No.

JAPAN INTERNATIONAL COOPERATION AGENCY
MINISTRY OF WATER AND IRRIGATION
THE HASHEMITE KINGDOM OF JORDAN

# THE STUDY ON WATER RESOURCES MANAGEMENT IN THE HASHEMITE KINGDOM OF JORDAN

# FINAL REPORT VOLUME II

# MAIN REPORT
# PART-B
# PRE-FEASIBILITY STUDY ON PRIORITY PROJECTS

DECEMBER 2001

YACHIYO ENGINEERING CO.,LTD.

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Exchange Rate Employed
in the Study

US$1.00=0.700JD=JP¥110
December, 2000

# PREFACE

In response to a request from the Government of the Hashemite Kingdom of Jordan, the Government of Japan decided to conduct the study on Water Resources Management in the Hashemite Kingdom of Jordan and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Noboru Saeki of Yachiyo Engineering Co., Ltd. to the Hashemite Kingdom of Jordan, five times between February 2000 and September 2001.

In addition, JICA set up an advisory committee headed by Dr. Masahiro Murakami, Professor of Kochi University of Technology, between February 2000 and December 2001, which examined the study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of the Hashemite Kingdom of Jordan and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Hashemite Kingdom of Jordan for their close cooperation extended to the Team.

December 2001

Takao Kawakami
President
Japan International Cooperation Agency

December 2001

Mr. Takao Kawakami
President
Japan International Cooperation Agency

# LETTER OF TRANSMITTAL

We are pleased to submit to you the final report of the Study on Water Resources Management in the Hashemite Kingdom of Jordan. The report includes the advise and suggestions of the authorities concerned of the Government of Japan and your Agency. Also included are comments made by the Ministry of Water and Irrigation, the Hashemite Kingdom of Jordan. This report consists of Summary Report, Main Report, Supporting Report and Drawings.

The report deals with the present conditions of water resources management in the Hashemite Kingdom of Jordan and presents the master plan for water resources management with the target year of 2020, as well as the results of the pre-feasibility study for the priority projects proposed in the master plan.

In accordance with the contract with your Agency, we Yachiyo Engineering Co., Ltd. in implemented this study during the period of February 4, 2000 to December 27, 2001. Based on a deep understanding of the existing conditions in the Hashemite Kingdom of Jordan we have prepared a plan that is feasible and can be implemented.

Finally we sincerely hope that this report will be effectively used for the realization of the master plan. We wish to express our deep gratitude to your Agency, the Ministry of Foreign Affairs and other concerned Governmental Agencies for the close cooperation and assistance extended to us during the Study.

Very truly yours,

Noboru Saseki
Team Leader
The Study on Water Resources Management
in the Hashemite Kingdom of Jordan

# ACKNOWLEDGEMENT

Upon completion of the Study on “Water Resources Management Plan” in the Hashemite Kingdom of Jordan, JICA Study Team would like to acknowledge with thanks the substantive and mutual cooperation of all competent staff members of the MWI, JVA and WAJ who were contacted in their offices in Amman or in the field as well.

Special gratitude are extended to those who have the most appreciable encouragement and guidance in implementing the Study to such an extent that made this Draft Final Report possible. They are His Excellency Dr. Hazem El-Naser the Minister of Ministry of Water and Irrigation, and His Excellency Mr. Fayez Bataineh, Acting Secretary General of the Ministry.

And Mr. Edward Qunqar, Ms. Suzan Taha, for their beneficial inputs and substantive contribution to the Study.

Many thanks are also extended to all counterparts who helped JICA Study Team in the implementation of the Study, data review and analyses, presentation of results and conclusions; Messers Rakad Ayed Ta’any, Waleed Sukkar, Mohamed Mansour, Mohamed Momani, Mazen Ar Rayyan, Nidal Khalifa, Saleh Malkawi, Salameh Al Khreisheh, Ali Subuh, Yaser Nazal, and Zakariya Zuhdi.

JICA Study Team members; Messers Noboru Saeki, Bader Hirzalla, Yosuke Sasaki, Toshio Murakami, Keiichi Sakaebara, Friz Kaeser, Xiaochang Wang, Masahiro Takeuchi, Yoshio Kawasaki, Naomichi Ishibashi, Abdul Karim Bourini, Naoto Mizuno, Akihiro Shimomura, Mrs. Hala Zawati, and Miss Rawan Habaybeh.

Deserve the worthy consideration and thanks for their excreted efforts to execute the Study according to the agreed upon as spelled out in the Inception Report.

# Abbreviations and Glossary

| | |
|---|---|
| a | anumm/year |
| abst. | abstraction |
| AHT | Agrar- und Hydrotechnik (Consulting firm) |
| AP | Aerated Ponds |
| Aq. | Aquifer |
| AS | Activated Sludge Process |
| a.s.l. | above sea level |
| Ass. Sec. Gen. | Assistant Secretary Genaral |
| ARD | Associates in Rural Development (Consulting firm) |
| ave. | average |
| avail. | available |
| AZB | Amman-Zarqa Basin |
| B | Baseflow |
| BGR | Geosciences and Natural Resources of Germany |
| BG, BGW | Brackish Groundwater |
| $BOD_5$ | Biochemical Oxygen Demand in 5 days |
| BOT | Build – Operate - Transfer |
| BOO | Build – Own – Operate |
| BCM | Billion Cubic Meters |
| CIDA | Canadian International Development Agency |
| COD | Chemical Oxygen Demand |
| cond. | conditionally |
| concent. | concentration |
| Cons. | Consumption |
| d | day |
| DAR | Deutsche Abwasserreinigungsgesellschaft (Consulting fim) |
| D/D | Detailed Design |
| Dept. | Department |
| Des. | Desalinated |
| DI | Ductile Iron |
| Dir. | Directorate |
| DN | Nominal Diameter (in mm) |
| Doc. | Document |
| DOS | Department of Statistics |
| Donum | 0.1 ha |
| DVS | Digital Visualization System (one of NWMP systems) |
| EA | Extended Aeration |
| EC | Electric Conductivity |

| | |
|---|---|
| EIA | Environmental Impact Assessment |
| EIRR | Economic Internal Rate of Return |
| Exp. | Expenses |
| | |
| F | Flood flow |
| FAO | Food and Agriculture Organization |
| Feddan | 0.405 hectar |
| Fils | 0.001 Jordan Dinar |
| FIRR | Financial Internal Rate of Return |
| F/S | Feasibility Study |
| | |
| g | gram |
| GDP | Gross Domestic Product |
| GNP | Gross National Product |
| GIS | Geographical Information System |
| GW | ground water |
| GCEP | General Cooperation for Environmental Protection |
| GKW | Gesellschaft fur Klaeranlagen und Wasserversorgung (Consulting firm) |
| Govt. | Governorate |
| GTZ | Deutsche Gesellschaft fur Technische Zusammenarbeit (German Technical Cooperation Society) |
| GW. | Groundwater |
| Gwh | Giga watt-hour |
| | |
| h | hour |
| hc | house connection |
| hh | household |
| HDPE | High Density Polyethylene |
| Ha | hector (2.469 Acres) |
| HKJ | Hashemite Kingdom of Jordan |
| | |
| i | hydraulic gradient |
| IAEA | International Atomic Energy Agency |
| IEE | Initial Environmental Examination |
| Indust. | Industrial |
| inh | inhabitants |
| Irr. | Irrigation |
| | |
| JBIC | Japan Bank for International Cooperation |
| JD | Jordanian Dinar |
| JES | Jordanian Environmental Society |
| JICA | Japan International Cooperation Agency |
| JS | Jordanian standard |
| JVA | Jordan Valley Authority |
| JRV | Jordan Rift Valley |

| | |
|---|---|
| JV | Jordan Valley |
| | |
| k | permeability |
| KAC | King Abdullah Canal |
| KTR | King Talal Reservoir |
| KfW | Kreditanstalt fur Wiederaufbau (German Bank for Development and Reconstruction) |
| kg | kilogram |
| km | kilometer |
| kW | kilowatt |
| Km2 | square kilometers |
| Km3 | cubic kilometers =MCM |
| | |
| lcd | litters per capita per day |
| lit | liter |
| LEMA | Suez Lyonnaise des Eaux – Montgomery Watson – Arabtech Jardaneh (Managing the Amman Water and Wastewater Services) |
| LR | Leaching Requirement |
| | |
| MW | mega watt |
| m | meters |
| $m^3/s$ | cubic meters per second |
| mm | millimeters |
| mm/a | millimeters per annum |
| mg | milligram |
| ml | milliliter |
| mio | million |
| $\mu$ s/cm | micro siemense per centimeter (unit of electric conductivity) |
| Max. | Maximum |
| MCM | million cubic meter |
| MIT | Municipal, Industrial and Touristic |
| Min. | Minimum |
| MOA | Ministry of Agriculture |
| MOH | Ministry of Health |
| MOP | Ministry of Planning |
| MOWI, MWI | Ministry of Water and Irrigation |
| MP | Maturation Pond |
| MPN | Most Probable Number (for coliform bacteria) |
| Mun. | Municipal |
| | |
| N | nitrogen |
| N | Newton |
| NA | not applicable |
| NCARTT | National Center for Agricultural Research and Technology Transfer (NGO) |

| | |
|---|---|
| NEAP | National Environmental Action Plan |
| NIR | Net Irrigation Requirement |
| NPV | Net Present Value |
| NWMP | National Water Master Plan (GTZ Project) |
| NWSCS | National Water Supply Control System |
| | |
| O&M | Operation and Maintenance |
| OCC | Opportunity Cost of Capital |
| | |
| pH | measure of alkalinity/acidity |
| ppm | parts per million |
| P | phosphorus |
| PE | polyethylene |
| pop. | population |
| PT | Peace Treaty |
| PV | Present Value |
| PVC | Polyvinyl Chloride |
| | |
| Q | rate of discharge, flow rate |
| | |
| R. | River |
| Reduc. | Reduction |
| Rev. | Revenue |
| R.C.C. | Roll Compacted Concrete |
| RO | Reverse Osmosis |
| RBC | Rotating Biological Contactor |
| RSCN | Royal Society for the Conservation of Nature |
| RSS | Royal Scientific Society |
| | |
| s | second |
| S | storage coefficient |
| SCADA | Supervisory Control and Data Acquisition |
| SF | Sand Filtration |
| S.G. | Secretary General |
| Sn. | Scenario |
| STP | Scenario Table Pool (one of systems of NWMP) |
| SS | Suspended Solids |
| SW | Surface Water |
| | |
| t | ton |
| T | Transmissivity |
| Ttl. | Total |
| TDS | Total Dissolved Solids |
| TF | Trickling Filter |
| TN | Total Nitrogen |

| | |
|---|---|
| TOC | Total Organic Carbon |
| Tour. | Touristic |
| TSE | Treated Sewage Effluent |
| TSS | Total Suspended Solids |
| TFCC | Total Fecal Coliform Count |
| TKN | Total Kjeldhal Nitrogen |
| TP | Treatment Plant |
| TSS | Total Suspended Solids |
| TWW | Treated Wastewater |
| uncond. | unconditionally |
| UFW | Unaccounted for Water |
| UP | Upland |
| USAID | United States Agency for International Development |
| v | velocity |
| WAJ | Water Authority of Jordan |
| WB | World Bank |
| WHO | World Health Organization |
| WIS | Water Information System |
| W/O | without |
| WQICP | Water Quality Improvement and Conservation Project (USAID project) |
| WRMP | Water Resources Management Plan (JICA project) |
| WRPS | Water Resources Policy Support (USAID project in AZB) |
| WSP | Wastewater Stabilization Pond |
| WWE | Wastewater Effluent |
| WWTP | Wastewater Treatment Plant |
| YEC | Yachiyo Engineering Company Ltd. (Consulting firm) |
| Yr | Year |

## Abbreviations Used for Governorates

| | |
|---|---|
| AJ | Ajloun |
| AM | Amman |
| AQ | Aqaba |
| BA | Balqa |
| IR | Irbid |
| JA | Jerash |
| KA | Karak |
| MA | Madaba |
| MF | Mafrak |
| MN | Ma'an |
| TA | Tafielah |
| ZA | Zarqa |

# GLOSSARY

| Term | Definition |
|---|---|
| Administrative Loss | The quantities of water actually supplied to consumers without bringing financial impacts to the suppliers due to such administrative factors as ill-functioning water meters, imperfect billing, non-paying customer, illegal connections, and water theft. |
| Aquiclude | A geologic formation, which contains water but cannot transmit it rapidly enough to furnish a significant supply to a well or spring. |
| Aquifer | A geologic formation, which contains water and transmit it from one point to another in quantities sufficient to permit economic development. |
| Base flow | Part of the surface water flow, which enters a stream channel from groundwater, and identified as rejected groundwater recharge. |
| Brackish Groundwater | Poor quality groundwater with high range of salinity (>1500-about 30,000 ppm of TDS), generally encountered at depth in the lower aquifer System. |
| Boundary Conditions | Basic conditions given for groundwater simulation modeling to define the peripheral and internal conditions at the simulation area. It is exemplified by no-flow, flow-constant and head-constant conditions. |
| Draw down (s) | Change in surface elevation of the groundwater resulting from withdrawal of water from a well. |
| Equipotential lines | A contour line, which represents or traces the equal head in the aquifer. |
| Electric conductivity | Reciprocal of electrical resistively of water. It is measured as indicators of water quality and is expressed in micro-mhos. |

| **Term** | **Definition** |
|---|---|
| Isohyetal Map | the map, which defines or describes rainfall distribution and behavior in a given period. |
| Isohyets: | lines of equal rainfall amount |
| Live Storage | Volume or cubic capacity of a lake or reservoir between the normal maximum and minimum operating levels. |
| Manning Roughness Coefficient | Characteristics of boundary conditions in a stream channel regardless of its slope and size or depth of water flow. |
| Non-renewable groundwater | Groundwater which occurs in the rock at its formation with no or nil annual recharge and occasionally highly saline. The terms Fossil or connate water are also used. |
| Parts per million (ppm) | It denotes water quality in weight-per-weights units. One part per million represents 1 milligram. |
| Permeability (k) | the capacity of a porous medium (aquifer) for transmitting waters. |
| Piezometric level | the elevation to which the water level rises in a well that taps an artesian (confined) aquifer. |
| Physical Loss | the quantities of water supplied but lost on the way to the customers due to such physical factors as broken pipes, inconstant water pressure and a high water pressure of the pumps. |
| Reference Year | 1998 |
| Runoff Coefficient | The ratio of surface runoff volume to total volume of storm rainfall over an area and depends on the characteristics of the drainage basin. |

| **Term** | **Definition** |
|---|---|
| Safe yield | the rate at which water can be withdrawn for aquifers without depleting the sustainable source to such an extent that withdrawal at this rate is no longer economically feasible. |
| Specific capacity (Q/s) | The yield per unit of draw-down in a pumping well |
| Storage coefficient (S) | The volume of water released from storage, or taken into storage, per unit of surface area of the aquifer per unit change in head. |
| Surface Runoff | That part of storm precipitation, which flows over the land surface before it reaches definite channel or stream. |
| Total Dissolved Solids | Total weight of dissolved mineral constituents in water per unit volume of weight of water in the sample. |
| Transmissivity (T) | The rate at which water will flow through a vertical strip of the aquifer with unit length wide and extending through the full saturated thickness, under a hydraulic gradient of 1.00. (aquifer thickness* permeability) |

# Glossary of Terms Related with the Computation Of Irrigation Requirements

ACTUAL CROP EVAPOTRANSPIRATION:

Rate of evapotranspiration equal to or smaller than predicted Etc depending on the level of available soil water, wilting phenomena, salinity, field size, or other causes; mm per month

ALLOWABLE DEPLETION. AD:

The readily available soil water over the root zone, which can be safely used by the crop without affecting its evapotranspiation and /or growth, mm.

ALLOWABLE DEPLETION DURING INITIAL PERIOD. AD:

The readily available soil water over the Initial root zone, which can be safely used by the crop without affecting its evapotranspiration and/or growth, mm.

AVAILABLE MOISTURE, AM:

Total available amount of soil water stored in the root zone one or two days after irrigation; difference between soil water content at field capacity and that at wilting point, mm/m soil depth.

.
CANOPY INTERCEPTION:

The process by which precipitation is caught and held by foliage and branches of trees and other vegetation and lost by evaporation without reaching the ground surface percentage.

CUMULATIVE NET EFFECTIVE PRECIPITATION DURING OFF SEASON, **CNEPO:**

The accumulated precipitation during non growing season excluding interception and occasional runoff during intense events and evaporation from the wet soil surface.

CONSUMPTIVE USE:

The amount of water used by the vegetative growth of a given area in transpiration or building of plant tissue and that evaporated from the soil or intercepted precipitation of the area in any specified time, mm.

TRANSFER EFFICIENCY:

Ratio between wate4r received at inlet to a block of fields and that released at the project head works. This is applicable in the case of king Abdullah Canal.

CROP DEVELOPMENT STAGE:

The time from the end of crop initial stage until the achievement of effective full groundcover (groundcover = 70-80 %), days.

CROP EVAPOTRANSPIRATION, ET:

Rate of evapotranspiration of a disease-free crop under non restricting soil water and fertility conditions and achieving full production potential under the given growing environment, mm/day.

CROP WATER REQUIREMENT:

The depth of water needed to meet the water loss through evapotranspiration of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment.

CROPPING PATTERN:

Sequence of different crops grown in regular order on any particular field or fields.

DEEP PERCOLATION;

Rate of downward movement of soil water from the root zone prior to and following attainment of field capacity after ample irrigation or heavy rains, mm.

DISTRIBUTION EFFICIENCY:

Ratio between water received at farm gate and the released at inlet to a block of fields. Applicable at King Abdullah canal outlets, and at point of abstraction from ground water or surface water.

DEW POINT TEMPERATURE, Dew P:

Temperature to which the air needs to be cooled down in order to become saturated and at which water vapor starts to condense, degree Celsius.

EFFECTIVE RAINFALL, $P_{eff}$

The fraction of total precipitation useful for meeting crop water requirements, it excludes deep drainage, run-off, and evaporation from the soil surface, it includes requirements for leaching, fraction.

ELECTRICAL CONDUCTIVITY, IRRIGATION WATER, $EC_w$,

Measure of salt content of irrigation water, mmhos/cm.

ELECTRICAL CONDUCTIVITY, SATURATION EXTRACTS, ECe:

Measure of salt content of soil water extracted from the soil, mmhos/cm.

EVAPORATION:

The process by which water is converted from liquid state to gaseous one through the transfer of heat energy, mm.

FIELD CAPACITY, Sfc:

The amount of water, expressed as percentage of the oven-dry soil, held in the soil after the excess of gravitational water has drained away and after the rate of downward movement of water has substantially decreased.

FULL GROUND COVER:

Amount of soil covered by crops approaching 100 when looking downward.

GROSS IRRIGATION REQUIREMENT. GIR:

Irrigation requirement at the source of irrigation supplies. It is equal to the net irrigation requirement plus water losses and operational wastes in transit, and water needed for leaching of accumulated salts from the root zone, mm.

GROUND COVER:

Percentage of soul surface shaded by the crop when sun is directly overhead, percentage.

GROWING SEASON:

For a given crop the time between planting or sowing date an harvesting date, days.

INITIAL ROOT DEPTH, $R_{z\,I}$:

The root depth during initial period of crop growth, m.

IRRIGATION FREQUENCY:

The elapsed time in days from the start of one's irrigation to the start of the next on the same field.

LATE SEASON DEPLETION, LSD:

The depletion amount of soil moisture that stored in the root zone near the end of the growing season without replacing it, mm.

LATE SEASON STAGE:

The time from end of mid-season stages until full maturity or harvest, days.

LEACHING:

Removal of soluble salts by passage of water through soil.

LEACHING RATIO. LR:

The fraction of water entering the soil that must pass through the root zone in order to prevent soil salinity from exceeding a specified value, in percentage.

