve toxic trace elements. Where a municipal wastewater system is the vehicle for such potential emissions, mitigation could be sought via an agressive and effective industrial wastes ordinances and permit program. It is not anticipated that municipal wastewater treatment processes, such as those contemplated, will prove effecative in removing such trace contaminants; thus, source control will be required.

A long range recommendation of tahe Master Plan, is the reuse of effluent for various applications. In order for this to be feasible from a public health standpoint, public awareness and understanding must be developed. Institutional arrangements also for administering and implementing such programs are essential. In this connection, it will be important to recognize the differences that exist between urban and rural areas in socio-economic levels, educational status, hygienic practices, relative safety of water and food, available sanitary facilities, and provision of primary health care services.

An indirect impact of providing new municipal wastewater treatment plants and expansion of the existing AGTP could be upon mosquito breeding potentials, due to increased wetted surfaces in watercourses, and in correspondingly increased

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larvicidal chemical emissions to the environment in an effort to control nuisance mosquitoes and disease vectors such as malaria. Malaria control is becoming increasingly important due to the influx of expatriate workers from countries where malaria is endemic.

Schistosomiasis appears destined to become a significant public health problem unless appropriate preventive measures are undertaken. Inasmuch as this waterborne disease involves pollution by human body wastes and an intermediary host (water snails), it may be important to exclude waders and swimmers from all bodies of water affected by treatment plant effluent discharges. Seil Zarqa and King Talal Reservoir are reported already to have been affected by the intermediary host. Mitigation may require exclusion of personnel from body contact with these waters. Expatriate carriers from endemic areas may become present in sufficient numbers to help complete the development cycle of the parasite. Agriculture irrigation should probably avoid ridge and furrow application if there is a possibility of significant skin contact with the effluent by workers.

AGRICULTURAL AND SILVICULTURAL RESOURCES

The focus of the this area of concern, as expressed in the scoping meeting, is the potential for beneficial use of sludge and reclaimed water for agriculture, reforestation, or land reclamation (Alternatives E1, SU2, SU3). The use of treated effluent as an irrigation resource was discussed in the previous section, Water Resources. This section will therefore emphasize the potential effects on agricultural and silvicultural resources other than changes in the amount of water available for irrigation. These effects have to do primarily with changes in soil productivity.

Effects

Both treated effluent and sludge are a source of plant nutrients. Secondary effluent contains sufficient amounts of nitrogen, phosphorus, and potash to compare favorably with commercial fertilizers. Sludge compares less favorably as a source of nutrients. It contains nitrogen, some phosphorus, and small amounts of potassium. The nitrogen is released too slowly for effective use with short season crops. The primary value of sludge lies in its effectiveness as a soil conditioner. It has a high organic content, and is excellent for improving the structure of poor soils. Both sewage effluent and sludge can therefore have a positive impact on agricultural and silvicultural resources by improving soil fertility. Such benefits could be significant in Jordan, where the amount of arable land is limited, and where soils are often of poor quality.

Negative impacts on soil resources can also result, however, from poorly planned or managed effluent and sludge use programs. Improper effluent application rates can cause soil clogging, buildup of salts in the soil, and accumulation of heavy metals. The use of sludge can also result in buildup of heavy metals in the soil. These negative effects are less likely in reforestation or land reclamation uses where applications are not as sustained as in agricultural use.

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All alternatives that would provide for expansion of sewage systems and treatment facilities would increase the amount of sludge available for beneficial use compared with the No-Project Alternatives. Alternative CA1 might encourage more extensive use of effluent by making it more readily available for use in the upper areas of the Amman-Zarqa Basin and vicinity. Making the sludge available in dewatered form (Alternative ST1) rather than liquid form (Alternatives ST2, ST3) would probably result in greater acceptability by farmers and increased use.

An attempt to obtain estimates of the amounts of land potentially available for effluent and sludge application in the Greater Amman Area was partially successful.[10] It is not possible to make estimates as to potential increases in productivity, since these can vary greatly with different soils, crops, sludge and effluent characteristics, and management techniques.

Mitigation

The use of proper management techniques is essential to prevent negative impacts on soil resources from the use of effluent and sludge. These techniques include thorough analysis of effluent content, sludge content, and soil type, together with proper selection of crops to insure that nutrients are taken up by plants and do not accumulate in the soil.

ENERGY RESOURCES

Tabulations previously presented in this Chapter have set forth the energy requirements of the proposed systems for this Master Plan. These have ranged from negligible energy consumption for the treatment systems involving facultative, total containment lagoons (for Sahab, Abu Alanda/Khirbet es Suq/Juweideh, Sukhneh, and Hashimiya) to substantial energy consumption for the expanded AGTP and future UWATP and KRTP, where roughing filters/activated sludge is the selected process. The basic energy source would be public utility electric power.

The low technology plants (facultative lagoons) in effect use solar energy, as the photosynthesis by algae is the basic source of oxygen used for the wastes stabilization. These have been recommended for all locations where space and other considerations permit.

In several locations, including the existing AGTP site, the available space is too limited to permit the adoption of low technology treatment. Also the flows are too great to make evaporation disposal practicable. Therefore, it has been necessary to employ roughing filters/activated sludge as the basic process. This has the disadvantage of being fairly energy-intensive but has the distinct advantage of producing an effluent of minimum quality for disposal in the adjacent wadis and in requiring minimal site space. For those larger plants where solids processing is to be undertaken (AGTP, KRTP, and Baqa'a) anaerobic digestion-produced gas will be burned to heat the incoming sludge, thus conserving energy. For AGTP, and the future KRTP sludge gas engine generators are being proposed to further increase the process' thermal efficiency. These are

mitigation measures. For the Fuheis/Mahis, Lower Wadi es Sir, and Na'ur plants, the facilities will be too small to warrant separate sludge digestion. The extended aeration process will be used and will provide in-stream aerobic digestion.

An additional mitigation being proposed for the small plants is the use of two-speed aerators. The lower HP speed will be used in the initial years, when flows are still fairly low, thus conserving energy. Later on, when the flows have built up sufficiently, the higher energy high speed will be used to produce the desired aeration.

ARCHAEOLOGICAL AND HISTORICAL RESOURCES

Recommended sites for the Ain Ghazal expansion, the Khirbet er Reuseifa Treatment Plant, and the plants at Upper Wadi Abdoun, Baqa'a, Fuheis, Lower Wadi es Sir, Na'ur, and Sahab have been visited by personnel from the Jordanian Department of Antiquities. These visits were brief inspections and not site surveys. Based on these visits and a search of archival records, the Department has determined that there are no know archaeological or historical resources at the proposed sites, and has issued permits for construction at these sites (Appendix C).

Effects on Resources

In an area as rich in archaeological and historical resources as Jordan, it is always possible that grading or excavation will reveal items of significance in areas not previously known to contain such resources. In particular, it is likely that the large amount of excavation that will be required for sewer systems will unearth findings of significance. The extensive size of these systems and the urban structures that presently overlie most of their length will preclude most prior survey work. The potential therefore exists for the damage or loss of artifacts and information if proper procedures are not followed to insure their protection.

There are no significant differences among alternatives relative to this impact category except the amount of grading or excavation required for each.

Mitigation

Site inspections should be made by qualified archaeologists during grading and excavation. Discovery of artifacts on a site during construction should result in a delay of work in the area of the discovery until the artifacts are properly salvaged. If such discoveries indicate that a site might have significant cultural value, a thorough survey of the site should be accomplished before continuing with construction.

BIOTIC RESOURCES

Construction of recommended treatment plants and sewage systems would result in the destruction of small amounts of vegetation and animal habitat. Previous tabulations in this Chapter have indicated site requirements for proposed plants. Most sites are already heavily disturbed, and no significant loss of vegetation or wildlife would occur for any alternatives. Differences among alternatives in this regard would be primarily a function of the amount of land disturbed. The No-Project alternatives would generally result in the least disturbance of vegetation and habitat, and those alternatives which include total containment lagoons or new drying beds in the most disturbance.

Effects on Resources

Effects on riparian habitats from discharge of effluent would include increased vegetation and animal habitat along the wadis as a result of the greater availability of water, and possibly some changes in species composition because of high levels of nitrogen and phosphorus in the water.

Effects on aquatic biota in streams and reservoirs would vary from place to place depending on the present quality of the receiving waters. In most cases effects would be negative because of the high nitrogen, phosphorus, and BOD content of the effluent. In particular, higher phosphate loading of the Seil Zarqa due to increased effluent flows would contribute to eutrophic conditions in the King Talal Reservoir. Greater effluent flows from the AGTP would also result in continuous flow downstream of the plant, which would cause more of the industrial wastes and agricultural runoff now discharged into the Seil Zarqa to reach the King Talal Reservoir. Therefore, effects on aquatic biota in all three reservoirs and in most streams would probably be negative. These effects would be most pronounced for those alternatives producing the most effluent No-Project alternatives producing the most effluent. No-Project alternatives, and total containment lagoons alternatives would produce less effluent than other alternatives.

Denitrification (TA3) would have an adverse impact on riparian biota. Due to the loss of nitrogen, the plant growth needed for the highly eroded wadis becomes rather inhibited. Denitrification would be beneficial to aquatic biota, however, since the improvement in water quality would discourage undesirable eutrophication and other forms of growth such as algal bloom.

Mitigation

Effects on terrestrial biota would be minor, and no mitigation is necessary. Increased levels of nutrient and BOD removal would reduce effects on aquatic biota, though it is not likely that these improvements would be significant in the Seil Zarqa or King Talal Reservoir unless other pollutant discharges into the Seil Zarqa were also reduced.

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LAND USE

Expansion of the AGTP is not likely to affect land use in the vicinity of the plant. There would be no significant worsening of nuisance conditions in the area of the plant, and it is possible that some decrease in odor would occur as a result of the proposed improvements. (See also comments in Appendix L.) It is doubtful that any land uses other than industrial facilities such as the existing slaughterhouse would occur in the vicinity of the plant with or without the implementation of the project.

The proposed UWATP would be located a distance from residential areas. Small amounts of agricultural land would be lost to plants construction in other places, but it is not likely that the new plants would have any significant effects on land use in their vicinities. Except for farm land and pasture, only scattered rural housing is in the immediate vicinity of these plant sites.

The expansion of sewer systems and increase of treatment capacities would not be likely to have any significant effect on growth in the Study Area, since the availability of water is far more important as a limiting factor. The location of sewer systems might have some effect on the distribution of growth in the Study Area. This would be minimal, however, since the location of the sewers is more a reflection of anticipated growth patterns than an influence on much patterns.

Wastewater effluents may affect land uses along the wadis into which they discharge. It is likely that unplanned agricultural and possibly other unsafe uses may be made of the effluent. Policies determining the type and location of planned uses of the effluent may affect to some degree the distribution of agricultural and industrial development within the Study Area. Such effects would be beneficial, since use of the effluent would allow increased flexibility on the siting of agricultural and industrial operations.

None of the proposed collection, treatment, or disposal/reuse options is in conflict with any existing land use plans or regulations for the Study Area.

No significant negative land use impacts would occur from any of the alternatives, and no mitigation is required.

CONSTRUCTION IMPACTS

Construction of treatment plants would result in temporary increases in noise and dust. These would occur in rural or commercial/industrial area, and would not be significant.

Construction of sewer systems, however, would occur to a large degree within street rights-of-way in populated areas. Such construction could be expected to cause significant local disruptions in traffic, as well as increased dust and noise. In this respect, Alternative CA1, with UWATP, has by far less adverse impacts than CA2, without UWATP, since the number and lengths of trunk sewers to be paralleled in CA1 is about 50 percent of that required for CA2. The location of

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the trunk sewers in fully developed and busy areas of town amplifies further the difference between the two alternatives. It is also possible that excavation might result in cracking or weakening of adjacent structures especially in steep sloped areas. There would be major differences between the project alternatives and the No-Project alternatives with regard to sewer construction impacts.

Construction of sewer systems should be scheduled so as to cause the least disruption of traffic, and detours should be carefully planned. Normal construction procedures for minimizing noise, dust, and damage to adjacent structures should be emphasized.

UNAVOIDABLE ADVERSE IMPACTS

The most significant potential impacts of the project involve the quantity and quality of water resources and the potential impacts on public health as related to water use and wastewater disposal. It is not possible to estimate accurately at this point the extent to which these impacts would be "unavoidable", since this would be determined by the success of mitigation measures that have still not been developed in detail (importation of water, sludge management and disposal procedures, etc).

The No-Project Alternatives would result in the continued degradation of groundwater resources by cesspool leachate, and probably in increasing health problems associated with such contamination and the absence of public sewage facilities in many areas.

Expansion of the sewage collection and treatment system would reduce groundwater contamination, but would also significantly decrease groundwater recharge. It can be argued that this should not be considered an adverse impact since the cesspool leachate now replenishing the aquifers is not of acceptable quality for such recharge.

Increased effluent flows from the expanded new sewerage systems would also degrade the quality of groundwater in the vicinity of streams carrying the effluent flows, in the streams themselves and in the King Talal, Kafrein, and Shu'eib Reservoirs. Effects on the water quality of the King Talal Reservoir are potentially the most significant, since this water may eventually be used for domestic purposes.

Small amounts of vegetation and wildlife habitat would be lost to the construction of new treatment plants, and degradation of water quality in streams and reservoirs by increased effluent discharges would adversely affect aquatic biota. Effects on biota of all kinds would be minimal, however, because of the degree to which biotic systems in the area have already been disturbed.

SHORT-TERM USES VERSUS LONG-TERM PRODUCTIVITY

In general, continuation of the No-Project Alternatives would result in long-term degradation of groundwater resources in the Study Area, while implementation of

improved collection and treatment facilities would protect these resources and slow their degradation. The project alternatives would also provide for more long-term flexibility in the use of the area's water.

Expanded collection and treatment systems would probably result in a trade-off between improved groundwater quality throughout most of the area's aquifer system and degraded groundwater quality along streams receiving effluent discharges. It is not possible to quantify this trade-off at this time, or to estimate its long-term significance. Water quality in the vicinity of the streams receiving effluent discharges should be carefully monitored to establish long-term trends.

The potential exists for long-term degradation of the water in the King Talal, Kafrein, and Shu'eib Reservoirs as a result of effluent flows into these bodies of water. This situation must also be carefully monitored to preclude the possible loss of water resources in the reservoirs, and particularly in King Talal Reservoir. Reservoir dewatering, such as at Shu'eib would reduce the effects.

The use of sludge and to a lesser degree treated effluent for agricultural and silvicultural programs could result in long-term damage to soil resources unless strict management procedures are implemented to prevent the build-up of toxic substances in the soil.

Because of the large amount of excavation that will be required for the installation of sewers, there is a potential for the damage or loss of archaeological and historical resources unless strict management procedures are followed to prevent this.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Except for the construction and operating costs of the proposed systems in terms of funds, manpower, energy, and materials, the long-term effects of the project alternatives would be almost entirely reversible. About 815 dunums of land would be permanently committed to treatment plant locations. Financial costs of implementing the proposed schemes would be very high (see previous tabulation under "Cost Analysis,") and would be a major factor in the phasing of the Master Plan.

RANKINGS OF ALTERNATIVES

Alternatives have been proposed for several individual communities or groups of communities within the Study Area where populations are projected to be sufficiently large and/or wastewater disposal and water pollution problems sufficiently serious to qualify for incorporation in this Master Plan for Wastewater Disposal. These alternatives have been grouped acccording to the categories of wastewater collection, treatment, sludge dewatering, effluent use/disposal, sludge use/disposal, and sludge transportation. The various alternatives must now be compared for purposes of determining which alternative or group of alternatives is best for an individual community or group of communities. Following this, a second ranking is required which will enable priorities to be

established among the selected alternatives for the various communities on a regional basis.

The initial ranking may appropriately be undertaken on a relative basis, that is, comparing the alternatives for specific communities with each other according to environmental objectives. This determines the recommended alternatives for each sub-basin. For determination of regional rankings sufficient to establish priorities of projects, it is necessary to undertake rankings on a more absolute basis and to consider other factors as well as environmental aspects.

Ranking Criteria

The following criteria are employed in the initial ranking of alternative projects according to community and sub-basin:

- Water Resources - Alternatives are ranked with regard to the net effect in making available the greatest quantities of water for beneficial use, the quality of which must meet minimum accepted standards for such use. Flexibility and type of water use are also considered.

- Public Health - Alternatives are ranked according to anticipated beneficial effects in reducing groundwater pollution, particularly where water system conditions and operation may produce high vulnerability to back-siphonage of polluted water as a result of intermittent deliveries.

- Agricultural and Silvicultural Resources - Alternatives are ranked according to potential beneficial or detrimental effects on soil productivity.

- Energy Resources - Alternatives are ranked in inverse order of energy requirements.

- Archaeological and Historical Resources - Alternatives are ranked according to the amount of excavation or grading required for facilities construction, the least earthwork giving the highest ranking.

- Terrestrial Biota - Alternatives are ranked according to potential beneficial or detrimental effects on terrestrial biota, including riparian species.

- Land Use - Alternatives are ranked according to the amount of land that would be removed from other productive uses, the lower the loss of land the higher the ranking.

- Construction Impacts - Alternatives are ranked according to the amount of noise, dust, and traffic disruption that would result from facilities construction, a high ranking denoting minimal impact.

Initial Rankings

Table 9-13 presents the rankings of groups of alternatives for the various areas proposed to be served according to their relative impacts. "A" denotes least severe or most beneficial impacts. Rankings indicate order within a group only and not degrees of difference. The difference between "A" and "B" in a given group may be greater or less than the difference between "C" and "D" or the difference between "A" and "B" in another group. No attempt has been made to weight the various impacts. It should be noted that the scoping meeting identified the first four categories as being of most concern.

In a few instances, it may not be possible to differentiate among alternatives, in which case they are given identical ratings.

As a result of the comparisons among alternatives and rankings shown in Table 9-13, the following recommended alternatives are chosen according to communities served and sub-basins:

Sub-Basin Community and Alternative	Recommended Alternative	Remarks
Seil Zarqa, AWSA Collection	CA1	Best potential for use of water, agricultural, and silvicultural resources. Least disrupton of Amman Streets for trunk sewer construction. Best flexibility for potential salvage of effluent in Jordan Valley and for reducing impacts upon King Talal Reservoir.
Treatment	TA2	Provides the minimum effluent quality suitable for discharge in Amman-Seil Zarqa.
	TA3	For long range (or earlier) implementation to improve effluent quality.
Dewatering	DA1	Provides best balance of impacts for the next several years.
	DA2	Will be necessary after several years when ZRTP is expanded. (UWATP will not process sludge).
Effluent Use/Disposal	E1	Initial objective.
	E2	Long range objective.
Sludge Use/Disposal	SU1	For immediate future.

TABLE 9-13

INITIAL RANKING OF ALTERNATIVES

Wastewater Collection Alternatives (C)	Water Resources	Public Health	Agricultural and Silvicultural Resources	Energy Resources	Archaeological & Historical Res.	Terrestrial Biota	Aquatic Biota	Land Use	Construction Impacts
Amman-Zarqa Seil Zarqa Sub-Basin									
Proposed Action. Expand AWSA sewer systems. Provide four treatment plants.....CA1	A	A	A	B	C	A	B	C	C
Expand system. Provide three plants.....CA2	B	A	B	B	B	B	C	B	B
No-Project. Planned expansion only. Provide two treatment plants.....CA3	C	B	C	A	A	C	A	A	A
Proposed Action. Provide sewers and treatment plant for Sukhneh CAS1	A	A	B	A	B	A	A	B	B
No-Project. Continued use of cesspools.....CAS2	B	B	A	A	A	B	A	A	A
Proposed Action. Provide sewers and treatment plant of Hashimiya CAH1	A	A	B	A	B	A	A	B	B
No-Project. Continued use of cesspools.....CAH2	B	B	A	A	A	B	A	A	A
Baqa'a Valley (Northwest Sub-Basin) (CB)									
Proposed Action. Provide sewers and treatment plant for Baqa'a Valley CB1	A	A	A	B	B	A	B	B	B
No-Project. Continued use of cesspools CB2	B	B	B	A	A	B	A	A	A
Fuheis/Mahis (Western Sub-Basin) (CF)									
Proposed Action. Provide sewers and one plant for Fuheis and Mahis CF1	A	A	A	B	B	A	B	B	B
No-Project. Continued use of cesspools.....CF2	B	B	B	A	A	B	A	A	A
Lower Wadi es Sir (Western Sub-Basin) (CW)									
Proposed Action. Provide sewers and treatment plant.....CW1	A	A	A	B	B	A	B	B	B
No-Project. Continued use of cesspools CW2	B	B	B	A	A	B	A	A	A
Na'ur (Southwest Sub-Basin) (CN)									
Proposed Action. Sewers and treatment plant.....CN1	A	A	A	B	B	A	B	B	B
No-Project. Continued use of cesspools CN2	B	B	B	A	A	B	A	A	A
Sahab (Southern Sub-Basin) (CS)									
Proposed Action. Provide sewers and treatment plant.....CS1	A	A	A	B	B	A	A	B	B
No-Project. Continued use of cesspools CS2	B	B	B	A	A	B	A	A	A

TABLE 9-13 (Cont'd)

	Water Resources	Public Health	Agricultural & Silvicultural Resources	Energy Resources	Archaeological & Historical Resources	Terrestrial Biota	Aquatic Biota	Land Use	Construction Impacts
Abu Alanda/Khirbet es Suq/Juweideh (Southern Sub-Basin)(CAA)									
Proposed Action. Provide sewers for all three towns and a single treatment plant.....CAA1	A	A	A	B	B	A	A	B	B
No-Project. Continued use of cesspools.....CAA2	B	B	B	A	A	B	A	A	A
Wastewater Treatment Alternatives (T)									
Amman-Zarqa Seil Zarqa Sub-Basin (TA)									
Proposed Action. Roughing filters - act. sl., thickeners, digesters, other modifications AGTP.....TA2	B	B	A	B	B	B	B	B	B
Add effluent filtration and denitrification to all plants.....TA3	A	A	C	D	D	C	C	D	D
No-Project. Existing system plus improvements now in progress. Only AGTP and ZRTP.....TA4	D	D	D	A	A	A	A	A	A
Baqa'a Valley (Northwest Sub-Basin) (TB)									
Proposed Action. Roughing filters - act. sl., digesters.....TB1	B	B	A	B	B	B	C	B	B
Add effluent filtration and denitrification.....TB2	A	A	B	C	C	C	B	C	C
No-Project. Continued use of cesspools.....TB3	C	C	C	A	A	A	A	A	A
Fuheis/Mahis, Lower Wadi es Sir, Na'ur, Sahab, Abu Alanda et al, Sukhneh and Hashimiya (Western, Southwestern, Southern and Amman-Zarqa Sub-Basins) (TF)									
Proposed Action. Activated sludge treatment plants.....TF1	B	B	A	C	B	B	D	B	B
Wastewater treatment ponds.....TF2	C	A	C	B	D	D	A	D	B
Add effluent filtration and denitrification.....TF3	A	A	B	D	C	C	C	C	C
No-Project. Continued use of cesspools.....TF4	D	C	D	A	A	A	B	A	A
Dewatering Alternative (D)									
Amman/Zarqa-Ruseifa (DA)									
Proposed Action short-term. Belt presses at AGTP, sludge drying beds at ZRTP.....DA1	B	A	B	B	C	C	A	A	B
Proposed Action (long-term.) Belt presses at all three plants...DA2	A	A	A	C	B	A	C	B	B
No-Project altern. Same as DA1 except no KRTP.....DA3	C	A	C	A	A	B	B	B	A
Other Treatment Plant Sites (DO)									
Proposed Action period. Drying beds.....DO1	A	A	A	A	B	B	A	B	B
No-Project. Continued use of cesspools.....DO2	B	B	B	A	A	A	B	A	A

TABLE 9-13 (Cont'd)

	Water Resources	Public Health	Agricultural & Silvicultural Resources	Energy Resources	Archaeological & Historical Resources	Terrestrial Biota	Aquatic Biota	Land Use	Construction Impacts
Effluent Use/Disposal Alternatives (E)									
All Sub-Basins									
Proposed Action. Agricultural use, after reservoir impoundment or filtration.....E1	B	B	A	B	B	C	C	B	B
Indirect Domestic Use (after filtration/denitrification, and groundwater or reservoir dilution).....E2	A	A	C	C	A	B	A	B	B
No-Project. Continued inadvertent aquifer recharge by substandard quality water.....E3	C	C	B	A	A	A	B	D	A
Sludge Use/Disposal Alternatives (SU)									
All Sites									
Proposed Action (short-term.) Landfilling at all sites.....SU1	A	A	D	B	D	B	A	B	A
Proposed Action (long-term.) Use of reforestation/ reclamation projects.....SU2	B	B	A	B	B	A	C	A	D
Proposed Action (Long-Term.) Use for agricultural projects....SU3	B	C	B	B	B	D	D	C	A
No-Project. Landfilling at existing dump site, small amount of agricultural use.....SU4	D	D	C	A	A	C	B	A	A
Sludge Transportation Alternatives (ST)									
Ain Ghazal Treatment Plant									
Proposed Action and No-Project. Truck dewatered sludge (transition period would exist during which liquid and dewatered sludge would be trucked).....ST1	A	A	A	A	A	C	A	A	A
Truck Liquid Sludge.....ST2	B	B	B	B	B	B	C	B	A
Pump Liquid Sludge.....ST3	B	B	C	C	C	A	B	C	C
All Other Plants Which Produce Sludge (SO)									
Proposed Action. Truck dewatered sludge.....SO1	A	A	A	B	B	B	B	A	A
No-Project. Continued use of cesspools; septage trucked to treatment plants.....SO2	B	B	B	A	A	A	A	B	A

Note: See text for explanation of rankings.

Sub-Basin Community and Alternative	Recommended Alternative	Remarks
	SU2)	As soon as programs and controls can
	SU3)	be developed.
Sludge Transportation	ST1	This is the most flexible and satisfactory in the overall
Seil Zarqa Collection,		
Sukhneh	CAS1)	Alleviate groundwater pollution
Hashimiya	CAH1)	potential
Treatment		
Sukhneh	TF2)	Sufficient space available for low
Hashimiya	TF2)	technology plant
Dewatering		
Sukhneh	-)	No significant sludge accumulation in
Hashimiya	-)	facultative lagoons
Seil Zarqa		
Effluent Use/Disposal		
Sukhneh	-)	No effluent production. Total
Hashimiya	-)	containment lagoons
Northwest Sub-Basin, Baqa'a		
Collection	BC1	Includes north-draining Suweileh
Treatment	TB1	Too much space required for lagoons
	TB2	Long range objective (or earlier)
Dewatering	DO1	
Effluent Use/Disposal	E1	Immediate future
	E2	Long range objective
Sludge Use/Disposal	SU1	Immediate future
	SU2)	As soon as programs and control can
	SU3)	be developed
Sludge Transportation	SO1	
Western Sub-Basin		
Collection		
Fuheis/Mahis	CF1	
Lower Wadi es Sir	CW1	

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Sub-Basin Community and Alternative	Recommended Alternative	Remarks
Treatment		
Fuheis/Mahis	TF1)	Not enough room for lagoons
Lower Wadi es Sir	TF2)	Long range objective (or earlier)
Dewatering		
Fuheis/Mahis	DO1	
Lower Wadi es Sir		
Effluent Use/Disposal		
Fuheis/Mahis	E1	Immediate future
Lower Wade es Sir	E2	Long range objective
Sludge Use/Disposal		
Fuheis/Mahis	SU1	Immediate Future
Lower Wadi es Sir	SU2)	As son as programs and controls can
	SU3)	be developed
Sludge Transportation		
Fuheis/Mahis	SO1	
Lower Wadi es Sir		
Southwest Sub-Basin, Na'ur		
Collection	CN1	
Treatment	TF1	Not enough room for lagoons
	TF2	Long range objective (or earlier)
Dewatering	DO1	
Effluent Use/Disposal	E1	Immediate future
	E2	Long range objective
Sludge Use/Disposal	SU1	Immediate future
	SU2)	As soon as programs and controls can
	SU3)	be developed
Sludge Transportation	SO1	
Southern Sub-Basin		
Collection		
Sahab	CS1	
Abu Alanda et al	CAA1	

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Sub-Basin Community and Alternative	Recommended Alternative	Remarks
Treatment		
Sahab	TF2)	Sufficient space available to permit
Abu Alanda et al	TF2)	low technology treatment
Dewatering		
Sahab	-)	No significant sludge accumulation
Abu Alanda et al	-)	in facultative lagoons
Effluent Use/Disposal		
Sahab	-)	No effluent production. Total
Abu Alanda et al	-)	containment lagoons

NEED FOR ENVIRONEMNTAL MONITORING

A project of the extent and scope of the Master Plan for Wastewater Disposal is bound to have effects upon the environment of the Greater Amman Area. It behooves the Government to institute an adequate environmental monitoring program at the earliest possible time for the following purposes:

- Establishing baseline conditions against which future conditions may be compared and the effectiveness of the project assessed.
- Modifying the planning and management of wastewater disposal facilities and various environmental resources to maximize benefits and minimize detriments in the light of future conditions as they unfold.
- Improving the criteria by which future facilities and resources management plans are developed.

Baseline Data

The NRA, Ministry of Agriculture, RSS and other governmental agencies have already established background data in many areas, and there are plans to augment this information. Specific areas in which certain data deficiencies appear in need of correction include:

- Surface water quality in the various wadis already receiving or destined to receive treatment plant effluent.
- Public and private exposure to and use of waters flowing in these wadis; also the extent of the "live streams" in dry weather.
- Groundwater quality in areas affected by or to be affected by effluent discharges, such as via various wadis.

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- Groundwater piezometric levels in various groundwater basin areas, preferably on an annual basis for most areas and a seasonal basis in certain key locations.
- Irrigation water quality, particularly where drawn from potentially polluted sources.
- Irrigation and cropping practices involving waters that already are or may be affected by effluent disposal.
- Effects upon soils, crops, and landscapted areas receiving diluted or undiluted effluent.
- Treatment plant sludge quality.
- Treatment plant sludge quantities and dispositions.
- Effects upon soils, crops and trees receiving treatment plant sludges, as compared with those without such sludges.
- Wastewater treatment plant influent and effluent qualities based on flow-proportional composite sampling.
- Additional hydrologic data, particularly for streamflow.
- Water system accounting, particularly in the matter of production versus actual deliveries.

The foregoing data are either directly or indirectly involved in the environmental monitoring that should be undertaken to provide a periodic assessment of the effects of the project. Water and other quality determinations should be expanded as much as possible to include parameters and characteristics of relevance to human health and the environment. Existing and newly acquired data should be collated and analyzed and background conditions determined.

Monitoring Program

The recommended monitoring program would basically be an extension and continuation of the program to establish the baseline data. The data would be augmented by actual wastewater production/discharge values as they occur together with sludge production/disposal values. Values for industrial discharges would be included. It would also be necessary to include non-point sources of pollution such as agricultural fertilizers, insecticides, and pesticides. Mosquito abatement activities involving applications of poisons or pollutants should also be assessed. There should also be additonal data acquired on quantities and qualities of storm run-off from both urban and rural areas.

Periodic appraisal of these data should be made and reported to all concerned. The period should preferably be annual but not less than biennial.

Institutional Aspects

The Government Agency that should be given the authority and responsibility for environmental monitoring could be any one of several, including:

- Natural Resources Authority (NRA)
- Ministry of Municipal and Rural Affairs and the Environment (MMRAE)
- Ministry of Health
- Proposed National Water and Sewerage Authority
- National Planning Council (NPC)
- Royal Scientific Society (RSS)

Inasmuch as the monitoring would involve primarily technical activities, it would appear logical to assign the responsibility to an existing or proposed organization already having technical expertise in its staff and capabilities in its laboratories. This would normally be the most efficient procedure.

An alternative would be for laboratory work to be conducted under agreement between a professionally staffed agency having no laboratory facilities and an agency having both laboratory facilities and staff.

From a philosophical point of view, it is sometimes found desirable to separate the responsibilities for monitoring from those of operating facilities producing the need for such monitoring. Where separate agencies have these separate responsibilities, the monitoring results may be somewhat less subject to possible bias then otherwise.

In any event, the monitoring should be undertaken diligently and methodically by the assigned agency or agencies and the results reported both to NPC and the the Prime Minister.

MINIMIZATION OF ADVERSE IMPACT THROUGH CONSTRUCTION PLANNING

Some general observations may be made on construction planning that will lead to minimization of adverse impact during project implementation, viz:

- To the extent possible, sewer construction should be coordinated with other utility construction involving public rights-of-way, including resurfacing activities, so as to minimize disruption of traffic circulation, pavement cutting, and related costs and annoyances.
- Sewer construction should be coordinated with treatment plant construction (new, upgrading, or enlargement) so that both are completed and

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ready for activation at about the same time, thereby minimizing the commitment of funds prior to commencement of benefits derived.

- Projects should be planned for implementation with due consideration to possible competing ventures involving qualified construction contractors and with realistic time frames for procurement and delivery of manufactured equipment, particularly that which is of foreign manufacture. Where warranted, consideration may be given to separate contracts for equipment procurement and equipment installation.

- Projects involving existing facilities that must remain in operation must be carefully designed and contractors required to follow proper sequences of work to ensure uninterrupted facilities operation.

- Projects promising the most immediate benefit should be constructed first and vice versa.

- Where existing facilities are not yet approaching an overload conditin, enlargment or modification of same may properly be given a lower priority than those that already are hardpressed or soon will be. Spreading out of trunk sewer construction over a period of a few years may be appropriate in some circumstances, particularly where economic and employment considerations may be important factors.

- Where possible, construction projects should be timed so that the bulk of the earthwork will have been completed before the rainy season begins. This will help minimize soil erosion.

- Only first class quality of equipment, materials, and workmanship should be accepted, thus minimizing contractor disputes and the need for reconstruction of defective facilities.

In addition to the general comments above, some specific factors for the proposed Master Plan are:

- King Talal Reservoir is already being impacted by effluent discharges from AGTP and probably by certain industrial discharges. It should be of the highest priority to effect needed expansions and upgrading at AGTP so that the impacts attributable to this source may be minimized. This is important inasmuch as additional connections to AWSA sewers continue to be made and wastewater flows increase.

- Lateral sewer construction programs within AWSA should be reviewed to ensure that there will be early utilization of the sewers at a significant level. Otherwise, consideration might be given to projects elsewhere having significant needs for funding and promising at least equivalent benefits.

- Construction contracts should be so drawn up that if archeological finds are made during the course of the work, the delays caused by their identification and recovery may properly be absorbed without excessive delays or expense. To this extent, the full cooperation of the Department of Tourism and Antiquities will be essential.

SELECTION OF REGIONAL PRIORITIES

The alternatives recommended for the various sub-basins as the result of the Environmental Assessment are to be prioritized on a regional basis. These various recommended alternatives for wastewater collection, treatment, disposal/reuse, and for sludge dewatering, transportation, and use/disposal comprise individual systems for the communities that they are proposed to serve. It is these systems that are now to be prioritized. To do so requires more absolute criteria than were previously employed.

REGIONAL RANKING CRITERIA

There are four basic quantitative parameters for regional ranking comparisons. These are:

- Annual Costs expressed on a per capita basis.
- Total investment expressed on a per capita basis.
- Annual energy consumption expressed on a per capita basis.
- Septage withdrawn from groundwater recharge expressed on an aeral basis related to a community's presumed zone of influence.

In addition to the foregoing, there are certain quantitative ranking indices. Also, a generalized cost-benefit analysis is undertaken to illustrate the relative merits of the individual systems.

Annual Per Capita Costs of Systems

Table 9-14 presents a listing of the annual per capita costs of alternative wastewater systems proposed to serve the several communities within the Greater Amman Area. The AWSA system of alternatives appears most economical of those analyzed.

Total Investment Per Capita

This is a measure of funding requirements. Table 9-15 presents the estimated per capita funding requirements, the investment being taken as the project costs of the respective systems. The investments shown are successive, not cumulative, for the two periods 1980-90 and 1990-2000.

TABLE 9-14

ANNUAL PER CAPITA COSTS OF ALTERNATIVE WASTEWATER SYSTEMS[a]

System of Alternatives	Areas Served	1990 Pop'n 1,000	1990 Annual Cost 1,000 JD	1990 Annual Cost JD/Capita	2,000 Pop'n 1,000	2,000 Annual Cost 1,000 JD	2,000 Annual Cost JD/Capita
CAI, TA2, DA1, E1, SU1, ST1	Amman, portions of Wadi es Sir, Suweileh, & Suburban Ring	592	4,722 (5,122)[b]	8.0 (8.7)[b]	1,573	11,838 (12,238)	7.5 (7.8)[b]
CASI, TF2	Sukhneh	3.6	52.4	14.5	5.6	72.3	12.9
CAH1, TF2	Hashimiya	3.0	58.0	19.3	4.8	77.3	16.1
CB1, TB1, DO1, E1, SU1, SO1	Baqa'a Valley, portion of Suweileh	82.8	823	9.2	103.2	1,031	10.0
CF1, TF1, DO1, EL, SU1, SO1	Fuheis/Mahis	6.7	134.7	20.1	9.5	167.5	17.6
CF1, TF1, DO1, E1, SU1, SO1	Lower Wadi es Sir	15.3	231.1	15.1	22.5	327.0	14.5
CN1, TF1, DO1, E1, SU1, SO1	Na'ur	4.0	71.7	17.9	6.9	103.4	15.0
CS1, TF2	Sahab	11.0	146	13.3	16.0	179	11.1
CAA1, TF2	Abu Alanda/Khirbet es Suq/Juweidah	11.0	164	14.9	15.3	169	11.0

[a]See previous tabulations, this chapter, for basic data.

[b]To include the approximate effects of the recently tendered sludge expansion facilities in AGTP, use the numbers shown in paratheses ( ).

TABLE 9-15

PER CAPITA INVESTMENTS OF ALTERNATIVE WASTEWATER SYSTEMS[a]

Areas Served	1990 Pop'n 1,000	1990 Project Cost JD 1,000	1990 Investment JD/Capita	2000 Pop'n 1,000	2000 Project Cost JD 1,000	2000 Investment JD/Capita
Amman & Vicinity	592	27,530	47	1,573	49,584	32
Sukhneh	3.6	428	119	5.6	164	29
Hashimiya	3.0	473	158	4.8	164	34
Baqa'a et al	89.8	6,089	68	103.2	1,274	12
Fuheis/Mahis	6.7	892	133	9.5	98	10
Lower Wadi es Sir	15.3	1,792	117	22.5	539	24
Na'ur	4.0	452	113	6.9	174	25
Sahab	11.0	1,240	113	16.1	272	17
Abu Alanda et al	11.0	1,383	126	15.3	33	2

[a] Systems represented in this and subsequent tables are similar to those of Table 9-10.

Annual Per Capita Energy Consumption

Table 9-16 presents a listing of the annual per capita energy consumption of alternative wastewater systems to serve the several communities within the Greater Amman Area. The facultative lagoon treatment, applied wherever possible, is the least energy-intensive, as expected. the Amman (AWSA) system is next most frugal with energy. Energy recovery by sludge gas engine-generator units would reduce the per capita energy consumption levels somewhat in the two AWSA plants incorporating sludge digestion (AGTP and KRTP).

Septage Withdrawn from Groundwater Recharge

Table 9-17 presents a simplified analysis of relative areal septage withdrawn via the proposed wastewater systems of the Study Area. The intent of Table 9-13 is to indicate the relative impacts of withdrawing septage discharges from the communities and diverting the wastewater flows to secondary treatment plants. The analysis utilizes the relative area concept previously presented in Chapter 6 with respect to current and possible future septage discharges to the undgerground.

Relative area in this report denotes a presumed area of influence of a community's septage discharges upon underlying aquifers or recharge areas, the areas arbitrarily being established by Thiessen Polygons. Such a procedure ignores the complexities of hydrogeology — which are beyond the scope of this Master plan study — and merely adopts a method of expressing the groundwater area under the presumed immediate influence of the urban center. In this method, it is readily apparent that a large urban center overlying a moderate sized relative area should produce a much greater relative areal septage load than a moderate sized community overlying a large relative area of groundwater influence. A perfect example of this is Amman and vicinity, which has a high relative septage load, in comparison with Sukhneh and Hashimiya, which have low relative septage loads.

This analysis deliberately ignores possible trade-off effects between discharging essentially raw wastewater underground and discharging secondary effluent into surface waters that may themselves recharge groundwater aquifers. Attention is confined to the former condition under the assumption that there is bound to be an overall benefit to the environment by converting from the former method of disposal to the latter. It is recognized that this may be an oversimplification, but it is sufficiently valid in this instance to be used as one of the quantitative parameters for regional ranking.

Other Ranking Factors

Other factors that should be considered when prioritizing alternative projects through regional ranking include:

- Relative benefits of alternative projects to differing income level populations.

TABLE 9-16

ANNUAL PER CAPITA ENERGY CONSUMPTION OF ALTERNATIVE WASTEWATER SYSTEMS[a]

Areas Served	1990 Pop'n 1,000	1990 Annual Energy Costs 10^6 kwh	1990 Annual Energy Costs kwh/capita	2000 Pop'n 1,000	2000 Annual Energy Costs 10^6 kwh	2000 Annual Energy Costs khw/capita
Amman & Vicinity[b]	872	13.2	15.1	1,853	25.1	16.0
Sukhneh	3.6	Negl.	Negl.	5.6	Negl.	Negl.
Hashimiya	3.0	Negl.	Negl.	4.8	Negl.	Negl.
Baqa'a et al	89.8	1.62	18.0	103.2	2.41	23.4
Fuheis/Mahis	6.7	0.42	62.7	9.5	0.61	64.2
Lower Wadi es Sir	15.3	0.31	20.3	22.5	0.69	30.7
Na'ur	4.0	0.22	55.0	6.9	0.36	52.2
Sahab	11.0	0.004	0.4	16.1	0.010	0.6
Abu Alanda/Khirbet es Suq/Juweideh	11.0	0.014	1.3	15.3	0.016	1.0

a Energy consumption levels of 1987 and 1995 are taken as being representative of the first and second periods, respectively, except for Amman and vicinity and Baqa'a et al, which use 1990 and 2000.

b For AWSA's system, it is proper to use the total (not incremental) population in computing per capita energy consumption, inasmuch as such consumption is based on total wastewater processing. Data shown are for net energy uses/costs, after accounting for power recovery at AGTP and (for year 2000) KRTP also.

TABLE 9-17

RELATIVE AREAL SEPTAGE LOAD WITHDRAWN VIA WASTEWATER SYSTEMS[a]

Areas[b] Served	Relative[c] Area, km^2	1990 Wastewater[d] Daily 10^3 m^3	1990 Wastewater[d] Annual MCM	1990 Wastewater[d] Relative m/yr	2000 Wastewater[d] Daily 10^3 m^3	2000 Wastewater[d] Annual MCM	2000 Wastewater[d] Relative m/yr
Amman & Vicinity	120	75	27.4	0.23	151	55.1	0.46
Sukhneh	450	0.26	0.095	0.0002	0.45	0.16	0.0004
Hashimiya	450	0.21	0.077	0.0002	0.39	0.14	0.0003
Baqa'a et al	340	4.0	1.46	0.0043	5.9	2.15	0.0063
Fuheis/Mahis	180	0.45	0.16	0.0009	0.70	0.26	0.0014
Lower Wadi es Sir	140	1.20	0.44	0.0031	1.90	0.69	0.0050
Na'ur	210	0.24	0.088	0.0004	0.48	0.18	0.0008
Sahab	170	0.66	0.24	0.0014	1.30	0.47	0.0028
Abu Alanda/Khirbet es Suq/Juweideh	170	0.66	0.24	0.0014	1.10	0.40	0.0024

a The analysis shown should be considered as approximate only and indicative of relative potential groundwater impacts of diverting wastewater of various communities from septage discharge into municipal wastewater systems producing secondary effluent with runoff into wadis.

b Same as for Tables 9-10 and 9-11.

c Relative area is estimated as the area of influence of the population area over the aquifer or recharge area below, based on Thiessen Polygons and including only the Study Area and proposed groundwater protection area (see Table 6-8.) For purposes of this analysis, certain approximations are made, viz:

- Upper Wadi es Sir, north-draining Suweileh, and various suburban ring communities which drain into the AWSA system are shown as if in the Amman relative area, even though some of the flow technically is originating in Wadi es Sir or Baqa'a area.

TABLE 9-17 (cont'd)

- o Both Sukhneh and Hashimiya are in the Zarqa relative area. Zarqa-Ruseifa project is not being evaluated here but is taken as programmed.
- o Baqa'a flows include not only the Baqa'a Valley but also north-draining Suweileh. The latter is also included in Amman & vicinity flow, for it would be diverted there by pumping if the Baqa'a project did not materialize or as an interim arrangement until the project was implemented.
- o Fuheis/Mahis are included in the Salt relative area.
- o Lower Wadi es Sir is entirely within the Wadi es Sir relative area. The Upper Wadi es Sir flow would actually be withdrawn from this area, not Amman's.
- o Na'ur is entirely within the Na'ur relative area.
- o Both Sahab and Abu Alanda/Khirbet es Suq/Juweideh systems lie within the Sahab relative area and close to the edge of the groundwater protection area.

d Wastewater flows are taken from previous tabulations, this Chapter, for the respective wastewater systems being proposed. For purposes of this analysis it is assumed that if the flow were not being taken into the wastewater systems, they would be discharged as septage via cesspools into the underground. Thus, the relative areal septage is the annual wastewater flow (MCM) divided by the relative area (km^2) to indicate the relative downward flow (m/yr) for the area.

- General flexibility of projects to adapt to changing conditions.
- General implementability.
- Needs for projects in comparison with other community needs.
- General environmental impact, beyond the energy and relative areal septage considerations.

The foregoing may only be presented in a qualitative sense because of limitations in available data or in means of readily quantifying those data that are available.

Benefits to Differing Income Levels

During the extensive field work conducted for this study, general impressions were gained of the income level represented in the various communities potentially to be sewered. The following qualitative appraisal has been made and is developed for use as a ranking parameter:

Community	Income Levels Represented	Remarks
Amman	Low - Refugee camps and southern areas	Already sewered or being sewered
	Middle - many centralized areas and some outer areas	Already sewered or being sewered
	Upper - outskirts, particularly western, such as Jabal Amman & Shmeisani	Many areas are now being sewered
University of Jordan and Vicinity	High for the most part Includes hospital and University Housing	Much area is already sewered via University of Jordan Pumping Station, this now to be supplanted by a gravity trunk sewer to UWATP
Jubeiha, Tila Al Ali, portion of Umm es Summaq	High for the most part	To be tributary to the trunk to UWATP
Khilda/Rural Khilda	Middle for the most part	
North-draining Suweileh	Mixture of low and middle. Pre-dominant level is low to middle	Could be pumped to gravity trunk to UWATP but will flow by gravity to Baqa'a Valley

Community	Income Levels Represented	Remarks
South-draining Suweileh, also KHMC and vicinity	Middle to high	For second stage connection to second gravity trunk to UWATP
Upper Wadi es Sir	Upper. Some middle	To be tributary to UWATP
Lower Wadi es Sir	Mixture of low and middle	To be served by Lower Wadi es Sir system
Marj el Hamam	Primarily middle	Could be tributary to AWSA network or pump to UWATP
Sukhneh	Predominantly middle	Separate facilities
Hashimiya	Some low, but predominantly middle	Separate facilities
Baqa'a Camp	Low	NPC decision made to provide special sewerage works
Safut and Ain al Basha	Mixture, predominantly middle	Tributary to Baqa'a system
Fuheis/Mahis	Mixture, predominantly middle	Separate facilities
Na'ur	Mixture, predominantly middle	Separate facilities
Sahab	Some low, but predominantly middle	Separate facilities
Abu Alanda/ Khirbet es Suq/ Juweideh	Abu Alanda is mixture; others are predominatly low	Separate facilities

In the light of the foregoing, the following characteristic income levels are likely to be benefitted by the wastewater systems adopted for the proposed alternative systems:

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Wastewater System	Characteristic Income Level to be Benefitted by Project	Communities Included
AWSA	Middle to Upper	Amman, portions of Wadi es Sir and Suweileh and Suburban Ring
Sukhneh	Middle	Sukhneh
Hashimiya	Lower to Middle	Hashimiya
Baqa'a	Lower	Baqa'a Camp, Safut, Ain al Basha, north-draining Suweileh
Fuheis/Mahis	Middle	Fuheis and Mahis
Lower Wadi es Sir	Lower to Middle	Lower Wadi es Sir
Na'ur	Middle	Na'ur
Sahab	Lower to Middle	Sahab
Abu Alanda/ Khirbet es Suq/ Juweideh	Lower to Middle	Abu Alanda/Khirbet es Suq/ Juweideh

Project Flexibility

The AWSA project involves expanding and extending an existing sanitary network and facilities for wastewater treatment. All other projects entail establishing a basic collection system of lateral and trunk sewers (including outfall sewer to the treatment plant) as well as a new treatment plant. The need for system flexibility may result from unforeseen changes in locations and rates of development and possibly from changing effluent use/disposal requirements that could differ significantly from those contemplated in this Master Plan.

For all treatment plants being proposed, including the three for AWSA, there is believed to be sufficient site space available to accommodate future filtration and denitrification, should these become necessary and desirable. In addition, there is an inherent treatment plant capability of accepting a moderate percentage more or less flow than the nominal plant capacity. Also, all recommended plant sites are sufficiently distant from existing population centers to allow for some development between points without disruption. In the cases of the proposed plants at Fuheis/Mahis, Lower Wadi es Sir, and Na'ur, there are topographic conditions along the wadis that limit expansion of plant sites. This reduces flexibility somewhat.

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As regards wastewater collection systems, most of those proposed have only limited trunk sewers in a primary network, and these are generally of a diameter considered to be minimum from a practical standpoint. There may therefore be somewhat less collection system flexibility for such systems than for a more extensive and diversified system such as AWSA's. Even so, the well defined terrain tends to restrict the routing of gravity trunk sewers to wadis and thus to make most systems in the Study Area generally equal in flexibility (or limited flexibility) as regards their collection systems. Exceptions may exist in the cases of Sahab and Abu Alanda/Khirbet es Suq/Juweideh where the terrain is flatter and more amenable to trunk sewer diversity than elsewhere.

It is concluded that the AWSA, Sahab, and Abu Alanda et al systems have greater collection system flexibility than the other systems and that this should be recognized in the regional rankings.

As regards treatment plant flexibility, it is difficult to distinguish among the various systems as to their relative merits. However, the AWSA system, by virtue of having multiple plants with some possibilities for capacity adjustment, is considered more flexible than the other systems.

General Implementability

This aspect has primarily to do with local and Governmental capabilities for financing and paying back the costs for facility construction. In this connection, the ability to stage the constructions, particularly the larger, capital-intensive projects is of some significance. Accordingly, the following comments are made with respect to the projects being proposed:

- Amman and Vicinity (AWSA System) - By far the largest capital expenditures would be involved here among all the projects. Trunk sewer reinforcement within Amman is already contemplated for stage construction over several years and is not a major factor. Trunk sewers for the peripheral areas are somewhat less amenable to stage construction. Two of these are foreseen as being built during the early part of the 1980-90 period, while a third is to be deferred until after 1990. Lateral sewer construction would be coordinated with trunk sewer construction.

  The chief cost item is that of expansion/upgrading of AGTP. An important, although less costly, investment is the proposed UWATP. The KRTP is a post-1990 project.

  A major part of the cost of the AGTP expansion/upgrading must be undertaken as a single project for engineering reasons. This would amount to about 65 percent of the First Phase work for AGTP. It is much larger than the total project costs of any of the other projects being proposed, including both sewers and treatment facilities. On the other hand, the benefitted population would be correspondingly higher than for the other projects in the Study Area.

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- For all other projects, stage construction is contemplated for the treatment facilities but would not be feasible for the trunk sewers. Lateral sewer construction would, of course, be staged to keep pace with development. The treatment plant staging, however, would be for two periods only: 1980-90, and 1990-2000, respectively. It would not generally be feasible for staging to take place within the First Phase Investment Program as in the case of AWSA facilities, although exceptions might be found. Therefore, on a relative standpoint AWSA's facilities would have somewhat greater implementability than those of the other projects.

As a result of the foregoing, it is concluded that AWSA's project is somewhat more implementable than those of other wastewater system provided that sufficient capital can be raised to proceed. The other projects are less capital demanding on an absolute basis but not on a relative (per capita) basis, as has previously been indicated in Table 9-15. The Government's special interest in Baqa'a Camp makes for extraordinary implementability for Baqa'a Valley Project.

Competing Community Needs

No special study was undertaken of this matter, but certain information generally available is believed sufficient to warrant the following observations:

- There are already many hospitals in Amman and immediate vicinity, including Zarqa, and Salt. Hospital care is generally available to the public. Wastewater facilities projects would apparently not be major competitors for public funds for hospitals. It is also understood that there are numerous health clinics dispersed throughout the Study Area. These are not normally as capital intensive as hospitals and would be even less in competition with wastewater facilities for public funds.

- Public schools are understood to be generally adequate and not a significant source of competition with wastewater facilities for public funds.

- There are public water supply facilities throughout the Study Area. However, as discussed in earlier chapters, these are not entirely adequate, mostly due to supply limitations but, in some instances, involving distribution facilities themselves. Certainly there is a need for extension of water distribution facilities within areas not now having sufficient — Baqa'a Camp is one example — and there is even a need for long range reconstruction of many water distribution systems to reduce the inordinate leakage that apparently is experienced. Primarily, however, the urgencies relate to water supply itself. These supply projects are already being undertaken on a regional basis. However, there may still be major supply undertakings needed within the next few years, and wastewater facilities programs could be in competition with these for public funds.

- Streets, highways, drainage, and other public utilities generally appear to be in a fair to good state of development and repair throughout the Study

Area and not in major competion with wastewater facilities for public funds.

In view of the above and the previously established conditions of water pollution and potential public health hazards resulting from present wastewater treatment/disposal practices, it is concluded that the proposed wastewater projects should generally occupy a fairly high priority among possible competing community needs. There appears to be no basis for differentiating among the proposed projects with respect to competing community needs except for Baqa'a Camp.

Other Environmental Impact Considerations

These considerations are those over and above the energy matters and groundwater pollution already addressed in Tables 9-16 and 9-17, respectively. As indicated previously, it is not possible to quantify most, if not all, of the significant environmental impacts that may be experienced. This is because of the complexities in such matters as water resources and the imponderables in such aspects as public health and archeological and historical resources. A possible indication of relative potential land use and construction impacts could be obtained by dividing the proposed site areas by benefitted populations and also lengths of sewers by populations. However, this would overlook significant differences that may exist among the various projects in land productivity, vulnerability of traffic circulation to temporary interferences from sewer construction, undiscovered archeological artifacts, and the like. Also, it would still leave unquantified most of the important types of impacts identified at the environmental scoping meeting.

As consequence of the above, it has been concluded as unjustified to attempt to differentiate among the various wastewater systems being proposed as regards as environmental impacts other than energy and septage aspects. Accordingly, they are all considered to be equal in this regard for the purpose of regional ranking of projects, except where unusual conditions require adjustments (Table 9-18).

REGIONAL PRIORITY RANKING OF PROJECTS

Table 9-18 presents the regional priority ranking of wastewater projects for the Greater Amman Area. The treatment facilities included in the system being ranked are limited to secondary (roughing filters-activated sludge or activated sludge alone) type for all installations except the facultative lagoon projects proposed for Sukhneh, Hashimiya, Sahab, and Abu Alanda/Khirbet es Suq/Juweideh. Consideration of the approximate costs and benefits of providing filtration and denitrification is considered subsequently.

Under the assumption that each of the ranking parameters bears equal weight to all the rest, the weighted ranking of each system is respresented inversely by the sum of the individual rankings by parameter. On this basis, Amman and vicinity is clearly the first in regional priority, Baqa'a second in priority, Lower Wadi es Sir third, etc. In general, these results harmonize with those developed merely by the exercise of intuitive judgment. There is probably not much actual difference

TABLE 9-18

REGIONAL PRIORITY RANKING OF WASTEWATER PROJECTS[a]

	I						1990				C O N D I T I O N											
	Per Capita Item																					
	Cost JD/yr.		Invest. JD		Energy Kwh/yr.		Relative Septage m/yr.		Income Levels Benefit		Project Flexi-bility		Imple-ment-ability		Com-peting Needs		Sub-total[b] of Rankings		Other[c] Envir'l Consid.		Total of Rankings	
Area Served	V	R	V	R	V	R	V	R	V	R	V	R	V	R	V	R	V	R	V	R	V	R
Amman & vicinity	8.7	1	47	1	15.1	4	0.23	1	M/U	4	F	1	G	2	Avg	2	16	1	1	1	17	1
Baqa'a Valley	9.2	2	68	2	18.0	5	0.0043	2	L	1	L	3	E	1	E	1	17	2	1	1	18	2
Lower Wadi es Sir	15.1	6	117	5	20.3	6	0.0031	3	L/M	2	L	3	S	3	Avg	2	30	6	1	1	31	3
Fuheis/Mahis	20.1	9	133	8	62.7	8	0.0009	5	M	3	L	3	S	3	Avg	2	41	9	1	1	42	4
Sukhneh	14.5	4	119	6	Negl	1	0.0002	7	M	3	L	3	S	3	Avg	2	29	4	14	4	43	5
Hashimiya	19.3	8	158	9	Negl	1	0.0002	7	L/M	2	L	3	S	3	Avg	2	35	8	9	2	44	6
Na'ur	17.9	7	113	3	55.0	7	0.0004	6	M	3	L	3	S	3	Avg	2	34	7	11	3	45	7
Abu Alanda et al	14.9	5	126	7	1.3	3	0.0014	4	L/M	2	M	2	S	3	Avg	2	28	5	18	5	46	8
Sahab	13.3	3	113	4	0.4	2	0.0014	4	L/M	2	M	2	S	3	Avg	2	22	3	25	6	47	9

[a]See Tables 9-14 through 9-17 for quantitative values listed. See discussion in text for qualitative values listed. Where the same quantitative or qualitative value is given to more than one area's system, the affected areas are given identical ranking values.

Abbreviations employed in the tabulations are as follows:

For Income Levels

- M/U Middle to Upper
- L Lower
- L/M Lower to Middle
- M Middle

For Project Flexibility

- F Fair
- L Limited
- M Moderate

For Implementability

- G Good
- S Satisfactory
- E Excellent. Limited to Baqa'a VTP because of the Government's great concern for improving conditions in the Baqa'a Camp

For Competing Needs

- Avg Average
- E Limited to Baqa'a VTP because of the Government's great concern for improving conditions in the Baqa'a Camp (water as well as wastewater)

[b]Subtotal of rankings gives an indication of relative importance of the project on a regional basis, assuming that all factors are of equal importance and are thus weighted evenly on an inverse basis. To a certain extent this assumption is justified, but the results tend to become somewhat distorted in the case of some of the rural areas, such as Sahab and Abu Alanda et al, where land costs and relatively flat terrain tend to produce favorable rankings vis-a-vis the closer-in urban areas located along steep wadis. For this reason, the final ranking factor "other environmental considerations" is also used as an adjustment factor.

[c]A certain amount of subjective judgment is exercised in establishing the rankings under this category. The adjustments, where employed, are justified on the basis of pragmatism to compensate for unreasonable conditions otherwise resulting from a uniform weighting of the ranking factors included in the subtotal. Where no adjustment is undertaken, uniform appraisals are given to the category of other environmental considerations.

[t]The primary basis for undertaking an individual project is that of priorities for 1990 conditions. In most cases, the priority rankings for 2000 conditions are generally similar to those for 1990 conditions, project-by-project.

TABLE 9-18

REGIONAL PRIORITY RANKING OF WASTEWATER PROJECTS[a]

Area Served	I Per Capita Item: Cost JD/yr. V	Cost JD/yr. R	Invest. JD V	Invest. JD R	Energy Kwh/yr. V	Energy Kwh/yr. R	Relative Septage m/yr. V	Relative Septage m/yr. R	2000 CONDITION: Income Levels Benefit V	Income Levels Benefit R	Project Flexibility V	Project Flexibility R	Implementability V	Implementability R	Competing Needs V	Competing Needs R	Subtotal[b] of Rankings V	Subtotal[b] of Rankings R	Other[c] Envir'l Consid. V	Other[c] Envir'l Consid. R	Total of Rankings V	Total of Rankings R
Amman & vicinity	7.8	1	32	8	16.0	4	0.46	1	M/U	4	F	1	G	2	Avg	2	23	3	1	1	24	1
Baqa'a Valley	10.0	2	12	3	23.4	5	0.0063	2	L	1	L	3	E	1	E	1	18	1	7	4	25	2
Lower Wadi es Sir	14.5	6	24	5	30.7	6	0.0050	3	L/M	2	L	3	S	3	Avg	2	30	5	1	1	31	3
Fuheis/Mahis	17.6	9	10	2	64.2	8	0.0014	6	M	3	L	3	S	3	Avg	2	36	7	1	1	37	4
Sukhneh	12.9	5	29	7	Negl	1	0.0004	8	M	3	L	3	S	3	Avg	2	32	6	6	3	38	5
Hashimiya	16.1	8	34	9	Negl	1	0.0003	9	L/M	2	L	3	S	3	Avg	2	37	8	2	2	39	6
Na'ur	15.0	7	25	6	52.2	7	0.0008	7	M	3	L	3	S	3	Avg	2	38	9	2	2	40	7
Abu Alanda et al	11.0	3	2	1	1.0	3	0.0024	5	L/M	2	M	2	S	3	Avg	2	21	2	20	6	41	8
Sahab	11.1	4	17	4	0.6	2	0.0028	4	L/M	2	M	2	S	3	Avg	2	23	4	19	5	42	9

[a] See Tables 9-14 through 9-17 for quantitative values listed. See discussion in text for qualitative values listed. Where the same quantitative or qualitative value is given to more than one area's system, the affected areas are given identical ranking values.

Abbreviations employed in the tabulations are as follows:

For Income Levels

- M/U Middle to Upper
- L Lower
- L/M Lower to Middle
- M Middle

For Project Flexibility

- F Fair
- L Limited
- M Moderate

For Implementability

- G Good
- S Satisfactory
- E Excellent. Limited to Baqa'a VTP because of the Government's great concern for improving conditions in the Baqa'a Camp

For Competing Needs

- Avg Average
- E Limited to Baqa'a VTP because of the Government's great concern for improving conditions in the Baqa'a Camp (water as well as wastewater)

[b] Subtotal of rankings gives an indication of relative importance of the project on a regional basis, assuming that all factors are of equal importance and are thus weighted evenly on an inverse basis. To a certain extent this assumption is justified, but the results tend to become somewhat distorted in the case of some of the rural areas, such as Sahab and Abu Alanda et al, where land costs and relatively flat terrain tend to produce favorable rankings vis-a-vis the closer-in urban areas located along steep wadis. For this reason, the final ranking factor "other environmental considerations" is also used as an adjustment factor.

[c] A certain amount of subjective judgment is exercised in establishing the rankings under this category. The adjustments, where employed, are justified on the basis of pragmatism to compensate for unreasonable conditions otherwise resulting from a uniform weighting of the ranking factors included in the subtotal. Where no adjustment is undertaken, uniform appraisals are given to the category of other environmental considerations.

[d] The primary basis for undertaking an individual project is that of priorities for 1990 conditions. In most cases, the priority rankings for 2000 conditions are generally similar to those for 1990 conditions, project-by-project.

between the indicated rankings for several of the projects, such as Abu Alanda el al vis-a-vis Sahab or Sukhneh vis-a-vis Hashimiya. Thus, if certain other factors should enter into the judgment, they should be recognized.

LEAST COST SOLUTION

The least capital and operations cost solution for the expansion and upgrading of the existing AGTP and/or for construction of new plants is embodied in the preceding tabulations of this Chapter and summarized in Tables 9-14 and 9-18.

SENSITIVITY ANALYSIS

It is appropriate to consider the effects upon the Master Plan if significant differences should develop in the future between actual and projected populations, wastewater production factors, and various cost elements. Such effects could be experienced in any of the systems being proposed. However, as the greatest stakes appear confined to the AWSA system, the primary emphasis of the analysis will be placed there.

Table 9-19 presents sensitivity analysis population data whereby assumed low and high population growth rates for the the 1979-2000 period of 3.00 percent per annum and 5.00 percent per annum, respectively, are applied. The results are compared with the 4.13 percent per annum growth rate used in this report. The alternative growth rates were arbitrarily assumed but were considered to represent reasonable outer limits for consideration.

It can be seen that the population variation for Amman plus Suburban Ring is roughly plus or minus 15 percent in 1990 and plus 5 percent or minus 26 percent in year 2000. The Amman plus Suburban Ring roughly approximates the future AWSA system.

Table 9-19 also indicates a possible future population variation for the remaining areas within Greater Amman Area of roughly plus or minus seven percent in 1990 and plus 35 percent/minus 15 percent for year 2000.

AWSA SYSTEM SENSITIVITY TO PROJECTION CHANGES

The socio-economic analyses presented in Chapter 3 and Appendix B have stressed the role that Amman's saturation population has upon influencing "spillover" growth into the surrounding "suburban ring." As Amman approaches saturation, growth in the Suburban Ring is accelerated and reaches its maximum once Amman can accept no more growth. With higher Study Area growth rates, saturation is achieved earlier, and vice versa. Inasmuch as Amman and most of the Suburban Ring may be generally considered as a unit as regards wastewater production, the plus or minus 15 percent population variations suggested for 1990 by Table 9-15 would be of particular interest to the treatment facilities. However, there could also be impacts upon the collection system's primary network if the flow variations were major on either a general or localized basis.

TABLE 9-19

SENSITIVITY ANALYSIS - POPULATIONS

Populations are in Thousands

Class	Growth Rate[a] 1979-2000 Percent	Year 1990 Study Area	Year 1990 Amman/ Suburban Ring	Year 1990 Other Areas	Year 2000 Study Area	Year 2000 Amman/ Suburban Ring	Year 2000 Other Area
Project	4.13	2,057	1,094	963	2,987	1,555	1,432
Low	3.00	1,833	935	898	2,365	1,144	1,221
High	5.00	2,270	1,251	1,019	3,559	1,630	1,929
Populations are expressed as percentage of Project Population							
Project	4.13	100	100	100	100	100	100
Low	3.00	89	85	93	79	74	85
High	5.00	110	114	106	119	105	135

[a] Annual growth rate for overall 21-year period (census date to planning horizon year) is expressed as annual percent, compounded annually.

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Another factor that could influence wastewater flows is per capita wastewater production, particularly if unit wastewater production factors were to vary in such a way as to accentuate population variations. In view of the current shortages of water and the probability of continuing need to emphasize consumer conservation, major increases in unit wastewater production factors would not be expected. Even so, it appears reasonable to consider the possibilities of about plus and minus 10 percent variation in future unit wastewater production, combined with plus and minus 15 percent deviation in Amman-Suburban Ring population for 1990. In round numbers, this corresponds to about plus and minus 25 percent of projected wastewater flow for 1990 condition. For year 2000 condition, the adverse combination of per capita wastewater flow and population deviations would correspond to about plus 15 percent minus 33 percent of projected wastewater flows.

Collection System Sensitivity

For increases in wastewater flow, trunk sewers of marginal capacity within the affected areas would require earlier relief than otherwise. Also, if it were apparent that the flows were becoming significantly larger than projected, the parallel relief sewers could be increased by one or more commercial pipe sizes as best determined by actual conditions. A common trunk sewer diameter in the relief sewers is 300 mm; another is 400 mm. It is noted that the capacity of a 400 mm diameter sewer is about 177 percent that of a 300 mm diameter sewer assuming same slope and flow conditions. Thus, a single pipe diameter increase for such relief trunks would readily accommodate flow increases of the magnitude contemplated, at least for the relief trunk reaches themselves. In comparison the price differential for the one size increase is only 17 percent. Special investigation would be needed for more precise determination of lengths and diameters of trunk sewers that would require additional reinforcement over that already included in the proposed systems. Such detail has not been considered in the scope of this report.

If the flow increases resulted solely from population increases, there would be no essential changes in wastewater concentrations. If increased per capita wastewater production were at least partially responsible for the flow increases, the wastewater would be correspondingly more dilute than otherwise and therefore less likely to produce sulfide.

If instead of flow increases, the future development resulted in less flows than projected, this would mean greater time intervals before relief sewers or second stage sewers would be required than otherwise. Inasmuch as the planning horizon is for year 2000 only, the capacities of trunk sewers sized for a projected year 2000 flow would be adequate for some years beyond year 2000. If a lower than projected unit wastewater production were to be experienced in the future, the pollutant concentrations would be increased inversely over projected values, which already contemplate per capita production increases. This would tend to make the concentrations more like their present levels than otherwise.

Treatment Facilities Sensitivity

The organic loading to the treatment facilities is basically a function of the tributary population. More tributary population means more solids to be removed and digested than otherwise as well as more aeration capacity for biological stabilization. Increased population also is likely to mean greater wastewater flows, requiring more hydraulic as well as organic treatment capacity for the plants. Increases in per capita wastewater production result in more dilute wastewater and shortened sedimentation tank and aeration tank retention times. The opposite is also true. In both instances adjustments can be made in design for an optimum balance.

The chief effect upon AWSA's treatment facilities of variations in wastewater flows would be limited by the tributary populations and flows, mostly from the westerly areas beyond Amman, including portions of Suweileh, Wadi es Sir, and the Suburban Ring. With greater than projected flows being experienced from these westerly areas, the enlargement for UWATP would logically be increased, and vice versa. On the other hand, AGTP's capacity is limited by existing site space. Thus, the KRTP plant capacity would be the ultimate adjustment up or down to accommodate unforeseen flow increases or smaller increases than had been expected. Site limitations for KRTP do not appear critical, although land in that area is relatively expensive.

The connecting trunk sewer between AGTP and KRTP would, of course, have to be of adequate capacity to meet actual flows experienced. If flows developed that were greater than inticipated, the trunk sewer might require paralleling, possibly before year 2000. However, it is more likely that differing growth and wastewater flow trends from those presently projected would have become evident by the time of design both of the trunk sewer and KRTP. In effect, the deferred nature of these downstream facilities provides considerable time for planners and designers to react appropriately to new developments in the next decade.

Within the size ranges of new treatment plants that would be involved in the AWSA system the economy of scale effects are not major for modest size changes. Thus, future wastewater production deviations within the ranges assumed above would not greatly influence unit costs of these facilities (JD/capita/yr.)

No illustration is presented as to conditions resulting from a growth slow-down and a less-than-anticipated wastewater production. It would simply mean that the costs would be spread over fewer people than otherwise. For example, a population of 85 percent of the currently projected service area population would be 0.85 (592/280) equals 741,000 persons total or 461,000 incremental benefitted population. If the total annual costs were spread only to the incremental population, this would correspond to (JD 4,793/461) or JD 10.4/c/yr, a 28 percent increase over that projected. Of course, if total population were used as the basis, the increase would be correspondingly less.

No illustration is presented of changes beyond 1990 as it is assumed that adjustments could properly be made to the planning during the latter part of the current decade in the light of developments as they appear.

SENSITIVITY OF OTHER SYSTEMS

Table 9-20 has indicated the possibilities of about plus and minus 20 percent population in 1990 and plus 35 percent/minus 15 percent in year 2000 populations. Combining such deviations with a 10 percent deviation in per capita wastewater production would produce even more extreme future flow deviations from those projected than anticipated for AWSA. The 10 percent deviation could be even on the low side considering the type of variables involved such as changes in social habits and installation of indoor plumbing facilities.

No attempt has been made herein to illustrate the possibilities of impacts upon facilities of such deviations. This is because of the many variables involved with the multiple systems outside the AWSA area. However, it is believed that the Government possesses considerable control over the planning that may affect such outside areas and that appropriate and time adjustments could be made in facilities implementation for such areas, particularly as they are considered to be of lower priority than the AWSA facilities.

The same principles as discussed for AWSA pertaining to the effects of significant future wastewater flow deviations would generally apply also to the outside areas. However, built-in flexibility should be provided in the design of the sewerage facilities to accommodate potential deviation in the projected future flows.

MASTER PLAN PROGRAM

Table 9-20 presents the recommended Master Plan Program for facilities construction in the Greater Amman Area. Lateral sewers are not listed but would be included pursuant to construction of trunk sewers to which they would discharge and to development of urban lands in which the wastewater would originate. Greater detail on the collection systems is presented subsequently in Chapters 10 and 12 of the Feasibility Report.

SPECIAL INTERIM MEASURES

Because of practical limitations on financial resources, it may be several years before many population centers in the Study Area are provided with centralized facilities, often essential to upgrading of sanitation conditions. This is because of priorities in allocating of resources for such works. In the interim, there may be certain measures that still-unsewered communities may adopt that can improve local conditions without incurring prohibitive expenses. These may involve a variety of arrangements for collection, treatment, and disposal of wastewaters, the specific combinations being best tailored to suit the actual needs and conditions of the individual community.

TABLE 9-20

MASTER PLAN PROGRAM FOR WASTEWATER FACILITIES CONSTRUCTION[a]

Service Area	1982-1990 Program Work Items[b]	Project Cost[c] JD 1,000
Amman and Vicinity	AGTP expansions, upgrading, sludge facilities	17,795
	Trunk Sewer Reinforcements, AWSA Network	292
	Marj al Hamam Force Main and Gravity Sewer	295
	Marj al Hamam Pumping Station	66
	UWATP, First Stage Construction, including land	3,030
	Sludge Line, UWATP to AWSA Network	165
	U of J Trunk Sewer to UWATP	849
	KHMC Trunk Sewer to UWATP	317
	Subtotal	22,809
Baqa'a Valley	Trunk Sewers	624
	Treatment Plant, including land	2,550
	Subtotal	3,174
Lower Wadi es Sir	Trunk Sewers	242
	Treatment Plant, including land	660
	Subtotal	902
GRAND TOTAL	Phase I, Master Plan	26,885

TABLE 9-20 (Cont'd)

MASTER PLAN PROGRAM FOR WASTEWATER FACILITIES CONSTRUCTION[a]

Service Area	1982-1990 Program Work Items[b]	Project Cost[c] JD 1,000
Amman and Vicinity	AGTP expansions, including sludge facilities	4,575
	Trunk Sewer Reinforcement, AWSA Network	326
	UWATP Expansion	6,045
	Trunk Sewer, AGTP to KRTP	500
	KRTP Construction	23,400
	Subtotal	34,846
Baqa'a Valley	Enlarge Treatment Plant	918
Lower Wadi es Sir	Enlarge Treatment Plant	450
Fuheis/Mahis	Trunk Sewers	275
	Pumping Station	69
	Force Main	15
	Treatment Plant	301
	Subtotal	660
Sukhneh	Trunk Sewers	42
	Treatment Plant	300
	Subtotal	342

TABLE 9-20 (Cont'd)

MASTER PLAN PROGRAM FOR WASTEWATER FACILITIES CONSTRUCTION[a]

Service Area	1982-1990 Program Work Items[b]	Project Cost[c] JD 1,000
Hashimiya	Trunk Sewers	85
	Treatment Plant	275
	Subtotal	355
Na'ur	Trunk Sewers	141
	Treatment Plant	195
	Subtotal	336
Abu Alanda/Khirbet es Suq/Juweideh	Pumping Stations	27
	Force Mains	39
	Trunk Sewers	339
	Treatment Plant, including land	920
	Subtotal	1,325
Sahab	Trunk Sewers	254
	Pumping Station	23
	Force Main	33
	Treatment Plant, including land	543
	Subtotal	853
GRAND TOTAL	Phase II, Master Plan	40,085

FOOTNOTES FOR TABLE 9-20

a Projects are listed generally according to the regional priority rankings presented under Table 9-18, and data are drawn from previous tabulations in this chapter except that Table 9-20 reflects a late decision to sewer North-draining Suweileh to Baqa'a Valley Treatment Plant and to divert Marj al Hamam flow to UWATP by pumping. For simplicity, lateral sewers, house connections, and their sewer manholes have not been included in the project cost data herein. However, they are included in the tabulations of Chapter 12 dealing with financing and revenue programs.

b The special provisions for Marka Refugee Camp are not included in this tabulation as the project was developed in connection with a special study undertaken subsequent to preparation of this Master Plan.

c All project costs are expressed in terms of late 1980 price levels. Appropriate escalation factors should be applied to convert these values to current or future levels.

For certain areas within a community or even for whole communities, if sufficient space is not normally available on individual building lots vis-a-vis requirements for on-site disposal, it will be necessary for at least a portion of the wastewater to be transported elsewhere, leaving only that portion of the flow that can be absorbed without undue difficulty in local cesspools. Depending upon local circumstances, flow may be removed periodically from individual cesspools on a scheduled basis by a local operating agency or it may be found preferable to link several cesspool systems together by small overflow sewers discharging into a common sump, from which the surplus septage is then regularly withdrawn. This latter arrangement would leave grease, other scum, and sludge to accumulate gradually in individual cesspools, requiring eventual cleanout but at very infrequent intervals. Removal of surplus septage from a few centralized locations would be somewhat more expeditious than from multiple, private lots. The septage might even be piped to a nearly treatment-dispoal site(s), within or adjacent to the community, if such should exist.

Treatment and disposal of septage on-site would normally be via community septic tanks and leaching cesspools and/or leaching tile fields, depending upon local circumstances. However, other possibilities would, of course, be considered. For example, there might be benefits enjoyed in converting community septic tanks to aerobic treatment for reasons of improving the leaching characteristics of the effluent. Also, in addition to cesspools or normal tile fields, consideration could be given to "mound" disposal, which relies upon local seepage via an improved design for effluent retention-distribution, and evapotranspiration disposal, which makes use of the moisture-absorbing characteristics of overlying vegetation. All on-site disposal systems would, of course, remain below ground. In some instances, with proper design, it would be permissible to provide a playground or park above the system at the surface, so that there would be a double benefit to the use of the land.

Where insufficient capabilities exist for on-site community treatment-disposal systems, the septage would be transported from the community to treatment-disposal elsewhere. Normally, this would be done by septage tank trucks, although under certain favorable circumstances it might be possible to pump septic tank effluent through a small diameter pipeline to a treatment-disposal facility, provided there is one such within reasonable distance. For example, the so-called STEP (septic tank effluent pumping) system has been employed in various localities in the United States with favorable results. These have sometimes involved publicly operated wastewater treatment facilities of conventional design. For outlying communities within the Greater Amman Area, it is likely that well-designed lagoons would prove very satisfactory for treatment of septage, whether they receive their flow via tank truck or via pipeline or a combination thereof. Disposal of lagoon effluent may be via percolation, irrigation, evaporation, or evapotranspiration, depending upon a review of local circumstances. Crop irrigation would, of course, be limited to those types suitable for undisinfected effluent, e.g, fodder and fiber crops. The entire operation would be of a rural nature and considerably less costly than a conventional sewerage system.

In the United States, on-site, wastewater management districts have been established in certain rural or semi-rural areas to oversee, assist, operate, and or facilitate the operation of these interim measures/facilities for wastewater collection/treatment/disposal. Their roles can range from educational-advisory only to complete operation. The centralized effort is invariably more efficient than the collective individual efforts of the participants. In the Study Area, a variety of administrative possibilities could be considered, and the apropriate one selected for one specific area might not necessarily be the best choice for another area. It is expected that the Water Supply Corporation, the Ministry of Health, and the National Planning Council would be in the best position to guide and implement the necessary interim physical and administrative measures for communities or portions of communities in need of improved sanitation but not having sufficient priority in the allocation of national resources to be provided with conventional sewerage facilities for the foreseeable future. Where appropriate, any interim facilities that become provided might anticipate the future possibility of conventional facilities and remain adaptable to same where reasonable.

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FINAL MASTER PLAN REPORT AND ENGINEERING DESIGN AND ECONOMIC ANALYSIS REPORT FOR WASTEWATER DISPOSAL FOR GREATER AMMAN AREA

VOLUME II

CHAPTERS 10-12

PLUS APPENDICES

PREPARED FOR

NATIONAL PLANNING COUNCIL
THE HASHEMITE KINGDOM OF JORDAN

FEBRUARY 1982

JMM/DMJM

-A JOINT VENTURE-

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CONSULTING ENGINEERING CENTER
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February 5, 1982

His Excellency The President
Dr. Hanna Odeh
National Planning Council
Box 555, Amman, Jordan

Re: Final Master Plan Report and Engineering Design and Economic Analysis Report for Wastewater Disposal for Greater Amman

Dear Dr. Odeh:

Pursuant to the agreement of May 17, 1980 between the National Planning Council and James M. Montgomery, Consulting Engineers, Inc., and DMJM International, a Joint Venture in association with Consulting Engineering Center, we are pleased to submit the Final Master Plan Report and Engineering Design and Economic Analysis Report for Wastewater Disposal for Greater Amman.

The subject report has been divided into two volumes. Volume I comprises Chapters 1-9, inclusive, and Volume II comprises Chapters 10-12, inclusive, plus the Appendices.

We express appreciation to the staff of NPC and the staffs of the many other governmental agencies for the cooperation extended us during the conduct of this important study.

Respectfully submitted,

Charles H. Lawrance,
Project Manager

Lee A. Francis
Senior Vice President
James M. Montgomery,
Consulting Engineers, Inc.

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CHAPTER 10

PRELIMINARY DESIGN AND COST ESTIMATE

INTRODUCTION

This chapter presents the Phase I Investment Program facilities for the Greater Amman area to cater to the needs up to 1990. Detailed descriptions, engineering data, and cost estimates are included. The work thus presented is the result of the regional priority rankings made in Chapter 9 for various wastewater projects in the Greater Amman area. The highest ranking of all was given to expansion and upgrading of the facilities of the Amman Water and Sewerage Authority (AWSA) and to certain new facilities that will serve developing areas westerly of Amman and integrate with those of AWSA. Due to the magnitude and cost of the work entailed as well as apparent limitations on available project funds, the Phase I Investment Program is limited to these facilities. Should additional funding become available, other high ranking projects defined in the Master Plan could be considered for implementation. (Subsequent special studies (in 1981) by the Consultant have resulted in accelerated projects for the Baqa'a Valley Treatment Plant project and the Lower Wadi es Sir Treatment Plant, not reported herein).

The Phase I Investment Program work involves the following:

- Upgrading and enlargement of Ain Ghazal Treatment Plant (AGTP).
- Construction of the new Upper Wadi Abdoun Treatment Plant (UWATP).
- Reinforcement of the AWSA primary sewer network.
- Construction of trunk sewers in certain areas westerly of Amman.
- Diversion of wastewater from the University of Jordan area to a new gravity trunk sewer leading to UWATP.
- Construction of sewage pumping stations and force mains for north-draining Suweileh for delivery of wastewater to the new University of Jordan gravity trunk sewer.
- Construction of secondary network facilities in newly sewered areas.

AIN GHAZAL TREATMENT PLANT

In order to be adequate for the wastewater flows of 1990, AGTP will need to be expanded to 60,000 cu m/da capacity by that year. A phased program of expansion and upgrading is necessary for the AGTP, so designed as to permit continuation of service at all times. The performance will be upgraded from the outset. The nature and the staging of work are dictated by the available site and the existing facilities.

APPROACH TO PLANT EXPANSION

The existing site is relatively narrow and of limited size (4.5 hectares). This is referred to herein as the northern plant site. It will be necessary for the municipally-owned vacant land between the existing AGTP facilities and the municipal slaughterhouse to be used for part of the AGTP expansion. This is referred to herein as the southern plant site (2.5 hectares). Even when the northern and southern plant sites are joined, their configuration will prevent centralization of facilities, as is usually desirable for ease of operation. This is illustrated in Figures 10-1 and 10-2.

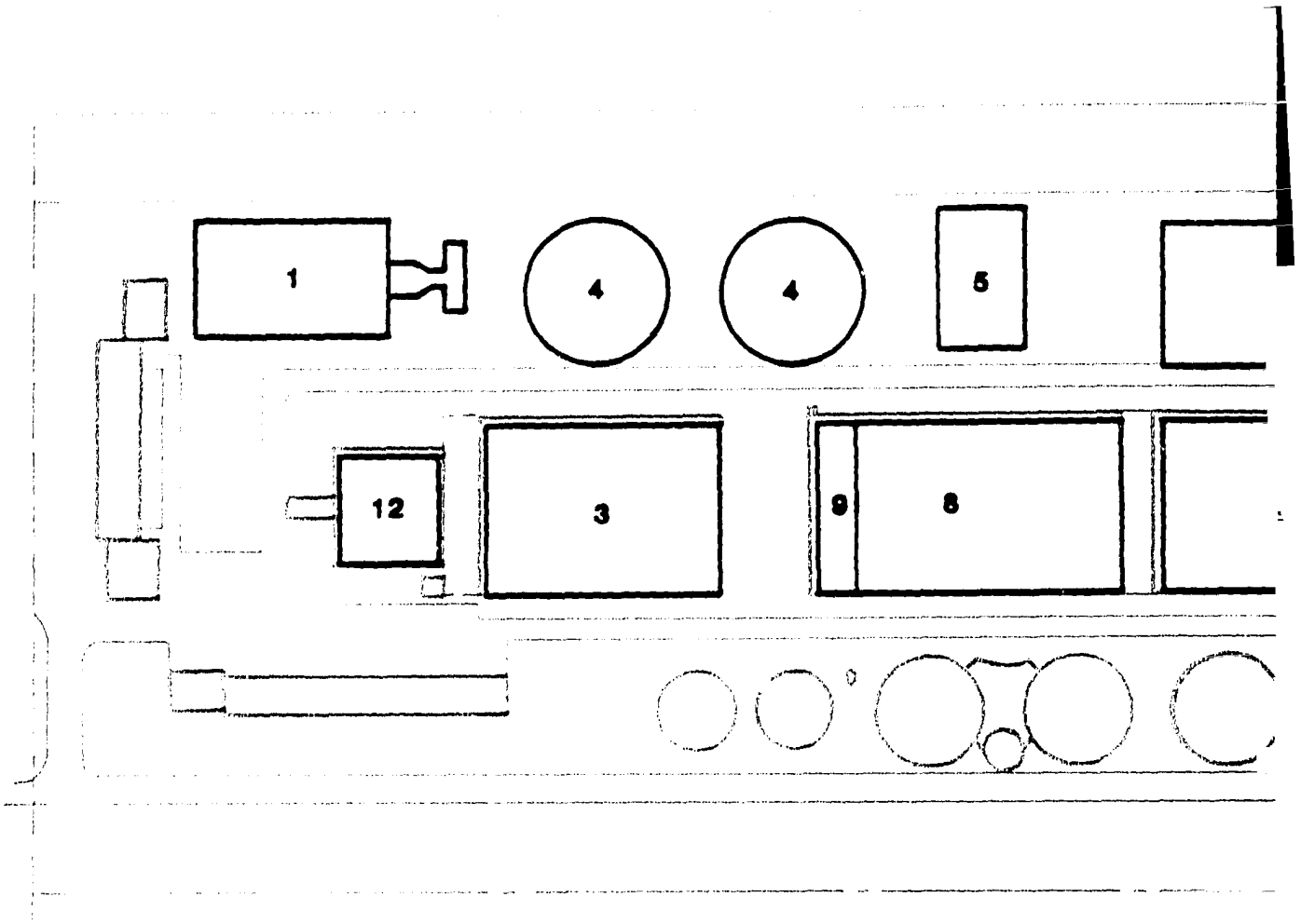
Figure 10-1 presents the AGTP Northern Site, Phase I Expansion. This shows a separate treatment plant at the existing site, including sludge digesters and digested sludge dewatering facilities. Special studies by the Consultant (in 1981) revealed the possibilities of upgrading, modifying, and expanding the existing facilities to produce a maximum capacity of 30,000 m^3/day. Despite site limitation, it will be possible to locate the ultimate digesters needed for year 2000 service on the northern site. Thus, it will not be necessary for any new digesters to be located on the southern site. This is illustrated in Figure 10-2, the AGTP Southern Site, Phase I Expansion. The plant capacity for Phase I is 30,000 m^3/day but the facilities will anticipate a future 50% expansion for an ultimate southern site plant capacity of 45,000 m^3/day, corresponding to a total future AGTP capacity of 75,000 m^3/day.

