Concept Paper for Jordan Water Policy Implementation Program

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CONCEPT PAPER FOR JORDAN WATER POLICY IMPLEMENTATION PROGRAM

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Executive Summary

Introduction

Jordan is one of the most water scarce countries in the world. Until recently it was able to meet the demands for freshwater by developing renewable supplies and mining groundwater. However, as the country faces rapidly increasing costs of supply expansion, it is becoming harder to manage the imbalance between the limited renewable supply and the increasing demand for freshwater. The current gap is being met by ad hoc measures that threaten the sustainability of water resources.

Projections of future freshwater needs suggest that unless policy actions are taken soon, the socio-economic costs of ad hoc management of supply/demand imbalances will only increase. The Government of Jordan (GOJ) recognizes this and has taken an impressive number of steps toward rationalizing water policies. The financial and operational problems of the autonomous operating authorities (the Water Authority of Jordan—WAJ and the Jordan Valley Authority—JVA) in the Ministry of Water and Irrigation (MWI) are being addressed by redefining their roles, increasing cost recovery, and exploring the possibilities of privatizing some services. The government is working on a new, digital, water master plan. It is developing an integrated institutional approach for identifying problems in the water sector, evaluating options for solving them, and linking both to the government's water sector investment program. It has also adopted a new overall water strategy, and has approved new policy statements in four water sub-sectors—utilities, irrigated agriculture, wastewater, and groundwater management. Taken together, those five documents reflect the government's commitment to implementation of policies that:

- Maximize the socio-economic returns to water;
- Sustain irrigated agriculture in the Jordan Valley;
- Manage wastewater so that it can be available for "unrestricted" use in irrigated agriculture;[1]
- Protect the quality of groundwater; and
- Limit abstraction of groundwater to sustainable yield.

Both the GOJ and USAID are keenly aware that it will take time to develop the capacity to design and implement specific policy interventions to achieve these objectives. Because of this, both have agreed to support an initial water policy program that moves water use practices in the desired directions.

USAID asked an EPIQ Water Policy Team (WPT) to work with the GOJ and USAID to identify the critical elements of a water policy program. Because there is no better way to

[1] It is important to recognize that there are several different definitions of the term "unrestricted" use in irrigated agriculture. Before wastewater can be managed to achieve this goal, a clear definition will have to be agreed upon.

learn how to implement a water policy program than by implementing it in a particular place, the WPT recommends choosing an initial site for implementation and then expanding to other sites. A water basin approach to policy implementation is recommended because basins are logical water management units within which policy interventions designed to affect performance in one part of the basin impact on others as well. The WPT recommends focusing on the Amman-Zarqa Water Basin (AZB) because of its size, population, and the large consumption of water within it; and, because the implementation of a water policy program within the AZB requires attention to two major problems that also affect other basins: 1) over abstraction of groundwater; and 2) the need to increase reliance on treated wastewater for irrigated agriculture in the Jordan Valley.

In short, initial focus on the AZB promises early and significant results, and it provides an opportunity to learn how to deal comprehensively with water and wastewater management problems on a larger (ultimately nationwide) scale.

Implementing a Water Policy Reform Program

Organizing for Implementation of a Water Policy Reform Program for the AZB

Experience elsewhere in the world suggests that successful implementation of new policies requires a strategic approach and close cooperation between policy analysts/planners and implementers. Since the policy implementation process is a circular one that moves from monitoring to analyzing/predicting the consequences of actions, to modifying policy responses, and back to monitoring, this cooperation must be close at all stages of the policy process policy design, policy implementation and evaluation of policy intervention outcomes. Beyond this, planners and policy analysts must have the capability to monitor and verify the consequences of policy actions and implementers must have the capability and flexibility to implement policy changes. Because collaboration is critical to the success of implementation, the WPT recommends the formation of a senior level joint MWI, JVA, and WAJ Water Policy Implementation Team (WPIT). This team should be responsible for oversight of all policy implementation activities and all policy support activities of the water policy program in the AZB and in other basins.

Policy Implementation Activities

The WPT has identified two specific policy interventions and three policy support activities for this water policy program for the AZB. The two policy interventions for the AZB are to:

Design and implement a water allocation program for upland agriculture in the AZB; and

Design and implement a wastewater reuse plan for the AZB and north Jordan Valley.

Design and implement a water allocation program for upland agriculture in the AZB

Moving toward a more sustainable water use trajectory in the AZB requires reducing the use of groundwater for irrigated agriculture in the uplands. It is widely recognized that this is politically difficult to do. The purposes of the water allocation policy intervention are to explore a range of options for reducing groundwater use in irrigated uplands agriculture, to test those that are most promising, and to develop a verification plan for assessing the impact of interventions on groundwater use in uplands agriculture.

Specific activities of this water allocation program include:

- Carrying out a rapid socio-economic appraisal by wellhead of groundwater use in irrigated uplands agriculture.
- Estimating the potential for reduction in groundwater depletion associated with upland agriculture.
- Developing and testing alternative incentive structures to encourage upland farmers to economize the use of groundwater.
- Developing an irrigation information service that would focus on on-farm water use efficiency programs that result in real water savings and help farmers to adjust to lower water abstractions from wells.
- Installing functioning water meters on all wells.
- Developing a verification plan that makes it possible to track the impact of policy interventions on groundwater use and on the socio-economic status of groundwater users in uplands irrigated agriculture.