MANAGEMENT ALLOWABLE DEPLETION PERCENTAGE, MADP:

The fraction of total available soil moisture, which can safely be depleted, by the crop without affecting its evapotranspiration and/or growth.

MAXIMUM ROOT DEPTH, $R_{z\ max}$:

The root depth of a full-grown crop, m.

MID-SEASON STAGE:

The time between the attainment of effective full ground cover and the start of maturing of the crop (i.e. leaves start of discolor or fall off). Days.

MINIMUM POSSIBLE IRRIGATION DEPTH, MPID:

The minimum depth of water that con physically be added to the soil due to constraints in the irrigation application system, mm.

NET IRRIGATION CONSUMPTION, NIC:

The quantity of the actual diverted irrigation water, which is evaporated from the an area excluding the amount of, evaporated effective precipitation, mm.

NET IRRIGATION REQUIREMENT, NIR:

The depth of irrigation water, exclusive of effective precipitation and moisture stored in the root zone near the end of the growing season, that is required consumptively for crop production, including the pre-plant irrigation depth whenever it is needed

ON-FARM APPLICATION EFFICIENCY, $Eff_{on\text{-}farm}$:

Ratio between water directly available to the crop and that received at the farm gate

OVERALL IRRIGATION EFFICIENCY, $Eff_{overall}$:

Ratio between water directly available to the crop and that released at headwork's (in the uplands) or Kind Abdullah Canal outlets in the Jordan Valley

PAN EVAPORATION:

The amount of evaporation from the water surface of an experimental tank under measured or observed climatic and cultural conditions.

PRECIPITATION:

The total measurable supply of water of all forms of falling moisture, including dew, rain, mist, snow, hail and sleet; usually expressed as depth of liquid water on a horizontal surface in a day, month, or year, and designated so daily, monthly, and annual precipitation, mm.

PRE-PLANT IRRIGATION DEPTH. PPI:

The amount of irrigation water used to moisten the soil prior to planting whenever it is needed. mm.

RAINFALL FREQUENCY:

The average time interval between rainfall occurrence of a given intensity, and that of an equal or greater intensity.

REFERENCE GRASS EVAPOTRANSPIRATION. $ET_o$:

The rate of evapo-transpiration from an extensive surface of 8 to 15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water. **mm/day.**

SALINITY:

The concentration of salts, usually sodium chloride, dissolved in a given volume of water. It is usually expressed in terms of the number of parts per million of chlorine.

SOIL WATER CONTENT:

At a given time the amount of water held in the soil, weight or volume percentage.

TRANSPIRATION:

Rate of water loss from the plant through the formation of water vapor in living cells which is regulated by physical and physiological processes. **mm/day.**

WILTING POINT, Sw:

The moisture content of the soil, as a percentage of the day weight, at the time when the leaves of a plant growing in the soil first undergo a permanent reduction in their moisture content, as the result of the deficiency in the soil-moisture supply.

WIND SPEED:

Speed of air movement at 2 m above ground surface in unobstructed surroundings; total wind run in Km/day.

# EXECUTIVE SUMMARY

## 1. Activities of the Study

The Study on Water Resources Management in the Hashemite Kingdom of Jordan was executed by JICA Study Team as per the request of the Ministry of Water and Irrigation (MWI) under the situation that have been experienced in Jordan as a result of the chronic imbalance in population and water demands. Water resources management aiming at the sustainable development is essential. The Study's objectives are;

*to formulate Water Resources Management Plan in Jordan using the tools that have been developed by the GTZ funded Water Sector Planning Support Project.*

*to conduct Pre-Feasibility Study of priority project based on the findings and results of Master Plan.*

*to transfer technologies to counterpart personnel in the course of the Study.*

All of the Study has been completed and Final Report will be presented in this Stage as shown on the Study Flow Chart below, which contained two main components of;

- Formulation of Water Resources Management Master Plan (Vol. I)
- Pre-Feasibility Study on Priority Projects (Vol. II)

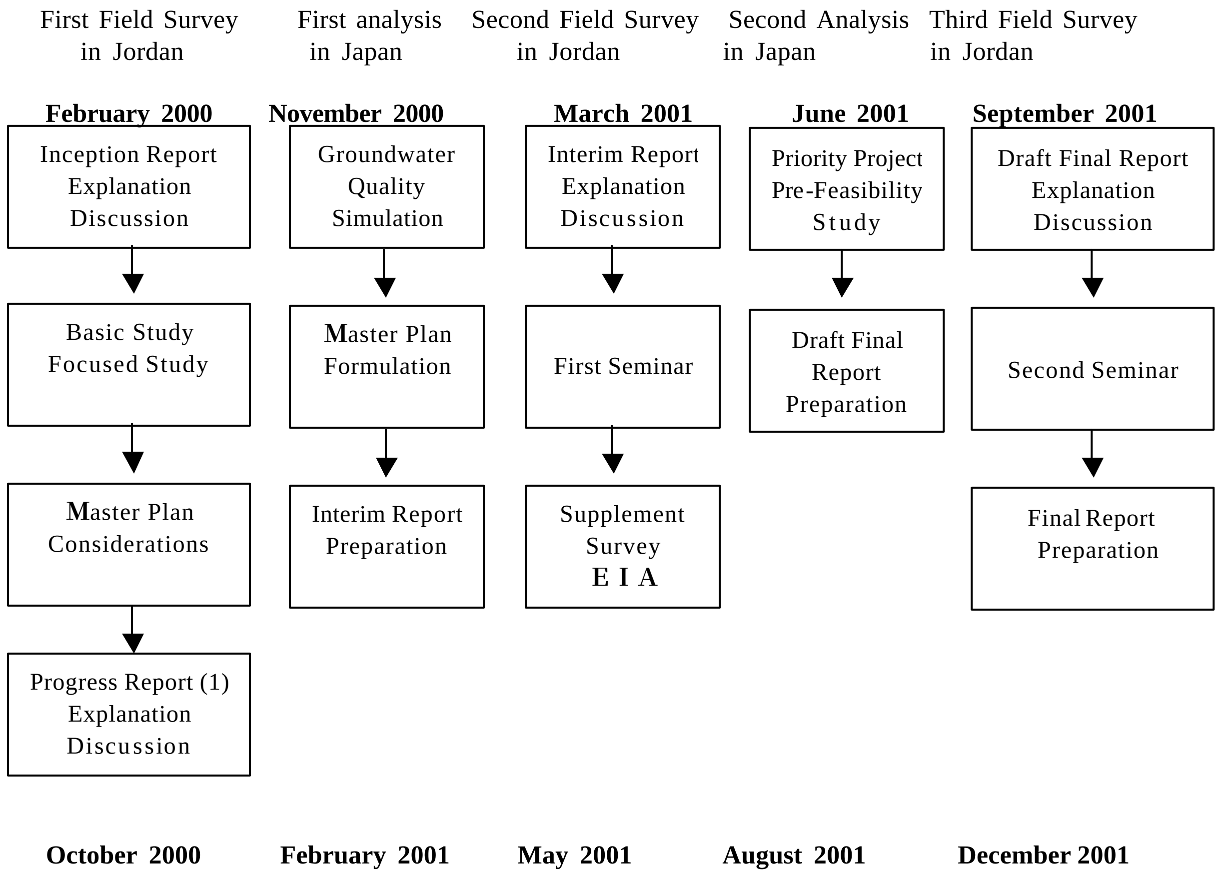



**Fig.Sum-1 Study Flow Chart**

## 2. Background of the Study

(1) Unbalance between Water Demand and Supply

The population of Jordan has recently been growing due to massive influx of refugees and displaced persons and high natural growth rate. Rapid population growth rates estimated during the past decade at 3.9% (1990 to 1999) is compound with rising per capita consumption twice as fast.

In addition urban expansion, mainly concentrated in Amman, Zarqa, Irbid, and Balqa, generated pressures on nearby water resources. This makes competition between various demands against very limited water resources availability sharp. Water demand has therefore constantly exceeded the supply in the urban areas. As the frequent cut off of the water supply and restricted water supply, the citizens have suffered inconvenience in their daily life.

Against the background described above, it has been promoting the country to conserve and ration water consumption.

(2) Restricted Water Resources

According to the Water Stress Index* which indicates the degree of the water shortage, Jordan is classified in the category of "Absolute Scarcity" and the water resources is chronically short to the demands. Due to the arid to semi-arid climate of the country, annual rainfall amounts highly fluctuate year by year with 85% of the total rainfall not being available for use due to high evaporation rates. The recent drought conditions and decreasing tendency of rainfall during past three years have exasperated the availability of surface water in the country**. Due to the reasons mentioned above, more than half of the total water resources depend on the groundwater resource of which the nonrenewable groundwater occupies at 14%. The regional groundwater level decline and groundwater quality deterioration have taken place because of the over abstraction of the renewable groundwater. Therefore, it is needed that the groundwater development management and quality conservation plan will be formulated standing on the long-term aspects.

For the surface water, although peace water is being conveyed from Israel to Jordan, this project implies sensitive factors and its amount will be subject to change according to the political and climatic conditions.

* Water Stress Index is the value of annual rainfall divided by the total population ($m^3$/capita/year) The value of under 1,700 is regarded as "Existing of Stresses", under 1,000 is regarded as "Scarcity" and under 500 is regarded as "Absolute Scarcity"

** Despite the lack of evidence that such a decrease in rainfall indicates global climatic change, some studies predict that the rainfall in the Middle East Area may fall to 10% to 15% after 50years (Hardley Center, UK) (Chapter 5.6).

(3) Request of the Study

Because of the limited water resources mentioned above, it is of the utmost importance for the government of Jordan to utilize the restricted water resources efficiently and to allocate the water resources properly. In September, 1997, the Government of Jordan requested Japanese Government to conduct the comprehensive study for the formulation of the water resources management master plan with the Ministry of Water and Irrigation (MWI) as a counter part agency.

In response to the request of the Government of Jordan, JICA dispatched preparatory study team and the Scope of Work for the Study was agreed upon between both sides, and signed in October, 1999.

## 2. Outline of the Study

(1) Basic Policy of the Study

In this Study, the Water Resources Management Master Plan was formulated, covering the period until year 2020, and aiming at "Unified, comprehensive and sustainable management of the water resources", and "Strategic development of remaining scarce water resources" while having in mind the future goal of "Shift to water re-cycling society". Special aspects in the country, "global climatic change and characteristic of climatic change of the arid region", and "cooperation for regional peace water development" are considered in formulation of the Master Plan. The relationship among these problems is schematically shown in next figure.

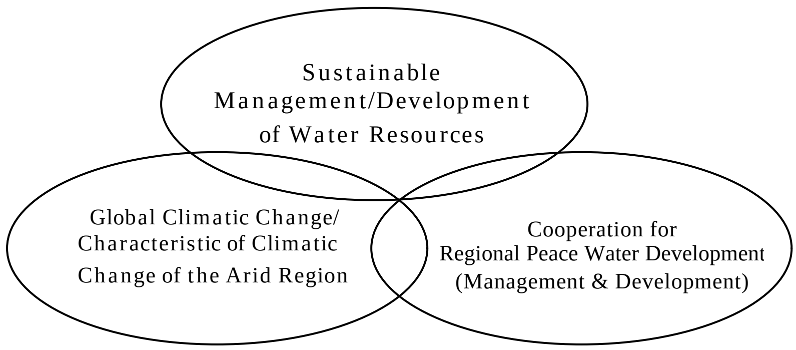



**Fig.Sum-2 The problems on the Water Resources Management in Jordan**

The comprehensive water resources management master plan for the twelve Governorates has been formulated in the Study under the circumstances mentioned above. Furthermore, the system and database of "Digital Master Plan", which was prepared in MWI with the technical cooperation of GTZ, was utilized for the formulation of the master plan. The Study area, target year of planning and water resources to be developed in the master plan are shown below:

| | |
|---|---|
| Study Area: | Whole Jordan and twelve Governorates in Jordan |
| Target Year: of Planning Horizon | Short Term------------------- 2000 to 2005<br>Mid Term---------------------2006 to 2010<br>Long Term--------------------2011 to 2020 |
| Water Resources: | In addition to the conventional water which comprised of surface water, peace water, renewable groundwater and fossil fresh groundwater, the non-conventional water resources which were desalinated brackish groundwater, desalinated sea water and treated wastewater were considered as water resources. |

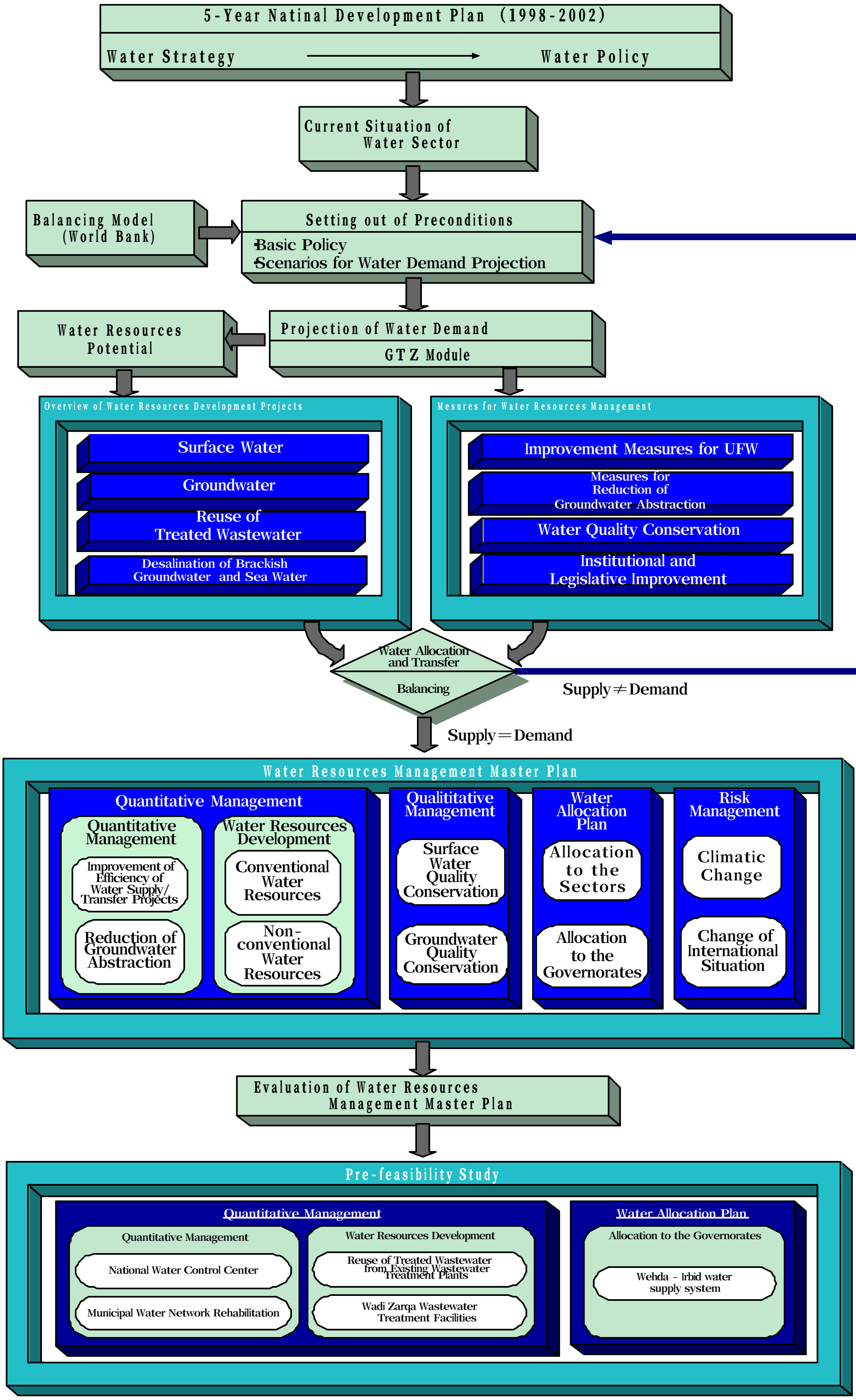



**Fig.Sum-3 General Flow of the Study**

(2) Contents of the Study

The Study Team started the Study in February, 2000 and conducted Phase-1 Investigation which aimed to formulate the Water Resources Management master Plan and Phase-2 Investigation which aimed to carry out the Pre-Feasibility Study on the priority projects selected in the Master Plan. The general flow of the Study is shown in Fig.Sum-3.

## 4. Formulation of Water resources Management Master Plan

For the formulation of the Water Resources management Master Plan, examinations were done on both of "Water Resources Management: Conventional/Non-conventional Water resources" and "Water Resources Management: Quantitative Management, Qualitative Management and Institutional/Legislative Management" under the umbrella of "Jordan's Water Strategy" and "Water Policies"

In the course of the formulation of the Water Resources management Master Plan, the Municipal/Industrial/Touristic (MIT) demand and agriculture demand were tried to be balanced with the restricted water supply as much as possible by taking account of the study results of USAID and GTZ projects. After the global balancing of water demand and supply in whole Jordan, the water resources development and water resources management plans including inter-Governorate water allocation plan and water conveyance plan were formulated for twelve governorates in order to supply the water efficiently.

The schematic concepts of the Water Resources Management Master Plan were shown in three drawings in the coming pages.

## 5. Pre-Feasibility Study on Selected Priority Projects

Selection of the priority projects for the Pre-Feasibility Study was done in Phase-2 Investigation. The selected priority projects for the Pre-Feasibility Study are as follows:

① Treated Wastewater Reuse Scheme of Five Existing Treatment Plants
Ma'an (including expansion of treatment plant), Abu-Nuseir, Fuhis, Tafielah, and Wadi Essir

② Construction of Wadi Zarqa Treatment Plant

③ National Water Supply Control System Integrating Surface and Groundwater

④ Municipal Water Distribution Networks Rehabilitation
Karak, Tafielah, Ma'an, Madaba and South Amman

⑤ Al Wehda Dam Water Supply Project/Irbid]

The Water resources Management Master Plan is described in the Vol. I and the Pre-Feasibility Study is described in Vol. II.