Comparison of Figures 10-1 and 10-2 shows that, in effect, there are two treatment plants on the expanded site formed by consolidation of the northern and southern plant sites. Administrative, maintenance, laboratory, chlorination, and sludge processing facilities will be centralized at the northern site as will the common headworks facilities. Otherwise treatment is split to the two respective sites.

The elongated nature of the site and decentralization of treatment units necessitates a substantial amount of yard piping. Both wastewater and sludge must be moved over relatively long distances thereby, entailing hydraulic losses. Figure 10-3 presents the AGTP hydraulic profile for 1990 conditions.

The secondary treatment process selected in Chapter 8 was roughing filters followed by conventional activated sludge employing mechanical aeration. (Improved diffused air aeration will be provided at the existing AGTP facilities, northern plant). Figure 10-4 presents the AGTP flow schematic, illustrating the process. The corresponding AGTP solids balance for 1990 is presented in Figure 10-5.

Set forth hereinafter are descriptions of individual plant units. These are followed by the cost estimates. Numbers and sizing of units are based upon available information at the time of report preparation and are considered adequate for budgeting purposes. However, they are subject to refinement during detailed design.



LEGEND: 1 = HEADWORKS (FOR NORTH &

2 = SEPTAGE FACILITIES

3 = MODIFIED PRIMARY CLARIFIERS

4 = ROUGHING FILTERS

5 = RECYCLE PUMP STATION

6 = INTERMEDIATE CLARIFIERS

7 = MODIFIED AERATION BASINS

8 = MODIFIED FINAL CLARIFIERS

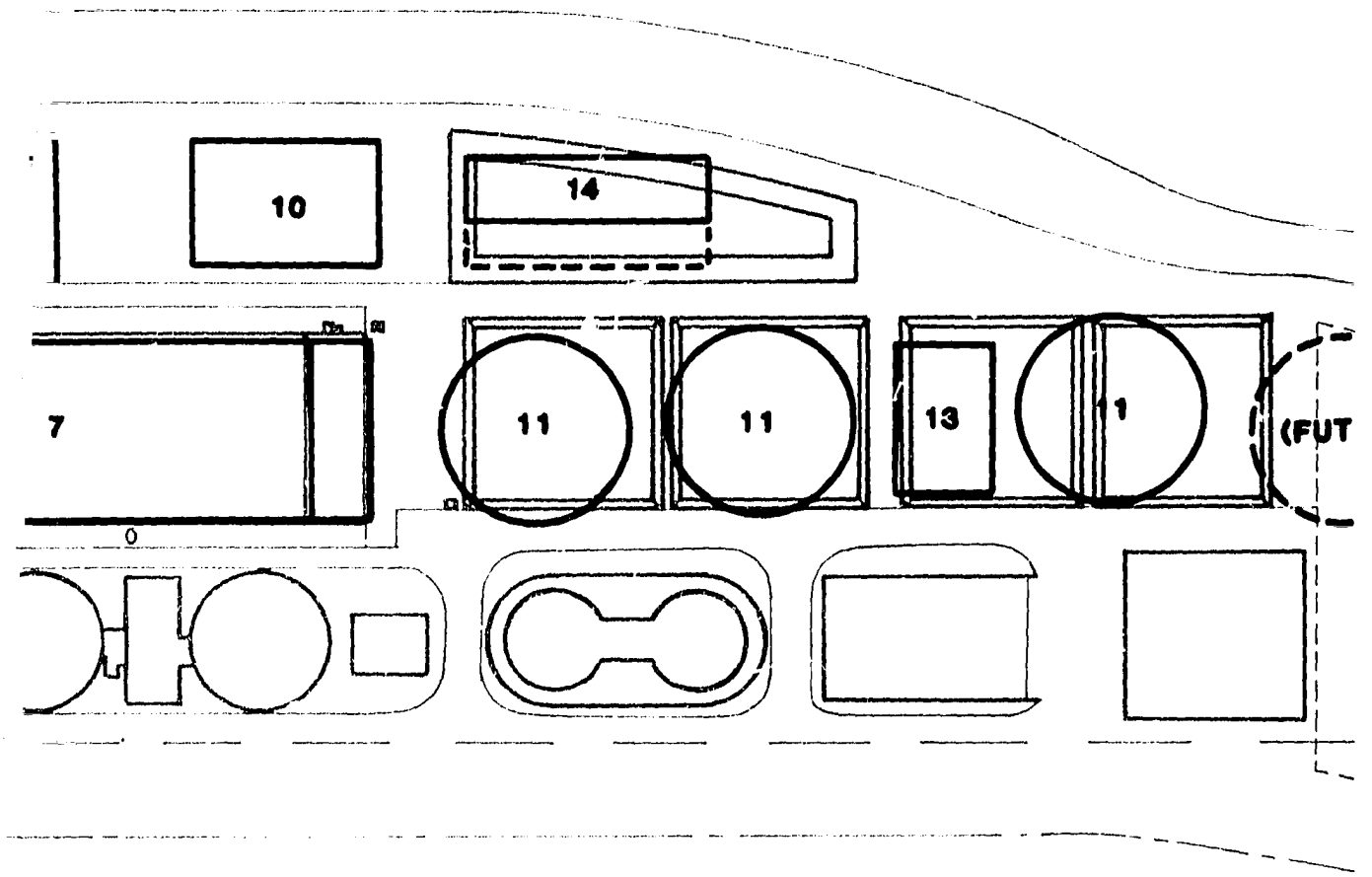
9 = MODIFIED RAS/WAS PUMP ST.

10 = ENGINE GENERATOR BUILDING

11 = ANAEROBIC DIGESTERS

12 = SLAUGHTERHOUSE WASTE FAC.

13 = DIGESTER CONTROL BUILDING



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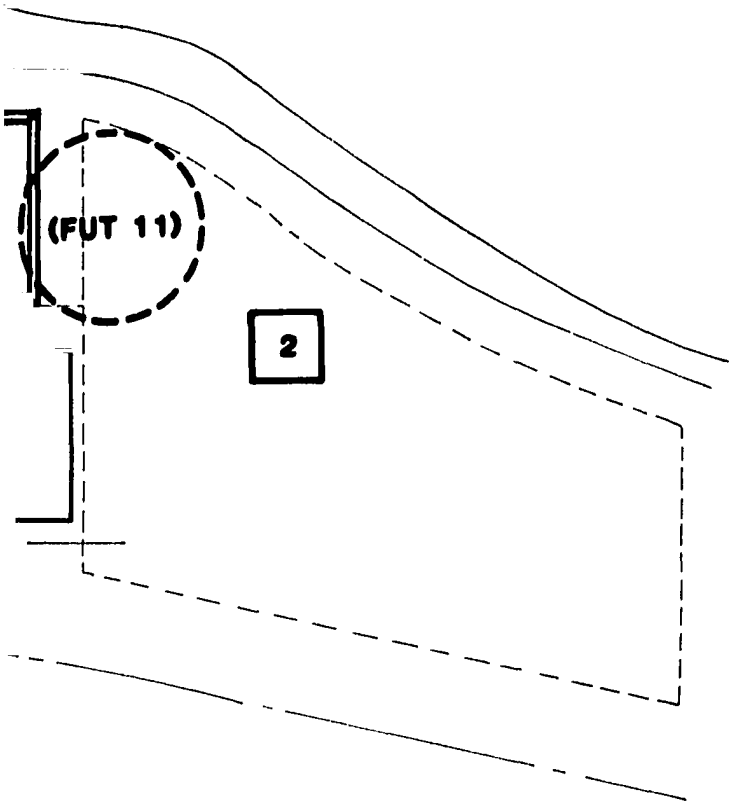
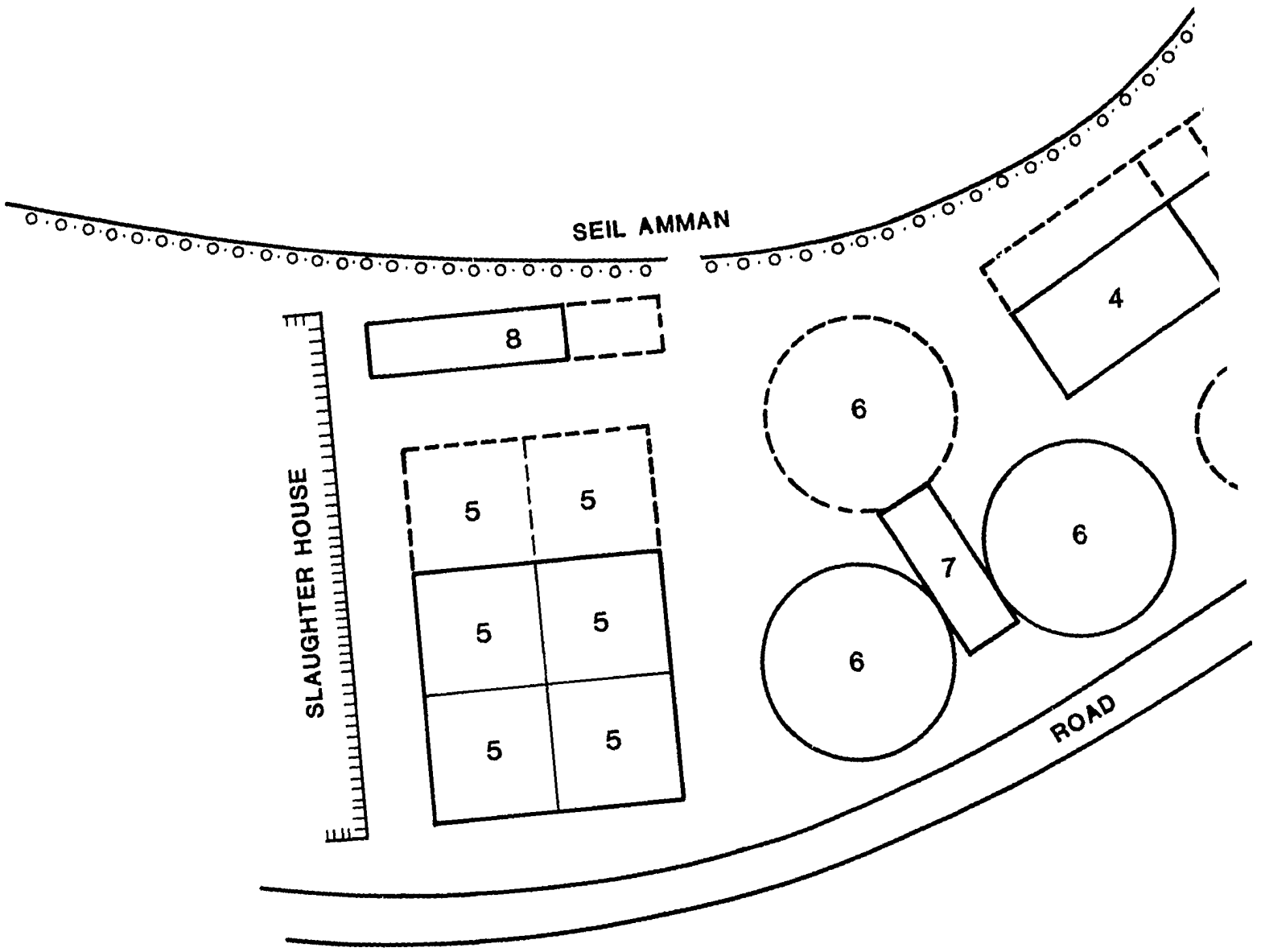


AIN GHAZAL TREATMENT PLANT
NORTHERN SITE
PHASE I EXPANSION

FIGURE 10-1



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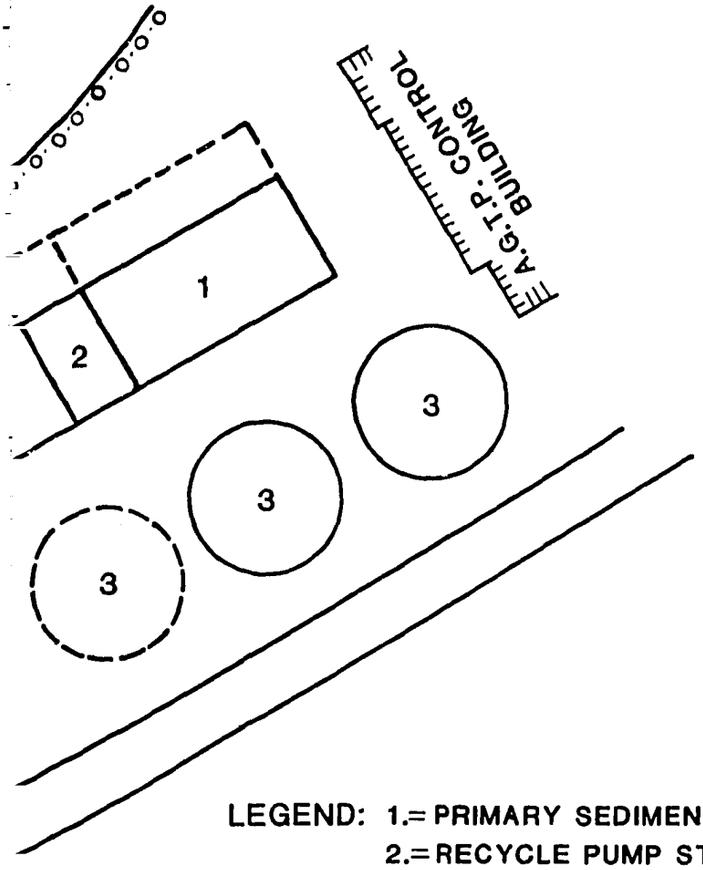

LEGEND: 1.= PRIMARY SEDIMENTATION
2.= RECYCLE PUMP STATION
3.= ROUGHING FILTERS
4.= INTERMEDIATE CLARIFIERS
5.= AERATION TANKS
6.= SECONDARY CLARIFIERS
7.= RAS/WAS PUMP STATION
8.= CHLORINE CONTACT

——— 1990 CONSTRUCTION

- - - - - - POST 1990 CONSTRUCTION

AIN GHAZAL
TREATMENT PLANT
SOUTHERN SITE
PHASE I EXPANSION

FIGURE 10-2

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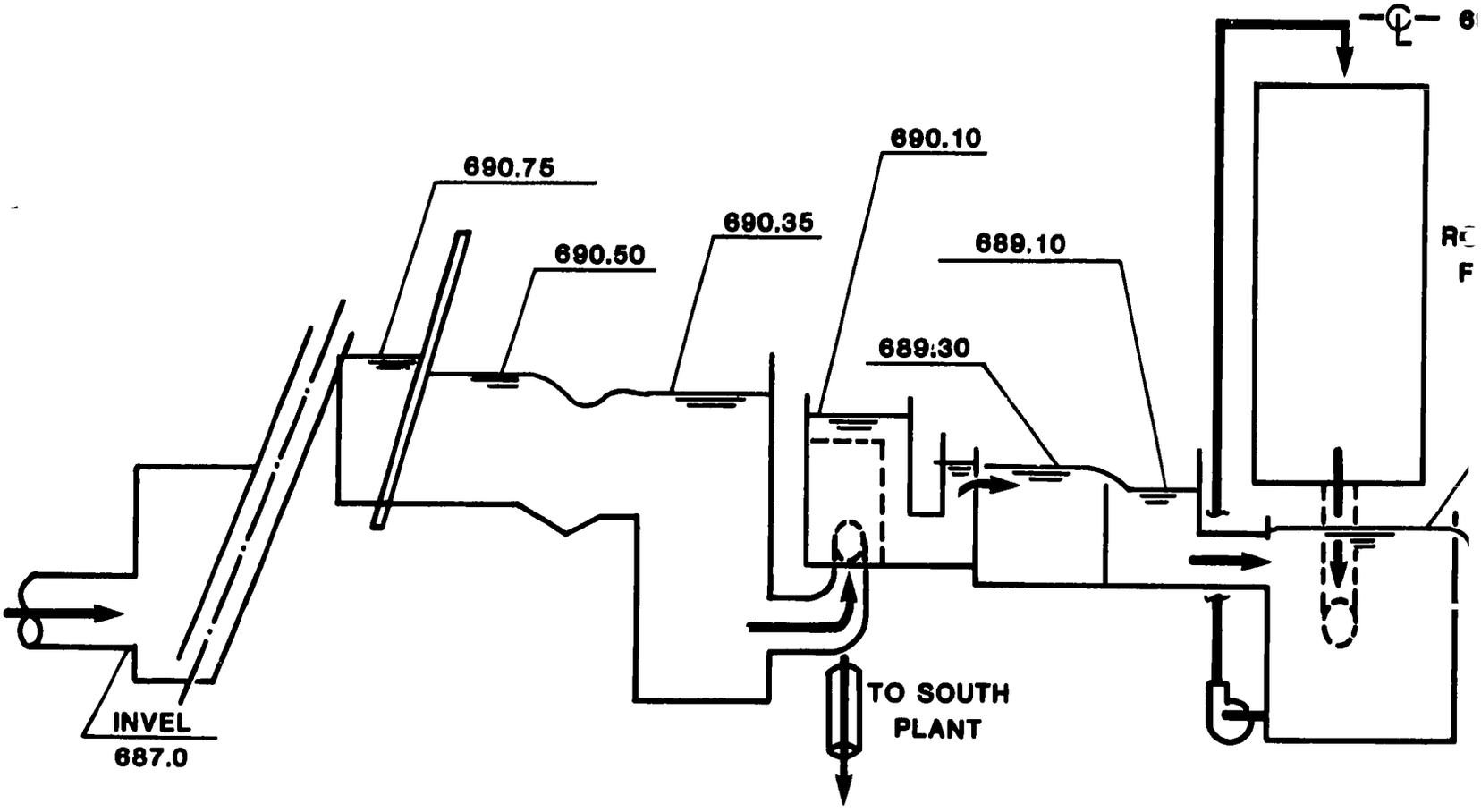
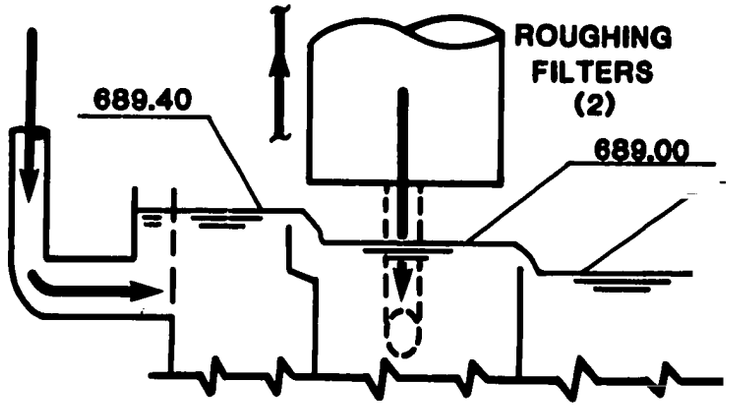


INFLUENT PUMPS (7) | BAR SCR'NS (3) | PARSH. FLUMES (2) | AER'D GRIT (2) | FLOW-SPLITTER (1) | PRIMARY SEDIMENT'N TANKS (6) | RECYCLE PUMP STATION (1)

NEW HEADWORKS

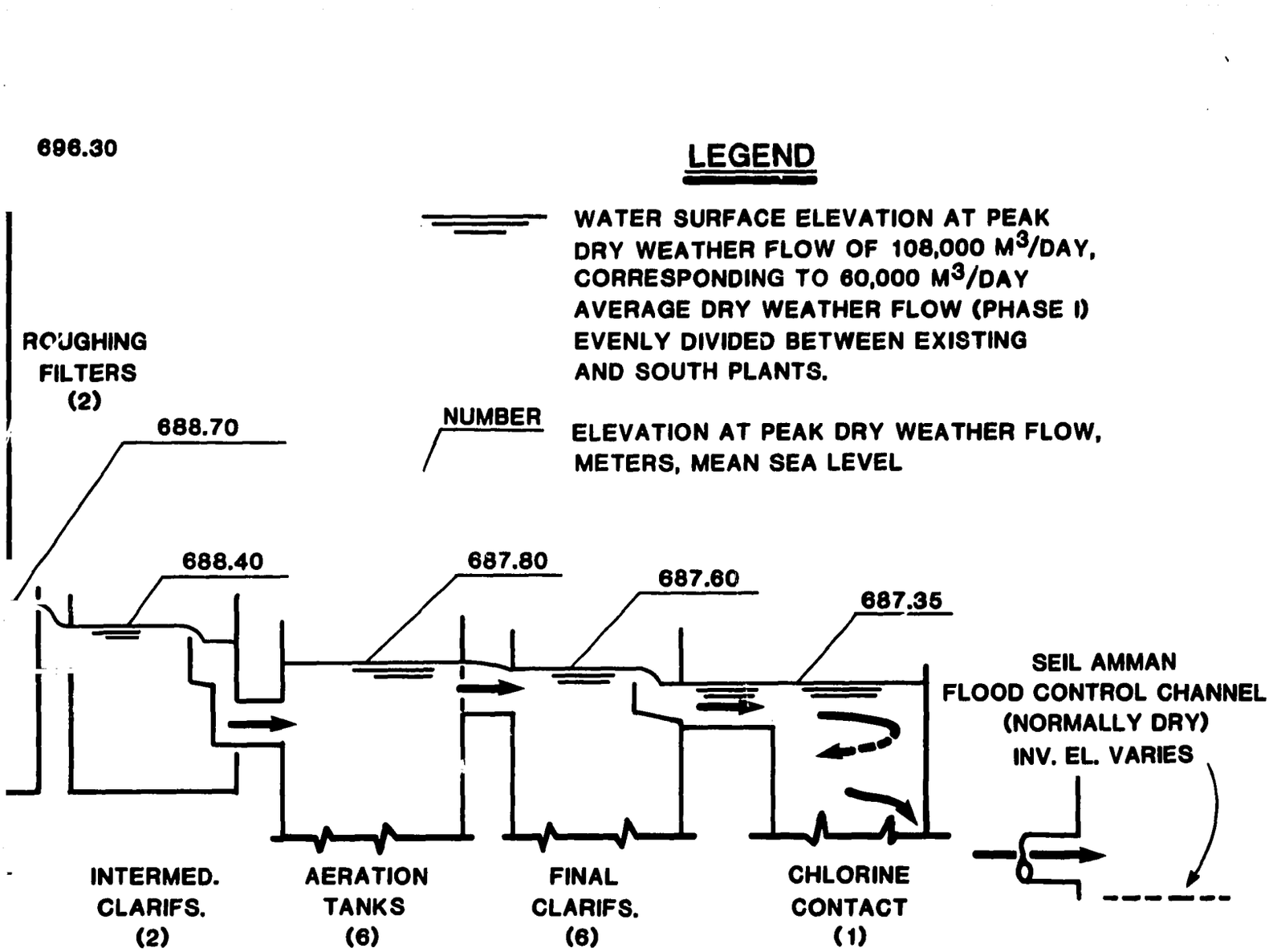
EXISTING AGTP AS



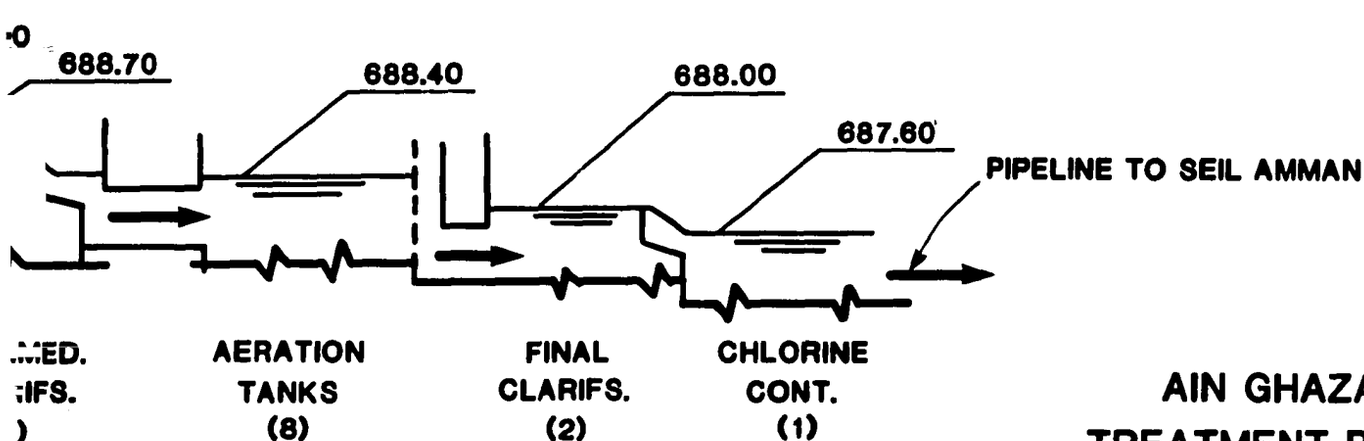
PRIMARY SEDIMENT'N TANKS (4) | RECYCLE P. STA. (1) | INTERME- CLARIFS (4)

NEW PLANT AT SOUTH

NOTE FACILITIES SHOWN ARE FOR PHASE I, 1990 CONDITION



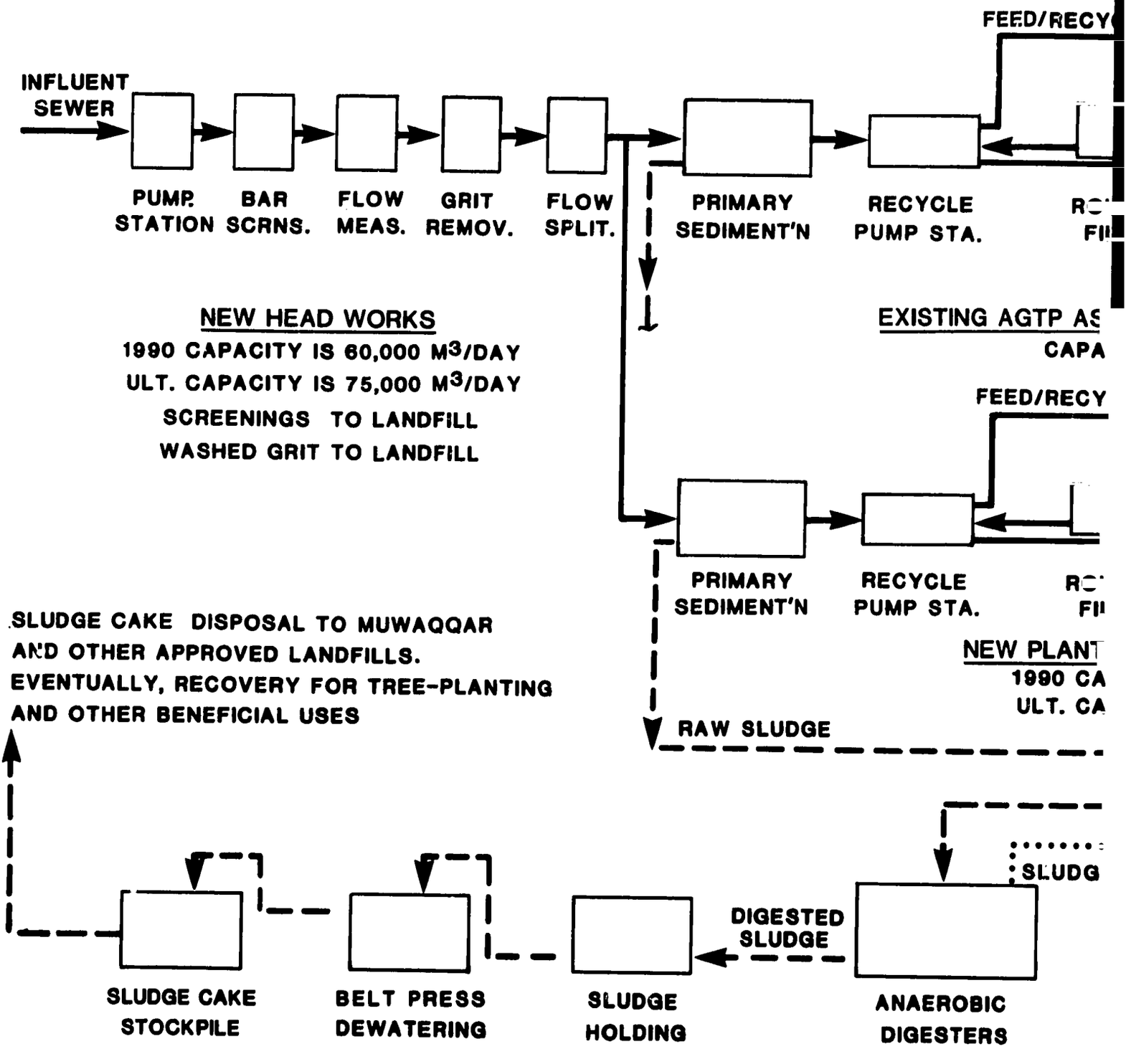
AS UPGRADED, MODIFIED AND EXPANDED



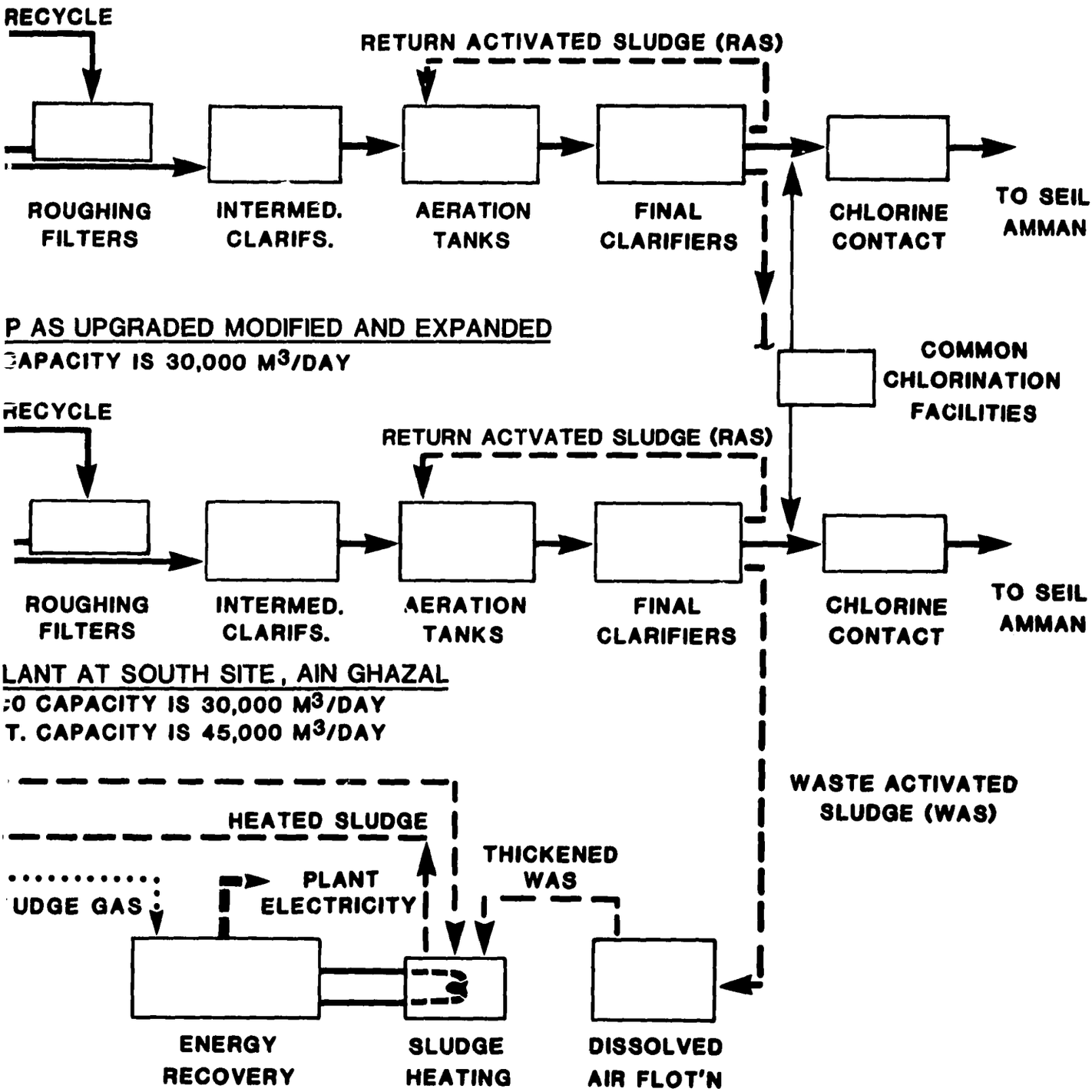
H SITE, AIN GHAZAL

AIN GHAZAL TREATMENT PLANT HYDRAULIC PROFILE

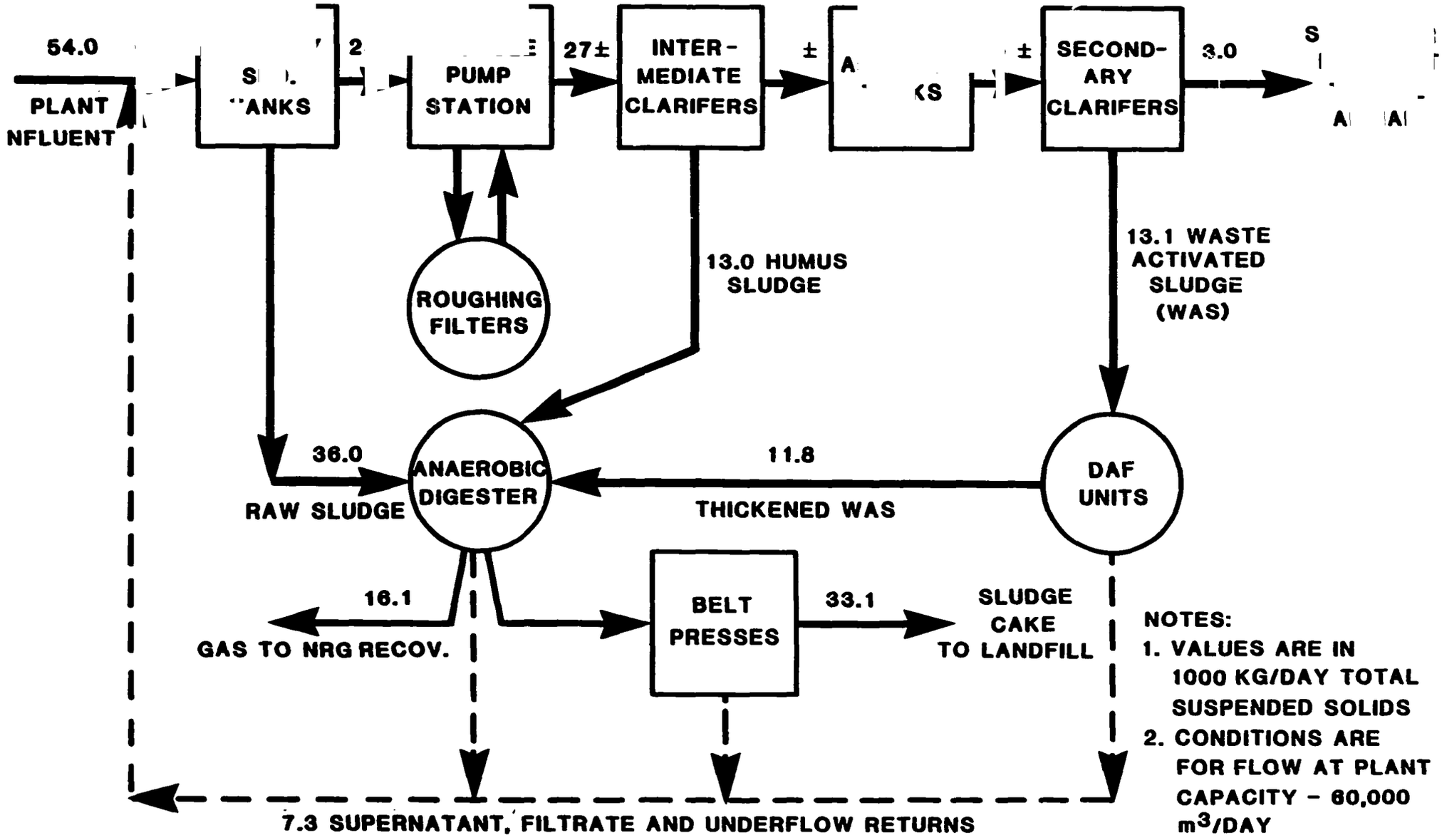
FIGURE 10-3



COMMON SLUDGE PROCE
1990 CAPACITY FOR 60,000 M3/D.
ULT. CAPACITY FOR 75,000 M3/DA



AIN GHAZAL
TREATMENT PLANT
FLOW SCHEMATIC
FIGURE 10-4



NOTES:
1. VALUES ARE IN 1000 KG/DAY TOTAL SUSPENDED SOLIDS
2. CONDITIONS ARE FOR FLOW AT PLANT CAPACITY - 60,000 m^3/DAY
3. GAS WEIGHTS ARE EQUIV. TO TSS

AIN GHAZAL TREATMENT PLANT
SOLIDS BALANCE
PHASE I EXPANSION
FIGURE 10 - 5

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PRELIMINARY DESIGN AND COST ESTIMATE

HEADWORKS FACILITIES

Currently, plant influent enters AGTP via a continuously surcharged outfall sewer. The terminal invert elevation of this outfall is 687.00 m, Mean Sea Level, but the wastewater must flow over a weir crest of elevation 691.37 m. This arrangement traps debris and will become even less satisfactory as flows increase and hydraulic losses grow. The existing barminutors and influent metering will prove less and less acceptable as time goes on. The existing grit removal is already unsatisfactory. Accordingly, it was concluded in Chapter 6 that it would be necessary and desirable to replace the existing headworks with a new one of different design, adequate for the future needs of the AGTP.

The new headworks will be fed by a rerouted outfall sewer and will comprise a low-lift influent pumping station, bar screens or comminution, flow measurement, grit removal, and a flow distribution structure. The new headworks and outfall sewer will be constructed "in the dry" and will not be activated until they and the downstream treatment facilities have been completed, tested, and proven functional and ready to receive the flow. The incoming flow will then be diverted to the new headworks and downstream units.

The rerouted outfall sewer will terminate in the influent pumping station west of the existing control building as indicated in Figure 10-1. The rerouted influent sewer will have a hydraulic capacity at least equal to that of the upstream sewer system, including that portion of the flow that eventually will by-pass AGTP and flow down a future trunk sewer to the Khirbet er Ruseifa Treatment Plant (KRTP). The AWSA primary network in future years should not be subjected to the unreasonable discharges of stormwater via illicit connections that now occur. On this assumption, the influent sewer capacity will be only moderately higher than the peak dry weather flow of year 2000. A by-pass structure will be incorporated in the wet well of the influent pumping station to permit future by-passing of surplus flows downstream to KRTP. For safety reasons, a plant by-pass to the Seil Amman will also be incorporated. It should be used only when absolutely necessary. Specific provisions for same should be developed and implemented in strict conformance with public health requirements.

Septage and slaughterhouse wastes facilities will require special provisions and are discussed in subsequent sections.

Influent Pumps

It is proposed that the influent pumps be of the Archimedes screw type as they have been found to be reliable in operation and are less expensive than comparable variable speed centrifugal pumps. The merits of this type of pump have been discussed in detail in Chapter 6. For the Phase I Expansion program, the pump station structure will be built for the year 2000 peak flow of 135,000 m^3/day. Seven pumps will be installed for year 1990 flows, of which five will be in use and two will act as standby units. Two additional pumps will be added subsequently to handle the year 2000 flows, corresponding to six or seven active pumps and three or two standby pumps.

The screw pumps will be installed in individual bays which can be isolated with slide gates to facilitate routine maintenance. A sump will be provided in each bay and a portable pump will be used to keep the bay dry during maintenance. Removable aluminum covers will be provided over each screw pump and a flow-through ventilation system will be installed. These covers should minimize problems due to thermal expansion, and potential odors, and provide safety protection from the moving screw. The screw pump drive mechanism will be protected by enclosures, which will also house the screw pump controls. A water spray system will be installed to aid in preventing thermal expansion of the screw pumps.

The screw pumps will handle varying rates of flow even when operating at fixed speed. The pumping rate increases as wet well level rises and vice versa. Each pump will have a nominal capacity of 21,500 m^3/day at 6 m lift, and the pumps will be automatically controlled via wet well level. Pumping sequences will be adjustable. A high water alarm will be included.

Design parameters are shown in Table 10-1. In addition to the by-pass at the wet well, there will be a by-pass downstream of the influent pumps to prevent the plant treatment units from being subjected to flows in excess of their hydraulic capacities. Such by-passes could be via overflow weirs set at predetermined levels. The details of these by-passes will be established during actual design. The intent is to minimize discharge of untreated sewage to the Seil Amman while protecting the treatment plant and its operating performance. Public health and safety considerations will be paramount.

Coarse Bar Screening or Comminution

Immediately downstream of the influent pumping station, the raw sewage flow will be directed either through coarse bar screens or comminutors. The latter remove coarse suspended solids from the flow entirely. The latter macerate the suspended solids and leave them in the flow. The preliminary design recommends the use of coarse bar screens, but defers the actual decision to the time of detailed design. The following discussion indicates relevant considerations.

Both coarse bar screens and comminutors are adaptable to essentially the same influent channels; there would be no significant structural or hydraulic differences between these alternatives. Cost differences are minor. Comminutors normally run constantly, while the automatic raking mechanism of coarse bar screens is actuated periodically by rising upstream water level.

Comminutors reduce the coarse suspended solids in the flow to about 10 mm size, and these are normally recovered in downstream treatment facilities. They have the advantage to the plant operators of avoiding any physical operations involving coarse bar screenings, often the most objectionable part of a wastewater treatment plant.

In contrast, coarse bar screens intercept and remove gross suspended solids only. These are screened out of the flow by vertical, sloping bars having clear openings between them usually in the range of 18-30 mm. The advantage of this system is

TABLE 10-1

DESIGN CRITERIA FOR
INFLUENT PUMPING, BAR SCREENS AND
FLOW MEASUREMENT

Parameter	Value
Influent Pumping[a]	
Average Dry Weather Flow, 1990	60,000 m^3/day
Peak Dry Weather Flow, 1990	108,000 m^3/day
Number of Pumps	7 (up to 5 active,2 standby)
Capacity, Each Pump	21,500 m^3/day
Screw Diameter	119 cm
Lift	6 m
Size	40 hp (30 kw)
Mechanically Raked Bar Screens	
Number	3
Capacity (each)	64,700 m^3/day (for peak hydraulic capacity)
Width (each)	1.98 m
Size (each)	3 hp (2.2 kw)
Parshall Flumes	
Number	2
Total Capacity (peak flow 2000)	194,000 m^3/day
Throat Width (each)	122 cm

[a] For year 2000 conditions, Average Day Weather Flow (ADWF) is 75,000 m^3/day and Peak Dry Weather Flow (PDWF) is 135,000 m^3/day. There would be 9pumps provided, with 7 active and 2 standby at PDWF. Peak hydraulic plant capacity would be limited by the capacity of all pumps, if active. Thus, for an ultimate of 9 pumps, assuming all active simultaneously, the peak hydraulic capacity of the plant would be 194,000 m^3/day.

the positive removal of certain suspended solids and the elimination of any possible future difficulties with settling such solids if they were to have been macerated in a comminutor. (This is not always an important consideration). Coarse bar screening may be expected to produce approximately 2 m^3/day of debris for 60,000 m^3/day of flow. This must be drained and disposed of, such as by incineration or landfill. If used at AGTP, the appropriate disposal would probably be by landfill.

Maintenance requirements for comminutors tend to be somewhat less than those for automatically raked bar screens. However, comminutor installations include a manually raked by-pass channel. The advantages of automatically raked bar screens are believed to outweigh those communitors for AGTP, and therefore coarse bar screens are recommended. Design criteria are presented in Table 10-1.

Flow Measurement

Influent flow measurement will be by two parallel Parshall flumes, the design criteria for which are presented in Table 10-1. Provision of dual flumes will provide a satisfactory accommodation of a wide range of flows, from near future minimum hourly flows to ultimate peak hydraulic flow. A single upstream depth measurement for each flume is converted automatically to the corresponding instantaneous flow measurement, using conventional equipment and installation.

Grit Removal

Two parallel aerated grit chambers will be provided downstream of the Parshall flumes. These will be of adequate capacity to handle year 2000 peak dry weather flows, as indicated in Table 10-2. There will be considerable flexibility in this arrangement, and it will be possible to have one or the other chamber out of service for maintenance without impairing overall performance. During the early years, only one chamber need be used. However, during later years, best results will be obtained when both chambers are in use.

Diffused air within the aerated grit chamber will roll the sewage helically as in an activated sludge aeration tank using diffused air aeration. This action maintains the organic material in suspension, aids its separation from inorganic grit particles, and permits the grit to settle to the bottom of the chamber. The air application rate should be adjustable to permit setting at the optimum rate. Deposited grit will be collected in hoppers and withdrawn via non-clog recessed impeller centrifugal pumps, designed such that the fluid being pumped does not pass through the vanes of the impeller. Even rags that sometimes enter the grit slurry will not clog these impellers.

The drawoff of grit will be automatically controlled by a timer which sets the frequency and duration of pumping. The timer will be adjustable in order to suit field conditions.

The grit will be pumped to twin centrifugal separators which will separate the grit (inorganic particles and heavy organic particles) from the liquid. The liquid will

TABLE 10-2

DESIGN CRITERIA FOR
GRIT REMOVAL

Parameter	Value
Aerated Grit Chambers[a]	
Average Dry Weather Flow, 2000	75,000 m^3/day
Peak Dry Weather Flow, 2000	135,000 m^3/day
Detention Time (at PDWF, 2000)	5 minutes
Chamber Volume (total of 2)	600 m^3
Depth, Each Chamber	5 m
Width, Each Chamber	6 m
Length, Each Chamber	8 m
Air Requirement (avg., to be adjustable)	9 m^3/min.
Recessed Impeller Pumps	
Number	3
Capacity (each)	1.1 m^3/min.
Grit Processing Units	
Centrifugal Separators	
Number	2
Capacity	1.1 m^3/min.
Grit Washer/Classifiers	
Number	2
Capacity	1.1 m^3/min.

[a] At 1990 Average Day Weather Flow (ADWF) one chamber will provide 5.8 minutes detention. At 1990 Peak Dry Weather Flow (PDWF) one chamber will provide 3.2 minutes detention time.

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return to the wastewater stream. The separated solids will pass through a grit washer/classifier (essentially a small screw conveyor) which further dewaters and cleans the grit. The dewatered grit is collected and disposal of by landfill. At the Phase I design flow, up to about 1 m^3/day of grit may be anticipated.

Flow Distribution

Flow leaving the aerated grit chambers will be distributed between the northern and southern plants in accordance with their respective design capacities. This will be done in a weir box using weirs of various crest lengths. By the end of Phase I design period, 30,000 m^3/day will flow to the southern plant site and 30,000 m^3/day to the northern plant site. (Following Phase II expansion of the Southern plant, the appurtenant weir length will be appropriately increased. The hydraulics of the flow distribution for Phase I may be seen on the Hydraulic Profile, Figure 10-3.

NORTHERN SITE WASTEWATER TREATMENT PLANT

In order for the northern plant site facilities to treat 30,000 m^3/day of flow by the year 1990, major changes, certain upgradings, modifications and expansions for the existing works will be required. The major change will be the introduction of roughing filters and intermediate clarifiers together with all appurtenant conduits, piping, controls, and related works.

Primary Treatment Facilities

The existing primary sedimentation tanks will be retained for this use. Upgrading for the Phase I expansion, will involve improvements for collection and removal of sludge and skimmings as well as provisions for addition of polymer to enhance sedimentation of raw suspended solids (Table 10-3).

The existing primary sedimentation tanks do not have automatic provision for the removal of skimmings. Therefore, each upgraded tank will have a separate skimmings collection system which will remove the skimmings from the surface of the sedimentation tank. This involves a gear motor drive and chain/flight collector plus a helical wiper which moves the skimmings up onto a beaching plate from which it is carried to a trough flushed by pumped primary effluent. As at present the skimmings will be collected in a sump and pumped to the digesters.

As there appears to be a problem with removing sludge from the existing tanks, possible modifications may be made to the speed of the sludge collection flights. Due to the high strength of the sewage, it appears that it may be necessary to have the flights move faster than normal to prevent gas formation and rising sludge phenomenon.

Equipment will be provided for adding polymer to the wastewater to improve the suspended solids and BOD removal efficiency of the primary sedimentation tanks. The most appropriate location for polymer addition will be determined during the final design phase.

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TABLE 10-3

DESIGN CRITERIA FOR
NORTHERN SITE
PRIMARY TREATMENT FACILITIES

Parameter	Value
Primary Sedimentation Tanks[a]	
Number, Total	6
Number Active, Phase I	4
Weir Length, Each Tank	110 m
Width, Each Tank	5 m
Length, Each Tank	51 m
Depth, Each Tank	3.0 m
Average Overflow Rate, 1990	29.4 $m^3/m^2/day$
Average Detention Time, 1990	2.4 hrs.
Sludge Collection	To be investigated/Upgraded
Skimmings Collection	To be investigated/Upgraded
Polymer Addition System[b]	
Capacity (dry Polymer)	3.33 kg/hr (maximum)
Solution Tanks	
Number	2
Capacity	1000 liters

[a] Existing primary sedimentation tanks. For 30,000 m^3/day.

[b] New facilities for improved BOD removal. Dosages to be optimized, depending upon field experience.

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Biological Treatment Facilities

The Phase I expansion of the northern plant will include the introduction of roughing filters and intermediate clarifiers ahead of the existing aeration tanks and related items. The design parameters are presented in Table 10-4. The blowers will be maintained and a new blower will have to be provided to provide sufficient air capacity even with the reduced influent BOD load. In particular, the diffusers system will require careful revamping to improve oxygenation efficiency and reduce burdensome maintenance requirements.

Final Clarifiers

The six, existing rectangular, final clarifiers will be modified for improved settling performance by removal of the horizontal "false floor" slab and appropriate bracing as described in Appendix G1. This will reduce bottom scour and consequent resuspension of flocculent particles. In addition, minor modifications for level control and skimmings collection/removal should be accomplished.

Chlorination Facilities

A new chlorine contact chamber, of the baffled, serpentine flow type, will be provided. The design criteria are as follows:

Number of basins	1
Type	3-pass, serpentine flow
Average Detention	90 minutes, at ADWF
Volume	1,875 m^3 total
Depth	5 m
Width by Length	5 m x 25 m (each pass)

The structure is indicated on Figure 10-1.

The existing chlorine feed facilities in the maintenance building will be replaced with new equipment, suitable for the expanded facilities and anticipating an ultimate peak flow and chlorine demand in year 2000. Chlorine feed will be automatic, flow-proportional, and a chlorine residual analyzer will be provided. The new chlorination facilities will deliver regulated quantities and strengths of chlorine solution to this chlorine contact chamber as well as to the southern plant chlorine contact chamber.

SOUTHERN SITE WASTEWATER TREATMENT PLANT

The southern plant site will contain a complete and independent 30,000 m^3/day wastewater treatment plant, expandable to 45,000 m^3/day capacity. However, the primary, humus and waste activated sludges from this plant will be processed in common with those produced at the northern plant, as will all skimmings.

TABLE 10-4

DESIGN CRITERIA FOR NORTHERN SITE BIOLOGICAL TREATMENT FACILITIES

Parameter	Value
New Roughing Filters	
Average Flow (Dry Weather)	30,000 m^3/day
Number of Units	2
Diameter by Height	26 m x 5.8 m
Area (each)	531 m^2
Media Volume (each)	3,078 m^3
Surface Loading (without recycle)	
Average Daily	28 m^3/m^2/day
Peak Hourly	51 m^3/m^2/day
BOD Loading[a]	
Total to Units	17,550 Kg/day
Unit Rate	2.9 Kg/m^3/day
BOD Removal, Typical	50%
Recirculation Ratio	3
Hydraulic Loading with Recycle	113 m^3/m^2/day
Recycle Pump Station	
Average Flow	120,000 m^3/day
Total Dynamic Head, Typical Pump	10 m
Total Pumps Required	3 Active, 1 Standby
Capacity, Each Pump	27.8 m^3/min.
Motor Size, Each Pump	100 HP (75 KW)
Intermediate Clarifiers	
Surface Loading	32 m^3/m^2/day
Total Surface Area	938 m^2
Number of Units	4
Width by Length (each)	6 m x 39 m
Depth (each)	3.3 m
Detention at ADWF[b]	2.5 hr
Humus Sludge Pumps (Direct to Digester)	
Number	3 Active, 1 Standby
Capacity (each)	1 m^3/min. (10 HP)
Aeration Tanks (Existing/Upgraded)	
Number of Units	6
Volume (each)	1,766 m^3
Detention at ADWF	8.5 hr
BOD Unit Loading	0.83 Kg/m^3/day

[a] Primary effluent assumed as 585 mg/l, corresponding to 35% primary removal.

[b] Average Dry Weather Flow (ADWF) is 30,000 m^3/day.

Primary Treatment Facilities

The design criteria for these primary tanks are presented in Table 10-5. A pipe gallery will be constructed at the influent end of the primary sedimentation tanks. This pipe gallery will house the primary sludge pumps and associated piping and valving. The present type of plunger pump already in use at AGTP appears suitable for this service. The design parameters for the pumps are included in Table 10-3. The frequency of sludge pumping will be controlled with timers which will set the on-off pumping cycles and the duration of pumping from each sedimentation tank. The amount of time for sludge drawoff from each tank will be controlled by automatically operated gate or plug valves controlled by individual timer for each tank. These timers will be easily adjustable based on the operators' observation of the amount of the sludge accumulating in the sludge hoppers.

The discussion of the northern site primary treatment facilities also applies generally to the southern site facilities. Sludge and scum removal facilities will be the same as for the northern plant. Primary effluent will flow directly to the recycle pump station serving the roughing filters.

Biological Treatment Facilities

The new biological treatment facilities in the southern plant are designed using the same criteria as those for the northern plant, as indicated in Table 10-6. The location of these and other facilities is shown in Figure 10-2.

Final Clarifiers

The discussion of final clarifiers in the northern plant should be used as a reference. The Returned Activated Sludge (RAS) and Waste Activated Sludge (WAS) pumps will be located in a pipe gallery between the final clarifiers. Each clarifier will be provided with an individual RAS pump with a third acting as standby. The design criteria for the final clarifiers and the RAS and WAS pumps are presented in Table 10-7.

Chlorination

The southern site plant will have its own chlorine contract basin. The chlorine solution will be generated by new equipment located in the existing chlorine room as discussed for the northern plant site. This will be pumped to this new chlorine contact chamber. It will be of similar design, baffled with serpentine flow, as the northern site basin. The design parameters are included in Table 10-7.

SLUDGE PROCESSING

By the year 1990, the AGTP will be generating at least 64,000 kg/day of primary, humus, and waste activated sludges including the sludge contribution from the UWATP. This will require an expansion of the sludge treatment facilities. These facilities, however, need not be constructed all at once but may be spread out over a few years. The "existing" 18,000 m^3 of digesters have an effective

TABLE 10-5

DESIGN CRITERIA FOR SOUTHERN SITE PRIMARY TREATMENT FACILITIES[a]

Parameter	Value
Primary Sedimentation Tanks	
Number (all active)	4
Average Overflow Rate	40 $m^3/m^2/day$
Average Detention Time	2.1 hrs
Weir Length	110 m
Width	5 m
Length	37.5 m
Depth	3.5 m
Primary Sludge Pumps	
Number	3
Type	3 stage, plunger type
Capacity	54 m^3/hr
Size	15 hp

[a] Phase I capacity is shown and corresponds to 30,000 m^3/day, expandable by 50 percent.

TABLE 10-6

DESIGN CRITERIA FOR SOUTHERN SITE BIOLOGICAL TREATMENT FACILITIES[a]

Parameter	Value
New Roughing Filters	
Average Flow	30,000 m^3/day
Number of Units	2
Diameter by Height	26 m x 5.8 m
Area (each)	531 m^2
Media Volume (each)	3,078 m^3
Surface Loading (without recycle)	
Average Daily	28 $m^3/m^2/day$
Peak Hourly	51 $m^3/m^2/day$
BOD Loading[b]	
Total to Units	17,550 Kg/day
Unit Rate	2.9 $Kg/m^3/day$
Recirculation Ratio	3
Hydraulic Loading with Recycle	113 $m^3/m^2/day$

[a] Phase I plant capacity is 30,000 m^3/day, expandable by 50 percent.

TABLE 10-6
(Continued)

Parameter	Value
Recycle Pump Station	
Average Flow	120,000 m^3/day
Total Dynamic Head, Typical Pump	10 m
Total Pumps Required	3 Active, 1 Standby
Capacity, Each Pump	27.8 m^3/min.
Motor Size, Each Pump	100 HP (75 Kw)
Intermediate Clarifiers	
Surface Loading	32 m^3/m^2/day
Total Surface Area	938 m^2
Number of Units	4
Width by Length (each)	6 m x 39 m
Depth (each)	3.3 m
Detention at ADWF	2.5 hr
Humus Sludge Pumps (Direct to Digesters)	
Number	3 Active, 1 Standby
Capacity (each)	1 m^3/min (15 HP)
Aeration Tanks	
Number of Basins	4
Length x Width (each)	22.5 m x 22.5 m
Sidewater Depth	6.0 m
Volume (each)	3,031 m^3
Detention, Average	9.7 hr
BOD_5 Applied	
Total Loading	8,775 Kg/day
Unit Volume Loading	0.724 Kg/m^3/day
Oxygen Required,	12,300 Kg/day
Connected Aeration Capacity	430 KW
F/M	0.34
MLVSS	2,130 mg/l

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TABLE 10-7

DESIGN CRITERIA
FOR SOUTHERN SITE
FINAL CLARIFIERS AND CHLORINE CONTACT CHAMBER

Parameter	Value
Final Clarifiers[a]	
Number (all active)	2
Diameter	35.7 m
Sidewater Depth	3.8 m
Weir Length	112 m
Surface Area	1,000 m^2, each
Design Surface Loading	
Average	15 $m^3/m^2/day$
Extended Peak	21 $m^3/m^2/day$
Peak	27 $m^3/m^2/day$
Design Detention Time	
Average	6.2 hrs
Extended Peak	4.3 hrs
Peak	3.4 hrs
Return Activated Sludge Pumps	
Number	3
Type	Centrifugal, nonclog, variable speed
Capacity	4,000 to 20,000 m^3/day
TDH	2.0 to 5.0 m
HP	40
Waste Activated Sludge Pumps	
Number	3
Type	Centrifugal, nonclog, variable speed
Capacity	1100 to 3000 m^3/day
TDH	3 m to 6.8 m
Size	7.5 hp
Chlorine Contact Chamber[a]	
Number Basins	1
Type	3 pass, serpentine flow
Average Detention Time	90 minutes
Volume	1,875 m^3
Depth	5 m
Dimension	10 x 37.5 m

[a] For 30,000 m^3/day ADWF = 1541.7 m^3/hr

capacity to process about 28,800 kg/day of the volatile solids component of the sludge or perhaps 36,000 to 40,000 kg/day of total sludge solids. Waste activated sludge will constitute a significant portion of the future load, and it is imperative that it be as concentrated as possible prior to digester feed so that digester capacity be full utilized. Therefore, in addition to three new anaerobic digesters, Phase I will also require a waste activated sludge thickener and expanded dewatering capacity for digested sludges.

Sludge Thickening Facilities

The inadequacies of the existing gravity thickeners have already been discussed in Chapter 6. To improve the sludge thickening process for Waste Activated Sludge (WAS), the existing gravity thickeners will be converted to dissolved air flotation type thickeners. The mechanical equipment associated with the new thickener units will be housed in a building to the south of the thickeners. This equipment consists of pumps, air compressors, and polymer mixing and metering equipment. The design parameters are presented in Table 10-8. During Phase I, the thickeners will be operated intermittently, as required. Future sludge quantities will require continuous operation and possibly the addition of a new unit located on the southern plant site.

Anaerobic Digestion

By the end of Phase I design period, the current four digesters will have been supplemented by three new anaerobic digesters to accomodate the increasing load of sludge produced at the expanded AGTP and new UWATP. Each digester will have a fixed cover, be completely mixed, and have a capacity of 6,500m^3. The temperature of the digesters will be maintained at 35°C to achieve optimum operation. Heating will be by steam injection. Mixing will be via compressed digester gas injection. The gas will be injected at the rate of 2.5 m^3 of gas per thousand m^3 of digester volume. One operating and one standby compressor will be required for each digester. Digested sludge will be collected from the digesters by gravity, drained to a digested sludge wet well and pumped to the sludge holding tanks. The design parameters for the anaerobic digesters are presented in Table 10-8.

Sludge Dewatering

It is estimated that the present programmed belt presses will be capable of dewatering the sludge generated until 1987. At that time two belt presses are projected to be operating continuously and the third intermittently. By this time, an additional belt press must have been installed as a standby . The belt presses will produce a minimum of 20% solids dewatered cake which will be discharged to sludge trucks and disposed of at the landfill.

Digested Sludge Trucking

The solids dewatering facilities will produce a dry sludge cake which will be transported to the Muwaqqar landfill site. The start-up of the solids dewatering facilities will dictate the need for four twelve cubic meter capacity trucks. By 1990, a total of nine trucks will be required. The projected dried sludge production and estimated requirement for haul trucks throughout Phase I are presented in Table 10-9.

TABLE 10-8

DESIGN CRITERIA FOR AGTP SLUDGE PROCESSING FACILITIES

Parameter	Value
Dissolved Air Flotation Thickeners[a]	
Number	2
Diameter	12.2 m
Effective Area (each)	93.4 m^2
Solids Loading Rate (TSS)	88 $kg/m^2/day$
Air to Solids Ratio	0.03 kg/kg
Polymer Dose	5 kg/1000 kg solids
Solids Capture	90%
Type of Pressurization	recycle flow
Polymer System	
Capacity (dry polymer)	14 kg/m
Storage Tanks	
Number and Capacity	2 @ 4500 liters
Metering Pumps	
Number and Capacity	3 @ 1.7 m^3/hr
Type	progressing cavity, variable speed
Size	2 hp
Anaerobic Digesters[b]	
Number and Volume (each)	3 @ 6500 m^3
Unit Volume	0.043 m^3/capita
Detention Time	20 days
Solids Loading Rate	1.6 kg $VS/m^3/day$
Volatile Solids Reduction	45%
Gas Production	0.94 m^3/kg VS reduced
Heat Value of Gas	6.21 kwh/m^3
Operating Temperature	35°C
Digested Sludge Dewatering (The fourth belt press of the current installation will be required prior to 1990)[c]	

[a] Converted from existing gravity thickeners. The effective (surface) area of the dissolved air flotation (DAF) unit is somewhat less than that of the gravity unit.

[b] Data shown are for the new facilities. These will augment the four existing digesters (two, original, at 3000 m^3 each; two under construction of 6,000 m^3 each). This will correspond to a connected population in 1990 of about 872,000 persons. Unit loadings to both existing and new digesters will be generally the same. Raw sludge and thickened WAS feed to the digesters is expected to average about 4 percent total solids, dry basis. The projected gas production from all digesters is 25,000 m^3/day, corresponding to a theoretical 6,570 kw at 100 percent thermal efficiency and an actual value of about 2,000 kw. It is proposed that two 500 kw units be provided initially, whenever funding so permits.

[c] The belt presses (designed by others) will operate at a unit loading rate of up to $kg/m^2/hr$. By 1990 the three belt presses will be operating at nearly 22 hr/day. The fourth unit will be on standby.

TABLE 10-9

DEWATERED SLUDGE PRODUCTION AND REMOVAL

Year	Projected Dewatered Sludge Kg/day	Projected Dewatered Sludge m^3/day[a]	Number of Haul Trucks[b]
1981	13,200	84	4
1982	16,500	105	5
1983	19,800	126	5
1984	23,100	147	6
1985	26,400	168	6
1986	29.700	188	6
1987	32,900	209	7
1988	36,300	230	8
1989	39,600	251	8
1990	42,800	270	9

[a] Assumes 20 percent dry solids by weight. Bulk density is 800 Kg/m^3.

[b] Assumes up to 8-hr/day, 7 days/wk operation for all trucks, operating between AGTP and Muwaqqar landfill.

Energy Recovery

An energy recovery facility using cogeneration with digester gas is recommended as part of the Phase I expansion if funding will permit. The facility would initially include two 500 kw gas engine generators. Digester gas resulting from digestion of sludge solids derived from 40,000 m^3/day of wastewater flow would support these units. Electricity generated would be available for plant use. The waste heat from the generators would be used for heating of digesters. The units would be housed in a building capable of accomodating future units as well with an ultimate system capacity equivalent to year 2000 flow of 96,000 m^3/day. The 40,000 m^3/day flow would be reached by about 1985.

The cost of this facility with initial units is estimated to be at least JD 760,000, possibly more, of which JD 650,000 is a foreign cost and JD 110,000 local cost. If capital funds availability permits undertaking this cogeneration project, purchased power costs would be significantly reduced.

SEPTAGE AND SLAUGHTERHOUSE WASTES

Discharges from septage tank trucks and the municipal slaughterhouse both have major impacts on the operation of the AGTP. The septage, which is largely discharged during the daylight hours, disturbs the plant operation and raises the plant influent BOD_5 an estimated 10 percent during this time. The slaughterhouse waste discharges are received at the plant from early morning to early afternoon and cause large quantities of grease to accumulate in the primary sedimentation tanks. Chicken feathers are a nuisance and are frequently observed floating on the surface of the final sedimentation tanks. The adverse effects of both these wastes can be minimized with pretreatment as discussed below.

There are two alternatives for handling the septage. The first involves a covered holding basin or catch tank from which the septage is pumped to AGTP in proportion to the raw sewage inflow. This method eliminates shock loads from the septage upon the treatment plant units.

The catch tank would be designed against sulfide-sulfuric acid corrosion as a precaution. However, the contents would not be deliberately aerated, as this would strip sulfide gas, exacerbating potention odor and corrosion problems.

The second alternative involves pumping the septage directly to the digesters. The septage is basically a partially anaerobically digested sludge. Thus, it seems reasonable to treat the sludge futher using the same process. This would improve the treatment plant operation and remove a BOD_5 load from the wastewater treatment process. A literature search has not revealed any installations where this is practiced, but the August 1980 EPA Research and Development publication "Septage Management" suggests disposal to anaerobic digesters as an alternative to disposal into the liquid stream at a municipal wastwater treatment plant. In either case, screening, degritting, and flow equalization are recommended.

Therefore, JMM/DMJM recommends that a pilot program be initiated. The effect on the anaerobic digesters' operation would be carefully monitored. If proven successful, this alternative would be adopted. The location of the new facility, including receiving tank, degritting, pumping, metering, etc., would be as indicated in Figure 10-1.

Slaughterhouse Wastewater

The wastewater from the slaughterhouse is of high strength but is still fresh and aerobic. Therefore it could be aerated with benefit prior to blending with AGTP influent. The flow should be screened adequately at the municipal slaughterhouse and then conveyed to an open, aerated basin at AGTP for subsequent metering into the influent stream, generally in proportion to influent flow. A grinder should be installed prior to the basin to macerate any large material. It is recommended that the existing pre-aeration facilities at AGTP be used. Existing diffused aeration may suffice; if not, mechanical aeration should be used to aerate and mix the waste. The aeration will not reduce the BOD significantly but will maintain freshness. After a few years of this operation, the slaughterhouse operations and wastewater production should be reevaluated. Currently, poultry slaughtering is the major producer of wastes, and it is planned that the operation be expanded. Sheep slaughtering is still significant, although sheep are now being imported in Jordan already "dressed" to a greater degree than previously. The future level of slaughtering of sheep and larger animals is somewhat uncertain; hence, the need for reevaluation.

The problem of chicken feathers in the wastewater could be eliminated by adequate pretreatment of the poultry processing wastewater. The flow already passes through a rotating screen located within the slaughterhouse, intended to intercept and remove chicken feathers and other solid wastes from the wastewater. Expanding and upgrading this operation could greatly lessen the problem with chicken feathers and entrails at the AGTP. However, pretreatment bypassing at the slaughterhouse must be eliminated. Also grease removal pretreatment would appear desirable.

ELECTRICAL DISTRIBUTION, CONTROLS AND INSTRUMENTATION

The electrical distribution, controls, and instrumentation at the expanded and upgraded AGTP deserve careful attention. These items represent significant costs in the overall plant. The electrical facilities for the new work must consider not only cost but also flexibility, reliability, ease of operation, and safety of personnel. Controls must anticipate all possible working conditions and avoid undue complexity. The instrumentation work must be adequate for process control needs but also have relative simplicity for operator use, understanding, and maintenance. The following discussions concerning instrumentation presume that a reasonable level of operator competence, commensurate with the nature of the process and importance of the AGTP, will be provided in future years to utilize and maintain the essential instrumentation.

Electrical Distribution

The existing distribution and utilization voltage at the plant is 220/380 volt, 3-phase, 4-wire, and the present system capacity has provisions for future loads. However, the proposed plant expansion exceeds these provisions and, therefore, major additions to, and modifications of, the electrical system are required. The large loads and longer distances between load centers lend themselves to a higher distribution voltage. This has been considered, but several other factors favor the continuation of the 220/380 volt system. The main factors are:

1) Safety. Low voltage versus high.

2) Ease of maintenance. All equipment is of same type.

3) Ease of operation. All equipment has basically same voltage rating.

4) Compatability with existing equipment.

5) Flexibility. System configuration can be easily changed by using transfer switches without the need of transformers.

6) Cost. Cost is comparable to high voltage system.

For the Phase I expansion, it is proposed that a second transformer station be supplied by the Power Company. This will take advantage of a new load center being served by high voltage (6.6 KV) without the associated drawbacks of high voltage equipment, since the Power Company will operate and maintain this 6.6 KV-220/380 volt transformer substation. A commitment from the Power Company for this arrangement shall be obtained in advance. Circuit breakers and enclosed switches will be utilized for safety, reliability, and ease of operation and maintenance.

Gas engine driven generators installed to utilize digester gas for cogeneration will involve manual switches for load transfer in most cases. Where appropriate, these switches will also serve as disconnecting means for switchgears. The underground portion of the distribution system will be with direct burial multiconductor cables, a protective cover of concrete or clay tile and earth as final backfill.

Controls

The controls for equipment will be straightforward with limited or no automatic feedback control. Feedback will be provided by the plant operating personnel by making manual adjustments based on the observed process conditions. Controls for major equipment would be as follows:

- Influent pumps: Hand-Off-Automatic (H-O-A), automatic sequencing on wet well level.

- Raw sludge pumps: H-O-A automatic on-off control with interval timers, and elapsed time meters.

- Aerators: On-off manual for each; manual switching from central control room's Main Control Board (MCB) for high-speed and low speed operation (if required). One switch for a group of aerators and indicating "unit running" lights for each unit at MCB.

- RAS and WAS pumps: On-off manual. Manual variable speed setting.

- Chlorination: H-O-A. Automatic flow pacing from influent flow.

- Start-up Control after power outage: Automatic start time sequencing of major equipment and group of loads will be provided to limit electrical power surges and prevent nuisance tripping of protective devices when power is restored after a power outage.

- Alarms: Alarms will be installed at the MCB and local panels, as an extension of the existing alarm system with horns and silencing push-bottons for such functions as flooding, major equipment failures, low suction shut-down of pumps, etc.

Instrumentation

Sufficient field proven equipment will be provided to allow reliable process monitoring and adequate process control. The following process variables will be metered indicated (I) and/or recorded (R) and/or quantities totalized (Q) either locally (local) only, or at the Main Control Board (MCB).

- Plant influent flow. Parshall Flumes with sonic level sensing unit or float unit in stilling well with continuous freshwater purging. Flow rate local: I, MCB:IRQ.

- Plant effluent flow. Same as influent except no water purging requirement.

- RAS flow. Magnetic flow meter with automatic electrode cleaning for each secondary clarifier. Flow rate local I, MCB:IR.

- WAS flow. Magnetic meter same as RAS. Local flow: I, MCB:IRQ.

- Sludge flow to Digester. Magnetic meter same as RAS with local IQ and resettable batch counter for valve control.

- Thickened WAS flow. Magnetic meter same as RAS. Local flow: I, MCB: IRQ.

- Digester gas flow. Vortex meter or combination venturi, valve and orifice meter for wide flow range application. Local flow rate: I, MCB: IRQ.

- Dissolved Oxygen (D.O.) meter. This will be a portable unit complete with calibration equipment.

- Chlorine residual: Local I, MCB = IR.

The units, such as transmitters, indicator, recorders, will be electronic for operation on 4-20 ma d.c. loops, except for batchmetering, where pulse rate will be utilized. Recorders will be 10 cm strip-chart type with indicator and chart scales to read in units rather than zero to 100 percent.

IMPLEMENTATION

Implementation of the improvements at AGTP should be undertaken in the most expeditious manner that will produce high quality results, in view of the need for the upgradings and capacity expansion. To this end, it is possible that separate contracts should be awarded for furnishing mechanical-electrical equipment and for civil type construction, respectively. The former would include furnishing such items as:

- Pumping units (pumps, motors, and appurtenances) and controls

- Valves, sluice gates, slide gates, and piping other than reinforced concrete

- Mechanical-electrical equipment for comminution or screening, primary and secondary clarification, activated sludge aeration, digester heating and mixing, sludge thickening and dewatering, chlorination, metering of wastewater and sludge, and ventilation.

- Instrumentation and control equipment

- Electrical power, control, and distribution equipment, conduit, wiring, and appurtenances

- Lighting, heating, and miscellaneous plumbing and mechanical equipment for buildings and structures

The mechanical-electrical equipment procurement would be via various tenders embodying detailed descriptions, references to recognized standards and other requirements, not merely performance type specifications. The civil type construction would include installation of the aforementioned equipment as well as of locally-produced piping, equipment, and building materials and imported reinforcing steel, structural steel and building materials. This would correspond generally to standard practice in Jordan. A series of construction contracts would be involved.

The alternative approach would be to have the general contractor(s) both furnish and install all mechanical-electrical equipment as well as performing construction with locally-produced materials and equipment. Prior to undertaking detailed design, an evaluation of current circumstances would be made and recommendations presented to the appropriate authorities for prior approval. This could be in conjunction with a predesign report.

PRELIMINARY DESIGN AND COST ESTIMATE

The tentative timetable of events for implementation of the construction program is as follows:

Event	Date
Commence Design Work	February, 1982
Complete Design Work	December, 1982
Begin Construction, Phase IA	February, 1983
Complete Construction, Phase IA	August, 1984
Begin Construction, Phase IB (Some overlap with Phase IA)	February, 1984
Complete Construction, Phase IB (Possibly, Phases IA and IB could be consolidated into a single package)	February, 1985

The construction work would include the major work items as previously described and as outlined subsequently in Table 10-10. The two phases could be consolidated into one package.

The construction work program will raise the AGTP's capacity to 60,000 m^3/day, including the capability of processing sludges generated at the UWATP.

COST ESTIMATE

This section presents the construction and project costs associated with the major sub-phases of the AGTP expansion. All costs are calculated for Fall, 1980, conditions in Jordanian Dinars. Table 10-10 presents a summary of construction costs of the major work items, including a breakdown between local and foreign costs.

Project costs are construction costs plus implementation costs, which include contingencies, engineering, legal, contract administration, surveying and inspection. The implementation cost of each project is estimated to be fifty percent of the construction costs. The estimated construction, implementation, and total project costs for Phase I Investment Program for AGTP are:

Phase	Construction Cost (JD 1000)	Implementation Cost (JD 1000)	Total Project Cost (JD 1000)
IA	10,882	5,441	16,323
IB	981	491	1,472
Total Cost	11,863	5,932	17,795

TABLE 10-10

AIN GHAZAL TREATMENT PLANT
CONSTRUCTION COST ESTIMATE FOR PHASE I EXPANSION [a]

	Major Work Item	Comments	Estimated Construction Cost, JD 1,000[b] Local	Foreign	Total
(1)	Site preparation, new influent sewer, new headworks including influent pumping station, mechanically raked bar screens, aerated grit removal facilities, flow splitting structure, sewer connections, new septage holding basin, initial connection to digester, and aeration for slaughterhouse wastes (using existing aerated grit removal as soon as available)	Site grading, anticipating future developments; relocation of septage dumping operation; new power transformer station and beginning of power distribution; associated yard piping; diversion structure on existing influent sewer; by-passes from headworks, including temporary rerouting of plant influent permitting existing influent sewer to be removed to make way for new treatment plant units.	340	435	775
(2)	Modifications of existing primary sedimentation tanks and of aeration basins on northern plant site	Involves sludge and scum removal improvements, air diffusion improvements, certain level controls and appropriate piping. Includes yard piping and electrical work.	14	46	60
(3)	New roughing filters, recycle[c] pump station, and intermediate clarifiers at existing AGTP (northern site)	To be introduced (in the process stream) between existing primary tanks and aeration tanks, for 30,000 m^3/day capacity.	550	1,122	1,672

TABLE 10-10

(Continued)

	Major Work Item	Comments	Estimated Construction Cost, JD 1,000 Local	Foreign	Total
(4)	Modifications of RAS/WAS[c] pump station and of final clarifiers on northern plant site.	Makes use of existing works with minimal modifications.	100	124	224
(5)	New roughing filters - activated sludge treatment plant on southern plant site, 30,000 m^3/day capacity.	Complete with basic process units (including chlorine contact), yard piping, electrical work, final grading, most paving and miscellaneous work. Must await removal of existing influent sewer, being supplanted by rerouted influent sewer and by-passes. Work should preferably precede Items (2), (3), and (4) for best continuity on trating plant influent.	1,200	2,430	3,360
(6)	Two anaerobic digesters on northern plant site, including control building.	Piping connections for raw sludge between new, existing, and future primary sedimentation tanks; for humus sludge from intermediate clarifiers; for WAS from existing thickeners (being converted to DAF units); for digested sludge to belt press buildings; for sludge gas to existing gas piping and future cogeneration site. Control Building to include piping anticipating two future digesters.	940	300	1,240

TABLE 10-10

(Continued)

	Major Work Item	Comments	Estimated Construction Cost, JD 1,000 Local	Foreign	Total
(7)	Conversion of gravity sludge thickeners to dissolved air flotation thickeners for WAS.	In order to maintain some thickening continuity, conversion of two existing units to DAF will be successive. Yard piping and electrical work are included.	70	242	312
(8)	One belt press unit in the new sludge dewatering building on the northern plant site	Existing installation (built during 1981) will anticipate this (fourth) unit.	25	90	115
(9)	Operations building for southern plant site	Including offices, laboratory, and motor control board room.	67	83	150
(10)	Motor control building for southern plant site	Providing centralized motor control for all major motors in the complex.	10	15	25
(11)	Chlorine and standby generator building	Includes chlorine storage, handling, and feeding for southern plant. Standby generator is for southern plant site facilities plus certain key elements on northern site (headworks).	15	20	35
(12)	Energy recovery system for digester heating and production of electro-mechanical energy from combustion of sludge gas	For operation on digester gas incorporating the results of Consultant study of alternatives. May incorporate direct drive of blowers via internal combustion engines. Based upon plant flow of 40,000 m^3/day, expandable to 60,000 m^3/day.	110	650	760

TABLE 10-10

(Continued)

	Major Work Item	Comments	Estimated Construction Cost, JD 1,000 Local	Foreign	Total
(13)	Related civil, architectural mechanical, structural, electrical and landscape work.	For work not otherwise included in items (1) through (8), including addition piping and power distribution, certain standby power facilities, miscellaneous structures, access roads, fencing, building additions, and landscaping.	754	1,130	1,884
Subtotal Phase IA, Items (1) through (13)			4,195	6,687	10,882
(14)	Permanent outflow arrangements from septage holding basin based upon laboratory and pilot test program results.	Piping either to plant influent ahead of aerated grit removal or direct to digesters (following grit removal), depending upon laboratory and pilot plant findings. Will include metering and controls.	15	20	35
(15)	Permanent modifications to initial arrangements for use of existing pre-aeration basins for aerating slaughterhouse wastes, based upon experience and laboratory studies.	Piping, flow metering, grinders, and miscellaneous electrical and other work.	10	15	25
(16)	One new anaerobic digester on northern plant site.	Includes usual piping and electrical work and will also anticipate possible future DAF at northern plant site.	470	150	620

TABLE 10-10

(Continued)

	Major Work Item	Comments	Estimated Construction Cost, JD 1,000 Local	Foreign	Total
(17)	New chlorination facilities[d] to serve entire AGTP.	Careful staging of new equipment during construction may avoid the need for temporary facilities while maintaining continuity of chlorination. Yard piping and electrical work are included.	10	110	120
(18)	New chlorine contact[d] chambers on northern plant site.	Occupies site of existing chlorine contact basin which must first be demolished. Possibly interim capacity could be provided if required.	55	26	81
(19)	Related civil, architectural, mechancial, structural, electrical and landscape work.	Generally comparable to Item (9) above	40	60	100
Subtotal Phase IB, Items (14) through (19)			**600**	**381**	**981**
GRAND TOTAL, PHASE I EXPANSION, AGTP			**4,795**	**7,068**	**11,863**

TABLE 10-10

(Continued)

[a] Cost levels are late 1980 basis.

[b] Project cost is 50 percent greater than construction cost, based on the following:

Item	Percent of Construction Cost
Basic Engineering	7
Soils Engineering for Construction	1
Surveys for Construction	1
Laboratory Testing for Construction	1
Construction Inspection	4
Contract Administration	3
Legal Work on Project	3
Contingencies, for Construction and various Implementation Items	30
Total	50

[c] An alternative would be to convert the existing final clarifiers to intermediate clarifiers following the roughing filters and to construct new final clarifiers and a new RAS/WAS pump station following the upgraded existing aeration tanks. Such a selection would increase the total costs for items (3) an (4) by about JD 600,000 but would provide improved system performance.

[d] Although not included in basic design packages, these facilities should be provided in Phase IB if not in Phase IA for reasons of improved disinfection.

UPPER WADI ABDOUN TREATMENT PLANT

A treatment plant site has been identified on the upper tributary of the Wadi Abdoun from which it is possible to discharge treated effluent directly into Wadi Kafrein, bypassing the Seil Zarqa. The advantages have already been discussed in Chapters 8 and 9. This treatment plant has been recommended for construction in the Phase I expansion.

The projected average and peak flows for the 20-year design period for UWATP are presented below:

	1990 (m^3/day)	2000 (m^3/day)
Average Flow	8,000	22,000
Peak Flow	17,600	42,700

It is anticipated that the plant will start up in May, 1985. At that time, the average daily flow is estimated to be about 4,000 m^3/day. The plant will be designed in modules such that expansion to meet increasing flows may be accomodated with ease.

Reliability of operation is another major concern. The treatment provision units as well as the mechanical equipment will have adequate standby provision such that the treatment will not be interrupted long enough to cause degradation of the effluent quality.

The UWATP will not have any solids handling facilities. Primary sludge and waste activated sludge will be returned to the sewer for treatment at the AGTP. This greatly simplifies the operation at the UWATP and makes the treatment plant site more acceptable to the general public and neighboring area.

At this writing, no survey has been performed for the proposed UWATP site. Thus, it is not possible to present a detailed site plan and hydraulic profile. However, a solids balance and a schematic flow diagram of the treatment facilities proposed are shown in diagram Figures 10-6 and 10-7. The following is a brief description of the treatment processes proposed. For additional details, reference is made to earlier discussion on the AGTP unit processes.

HEADWORKS FACILITIES

As with any treatment plant, pretreatment facilities are necessary at the UWATP to remove rags, and large debris. The same concepts are used for the UWATP as for the AGTP, except that grit removal will not be required at UWATP inasmuch as its sludges will be conveyed by truck sewer to AGTP for recapture and processing. Grit removal, which is a major concern for protection of anaerobic digesters, is to be provided at AGTP.

Influent Pumping

Every reasonable attempt will be made in plant siting and influent sewer design to avoid the necessity of influent pumping. However, for the sake of conservatism in estimating costs, it is assumed that such pumping may prove necessary. Archimedes screw pumps will be provided to lift the raw sewage into the headworks facilities. During the Phase I expansion, two pumps will be capable of handling the peak flow through the year 1990. A third pump will be provided to act as a standby in case of a pump breakdown. By the year 2000, two additional pumps will be required.

Coarse Bar Screens and Flow Measurement

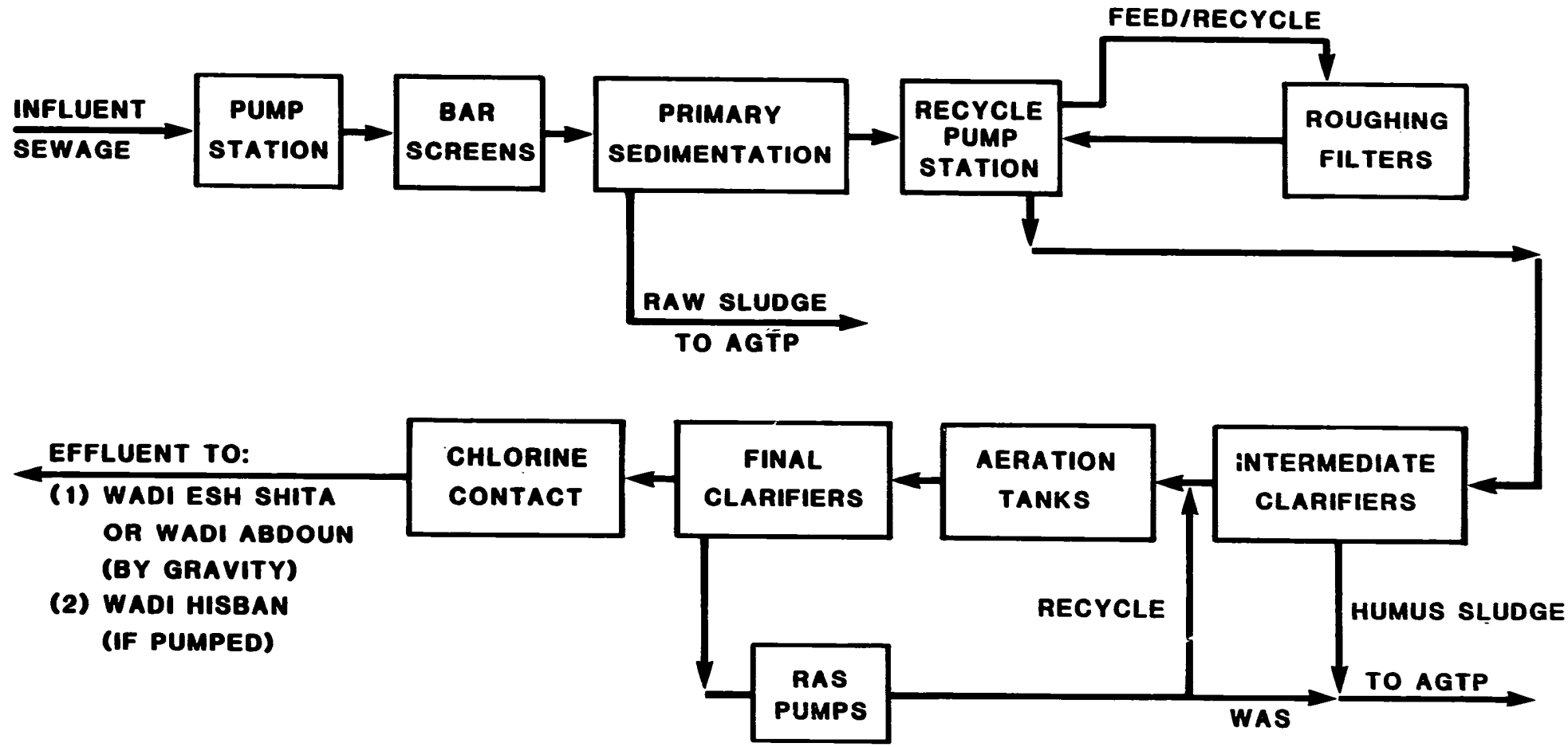
Coarse bar screens will be provided to screen and remove large material entering the treatment plant. Two additional units will be provided to handle the peak sewage flow by past the year 2000. A bypass channel with a manual bar screen will be provided in case mechanical problems require the shutdown of the coarse bar screens, which will be mechanically raked. Screenings will be drained and then disposed of to a suitable landfill.