Design and implement a wastewater reuse plan for the AZB and north Jordan Valley

To be safe, sustainable, and economically efficient, wastewater reuse must be by design rather than by accident, and it must be integrated into wastewater collection and treatment. A comprehensive wastewater reuse plan includes a detailed analysis of the area that will be receiving the treated wastewater. This analysis must identify the nature of the demand for water and the associated water quality requirements. These must then be integrated with the characteristics of the expected influent and the wastewater treatment facility designed accordingly.

The *Amman-Zarqa Wastewater Master Plan* addresses near future plans for wastewater treatment in the AZB. As a first step, this plan should be thoroughly reviewed with a focus on how it addresses the integrated reuse of the treated wastewater. The comprehensive wastewater reuse plan for the AZB should also:

1. Identify, evaluate, and implement technically feasible and economically viable irrigation management interventions that increase the effectiveness of irrigating with treated wastewater. Specific interventions that should be evaluated include:

    - Assessing the maximum sustainable irrigable area (based on salt balances) relative to renewable water supplies, including treated wastewater from the King Talal Reservoir (KTR), in the Jordan Valley.

- Assessing opportunities for wastewater reuse in upland and midland irrigated agriculture.
- Integrating operations/releases from the KTR so that they might be used during periods of low irrigation demand to leach soils.
- Increasing irrigation frequency flexibility to permit high frequency irrigation with moderately saline water on the salt sensitive crops grown in the Jordan Valley.
- Providing farmer training, mentoring, and information services to achieve better salt management practices and to improve on-farm irrigation management.
- Implementing an operational plan for the use of treated wastewater in the middle Jordan Valley.
- Evaluating the opportunity cost of not improving the quality of treated wastewater, particularly water coming from KTR.
- Evaluating the consequences of keeping treated wastewater separate from the fresh water in the King Abdullah Canal (KAC) and using it directly in irrigated agriculture

2. Identify, evaluate, and implement technically feasible and economically viable low-cost, in-stream interventions that improve water quality in the AZB. Specific interventions that should be evaluated include:

   - Possible use of constructed wetlands to reduce pollution loading from industrial and storm water sources into the As-Samra wastewater treatment plant and pollution loading from partially treated effluent from treatment plants in the Amman-Zarqa Basin other than As-Samra.
   - Use of artificial rapids to increase the assimilation capacity of the Zarqa River.
   - Use of disinfectants (chlorination, ozonation, and filtering of the water column) to reduce fecal coliform counts.
   - Use of reverse-osmosis that takes advantage of the hydraulic head between the KTR and the Jordan Valley to treat discharges from the KTR.

Policy Support Activities

If policy analysis and policy implementation are to be guided by facts (data) and analytical/ predictive tools which make it possible to organize facts (data) for policy purposes, the WPIT needs access to both for policy design, policy implementation, and policy evaluation. Because USAID has made a substantial investment in expanding the capability of MWI to collect, manage, evaluate and analyze data, the WPT recommends that the new water policy implementation program build-on these activities. Each should be adapted to the needs of an integrated policy implementation program that uses the Amman-Zarqa water basin as the unit of analysis. Specifically, the WPT recommends:

Adapting the ministry's integrated water quantity and water quality monitoring program for the AZB

An integrated water quality/quantity-monitoring network is critical to verifying the expected effects from policy interventions in the AZB and throughout the country. Discussions with MWI suggest that this monitoring network for the AZB is virtually completed. The WPT recommends that this network be evaluated from the perspective of its ability to track the impact of policy interventions, and that needed adaptations be supported under the program. The WPT also recognizes that if the monitoring program to be implemented in the AZB is to become a model for other basins in the country work begun during the WQICP for developing a country-wide monitoring program needs to be completed. This would allow for an easier transition of the policy program to other basins in the country.

Adapting the ministry's policy responsive "tool-kit" so that it can be used in the AZB

If data are to be useful to policy analysts, policy-makers, and operators of water systems, they must be linked with analytical tools that make it possible to predict and evaluate outcomes of policy interventions. Fortunately, USAID through the WQIC Project, and other donors have funded the development of a substantial analytic "tool-kit" for MWI. This includes tools in the new, digital, water master plan; groundwater models; surface water models; and a water quality model for the Zarqa River. The WPT recommends that this tool-kit be evaluated from the perspective of its usefulness for supporting a policy implementation program for the AZB. Needed adaptations and additions to the tool-kit could be supported under the program.

For these data and tools to be useful, the WPIT must have easy access to both; they must have system support to maintain data bases and tools; and they must be able to turn to Management Information System (MIS) support staff for assistance. Because of these needs, the WPT recommends sustaining, strategically building-on, and consolidating MWI's MIS.

Sustaining, strategically building-on, and consolidating MWI's MIS

The WQIC Project led to creation of a Unified Management Information System (UMIS) in MWI that is available to users in the central ministry building through a Local Area Network (LAN).

The LAN links email users and provides access to software and for the sharing of some water data from the Water Information System (WIS). But the WIS is not yet fully operational. Data in the WIS are not complete. It is not yet possible to use the WIS to generate statistical reports. And there are no linkages between the data in the WIS and software tools. MWI needs help in overcoming these problems. The WPT recommends that this help be guided by a needs assessment designed to identify the staff, technical assistance, hardware, and software required to: sustain basic system operation and management; develop and implement a strategic action plan for completing/expanding the system, particularly to meet the needs of an initial water policy implementation program; and develop a plan for consolidating the three MIS information units in the ministry.