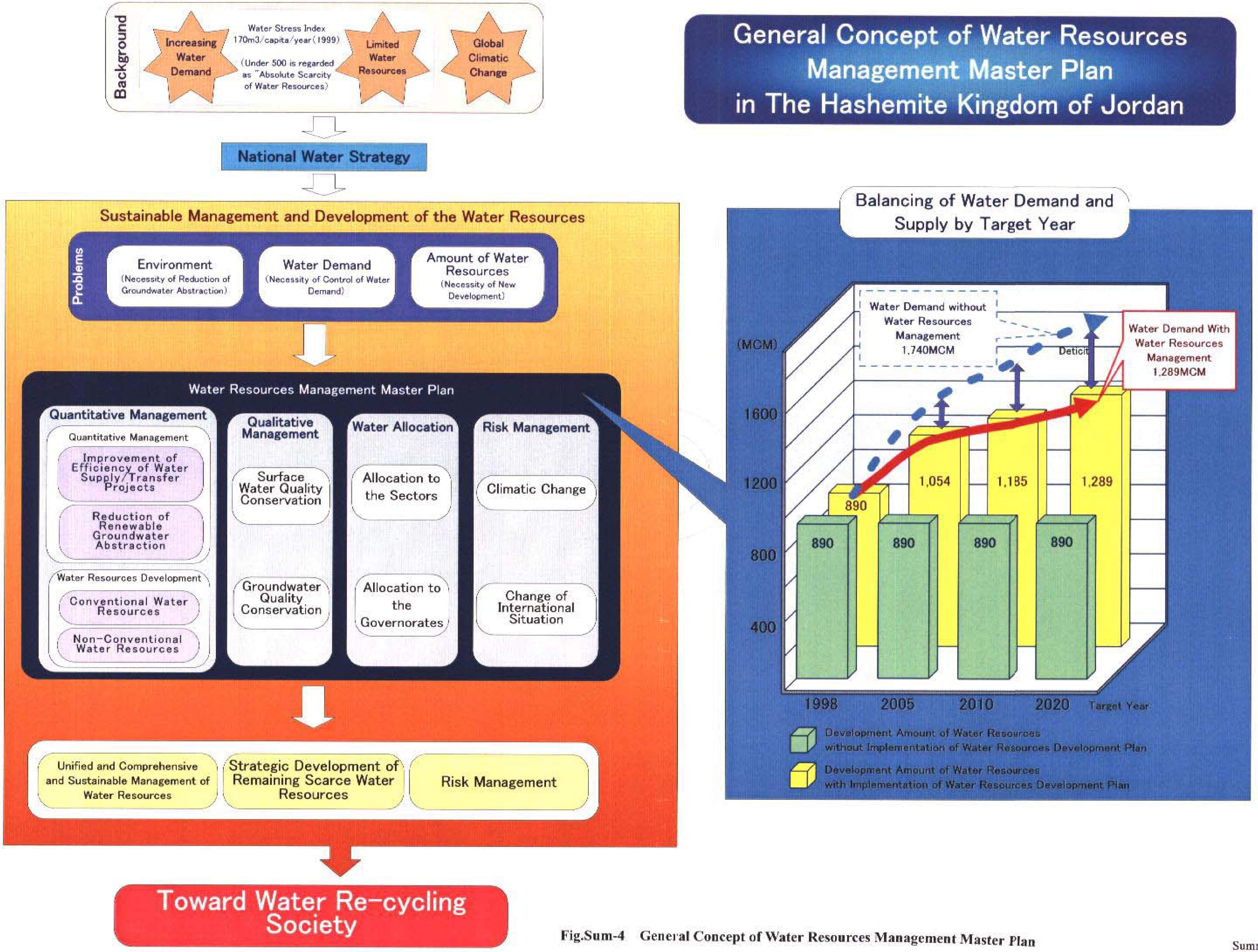



Fig.Sum-4 General Concept of Water Resources Management Master Plan

# Comprehensive Water Resources Management

**Quantitative Management**

- Quantitative Management
  - ・Improvement of Water Supply System
    - Improvement of UFW* (Rehabilitation Plan of Existing Water Supply System, Establishment of National Water Supply Control System)
    - Improvement of Institution (Improvement Plan of Institutional and Legislative System)
  - ・Reduction of Renewable Groundwater Abstraction
- Water Resouces Development (Conventional/Non-conentional)

**Qualititative Management** Water Quality Conservation (Surface Water / Groundwater)

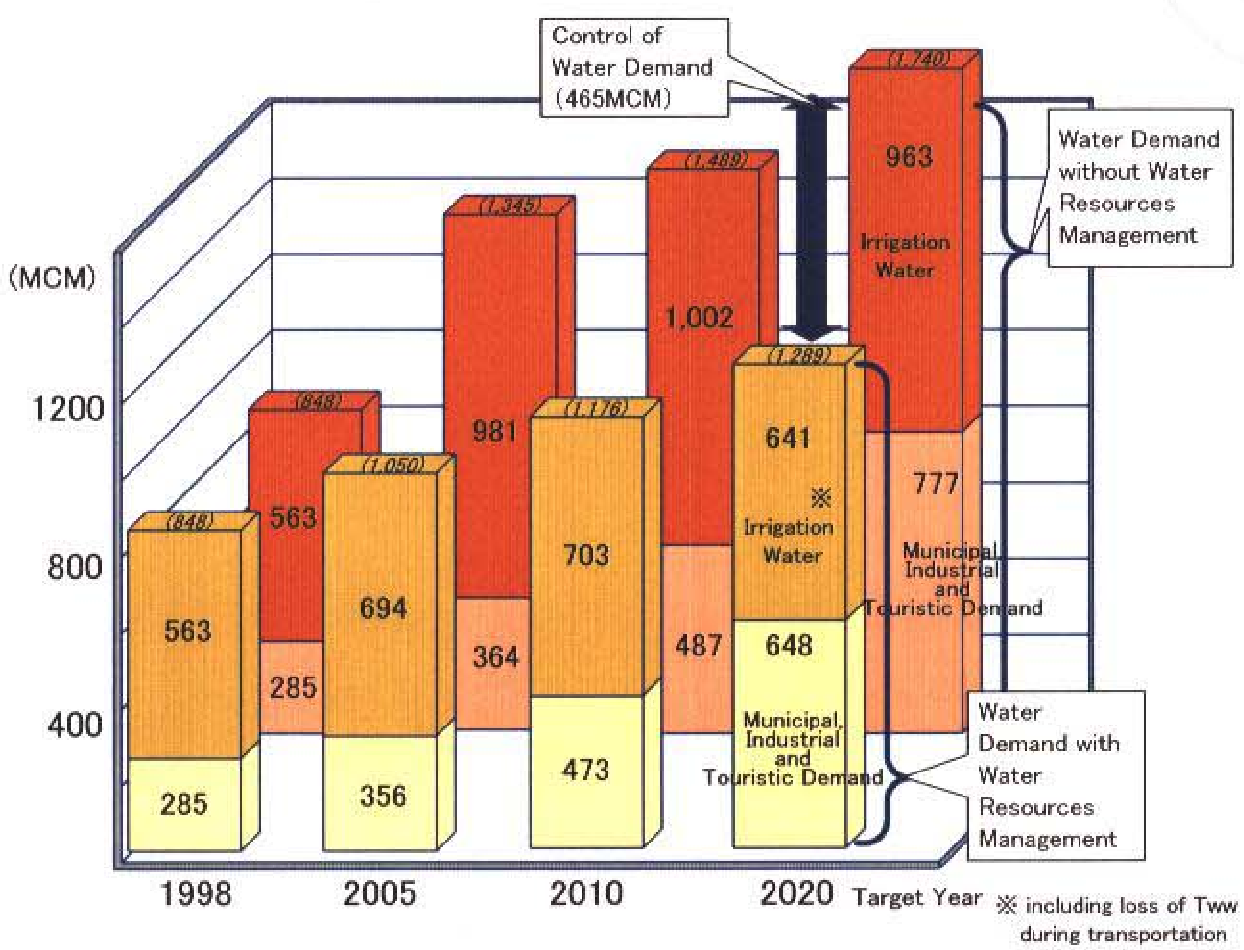
**Water Allocation Plan** Water Allocation and Transfer

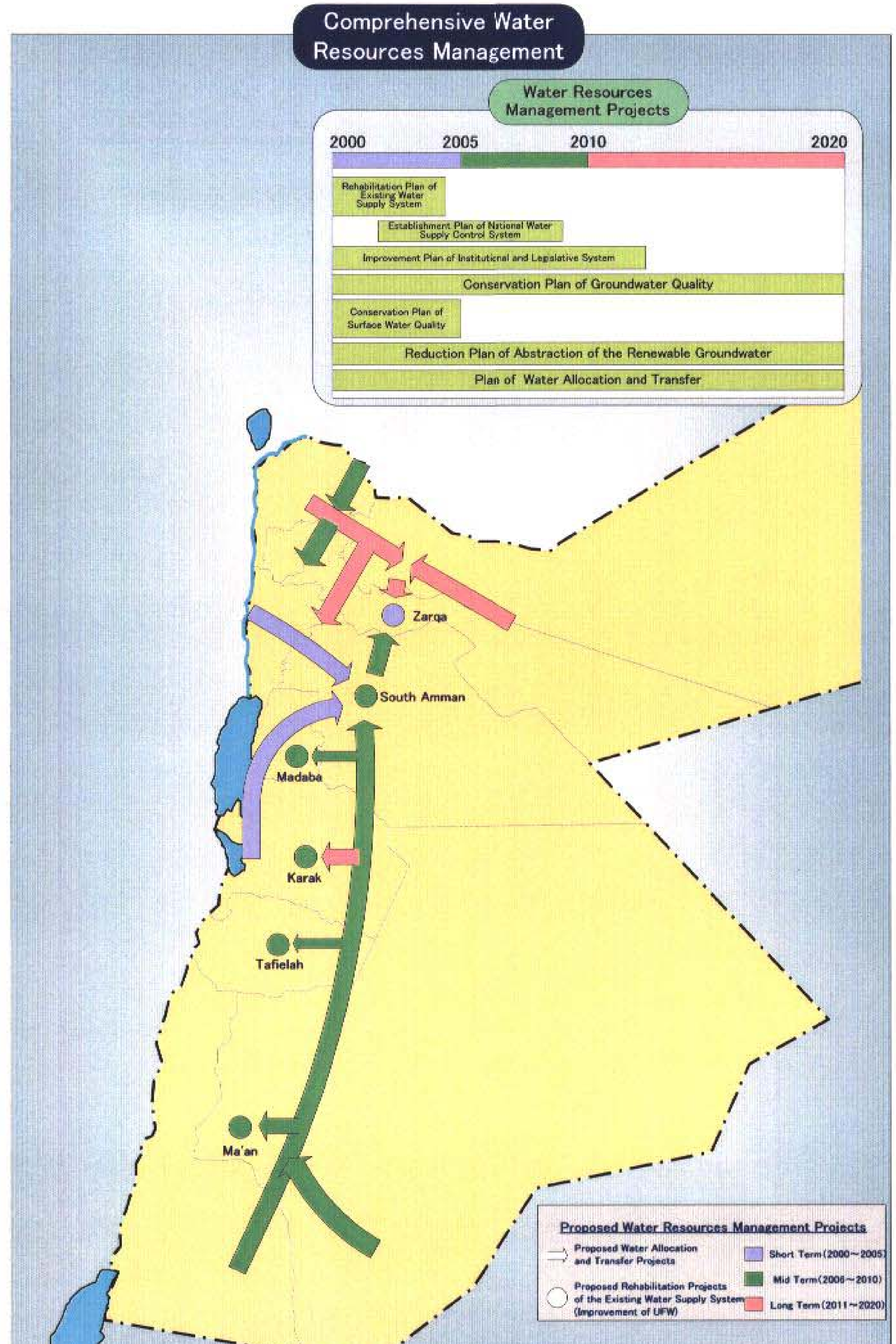
**Risk Management**

→

- Securing of Necessary Quantity
- Conservation of Quality
- Apropriate Water Allocation
- Risk Management

## Change of Water Demand by Target Year

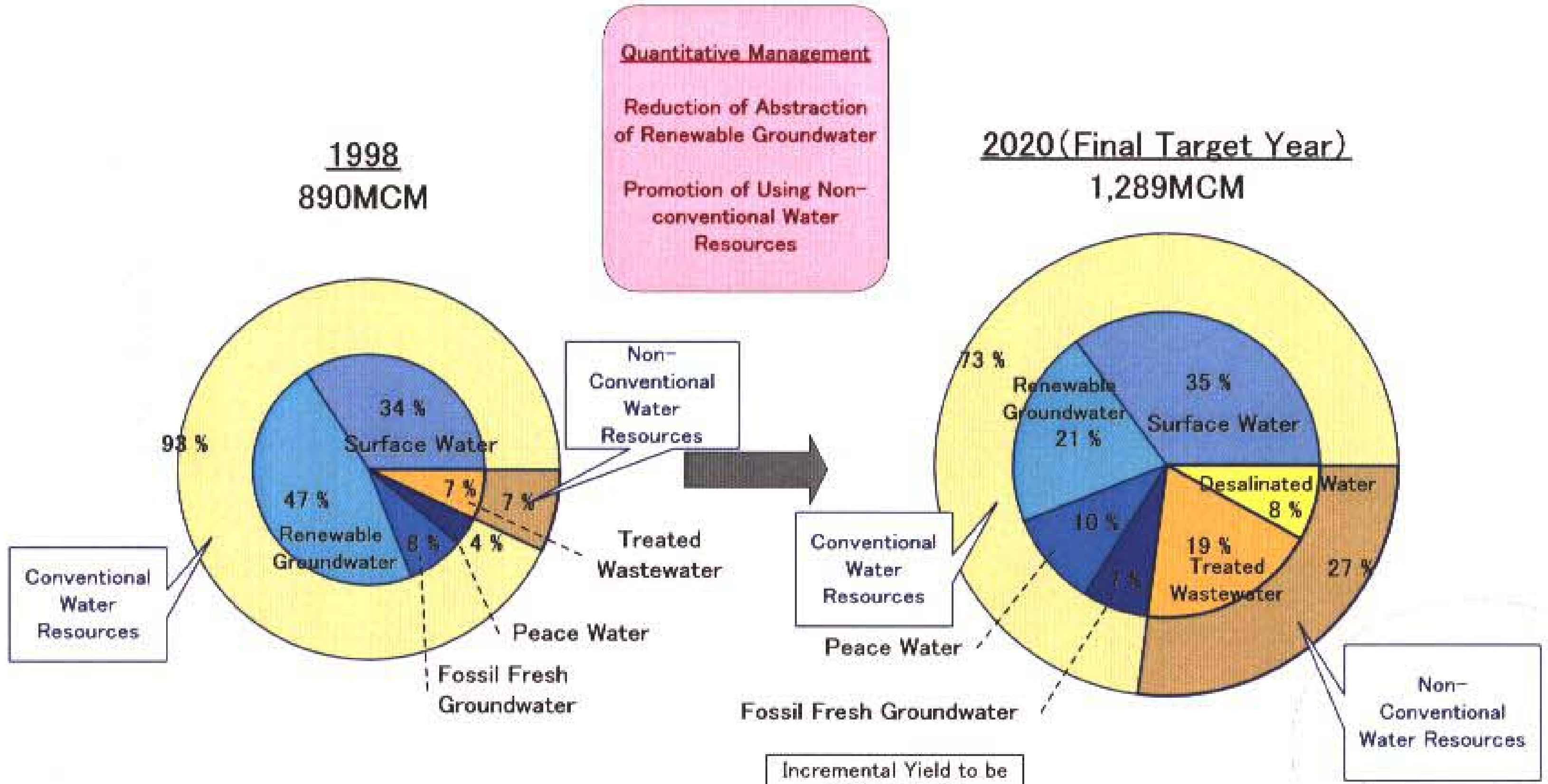


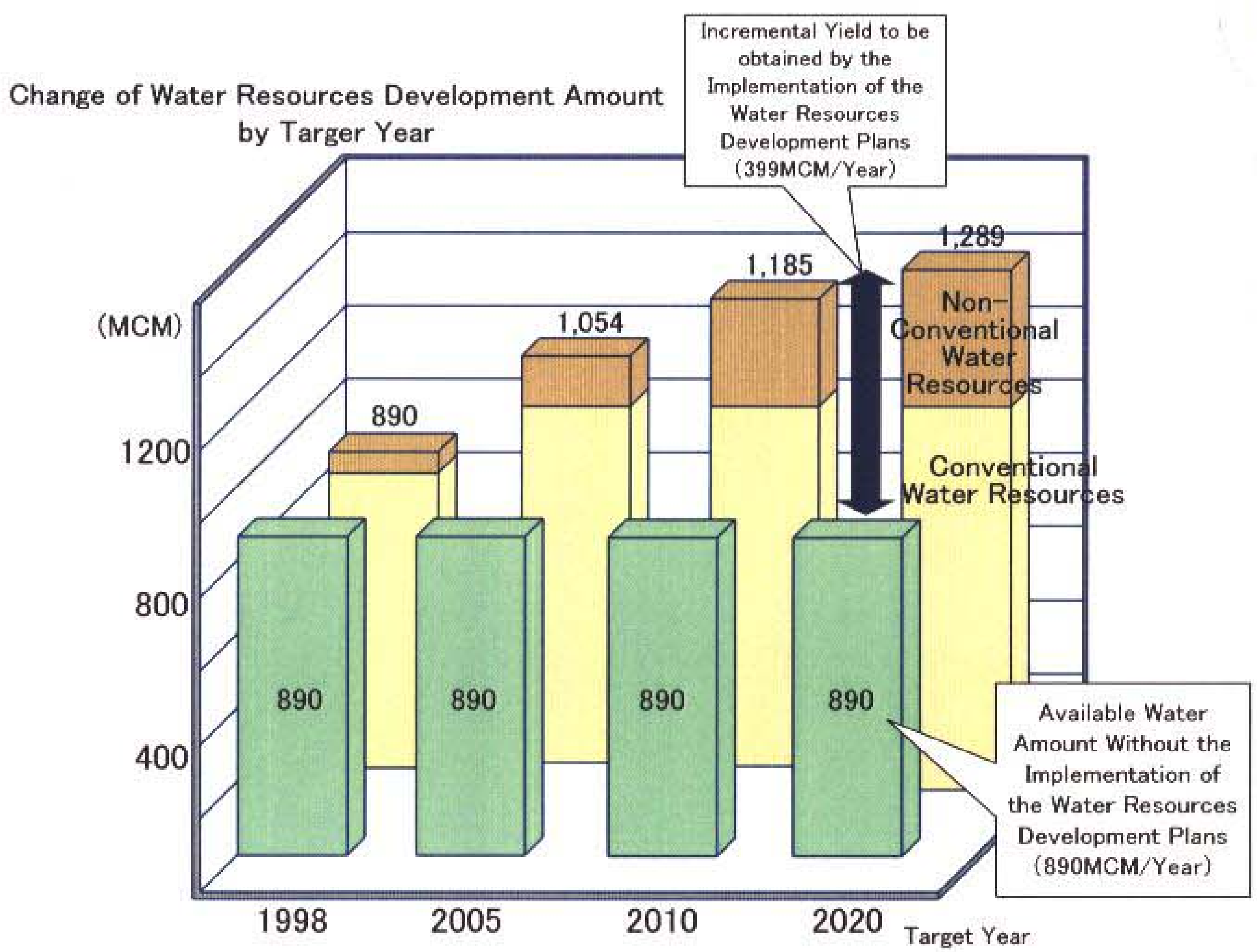




Location Map of Main Water Resources Management Projects

**Fig.Sum-5 Water Resources Management Plan of the Water Resources Management Master Plan**

# Water Resources Development



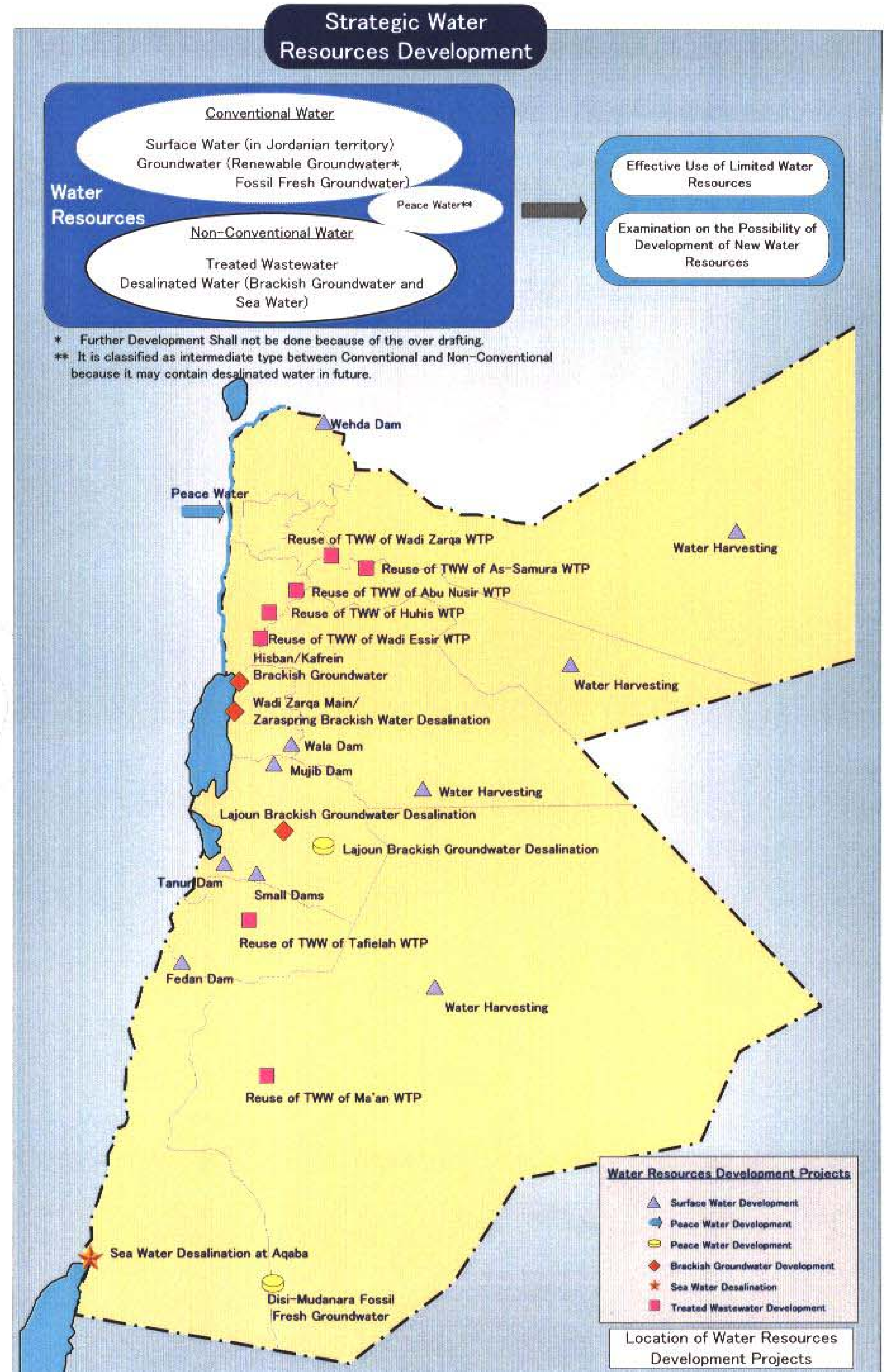




Fig.Sum-6 Water Resources Development Plan of the Water Resources Management Master Plan

**The Study on Water Resources Management in the Hashemite Kingdom of Jordan**

## FINAL REPORT VOLUME II

## MAIN REPORT PART-B
## PRE-FEASIBILITY STUDY ON PRIORITY PROJECTS

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# CHAPTER 1

## REHABILITATION AND EXTENSION OF MA'AN WASTEWATER TREATMENT PLANT AND TREATED WASTEWATER REUSE OF FIVE EXISTING TREATMENT PLANTS

# CHAPTER 1 REHABILITATION AND EXTENSION OF MA'AN WASTEWATER TREATMENT PLANT AND TREATED WASTEWATER REUSE OF FIVE EXISTING TREATMENT PLANTS

## 1.1 Project Area (Ma'an)

The boundaries of the project area correspond to the urban area of Ma'an. No other city or village is and will be served by the wastewater collection, treatment and disposal system. However, only a part of the urban area of Ma'an will be sewered. The collected sewage is discharged to the Wastewater Treatment Plant of Ma'an.