A Parshall flume will measure the sewage flow as it enters the plant. Provision will be made for a second unit for Phase II conditions. The flow level at approach will be measured by a float within a stilling well. The level will be automatically converted into a flow signal which will be transmitted to an indicator/totalizer/recorder in the control building. The design parameters for the influent pumping station, bar screens, and flow measurement are shown in Table 10-11.

PRIMARY TREATMENT FACILITIES

The primary sedimentation tanks are designed using the same criteria adopted for the design of the new sedimentation tanks at the AGTP. These criteria are presented in Table 10-12. Two tanks will be provided as part of the Phase I construction. By the year 2000, four additional tanks will be required. For the Phase I construction, two plunger type sludge pumps, will be provided. The design criteria for these pumps are presented in Table 10-12. Each pump will serve one primary sedimentation tank with appropriate piping and valving to allow one pump to remove sludge from both tanks. Pumping frequency and duration will be controlled by a time clock and timers.

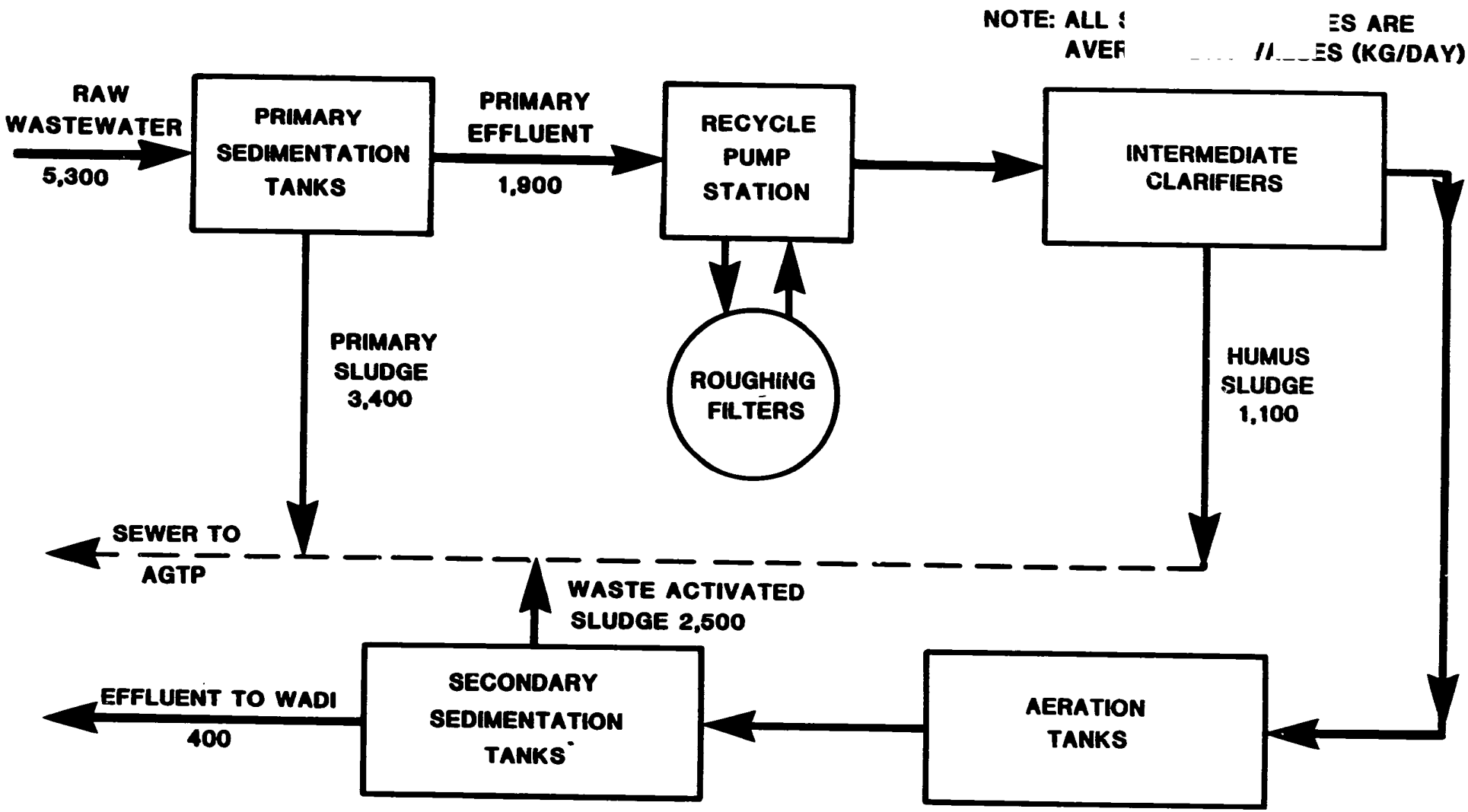
During the early stage of the plant operation the moderate flows anticipated may require use of only one of the two primary sedimentation tanks. However, increasing flows will require that both tanks be used.



1990 CAPACITY: 8,000 M^3/DAY

POST 1990 CAPACITY: 20,000 M^3/DAY

UWATP FLOW SCHEMATIC
FIGURE 10-6



UWATP SOLIDS BALANCE
PHASE I EXPANSION
FIGURE 10 – 7

TABLE 10-11

DESIGN CRITERIA FOR INFLUENT PUMPING, BAR SCREENS AND FLOW MEASUREMENT, UWATP

Parameter	Value
Influent Pumping[a]	
Average Dry Weather Flow, 1990	8,000 m^3/day
Peak Dry Weather Flow, 1990	17,600 m^3/day
Number of Pumps	3 (up to 2 active, 1 standby)
Capacity, Each Pump	11,000 m^3/day
Mechanically Raked Bar Screens	
Number	1
Capacity	18,000 m^3/day (for peak hydraulic capacity)
Width (each)	0.6 m
Size (each)	1 hp
Parshall Flume	
Number	1
Total Capacity (peak flow 2000)	22,000 m^3/day
Throat Width	30.5 cm

TABLE 10-12

DESIGN CRITERIA FOR UWATP PRIMARY TREATMENT FACILITIES

Parameter	Value
Primary Sedimentation Tanks	
Number, Total	2 (6 ultimate)
Number Active, Phase I	4
Width, Each Tank	5 m
Length, Each Tank	30 m
Depth, Each Tank	3.0 m
Average Overflow Rate, 1990	26.7 $m^3/m^2/day$
Average Detention Time, 1990	2.7 hrs.
Sludge Collection	Chain and flight
Skimmings Collection	Chain and flight, helical wiper and beach
Sludge Pumping Units	
Number Required	2 (4 ultimate)
Capacity, Each, m^3/hr	54

BIOLOGICAL TREATMENT FACILITIES

The biological treatment facilities will comprise roughing filter, recycle pump station, intermediate clarifiers, activated sludge aeration, secondary clarification, and chlorination. Sludge pumping is an integral part of the process, especially return activated sludge (RAS) for the aeration tanks. Design parameters are presented in Table 10-13 for all items except the secondary clarifiers and chlorination. Capacity increase will be effected, in general, by trebling the number of units to meet ultimate capacity requirements.

FINAL CLARIFIERS

Two final clarifiers will be provided as part of the Phase I expansion. Four will be required by the year 2000. Here again, two units must be provided to ensure reliability of treatment, although, only one clarifier is needed. The design parameters are presented in Table 10-14.

The return activated sludge (RAS) pumps will be installed in a pipe gallery adjacent to the clarifiers. The design parameters are presented in Table 10-14. Since the waste activated sludge is to be discharged to the sewer, pumping would not be required. An automatic valve on the RAS pump discharge line can be used to control the quantity of sludge wasted.

CHLORINE CONTACT CHAMBER

The chlorine contact chamber's design criteria are included in Table 10-14. The chlorine tank will be designed to permit inactivation of one or more compartments (temporaily) for maintenance pruposes. Chlorination facilities will be comparable to those of AGTP.

CONTROL BUILDING

A control building will be provided to house the following:

- The main electrical switchboard
- The master control board and operator center
- The chlorine room and chlorinator room
- A small laboratory
- Minior maintenance facilities, including some supplies
- A locker room

A function of the main electrical switchboard is to centralize the circuit breakers for the major plant equipment; that of the master control board is to centralize flow indicators/totalizers/recorders in one location for ease of record keeping and monitoring.

TABLE 10-13

DESIGN CRITERIA FOR UWATP BIOLOGICAL TREATMENT FACILITIES

Parameter	Value
New Roughing Filters	
Average Dry Weather Flow, 1990	8,000 m^3/day
Number of Units	1
Diameter by Height	16.5 m x 5.8 m
Area	214 m^2
Media Volume (each)	1,241 m^3
Surface Loading (without recycle)	
Average Daily	37.4 m^3/m^2/day
Peak Hourly	81.5 m^3/m^2/day
BOD Loading[a]	
Total to Units	3,550 Kg/day
Unit Rate	2.9 Kg/m^3/day
BOD Removal, Typical	50%
Recirculation Ratio	2.5
Hydraulic Loading with Recycle	9.4 m^3/m^2/day
Recycle Pump Station	
Average Flow	28,000 m^3/day
Total Dynamic Head, Typical Pump	10 m
Total Pumps Required	1 Active, 1 Standby
Capacity, Each Pump	19.4 m^3/min.
Motor Size, Each Pump	75 HP
Intermediate Clarifiers	
Surface Loading	32 m^3/m^2/day
Total Surface Area	250 m^2
Number of Units	2
Width by Length (each)	5 m x 24 m
Depth (each)	3.3 m
Detention at ADWF[b]	2.4 hr
Humus Sludge Pumps (Direct to Digester)	
Number	1 Active, 1 Standby
Capacity (each)	1 m^3/min. (10 HP)
Aeration Tanks	
Number of Units	2
Volume (each)	2,282 m^3
Sidewater Depth	6.0 m
Length x Width (each)	19.5 m x 19.5 m
Detention at ADWF	13.7 hr
BOD Unit Loading	0.73 Kg/m^3/day
F/M	0.33
MLVSS	2,190 mg/l
O_2 Required	4,700 kg/day
Connected Aeration Capacity	107 kw

[a] Primary effluent assumed as 443 mg/l, corresponding to 30% primary removal.

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TABLE 10-14

DESIGN CRITERIA
FOR UWATP
FINAL CLARIFIERS AND CHLORINE CONTACT CHAMBER

Parameter	Value
Final Clarifiers	
Number (all active)	2
Width x Length	5 m x 54 m*
Sidewater Depth	3.8 m
Surface Area	270 m^2, each
Design Surface Loading, ADWF	15 $m^3/m^2/day$
Design Detention Time, ADWF	6.2 hrs
Return Activated Sludge Pumps	
Number	1 active, 1 standby
Type	Centrifugal, nonclog, variable speed
Capacity	2,000 to 10,000 m^3/day
TDH	2.0 to 5.0 m
HP	20
Chlorine Contact Chamber	
Number Basins	1
Type	3 pass, serpentine flow
Detention Time, ADWF	90 minutes
Volume	500 m^3
Depth	4 m
Width x Length (Each Pass)	4 x 10.5 m

*Circular clarifiers will also be considered during final design.

The chlorine room will house ton containers of liquid chlorine. The chlorinators room will house the chlorinators. Post-chlorination will be to the chlorine contact chamber. Pre-chlorination capability may be included. These rooms will be isolated from the rest of the building and provided with special monitoring and ventilation equipment to protect plant personnel against leaks.

The laboratory will contain the facilities for the basic process control measurements: suspended solids, BOD_5, sludge volume index, and DO. More elaborate tests would be done at the facilities of the Royal Scientific Society and/or at the AGTP laboratory.

Maintenance facilities consisting of a workbench and certain useful hand and power tools will be provided. This will enable the treatment plant operators to perform minor maintenance. Major items of maintenance should be performed at the AGTP in the more extensive facilities available there or by crews from the AGTP. It is not intended that the UWATP staff be large enough to deal with major maintenance.

A locker room with shower facilities will be provided for the convenience of the operators.

IMPLEMENTATION

The first phase of construction for the UWATP will provide treatment capacity adequate to the year 1990. A schedule for design and construction is presented below:

Commence Design Work	-	September, 1982
Conclude Design	-	February, 1982
Begin Construction Phase I	-	April, 1983
Finish Construction Phase I	-	May, 1985

COST ESTIMATE

This section presents the construction and project costs associated with Phase I construction at the UWATP. All costs are calculated for Fall, 1980, in Jordanian Dinars. Table 10-15 presents a breakdown of costs by treatment process and the proportion of local and foreign cost. The implementation cost of each project is estimated to add an additional fifty percent above the construction costs. Implementation costs include: contingencies, engineering, legal, contract administration, surveying and inspection. The construction, implementation and total costs for this first phase of construction at the UWATP are presented below:

Construction Cost (JD 1000)	1,970
Implementation Cost (JD 1000)	985
Total Project Cost (JD 1000)	2,955

Implementation of the UWATP project would entail design no later than 1982-83 and construction during 1983-85.

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TABLE 10-15

UPPER WADI ABDOUN TREATMENT PLANT
CONSTRUCTION COST ESTIMATE FOR PHASE I PROGRAM[a]

Major Work Item[b]	Estimated Construction Cost, JD 1,000		
	Local	Foreign	Total
Headworks	40	50	90
Primary Sedimentation	20	38	58
Oxidation Towers/Recycle P. Sta.	210	430	640
Intermediate Clarifiers	20	38	58
Aeration Tanks	112	228	340
Secondary Clarifiers	70	135	205
Chlorination Facilities	26	39	65
Laboratory and Control Building	58	72	130
Electrical Work and Yard Piping	130	195	325
Site Preparation, Grading, Paving	25	34	59
	711	1,259	1,970

[a] Costs are stated in terms of late 1980 price levels.

[b] Appurtenant pumping equipment (e.g. RAS pumps) is included in applicable work items.

REINFORCEMENT OF AWSA PRIMARY NETWORK

As indicated previously in Chapters 6 and 9, the AWSA primary network of trunk sewers will require reinforcement to meet the 1990 flows and those anticipated to year 2000 and beyond. Primarily, the need for reinforcement arises from the requirement of bringing flows to the AGTP from outer parts of the AWSA network. These new developments, coupled with additional developments within areas already sewered, will cause peak flows to exceed the carrying capacities of certain reaches of existing trunk sewers. The critical reaches are those where construction slopes were flattened somewhat in following the terrain without sufficient increase in pipe diameter to maintain continuity of capacity. Construction and activation of the UWATP will have limited greatly the inflows from peripheral areas westerly of Amman. Without UWATP, greater reinforcements would be required.

AREAS REQUIRING REINFORCEMENT

Except for limited reinforcement of the local trunk sewer in the Sports City-Shmeisani area known as the University of Jordan Trunk, the reinforcements are limited to the central arterial trunk(s) that convey the wastewater from the Wadi Abdoun area downstream. These generally follow the Seil Amman through the downtown area and Ain Ghazal direct to AGTP. The study sub-areas previously used for analyzing the adequacies of the existing trunks sewers to accomodate future flows were delineated previously in Figure 6-1.

NATURE OF REINFORCEMENTS

The existing trunk sewers should be so reinforced that there will be an uninterrupted run of gradually increasing capacity from the upper-most reaches of the network to AGTP. These capacity increases would be so staged as to provide the greatest flexibility and reserve capacity possible, consistent with the ultimate requirements of the system. However, due to competing needs for public funds, only those trunks that will require reinforcement by 1990 will be identified for Phase I implementation. The reinforcement will meet the criteria stated above and will handle the estimated year 2000 flows.

In comparing the carrying capacity of the trunk sewers with the corresponding estimated year 2000 flows, certain reaches required only small diameter relief sewers. It is not reasonable to parallel restrictive sewer reaches with unduly small diameter relief sewers. Therefore, it has been deemed appropriate to size the relief lines at no less than one-half the diameter of the trunk sewer being paralleled or at least 200 mm diameter. This criterion was invoked in a few of the reaches, but the increased costs thus experienced were not major. During detailed design, a refinement of this approach would be carried out, including more detailed investigation of individual reaches of trunk sewers.

The relief of the specific reaches of inadequate capacities will be done by diverting the surplus flow to a parallel line at the beginning of the restrictive reach and returning the surplus to it at the end of the restriction. Special junction manholes or junction structures would be needed for this work, and standard manholes be used on runs of relief sewers, as appropriate.

COSTS OF REINFORCEMENTS

Table 9-16, Master Plan Program for Wastewater Facilities Construction, has set forth the project estimates for the various trunk sewer reinforcements in the AWSA primary network for the Phase I Investment Program (to year 1990). The construction costs and project costs for this total work are as follows:

	JD 1,000		
Cost Item	Local	Foreign	Total
Construction	193	1.4	194.4
Project	290	2	292

Implementation would involve design during 1982-83. However, construction could probably be spread over the period 1983-85. This matter would be refined during detailed design.

PROPOSED NEW TRUNK SEWERS

Trunk sewers westerly of Amman would be confined to the new University of Jordan trunk sewer to UWATP, the Marj al Hamam to AWSA network trunk sewer, and miscellaneous connections. The sludge line for UWATP is really part of the plant construction work but is identified as a separate item (Table 10-17). The diversion of flow from the University Pumping Station to the new University of Jordan trunk sewer would be a routine operation, and the nominal cost of this work has been included in the trunk sewer costs. Construction and project costs are as follows:

	JD 1,000		
Cost Item	Local	Foreign	Total
U of J to UWATP	561	5	566
Marj al Haman (Gravity)	60	1	61
UWATP Sludge Line	57	53	110
KHMC TO UWATP (Gravity)	209	2	211
Construction Total	887	61	948
Project Total	1,331	91	1,422

Marj al Haman trunk sewer should be designed during 1982-83 and constructed during 1983-84. U of J to UWATP trunk sewer should be designed during 1982-83 and constructed during 1983-84, as should the KHMC trunk and UWATP sludge line.

SEWAGE PUMPING STATION AND FORCE MAIN

A sewage pumping station and force main for the First Phase Investment Program would be provided for Marj al Haman. These would actually be built for ultimate capacity initially (taken to be projected year 2000 requirements). This is customary procedure for facilities of this size and nature.

SEWAGE PUMPING STATION

Appendix I presents certain design criteria for sewage pumping stations. The specifics of the pumping station would be established during final design. There are three basic layout choices:

- Provide submersible pumps or wet pit pumps in a wet well. The controls and motors (for wet pit units) would be located at ground level. A housing would enclose these works.
- Provide dry pit pumps taking suction from an adjacent wet well. A housing would also enclose the dry pit and upper level motors and controls.
- Provide a manufactured underground station, complete with piping, pumping units, controls, ventilation, and accessories.

For purposes of preliminary engineering, the first method, that of submersible or wet pit pumps, has been rejected as being poorly suited to the sizes of station contemplated and the type of maintenance and reliability sought. It would be considered only if severe space restrictions were found and then only if it could clearly be demonstrated to be superior to the other two alternatives.

The second method of station layout is conventional and would work quite well in the proposed pumping stations. It would have the advantage of having a substantial local cost component, thereby contributing to the local economy directly. On the other hand, the space requirements of this station are the greatest of all three alternatives. No specific investigations were made of the candidate sites that would be considered for pumping station locations in Suweileh. However, from a general knowledge of the area, it is apparent that there is not must extra space in which pumping stations might be located. The second method of layout is well suited to the incorporation of standby power generation facilities or a standby prime mover for at least one pumping unit.

The third method of station layout has found great favor in small and moderate sized pumping stations. This is the prefabricated (factory assembled) pumping station that is buried and has its access from above via a hatch and ladder shaft. The entire unit is constructed of steel, although in some cases, the housing may be of fiberglass. Protection against external corrosion is by sacrificial anodes. The interior is dry and clean, made possible by automatic ventilation and, where necessary, a dehumidifier. Piping is prefitted and protective coated but may be dissassembled when necessary. Electrical work is suitable to the conditions of operation. Pump suction is via piping from an adjacent sewer manhole of standard construction. Function, ease of maintenance, and reliability are stressed. Standby power may be incorporated under special circumstances.

The only obvious disadvantage of this method of station layout for Jordan would appear to be the nearly 100 percent foreign cost component. This might be significant because of the additive costs for shipping and commissions as well as reductions in local labor requirements.

PRELIMINARY DESIGN AND COST ESTIMATE

For the purposes of this preliminary engineering work, including cost estimate, it has been assumed that the second method (dry pit type pumping station) would be employed.

The pumping units to be incorporated will be used for Marj al Haman and must develop fairly high head in relation to the quantity of wastewater to be discharged. This requires a compromise between mechanical efficiency and pump speed. In order to maintain best efficiency for modest flows, a higher pump speed (rpm) than desirable would be necessary. Thus, an intermediate pump speed, 1150 rpm, will probably be selected in final design.

The nature of the available pumping units in relation to the quantities of wastewater to be handled at peak hourly flow dictates that a single active pumping unit be provided and a duplicate unit held as standby. Either unit would be capable of handling the entire flow. The discharge of the active pump must be coordinated with the sizing of the force main in such a way that the force main velocities are sufficient to produce scouring (about 1 m/sec) but not excessive in developing friction losses. Preliminary sizing of the pumping units and force main has been as follows:

Pumping	Pumping Unit Characteristics			Force Main	
Station	Disch. l/sec	TDH, m	Motor HP	Dia. mm	Length, m
Marj al Haman	63.4	40.9	60	300	3,560

During the initial years, the active pump will run only a relatively small percentage of the time. As flows build up, the running time will increase. However, there will still be adequate capacity with only a single unit active at a time.

The pumping units proposed are vertical, electrically-driven. Fixed speed pumps are recommended for reasons of simplicity, but dual speed pumps might be explored during detailed design. Variable speed pumps were considered but rejected as being inappropriate for the intended application. Wet well sizing will be such as to limit the cycling of pumps during high flow periods but still able to minimize average retention time.

Pumping controls will be adjustable, based upon wet well liquid level. Pumps will be automatically alternated but can be manually selected, if desired. Running time meters will be incorporated in the control system.

Standby power will be provided unless detailed design investigations show that a high degree of reliability of electrical power supply to the station exists and interruption of power would not be more than for a few minutes at most. Standby power would normally be a gasoline or propane engine driving the pump shaft via a right angle drive. A standby electrical generator could be used in lieu of a direct drive prime mover.

A high water alarm will be incorporated. The alarm signal should be automatically telemetered to a central monitoring station, assuming the station is not attended continuously. In order to protect the station and tributary manholes from flooding, a high water emergency overflow will be included, but the intent would be that this be invoked only under emergency conditions. Public health authorities rightfully object to the presence of such overflows. The discharge points of such overflows must be carefully selected to keep public exposure to the absolute minimum.

Pumping stations would be designed during 1982-83 and constructed during 1984.

FORCE MAIN

The force main will primarily be located in public streets and highways and separated as far as feasible from potable water mains. Construction will be of cast iron or ductile iron with rubber gasket joints of demonstrated integrity and durability. The force main profile and discharge conditions are such that potentials for waterhammer should be investigated to ensure that no problem is permitted to develop. The force main may require intermediate valving. If so, provision will be needed for force main drainage. This is normally directed into the wet well via the local piping appurtenant to the pumping unit but intermediate drainage facilties may also prove necessary. Special provisions will be required for sulfide control.

Estimated costs of the pumping station and force main are as follows:

		JD 1,000	
Cost Item	Local	Foreign	Total
Pumping Station			
Construction	20	24	44
Project	30	36	66
Force Main			
Construction	72	63	135
Project	109	94	203

The force main would be designed simultaneously with the pumping station, during 1982-83. They would be constructed during 1983-84 so that they would be ready for use when the gravity Marj al Haman to UWATP trunk and the UWATP were completed.

SECONDARY NETWORK FACILITIES

Secondary network facilities would be included in the First Phase Investment Program. These would comprise both lateral sewers and house connections. In general, standards already in effect for AWSA would be followed in the design and construction work. However, strict attention would be paid to proper vertical and horizontal separation of sewers from water mains for reasons of sanitary protection of the latter. The work would include newly sewered areas within Amman, areas westerly of Amman, and a few miscellanous areas.

Chapter 12 subsequent presents the cost allowances for the various lateral sewers and house connections for the First Phase Investment Program. The tabular information of Chapter 12 actually includes outlying collection systems as well as the AWSA system, areas tributary to UWATP and Marj al Haman. These latter are considered likely to be built during the First Phase Investment Program. Due to the apparent limitations of funding, the outlying communities and their wastewater systems are not thought likely to be implemented in this First Phase.

Lacking specifics of the secondary network facilities, other than the previously mentioned cost allowances of Chapter 12, no additional detail is included on this aspect in Chapter 10.

CHAPTER 11

PROJECT IMPLEMENTATION PLAN

The previous chapter outlined the investment program for AGTP and other improvements. This chapter comments briefly upon the institutional, legal, jurisdictional and financial structures within the Greater Amman Area as they may relate to the Master Plan for Wastewater Disposal. It then considers in some detail the operation and maintenance personnel programs and conditions of AWSA and training program needs. It concludes with discussion and recommendations concerning plumbing, sewer construction and industrial wastewater discharges.

INSTITUTIONAL AND OTHER ASPECTS

Chapter 7 has presented summary information on the current status of institutional, legal and jurisdictional structures of relevance to wastewater disposal, water quality control, water resources management. These structures are established by the highest levels of the Government and may be revised from time to time. It is understood that recommendations are being considered to both broaden and strengthen the laws controlling water pollution and the authorities of certain public agencies engaged in water supply and wastewater management activities.

A Master Plan for Wastewater Disposal has been presented in Chapter 9, and the following general comments on institutional, legal, jurisdictional, and financial aspects are offered in connection with a successful implementation of the Master Plan:

1. The current arrangements give AWSA ample authority to operate within its service area and, if necesary, outside its jurisdiction. The same holds true for the Water Supply Corporation. The latter has only recently begun to exercise its prerogative regarding wastewater system operations. These arrangements could be readily adaptable to the future conditions contemplated by the Master Plan if WSC would assume responsibility for the wastewater systems for the outlying areas and AWSA would extend its jurisdiction to include not only the municipality of Amman but also those areas westerly of Amman (north-draining Suweileh), upper Wadi es Sir, Marj al Hammam, (portion of Suburban Ring) and certain Suburban Ring Areas southerly and southeasterly of Amman in which the physical facilities to be integrated into those of AWSA will be developed.

2. Agreements for system operation could continue to be made between AWSA and other agencies, such as KHMC, but would probably be for an interim basis only. Eventually, there would normally be separate operations by AWSA and WSC, respectively.

3. In order for there to be uniform high standards of system operation, maintenance, and performance throughout the Greater Amman Area and other parts of Jordan, an authority higher than eigher AWSA or WSC

would be needed. A parent governmental agency, the National Water and Sewerage Authority, has been suggested by certain Jordanian officials and is under consideration by the Government. This would appear to be a good solution to the organizational problem. Both AWSA and WSC might become major departments within such a national authority. So might the JVA for areas within its jurisdication.

4. A national authority is needed which would establish standards to be upheld and require operating agencies to conform to them. This national authority could be the same organization as that now being considered, and the operating agencies could be departments within the same organization. Such an arrangement would probably work well within the framework of governmental agencies, laws, and traditions of Jordan. There could also be advantages in having the agency that sets standards that are to be followed be independent of the operating agencies. In the United States, this is the general method followed, and it is found that the likelihood of compliance is usually improved by this arrangement.

5. The legal basis for protection of the public health and the environment should be broadened, coordinated, and made more comprehensive than it presently is. In the United States and elsewhere, public health authorities still retain ultimate jurisdiction, legal or de facto, over those aspects that bear directly upon the public health. However, other matters, such as these of environmental consequence, are usually under the jurisdiction of another regulatory authority.

6. The Government already excercises its broad authority for planning of future developments via the Five-Year Plan. The plan recommends both developments to be undertaken and funds to be allocated. This system should continue to work well in the future and to accommodate the goals of the Master Plan for Wastewater Disposal among many diverse goals of the various ministeries, departments, and authorities of the Government.

7. Incentives or other devices to encourage property owners to connect to future or existing sewer systems are apparently needed in some areas. This is not only important from the standpoint of public health enhancement and environmental protection but also as regards the financial integrity of wastewater facility operations.

8. The subject of wastewater disposal is neither commonly discussed nor adequately understood by the general public. Yet wastewater disposal has such an impact upon the limited water resources of Jordan and upon the public health that increased public awareness of these matters would undoubtedly contribute towards protection of the public health and environment.

   Recently a special Department of the Environment within The Ministry of Municipal and Rural Affairs and the Environment has been established. The Prime Minister's office has been aggressively pursuing industrial

wastes pollution abatement, while the Industrial Wastes Control Committee has been screening the proposed operations and controls of new industries and setting forth requirements for them (Specifications Standards 202). Various studies and resports pertaining to water resources include information on water quality and water pollution. The Ministry of Agriculture is conducting experiments on controlled application of AGTP digested sludges to agricultural test plots in the Jordan Valley. The Five Year Plan of NPC reflects the needs for development of wastewater facilities in major urban areas such as Amman, Zarqa, Ruseifa, and elsewhere in Jordan.

Public appreciation and understanding of these matters can be fostered through the schools and the media. The process is a long range one but should gradually yield benefits in the form of increased use of and support for public wastewater facilities and control of water pollution for the public good.

The engineering aspects of project implementation have been discussed in Chapter 10. The operation and maintenance aspects are discussed in the following section.

OPERATIONS AND MAINTENANCE PERSONNEL AND PROGRAMS

Careful consideration must be given to treatment plant operations and maintenance in any project implementation plan. Therefore, this section reviews the current situation with regards to the staffing and operation and maintenance of AGTP, sanitary network pumping stations and KHMCTP. It also considers conditions at the Salt TP. Conclusions are drawn and a proposed staffing and training program is offered, based on the recommended alternatives of the Master Plan. Also, the discussion develops proposed operation, maintenance, and training programs to be implemented.

EXISTING PERSONNEL AND OPERATION AND MAINTENANCE POLICIES

The current AWSA staff devoted to the operation and maintenance of the Ain Ghazal Treatment Plant, the King Hussein Military Center (KHMC) treatment plant and the two related pumping stations in 98 persons. Table 11-1 gives the official AWSA job titles, the number of employees in each position and the salary ranges for each position. The AWSA salary philosophy, based on assumptions made from reviewing the table, is to provide greater remuneration for those positions requiring higher educational background and greater technical and mechanical skills. The position titles, presented in order of decreasing starting salaries, reflect the AWSA determination of the relative values of the educational and technical skill required for each position.

Staffing

Since an official AWSA Table of Organization was not available for the personnel at the Ain Ghazal plant and related facilities, interviews were held with the plant manager and his subordinates to determine who was responsible for the various operational and maintenance plant functions and which personnel reported to each supervisor. The Table of Organization for the Ain Ghazal Treatment Plant as presented in Table 11-2, requires some clarification and explanation in order to

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TABLE 11-1

CURRENT STAFFING FOR

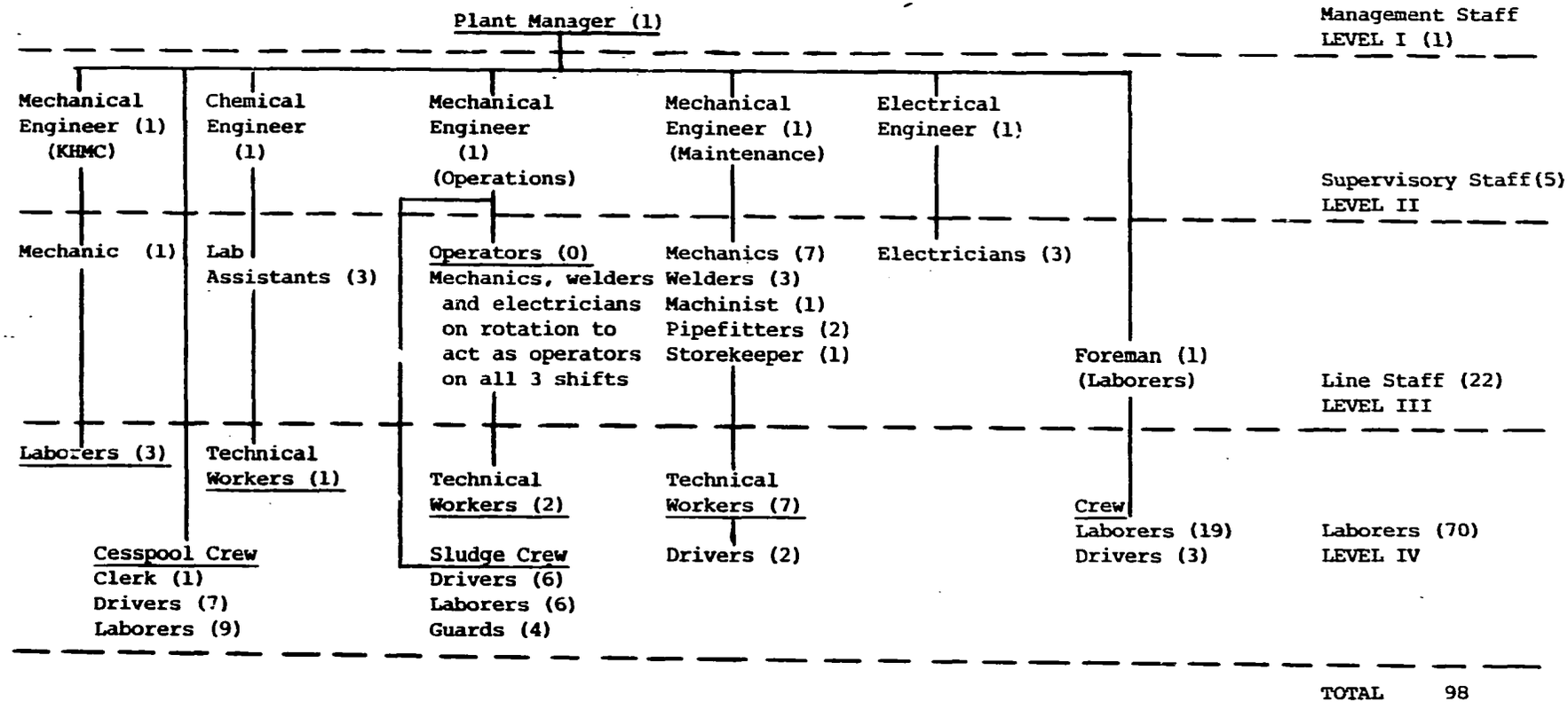
AIN GHAZAL TREATMENT PLANT[a]

Position	No. of Employees	JD/Mo. Salary Range	Organizational Level
Plant Manager	1	350 - 400	I
Mechanical Engineer	3	350 - 400	II
Electrical Engineer	1	350 - 400	II
Chemical Engineer	1	350 - 400	II
Drivers	18	120 - 150	IV
Lab. Technician	3	100 - 130	III
Machinists	1	110	III
Electricians	3	90 - 120	III
Pipefitters	2	90 - 120	III
Mechanics	12	90 - 120	III
Storekeeper	1	100	III
Technical Workers	10	80 - 90	IV
Clerk	1	70 - 80	IV
Guards	4	70 - 80	IV
Laborers	37	70 - 80	IV
Total Staff	98		

[a] Currently all authorized positions are filled.

TABLE 11-2

AIN GHAZAL TREATMENT PLANT - TABLE OF ORGANIZATION



truly represent the functioning of the various positions.

Although the engineering positions are designed as supervisory of very specific functional groups (electrical, operations, maintenance, lab, etc.), all of these individuals and their subordinate staffs function in a cooperative effort to operate and maintain the facility in an efficient manner. The table of organization does not list any personnel in the position of operators due to the fact that the mechanics, welders and electricians rotate as needed to fill these positions on the various shifts. the operational staff on one shift may consist of a mechanic and two electricians and on the next shift may consist of two mechancis and a welder. Although the individuals all serve as operators a good percentage of their time, it should be noted that they have not had any formal training as operators and function primarily as maintenance personnel on these shifts. A similar situation holds true for the laborers and technical workers. They are formally assigned to a specific functional group, but work for any group that has a need for manpower on any given day.

The table of organization has been divided into four levels. The highest level of organization (Level I) represents the management staff (1 person). This level is responsible, in general, for the coordination of all treatment plant related matters, including budgetary and personnel, with the General Manager of AWSA and assure that the plant functions to its optimum capabilities within the general policy and procedure framework of AWSA.

The second level of organization (Level II) repreesnts the supervisory staff (5 people). These people are the first level supervisors and are directly responsible for the operation, maintenance, and process control monitoring for the AGTP, the KHMC treatment plant and the pumping stations. All of the staff at this level are degreed engineers and are responsible for supervising all of the line and laborer staffs and report directly to the Plant Manager.

The third level of organization (Level III) represents the line staff (22 people). These people possess the technical and mechanical skills necessary to implement the directions of the first line supervisory and are directly responsible for keeping the plant functional at all times and/or repairing or replacing any worn out or damaged equipment.

The fourth level of organization (Level IV) represents the laborer staff (70 people). these people are the non-skilled laborers and workers who assist the line staff in the performance of their duties, perform the general housekeeping duties and perform the essential, but non-technical duties of operating the cesspool dumping facilities and the sludge disposal operation.

The organizational levels (I-IV) used in Table 11-2 do not necessarily reflect a decreasing order of starting salaries paid for the different positions, but do reflect the decreasing level of educational background and technical skills needed to operate and maintain the facilities. For example, the position of driver, Level IV, can receive a compensation greater than any of the positions in Level III, but his skills, although valuable for the job of disposing of the sludge, do not directly

impact the operations and maintainance of the facility as much as any of the Level III positions. The remainder of the discussion of personnel and salaries will focus on the management and operations staff (Level I-III) because of the educational and experience requirement necessary to perform their specific duties as opposed to the semi or non-skilled positions of the Level IV personnel.

AWSA Policie

During discussions with the AGTP plant manager and AWSA officials, it was determined that formalized policies do not exist establishing minimum educational and experience requirements for the management and operations staff positions. (Levels I-III). Typically, when a vacancy occurs, the management establishes the minimum qualifications for the position based on what is available in the job market and on the qualifications of the person one can reasonably expect to recruit based on the salary and working conditions that are being offered. Evaluation of the existing personnel with respect to educational and experience qualifications cannot be accomplished without minimum requirements. Therefore, discussions were held with the plant manager and supervisory staff to establish reasonable minimum requirements for each management and operational staff position and optional (but less desirable) requirements if the educational and experience requirements were not met.

The minimum requirements are presented in Table 11-3 and summarized below.

Level I - Management Staff. Educational requirement: B.S. degree in Engineering. Experience requirement: 10 years of related experience, 3 to 6 of which are in sewage treatment.

Level II - Supervisory Staff. Educational requirement: B.S. degree in Engineering. Experience requirement: 3 to 5 years of related experience.

Level III - Line Staff. Educational requirement: Varies by position from completion of secondary school to an academic degree. Experience requirement: Varies by position from 0-8 years related experience.

The minimum requirements stated above represent those requirements the manager and supervisory staff determined should be required in the recruitment of new personnel and do not reflect official AWSA policy.

Qualifications of Personnel

Table 11-4 presents a review of the qualifications of the present management and operations staff at the AGTP including years at the AGTP facility, educational background when hired, and previous years of related experience when hired.

TABLE 11-3

PROPOSED MINIMUM STAFF QUALIFICATIONS[a]

Staff Position	Minimum Educ. Requirements	Minimum Exp. Requirements	Optional Requirements
Level I			
Plant Manager	B.S. in Eng.	6 yrs. in sewage treatment	--
Asst. Plant Manager	B.S. in Eng.	3 yrs. in sewage treatment	--
Level II			
Operation Supervisor	B.S. in Eng.	3 yrs. in sewage treatment	B.S. degree in related field + 5 yrs experience
Laboratory Supervisor	B.S. in related science field	3 yrs. related lab. experience	10 yrs in related lab analysis work
Maintenance Supervisor	B.S. in Eng.	3 yrs. related maint. experience	2° Voc. Cert. in mech. + 10 yrs related experience
Mechanical Maint.Foreman	2° Voc. Cert. in mechanics	5 yrs. related maint.experience	10 yrs related maint. experience
Electrical Maint. Foreman	2° Voc. Cert. in electricity	5 yrs. related elect. exp.	10 yrs related elect. experience
Level III			
Maintenance Staff (Mechanics, welders, pipefitters, machinists, & electricians)	2° Voc. Cert. in related field	2-5 yrs. related experience	5-8 yrs, in trainee position
Storekeeper	2° School Certificate	2 yrs related experience	5 yrs. related experience
Lab. Assistants	2° School Certificate	2 yrs. related experience	5 yrs. related experience
KHMCTP Operations Supt.	2° School Cert. or Voc. Certificate	5 yrs. in sewage treatment	8 yrs. in sewage treatment
AGTP Shift Supervisors	2° School Cert. or Voc. Certificate	3 yrs. in sewage treatment	5 yrs in sewage treatment
Operators	2° School Cert. or Voc. Certificate	No prior experience	5 yrs as operator trainee

[a]Applicable to the existing AGTP.

TABLE 11-4

REVIEW OF QUALIFICATIONS OF PRESENT MANAGEMENT AND OPERATIONS STAFF OF AGTP

ENGINEERING STAFF (LEVELS I AND II)

Position	Level	Yrs. on Staff	Ed. When Hired	Yrs.Exp. When Hired	Desired Min. Education	Desired Min. Experience	Options
Plant Supt.	I	12	B.S. in Mech.	9	B.S. in Engr.	10 yr.	--
Mech. Engr.	II	10	B.S. in Mech.	0	B.S. in Engr.	2 yr.	5 yrs in W.W.
Mech. Engr.	II	5	B.S. in Mech.	0	B.S. in Engr.	2 yr.	5 yrs in W.W.
Elect. Engr.	II	4	B.S. in S.S.	6	B.S. in Engr.	2 yr.	5 yrs in W.W.
Chem. Engr.	II	6	B.S. in Chem.Eng.	0	B.S. in Engr.or Chem	2 yr.	5 yrs in W.W.
Mech. Engr.	II	0.5	PhD in Eng.	9	B.S. in Engr.	2 yr.	5 yrs in W.W.

Table 11-4, Cont'd.

OPERATING AND MAINTENANCE STAFF (LEVEL III)

Position	Level	Yrs. on Staff	Ed. When Hired	Yrs. Exp. When Hired	Desired Min. Education	Desired Min. Experience	Options
Senior Mech.	III	1	--	20 yrs.	Voc. Cert. Mechanics (2nd sch)	10 yrs.	15 yrs. w/o cert
Mechanic	III	5	Voc.Cert. Sanitary	2 yrs.	Voc. Cert. Mechanics	5 yrs.	10 yrs. w/o cert
Mechanic	III	2	Voc.Cert.	6 yrs.	" "	5 yrs.	10 yrs. w/o cert
Mechanic	III	2	" "	3 yrs.	" "	3 yrs.	5 yrs. w/o cert
Mechanic	III	3	--	--	" "	3 yrs.	5 yrs. w/o cert
Mechanic	III	4	--	--	" "	None	--
Mechanic	III	0.5	--	2 yrs.	" "	None	--
Welder	III	5	--	15 yrs	Voc.Cert. in Welding (2nd sch)	5 yrs.	7 yrs. w/o cert
Welder	III	8	--	16 yrs	Voc.Cert. in Welding (2nd sch)	5 yrs.	7 yrs. w/o cert
Electrician	III	8	--	9 yrs	Voc.Cert in Elect. (2nd sch)	2 yrs.	5 yrs w/o cert
Electrician	III	10	--	3 yrs	Voc.Cert in Elect. (2nd sch)	2 yrs.	5 yrs w/o cert
Electrician	III	5	3 yrs. Ind. Cert Elect.	2 yrs	Voc.Cert. in Elect. (2nd sch)	2 yrs.	5 yrs. w/o cert

TABLE 11-4, Cont'd.

OPERATIONS AND MAINTENANCE STAFF (LEVEL III)

Position	Level	Yrs. on Staff	Ed. When Hired	Yrs. Exp. When Hired	Desired Min. Education	Desired Min. Experience	Options
Class I Welder	III	10	—	25	Voc.Cert.in Weldg. (2nd school)	10 yrs.	15 yrs. w/o cert
Machinist	III	2	—	30	Voc.Cert.as Mach.(2nd sch)	6 yrs.	10 yrs w/o cert
Pipefitter	III	5	—	—	Voc.Cert. in Sanity(2nd sch)	3 yrs.	5 yrs w/o cert
Pipefitter	III	0.5	—	1	" "	3 yrs.	5 yrs w/o cert
Storekeeper	III	7	B.A.	—	Secondary School	2 yrs.	—
Foreman	III	10	—	20	Secondary School	5 yrs.	—
Mechanic	III	2	—	1	Voc.Cert.in Mech.(2nd sch)	—	—
Lab.Asst.	III	0.5	Secondary Academic	9	B.A. in Bacteriology	5 yrs.	—
Lab.Asst.	III	0.5	2 yrs in Univ.	2	B.A. in Chemistry	2 yrs.	—
Lab. Asst.	III	10	2nd^{o} Ed. Cert academic	0	2nd^{o}Educ. Academic	3 yrs.	5 yrs. w/o 2nd^{o} ed.

Although most of the present staff was hired without the guidelines of formalized minimum requirements or optimal experience requirements, a comparison of their qualifications when hired to the proposed minimum or optimal requirements can be justified since the median value for years of experience at AGTP is only 4 years. The information highlighted below is presented in Table 11-5.

A review of the qualifications and experience of the management and supervisory staff (Levels I and II) compared to the proposed minimum or optimal requirements can be justified since the median value for years of experience at AGTP is only 4 years. The information highlighted below is presented in Table 11-5.

A review of the qualifications and experience of the management and supervisory staff (Levels I and II) compared to the proposed minimum requirements or optimal requirement produces the following statistics:

- If the proposed minimum or optimal requirements were enforced when the individuals (6) were orginally hired, only 33% (2) would have been eligible for employment.

- All of the present staff met the minimum educational requirement but only 33% (2) met the requirements for prior related work experience. Half of the staff was hired with no prior experience.

- The average number of years of experience at the AGTP is 6.25 years, although 50% of the staff has been at the facility 5 years or less.

A review of the qualifications and experience of the line staff (Level III) compared to the proposed minimum requirements or optimal requirement produces the following statistics:

- If the proposed minimum or optimal requirements were enforced when the individuals (22) were originally hired, only 14% (3) would have been eligible for employment under the minimum requirements and an additional 27% (6) eligible under the optimal requirement.

- The average number of years prior, related work experience is 7.5 years. However, since six of the individuals have an average of over 21 years of prior experience, the majority of the staff (72%) have an average of only 2.5 years of previous experience.

- The average number of years at the AGTP for all Level III personnel is less than 5 years (4.6 years) and 68% (15) of the line staff have 5 years or less experience at the facility. The figure for years experience at AGTP is slightly inflated because several employees worked as laborers (Level IV) before being promoted to the line staff and the actual years of experience at the AGTP facility in a line staff position is closer to 4 years.

TABLE 11-5

SUMMARY OF STAFF EXPERIENCE AND EDUCATION

	Line Staff Level III	Management and Supervisory Staff Levels I & II	All Staff Levels I, II & III
Number of Personnel	22	6	28
Average Number of Years at AGTP	4.6	6.25	4.9
Average Number of years experience when hired	7.5	4.0	6.8
Employees with 5 yrs or less at AGTP	15	3	18
% of Total	68%	50%	64%
Number meeting Min. Ed. requirements	5	6	11
% of Total	22%	100%	39%
Number with Voc. Cert. or degrees when hired	8	6	14
% of Total	36%	100%	50%
Number meeting Min. Exp. requirement	13	2	15
% of Total	59%	33%	54%
Number meeting all Min. requirements	3	2	5
% of Total	14%	33%	18%
Number meeting optional requirements	6		6
% of Total	27%	0	21%
Number meeting minimum or optional requirements	9	2	11
% of Total	41%	33%	39%

A review of the qualifications and experience for the entire management and operations staff (28 people) compared to the proposed minimum and/or optimal requirements produces statistics similar to those presented above, the most noteworth as follows:

- If the proposed minimum or optimal requirements were enforced when the individuals were originally hired only 18% (5) would have been eligible for employment under the minimum requirements and only an additional 21% (6) under the optional requirement.

- The average number of years of prior related work experience is 6.8 years. However, over 50% of the staff came to AGTP with 3 years or less prior experience.

- The average number of years experience at the AGTP for all management and operational personnel is less than 5 years (4.9 years) and almost two-thirds of the staff (64%) have 5 years or less experience at the AGTP.

Turnover of Employees

Although the staff at the AGTP has expanded somewhat in the last five years, none of the employees with less than 5 years experience was employed due to this expansion. The large number of employees with less than 5 years experience is indicative of a fairly large turnover rate. Also, the expansion of existing treatment facilities and the building of new facilities in the Kingdom of Jordan will create a tremendous demand for the small number of existing experienced sewage treatment plant personnel. This, along with the increasing demand for experienced personnel from neighboring Arab countries is likely to produce a turnover in the coming years at the AGTP which will approach and likely equal 20% per year. Procedures that could be implemented by the NPC or other appropriate agencies to mitigate the impact of this excessive turnover rate are addressed in subsequent sections.

TRAINING PROGRAMS, CURRENT STATUS AND NEEDS

According to discussions with AWSA personnel, the effort and expenditures put forth by AWSA during the past five years for formalized training for the management, supervisory and line personnel have not been emphasized. A few employees have been sent to other facilities to observe their operations and maintenance procedures or to attend related seminars, but these training functions occured only on rare occasions. The training that does take place at the facility consists of one-on-one assistance between the manager and/or supervisors and the line personnel in response to a specific operations or maintenance problem. Although of some benefit this after-the-fact training has limited value and usually relates to one specific problem with limited application in preparing the line personnel and/or supervisors to be able to cope with future problems.

One of the primary purposes of the Ain Ghazal plant is to provide maximum removal of pollutants from the incoming sewage and to discharge an effluent that

will have minimal adverse impact on the receiving waters. This goal can only be achieved through constant process control monitoring and appropriate operational response to changes in the process parameters. The maintenance of the various equipment within a facility is critical to good operations, but only in the sense that it is a support function necessary to achieve the goal of efficient operations. The staffing of the Ain Ghazal Treatment Plant as can be seen in Table 11-1, is maintenance oriented, not operations oriented. Only three of the 98 people at the Ain Ghazal plant appear to have a good grasp of operations. They are the plant manager, the chemical engineer and the mechanical engineer in charge of operations. The mechanics, welders and electricians who function as the only operations staff 16 hours per day and on days off and holidays appear to have very little understanding of the concept of operations control as it relates to a sewage treatment facility.

The need to provide training to upgrade the capabilities of the existing personnel at the facility is very great. The following are some of the areas of immediate concern that should be addressed by a comprehensive training program.

Level I Plant Manager. Within the near future, the plant manager will be responsible for directing his staff in the operation and maintenance for the proposed new and unfamiliar sludge handling facilities. It is also possible that he will be required to provide input for the evaluation of certain new design concepts for a proposed expansion of the existing AGTP and subsequently direct this staff in the operation and maintenance of the new and modified facilities.

Level II Supervisory Staff. All of the engineers should have a good grasp of the basic principles of operational control together with an understanding of the specific relationship of the function of their respective departments to the overall objectives of the AGTP. These supervisors will soon be responsible for the operations and maintenance of the new sludge handling facilities and, later, the new plant facilities.

Level III Line Personnel. As presented in the discussion on staff experience, the median number of yers of prior, related experience, for the line personnel when they joined the ASTP staff was 3 years. Although many of them have had previous mechanical maintenance experience, little, if any of it was on the type of equipment typically encountered in a sewage treatment facility. Also, none of the line staff has had any training in the operation of sewage treatment facilities.

Level IV Laborer Staff. These positions are semi- or non-skilled, and most of these workers have little concept of the basic objectives of the facility and basic personal hygiene procedures.

In addition to the above areas, a training program should be initiated for all employees that stresses the inherent hazards of working in a sewage treatment facility and necessary safety precautions that should be taken.

CURRENT OPERATIONS AND MAINTENANCE PROGRAMS

AWSA personnel operate and maintain both the AGTP and, by contract, the KHMCTP as well. The Salt TP is the responsibility of the Municipality of Salt. Good operations are dependent upon a reliable process control testing program, correct interpretation of the results and proper process control charges based on interpretations.

Operations at AGTP

Daily samples are collected throughout the AGTP and taken to the laboratory for analysis. The following process control and monitoring analyses are performed on the samples:

Daily analysis

Settleable solids, dissolved oxygen, sight depth, chlorine residual and coliforms.

Biweekly analysis

Temperature, pH, total solids, suspended solids, BOD_5, sludge volume index, volatile solids and chemical oxygen demand

Previous attempts to operate the facility based on the accepted parameters of F/M ratio and mean cell residence time have not been successful. The amount of mixed liquor suspended solids needed in the aeration tanks under these conditions exceeds the capacity of the aeration system. Also, it is almost impossible to balance the solids loadings on the four tanks. The only process control readily available to the operational staff is the control of wasting rate from the individual aeration tanks. Control of this parameter is limited due to the V-notch weirs assembly air lift pumps and the amount of solids that can be wasted daily to the gravity thickeners.

Scum and grit originating mainly at the cesspool operation are also causing operations problems resulting in grit accumulation in the digesters and some scum in the final effluent. Also, considerable operational problems exist due to lack of digester space and non-functional equipment associated with the solids handling. The implementation of the results of this study should alleviate these problems.

In general, little improvement in effluent quality could be achieved through changes in the operational procedures of the AGTP due to the limitations of the existing equipment and influent load. Little improvement in effluent quality can

be expected until expansion relieves the excessive loads to the facility. The operation and maintenance procedures are adequate considering the overloaded conditions.

Maintenance Procedures at AGTP

The AGTP employs a wel qualified staff of supervisory personnel for the maintenance of mechanical and electrical equipment. The line maintenance personnel are sufficient in number to handle the majority of the maintenance tasks although most were hired with limited vocational education and maintenance experience, especially experience in sewage treatment field. The maintenance tools, equipment and machinery at the facility are sufficient for most minor and major repairs.

Two separate record systems are employed at the AGTP to direct routine (preventive) maintenance program and to document breakdown (repair) maintenance program. The routine maintenance program is controlled by a large wall chart spanning a one year period that tests each piece of equipment and the type of periodic maintenance that must be performed. The mechanical engineer (maintenance) directs the weekly routine maintenance program from this chart. However, at the end of each week, no record is made of the routine maintenance tasks performed.

An equipment card exists on each piece of machinery at AGTP. The type of equipment, manufacturer, supplier, serial number and other important information used frequently or not readily available in the manufacturer's equipment literature, is recorded. The back of the card contains and date and type of repairs. The following observations are based on a review of the equipment cards:

- Barminutors 1 and 2 - Out of service for repairs a total of seven times since they were both overhauled two years ago.
- Chlorinators 1, 2 & 3. One entry for cleaning since units were installed.
- Grit screws 1 and 2. Two reports of minor repairs although units have been broken several times and out-of-service for some time.
- Sludge pumps all overhauled in 1973. No other record of repair.
- Air compressors 1, 2 & 3. Only one entry for each in 1975.
- Primary sedimentation scraper, chains and drive units (6). Only two repairs recorded since installation.
- Final sedimentation, scrapers, chains and drive units (12). Only one recorded repair since installation.
- Blower No. 1. Overhauled in 1977. Out-of-service for 9 months.

- Blower No. 3. Overhauled in 1978.
- Blower No. 4. Cleaned in 1974.
- Blower No. 5. Repaired and/or overhauled in 1975, 1978 and 1980.
- Blower No. 6. Reported vibrating in 1975. No other entry.
- Blower - spare. Overhauled in 1977, 1978 and 1980.
- Flushing Pump No. 1. Overhauled in 1977, 1978 and 1980.
- Flushing Pump No. 2. Overhauled in 1980.
- Heat exchangers 1 & 2. No record of repair.

The previous information would indicate that the equipment at the AGTP is relatively maintenance free. Discussion with plant maintenance personnel have indicated that this is not the case. It is more likely that the plant record system is not updated regularly.

The equipment initially installed at the Ain Ghazal plant is over 12 years old. It is obvious from the repair records just listed, although incomplete, that the frequency of breakdown, repair and overhauling of equipment is increasing. Observation also indicates that replacement of the scrapers, chains and sprockets on the primary clarifiers and repair on other major equipment are imminent. In the past five years, the mechanical maintenance staff has almost doubled, a further indication of the increased occurrence of major maintenance tasks.

The maintenance staff has attempted to keep an adequate supply of frequently needed spare parts in the store room. This task is becoming more difficult. Many original replacement parts are no longer available for much of the equipment and instrumentation. Substitute replacement parts have been located for many items no longer available but the adequacy of future supplies is questionable. Frequently, specialized replacement parts are purchased locally at exorbitant prices, or ordered from the original equipment supplier with a 6-12 month wait.

Also indicative of the limited future lifespan of the equipment is the list of items that are no longer functional. These items include:

- Influent flow meter
- Chlorine residual analyzer
- All gas, sludge and other flow meters on the main control panel
- Digester gas mixing system
- Some digester pumps

- Grit screw

A considerable increase in the cost of equipment repairs, maintenance man-ower and the cost of replacing major pieces of equipment can be anticipated in the next five years at the Ain Ghazal plant.

Conditions at KHMCTP

The King Hussein Medical Center Treatment Plant is operated by the AGTP staff. The plant influent exceeds design capacities for flow and solids loading. The process control capabilities are also limited. Settleability tests are run daily and influent and effluent BOD_5 tests are run weekly by the Ain Ghazal lab. No other process control tests are performed. The only control over the entire activated sludge process is the wasting of sludge by air lift pumps. Practically, the wasting rate should be based on the MLSS concentrations in the aeration tanks. However, this test is not performed. Wasting to the sludge drying beds is done every two days based only on the settleability results and the color of the mixed liquor. Equipment has been ordered that will allow the staff to measure D.O. and pH in the future.

Considerable scum accumulates on the surface of the clarifiers since no scum removal equipment was provided for the secondary clarifiers. The staff has installed crude screens at the end of the effluent weirs to collect some of the scum. This has resulted in the complete flooding of the effluent weirs uch that the clarifier water level is approximately 1 cm over the weir level.

The chlorine is injected into the effluent flow just prior to entering the pipe that discharges to the adjacent wadi. The point of injection provides little mixing and the contract time prior to discharge is only a few minutes. the chlorination system was not functioning at the time of the plant inspection, and it appears that it will require considerable maintenance in the near future. Dewatering and maintenance on either of the two aeration tanks causes the remaining aerator to overload and shutdown, thus stopping all treatment. The aerators were overhauled recently and will require minimal maintenance in the near future. The two air compressors for the air lift pumps were recently abandoned and new compressors installed.

The sludge drying bed underflow drains into an earthen reservoir adjacent to the wadi. The pump used to return the flow to the headworks is out of service and a new pump is on order. The plant flow meter was also out of service.

Conditions at Salt Treatment Plant

At the time of this writing, the new Salt TP was under the operational control of the contractor. The facility appeared to be performing adequately although there are operational and design considerations that make the plant very inefficient and costly to operate and will continue to create problems with the effluent quality. The aeration tank is overdesigned for the current and projected flows. Six mechanical aerators are in use at all time, 33% of the time at high speed and 66%

of the time at low speed. If positioned correctly, 2 or 3 of the aerators would be sufficient to maintain adequate D.O. and mixing.

The secondary clarifier is not equipped with a scum removal mechanism. All scum is discharged with the effluent. The removal of sludge from the clarifier is by gravity feed to a wet wall containing 2 Archimedean screw lift pumps. This arrangement is susceptible to plugging as was the experience during the plant visit. Subsequent denitrification was causing most of the solids loading to the clarifier to be discharged with the effluent. The RAS is discharged at the effluent end of the aeration tanks only 30 m from the effluent weir. This should be modified to provide for RAS discharge at the inlet end of the tank.

The contractor has installed a bypass connection on the line leading from the gravity thickener to the sludge drying beds. This line is used during inclement weather to dispose of waste solids directly to the adjacent wadi. Capacity and settling problems with the drying beds should be corrected and the bypass line eliminated. Standby generators capable of operating all major plant functions have been provided.

Due to the recent start up of the facility and low loadings, current process control testing and maintenance procedures are minimal. Maintenance records are kept on major equipment items, mainly due to the requirements of manufacturers' warranties. Process control testing is negligible. D.O. and settleability tests are run daily. Every 15 days, influent and effluent samples are taken for BOD_5 analysis by the Royal Scientific Society. The entire operational process control is based on the settleability tests. If the settleability rises, the wasting rate is increased and vice versa.

Although marginally adequate at the present, this procedure will not be sufficient for process control as the loadings increase on the facility. It is anticipated that considerable training of the operations and maintenance staff will still be needed when control of the facility is assumed by the Municipality of Salt.

Additionally, the plant influent includes discharges from roof drainage (wet weather), a pharmaceutical manufacturer, a hospital, and numerous gas stations. The gas stations contribute spent oil from garage operations, this tending to impair operations. The downspout discharge causes excessive flows during high intensity rainstorms. The other discharges have the potential for disruption of the treatment process or effectiveness. A source control program for these discharges should be implemented. (The pharmaceutical manufacturer's discharge, reportedly has not yet caused any plant process problems).

GROWING IMPORTANT OF WASTEWATER MANAGEMENT

For many years, the Ain Ghazal Treatment Plant was the only sewage treatment facility in Jordan. The only responsible agency was Amman Water and Sewage Authority. The addition of treatment facilities at Salt, KHMC and other areas in recent years and the proposed addition of treatment facilities in Irbid, Zarqa-Ruseifa, Jarash, etc., have broadened the importance of these activites from a local to a national level. As a result, there is a need for the National Planning

Council, or other appropriate agency(s), to establish and/or further certain essentail programs for improving wastewater management. Some of the programs are of long-term concern and others of immediate concern for implementation. They should be developed in keeping with the goals and objectives of the Kingdom of Jordan.

National Monitoring Program

The increased utilization of sewage treatment plants as opposed to cesspool systems is going to concentrate the potential for adverse effects on the groundwater supplies and other environmental parameters. This will not be a concern however, if the loading to these facilties does not greatly exceed design loadings and the plants are operated in accordance with accepted standards. To assure that this does not become a concern, the appropriate agency should establish a simple form of effluent guidelines for each treatment facility. Each municipality or plant should be required to report compliance or non-compliance with these guidelines on a monthly basis. This procedure will allow the regulatory agency to spot problems or potential problem areas quickly and to provide technical or other assistance in a timely fashion.

Public Awareness Program

Successful operation of sewage treatment facilities depend upon efficient conveyance of the sewage to the treatment plant and proper functioning of the mechanical equipment and biological processes. The dumping of garbage, debris and many waste liquids into the sewer system can be detrimental to the entire system. A general public information and education program could lead to a reduction of the dumping of harmful substances into the collection and stormwater systems.

Private Industry Awareness Program

The dumping of certain substances used or produced in private industries can be harmful to the treatment systems and in some instances dangerous to plant personnel. Private industry should be educated on the potential harm that can result from the discharge of certain materials. Eventually, it will be essential to formulate regulations on the type and quantities of certain materials that can be legally discharged to the collection system.

Sewage Operator Training

Expansion of existing facilities and construction of new facilities will create an increased demand on the currently almost non-existent manpoer force with experience in the operation and maintenance of sewage treatment facilities. The only alternatives to satisfying the demand with qualified personnel are to import expensive expatriate labor or to develop the institutional capabilities to train the labor force in-country. The latter alternative is the most cost effective and consonant with goals and objectives of the Kingdom of Jordan. The NPC is already investigating this option and AWSA has recently appointed a training department

head to initiate such a program. This issue will be discussed later in this section.

RECOMMENDED AWSA PERSONNEL PROGRAM

It is recommended that a revised personnel program be implemented by AWSA as regards the operations of the AGTP and other treatment and wastewater management facilities with which it may be involved in the future. Such recommendations are developed in the light of the current table of organization, for which a brief appraisal is as follows:

- The current organization is a "flat" organization (typical for Jordan) with considerable direct responsibility on the plant manager. Although the ultimate authority for all operations and maintenance must reamin with this position, the responsibility for the plant functions should be delegated to other staff members. Currently, seven plant functional groups report to this one position.

- The staff consists of more engineers than normally would be required to operate a facility of this size. This is consistent with AWSA objective of having staff on hand to fill vacancies immediately with experienced engineers.

- The present staff does not contain line personnel whose training specifically qualified them as operators. Four or five of the personnel who fill in as operators should be trained to function as operations personnel and permanently assigned to their position. Their mechanical skills make them excellent candidates for this position.

- Operations of the current facility is very labor intensive. The proposed elimination or upgrading of the labor intensive unit processes should allow AWSA to reduce the current labor force in the future. The current labor force at the AGTP could be reduced substantially without loss in treatment efficiency. However, this remains a policy decision for AWSA.

New Table of Organization

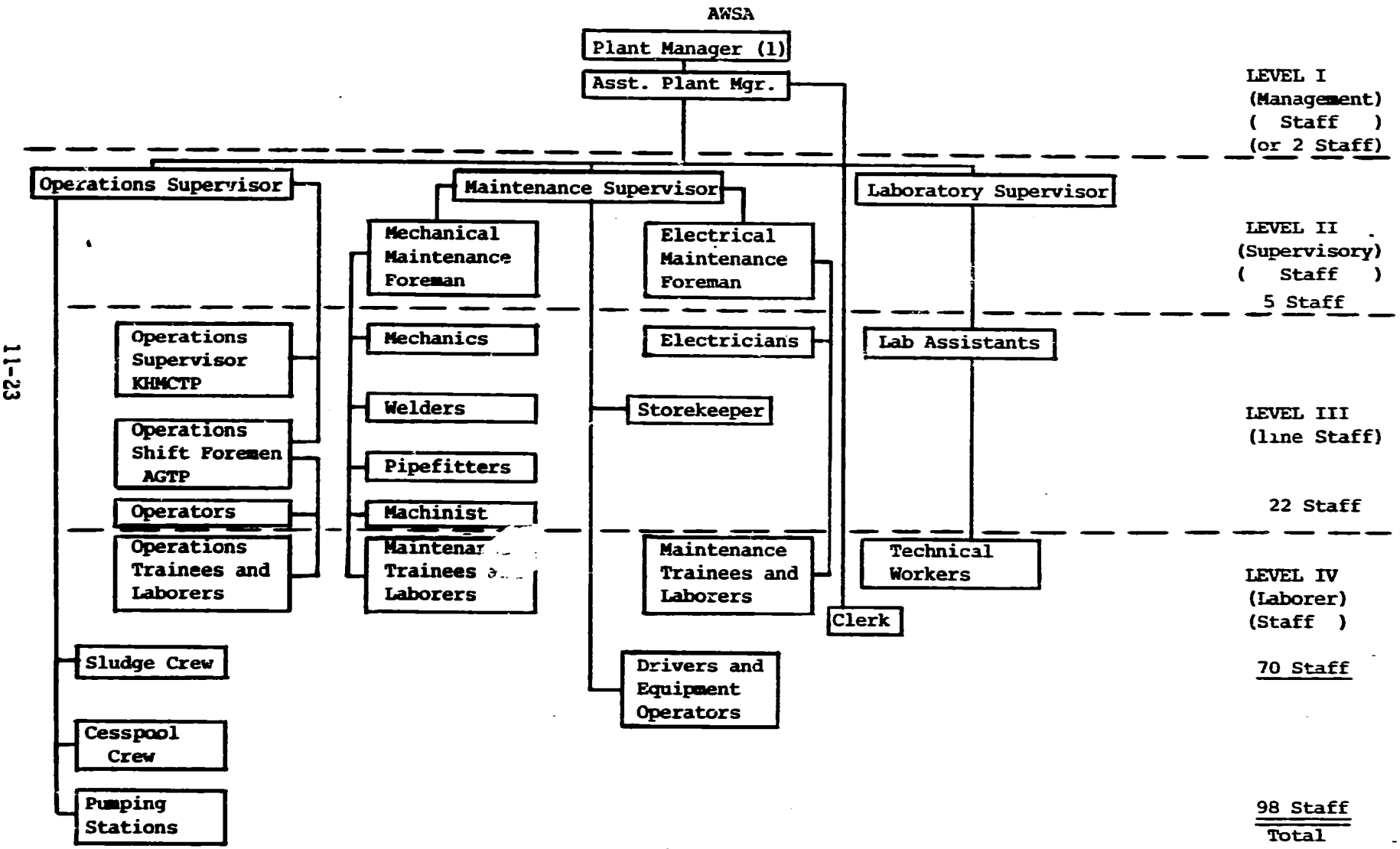
A proposed table of organization for the existing Ain Ghazal staff is presented in Table 11-6. This table includes all of the existing staff and is not intended to streamline or reduce the staff size. Salient features of the proposed table or organization area as follows:

- The table represents a pyramidal organization where responsibilities are distributed throughout the staff from the management down to the line staff.

- An assistant plant manager position (optional) provides a position familar with all plant functions able to assume responsibility in the absence of the plant manager.

TABLE 11-6

PROPOSED TABLE OF ORGANIZATION FOR EXISTING AGTP STAFF



- The supervisory staff is divided into three main functional groups (operations, maintenance and laboratory), as opposed to the previous organization of six functional groups and a facilities group (KHMC treatment plant). In this arrangement, the Operations Supervisor is responsible for all sewage operations related functions (AGTP, KHMCTP, sludge crew, cesspool crew and pumping station) and reports directly to the assistant or plant manager. The laboratory supervisor is responsible for process control testing and effluent monitoring at all facilities. The maintenance supervisor is responsible for mechanical and electrical maintenance at all facilities.

- It is assumed that the present cooperation between the various supervisors, line staff and laborer staff would continue in the sharing of manpower and information because each functional group is dependent upon the other.

- The proposed new sludge handling facilities would not affect the chart as presented. Each supervisor may require additional manpower but each supervisor would assume responsibility for his functional area for the proposed facilities. The same would apply to any proposed expansion to AGTP or KHMC treatment plant.

- The staff currently designated as technical workers have been assigned to the three functional groups and are called trainees. If used correctly in their capacity, they will become the source of some of the line personnel needed in the future.

Reevaluation of Minimum Qualifications

Concurrent with a change in a table of organization sould be a reevaluation of the minimum requirements for each position. The minimum position requirements presented in Table 11-3 were staff suggested requirements for the purpose of evaluating the qualifications of the current staff. At present, AWSA does not have official guidelines for the minimum qualifications for new staff at AGTP and related facilities. The lack of official guidelines has resulted in a staff that has the following characteristics:

- The staff is very labor intensive. Over 70% of the staff are laborers (Level IV).

- Most of the line personnel (Level III) could not qualify for employment under the proposed minimum qualifications.

- The management and supervisory staff are more qualified and in greater numbers than would normally be required at a facility the size of AGTP. As stated previously, this is attributed to AWSA policy and to the lack of qualifications of the line staff.

The staffing projections presented in this section for the proposed expansion at AGTP and for the construction of new facilities are directed at modifying these staff characteristics. This can be accomplished by the formulation and adoption of official minimum qualification guidelines. New minimum qualification guidelines, based on the proposed table of organization, should be as in Table 11-3. These guidelines emphasize the need to hire personnel with a minimum or secondary academic or vocational training and prior experience in sewage treatment or related fields. The optional requirements allow for upward mobility of personnel with extensive experience in line with current AWSA policy.

Staffing the AGTP and other new facilities with personnel that meet these requirements will not be readily accomplished without related changes in other AWSA policies. Policy decisions should be reviewed in the following areas:

- Salaries - Hiring and retaining employees with superior qualifications depends upon, among other considerations, salaries that are competitive with other public and private sectors competing for the same manpower force. A review of salaries being offered in other sectors for this manpower should be conducted to determine if the current salary structure is adequate to compete. Special consideration should be given to salaries being offered in neighboring oil-rich countries.

- Training - One option to hiring personnel with all desired qualifications is to hire the best qualified personnel available and to train them for the specific duties to be performed. The training of personnel has also proven to reduce turnover rates and substantially improve operational efficiencies. It is recommended that AWSA initiate a comprehensive training program. The next section addresses the implementation of a training program.

TRAINING PROGRAM

AWSA has recognized the need for training and recently appointed a Director of Training. Also AWSA is planning to adopt and implement a training program similar to those offered in the United Kingdom. In implementing training programs, it is recommended that consideration should be given to certain essential steps during the program implementation.

Needs Assessment

In order for a training program to be effective and efficient, a needs assessment survey should be conducted intially. This survey should identify the types of information needed to perform a given task and the current skills and knowledge of the personnel performing these tasks. To determine the skills needed to perform a task, specific job titles need to be established as presented in Table 11-6. For each job title, a job description is formulated that lists the minimum qualifications and specific duties to be performed. For example, one duty statement for a maintenance mechanic might be that he will be able to replace the packing on all pumps. To accomplish each duty, a number of specific skills must be used by the

individual. In repacking a pump, some of the skills that would be needed include:

- locking out the pump
- isolating the pump from the system
- actuating the standby pump
- removing the lantern ring
- removing the old packing
- installing the new packing, etc.

The process can become cumbersome if too much detail is involved.

Once the specific skills are identified an assessment is performed to determine the skills already possessed by the existing staff. This can be performed in several ways. The simplest method is to ask the supervisory personnel if the individual can perform the tasks. A more detailed procedure involves asking the individual to perform the task or how he would perform the task. The detailed listing of specific job skills and the assessment of the current skills becomes the basis for the training program. They describe the skills that must be demonstrated.

Training Delivery Method

The appropriate methods to deliver the training must next be determined. Training may be in the form of classroom training, on the job training or a combination of both. Each training method can be presented in different ways. Classroom training may consist of lectures, demonstrations, worksheets, use of audiovisual techniques, or hands-on work. On the job training may consist of lectures, demonstrations, actual performance of the task by the trainees or a combination of methods. It is also important to determine when the training will take place. Training activities can take place during working hours, after hours or on days off. The determination of the appropriate training delivery method will depend entirely on the results of the needs assessment and other local conditions. For some staff positions, it may be determined that the best training can be obtained through overseas visits to other sewage treatment facilities, attendance at specific seminars or conferences or consultant training services.

Selection of Trainees

The method of selection of trainees will depend upon AWSA objectives. Although it would be desirable to train all level I, II and III employees, the best alternative may be to initially train those individuals requiring the least amount of training. Initially, trainees should be selected that have similar background and present skills.

Development of Training Materials and Lessons

The needs assessment information is used to develop specific behavorial objectives for each training segment. The specific, detailed lesson plans, are developed based onthe behavorial objectives. The lesson materials, handouts, visual aids and demonstration equipment are acquired after the lessons have been

developed.

Presentation of Evaluation

After completion of the previous steps, presented of the training materials is a simple task. Subsequent to the delivery of each lesson or groups of lessons, the trainees should be evaluated to determine if the training objectives have been met. This will serve as feedback for revisions, as necessary, to the lessons.

The implementation of a training program using these quidelines will be a major undertaking for AWSA. It may be advantageous for AWSA to seek the assistance of the Vocational Training Corporation, other appropriate educational agencies, or an outside consultant with considerable expertise in vocational training in the sewage treatment field.

In addition to training of existing staff, AWSA and other municipalities will be faced with hiring and training new personnel for the proposed expansion of AGTP, KHMC treatment plant and for other proposed new facilities. Ninety-eight people are currently employed at the AGTP but this will increase greatly. Table 11-7 projects the treatment plant personnel requirements in the Greater Amman Area for 1990 and year 2000, assuming implementation of all alternatives. Even with only selective implementation of projects, the need will be substantial. The training of personnel for the proposed and expanded new facilities must begin well before the starting of the facilities. Most personnel for these facilities should be hired from 6 months to a year prior to the start of these facilities to provide adequate training. The training responsibilities for AWSA are going to increase tremendously in the next years.

The above training programs may prove to be too costly a program for AWSA to implement on its own. Serious consideration should be given to establishing a national training center within the Kingdom of Jordan. A training center would have the following advantages.

- The cost of training would be disturbed over a larger base.
- Smaller municipalities who could not afford a training program would be able to participate.
- It would help prevent duplication of training efforts.
- It could provide upgrade training to existing personnel and entry level training.
- It would be able to supply entry level personnel to meet the projected sewage treatment manpower needs within Jordan and possible other Middle East countries.
- The trainees would become familiar with a variety of treatment plants and processes and not just one specific type.

TABLE 11-7

PROPOSED STAFFING OF WASTEWATER TREATMENT PLANTS, GREATER AMMAN AREA

Personnel		AGTP	UWATP	KRTP	Salt	Baqa'a	L.W.Sir	Sahab	Na'ur	Fuh/Mah	Abu Al'a	Hashimiya	Sukhneh
For 1990													
Level II													
Plant Manager	(2)	1											
Assist. Plant Mgr.	(1)	1											
Subtotal		2											
Level III													
Supervisors	(8)	5	1										
Subtotal		5	1										
Level IV													
Maintenance Personnel	(19)	14	2		1	1	1.0						
Operations Foreman	(9)	5	1		1	1.0	1.0						
Operators	(21.5)	12	3		2	.5	[illegible]	.5	1	1	.5	.5	.5
Lab Assistant	(5.5)	4	1			.5							
Subtotal		35	7		4	3	2	.5	1	1	.5	.5	.5
Level IV													
Laborers	(85)	67	4		5	3	2	.5	1	1	.5	.5	.5
Total	(148)	109	12		9	6	4	1.0	2	2	1.0	1.0	1.0
For 2000													
Level II													
Plant Manager	(2)	1		1									
Assist. Plant Mgr.	(1)	1											
Subtotal		2		1									
Level III													
Supervisors	(9)	5	2	2									
Subtotal		5	2	2									
Level IV													
Maintenance Personnel	(33)	18	5	6	2	1	1						
Operations Foreman	(12)	5	3	3	1								
Operators	(49)	18	8	12	2.5	2.5	2	.5	1	1	.5	.5	.5
Lab assistant	(10)	5	2	2	0.5	.5							
Subtotal		46	18	23	6	4	3	.5	1	1	.5	.5	.5
Level IV													
Laborers	(118)	75	10	13	7	4	3	.5	1	3	.5	.5	.5
Total	(234)	128	30	39	13	8	6	1.0	2	4	1.0	1.0	1.0

PROJECT IMPLEMENTATION PLAN

Implementation of a national training program will be a major undertaking. It is recommended that programs of a similar nature to those that exist in most of the United States be visited and evaluated prior to any program of implementation.

OPERATOR CERTIFICATION PROGRAM

A logical extension to national monitoring and training program is the certification of sewage treatment operations and maintenance personnel. Such a program aids in the establishment of universally acceptable minimum educational and experience requirements within the Kingdom. This also facilitates the movement of employees from on facility to another which will become routine in the near future. Certification programs have been shown to improve the operational efficiencies of personnel and to aid in the recruitment of new personnel into the sewage treatment field.

A model certification program used extensively in the U.S.A. is that which was adopted by the State of California and is administered by the State Water Resources Control Board. The following excerpts are from California Adminstrative Code, Chapter 3, Title 23, Subchapter 14, "Classification of Wastewater Treatment Plants and Operator Certification."

> "2480. CERTIFICATION OF ELIGIBILITY. Eligibility for certification shall be based on the following qualifications for each designated grade of wastewater treatment plant operator.
>
> (a) GRADE I
>
> (1) One year of full-time employment in actual operation of a wastewater treatment plant and six educational points. Education may not be substituted for experience.
>
> (2) Applicants will be required to pass a written examination to demonstrate their knowledge in these specific areas: general knowledge of the basic principles and methods of wastewater treatment and specific knowledge of the procedures involved in operating and maintaining stabilization ponds and primary treatment plants.
>
> (b) GRADE II
>
> (1) High school education or equivalent satisfactory to the division and two years of full time experience in actual operation and maintenance of a wastewtaer treatment plant and six educational points, or
>
> (2) One and one-half years of experience while in possession of any Grade I certificate,

(3) Applicants will be required to pass a written examination to demonstrate their knowledge in these specific areas: basic knowledge about record keeping and interpretation, and reporting and specific knowledge about functionsl of plant components, normal performance characteristics for commonly used primary and secondary treatment processes, chlorination, routine service and care of equipment, routine tests for evaluation of plant performance and plant and personnel safety procedures.

(c) GRADE III

(1) An AA degree including 15 units of basic science from a community college or two years at a college or university including 15 units of basic science and two years experience in the operation and maintenance of a wastewater treatment plant or a major part thereof, or

(2) High school education or equivalent satisfactory to the division and four years of experience in the operation of a wastewater treatment plant and a minimum of 16 educational points, or

(3) Three years experience while in the possession of any Grade II certificate.

(4) Applicants will be required to pass a written examination to demonstrate their knowledge of these specific areas: specific knowledge relating to design applications, operations, control and calculations involved in treating waste by the primary treatment and biofiltration methods and various modifications of the activated sludge process and basic knowledge of the principles of tertiary treatment.

(d) GRADE IV

(1) A Bachelor's degree with a major relted to the wastewater treatment field and two years of experience in wastewater treatment satisfactory to the division, or

(2) An AA degree including 15 units of basic science from a community college or two years at a college or university including 15 units of basic science and four years of experience in the operaiton and maintenance of a wastewater treatment plant or a major part

thereof, or

(3) Graduation from high school or equivalent satisfactory to the division and six years experience in the operation and maintenance of a wastewater treatment plant, or part thereof, and a minimum of 32 educational points, or

(4) Four years experience while in the possession of any Grade III certificate.

(5) Applicants will be required to pass a written examination to demonstrate their knowledge in these specific areas: specific knowledge relating to design applications, operation, control and calculations involved in treating wastes by the primary treatment and biofiltration methods and various modifications of the activated sludge process and a working knowledge of tertiary treatment and the various types utilized.

(e) GRADE V

(1) A license as a professional engineer in the State of California and four years experience in wastewater treatment satisfactoyr to the divison, or

(2) A Bachelor's degree in engineering or a Bachelor's degree with a major related to the wastewater treatment field and five years experience in wastewater treatment satisfactory to the division, or

(3) An AA degree including 15 units of basic science from a community college or two years at a college or university including 15 units of basic knowledge and six years of experience in the operation and maintenance of a wastewater treatment plant or a major part thereof, or

(4) Graduation from high school or equivalent satisfactory to the division and ten years of experience in the operation and maintenance of a wastewater treatment plant or part thereof, and a minimum of 48 educational points, or

(5) Six years of experience in the possession of any Grade IV certificate.

(6) Applicants will be required to pass a written examination to demonstrate their knowledge in these specific areas: specific knowledge relating to design applications, operation, control and calculations involved in treating wastes by the primary treatment and biofiltration methods and various modifications of the activated sludge process and a working knowledge of tertiary treatment and the various types utilized.

2481. EXPERIENCE EQUIVALENCE

(a) Two or more years of experience in the operation of a water treatment plant may be substitued for one year of experience as a wastewater treatment plant operator provided that the plant included two or more of the following processes: Coagulation, sedimentation, aeration, filtration, oxidation or chlorination.

(b) Except for the requirements under Section 2480(a) and 2480(d) (1), educational points may be substituted for one year of experience. Educational points used qualifying for a grade may not be used to reduce the time required in that grade to qualify for the next higher grade.

(c) Experience shall not be substitued for educational points.

(d) A list of approved training courses and assigned educational points shall be maintained by the division and shall be made available to all persons upon request.

(e) Credit for education will be allowed as follows:

(1) Sixteen educational points may be substitued for one year experience. Educational points substituted shall not be resubstituted for experience for subsequent examinations for a higher grade.

(2) One three-unit semester accredited college course related to wastewater treatment will be equivalent to eight points.

(3) Successful completion of training courses such as the Environmental Protection Agency correspondence course will be equivalent to 16 points.

(4) Other training courses equivalent to a three-unit semester accredited college course, and approved by the board will be equivalent to eight points.

1,416

(5) Training courses in water quality control conducted by community college adult evening school, 24 weeks or one semester will be equivalent to eight points.

(6) Short courses shall be equivalent to one point per day attended with a maximum of three points.

(7) In-house training courses will be assigned points based upon length of course and course content.

2482. HIGH SCHOOL EQUIVALENT. High school equivalence may be obtained by substituting six educational points for each uncompleted year of school through grade 12 or through passing an approved GED tes."

ORDINANCES

Ordinances to be considered include those for regulating sewer construction and use, plumbing, and control of industrial waste discharges. The objectives are to develop and maintain high standard of construction maintenance and operation, for the protection of the public health, the environment, and public investments.

SEWER CONSTRUCTION AND USE

Appendix D-1 contains information excerpts on sewer construction, sewer use and industrial wastewater discharge ordinance provisions for both the City of Los Angeles and the County Districts of Los Angeles County, which is a large agency for operation of trunk sewers. Appendix D-2 contains rules and regulations governing disposal of industrial wastes to the sanitary sewers and storm drain systems of the City of Los Angeles, California. Previous discussions in Chapter 5 have alluded to some of the features of this ordinance. One of the important provisions of the sewer use ordinance is the authority of the Districts to require correction of improper use of connected sewers, under pain of disconnection. Improper use includes that which results in discharges of septic wastewater, excessive groundwater, debris or other objectionable material to the Districts' sewers. Discharges of rainwater are considered an improper use. The City of Los Angeles, which operates both lateral sewers and trunk sewers has essentially the same provisions.

Both of these agencies have long recognized the need for exclusion of storm water from their systems. The climates of Los Angeles and the Greater Amman Area are somewhat similar, at least in terms of rainfall patterns. If rainwater (from roof and yard drains, etc.) could be better excluded from the network of AWSA, Salt, and future wastewater systems, the treatment plants would not have to by-pass inadequately treated wastewater to the receiving streams during high intensity storms nor lose undue quantities of the activated sludge itself due to

excessive flushing action in the aeration and final sedimentation tanks. This would reduce stream pollution. A long range program for removal of stormwater from existing sanitary sewers and an immediate program for exclusion of new stormwater connections should be undertaken. In part, this is an aspect of plumbing ordinances.

PLUMBING ORDINANCES

Detailed consideration of plumbing ordinances is beyond the scope of this Master Plan report. However, in order for the sewer systems to be used to convey only those liquid and waterborne solid wastes for which they are intended, it will be necessary for greater attention to be paid to standards and practices for building plumbing. To this end, the Plumbing and Gasfitting Regulations of the Washington Suburban Sanitary District appear to offer a good example. The District is a "sister agency" of the Municipality of Amman, and technology transfer already occurs between these agencies. Upgrading of plumbing standards and practices is probably an indirect, but nonetheless essential, part of the project implementation.

INDUSTRIAL WASTES CONTROLS

Chapter 5 provided a discussion of industrial wastes controls primarily from the technical standpoint. In order to be effective, an adequate means of establishing and updating standards and enforcing compliance must be provided. The permit system has been found to be a very satisfactory means of implementing industrial wastes control ordinances. Under this arrangement, the allowable discharges from various contributors of industrial wastes may be revised from time to time in the light of circumstances. That is, the industrial wastes discharge permit, together with its limitations on pollutant discharges, no only may be revoked for non-compliance but also made more restrictive if conditions so warrant. They system is based on sound technical criteria and an equitable means of administration. Requirements for contributors to the sewer system are in accordance with the impact that such contributions have or may have upon the system including the treatment and disposal works.

It is noted that Specifications Standard 202, now applicable to industrial wastes, could be readily amended to cover wastewater collection and treatment as well.

CHAPTER 12

FINANCING ANALYSIS AND REVENUE PROGRAM

FINANCIAL ANALYSIS CONCLUSIONS

This is a summary of the financial analysis findings set forth in this chapter and the supporting schedules. Essentially, the cost of implementing the Phase I Improvement Program cannot be fully supported by sewerage utility revenue alone. This is apparent even when escalating the rates and charges to the fringes of the calculated "ability to pay" of the lower income groups. The shortfall of revenue generation essentially affects the ability of the utility system to repay capital costs financed through long term loans. This is especially apparent in the eight proposed independent systems where no initial sewerage investment has been previously made. Table 12-1 is a synopsis of operating results as detailed in this chapter:

TABLE 12-1

SUMMARY OF PROJECTED OPERATING RESULTS - YEAR 1990

	Operating Revenue	Operating Costs	Net before Debt service	Total Debt Service(1)
		(in JD 1,000)		
Expanded AWSA System	5,403	6,284	(881)	5,445
Sahab System	71	47	24	239
Abu Alanda System	71	56	15	392
Baqa'a System	222	475	(253)	1,090
Sukhneh System	28	42	(14)	97
Hashimiya System	26	72	(46)	101
Lower Wadi es Sir System	97	121	(24)	624
Fuheis and Mahis System	47	121	(74)	175
Na'ur System	26	87	(61)	88

(1) Based on 10%, 25 year loan terms. (Note: This is a revision of the draft report which used 9%, 30 year loan repayments).