Conclusions

The GOJ has taken an impressive number of steps that suggest it is committed to improving its capability to strategically manage its very limited water resources. The government realizes that it will take time and substantial effort before it has the necessary capabilities for data collection, analysis, and decision support for better strategic water resources management.

Because of this, it is important to begin to tackle some of the country's water problems in a way that supports development of a long-range water policy program and the capabilities within government to manage such a program. The Water Policy Team believes the best way to do this is by developing a small number of interventions in one water basin—the Amman Zarqa Basin. Proposed implementation activities for the AZB are consistent with Jordan's stated water policy objectives; they are implementable within a two to three year period; and they lay the groundwork for development of a full fledged, integrated, water policy implementation plan for the AZB and other water basins.

The proposed policy implementation activities are expected to achieve two other goals. They link past investments in MWI's MIS to policy-oriented data needs, policy analysis, and policy-oriented analytical activities. They also provide the basis for hands-on learning in policy implementation and development of capacity to implement policy that can be extended to the country's other water basins and to the freshwater supply and use systems for the country as a whole. If successful, the AZB policy implementation activities could go a long way to putting Jordan on a more sustainable water use trajectory.

1. State of Water Resources and Uses of Water in Jordan

Jordan is one of the most water scarce countries in the world. Because of this, the demand for fresh water to meet the needs of a growing population, growing industrial and service sectors, and a substantial agricultural sector that is heavily dependent on irrigation is putting enormous pressure on the country's limited annual renewable fresh water resources. Until recently, the country was able to meet these demands for fresh water by developing renewable supplies and mining groundwater. Progress in expansion of renewable supplies has been particularly impressive. Most Jordanians are now served by a municipal water supply system, and the wastewater treatment system has and is being expanded. There is a large surface irrigation system in the Jordan Valley. The government should be commended for its achievements in supply expansion.

But as the country approaches the limits of relatively easy and inexpensive options for increasing renewable supply, successfully balancing between the supply and demand for fresh water is becoming more difficult. Currently, demand exceeds renewable supply, and the gap between them is being met by modest investments in supply expansion, unsustainable abstractions from renewable (and fossil) groundwater aquifers, quantitative rationing of fresh water in urban and rural areas, and augmenting supplies for irrigated agriculture by using treated wastewater.

These ad hoc means for meeting current demands for fresh water impose high costs on users, and on Jordan's fresh water supply system. In urban areas, households have responded to repeated supply shortages by investing in water tanks and buying water in formal and informal water markets. Costs of water delivery shortfalls in irrigated agriculture include economic losses associated with lack of sufficient water to irrigate all the area served by irrigation infrastructure, loss of land to salinization, declining yields, and costly shifts in crop mixes required by the delivery of low quality wastewater. Costs to Jordan's freshwater supply system include unsustainable abstraction, pollution, and salinization of groundwater aquifers, and deterioration of water distribution networks. Each of these threatens future sustainable use of the country's freshwater supplies. All of these problems are exacerbated by variations in annual rainfall and by the political difficulties of finding regional solutions to pressing freshwater needs. In low rainfall years, such as this year (1998-1999), these problems are particularly severe. Projections of future freshwater needs, and of the costs and limits to developing new renewable supplies, suggest that unless additional policy actions are taken soon, current imbalances and the socio-economic costs associated with them will substantially increase.

The government is keenly aware that some of its current water use practices are neither sustainable nor efficient, and it has recently taken a number of significant steps to address these problems. The financial and operational problems facing the Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA) are being addressed by redefining their roles, increasing cost recovery from users, and contracting out the management of the municipal water supply system of Greater Amman. The government is working on a new, digital, water master plan. It is developing an integrated approach for identifying problems in the water sector, analyzing them, and evaluating options for successfully tackling them that link planning and policy analysis to the government's water sector investment program. It has also adopted a new overall water strategy and new policy statements in four water sub-sectors—utilities, irrigated agriculture, wastewater management, and groundwater management. Taken together, these five policy documents reflect the government's commitment to implement policies that:

- Maximize the socio-economic returns to water;
- Sustain irrigated agriculture in the Jordan Valley;
- Manage wastewater so that it can be available for "unrestricted" use in irrigated agriculture;
- Protect the quality of groundwater; and
- Limit abstraction of groundwater to sustainable yield.

The government's commitment to achieving these objectives provides a sound basis for USAID support for a policy implementation program. The government is also keenly aware that it will take time to develop the capacity to design and implement specific policy interventions to achieve these objectives. Because of this, it has agreed to initiate a water policy program that

- Improves the socio-economic returns to water;
- Encourages more sustainable irrigation practices in the Middle Jordan Valley;
- Treats wastewater so that it can be used for "unrestricted" use in irrigated agriculture;
- Begins protecting aquifers from contamination by salts and other pollutants; and
- Begins reducing abstractions of groundwater to sustainable yield.

Both the government and USAID/Jordan have agreed that an initial policy implementation program should focus on a small sub-set of the already approved policies that:

- Can be implemented within two to three years;
- Lay the groundwork for development within MWI of the capability to design an Integrated Water Policy Implementation Plan (IWPIP) that can guide future policy interventions; and
- Will make a substantial contribution to the long-term task of putting Jordan on a more sustainable water use trajectory.

USAID asked an EPIQ Water Policy Team (WPT) to work with the government and USAID to identify the critical elements of a water policy program that meets these objectives. This requires placing Jordan's water problems and its approved water policies in a larger conceptual framework that allows identification of explicit policy interventions.