The City of Ma'an is located in the western reaches of the desert region, 220 km south of Amman and 120 km north of Aqaba along the Desert Highway. It is situated at the intersection of the Desert Highway, which is the main route between Aqaba and the populous areas around Amman and also the principal route to Iraq. Ma'an is the seat of the Ma'an Governorate and is rapidly growing in size and importance.

Commercial activities in Ma'an are important for the city itself and the entire Governorate. A glass factory constructed in the early 90ies has closed meanwhile. Industrial factories within the project area do not exist. However, phosphate mines are located in the surroundings of Ma'an. A housing area of the Jordan Phosphate Mines Company was under construction in April 2001 providing 100 houses for the company's employees (in total about 600).

On an area northeast of Ma'an (road to Wadi Mousa) the new Al Hussein Bin Talal University is proposed. Minor construction activities have commenced.

The topography of the project area is generally flat with a gradual slope upwards to the west. Within the region there are distinct hills, and although the terrain generally slopes to the east, there are localized low spots where runoff collects and ponding of stormwater results. The altitude is 1,060 m a.s.l..

The ground surface within the project area and the tributary watersheds is relatively pervious with very little vegetation. Ma'an lies within an arid desert region. Most of the rainfall occurs between the months of November and April. Typical annual rainfall with the vicinity of Ma'an is 50 mm only. The flow in the major wadis traversing the study area only flow during rainy periods and dry up shortly after the rain ends.

## 1.2 Existing System (Ma'an)

### 1.2.1 Sewerage System (Ma'an)

The wastewater of Ma'an is collected by a separate system. The sewerage system has a length of about 53 km in 2001 and serves the centre of Ma'an only. Specific length per connected capita is about 2.5 meters per capita, which is a rather high value resulting from the low-density urban areas (see also Annex 1.2).

The sewerage system exists of the sewers having diameters of 200 mm (minimum) and 300 mm (maximum). The transmission main (4 km) between the city and the treatment plant is of DN 300 too (see Figure 1.2.1-1). House connections are generally of DN 150. All sewer pipes are made of concrete.

The whole sewer network is drained by gravity, which required in some places considerable depths. 65 manholes of the network and further 35 of the transmission main are 5 m deep.

The not-connected houses dispose their wastewater into cesspools, septic tanks or directly into wadis or into the underground. It is supposed that most of not-connected houses dispose their produced sewage either untreated or insufficiently treated. The content of the septic tanks is not brought to the treatment plant and discharged into the existing acceptance works, but transported and discharged by the suction trucks on the dumping ground 3 km distant of Ma'an. Empting of private cesspools costs about 15 JD.

At present (January 2001), in Ma'an some 900 existing house connections (to the sewerage system) are registered. Table 1.2.1-1 presents the development of the connections to the sewerage within the sewered urban areas since 1998. Assuming 25 persons are served per house connection would mean 22,500 inhabitants are connected, i.e. the connection rate in the sewered urban areas would be 80 %. Based on the pollutional load of the last 4 years and on a specific pollution of 65 g/c/d, an average connection rate of 75 % (equal to 21,000 inhabitants) is estimated.

Finally we assumed that the connected population is about 21,200. This would mean a connection rate related to the total present population of 27,900 living in Ma'an of 75 %. This figure can also be justified by the water supply figures in relation to the wastewater influent to the Ma'an Wastewater Treatment Plant (see section 1.2.2).

**Table 1.2.1-1: Development of House Connections 1995/2001**

| Year | No. of existing house connections |
|---|---|
| 1997 | |
| 1998 | 843 |
| 1999 | 871 |
| 2000 | 884 |
| Jan.2001 | 900 |

Ma'an has a tanker with a jetting device for operation and maintenance and to clean the sewers. According to the responsible person about 5 blockages per day have to be cleaned. Most of the blockages are due to deposits of sand probably caused by low slopes in the sewer lines.

An obvious problem of hydraulic capacity in the sewerage network does not exist.

Industries within the sewered areas do not exist. However, there is a slaughterhouse in Ma'an. All liquid wastes including blood of the slaughtering process is discharged into the sewerage network. The solid waste of the slaughterhouse is transported to the dumping ground of Ma'an.

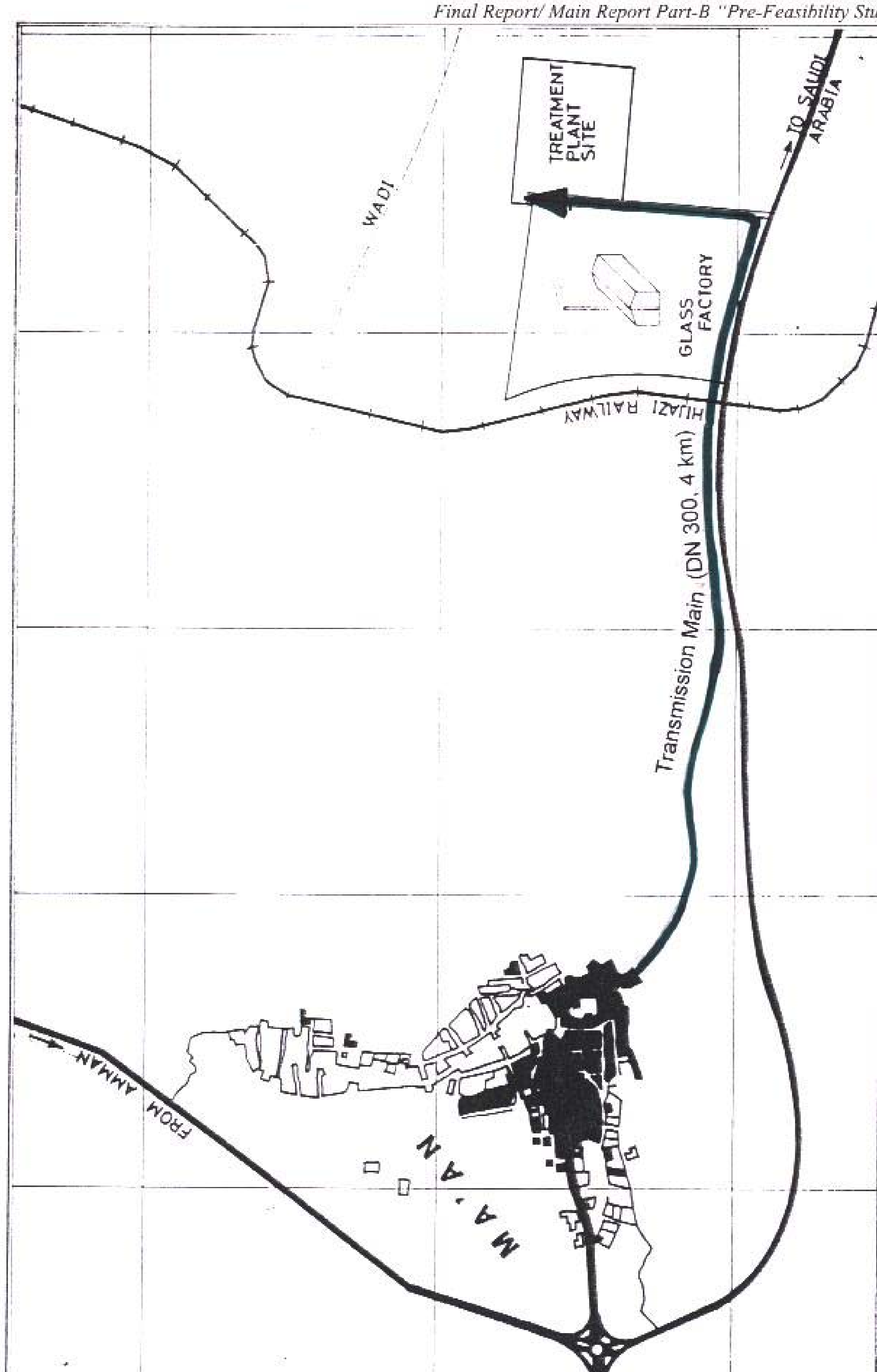



**Figure 1.2.1-1 General Layout of the Ma'an Wastewater System**

### 1.2.2 Treatment and Disposal System (Ma'an)

#### 1.2.2.1 Discharge and Load

Figure 1.2.2-1 illustrates the development of the $BOD_5$-concentration of the influent and effluent as well as the discharge to the Ma'an Wastewater Treatment Plant since 1990, when it was put into operation. The flow to the plant has increased by a factor of more than 3 since its start of operation. Wastewater from a slaughterhouse contributes to the pollutional load.

Table 1.2.2-1 summarizes the development of water quality of influent and effluent ($BOD_5$, COD, TSS and TDS) for the years 1990/2000, while Table 1.2.2-2 shows the basic monthly data of the influent and effluent in 2000. The data reveal clearly that the effluent quality was not satisfactory since the plant was put into operation.

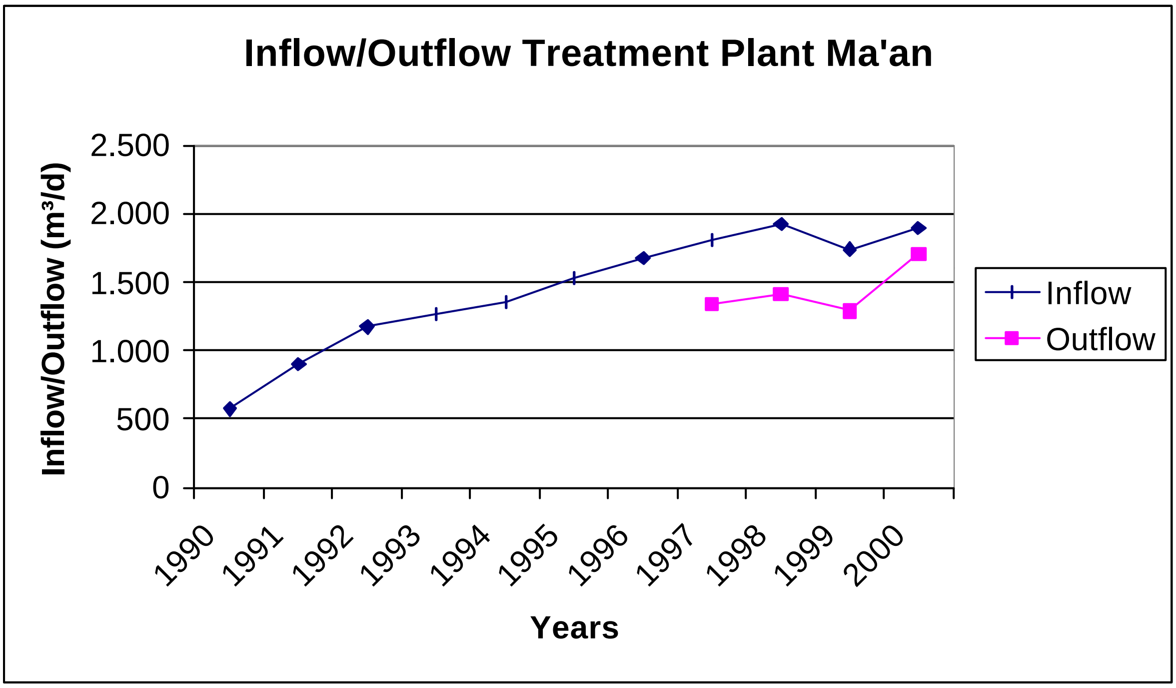
**Table 1.2.2-1 Quality of Influent and Effluent of Ma'an WWTP (1990/2000)**

| Year | Influent (mg/l) | | | | Effluent (mg/l) | | | |
|---|---|---|---|---|---|---|---|---|
| | $BOD_5$ | COD | TSS | TDS | $BOD_5$ | COD | TSS | TDS |
| 1990 | 354 | 1,450 | 331 | | 96 | 340 | 290 | 1,300 |
| 1991 | 806 | 1,537 | 707 | | 85 | 300 | 181 | 1,309 |
| 1992 | 1,006 | 2,185 | 1,055 | | 115 | 402 | 192 | 1,127 |
| 1993 | 853 | 1,719 | 727 | | 127 | 331 | 191 | 1,022 |
| 1994 | 828 | 1,967 | 737 | | 107 | 308 | 166 | 1,216 |
| 1995 | 1,047 | 1,837 | 703 | | 170 | 358 | 211 | 1,130 |
| 1996 | 921 | 1,841 | 812 | | 217 | 447 | 235 | 1,000 |
| 1997 | 1,140 | 2,272 | 886 | 948 | 171 | 613 | 210 | 947 |
| 1998 | 701 | 2,293 | 983 | 1,254 | 178 | 670 | 443 | 1,495 |
| 1999 | 549 | 1,582 | 715 | 954 | 118 | 418 | 213 | 945 |
| 2000 | 684 | 1,246 | 617 | 856 | 128 | 392 | 227 | 928 |

The present (2000) flow and load in comparison to the design capacity of the Ma'an treatment plant is as follows:

| | Unit | Design capacity | Average flow and load in 2000 | Used design Capacity (%) |
|---|---|---|---|---|
| Inflow | $m^3/d$ | 1,600 | 1,890 | 119 |
| $BOD_5$-load | kg/d | 870 | 1,254 | 144 |

These figures reveal clearly the overloading (in particular with regard to pollutional load given in $BOD_5$) and the need for the extension of the existing treatment facilities.



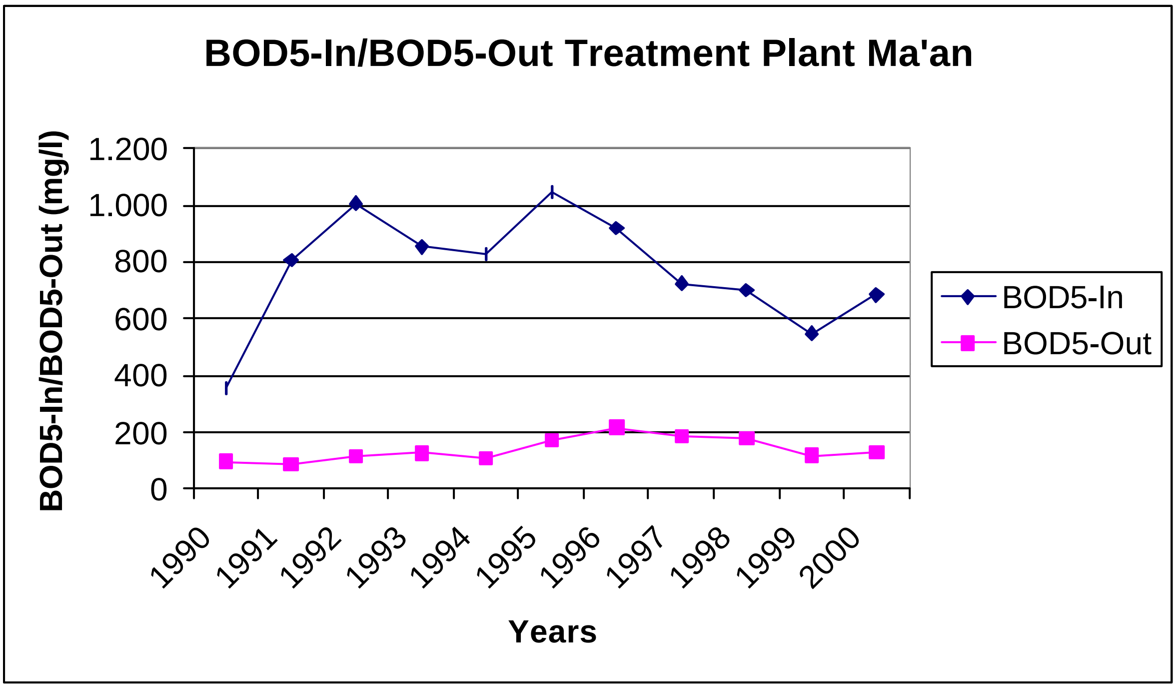




**Figure 1.2.2-1 Development of Influent/Effluent $BOD_5$-concentration and Flow**

**Table 1.2.2-2 Influent and Effluent Data of Ma'an Treatment Plant (2000)**

| | | Unit | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Average | Min. | Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inflow | | m³/d | 1,617 | 1,250 | 1,600 | 2,141 | 2,098 | 2,010 | 2,839 | 2,000 | 1,800 | 1,677 | 1,936 | 1,733 | 1,892 | 1.250 | 2.839 |
| Outflow | | m³/d | 1.569 | 1,110 | 1,449 | 1,933 | 1,889 | 1,746 | 2,522 | 1,712 | 1,564 | 1,604 | 1,761 | 1,583 | 1,704 | 1,110 | 2.522 |
| pH | in | - | 7.0 | 6.2 | 8.2 | 7.6 | 8.0 | 6.9 | | 7.1 | 6.7 | 7.9 | 7.2 | 7.0 | 7.3 | 6,2 | 8,2 |
| | out | - | 8.0 | 6.7 | 8.3 | 8.0 | 7.9 | 7.7 | 7.6 | 7.6 | 7.0 | 8.4 | 7.5 | 7.8 | 7.7 | 6,7 | 8,4 |
| TDS | in | mg/l | 730 | 834 | 870 | 886 | 818 | 948 | | | | | 906 | | 856 | 730 | 948 |
| | out | mg/l | 612 | 948 | 912 | 880 | 888 | 1,012 | 956 | 1,002 | 964 | 1,036 | 898 | 1,032 | 928 | 612 | 1.036 |
| TSS | in | mg/l | 337 | 683 | 490 | 999 | 439 | 637 | | | | | 735 | | 617 | 337 | 999 |
| | out | mg/l | 528 | 78 | 82 | 275 | 225 | 295 | | 211 | 179 | 229 | 189 | 207 | 227 | 78 | 528 |
| $BOD_5$ | in | mg/l | 323 | 1,014 | 885 | 627 | 645 | 472 | 692 | 1,150 | 650 | 612 | 430 | 709 | 684 | 323 | 1.150 |
| | out | mg/l | 104 | 196 | 192 | 55 | 128 | 101 | 84 | 315 | 82 | 76 | 76 | 122 | 128 | 55 | 315 |
| COD | in | mg/l | 890 | 1,965 | 1,412 | 1,862 | 1,260 | 990 | 910 | | | | 679 | | 1,246 | 679 | 1.965 |
| | out | mg/l | 386 | 514 | 556 | 462 | 427 | 391 | 351 | 473 | 404 | 245 | 286 | 207 | 392 | 207 | 556 |
| $NH_4$ | in | mg/l | | 170 | 245 | 105 | | 107 | | | | | | | 157 | 105 | 245 |
| | out | mg/l | 31 | 129 | 131 | 108 | 123 | 92 | 50 | 99 | 59 | 53 | 78 | 86 | 87 | 31 | 131 |
| TCC-effluent | | 1/100ml | 300,000 | 160,000 | 1,300,000 | 3,000 | 1,600,000 | 1,600,000 | 1,600,000 | 1,600,000 | 230,000 | 800,000 | | 1,600,000 | 981,182 | 3,000 | 1.600.000 |
| TFCC-effluent | | 1/100ml | | 160,000 | 500,000 | 3,000 | 1,600,000 | 1,600,000 | 1,600,000 | 1,600,000 | 230,000 | 300,000 | | 1,600,000 | 919,300 | 3,000 | 1.600.000 |
| Ni-effluent | | mg/l | 0.01 | | | | | 0.12 | | | | | | | 0.065 | 0.010 | 0,120 |
| Zn-effluent | | mg/l | 0.74 | | | | | 0.06 | | | | | | | 0.400 | 0.060 | 0,740 |
| Cr-effluent | | mg/l | 0.11 | | | | | 0.07 | | | | | | | 0.090 | 0.070 | 0,110 |
| Pb-effluent | | mg/l | 0.04 | | | | | 0.06 | | | | | | | 0.050 | 0.040 | 0,060 |
| Mn-effluent | | mg/l | 0.15 | | | | | 0.06 | | | | | | | 0.105 | 0.060 | 0,150 |
| Cd-effluent | | mg/l | 0.002 | | | | | 0.004 | | | | | | | 0.003 | 0.002 | 0,004 |
| Cn-effluent | | mg/l | 0.02 | | | | | 0.02 | | | | | | | 0.020 | 0.020 | 0,020 |
| Fe-effluent | | mg/l | 0.14 | | | | | 0.14 | | | | | | | 0.140 | 0.140 | 0,140 |