The benefits of adequate sewage disposal exceed the direct benefit received by the system user. Indirect benefits include public health, productivity, protection of the environment and water resources, enhancement of aesthetics and general improvement to the standard of life. The eight independent systems under study are encumbered by large capital requirement because no investments were made in sewage disposal systems during prior years.

Careful consideration should be given to these indirect benefits and lack of previous investment programs in conjunction with justifying a government "equity investment" or participation in the capital improvement cost. This may be the only method of financing these projects without undue financial hardship on the system users.

PHASE I INVESTMENT PROJECT COST SUMMARY

The project costs associated with the Phase I Investment Program are summarized in this section. Capital improvements and expenditures are calculated on late-1980 price levels and are subsequently escalated based upon the year of expenditure. A factor of 50% has been added to the 1980 construction cost estimates to cover the following (See Table 10-11):

Engineering and Construction Supervision	14%
Management Services and Staff Training	6%
Miscellaneous and Contingency Allowance	30%

Table 12-2 details costs of the nine separate system improvements divided between local and foreign cost components and incorporating the 50% factor described above.

TABLE 12-2

PHASE I INVESTMENT PROGRAM COSTS - 1980 PRICES

	System	Local Costs	Foreign Component (in JD 1000)	Total
1.	Expanded AWSA Sewerage System			
1.1	Ain Ghazal TP Upgrading and Expansion	7,193	10,602	17,795
	Sludge Hauling Equipment	-	270	270
	House Connection and Lateral Sewers	5,005	45	5,050
	Trunk Sewers	290	2	292
1.2	Marj al Hamam Tributary System			
	House Connections and Lateral Sewers	325	7	332
	Trunk Sewers	90	2	92
1.3	Upper Wadi Abdoun TP			
	Land Costs	75	-	75
	Treatment Plant	1,067	1,888	2,955
	Sludge Line	86	79	165
	House Connections and Laterals	3,744	87	3,831
	Trunk Sewers and Force Mains	1,354	107	1,461
	Pumping Stations	30	36	66
	Totals - AWSA Expansion	19,259	13,125	32,384

	System	Local Costs	Foreign Component (in JD 1000)	Total
2.	Independent Systems - Activated Sludge Plants			
2.1	Baqa'a System			
	Treatment Plant	1,200	1,350	2,550
	House Connections and Laterals	3,276	73	3,349
	Trunk Sewers	616	8	624
	Totals - Baqa'a	5,092	1,431	6,523
2.2	Fuheis and Mahis System			
	Treatment Plant	122	85	207
	House Connections and Laterals	471	8	479
	Trunk Sewers and Force Mains	280	11	291
	Pumping Stations	32	38	70
	Totals - Fuheis and Mahis	905	142	1,047
2.3	Na'ur System			
	Treatment Plant	63	44	107
	House Connections and Laterals	275	6	281
	Trunk Sewers	138	2	140
	Totals - Na'ur	476	52	528
2.4	Lower Wadi es Sir System			
	Treatment Plant	396	268	664
	House Connections and Laterals	2,817	23	2,840
	Trunk Sewers	238	3	241
	Totals - Lower Wadi es Sir	3,451	294	3,745
3.	Independent Systems - Lagooning Treatment			
3.1	Sahab System			
	Land Cost	147	-	147
	Treatment Plant	203	11	214
	House Connections and Laterals	750	15	765
	Trunk Sewers and Force Mains	269	19	288
	Pumping Stations	10	12	22
	Totals - Sahab	1,379	57	1,436
3.2	Sukhneh System			
	Land Costs	73	-	73
	Treatment Plant	203	23	226
	House Connections and Laterals	233	4	237
	Trunk Sewers	42	1	43
	Totals - Sukhneh	551	28	579

System	Local Costs	Foreign Component (in JD 1000)	Total
3.3 Hashimiya System			
Land Costs	62	-	62
Treatment Plant	176	20	196
House Connections and Laterals	254	5	259
Trunk Sewers	83	2	85
Totals - Hashimiya	575	27	602
3.4 Abu Alanda-Khirbet es Suq-Juweideh System			
Land Cost	760	-	760
Treatment Plant	212	10	222
House Connections and Laterals	947	19	966
Trunk Sewers and Force Mains	355	22	377
Pumping Stations	12	15	27
Totals - Abu Alanda	2,286	66	2,352
Summary of Investment Programs Costs - 1980 Prices			
Expanded AWSA System	19,259	13,125	32,384
Separate Activated Sludge Systems	9,924	1,919	11,843
Separate Lagooning Systems	4,791	178	4,969
Totals at 1980 Price Levels	33,974	15,222	49,196

The total Phase I project cost of JD 49,196,000 is stated in 1980 costs and is not escalated by inflation of materials and construction costs in the year of expenditures. Capitalized interest during construction is included under Table 12-3. (See Schedules 12.1, 12.2 and 12.3 for itemized details of the various project costs).

ESCALATED CAPITAL REQUIREMENTS - PHASE I PROGRAM

A projection of anticipated capital requirements is shown in Table 12-3 incorporating an assumed inflationary factor. Since world economic trends are presently very volatile and difficult to predict with any accuracy into the 1990's, a common escalation assumption is used for both local and foreign cost components. This annual rate of 10% was also used to calculate inflationary trends in future operating costs. Itemized details of price escalations are shown on Schedules 12.4, 12.5 and 12.6. Included in Table 12-3 is the capital requirement for interest during construction as detailed in Schedule 12.7.

TABLE 12-3

PHASE I IMPLEMENTATION COSTS - IN YEAR OF EXPENDITURE

	System	Local Costs	Foreign Component (in JD 1000)	Total
1.	Expanded AWSA Sewerage System			
	Treatment Plants and Sludge Disposal	11,824	18,336	30,160
	House Connections and Laterals	15,457	234	15,691
	Trunk Sewers and Force Mains	2,284	313	2,597
	Pumping Stations	44	53	97
	Totals - AWSA System	29,609	18,936	48,545
2.	Independent Activated Sludge Systems (4)			
	Treatment Plants and Sludge Disposal	2,727	2,230	4,957
	House Connections and Laterals	9,555	157	9,712
	Trunk Sewers and Force Mains	1,812	20	1,832
	Pumping Stations	44	54	98
	Totals - Activated Sludge	14,138	2,461	16,599
3.	Independent Lagooning Systems (4)			
	Land Costs	1,456	-	1,456
	Treatment Plants	1,110	89	1,199
	House Connections and Laterals	3,053	59	3,112
	Trunk Sewers and Force Mains	1,038	72	1,110
	Pumping Stations	31	37	68
	Totals - Lagooning	6,688	257	6,945
	Grand Total - Capital Expenditures	50,435	21,654	72,089
	Add: Capitalized Interest During Construction			4,527
	Total Capital Requirement in 1,000 JD			76,616

The total of JD 76,616,000 represents the anticipated amount of capital needed to finance the Phase I Implementation Program and is the basis for projecting debt servicing costs in the statements of operating results.

PROJECTED REVENUE ANALYSIS CRITIERIA

To equitably evaluate the financing capabilities of the nine separate improvement projects, certain factors and assumptions are used to adjust operating results in line with escalated capital requirements set forth previously. A common ground was desired for evaluation purposes. Eight of the nine projects represent initial improvements without any prior investment in the provision of sewerage systems. Consequently, revenue requirements reflect the total cost of debt repayment including interest and principal. Utility plant depreciation costs are not shown

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due to the newness of the eight systems. This concept is also used in evaluating the expanded AWSA system to provide uniformity among analyses. A modest allocation of costs is provided for normal improvements and replacements.

The following factors and assumptions are used in evaluating future operating results and in determining the ability to finance capital improvement costs through operating revenues. Factors used in the analyses were:

- Service Connection Growth
- Water Consumption Surcharge Base
- Projected Sewerage Surcharge Rate
- Average Connection Fees
- Operating Revenue
- Operating Costs
- Net Operating Surplus

Service Connection Growth

Projections of growth in active sewer service connections are of prime importance from the revenue generation standpoint. Revenues from surcharge rates and connection fees directly correlate to the number of projected active connections.

Expanded AWSA System. Based upon a historical increase projection basis for the years 1981 through 1983 and subsequent increases estimated for enlarged service areas tributary to the Upper Wadi Abdoun plant and the Marj al Hamam service area. The projected increase includes new connections to be accommodated by the upgrading and expansion of the Ain Ghazal treatment facility.

Eight Independent Systems. Based upon the study estimates of potential service connections and maximum capacity of proposed treatment facilities. Active connections are projected immediately upon completion of the capital works with smaller annual increases through 1990.

Water Consumption Surcharge Base

Projections of operating revenues based on water consumption surcharges are reliant upon metered water usage and not individual loading contributions to the sewage treatment plants. This assumes that all sewer connectors will have water connections that are adequately metered and billed. This revenue billing practice represents a fair and equitable method of generating a portion of the revenue requirements even though it may be excessive to a minority of customer classes and types. The methods of collecting revenues on the surcharge basis are relatively simple to administer and easy for customers to understand. The following factors were used in projecting the revenue base for sewerage surcharge rates:

Expanded AWSA System. The per-connection water consumption has averaged about 300 m^3 annually during recent years. This formed the basis for projecting the following water consumption projections.

Years	Average Annual Water Use - m^3
1981 - 1982	300
1983 through 1985	330
1986 through 1990	360

These factors are used in the water consumption surcharge base projected in the ability-to-pay analysis.

Eight Independent Systems. Per-connection water consumption is based upon the sewage loading estimates times a factor of 1.5. This assumption is considered to be quite conservative but no actual water consumption data are available for these areas to provide a statistical base for higher projections. As actual water use data accumulates, this projection should be adjusted accordingly. Schedules 12.9 through 12.16 show the water consumption projections for each new system.

Projected Sewerage Surcharge Rate

An escalating surcharge rate was developed for testing revenue generation based on historical rates, recommended rates by the World Bank (IBRD) and inflationary escalation calaculated to be within the user's ability to pay (as discussed in "ability-to-pay"). The effects of further rate increases upon revenue requirements are demonstrated in the sensitivity analysis.

Expanded AWSA System. Surcharge rate increases are projected to start at the end of 1981 at 65 fils per m^3 and progressively increase to 210 fils in 1990. Effects of this rate structure are discussed in later sections of this chapter.

Eight Independent Systems. Surcharge rates are calculated at 80 fils per m^3 in July, 1984, the estimated starting of new sewerage facilities. This rate is progressively increased in 145 fils in 1990. The increases are smaller than projected for the AWSA system due to the financial burden of new connection fees on these system users. (See subsequent sections for the effects on these proposed rates).

Average Connection Fees

Connection fees are direct contributions to capital cost by each new system user and are not offset by any costs incurred by the utility for physical connection. The fees are related in cost escalation, historical practices and the ability to pay. A connection fee schedule would require higher contributions by larger system users and the fees shown are averaged. Therefore, it is estimated that the standard single-family residential unit would pay a connection charge approximately 10% less than the average fee shown below and in the operating results schedules. This assumes that about 10% of the connected users will be classified other than single-family users.

Expanded AWSA System. The historical average connection revenue has been slightly under JD 100 per connection. The projections used in the financial analysis start at an average of JD 125 in 1981 escalating by 10% annually to JD 280 in 1990. This assumes a fee adjustment equivalent to the escalation in future capital costs.

Eight Independent System. An initial fee of JD 240 is established for 1984 escalating to JD 420 in 1990. These new systems are expected to have a high number of connections upon completion of construction in 1984 and therefore a higher fee is projected for revenue generation purposes. Also, the eight outside systems have no anticipated revenue from sewerage taxes. In contrast, tax revenue significantly benefits the AWSA operations. Higher connection fees are necessary for revenues in the outside areas in order to compensate for the lack of tax revenues. The financial analyses in Schedules 12.9 through 12.16 show corresponding revenues in the year of connection. However, it may be necessary to allow installment payments of connection fees over a several year period to avoid undue financial burden on lower income connectors. An installment financing plan would defer some connection fee revenues into subsequent years. The large influx of revenue during 1984 and 1985 also creates an initial cash surplus of some significance. Reinvestment of this surplus will assist the individual systems in deferring a future cash deficit position and is considered in this analysis.

Operating Revenue

For the purpose of the analysis, revenue from surcharges is discounted by 2% for the AWSA system and 5% for the independent systems to recognize uncollectible accounts or bad debt write-offs. With a uniformly applied collection enforcement program, uncollectible accounts should be maintained under 2% of total billings.

For the AWSA system, revenue from sewerage taxes, based on 4% of the net rental value of properties within the Amman municipal boundaries, is projected at historical increase trends until 1984 when properties taxed for 20 years will be dropped from the sewerage tax rolls. However, with the growth of Amman and high rate of new construction, the revenue from taxation continues to be a significant portion of revenues and represents 27% of total revenues in 1990. The number of connections being served outside the Amman municipal boundaries has been growing which causes an inequity in the revenues from users outside of Amman. Some system is needed to recover tax revenue or in lieu tax income from properties served outside the Municipality of Amman.

Operating Costs

Generally, the same factors and assumptions are used for all systems and improvements proposed under the Phase I program. Annual inflation of operating expenses is estimated at 10%. Salaries and wages and other operating expenses are escalated by the inflationary factor plus a calculated percentage of increased work load and costs caused by the addition of new service connections. This escalation formula is applied to labor costs, chemicals, maintenance materials, other expenses and administrative costs.

The basis for operating costs of the new independent systems is the engineering estimates of annual operation and maintenance expense calculated for each system. These were calculated on 1980 price levels and escalated by the factors discussed above.

Power and fuel costs have been treated separately in the cost projections. An escalation factor of 14% annually is used for all power costs calculated at 1980 rate levels. This assumes a rate of 35 fils per KWH within Amman and 39 fils per KWH in the outlying areas. The higher escalation rates for power are considered reasonable in light of world-wide increases in petroleum prices and their effect on fossil fuel generated electricity.

Net Operating Surplus

The net operating surplus (or deficit) is shown for the AWSA system on Schedule 12.8 calculated on new capital financing at 10% interest over 25 years. An alternative is shown assuming a much lower debt interest rate of 3½% over a 30 year repayment period.

The eight independent systems will experience an inordinately high income from service connection fees during the first two years of new system operations. The supporting schedules reflect this accumulated cash surplus and assume that reinvestment of excess funds will realize interest earnings of approximately 6% annually. This creates an enlarged cash surplus to meet the upcoming years of high cash demands and deficit operations.

FINANCIAL ALTERNATIVES

As summarized previously, the Phase I Investment Program is not financially viable if solely dependent upon operating revenues as projected in this analysis. Several alternatives could be considered to improve the financial viability within the individual service areas.

Revenue from Taxation

The AWSA operations within the Amman municipality would be benefited in an upward adjustment of the present 4% annual assessment allocated to sewerage service. The present rate was increased during recent years and further increases may be impracticable. However, the matter deserves further study as a method to defray part of the long range capital improvement costs. The areas served outside municipal boundaries should be considered for assistance from the existing tax levy revenues being assessed in those areas.

The eight independent systems cover towns and villages both in total and in part and therefore may be extremely difficult to equitably divide into taxing

revenues distribution areas that only cover properties subject to sewerage service benefits. The administrative mechanisms may be too difficult and complex to warrant generating revenues through taxation allocation to the specific properties benefited.

Special Assessment Districts

The formation and administration of special improvement districts has been widely used in the United States and other first-world nations to finance the local costs of sewerage improvements. These districts finance the capital costs of collection lines, service connections and a prorata share of trunk and force mains. Collection methods involve allocation of costs to specific properties on an assessment formula and the payment of these costs in lump sum by property owners or through annual assessments based on the loan servicing costs of financing the unpaid assessments through borrowing from loaning institutions. The implementation of this type of capital financing may be worth further study although the complexities and cost of administering improvement districts could far outweigh their advantages as an alternatie financing method.

Design of Improved Tariff Structures

The present surcharge rate basis restricts the revenues from this source to a simple formula applied to metered water consumption. A more structured rate could be developed to apply a service charge to cover fixed costs and a consumption rate based on user classification. The present system assumes that an equal proportion of each water users consumption is contributed to the sewerage system. This is obviously not the case and large users of the sewerage system may not be paying their fair share of costs. A complete tariff study would be required to assess the alternative rate structures and their effects on operating revenues and revenue requirements.

Policy of Capital Cost Subsidies

The table on page 12-1 demonstrates the inability of all nine improved areas to cover revenue requirements under reasonable and acceptable rates and charges. The major shortfall is in financing or repaying the capital costs of improvements. Low debt interest rates, deferred repayment programs or direct government participation in capital costs may be the only effective solutions to this financial situation. Benefits to the public health, welfare, environment and standard of living are viable direct and indirect benfits that are impossible to evaluate in strict financial terms. These intangible benefits must be weighed by the government to determine the level of subsidy that would be appropriate. Table 12-4 demonstrates the subsidy requirements based upon the revenue assumptions used in Schedules 12-8 through 12-16.

Reduction of Capital Requirements

This would involve a significant reduction in improvement costs by eliminating service to possible fringe areas, reducing the level of treatment or trimming capital requirements through other methods. The Phase I Investment program is developed to minimize costs wherever possible.

TABLE 12-4

SUBSIDY REQUIREMENT IN PROJECTED OPERATING RESULTS

System	Subsidy Requirement(1) Total To 1991	The Year 1990
	(JD 1,000)	
Expanded AWSA System	33,916	6,556
Sahab	1,056	215
Abu Alanda-Khirbet-Juweideh	1,983	377
Baqa'a	6,778	1,343
Sukhneh	546	111
Hashimiya	731	147
Lower Wadi es Sir	3,602	648
Fuheis and Mahis	1,195	249
Na'ur	708	149

(1) Calculated on Loan Serving at 10% for 25 years.

REVIEW OF OPERATING RESULTS

Schedules 12.9 through 12.16 depict the operating results of the expanded AWSA system and eight independent systems. The projections shown are based on the factors and assumptions cited earlier in this chapter. The AWSA analysis includes the total costs of capital repayment shown at 9% and 3½% interest rates.

The independent systems reflect only that portion of debt servicing costs that can be repaid through operating revenues. This portion of debt coverage through operations ranges from only 30% for Sahab to nil for two systems.

The effects of major alterations in revenue producing categories are analyzed subsequently. The operating results, stated in accumulated cash surplus, for the nine systems are summarized from the supporting schedules as follows:

TABLE 12-5

PROJECTED OPERATING RESULTS TO 1991

System	Schedule Ref.	Debt Service Included	Debt Terms	Accumulated Cash Surplus (Def.) at 1/1/91 (1,000 JD)
Expanded AWSA System	12.8	100%	10%/25 yrs.	(35,196)
Expanded AWSA System	12.8	100%	3½%/30 Yrs.	(23,058)
Sahab System	12.9	30%	10%/25 yrs.	(52)
Abu Alanda System	12.10	20%	" "	(99)
Baga'a System	12.11	15%	" "	(1,213)
Sukhneh System	12.12	20%	" "	(69)
Hashimiya System	12.13	10%	" "	(182)
Lower Wadi es Sir System	12.14	10%	" "	(204)
Fuheis and Mahis System	12.15	0	" "	(127)
Na'ur System	12.16	0	" "	(175)

The accumulated cash deficit figure for the expanded AWSA system covers the period from 1982 through 1990 and includes depreciation expense, a non-cash item. It is assumed that the amount charged as depreciation will be expended in that approximate amount for normal improvments and replacements to the existing utility plant.

The review of the supporting schedules further confirms the inability of the systems to generate sufficient revenues to cover capital cost requirements.

SENSITIVITY ANALYSIS

Since operating revenues, based on assumed acceptable limits, are insufficient to cover all revenue requirements, a further analysis is made to determine the effects of major adjustments in revenue sources. These results are shown in percentage reductions to total debt servicing costs based on 10% loans over 25 years repayment period.

TABLE 12-6

EFFECTS OF ADJUSTING REVENUE SOURCES
AWSA SYSTEM

		Annual Increase	Average New Debt Service (JD 1,000)	Percent of Debt Service
1.	Extended AWSA System			
a.	Increase Surcharge Rate 50%	726	3,322	22%
b.	Increase Surcharge Rate 100%	1,453	3,322	43%
c.	Increase Connection Fee 100%	543	3,322	16%
d.	Increase Tax Rate to 8%	1,070	3,322	32%

The same adjustments on 1990 Revenues and 1990 Debt Service are as follows:

		Debt Service-1990 10%/25	Debt Service-1990 3½%/30 (JD 1,000)	Additional Revenues
a.	Surcharge plus 50%	5,445	2,268	1,566
b.	Surcharge plus 100%	5,445	2,268	3,132
c.	Connection Fee plus 100%	5,445	2,268	577
d.	Tax Rate to 8%	5,445	2,268	1,463

It is demonstrated that no single major revenue adjustment will meet revenue requirements at a 10% interest rate. Only adjustment b. would be sufficient to meet these requirements if loan interest rates were at 3½%.

A similar analysis follows for the eight independent systems proposed under Phase I Investment Program.

TABLE 12-7

EFFECTS OF ADJUSTING REVENUE SOURCES
Eight Independent Systems

	System	Ave. Annual Increase	Annual Debt Service at 10% (JD 1,000)	% of Debt Service
Sahab				
a.	Increase Surcharge by 100%	35	239	15%
b.	Increase Connection Fee 100%	64	239	27%

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System	Ave. Annual Increase	Annual Debt Service at 10% (JD 1,000)	% of Debt Service
Abu Alanda			
a. Surcharge by 100%	35	392	9%
b. Connection Fee by 100%	58	392	15%
Baga'a			
a. Surcharge by 100%	138	1090	13%
b. Connection Fee by 100%	150	1090	14%
Sukhneh			
a. Surcharge by 100%	13.5	97	14%
b. Connection Fee by 100%	21.2	97	22%
Hashimiya			
a. Surcharge by 100%	13.5	101	13%
b. Connection Fee by 100%	17.7	101	18%
Na'ur			
a. Surcharge by 100%	12.5	88	14%
b. Connection Fee by 100%	20.9	88	24%
Fuheis and Mahis			
a. Surcharge by 100%	24	175	14%
b. Connection of Fee 100%	41	175	23%
Lower Wadi es Sir			
a. Surcharge by 100%	52	624	8%
b. Connection Fee by 100%	54	624	9%

This comparison indicates that the doubling of rates and revenues of both major revenue sources would not generate sufficient revenues to meet all debt service requirements. This applies to all eight independent systems.

Tests could be made on the effects of increasing the active service connections for these systems. However, total connections in the year 1990 are predicated upon the treatment plant capacities and an assumption of increased connections would require a reworking and increase in capital costs relating to treatment facilities.

ABILITY TO PAY ANALYSIS

In the socio-economic analysis chapter of this report, several estimates were made concerning the average household incomes of lower income families. This average is used to test the ability to pay the charges and rates used in the financial projections of this chapter. Since the eight new systems are scheduled for completion and operation in mid-1984, the first year of full service would be 1985. Thus, the average low income groups household income was escalated to the year 1985. This computes to approximately JD 2,100 annually or JD 176 per month. The 1985 rates and charges were used in the test.

It was further assumed that the maximum percent of this income group's spendable income should not exceed 5% for both water and sewerage service. This was arbitrarily divided equally into 2½% for water service and 2½% for sewerage services. The maximums are based on generally-accepted limits applied internationally and are strictly hypothetical, but are presented to form a basis for comparison. Further, the imposition of a service connection fee in the eight new independent systems creates a real financial burden for the lower income group. It is assumed that installment payment terms may be available to this group to amortize their connection fees and that they could amortize these fees over a five-year period. This cost was also considered for the AWSA system users even though many connections already exist and no further costs are due from present system users.

TABLE 12-8

ABILITY TO PAY ANALYSIS - 1985 RATE LEVELS

System	Monthly Rates	Monthly Connection Fee(1)	Percent of Spendable Income(2)
Expanded AWSA	JD 1.940	JD 2.830	2.7%
Sahab	1.770	3.900	3.2%
Abu Alanda	1.650	3.900	3.2%
Baga'a	2.790	3.900	3.8%
Sukhneh	1.770	3.900	3.2%
Hashimiya	2.050	3.900	3.4%
Lower Wadi es Sir	2.390	3.900	3.6%
Fuheis and Mahis	1.560	3.900	3.1%
Na'ur	1.670	3.900	3.1%

(1) Amortized over 5 years
(2) Based on JD 176 Average

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According to the above analysis, all sewerage cost tests slightly exceed the 2½% of spendable income. However, the service connection fee amortization is a one time charge that will not repeat itself in future years. Also, to further ameliorate this slightly excessive sewerage cost to lower income groups is the fact that in many instances, the landlord or property owner may shoulder the cost of the sewer connection. Offsetting this advantage are the costs to the new connector for running his house sewer line to the property edge, or public street where the publicly-owned house connection terminates.

If rates were established at levels to recover all revenue requirements including dept servicing, the monthly rates for low income families would greatly exceed the 5% limitation without including an allowance for new connection fees. In some systems, sewerage usage charges would represent about 20% of the projected monthly spendable of the low income group.

INSTITUTIONAL ARRANGEMENTS

There are distinctive advantages in having the organization providing water service to a particular area also directly involved in providing sewage collection and disposal services. When water surcharges are used as a basis for sewerage revenues, this joint service activity is almost essential. There are several exceptions to this discussed later in this section.

The Water Supply Corporation is empowered to provide both water and sewerage service outside area of AWSA. Presently, the WSC does not render sewerage services nor is it staffed to provide the service. It is providing water supply to many towns and villages adjacent to Amman either in bulk supply to the town concils or directly the customer's service. The Municipality of Salt has contracted with AWSA to assist in the operation of its new sewerage system but this is because AWSA is experienced in sewerage operations and WSC is not yet equipped to assist Salt. The WSC is expected to assume the operational responsibility for the Salt Sewerage System in the near future.

The AWSA provides sewerage service through an integrated system and the expanded system under Phase I Investment Program will also be integrated with the existing system. Therefore, it is logical that AWSA should own, control, operate and maintain the entire expanded system. This is somewhat complicated by their enabling legislation that restricts the AWSA service area to the corporate boundaries of Amman. However, special authorization can be obtained to serve outside the municipality. Another complicating factor is that some new service areas will be receiving water supplies directly or indirectly through WSC. This will require cooperative coordination between agencies especially in relation to determining water consumption for billing purposes. Also, areas outside Amman may not contribute sewerage tax receipts and therefore and will receive service under advantageous costs unless this is equalized through "in lieu of taxes" assessments or a method to allocate existing sewer tax.

It is recommended that AWSA own, operate and and develop revenues from all those who use the expanded sewerage system.

For the eight independent systems, it is recommended that they be owned, controlled, operated and maintained by the Water Supply Corporation. This will require staffing of WSC to meet these responsibilities and should also lead to the complete takeover of the involved local water systems for ownership, operation, maintenance and customer billing.

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SCHEDULE 12-1

PROJECT COST DATA - AMMAN, JORDAN

Expanded AWSA System

Facility	in 1,000 JD - 1980 Costs Local	Foreign (Incls.50%)	Total	Years Expended
AWSA System - Expanded Westerly				
Ain Ghazal Treatment Plant				
Expansion and Upgrading	2,874	4,236	7,110	6/83-6/84
	3,957	5,833	9,790	6/84-6/85
	362	533	895	6/85-6/86
Sludge Hauling Trucks - 9	-	270	270	82 - 90
Subtotal	7,193	10,872	18,065	
House Connections	3,270	-	3,270	83 - 90
Lateral Sewers	1,735	45	1,780	83 - 90
Trunk Sewers	290	2	292	83 - 85
Marj al Hamam - Tributary Systems				
House Connections	126	-	126	83 - 84
Lateral Sewers	199	7	206	83 - 84
Trunk Sewers	90	2	92	1983-84
Upper Wadi Abdoun Treatment Plant	1,067	1,888	2,955	1/83 - 1/85
Land Costs	75	-	75	1982
Sludge Line	86	79	165	1/84 - 7/84
House Connections	900	-	900	83 - 85
Lateral Sewers	2,844	87	2,931	83 - 85
Trunk Sewers	1,246	12	1,258	83 - 84
Force Main	108	95	203	83 - 84
Pumping Station	30	36	66	1984
TOTALS	19,259	13,125	32,384	

SCHEDULE 12.2

Project Cost Data - Independent Systems
Activated Sludge Treatment Plants

Facility	1,000 JD - 1980 Cost Levels Local	Foreign	Total (Incl. 50%)	Years Expended
Baqa'a				
STP	1,200	1,350	2,550	7/83 -7/84
Sludge Removal	-	20	20	84 - 90
House Connections	435	-	435	7/83 -7/84
Lateral Sewers	2,841	73	2,914	7/83 -7/84
Trunk Sewers	616	8	624	7/83 -7/84
Totals	5,092	1,451	6,543	
Fuheis and Mahis				
STP	122	81	203	7/83 -7/84
Sludge Removal	-	4	4	84 - 90
House Connections	150	-	150	7/83-7/85
Lateral Sewers	321	8	329	7/83 -7/85
Trunk Sewers	271	5	276	7/83 -7/85
Pumping Stations	32	38	70	7/83 -7/85
Force Mains	9	6	15	7/83-7/85
Totals	905	142	1,047	
Na'ur				
STP	63	42	105	7/83-7/84
Sludge Removal	-	2	2	84 - 90
House Connections	75	-	75	7/83-7/84
Lateral Sewers	200	6	206	7/83-7/84
Trunk Sewers	138	2	140	7/83-7/84
Totals	476	52	528	
Wadi es Sir (Lower Area)				
STP	396	264	660	7/83-7/84
Sludge Removal	-	4	4	84 - 90
House Connections	1,950	-	1,950	7/83-7/84
Lateral Sewers	867	23	890	7/83-7/84
Trunk Sewers	238	3	241	7/83-7/84
Totals	3,451	294	3,745	
GRAND TOTAL	9,561	1,147	10,708	

SCHEDULE 12.3

Project Cost Data - Independent Systems
Lagooning Treatment Plants

Facility	1,000 JD - 1980 Cost Levels Local	Foreign	Total (Incl. 50%)	Years Expended
Sahab				
STP	203	11	214	7/83-7/84
House Connections	195	-	195	7/83-7/84
Lateral Sewers	555	15	570	7/83-7/84
Trunk Sewers	249	5	254	7/83-7/84
Force Mains	20	14	34	7/83-7/84
Pumping Stations	10	12	22	7/83-7/84
Land Cost (w/o 50%)	147	-	147	1982
Totals	1,379	57	1,436	
Sukhneh				
STP	203	23	226	7/83-7/84
House Connections	77	-	77	7/83-7/84
Lateral Sewers	156	4	160	7/83-7/84
Trunk Sewers	42	1	43	7/83-7/84
Land Cost (w/o 50%)	73	-	73	1982
Totals	551	28	579	
Hashimiya				
STP	176	20	196	7/83-7/84
House Connections	65	-	65	7/83-7/84
Lateral Sewers	189	5	194	7/83-7/84
Trunk Sewers	83	2	85	7/83-7/84
Land Cost (w/o 50%)	62	-	62	1982
Totals	575	27	602	
Abu Alanda-Khirbet es Suq-Joweideh				
STP	212	10	222	7/83-7/84
House Connections	210	-	210	7/83-7/84
Lateral Sewers	737	19	756	7/83-7/84
Trunk Sewers	333	5	338	7/83-7/84
Force Mains	22	17	39	7/83-7/84
Pumping Stations	12	15	27	7/83-7/84
Land Cost (w/o 50%)	76	-	76	1982
Totals	1,602	66	1,668	
GRAND TOTAL	4,107	178	4,285	

SCHEDULE 12-4

ANNUAL CAPITAL EXPENDITURES
AWSA SEWERAGE SYSTEM WITH WESTERLY EXPANSION

Costs are stated in 1,000 JD

System and Facility	1980 Project Costs	Period Expended and Totals	Annual Construction Cost at 10 Percent Inflation									
			1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
AGTP	7,110	1983										
Improvements	9,790	1984			9,463*							
	895	1985				14,334*						
		1985					1,441					
Subtotal	17,795	25,238			9,463	14,334	1,441					
Sludge Trucks	270	424		180	-	44	-		58	64		78
Subt. AGTP	18,065	25,662		180	9,463	14,378	1,441		58	64		78
AWSA Syst.												
H'se. Conns.	3,270	'83-90			544	598	658	724	796	876	963	1,059
Lat. Sewers	1,780	'83-90			296	326	358	394	433	477	524	577
Tr'k. Sewers	292	'83-85			130	142	157	-	-	-	-	-
Subt. Coll. Syst.	5,342	10,032			970	1,066	1,173	1,118	1,229	1,353	1,487	1,636
Marj al Hamam												
H'se. Conns.	126	'83-84			84	92						
Lat. Sewers	206	'83-84			137	151						
Tr'k. Sewers	92	'83-84			61	67						
Subtotal	424	592			282	310	-	-	-	-	-	-
UWATP												
Land	75	1982		91								
Plant	1,200	1983			1,596*							
Plant	1,755	1984				2,569*						
Sludge P/L	165	1984				242						
Subtotal	3,195	4,498		91	1,596	2,811*	-	-	-	-	-	-
H'se. Conns.	900	'83-85			399	439	483					
Lat. Sewers	2,931	'83-85			1,300	1,430	1,573					
Tr'k. Sewers	1,258	'83-84			837	920						
Force Mains	203	'83-84			135	148						
Pump Sta.	66	'83-84				97						
Subtotal	5,357	7,761		-	2,671	3,034	2,056	-	-	-	-	-
GRAND TOTAL	32,384	48,545		271	14,982	21,599	4,670	1,118	1,287	1,417	1,487	1,714

* Entails capitalized interest during construction.

SCHEDULE 12-5

ANNUAL CAPITAL EXPENDITURES AND O & M
INDEPENDENT SYSTEMS - ACTIVATED SLUDGE

Facility	1980 Costs	Escalated Costs	1982	1983	1984	1985	1986	1987	1988	1989	1990
Baqa'a											
Service Connections					1,600	3,375	3,400	3,425	3,450	3,475	3,500
STP	2,570			1,710	1,903						
O&M					88	28	106	117	129	141	156
Power					34	116	134	155	177	205	234
House Connections	435			289	318						
Laterals & Trunks	3,538			2,355	2,590						
O&M	6,545	9,165			12	16	17	19	21	23	25
Fuheis & Mahis											
Service Connections					400	850	880	910	940	970	1,000
STP	207			138	151						
O&M					11	16	18	21	24	27	31
Power					16	31	34	39	44	50	57
House Connections	150			100	110						
Force Mains, Laterals & Trunks	620			413	454						
O&M					3	3	3	4	4	4	4
Pumping Stations	70			47	51						
O&M	1,047	1,464			1	1	1	1	1	1	1
Power					1	2	2	3	3	3	4
Na'ur											
Service Connections					190	400	420	440	460	480	500
STP	107			71	78						
O&M					8	13	15	18	21	24	27
Power					8	15	18	22	25	28	32
House Connections	75			50	55						
Laterals & Trunks	346			230	253						
O&M	528	737			2	2	2	2	2	2	3
Wadi es Sir (Lower)											
Service Connections					500	1,050	1,100	1,150	1,200	1,250	1,300
STP	664			442	486						
O&M					8	16	19	22	25	29	33
Power					10	21	25	31	35	40	45
House Connections	1,950			1,298	1,427						
Laterals & Trunks	1,131			752	828						
O&M	3,745	5,233			4	6	6	7	7	8	9
Grand Total	11,863	16,599									

Capital Costs	Total	1983	1984	Cost 1980
Baqa'a	9,165	4,354	4,811	6,543
Fuheis & Mahis	1,464	698	766	1,047
Na'ur	737	351	386	528
Wadi es Sir	5,233	2,492	2,741	3,745
Totals	16,599	7,895	8,704	11,863

SCHEDULE 12-6

ANNUAL CAPITAL EXPENDITURES AND O&M
INDEPENDENT SYSTEMS - LAGOONING PLANTS

	1980 Costs	Escalated Costs	1983	1984	1985	1986	1987	1988	1989	1990
Sahab										
Service Connections				500	1,050	1,100	1,150	1,200	1,250	1,300
STP (Incl. Land Cost)	361		240	264						
O&M				4	8	9	10	11	12	13
Power (Negl.)				-	-	-	-	-	-	-
House Connections	195		130	143						
Force Mains, Laterals & Trunks	858		571	628						
O&M				4	4	5	5	6	6	7
Pumping Stations	22		15	16						
O&M				0.1	0.1	0.2	0.2	0.2	0.2	0.3
Power				0.3	0.4	0.4	0.5	0.6	0.7	0.7
	1,436	2,007								
Sukhneh										
Service Connections				200	410	430	450	470	490	510
STP (Incl. Land Cost)	299		199	219						
O&M				3	6	6	7	8	9	9
House Connections	77		51	56						
Laterals & Trunks	203		135	149						
O&M				1	1	1	1	2	2	2
	579	809								
Hashimiya										
Service Connections				175	355	370	385	400	415	430
STP (Incl. Land Cost)	258		172	189						
O&M				3	6	7	8	8	9	10
House Connections	65		43	48						
Laterals and Trunks	279		186	205						
O&M				1	1	2	2	2	2	2
	602	843								
Abu Alanda-Khirbet es Suq-Juweideh										
Service Connections				550	1,150	1,200	1,250	1,300	1,350	1,400
STP (Incl. Land Cost)	982		653	719						
O&M				4	7	8	10	11	12	13
House Connections	210		140	154						
Force Mains, Laterals & Trunks	1,133		754	829						
O&M				5	6	6	7	7	8	9
Pumping Stations	27		18	19						
O&M				1	2	2	3	3	3	4
Power				1	2	2	2	3	3	3
	2,352	3,286								

1980 Costs	Capital Costs	Total	1983	1984
1,436	Sahab	2,007	956	1,051
579	Sukhneh	809	385	424
602	Hashimiya	843	401	442
2,352	Abu Alanda	3,286	1,565	1,721
4,969		6,945	3,307	3,638

SCHEDULE 12-7

EXPANDED AWSA SEWERAGE SYSTEM

Capital Expenditures and Debt Servicing
(Including Capitalized Interest)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Totals
Interest During Construction - Treatment Plants											
Ain Ghazal Treatment Plant											
Capitalized Interest During Construction			9,463	14,334	1,441						25,238
			284	1,530							1,814
Total Capital Costs			9,748	15,864	1,441						27,052
Upper Wadi Abdoun Treatment Plant											
Construction			1,596	2,569							4,165
Capitalized Interest During Construction			48	265							313
Total Capital Costs			1,644	2,834							4,478
System Tributary to UWATP											
Capitalized Interest During Construction			2,671	3,034							5,705
			80	386							466
Total Capital Costs			2,751	3,420							6,171
Annual Capital Requirements - Schedule No. 12-4											
Annual Totals		271	14,982	21,599	4,670	1,118	1,287	1,417	1,487	1,714	48,545
Add: Interest During Construction			412	2,181							2,593
Adj. for Deferred Capital Repayment			(13,730)	(19,937)	33,667						
Adjusted Annual Requirements		271	1,664	3,843	38,337	1,118	1,287	1,417	1,487	1,714	51,138
Cumulative Capital Requirements		271	1,935	5,778	44,115	45,233	46,520	47,937	49,424	51,138	51,138
Annual Debt Servicing at 10% - 25 yrs		-	30	213	637	4,860	4,983	5,125	5,281	5,445	
Annual Debt Servicing at 3.5% - 25 yrs		-	16	117	351	2,676	2,744	2,822	2,908	2,999	

SCHEDULE 12-8

AWSA INTEGRATED SEWERAGE SYSTEM

Projected Operating Results-Expanded System

Year Ending	Actual 1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
		Projected in JD 1,000										
Service Connections - Active	11,588	13,880	16,380	17,060	17,780	18,530	19,310	20,120	20,960	21,840	22,760	23,720
Additional-Expanded Area												
Upper Wadi Abdoun T.P.						2,000	2,000	2,000				
Marj al Hamam Area						401	401					
Expanded AGTP Area				1,400	1,400	1,300	1,300	1,300	1,300	1,200	1,200	1,100
Total Active Service Connections	11,588	13,880	16,380	18,460	20,580	25,031	29,512	33,622	35,762	37,842	39,962	42,022
Water Surcharged in m^3 million	4.05	3.80	4.91	5.54	6.79	8.26	9.74	12.10	12.87	13.62	14.39	15.13
Projected Surcharge Rate-Fils/m^3	30	30	30	65	70	75	90	110	130	155	180	210
Projected Connection Fee - JD's			125	130	140	155	170	190	210	230	255	280
REVENUE												
Water Surcharges at 98%	122	114	144	353	466	607	859	1,304	1,640	2,069	2,538	3,114
Connection Fees	237	275	313	270	297	690	762	781	449	478	541	577
Sewerage Tax Revenue	448	533	634	755	898	1,042	853	981	1,099	1,209	1,330	1,463
Other Income	87	96	105	116	127	140	154	169	186	205	226	249
Total Revenue	894	1,018	1,196	1,494	1,788	2,479	2,628	3,235	3,374	3,961	4,635	5,403
OPERATING COSTS												
Salaries and Wages	427	517	631	719	816	1,000	1,210	1,330	1,460	1,610	1,890	2,070
Power and Fuel*	68	116	220	270	330	700	800	860	980	1,180	1,420	1,720
Chemicals	12	16	20	26	30	38	47	58	68	78	91	105
Maintenance Materials	50	65	84	109	131	188	226	271	325	390	460	550
Other Expenses	90	99	109	120	157	172	193	256	281	320	353	399
Depreciation	175	336	378	392	432	510	535	560	590	600	575	540
Normal Improvements & Replacements	-	-	-	-	-	-	300	500	700	700	900	900
Total Operating Costs	822	1,149	1,442	1,636	1,896	2,608	3,311	3,835	4,404	4,878	5,689	6,284
Revenue over Costs (Deficit)	72	(131)	(246)	(142)	(108)	(129)	(683)	(600)	(1,030)	(917)	(1,054)	(881)
Interest Cost - Previous Loans	98	175	252	241	230	230	230	230	230	230	230	230
Debt Servicing - New Loans @ 10%	-	-	-		30	213	637	4,860	4,983	5,125	5,281	5,445
Net Operating Surplus	(26)	(306)	(498)	(450)	(368)	(572)	(1,650)	(5,690)	(6,243)	(6,272)	(6,565)	(6,556)
Revised Net Operating Surplus Based on 3.5% Loans-30 years	(26)	(306)	(431)	(420)	(354)	(476)	(1,264)	(3,506)	(4,004)	(3,969)	(4,192)	(4,110)

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SCHEDULE 12.9

GREATER AMMAN SEWERAGE IMPROVEMENTS

Financial Analysis - Independent Systems

Sahab System	1983	1984	1985	1986	1987	1988	1989	1990	Totals
			(in 1,000 JD)						
Capital Improvements									
Annual Capital Costs	956	1,051							2,007
Capitalized Interest During Construction	29	136							165
Total Capital Costs	985	1,187							2,172
Less: Amount Not Recoverable from Revenues-70%									1,520
Net Recovered from Operations - 30%									652
System Usage and Financial Assumptions									
Active Sewer Connections		500	1,050	1,100	1,150	1,200	1,250	1,300	
Metered Water Use in 1,000 m^3 (Load x 1.5)		139	291	305	319	333	347	361	
Water Surcharge Rate per m^3		.080	.085	.095	.105	.115	.130	.145	
Average New Connection Fee in JD		240	260	285	315	345	380	420	
Average Monthly Sewer Bill			2.0	2.2	2.4	2.7	3.0	3.4	
Operating Revenue									
Revenue from Surcharges (at 95%)		11	23	28	32	36	43	50	223
New Connection Fees		120	143	14	16	17	19	21	350
Total Revenue		131	166	42	48	53	62	71	573
Expenditures									
Operating Expenses		8	12	14	15	17	18	20	104
Power Costs		(Negligible)	(Negligible)		1	1	1	1	4
Administrative Expenses (at 100% of O.E.)		8	12	14	15	17	18	20	104
Normal Improvements and Replacements		-	-	-	2	3	4	6	15
Total Expenditures		16	24	28	33	38	41	47	227
Operating Gain (or Loss)		115	142	14	15	15	21	24	346
Less: Net Debt Servicing Cost at 10% Interest		-	72	72	72	72	72	72	432
Net Gain (Loss)		115	70	(58)	(57)	(57)	(51)	(48)	(86)
Accumulated Cash Surplus		115	185	127	70	13	38	(86)	(86)
Interest Revenue at 6% (Averaged)		2	9	10	7	4	2	0	34
Net Cash Surplus		117	196	148	98	45	(4)	(52)	(52)

SCHEDULE 12-10

GREATER AMMAN SEWERAGE IMPROVEMENTS

Financial Analysis - Independent Systems

Abu Alanda-Khirbet-Juweideh System	1983	1984	1985	1986	1987	1988	1989	1990	Totals
			(in 1,000 JD)						
Capital Improvements									
Annual Capital Costs	1,565	1,721							3,286
Capitalized Interest During Construction	47	223							270
Total Capital Costs	1,612	1,944							3,557
Less: Amount Not Recoverable from Revenues-80%									2,845
Net Recovered from Operations - 20%									711
System Usage and Financial Assumptions									
Active Sewer Connections		550	1,150	1,200	1,250	1,300	1,350	1,400	
Metered Water Use in 1,000 m^3 (Load x 1.5)		142	297	310	323	335	348	361	
Water Surcharge Rate per m^3		.080	.085	.095	.105	.115	.130	.145	
Average New Connection Fee in JD		240	260	285	315	345	380	420	
Average Monthly Sewer Bill			1.8	2.0	2.3	2.5	2.8	3.1	
Operating Revenue									
Revenue from Surcharges (at 95%)		11	24	28	32	37	43	50	225
New Connection Fees		132	156	14	16	17	19	21	375
Total Revenue		143	180	42	48	54	62	71	600
Expenditures									
Operating Expenses		10	15	16	20	21	23	26	131
Power Costs		1	2	2	2	3	3	3	16
Administrative Expenses (at 80% of O.E.)		8	11	13	16	17	18	21	104
Normal Improvements and Replacements		-	-	-	3	4	5	6	18
Total Expenditures		19	28	31	41	45	49	56	269
Operating Gain (or Loss)		124	152	11	7	9	13	15	331
Less: Net Debt Servicing Cost at 10% Interest		-	78	78	78	78	78	78	468
Net Gain (Loss)		124	74	(67)	(71)	(69)	(65)	(63)	(137)
Accumulated Cash Surplus		124	198	131	60	(9)	(74)	(137)	(137)
Interest Revenue at 6% (Averaged)		3	10	11	8	5	1	-	98
Net Cash Surplus		127	211	155	92	28	(36)	(99)	(99)

SCHEDULE 12-11

GREATER AMMAN SEWERAGE IMPROVEMENTS

Financial Analysis - Independent Systems

Baqa'a System	1983	1984	1985	1986	1987	1988	1989	1990	Totals
			(in 1,000 JD)						
Capital Improvements									
Annual Capital Costs	4,354	4,789							9,143
Capitalized Interest During Construction	131	621							752
Total Capital Costs	4,485	5,410							9,895
Less: Amount Not Recoverable from Revenues-85%									8,411
Net Recovered from Operations - 15%									1,484
System Usage and Financial Assumptions									
Active Sewer Connections		1,600	3,375	3,400	3,425	3,450	3,475	3,500	
Metered Water Use in 1,000 m^3 (Load x 1.5)		701	1,478	1,489	1,500	1,511	1,522	1,533	
Water Surcharge Rate per m^3		.080	.085	.095	.105	.115	.130	.145	
Average New Connection Fee in JD		240	260	285	315	345	380	420	
Average Monthly Sewer Bill			3.1	3.5	3.8	4.2	4.7	5.3	
Operating Revenue									
Revenue from Surcharges (at 95%)		53	119	134	150	165	188	211	1,020
New Connection Fees		384	462	7	8	9	10	11	891
Total Revenue		437	581	141	158	174	198	222	1,911
Expenditures									
Operating Expenses		74	76	98	100	111	122	134	715
Power Costs		34	116	134	155	177	205	234	1,055
Administrative Expenses (at 60% of O.E.)		44	46	59	60	67	73	80	429
Normal Improvements and Replacements		-	-	-	15	19	22	27	83
Total Expenditures		152	238	291	330	374	422	475	2,282
Operating Gain (or Loss)		285	343	(150)	(172)	(200)	(224)	(253)	(371)
Less: Net Debt Servicing Cost at 10% Interest			163	163	163	163	163	163	978
Net Gain (Loss)		285	180	(313)	(335)	(363)	(387)	(416)	(1,349)
Accumulated Cash Surplus		285	465	152	(183)	(546)	(933)	(1,349)	(1,349)
Interest Revenue at 6% (Averaged)		9	31	37	29	20	10		136
Net Cash Surplus		294	505	229	(77)	(420)	(797)	(1,213)	(1,213)

SCHEDULE 12.12

GREATER AMMAN SEWERAGE IMPROVEMENTS

Financial Analysis - Independent Systems

	1983	1984	1985	1986	1987	1988	1989	1990	Totals
				(in 1,000 JD)					
Sukhneh System									
Capital Improvements									
Annual Capital Costs	385	424							809
Capitalized Interest During Const.	12	55							67
Total Capital Costs	397	479							876
Less: Amount Not Recoverable for Revenues - 80%									701
Net Recovered from Operations - 20%									175
System Usage and Financial Assumptions									
Active Sewer Connections		200	410	430	450	470	490	510	
Metered Water Use in 1,000 m^3 (Load x 1.5)		56	114	120	126	131	137	142	
Water Surcharge Rate per m^3		.080	.085	.095	.105	.115	.130	.145	
Average New Connection Fee in JD		240	260	285	315	345	380	420	
Average Monthly Sewer Bill			2.0	2.2	2.5	2.7	3.0	3.4	
Operating Revenue									
Revenue from Surchages (at 95%)		4	9	11	13	14	17	20	88
New Connection Fees		48	55	6	6	7	8	8	138
Total Revenue		52	64	17	19	21	25	28	226
Expenditures									
Operating Expenses		4	10	12	14	15	17	19	91
Power Costs		(Negligible)							
Administrative Expenses (at 100% of O.E.)		4	10	12	14	15	17	19	91
Normal Improvements and Replacements		-	-	-	2	2	3	4	11
Total Expenditures		8	20	24	30	32	37	42	193
Operating Gain (or Loss)		44	44	(7)	(11)	(11)	(12)	(14)	33
Less: Net Debt Servicing Cost at 10% Interest		-	19	19	19	19	19	19	114
Net Gain (Loss)		44	25	(26)	(30)	(30)	(31)	(33)	(81)
Accumulated Cash Surplus		44	69	43	13	(17)	(48)	(81)	(81)
Interest Revenue at 6% (Averaged)		1	4	4	2	1	-	-	12
Net Cash Surplus		45	74	52	24	(5)	(36)	(69)	(69)

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SCHEDULE 12.13

GREATER AMMAN SEWERAGE IMPROVEMENTS

Financial Analysis - Independent Systems

Hashimiya System	1983	1984	1985	1986	1987	1988	1989	1990	Totals
				(in 1,000 JD)					
Capital Improvements									
Annual Capital Costs	401	442							843
Capitalized Interest During Const.	12	57							69
Total Capital Costs	413	499							912
Less: Amount Not Recoverable from Revenues - 90%									821
Net Recovered from Operations - 10%									91
System Usage and Financial Assumptions									
Active Sewer Connections		175	355	370	385	400	415	430	
Metered Water Use in 1,000 m^3 (Load x 1.5)		45	114	120	126	131	137	142	
Water Surcharge Rate per m^3		.080	.085	.095	.105	.115	.130	.145	
Average New Connection Fee in JD		240	260	285	315	345	380	420	
Average Monthly Sewer Bill		-	2.3	2.6	2.9	3.1	3.6	4.0	
Operating Revenue									
Revenue from Surcharges (at 95%)		3	9	11	13	15	17	20	88
New Connection Fees		42	47	4	5	5	6	6	115
Total Revenue		45	56	15	18	20	23	26	203
Expenditures									
Operating Expenses		6	16	20	25	28	31	34	160
Power Costs		(Negligible)							-
Administrative Expenses (at 100% of O.E.)		6	16	20	25	28	31	34	160
Normal Improvements and Replacements		-	-	-	2	2	3	4	11
Total Expenditures		12	32	40	52	58	65	72	331
Operating Gain (or Loss)		33	24	(25)	(34)	(38)	(42)	(46)	(128)
Less: Net Debt Servicing Cost at Interest		-	10	10	10	10	10	10	60
Net Gain (Loss)		33	14	(35)	(44)	(48)	(52)	(56)	(188)
Accumulated Cash Surplus		33	47	12	(32)	(80)	(132)	(188)	(188)
Interest Revenue at 6% (Averaged)		1	3	2	-	-	-	-	6
Net Cash Surplus		34	51	18	(26)	(74)	(126)	(182)	(182)

SCHEDULE 12.14

GREATER AMMAN SEWERAGE IMPROVEMENTS

Financial Analysis - Independent Systems

	1983	1984	1985	1986	1987	1988	1989	1990	Total
				(in 1,000 JD)					
Lower Wadi es Sir System									
Capital Improvements									
Annual Capital Costs	2,492	2,741							5,233
Capitalized Interest During Const.	75	355							430
Total Capital Costs	2,567	3,096							5,663
Less: Amount Not Recoverable from Revenues - 90%									5,097
Net Recovered from Operations - 10%									566
System Usage and Financial Assumptions									
Active Sewer Connections		500	1,050	1,100	1,150	1,200	1,250	1,300	
Metered Water Use in 1,000 m^3 (Load x 1.5)		211	443	464	485	506	527	548	
Water Surcharge Rate per m^3		.080	.085	.095	.105	.115	.130	.145	
Average New Connection Fee in JD		240	260	285	315	345	380	420	
Average Monthly Sewer Bill			3.0	3.3	3.7	4.0	4.6	5.1	
Operating Revenue									
Revenue from Surcharges (at 95%)		16	36	42	48	55	65	76	338
New Connection Fees		120	143	14	16	17	19	21	350
Total Revenue		136	179	56	64	72	84	97	688
Expenditures									
Operating Expenses		12	22	25	29	32	37	42	199
Power Costs		10	21	25	31	35	40	45	207
Administrative Expenses (at 60% of O.E.)		7	13	15	17	19	22	26	119
Normal Improvements and Replacements		-	-	-	3	4	6	8	21
Total Expenditures		29	56	65	80	90	105	121	546
Operating Gain (or Loss)		107	123	(9)	(16)	(18)	(21)	(24)	142
Less: Net Debt Servicing Cost at 10% Interest		-	62	62	62	62	62	62	372
Net Gain (Loss)		107	61	(71)	(78)	(80)	(83)	(86)	(230)
Accumulated Cash Surplus		107	168	97	19	(61)	(144)	(230)	(230)
Interest Revenue at 6% Averaged)		2	9	9	5	1	-	-	26
Net Cash Surplus		109	179	117	44	(35)	(118)	(204)	(204)

SCHEDULE 12.15

GREATER AMMAN SEWERAGE IMPROVEMENTS

Financial Analysis - Independent Systems

Fuheis and Mahis System	1983	1984	1985	1986	1987	1988	1989	1990	Total
				(in 1,000 JD)					
Capital Improvements									
Annual Capital Costs	698	766							1,464
Capitalized Interest During Const.	21	99							120
Total Capital Costs	719	865							1,584
Less: Amount Not Recoverable from Revenues - 100%									1,584
Net Recovered from Operations	-0-								-0-
System Usage and Financial Assumptions									
Active Sewer Connections		400	850	880	910	940	970	1,000	
Metered Water Use in 1,000 m^3 (Load x 1.5)		98	209	216	224	231	239	246	
Water Surcharge Rate per m^3		.080	.085	.095	.105	.115	.130	.145	
Average New Connection Fee in JD		240	260	285	315	345	380	420	
Average Monthly Sewer Bill			1.7	1.9	2.2	2.4	2.7	3.0	
Operating Revenue									
Revenue from Surcharges (at 95%)		7	17	19	22	25	30	34	154
New Connection Fees		96	117	9	10	11	12	13	268
Total Revenue		103	134	28	32	36	42	47	422
Expenditures									
Operating Expenses		14	19	21	24	28	31	35	1.2
Power Costs		14	27	32	39	44	50	57	263
Administrative Expenses (at 70% of O.E.)		10	13	15	17	20	22	24	121
Normal Improvements and Replacements		-	-	-	2	3	4	5	14
Total Expenditures		38	59	68	82	95	107	121	570
Operating Gain (or Loss)		65	75	(40)	(50)	(59)	(65)	(74)	(148)
Less: Net Debt Servicing Cost at 10% Interest		-	-	-	-	-	-	-	-
Net Gain (Loss)		65	75	(40)	(50)	(59)	(65)	(74)	(148)
Accumulated Cash Surplus		65	140	100	50	(9)	(74)	(148)	(148)
Interest Revenue at 6% Averaged)		1	6	7	5	2	-	-	21
Net Cash Surplus		66	147	114	69	12	(53)	(127)	(127)

SCHEDULE 12. 16

GREATER AMMAN SEWERAGE IMPROVEMENTS

Financial Analysis - Independent Systems

Na'ur System	1983	1984	1985	1986	1987	1988	1989	1990	Total
				(in 1,000 JD)					
Capital Improvements									
Annual Capital Costs	351	386							737
Capitalized Interest During Const.	11	50							61
Total Capital Costs	362	436							798
Less: Amount Not Recoverable from Revenues - 100%									798
Net Recovered from Operations -0-									-0-
System Usage and Financial Assumptions									
Active Sewer Connections		190	400	420	440	460	480	500	
Metered Water Use in 1,000 m^3 (Load x 1.5)		50	105	110	116	121	126	131	
Water Surcharge Rate per m^3		.080	.085	.095	.105	.115	.130	.145	
Average New Connection Fee in JD		240	260	285	315	345	380	420	
Average Monthly Sewer Bill			1.9	2.1	2.3	2.5	2.8	3.2	
Operating Revenue									
Revenue from Surcharges (at 95%)		4	9	10	12	13	15	18	81
New Connection Fees		46	55	6	6	7	8	8	136
Total Revenue		50	64	16	18	20	23	26	217
Expenditures									
Operating Expenses		10	15	17	20	23	26	30	141
Power Costs		7	15	18	22	25	28	32	147
Administrative Expenses (at 70% of O.E.)		7	10	12	14	16	18	21	98
Normal Improvements and Replacements		-	-	-	2	2	3	4	11
Total Expenditures		24	40	47	58	66	75	87	397
Operating Gain (or Loss)		26	24	(31)	(40)	(46)	(52)	(61)	(180)
Less: Net Debt Servicing Cost at 10% Interest		-	-	-	-	-	-	-	-
Net Gain (Loss)		26	24	(31)	(40)	(46)	(52)	(61)	(180)
Accumulated Cash Surplus		26	50	19	(21)	(67)	(119)	(180)	(180)
Interest Revenue at 6% Averaged)		1	2	2	-	-	-		5
Net Cash Surplus		27	53	24	(16)	(62)	(114)	(175)	(175)

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APPENDIX A

LIST OF ABBREVIATIONS OF TECHNICAL TERMS

Abbreviation	Term
A	Area of cros-section of flow, in conduit
BOD or BOD_5	Biochemical Oxygen Demand, 5-Day, 20^oC
COD	Chemical Oxygen Demand
CRF	Capital Recovery Factor
CA	Collection Alternative
cu.m	cubic meters
DO	Dissolved Oxygen
EBOD	Effective BOD, (Temperature corrected)
EC	Electrical Conductivity (Specific Conductance)
g	gram
HGL	Hydraulic Grade Line
HP	Horsepower
kva	kilovolt amperes
kw	kilowatts
kwh	kilowatt-hours
km	kilometer
kv	kilovolt
lcd or l/c/da	liters per capita per day
l/sec	liters per second (discharge rate)
MCM	Million cubic meters
MCM/yr	Million cubic meters per year
MCRT	Mean Cell Residence Time (in aeration tanks)
MPN	Most probable number (coliform organisms)
m^3/da or cu m/da	cubic meters per day
mg/l	milligrams per liter (equivalent to parts per million)
MH	manhole
MLSS	Mixed Liquor Suspended Solids
"n"	Manning's roughness coefficient
mm/m	Slope in millimeters per meter
m/m	Slope in meters per meter
m	meter
m/s	meters per second, flow velocity
PF	Power Factor
PS	Pump Station

Abbreviation	Term
PVC	Polyvinyl Chloride (pipe)
Q	Rate of Discharge
R	Hydraulic radius (flow area divided by the wetted perimeter)
RCP	Reinforced Concrete Pipe
RAS	Return Activated Sludge
SS	Suspended Solids
S	Slope
STP	Sewage Treatment Plant
TA	Treatment Alternative
TDH	Total Dynamic Head (for pumping units)
TDS	Total Dissolved Solids
TP	Treatment Plant
v	velocity, of flow
VSS	Volatile Suspended Solids
WAS	Wastewater
WWTP	Wastewater Treatment Plant

APPENDIX A

LIST OF PROPER NAMES OF INSTITUTIONS, AGENCIES, AND FACILITIES

Acronym	Title
AGTP	Ain Ghazal Treatment Plant
AURPG	Amman Urban Region Planning Group
AWSA	Amman Water and Sewerage Authority
EPA	Environmental Protection Agency (United States)
JEA	Jordan Electricity Corporation
JEC	Jordan Electricity Company, Ltd.
KHMC	King Hussein Medical Center
KRTP	Khirbet er Ruseifa Treatment Plant
MMRAE	Ministry of Municipal and Rural Affairs and the Environment
MTA	Ministry of Tourism and Antiquities
MTI	Ministry of Trade and Industry
NHC	National Housing Corporation
NPC	National Planning Council
NRA	Natural Resources Authority
RSS	Royal Scientific Society
U of J	University of Jordan
UNRWA	United Nations Relief & Works Agency
USAID	United States Agency for International Development
UWATP	Upper Wadi Abdoun Treatment Plant
WHO	World Health Organization
WSC	Water Supply Corporation

APPENDIX B

SOCIO-ECONOMICS

METHODOLOGY USED FOR PROJECTION OF SATURATION POPULATION

Saturation populations for the cities of Amman, Wadi es Sir, Suweileh, Madaba, Sahab and Na'ur were projected using the following method:

Step 1 - Town plans of the cities listed above were measured to determine the size of their individual segments of residential zoning. Measurement was achieved through use of a planimeter.

Step 2 - Aerial photographs of those cities from 1978, 1979, were used to estimate the proportion of each zoned area that is currently undeveloped. In many population sub-areas, several separate areas of a particular zoning designation (such as zone A) were found; and as they had varying proportions of undeveloped area, they were treated separately. Aerial photographs of Madaba were taken in 1980, those of Amman were from 1978 and 1979, and those of the other cities were from 1978. Visual reconnaissance via automobile was used to supplement 1978 and 1979 photographs.

Step 3 - Gross undeveloped residentially zoned area was converted to net, by subtracting total surface area of streets within each zoned segment of each population sub-area. Street area was estimated from town plans of the cities of this analysis to be 15 percent of the total area of all residential zones.

Step 4 - Subtracted 10 percent from net residential undeveloped area, based on the assumption that ten percent of net residential land available for development would always remain undeveloped due to speculation, and the interim state between demolition of old structures and reconstruction of new structures.

Step 5 - Subtracted 20 percent from the total area that will contain structures based on the assumption that commercial and institutional structures would form 20 percent of the total building floor space within a residential zone. This assumption is based on current conditions and future zoning which have only large areas of commercial uses in a few commercial zones, and neighborhood community and strip commercial areas scattered throughout residential zoning. Institutional uses within residential zones include mosques, smaller schools and a large percentage of the public buildings scattered throughout cities. Only a small proportion of the total public buildings are currently in zones designated for government uses- and current zoning allows for only a few new areas with that designation.

Step 6 - Projected the split between high-rise and low-rise structures for each of the zoned areas of the various zoning types. High-rise structures were assumed to occupy five percent of the total net area of residential structures in the outlying cities of the study area (including Suweileh, Wadi es Sir, Madaba, Sahab and Na ur); while the Municipality of Amman and its Suburban Ring area were assigned fifteen percent of the net area of their residential structures as high-rise.

Step 7 - Separate zoned segments of the same zoning type within a single population sub-area, were totalled for that sub-area (e.g., areas of all segments zoned Residential A were added together to form a total of all A zoning in that particular sub-area.)

Step 8 - Zoning and building regulations from the 1979 Planning and Building Code regarding lot coverage and building height were applied to the area of each zone to determine the maximum number of dwelling units that could be accommodated. Table B-1 presents the derivation of the maximum dwelling units allowable per dunum for each zoning type.

The approach used to determine total units allowable in the undeveloped area of any zone was based on assumptions of average size of housing units (single family and multi-family), average number of residential floors per building and total floor space available for units per dunum of residential land. Both high-rise and low-rise structures were considered, with high-rise structures assumed to average 5 floors of residential units, and low-rise structures were assumed to average 2 floors. Total floor area space available for units per dunum was calculated by multiplying the maximum building ratio by the average number of floors. In addition to the "maximum building ratio" the code also specifies a minimum size plot for each zone. For example the Green Zone B allows a minimum plot size of 2000 m^2 while Zone A allows a minimum plot size of 1,000 m^2. Refer to Table 3-2. Both regulations give the same number of units per dunum. Because of the high cost of urban land, it was assumed that the maximum area of plots will be covered for all future development. This may in fact be conservative, as it implies full compliance with Building Code regulations. The floor area of residential buildings was reduced by 15 percent to allow for non-dwelling unit space in residential structures (e.g., elevator shafts in high-rise buildings, stairwells, service rooms, communal foyers, etc.), as assumed average living quarter space was to be net space for each family. The lower-density zones such as Green Zone B, Zone A and Zone B were assumed to be occupied by higher-income households than those in Zones C and D, as land in those outer areas of the city is generally more costly. For areas farthest from Metopolitan Amman, where the land would be less expensive, the pressure is not as great to maximize the number of units as in the inner city areas. The assumed average housing unit sizes, ranging from 150 in less dense areas to 75 in the crowded inner cities, were based on NHC estimates and building permit data from the Department of Statistics. High-rise structures were assigned smaller unit sizes in all zones than their equivalent low-rise structures. The total number of units projected per dunum for each zone ranged from 0.41 in the mixed agricultural/Residential Zone to 11.79 in Zone D for low-rise structure, and from 12.24 in Zone A to 29.47 in Zone D for high-rise structures. The mixed agricultural zone and Green Zone B were assumed to have no high-rise structures.

Step 9 - The projected number of units was then multiplied by the assumed 6.5 persons per family to project the total population increase per zoned area.

Step 10 - Individually zoned area projected population increases were aggregated into groupings which coincided with the population sub-areas identified in Chapter 3 (administrative units of the Municipality of Amman, and drainage areas based population sub-areas for the other cities.) Table B-2 presents an example of a saturation population projection for a particular population sub-area carried through from identification of the amount of developable area to the calculation of total saturation population for that area.

TABLE B-1

MAXIMUM DWELLING UNITS PER DUNUM POR PLANNING ZONES

	Residential Zone	Maximum Building Ratio %	Assumed Average Number of Floors	Floor Area of Residential Buildings per dunum (m^2)	Less 15% For Building Area Outside Units	Assumed Avg. Unit Size[a] (m^2)	Total Numb Units per
Low-rise							
	Mixed Agriculture and Residential A	36	2	72[b]	61	150	0.41
	Green Zone B	42	1.5	630	536	125	4.29
	A	36	2	720	612	150	4.08
	B	42	2	840	714	125	5.71
	C	48	2	960	816	100	8.16
	D	52	2	1,040	884	75	11.79
High-rise							
	Mixed Agriculture[c] and Residential A	--	--	---	---	---	---
	Green Zone B[c]	--	--	---	---	---	---
	A	36	5[c]	1,800	1,530	125	12.24
	B	42	5[c]	2,100	1,785	125	14.28
	C	48	5[c]	2,400	2,040	75	27.20
	D	52	5[c]	2,600	2,210	75	29.47

[a] Based on estimates from NHC and Department of Statistics building permit records.

[b] Same building code specifications as regular Residential A Zone, but only 10 percent of the zoned area can be occupied by residential uses.

[c] This zone was assumed to contain no high-rise structures due to low-densidy regulations.

Source: Planning and Building Code, 1979.

TABLE B-2

EXAMPLE OF DERIVATION OF SATURATION POPULATION FOR POPULATION SUB-AREAS

Municipality of Amman

Unit: 97 Katana

Zone	Total Area (Dunums)[a]	Estimated Percent Undeveloped[b]	Gross Undeveloped Area	Less Interior Streets area@ 15%[c]	Net Undeveloped Area	Less Permanently Undeveloped Land @ 10%	Total Area to Contain Structures	Less Commercial and Institutional Uses @ 20%	Net Undeveloped Residential Area	High-rise @ 15% of Net Undeveloped Residential Area	Low-rise @ 85%
A	403	40	161.2	24.2	137.0	13.7	123.3	24.7	98.6	14.8	83.8
A	297	50	148	22.3	126.2	12.6	113.6	22.7	90.9	13.6	77.3
C	233	30	69.9	10.5	59.4	5.9	53.5	10.7	42.8	6.4	36.

Zone	Total Area (dunums)	Total Floor Space/Dunum (m^2)[e]	Total Floor Space in Zone (m^2)	Average Size Per Unit (m^2)[f]	Total Units Per Zone	Average Population Per Unit	Population Increase
Low-Rise Structures							
Total A	161.1	612	98,593	150	657	6.5	4,270
Total C	36.4	816	29,702	100	297	6.5	1,930
TOTAL LOW-RISE	—	—	—	—	—	—	6,200
High-Rise Structures							
Total A	28.4	1,530	43,452	125	348	6.5	2,262
Total C	6.4	2,040	13,056	75	174	6.5	1,132
TOTAL HIGH-RISE	—	—	—	—	—	—	3,394
TOTAL UNIT 97	—	—	—	—	—	—	9,594

[a] Planimetered from Town Plan

[b] Estimated from 1978 aerial photography supplemented by auto reconnaissance survey

[c] Estimated from Town Plan

[d] Most commercial land use occupied land within residential zones, as only a few are zoned for commercial uses. Institutional used within residential zones are usually mosques, smaller schools (large schools are in governmental zones), and all public buildings not in governmental of civic center zones (a large percentage of such buildings are scattered throughout residentially zoned areas).

[e] Based on maximum plot coverage and an average of 5 floors per high-rise structure and 2 floors per low-rise structure for zones as specified in Planning and Building Code, 1979 and derived in Table B-1.

[f] Based on data for 1978 and 1979 from building permit reports to Department of Statistics, and NHC estimates

Source: Municipality of Amman Town Plan, 1980; National Geographic Center aerial photographs, 1978; National Housing Corporation; Department of Statistics Statistical Year book, 1978; Planning and Building Code, 1979.

DISAGGREGATION OF POPULATION PROJECTIONS FOR THE AMMAN SUBURBAN RING AND OTHER MAJOR CITIES FOR 1990 and 2000

Tables B-3 through B-8 present population projections for 1990 and 2000 for the population sub-areas of the Amman Suburban Ring area and the Municipalities of Wadi es Sir, Madaba, Suweileh, Sahab and Na'ur.

Population of the population sub-areas in 1990 and 2000 were projected using the following methodology:

Step 1 - total city populations, taken from the 1979 Census, were disaggregated into population sub-areas by estimation through interpretation of 1978, 1979 or 1980 aerial photographs. 1979 populations of sub-areas within the Amman Suburban Ring were taken directly from the 1979 Census whenever possible, and remaining areas were estimated through inspection of aerial photographs.

Step 2-1990 and 2000 total city populations were projected by applying assumed annual percentage increases (as identified in Chapter 3 Population Projection section.)

Step 3 - Saturation populations were projected for each of the population sub-areas (as presented in Chapter 3 Saturation Population section.)

Step 4 - The population increases for each sub-area required to reach saturation were calculated by subtracting 1979 estimated populations from projected saturation populations.

Step 5 - The ratios of saturation increase for each sub-area to the saturation increase for the total city were calculated.

Step 6 - The ratios derived in Step 5 were applied pro rata to the projected increase for the total city between 1979 and 1990 to project individual increases for sub-areas from 1979 to 1990. The projected increases for the total cities were calculated using annual rates of increase which were based on assumptions of birth rate, death rate and migration trends (as outlined in Chapter 3 Population Projections section.)

Step 7 - Total 1990 population was calculated for each sub-area by adding 1979 estimated population to the projected increase for 1979 to 1990.

Step 8 - Step 6 was repeated to project the year 2000 increases for each sub-area.

Step 9 - Step 7 was repeated to derive total 2000 populations for each sub-area.

Table B-9 shows a breakdown of the gross undeveloped area and projected saturation total number of housing units in each zone. The derivation was based on the methodology outlined earlier and shown in Tables B-1 and B-2. Tables B-9 through B-15 show the same for the population sub-areas of the Amman Suburban Ring, and the Municipalities of Wadi es Sir, Madaba, Suweileh, Sahab and Na'ur.

TABLE B-3

POPULATION PROJECTIONS FOR AMMAN SUBURBAN RING AREA[a]

Population Sub-area	1979[b]	Total Saturation Population	Saturation Adition[c]	% of Total Saturation Addition	1990 Addition[d]	1990 Total	2000 Addition[e]	2000 Total
1 Marj Al Hamam	1,500	71,637	70,137	9	5,100	6,600	15,900	22,500
2 Al Hilal	200	23,716	23,516	3	1,500	1,700	5,100	6,800
3 Al Muqablein	800	41,223	40,423	5	2,800	3,600	8,900	12,500
4 Queismeh - East of Wahdat	8,500	125,206	116,706	15	12,000	20,500	30,900	51,400
5 East Marka	100	121,670	121,570	16	7,600	7,700	26,500	34,200
6 Ain Ghazal Road	100	83,630	83,530	10	4,800	4,900	16,500	21,400
7 Katana - Tila Al Ali	1,500	115,016	113,516	15	8,000	9,500	25,800	35,300
8 South University	200	31,920	31,720	4	2,000	2,200	6,700	8,900
9 Rural Khilda	100	5,202	5,102	1	500	600	1,800	2,400
10 Khilda	200	8,286	8,086	1	600	800	1,800	2,600
11 Medical Center Area	100	24,540	24,440	3	1,500	1,600	5,000	6,600
12 Umm es Summaq	1,500	127,209	125,709	16	8,400	9,900	27,500	37,400
13 Jubeiha	1,600	19,105	17,505	2	1,900	3,500	4,400	7,900
Total	16,400	798,360	781,960	100	56,700	74,000	176,000	250,000

[a] This table shows derivation of projected population totals. Actual numbers used in calculations are shown; they are not intended to imply accuracy to more than two significant figures.

Estimated from 1979 Census.

Projected from estimates of undeveloped area per zone type, and assuming maximum building coverage per zone building code.

Based on annual growth rage of 4.2 percent for the period 1979 to 1990 - plus a pro rata apportionment of 25 percent of the Amman Municipality excess above saturation, apportioned based on subarea percentage of the total saturation population increase.

Based on an annual growth rate of 3.9 percent for the period 1991 to 2000, plus a pro rata apportionment of 75 percent of the Amman Municipali excess above saturation, apportioned based on subarea percentage of the total saturation population increase.

Source: Department of Statistics, 1979 Census of Population, Planning and Building Code, 1979, National Geographic Center, aerial photographics 1978, AURPG, Land Use Plan Greater Amman Region.

TABLE B-4

WADI ES SIR POPULATION PROJECTIONS[a]

Population Sub-area	% of 1979 Total[b]	1979 Estimate[c]	Saturation Addition[d]	Saturation Addition % of Total Addition	1990 Addition[e]	1990 Total	2000 Addition[f]	2000 Total	Total Saturation Population
1	7	1,714	19,261	13	1,823	3,537	2,988	6,525	20,975
2	8	1,960	7,371	5	701	2,661	1,149	3,810	9,331
3	12	2,940	10,828	7	981	3,921	1,609	5,530	13,768
4	14	3,430	7,559	5	701	4,131	1,149	5,280	10,989
5	16	3,920	17,242	12	1,682	3,602	2,758	6,360	21,162
6	10	2,449	25,918	18	2,524	4,973	4,137	9,110	28,367
7	13	3,184	4,659	3	140	3,324	690	4,014	7,843
8	3	735	2,457	2	280	1,015	460	1,475	3,192
9	1	245	4,959	3	140	385	690	1,075	5,204
10	1	245	10,582	7	981	1,226	1,609	2,835	10,827
11	1	245	7,521	5	701	946	1,149	2,095	7,766
12	2	490	8,182	6	841	1,331	1,379	2,710	8,672
13	8	1,960	6,071	4	561	2,521	919	3,440	8,031
14	4	980	14,114	10	1,402	2,382	2,299	4,681	15,094
Total City	100	24,497	146,724	100	14,020	38,517	22,985	61,502	171,221

[a]This table shows derivation of projected population totals. Actual numbers used in calculations are shown; they are not intended to imply accuracy to more than two significant figures.

[b]Based on matching 1978 aerial photographs to current residentially zoned areas from current zoning maps, supplemented by site visits

[c]Calculated by applying estimated percent of city population to 1979 census total city population.

[d]Projected from estimates of undeveloped area per zone type, and assuming maximum building coverage per zone building code.

[e]Calculated by applying 4.2 percent annual growth rate to the total city present population and the projected increase was apportione among the subareas using their respective percents of saturation addition.

[f]Same as footnote e, using 3.9 percent annual growth rate applied to projected total city increase for 1991 to 2000.

Source: Department of Statistics, 1979 Census of Population, Planning and Building Code, 1979, National Geographic Center aerial photographs, 1978, Wadi Es Sir Town Plan, 1980.

TABLE B-5

MADABA POPULATION PROJECTIONS[a]

Population Sub-area	% of 1979 Total[b]	1979 Estimate[c]	Saturation Addition[d]	Saturation Addition % of Total Addition	1990 Addition[e]	1990 Total	2000 Addition[f]	2000 Total
1	21	5,987	7,805	8	979	6,966	1,338	8,304
2	25	7,127	19,533	19	2,325	9,452	3,179	12,631
3	29	8,268	5,486	5	612	8,880	837	9,717
4	6	1,711	11,485	12	1,468	3,179	2,008	5,187
5	10	2,851	21,638	21	2,570	5,421	3,513	8,934
6	8	2,280	16,268	16	1,958	4,238	2,677	6,915
7	1	285	18,857	19	2,325	2,610	3,179	5,789
Total City	100	28,509	101,072	100	12,237	40,746	16,730	57,476

For detailed footnotes see Table B-4.

Source: Department of Statistics, 1979 Census of Population, Planning and Building Code, 1979, National Geographic Center aerial photographs, 1980, Madaba Town Plan, 1980.

TABLE B-6

SUWEILEH POPULATION PROJECTIONS[a]

Population Sub-area	% of 1979 Total[b]	1979 Estimate[c]	Saturation Addition[d]	Saturation Addition % of Total Addition	1990 Addition[e]	1990 Total	2000 Addition[f]	2000 Total	Total Saturation Populatio
1	5	1,072	7,805	12	1,104	2,176	1,543	3,719	8,157
2	5	1,072	3,387	6	552	1,624	772	2,396	4,459
3	10	2,144	4,296	7	644	2,788	900	3,688	6,440
4	25	5,362	3,612	6	552	5,914	772	6,686	8,974
5	3	643	2,580	5	460	1,103	643	1,746	3,223
6	13	2,788	4,249	7	644	3,432	900	4,332	7,037
7	16	3,431	6,558	11	1,012	4,443	1,415	5,858	9,989
8	13	2,787	6,040	11	1,012	3,799	1,415	5,214	8,827
9	1	214	9,832	18	1,657	1,871	2,315	4,186	10,046
10	1	214	2,210	4	368	582	514	1,096	2,424
11	8	1,715	7,690	13	1,197	2,912	1,672	4,584	9,405
Total City	100	21,442	57,539	100	9,204	30,646	12,860	43,506	78,981

For detailed footnotes see Table B-4.

Source: Department of Statistics, 1979 Census of Population, Planning and Building Code, 1979, National Geographic Center aerial photographs, 1978, Suweileh Town Plan, 1980.

TABLE B-7

SAHAB POPULATION PROJECTIONS[a]

Population Sub-area	% of 1979 Total[b]	1979 Estimate[c]	Saturation Addition[d]	Saturation Addition % of Total Addition	1990 Addition[e]	1990 Total	2000 Addition[f]	2000 Total	Total Saturation Population
1	52	6,192	546	1	51	6,243	70	6,313	6,734
2	7	834	2,106	6	307	1,141	419	1,560	2,490
3	8	953	4,570	11	562	1,515	769	2,284	5,523
4	1	119	11,698	28	1,431	1,550	1,957	3,507	11,817
5	1	119	11,057	26	1,329	1,448	1,817	3,265	11,176
6	13	1,548	4,655	11	562	2,110	769	2,879	6,303
7	18	2,143	7,176	17	869	3,012	1,188	1,188	9,319
Total City	100	11,908	41,808	100	5,111	17,019	6,988	24,007	53,716

For detailed footnotes see Table B-4.

Source: Department of Statistics, 1979 Census of Population, Planning and Building Code, 1979, National Geographic Center aerial photographs, 1978, Sahab Town Plan, 1980.

TABLE B-8

NA'UR POPULATION PROJECTIONS[a]

Population Sub-area	% of 1979 Total[b]	1979 Estimate[c]	Saturation Addition[d]	Saturation Addition % of Total Addition	1990 Addition[e]	1990 Total	2000 Addition[f]	2000 Total	Total Saturation Population
1	19	988	3,712	21	404	1,392	554	1,946	4,700
2	48	2,495	1,060	6	116	2,611	158	2,769	3,555
3	7	364	5,597	32	616	980	843	1,823	5,761
4	16	832	2,744	16	308	1,140	422	1,562	3,576
5	10	520	4,460	25	481	1,001	659	1,660	4,980
Total City	100	5,199	17,573	100	1,925	7,124	2,636	9,760	22,772

or detailed footnotes see Table B-4.

Source: Department of Statistics, 1979 Census of Population, Planning and Building Code, 1979, National Geographic Center aerial photographs, 1978, Na'ur Town Plan, 1980.

MUNICIPALITY OF AMMAN

SATURATION AND DEVELOPMENT AREA AND HOUSING UNITS

Unit No.	Zone	Area (Dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturation Total Units
11-19	——	0	0	0	0
21	C	44	100	44.0	299
	D	1,839	5	91.9	805
22	D	343	0	0	0
23	C	572	5	28.6	
	C	642	90	578.1	4,090
24	A	334	100	334.0	1,085
	B	334	100	334.0	1,405
	C	229	30	68.7	
	C	334	100	334.0	2,715
Green	B	1,434	95	1,362.7	3,576
	C	237	60	142.2	957
26	A	484	95	459.8	1,493
	B	484	95	459.8	1,935
	C	484	95	459.8	
	C	607	25	151.8	4,123
31	D	116	0	0	0
32	C	365	0	0	0
33	C	224	40	89.6	604
34	C	365	15	54.7	368
35	——	0	0	0	0
41	D	1,368	0	0	0
42	D	1,111	10	111.1	975
43	C	256	35	89.6	
	C	418	90	376.2	3,141
	D	56	25	133.0	1,166
44	C	1,026	90	923.4	
	C	627	35	219.5	7,707
51	D	1,495	0	0	0
52	D	678	0	0	0
53	C	964	35	337.4	2,275
56	C	403	30	120.9	815

TABLE B-9

MUNICIPALITY OF AMMAN (Cont'd)
SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Unit No.	Zone	Area (Dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturatic Total Uni
61	D	1,050	0	0	0
62	C	1,767	50	795.1	5,361
63	C	2,202	65	1,431.3	9,649
	D	444	10	44.4	389
64	A	303	50	151.5	601
	B	505	65	328.3	1,374
71	C	480	40	192.0	1,294
	D	557	35	194.9	1,710
72	C	96	40	38.4	257
	D	1,805	25	451.2	3,958
73	B	950	60	570.0	2,398
	C	297	60	178.2	1,202
74	B	269	65	174.8	735
	C	211	40	84.4	567
	D	528	40	211.2	1,853
81	C	1,810	5	90.5	609
82	A	3,546	85	3,014.1	9,784
	B	1,009	80	807.2	
	B	198	50	99.0	
	B	62	50	31.0	3,935
83	A	2,891	40	1,156.4	3,753
85	B	239	35	83.7	352
86	A	1,029	35	360.2	1,169
	B	676	35	236.6	
	B	281	15	42.1	1,173
91	C	1,261	10	126.1	850
92	B	477	30	143.1	601
	C	1,558	5	77.9	526
93	A	1,484	40	593.6	1,917
	B	1,441	35	504.3	
	B	498	35	174.3	2,855

OF AMMAN (Cont'd)

SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Unit No.	Zone	Area (Dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturation Total Units
94	B	1,494	40	597.6	2,515
95	A	1,134	50	567.0	1,840
	b	583	40	233.2	
	B	318	50	159.0	1,650
96	A	403	40	161.2	
	A	297	50	148.5	1,005
	C	233	30	69.9	471
otal City	—	—	—	25,618.3	133,002

ource: National Geographic Center aerial photographs 1978, Planning and Building Code 1979, Municipality of Amman Town Plan, 1980.

AMMAN SUBURBAN RING AREA

SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Sub-area No.		Zone	Area (Dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area		Saturation Total Units
1		A	950	80	760.0	A	2,467
		B	950	80	760.0	B	3,198
		C	950	80	760.0	C	5,125
2		B	905	95	859.8	B	3,618
3		B	1,739	85	1,478.2	B	6,219
4		A	1,581	80	1,264.8	A	4,106
		B	1,581	80	1,264.8	B	5,322
		C	1,581	80	1,264.8	C	8,527
5		C	2,920	95	2,774.0	C	18,703
6		A	953	95	905.4	A	2,939
		B	953	95	905.4	B	3,809
		C	953	95	905.4	C	6,103
7		A	1,538	80	1,230.4	A	3,994
		B	1,538	80	1,230.4	B	5,176
		C	1,538	80	1,230.4	C	8,294
8	Green	B	2,637	90	2,373.3	Green B	6,228
9	Agr./Res.	A	699	90	629.1	Agr/Res A	1,570
10	Green	B	756	80	604.8	Green B	1,587
11	Green	B	1,925	95	1,828.8	Green B	4,799
12		A	1,703	80	1,362.4	A	4,422
		B	1,703	80	1,362.4	B	5,732
		C	1,703	80	1,362.4	C	9,186
13		A	190	100	190.0	A	616
		B	190	100	190.0	B	798
		C	190	100	190.0	B	1,279
Total City		—	—	—	27,687.0		123,817

Source: National Geographic Center Aerial photographs 1978, Planning and Building Code, 1979, Land Use Plan Greater Amman 1980.