2. Jordan's Integrated Water Supply and Use System

Jordan's freshwater supply consists of an integrated system of surface and renewable and fossil aquifers that, for the most part, naturally flow to the Jordan Valley and the Dead Sea. This freshwater system is managed publicly and privately to meet freshwater needs for municipal and industrial (M&I) use in urban and rural areas and for irrigated agriculture in the Jordan Valley, the uplands, and the southern part of the country. This system and the present allocation of water are depicted in figure 1.

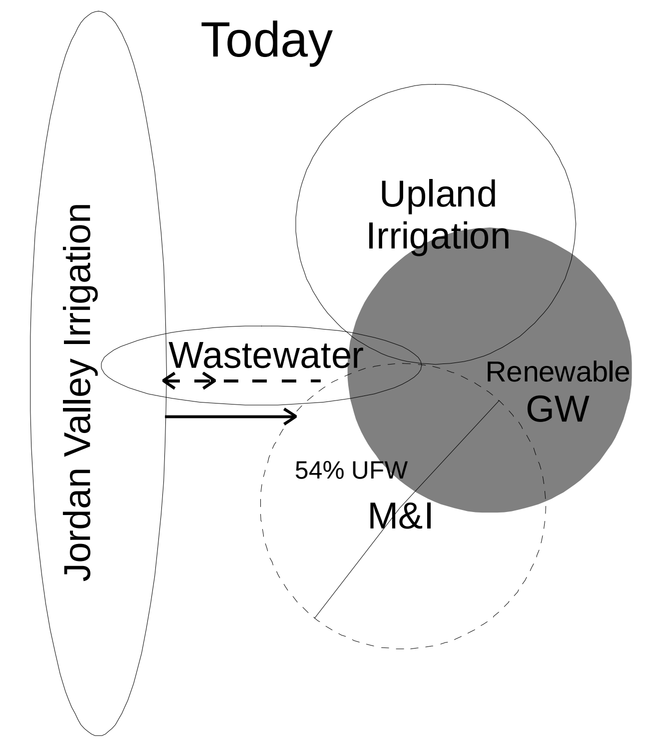

Figure 1

The size of the circles and ellipses in the figure represent the average amounts of water: (a) used in irrigated agriculture in the Jordan Valley and the uplands; (b) used for M&I; (c) abstracted from renewable groundwater; and (d) exported from the Jordan Valley and exchanged for treated wastewater. The figure shows that irrigated agriculture in the Valley is a large user of freshwater; abstraction of groundwater is roughly equally divided between upland irrigation and M&I use; and the import of treated wastewater into the Valley exceeds the export of freshwater out of the Valley. Because there is sufficient concern about the quality of this wastewater transfer to the Valley, movement of it is signified as a dashed line with arrows pointing in both directions. If wastewater quality is low enough, transfer of this wastewater to the Valley could in fact represent an additional abstraction of freshwater out of the Valley. This happens when treated wastewater can only be used when mixed with large quantities of freshwater.

Two other aspects of figure 1 should be mentioned. First, the dotted circle for M&I use reflects an assumption that the policy issues discussed here will not focus on M&I use. Second, the line drawn through the M&I circle and the term "54% UFW" represents the current level of unaccounted for M&I water

Figure 1 does not reflect either economically efficient or sustainable use of freshwater in Jordan. Losses in economic efficiency occur because water is misallocated to low valued users and because there are few incentives to use water efficiently. Efficiency losses in agriculture include salinization of irrigated land, declining yields, and costly changes in crop mixes needed to successfully irrigate with low quality wastewater. Efficiency losses in M&I use are manifest in rapid deterioration of the water distribution network and costly household strategies to avoid repeated interruptions in supply. Unsustainable use of freshwater occurs when abstractions of groundwater exceed sustainable or safe yield (275 MCM per year) and when farmers try to sustain irrigated area even though there is not sufficient water to maintain salt balances.

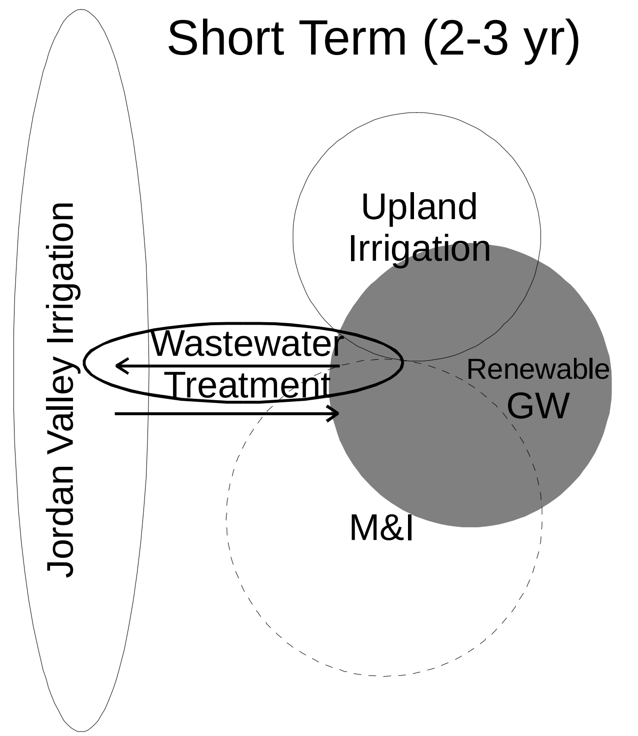

Figure 2

How might a water policy program change these outcomes? This is depicted in figure 2. The sizes of ellipses and circles in the figure reflect the amounts of surface/groundwater and treated wastewater used in irrigated agriculture in the Valley and the uplands, and the amounts of freshwater allocated for M&I use. The figure also reflects the success of policy actions taken to treat wastewater so that it can be used “unrestricted” in agriculture. (Because of this success, the arrows to and from the Jordan Valley are of equal length.) Comparison of figure 1 to figure 2 shows that after implementation of an initial water policy program:

Use of groundwater in uplands agriculture falls;
Use of freshwater for M&I purposes rises; and
Use of “effectively” treated wastewater in the Jordan Valley rises;

Because of these changes, future water use should be both more economically efficient and sustainable.