#### 1.2.2.2 Wastewater Treatment

The Ma'an Wastewater Treatment Plant is located 3 km east of the city at the road to Saudi Arabia. The plant is built on the plain, which is gently sloping to the east. Figure 1.2.2-2 shows a schematic layout of the existing Wastewater Treatment Plant of Ma'an, while Figure 1.2.2-3 presents a location plan.

At the inlet of the plant a screen is available. However, presently influent to the plant bypasses the facility and, therefore, is not screened. The wastewater stabilization pond system of Ma'an consists of 2 anaerobic ponds (operated in series), 3 facultative ponds (operated in parallel) and 1 maturation pond. Pipe connections within the plant allow operating the anaerobic and facultative ponds either in parallel or in series (see Figure 1.2.2-3). Disinfection of the effluent is possible by a chlorination plant, but was not in operation in March 2001. Treated wastewater may be recirculated from the outlet of the maturation pond to the headworks. Drying beds for sludge are not available. Annex 1.2 contains a detailed description of the existing treatment plant and the dimension of individual facilities.

Existing septic sludge acceptance facilities at the treatment plant were never used. Sludge of the houses not connected to the sewerage system is transported suction trucks to the dumping site.

Concrete structures, gratings and penstocks are in good condition. Discharge from the Venturi-flume to the screens is not properly arranged. Velocity to the screen is too high. Presently, screen is by-passed by the incoming wastewater flow.

Land owned by WAJ within the treatment plant area and in the vicinity is sufficient to extend the plant by facultative ponds and maturation ponds.

In 1997, the anaerobic ponds were desludged for the first and the only time, since the treatment facilities were put in operation in 1989. Sludge was emptied of the ponds and filled in excavated trenches within the treatment plant area for drying and infiltration.

The inflow of the 1989 completed plant has reached its hydraulic capacity and is meanwhile overloaded by almost 20 %. With regard to the organic pollutional load the plant is overloaded by more than 40 %. The average $BOD_5$-strength since 1990 (in the influent) of about 770 mg/l is in a normal range in comparison to other plants in Jordan.

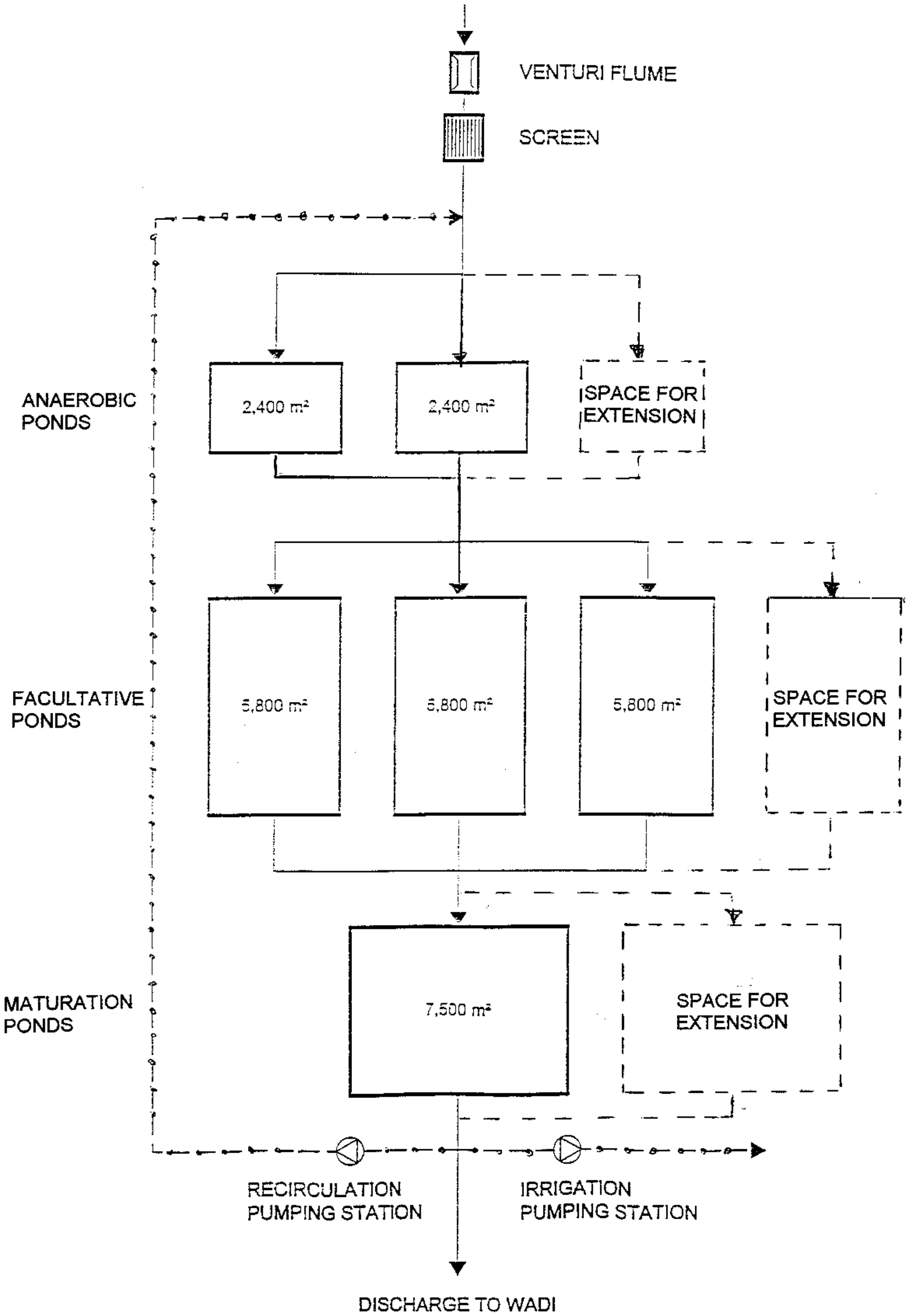



**Figure 1.2.2-2 Schematic Layout of Existing Ma'an Wastewater Treatment Pant**

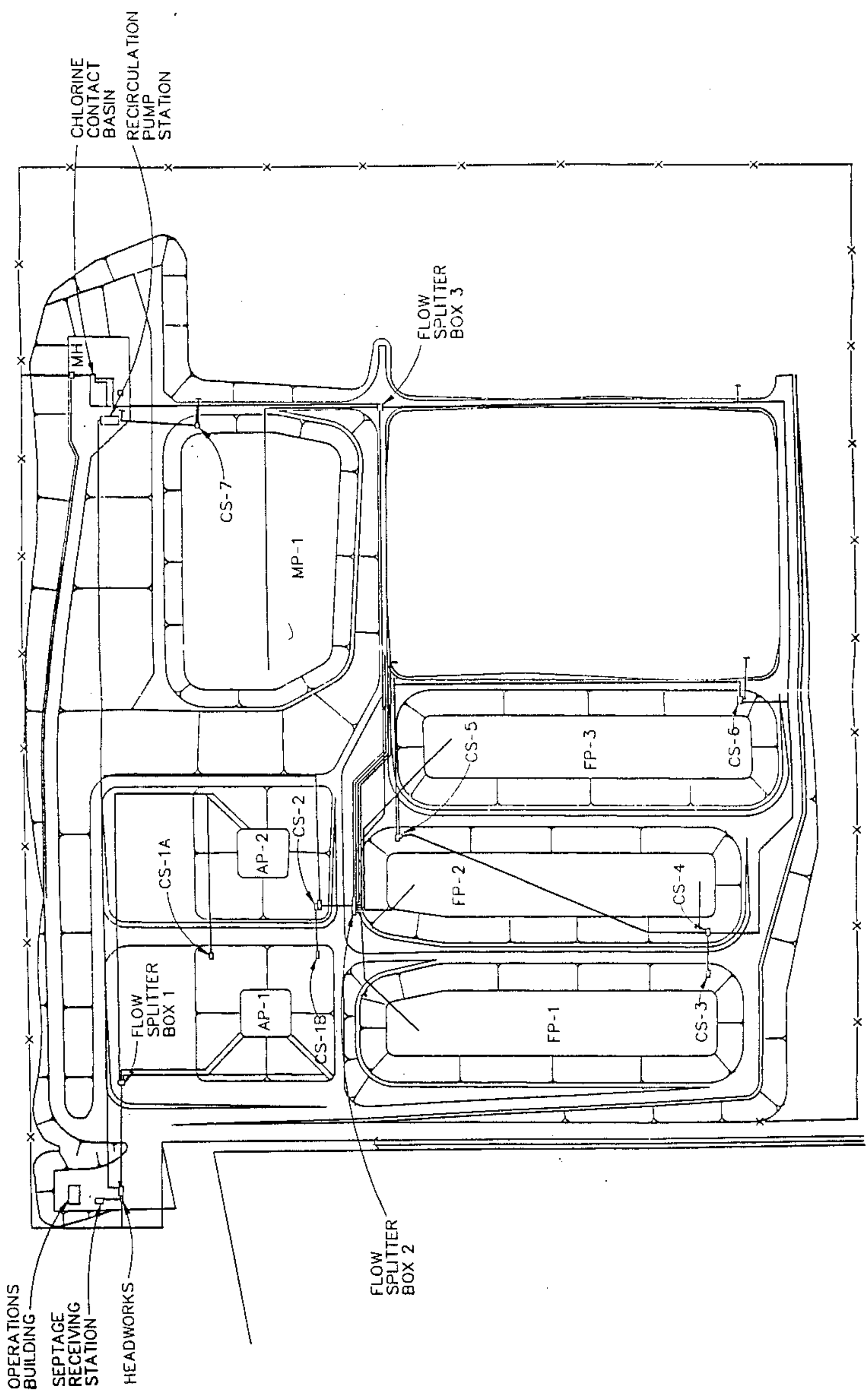



**Figure 1.2.2-3 Location Plan of the Existing Ma'an Wastewater Treatment Plant**

#### 1.2.2.3 Effluent Quality and Water Reuse

The average treatment efficiency in 1999/2000 was 80 % ($BOD_5$-elimination), which is too less in comparison to the expected range of efficiency applying pond system technology (about 95 %). This low efficiency is due to the overloading with regard to both hydraulic and pollutional load. However, the plant has never reached satisfactory performance, even not in the years when it was operating below the design capacity.

Main receiving water is Wadi Mahatta. The average $BOD_5$-concentration in the effluent of the plant is unsatisfactory (average since 1990: 140 mg $BOD_5$/l) and exceeds the relevant Jordanian Standards 893/1995 for discharge into wadis and catchment areas of 50 mg $BOD_5$/l.

As far as the reuse of effluent is concerned, the faecal coliform count (in average about 1,000,000 per 100 ml for all analysis in 2000, see Table 1.2.2-2) at the outflow of the plant does not allow unrestricted agricultural irrigation. According to Jordanian Standards 893/1995 the faecal coliform shall not exceed 1,000 counts/100 ml for the category "vegetables eaten cooked" (see Table 1.3.3-1 in section 1.3.3.1). Due to the poorly treated wastewater having still high contents of organic compounds it is not advisable to use the existing chlorination plant for reduction of the bacterial pollution (fecal coliform count).

At present, in summer 500 to 700 $m^3$/d of treated wastewater is reused for agricultural irrigation, while this quantity decreases to some 200 $m^3$/d in winter. About 50 donums of farmland are irrigated by treated wastewater. An association of farmers has installed pumping equipment at the treatment plant's outlet to discharge effluent to an area of 50 donums (fodder and olive trees) for irrigation. These farmers pay 2 Fils/$m^3$ for treated wastewater, which is used outside of the treatment plant area. In addition, within the treatment plant area about 40 donums of olive trees is irrigated. About 3 km downstream of the treatment plant a farmer has impounded by simple means the wadi conducting the effluent to pump water to his olive plantations.

#### 1.2.2.4 Cost of Treatment

Cost for wastewater treatment during the last four years is reported as shown in Table 1.2.2-3. The presented costs consider expenses for operation and maintenance only. During this period the total cost increased from 29,189 to 53,161 JD/a or by more than 80 %.

Specific treatment costs are related to influent wastewater quantity. In comparison to costs reported for other treatment plants in Jordan the one for Ma'an are quite low, i.e. 0.077 JD/m³ in 2000. Lowest specific costs are reported for the treatment plants of As Samra and Aqaba (As Samra: 0.021 JD/m³ in 2000), while highest costs are found for Kufranja, Tafielah, Wadi Essir and Fuhis (Kufranja: 0.322 JD/m³ in 2000).

Cost for operation and maintenance are significantly lower for the treatment by wastewater stabilization ponds in comparison to the conventional treatment systems (extended aeration, trickling filters, activated sludge etc.). In average the specific cost for wastewater treatment by pond system is in the order of 0.065 and for conventional systems it equals to 0.190 JD/m³. This fact should be taken into account for the planning of the future extension of the Ma'an Wastewater Treatment Plant.

**Table 1.2.2-3 Operation and Maintenance Cost for Wastewater Treatment**

| Cost item | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|
| Salary | 25,104 | 27,734 | 37,385 | 41,123 |
| Electricity | 1,152 | 968 | 1,080 | 1,323 |
| Telephone | 0 | 0 | 0 | 0 |
| Water | 53 | 200 | 200 | 200 |
| Spare parts | 460 | 0 | 5,630 | 7,500 |
| Chlorine chem. | 100 | 175 | 0 | 135 |
| Sludge disposal | 0 | 0 | 0 | 0 |
| Laboratory matter | 0 | 0 | 0 | 0 |
| RSS tests | 600 | 288 | 0 | 0 |
| Fuel and oil | 1,000 | 560 | 1,430 | 1,600 |
| Pesticides | 500 | 1,200 | 480 | 580 |
| Others | 220 | 740 | 145 | 700 |
| Total cost | 29,189 | 31,865 | 46,350 | 53,161 |
| Cost in JD per treated $m^3$ | 0.044 | 0.045 | 0.073 | 0.077 |

(costs in JD/a)

#### 1.2.2.5 Man Power for Operation and Maintenance of Facilities

The local WAJ-Office has 4 employees for the operation and maintenance of the existing sewerage system of Ma'an. This means 4.4 employees per 1,000 house connections or 0.08 employees per 1 km of sewer. These ratios seem to be in an acceptable order of magnitude taking into account specific local condition.

At the wastewater treatment plant 15 persons are employed. This number is considered to be far too high. A total staff number of less than 5 would be adequate taking into account the particular local condition of Ma'an Treatment Plant.

## 1.3 Design Criteria

### 1.3.1 Wastewater Collection (Ma'an)

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

#### 1.3.1.1 Hydraulic Design Criteria for Sewers

For sewers, continuous head losses are calculated by using the Manning equation in connection with resistant coefficient.

The operational roughness not only allows for the pipe roughness, but also for the influence of junctions, joints, bends, and encrustation. A Manning's coefficient of 0.015 is used for the dimensioning of all sewer pipes.

Criteria for the minimum velocity in a sewer pipe are self-cleansing capacity and prevention of extensive sulfide generation. To avoid sedimentation of sludge and sand grains in the sewers the minimum gradient of 0.2 % is respected. Minimum flow velocity in small collecting pipes should not be less than 0.7 m/s, which is generally respected assuming a slope of more than 0.2.

The sewers may have to be cleaned regularly (about every 5 year depending on the local conditions) with a ball or other hydraulic device. Good ventilation, in particular at points of high water turbulence, has to be provided. This is also valid in cases of long collectors (transmission main from center of Ma'an to the treatment plant).

For maximum velocity, abrasion at the pipe walls by transported sand as well as the load, e.g. on bends, is the limiting factor. The maximum flow velocity should not exceed 4.5 m/s.

For sewer flow design it is adopted that generally only about 80 % of pipe is filled in case of maximum discharge.

#### 1.3.1.2 Design Principles for Construction of Sewers

*A. Minimum Sewer Diameter and Manhole Spacing*

To prevent sewer blockage caused by bulky wastes entering the system, sewers are proposed having the following minimum internal diameter.

- Private house connections DN 150 - 200 mm
- Collecting sewers DN 200 mm

Manholes are located at the junction of sewers and at changes in slope or alignment and at distances enabling easy sewer maintenance. The manholes are not specified in the project but they are included in unit prices of pipes per linear meter. Space between two manholes should be not more than 50 m.

*B) Depth of Sewers*

Sewers shall be constructed as shallow as practicable for economic reasons. The minimum required cover for street sewers is 1.00 m otherwise considerable costs are incurred to safeguard street sewers and drains and service connections against breakage by traffic loads.

The depth of sewers is affected by other services to be crossed. Sewers must pass below water supply pipes for hygiene reasons. In case of such crossings a minimum vertical distance of 0.3 m should be respected.

*C) Materials for Sewers*

In general, factors to be considered in the selection of the material for sewer construction are:

- flow characteristics, roughness coefficient;
- life expectancy;
- internal resistance to acids, alkalis, gases, solvents etc.;
- external resistance to corrosion;
- ease of handling and installation;
- physical strength;
- type of joint, which should be watertight and easy to apply;
- availability of required sizes;
- cost of materials.

Taking into account the local conditions in Ma'an PVC is the preferred material for the DN 150 for house connections, because of its corrosion resistance and ease of handling. Over DN 200, the choice fall to concrete, because concrete is a commonly used material for sewers.