WADI ES SIR

SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Sub-area No.	Zone	Area (Dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturation Total Units
1	C	171	80	136.8	
	C	112	65	72.8	
	C	183	80	146.4	
	C	43	80	34.4	
	C	166	30	49.8	C 2,463
	D	186	35	65.1	D 500
2	C	147	80	117.6	
	C	139	50	69.5	C 1,044
	D	63	20	12.6	D 90
3	C	160	70	112.0	
	C	120	10	12.0	C 702
	D	154	70	107.8	
	D	126	15	18.9	D 974
4	C	166	30	49.8	
	C	142	10	14.2	
	C	161	90	144.9	C 1,163
5	A	42	100	42.0	
	A	199	25	49.8	
	A	246	15	36.9	A 354
	B	282	30	84.6	
	B	245	30	73.5	
	B	182	15	27.3	
	B	226	15	33.9	B 806
	C	160	25	40.0	
	C	205	80	61.5	
	C	156	40	62.4	
	C	207	50	103.5	C 1,493

WADI ES SIR (Cont'd)

SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Sub-area No.	Zone	Area (Dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturation Total Units	
6	A	74	95	70.3		
	A	296	75	222.0	A	802
	B	220	65	143.0		
	B	235	65	152.8	B	1,087
	C	227	70	158.9		
	C	168	60	100.8		
	C	192	60	115.2	C	2,098
7	A	148	25	37.0		
	A	113	40	45.2		
	A	15	30	4.5	A	238
	B	92	30	27.6		
	B	160	40	64.0	B	328
	C	142	20	28.4	C	183
8	A	230	60	138.0	A	378
9	B	195	85	165.8		
	B	60	70	42.0	B	763
10	A	218	90	196.2		
	A	94	95	89.3		
	A	67	100	67.0	A	964
	B	201	90	180.9	B	664
11	B	183	95	173.9		
	B	26	100	26.0		
	B	128	90	115.2	B	1,157
12	A	191	95	181.5	A	499
	B	230	90	207.0	B	760
13	A	254	60	152.4	A	418
	B	73	30	21.9		
	B	140	40	56.0		
	B	84	70	58.8	B	516

WADI ES SIR (Cont'd)

SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Sub-area No.	Zone	Area (Dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturation Total Units	
14	A	169	80	135.2		
	A	201	85	170.9	A	840
	B	233	70	163.1		
	B	220	90	198.0	B	1,331
Total City	—	—	—	5,516.0		22,615

Source: National Geographic Center Aerial photographs 1978, Planning and Building Code, 1979, Wadi Es Sir Town Plan 1980.

MADABA
SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Unit No.	Zone	Area (Dunums)	Estimated 1979% Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturation Total Units
1	C	80	65	52.0	
	C	18	10	1.8	C 307
	D	209	30	62.7	
	D	138	20	27.6	
	D	119	75	89.3	D 894
2	C	203	85	172.6	
	C	178	85	151.3	C 1,806
	D	156	60	93.6	
	D	125	50	62.5	D 1,199
3	D	209	25	52.3	
	D	135	15	20.3	
	D	127	15	19.1	
	D	120	15	18.0	D 844
4	C	115	80	92.0	
	C	164	90	147.6	
	C	104	80	83.2	C 1,767
5	C	278	80	222.4	
	C	227	75	170.3	
	C	222	80	177.6	C 3,179
	D	105	20	21.0	D 150
6	C	307	90	276.3	
	C	147	50	73.5	
	C	103	30	30.9	C 2,126
	D	123	40	49.2	D 377
7	A	99	95	94.1	A 490
	B	216	90	194.4	
	B	208	95	197.6	
	B	162	90	145.8	
	B	91	95	86.5	
	B	32	100	32.0	B 2,411
Total City	—	—	—	2,917.5	15,550

Source: National Geographic Center Aerial photographs 1980, Planning and Building Code, 1979, Madaba Town Plan 1980.

SUWEILEH

SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Unit No.	Zone	Area (Dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturation Total Units	
1	A	182	70	127.4		
	A	138	75	103.5		
	A	175	75	131.3	A	1,016
	B	87	25	21.8	B	74
2	A	102	85	86.7		
	A	55	60	33.0	A	328
	B	81	65	52.7	B	193
3	B	185	60	111.0		
	B	230	30	69.0	B	661
4	B	252	50	126.0	B	464
	C	231	5	11.6		
	C	136	5	6.8	C	92
5	B	135	80	108.0	B	397
6	B	41	95	39.0		
	B	30	60	18.0		
	B	126	50	63.0	B	440
	C	70	25	17.5	C	83
	C	23	80	18.4	C	131
7	C	194	40	77.6	C	433
	D	64	50	32.0		
	D	40	5	2.0		
	D	74	55	40.7	D	576
8	A	112	90	100.8		
	A	136	75	102.0	A	557
	B	102	10	10.2		
	B	86	25	21.5		
	B	58	95	55.1	B	320
	C	14	40	5.6		
	C	50	10	5.0	C	52

SUWEILEH (Cont'd)

SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Unit No.	Zone	Area (Dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturation Total Units	
9	A	124	90	111.6	A	307
	B	43	70	30.1		
	B	65	85	55.3	B	314
	C	200	80	160.0	C	892
10	A	155	80	124.0	A	340
11	A	78	50	39.0	A	107
	B	101	80	80.8		
	B	250	50	125.0		
	B	109	80	87.2	B	1,076
Total City	--	—	—	2,410.0		8,853

Source: National Geographic Center Aerial photographs 1978, Planning and Building Code, 1979, Suweileh Town Plan 1980.

TABLE B-14

SAHAB

SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Unit No.	Zone	Area (Dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturation Total Units	
1	A	22	30	6.6	A	16
	C	90	15	13.5	C	68
2	A	236	50	118.0	A	324
3	A	122	70	85.4		
	A	241	60	144.6		
	A	38	70	26.6	A	703
4	A	160	60	96.0		
	A	286	80	228.8		
	A	18	60	10.8	A	921
	B	83	80	66.4		
	B	233	75	174.8	B	879
5	A	274	90	246.6		
	A	63	80	50.4	A	815
	B	301	80	240.8	B	886
6	A	47	90	42.3	A	116
	B	176	75	132.0		
	B	45	5	2.3	B	494
	C	71	30	21.3	C	106
7	A	223	60	133.8		
	A	188	20	37.6		
	A	212	80	169.6	A	1,018
	B	168	15	25.2	B	86
Total City				2,073.4		6,432

Source: National Geographic Center Aerial photographs 1978, Planning and Building Code, 1979, Sahab Town Plan 1980.

TABLE B-15

NA'UR

SATURATION DEVELOPMENT AREA AND HOUSING UNITS

Unit No.	Zoned Area	Area (dunums)	Estimated 1979 % Undeveloped	Estimated 1979 Gross Undeveloped Area	Saturation Total Units	
1	A	114	60	68.4	A	188
	B	235	25	58.8		
	B	117	50	58.8	B	431
2	C	185	10	18.5		
	C	189	10	18.9	C	187
3	A	68	90	61.2	A	168
	B	150	60	90.0		
	B	186	50	93.0		
	B	25	70	17.5	B	737
4	A	31	85	26.4	A	66
	B	196	50	98.0	B	360
5	A	230	80	184.0		
	A	41	95	39.0	A	609
	B	134	35	46.9	B	172
Total City	--	—	—	1,779.1		2,918

Source: National Geographic Center Aerial photographs 1978, Planning and Building Code, 1979, Na'ur Town Plan 1980.

INVITATION BY NATIONAL PLANNING COUNCIL
TO ENVIRONMENTAL SCOPING MEETING,
GREATER AMMAN WASTEWATER DISPOSAL PROJECT

Invitations from NPC were personally delivered by the Joint Venture on July 24 and 26, 1980, requesting the following ministries/agencies, to send representatives to attend the scoping meeting set for 10 AM Wednesday July 30, 1980:

1. U.S. AID
2. Ministry of Health
3. Ministry of Municipal, Rural Affairs and the Environment (MMRAE)
4. Ministry of Trade & Industry
5. Water Supply Corporation (WSC)
6. Natural Resources Authority (NRA)
7. Amman Water & Sewerage Authority (AWSA)
8. Royal Scientific Society (RSS)
9. Mayor of Jbaihah
10. Mayor of Suweileh
11. Mayor of Wadi es Sir

The invitation material is attached.

ENVIRONMENTAL SCOPING FOR
GREATER AMMAN WASTEWATER
MANAGEMENT PROJECT

INTRODUCTION

On May 17, 1980, the National Planning Council entered into an agreement with the Joint Venture of James M. Montgomery, Consulting Engineer, Inc., and DMJM International, a Joint Venture, in association with Consulting Engineering Center, for the preparation of preliminary study and master plan for wastewater disposal for Greater Amman Area, including technical and economic feasibility studies to meet the area's wastewater management needs for the planning period up to the year 2000.

The area includes all the cities, municipalities and villages located within a 30 km radius from the center of Amman. Please refer to the attached figure. The Zarqa and Ruseifa sewerage system is being studied under a separate contract. Madaba sewerage system will be evaluated under a separate study also. Salt sewerage system has recently been constructed.

Based on the technical and financial recommendation of the study, final design and contract drawings of the first phase of the Investment Program will be prepared to provide for the needs of the area up to year 1990.

It is anticipated that the Master Plan will be completed by November 17, 1980.

SCOPE OF WORK

As a result of its analyses and addressing of key issues, the Master Plan will:

1. Identify the areas within Amman and surrounding towns that can be tied up economically to the existing plant at Ain Ghazal.
2. Identify the areas of Greater Amman that should be connected to new treatment plant(s).
3. Suggest the percentage of the population to be connected to and served by the sewerage system, in Phase I Investment Program and for the year 2000.
4. Recommend location of the new treatment plants and the areas to be served.
5. Recommend the timing of construction of each plant and its primary sewerage network.
6. Devdop a least capital and operation cost solution of the Phase I Investment Program after considering various sewerage management alternatives within Greater Amman.
7. Recommend appropriate expansion and upgrading of the existing wastewater treatment facilities at Ain Ghazal taking into consideration (a) the adequacy of the existing sewer trunk lines to carry additional quantities of wastewater flow generated in Amman and vicinity and (b) various constraints upon plant expansion.

8. Suggest alternative uses or disposal of treated wastewater and sludge, including costs and benefits.

9. Suggest minimum quality to be attained for treated wastewater with special reference to beneficial reuse and preserving environmental aspects of affected areas.

10. Generally appraise the present situation with respect to waterborne diseases and health aspects vis-a-vis sewerage works and wastewater treatment facilities and recommend goals and objections for improvement to be expected from project implementation, according to phases.

11. Assess environmental problems that may arise or be aggravated by expansion of Ain Ghazal Treatment Plant or other plants with particular reference to sludge processing and disposal.

12. Consider potential impacts of the project upon the water resources of North Jordan and operations of the Jordan Valley Authority.

OBJECTIVES OF THE ENVIRONMENTAL SCOPING MEETING:

The objectives of the environmental scoping meeting are:

(1) To identify the forseeable significant effects of the project, both beneficial and adverse, and to ensure environmental factors and values are integrated fully and early into the decision-making process involved in the study.

(2) To focus on the issues that have adverse environmental impacts and to provide reasonable alternatives which would avoid or minimize these adverse impacts.

POTENTIAL ENVIRONMENTAL IMPACTS OF THE PROJECT:

It is anticipated that the project will have both short-term and long-term impacts upon the physical environment as well as the human environment of Greater Amman Area. These impacts will vary in degree and may be felt on the regional level or be limited to a specific site. There may be both beneficial and adverse impacts.

Although the extent and significance of potential impacts cannot be assessed prior to investigation, it is anticipated that the significant long-term impacts may involve the following:

1. Water Resources.

   a. Surface water - quality and quantity in wadis, rivers, and impoundments, including King Talal Reservoir and other resources of North Jordan.

   b. Groundwater - quality and quantity in both upper and lower aquifers, as a result of diversion of wastewater from cesspools to centralized treatment plants and surface disposal.

General recognition will be given to various plans for importation of surface water to Greater Amman and to the interface between such importation developments and the wastewater project, including the matters of effluent discharge to wadis and diversions to potential local beneficial reuse areas.

2. Land Resources

   a. Commitment of land to wastewater treatment and disposal facilities. Also plant siting impacts (grading, aesthetics, etc.)

   b. Potential impacts of digested sludge utilization for beneficial purposes and/or of sludge disposal.

   c. Historic sites, including archaeological sites.

3. Human Resources

   a. General effects upon personal hygiene practices from having improved sewage disposal facilities.

   b. General effects upon health and waterborne diseases attributable to expanded and upgraded wastewater management facilities, particularly for low-income and rural areas.

   c. Growth inducement and urban development potentials due to availability of sewer service.

   d. Allocation of project costs and charges to affected populations including the urban poor.

4. Conservation of Energy and Natural Resources

   a. Effluent and sludge reuse.

   b. Utilization of digester's methane gas for beneficial uses.

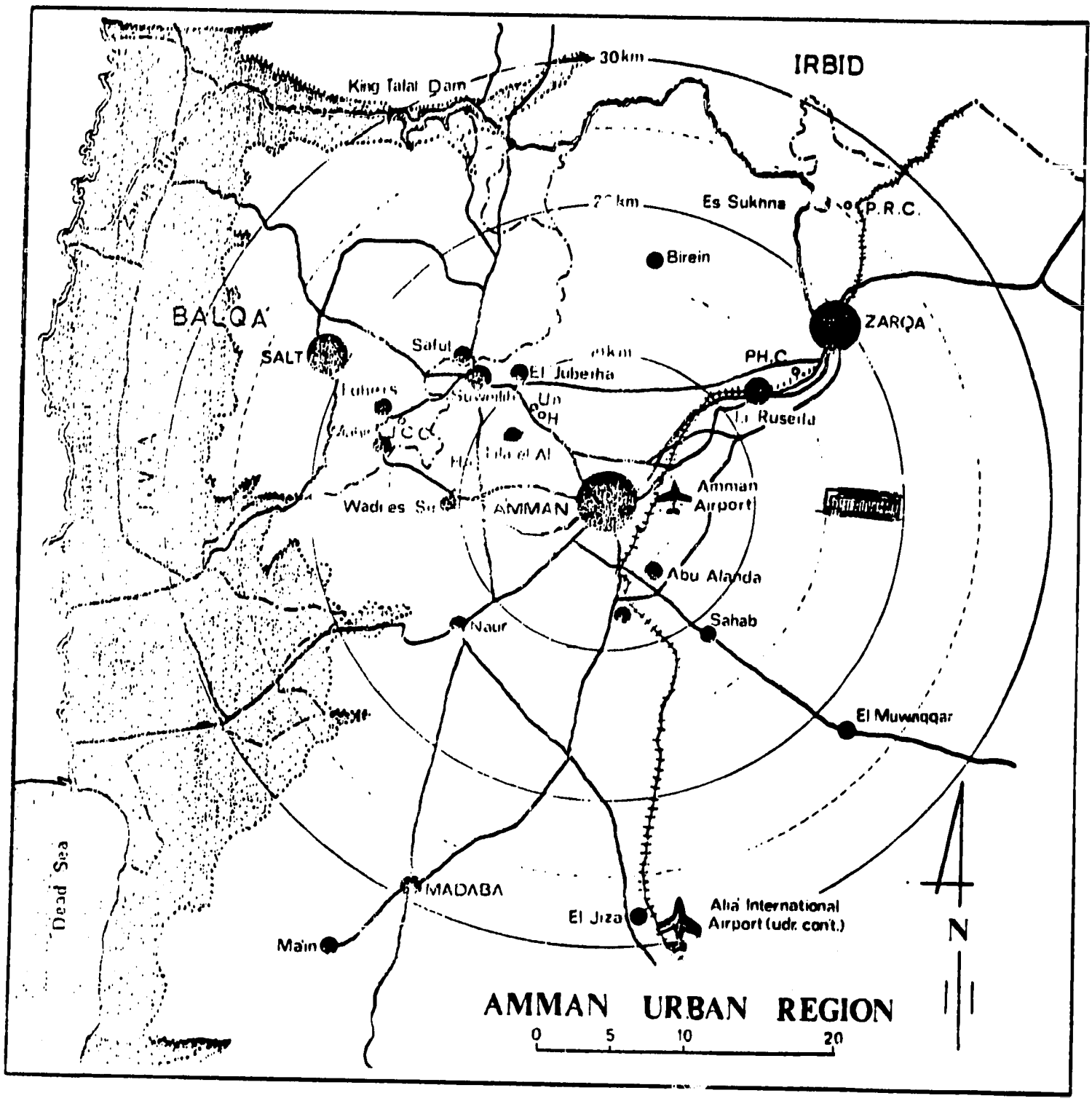
Items of particular concern to individual sites of treatment plant(s) location, sludge disposal location(s) and sewer construction include:

- Construction impacts
- Odor and visual impacts

The impacts of the expansion/modification at Ain Ghazal Sewage Treatment Plant on the neighboring area will be assessed. Other site-specific impacts will be identified once the wastewater management alternatives are defined.

PARTICIPATION

The scoping meeting participants are urged to give their views and comments on the potential impacts of the project and the means for mitigating the adverse impacts.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Es Sukhna
P.R.C.
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MINUTES OF ENVIRONMENTAL SCOPING MEETING
AT NATIONAL PLANNING COUNCIL, 30 JULY 1980,
GREATER AMMAN WASTEWATER DISPOSAL PROJECT

MEETING

The meeting was held under the auspices of the National Planning Council on Wednesday, 30 July 1980. The meeting had been announced by a four page handout which described the project scope of work, objectives of the environmental scoping meeting, potential environmental impacts of the project, and participation desired of meeting participants (see attached.) The announcement was delivered to the representative of: U.S.A.I.D; Ministry of Health; Ministry of Municipal, Rural Affairs and the Environment; Ministry of Trade and Industry; Water Supply Corporation; Natural Resources Authority; Amman Water and Sewerage Authority; Royal Scientific Society; and the municipalities of Jubeihah, Suweiheh; and Wadi es Sir.

The Attendance List is attached. No representatives were present from Water Supply Corporation, AWSA, Royal Scientific Society, or the Municipality of Suweileh.

Messrs. Yousef Batshon and Boulos Kifaya of NPC acted as Co-Chairmen for the meeting. Most of the meeting was conducted in English. Arabic was spoken occasionally to aid in emphasis of certain points. Mr. Batshon opened the meeting, explained its purpose, and noted that one of the requirements for the project was the assessment of its impacts upon the environment. He then introduced Mr. Lawrance, the Project Manager.

Mr. Lawrance made an opening statement on behalf of JMM/DMJM, a Joint Venture in association with Consulting Engineering Center, and he introduced the staff. He summarized the work done to date and reviewed the information presented in the handout. Mr. Shamieh then gave a brief description, in Arabic, of the project and the objectives of the scoping meeting and encouraged attendants to present their views. The meeting was then turned back to Mr. Batshon in anticipation of group discussion.

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DISCUSSION

Water Pollution

Mr. Kifaya stated that it would be necessary for the consultant to visit the municipalities in the Study Area and inspect the local conditions, though it would not be necessary for the Consultant to visit all of the small villages.

Mr. Dajani noted that AWSA is expanding its sewerage service area around Amman, and this must be taken into account. He voiced his concern about water pollution, calling for a distinction between true pollution and less serious conditions. He noted the existence of many past reports bearing upon water pollution and called for their review, updating, and modification of findings, as appropriate. He mentioned that as Jordan develops, it experiences certain associated problems.

Mr. Batshon indicated that solving the pollution problem in one area (e.g., by providing sewers and a treatment plant in lieu of individual on-site disposal) may create a problem for some other area, notably a location downstream from the first community.

In answer to Mr. Batshon's question about the considerations to be given to sources of potential pollution outside the Greater Amman Area, Mr. Lawrance replied that our study would give such situations due recognition but no detailed analysis.

Mr. Batshon noted that our report should identify areas of surface and ground water pollution and areas where further study is needed.

Mr. Khatib indicated that NRA had considerable data on water quality and quantity sewage disposal operations, and water pollution conditions.

Mr. Nasser expressed deep concern about the potential water pollution hazard in Wadi es Sir due to the sloping terrain. Sewage disposal on the higher areas could reach and pollute the ground water at the lower areas. Other agreed.

Industrial Wastes

Mr. Dajani called attention to the existing industrial development in Amman and in the Zarqa-Ruseifa area, mentioning that the latter area does witness water quality problems and that the industries responsible are being asked to amend the conditions.

Mr. Kifaya stated that the Royal Scientific Society should be contacted concerning updating studies of industrial wastes for the Zarqa-Ruseifa area, and Mr. Lawrance agreed to do so. Mr. Hani Shaqa'a was the suggested contact.

Mr. Batshon asked if the Consultant would consider industrial wastes in the report, including ordinances, and Mr. Lawrance replied affirmatively. Mr. Batshon then pointed out the difficulties for some industries to pay for pre-treatment or pollution control facilities, and he suggested that implementation of controls might have to be phased, allowing for some relaxation of standards for an interim period.

Mr. Lawrance then stated that the relative importance of industry to the total pollution load will be established along with possible pre-treatment or separate treatment and corresponding costs and benefits.

Mr. Dajani said a problem is being experienced with the industries established generally over two years ago, because they were established without much control. Newer industries, however, are being required to provide their own treatment or else connect to the municipal sewer system.

Mr. Kifaya noted the existence of an Industrial Committee of the Government which was considering effluent limitations.

Water Quality Standards

Mr. Dajani suggested that effluent limitations might properly be related to receiving water standards and the former might vary from location to location depending upon the beneficial use to which the water was to be put. The Ministry of Health is using WHO, APHA, and other standards as guides and is

tempering these with scientific judgment.

Mr. Khatib said that because of the great need for water reuse in Jordan, local effluent standards might have to be different from those in other countries. By this he apparently meant the possibility of lower standards than otherwise.

Water Resources

Mr. Kifaya asked if the Consultant would address the hydrologic cycle concerning the importation of water, and Mr. Lawrance responded that the Consultant would give adequate (reconnaissance level) but not detailed consideration to this matter, inasmuch as detailed consideration would require a special study. The intent of the study is to give adequate consideration to the important interfaces between wastewater disposal and water resources in their various aspects. He discussed these matters briefly and generally.

Mr. Khatib noted the relative scarcity of water in Jordan and felt that it was important that Jordan "use every drop of water it has" and Mr. Dajani endorsed this principle.

Mr. Lawrance agreed with Messrs. Khatib and Dajani on the matter of conservation and reuse of wastewater as an important element of the total water resources.

Mr. Lawrance also pointed out that the JVA was counting upon the unimpaired flow of wastewater treatment plant effluents within the watershed of the Seil Zarqa as a future source of supply for its catchments and irrigation works downstream. JVA's water resources planning allows for a maximum depletion of produced water within the Greater Amman Area of 60 MCM/yr (60 million cubic meters per year.) Furthermore, JVA discourages groundwater recharge with reclaimed wastewater, preferring surface runoff. They do not believe that wadi

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storage would be an important factor with respect to irrigation demands because the wastewater is generally uniform and similar to spring-fed (base) flow, in this regard. Also, the flows in the wadis would not suffer much consumptive loss, because the wadis do not contain much water-loving vegetation.

In answer to Mr. Nasser's question on the need for studying water resources outside the Greater Amman Area, Mr. Shamieh said our report would point out this need, if warranted, and recommend that it be considered in a separate study.

Mr. Nasser indicated that Wadi es Sir has been contemplating a water supply reservoir project for its area.

It was also noted that importation to Amman from both East Ghor Canal and Azraq Well Field is contemplated. (This will also tend to increase the flow of wastewater.)

Reclamation and Reuse

In a discussion, Messrs. Dajani and Lawrance agreed that wastewater reclamation and reuse should be important factors in the Master Plan, due to the acute shortage of water in Jordan.

Mr. Khatib concurred with this concept, particularly if those methods were directed towards nonpotable uses, e.g. irrigation. Costs of such programs would have to be balanced against their benefits. He even suggested groundwater recharge, and Mr. Lawrance noted some of the constituents that would have to be reduced prior to recharge (e.g. nitrates) and that JVA was opposed to groundwater recharge but favored surface discharge of effluent.

Mr. Kifaya suggested the possibility of diverting reclaimed wastewater for irrigation on the plateau rather than discharging it into the Seil Zarqa and, eventually, King Talal Reservoir.

There appeared to be a general agreement among the participants as to the desirability of proper reclamation and reuse of wastewater.

Location of Treatment Plants and Tributary Areas

Mr. Khatib felt that a major point to be considered regarding effects of wastewater effluent upon water resources is the location of the treatment plants. For example, he thought it possible for the Ain Ghazal Treatment Plant to be able to extend its catchment area downstream as far as Sukhneh. Some areas, however, should remain outside of the AWSA network, such as Wadi es Sir, Madaba, etc. He felt that it would have been advantageous for the current wastewater disposal Master Plan to have been prepared prior to the recent Zarqa-Ruseifa study, in this regard. He also cautioned that treatment plants not be located in wadi areas.

Mr. Batshon thought that the locations of treatment plants could be major issues, particularly in urban areas. This included the existing Ain Ghazal Treatment Plant.

Sludge Utilization and Disposal

Mr. Johnson felt sludge disposal should be a major issue in the environmental considerations.

Mr. Lawrance concurred with this assessment and noted the several possibilities for dealing with treatment plant sludge, none of which is particularly easy.

In response to Mr. Kifaya's question about the utilization of methane gas from sludge digesters, Mr. Lawrance responded that this was normally an engineering consideration, including the analysis of costs and benefits. Normally, primary sedimentation plants of significant size produce more digester gas than is needed to preheat the raw sludge prior to digestion, so the surplus gas can be used for beneficial purposes (running pumps, generators or blowers). With secondary treatment plants, especially activated sludge, there is usually a net requirement for energy.

Growth Inducement Due to Sewer Availability

Mr. Shamieh raised the question of possible growth inducement resulting from provision of public sewerage, and Mr. Nasser pointed out that the growth is

going to proceed at a certain rate irrespective of sewer availability. The installation of sewers would not add more population to an area than would occur without those improvements.

Mr. Klein reported that NPC and AURPG personnel thought that sewer availability might affect the spatial distribution of population, mainly by placing more people within a particular locality than otherwise. It would not attract population to the region or an individual city more than would otherwise come there. Land values, however, would probably increase as a result of sewer availability.

Mr. Shamieh felt that in Jordan water and electricity are the essential utilities to encourage buildings and land development, while sewer availability is a secondary factor.

Mr. Kifaya thought that growth induction might become a factor resulting from sewer availability in later years but not for a while.

Mr. Nasser indicated that sewer availability would be important to the residents of Wadi es Sir at least for health and aesthetics. Also there was an economic incentive, because septage pumpout costs may be as much as JD50/month for a typical homeowner in Wadi es Sir.

Major Environmental Issues

In summarizing the feelings of the meeting participants, Mr. Lawrance obtained concurrence that the following were felt to be major environmental issues to be addressed in the Phase I work by the Consultant:

- Water quality
- Water quantity
- Sludge disposal
- Treatment plant siting (including location)
- Effects upon land resources

There was general concurrence that aquatic life or riparian life was not a major

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concern or issue to be addressed.

The matter of archaeological resources and historic resources was not anticipated to be a major concern but judgment would have to be reserved, depending upon the location of actual facilities being proposed.

Atts: (2)

ENVIRONMENTAL SCOPING MEETING
GREATER AMMAN WASTEWATER DISPOSAL PROJECT

30 July, 1980

A T T E N D A N C E L I S T

National Planning Council

Yousef Batshon, Director of Infrastructure Department

Boulos Kifaya, Civil Engineer in Charge of Water and Sewerage Projects

Pat Johnson, Civil Engineer, UN Advisor

Sverker Skans, Civil Engineer, UN Advisor

U.S.A.I.D., Jordan

James Cassanos, Chief Engineer

Royal R. Cline, Environmental Officer

Ministry of Health

Mohammed Hussein Dajani, Director of Environmental Health

Natural Resources Authority

Abdelhamid Khatib, Chemical Engineer

Ministry of Industry and Trade

Remon Halteh, Head of Planning & Quality Work Division

Ministry of Municipalities, Rural Affairs and the Environment

Hani Shaqa'a, Dr. Chemistry

Ali Abu-Rabiha, Geological Engineer

Al Jubeihah Municipality

Mohammed I. Abufar, Surveyor

Wadi es Sir Municipality

Akram El Nasser, Chairman

JMM/DMJM, a Joint Venture

Charles H. Lawrance, Project Manager

Edward H. Shamieh, Consulting Sanitary Engineer

Gerhardt Van Drie, Sewer Design Engineer

Robert E. Klein, Socio-Economist

Consulting Engineering Center

Yasir A. Khamnash, Partner and Civil Engineer

Aziz A. Sajdi, Partner and Director

George S. Kakish, Civil Engineer

GREATER AMMAN WASTEWATER DISPOSAL MASTER PLAN

CONTRACT NO. 278-00234 - JORDAN

The attached Environmental Scoping Statement is in conformance with the requirements of the United States Agency for International Development, AID. "Pesticides and other Environmental Procedures, Proposed Amendment of Regulation", 22 CFR Part 216 as appeared in the Federal Register Vol. 44 No. 151 dated October 1, 1979.

The purpose of the Statement is to document the major environmental concerns/issues relevant to the Master Plan as they were identified in the scoping meeting.

ENVIRONMENTAL SCOPING STATEMENT
GREATER AMMAN WASTEWATER DISPOSAL MASTER PLAN

In order to identify the significant environmental issues and integrate them "fully and early" into the selection process of the wastewater disposal management alternatives for the Greater Amman Area, an environmental scoping meeting was held on July 30, 1980 at the offices of the National Planning Council. Participants were invited to the meeting and represented a spectrum of governmental and public agencies. The list of participants is attached.

A. POTENTIALLY SIGNIFICANT ISSUES

The potentially most significant environmental issues appeared to be related directly to the physical environment, more so than the human or biological environments. Concerns expressed involved:

- o Conservation and enhancement of water quality for both surface and ground water
- o Conservation of natural resources, i.e, water, sludge, and energy
- o Conservation of land resources
- o Financial impacts upon industries resulting from industrial wastewater pollution abatement

The major issues reflecting the above concerns were thought to be:

- o Sewage treatment processes and related effluent quality and cost of treatment: One goal or objective of this Master Plan is to improve water quality both in surface streams and impoundments and in groundwater aquifers. Another objective of the Project is to suggest minimum quality to be attained for treated wastewater with special reference to cost and to preserving environmental aspects of affected areas. In this respect, the impacts upon the Seil Zarqa, King Talal Reservoir, and the Wadi es Sir area are of particular interest. Control of water quality via an industrial wastes control program is also considered an important element of the Project. Water quality standards and the economical means of achieving them are also important considerations from the standpoint of programs for wastewater reclamation and reuse.
- o Reuse of Reclaimed Water: It is a well recognized fact that North Jordan, including Greater Amman Area, suffers from a shortage of water and that even with implementation of projects for importation of water to the Amman area there will continue to be a need for conservation and reuse of water under proper standards and control. Therefore the manner in which the wastewater treatment plants effluent is to disposed of and/or reused may be of great significance to the

water inventory available to municipalities, industry, and agriculture. It may also affect land productivity and availability. Effluent disposal/reuse will certainly affect the surface water developments of the Jordan Valley Authority to some extent. Consideration should be given to optimum arrangements for balancing costs and benefits, but such consideration must necessarily be limited to conceptual levels. Detailed analyses, if warranted, will be recommended for separate study.

- Sludge Disposal: Sewage treatment plant sludges will be generated from communities with tributary populations ranging from a few thousand to hundreds of thousands and more. The processing, disposal, and possible beneficial use of this by-product of sewage treatment in the Greater Amman Area requires serious consideration. Ultimate disposal must be to land and/or (by incineration) to air. The means of achieving economy of disposal and beneficial use of digested sludge, while meeting environmental standards, requires in-depth study. This must be done also within the context of reliable facilities to be operated and maintained by Jordanian personnel. Soil conditioning and fertilizer potentials of the sludge must be considered. Exclusion of toxic materials from the sludge by appropriate controls and treatment must be accomplished for environmental protection and enhancement of long-range land productivity.

- Treatment Plant Siting: Wadis are natural drainage channels and might be logical candidates for treatment plant locations, including gravity collection of wastewater. However, careful siting must be accomplished to avoid flood hazards and to ensure uninterrupted performance. In determining which areas should be tributary to various treatment plants, logical arrangements will minimize pumping and maximum gravity inflow, in order to limit the expenditure of energy. Siting of treatment plants must also consider the locations of effluent disposal facilities, particularly if the flow is to be taken to areas other than down a nearby wadi. Also the siting of plants must be realistic from the standpoint of neighboring populations, both current and future. Thus, treatment plant siting requires careful study.

B. LESS SIGNIFICANT ISSUES

The following issues are not expected to be significant, as discussed below. These issues along with other possible minor issues and impacts will be discussed briefly in the environmental assessment of the Master Plan:

1. Growth Inducement: It is generally acknowledged that, in the past, the determining factors for land development in the Greater Amman Area have been the availability of water and electricity services. Availability of sewerage system is a secondary factor as evidenced by the development that has taken place and still goes on in unsewered areas within Greater Amman.

   Although construction of sewage facilities is not likely to attract more population to a given urban area than would otherwise occur and therefore is not a significant issue, it should be assessed since it affects land values and also the spatial distribution of land use within an urban area.

2. Industrial Waste Discharges: The industrial waste discharges in the Greater Amman Area are mainly centered in the Zarqa-Ruseifa area and in the future planned industrial city of Sahab. The major pollution problem is being experienced with the industries already established, because there were no regulations to control potential pollutants. Plans for industrial pollution control for the city of Sahab are expected to be an integrated part of the industrial overall plan and hence a pollution potential is not expected. The environmental impact of the industrial waste discharges for the Zarqa-Ruseifa has been covered as part of the Zarqa-Ruseifa Wastewater Master Plan and therefore need not be covered again in this Master Plan.

3. Air Quality and Odors: Provision of a system of sanitary sewers and treatment works tends to consolidate air quality considerations into a single location rather than in many smaller, dispersed locations. With properly designed and operated wastewater treatment plants, local odors should be minimal. In certain plants they may be nearly non-existent. By extending sewer systems and increasing capacities of the Ain Ghazal Treatment Plant, the need for septage handling and the existence of overflowing subsurface disposal systems should be reduced, along with odors associated with these operations and conditions.

4. Archaeological and Historical: As with Jordan, the Greater Amman Area is rich with history. Amman, Madaba, and Sahab among others, provide examples of sites of many antiquities and historical findings. Development, however, has been taking place right at these sites. Sahab, although known for over eight years to have antiquities that date back and span over 3000 years, is the site of an industrial city under construction.

   Antiquities did not receive much concern from the participants*. The project does not contemplate deep excavations in the most part and hence the prospects of encountering important historical sites in the course of construction of sewers, treatment plants, and disposal/reclamation facilities appear to be minimal. Even so, a meeting will be held with the Ministry of Tourism and Antiquities to confirm the above and coordinate with them for any potential identified historical sites.

5. Flora and Fauna: Although the Seil Amman was once a pleasant flowing stream supporting fish life, gradual urbanization of Amman has virtually eliminated the dry-weather flow save for wastewater effluents. Downstream of Ain Ghazal, the flow in the Seil Ruseifa and Seil Zarqa is largely the effluent from the Ain Ghazal Treatment Plant and untreated or lightly treated wastewaters from riparian industries and municipalities. As a consequences of low flow and poor water quality, the suitability of the Seil Zarqa as an aquatic habitat has been seriously hampered. The discharges of treatment plant effluent from a new plant (Jarash) outside the Greater Amman Area into the Seil System and from the Zarqa-Ruseifa area should have not overall adverse effects upon the Seil Zarqa or King Talal Reservoir from the standpoint of present flora and fauna. Most of the wadis which are potential candidates for receipt of treatment plant effluent from new plants have very little dry-weather flow and, hence, little

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* It is worth noting that the Ministry of Tourism and Antiquities was not represented at the scoping meeting.

significant flora and fauna. Discharge of suitably treated plant effluent into such watercourses would be expected to produce riparian flora and fauna where they are absent at the present and will not interfere with any present wildlife. Terrestrial flora and fauna of importance are not expected to be affected adversely by construction of wastewater treatment and disposal facilities, even in cases where land treatment may be recommended.

Endangered and/or Threatened Species: Only one Jordanian animal appears on the U.S. Fish and Wildlife Service's list of Endangered and Threatened Wildlife and Plants (1977 Edition), this being the Arabian Ostrich. Much of Jordan's larger wildlife was exterminated by overhunting between 1930 and 1960, and there has also been an adverse impact upon wildlife from livestock overgrazing in the semiarid zones.

6. Construction Impacts: Short and long-term construction impacts will result from any recommended wastewater management alternative. The alternatives, however, may vary from one to another by the extent and location of the construction, developed areas vs. undeveloped. Additional trunk sewers discharging into the existing Ain Ghazal Treatment Plant, for example, would create the most noise, dust, congestion and disruption of traffic. Sewering certain developed areas may affect stability of building foundations. Disruption of water distribution may occur in certain areas and for varying periods of time. Similarly, construction of treatment plants and disposal works may require local grading and alteration of drainage patterns. The construction impacts must be clearly identified, mitigation measures recommended, and mitigation cost allowances included in the project estimates.

C. IMPACT ANALYSIS TIMING

The environmental impact analysis will be an integral part of the selection process of the wastewater disposal Master Plan. Environmental considerations along with monetary cost will be used to rate the various wastewater management alternatives and select the recommended action (project.)

The potentially significant issues identified in the scoping meeting will receive due consideration in the preparation of the Master Plan. The completion date of the Master Plan draft is October 17, 1980. The draft will be reviewed by NPC and other government agencies with the municipalities in the Study Area which will assure adequate review and participation of the governmental and public sectors.

D. IMPACT ANALYSIS METHOD AND STAFFING

In the process of selecting the recommended project, the environmental impacts of the major issues will be assessed for the potential wastewater management alternatives. The alternatives will have been described earlier including technical details of the wastewater flows generated, wastewater treatment processes plants sitings, effluent quality, and effluent and sludge disposal/reclamation.

As a base, the existing environmental conditions will be used to analyse the impacts of the alternatives. The analysis will evaluate to a varying extent several components of the impacts such as:

- o Quality - beneficial or adverse
- o Magnitude - how significant or major the impact is
- o Extent - large or small area
- o Duration - long or short-term
- o Reversibility - reversible or irreversible
- o Probability - general terms for the likelihood of impact
- o Relationship to alternative - direct or indirect

The impacts will primarily be analyzed for the potentially significant issues cited earlier.

An attempt may be made to quantize the degree of significance of the impacts to produce ratings which will be used for comparing the alternatives and selecting the most viable. Unavoidable adverse impacts which are generally common to all the alternatives will be briefly described. Such impacts may be related to construction, land use for the wastewater facilities, aesthetics, potential nuisances related to the treatment plant locations and operations, and capital and O&M costs.

Once the recommended project is identified, the environmental impacts of the project will be described to the extent necessary, and commensurate with the depth of analysis used in comparing the alternatives.

Measures that could mitigate the adverse impacts will be presented.

The environmental impact analysis will be prepared by John Pearson, a specialized environmental analyst assisted by other disciplines pertaining to the different aspects of the environment. For the human environment, Robert Klein, a socio-economist, and Dr. Aftim Acra, a public health specialist, will describe the existing human environmental setting and will assist in projecting the impacts of the alternatives. For the physical environment, the engineering staff will have their imputs in matters concerning water resources quality and quantity, effluent discharges and sludge disposal.

(English translation of Permit from the Department of Antiquities regarding the construction of wastewater facilities at certain locations.)

Department of Antiquities
Amman, Jordan

Reference No. 5-1-2486
Date: November 12, 1980

Messrs. James Montgomery Company:*

After inspecting the sites at Na'ur, El Bassa, Iraq el Amir, Fuheis, Mahis, Ain Ghazal, Baqa'a and Rumeimin, we are pleased to inform you that the Department of Antiquities does not have any objections to the constructing of these plants.** In case any antiquities have been uncovered during construction and excavation you are kindly requested to inform us. Thank you for your cooperation.

Regards,

(signed) General Manager for Antiquities

* Referring to JMM/DMJM, a Joint Venture

** Referring to treatment plants and pump stations

بسم الله الرحمن الرحيم

دائرة الآثـــار العامة

عمان

ص.ب ٨٨

هاتف ٤٤٣٢٠ - ٤٤٣٣٦

الرقم ١/٥/٦٥٤٦

التاريخ ٥/١٢/١٤٠١ هجرية

التاريخ ٢٨/١١/١٩٨٠ ميلادية

السادة شركة جميس ماتغـــــــــــــــرى

بعد اجراء الكشف الحسي على مواقع المحطات في ناعور والبصه وعراق الامير والفحيص وماحص وعين غزال والبحقه والرميمين .

ارجو ان اعلمكم بانه لا مانع لدى دائرة الاثار العامه من اقامة هذه المحطات شريطـــة ابلاغ الدائرة عن اية اثار قد تظهر اثناء عمليات الحفر والانشاء ، شاكرين لكم حسن تعاونكـــم المستمر . .

واقبلـــــــوا فائق الاحـــــــــترام

المدير العام للاثـــــــار

نسخه / الى رئيس مفتشي اثار العاصمـــــــــه .

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كتاب رقم ٣٠١٠٠/٥٠٥/٧٨/٩٦٧

APPENDIX D1

INDUSTRIAL WASTEWATER COMPOSITION AND LOADINGS

For this Master Plan Report, the three basic considerations for industrial wastewater composition are:

- o Raw wastewaters from various processes prior to treatment.
- o Effluents from on-site pretreatment facilities to be provided by industries prior to discharge into municipally-operated treatment works.
- o Effluents from on-site treatment facilities which will discharge directly to local watercourses without further treatment.

The first two items are considered in this Appendix; the third item is considered in Chapter 8, Master Plan for Wastewater and Sludge Disposal.

RAW INDUSTRIAL WASTEWATERS

The MPI-Jouzy Report[1] provides considerable detail on the pollutant loads emanating from the several industries in the Zarqa-Ruseifa area, and the data will not be repeated in this Master Plan Report. However, it is appropriate to present general information herein on pollutant loads to be expected as a result of various manufacturing processes. This should provide some basic reference material for existing industries and those which may develop in the Study Area in the future, the extent of which is not presently known.

Table D1-1 presents a summary of unit waste loadings expected from the potential industries expected to be (or already located) in the Greater Amman Area. It should be noted that the list is not necessarily comprehensive, because many of the potential industries have yet to be affirmed. Also, the list is confirmed to normally "wet" industries. Table D1-1 may serve as a caveat as to what may occur if adequate pre-treatment is not provided.

PRE-TREATED INDUSTRIAL WASTEWATER

Pre-treatment denotes initial treatment, usually of a limited nature, to be followed by more substantial treatment, often as part of a municipal waste-

TABLE D1-1

UNIT WASTE LOADINGS EXPECTED FROM POTENTIAL INDUSTRIES, GREATER AMMAN AREA[a]

Industry[b]	Waste Load Production[c]	Raw Wastewater Characteristics[d]
Aerospace	May be comparable to metal finishing or other industries, depending upon nature of process[2]	
Battery Mfr	Not normally a categorized industry	Water consumption by United Industry Corp. (Marqa) was 235 m^3/da in 1975.[3] Pollutant data by MPI-Jouzy
Brewery	0.77 - 1.4 kg BOD/bbl[4] 0.77 - 0.82 kg SS/bbl[4]	BOD 850 - 1832; SS 470 - 1028 BOD 1622 SS 772[26]
Canning Bean	0.30 - 0.60 kg BOD/case[4] 0.023 - 0.045 kg SS/case[4]	BOD 1,740 - 2880 SS 160 - 600
Canning Tomato	0.050 - 0.077 kg BOD/case[4]	BOD 180 - 4,000 SS 140 - 2000
Chemical	A very wide range of possibilities depending upon specific process and product.[5]	No details, this table.
Chlorine Mfr	No basic parameters established. See MPI-Jouzy Report re Jordan Distilled Chemical Co.	
Dairy Milk Cheese	0.05 - 0.26 kg BOD/kg product[4] 0.45 - 3.0 kg BOD/kg product[4]	BOD 102,500 (whole milk) BOD 1,890 (process wastes)
Detergent	MPI-Jouzy data provided on installation in Hussein Industrial City. Detergents themselves may be high in BOD and saponified soaps.[5] Hard detergents may have ABS.	
Distillery	MPI-Jouzy[1] data on Eagle Distilleries Co., indicate a growing pollutant load. 1984 projection was 1,400 kg/da BOD. In 1979 the alcohol plant produced 500 tonne, equivalent to 1.37 tonne/da	BOD 34,000 SS 24,800 (spirit type distillery slops)[5]
Electronics	Variable in processes. Normally, liquid wastewaters would primarily be from electroplating. See metal finishing.	
Food	Varies with the process and food. For washing dirt from root type vegetables, high SS are produced. For dried packaging of fruit very little wastewater is produced. For slicing apples, citrus, and peaches, the kg BOD/tonne of fruit are 11, 8, and 22.5, respectively; for SS, the respective numbers are 3.1, 3.0 and 4.6.	

TABLE D1-1 (Cont'd)

Industry[b]	Waste Load Production[c]	Raw Wastewater Characteristics[d]
Laundry	Varies with laundry. (Commercial shown)	BOD 400 - 1,860[5]
Meat Slaughterhouse	14.4 kg BOD/1,000 kg LWK[4] 5.8 kg BOD/1,000 kg LWK[6] 4.7 kg SS/1,000 kg LWK[6] 2.5 kg Gr./1,000 kg LWK[6]	BOD 2240 (mixed animals; both slaughter and packing)[5] BOD 996 (cattle; both slaughterhouse and packinghouse)[5]
Meat Packinghouse	12.1 kg BOD/1,000 kg LWK 8.7 kg SS/1,000 kg LWK 6.0 kg Gr./1,000 kg LWK	BOD 635 (mixed animals; both slaughter and packing)[5] BOD 448 (cattle; both slaughterhouse and packinghouse)[5]
Metal Finishing	E.g. electroplating. Highly variable wastes, depending upon process, recycling, etc.[7] Wastes may include acids, cyanides, zinc, nickel, chromium, cadmium, etc., for which EPA has established effluent guidelines.[5]	
Paint	Highly variable, depending upon process.[5]	
Petroleum Refining	0.045 kg BOD/bbl[4] 0.0045 kg [illegible] 1/bbl[4] 0.00014 kg sulfide/bbl[4] 0.00009 - 0.227 kg BOD/bbl[8] (depends upon particular process)	BOD 20 per bbl crude[2] (However, BOD concentrations may be much higher and independent of feedstock but related to the various processes in the refinery.)
Pharmaceutical	Varies, usually very high BOD, such as from yeast fermentation. Low PH	BOD 1500-1900[5] (Penicillin BOD 8,000-13,000) SS 500-1000[5] (General values)
Phosphate	See MPI-Jouzy	
Poultry	13.6 kg BOD/1,000 birds[5] 7.0 kg SS/1,000 birds[5] 4.3 kg Sett.Sol./1,000 birds[5] 0.6 kg Grease/1,000 birds[5]	BOD 954 (older plants)[4] BOD 424 (newer plants)[4] BOD 560 plant effluent, example[9] SS 375 plant effluent, example[9] COD 722 plant effluent, example[9]

TABLE D1-1 (Cont'd)

Industry[b]	Waste Load Production[c]	Raw Wastewater Characteristics[d]
Pulp and Paper	For local paper and cardboard, see MPI-Jouzy. For Jordan, assume no pulping; 5 - 12.5 kg BOD/tonne product (coarse paper)[5] 5 - 15 kg SS/tonne product (coarse paper)[5] Note: Special industrial paper BOD is 10 times stronger, SS is 15 times.[5]	BOD 180 mg/l coarse paper, mean[5] SS 240 mg/l coarse paper, mean[5]
Soap	Similar, generally to Detergent. See MPI-Jouzy data.	
Steel (Rolling Mill, Wire Mill, and Related)	Pickle liquor contains sulfuric acid, ferrous sulfate, and ferric sulfate.[5] Sometimes nitric or hydrochloric acid used.[32]	Very low pH and fairly high metals content (Reference 32 discusses acid recovery and neutralization procedures.)
Tannery	0.0883 kg BOD/kg leather processed[4] 0.250 kg SS/kg leather processed[4] 0.350 kg TDS/kg leather processed[4]	BOD 11,200 (mean condition)[4] SS 23,600 (mean condition)[4]
Textiles (Wool)	0.300 kg BOD/kg cloth produced[4] 0.219 - 0.72 kg SS/kg cloth produced, or 0.029 - 0.44 kg SS/kg cloth produced, for "greasy" wool and scoured wool, respectively.[10]	BOD 563 (overall for scouring, dyeing, washing, and carbonizing.)[10]

TABLE D1-1(Cont'd)

[a] A number of sample industries, such as already exist or else are contemplated for development in the Greater Amman Area.

[b] This tabulation is not intended to be all-inclusive but rather to afford a ready reference for general estimation of the magnitude of potential wastes generated as a function of industrial raw materials or finished product.

[c] BOD denotes 5-Day, 20°C Biochemical oxygen demand. SS denotes suspended solids.
bbl denotes barrel (in the petroleum industry this corresponds to 42 U.S. gallons or 0.159 cubic meters.)
LWK denotes Live Weight Kill (of animals slaughtered.)
TDS denotes Total Dissolved Solids.

[d] Raw water characteristics can vary. Normally, values shown are representative of "average" or "newer" industries, not the "older" (and "dirtier") industries. Values shown, unless otherwise noted, are in milligrams/liter (mg/l.)

water treatment system. In certain heavily industrialized localities in the United States and Europe it has been possible for groups of contiguous similar industries to provide themselves with common treatment facilities. Normally, however, individual on-site pre-treatment is provided. The objective of any pre-treatment is to reduce sufficiently the pollutants and contaminants in the industrial wastewater so that they are no longer dangerous or difficult to handle in the municipal wastewater collection system, treat in the municipal treatment plant, or dispose of as treated municipal effluent in the receiving waters.

Pre-treated industrial wastes can normally be counted upon to be diluted by domestic wastewaters so that many of the troublesome constituents — such as trace metals — emanating from industry need not be overly reduced by on-site pre-treatment. Oftentimes it is permissible for an industrial wastewater to contain as much as ten times the concentration of trace metal (e.g., chromium) that constitutes an effluent limitation upon a municipal effluent discharge which includes the industrial contribution.

Direct Discharge Industrial Effluent

In Jordan, there are reportedly effective governmental pollution controls on new industries but shortcomings on controls for many existing industries (see also discussion in Chapter 7.) In the United States, there was no nationwide effective control over industrial water pollution until the passage of Public Law 92-500, the 1972 Amendments to the Federal Water Pollution Control Act. That landmark legislation specified, among other things, provision by industry for all its direct discharges to the "navigable waters" (generally any surface water):

- o BPCTCA (Best Practicable Control Currently Available) - to be in effect by July 1, 1977.
- o BATEA (Best Available Technology Economically Achievable) - to be in effect by July 1, 1983.

The foregoing is cited, not to hold it up as an example for Jordan necessarily, but rather as an illustration of possible staging of discharge requirements to

provide industry a period of years in which to comply first, with fairly achievable standards that are of an intermediate level and second, with more difficult standards that provide fairly high effluent and receiving water quality. As an illustration of the staging of BPCTCA and BATEA requirements for certain industries, Table D1-2 is presented. The reduction sought between raw wastewater and Best Available Technology Economically Achievable is quite striking. Table D1-2's consideration is limited to high organic content industrial wastewaters, these often being among the most difficult to treat. The consideration of discrete (point source) industrial wastewater discharges is not specifically within the scope of work of this Master Plan Report. Should it become necessary to provide such consideration, this could be a suitable subject for later study.

Industrial Wastes Ordinances

The subsequent discussions are confined to considerations of industrial wastes discharged into municipal wastewater systems. The key to control of industrial wastewater pollutant discharges is enactment and vigorous enforcement of proper industrial wastes ordinances. In this connection, two examples of successful ordinances are discussed herein: (a) The City of Los Angeles, California, "Rules and Regulations Governing Disposal of Industrial Wastes to the Sanitary Sewer and Storm Drain Systems of the City of Los Angeles;" and (b) The Sanitation Districts of Los Angeles County, "An Ordinance Regulating Sewer Construction, Sewer Use and Industrial Wastewater Discharges."

City of Los Angeles The Rules and Regulations adopted by the Board of Public Works on July 7, 1971, and subsequently amended (March 24, 1972, December 18, 1972, and June 25, 1975)[11] contain the following relevant information:

> "II. Section 2. GENERAL STATEMENT
>
> The Board of Public Works, through its Bureau of Sanitation, is responsible for operating and maintaining the sanitary sewers, storm drains and watercources. Sewage and storm water pumping plants, and the sewage treatment and disposal facilities of the City of Los Angeles Wastewaters discharged to these systems eventually reach the surface or underground waters of the State of California.
>
> Regulation of these wastes through physical inspection of disposal facilities and chemical testing is necessary to:
>
> A. Protect the facilities from damage by deleterious wastes.
> B. Protect the treatment processes.
> C. Protect the operating and maintenance personnel.
> D. Preserve capacity in the sanitary sewer system for sanitary wastes and appropriate industrial wastes.

TABLE D1-2

ILLUSTRATION OF HIGH ORGANIC CONTENT INDUSTRIAL WASTEWATER CHARACTERISTICS AND STAGED EFFLUENT LIMITATIONS FOR BPCTA AND BATEA[a]

Concentrations are shown in milligrams per liter

Industry	BOD_5	COD	SS	Oil & Grease
Textile Mills	--/11/7	--/144/38	—/48/32	———
Leather Tanning and Finishing	2850/120/42	7800/—/—	4200/150/45	570/22/16
Cane Sugar Refinings*	1200/11/1	2300/—/—	55/2/1	———
Milk Processing*	----/15/2	———	———	———
Apple Processing*	1200/130/24	———	150/130/20	———
Citrus Processing*	320/48/8	———	130/102/12	———
Potato Processing*	2010/125/15	———	1840/125/50	———
Meat Products	1300/18/5	———	1030/28/9	530/10/10
Catfish Processing*	340/100/61	700/—/—	400/250/61	200/21/10
Crab Processing*	740/133/25	1200/—/—	510/64/22	180/3/1
Shrimp Processing*	1600/470/50	3100/—/—	1500/185/130	400/30/3
Tuna Processing*	710/430/28	1900/—/—	550/164/28	320/48/4
Petroleum Refining	100/12/3	300/84/16	200/8/3	5/4/0.5
Breweries (New)	1070/—/—	———	580/--/--	———
Kraft Paper*	315/50/31	———	365/85/42	———
Paperboard*	260/28/15	———	450/34/13	———

[a]Abstracted from consultant report to Jet Propulsion Laboratory. Asterisk (*) denotes subcategory of larger (U.S.A.) Standard Industrial Category (SIC.) All SIC's and subcategories have year-round operation with the possible exception of fruits and vegetables canning.

E. Insure the safety and welfare of the public.

F. Prevent contamination, pollution and nuisance, and protect the established beneficial uses of receiving waster as required by the California Regional Water Quality Control Board, Los Angeles Region.

G. Conserve a reclaimable resource (water reclamation.)

Section 3. CRITERIA FOR DISPOSAL OF INDUSTRIAL WASTES

Accordingly, to meet the foregoing objectives, the Board of Public Works has adopted the following criteria for disposal of wastes:

A. Storm water may not be collected and discharged to the sanitary sewer system.

B. Single pass cooling water may not be discharged to the sanitary sewer system. The blowdown or bleedoff from cooling towers or other evaporative coolers may be accepted in the sanitary sewer system.

C. Material which will readily settle such as sand, glass, metal filings, diatomaceous earth, etc., or floatable material which is readily removable must be removed from the wastewater prior to discharge to either the sanitary sewer system or the storm drain system.

D. Petroleum products or any other product which by reason of its nature or quantity may cause a fire or explosion, or in any way be injurious to persons must be removed from the wastewater prior to discharge to either the sanitary sewer system or the storm drain system.

E. Wastewater constituents such as mercury, DDT, other chlorinated hydrocarbons, or other substances that enter food webs or biological systems in concentrations deleterious to human or animal life must be removed from the wastewater prior to discharge to either the sanitary sewer system, the storm drain system or any waters under the jurisdiction of the City of Los Angeles.

F. Limitations on wastewater constituents such as heavy metals, toxic substances, suspended and dissolved solids, dispersed grease and oil, phenols, or other deleterious substances will be imposed to protect the structural integrity of the systems, assure the safety of operating personnel, minimize irregularities in the treatment processes, and insure compliance with California Regional Water Quality Control Board receiving water quality objectives.

G. Materials listed in C, D, E and F above, which are removed from the wastewater shall be legally disposed of. Satisfactory proof of legal disposal will be required.

H. Commercial garbage, food market wastes, food plant wastes, and certain other organic wastes may be disposed of to the sanitary sewer system after suitable grinding. The following fineness of grind grquirements for all types of grinders shall be met at all times:

At least 40% shall pass a No. 8 sieve.
At least 65% shall pass a No. 3 sieve.
100% shall pass a ½-inch screen.

I. Disposal of radioactive wastes shall be in accordance with the State of California Administrative Code Title 17, Public Health, Regulations of the Bureau of Radiological Health.

J. Hospital wastes which are defined as "infectious wastes" by the Hospital Council of Southern California may be disposed of to the sanitary sewer system subject to the following limitations and requirements:

1. Pathologic specimens may not be disposed of to the sanitary sewer system.

2. The material shall be ground by an approved grinder system capable of meeting the fineness of grind requirements of Section 3 (H) of these Rules and Regulations. Entry to the grinding mechanism shall be restricted to a 6-inch by 9-inch opening. The material shall be segregated from other solid wastes and shall be contained in plastic bags or other suitable disposable containers which shall not exceed five (5) gallons capacity and shall be colored red for identification. Container and contents shall be weighed and recorded prior to disposal. These records shall be made available to the Board for inspection.

3. The materials must not violate any other requirements of Section 64.30 of the Los Angeles Municipal Code or of these Rules and Regulations.

K. Disposable hypodermic needles, syringes, and associated articles following their use in hospitals, out-patient clinics, medical and dental offices, etc., may be ground and discharged to the sanitary sewer system subject to the following limitations and requirements:

1. The material shall be ground by an approved grinder not exceeding five (5) horsepower and shall meet the fineness of grind requirements of Section 3(H) of these Rules and Regulations.

2. The materials must not violate any other requirements of Section 64.30 of the Los Angeles Municipal Code or of these Rules and Regulations.

L. Individual requirements on wastewater characteristics shall be established for each discharge after an evaluation of the proposed discharge. All discharges shall meet the following general requirements:"

More detailed information pertaining to this ordinance may be found in Appendix D2.

Sanitation Districts of Los Angeles County This agency, also known as the Los Angeles County Sanitation Districts (LACSD), enacted "An Ordinance Regulating Sewer Construction, Sewer Use and Industrial Wastewater Discharges," on April 1, 1972 and subsequently amended the ordinance on July 1, 1975.[12] The LACSD does not operate both a sanitary sewer system and a storm drain system, as the City of Los Angeles does, but the LACSD's sanitary sewer network is even more extensive than that of Los Angeles and the area served is even more industrialized. There are great similarities between the Los Angeles and the LACSD ordinances in that both incorporate the permit sustem, standards, surcharges, specifications for flow measurement and sampling, and prohibitions.

For example, the LACSD section on "permit for industrial wastewater discharge" reads:[3]

> "Except as provided in Section 215 no person shall discharge or cause to be discharged any industrial wastewaters directly or indirectly to sewerage facilities owned by the Districts without first obtaining a Districts' Permit for Industrial Wastewater Discharge. A separate Permit for Industrial Wastewater Discharge shall be required for each industrial wastewater connection to a public sewer discharging directly or indirectly to the Districts' sewerage system.
>
> The Permit for Industrial Wastewater Discharge may require pretreatment of industrial wastewaters before discharge, restriction of peak flow discharges, discharge of certain wastewaters only to specified sewers of the Districts, relocation of point of discharge, prohibition of discharge of certain wastewater components, restriction of discharge to certain hours of the day, payment of additional charges to defray increased costs of the Districts created by the wastewater discharge and such other conditions as may be required to effectuate the purpose of this Ordinance.
>
> No Districts Permit for Industrial Wastewater Discharge is transferable without the prior written consent of the Chief Engineer.
>
> No person shall discharge industrial wastewaters in excess of the quantity or quality information stated in the Permit for Industrial Wastewater Discharge. Any person desiring to modify his industrial plant, process, or wastewater treatment facilities in a manner which would increase or decrease the flow rate or alter the quality of the wastewater discharge described in his Industrial Wastewater Discharge Permit shall apply for an amended permit."

Similarly, the LACSD introduction to the ordinance section on "prohibition" reads:

> "No person shall discharge or cause to be discharged to any public sewer which directly or indirectly connects to the Districts' sewerage systems any wastes which may have an adverse or harmful effect on sewers, maintenance personnel, wastewater treatment plant personnel or equipment, treatment plant effluent quality, public or private property, or which may otherwise endanger the public, the local environment or create a public nuisance, included within the prohibition above set forth, is the discharge of any wastes which may adversely affect water reclamation procedures.
>
> The Chief Engineer, in determining the acceptability of specific wastes, shall consider the nature of the waste and the adequacy and nature of the collection, treatment and disposal system available to accept the waste."

References for Appendix D1

1. Malcolm Pirnie, Inc., in Association with Jouzy & Partners, "Feasibility Study, Zarqa - Ruseifa Water Distribution, Sewerage and Stormwater Systems, Draft Investigations, Preliminary Engineering Design, Finaicial, and Socio-Economic Analysis Report," 1980.

2. Lund, Herbert F., "Industrial Pollution Control Handbook," McGraw-Hill, 1971.

3. Stanley Consultants, "Environmental Assessment on Amman Water and Sewerage Project," July 21, 1978.

4. Eckenfelder, W. Wesley, Jr., "Water Quality Engineering for Practicing Engineers," Boston, 1970.

5. Nemerow, Nelson L., "Industrial Water Pollution, Origins, Characteristics, and Treatment," 1978.

6. U.S. Environmental Protection Agency, "Waste Treatment, Upgrading Meat Packing Facilities to Reduct Pollution," EPA Technology Transfer Seminar Publication, Volume 2, October 1973.

7. U.S. Environmental Protection Agency, "In-Process Pollution Abatement, Upgrading Metal-Finishing Facilities to Reduce Pollution," EPA Technology Transfer Seminar Publication, July 1973.

8. Azad, Hardam S., "Industrial Wastewater Management Handbook," McGraw-Hill, 1976.

9. U.S. Environmental Protection Agency, "In-Process Pollution Abatement, Upgrading Poultry-Processing Facilities to Reduce Pollution," EPA Technology Transfer Seminar Publication, July 1973.

10. U.S. Environmental Protection Agency, "In-Plant Control of Pollution, Upgrading Textile Operations to Reduce Pollution," EPA Technology Transfer Seminar Publication, October 1974.

11. Board of Public Works of the City of Los Angeles, California, "Rules and Regulations Governing Disposal of Industrial Wastes to the Sanitary Sewer and Storm Drain Systems of the City of Los Angeles," July 7, 1971, amended on March 24, 1972, December 18, 1972, and June 25, 1975.

12. Sanitation Districts of Los Angeles County, "Wastewater Ordinance, an Ordinance Regulating Sewer Construction, Sewer Use and Industrial Wastewater Discharges," April 1, 1972 as amended July 1, 1975.

RULES AND REGULATIONS GOVERNING DISPOSAL
OF INDUSTRIAL WASTES TO THE SANITARY
SEWER AND STORM DRAIN SYSTEMS OF THE
CITY OF LOS ANGELES, CALIFORNIA

Industry	Permit Req'd	Classif. No.	Mean Value, mg/l* SS	BOD	Surcharge Factor
Air Cond. & Refrig. Eqpt. & Service	Yes[1]	1	--	--	0.00
Aircraft Mfg. Serv.& Maint.	Yes[2]	5	331	1383	0.07390
Sm. Animal Hosp. & Kennels	Yes	2	--	--	0.00
Apartments	P.I.P.				0.00
Asphalt & Asphalt Prod.Mfg.	Yes	5	487	117	0.01082
Auto Mfg., Serv., Maint.	Yes	3 & 5	1164	1262	0.10456
Auto Laundry	Yes	3	283	252	0.00285
Bakeries	Yes	3	2538	3021	0.27440
Banks	P.I.P.				0.00
Barber Shops	No				0.00
Bars	No				0.00
Batteries, Mfg.,& Servicing	Yes	5			0.00
Beauty Salons	No				0.00
Beverage Mfg.	Yes	4	130	541	0.01893
Blueprint Equip.Supplies	Yes	2			0.00
Boiler Mfg. & Servicing	Yes	3			0.00
Bonding Mtls.	Yes	5	1134	1310	0.10612
Breweries	Yes	5			Special
Bus Mfg.,Repair & Service	Yes	5	1164	1262	0.10456
Buildings:					
Private	P.I.P.				0.00
Public	P.I.P.				0.00
Candy Mfg. & Confectioners	Yes	3	2538	3021	0.27440
Carpet & Rug Clng & Dyeing	Yes	3	617	153	0.01676
Caterers	Yes	3	429	1122	0.06248
Ceramic & Clay. Prod. Mfg.	Yes	5	487	117	0.01082
Chemical Mfg., & Pkg.	Yes	5	599	298	0.02008
Churches	No				0.00
Cleaners & Dyers	Yes	2			0.00
Comp. Gases-Mfg.,Handling	Yes	5			0.00
Concrete Prod. Mfg.	Yes	5	487	117	0.01082
Cooling Water(Single Pass)	Yes	1			0.00
Cooperage	Yes	4			Special
Convalescent Homes	P.I.P.				0.00
Cosmetic Mfg.	Yes	1	443	1534	0.08820
Dairies, Dairy Barns,Stables	Yes	4	323	1510	0.08126
Dairy Products Mfg.	Yes	4	323	1510	0.08126
Distilleries	Yes	4			Special
Etchers & Engravers	Yes	4	394	867	0.04536
Film Processing:					
Studio	Yes	1			0.00
Laboratory	Yes	4			Special

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Industry	Permit Req'd	Classif. No.	Mean Value, mg/l* SS	BOD	Surcharge Factor
Filter Cleaning	Yes	3	1164	1262	0.10456
Food Processing:					
Citrus	Yes	5	2327	3716	0.30707
Egg	Yes	2	1453	2213	0.17566
Fish	Yes	5	1453	2213	0.17566
Fruit	Yes	5	1453	2213	0.17566
Meat	Yes	5	740	1155	0.07869
Olives	Yes	5	1453	2213	0.17566
Pickles	Yes	5	1453	2213	0.17566
Poultry	Yes	5	740	1155	0.07869
Tortilla & Tamale Mfg.	Yes	5	1453	2213	0.17566
Vegetable	Yes	5	1453	2213	0.17566
Foundries	Yes	2	487	117	0.01082
Grinding (Minerals)	Yes	2	757	318	0.02851
Grinding & Disposal (Market waste, Food Plant waste, Hospital waste)	Yes	5			Special
Heliport	Yes	2			0.00
Hospitals	P.I.P.				0.00
Hotels	P.I.P.				0.00
Insecticide Mfg.	Yes	5	599	298	0.02008
Jewelry-Repair & Cleaning	Yes	3			0.00
Laboratories:					
Analytical	Yes	2	114	300	0.00426
Biological	Yes	2			0.00
Dental	Yes	2	373	74	0.00562
Medical	Yes	2	151	339	0.00664
Pharmaceutical	Yes	2	101	252	0.00134
Soil & Foundation	Yes	2	1889	130	0.07484
X-Ray	Yes	2			0.00
Latex & Rubber Products	Yes	3	312	80	0.00283
Laundries - Self Service	Yes	1[3] & 3[3]			0.00
Laundries - Linen & General	Yes	3	368	550	0.02487
Laundries - Towel & Uniform	Yes	5	660	576	0.03979
Liquid Waste Disposal	Yes	5			0.00
Lumber Treating	Yes	5			0.00
Markets (Fish,Meat,Food,etc.):					
Retail	Yes	2			0.00
Wholesale	Yes	2			0.00
Metal Fabrication (Weld)	Yes	1			0.00
Metal Finishing & Plating	Yes	5			0.00
Metal Treating	Yes	5			0.00
Mirror Mfg. & Glass Treatment	Yes		757	318	0.02851
Mortuaries	P.I.P.				0.00
Motels	P.I.P.				0.00
Medical-Dental Offices	P.I.P.				0.00

Industry	Permit Req'd	Classif. No.	Mean Value, mg/l* SS	BOD	Surcharge Factor
Nurseries	Yes	1			0.00
Oil Producers	Yes	5			0.00
Oil Refineries	Yes	5			Special
Oils:					
Mfg. & Packaging	Yes	5			0.00
Fuel & Heating	Yes	5			0.00
Lubricating	Yes	5			0.00
Mineral	Yes	5			0.00
Olive	Yes	5	1453	2213	0.17566
Reclaimed	Yes	5			0.00
Re-Refined	Yes	5			0.00
Vegetable	Yes	5	1453	2213	0.17566
Paper Mfg.	Yes	5	493	676	0.03825
Paint Mfg.	Yes	5	1134	1310	0.10612
Paint Removers,Mfg.,Serv.	Yes	3	1134	1310	0.10612
Paint Spray Booths	Yes	3	1134	1310	0.10612
Paper Products Mfg.	Yes	5	493	676	0.03825
Pharmaceutical Prod. Mfg.	Yes	5			Special
Phonograph Record Mfg.	Yes	5			0.00
Photo Engraving & Etching	Yes	5	394	867	0.04536
Pipe Cutting & Threading	Yes	5			0.00
Plastics	Yes	3			0.00
Printing:					
Glass-Metal-Plastic	Yes	2	1134	1310	0.10612
Silkscreen	Yes	2	1134	1310	0.10612
Textile	Yes	2	1134	1310	0.10612
Type-setting	Yes	2			0.00
Railroad Equip,Repair & Mfg.	Yes	5	1164	1262	0.10456
Restaurants	Yes	1	429	1122	0.06248
Rendering Plants	Yes	5			Special
Sanitariums	P.I.P.**				0.00
Schools	P.I.P.				0.00
Service Stations	Yes	1	1176	1952	0.14712
Shipbuilding & Repair	Yes	5	1164	1262	0.10456
Ship Cleaning & Washing	Yes	5	1164	1262	0.10456
Steam Cleaning:					
Auto	Yes	3	1164	1262	0.10456
Commercial	Yes	3	1164	1262	0.10456
Industrial	Yes	3	1164	1262	0.10456
Swimming Pools - Public	Yes	1			0.00
Tank Car Cleaning	Yes	5	1164	1262	0.10456
Tanning	Yes	5			Special
Textiles	Yes	3	119	717	0.02965
Theaters	P.I.P.				0.00
Tire Mfg. & Servicing	Yes	5	312	80	0.00283
Truck & Trailer Mfg.	Yes	5	1164	1262	0.10456
Truck Repair & Service	Yes	5	1164	1262	0.10456
Truck Washing & Steam Clng	Yes	5	1164	1262	0.10456
Wax Mfg	Yes	3	272	122	0.00100
Water Treating & Serv.Eqp.	Yes	5			0.00
Wineries	Yes	5			Special

NOTES:

1. An Industrial Waste Permit is required for any discharge to other than the sanitary sewer system. An Industrial Waste Permit is not required for discharge to the sanitary sewer system:
   a. When the discharge is less than 100 gpd and pretreatment is not required.
   b. From restaurants with seating capacity less than 150.
   c. For cooling towers, evaporative condensers or other recirculating water from heat exchange devices with rated capacity of 5 tons or less.
2. An Industrial Waste Permit is required for small animal hospitals and kennels where storm water diversion devices are necessary.
3. Self service laundries with washing machines of 50 pound capacity and over will be placed in Classification No. 3.

* Only those mean values are shown where either or both suspended solids or BOD exceeded 250 mg/l and 230 mg/l respectively.

** Permit according to Individual Process.

APPENDIX D3

Appendix D3 includes the listing of some typical industries in the Greater Amman Area. The listing was taken from information compiled by the Amman Chamber of Industry. Asterisks shown denote industries covered by the survey. Of all the industries visited, two large water consumers/wastewater producers were identified. Information relevant to these two industries is included herein also.

APPENDIX D3

LIST OF INDUSTRIES IN THE STUDY AREA BY LOCATION[a]

MARQA AREA

File No.		No. of Workers
123	The Jordan Feed Co., Ltd.	30
140	Arab Feed Manufacturing Co., Ltd.	30
1896	Fodder Mill	10
358	Agricultural Processing Co.	56*
76	Preserved Food Factory	10
481	The Jordan Food Factory	15
831	Awto Packing Co.	10
356	The Palestinian Factory for Ice Cream Biscuits	14
429	Zahi Factory for Biscuits	20
579	Elias Banayet Hoshe & Son (biscuits)	20
311	Select Factory for Manuf. Confectioneries	17
335	The Jordan Venus Factories	20
376	Rex Confectionery Factory & Chocolate	25
379	Jordanian Factory for Chocolates/Conf.	--
1720	M. Moafak Azizeh Con.	45
2678	Wozan Chocolate	30
	Aerated Water Co., Ltd.	300*
1509	Jordanian Sesame Press	10
101	Nugul Bros. Co.,(hygienic prod.)	164*
62	Wasif Shamout Co.	15
2303	Kotob Printing Press and Carton Boxes	10
465	Modern Copy Books Factory	12
214	Woollen Industries Co., Ltd.	46*
2529	Haikal & Partners Trico Co.	12
1087	Nile Trico & Suline Co.	18
786	Aladdin Trico Factory	10
560	Damir Industrial Eng.	150
56	Omegaz Industry (cooking stove burners)	20
358	Agricultural Processing Co.	56*
1375	Canning Industries Co.	57*
78	Jordan Nails & Bar Bed Wires Manu. Co.	30
835	Modern Nail Factory	10

File No.	MARQA (Cont'd)	No. of Workers
2712	Nails & Metals Industries	13
	Oris Industrial Co.	18
	Chemical Detergents Industries Co., Ltd.	80*
1571	Jordan Carton Co.	25
1928	Jordan Match Co.	55*
2091	The Jordanian Co., for Mfg. Cosmetics (J.C.M.C.)	12
233	Adnan Shalan & Co. (varnish, liquid, glue, shampoo)	40
44	United Industries Co. (wet batteries)	253*
274	Jordan Electro Chemical Co. (dry batteries)	18
966	Electric Industries Co. (fluorescents & transformers,)	15
1710	The Ideal Printing Press Co., Ltd.	48
	Middle East Printing Press	13
613	Talib Printing Press Co.	11
	The Jordan Feed Co., Ltd., (fodder & poultry)	30*
1294	Sami Hababeh Furniture Co.	25
261	Sandoca Factory for Mfg.(furniture & hangers)	15
143	Al-Jamil Factory & Exhibition (wooden furniture)	22
	Ghazi Basha Shoes & Handbags Workshop	25
	Jordan Glasses Industry (housewares)	60
2293	Rabah Abdeen Co., (brushes & sweepers)	15*
004	Arab Foam Industries Co.	45*
	National Foam Factory	50
	Modern Plastic Yarn Factory	20
2059	Plastic Al Wafa'a Est.	10
2178	Al Nasr Factory for Mfg. Plastic Elect. Tubes	10
	United Jordan Electrical Tube Mfg. Co.	18*
	Arab Plastic Co., Ltd. P.V.C. Pipe	24
279	Orient Plastic Co.	15
1782	Technical Plastic Co. P.V.C.	20
	General Plastic Industry	15

MARQA (Cont'd)

File No.		No. of Workers
2546	Ghazi Basha Shoes & Handbag Workshop	25
2612	Samender & Co., Industrial Trading Co.	20
88	Jordan Bata Co., Ltd.	151
312	The Eagle Rubber Mfg., Co., Ltd.	150
350	Union Plastic Co.	20
788	Al Ahram Industrial Shoes Co.	40*
1870	The Jordan Gases Co.	19
	The Jordan Provimi Feed Co.	8*

MARJ EL HAMAM

File No.		No. of Workers
1921	Confectionery & Chewing Gum Factory	43
1578	Abdul Hakeem Shassawi & Sons Co. (biscuits)	18
	-Hasan Ashou & Sons Co. Ind.	30
2003	National Radiator Factory	16
147	Jordan Aluminum Manufacturing Co.	45
1100	Prefabricated Structures Mfg. Co.	61
1385	Jordan Metal Works Co., Ltd.	65
1165	Prefabricated Building Co.	40
2538	Hudhud Indus. Co. (steel wool)	20
1097	The Lebanese Modern Indu. & Trading Co. (refrigerators)	25
	National Paints Factory Co.	45
2682	Modern Co., Ltd.	30
39	Star Suit Case Factory	17
2741	Jamil M. Sahoury & Bros. Co. (household appliances)	12
198	Mosily & Co.	10
277	National for Manufg. Plastic	40
950	White Plastics Factory Co. (plastic)	17
1769	International Plastic Co.	12
2086	Genco Industrial Co. (tiles & mosaic)	20
99	Abdul Azeem Sharaw, and Bros. Co. (gum)	40
1455	Arab Veterinary Ind. Co.	10
2504	Kabatilo Ind. & Trading Est. (fruit juices)	
	Jordan Plastic Co., (foam & kitchen plastic tools)	169

File No.	AIN EL BASHA	No. of Workers
2405	Jordan Fruit Juice Co.	50*
2651	Reem Fruit Juice Products Co.	10
2571	Jordan Electrode Co. (elect. wire bars)	18
2016	Forum Furniture Co.	20*
2567	Nogul D. Salem Co. (plastic bags)	17*
2759	Al-Mimam Est. Trade and Indus. (pvc window/door factory)	
688	Jordan French Marble Products Co.	36
689	Bishtawi, Shamali & Halheers Co. (gypsum, artwares factories)	50*
355	Marmor Resin Plants Co., Ltd.(Marpco) (marble)	57*
426	Arabian Industrial Processing Investment Co. (tiles)	15
	Paper Bags Factory	30*
	NA'UR CITY	
2180	Dar Al Dawa (drugs)	71
2300	Jordanian Pharmaceutical & Medical Equipment Co.	47
	SALT	
275	The Arab Pharmaceutical Mfg. Co., Ltd.	300
	RING ROAD	
2021	Insustrong Insulation Indus. Co., Ltd. (polystrene pipes and furniture)	51

File No.	ABU ALANDA-Ragib Area	No. of Workers
1772	National Gas Industries Co. Ltd.	20
2642	Zaghat Industrial Co. (shoes)	43
2235	Sugayer & Turjman Indus. Co. Ltd.	10
2617	The Arabian Pipes Co., Ltd. (fiberglass pipes)	25
1983	Jordan Sipes Paints Co.	20
1127	Households & Toiletries Mfg. Co. (detergents and shampoo)	25
2623	Abu-Hadbeh Co., for Mfg. and Casting Metal	12
2436	Modern Textile Cor. (floor wipers)	6
1116	Jordan Carpet Mfg. Co. Ltd.	86
1868	Jaffa Juice and Beverages Co., Ltd.	18

INDUSTRIAL WATER USE AND WASTEWATER SURVEY

Industry Agricultural Processing Co. Location Marqa

Principal Activities Tomato paste, vegetable canning

No. of employees 30 Operation 8 Hr./day 6

Raw materials Vegetables

Products Canned vegetables; tomato paste

Water Source Municipality of Amman

Avg. consumption 150 m^3/day

Industrial Processes	Water Use m^3/day	Wastewater Flow m^3/day
Information is not available, but it is believed that about 100 m^3/day is industrial wastewater.		
Sanitary Waste (estimated)	1.5	1.5

Wastewater Treatment

None

Disposal

Industrial wastewater to an impoundment in a nearby wadi.
Sanitary waste to septic tank.

Comments

Industrial wastewater flow fluctuates between 130 m^3/day to 170 m^3/day depending on type of product.

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INDUSTRIAL WATER USE AND WASTEWATER SURVEY

Industry Aerated Water Co., Ltd. Location Marqa

Principal Activities

No. of employees 350 - 400 Operation 8 Hr./day 6

Raw materials

Products Pepsi-Cola and soft drinks

Water Source Private wells

Avg. consumption Summer: 600 m^3/day Winter: 240 m^3/day

Industrial Processes	Water Use m^3/day		Wastewater Flow m^3/day	
	Summer	Winter	Summer	Winter
Process	160	64	0	0
Washing	440	140	440	140
Cooling	Negligible			
Sanitary Waste (estimated)				
	10	10	10	10

Wastewater Treatment

None

Disposal

Industrial wastewater to an impoundment in a nearby wadi.

Sanitary waste to septic tank.

Comments

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APPENDIX E

SANITARY SEWER INFORMATION

HYDROGEN SULFIDE CONSIDERATIONS

Hydrogen sulfide (H_2S) is probably the most damaging and toxic of all substances that are released by natural processes into the environment in substantial amounts. It is often present in sewers and is responsible for the deaths that are reported as "asphyxiation."

Hydrogen sulfide is objectionable also because of its well-known odor. When a wastewater treatment plant or pump station is a source of odor complaints, it is nearly always because of hydrogen sulfide.

In developing the Greater Amman Wastewater Disposal Master Plan, the corrosion danger from H_2S must also be planned against. Hydrogen sulfide may stimulate corrosive damage to metals, but of greater concern in connection with wastewater works is the corrosion of concrete. Hydrogen sulfide does not attack concrete directly, but on moist surfaces bacteria of the genus Thiobacillus will oxidize H_2S to sulfuric acid (H_2SO_4). The acid attacks the concrete, converting it to a pasty mass of gypsum plus the residual sand and gravel from the concrete.

Numerous concrete sewers have collapsed because of this indirect effect of H_2S. Large trunklines built with concrete walls 10 cm or more in thickness have been known to fail in 15 years, and there are many examples of failures in small sewers in ten or even five years. Most of the reports of concrete corrosion have been from the United States, Australia, South Africa and the United Kingdom, with some scattered accounts of problems elsewhere. Engineers in many countries have thought in the past that they were immune to these problems because of climatic factors or other reasons.

It is now evident that H_2S problems may be created in any climate, as witnessed by such corrosion in various places in South America and Europe. For example, even the City of Hamburg has experienced serious corrosion. There have also recently been some notable failures in the Middle East, mostly because large concrete or asbestos cement sewers were designed for large future wastewater flows. Thus, the initial flows were smaller quantities, and flowed sluggishly in the large pipes generating high H_2S concentrations.

SULFIDE

The sulfate ion (SO_4) is present in wastewaters of all origin. Under anaerobic (zero oxygen) conditions, bacteria first reduce sulfate to sulfide (S) and then to H_2S. The previously described conversion of H_2S to H_2SO_4 and its resultant corrosion can then occur.

A smaller amount of H_2S that may be produced in sewers may also be present from the decomposition of sulfur-containing organic matter, especially the albuminoid proteins. The principal source of H_2S in sewers, however, is not the decomposition of organic matter, but the previously described bacterial reduction of sulfate.

On the walls of sewer pipes, microbes establish themselves and build up a slime layer. Even though this layer may only be as thick as a millimeter, oxygen cannot penetrate the slime because of its intense bacterial activity. It is in this slime layer that sulfate reduction and the production of sulfide take place. Sludge which deposits in the bottom of the sewers may also produce sulfide, but a stable sludge deposit seldom produces as much as does a slime layer on the wall.

It is known that the oxygen supply to the stream is of major importance in retarding H_2S build-up. The bacterial reduction of sulfate is prevented by even the smallest trace of dissolved oxygen. Wastewater flowing in a sewer under normal conditions (i.e., in a partly filled pipe is continually absorbing oxygen from the atmosphere. Thus, there is always a little oxygen in solution, despite its continued use by aerobic bacteria. Hence, sulfide is not produced in wastewaters flowing in partly filled sewers.

SULFIDE PRODUCTION

Despite widespread occurrences of corrosion of sewers due to H_2S, most wastewater systems operate with no problems of this sort. Early interest was generated in the attempt to find out why H_2S appeared in some sewers and not in others. The Sanitation Districts of Los Angeles County (LACSD), in the United States, are the leaders in research regarding this question. The LACSD has contributed a major part of the knowledge about sulfide generation and control in sewers. The work of the LACSD is the major foundation for the Sulfide Control Manual published by the United States Environmental Protection Agency.

A study was conducted in 1960 in 64 small diameter, free-flowing sewers. The condition herein as "free-flowing" is generally equivalent to "gravity" sewers that are not flowing full. The study, which took place in residential areas in Southern California, began at the upper ends of the sewers. The frequency of household connections to the sewers was one per 10 meters. Sulfide concentrations were measured, and the results were grouped into four slope categories. These results per category are plotted in Figure E-1 as average sulfide concentrations vs. distance from the upper ends of the sewers.

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At the flattest slopes, averaging 0.23%, piles of debris tend to collect in the sewers and the wastewater flows through a series of semi-stagnant pools. This represents a condition favorable for sulfide production and is shown by Curve A. This same condition prevails to some extent at a 0.4% slope (Curve B), but scarcely at all at slopes of 0.6% or more (Curves C and D). It should be remembered that the first 0.2 mg/l of sulfide is likely to be mostly insoluble sulfide, which does not oxidize readily nor escape to the atmosphere. Little or no H_2S is likely to be produced under the conditions represented by Curves C and D. Most of the Greater Amman Area where sewers already exist or may some day exist experience slopes in the Curve D category or steeper. Thus, sulfide production would not normally be a major matter of concern. Nonetheless, the matter does warrant consideration.

The strength of wastewater in Amman is much greater than that in Southern California, this being the result of a per capita wastewater contribution of only about one-fourth or one-fifth that of the latter's. The organic load, however, is about normal, so the BOD_5 concentration in Amman becomes correspondingly high.

Over a period of 30 years, there have been several developments in the efforts to predict rates of sulfide build-up in larger sewers. These have culminated in a set of equations published by the Clay Pipe Development Association of the United Kingdom, which are based upon the research data of LACSD. However, such quantitive predictions are not necessary in the development of recommendations for the Greater Amman Area designs. This is because the objectives are to construct a system that will not develop sulfide conditions in the ranges where such equations are applicable. As noted previously, nearly all candidate areas for sewering appear to offer substantial sewer construction slope potentials, these minimizing the possibilities for sulfide generation except as these may be encouraged by the unusually strong wastewater.

AWSA SYSTEM FIELD WORK

Field inspections and flow gagings were conducted on the AWSA sanitary network on September 17 and 19, 1980, and also on October 12 and 13, 1980. Regarding sulfide concerns, the objective was to assess the extent of sulfide production in the network and possible corrosive effects upon the concrete sewer pipe. A parallel interest was in an hydraulic assessment of network conditions.

Visual inspection was made of sewer manholes that were opened and of as much of the appurtenant sewers as could be seen from street level, it being impracticable to enter the manholes. Concurrently, depth and flow gagings were conducted and calculations subsequently made.

The inspections revealed no significant sulfide corrosion of the concrete sewering materials, while the gagings confirmed the high velocities of flowing wastewater anticipated from the relatively steep sewer slopes.

As a result of the foregoing observations and general considerations pertaining to the AWSA network, the following conclusions appear reasonable:

- The steep terrain of Amman inevitably results in steep construction slopes for the various sewers of the sanitary network of AWSA, making for relatively high velocities.
- Coincidentally, the design of the collection system was premised on a higher per capita flow than has been realized, so that conditions are favorable for aeration of the flow, thereby inhibiting the generation of sulfides at least under present conditions.
- Unless special investigations indicate otherwise, it appears satisfactory to employ concrete pipe sewering materials in the AWSA net work and in future sanitary sewer networks, provided the terrain is steep (as is typical of Amman.) Normal experience is that as flows increase and flow stages rise in sanitary sewers, velocities increase, aeration increases, and sulfide problems tend to diminish. (See also later discussion.)