3. Defining and Implementing a Water Policy Program

3.1 Conceptual Issues

Defining and implementing a water policy program that moves water use in the directions outlined above begins with recognizing that Jordan's water supply and use systems are hydraulically and institutionally linked as water flows from its original surface and ground water sources to users and back again. To be effective a water policy program must be based on an understanding of how actions designed to affect one part of the system affect others as well. To achieve such an understanding, tools must be developed that facilitate analysis of how surface-water, groundwater, and wastewater sub-systems function as an integrated whole. While over time this should be done for the country as a whole, an initial focus on the Amman-Zarqa water basin (AZB) is proposed for two reasons. First, in terms of population, area and water use (and overuse), AZB is of particular importance in the context of finding a solution for the problem of managing Jordan's limited water resources efficiently and sustainably. Secondly, AZB includes both upland areas where groundwater abstraction exceeds safe yields, and the Jordan Valley where extensive use of treated wastewater is a critical element of Jordan's long-term water strategy. Because these problems are common to many of Jordan's other water basins, successful implementation of an integrated strategy for sustainable water management in the AZB will include elements that can be readily adapted to the management needs of other basins. At the same time, because of its size and importance, focusing on the AZB promises early results in terms of reducing Jordan's imbalance between supply and demand for water.

The point of departure for development of an integrated analytical description of the AZB basin is a schematic diagram of the location, amounts, sources and uses of water in the AZB. This is provided in figure 3. The sizes of circles and ellipses in the figure represent the relative amounts of groundwater used in upland agriculture, the amounts of surface and treated wastewater used in irrigated agriculture in the Jordan Valley, the amounts of surface and groundwater used for M&I purposes, and the area covered by groundwater.

The amount of groundwater used for upland agriculture is roughly equal to the amount used for M&I in the basin.[2] The figure also shows that a relatively large and stable amount of treated (and inadequately treated) wastewater is available for irrigated agriculture in the Jordan Valley. As depicted, the treated and inadequately treated wastewater discharged into the river when added to the base flow of the river and the KTR constitute the single largest stable source of water for the Jordan Valley. Because the annual flow of treated wastewater into and out of the KTR is highly reliable, if the water were of higher quality, it would be the best water for agriculture in Jordan.

[2] But it is important to note that total M&I use in the AZB as depicted in figure 3 is significantly larger than total use of groundwater in irrigated uplands agriculture in the AZB. This is because total M&I use in the AZB includes, as mentioned in the previous paragraph, a relative large amount of surface water.