Special attention should be paid to the design and construction of the joints. The best quality bell-and-spigot joints with rubber rings are recommended for all pipes.

### 1.3.2 Wastewater Generation and Strength (Ma'an)

Estimations on future wastewater flows and loads are based on existing data available for the Ma'an service area.

The analysis of WAJ data on water supply of Ma'an showed that water billed had decreased from 87 l/c/d in 1995 to 83 l/c/d in 1998. In 1999 the water consumption reduced again dramatically to some 60 l/c/d. Details on water consumption is presented in Table 1.3.2-1.

For 2000 UFW is estimated to about 60 % according information got from WAJ. It seems that the major portion of the UFW is due to administrative losses. This may be justified by the fact that the water production has not decreased during the last 6 years and the water distribution network could not be deteriorated during the same time to attribute the increased UFW to the technical losses. Therefore, the total UFW is estimated comprising some 25 - 30 % of physical leakage and some 30 - 35 % administrative losses. Details of the evaluation are given in Table 1.3.2-2 for the period January to September 2000.

Taking into account specific billed water of presently 60 l/c/d and about 35 % of administrative losses, then "adjusted consumption", i.e. water produced or supplied minus leakage in transmission and distribution, would be about 92 l/c/d in 2000. With respect to the inflow to the treatment plant, which was in the order of 1,800 $m^3$/d during the last four years, the "adjusted specific consumption" is supposed to be 105 l/c/d. Therefore, we assumed this figure as the actual consumption in 2000.

**Table 1.3.2-1 Quarterly Billed Water**

| YEAR | User Type | Unit | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter | Annual Total |
|---|---|---|---|---|---|---|---|
| 1995 | Commercial | m³/quarter | 51,187 | 50,909 | 49,982 | 51,719 | 203,797 |
| | Domestic | m³/quarter | 119,390 | 131,717 | 152,857 | 133,246 | 537,210 |
| | Small Industries | m³/quarter | 3,000 | 2,991 | 3,465 | 3,408 | 12,864 |
| | Tourism | m³/quarter | 159 | 238 | 40 | 50 | 487 |
| | 1995 Total | m³/quarter | 173,736 | 185,855 | 206,344 | 188,423 | 754,358 |
| | Spec.water billed | l/c/d | 81 | 87 | 96 | 88 | 87 |
| 1996 | Commercial | m³/quarter | 43,211 | 57,797 | 66,211 | 63,609 | 230,828 |
| | Domestic | m³/quarter | 125,649 | 137,418 | 146,864 | 136,473 | 546,404 |
| | Small Industries | m³/quarter | 3,075 | 3,294 | 3,691 | 3,155 | 13,215 |
| | Tourism | m³/quarter | 52 | 74 | 50 | 70 | 246 |
| | 1996 Total | m³/quarter | 171,987 | 198,583 | 216,816 | 203,307 | 790,693 |
| | Spec.water billed | l/c/d | 77 | 89 | 98 | 92 | 88 |
| 1997 | Commercial | m³/quarter | 47,837 | 58,173 | 61,066 | 56,985 | 224,061 |
| | Domestic | m³/quarter | 137,452 | 135,171 | 145,938 | 140,020 | 558,581 |
| | Small Industries | m³/quarter | 2,798 | 3,177 | 3,082 | 2,838 | 11,895 |
| | Tourism | m³/quarter | 96 | 88 | 136 | 145 | 465 |
| | 1997 Total | m³/quarter | 188,183 | 196,609 | 210,222 | 199,988 | 795,002 |
| | Spec.water billed | l/c/d | 82 | 85 | 91 | 87 | 85 |
| 1998 | Commercial | m³/quarter | 60,611 | 71,691 | 66,107 | 43,403 | 241,812 |
| | Domestic | m³/quarter | 130,430 | 136,261 | 152,097 | 136,610 | 555,398 |
| | Small Industries | m³/quarter | 2,185 | 2,000 | 2,127 | 1,883 | 8,195 |
| | Tourism | m³/quarter | 32 | 41 | 60 | 37 | 170 |
| | 1998 Total | m³/quarter | 193,258 | 209,993 | 220,391 | 181,933 | 805,575 |
| | Spec.water billed | l/c/d | 81 | 88 | 93 | 76 | 83 |
| 1999 | Commercial | m³/quarter | 49,310 | 0 | 6,786 | 4,559 | 60,655 |
| | Domestic | m³/quarter | 138,067 | 0 | 120,561 | 110,648 | 369,276 |
| | Small Industries | m³/quarter | 1,941 | 0 | 1,184 | 1,146 | 4,271 |
| | Tourism | m³/quarter | 98 | 0 | 25 | 25 | 148 |
| | 1999 Total | m³/quarter | 189,416 | 0 | 128,556 | 116,378 | 434,350 |
| | Spec.water billed | l/c/d | 77 | - | 52 | 47 | 59 |
| 2000 | Commercial | m³/quarter | 4,726 | 0 | 0 | 0 | 0 |
| | Domestic | m³/quarter | 105,947 | 0 | 0 | 0 | 0 |
| | Small Industries | m³/quarter | 880 | 0 | 0 | 0 | 0 |
| | Tourism | m³/quarter | 25 | 0 | 0 | 0 | 0 |
| | 1999 Total | m³/quarter | 111,578 | 0 | 0 | 0 | 0 |
| | Spec.water billed | l/c/d | 44 | 0 | 0 | 0 | 0 |

**Table 1.3.2-2 Determination of UFW in 2000**

| Months | Water production m³/quarter | Water billed M³/quarter | Water losses m³/quarter | Water losses % |
|---|---|---|---|---|
| Jan.-March | 1,310,701 | 734,920 | 575,781 | 43.9 |
| April-June | 2,259,643 | 758,169 | 1,501,474 | 66.4 |
| July-Sept. | 2,322,473 | 859,766 | 1,462,706 | 63 |
| Jan.-Sept. | 5,892,817 | 2,352,855 | 3,539,961 | 60 |

Water demand will increase in future due to higher living standards. Water supply will be improved by the development of additional resources and extension of capacities of existing water production facilities. Therefore, an increase of 0,5 l/c/d per year is supposed. Table 1.3.2-3 shows assumptions on specific adjusted water demand until 2025, i.e. values adopted for the project area of Ma'an in comparison to the values adopted in the Master Plan Study of JICA/YEC of 2001. For the years 2010/20 water demand assumed for Ma'an is lower than the average adopted by MOWI/WB (Ministry for Water and Irrigation and World Bank) for whole Jordan. This seems justifiable considering that the demand of Ma'an will certainly be lower than the Jordanian average (dominated by high consumption of the Capital Amman). In this context it has to be mentioned that present specific water consumption is already relatively high compared with other regions of Jordan.

**Table 1.3.2-3 Adjusted Specific Water Demand of Different Studies (2000/25)**

| | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 |
|---|---|---|---|---|---|---|
| JICA for Ma'an 1) | 105 | 108 | 110 | 113 | 115 | 118 |
| Scenario 1 2) | 103 | 104 | 129 | 136 | 133 | |
| Scenario 2 3) | 103 | 104 | 129 | 150 | 155 | |

All values in l/c/d

1) Adopted by JICA for this Pre-Feasibility Study of Ma'an
2) Scenario 1: MOWI/WB assumptions for total Jordan (see YICA/YEC, Master Plan 2001)
3) Scenario 2: MOWI assumptions for total Jordan (see YICA/YEC, Master Plan 2001)

Evaluation of influent quantities at the wastewater treatment plant of Ma'an showed that the coverage (percentage of population connected to the sewerage) is presently about 75 % assuming a return factor of 0.85. The connection rate will increase in future due to extension measures of the collection network. We estimate a connection rate of 85 % after completion proposed measures in 2005.

Due to the fact that there are no specific water consuming factories in Ma'an, no particular allowance was made for industrial wastewater production.

However, it has to be mentioned that in the slaughterhouse of Ma'an about 3 to 5 big animals (cows, camels) and some 50 small animals are slaughtered. No pre-treatment is provided for the sewage, which discharged into the public sewerage system. At several locations within the town car washing garages or places exist. Produced wastewater is not particularly pre-treated except of a simple screen.

Historical wastewater quality data compiled by WAJ have been used to estimate organic, solids and nutrient loadings rates. The high concentration of $BOD_5$, total suspended solids(TSS) and ammonia-nitrogen ($NH_4$-N) characterize the sewage as a high strength sewage, which is typical for area in which specific water supply is low. Presently per capita daily $BOD_5$-contribution of the resident population has been taken as 60 g/c/d presently based on measured average daily wastewater, $BOD_5$-concentration and load in the inflow of Ma'an's treatment plant. Specific daily per capita daily $BOD_5$-production will increase to 65 g/c/d, which is in line with the loadings of other comparable treatment plants in Jordan.

All basic assumptions for future wastewater flow and load are summarized in Table 1.3.2-4.

**Table 1.3.2-4 Basic Assumptions on Wastewater Flows and Pollutional Load**

| Basic data: | Unit | 1994 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 |
|---|---|---|---|---|---|---|---|---|
| Spec.water demand | l/c/d | 100 | 105 | 108 | 110 | 113 | 115 | 118 |
| Increase of spec.water demand | l/c/d per a | | 0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Coverage (sewerage) | % | 70 | 75 | 85 | 85 | 90 | 90 | 90 |
| Return factor | - | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 |
| Losses/inflow | % | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Specific pollutional load | $gBOD_5$/c/d | 60 | 60 | 63 | 65 | 65 | 65 | 65 |

### 1.3.3 Wastewater Treatment (Ma'an)

#### 1.3.3.1 Effluent Criteria

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

Most important effluent criteria are summarized in Table 1.3.3-1 in case of discharge to wadis, irrigation of vegetables eaten cooked, fruit trees, forestation, fodder plants, which are expected as potential effluent paths of the treatment plant of Ma'an.

**Table 1.3.3-1 Quality Criteria for Treated Domestic Wastewater According Jordanian Standard 893/1995 (summary)**

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

50 $BOD_5$ for wastewater stabilization ponds is filtered samples, and non-filtered in other plants
51 Most Probable Number (MPN)
52 Mean Safaris, Enclostoma and Trycus

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

Effluent criteria as presented may be reached by well-designed and properly operated pond system.

### 1.3.3.2 Design of Pond System

**A. Primary (mechanical) treatment**

With primary treatment non-dissolved matters are removed from sewage. Rough solids of bigger size are removed by screens and granular solids, like sand and grit, by grit chambers. For the treatment system of Ma'an screening only is proposed.

Between the primary treatment units and the distribution chamber to the anaerobic ponds a Venturi-channel is proposed to measure the discharge of wastewater.

The screening channel is equipped by a screen, which is mechanically cleaned. Circular bar screens are proposed. The slope of the channel bottom is about 2 %.

Basic parameters for dimensioning of the screening facilities are as follows:

| | | |
|---|---|---|
| • Number of parallel basins: | ≥ 2 | units |
| • Max. velocity in the channel: | 1.0 | m/s |
| • Bar size: | 10 | mm |
| • Space between bars: | 20 | mm |

For security and continuity of treatment plant operation, a minimum of two screening channels (by-pass) should be provided. Containers have to be provided to collect screened matter.

**B. Secondary Treatment**

With respect to the existing wastewater stabilization system and the general local conditions in Ma'an pond systems are the most effective method of sewage treatment, being the least expensive in terms of investment, operation and maintenance costs (see section 1.5.2). Maturation or stabilization ponds are effective in destroying pathogenic bacteria and the eggs of intestinal parasites. They do, however, require large areas of land, but WAJ owns already necessary extension areas.

All biological (secondary) treatment processes depend strongly on the temperature of wastewater. Average minimum treatment temperature was estimated on he basis of average minimum air temperature (8 °C) in Ma'an. Therefore, average minimum temperature of wastewater is estimated to 16 °C.

**B.1 Anaerobic Ponds**

Anaerobic ponds are usually up to 5 meters deep and operate essentially as open septic tanks. Few algae grow and the pond is often dark red or purple in color due to the growth of anaerobic bacteria.

Such ponds can be used to treat large flows of strong wastes. With volumetric loads below 0.250 kg $BOD_5/m^3/d$ and stable alkaline fermentation with methane evolution, odor release should be minimal.

The use of anaerobic ponds as pre-treatment units for facultative ponds is often desirable to minimize land requirements in a pond treatment system.

Basic parameters for dimensioning of the anaerobic ponds are as follows:

| | | |
|---|---|---|
| • Number of parallel basins: | ≥ 2 | units |
| • Volumetric load ($C_v$): | 50 - 250 | $g/m^3/d$ |
| • Depth of basins (H): | 3 - 4 | m |
| • Retention time ($t_R$): | 3 - 5 | d |
| • Surface load ($C_s$): | >1,000 | kg/ha/d |

The ground of the anaerobic ponds will be compacted without additional measures to reduce the permeability of the pond's bottom. The infiltration in the underground will decrease considerably after a certain time due to sedimentation of the sludge leading to an impermeabilization of the bottom.

### B.2 Facultative Ponds

Such ponds are shallow, less than 1.6 meters deep, being aerobic near the water surface where bacteria oxidize waste and prolific algae growth should occur, and anaerobic at the pond bottom where solids settle and are digested.

Photosynthesis is the essential element in pond activity but, in hot climates, there is always sufficient light energy to promote algae growth. However, whilst high solar energy inputs promote high algae and bacterial growth, it also increases pond temperature and the risk of stratification of the pond liquid, especially in the absence of wind. Stratification can be overcome by installing a circulating pump(s) for which the power input should be less than 1 kW/ha of pond surface.

Prolonged periods of stratification can result in the growth of blue/green algae species, which decay on the surface of the pond causing an odor nuisance. Odor may also occur in these conditions by the generation of sulfide gases at the pond bottom.

Although the facultative pond is effective in oxidizing organic pollutants, it has little effect on pathogenic bacteria, and maturation ponds need to be included to control effluent quality and the overall efficiency of the treatment system (see next paragraph).

The facultative ponds (downstream of aerobic ponds) are dimensioned taking into account the following basic parameters:

| | | |
|---|---|---|
| • Number of parallel basins: | ≥ 2 | units |
| • Depth of basins (H): | 1.2 - 1.6 | m |
| • Retention time ($t_R$): | 15 - 30 | d |
| • Surface load ($C_s$): | 100 - 200 | kg/ha/d |

The process in the facultative ponds depend strongly on the temperature of wastewater. For verification of the surface load the formula of McGarry and Pescod were applied:

$$C_s = 60.3 * 1.0993^{Ta} / 1.5$$

$T_a$ is the average temperature of the ambient air for which 8 °C is assumed.

### B.3 Maturation Ponds

Maturation ponds should be completely aerobic and have about the same depth as facultative ponds. They serve in particular to reduce the fecal coliforms concentration of pre-treated wastewater. In case of reuse of treated wastewater for agricultural irrigation treatment by maturation ponds is required. The reduction of coliforms concentration depends on the water temperature and retention time of water in the maturation ponds. Therefore, minimum two basins in series should be provided.

Maturation ponds are dimensioned respecting following basic parameters:

| | | |
|---|---|---|
| • Number of basins in series: | $\geq 2$ | units |
| • Depth of basins (H): | 1.0 - 1.5 | m |
| • Retention time ($t_R$): | 5 - 7 | d (for the first basin) |
| | 3 | d (for the basins in series) |
| • Surface load ($C_s$): | < 140 | kg/ha/d |

The coefficient k of coliform reduction is calculated by:

$$K = 2.6 * 1.19^{(T-20)}$$

Where: T = wastewater temperature in °C

### 1.3.4 Design Criteria for Reuse Facilities

Technical design of treated wastewater reuse systems aims at providing adequate facilities to hold and convey adequate amounts of irrigation water that allow the optimal utilization of this major resource for agricultural irrigation.

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

#### 1.3.4.1 Availability of Treated Effluent

Quantification of the resource is a basic and first step towards evaluating the degree to which extent treated effluent can be used within the ultimate planning horizon for agricultural development. In Jordan the basic limiting factor in crop production is the quantity of available water resources in general and of treated effluent in particular. Its availability sets the frames for farming activities. In this case the effluent is of major concern in reuse schemes, and its availability depends on influent and wastewater treatment plant losses.

Monthly influent to the treatment plants is evaluated in the Interim Report. Generally, the peak month flows to the treatment plants appear during the summer months, when the water consumption is highest (as expected). However, some peak flows are observed in wintertime depending on treatment plant and year. The winter peaks are in particular due to the storm water and/or groundwater (of high groundwater table) entering the sewerage system during rainy season as well as due to the suppressed water demand during summer, because potable water is not available in sufficient quantities.

The peak month flow factors as found by the analysis of monthly discharges to the treatment plants range between 1.1 and 1.25. A certain tendency with regard to the order of magnitude of the factors may be observed as follows:

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

All of the towns for which effluent reuse systems were planned are in range of less than 30,000 population, therefore a peak factor of 1.25 was considered for all schemes. Seasonal variation of treated effluent was assumed as shown in Figure 1.3.4-1.

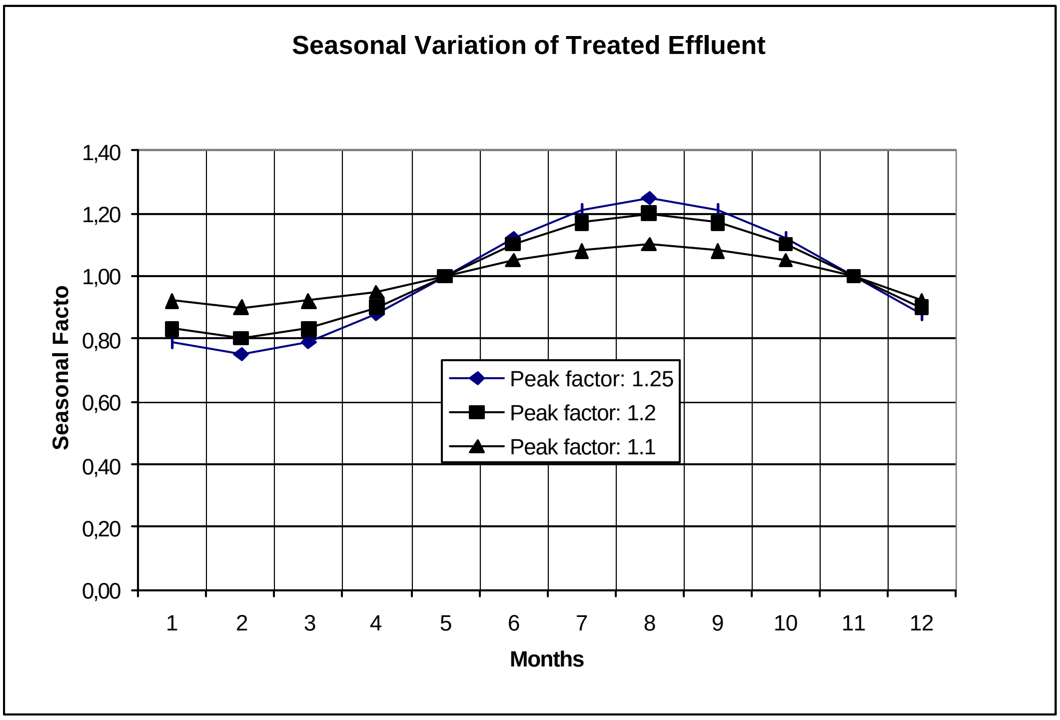



**Figure 1.3.4-1 Seasonal Variations of Treated Effluent**

### 1.3.4.2 Cropping Pattern

The following crops are selected for the five reuse schemes:

Previous experience with reuse in Jordan indicates that **olive trees** offers a safe, sustainable and economic choice, which is well adapted to a wide range of terrain, climate and soil conditions. Olive trees is also tolerant to salinity, which may develop in long term irrigation with effluent.