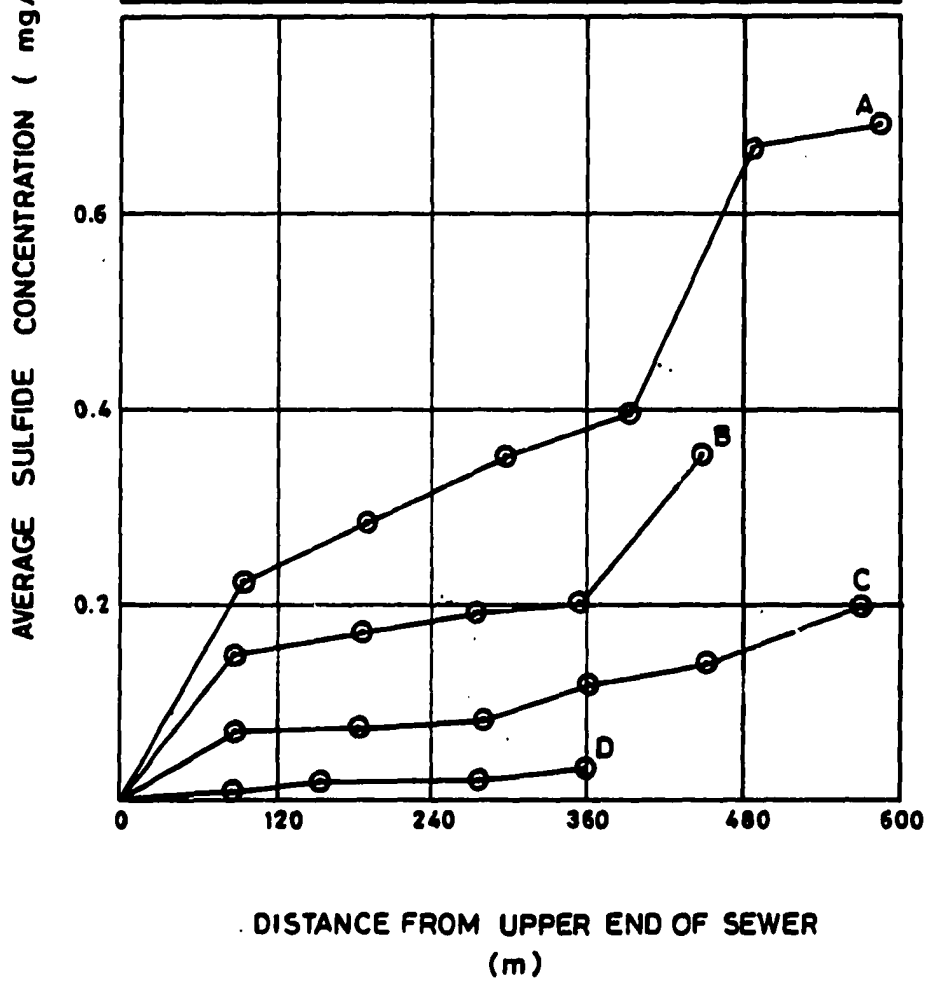
FLOW GAGING

Table E-1 presents the results of the flow gagings. Gaging was done by means of the so-called "velocity stick." The velocity stick (Figure E-2) is a thin graduated wooden blade, one edge of which is symmetrically tapered into a knife edge. The opposite edge is squared off. The velocity stick is inserted into flowing wastewater near the inlet of the main sewer, first blade forward and then blunt edge forward. The liquid depths for these respective positions are noted, and the difference between the blunt edge-first depth and the knife edge-first depth is obtained by subtraction. This represents the velocity head, which is then converted, by calculation, to velocity. The discharge is obtained by multiplying the velocity by the cross-sectional area of the sewer conduit corresponding to the depth of flow.

Velocity stick determinations were made at the following locations:

- Two manholes on Wadi Nasir Street (representing a major trunk sewer draining portions of Yarmouk and Al Nasir) close to its confluence with the main outfall sewer to AGTP.
- The main outfall sewer at one manhole on Mahatta Street, a few hundred meters upstream of the Wadi Nasir Street Junction manhole. (Actually, at this location, the flow was so great and velocity so high, that the velocity stick could not be used effectively, so the flow was estimated roughly.)
- The trunk sewer at the lower end of Jabal Hussein on Wadi Haddadah Street, across from the King's Palace, a single manhole.
- The trunk sewer on the Sport City - University Road at a single manhole opposite the Jordan Times News Agency. The trunk sewer's flow at this location is generally representative of the discharge from the University Pumping Station.

LINE	SLOPE (%) RANGE	SLOPE (%) AVG.	NUMBER OF SEWERS	AVERAGE RESULTS B.O.D.	AVERAGE RESULTS TEMP. °C
A	0.20 - 0.25	0.23	18	253	24.7
B	0.32 - 0.46	0.40	22	212	24.4
C	0.52 - 0.64	0.57	16	178	24.7
D	0.72 - 1.20	0.9	8	184	24.3



SULFIDE OCCURRENCE IN SMALL SEWERS

FIGURE E - 1

TABLE E-1

SUMMARY OF 1980 HYDRAULIC DATA DERIVED FROM SELECTIVE SEWER GAGING, AWSA NETWORK

Manhole Location	Date	Time	d,m	D_1,m	D_2,m	H_v,m	V,m/sec	D_1/d	c	d^2	A,m^2	Q,m^3/sec
Wadi Haddada Street												
W. of entr. to Palace	17 SEP	0940	0.400	0.10	0.31	0.21	2.0	0.25	0.154	0.160	0.0246	0.049
		1000		0.10	0.32	0.22	2.1	0.25	0.154	0.160	0.0246	0.052
		1020		0.10	0.32	0.22	2.1	0.25	0.154	0.160	0.0246	0.052
		1145		0.12	0.33	0.21	2.0	0.30	0.198	0.160	0.0317	0.063
	18 SEP	1130	0.400	0.11	0.32	0.21	2.0	0.28	0.176	0.160	0.0282	0.056
Mahatta Street[c]	17 SEP	1138	1.000	Flow velocity too strong for velocity stick gaging. V estimated visually up to about 3 m/sec. A estimated by top width and soffit to surface of flow. T =0.84m D=D/d =0.25 A =0.154 m^2 Q = 0.46 m^3/sec = 40,000m^3/da Note: If v = 2.5m/sec, Q = 33,300 m^3/da									
Short dist. SW of Street leading Uphill to Jabal Taj												
Wadi Nasir Street[d]	17 SEP	1042	0.500	0.05	0.13	0.08	1.25	0.10	0.041	0.250	0.010	0.013
150-200 m above		1105		0.05	0.15	0.10	1.40	0.10	0.041	0.250	0.010	0.014
Mahatta Street	18 SEP	1150	0.500	0.08	0.17	0.09	1.33	0.16	0.081	0.250	0.020	0.027
Wadi Nasir Street[d]	17 SEP	1115	0.500	0.06	0.16	0.10	1.40	0.12	0.053	0.250	0.013	0.019
Sport City - U of J. Rd[e]	17 SEP	1210	0.300	0.03	0.08	0.05	0.99	0.10	0.041	0.090	0.004	0.004
Opposite Jordan Times		1216		0.02	0.06	0.04	0.89	0.07	0.024	0.090	0.002	0.002
Newspaper Office	18 SEP	1110	0.300	0.09	0.32	0.23	2.12	0.30	0.198	0.090	0.018	0.038

TABLE E-1 (Cont'd)

Manhole Location	Date	Time	d,m	D_1,m	D_2m	H_v,m	V,m/sec	D_1d	c	d^2	A,m^2	Q,m^3/sec
Wadi Sakhra Street near Holiday Inn												
No. 1	Oct. 12	9:55	0.300	0.13	0.38	0.25	2.22	0.433	0.180	0.090	0.0720	0.160
No. 2	Oct. 12	10:10	0.300	0.12	0.36	0.24	2.17	0.400	0.156	0.090	0.0140	0.030
No. 1	Oct. 12	11:55	0.300	0.11	0.37	0.26	2.26	0.367	0.133	0.090	0.0120	0.027
No. 2	Oct. 12	12:05	0.300	0.10	0.35	0.25	2.22	0.333	0.110	0.090	0.0099	0.022
No. 1	Oct. 12	14:00	0.300	0.13	0.36	0.23	2.12	0.433	0.180	0.090	0.0162	0.034
No. 2	Oct. 12	14:05	0.300	0.12	0.34	0.22	2.08	0.400	0.156	0.090	0.0140	0.029
No. 1	Oct. 12	21:45	0.300	0.07	0.25	0.18	1.88	0.233	0.055	0.090	0.0050	0.009
No. 2	Oct. 12	21:55	0.300	0.05	0.25	0.20	1.98	0.167	0.028	0.090	0.0025	0.005
No. 1	Oct. 12	23:55	0.300	0.04	0.25	0.21	2.03	0.133	0.018	0.090	0.0016	0.003
No. 2	Oct. 12	24:00	0.300	0.03	0.23	0.20	1.98	0.100	0.010	0.090	0.0009	0.002
No. 1	Oct. 13	08:10	0.300	0.11	0.33	0.22	2.08	0.367	0.133	0.090	0.0120	0.025
No. 2	Oct. 13	08:15	0.300	0.10	0.32	0.22	2.08	0.333	0.110	0.090	0.0099	0.021

[a] Gaging was done using a velocity stick (Figure E-2) All results are approximate (see text.) Nomenclature in column headings is: d-pipe diameter; D, depth of water when velocity stick blade faces the current; D_2- depth of water when the blunt edge of the velocity stick faces the current; H_v- velocity head of flowing wastewater; V-velocity of flowing wastewater; c-a coefficient dependent upon the ratio of depth to diameter; d^2-diameter squared- A-cross-sectional area of sewer conduit; Q-discharge of wastewater through the sewer conduit.

[b] Timing of September gagings was such as to include probable peak flow condition during at least one gaging episode. October gagings were timed to include also off-peak conditions.

[c] This is the main trunk sewer which shortly becomes the main outfall to AGTP. The approximated peak value of 40,000 m^3/da discharge rate would correspond to over 200% of average flow at the AGTP, but the flow indicated at the influent weir at AGTP indicated the peak at 1600 was only 161% of the day's average. The difference may be due to the very approximate nature of the "gaging" at this location and also the damping effect of sewer surcharge from the AGTP and upstream for several manholes. Also, if the velocity were actually less than estimated.

TABLE E-1, (Cont'd)

[d] Preliminary indication of Manning's "n" (friction coefficient) based on gaging contiguous manholes was about 0.013, a satisfactory value.

[e] This trunk sewer carries flow mostly from the University of Jordan area via the University Pumping Station. A nominal amount of gravity contributions occurs between the discharge point of the pumping station's force main and the manhole used for gaging. (It was not practical to gage closer to the end of the force main because of too great an invert depth.) As an approximation, the higher flow measured represents one or two pumps' discharge plus gravity contributions, while the lower flow represents one pump's flow or simply a sewer draining condition, following backup pump shutdown, plus the small gravity contributions upstream.

The three pumps at the University Pumping Station are apparently individually designed to produce 450 Imperial gallons per minute at 90 feet total dynamic head and with a brake horsepower of about 31, corresponding to 23 KW. It is not known what the actual hydraulics of pumping are with a lead pump alone or with a lead pump plus backup pump active simultaneously. However, assuming that the KW input cited represents one pump operating at the design point, it is possible to approximate the station output of a period of time, viz:

KWhr consumption for Calendar 1979 was 57,380 (AWSA data)
Average KW during this period is 57,380/8,760 hrs = 6.55 KW, avg.
This is 6.55/23 = 28.5 % pump activity (one pump)
Average output is 0.285 (450 Igpm) = 128 Igpm = 184,000 Igpd.
Or, 184,000 Igpd (0.00455) = 837 m^3/day

[f] This trunk sewer was selected because its flow was representative of one of the sub-drainage areas of the network. (The population tributary to the manholes gaged was estimated to be about 15,300 persons. It was not know how many were connected to the sewer.) In addition to permitting approximation of diurnal flow variations, the gagings enabled computations to be made of Manning's "n." The twelve values of "n" computed from the data ranged between 0.0109 and 0.0145 and averaged slightly less than 0.013, thus confirming the data of footnote "d" and the design criteria for the network.

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- Two manholes on a trunk sewer on Wadi Sakhra Street (near the Holiday Inn.)

As indicated in Table E-1, velocities were relatively high, even at low flows (Wadi Sakhra Street manholes only) and hydraulic calculations indicated that Manning's "n" was about 0.013, a satisfactory value.

FUTURE OUTLOOK

Based upon the limited observations reported above and information from AWSA personnel, it appears that the sanitary sewer network of AWSA has successfully withstood some eleven years of service without exhibiting any significant signs of deterioration of the concrete sewering materials. As indicated previously, slopes are very favorable for aeration and preventing sulfide buildup. The only remaining consideration was as to whether in future years, certain trunk sewers might become sufficiently full to diminish aeration capabilities significantly, thereby tending to cause sulfide buildup.

Z FORMULA APPLICATION

In order to consider the future possibilities of sulfide buildup in selected trunk sewers, a brief application was made of the Pomeroy "Z" Formula as described in Dr. Pomeroy's publication "The Problem of Hydrogen Sulphide in Sewers."[1] The results of this brief investigation are presented in Table E-2. As noted, it appears that as a result of the calculated value of "Z" in the sample reach of trunk sewer, sulfide might sometimes be expected to develop in sufficient proportion materially to increase odors and damage concrete structures, especially near points of turbulence. However, the present conditions have apparently not had significant effects of this kind, and it is indicated that the future effects would not be much different, although slightly improved. Lacking current evidence of sulfide damage to the sewer system, it is thus concluded that future sulfide conditions in the trunk sewer reach considered should be no worse than those at present.

The construction slope of the reach considered is probably typical of most of the flatter trunk sewers, although there are some reaches with slightly less slope. However, these latter slopes are relatively short in length. Thus, the sulfide propensities should not be great. Most of the network involves trunk sewers with substantial slopes, and these would have even less sulfide generation characteristics.

FORCE MAINS

As pointed out in the Pomeroy publication[1] pressure mains (force mains) do have sulfide generating potentials, and when these discharge into gravity sewers, the turbulence frequently releases hydrogen sulfide gas and may lead to corrosion of concrete pipe and structures. This should be borne in mind in design of new systems and measures taken to minimize or prevent such conditions. Fortunately, neither the AWSA wastewater collection system nor other collection systems will entail much pumping. However, when pumping through force mains is unavoidable, special precautions should be observed in design. This might include special thicknesses of sacrificial concrete (calcareous aggregate) or other measures, where warranted.

TABLE E-2

TRIAL APPLICATION OF "Z" FORMULA FOR

INVESTIGATING SULFIDE BUILDUP POTENTIALS[a]

Item	Current	Future
Diameter, m	1.000	1.000
Slope	0.010	0.010
Manning's "n"	0.013	0.013
Peak Flow Depth, m	0.250	0.750
Peak Discharge, l/s	325	2,170
Top Surface Width, m	0.866	0.866
Wetted Perimeter, m	1.044	2.093
BOD, mg/l	1,000	800
EBOD (for 30°C)	1,970	1,570
"Z", Calculated[b]	10,400	8,820
Sulfide Propensities[c]	some	some

a
Main trunk sewer reach considered is immediately upstream of manhole on Mahatta Street used for inspection "gaging" and sampling. No adverse sulfide conditions actually noted in this manhole. In applying the "Z" formula, if the computed value of "Z" (around 10,000) were characteristic of conditions existing for two or three km upstream from this manhole, it would be expected that sulfide might sometimes develop in sufficient proportion materially to increase odors and to result in substantial damage to concrete and masonry structures, especially near points of turbulence.

b

$$Z = \frac{3(\text{EBOD})\,(\text{Wetted Perimeter})}{(\text{Slope})^{\frac{1}{2}}\,(\text{Discharge})^{1/3}\,(\text{Top Width})}$$

c
Even with greater flows in this reach, the future Z values do not appear much different than the present ones. Thus, future sulfide conditions would supposedly be similar. However, present conditions apparently do not show adverse sulfide effects. Thus, future conditions are expected to be similar. Other trunk sewers in the system often have steeper slopes, resulting in lower Z values and reduced sulfide propensities.

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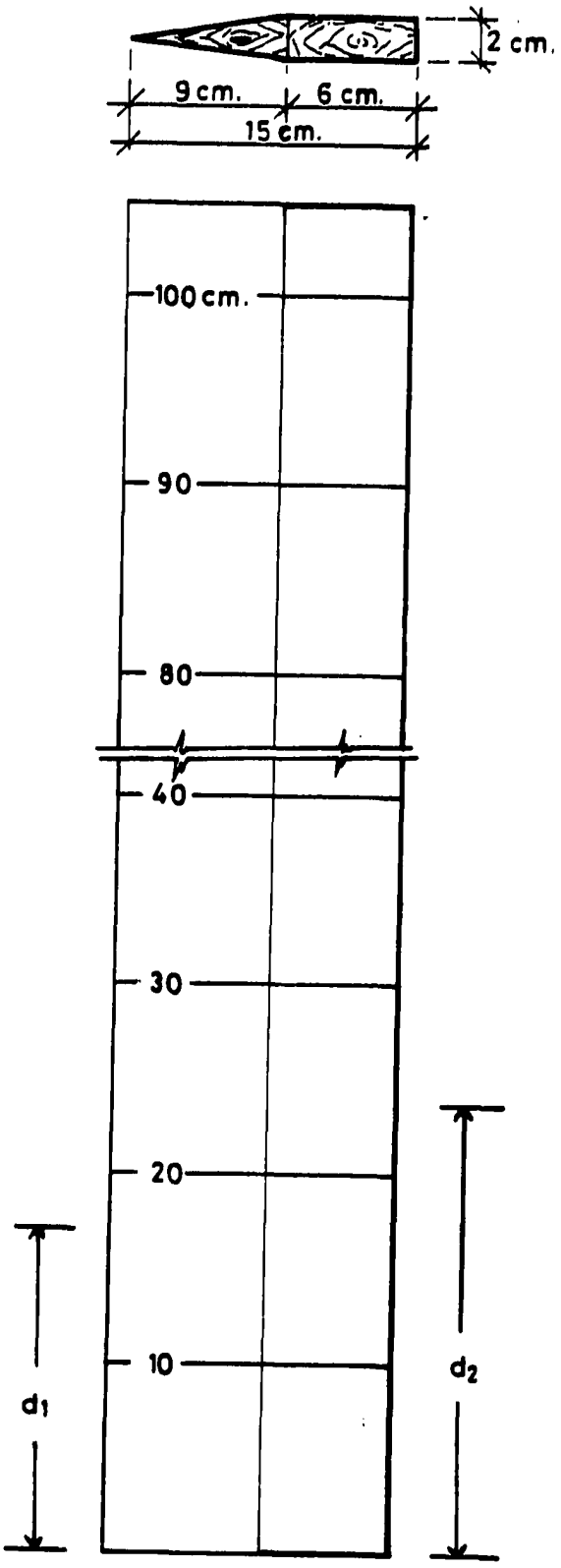

$V = 4.43 \sqrt{d_2 - d_1}$

= m/sec, where d_2 and d_1 are in meters

VELOCITY STICK

FIGURE E-2

Reference for Appendix E.

1. Pomeroy, Richard D., PhD, "The Problem of Hydrogen Sulphide in Sewers," Clay Pipe Development Association, Ltd., 1977.

APPENDIX F

COMMUNITY SANITATION RECONNAISSANCE

A limited community sanitation reconnaissance was undertaken in the summer and fall of 1980 of communities within the Greater Amman Area for the purpose of obtaining general information on sanitation conditions relating to water supply and, particularly, sewage disposal. A questionnaire was devised to develop this and related information, and visits were made in the field and interviews held with responsible officials or other representatives of the individual communities. Sample questionnaire, for Na'ur and Fuheis are presented herewith.

The results of the reconnaissance were necessarily of a general and subjective nature, due to lack of definitive date and limitations of time. Therefore, the results should be considered as indicative of current and possible future conditions.

Table F-1 presents an overall summary of subsurface sewage disposal information from the Community Sanitation Reconnaissance. Tables F-2 through F-6 summarize the subsurface sewage disposal data for each of the 29 communities surveyed broken down by population sizes.

The general impression gained from these tables is that the problem of subsurface sewage disposal is already manifested in the majority of the communities to at least a moderate extent and that in many cases, the outlook is increasingly unfavorable. A substantial population is already affected. The problem is in the form of cesspools which already overflow or else require inordinately frequent pumpouts to prevent overflows. The results of the reconnaissance also assisted in identifying potential cesspool disposal problem areas and in setting priorities for wastewater collection and treatment.

SUMMARY OF SUBSURFACE SEWAGE DISPOSAL INFORMATION[a] FROM COMMUNITY SANITATION RECONNAISSANCE

Population Group in Thousands

Item	Up to 4			5 - 14			15 - 24			25 - 34			45 and over		
	M	S	N[b]	M	S	N	M	S	N	M	S	N	M	S	N
Conditions Disfavoring Cesspools															
Rocky soil	1	10	4	4	1	3	1	0	0	1	1	1	1	0	1
Steep slopes	2	6	7	4	2	2	1	0	0	1	1	1	1	0	1
Thin soil mantle	2	3	10	2	2	4	0	1	0	2	0	1	1	0	1
Tight soils	3	1	11	0	3	5	1	0	0	0	2	1	0	2	0
Small building lots	3	3	9	2	5	1	1	0	0	2	1	0	1	1	0
Conditions experienced[c]															
Cesspools overflowing	2	7	3	0	6	2	1	0	0	1	0	2	1	1	0
Frequency of pumpout (approx.)															
Monthly	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Quarterly	1	1	0	1	0	0	1	0	0	0	0	0	2	0	0
Semi-annually	1	1	0	3	0	0	0	0	0	1	0	0	0	0	0
Annually	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greater than annually	11	0	1	4	0	0	0	0	0	0	0	0	0	0	0
Cost of pumpouts, JD/yr.															
0 - 10	10	0	0	5	0	0	0	0	0	0	0	0	0	0	0
10 - 100	4	0	0	2	0	0	0	0	0	1	0	0	2	0	0
100 - 200	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
200 - 300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Over 300	0	0	0	0	0	0	0	0	0	*1	0	0	0	0	0
Future outlook for cesspools[d]															
No change for present	11	0	2	8	0	0	0	0	1	2	0	1	2	0	0
Eventual worsening	3	1	4	3	4	7	1	0	0	2	1	0	1	1	0
Imminent worsening	2	0	6	0	0	7	0	1	0	2	0	1	1	0	1

[a] Community Sanitation Reconnaissance conducted in Greater Amman Area, 1980 in the following unsewered population size communities (in thousands), per 1979 census:

Up to 4	Jureineh, Teachers Housing (Marj el Hamam), Hisban, El'Al, Ein el Basha, Jubeiha, Talbeih Camp, Khirbet Suq, Juweideh, Muwaqqar, Um el Basatin, Rawda, Mahis, Safut, Officers Housing (Marj el Hamam)
5 - 14	Abu Alanda, Queismeh, Sahab, Sukhneh, Fuheis, Hashimiya, Na'ur, Taibeh/Qaisiya
15 - 24	Suweileh
25 - 34	Schneller Camp, Madaba, Wadi es Sir (None in 35 - 44 category)
45 and over	Baqa'a Camp

TABLE F-1 (Cont'd)

Footnotes

a (cont'd)
All of these communities relied upon cesspool installations for subsurface sewage disposal. The communities included 14 municipalities, 13 towns and villages, and 2 outlying refugee camps. All data shown except census data must be considered as approximate.

[b]Data breakdown is according to approximate residence, viz: M denotes many, S denotes some, and N denotes negligible or none.

[c]Where adverse conditions exist for subsurface disposal, it is normal for many overflowing cesspools to be reported or else fairly frequent (and costly) cesspool pumpouts to be required.

[d]Worsening of conditions may be attributed to saturating the subsoil, inability to provide additional on-site disposal facilities, increased wastewater flow occasioned by a relaxing of water shortages, or some combination of these factors.

*Data reported from local official might be subject to confirmation. Results appear unusually high.

TABLE F-2

RECENT SUBSURFACE SEWAGE DISPOSAL DATA FROM OUTLYING COMMUNITIES[a]
1979 POPULATION OF COMMUNITIES OF UP TO 4,000

Item	Jureineh (1,228)			Teachers Housing (Marj el Haman) (0,500)			Hisban (1,226)			El'Al (1,683)			Ein el Basha (3,141)			Jubeiha (1,587)		
Community Visited (Population)																		
Overall Density, Persons/dunums																		
Conditions Disfavoring Cesspools[b]	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N
Rocky Soil		X			X			X			X			X		X		
Steep slopes		X				X		X			X				X	X		
Thin soil mantle		X			X				X			X			X		X	
Tight soils		X		X					X			X			X	X		
Small building lots		X		X					X			X		X			X	
Conditions experienced[c]																		
Cesspools overflowing	X					X		X			X			X			X	
Frequency of pumpouts (approx.)																		
Monthly																		
Quarterly																		
Semi-annually															X			
Annually																		
Greater than annually	X			X			X			X						X		
Costs of pumpouts, JD/yr																		
0-10	X			X			X			X								
10-100													X					
100-200																X		
200-300																		
Over 300																		
Future Outlook for Cesspools[d]																		
No change from present		X		X			X			X			X			X		
Eventual worsening				X				X			X			X				
Imminent worsening								X			X			X		X		

TABLE F-2 (Cont'd)

Item	Talbieh Camp (3,949)			Khirbet Suq (3,568)			Juweideh (3,014)			Muwaqqar (1,399)			Um el Basatin (1,512)			Rawda (1,000)		
Community Visited (Population)																		
Overall Density, Persons/dunums																		
Conditions Disfavoring Cesspools[b]	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N
Rocky soil		X		X			X				X		X			X		
Steep slopes		X			X		X						X			X		
Thin soil mantle	X				X		X				X			X			X	
Tight soils	X				X			X			X			X			X	
Small building lots	X				X			X			X			X			X	
Conditions experienced[c]																		
Cesspools overflowing	X			X			X											
Frequency of pumpouts (approx.)																		
Monthly																		
Quarterly		X																
Semi-annually		X																
Annually																		
Greater than annually				X			X				X		X			X		
Cost of pumpouts, JD/yr																		
0-10				X			X			X			X			X		
10-100	X																	
100-200																		
200-300																		
Over 300																		
Future Outlook for Cesspools[d]																		
No change from present				X			X				X		X			X		
Eventual worsening								X										
Imminent worsening																		

TABLE F-2 (Cont'd)

Item	Mahis (3,892)			Safut (1,097)			Officers Housing Scheme Marj el Hamam (1,120)			Alia Housing (Not occupied yet)
Community Visited (Population)										
Overall Density, Persons/dunums										
Conditions Disfavoring Cesspools[b]	M	S	N	M	S	N	M	S	N	
Rocky soil		X			X				X	
Steep slopes	X				X				X	
Thin soil mantle		X				X			X	
Tight soils			X			X		X		
Small building lots		X				X	X			
Conditions experienced[c]										
Cesspools overflowing	X					X			X	
Frequency of pumpouts (approx.)										
Monthly										
Quarterly	X									
Semi-annually										
Annually										
Greater than annually					X			X		
Costs of pumpouts, JD/yr										
0-10										
10-100	X				X			X		
100-200										
200-300										
Over 300										
Future Outlook for Cesspools[d]										
No change from present		X		X				X		
Eventual worsening	X					X		X		
Imminent worsening		X				X		X		
							New location			

TABLE F-2 (Cont'd)

[a] All of the communities visited during summer and autumn, 1980 were without sewer service and relied upon cesspool installations for subsurface sewage. All data shown except census data must be considered as approximate.

[b] Data breakdown is according to approximate residence, viz: M denotes many, S denotes some, and N denotes negligible or none.

[c] Where adverse conditions exist for subsurface disposal, it is normal for many overflowing cesspools to be reported or else fairly frequent (and costly) cesspool pumpouts to be required.

[d] Worsening of conditions may be attributed to saturating the subsoil, inability to provide additional on-site disposal facilities, increased wastewater flow occasioned by a relaxing of water shortages, or some combination of these factors.

[e] Results as reported by local official appear unusually high. Should be confirmed.

TABLE F-3

RECENT SUBSURFACE SEWAGE DISPOSAL DATA FROM OUTLYING COMMUNITIES[a]
1979 POPULATION OF COMMUNITIES BETWEEN 5 AND 14,000

Item	Abu Alanda (4,202)			Queismeh (8,500)			Sahab (11,908)			Sukhneh (4,387)			Fuheis (5,215)			Hashimiya (4,179)			Na'ur (5,199)			Taibeh/Qaisiy (4,894)		
Community Visited (Population)																								
Overall Density, Persons/dunums																								
Conditions Disfavoring Cesspools[b]	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N	M	S	N
Rocky Soil	X			X					X			X	X			X				X				X
Steep slopes	X			X					X			X	X				X		X				X	
Thin soil mantle		X		X					X			X	X					X		X				X
Tight soils			X		X				X			X		X				X		X				X
Small building lots		X		X				X				X		X			X			X		X		
Conditions experienced[c]																								
Cesspools overflowing		X			X			X				X		X				X		X			X	
Frequency of pumpouts (approx.)																								
Monthly																								
Quarterly	X																							
Semi-annually				X									X						X					
Annually																								
Greater than annually							X			X						X						X		
Costs of pumpouts, JD/yr																								
0-10							X			X			X			X						X		
10-100	X			X															X					
100-200																								
200-300																								
Over 300																								
Future Outlook for Cesspools[d]																								
No change from present	X			X			X			X			X			X			X			X		
Eventual worsening	X			X				X				X		X				X	X				X	
Imminent worsening			X	X					X			X			X			X			X			

TABLE F-3 (Cont'd)

[a] All of the communities visited during summer and autumn, 1980 were without sewer service and relied upon cesspool installations for subsurface sewage. All data shown except census data must be considered as approximate.

[b] Data breakdown is according to approximate residence, viz: M denotes many, S denotes some, and N denotes negligible or none.

[c] Where adverse conditions exist for subsurface disposal, it is normal for many overflowing cesspools to be reported or else fairly frequent (and costly) cesspool pumpouts to be required.

[d] Worsening of conditions may be attributed to saturating the subsoil, inability to provide additional on-site disposal facilities, increased wastewater flow occasioned by a relaxing of water shortages, or some combination of these factors.

TABLE F-4

RECENT SUBSURFACE SEWAGE DISPOSAL DATA FROM OUTLYING COMMUNITIES[a]
1979 POPULATION OF COMMUNITIES BETWEEN 15 AND 24,000

Item	Suweileh (21,442)		
	M	S	N
Community Visited (Population)			
Overall Density, Persons/dunums			
Conditions Disfavoring Cesspools[b]			
Rocky Soil	X		
Steep Slopes	X		
Thin soil mantle		X	
Tight soils	X		
Small building lots	X		
Conditions experienced[c]			
Cesspools overflowing	X		
Frequency of pumpouts (approx.)			
Monthly			
Quarterly	X		
Semi-annually			
Annually			
Greater than annually			
Costs of pumpouts, JD/yr			
0-10			
10-100			
100-200	X		
200-300			
Over 300			
Future Outlook for Cesspools[d]			
No change from present			X
Eventual worsening	X		
Imminent worsening		X	

TABLE F-4 (Cont'd)

[a] All of the communities visited during summer and autumn, 1980 were without sewer service and relied upon cesspool installations for subsurface sewage. All data shown except census data must be considered as appropriate.

[b] Data breakdown is according to approximate residence, viz: M denotes many, S denotes some, and N denotes negligible or none.

[c] Where adverse condition exist for subsurface disposal, it is normal for many overflowing cesspools to be reported or else fairly frequent (and costly) cesspool pumpouts to be required.

[d] Worsening of conditions may be attributed to saturating the subsoil, inability to provide additional on-site disposal facilities, increased wastewater flow occasioned by a relaxing of water shortages, or some combination of these factors.

TABLE F-5

RECENT SUBSURFACE SEWAGE DISPOSAL DATA FROM OUTLYING COMMUNITIES[a]
1979 POPULATION OF COMMUNITIES BETWEEN 25 AND 34,000

Item	Schneller Camp (24,229)			Madaba (28,509)			Wadi es Sir (24,497)		
Community Visited (Population)									
Overall Density, Persons/dunums									
Conditions Disfavoring Cesspools[b]	M	S	N	M	S	N	M	S	N
Rocky Soil	X					X		X	
Steep Slopes		X				X	X		
Thin soil mantle	X					X	X		
Tight soils		X				X		X	
Small building lots	X				X		X		
Conditions experienced[c]									
Cesspools overflowing			X			X	X		
Frequency of pumpouts (approx.)									
Monthly							X		
Quarterly									
Semi-annually				X					
Annually									
Greater than annually									
Costs of pumpouts, JD/yr									
0-10									
10-100				X					
100-200									
200-300									
Over 300							X		
Future Outlook for Cesspools[d]									
No Change from present	X			X					X
Eventual worsening	X				X		X		
Imminent worsening	X					X	X		

TABLE F-5 (Cont'd)

[a] All of the communities visited during summer and autumn, 1980, were without sewer service and relied upon cesspool installations for subsurface sewage. All data shown except census data must be considered as appropriate.

[b] Data breakdown is according to approximate residence, viz: M denotes many, S denotes some, and N denotes negligible or none.

[c] Where adverse conditions exist for subsurface disposal, it is normal for many overflowing cesspools to be reported or else fairly frequent (and costly) cesspool pumpouts to be required.

[d] Worsening of conditions may be attributed to saturating the subsoil, inability to provide additional on-site disposal facilities, increased wastewater flow occasioned by a relaxing of water shortages, or some combination of these factors.

TABLE F-6

RECENT SUBSURFACE SEWAGE DATA FROM OUTLYING COMMUNITIES[a]
1979 POPULATION OF COMMUNITIES FROM 45,000 AND OVER

Item	Baqa'a Camp (45,291)			Ruseifa (49,622)		
Community Visited (Population)						
Overall Density, Persons/dunum						
Conditions Disfavoring Cesspools[b]	M	S	N	M	S	N
Rocky Soil			X	X		
Steep Slopes			X	X		
Thin soil mantle			X	X		
Tight soils		X			X	
Small building lots	X				X	
Conditions experienced[c]						
Cesspools overflowing	X				X	
Frequency of pumpouts (approx.)						
Monthly						
Quarterly	X			X		
Semi-annually						
Annually						
Greater than annually						
Costs of pumpouts, JD/yr						
0-10						
10-100	X			X		
100-200						
200-300						
Over 300						
Future Outlook for Cesspools[d]						
No change from present	X			X		
Eventual worsening	X				X	
Imminent worsening	X					X

TABLE F-6 (Cont'd)

[a] All of the communities visited during summer and autumn, 1980, were without sewer service and relied upon cesspool installations for subsurface sewage. All data shown except census data must be considered as appropriate.

[b] Data breakdown is according to approximate residence, viz: M denotes many, S denotes some, and N denotes negligible or none.

[c] Where adverse conditions exist for subsurface disposal, it is normal for many overflowing cesspools to be reported or else fairly frequent (and costly) cesspool pumpouts to be required.

[d] Worsening of conditions may be attributed to saturating the subsoil, inability to provide additional on-site disposal facilities, increased wastewater flow occasioned by a relaxing of water shortages, or some combination of these factors.

GREATER AMMAN WASTEWATER DISPOSAL PROJECT

COMMUNITY SANITATION RECONNAISSANCE

Community Na'ur Date of Visit _____ By Y.A. Kammash

Community Official Mr. Ishaq (Isac) Title Lord Mayor

1. Sanitation Conditions (Including Location)

	Many	A Few	None
a. Overflowing Cesspools		X	
b. Septage Truck Spills			X
c. Lack of Flush Toilets	X		
d. Sink Drainage to Ground	X in midtown		
e. Epidemics Experienced			X

2. Problems of the Poor — Explanation

a. Locations of Poorest People: Generally same class

b. Same Locations as in 1.? _____

c. Most Serious Problems? _____

(1) No Good Sewerage? _____

(2) Not Enough Water? _____

(3) Other? _____

3. Cost of Cesspool Pumpout

Frequency/Area	Cost, JD
Average twice/yr	50/yr

4. Areas Likely to Develop

Location	Reason
High areas west of town are being developed rapidly.	

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Greater Amman Wastewater Disposal Project Cont'd Na'ur

5. Employment Patterns

Employment Patterns	Location of Jobs	Types of Jobs
Farm labor	in town	
Construction	in town	labor
Employees	Amman	Govt.

6. Drinking Water Wells

		Explanation
a. Near Septic Tanks-Cesspools?		None
b. Affected by Sewage Disposal?		None

7. Seasonal Population Influx

	Many	Some	Negligible None
a. Vacationers	X		
b. Students			X
c. Tourists			X
d. Migrant Workers		X	
e. Others			

8. Seasonal Population Drop

	Many	Some	Negligible None
a. Migrant Workers		X	
b. Students			X
c. Military			
d. Other			

9. Water Supply Planning

	Explanation
a. Need for Additional Supply?	Gets water from Qastal
b. What Additional Supply is Coming?	—

10. Areas Without Sanitation Problems

Explanation

None

Greater Amman Wastewater Disposal Project Cont'd Na'ur

11. Conditions Unfavorable for Subsurface Sewage Disposal	Explanation
a. Rocky Soil?	X
b. Steep Slopes?	X
c. Thin Soil Mantle?	
d. Tight Soils?	X
e. Building Lots Too Small?	

12. Outlook for Subsurface Disposal	Explanation
a. Good Conditions, Several Years?	Not good
b. Likely to Worsen Soon?	Yes

13. Effect of Plentiful Water	Explanation
a. Upon Local Sanitation?	increases problem
b. Upon Personal Hygiene?	improves

14. Potential Benefits to Public	Explanation
a. If Adequate Water Provided?	Both equally useful
b. If Public Sewers Provided?	Both equally useful

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GREATER AMMAN WASTEWATER DISPOSAL PROJECT

COMMUNITY SANITATION RECONNAISSANCE

Community Fuheis Date of Visit _____ By Y.A. Kammash

Community Official _____ Title Lord Mayor

1. Sanitation Conditions (Including Location)

	Many	A Few	None
a. Overflowing Cesspools		X	
b. Septage Truck Spills			X
c. Lack of Flush Toilets	Some houses equipped- some none		
d. Sink Drainage to Ground	Connected to septic tanks		
e. Epidemics Experienced	None		

2. Problems of the Poor — Explanation

a. Locations of Poorest People: Just about same class people

b. Same Locations as in 1.? _____

c. Most Serious Problems? _____

(1) No Good Sewerage? All no good sewerage

(2) Not Enough Water? _____

(3) Other? _____

3. Cost of Cesspool Pumpout

Frequency/Area	Cost, JD
Average twice/yr	40/yr

4. Areas Likely to Develop

Location	Reason
All areas except east side where the cement factory is located.	

Nearby cement factory caused pollution to a spring.

Cement factory will have its treatment plant to improve industrial liquid waste

Greater Amman Wastewater Disposal Project Cont'd Fuheis

5. Employment Patterns

Employment Patterns	Location of Jobs	Types of Jobs
Worker	Cement Factory	
Farmers	in village	
Employment	in Amman	in Government

6. Drinking Water Wells

	Explanation
a. Near Septic Tanks-Cesspools?	None
b. Affected by Sewage Disposal?	None

7. Seasonal Population Influx

	Many	Some	Negligible None
a. Vacationers	X		
b. Students			X
c. Tourists			X
d. Migrant Workers		X	
e. Others			

8. Seasonal Population Drop

	Many	Some	Negligible None
a. Migrant Workers		X	
b. Students			X
c. Military			
d. Other			

9. Water Supply Planning

	Explanation
a. Need for Additional Supply?	Yes
b. What Additional Supply is Coming?	Planning to add more water from nearby Azrak spring

10. Areas Without Sanitation Problems

Explanation

Nil

Greater Amman Wastewater Disposal Project Cont'd Fuheis

11. Conditions Unfavorable for Subsurface Sewage Disposal — Explanation

a. Rocky Soil? X

b. Steep Slopes? X

c. Thin Soil Mantle?

d. Tight Soils? X

e. Building Lots Too Small? X in midtown

12. Outlook for Subsurface Disposal — Explanation

a. Good Conditions, Several Years? No

b. Likely to Worsen Soon? Yes

13. Effect of Plentiful Water — Explanation

a. Upon Local Sanitation? Increase sanitation problem

b. Upon Personal Hygiene? Improves hygiene

14. Potential Benefits to Public — Explanation

a. If Adequate Water Provided? Both needed

b. If Public Sewers Provided? Both needed

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Amman - Jordan
Tel. : 61251
P.O.B. : 8180
Cable : CENTER

C.E.C

مركز الاستشارات الهندسية
عمان - الاردن
تلفون : ٦١٢٥١
ص.ب : ٨١٨٠
برقياً : سنتر

Date November 17, 1980 Ref. P/19/2342 الاشارة ..... التاريخ .....

Mr. C.H. Lawrance, Project Manager
James M. Montgomery
Consulting Engineers Inc.
Amman.

Dear Mr. Lawrance,

Subject: Structural Modification of the Secondary Sedimentation Tanks-Ain Ghazal Treatment Plant

Per your request, the following report is submitted as an assessment of the structural feasibility of converting the existing "double decker' sedimentation tanks to deep type tanks by eliminating the existing middle slab We understand that this is essential for the efficient removal of solids.

To establish if the middle slab provided any structural functions in the existing design, an attempt has been made to locate the structural drawings. Unfortunately we were not successful. Nevertheless, we feel that there are two alternatives that can be utilized to fulfill the needed modifications. These are:

1- Building up the existing walls to enough thickness to stand the hydraulic load, once the middle slab is removed. And construction of reinforced beams at the top to tie up the walls together. These beams should be tied up by perpendicular horizontal beams at specified intervals.

2- Knocking down middle slab only partially (i.e., leaving a slab, beam about .5 meters wide every 2 meters. The to-be beams will be tapered off the center to minimize accumulation of sediments.

At any rate the design criteria will be such that any tank be empty at one time while the adjacent tanks are full. The sketches on the attached sheets illustrate the two alternatives described above. We would like to emphasize that the walls will not sit as cantilevers under any circumstances.

Hoping this will meet your satisfaction.

Very truly yours,

A.A. Sajdi

~~Aziz~~ Abdo Sajdi
Director

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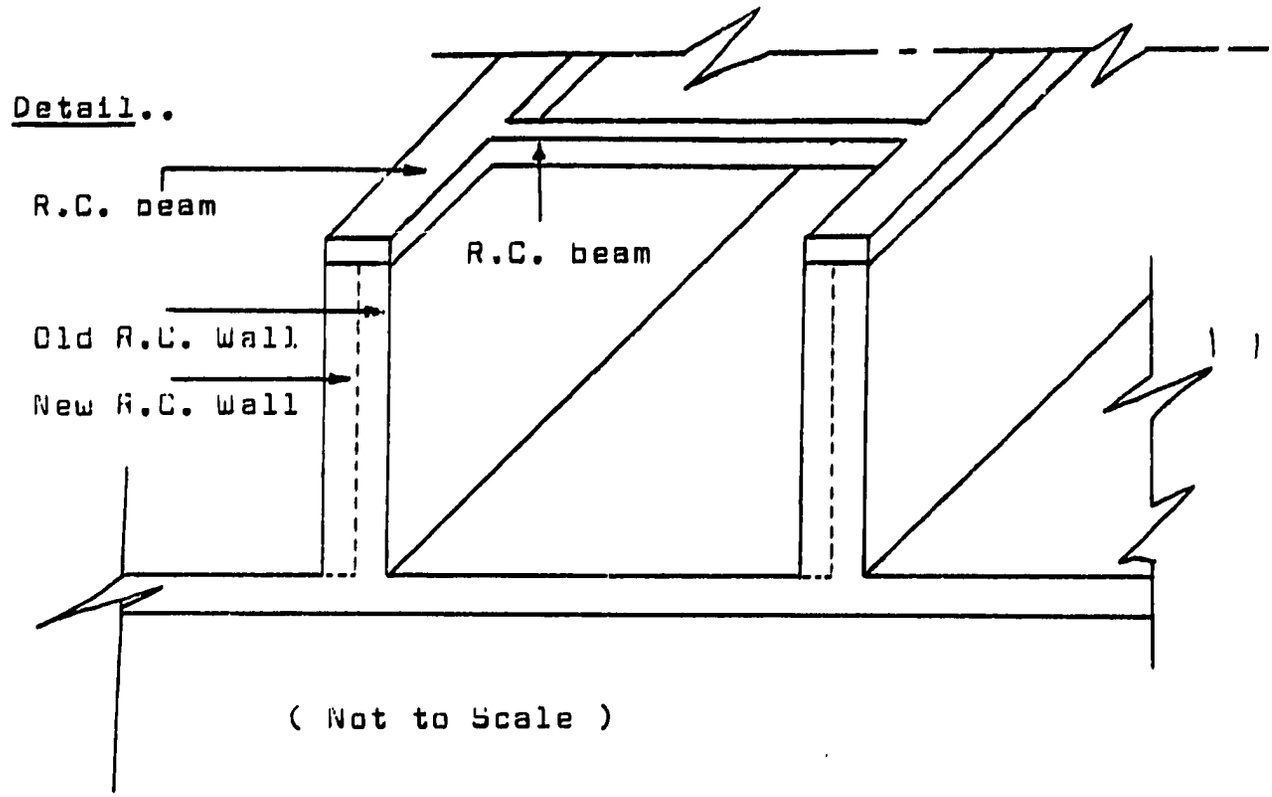
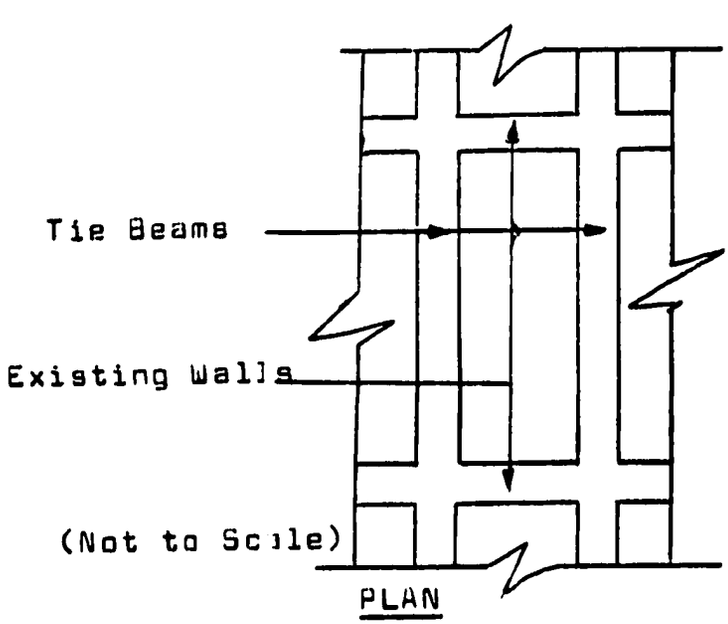
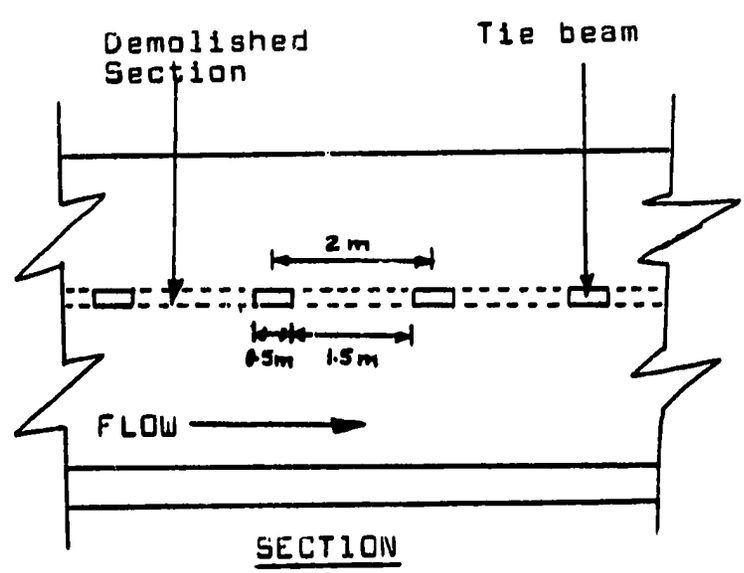
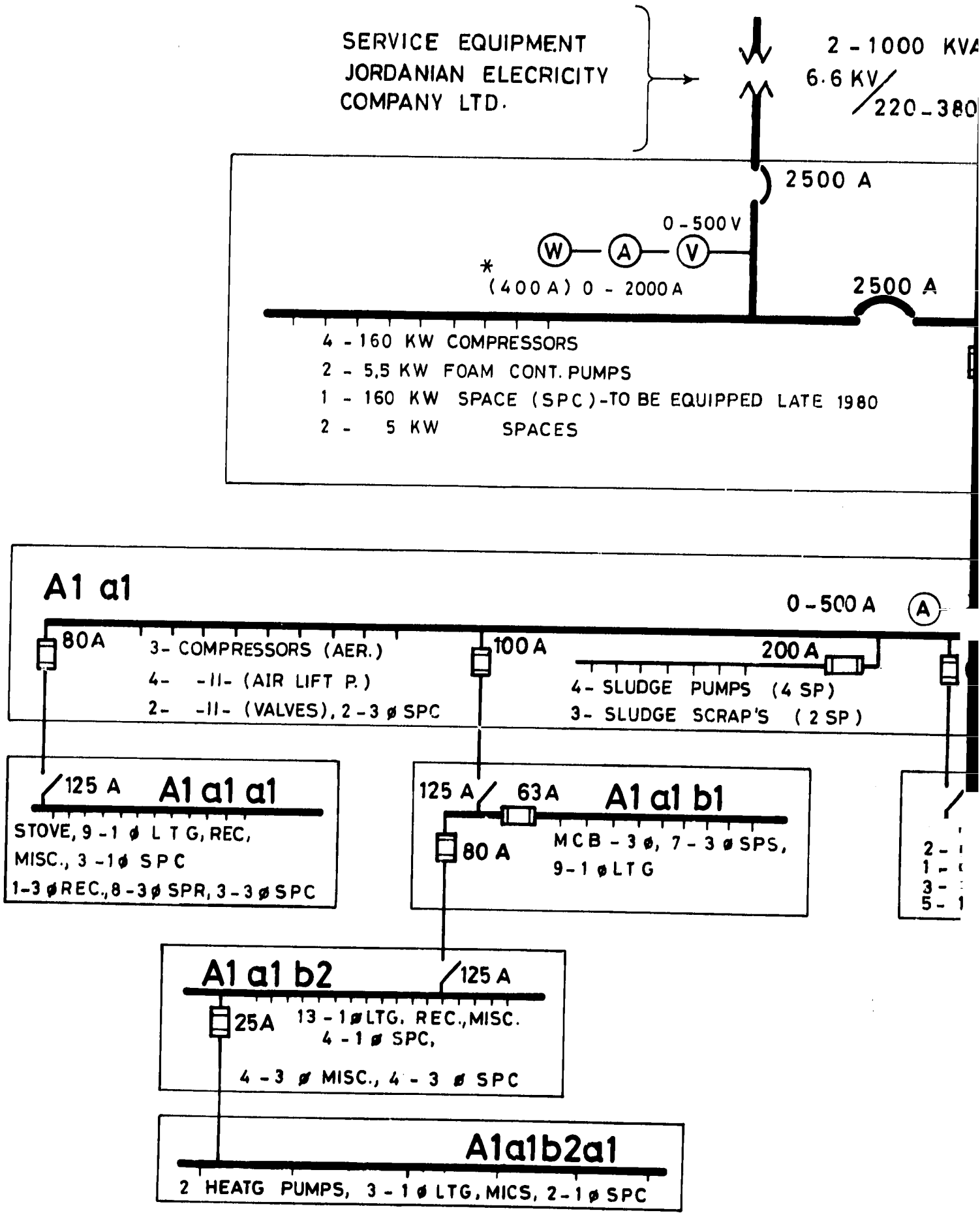
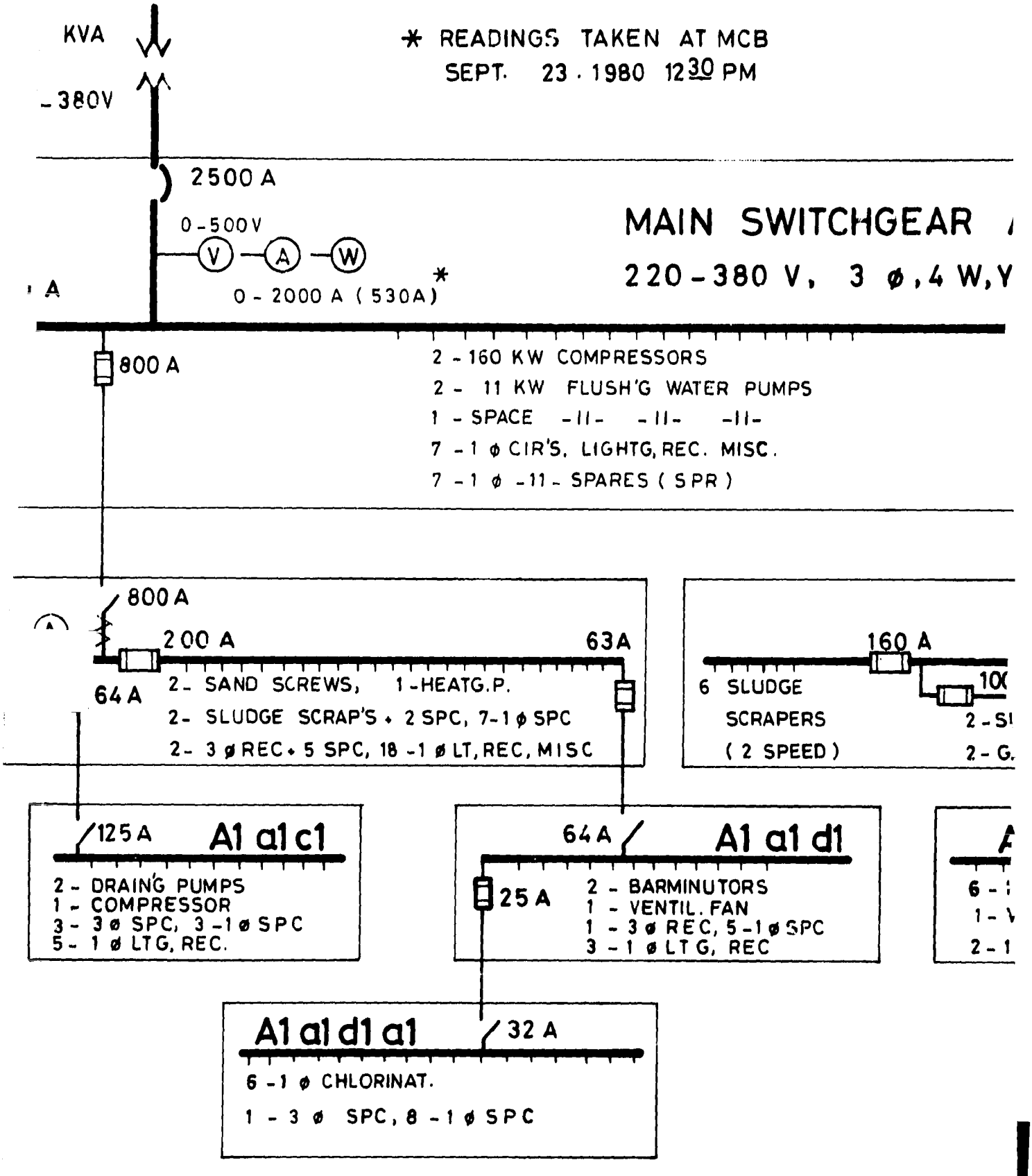

Detail..
R.C. beam
R.C. beam
Old R.C. Wall
New R.C. Wall
(Not to Scale)

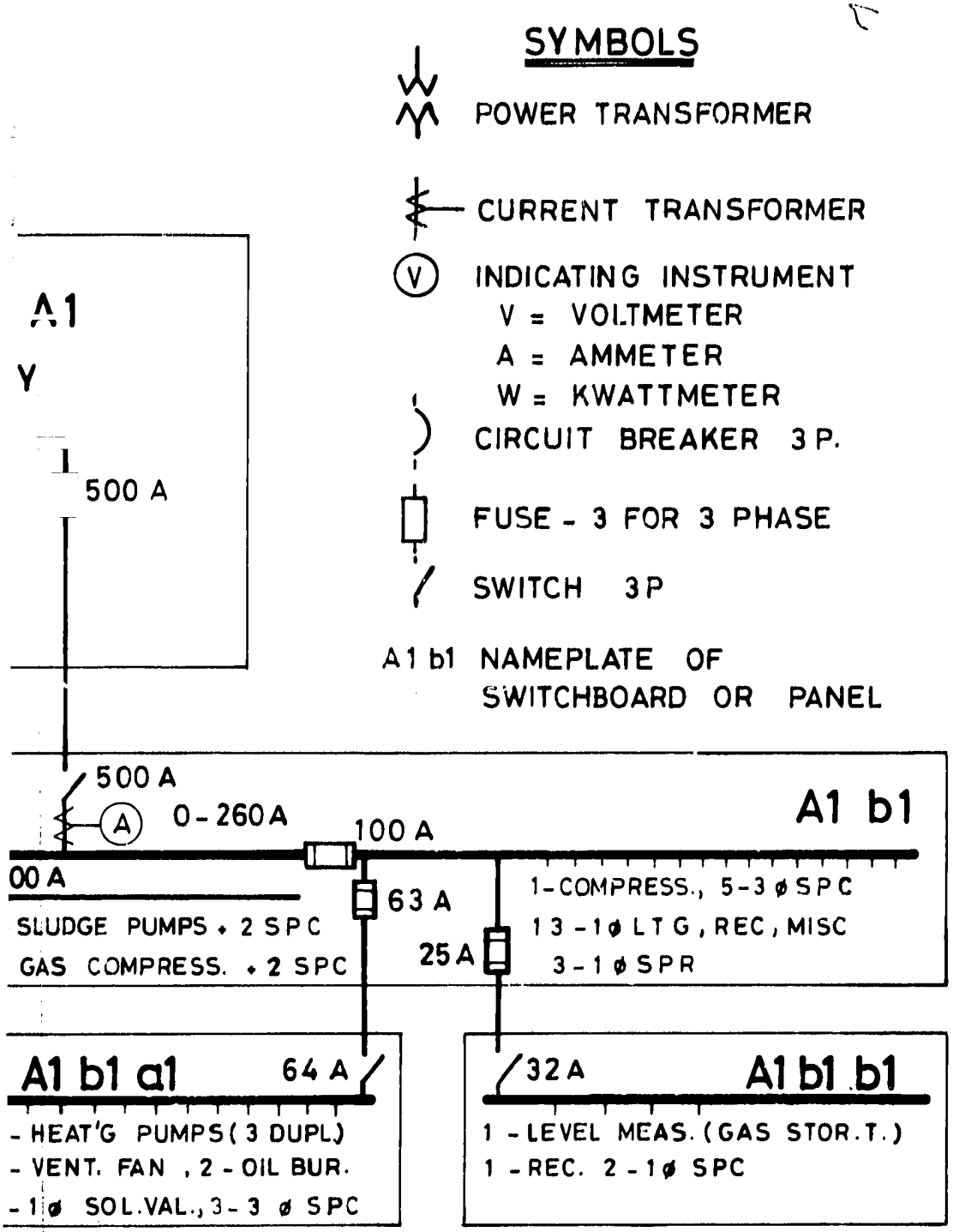

Tie Beams
Existing Walls
(Not to Scale)
PLAN


Demolished Section
Tie beam
2 m
0.5m
1.5m
FLOW
SECTION

193


SERVICE EQUIPMENT
JORDANIAN ELECRICITY
COMPANY LTD.
2 - 1000 KVA
6.6 KV/220-380
2500 A
0 - 500 V
W
A
V
*
(400 A) 0 - 2000 A
2500 A
4 - 160 KW COMPRESSORS
2 - 5,5 KW FOAM CONT. PUMPS
1 - 160 KW SPACE (SPC)-TO BE EQUIPPED LATE 1980
2 - 5 KW SPACES
A1 a1
0 - 500 A
A
80A
3- COMPRESSORS (AER.)
4- -II- (AIR LIFT P.)
2- -II- (VALVES), 2 - 3 ø SPC
100 A
200 A
4- SLUDGE PUMPS (4 SP)
3- SLUDGE SCRAP'S (2 SP)
125 A
A1 a1 a1
STOVE, 9 - 1 ø L T G, REC,
MISC., 3 - 1ø S P C
1-3 ø REC., 8 - 3 ø SPR, 3 - 3 ø SPC
125 A
63A
A1 a1 b1
80 A
MCB - 3 ø, 7 - 3 ø SPS,
9 - 1 ø LTG
A1 a1 b2
125 A
25A
13 - 1 ø LTG. REC., MISC.
4 - 1 ø SPC,
4 - 3 ø MISC., 4 - 3 ø SPC
A1a1b2a1
2 HEATG PUMPS, 3 - 1 ø LTG, MICS, 2 - 1 ø SPC


KVA
-380V
* READINGS TAKEN AT MCB
SEPT. 23 . 1980 12 30 PM
2500 A
0-500V
V
A
W
0 - 2000 A (530A)
MAIN SWITCHGEAR
220-380 V, 3 ø, 4 W, Y
800 A
2 - 160 KW COMPRESSORS
2 - 11 KW FLUSH'G WATER PUMPS
1 - SPACE -11- -11- -11-
7 - 1 ø CIR'S, LIGHTG, REC. MISC.
7 - 1 ø -11- SPARES (SPR)
800 A
200 A
63A
64 A
2- SAND SCREWS, 1-HEATG.P.
2- SLUDGE SCRAP'S + 2 SPC, 7-1 ø SPC
2- 3 ø REC + 5 SPC, 18 -1 ø LT, REC, MISC
160 A
6 SLUDGE SCRAPERS (2 SPEED)
125 A
A1 a1 c1
2 - DRAING PUMPS
1 - COMPRESSOR
3 - 3 ø SPC, 3 -1 ø SPC
5 - 1 ø LTG, REC.
64 A
A1 a1 d1
25 A
2 - BARMINUTORS
1 - VENTIL. FAN
1 - 3 ø REC, 5 -1 ø SPC
3 - 1 ø LTG, REC
A1 a1 d1 a1
32 A
6 -1 ø CHLORINAT.
1 - 3 ø SPC, 8 -1 ø SPC

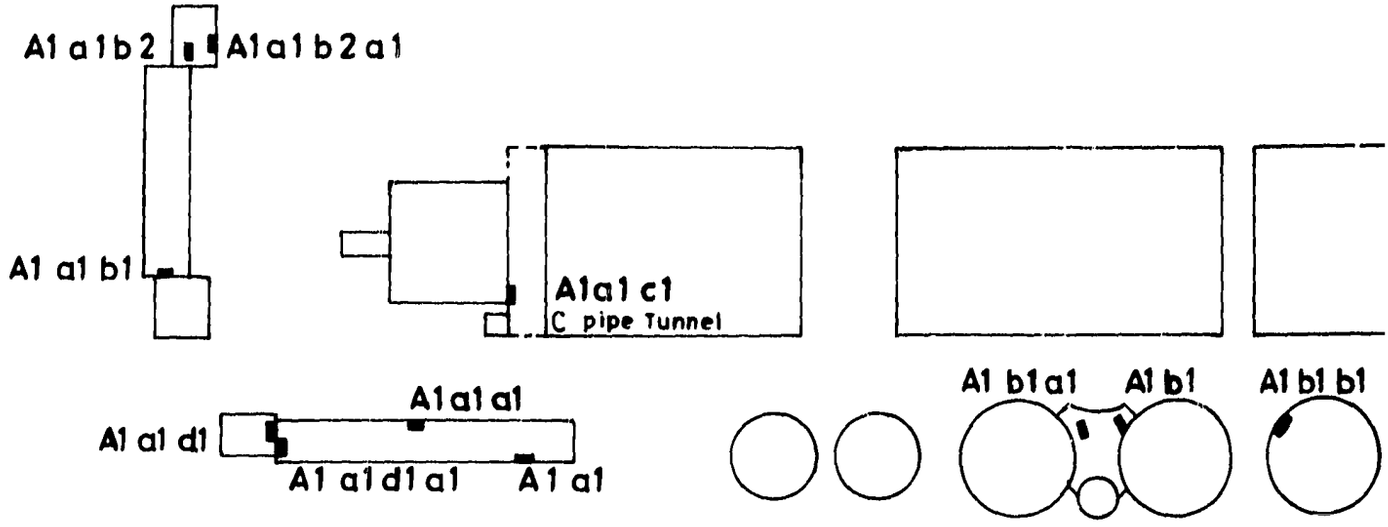


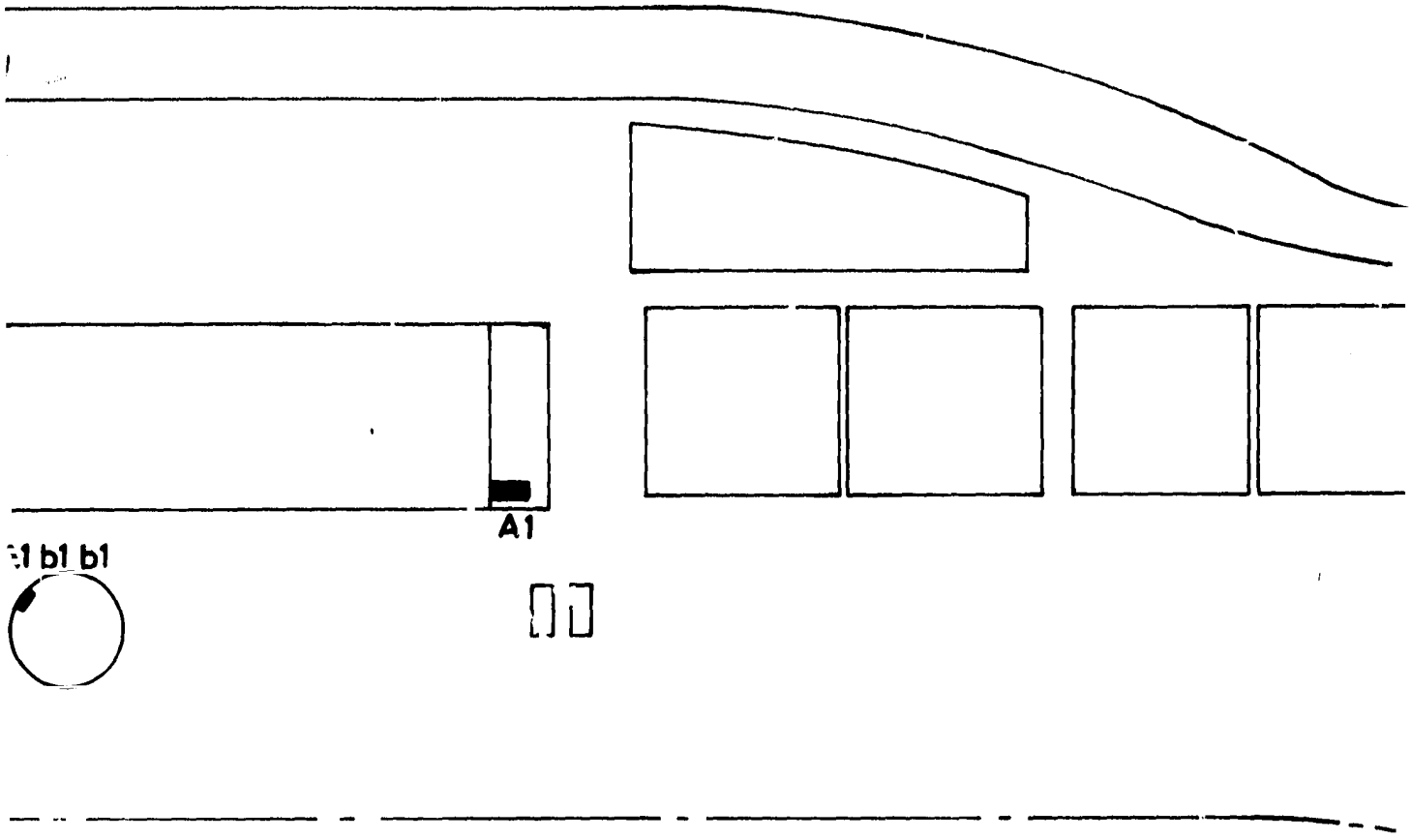
AIN GHAZAL TREATMENT PLANT

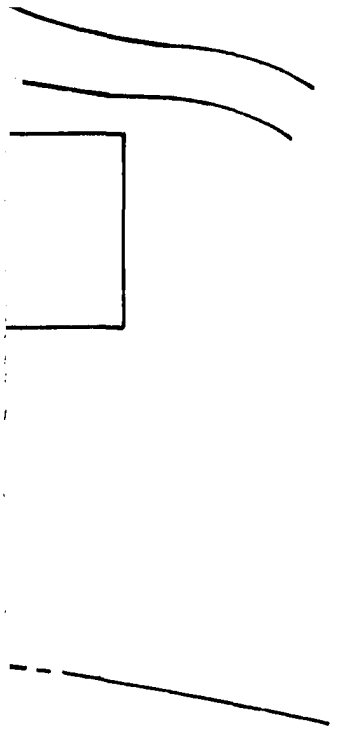
ELECTRICAL DISTRIBUTION SINGLE LINE DIAGRAM

EXISTING CONDITIONS 1980

FIGURE G2-1


A1 a1 b2
A1a1 b2 a1
A1 a1 b1
A1a1 c1
C pipe Tunnel
A1 a1 d1
A1a1 a1
A1 a1d1 a1
A1 a1
A1 b1a1
A1 b1
A1 b1 b1


A1
:1 b1 b1



AIN GHAZAL TREATMENT PLANT
ELECTRICAL DISTRIBUTION
EXISTING CONDITIONS 1980

FIGURE G2 - 2

795b

APPENDIX H1

WATER QUALITY DATA

Information will become available upon compilation of sampling data from Royal Scientific Society regarding Seil Zarga and King Talal Reservoir.

APPENDIX H2

Water reclamation potentials for the Greater Amman Area that may be considered are:

- Landscape irrigation
- Recreational impoundment
- Agricultural irrigation
- Body contact recreation and spray irrigation
- Industrial applications

The primary quality criteria listed hereinunder are those of the California State Department of Health.

LANDSCAPE IRRIGATION

Table H2.1 presents California State Department of Health reuse criteria for landscape irrigation. Because of the critical shortages of water in Jordan, it is doubtful that much priority can be given to developing large-scale landscape irrigation works. There is very little public urban area devoted to parks or other areas planted to grass and for shrubs. Few private homes have these amenities either. It has not been customary in water-short Jordan to do so. Even if there already were parks, golf courses, cemeteries, and freeway landscaping in existence, it is not always economical to substitute reclaimed water for potable water for their irrigation as has been demonstrated in a recent comprehensive study in Orange and Los Angeles Counties in Southern California.[1] It was found that favorable circumstances regarding convenient clustering of potential users had to be present to make such a water reuse application economically attractive.

Landscape irrigation results in the consumptive use via evapotranspiration of a large portion of the applied water. In view of water shortages, it is questionable whether much of this can be afforded in Jordan. Nevertheless, there will be a need for more public amenities, particularly in Amman, as Development continues. Thus, in isolated instances, landscape irrigation may become a factor in the long-range future. Hence, criteria in Table H2-1 are presented.

TABLE H2-1

CALIFORNIA STATE DEPARTMENT OF HEALTH

REUSE CRITERIA FOR LANDSCAPE IRRIGATION[2,3]

Reuse	Required Treatment[a]	Allowable Coliforms[b] (MPN/100 ml)
Golf courses, cemeteries freeway landscaping and landscaping	Bio-oxidation, disinfection	23[c]
Parks, playgrounds, and schoolyards	Bio-oxidation, coagulation/ clarification, filtration, disinfection	2.2[d]

[a]Primary effluent must not contain more than 0.5 milliliters per liter per hour of settleable solids. Filtration must provide an effluent with a turbidity that does not exceed an average of 2 turbidity units and does not exceed a maximum of 5 turbidity units. Alternative methods of treatment may be accepted if the applicant demonstrates to the satisfaction of SDH that they will assure an equal degree of treatment and reliability.

[b]Median as determined from results of last 7 days for which analyses have been completed.

[c]Shall not exceed 240 MPN/100 ml in two consecutive samples.

[d]Shall not exceed 23 MPn/100 ml in any sample.

RECREATIONAL IMPOUNDMENTS

Table H2-2 presents California State Department of Health criteria for recreational impoundments. There are no recreational impoundments within the Greater Amman Area, yet this type of amenity is something that could be a public benefit in a large urban area such as Amman. There has already been discussion of a potential recreational impoundment at Wadi Abdoun, combining natural runoff and reclaimed wastewater.[4] A possible wastewater treatment plant in the Wadi Abdoun area has been discussed.[5] The Lord Mayor of Amman is very much interested in public amenities for the people of Amman, including the possibilities of a recreational impoundment at some suitable site.[6] Recreational impoundments do not of themselves consume much water by evapotranspiration. Potential reservoir sites exist in the hills southeast of Amman as well as in the Wadi Abdoun area. These might be investigated in greater detail as long-range prospects for recreational impoundments. Because of costs, possible projects would have to be carefully evaluated in the light of competing public priorities.

Table H2-2 presents California State Department of Health criteria for recreational impoundments. Table H2-3 presents existing standards governing the use of reclaimed water in agriculture. This table includes not only California State Department of Health but other international authorities as well.

If it were to be decided at some future time that one or more local recreational lakes might be public amenities that would be worth the costs of treatment and a modest loss of water from the system, then the experiences of the other agencies elsewhere should be of interest.

Santee Project In Santee, California, a semi-arid community inland from San Diego, a successful project was developed in a canyon in which natural sands and gravels had been excavated in a commercial enterprise.[7] The excavations were converted into a series of small lakes, the lowest of which served as an oxidation pond for municipal plant primary effluent (eventually for secondary effluent) with the upper lakes serving for multiple

TABLE H2-2

CALIFORNIA STATE DEPARTMENT OF HEALTH

REUSE CRITERIA FOR RECREATIONAL IMPOUNDMENTS [2,3]

Reuse	Required Treatment[a]	Allowable Coliforms[b] (MPN/100 ml)
Non-restricted access	Bio-oxidation, coagulation/ clarification, filtration, disinfection	2.2[c]
Restricted to non-body contact	Bio-oxidation, disinfection	2.2
Landscape-non-contact	Bio-oxidation, disinfection	23

[a]Primary effluent must not contain more than 0.5 milliliters per liter per hour of settleable solids. Filtration must provide an effluent with a turbidity that does not exceed an average of 2 turbidity units and does not exceed a maximum of 5 turbidity units. Alternative methods of treatment may be accepted if the applicant demonstrates to the satisfaction of SDH that they will assure an equal degree of treatment and reliability.

[b]Median as determined from results of last 7 days for which analyses have been completed.

[c]Shall not exceed 23 MPN/100 ml in more than one sample within any 30-day period.

use recreation. The oxidation pond effluent (3,400 m^3/da) was pumped to intermittent sand percolation beds ahead of the uppermost recreational lake, and the percolate surfaced as rising groundwater and was directed successively into the four recreational lakes, these averaging 3.3 ha in surface area and providing about 15 days total flow-through retention. The oxidation pond effluent was high in ammonium content (41 mg/l) and phosphate (31 mg/l), but the intermittent sand filtration effectively reduced the nitrogen, phosphorus, and chemical oxygen demand levels as well as bacterial and viral densities so that, with chlorination, the microorganism levels were well within acceptable limits and algal regrowth was not a problem. A popular public fishing program was developed, and it was determined (after extensive testing) that the fish grown in the lakes could be consumed without health concerns. Boating and aesthetic enjoyment are other recreational uses of the lakes. The water loss by evaporation from this system was probably in the order of 12 percent of the inflow.

Lancaster Project In the high desert community of Lancaster, California, municipal wastewater was given primary treatment followed by a large oxidation pond.[8] The primary effluent was high in phosphate, ammonia nitrogen, COD, and organic nitrogen, all of which supported the oxidation pond algae. The oxidation pond greatly reduced the bacterial and viral densities of the influent and stabilized the flow through oxidation. However, the phosphate and ammonia contents of the effluent were inversely proportional to the metabolic activity of the algae, which is highest during the summer and lowest during the winter.

Inasmuch as it was desired to use the effluent stream as makeup water for a proposed recreational lake pilot plant, experiments were conducted to determine the additional treatment necessary to provide low turbidity and phosphate levels suitable for the proposed recreational lake. As a result of these studies, the tertiary plant that was built and operates successfully comprises alum coagulation flocculation, sedimentation, dual media filtration, chlorination, and chlorine contact. This process clarifies the water less than 5JTU and reduces the total phosphate to a point below the algae regrowth threshhold level of 0.5 mg/l. The recreational lake, thus supplied is widely used by the public for boating, fishing, and aesthetic enjoyment.

AGRICULTURAL IRRIGATION

Table H2-3 presents California State Department of Health criteria for agricultural irrigation. Table H2-4 presents standards governing the use of reclaimed water in agriculture. This latter table includes not only California State Department of Health but other international authorities as well. Table H2-5 presents guidelines for interpretation of quality of water for irrigation.

With respect to both landscape and agricultural irrigation, it is important to consider the chemical parameters of the water that affect plant growth and survival, soil conditions, and the underlying ground water. The chemical parameters of major importance are salinity, sodium adsorption ratio (SAR) and the concentrations of specific ions known to have toxic effects on plants. These parameters interact with each other and with local conditions such as soil permeability, plant types and irrigation practices such that there is no absolute standard by which their combined effect can be evaluated. The University of California Cooperative Extension guidelines[9] presented in Table H2-5 do, however, provide a useful and widely accepted guide for evaluating the suitability of irrigation water and identifying areas of potential concern. The general significance of salinity, sodium adsorption ratio, specific ion toxicity, and trace constituents is discussed below.

Salinity

Salinity is a vital consideration for irrigation waters. If the salinity exceeds the level of tolerance for a specific plant, osmotic regulation by the root membrane will inhibit the adsorption of water. The plant will then dehydrate and wilt even though the soil shows an apparent excess of moisture.

The salinity of irrigation water is commonly reported in electrical conductivity units (EC) or total dissolved solids (TDS.) The reclaimed water source in the study area has a TDS of approximately 600-800 mg/l which corresponds

TABLE H2-3

CALIFORNIA STATE DEPARTMENT OF HEALTH

CRITERIA FOR AGRICULTURAL IRRIGATION [2,3]

Reuse	Required Treatment[a]	Allowable Coliforms[b] (MPN/100 ml)
Spray Irrigation of Food Crops	bio-oxidation, coagulation/ clarification, filtration, disinfection	2.2[c]
Surface Irrigation		
1) Food Crops	bio-oxidation, disinfection	2.2
2) Orchards, vineyards	primary effluent[d]	-
Fodder, Seed and Fiber Crops	primary effluent	-

[a]Primary effluent must not contain more than 0.5 ml/l/hr of settleable solids. Filtration must provide an effluent with a turbidity that does not exceed an average of 2 turbidity units and does not exceed a maximum of 5 turbidity units. Alternative methods of treatment may be acceptable if the applicant demonstrates to the satisfaction of SDH that it will assure an equal degree of treatment and reliability. Exceptions to quality requirements for irrigation of food crops may be considered by SDH where crop must undergo extensive commercial, physical or chemical processing sufficient to destroy pathogenic agents before it is suitable for human consumption.

[b]Median as determined from results of last seven days for which analyses have been completed.

[c]Shall not exceed 23 MPN/100 ml in more than one sample within any 3-day period.

[d]Provided no fruit is harvested that has come in contact with the irrigating water or the ground.

TABLE H2-4

EXISTING STANDARDS GOVERNING THE USE OF RECLAIMED WATER IN AGRICULTURE[a]

	California[b]	South Africa	Federal Republic of Germany
Orchards and vineyards	Primary effluent or better; no spray irrigation; no use of dropped fruit	Tertiary effluent, heavily chlorinated where possible. No spray irrigation.	No spray irrigation in the vicinity.
Fodder, fiber, and seed crops	Primary effluent; surface c. spray irrigation.	Tertiary effluent.	Pretreatment with screening and settling tanks. For spray irrigation, biological treatment and chlorination.
Crops for human consumption that will be processed to kill pathogens.	For surface irrigation, primary effluent. For spray irrigation, disinfected secondary effluent (no more than 2.2 coliform organisms per 100 ml).	Tertiary effluent.	Irrigation up to 4 weeks before harvesting only.
Crops for human consumption in a raw state	For surface irrigation, no more than 2.2 coliform organisms per 100 ml.		Potatoes and cereals—irrigation through flowering stage only.

TABLE H2-4 (Cont'd)

[a] Except for California, the standards are taken from the VBB report.[10]

[b] "California Department of Health Wastewater Reclamation Criteria."

TABLE H2-5

UC COOPERATIVE EXTENSION GUIDELINES FOR INTERPRETATION OF QUALITY OF WATER FOR IRRIGATION

Problems and Related Constituent	Water Quality Guidelines[a] No Problems	Increasing Problems	Severe
Salinity[b]			
EC of irrigation water, umo/cm	750	750-3,000	3,000
Permeability			
EC of irrigation water, umo/cm	500	500-2,000	2,000
SAR	6.0	6.0 - 9.0	9.0
Specific ion toxicity[d]			
From root adsorption			
Sodium (evaluate by SAR)	3	3 - 9	9
Chloride			
meq/l	4	4 - 10	10
mg/l	142	142-355	355
Boron	0.5	0.5 - 2.0	2.0-10.0
From foliar adsorption[e] (Sprinklers)			
Sodium			
meq/l	3.0	3.0	--
mg/l	69	69	--
Chloride			
meq/l	3.0	3.0	--
mg/l	106	106	--
Miscellaneous[f]			
NH_4 as N mg/l for sensitive crops	5	5 - 30	30
HCO_3 (only with overhead sprinklers)			
meq/l	1.5	1.5 - 8.5	8.5
mg/l	90	90 - 520	520
pH Normal range 6.5 - 8.4			--

[a]Interpretations are based on possible effects of constitutents on crops and/or soils. Guidelines are flexible and should be modified when warranted by local experience or special conditions of crop, soil, and method of irrigation.

[b]Assumes water for crop plus needed water for leaching requirement (LR) will be applied. Crops vary in tolerance to salinity. Refer to tables for crop tolerance and LR. The mho/cm x 0.64 = approximate total dissolved solids (TDS) in mg/l or ppm.

TABLE H2-5 (Cont'd)

[c]SAR (sodium adsorption ratio) is calculated from a modified equation developed by U.S. Salinity Laboratory to include added effects of precipitation and dissolution of calcium in soils and related to CO_3+ HCO_3 concentrations.

[d]Most tree crops and woody ornamentals are sensitive to sodium and chloride (use values shown.) Most annual crops are not sensitive (use salinity tolerance tables.) For boron sensitivity, refer to boron tolerance tables.

[e]Leaf areas wet by sprinklers (rotating heads) may show a leaf burn due to sodium or chloride adsorption under low humidity/high evaporation conditions. (Evaporation increases ion concentration in water films on leaves between rotations of sprinkler heads.)

[f]Excess N may affect production or quality of certain crops; e.g., sugar beets, citrus, avocados, apricots, etc. (1 mg/l NO_3 as N = 2.72 lbs. N/ac-ft of applied water.) HCO_3 with overhead sprinkler irrigation may cause a white carbonate deposit to form on fruit and leaves.

to an EC of around 1,500 micromhos(centimeters (mho/cm.) This level of salinity would be classified in the mid-range of values termed "increasing problems" in the U.S. Cooperative Extension Guidelines. The hazard of moderate salinity levels such as these can be operationally controlled by leaching. This washes salts below the root zone before toxic accumulations can occur.

Sodium Adsorption Ratio (SAR)

SAR is a criterion developed by the U.S. Salinity Laboratory for evaluating the sodium hazard in water. It measures the ratio of sodium to divalent magnesium and calcium cations in the soil and is calculated as follows:

Water Reclamation Regulations and Criteria

$$SAR = \sqrt{\frac{Na^{+}}{(Ca^{++} + Mg^{++})/2}}$$

(concentration in milliequivalents per liter)

In the proper ratio, calcium and magnesium in the soil indicate that the soil will be granular in texture, easily worked and permeable. With increasing proportions of sodium the soil will tend to become less permeable and water-logging may occur.

An adjusted equation for the SAR includes the effect of precipitation or dissolution of calcium in soils and the content of carbonate (CO_3) and bi-carbonate (HCO_3) alkalinity in the water.

Specific Ion Toxicity

Boron toxicity in many areas can be traced to the use of irrigation waters with a boron concentration in excess of 1 mg/1. At the present time there is no economically feasible method of removing boron from irrigation water. Similarly, there is no chemical or soil amendment which can economically be added to the soil to render it nontoxic. However, marginal problematic boron, like salinity concentrations, can be alleviated somewhat by irrigating slightly in excess of plant consumptive use. Overall, boron concentrations in wastewater may be influenced by use of cleaning compounds.

Chloride ions are known to have toxic effects on plants, particularly on woody perennial shrubs and fruit trees. Table H2-5 shows increasing problems of foliar deterioration and leaf scorching for chloride concentrations between 142 and 355 mg/l, if the ions are adsorbed by the roots, and for concentrations above 106 mg/l if spray irrigation is used and the ions adsorb to the leaves. While sodium may be beneficial to plants in small quantities, similar leaf scorch observations have been made for irrigation waters high in sodium. Adequate care should be exercised in potential reuse studies to prevent sodium toxicity problems.

Trace Elements

In addition to the major chemical quality requirements, numerous trace elements in reclaimed water may affect plant growth. Recommended maximum concentrations of various trace elements in irrigation water are presented in Table H2-6.[11]

BODY-CONTACT RECREATION AND SPRAY IRRIGATION MODES OF REUSE

The California Department of Health has issued criteria for irrigation and landscape or recreational impoundments. The Department has three levels of Health control criteria that cover water reclamation applications, and they cover the areas of treatment process, treatment reliability, and delivery system design, such as separation from potable distribution systems and provision of back flow prevention. For body-contact recreation and spray irrigation modes of reuse, the Department is particularly concerned about virus disease transmission and prescribes various secondary treatment, chemical coagulation, filtration, and disinfection criteria, based upon the so-called "Pomona Virus Study."[12] Inasmuch as these details are not likely to be of early application in Jordan, the criteria are not reproduced herein.

TABLE H2-6

RECOMMENDED MAXIMUM CONCENTRATIONS OF TRACE ELEMENTS IN IRRIGATION WATERS[11]

Element	Maximum Concentration[a] For Waters Used Continuously All Soil	For Use up to 20 Years on Fine Textured Solids of pH 6.0 to 8.5
Aluminum (Al)	5.0	20.0
Arsenic (As)	0.10	2.0
Beryllium (Be)	0.10	0.50
Boron (B)	0.75	0.05
Cadmium (Cd)	0.010	0.05
Chromium (Cr)	0.10	1.0
Cobalt (Co)	0.050	5.0
Copper (Cu)	0.20	5.0
Fluoride (F)	1.0	15.0
Iron (Fe)	5.0	20.0
Lead (Pb)	5.0	10.0
Lithium (Li)[b]	2.5	2.5
Manganese (Mn)	0.20	10.0
Molybdenum (Mo)	0.01	0.05[c]
Nickel (Ni)	0.20	2.0
Selenium (Se)	0.02	0.02
Vanadium (V)	0.10	1.0
Zinc (Zn)	2.0	10.0

[a]Expressed as milligrams per liter. These levels will normally not adversely affect plants or soils. No data available for mercury, silver, tin, titanium, tungsten.

[b]Recommended maximum concentration for irrigation of citrus is 0.075 mg/l.

[c]For only acid, fine textured soils or acid soils with relatively high iron oxide contents.

INDUSTRIAL APPLICATIONS

There is no comprehensive list of quality requirements for specific industrial applications. This is due in large part to the variation in water use applications from plant to plant or even within a single plant, for similar processes. There is no "typical" application. A second factor which handicaps attempts to place tolerance on limits of water constituents in industry may be tolerated is that the question is rarely addressed in practical operations. Industries for the most part utilize drinking quality water, with treatment utilized if a specific problem develops. Such treatment usually removes all or the majority of the offending constituent(s) and so a level of tolerance is never identified.

The widely published 1972 National Academy of Sciences Industrial Water Criteria values[11] often serve as a basis for quality evaluation. They are sometimes modified by more recent observations and experience. In the Greater Amman Area, there are no obvious industrial reuse applications evident. In the Los Angeles and Orange Counties, California, it was found recently that industrial demand for reclaimed water was largely for cooling but sometimes for process work in electroplating rinse tanks, paper making, carpet making and other "wet" industrial applications.[1] It would require a market survey and special feasibility studies in the Greater Amman Area to determine if such possibilities might exist in select areas in the future. This type of activity could be considered for future years.

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11. National Academy of Sciences and National Academy of Engineering Environmental Studies Board, "Water Quality Criteria," 1972.