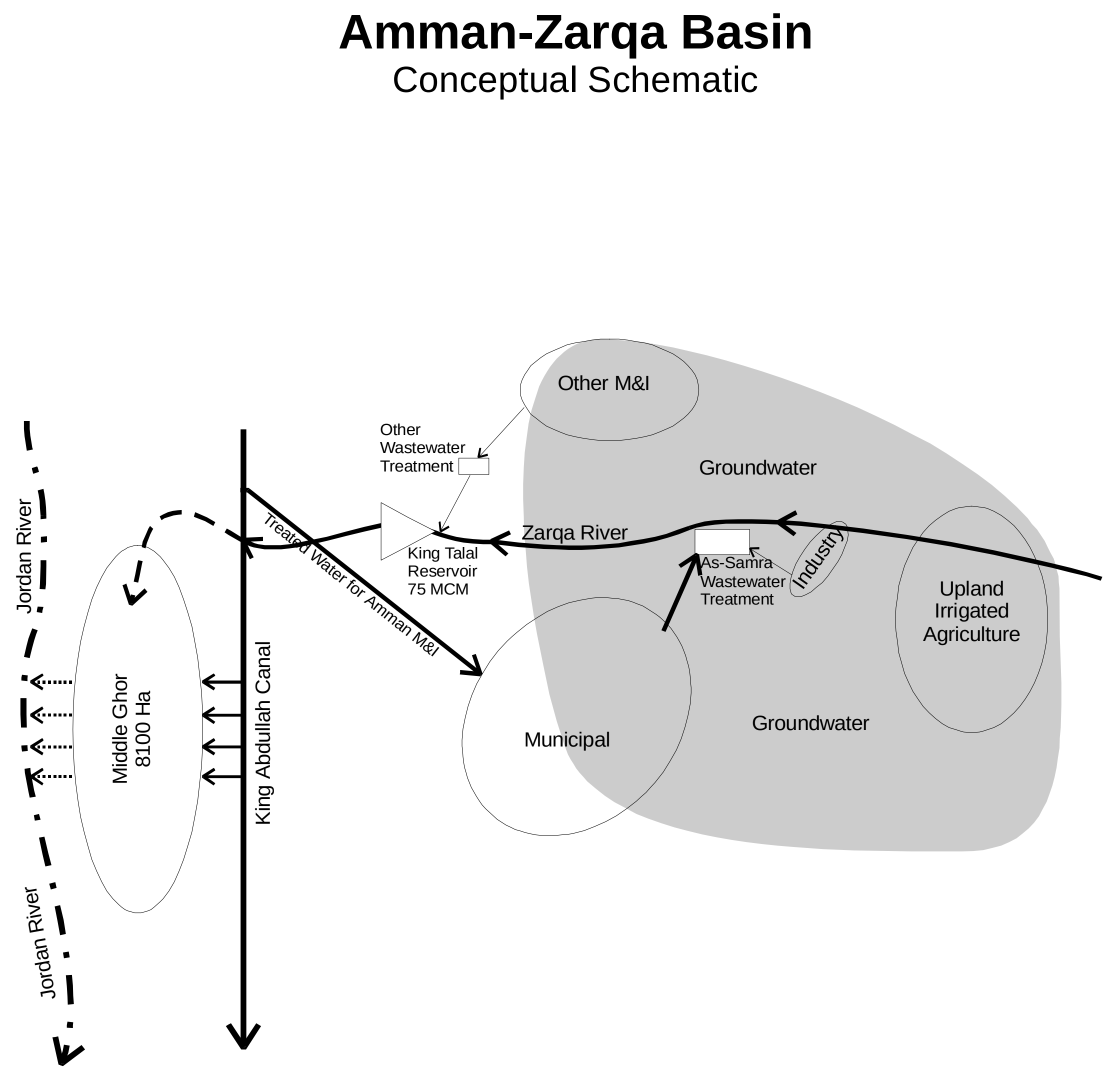

Figure 3

Although not depicted in the figure, water use in the AZB is not sustainable. Nor is it economically efficient. Unsustainable practices include abstraction of groundwater at rates in excess of sustainable yield and pollution of aquifers by salts and other pollutants. Inefficient practices include failure to treat wastewater to appropriate quality standards and stretching of water supplies to cover irrigated area without adequate leaching.

Because of these problems, the ultimate aims of an initial water policy program for the AZB should be to:

Work towards limiting abstractions of groundwater to sustainable yield;
Work towards protecting aquifers from contamination by salts and other pollutants;
Work towards treating wastewater so that it can be used for "unrestricted" use in irrigated agriculture; and

Work towards encouraging sustainable irrigation practices in the Middle Jordan Valley.

These are, in fact, the exact policies the government has adopted in its groundwater management, wastewater management, and irrigation sector policy papers.

To implement concrete and specific policies that contribute to overcoming water management problems in the AZB, analysts, policy-makers, and system operators must adopt a strategic approach to policy design and intervention. This requires developing a better understanding of how surface-water, treated wastewater, and groundwater sources and uses interact to produce current outcomes. It requires developing the analytical capacity to use data and decision support tools to predict and evaluate the impact of alternative policies on sources and uses of water. It also requires implementing actions and then monitoring outcomes to verify that they are moving water use practices in the desired directions.

This entire process should build-on, rather than replicate, existing studies and analytical models (such as groundwater models currently used to understand the renewable aquifers in the AZB). Wherever possible, the process should use, and selectively build upon, previous USAID investments in capacity building in MWI for data gathering, data analysis, and model building. These new investments need to be strongly linked to support for the policy program. Because the Water Resources and Planning Directorate within MWI has developed, with support from USAID, a substantial MIS, the WPT recommends that it be responsible for both basin-level water quantity/quality monitoring data and for basin-level decision support tools.

Experience elsewhere in the world suggests that successful implementation of new policies also requires close cooperation between policy analysts/planners and implementers. Since the policy implementation process is a circular one (see figure 4) that moves from monitoring to analyzing/predicting the consequences of actions, to modifying policy responses, and back to monitoring, collaboration is needed in policy design, policy implementation and evaluation of policy intervention outcomes. Planners and policy analysts must have the capability to monitor and verify the consequences of policy actions, and implementers must have the capability and flexibility to implement policy changes. Because collaboration is critical to the success of implementation, the WPT recommends the formation of a senior level joint MWI, JVA, WAJ Water Policy Implementation Team (WPIT).

When strategic policy analysis and policy interventions are designed and implemented in this way, as they have been in the western United States, conflicts among operational units over access to water tend to get resolved in discussions over the facts gathered by the verifiers. This makes it easier for the Water Resources and Planning Directorate to make recommendations to policy-makers based on agreed upon policy objectives; on the facts on the ground; on analysis of the trade-offs involved in specific intervention strategies; and on the difficulties facing operating units.