In Aqaba a date farm was established in 1986 and covers about 650 donums. Plantations are irrigated with treated effluent of the Aqaba Wastewater Treatment Plant. Satisfactory results are achieved and it is proposed to continue this reuse practice in Aqaba. Well established **date palm trees** with excellent management, including the provision of the optimum amount of water should produce on average a yield of 150 to 200 kg/tree.

Winter cereals are wide spread in Jordan. Yields of **barley and wheat** were in 1993 60 to 70 kg/donum respectively. With supplementary irrigation using treated effluent, the yield could be increased to 300 kg/donum.

A common practice in Jordan is the local reuse of treated effluent for irrigation of fodder plants such as **alfalfa** close to existing treatment plants. These crops offer the possibility to increase and decrease the irrigated land according to the seasonal availability of the treated effluent.

Vegetables are not recommended for cultivation and irrigation with treated effluent due to safety reasons with regard to human health.

#### 1.3.4.3 Irrigation Water Requirements of Crops

Generally, due to the availability of large cultivable commanded land areas within and around the wastewater treatment plants, it is only natural to concentrate on selecting a proper crop pattern in order to meet the availability of irrigation water. Water demand, for each agro-climatic zone of Jordan, is determined by the nature of crops planted and related cultivated area. Present agreements between WAJ and farmers specify fodders cultivation as the major cropping activity to which 3 m³/donum/day, all year round, of effluent is allocated.

In this study, a more rigorous cropping pattern is proposed including olives, date palms, grains (barley, wheat) and fodder (alfalfa). Monthly values of net irrigation water requirement for each crop were adopted and gross irrigation demand was calculated as for the anticipated irrigation efficiency for the target year 2010 (planning horizon). Values for net irrigation demand were assumed as applied presently by the MWI. These values are developed for various agro-zones and respect related regional precipitation. If there would be a modification of these values, related changes have to be respected within the Feasibility Study phase. Land area for each crop is determined by dividing the available effluent by the gross water demand per unit area.

The following irrigation efficiencies were adopted, where drip irrigation systems is recommended for irrigation of olive and date palm trees and surface irrigation for wheat, barley and fodder (alfalfa):

| | Olives (dip irrigation) | Date palms (dip irrigation) | Barley/wheat (surface irrig.) | Fodder (surface irrig.) |
|---|---|---|---|---|
| Efficiency factor (%) | 84 | 84 | 60 | 60 |

#### 1.3.4.4 Irrigation Water Conveyors

A main pipeline is required to handle and convey the effluent from the treatment plant to the proposed reservoir site or reuse areas. Diameters of conveyors (transmission mains) are determined by hydraulic calculations adopting the Manning's equation and the principles of continuity. Treated effluent can be conducted to the reuse areas either by gravity or pumping depending on ground elevation of the areas in relation to the treatment plant.

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

#### 1.3.4.5 Storage Facilities

In this study, it is assumed that a storage capacity adequate to accommodate two days flows of effluent is essential for operational purposes. Such a reservoir is required to maintain a more or less constant water flow to the fields to be irrigated. In addition, in cases of emergency, stoppages or unexpected breakdowns of pumps, or effluent flow fluctuations, it is important to secure a minimum of allowable storage requirement. However, storage capacity will not be provided to compensate seasonal variation in available effluent and demand. This would increase cost for investment and operation tremendously.

However, such an additional storage reservoir was not proposed in cases, where the treatment plant comprises wastewater maturation ponds and the treated effluent is discharged by gravity to the irrigation areas. It is assumed that the ponds provide sufficient storage volume (e.g. Ma'an, Fuhis) in these cases.

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

The problem of maximization of the reuse of treated effluent is obvious in the case of Ma'an, because excess water would be discharged unused into the wadi (without storage reservoir) and could lead to possible groundwater contamination, especially in the presence of shallow groundwater aquifers such as those of Ma'an region. In the cases of Abu-Nuseir, Fuhis and Wadi Essir, the matter can be resolved by using King Talal Reservoir, Wadi Shua'ab Dam and Kafrein Dam existing storage capacity.

Additionally, expected effluent deficits and/or excess can be dealt with either by peak demand shaving resulting from either adopting deficit irrigation in the wintertime, improving on- farm water management practices or enhance planned reductions in cultivated areas. In the summer time, excess effluent can support farm activities of increasing fodder production or providing an optimal leaching fraction to control the build up of salt levels in the root zone of crops.

### 1.3.4.6 Quality Criteria

According to the water quality of effluent and the Jordanian Standard JS 893 of 1995 (see summary in Table 1.3.3-1), wastewater is considered for the use in restricted irrigation only with potential impacts based on the following water quality criteria particularly.

The standard pays special attention to the agricultural irrigation:

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

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

Regarding the cropping pattern the policy calls for selecting the crops that match the existing water quality and those that are tolerant to salinity. Table 1.3.4-1 shows the important water quality parameters and their potential effect on irrigated agriculture either directly or indirectly.

**Table 1.3.4-1 Water Quality Parameters and Their Potential Effect on Irrigated Agriculture**

| Potential Impact on Irrigated Agriculture | Water Quality Parameter(s) |
|---|---|
| Salinity Hazard (Yield Potential) | $EC_w$ |
| Crop Toxicity (visual crop injury) | Boron (B), Chloride (Cl), Sodium (Na) |
| Accumulation of Trace Elements | All Heavy Metals and Trace Elements |
| Water Infiltration Problem | $EC_w$, SAR |
| Crop Nutrient Requirement | N and P |
| Clogging of Drip Emitters | Suspended Solids, N, P (algae), pH, $HCO_3$ |
| Public Health, Consumer Confidence | Total fecal coliforms, Nematodes |

#### (1) Electrical Conductivity of Irrigation Water ( ECw)

Electrical conductivity is a measure of salt accumulation in the irrigation water, which is enhanced – however to a minor extend - in the effluent due to evaporation in the treatment plant, if this is a wastewater stabilization pond system. Different crops respond differently to various levels of salinity in irrigation water. They are classified as very tolerant, tolerant, sensitive and very sensitive to the presence of salts in irrigation water. Salinity hazard is reflected in this case in loss of yields at percentages of 10, 25, and 50 % beyond which agricultural production is fruitless. Crops like fodders, barley and date palms are recommended because of their high adaptability to grow in saline cultures. Although sugar beet and cotton have distinguished ability to grow under such conditions, industrial requirements are unavailable presently to support this activity. Leaching fractions of 15 – 25 % with proper drainage of agricultural lands are normally enough to maintain a favorable salt balance within the root zone of crops securing adequate crop yields.

**(2) Toxicity**

Crop toxicity occurs due to the presence of higher concentrations of certain elements above those permissible limits, which might result in visual injury such as leaf injury, and ultimate loss of crop. Boron (B), Chloride (Cl) and Sodium (Na) are the main elements causing this injury. Whereas, trace elements and heavy metals accumulation in the plant tissues is both injurious to plants, animals and human life. Sources of contaminants must be avoided to reduce any unforeseen risks hazards and unfavorable consequences.

However, there are almost no significant sources of pollution in the existing collection networks others than domestic wastewater, such as industries and, therefore, this risk of pollution of toxic or other harmful constituents is not of importance. According to information got from the personnel responsible for wastewater collection and treatment, in most of the towns having a sewerage system and a treatment plant no important water polluting industries are connected to the sewerage system.

**(3) Infiltration**

The presence of high levels of sodium in the soil media and at the same time low levels of calcium and magnesium results in deflocculating of soil particles. This phenomena leads to a lowering in the velocity of flow of water through the porous media and unavailability of adequate water supplies essential for plant growth. Soil amendments could prove beneficial to counter balance the adverse effects of lowered infiltration rates due to high sodium adsorption ratios.

**(4) Nitrogen and Phosphorous**

Although these two elements are considered as two major nutrient elements essential for both plant leaves and fruits development, they may still be considered a menace causing clogging of drip emitters if added to irrigation water. Algae formation is enhanced in this case and together with suspended solids formation may result in a serious situation leading to lower irrigation water distribution efficiency and eventually lower crop yields. The crop nutrient requirement must be observed sharply in order to avoid any excessive vegetative growth or the waste in fertilizer application.

**(5) Total Fecal Coliforms and Nematodes**

Fecal coliforms and nematodes eggs are two major causes of diseases and distress to the human health that should be avoided through following protective and curative measures and observing JS893 of 1995. Infested agricultural crops are a source of diseases and suffering for the consumer. This will soon lead to lower confidence limits and eventually a total loss of foreign markets. Farmer incomes will therefore be influenced adversely, which is closely related with the general welfare of the national economy. Therefore, fecal coliforms and nematodes must be removed from the treated wastewater if it will be reused for irrugation.

## 1.4 Demographic Development, Projection of Sewage Flow and Pollution Load (Ma'an)

### 1.4.1 Demographic Development (Ma'an)

Ma'an has a relatively low population density. The phosphate mining activity in the surroundings and the importance of the city as the transportation center are factors that indicate continued rapid growth. The new Al Hussein Bin Talal University to be constructed will certainly have an additional impact on the growth of Ma'an.

A Jordan Phosphate Mines Company Employees Housing Project was under implementation in 2001. Construction will be completed in April 2002. In a first stage about 100 houses are provided for some 600 employees of the company, which has its mines in the surrounding of Ma'an. A second stage is foreseen in the next five to ten years.

**Table 1.4.1-1 Population Projection According to Various Sources**

| | Unit | 1994 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 |
|---|---|---|---|---|---|---|---|---|
| **DAR 1999** | | | | | | | | |
| Annual growth | % | | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 |
| Population | C | 22,989 | 27,933 | 32,857 | 38,648 | 45,460 | 53,472 | 62,897 |
| **Scenario 1 (MOWI/WB)** | | | | | | | | |
| Annual growth | % | | 3.6 | 3.2 | 3.1 | 2.9 | 2.7 | 2.5 |
| Population | C | 22,989 | 28,407 | 33,269 | 38,755 | 44,710 | 51,081 | 57,793 |
| **Scenario 3 (DOS)** | | | | | | | | |
| Annual growth | % | | 3.4 | 2.5 | 2.5 | 2.3 | 2.0 | 2.0 |
| Population | C | 22,989 | 28,096 | 31,819 | 36,000 | 40,335 | 44,533 | 49,168 |
| **JICA 2001** | | | | | | | | |
| Annual growth | % | | 3.3 | 2.9 | 2.8 | 2.6 | 2.4 | 2.2 |
| Additional housing areas 1) | | | 600 | 600 | | | | |
| Population | C | 22,989 | 27,933 | 32,918 | 38,480 | 43,750 | 49,258 | 54,920 |

1) New Housing Areas (Stage 1 and 2) of Jordan Phosphate Mining Company

Table 1.4.1-1 presents rates assumed by various sources including the values assumed by DAR in 1999 and of Scenarios 1 and 3 taken into account in the Master Plan Study of 2001 for the total Jordan. Constant growth rates of 3.3 % per year assumed by DAR for Ma'an in 1999 will be certainly too high. The growth rates adopted in this Pre-Feasibility Study (JICA 2001) are 0.3 % lower than the rates estimated by MOWI/WB for the entire Jordan. These lower rates may be justified by the fact that the growth rates of the Capital Amman are higher in comparison to other regions of Jordan because there is still an ongoing migration from these other regions of Jordan to Amman.

### 1.4.2 Development of Wastewater Flow and Pollution Load (Ma'an)

Based on the assumptions presented in section 1.3.2 the total wastewater flow and load was calculated up to the year 2025. Results are summarized in Table 1.4.2-1. Annual wastewater production will increase from about 0.68 in 2000 to more than 1.8 MCM in the year 2025, i.e. an increase by a factor of 2.6. However, it has to be mentioned that these quantities depend strongly on the development of fresh water resources, because an increasing specific water consumption was taken into account assuming that the presently suppressed water demand will not exist in future.

Pollutional load will increase in the same period by a factor of 2.5 or from 1.26 to 3.21 t $BOD_5$/d. This load may be considered as independent on the water consumption development.

Considering a water loss of about 22 % within the Ma'an Wastewater Treatment Plant the effluent will rise from about 0.53 MCM after the completion of the plant to some 1.4 MCM in 2025.

**Table 1.4.2-1 Projection of Wastewater Flows and Pollutional Load**

| | Unit | 1994 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 |
|---|---|---|---|---|---|---|---|---|
| **Population** | c | 22,989 | 27,933 | 32,918 | 38,480 | 43,750 | 49,258 | 54,920 |
| Connected (sewerage) | c | 16,092 | 20,950 | 27,980 | 32,708 | 39,375 | 44,332 | 49,428 |
| Not connected (sewerage) | c | 6,897 | 6,983 | 4,938 | 5,772 | 4,375 | 4,926 | 5,492 |
| **Water demand (without phys.losses)** | | | | | | | | |
| Domestic/tourist/commercial | m³/d | 2,299 | 2,933 | 3,539 | 4,233 | 4,922 | 5,665 | 6,453 |
| | m³/d | | | | | | | |
| Total | m³/d | 2,299 | 2,933 | 3,539 | 4,233 | 4,922 | 5,665 | 6,453 |
| **Wastewater production** | | | | | | | | |
| Domestic/tourist/commercial | m³/d | 1,368 | 1,870 | 2,557 | 3,058 | 3,765 | 4,333 | 4,937 |
| | m³/d | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | m³/d | 1,368 | 1,870 | 2,557 | 3,058 | 3,765 | 4,333 | 4,937 |
| | m³/month | 41,035 | 56,094 | 76,700 | 91,747 | 112,956 | 130,004 | 148,098 |
| | MCM | 0.50 | 0.68 | 0.93 | 1.12 | 1.37 | 1.58 | 1.80 |
| **Pollutional load** | | | | | | | | |
| Poll. load (dom.demand) | $kgBOD_5/d$ | 966 | 1,257 | 1,763 | 2,126 | 2,559 | 2,882 | 3,213 |
| Poll. load (industries) | $kgBOD_5/d$ | | | | | | | |
| Total load | $kgBOD_5/d$ | 966 | 1,257 | 1,763 | 2,126 | 2,559 | 2,882 | 3,213 |
| Concentration | $mgBOD_5/l$ | 706 | 672 | 689 | 695 | 680 | 665 | 651 |
| **Reuse of wastewater** | | | | | | | | |
| Inflow treatment plant | MCM | 0.499 | 0.682 | 0.933 | 1.116 | 1.374 | 1.582 | 1.802 |
| Losses in treatment plant | % | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| | MCM | 0.110 | 0.150 | 0.205 | 0.246 | 0.302 | 0.348 | 0.396 |
| Effluent of treatment plant | MCM | 0.389 | 0.532 | 0.728 | 0.871 | 1.072 | 1.234 | 1.405 |

Table 1.4.2-2 summarizes the basic parameters for the dimensioning of the treatment plant for the target year 2015 for extension of the existing treatment plant in Ma'an.

**Table 1.4.2-2 Basic Parameters for Sewerage and Treatment Plant Extension (year 2015)**

| Component | | Unit | Quantity |
|---|---|---|---|
| Discharge (average daily) | Q | $m^3/d$ | 3,770 |
| (max. hourly) | $Q_{max}$ | l/s | 88 |
| $BOD_5$-load | $C_a$ | kg/d | 2,560 |
| Total population | c | c | 43,800 |
| Connection rate | | % | 90 |
| Total connected population | c | C | 39,400 |

## 1.5 Preliminary Design of Facilities of Sewerage and Treatment System (Ma'an)

### 1.5.1 Sewerage System (Ma'an)

In this Pre-Feasibility Study required sewerage extension is not identified by a hydraulic network analysis. In addition, it is even not required, because the preliminary design serves for rough cost estimation. Therefore, we have chosen an approach to identify needs of network extension without specifying, where in detail these new networks will be allocated.

Supposed increase of connection rate from 75 to 90 % in 2015 requires an extension of existing sewerage system and an increase of the house connections. It is estimated that in 2005 some 7,000 inhabitants more will be sewered (compare Table 1.4-2). Taking into account a specific length per connected inhabitant of 2 m in the areas to be newly sewered a total additional length of about 14 km may be expected. It can be assumed that all new sewers are of minimum diameter DN 200 because they will particularly sewer outskirts, where required hydraulic capacity is by far covered by the minimum diameter.

Applying the same method in total some 18,500 more inhabitants (in comparison to the year 2000) will be connected until 2015. This will lead to a required additional sewer length of 37 km between 2000 and 2015.

### 1.5.2 Treatment Facilities (Ma'an)

#### 1.5.2.1 Pre-selection of Treatment Process

**(1) General Selection Criteria**

In general, the sequence for alternative solution evaluation consists of:

- a selection of the criteria to be considered in evaluating alternatives,
- weighting of criteria,
- rating of alternatives,

- presentation of results of screening to produce recommended alternatives or to evaluate advantages and disadvantages of one or the other alternative.

This procedure is applied for comparison of alternative treatment processes as presented in the following sections 1.5.2.1.3

There are many factors that should be considered in the development of a suitable feasibility study for wastewater collection, treatment and disposal/reuse of effluent. Possible criteria and considerations include:

**Appropriateness of Technology**

- Experience with the process and comparable size facilities
- Reliability of the process to meet required standards
- Efficiency of proposed solution with regard to desired result
- Flexibility of the process to suit changing conditions, both of influent quality and quantity and effluent requirements
- Stability of proposed solution
- Simplicity of construction/operation of proposed solution
- Dependence on external input (electric power, imported equipment, etc.)
- Degree of operating/maintenance staff's knowledge/experience required
- Sustainability of proposed solution
- Availability of land area

**Economic aspects**

- Construction costs
- Operation and Maintenance (O&M) costs
- Requirement of consumables (chemicals, electric power, etc.)

**Environmental aspects**

- Positive/negative environmental impacts (emissions, visible nuisance, noise etc.)
- Environmental soundness, both short-term, during construction and long-term or permanent
- Risk for water resources contamination

**Disposal aspects**

- Treated effluent disposal/reuse (reuse maximization)
- Sludge disposal/reuse (reuse maximization)
- Water losses due to evaporation
- Potential of effluent reuse (availability of agricultural land, industrial reusers)

**(2) Description of Alternatives**

The existing wastewater treatment in Ma'an is based on wastewater stabilization. However, a change of the treatment process could be envisaged in the frame of the proposed capacity extension measures. Therefore, an adequate process is selected applying screening of alternative treatment technologies common in Jordan. In particular, the following processes are studied for possible application in Ma'an.

***Alternative A: Wastewater Stabilization Ponds***
Treatment by stabilization pond system consists of anaerobic, facultative and maturation ponds used in series. Anaerobic ponds have a depth of 3 to 5 m and pre-treat the sewage of high organic load and, therefore, the surface of the subsequent ponds may be reduced. Facultative ponds are 1.2 - 2 m deep. Maturation ponds are quite shallow (1 – 1.2 m) and function in an aerobic milieu. These ponds serve to reduce in particular the bacteria and to improve the microbiological quality of the sewage (tertiary treatment). The detention time in all the ponds is in average 20 days. Treatment efficiency of stabilization ponds, if properly operated, is high and would allow effluent reuse for agricultural irrigation.

***Alternative B: Extended Aeration***
Extended aeration process consists of mechanical aeration and intensive recycling of activated sludge. The bacteria float in the sewage in form of flocs. Sewage is aerated e.g. in a continuous (looped) channel in form of a carousel, which creates a recirculation flow of sewage. Cylindrical steel brushes with a horizontal axis provoke a flow velocity of 0.3 – 0.4 m/s in the channel and a good aeration at the same time. The process requires only one (secondary) clarifier downstream of the aeration tank. The eliminated sludge has to be recycled by 95 % to the aeration tank. This results in detention times of the sewage of 1 to 3 days and of the sludge of 20 to 30 days. The highly mineralized sludge has to be dried in a drying bed. The clarifier tank is constructed in reinforced concrete and it is equipped by automatic sludge scrappers at the bottom.