12. Los Angeles County Sanitation Districts, "Pomona Virus Study, Final Report," A Technical Report by the Los Angeles County Sanitation Districts Submitted to the State Water Resources Control Board, June 1977.

APPENDIX H

WASTEWATER RECLAMATION CRITERIA

An Excerpt from the

CALIFORNIA ADMINISTRATIVE CODE
TITLE 22, DIVISION 4

ENVIRONMENTAL HEALTH

1975

STATE OF CALIFORNIA
DEPARTMENT OF HEALTH
Water Sanitation Section
2151 Berkeley Way, Berkeley 94704

INTENT OF REGULATIONS

The intent of these regulations is to establish acceptable levels of constituents of reclaimed water and to prescribe means for assurance of reliability in the production of reclaimed water in order to ensure that the use of reclaimed water for the specified purposes does not impose undue risks to health. The levels of constituents in combination with the means for assurance of reliability constitute reclamation criteria as defined in Section 13520 of the California Water Code.

As affirmed in Sections 13510 to 13512 of the California Water Code, water reclamation is in the best public interest and the policy of the State is to encourage reclamation. The reclamation criteria are intended to promote development of facilities which will assist in meeting water requirements of the State while assuring positive health protection. Appropriate surveillance and control of treatment facilities, distribution systems, and use areas must be provided in order to avoid health hazards. Precautions must be taken to avoid direct public contact with reclaimed waters which do not meet the standards specified in Article 5 for nonrestricted recreational impoundments.

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CHAPTER 4. RECLAMATION CRITERIA

Article 1. Definitions

60301. Definitions. (a) Reclaimed Water. Reclaimed water means water which, as a result of treatment of domestic wastewater, is suitable for a direct beneficial use or a controlled use that would not otherwise occur.

(b) Reclamation Plant. Reclamation plant means an arrangement of devices, structures, equipment, processes and controls which produce a reclaimed water suitable for the intended reuse.

(c) Regulatory Agency. Regulatory agency means the California Regional Water Quality Control Board in whose jurisdiction the reclamation plant is located.

(d) Direct Beneficial Use. Direct beneficial use means the use of reclaimed water which has been transported from the point of production to the point of use without an intervening discharge to waters of the State.

(e) Food Crops. Food crops mean any crops intended for human consumption.

(f) Spray Irrigation. Spray irrigation means application of reclaimed water to crops by spraying it from orifices in piping

(g) Surface Irrigation. Surface irrigation means application of reclaimed water by means other than spraying such that contact between the edible portion of any food crop and reclaimed water is prevented

(h) Restricted Recreational Impoundment. A restricted recreational impoundment is a body of reclaimed water in which recreation is limited to fishing, boating, and other non-body-contact water recreation activities.

(i) Nonrestricted Recreational Impoundment. A nonrestricted recreational impoundment is an impoundment of reclaimed water in which no limitations are imposed on body-contact water sport activities.

(j) Landscape Impoundment. A landscape impoundment is a body of reclaimed water which is used for aesthetic enjoyment or which otherwise serves a function not intended to include public contact

(k) Approved Laboratory Methods. Approved laboratory methods are those specified in the latest edition of "Standard Methods for the Examination of Water and Wastewater", prepared and published jointly by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation and which are conducted in laboratories approved by the State Department of Health.

(l) Unit Process. Unit process means an individual stage in the wastewater treatment sequence which performs a major single treatment operation.

(m) **Primary Effluent.** Primary effluent is the effluent from a wastewater treatment process which provides removal of sewage solids so that it contains not more than 0.5 milliliter per liter per hour of settleable solids as determined by an approved laboratory method.

(n) **Oxidized Wastewater.** Oxidized wastewater means wastewater in which the organic matter has been stabilized, is nonputrescible, and contains dissolved oxygen.

(o) **Biological Treatment.** Biological treatment means methods of wastewater treatment in which bacterial or biochemical action is intensified as a means of producing an oxidized wastewater.

(p) **Secondary Sedimentation.** Secondary sedimentation means the removal by gravity of settleable solids remaining in the effluent after the biological treatment process.

(q) **Coagulated Wastewater.** Coagulated wastewater means oxidized wastewater in which colloidal and finely divided suspended matter have been destabilized and agglomerated by the addition of suitable floc-forming chemicals or by an equally effective method.

(r) **Filtered Wastewater.** Filtered wastewater means an oxidized, coagulated, clarified wastewater which has been passed through natural undisturbed soils or filter media, such as sand or diatomaceous earth, so that the turbidity as determined by an approved laboratory method does not exceed an average operating turbidity of 2 turbidity units and does not exceed 5 turbidity units more than 5 percent of the time during any 24-hour period.

(s) **Disinfected Wastewater.** Disinfected wastewater means wastewater in which the pathogenic organisms have been destroyed by chemical, physical or biological means.

(t) **Multiple Units.** Multiple units means two or more units of a treatment process which operate in parallel and serve the same function.

(u) **Standby Unit Process.** A standby unit process is an alternate unit process or an equivalent alternative process which is maintained in operable condition and which is capable of providing comparable treatment for the entire design flow of the unit for which it is a substitute.

(v) **Power Source.** Power source means a source of supplying energy to operate unit processes.

(w) **Standby Power Source.** Standby power source means an automatically actuated self-starting alternate energy source maintained in immediately operable condition and of sufficient capacity to provide necessary service during failure of the normal power supply.

(x) **Standby Replacement Equipment.** Standby replacement equipment means reserve parts and equipment to replace broken-down or worn-out units which can be placed in operation within a 24-hour period.

(y) **Standby Chlorinator.** A standby chlorinator means a duplicate chlorinator for reclamation plants having one chlorinator and a duplicate of the largest unit for plants having multiple chlorinator units.

(z) **Multiple Point Chlorination.** Multiple point chlorination means that chlorine will be applied simultaneously at the reclamation plant and at subsequent chlorination stations located at the use area and/or some intermediate point. It does not include chlorine application for odor control purposes.

(aa) **Alarm.** Alarm means an instrument or device which continuously monitors a specific function of a treatment process and automatically gives warning of an unsafe or undesirable condition by means of visual and audible signals.

(bb) **Person.** Person also includes any private entity, city, county, district, the State or any department or agency thereof.

NOTE: Authority cited Section 208, Health and Safety Code and Section 13521, Water Code. Reference: Section 13521, Water Code.

History: 1. New Chapter 4 (§§ 60301–60357, not consecutive) filed 4-2-75, effective thirtieth day thereafter (Register 75, No. 14).

Article 2. Irrigation of Food Crops

60303. Spray Irrigation. Reclaimed water used for the spray irrigation of food crops shall be at all times an adequately disinfected, oxidized, coagulated, clarified, filtered wastewater. The wastewater shall be considered adequately disinfected if at some location in the treatment process the median number of coliform organisms does not exceed 2.2 per 100 milliliters and the number of coliform organisms does not exceed 23 per 100 milliliters in more than one sample within any 30-day period. The median value shall be determined from the bacteriological results of the last 7 days for which analyses have been completed.

60305. Surface Irrigation. (a) Reclaimed water used for surface irrigation of food crops shall be at all times an adequately disinfected, oxidized wastewater. The wastewater shall be considered adequately disinfected if at some location in the treatment process the median number of coliform organisms does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed.

(b) Orchards and vineyards may be surface irrigated with reclaimed water that has the quality at least equivalent to that of primary effluent provided that no fruit is harvested that has come in contact with the irrigating water or the ground.

60307. Exceptions. Exceptions to the quality requirements for reclaimed water used for irrigation of food crops may be considered by the State Department of Health on an individual case basis where the reclaimed water is to be used to irrigate a food crop which must undergo extensive commercial, physical or chemical processing sufficient to destroy pathogenic agents before it is suitable for human consumption.

Article 3 Irrigation of Fodder, Fiber, and Seed Crops

60309. **Fodder, Fiber, and Seed Crops.** Reclaimed water used for the surface or spray irrigation of fodder, fiber, and seed crops shall have a level of quality no less than that of primary effluent.

60311. **Pasture for Milking Animals.** Reclaimed water used for the irrigation of pasture to which milking cows or goats have access shall be at all times an adequately disinfected, oxidized wastewater. The wastewater shall be considered adequately disinfected if at some location in the treatment process the median number of coliform organisms does not exceed 23 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed.

Article 4. Landscape Irrigation

60313. **Landscape Irrigation.** Reclaimed water used for the irrigation of golf courses, cemeteries, lawns, parks, playgrounds, freeway landscapes, and landscapes in other areas where the public has access shall be at all times an adequately disinfected, oxidized wastewater. The wastewater shall be considered adequately disinfected if at some location in the treatment process the median number of coliform organisms does not exceed 23 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed.

Article 5. Recreational Impoundments

60315. **Nonrestricted Recreational Impoundment.** Reclaimed water used as a source of supply in a nonrestricted recreational impoundment shall be at all times an adequately disinfected, oxidized, coagulated, clarified, filtered wastewater. The wastewater shall be considered adequately disinfected if at some location in the treatment process the median number of coliform organisms does not exceed 2.2 per 100 milliliters and the number of coliform organisms does not exceed 23 per 100 milliliters in more than one sample within any 30-day period. The median value shall be determined from the bacteriological results of the last 7 days for which analyses have been completed.

60317. **Restricted Recreational Impoundment.** Reclaimed water used as a source of supply in a restricted recreational impoundment shall be at all times an adequately disinfected, oxidized wastewater. The wastewater shall be considered adequately disinfected if at some location in the treatment process the median number of coliform organisms does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed.

60319. **Landscape Impoundment.** Reclaimed water used as a source of supply in a landscape impoundment shall be at all times an adequately disinfected, oxidized wastewater. The wastewater shall be considered adequately disinfected if at some location in the treatment process the median number of coliform organisms does not exceed 23 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed.

Article 6. Sampling and Analysis

60321. **Sampling and Analysis.** (a) Samples for settleable solids and coliform bacteria, where required, shall be collected at least daily and at a time when wastewater characteristics are most demanding on the treatment facilities and disinfection procedures. Turbidity analysis, where required, shall be performed by a continuous recording turbidimeter.

(b) For uses requiring a level of quality no greater than that of primary effluent, samples shall be analyzed by an approved laboratory method of settleable solids.

(c) For uses requiring an adequately disinfected, oxidized wastewater, samples shall be analyzed by an approved laboratory method for coliform bacteria content.

(d) For uses requiring an adequately disinfected, oxidized, coagulated, clarified, filtered wastewater, samples shall be analyzed by approved laboratory methods for turbidity and coliform bacteria content.

Article 7. Engineering Report and Operational Requirements

60323. **Engineering Report.** (a) No person shall produce or supply reclaimed water for direct reuse from a proposed water reclamation plant unless he files an engineering report.

(b) The report shall be prepared by a properly qualified engineer registered in California and experienced in the field of wastewater treatment, and shall contain a description of the design of the proposed reclamation system. The report shall clearly indicate the means for compliance with these regulations and any other features specified by the regulatory agency.

(c) The report shall contain a contingency plan which will assure that no untreated or inadequately-treated wastewater will be delivered to the use area.

60325. **Personnel.** (a) Each reclamation plant shall be provided with a sufficient number of qualified personnel to operate the facility effectively so as to achieve the required level of treatment at all times.

(b) Qualified personnel shall be those meeting requirements established pursuant to Chapter 9 (commencing with Section 13625) of the Water Code.

60327. **Maintenance.** A preventive maintenance program shall be provided at each reclamation plant to ensure that all equipment is kept in a reliable operating condition.

60329. **Operating Records and Reports.** (a) Operating records shall be maintained at the reclamation plant or a central depository within the operating agency. These shall include: all analyses specified in the reclamation criteria; records of operational problems, plant and equipment breakdowns, and diversions to emergency storage or disposal; all corrective or preventive action taken.

(b) Process or equipment failures triggering an alarm shall be recorded and maintained as a separate record file. The recorded information shall include the time and cause of failure and corrective action taken.

(c) A monthly summary of operating records as specified under (a) of this section shall be filed monthly with the regulatory agency.

(d) Any discharge of untreated or partially treated wastewater to the use area, and the cessation of same, shall be reported immediately by telephone to the regulatory agency, the State Department of Health, and the local health officer.

60331. Bypass. There shall be no bypassing of untreated or partially treated wastewater from the reclamation plant or any intermediate unit processes to the point of use.

Article 8. General Requirements of Design

60333. Flexibility of Design. The design of process piping, equipment arrangement, and unit structures in the reclamation plant must allow for efficiency and convenience in operation and maintenance and provide flexibility of operation to permit the highest possible degree of treatment to be obtained under varying circumstances.

60335. Alarms. (a) Alarm devices required for various unit processes as specified in other sections of these regulations shall be installed to provide warning of:

(1) Loss of power from the normal power supply.
(2) Failure of a biological treatment process.
(3) Failure of a disinfection process.
(4) Failure of a coagulation process.
(5) Failure of a filtration process.
(6) Any other specific process failure for which warning is required by the regulatory agency.

(b) All required alarm devices shall be independent of the normal power supply of the reclamation plant.

(c) The person to be warned shall be the plant operator, superintendent, or any other responsible person designated by the management of the reclamation plant and capable of taking prompt corrective action.

(d) Individual alarm devices may be connected to a master alarm to sound at a location where it can be conveniently observed by the attendant. In case the reclamation plant is not attended full time, the alarm(s) shall be connected to sound at a police station, fire station or other full-time service unit with which arrangements have been made to alert the person in charge at times that the reclamation plant is unattended.

60337. Power Supply. The power supply shall be provided with one of the following reliability features:

(a) Alarm and standby power source.

(b) Alarm and automatically actuated short-term retention or disposal provisions as specified in Section 60341.

(c) Automatically actuated long-term storage or disposal provisions as specified in Section 60341.

Article 9. Alternative Reliability Requirements for Uses Permitting Primary Effluent

60339. Primary Treatment. Reclamation plants producing reclaimed water exclusively for uses for which primary effluent is permitted shall be provided with one of the following reliability features:

(a) Multiple primary treatment units capable of producing primary effluent with one unit not in operation.

(b) Long-term storage or disposal provisions as specified in Section 60341.

Article 10. Alternative Reliability Requirements for Uses Requiring Oxidized, Disinfected Wastewater or Oxidized, Coagulated, Clarified, Filtered, Disinfected Wastewater

60341. Emergency Storage or Disposal. (a) Where short-term retention or disposal provisions are used as a reliability feature, these shall consist of facilities reserved for the purpose of storing or disposing of untreated or partially treated wastewater for at least a 24-hour period. The facilities shall include all the necessary diversion devices, provisions for odor control, conduits, and pumping and pump back equipment. All of the equipment other than the pump back equipment shall be either independent of the normal power supply or provided with a standby power source.

(b) Where long-term storage or disposal provisions are used as a reliability feature, these shall consist of ponds, reservoirs, percolation areas, downstream sewers leading to other treatment or disposal facilities or any other facilities reserved for the purpose of emergency storage or disposal of untreated or partially treated wastewater. These facilities shall be of sufficient capacity to provide disposal or storage of wastewater for at least 20 days, and shall include all the necessary diversion works, provisions for odor and nuisance control, conduits, and pumping and pump back equipment. All of the equipment other than the pump back equipment shall be either independent of the normal power supply or provided with a standby power source.

(c) Diversion to a less demanding reuse is an acceptable alternative to emergency disposal of partially treated wastewater provided that the quality of the partially treated wastewater is suitable for the less demanding reuse.

(d) Subject to prior approval by the regulatory agency, diversion to a discharge point which requires lesser quality of wastewater is an acceptable alternative to emergency disposal of partially treated wastewater.

(e) Automatically actuated short-term retention or disposal provisions and automatically actuated long-term storage or disposal provisions shall include, in addition to provisions of (a), (b), (c), or (d) of this section, all the necessary sensors, instruments, valves and other devices to enable fully automatic diversion of untreated or partially treated wastewater to approved emergency storage or disposal in the event of failure of a treatment process, and a manual reset to prevent automatic restart until the failure is corrected.

60343. **Primary Treatment.** All primary treatment unit processes shall be provided with one of the following reliability features:

(a) Multiple primary treatment units capable of producing primary effluent with one unit not in operation.

(b) Standby primary treatment unit process.

(c) Long-term storage or disposal provisions.

60345. **Biological Treatment.** All biological treatment unit processes shall be provided with one of the following reliability features:

(a) Alarm and multiple biological treatment units capable of producing oxidized wastewater with one unit not in operation.

(b) Alarm, short-term retention or disposal provisions, and standby replacement equipment.

(c) Alarm and long-term storage or disposal provisions.

(d) Automatically actuated long-term storage or disposal provisions.

60347. **Secondary Sedimentation.** All secondary sedimentation unit processes shall be provided with one of the following reliability features:

(a) Multiple sedimentation units capable of treating the entire flow with one unit not in operation.

(b) Standby sedimentation unit process.

(c) Long-term storage or disposal provisions.

60349. **Coagulation.**

(a) All coagulation unit processes shall be provided with the following mandatory features for uninterrupted coagulant feed:

(1) Standby feeders,

(2) Adequate chemical storage and conveyance facilities,

(3) Adequate reserve chemical supply, and

(4) Automatic dosage control.

(b) All coagulation unit processes shall be provided with one of the following reliability features:

(1) Alarm and multiple coagulation units capable of treating the entire flow with one unit not in operation;

(2) Alarm, short-term retention or disposal provisions, and standby replacement equipment;

(3) Alarm and long-term storage or disposal provisions;

(4) Automatically actuated long-term storage or disposal provisions; or

(5) Alarm and standby coagulation process.

60351. **Filtration.** All filtration unit processes shall be provided with one of the following reliability features:

(a) Alarm and multiple filter units capable of treating the entire flow with one unit not in operation.

(b) Alarm, short-term retention or disposal provisions and standby replacement equipment.

(c) Alarm and long-term storage or disposal provisions.

(d) Automatically actuated long-term storage or disposal provisions.

(e) Alarm and standby filtration unit process.

60353. **Disinfection.**

(a) All disinfection unit processes where chlorine is used as the disinfectant shall be provided with the following features for uninterrupted chlorine feed:

(1) Standby chlorine supply,

(2) Manifold systems to connect chlorine cylinders,

(3) Chlorine scales, and

(4) Automatic devices for switching to full chlorine cylinders.

Automatic residual control of chlorine dosage, automatic measuring and recording of chlorine residual, and hydraulic performance studies may also be required.

(b) All disinfection unit processes where chlorine is used as the disinfectant shall be provided with one of the following reliability features:

(1) Alarm and standby chlorinator;

(2) Alarm, short-term retention or disposal provisions, and standby replacement equipment;

(3) Alarm and long-term storage or disposal provisions;

(4) Automatically actuated long-term storage or disposal provisions; or

(5) Alarm and multiple point chlorination, each with independent power source, separate chlorinator, and separate chlorine supply.

60355. **Other Alternatives to Reliability Requirements.** Other alternatives to reliability requirements set forth in Articles 8 to 10 may be accepted if the applicant demonstrates to the satisfaction of the State Department of Health that the proposed alternative will assure an equal degree of reliability.

Article 11. Other Methods of Treatment

60357. **Other Methods of Treatment.** Methods of treatment other than those included in this chapter and their reliability features may be accepted if the applicant demonstrates to the satisfaction of the State Department of Health that the methods of treatment and reliability features will assure an equal degree of treatment and reliability.

APPENDIX I

DESIGN CRITERIA

The preparation of a wastewater disposal master plan requires consistent criteria for preliminary designs and cost estimates. The technical criteria that have been used in this study are summarized in this Appendix.

WASTEWATER COLLECTION SYSTEM CRITERIA

The collection systems being proposed for the Greater Amman Area are based upon generally accepted or assumed criteria. These design criteria result from a combination of local practices in Amman, material developed during the study, and generally accepted engineering practices. Although these criteria are used for determination of future facility requirements herein, it is nonetheless advisable that periodic review be made to take into account possible changing conditions as well as improvements that may be experienced in engineering technology and construction materials and practices.

WASTEWATER FLOW RATES

Wastewater collection systems must be capable of accepting the wastewater discharges regardless of diurnal variations. Peak rates of discharge form the design conditions for lateral and trunk sewers and for sewage pumping stations and force mains as well. These peak discharge rates may vary among the components contributing to flow in the collection system, notably domestic, commercial, and industrial sources, as well as infiltration and wet weather inflow.

Hourly variations in domestic wastewater discharges are greatest at times of greatest household water use -- often mid-morning to early afternoon -- and least during late night hours when most people are sleeping. Industrial wastewater flows vary with employee activity and, particularly, with the processes involved. Commercial flows usually are concentrated during

business hours. Groundwater infiltration flows have little variation except seasonally or as a result of heavy rainstorms. In summer months, exfiltration may actually occur, while during and following wet weather, infiltration is normally greatest. Inflows are from storm runoff and are discussed separately.

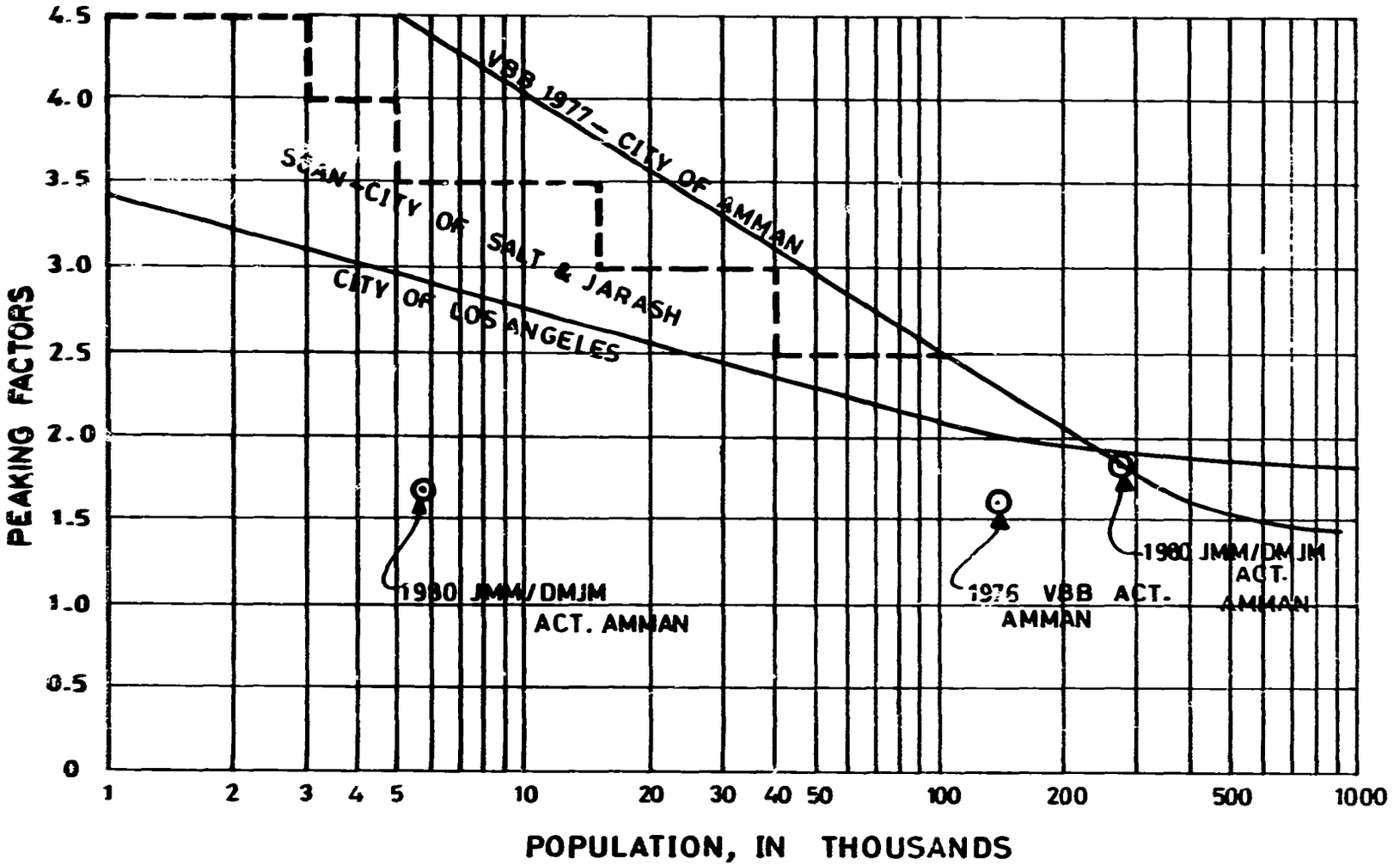
Peaking Factors

It is neither feasible nor necessary in these studies to segregate the peaking effects of domestic, commercial, industrial, and infiltration inflows. Rather, an overall system peaking factor is employed that has been found acceptable for application in many communities and which relates peaking factors to size of tributary population.

Figure I-1 presents a graph relating collection system peaking factors to the size of the population being served. The peaking factor is the ratio between peak hourly flow rate and average daily flow rate. It is greatest when applied for small tributary populations and vice versa. The graph was developed by the City of Los Angeles, California, as a result of extensive experience in flow gaging from many different sized neighborhoods and larger areas within the vast sewer network tributary to the Hyperion Treatment Plant. Trial applications within the AWSA network during the course of these studies have indicated that the curve is correct for the larger values of population and very conservative for the lower population values. Thus, the curve was deemed appropriate for a peaking criterion and has been adopted for such purposes herein.

Average Flow Factors

The peaking factor is applied to average daily flows computed from estimated populations and per capita values. These latter were derived in Chapter 5 of this Master Plan Report, and they do not discriminate among residential, commercial, or industrial uses, inasmuch as no data were available to permit this. Rather, they represent overall system values which reflect all of these uses. As applied for Amman, the mix of these uses is typical of recently experienced conditions, particularly of dry weather.



RATIO OF PEAK TO AVERAGE DAILY SEWAGE FLOW

FIGURE I - 1

It is recognized that some variations occur in unit wastewater production between high income areas and low income areas. However, except in unusual circumstances, no effort is made to differentiate between such flows. For example, for the areas specifically tributary to Upper Wadi Abdoun Treatment Plant, per capita flows were assumed higher than the average for Amman in order to recognize high income conditions.

Where specific industrial areas producing significant wastewater flows are known to be a potential factor, an allowance of.09 cu m/da average flow per dunum of industrial area is made. Otherwise, the industrial contributions are assumed included in the system per capita flow.

Infiltration

Infiltration effects should be considered in the design of the collection systems of Greater Amman Area. It is prudent to allow for such an effect for sizing of sewers and pumping systems. It is not necessary to do so for treatment plant design, as there is sufficient latitude in the hydraulic capacity employed there to accommodate both winter infiltration and summer exfiltration from sanitary sewers.

AWSA personnel have reported only one instance of groundwater being encountered in a sewer trench during the course of construction of over 400 km of sewers. It is possible that seepage from adjacent cesspools may have been at least partially responsible for this condition. On the other hand, most sewer construction is carried on during dry weather, so to have a conservative design, an infiltration allowance of 10 cu m/day per km of sewer laterals is made in system sizing. Most of the laterals in the collections systems will be of no more than 200 mm diameter, for which the above value is appropriate. Infiltration, when experienced (through leaky pipe joints) is uniform in flow rate and is not peaked.

Inflow

Inflow to the sewer system is a wet weather phenomenon resulting from flooding of manholes sufficient to permit entry and illicit connections of roof, yard, other (non-sanitary) building drains, and various external

connections. It has even been reported that during severe rainstorms, manhole covers in flooded areas are sometimes deliberately removed to relieve surface flooding. It is believed that most sewer manholes in the AWSA system are not only watertight against surface flooding but also difficult to remove under any circumstances. In fact, this report recommends improvement of this latter condition for reasons of expediting proper sewer maintenance.

Inflow to the AWSA system reportedly can be severe at times. Even so, it is not considered a proper function of a Master Plan Report or Preliminary Engineering Feasibility Report to base a design upon inflow believed to be largely the result of illicit or otherwise unreasonable connections to the sanitary network. Therefore no specific provision is made in the design criteria for inflow effects from storm runoff. It is, however, strongly recommended that a program be undertaken to remove illicit connections from the AWSA sanitary network and to exclude them from systems not yet constructed.

ENGINEERING CRITERIA

For siting of sewers, the following criteria were adopted:

- Pipe flow - full without pressure at peak flow, using the Manning Formula, with "n" equals 0.013.
- Minimum flow velocity at peak flow - 0.7 m/sec.
- Minimum sewer pipe slope:

Diameter, mm	Slope*
200	0.0043
250	0.0036
300	0.0030
350	0.0024
400	0.0019
500	0.0014
600	0.0010
800	0.0008

*These provide the requisite scouring velocity. In nearly all applications, greater slopes than these can be obtained, due to the steep terrain. It is advisable that this be done in order to minimize sulfide generation.

- Invert changes at junctions and diameter increases - sufficient energy grade line drop to account for hydraulic losses, in accordance with standard practice.
- Design details, such as separation from water lines and other matters, should follow the best practice from the standpoint of reliability, function, and protection of the public health and safety.

For sewering materials, it was determined that locally produced concrete pipe materials would be acceptable (see Chapter 6.) Vitrified clay pipe with plastic joints would be the best possible application, but it is expensive and not locally produced. Polyvinyl chloride pipe has been employed with success in some areas in Jordan and could be given consideration as an alternative to concrete pipe provided that strict specifications of manufacture, handling, and installation are required and observed. The cost estimates in this report are based upon concrete sewering materials.

For pumping stations and force mains, the following apply:

- Peak hourly flow must still be accommodated with the largest pumping unit out of service.
- Adequate provisions against flooding of electro-mechanical equipment must be incorporated.
- Reliable, automatic controls must be provided, responding to wet well depth.
- Standby power, automatically actuated must be provided, either as a standby generator, standby engine prime mover, or standby utility system power sufficiently reliable to prevent more than momentary interruption.
- Force main flow velocities must be not less than 0.9 m/sec, in order to achieve scouring during flow.
- The best practice in station and force main design will be required throughout, in order to ensure reliability, function, and safety for operating personnel and the public.

APPENDIX J
COST ESTIMATING

The purpose of this appendix is to provide the basis on which the estimates of construction cost for the sewer collection network and sewage treatment facilities and related works were prepared.

The sewer line unit costs were taken from the actual low bid submitted on June 1980 for the Amman Contract 1S - Stage 3B of AWSA.

These unit costs were then realistically projected to Fall 1980 prices, by adding 5 percent for price increases.

Sewage treatment plant costs for local labor and material items such as concrete and excavation were developed through discussions with general contractors operating in Jordan. A major source of information was Gama A.S. This firm is acting as the general contractor on the recently tendered sludge facilities at the Ain Ghazal Treatment Plant. Their prices were compared with other information and used to develop costs for Fall 1980. Where equipment is required, it was presumed to be manufactured in the United States. Local representatives or U.S. offices were contacted for quotes, and allowances were made for shipping from the United States.

SANITARY SEWER CONSTRUCTION COSTS

In June 1980 bids were opened for Contract 1S - Stage 3B. Inasmuch as all quantities were established on a lump sum basis for each contract drawing, the unit cost per lineal meter for various sizes on each drawing could not be determined. However, since 91.6 percent of the project consisted of 150 mm diameter concrete pipe, a reliable cost figure was obtained. Additionally, the contractor's itemized breakdown of installation and material costs for the various sizes of pipe as well as labor costs was helpful.

Installation Costs

Shown below are the various areas in Amman where sewers were installed, the price per lineal meter for installation (material not included) and the percentage of 150 mm diameter pipe. Note the significance of the variation in installation cost per meter from a low of 15.380 to a high of 24.930 JD's.

INSTALLATION COST OF SEWERS
IN VARIOUS AREAS IN AMMAN

Area	Cost/Meter* JD	% 150 mm Diameter
Nadif	15.380	92.4
Ashrafiya	17.040	84.6
Jofeh	18.790	93.7
Tadj	16.230	95.7
Nasser	19.080	80.2
Mahatta	24.930	100.0
Quala	21.040	86.4
Shaleh	19.800	100.0
Average	19.036	91.6

* Note: The cost per lineal meter is for installation only; add 3.96 JD per meter for material cost and 0.24 JD for staff vehicles.

Project 1S - Stage 3B was bid in the given amounts by category as follows:

Civil works in mainlines and laterals	JD 790,467
Civil work in house connections	116,800
Material supply	200,711
Staff vehicles	12,000
Total	119,978

The house connections were 13 percent of the total project cost.

Labor Costs

Shown below are the bid rates for several classifications of labor which were quoted by the successful bidder of 1S - Stage 3B:

RATES FOR SEVERAL LABOR CLASSIFICATIONS
PROJECT 1S - STAGE 3B

Class of Labor	Bid Rate/hr. JD
Common laborer	0.624
Trench laborer	0.624
Trench leveller	0.936
Pipe layer	1.040
Carpenter	1.248
Steel worker	1.248
Vehicle/track drive	1.144
Excavator/track drive	1.456
Working supervisor	1.248

Manhole Construction

The bids on Contract 1S - Stage 3B for 900 mm diameter manholes of various depths complete excluding cost of rings and covers are as follows:

Depth	Price/manhole JD
0 - 2 meters	132
0 - 3 meters	124
0 - 4 meters	210
0 - 5 meters	320
0 - 6 meters	450

For 1000 mm diameter manholes:

Depth	Price/manhole JD
0 - 2 meters	155
0 - 3 meters	165
0 - 4 meters	285
0 - 5 meters	410
0 - 6 meters	495

For 1200 mm diameter manholes:

Depth	Price/manhole JD
0 - 2 meters	275
0 - 3 meters	290
0 - 4 meters	370
0 - 5 meters	455
0 - 6 meters	535

Manhole rings were bid at an average price of 15 JD per ring. Covers were 45 JD each for heavy duty, 40 JD for medium duty, and 25 JD for light duty, per unit.

Based on random sampling of 44 manholes on 150 mm diameter sewer line, the average depth of manholes was determined to be 1.67 meters.

To determine the manhole spacing required for estimating purposes, 10 pro[illegible] sheets of laterals of Project 1S - Stage 3B were randomly selected and [illegible]mined. Average manhole spacing of 60 meters was obtained for laterals. For trunk sewers a spacing of 100 m was thought to be a reasonable figure to use.

For estimating the cost of manholes on this project, the following was adopted: For trunk sewers, 1200 mm diameter manhole with heavy duty cover will be used at an average depth of 2.5 meters. The cost basis is 370 JD for Fall 1980. The cost allows for a 5 percent inflation rate over

the present rate; for laterals, a 1000 mm diameter manhole with medium duty cover will be used at an average depth of 1.67 meters. The cost on this basis is 220 JD including the 5 percent inflation rate. This covers the bulk of the trunk sewers to be provided. For a lateral sewer spacing of 60 m, this amounts to 3.67 JD/m. For trunk sewer spacing of 100 feet, it corresponds to 2.20 JD/m.

House Connection Construction

House connections consist of 2 types - wye or tee connections to a line and connections made directly to a manhole.

In Contract 1S - Stage 3B, 2890 connections were bid at 116,800 JD's for an average of 40.415 JD's per connection. The material cost was 25,892 JD's or 8.959 JD's per connection. The share of the staff vehicles was 1,548 JD, or 0.536 JD per connection.

The average total bid cost per connection was 49.910 JD. However, as explained below, this value of nearly 50 JD per connection is not being used for purposes of cost estimating because it is felt that typical values may exceed this appreciably. Assuming a typical street width of 16 m., AWSA practice now is to have its contractors lay house connections on either side of the sewer to within 1.5 m of the property line. This means that the average run of house connection would be half of 13 m or 6.5 m, and at a cost of about 15 JD/m would correspond to about 98 JD per connection. Allowing for some inflation, the unit value for house connection used in this report is 100 JD.

Sewer Line Construction

Sewer line construction costs were developed for this report based on those of the 1S - Stage 3B AWSA contract of June 1980. The contract provided the construction cost of 150 mm sewers inclusive of material, excavating, backfilling, pavement removal and replacement. However, the cost for the other sizes of sewer pipe were given for pipe material only.

on cost i zes other than 150 mm, the cost of the latter was prorated to take into account the increase in excavation, backfilling, pavement removal and replacement. In addition a 5 percent inflation rate was added to establish the Fall 1980 prices. The construction cost curves are depicted in Figure J-1.

No curves are given for the annual operation and maintenance costs of pipe line facilities. These annual costs may be estimated as 0.50 percent of the construction costs.

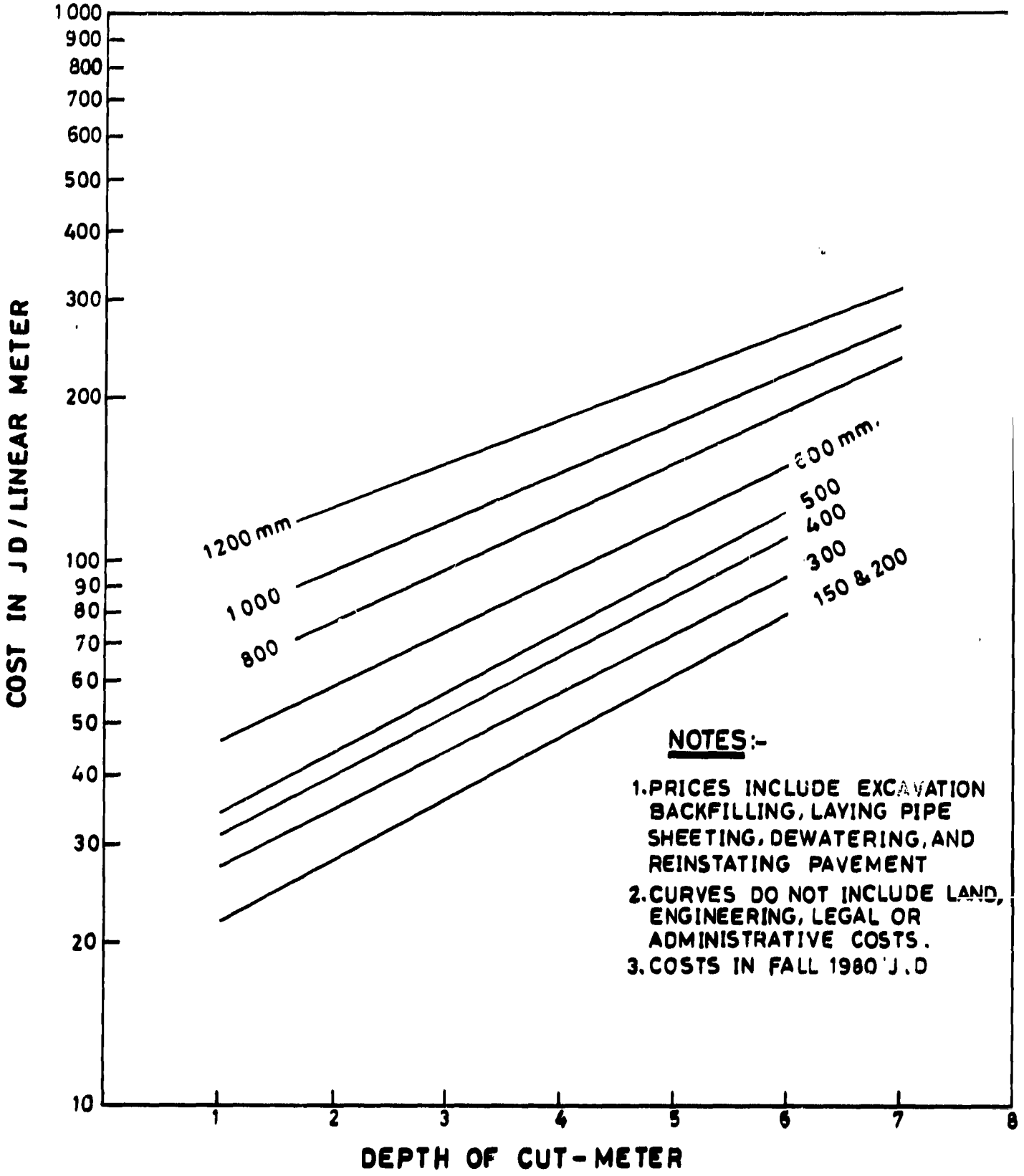
Pumping Stations

Shown in Figure J-2 is a cost curve for the construction of a medium complexity pumping station. The curve relates the unit cost in Jordanian Dinars per brake HP to the total installed brake HP which itself is a direct measure of the pumping capacity and total dynamic head. Adjustment to the curve can be made depending upon alternate power sources, i.e., diesel or gas driven, and complexity or multiple phasing.

Maintenance and operating costs for pumping stations shown in Figure J-3 are the sum of (1) power costs for average daily demand and pumping head, and (2) "other costs" of operation and maintenance. Power costs are based on a wire to water efficiency of 55 percent and an energy cost of 39 fils per kilowatt-hour. "Other costs" include labor, supplies, replacement parts (excluding replacement of major equipment) repairs and administration.

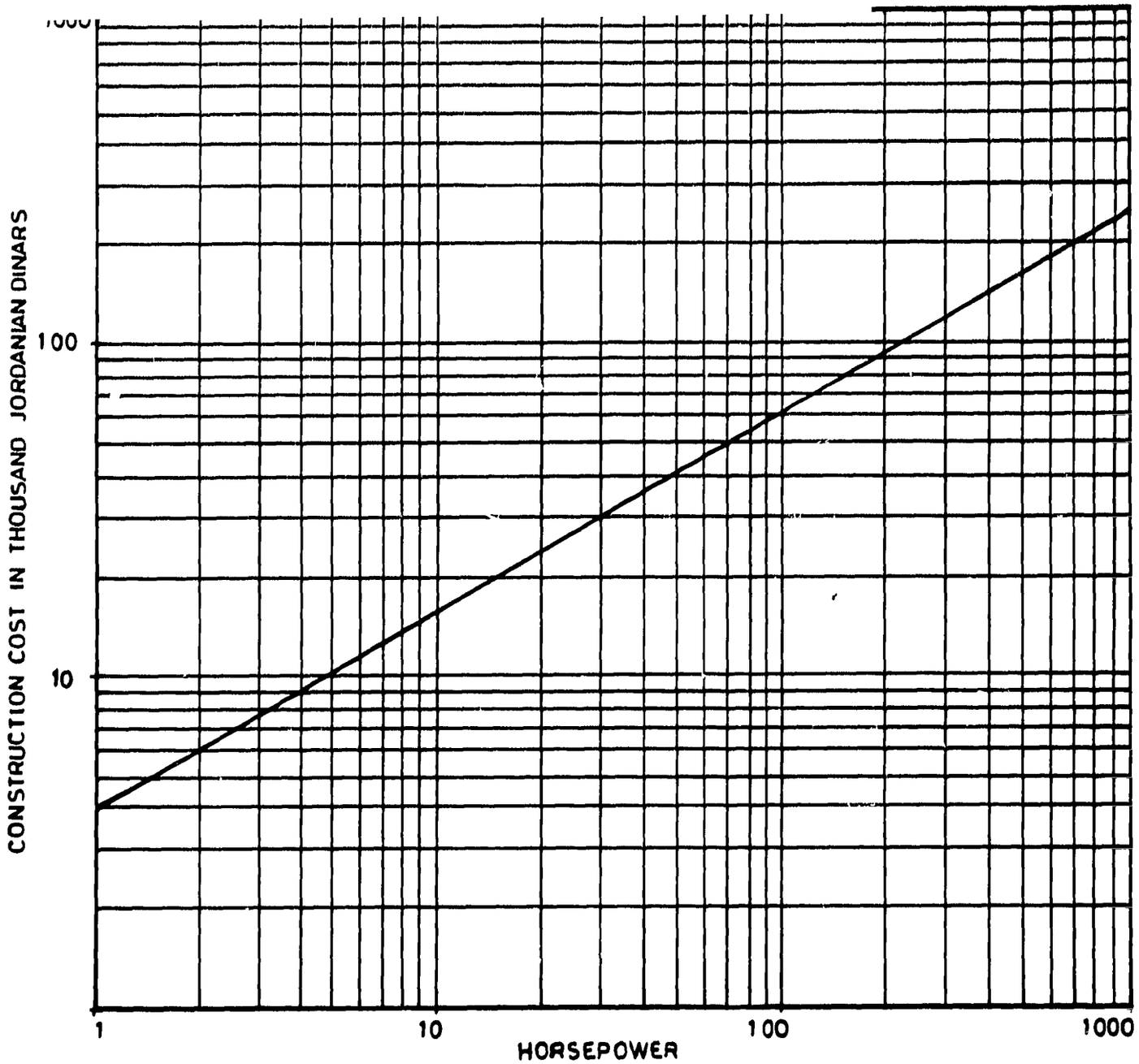
METHODOLOGY FOR SEWER COST ESTIMATES

For trunk sewers within the AWSA primary network, peak flows were determined from projected populations and per capita values in conjunction with suitable peaking factors and were compared with computed capacities. Wherever inadequate capacity was determined for any reach, a parallel trunk sewer was estimated having sufficient capacity to correct the deficiency. Estimates were made thus for both 1990 and 2000 conditions. In this manner, staging could be allowed for. Detailed design would refine these sizes in the light of field conditions and current developments. This method is acceptable because, except for the loadings



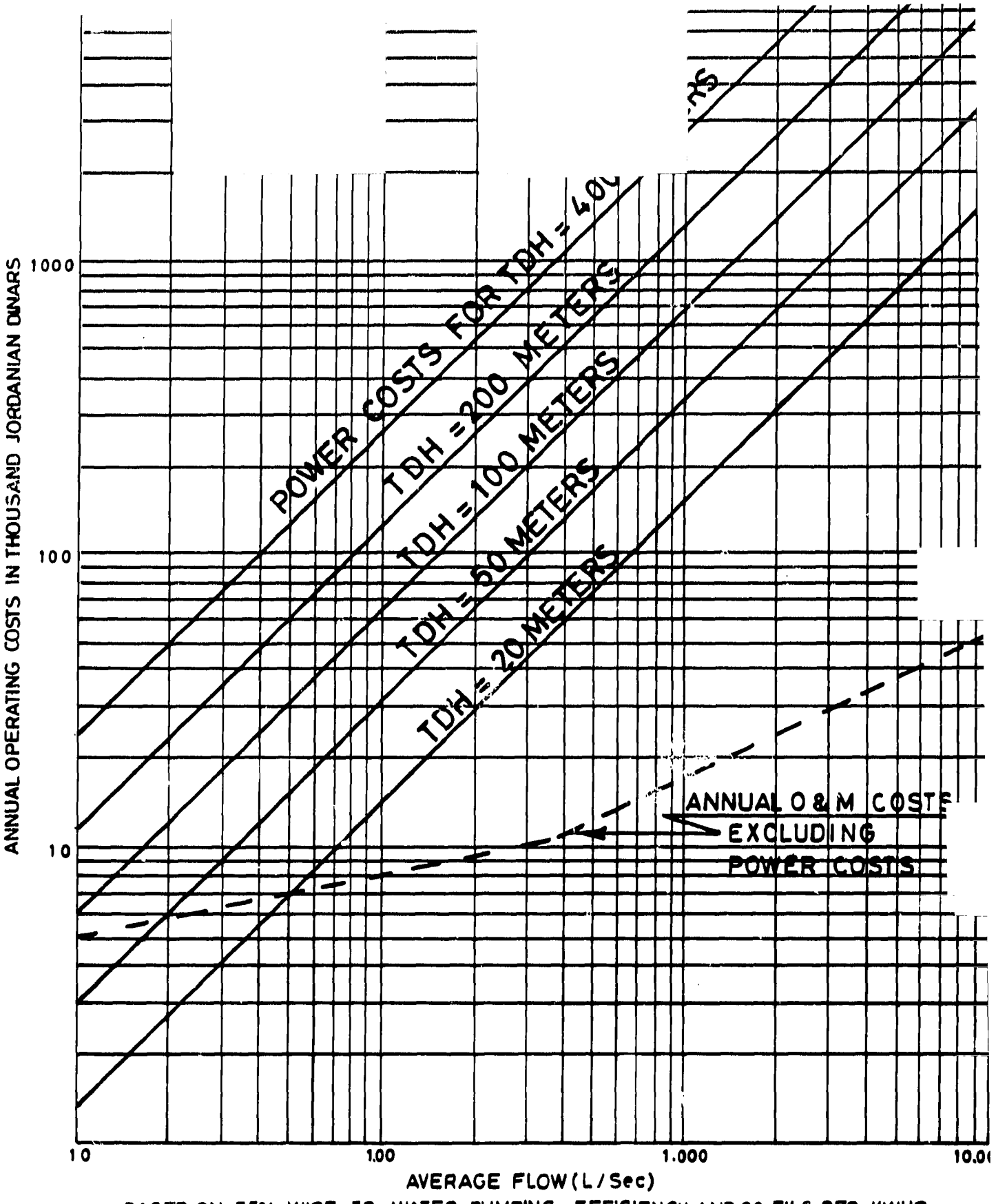
COST CURVES - R.C. SEWERS

FIGURE J - 1



CONSTRUCTION COSTS OF
PUMPING FACILITIES

FIGURE J - 2



BASED ON 55% WIRE-TO-WATER PUMPING EFFICIENCY AND 39 FILS PER KWHR

OPERATING COST OF
PUMPING FACILTES 1980

FIGURE J - 3

caused by external flows originating outside of Amman, the primary network is essentially complete and has little need of local reinforcements.

For trunk sewers outside of Amman, such as westerly of the AWSA network, trunk sewer construction is planned to accommodate flows projected for year 2000 conditions. It was not practical to attempt staging of trunk sewer construction over a period of several years. Trunk sewers to serve the developed areas would be constructed in Phase I and would run along well-defined wadis, thus limiting the possibilities of both routing and staging. It would not be economical to construct a trunk sewer of limited capacity initially and then parallel it within 10 years. The preferable method, which was followed, was to size the trunks to meet the needs of the planning period (year 2000.)

Lateral sewers were sized for ultimate development or as otherwise projected for year 2000 conditions. A minimum of 200 m diameter was allowed for. This sizing, coupled with construction slopes normally available, made for adequate capacity. Length was taken as 0.08 Km/1,000 population for 1980-90 and 0.14 Km/1,000 for 1990-2000, reflecting much unused capacity now, less later.

Based on detailed sewer layouts, developed for many areas by field work and office studies, a relationship was developed for estimating and lengths of lateral sewers needed to serve specific sizes of residential areas. It was found that approximately one kilometer per one thousand population was a suitable estimating value for lateral sewers. This was adopted for newly sewered areas outside of Amman. Inside Amman, the lateral sewers have been extended in many instances without substantial numbers of contiguous property-owners connecting. Because of this unused lateral sewer capacity the one km per 1,000 population was felt to be too high, and a smaller value was adopted.

In determining the breakdown of local and foreign costs for both trunk and lateral sewers, the only items for which foreign manufactured components would be necessary were assumed to be the manhole frames (rings) and covers. The local iron foundry in Zarqa has limited capabilities for casting such manhole devices. For any major sewer construction, it

be necessary to import cast iron frames and covers. Remaining items were concrete, of local manufacture.

House connections are entirely of local manufacture. The numbers of persons served by individual house connections were estimated on a gross basis, no data being available upon which to segregate residential, commercial, and industrial types of use. In making these estimates, recognition was taken of historic conditions and future prospects, as in the case of Amman Municipality. For areas outside Amman, local knowledge of housing conditions, such as approximate percentages of persons residing in apartments and single-family dwellings, respectively, was applied, together with appropriate density factors. The values thus derived were used in financing plan and revenue program calculations.

PRESSURE PIPELINE COSTS

As part of the analyses and program, it was necessary to estimate costs of pressure pipelines. These would be used to carry raw sewage as force mains from sewage pumping stations or as pressure conveyances for plant effluent or wet, digested sludge to reuse/disposal areas.

Table J-1 presents unit estimating costs for wastewater, effluent or sludge transmission lines. Price levels are those of late 1980. The basis of cost development is explained in the footnotes.

If these plotting points corresponding to various diameter pipelines were to be plogged on log-log paper, it would be found that the curve thus formed is not straight line but rather rises with increasing diameter somewhat as a parabola. This is as expected. In very small diameter pipes (150 mm) the cost of earthwork for trenching is much more significant than it is with larger pipelines where the pipe wall thickness and pipe weight normally increase rapidly with increasing diameter. This results in increased costs for supply, handling, fittings and valves, etc. The Azraq Pipeline of AWSA, nearing completion, has a diameter of 600 mm and is beyond the size of those considered for this Master Plan Report. However, the unit cost experienced for this

pipeline's construction harmonizes suitably with those of Table J-1.

SEWAGE TREATMENT PLANT COSTS

A series of cost estimating curves was developed for various types of wastewater treatment plants considered for this project. The curves were in two sets: one for construction costs and one for operation and maintenance costs (O & M costs.)

The estimating curves for construction cost were used for the studies reflected in Chapters 8 and 9 of the Master Plan Report, except that specific study and cost estimation was necessary for the developments at AGTP, where local circumstances required more detailed investigation. Operation and maintenance curves are divided between power costs and "other" costs, i. e., O & M costs excluding power costs. These latter may be particularly significant in the case of activated sludge plants due to the nature of the process and the strength of the wastewater.

Figure J-4 presents a construction cost curve for conventional activated sludge plants. Figure J-5 depicts the construction costs for extended aeration plants over the size ranges considered. This modification of the activated sludge process was considered applicable for smaller size plants, up to about 3,800 cu m/da capacity. Construction cost for total containment lagoons, a low technology process applicable where relatively large and flat land areas are available without much cost, is presented in Figure J-6.

Figure J-7 presents the operation and maintenance cost curves for conventional activated sludge plants. The portion of the operation and maintenance costs other than power for conventional activated sludge plants has been developed into two separate curves. The first curve is for smaller conventional activated sludge plants. This curve ends at approximately 6000 m^3/day of wastewater flow. The second is for the larger conventional activated sludge plants and begins at 6000 m^3/day. The difference between them is that the cost of polymer which is used to enhance primary settling, thickened waste activated sludge, and assists

TABLE J-1

UNIT ESTIMATING COSTS FOR EFFLUENT OR SLUDGE TRANSMISSION LINES[a]

Item	150	200	250	300
Trenching[b]	6	7	8	9
Laterals Purchase[c]	9	12	15	18
Pipe Handling[d]	7	8	9	10
Total, Bid Price[e]	22	27	32	37

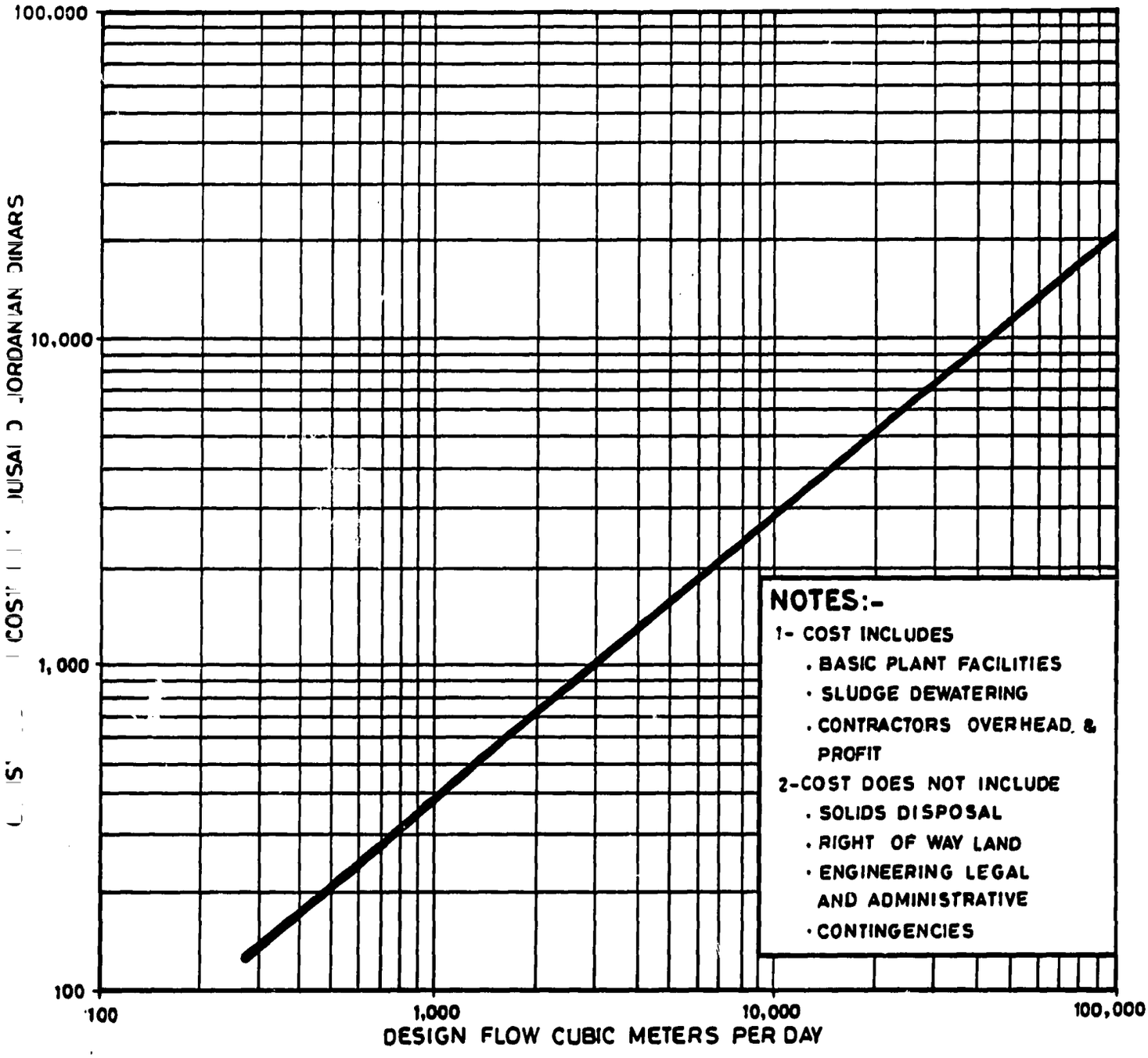
a
Unit costs have been rounded off to nearest dinar per meter for simplicity. Costs are approximate and were derived from consideration of recent contract bids, materials, quotations, and estimation of excavating, backfill and repavement quantities.

b
Includes excavation, backfill, and an allowance for pavement restoration, although some of the pipelines would be out of paved areas. Depth of cover is assumed 0.7 m, minimum. Trench widths vary from 500 mm for 150 mm diameter pipe to 700 mm for 300 mm diameter pipe. Overhead and profit are included for this element.

c
Includes taxes, duties, and commissions, assuming ductile iron pipe or steel pipe. Valves and fittings are included.

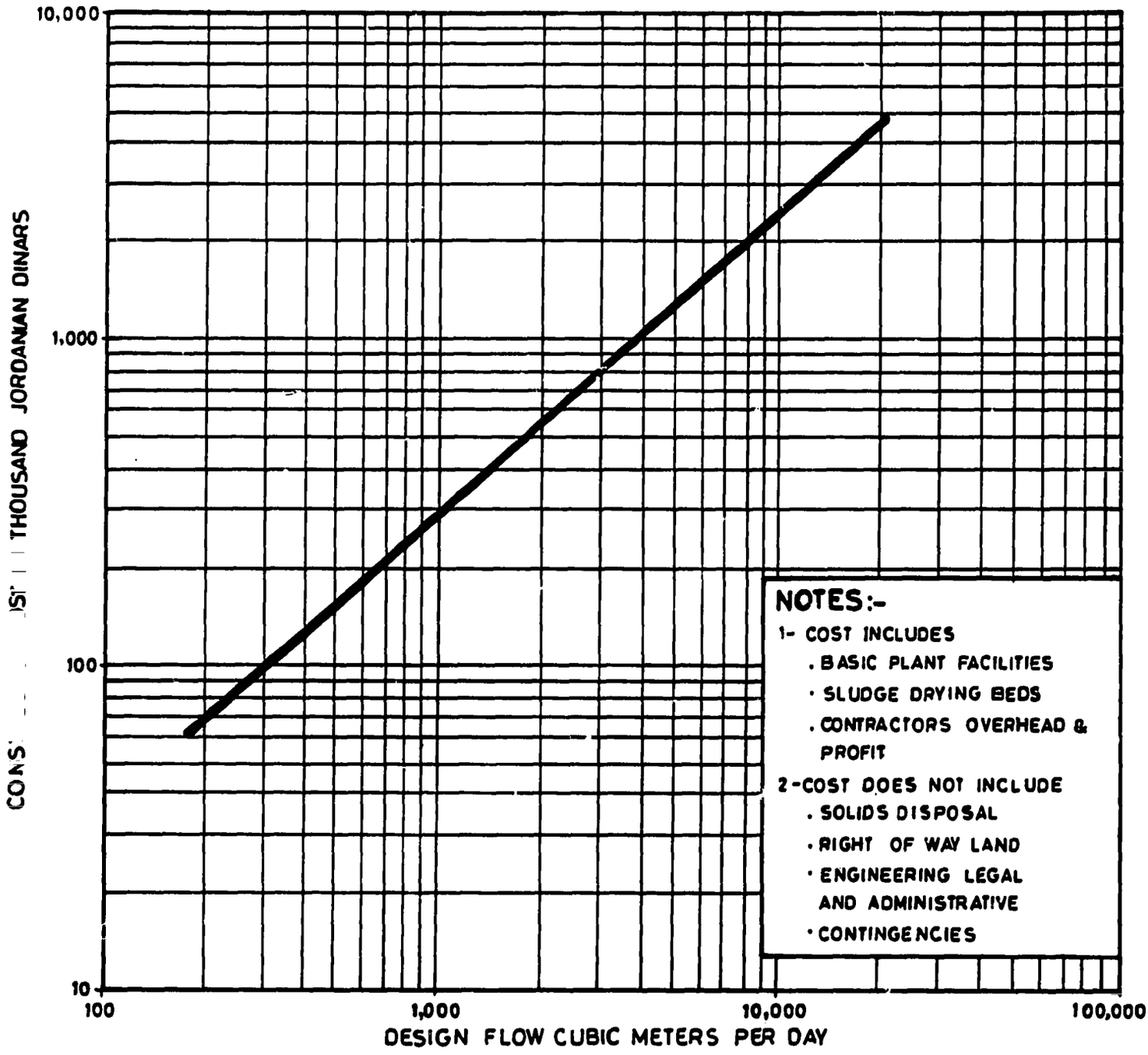
d
Includes local transportation, laying, testing, plus allowances for overhead and profit.

e
Believed suitable for estimating wastewater force mains and effluent and sludge transmission pipelines, part of which would be in urban areas and part in rural areas.



CONSTRUCTION COST
CONVENTIONAL ACTIVATED SLUDGE

FIGURE J - 4



CONSTRUCTION COST FOR
EXTENDED AERATION
ACTIVATED SLUDGE

FIGURE . 7

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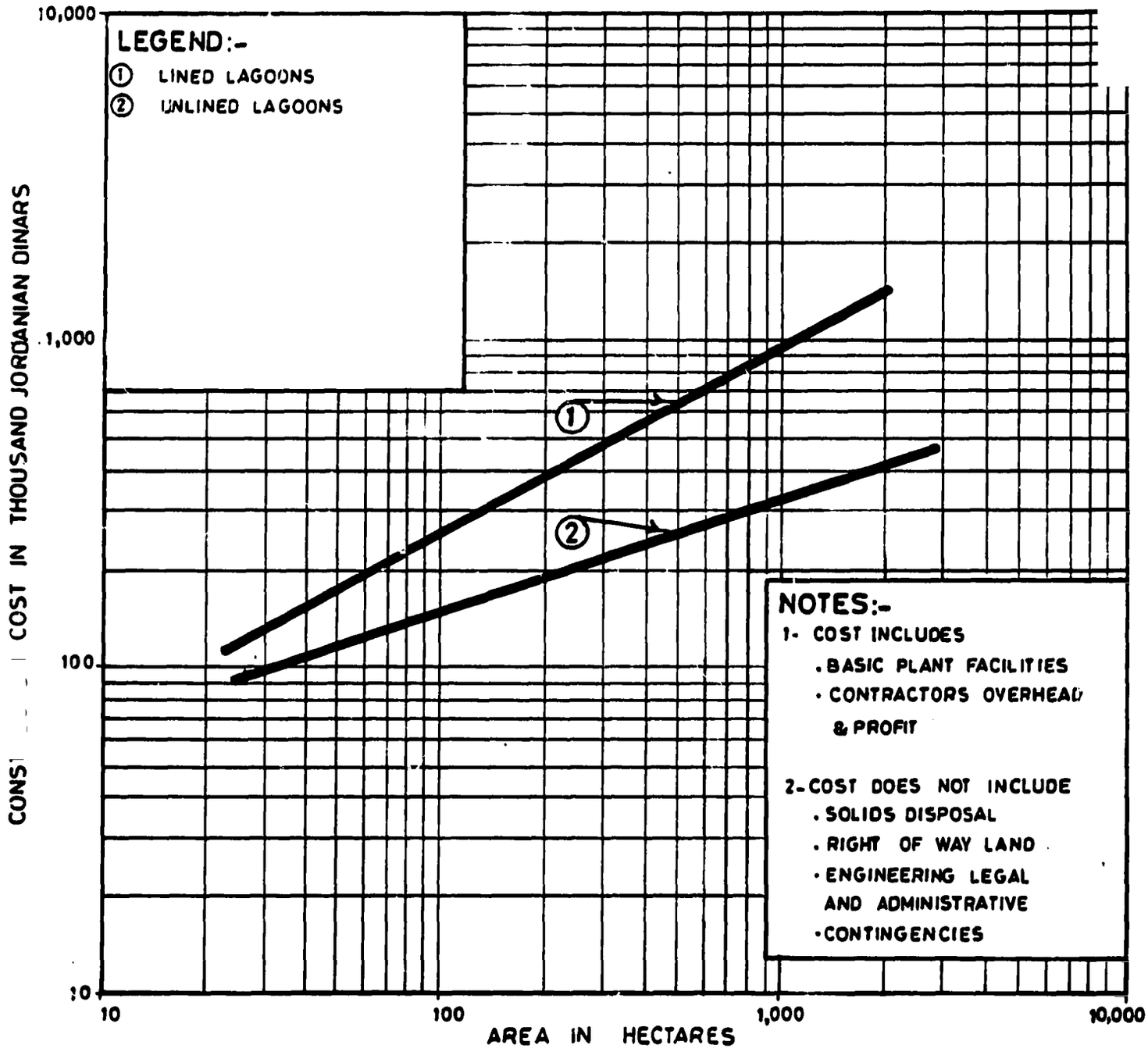
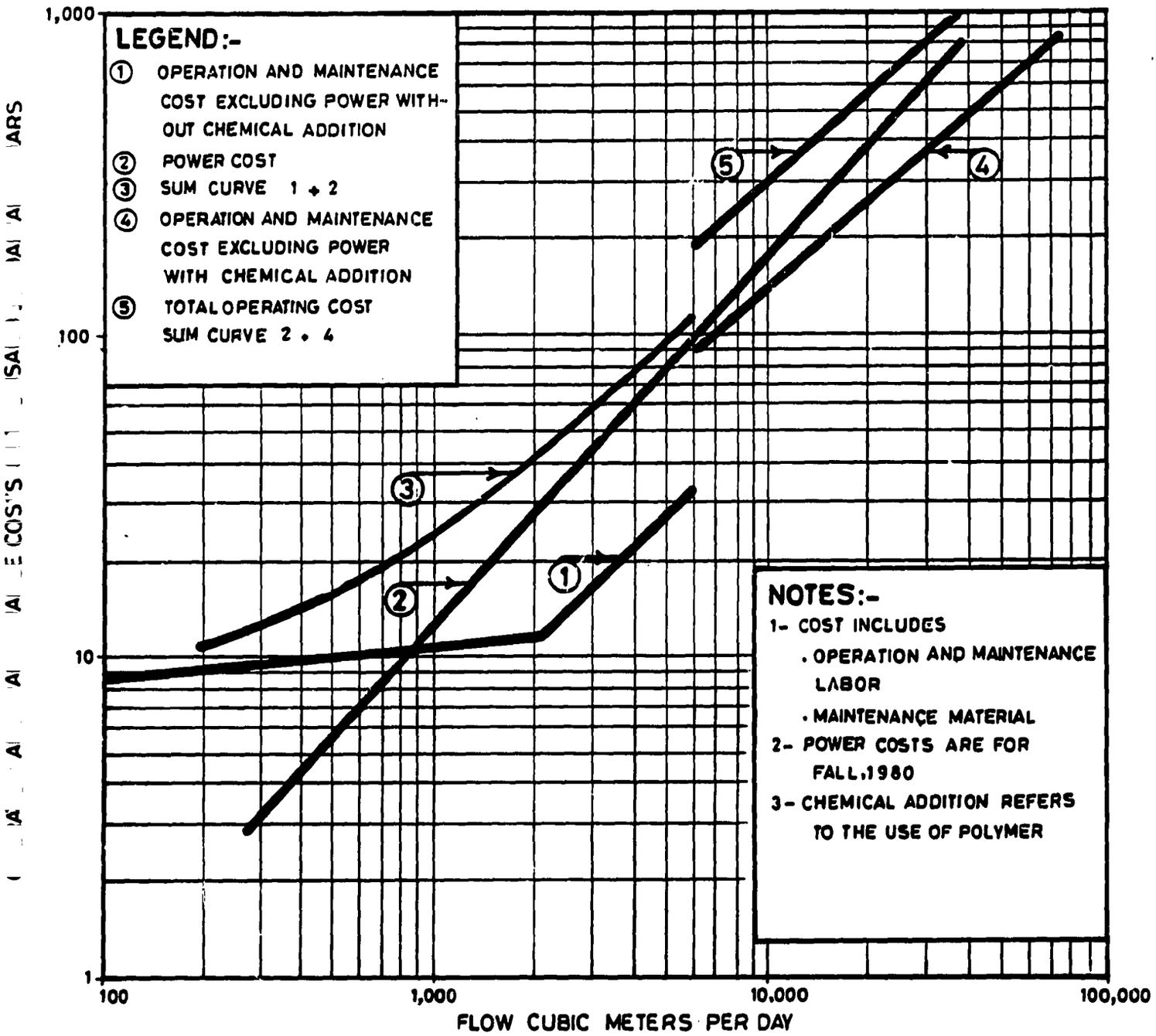


CONSTRUCTION COST
TOTAL CONTAINMENT LAGOON

FIGURE J - 6



OPERATION AND MAINTENANCE
CONVENTIONAL ACTIVATED SLUDGE

FIGURE J - 7

is not necessary at the smaller plants. Power costs were based on assumed 39 fils per kwh, and Figure J-9 shows corresponding costs for total containment lagoons. These latter have essentially no energy costs as no power is required for their operation.

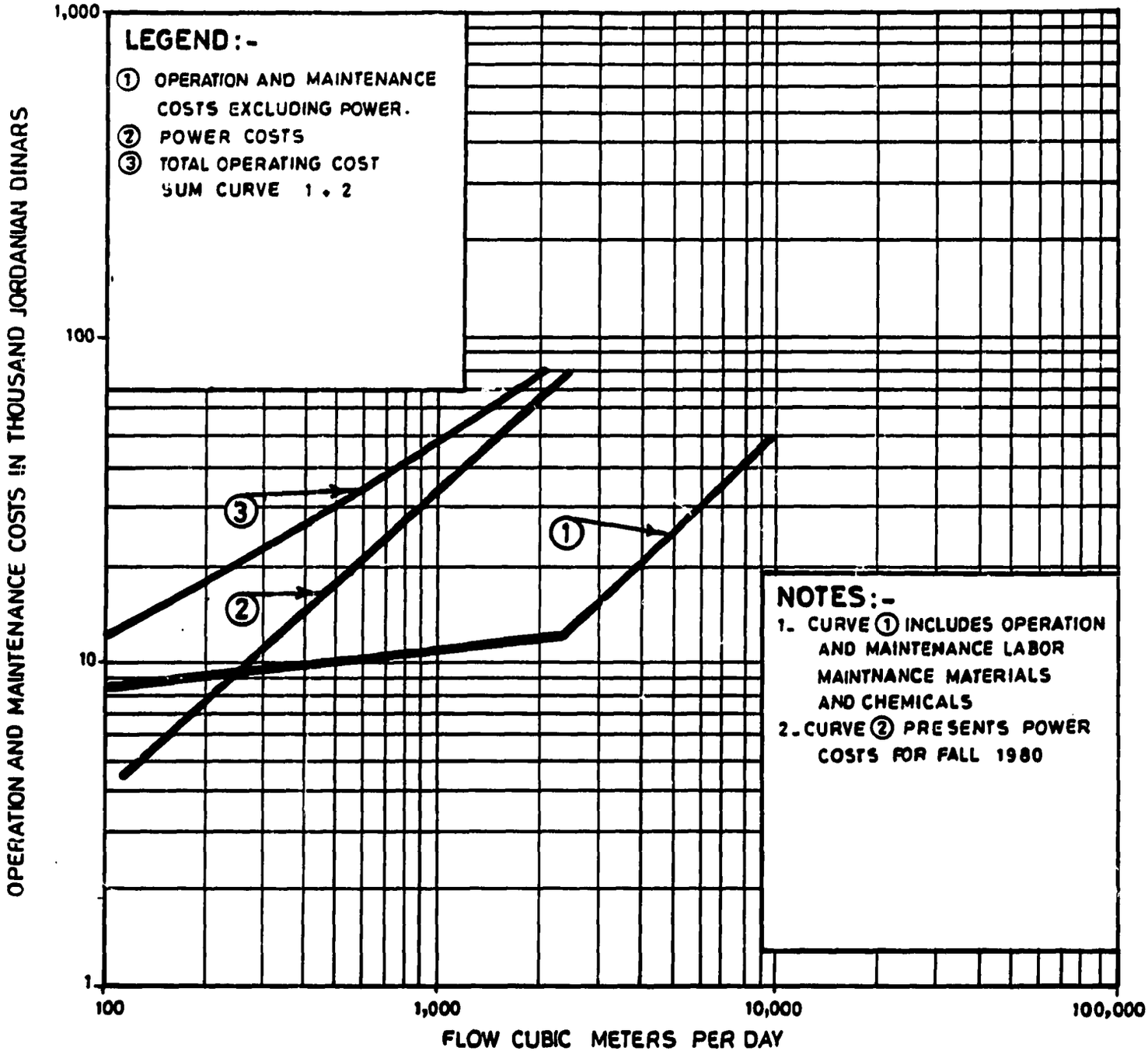
Where comparisons of treatment processes are made in Chapter 8, land is assumed to have one hundred percent salvage value and as such does not enter into the cost comparison. This is most significant where total containment lagoons are compared to other treatment processes. In Chapter 9, however, where the actual annual cost to the community must be calculated, the cost of land is included as part of the capital cost. Thus, the cost of land does not influence the choice of a treatment process except when the quantity and cost of the land is absurdly large as in the case of the Baqa'a Valley treatment plant. But, it does enter into the ranking of the feasibility of the alternatives.

DERIVATION OF SEWAGE TREATMENT PLANT COSTS

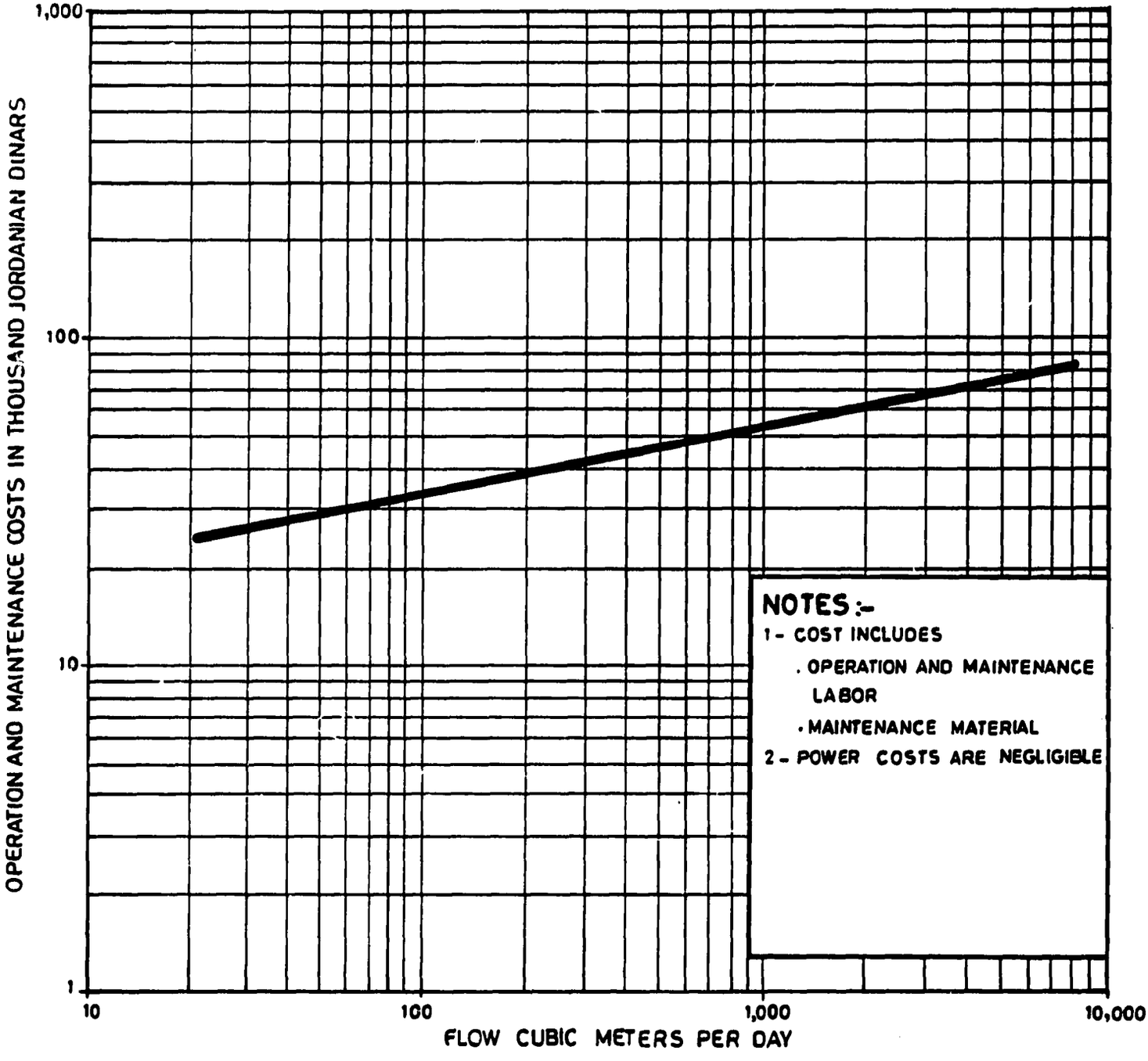
The construction cost curves were basically derived from published cost data in the EPA Publication "Construction Costs for Municipal Wastewater Treatment Plants: 1973-1977," January 1978. This document (MCD-37) presents median curve as well as plotting point data for various types of treatment plants as a function of their nominal capacities. The data include four orders of construction costs: total plants, unit processes and plant construction component costs within the plants, and process construction component costs. JMM/DMJM scaled up the construction costs from the dates represented to late 1980 levels using the Engineering News-Record Construction Cost Index and synthesized the various process component construction costs on the basis of local and foreign elements. Local elements were estimated directly as applicable in Jordan, e.g. earthwork, reinforced concrete, paving, etc. For example,structural reinforced concrete was estimated at JD 120/m^3, in place. Foreign elements were basically the manufactured items, e.g. mechanical equipment, piping, electrical work, etc. These were assumed to be purchased in the U.S. at prevailing prices, which were then increased appropriately to reflect handling, shipping, commissions, and other relevant items. In some cases, foreign costs were a minor portion of the total, but in most cases they were a major portion.

Roughing filter costs were separately estimated by the foregoing procedures, but no curves are presented herein for same.

Operation and maintenance costs were derived on the basis of labor, materials, chemicals, replacement parts, and electrical energy components. For simplicity, following a few trials for verification against known costs in the United States, the elements were consolidated into non-energy operation and maintenance (O&M) and energy costs components of O&M. EPA data were used primarily for energy costs pertaining to treatment plant operation for various processes, and unit energy costs of 39 fils/kwh were used as the baseline condition (35 fils/kwh for AGTP and any other areas within Amman). Jordanian labor requirements and costs were incorporated, as were allowances for materials and replacements as a percentage of the construction cost, as appropriate.



OPERATION AND MAINTENANCE COSTS
EXTENDED AERATION ACTIVATED SLUDGE



OPERATION AND MAINTENANCE
TOTAL CONTAINMENT LAGOON

FIGURE J - 9

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APPENDIX K

CHARACTERISTICS OF SEWAGE SLUDGE

Sludge characteristics are very important because of environmental and health impacts that may result from their disposal and/or beneficial use. Within the Greater Amman Area, only three local treatment plants currently operate and produce sludge.

SLUDGES WITHIN GREATER AMMAN AREA

Available data for the sludges of the AGTP, Salt Treatment Plant, and KHMC Treatment Plant are very limited. Information obtained by telephone from a representative of the Ministry of Agriculture concerning digested sludge from the Salt Plant indicated the following:[1]

Parameter	Value
Total Solids	68,200 mg/l (6.82 percent)
Calcium	840 mg/l
Potassium	2,500 mg/l
Iron	1,479 mg/l
Sulfur	6,250 mg/l
Phosphorus	90 mg/l
Manganese	14 mg/l
Nitrogen	44,000 mg/l
Copper	630 (may be spurious)
Boron	zero
Cobalt	76 mg/l
Chloride	630 mg/l
Molybenum	zero

The single sample reflected in the above values was taken in June 1980 and analyzed by the Royal Scientific Society Laboratory. The data cover certain nutrients and metals, many of which are of potential relevance to agri ultural applications. Nitrogen, phosphorus, calcium and potassium are of particular intetes to agriculture as essential fertilizer elements. Although the

concentrations of these elements in digested sludges is less than obtainable in mineral fertilizers, the sludge can be a valuable fertilizer supplement and soild conditioner. These elements are known as "macronutrients."

Heavy metals that are considered as toxicants when in substntial quantities include arsenic, cadmium, chromium, copper, lead, nickel, and zinc. Chlorinated hydrocarbons are also considered toxicants or, more suitably, carcinogens. On the other hand, very small quantities of certain metals, such as zinc, copper, boron, and cadmium, are essential to proper plant growth and are considered "micronutriants."

Previous reports for regions within the Study Area presented the following[2] characteristic parameters for AGTP digested sludge:

Parameter	Value	Date
pH Value	6.8	19 September 1980
	7.0 - 7.1	January through August, 1980 range of 12 samples
Total Solids, percent	2.8 to 5.4	September through December, 1980, range of 3 samples
	2.77	Average of 12 samples, January through August 1980
Volatile Solids, percent of Total	65.4 to 74.0	September through December, 1980, range of 3 samples
	62	Average of 12 samples, January through August 1980

The report noted that although the detergent content of the AGTP raw sludge was not exceptionally high, it was a level where it could be inhibitory to digestion. Heavy metals concentrations in the AGTP digested sludge are presented in Table K-1.

The Sludge data indicate "normal" characteristics for the AGTP and Salt Plant sludges, with the possible exception of copper content, believed to be unusually high.

No data were available for the KHMC plant sludge at the time of preparation of this report.

TABLE K-1

HEAVY METALS CONCENTRATION IN THE AGTP DIGESTED SLUDGE

Constituent	Units	Dry Slduge From Drying Beds 28 December 1976	Wet Sludge From Digester with Contents at 3% Solids 25 January 1977
Organic Matter	%	65.15	64.60
Fixed Solids	%	34.85	35.40
Nitrogen (N)	%	3.60	3.70
Phosphorus (P)	%	1.55	1.50
Potassium (K)	%	0.40	0.56
Sodium (Na)	%	0.67	0.83
Calcium (Ca)	%	6.30	6.30
Magnesium (Mg)	%	0.45	0.50
Iron (Fe)	%	0.92	0.89
Zinc (zn)	mg/l	238	180
Copper (Cu)	mg/l	325[a]	300[a]
Manganese (Mn)	mg/l	183	165
Lead (Pb)	ppb	-	35
Cadmium (Cd)	N/S[b]	-	10
Chromium (Cr)	N/S	-	15
Nickel (Ni)	N/S	-	80
Cobalt (Co)	N/S	-	60

[a]Appears unusually high. Might be an analytical anomaly.

[b]Not stated. Believed to be ppb (parts per billion).

Table K-2 is presented to indicate examples of certain toxic constituents in sewage sludges in two major sewerage system of the Los Angeles, California, area, as contained in the Loas Angeles River Basin Plan. It should be pointed out that both the Hyperion system of the City of Los Angeles and the Joint Outfall System of the Los Angeles County Sanitation District (LACSD) involve major industrial contributions. The Joint Water Pollution Control Plant (JWPCP) of the LACSD is the terminal treatment facility for one very large network, within which the Whittier Narrows Water Reclamation Plant selectively diverts wastewater flows from which most industrial wastes have been excluded. The Hyperion Treatment Plant of the City of Los Angeles is the terminal (coastal) treatment plant of the second major sewer network. The data reflect conditions prior to implementation of the most recent program for industrial waste controls required by Federal legislation.

FUTURE STUDY AREA SLUDGES

The Los Angeles data shown in Table K-2 are based on extensive sampling and analysis while the data presented above for AGTP and Salt Plant are quite limited and should be considered as such. Nevertheless, the data for these local plants tentatively appear to confirm the impression that industrial wastes are not presently a major factor in treatment plant sludges for these local plants, despite the fact that the Municipal Slaughterhouse has a major impact on the existing AGTP basic treatment process. In Salt, the local pharmaceutical firm is using approximately 50 m^3/day of water and as such makes only a small contribution to the plant. The firm manufactures a broad range of antibiotics, vitamins, and other medicines, and does not appear to be having any effect on the plant operation.

The future characteristics of the AGTP digested sludge should not be much different from those that have been indicated above, with the following possible exceptions:

- With the provision of adequate anaerobic digestion facilities, the digested sludge should be somewhat lower in volatile solids than is presently the case. There will have been longer residence time in the digesters and improved mixing, all of which make for better digestion and better reduction of pathogens.

TABLE K-2

EXAMPLES OF CERTAIN TOXIC CONSTITUENTS IN SEWAGE SLUDGES

(After Los Angeles River Basin Plan)

Identification of Sewage Sludge	Units of Conc.	Toxic Metal Constituents[a]							Total Identifiable Chlor. Hydr.
		Arsenic as As	Cadmium as Cd	Chromium as Cr	Copper as Cu	Lead as Pb	Nickel as Ni	Zinc as Zn	
JWPCP Digested Sludge Grab Sample, No. A-4[b]	mg/l	0.00	2.38	105	60.0	-	9.70	244	-
Whittier Narrows WRP[c]									
Primary Sludge	mg/l	0.02	0.43	31	19	9.8	6.4	56	0.84
Waste Activated Sludge	mg/l	0.09	0.26	22	9.2	3.8	4.0	44	0.048
Average 4 W.R.P.[c]									
Primary Sludge	mg/l	0.01	0.46	10	7.4	19.7	2.5	28	0.29
Waste Activated Sludge	mg/l	0.05	0.30	7.6	5.2	4.1	1.4	21	0.01
Hyperion Sludge Outfall[d]	mg/l	0.03	0.40	1.65	9.25	1.20	2.80	10.2	0.052

[a]Mercury and silver results are deliberately omitted as they are normally present only in trace quantities, if at all. It is recognized that trace amounts of many heavy metals are essential to healthy plant growth, but that excessive concentrations are toxic.

[b]Taken on April 4, 1972.

[c]From LACSD Technical Report, Waste Discharge to the Ocean, January 15, 1973 Volume I pp. II-25 and II-26.

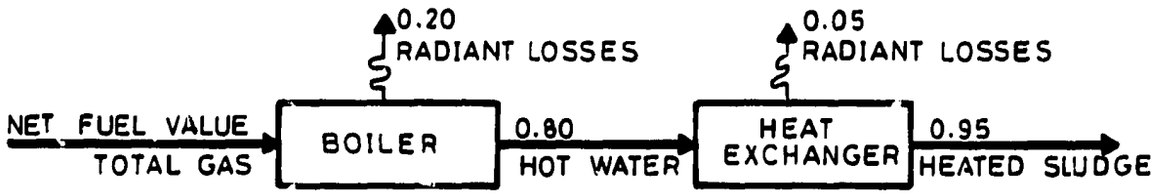
[d]From City of Los Angeles Technical Report on Waste Discharges at the Hyperion Treatment Plant, January 8, 1973, Volume II, p. 110. This represents digested sludge.