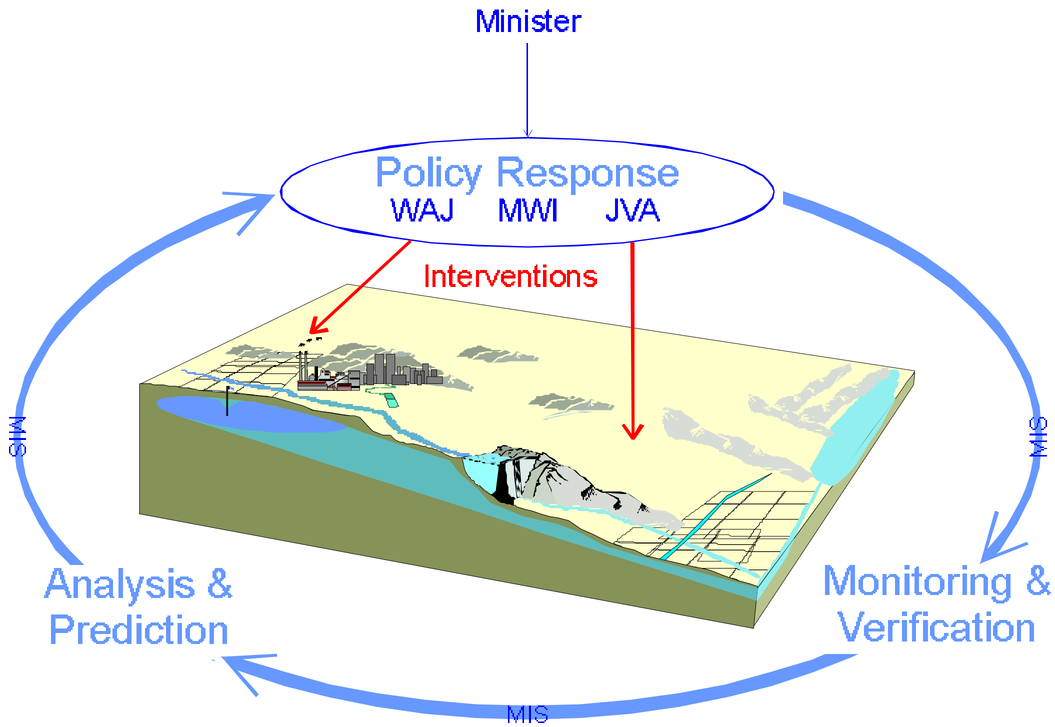

Figure 4

3.2 Proposed Water Policy Program

3.2.1 Development of an Integrated Water Policy Implementation Plan for the AZB

Over the longer term, the MWI will need to develop an Integrated Water Policy Implementation Plan (IWPIP) for the AZB to guide its policy interventions. While development of an IWPIP is beyond the scope of the initial water policy program proposed here, an IWPIP will need to be organized around how surface and groundwater are used and how they flow through a water basin. Water by its very nature is integrating as it is diverted, used, treated, and reused. Integrated planning anticipates effects of interventions, some of which will be beneficial, some benign, and some adverse. These can all be analyzed with a matrix of interventions and flow paths, where interventions are listed across the top of the matrix and flow paths are listed down the side. This matrix of interventions/ flow paths can be used to prioritize interventions based on one or more criteria such as maximizing the net socio-economic returns to water or cost-effectiveness.

Development of an implementation plan for integrated water policy in the AZB will require the following analytic steps:

Development of detailed water balances and flow paths for the AZB. Where possible, the development of water balances and flows paths should build on existing monitoring data and the national Water Master Plan.

Questions to be answered include:

- How much water is flowing when and where in the basin?
- How has this changed over time?

2. Construction of a matrix of AZB water policy interventions by flow path.

3. Analysis of the expected effects (impacts) and costs (per cubic meter of water) of potential AZB interventions.

4. Analysis of the effects of the wastewater effluent from As Samara on unsanctioned irrigated agriculture on the Zarqa River between the As-Samra wastewater treatment plant and the KTR.

5. Analysis of the water in the KTR and implications for its use in irrigated agriculture in the middle Jordan Valley. Key questions to be addressed include:

   What are the downstream requirements for unrestricted agricultural use of KTR water as is?
   Do these requirements vary by time of year?
   Can they be overcome by changing irrigation practices, or does overcoming them require additional treatment?
   If additional treatment is required, what treatment options are available at what cost (per cubic meter of water treated)?

Investigation of the technical and economic feasibility of using low-cost, in-stream methods to improve the over-all water quality of the Zarqa River and discharge from the King Talal Reservoir to meet standards for "unrestricted" agricultural use. These improvements could include:

   Using constructed wetlands for improving stormwater runoff quality; for primary treatment of industrial wastewater; and for polishing treated municipal wastewater for smaller plants as in Jerash and Basqa to reduce nutrient, coliform, trace metals, and other pollutants in the stream.
   Constructing artificial rapids before the King Talal Reservoir to improve aeration and increase the assimilation capacity of the stream.

Investigation of the technical and economic feasibility of disinfecting, reverse-osmosis, or other methods for the treatment of discharges from treatment plants and KTR so that the water meets standards for "unrestricted" agricultural use.

Determining the efficacy of possible interventions involves the use of demonstration projects and other methods. Careful attention to monitoring results is critical.

Building the capacity in MWI to develop and implement an IWPIP for the AZB (and for other water basins) will take time. In the meantime, an initial water policy support program can provide technical assistance, training, hardware, software, and experience in developing such a program. The WPT has identified specific policy interventions and policy support activities that:

- Can be implemented within two to three years;
- Are based on already approved policies;
- Lay the groundwork for development within MWI of an IWPIP for the AZB;
- Build-on and reinforce accomplishments of previous USAID financed activities; and
- Hold promise for early and significant results.

3.2.2 Policy Implementation Activities

The WPT recommends two policy interventions for the AZB:

1. Design and implement a water allocation program for upland agriculture in the AZB; and
2. Design and implement a wastewater reuse plan for the AZB and north Jordan Valley.

Details of these interventions follow.

Design and implement a water allocation program for upland agriculture in the AZB

Moving toward a more sustainable water use trajectory in the AZB requires reducing the use of groundwater for irrigated agriculture in the uplands. It is widely recognized that this is politically difficult. The purposes of this program are: 1) to explore a range of options for reducing groundwater use in irrigated uplands agriculture and 2) to develop a verification plan for assessing the impact of interventions on groundwater use in uplands agriculture.