***Alternative C: Activated Sludge Treatment***
The process consists of an artificial intensification of the phenomenon of natural self-purification by microorganisms (mechanical aeration and recycling of activated sludge). The bacteria float in the sewage in form of flocs. The detention time of the sewage in the activated sludge tank is 4 to 8 h and the one of sludge 5 to 10 h. An activated sludge tank and a secondary clarifier follow a primary clarifier. The sludge has to be dried and stabilized in a drying bed (or better in an aerobic or anaerobic digester). The clarifier tanks are constructed in reinforced concrete and they are equipped by automatic sludge scrappers at the bottom.

***Alternative D: Trickling Filters***
The process consists of an artificial intensification of the phenomenon of natural self-purification by microorganisms. The sewage flows over fixed bed (e.g. stones). Biological slimes form on the fixed bed, which assimilate and oxidize organic substances in the wastewater. By the creation of optimum conditions for the microorganisms, the number of microorganisms is increased significantly in comparison to natural conditions. This leads to an intensified decomposition of organic matter. The trickling filter and a secondary clarifier follow a primary clarifier. The sludge has to be dried and stabilized in a drying bed (or better in an aerobic or anaerobic digester). The clarifier tanks are constructed in reinforced concrete and they are equipped by automatic sludge scrappers at the bottom.

**Alternative Sites of Treatment Plant**
Existing Ma'an Wastewater Treatment Plant is located 3 km east of the city at the road to Saudi Arabia (see Figure 1.2-1). The location is more than 1,000 m distant to the next

closed settlement. Therefore, no odor disturbances by the treatment plant with regard to built-up areas are reported nor expected in future. In close vicinity to the plant land is presently used for agricultural purposes. This allows an ease reuse of treated effluent for agricultural irrigation. There are many reasons and advantages, why the existing plant's site should be kept for future extension. The most important ones are as follows:

- A minimum distance between the plant's site and existing built-up areas of Ma'an is more than 500 m to be respected generally to exclude any nuisance by odor emissions.
- Any shifting of the plant would lead to additional cost of investment and operation.
- Land for extension of the treatment plant is already in possession of WAJ.
- Potential reuse areas are in direct vicinity of the plant and will not require excessive cost for additional transfer of treated effluent.

With respect to these reasons a new location of the treatment plant is not advisable and an alternative site was not taken into account.

**(3) Evaluation of Alternatives and Final Selection of Proposed Treatment Process**

The following evaluation of alternatives for the treatment process for the future extended treatment plant of Ma'an is based on experiences gained in similar plants in other countries in general and of Jordanian Plants in particular. Generally, evaluation of applied criteria and their ranking is done by a comparison of impacts in relation to the studied alternatives.

Capital cost aspects are evaluated by preliminary investment cost estimation on the basis of cost curves established on the basis of prices of recently constructed plants and/or offers. Connected population and population equivalents are considered as about 39,000 for the year 2015:

| | Wastewater stabilization ponds system | Extended aeration system | Activated sludge system | Trickling filters system |
|---|---|---|---|---|
| Costs in mill. JD | 2.19 [1)]<br>1.06 [2)] | 3.75 | 2.62 | 3.35 |

1) New construction for about 39,000 population equivalents
2) Extension of existing plant only (18,000 additional population equivalents)

Costs for operation and maintenance are based on actual costs as found for existing plants in Jordan for the years 1999 and 2000:

| | Wastewater stabilization ponds system | Extended aeration system | Activated sludge system | Trickling filters system |
|---|---|---|---|---|
| Costs in JD/m³ | 0.07 | 0.17 | 0.15 | 0.18 |

Applied criteria are presented in Table 1.5.2-1. Due to the fact that some criteria are more and others less important a weighting factor was introduced. The sum of the weighting factors is for the three groups of aspects in the same range i.e. 7. Three ranks were considered for evaluation:

- Relative negative impact: rank 0
- Medium impact: rank 1
- Relative positive impact: rank 2

Applying this procedure Alternative A shows obvious advantages compared with the other Alternatives: As determined in Table 1.5.2-1 Alternative A is ranked with 46 points before Alternative C with 33 points only.

Taking into account the result of the evaluation of alternative treatment processes we selected the wastewater stabilization pond system as optimum solution for wastewater treatment in Ma'an.

**Table 1.5.2-1 Evaluation of Alternative Treatment Processes**

| | **Criteria** | | Alternative A | | Alternative B | | Alternative C | | Alternative D | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | WW.Stab.Ponds | | Extend.Aeration | | Activated Sludge | | Trickling Filters | |
| | | Weighting factor | Rank | Final Rank | Rank | Final Rank | Rank | Final Rank | Rank | Final Rank |
| **1.** | **Assessment of applied treatment process** | | | | | | | | | |
| **1.1** | Ability of the technology to meet requir.standard | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| **1.2** | Risks for failures due to miss-operation | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| **1.3** | Process stability (choc loads, power cuts, etc.) | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| **1.4** | Dependence on qualified staff | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| **1.5** | Dependence on imported equipment | 2 | 2 | 4 | 1 | 2 | 1 | 2 | 1 | 2 |
| **1.6** | Land requirement | 1 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 |
| | Subtotal 1 | 7 | | 12 | | 8 | | 8 | | 8 |
| **2.** | **Economic aspects** | | | | | | | | | |
| **2.1** | Construction costs | 3 | 2 | 6 | 0 | 0 | 1 | 3 | 0 | 0 |
| **2.2** | Operation and maintenance costs | 3 | 2 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2.3** | Requirements of consumables | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Subtotal 2 | 7 | | 14 | | 1 | | 4 | | 1 |
| **3.** | **Environmental impacts** | | | | | | | | | |
| **3.1** | Odour emissions | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| **3.2** | Adaptability of the plant in the landscape | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 0 |
| **3.3** | Noise emissions | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 0 |
| **3.4** | Development of insects | 1 | 0 | 0 | 2 | 2 | 2 | 2 | 1 | 1 |
| **3.5** | Risk for pollution of water resources | 3 | 2 | 6 | 2 | 6 | 2 | 6 | 2 | 6 |
| | Subtotal 3 | 7 | | 10 | | 11 | | 11 | | 8 |
| **4.** | **Reuse potential of effluent** | | | | | | | | | |
| **4.1** | Water losses within the plant | 2 | 0 | 0 | 2 | 4 | 2 | 4 | 2 | 4 |
| **4.2** | Bacteriological quality of effluent | 2 | 2 | 4 | 1 | 2 | 1 | 2 | 1 | 2 |
| **4.3** | Available agricultural area for effluent reuse | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **4.4** | Storage capability of plant | 2 | 2 | 4 | 1 | 2 | 1 | 2 | 1 | 2 |
| | Subtotal 4 | 7 | | 10 | | 10 | | 10 | | 10 |
| | Total | | | 46 | | 30 | | 33 | | 27 |

### 1.5.2.2 Preliminary Design of Treatment Facilities

Function and basic design parameters of proposed treatment facilities are described in section 1.3.3.2. Annex 1.5.2.2 contains details of the dimensioning of the treatment units. In the following paragraphs the required dimension of the units are summarized.

**(1) Screens**
The dimension of each screening facilities will be the following:

| | Unit | 2015 [1)] | Existing (2000) |
|---|---|---|---|
| Number of screening channels | - | 1 | 1 |
| Total required width | m | 0.5 | 0.3 |

1) Including existing units

**(2) Anaerobic Ponds**
The dimension of each basin will be the following:

| | Unit | 2015 [1)] | Existing (2000) |
|---|---|---|---|
| Number of basins | - | 4 | 2 |
| Total surface | ha | 0.690 | 0.320 |
| Depth | m | 3.5 | 5.0 |
| Total volume | $m^3$ | 24,000 | 24,000 [2)] |

1) Including existing units 2) Depth of the existing basins may be reduced

**(3) Facultative Ponds**
Taking into account the above mentioned parameters and conditions the dimension of each basin will be the following:

| | Unit | 2015 [1)] | Existing (2000) |
|---|---|---|---|
| Number of basins | - | 7 | 3 |
| Total surface | ha | 7.787 | 1.740 |
| Depth | m | 1.2 | 2.5 |
| Total volume | $m^3$ | 93,450 | 43,500 |

1) Including existing units

**(4) Maturation Ponds**
Results of dimensioning can be summarized follows:

| | Unit | 2015 [1)] | Existing (2000) |
|---|---|---|---|
| Number of basins | | | |
| in series | - | 3 | 1 |
| in parallel | - | 1 | 1 |
| Total surface | ha | 1.483 | 0.750 |
| Depth | m | 1.25 | 1,25 |
| Total volume | $m^3$ | 18,500 | 9,400 |

1) Including existing units

Space next to the existing anaerobic ponds is sufficient to place (north of existing anaerobic ponds) additional two ponds for the extension. Additional facultative ponds are foreseen on the free space proposed for extension already in initial implementation phase in 1989 (east of the existing ones). Proposed additional maturation ponds will be placed northeastern part of the treatment plants area.

WAJ possesses enough land for the planned treatment plant extension. It not only owns the land actually surrounded by the fence, but also considerable area outside of it.

Figure 1.5.2-1 shows the planned arrangement of existing and proposed treatment facilities for Ma'an. The headworks will remain on the same place.

Agricultural land for irrigation is east and north of the treatment plant.

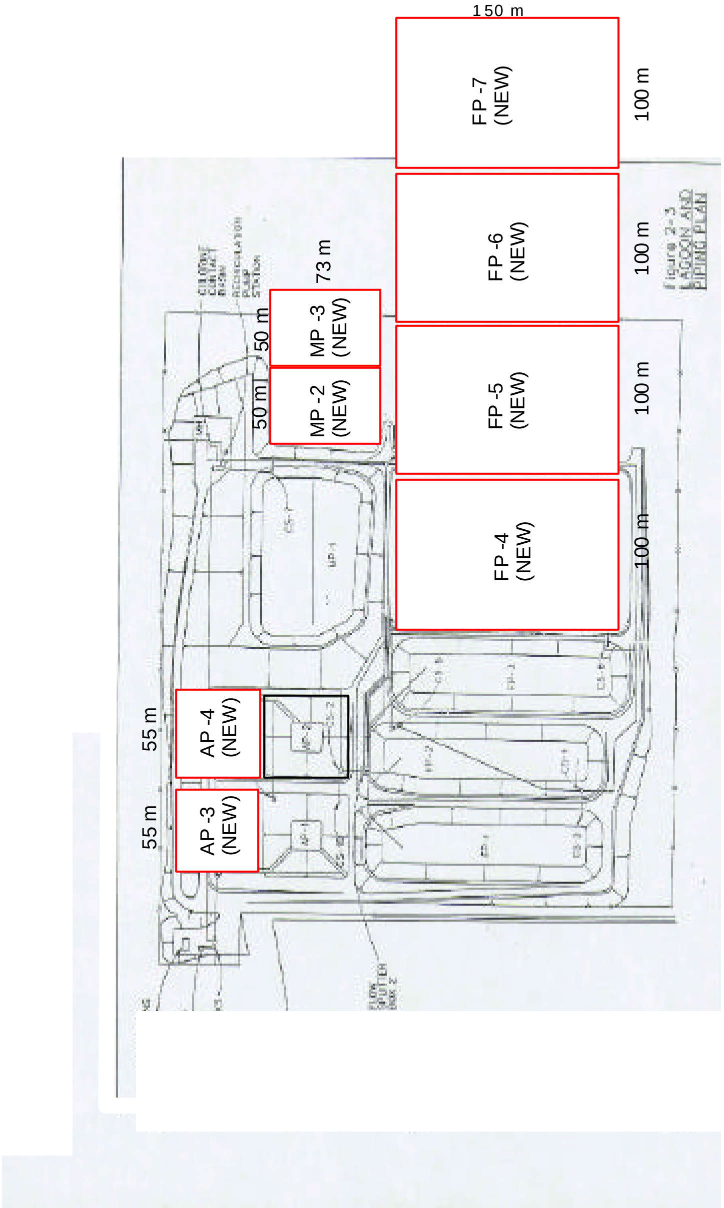



**Figure 1.5.2-1 Plan of Treatment Plant's Extension**

1.5.2.3 Effluent Disposal (Ma'an)

Discussions with farmers owning land downstream of the treatment plant have revealed that there is a great interest to reuse the treated effluent. It was mentioned that some 15 farmers could form an association with the objective to operate commonly the distribution system of irrigation water. Up to now some of these farmers have operated own groundwater wells for agricultural irrigation. However, the yield of these wells reduced considerably during the last years.

Proposed reuse facilities for Ma'an are presented in section 1.7.

## 1.6 Operation and maintenance procedures

### 1.6.1 Wastewater Stabilization ponds

The following summary on operation and maintenance procedures are based on the recommendations as given in the "WHO Technical Report on Wastewater Stabilization Ponds" of 1987.

#### 1.6.1.1 Operation and Maintenance of Anaerobic Ponds

The indicators of proper functioning of an anaerobic stabilization pond are: No plants or weeds on the inner (wet) slope (grass and weeds must be cut periodically in order to control insect breeding).

The surface is partly or completely covered be a scum layer which contains oils, greases and various floating matter: This floating scum layer helps to maintain anaerobic conditions in the pond, isolates the contents of the pond from atmospheric oxygen, insulates the wastewater against heat loss and hinders the liberation of offensive odors.

The operator must check every day to see that there is:

- no seepage through the embankments;
- no clogging of the inlet pipe, especially if it is submerged;
- no floating scum being carried over to the secondary facultative pond;
- uniform flow distribution, where two or more inlets exist. With time, the operator will learn to recognize flow uniformity by sight.

If there is an interest in knowing the sludge layer thickness in an anaerobic pond, determinations should be carried out periodically at several points across the bottom of the pond. Several simple devices allow this measurement to be accomplished easily.

#### 1.6.1.2 Operation and Maintenance of Facultative and Maturation Ponds

The visual signs of proper functioning of facultative and maturation ponds are:

- An intensely green-colored effluent (paler in case of maturation pond effluents), practically devoid of settlable suspended solids. If the effluent has a very light and somewhat transparent green color, or even a yellowish color, this indicates that predators are present and that some forms of zooplankton are feeding on the algae;

- Absence of weeds and water-plants inside the pond. Waterweeds foster insect breeding. If there is a protective grass strip on the inside slope of the pond embankment, it must be kept at least 10 cm above the highest water level. Seeding must be limited to the area above this bald protection ribbon;

- Absence of bluish-green colored appearance. A bluish-green appearance indicates an objectionable bloom of blue-green algae (Cyanophyceae). Such an outbreak has a detrimental effect on sunlight penetration, this reducing the oxygen concentration in the pond;

- With some warm wastewaters, the precipitation of magnesium hydroxide and calcium phosphate may occur as a consequence of an increase in the pH-value in a facultative pond. This reaction is called self-flocculation and causes the pond to display a milky-green appearance. It may result in pond failure.

#### 1.6.1.3 Desludging of Ponds

Sludge is produced in the anaerobic and facultative ponds accumulating at the bottom of the ponds. The sludge has to be removed from time to time and transported to drying beds for further treatment.

The specific annual production of sludge is assumed to 0.040 $m^3$/c/a. Generally, every anaerobic pond is emptied once in five year, while every facultative ponds is emptied once in ten years depending on the real sludge production.

Generally, there are 2 methods for desludging the ponds:

- desludging after emptying the pond of water (by-passing the pond, homogenization of the sludge and pumping of sludge)

- desludging by submersible pumps without emptying the pond of water (suction of sludge from a pontoon, displacement of the pontoon by cables connected to the dikes of the ponds)

It is recommended to apply desludging by bypassing the pond, which is the simpler method with respect to the fact that there are several ponds in parallel, where the supplementary flow can be discharged easily.

### 1.6.2 Reuse of Treated Effluent

Operation and maintenance procedures of effluent reuse facilities include the day-to-day practices required for the sustainable efforts in managing and operating the irrigation and drainage reuse areas infrastructure.

#### 1.6.2.1 Overall Supervision and Management

To maintain the project site, adequate incentives for concerned staff must prevail to meet the considerable challenges within the water reuse system. The managerial organizational structure must provide for mutual cooperation between WAJ and the ultimate wastewater users. This is essential for the well being of the project within the objective settings of its operation and maintenance procedures.

Proper effective planning methods must be adopted for work and for securing adequate supplies of equipment and materials. This involves data collection, processing and analysis leading to infrastructure monitoring and evaluation. The aim is, therefore, to develop procedures and methods to improve the general picture of operation and maintenance in the project and its systems technical performance.

Supervision, training, budget allocation and effective operating rules are key elements in the successful operation of irrigation projects. A comprehensive operation and maintenance guide giving all important details for individual infrastructure components, must be provided.

Human resources development must be given a high priority in developing required profile for appropriate staffing. Every effort should be made to recruit qualified professionals and skilled labor to meet current and future challenges. This also involves incentives, adequate working conditions and good training skills necessary to safeguard satisfactory maintenance for the wastewater reuse schemes.

#### 1.6.2.2 Operation of the Head Works

In an effort to ensure satisfactory day-to-day operation and long term sustainable performance and secure record keeping and future analysis, the following points must be observed.

Regular attendance and inspection of the head works installations (e.g. diversion chamber, weirs, pump station, if any, at the treatment plant area) to maintain adequate greasing of movable parts. Periodic assessment of proper hydraulic functioning and the structural conditions of the head works complexes must be undertaken. Water levels at the measurement weirs and storage reservoirs must be continuously observed.

Records of effluent discharge to the reuse areas must be kept for future references to provide periodic quantitative analysis as the basis for rational decision making to sustain optimal systems performance and provide an opportunity to plan improvements and safe guard future benefits.

#### 1.6.2.3 Operation of the Pump Stations

It is a matter of fact that the ageing of pumps and associated equipment, which is of prime consideration in this context, can be reduced by a proper staff training on day-to-day operating rules and on recognizing deteriorating performance.

Power supply facilities are checked continuously to secure adequate supply of effluent to the reuse areas.

Predetermined performance targets, either through a contractor or WAJ staff, must ensure that pump stoppages must be less than 24-hrs per month except for general stoppages or emergency. The station manager must keep a record of the status of the main system components, ancillary fittings and defects. Pressure and flow meter readings must be reviewed to check for incipient problems, and records of which must be analyzed monthly.

An annual report should include technical performance, data analysis and a comparison of actual status to anticipated targets. Also to be considered are the main activities undertaken and costs incurred, identifying main operation and maintenance expenses expected within the planning horizon.

#### 1.6.2.4 Operation of the Transmission Pipes and Distribution Network

Operation and maintenance of the transmission pipes and irrigation distribution system is aimed mainly at day-to-day operation of valves in order to secure proper amounts of effluent to meet the concerned development areas irrigation water demands. It is also important to ensure proper pipeline management to secure proper operating conditions and meet any occasional emergency within the current operational practices.

Water Users Associations could prove benefice in managing the allocation and distribution of irrigation water among the various users. Whenever feasible, the construction of storage reservoirs at elevations higher than the reuse areas will allow gravity flow and, therefore, save the farmers the extra burden of pumping to their farms.

In order to prohibit the possibility of a major future extensive rehabilitation of the pipeline transmission network, a general management operating scheme must be envisaged. This schemes calls for regular observations, testing and inspections as well as periodic flushing, hydro-mechanical removal of silt and timely repairs and replacement of expired equipment. Data record keeping proves beneficial in infrastructure performance management planning and in preparing budgets within the pre-specified planning horizon.

Preventative maintenance schemes should prove effective in minimizing corrective maintenance, less damage leads to lower cost incurred, preplanning and securing materials in advance make the difference, especially in the presence of skilled labor.

An annual report should include summary of conditions, data observations and trend analyses to realize a short-term strategy and check the validity of longer term strategies.

## 1.7 Reuse of Effluent in Ma'an

### 1.7.1 Existing System of Wastewater Collection, Treatment and Disposal (Ma'an)

The existing system of wastewater collection, treatment and disposal is described in section 1.2.

### 1.7.2 Wastewater Quantity and Quality (Ma'an)

Development (since 1990) of wastewater quantities (influent to the treatment plant) as well as $BOD_5$-concentration (influent and effluent) is presented in section 1.2.2.1.

Assumed future demographic development, wastewater flow and pollution load for Ma'an is presented in section 1.4.2.