- If industrial activity is permitted to increase within the AWSA network and if industrial wastes ordinances and enforcement thereof are not sufficient, increases in heavy metals constituents might occur and be found detrimental.

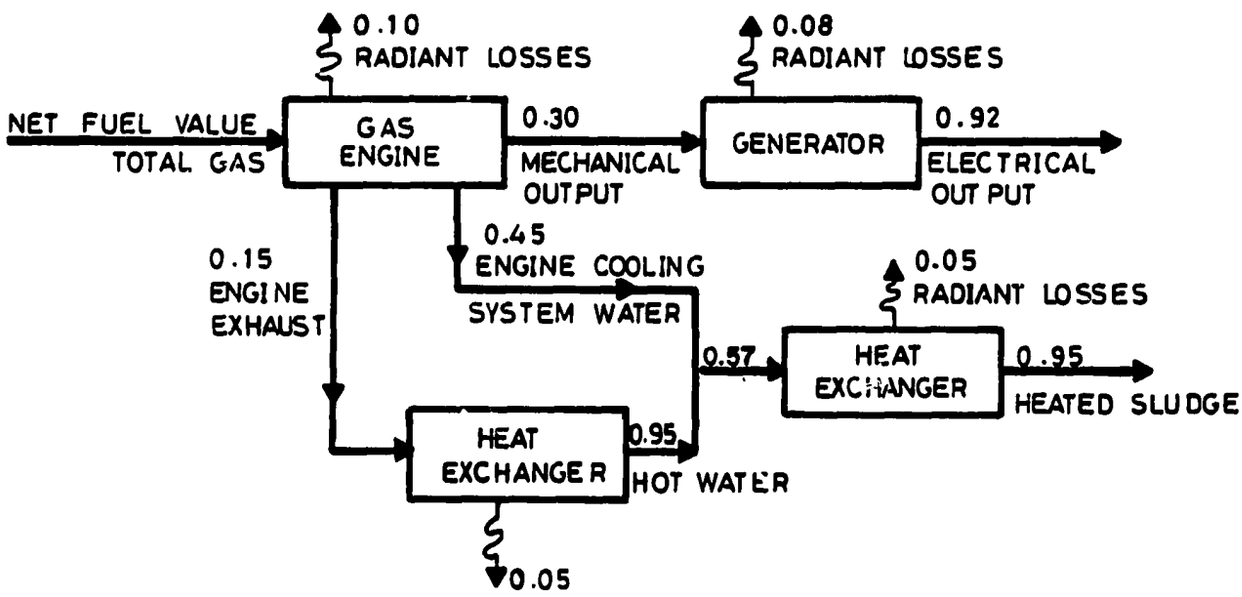
The first instance would be an expected betterment. The second instance would be an unexpected detriment, because the intention is that the new industrial wastes ordinance be adopted and enforced vigorously.

Regarding the future Zarqa-Ruseifa Treatment Plant, digested sludges produced from this facility would be more likely than those of AGTP to reflect industrial activity, for there is significant heavy or "wet" industry in the tributary area. The effects of the wet industries on the sludge characteristics can only be assumed but with adequate controls, they would be minimal. If pretreatment and controls are not sufficient, the increase in toxic metals content in the sludges would be sufficient to dissuade their beneficial uses. The program for such beneficial use will have to be developed deliberately and in consideration of an expanding data base, which will be essential to the program.

GAS UTILIZTION FOR
SLUDGE HEATING



GAS UTILIZATION FOR
ELECTRICAL GENERATION
AND SLUDGE HEATING



NOTE: UNITS ARE DECIMAL
PERCENTAGES OF THE
THERMAL VALUE LEAVING
THE INDIVIDUAL PROCESSES

UTILIZATION OF
DIGESTER GAS

FIGURE K - 1

REFERENCE FOR APPENDIX K

1) Personal communication, Charles H. Lawrance, JMM/DMJM, a Joint Venture, and Marwan Kharabsheh, Ministry of Agriculture, 2 Sept. 1980.

2) Binnie & Partners, Jouzy & Partners, "Ain Ghazl Treatment Works, Draft Report on Immediate Improvements and Expansion of Sludge Facilities, "January 1978".

APPENDIX L

COMPARISON OF ACTIVATED SLUDGE WITH ROUGHING FILTERS-ACTIVATED SLUDGE

This appendix presents some of the detailed information developed in comparing the basic alternatives for future secondary treatment at the Ain Ghazal Treatment Plant, the summary of which is included in Chapter 8. The basic alternatives involved secondary treatment by activated sludged alone (designated as Treatment Alternative One or TA1) and secondary treatment by roughing filters (trickling filters) followed by activated sludge (designated as Treatment Alternative Two or TA2). Under TA2, the activated sludge facilities would not be required to remove as much organic load as under TA1, because a significant portion of such load would already have been removed by the roughing filters. Accordingly, TA2's activated sludge facilities would not need to be as extensive as those for TA1.

The bases for sizing TA1 and the actual sizing of both TA1 and TA2 were presented in Chapter 8 in the main body of this report. The ensuing discussion provides the bases for the assumed sizing of the facilities for alternative TA2.

Cold Weather Reduction of BOD Removals

The plant operational data on BOD loadings and subsequent removals at AGTP are difficult to analyze for possible trends of seasonal effects associated with air temperature or wastewater temperature. This is primarily due to current conditions at the AGTP, including the inadequately controlled discharges of septage and contributions from the municipal slaughterhouse. Irrespective to this, it is recognized that biological activity generally varies exponentially with temperature.

As an illustration of this, it is a well established fact that trickling filters are more efficient in warmer climates than in colder ones. This is reflected for example, in the reduced ratings accorded trickling filters as the site latitude increases. Of course, some of this may be due to the effects of surface icing during very cold weather, but a great deal is due to the wastewater temperature effects upon the biological reaction rates.

For example, the theoretical biological reaction rate for trickling filters at 10°C is only about 46 percent of that experienced at 20°C; at 5°C, it is only about 32 percent of the 20°C rate. The relevant temperature is that of the wastewater and not of the air. Even so, the air temperature has an effect upon the wastewater temperature, particularly for high-rate filters with significant recirculation.

In illustration of the foregoing, Benzie, Larkin, and Moore, reporting in the April 1963 Journal WPCF, concluded that there was a significant difference in the BOD removal efficiencies in 17 Michigan (USA) community trickling filter plants between the summer and winter months and that in those plants having recirculation, the winter filter efficiency was 21 percent less than the summer efficiency. Their plots show a pronounced winter fall-off in BOD removal efficiency and indicate that even when the mean air temperature averaged about 10°C, the efficiency declined nearly 20 percent from 20°C levels for the two

plants depicted with recirculation. Some of this may be due to icing. However, even with average temperatures dropping only to 15°C, the decline in BOD removal efficiency was at least 10 percent from that of the 20°C level.

In Amman and other Jordanian communities, a large proportion of the public water supply undergoes storage in uninsulated roof tanks prior to being used and converted into wastewater. On the other hand, the proportion of the wastewater that has been heated - such as in the course of bathing, laundering, and culinary activities - is probably not very high, at least not in comparison with Western standards. Thus, the wastewater is not of greatly higher temperature than that of the delivered water, and winter cooling effects via roof tanks may be significant. As a result, there is a fairly good opportunity for the local water supply drawn into household taps during cold weather and subsequently discharged into the Amman secondary network to be significantly colder than such flow during the average and warmer months of the year. Furthermore, the residence time of the flowing wastewater in the secondary and primary networks is relatively short, due to the steep grades and relatively high flow velocities experienced. Thus, the relatively constant ground temperature effects on moderating wastewater temperature are thought to be minimal. Consequently, the cold weather months of the year may be expected to witness colder wastewater at AGTP than at other times, and this could be somewhat adverse to the performance of roughing filters at such times.

Cold weather fall-off of roughing filter performance could be compensated for either by overdesigning the filters or by providing reserve capacity in the following activated sludge units. This would, of course, entail additional capital outlay and greater use of space than otherwise required.

It would not seem advisable to relax effluent standards on a seasonal cold weather basis, for the public health exposure would not be diminished at such time. Cold wather is not necessarily coincidental with the flow of diluting water in the Seil Amman/Seil Zarqa. In fact, due to the flashy nature of the watershed, there is very little run-off in the Seil Amman except during, and for a limited period following, heavy rainstorms and snowmelt episodes.

Activated sludge efficiency is also affected by dropping wastewater temperatures, but the effects are less pronounced than those for trickling filters. For example, the typical, theoretical biological reaction rate for 10°C wastewater for activated sludge is 82 percent that of the 20°C reaction rate. This compares with the 46 percent rate for trickling filters.

Activated sludge process efficiency is highly dependent upon efficient separation of suspended solids (activated sludge floc) in the final clarifiers. This flow is very light and is easier to settle in warm wastewater than in cold wastewater, due to viscosity effects. These factors have been pointed out in the literature. For example, Keefer, writing in the November 1962 Journal WPCF, reported reduced BOD removals by activated sludge treatment at Baltimore as the wastewater temperature dropped from 26°C to 20°C and further to about 12°C. However, the BOD efficiency fall-off due to lowering wastewater temperatures was not nearly as pronounced as the comparable fall-off in the performance of the trickling filters in the Michigan plants reported earlier, with only about 2 percent

for a temperature drop from 20°C to 15°C. This experience is generally consonant with commonly accepted criteria.

Activated sludge facilities, when well designed and operated, have greater flexibility than those of trickling filters for making adjustments to accommodate seasonal effects. Furthermore, it is planned that the activated sludge secondary clarifiers for both Alternatives TA1 and TA2 be conservatively designed to minimize solids separation difficulties.

In view of the foregoing, it is concluded that the activated sludge (TA1) process would have a certain advantage over the combination roughing filters-activated sludge process (TA2) at AGTP relative to cold weather performance.

Intermediate Clarifiers Following Roughing Filters

Trickling filter plants always include final clarifiers for removal of humus sludge and effluent clarification. On the other hand, two stage trickling filter plants sometime eliminate the intermediate clarifiers between stages but, of course, retain final clarifiers. Combined aerobic treatment plants incorporating series trickling filter and activated sludge processes may not require intermediate clarification, depending upon local circumstances. For example, Roskopf, Young, and Baumann, writing in the October 1976 Journal of the Environmental Engineering Division, ASCE, reported upon a pilot plant evaluation of trickling filter-activated sludge combinations. These had been studied with particular reference to the possibilities of using the activated sludge process to upgrade an existing trickling filter plant in order to meet new and stricter state and Federal water quality standards. Three modes were studied: (1) a parallel trickling filter-activated sludge combination; (2) a series trickling filter-activated sludge combination with no intermediate settling of trickling filter effluent; and (3) a series activated sludge-trickling filter combination with intermediate settling and recycle of activated sludge mixed liquor suspended solids. It was not intended to imply by the findings that any one of the combinations was universally best but rather to add to the available body of engineering information. The pilot plant work was conducted at the Ames, Iowa Water Pollution Control Plant and was supported in part by the City of Ames, Iowa. The wastewater supplied to the pilot plant(s) was primary effluent from the Ames Plant.

The Ames pilot plant findings showed that the combined trickling filter-activated sludge system (which had no intermediate clarifiers) provided better operating stability than single-stage systems and that the series system provided a higher efficiency than either a single-stage trickling filter or activated sludge system. In commenting upon whether or not to provide intermediate settling in the expansion of an existing trickling filter plant, the authors noted that existing clarifiers following the trickling filters could be used, at the option of the operators, for removal of humus sludge during periods of heavy filter sloughing. At other times, the process performance might be improved by bypassing the intermediate clarifiers.

In theory, there might be good justification for eliminating intermediate clarifiers entirely. The microogranisms in the growths sloughing from the

roughing filters (oxidation towers) are not initially very active, so the oxygen uptake of the humus sludge is relatively low. Thus, they would not be expected to exert a major load in the aeration tanks but they would soon become active in the presence of oxygen and wastewater BOD, and would become part of the activated sludge. Also, they would be expected to settle readily in the final clarifiers following the aeration tanks. Humus sludge settles much more readily than activatedd sludge. Furthermore, if intermediate clarifiers could be eliminated altogether, there would be a savings in both capital cost and on-going operation and maintenance, both of which could be important.

On the other hand, provision of intermediate clarifiers could increase the operating flexibility of the plant, albeit at additional capital and O&M expense. There could be a tradeoff between the possible benefits of the intermediate clarifiers and the additional upkeep and plant complexity that they would bring. Unfortunately, the literature does not contain much helpful information on these aspects. Accordingly, JMM/DMJM drew upon its own current experience in certain generally comparable installations in the United States to aid in making its judgement on this matter. Brief summaries follow.

At Yuba City, California, a pure oxygen activated sludge system is normally used to treat combined municipal wastes and wastewater from a prune cannery. The system works successfully and reduces an influent BOD of some 800 mg/l to about 5 to 10 mg/l. During about two months of the year, a fairly high flow of high BOD wastes (well over 1,300 mg/l) is added to the base flow from a peach cannery that operates seasonally. During such times, it is necessary to activate a standby oxidation tower to act as a roughing filter for the entire flow. There is no intermediate clarifier between the oxidation tower and the activated sludge units.

The unusually high strength wastewater causes buildup of humus sludge on the plastic media tower surfaces as BOD is removed from the influent. About every five days, major sloughing is experienced. This causes a substantial increase in the BOD entering the aeration system, because of the anaerobic inner layers of the filter slime. Such episodes can upset the aeration units' operation if the monitoring and adjustments are not sufficient. Similar potentials for difficulty are present when filamentous growths from the roughing filter occasionally are discharged into the aeration tanks.

On the opposite extreme, the roughing filter is so efficient, particularly when lightly loaded and provided with adequate air circulation, that at such times the BOD entering the aeration tanks may be much less than the aeration tanks anticipate and the activated sludge system may be partially "starved," reducing its continuing effectivess. Very alert and careful operation may compensate for these vaying conditions of unbalance. However, the responsible official feels that there would probably be some benefits derived in the case of heavy sloughing and filamentous growth discharges from the roughing filter in having at least nominal intermediate clarifier capacity.

At Twin Falls, Idao, municipal wastes account for about 76 percent of the combined influent flow to the municipal treatment works but only about 26 percent of the influent BOD. Potato processing wastes are largely responsible for

the industrial component (about 24 percent of the flow and 74 percent of the plant influent BOD). The influent BOD concentration approaches 600 mg/l. There are some significant return wastes streams from sludge processing. The plant incorporates primary sedimentation, oxidation towers, and activated sludge treatment. The process includes the option of returning activated sludge to the oxidation tower for conditioning. There are no intermediate clarifiers between the tower and the activated sludge.

The oxidation towers, comprising several redwood modules, are operated as an activated biofilter (ABF) which entails returning the return activated sludge (RAS) over the tower. A plastic media tower was tested on a pilot plant basis in early 1981, and BOD removals were determined from primary effluent both by the tower alone and by the tower followed by intermediate settling. The testing indicated that the addition of 30 minutes of settling would improve the BOD removal by the tower from about 30 percent of applied to about 44 percent of applied, an improvement approaching 45 percent.

City of Twin Falls laboratory experiments upon the settling characteristics of the tower effluent indicated that the majority of the humus sludge would settle in an Imhoff cone in 30 minutes. Based upon these data and other considerations, JMM deemed it realistic to plan on a clarifier overflow rate of 1.1 m/hr (about 27 $m^3/day/m^2$). Although a very shallow clarifier could theoretically be effective, practical aspects dictated a minimum side water depth of about 3 m, and included provisions of rapid removal of the humus sludge from the intermediate clarifier. The averagve flow detention time for this installation was 2.7 hr, and the peak flow detention was about 1.8 hr. Provision of intermediate clarification is being recommended at Twin Falls as an aid to the operation of the activated sludge system, which has 6 to 8 hours aeration time. Removal of high BOD humus sludge ahead of the activated sludge system should result in savings in power costs. This would be a net savings even when accounting for clarifier construction costs.

At Fairfield, California, generally comparable JMM studies were made and findings obtained indicating the merits of intermediate clarifiers. The plant influent strength was high, due to local brewery wastes. Data from generally similar plants in central California have affirmed these general findings. JMM has so far incorporated intermediate clarifiers in at least two trickling filter-activated sludge plants and is recommending incorporation in two more.

As a result of the foregoing, JMM/DMJM has deemed it appropriate to include intermediate clarifiers in the TA2 facilities for comparison with TA1 facilities (Table 8-4). This is taken as a conservative approach, tempered by operating experiences. An indication is later given of the physical and cost ramifications of such provisions together with a weighing of their advantages and disadvantages. The presumed value of the controlling design parameter is 57 m/day overflow rate at peak flow. In allowing for a reasonable sidewater depth of 3.3 m, the peak detention becomes 1.4 hr. If TA2 were to be recommended for adoption, there should be pilot plant testing undertaken to determine the optimum sizing of the intermediate clarifiers following the roughing filters.

Design Criteria for Roughing Filters-Activated Sludge

Table 8-4 in the main body of the report has presented design criteria for Treatment Alternative TA2.

Need for Ventilation and Odor Control for Oxidation Tower

If very high strength wastes are introduced to oxidation towers, a potential for odor generation may exist. This is a consideration even though the plant influent is not expected to have much sulfide content. Thus, there is concern that if oxidation towers were to be operated at the AGTP ahead of activated sludge facilities, there could be significant potential for troublesome odors. This is due to the high strength waste that would be involved. Similarly, the air supply available by natural draft alone might not suffice in the towers. Towers would be favored over shallower and broader trickling filters because of space limitations. Both induced draft air circulation and odor control, if required, could add to the costs of the oxidation towers and reduce their possible economic advantages over activated sludge alone (TA1). Therefore, it is appropriate to summarize certain relevant experiences and considerations on these aspects.

At Yuba City, the 6.6 m high, plastic media oxidation tower reportedly is sometimes the source of odors, including hydrogen sulfide, from the anaerobic undersides of layers of humus sludge occasionally sloughing from the media. (The BOD loadings are exceptionally high, even higher than those anticipated at the AGTP). A fiberglass dome was installed by the City over this 24.4 m diameter tower in order to contain the odors, and an activated carbon scrubber was employed to remove the hydrogen sulfide and other impurities from the circulating air flow (forced draft). However, this odor containment system has reduced the capacity of oxygen supply to the media in the tower, thereby limiting its BOD-reduction capabilities. Part of the difficulty is due to the nature of the scrubber, whose support media become plugged with biological growth that is difficult to remove. When this occurs, oxidation tower performance falls off dramatically. It is suspected that water scrubbing ahead of the activate carbon scrubber might help alleviate the underdrain plugging problem. Additionally, it is likely that increased air circulation capacity may be required. Also, the activated carbon requires periodic regeneration or replacement. This situation illustrates the additional complexities and costs that odor control for oxidation towers receiving high strength wastes may entail.

At Twin Falls, JMM is proposing installation of induced draft ventilation for the oxidation towers in order to control potential odors and improve performance. The additional air is intended to supply increased oxygen to the tower biomass and also to dilute the natural ventilation air to help maintain atmosphere hydrogen sulfide concentrations about the plant at tolerable levels.

The AGTP lies within an industrial belt along the Seil Amman that is overlooked to the east by an extensive residential development. During the course of the studies by JMM/DMJM in the latter half of 1980, it did not appear that the plant odors were abnormal or that they carried very far. It is conceivable that this condition might still be generally true with a much larger flow and with expanded

activated sludge and solids processing facilities, but it is more likely that the odors would be somewhat more widespread and noticeable than they are at present. Conservative design, careful operation and scrupulous housekeeping would, of course, help minimize any odor problems.

If oxidation towers are to be added as roughing filters, the prospect for emanation of odors may be increased, even with forced draft ventilation. The extent of this is uncertain, and it may not be too significant inasmuch as the future influent sulfides should not be very high and the primary treatment facilities will remove a portion of the high organic load. Thus, if some oxidation tower ordors do develop, it is possible that they would be sufficiently limited that the neighboring population could tolerate them. However, it would appear to be more in the public interest to suppress any odors that might develop by prechlorination suitable scrubbing, or other means. The City government is known to be interested in providing public services such as sewers and amenities such as parks and is thought to disfavor procedures that would knowingly have negative impacts upon local residential areas. Thus, for the purpose of the comparison of TA2 and TA1, certain odor control facilities are assumed for the oxidation towers, and the costs therefor are suitably identified but can be deducted if suitable.

Layout Considerations

Under TA2 it would be logical for the layout to be shown in Figures 8-7 and 8-8, whereby all new digestion facilities are located near the municipal slaughterhouse, while the roughing filters, recycle pump station, and intermediate clarifiers are located to the north within this currently vacant site. As in the case of TA1, the new headworks would be located on the existing site as would new activated sludge facilities.

Because of land requirements and space limitations, there would be somewhat less allowable capacity for TA2 ultimate facilities than for TA1. This may be seen by comparing Figures 8-5 and 8-6 with Figures 8-7 and 8-8. Inasmuch as the TA2 capacity would be only 75,000 m^3/day, there would be only six new digesters required on the southern plant site, as compared to seven new digesters for TA1, whose capacity is 96,000 m^3/day. The former makes for a neater arrangement, but the latter is feasible and has been used with success in large treatment plants where space is at a premium. An example of this is the Joint Water Pollution Control Plant of the County Sanitation Districts of Los Angeles County (plant capacity about 1.42 million m^3/day).

It may be noted that if intermediate clarifiers were not to be provided for TA2, there would be some additional space made available, and this could support increased oxidation tower capacity and digester capacity on the southern site (Figure 8-7). There might even be enough space on the southern plant site to double the oxidation tower capacity, although this would crowd the facilities. This provision would reduce the BOD concentration of the flow of tower effluent to the north site, even if the total plant flow were to increase moderately.

As an approximation, it has been estimated that if intermediate clarifiers were to be eliminated and the oxidation tower capacity of TA2 doubled (not actually

recommended), the flow capacity of the total system could be increased to about 85,000 m^3/day. There would still be a need to convert the northern site secondary facilities to primary sedimentation tanks and to utilize most of the existing primary tanks. There would be about the same volume in new and converted activated sludge aeration tanks as in the basic (75,000 m^3/day) TA2 arrangement, but the secondary clarifiers would have to be increased slightly. The basic tradeoffs would be for obtaining a 10 to 15 percent increase in total plant capacity at the risk of establishing a plant that might sometimes be more difficult to operate than if the intermediate clarifiers were to be provided.

Energy Considerations

Activated sludge aeration is assumed to consume about 1.48 kwh per kg of BOD removed in the aeration tanks in the facilities under consideration, assuming about 90 percent of the BOD is removed. On the other hand, for high rate oxidation towers employing a recirculation ratio of 2:1, the power requirement for applying the influent plus recycle to the towers would be about 0.48 kwh per kg of BOD removed by the towers.

Due to relatively flat site and the hydraulic profile considerations, it would probably be necessary to pump the tower effluent into the intermediate clarifiers and activated sludge units downstream. This would reduce the energy advantage of the oxidation towers somewhat, as would the provisions of intermediate clarifiers sludge collectors and sludge pumps.

The oxidation towers would be anticipated to require a certain amount of forced draft ventilation, and this would add to the power load for Alternative TA2. In addition, if odor control via scrubbing were to be needed, as is assumed likely, the power load would be increased commensurately.

Table L-1 summarizes and compares the year 2000 average energy consumption for the biological treatment Alternatives TA1 and TA2. It is indicated that the energy demands of TA2 would be about 79 percent those of TA1 at that time. The demands at an intermediate point, such as 1990, would be roughly proportional to the flow but would depend, to some extent, on the sizes of units as dictated by construction staging.

Construction Costs

Table L-2 summarizes the estimated construction costs for both TA1 and TA2 for year 2000 conditions. The itemized costs are based on late 1980 price levels and involve only the biological treatment system for AGTP exemplified by the two alternatives. The respective construction costs of JD 7.16 million and 8.10 million are increased by 50 percent to establish the project costs. The annual capital cost assumes 20 year life and 10 percent interest and is applied to the project costs. Although the annual capital cost of TA2 is only 13 percent higher than that of TA1, TA2's unit cost (related to flow handled) is 44 percent higher than TA1's.

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COMPARISON OF ACTIVATED SLUDGE WITH ROUGHING FILTERS-ACTIVATED SLUDGE

TABLE L-1

COMPARATIVE ENERGY REQUIREMENTS OF SECONDARY TREATMENT ALTERNATIVES FOR AGTP IN YEAR 2000
Numbers are in average kilowatt consumption

Item	TA1 Activated Sludge Alone	TA2 Roughing Filters plus Activated Sludge
Oxidation Towers		
Supply Pumps	----	440
Ventilation Air	----	25
Odor Control	----	400
Intermediate Clarifiers		
Influent Pumps	----	100
Sludge Collectors	----	6
Sludge Pumps	----	11
Aeration Tanks		
North Site	1,780	1,275
South Site	1,050	----
Secondary Clarifiers Drives		
North Site	15	17
South Site	7.5	----
Return Activated Sludge Pumps		
North Site	60	40
South Site	27	----
Waste Activated Sludge Pumps		
North Site	12	8
South Site	6	----
Total	2,957.5	2,322

At a basic unit energy cost at AGTP of 35 fils/kwh the year 2000 biological treatment costs for TA1 and TA2 would be as follows:

Item	TA1	TA2	Difference
Annual kwh (in millions)	25.9	20.3	5.6
Cost in millions of JD			
Without escalation	0.907	0.711	0.196
With escalation at 4 percent	1.987	1.557	0.430

TABLE L-2

COMPARISON OF CONSTRUCTION COSTS OF BIOLOGICAL TREATMENT ALTERNATIVES TA1 AND TA2 FOR YEAR 2000
Numbers are in JD 1,000

Item	TA1 Activated Sludge Alone	TA2 Roughing Filters plus Activated Sludge
Oxidation Towers		
Supply Pumps	----	170
Ventilation System	----	515
Odor Control	----	435
Tower Structures	----	2,900
Intermediate Clarifiers		
Influent Pumps	----	70
Clarifier Units	----	400
Aeration Tanks		
North Site	3,372	2,472
South Site	2,031	----
Secondary Clarifiers		
North Site	1,088	1,076
South Site	613	----
Miscellaneous Work	56	62
Total, Construction Cost	7,160	8,100

Notes:

1. Numbers presented for intermediate clarifiers (TA2 only) include humus sludge pumping facilities.

2. Numbers presented for secondary clarifiers (TA1 and TA2) include both RAS and WAS pumping facilities.

3. Unit costs for biological treatment area as follows:

	TA1 (35.0 MCM/yr)	TA2 (27.4 MCM/yr)
Implementation Cost (10^3)	3,580	4,050
Total Project Cost (10^3)	10,740	12,150
Annual Capital Cost (10^3)	1,262	1,428
Unit Capital Cost JD	36,100	52,100

4. If ventilation system and odor control were to be eliminated, TA2's costs would drop by over 11 percent.

The costs depicted in Table L-2 are believed conservative but realistic. If oxidation tower ventilation and odor control were to be deferred or eliminated, there would be a decrease in TA2's capital and unit costs by some 11.7 percent. If intermediate clarifier units were eliminated, the reduction from the basic value would be about 5 percent. These matters are discussed subsequently.

Basic Comparison

A basic comparison, without considerations of sludge processing or power recovery ramifications, is made between TA1 and TA2 as follows:

Item	Costs are expressed in JD TA1	TA2
Annual Energy, Millions, Year 2000		
No Escalation, Table L-1	0.907	0.711
With Escalation, Table L-1	1.987	1.557
Annual Capital Cost, Millions, Table L-2	1.262	1.428
Total Annual Cost, Millions		
No Energy Escalation	2.169	2.139
With Energy Escalation	3.249	2.985
Unit Cost, JD/MCM		
No Energy Escalation	62,000	78,100
With Energy Escalation	92,800	108,900

Energy escalation, where applicable, is assumed at 4 percent per annum, compounded, over and above general inflation.

Effect of Eliminating Tower Ventilation and Odor Control

It should be noted that if the ventilation system and odor control system for the oxidation towers were to be eliminated, about 425 kw or 3.68 million kwh/yr might be saved for TA2. This would correspond to JD 0.129 million without energy escalation and JD 0.283 million with energy escalation. When combined with a capital cost reduction in TA2 of some 11.7 percent, the numbers would become:

Item	TA1	TA2
Total Annual Cost, JD Millions		
No Energy Escalation	2.169	1.843
With Energy Escalation	3.249	2.535
Unit Cost, JD/MCM		
No Energy Escalation	62,000	67,300
With Energy Escalation	92,800	92,500

This indicates that the two alternatives would be very close, particularly if energy escalation effects are realized in the future. If tower ventilation and odor control were to be eliminated, it could be at the expense of reduced operating efficiency of the treatment facilities and creation of potential nuisance conditions. However, for TA2 implementation, it might be possible for the design to anticipate such facilities to be provided at such future time as their needs had been demonstrated by operational experience.

Effect of Eliminating Intermediate Clarifiers

No detailed calculations have been made upon the costs ramifications of possibly eliminating the intermediate clarifiers, because it is not believed that this is a conservative approach for wastewater treatment planning. However, an indication may be obtained from the previous approximation of supposed increased plant capacity to about 85,000 m^3/day. This would entail about the same aeration facilities as used for the 75,000 m^3/day system, although a slight increase in secondary clarifier capacity would be involved. The oxidation towers influent/recycle pump station would have to be enlarged and the tower structures would, of course, be doubled. Indications are that the unit cost for the modified TA2 biological treatment (no intermediated clarifiers, also no ventilation or odor control) would be about JD 75,000/MCM without differential energy escalation and JD 97,000/MCM with the escalation. On this basis, there would be no benefit in eliminating the clarifiers for the purpose of making room for additional towers and, in fact, the unit cost would rise somewhat.

Considerations of Sludge Processing

If TA2 were to be selected, there would be less waste activated sludge to thicken prior to sludge disgestion than for TA1. Humus sludge, produced by the oxidation towers, settles quite readily and would not require as much thickening as the activated sludge, perhaps not any at all. This could represent a savings favoring TA2. The effects have not been quantified in this analysis.

Another factor of potential significance is the nature of the humus sludge itself as regards gas production potential in anaerobic digestion. Due to its biochemical nature, humus sludge often undergoes a greater degree of decomposition in anaerobic digestion than does waste activated sludge, thereby yielding somewhat greater quantities of sludge gas than the waste activated sludge. This factor would be of potential significance at AGTP if power recovery were to be attempted. Table L-3 presents a preliminary analysis of the power recovery potentials of the biological treatment alternatives TA1 and TA2, in which it is indicated that there might be nearly 15 percent greater unit gas production for TA2 than for TA1. It should be noted, however, that considerable gas production potential exists from the primary sludge derived ahead of either TA1 or TA2, so the overall plant advantage of TA2 over TA1 would probably be in the order of 10 percent. Even so, if both TA2 and power recovery were undertaken, there could eventually be an advantage from this aspect, favoring TA2. It has been

TABLE L-3

COMPARISON OF POWER RECOVERY POTENTIALS OF TA1 and TA2
FOR YEAR 2000 CONDITIONS

Item	TA1	TA2
Average Flow, m^3/day	96,000	75,000
Primary Effluent		
BOD, mg/l	585	585
BOD, kg/day	56,200	43,900
SS, mg/l	450	450
SS, kg/day	43,200	33,800
BOD Removal by Roughing Filters		
kg/da @ 50%	----	21,950
VSS, Filter Sludge		
kg/da @ 60% of BOD	----	13,200
BOD to Aeration Tanks		
kg/day	56,200	21,950
BOD Removed as Act.Sl.		
for 50 mg/l effluent	51,400	18,200
VSS from Act Sl (WAS)		
kg/da @60% of BOD	30,800	10,900
Sludge gas from Humus Sludge[a]		
m^3/day @ 0.47 m^3/kg VSS feed	----	6,200
Sludge gas from WAS[b]		
m^3/day @ 0.37 m^3/kg VSS feed	11,400	4,000
Total Sludge Gas, m^3/day	11,400	10,200
Total Gas/yr. $10^6 m^3$	4.16	3.72
Unit Gas Production/MCM	119,000	136,000
Assume the following		
Rounded Values, m^3 gas/MCM	120,000	138,000
Then Annual Gas, $10^6 m^3$	4.20	3.78

[a] For humus sludge, assume 50% destruction or 0.5 (0.935) = 0.47 m^3/kg VSS fed to digester.

[b] For WAS, assume 40% destruction or 0.4 (0.935) = 0.37 m^3/kg VSS fed to digester.

estimated that there could be a net economic benefit to either TA1 or TA2 with cogeneration implemented. If differential energy escalation is ignored, the difference between the alternatives TA1 or TA2 would be slight. If differential escalation is considered, TA2 would be favored by this operation by perhaps JD 2,000/MCM/yr wastewater flow, depending upon assumptions used.

Other Considerations

Certain items of significance not immediately amenable to monetary quantification are also of relevance in the comparison between TA1 and TA2:

- Amenability to stage construction
- Extent of the process train vis-a-vis O&M requirements
- Adaptability to unforeseen developments
- Timing upon need for downstream facilities

AGTP will require major expansions and upgrading in the near future to accommodate rapidly increasing loads and to simultaneously improve the quality of the effluent being discharged to the Seil Amman. TA1 is more amenable to stage construction than TA2 in that a completely new activated sludge plant would first be built on the southern plant site under TA1, thereby taking up the load and permitting subsequent conversion work to be done on existing secondary sedimentation tanks and aeration tanks. TA2 would not permit this and would be less flexible. This is a significant advantage of TA1 and TA2.

Introducing an extra process in the overall treatment process train automatically adds to the complexity of the total process, even when the added process is relatively straightforward, as in the case of roughing filters (oxidation towers). Having such added facilities in the system adds to the probability of process interruption due to mechanical failure or human error and places an additional burden upon operation and maintenance (O&M) personnel. This is of some significance in industrial countries but should be taken even more seriously in developing nations, particularly if there are likely to be difficulties in obtaining and retaining adequatedly qualified O&M personnel.

The benefits in energy cogeneration would favor TA2 over TA1, slightly to moderately. In the United States, there is already considerable interest in such endeavors in municipal treatment plants because of high energy costs. However, there are substantial capital and O&M costs entailed. In the case of AGTP, it is uncertain whether such a factor should be relied upon in deciding between TA1 and TA2, in view of the complexities and the need to have fairly reliable operation in order for the system to pay off. Cogeneration should be undertaken on its own merits regardless of the biological treatment method selected but only when it is assured that both adequate capital and O&M funds are available.

The future quantities and characteristics of the wastewater to be treated at AGTP have been projected based upon the best available information. The future strength of the wastewater has been assumed to be about the same as the present strength, even though the per capita wastewater production has been projected to increase moderately, due to greater availability of water supply to populated

areas. This conservative approach was undertaken to ensure adequate capacity in the facilities being planned for AGTP. It recognizes that only a modest increase in industrial organic contributions is likely, due to the effects of planned industrial developments outside the AWSA system.

It does not appear very likely that the future wastewater will be any stronger than that which has been projected, but it could turn out to be somewhat weaker than premised. If this should occur, the effects upon TA1 and TA2 would probably not be much different. However, there would be commensurately reduced justification for introducing roughing filters to the process train in order to facilitate downstream activated sludge operations.

If the future wastewater flows should be less than projected, both TA1 and TA2 would be affected in about the same way. However, if the flows became greater than projected, there would be an earlier need for full utilization of the AGTP site, and TA1 would have an advantage because the process is less land-intensive.

Future flow coming to the AGTP site will eventually exceed the capacity of the future AGTP facilities, and it will be necessary for the excess to be diverted downstream in a new trunk sewer leading to a new, future treatment plant at Khirbet er Ruseifa (the KRTP). Under normal times of limited inflation, a present worth analysis could be made of the value of deferring construction of these facilities. However, present economic conditions are probably too uncertain to warrant such a calculation, and it should suffice to indicate that if other demands for capital and O&M funds exist in the mid-future, these would be more readily satisfied under TA1 and TA2. As regards future trunk sewer and KRTP capacity, the 21,000 m^3/day difference between the basic 96,000 m^3/day of TA1 and 75,000 m^3/day of TA2 can be placed into some perspective as follows:

- The trunk sewer capacity difference would be about 1.8 times 21,000 m^3/day or 26.3/m^3/min (438 l/sec). In the flow sizes and construction/hydraulic slopes that would be involved, this incremental peak flow would probably require one commercial diameter increase and at least JD 20/m increased project cost. For about 5,000 meters of trunk sewer run, this would correspond to JD 100,000 additional cost, possibly considerably more.

- The KRTP is located in an industrial area where land costs are very appreciable, in the order of JD 15,000/dunum. Inasmuch as the additional 21,000 m^3/day of treatment plant would require from about 15 to 30 dunums, depending upon the process used and the amount of crowding to be tolerated, the increased capital outlay could approach JD 0.5 million. There might also be cost differences between AGTP and KRTP in providing the same amount of capacity.

Conclusion as to Preferable Alternative

The foregoing discussions have indicated capital outlay advantages favoring TA1 over TA2 and, in most instances, O&M cost advantages as well. If future energy

cost escalations are experienced, this would reduce the O&M and overall cost advantages of TA1. If oxidation tower ventilation and odor control system facilities for TA2 were to be deferred or eliminated, the overall cost advantage could swing into the favor of TA2, particularly if energy recovery through cogeneration is to be practiced and provided energy cost escalation materializes. Elimination of intermediate clarifiers between the oxidation towers and activated sludge system appears unwarranted, both as regards conservation practice and according to any likely monetary benefits to be achieved. Finally, intangible considerations such as system complexity and reliability, amenability to adapt to unforeseen circumstances, and integration with the future downstream KRTP facilities generally favor TA1 over TA2.

The weighing of the several aspects of the matter, described above, leads JMM/DMJM to the conclusion that either TA1 (activated sludge alone) or TA2 (roughing filters-activated sludge) could properly be selected as the appropriate biological treatment process for AGTP for the future. Inasmuch as NPC (and AWSA) favor TA2, JMM/DMJM have concurred. The remainder of this report proceeds on this basis.

070

Even with steep urban terrain, the misuse of sanitary sewers can sometimes lead to a partial obstruction in the AWSA collection system.

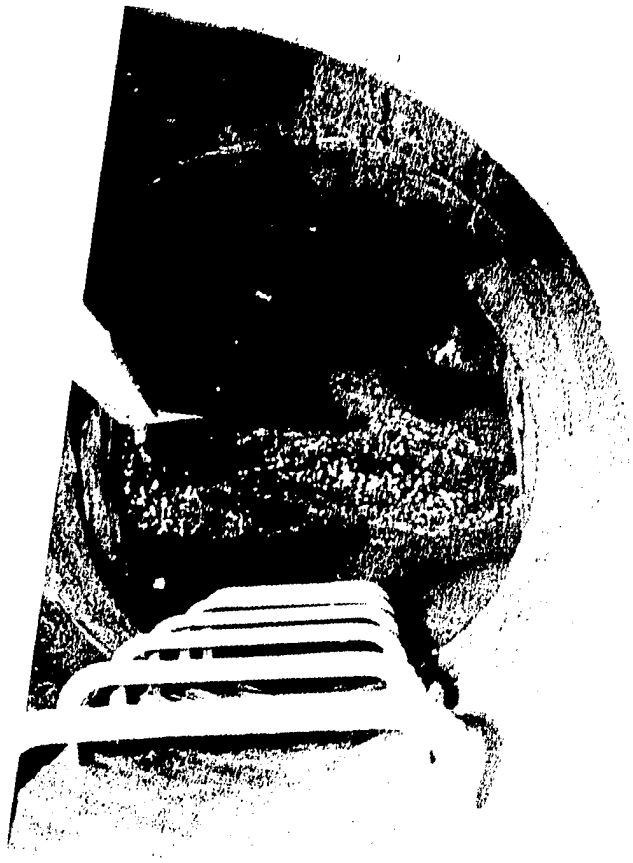
The result . . . an overflowing manhole.

Manhole covers in the sanitary sewer network are frequently paved over, making for difficult access

Even when the covers are not paved over, they often resist removal.

Once manhole covers are removed, velocity stick gaging of the flow is undertaken . . . .
(above)

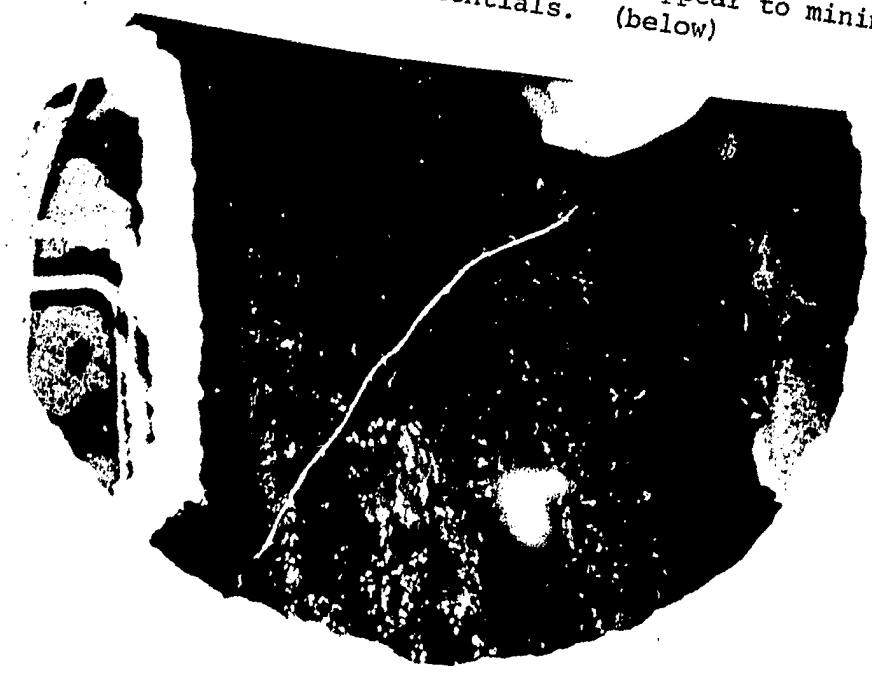
. . . . yielding helpful hydraulic data, and enabling engineers to check conditions of manhole concrete and steel rungs. (right)



Most manholes appear to be in good conditions.

Occasionally, local conditions may result in evidence of minor deterioration . . . .

. . . . but typically high flow velocities appear to minimize the sewer sulfide corrosion potentials. (below)



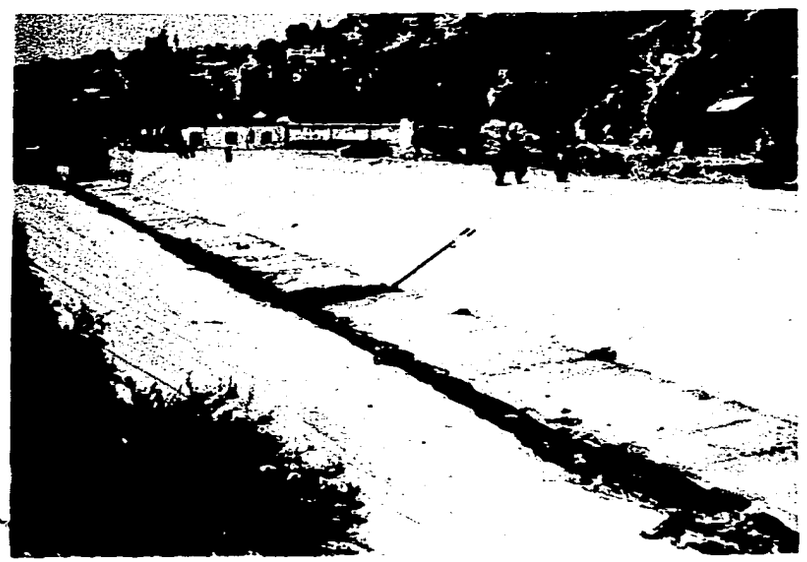
As sewers are extended and buildings connected, there will be fewer discharges of wastewater to the Seil Amman than recently . . . .

(left)

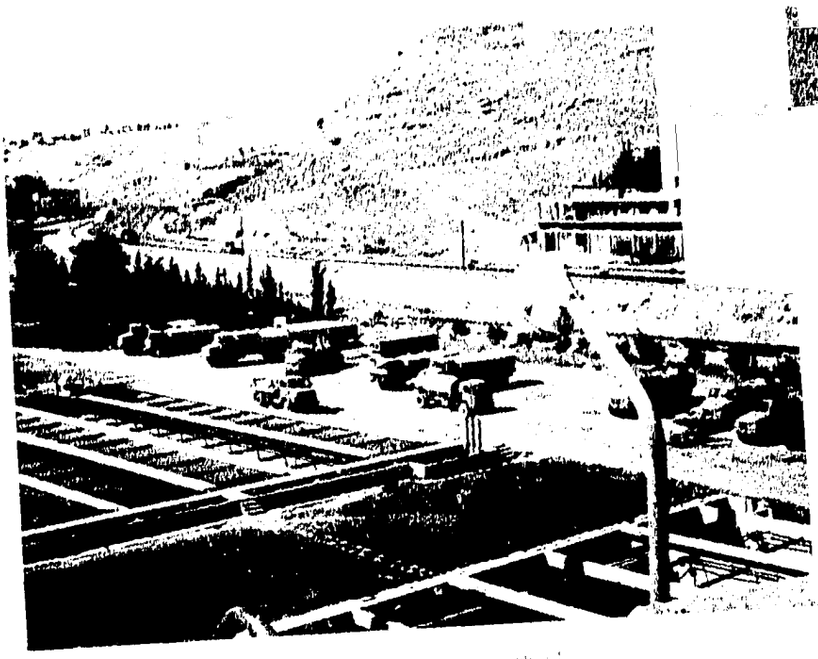
. . . . or overflows or seepage from cesspools.

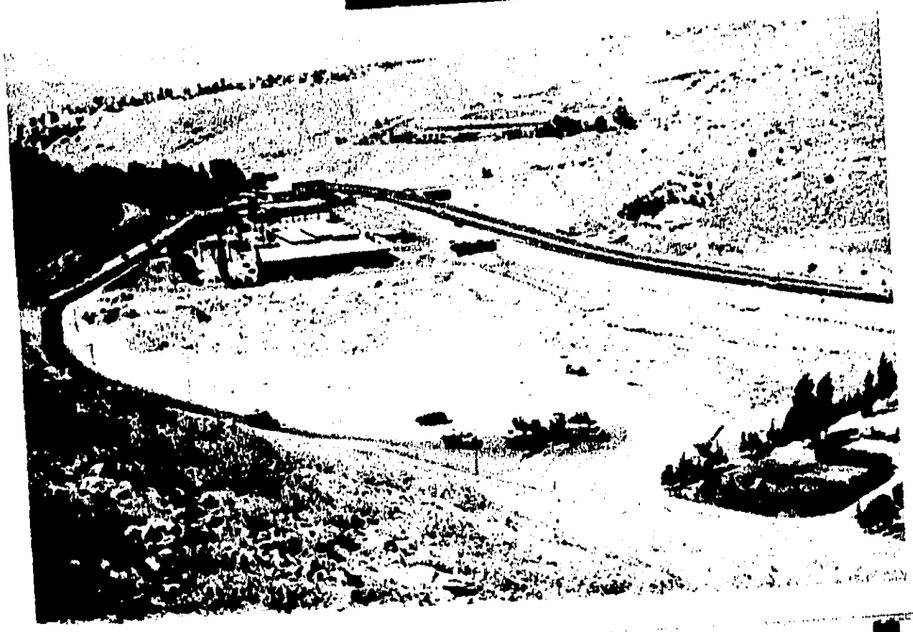
(above)

Most of the dry-weather Seil Amman flow above Ain Ghazal Treatment Plant is wastewater. (below)



The Ain Ghazal Treatment Plant (AGTP) lies next to the Seil Amman in a very narrow valley . . .





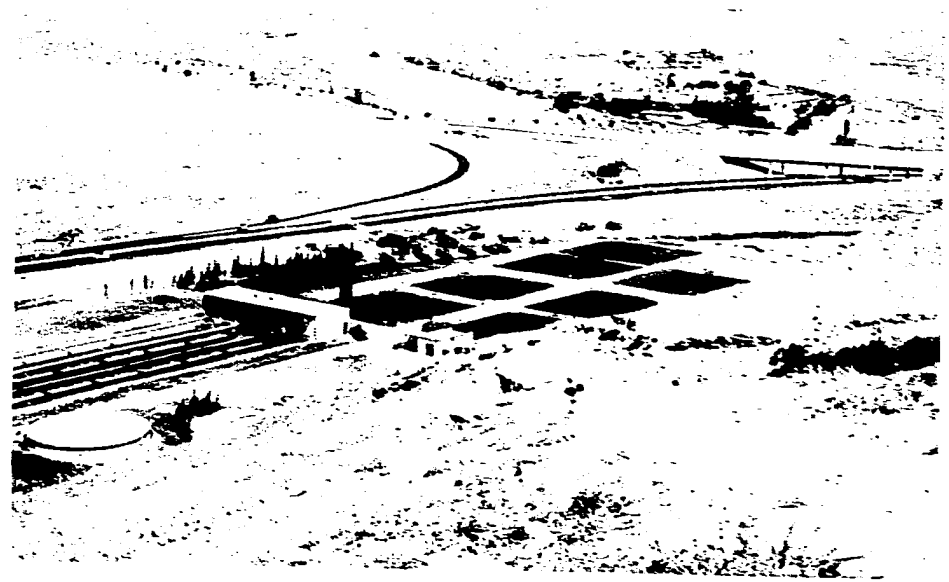
. . . below the municipal slaughterhouse (background), and immediately below the septage dumping manhole (trucks in foreground.)

AGTP expansion to the east is prevented by the Hejaz Railroad and steeply rising terrain. Expansion to the south (towards the slaughterhouse.) The vacant land has been used for dumping of fill material.

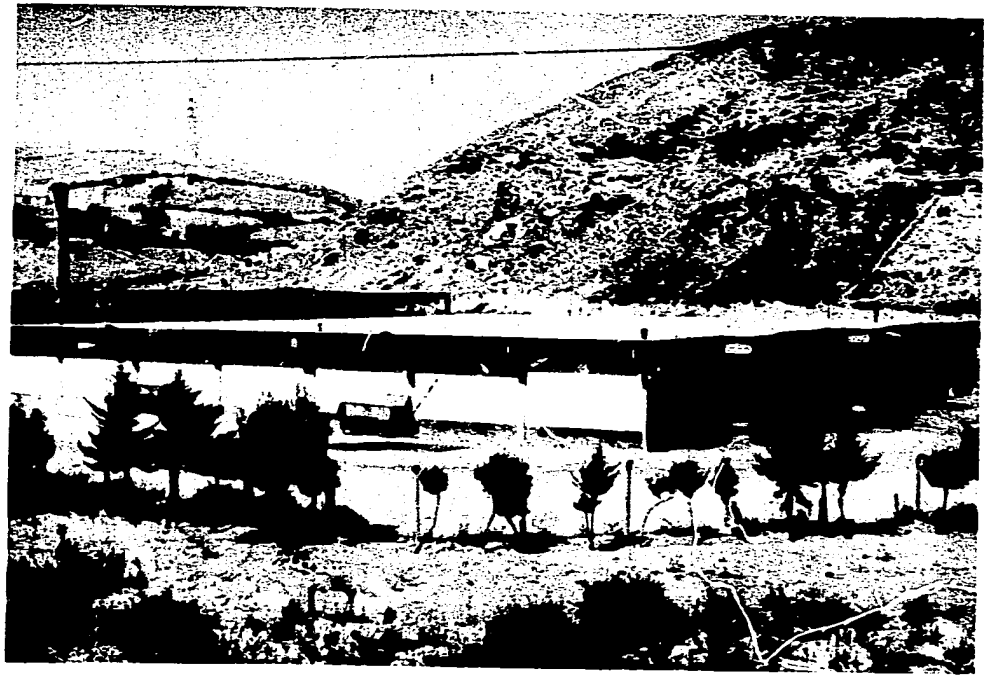
Looking westerly across AGTP from the hillside to the east. The Seil Amman flows in a flood control channel adjacent to AGTP.
(above)

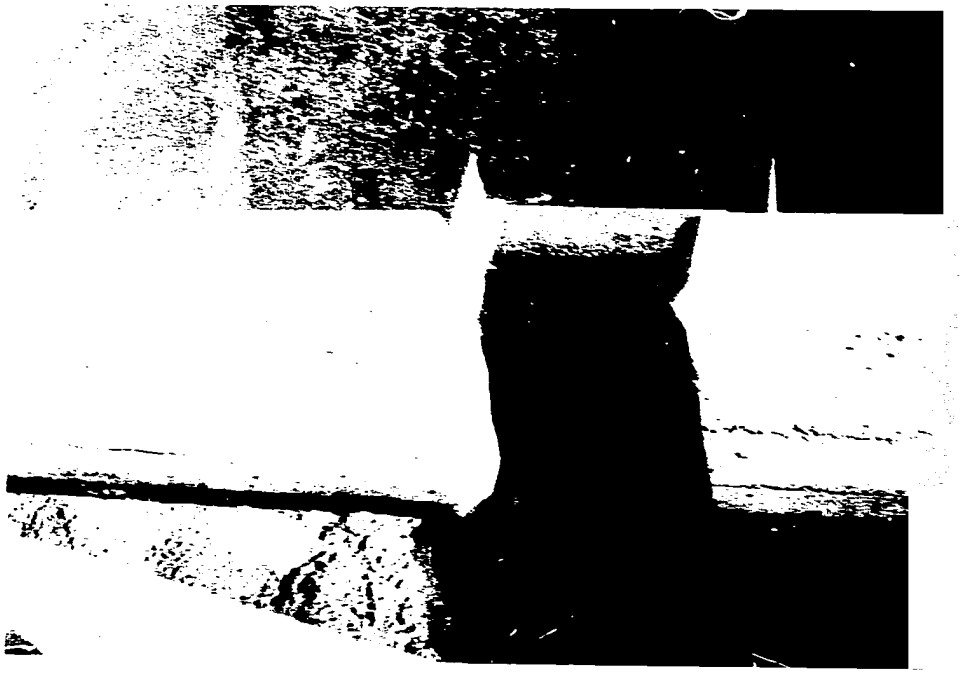
Looking northerly across the blower building and sludge drying beds of AGTP. The Seil Amman is no longer channelized past the AGTP.

(right)

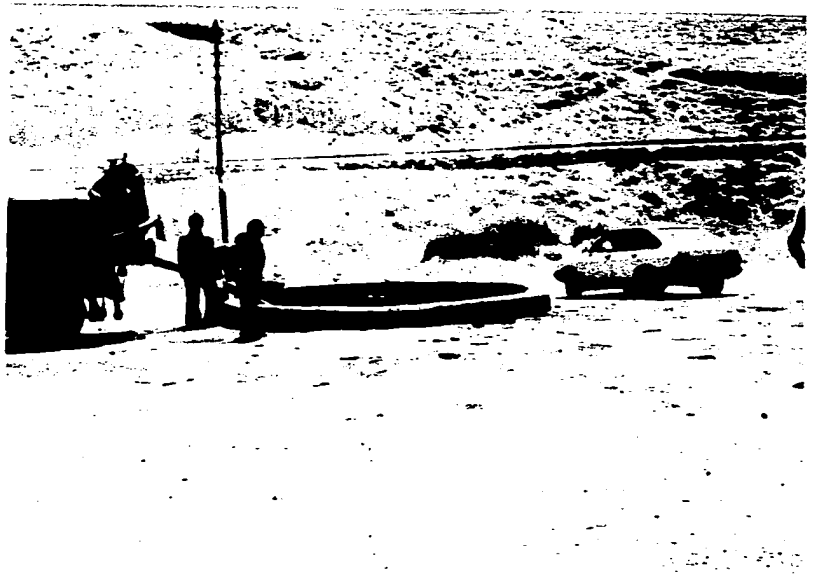


The AGTP site is unusually elongated, dictated by the terrain.





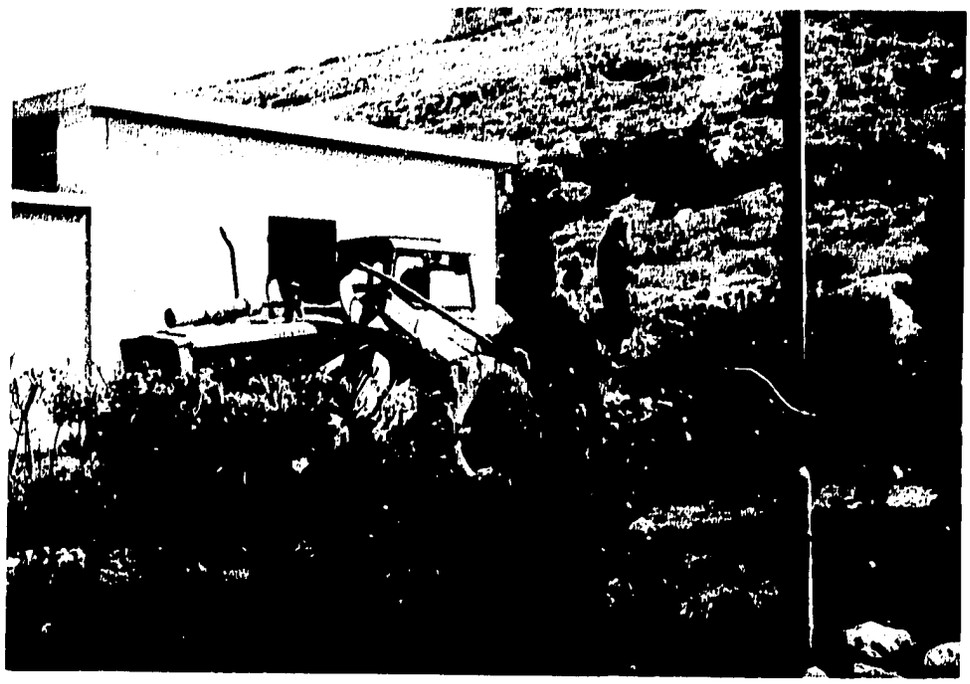
Industrial wastes from the Municipal Slaughterhouse . . . have an impact throughout much of the AGTP.



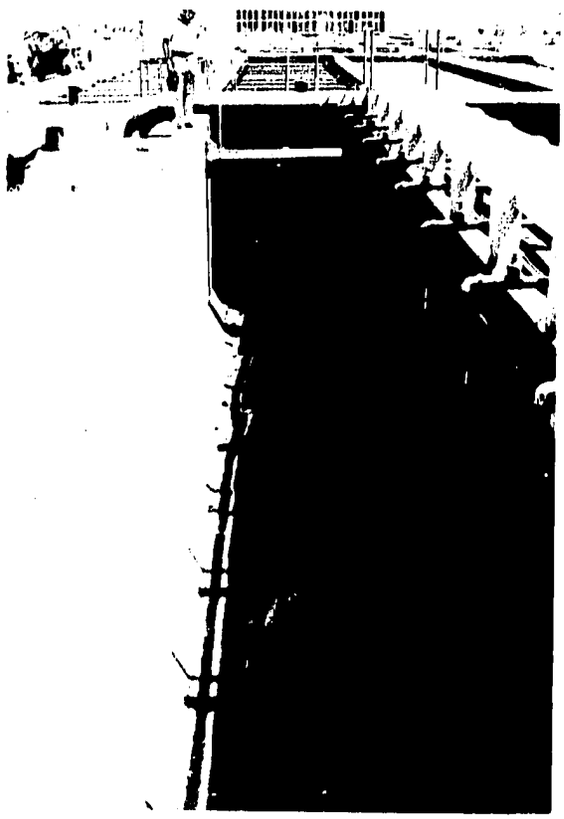
The intermittent high strength loadings of septage discharges at the dumping manhole . . .

. . ; in biological stabilization at A

Plant influent is forced to rise over a concrete weir in the AGTP headworks, causing the flooded influent sewer to trap debris which must be removed by laborers. Barminutors are in the building shown.

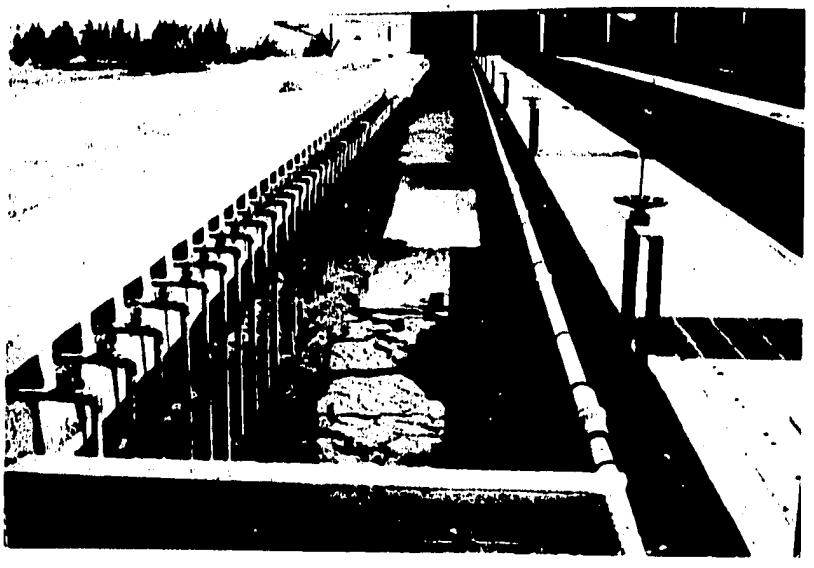


The stage recorder at the Sutro weirs for measuring plant inflow often requires maintenance.

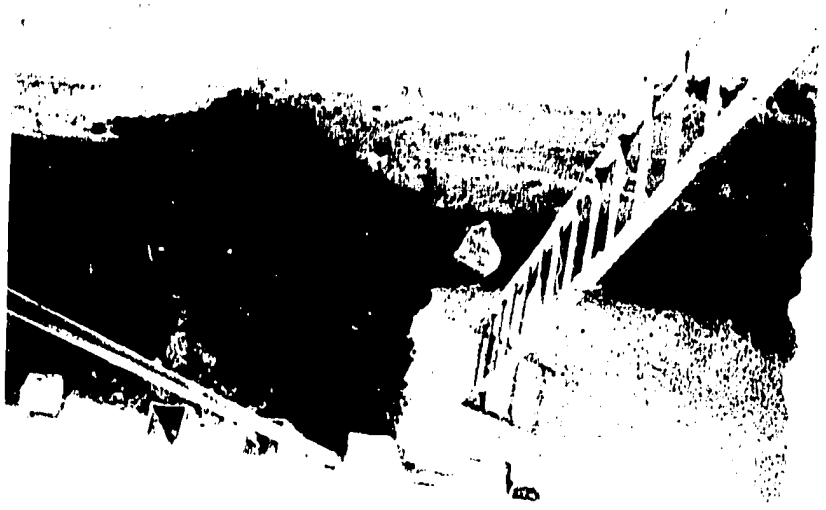


Due to mechanical difficulties, some preaeration basins used for grit removal may be shut down for weeks on end.

The ineffectiveness of the aerated grit removal facilities in removing grit adequately . . .



. . . impacts various downstream facilities.

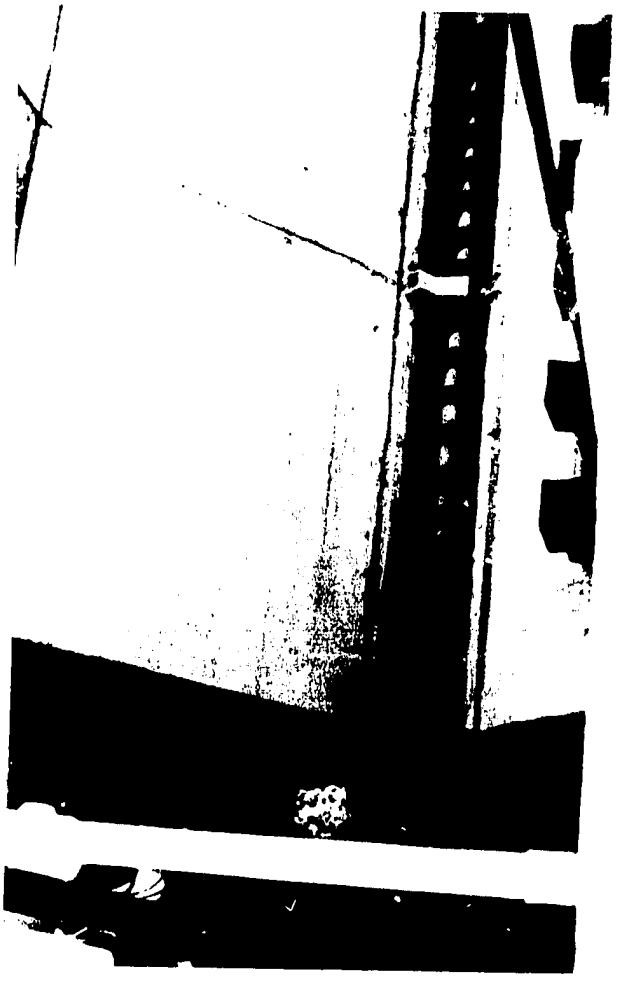


Dewatering has begun. Grit deposits are now draining. Screw conveyor is completely covered and impacted. (above)

Dewatering progressing, many days after the start. (right)

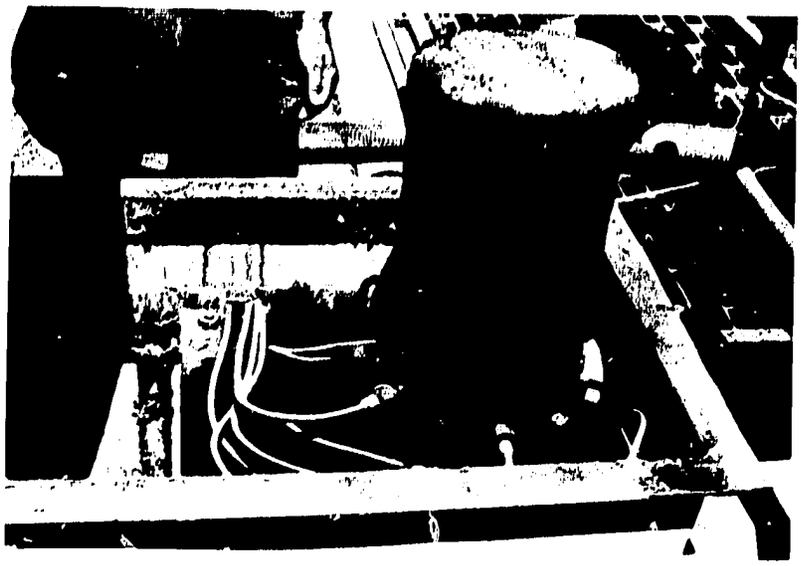
After many weeks of draining, grit is partially removed. Part of screw conveyor is finally exposed. (below)

After complete cleaning of the tank, screw conveyor is fully exposed. (below)



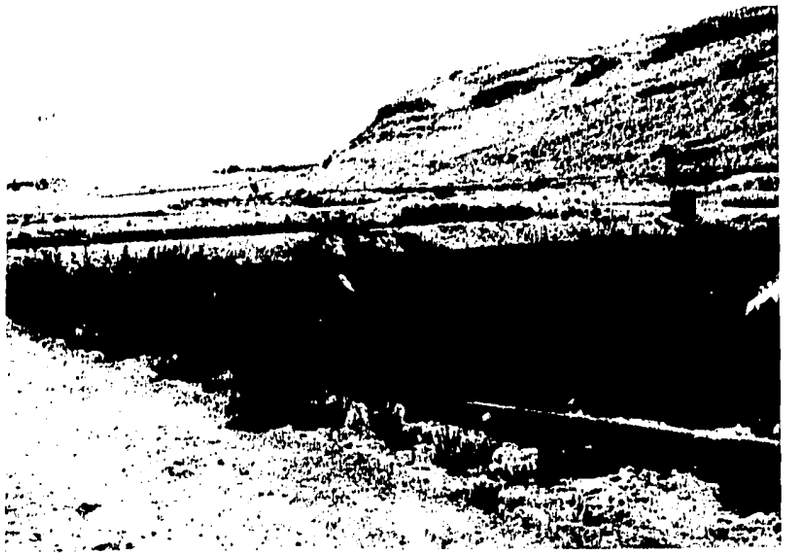
LOOKING DOWN INTO A PREAERATION TANK AT AGTP.

Operations conditions are sometimes difficult. Maintenance requirements are often unusual . . .

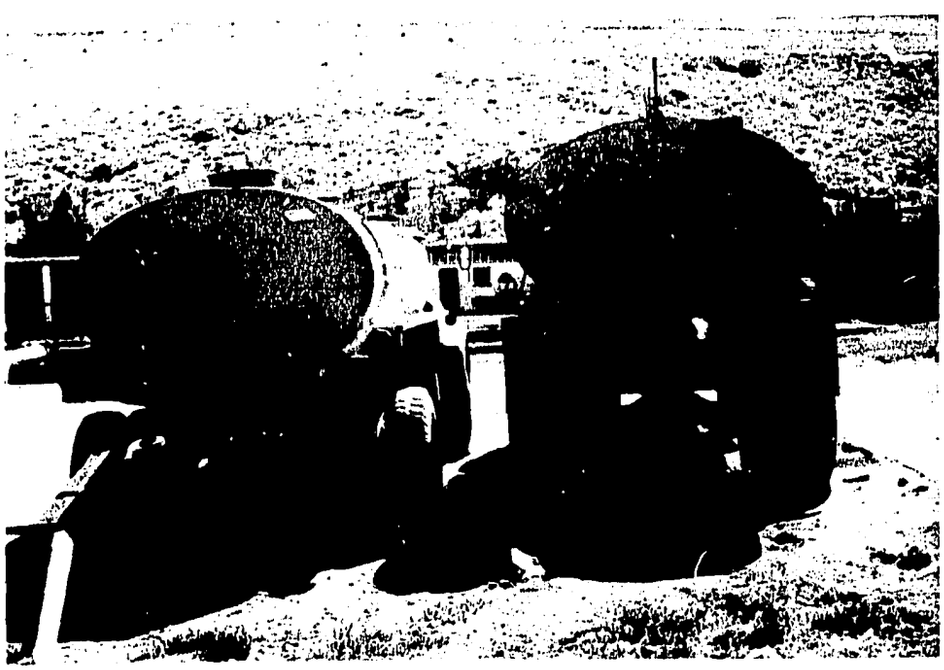


. . . in many parts of AGTP.

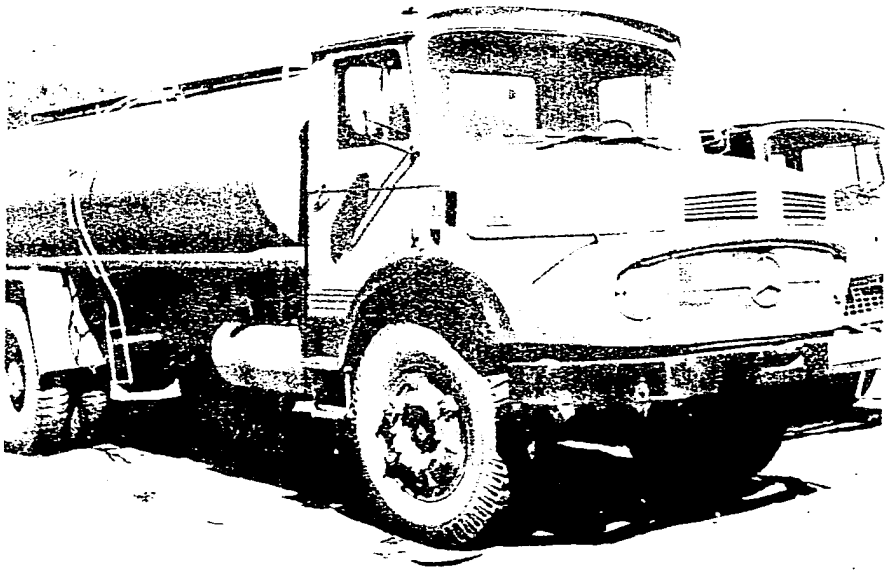
As in most wastewater treatment plants, sludge disposal is a continuing challenge for AGTP.

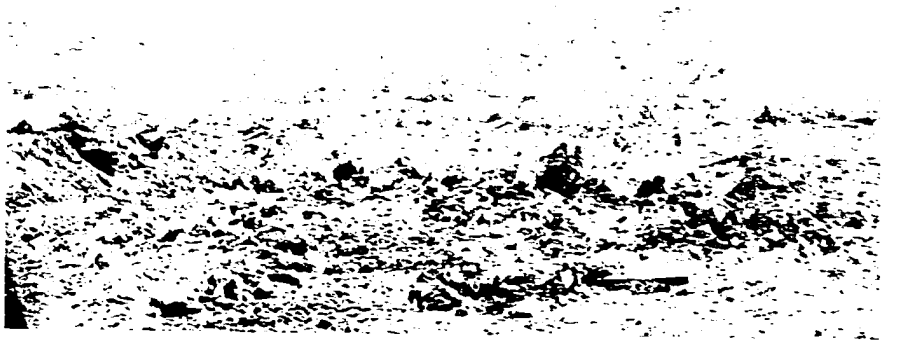


The AGTP sludge drying beds were never intended to have full dewatering capability for all the plant's sludge. They handle only a portion of the production.



Most of the wet sludge from the digesters leaves AGTP via trucks such as these.

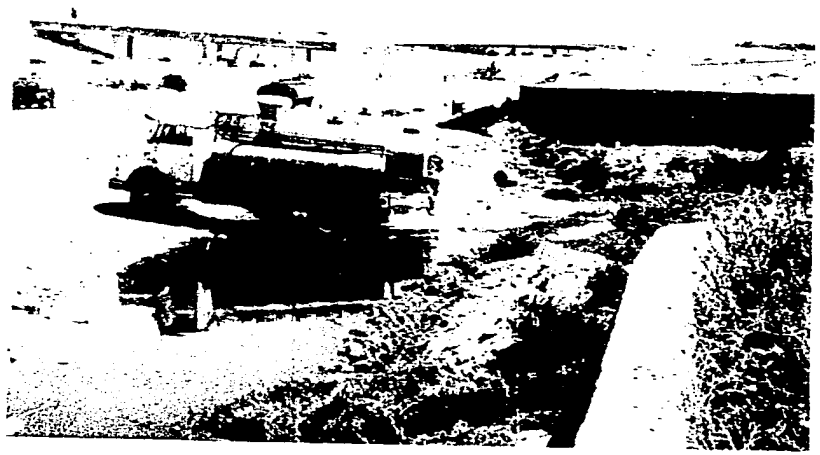


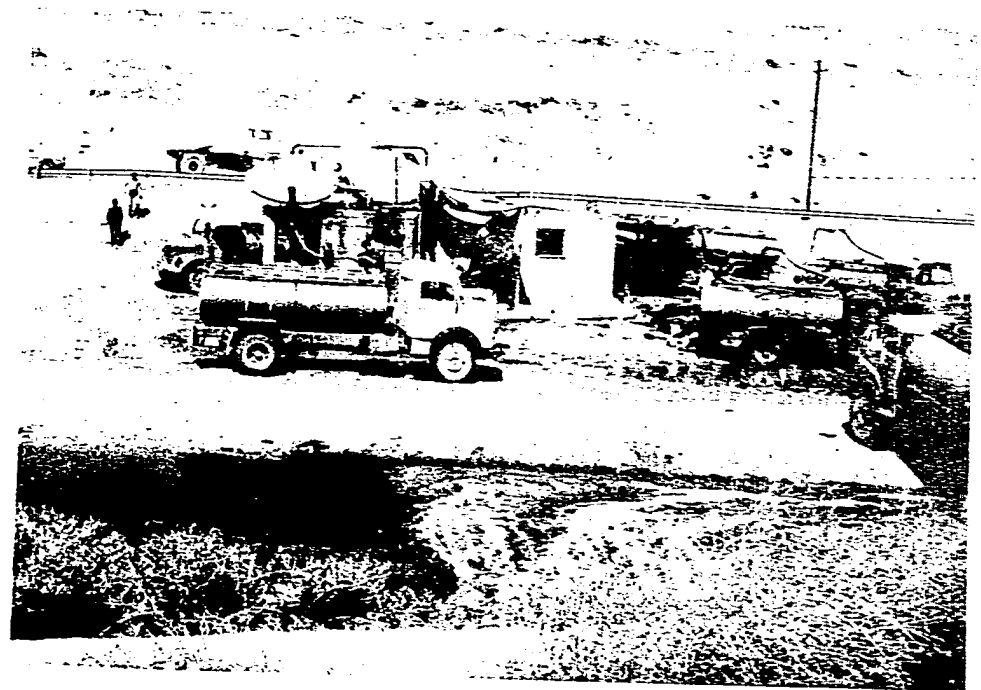


AGTP digested sludge is trucked about 4 km. . . . . to the municipal dump. . . . .

. . . . where it is worked into the other wastes . . . . . and normally covered over with dirt.

Chlorinated AGTP effluent empties into a small shallow lagoon and discharges to the otherwise nearly dry Seil Amman below AGTP . . .





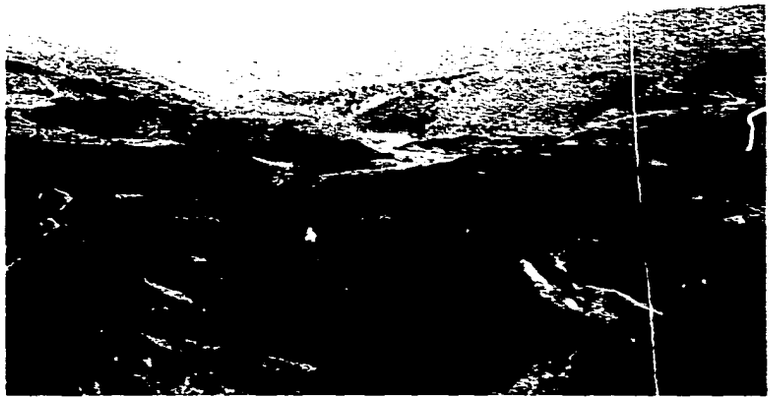
. . . and past a potable drinking water well which is used to fill tanker trucks.

Seil Amman flows towards King Talal Reservoirs, becomes Seil Zarga . . .

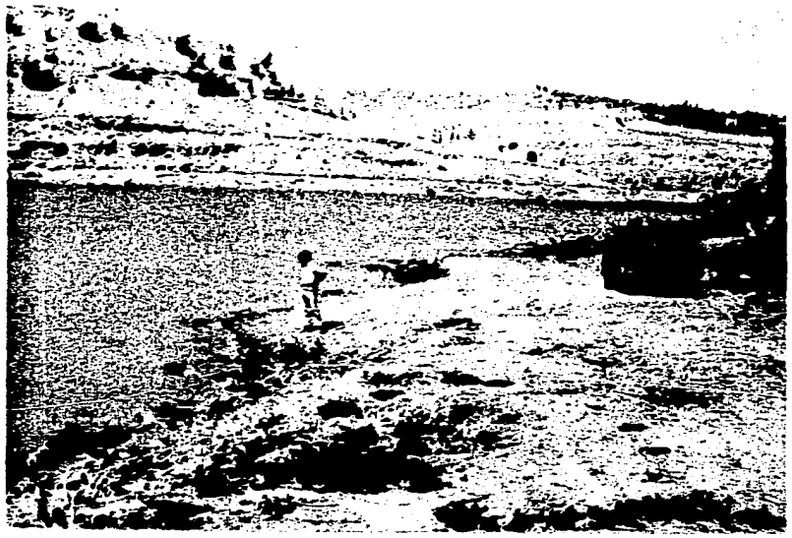
for irrigation directly or via wells.

8816

The Seil Zarga flows through both urban and rural agricultural areas . . .



. . . before dropping into the upstream reaches of King Talal Reservoir . . .

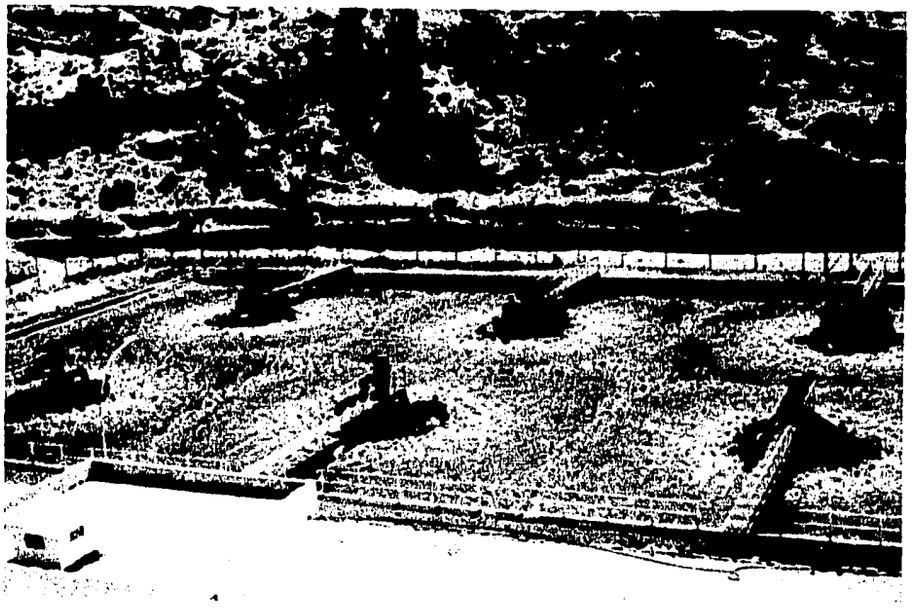


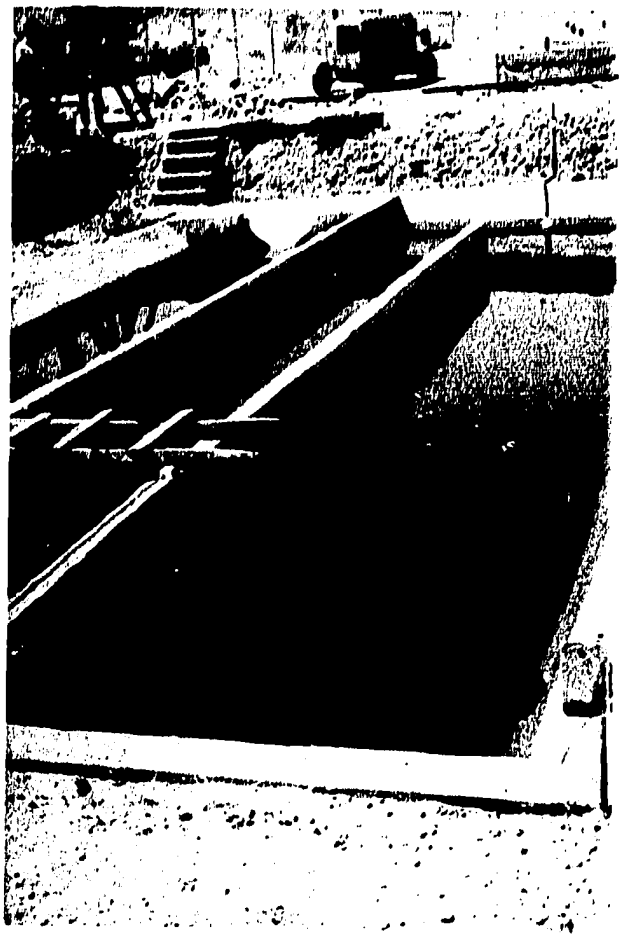
. . . whose waters are open to the public and are already eutrophic.

Sewerage works construction may expose antiquities such as at Salt.

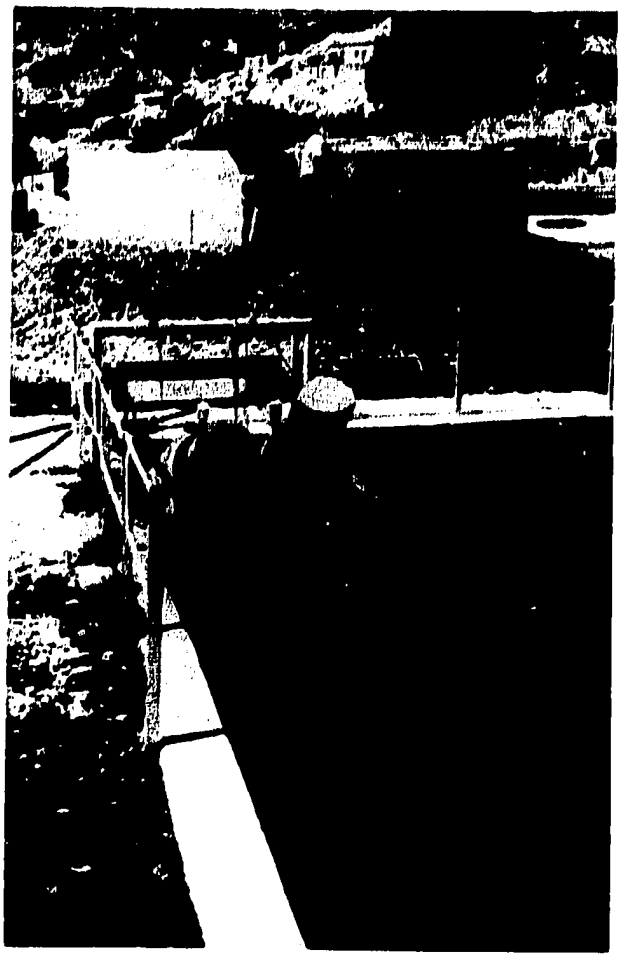
Antiquities uncovered near newly built treatment plant.

Treatment plant space along natural drainage courses is often very limited.

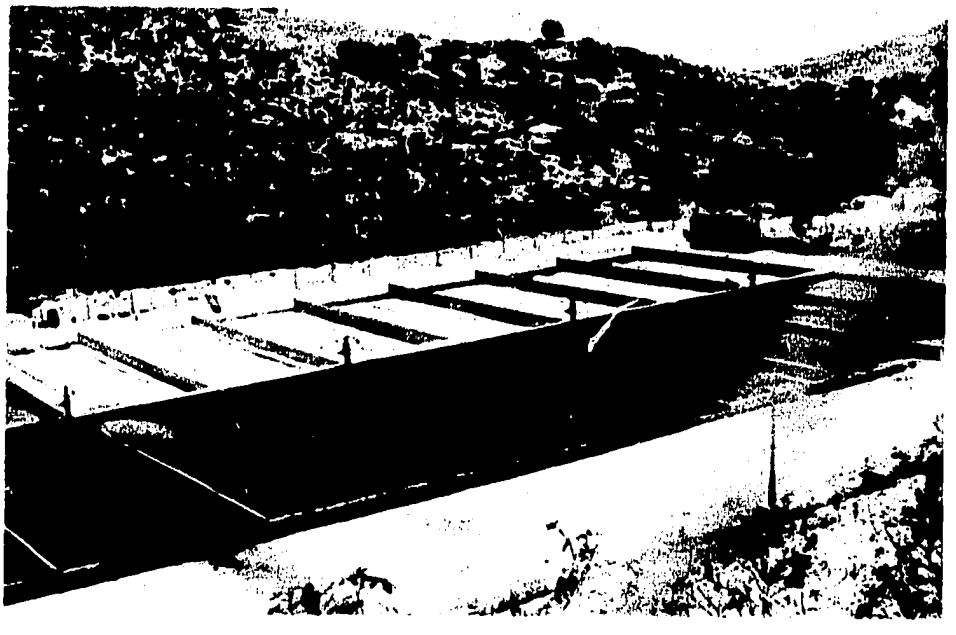




Flow measurement and disinfection are important steps at all treatment plants.



Simplicity of operation is desirable, especially in the smaller plants.



Treatment Plant Sludge processing and disposal are important concerns.

The steep terrain confines treatment plant effluents to the nearest wadi.

Flowing water has attractions in water deficient Jordan.

Wadis are usually precipitous and offer limited space for treatment plant siting.