To start, the WPT recommends carrying out a rapid appraisal socio-economic survey by wellhead of groundwater use in irrigated uplands agriculture. This study should build on the Ministry's Groundwater Basins Project. The purpose is to increase understanding of groundwater use by wellhead by cross-linking the physical characteristics of well water use with social and economic aspects of that use. This forms the basis for determining the economic return per cubic meter of groundwater consumed by upland agriculture, and provides information for assessing possible incentive structures (positive and negative) for reducing upland agricultural consumption of water. Items to be addressed by this survey should include the following for each well:

History of the well (when drilled, major events, changes in water level, changes in quality) and associated farm enterprise characteristics (was farm rainfed before well development, crop history, etc.).

Engine type (diesel, electric, etc.) and size (hp). Operating hours per year. Annual fuel consumption or electricity use. This information is necessary to determine the cost of pumping, and is useful in checking or estimating the amount of pumping.

Area served by well. Is this area all under a single ownership? Does the owner lease irrigated land served by this well? If water from the well is sold to other users, at what price is it sold, by what method of measurement and conveyance, and how are arrangements for conveyance made and water deliveries scheduled?

Is the farming operation commercial? What is the history of investment in the well and the associated irrigated farming infrastructure? Has the capital investment in the farming operation been recovered? What is the estimated real value of the well and associated farming activities? Does the owner have other irrigated upland holdings? Is the owner involved in other commercial activities besides farming? In other words, how dependent is the well owner's economic livelihood on the well?

What crops are grown with the water from the well? What is the cropping history? What yields are obtained? How variable are crop yields, and what are the explanations for that variability? What are the market conditions (percent of harvest or production sold, price range, buyers, production contracts, etc.) for the crops grown?

What are the methods (trickle, sprinkler, or surface) of irrigation? What is the method of conveyance (pipe or open ditch)? Are there weeds or other sources of incidental consumptive losses? This information is necessary to determine the total consumptive portion of the water diverted and estimate the potential for real water savings.

What is the farm labor source?

What is the impact on socio-economic welfare of the potential losses associated with reduced agricultural production in the uplands?

Condition of flow meter and ease of access to well head for reading flow meter.

Proximity of well to the national conveyance system. Willingness/receptivity of well owner to participate in water transfer program (e.g., revenue neutral on-farm water savings, government buyout, exchange for land in Jordan Valley).

Most physical characteristics (depth, capacity, etc.) of licensed wells are known. This information needs to be cross-linked to the other survey information listed above, and to surveys conducted by others such as the Department of Statistics and USAID under the Forward project. In the case of unlicensed wells, information is lacking and must be obtained. The socio-economic information in this regard will be particularly useful in understanding the resistance to licensing and regulation and in designing effective controls.

It is recognized that some of the survey information needed may be difficult or impossible to obtain, particularly in a timely manner. Thus, surveyors must be trained to estimate critical information when responses are lacking.

Following this socio-economic survey, the program for water allocation in the uplands will need to:

Estimate the potential for reduction in groundwater depletion associated with upland agriculture.

This will require an assessment of the real water savings potential associated with minimal decrease in upland production as well as effective savings from individual well closures. Such an assessment would include determining the non-productive losses of pumped groundwater to consumption by weeds and evaporation, and an estimate of the non-recoverable fraction of the deep percolation. The latter may require the application of groundwater modeling. Where deep percolation is returning to the pumped aquifer, it is not a loss to the groundwater system; however, it may be a cause of pollution to the groundwater.

Develop and test alternative incentive structures to encourage upland farmers in the AZB to economize on the use of groundwater by, among other things, assisting farmers in converting to more efficient irrigation systems.

This might include a review of private to public water transfer programs elsewhere in the world. For example, the Metropolitan Water District of Southern California buys options from farmers on an individual and voluntary basis to call (exercise) on the participating farmers' water at any time during the effective period of the options. Other transfer mechanisms that could be reviewed include farmer buyout (seasonal, perpetual, and permanent) programs, flow restrictions, and subsidy/price support removal for agriculture. The need to transfer water from agriculture to other higher value uses is certainly not unique to Jordan. Thus, opportunities exist to learn from experience elsewhere, and to adapt effective mechanisms to the conditions specific to Jordan.

Develop an irrigation information service for farmers that would focus on on-farm water efficiency programs that result in real water savings and help farmers adjust to lower water abstractions from wells.

There appear to be cost effective opportunities to save water in Jordan by improving on-farm water management rather than by additional investment in high technology hardware. Improving on-farm water management requires applying the right amount of water at the right time—irrigation scheduling. MWI or WAJ could run an irrigation scheduling service that is directly linked to the water-monitoring network. Several states in the US provide such services. The best known is CIMIS, California Irrigation Management Information Service. In this way, the Government of Jordan would be assisting and collaborating with farmers to decrease water use. By linking this with the monitoring system, bi-directional flow of information is achieved. The monitoring network is kept updated with near real time field data, and the farmers benefit from the data. Thus, when the government irrigation advisor visits a farm he has something of value to offer the farmer, rather than simply reading his water meter.

4. Install functioning water meters on all wells and link them to the integrated water quality/quantity-monitoring program for the AZB.

   Functioning water meters on all wells is important for monitoring the groundwater system and verifying conservation activities. The WPT was informed by WAJ officials that currently well owners must pay for their water meters, and that often they are made inoperable by the farmers and well owners. Thus, the project might consider supplying water meters. This way the meters also become government property, which may help protect them from vandalism. This arrangement should also make it easier for the government to impose penalties on farmers who damage water meters.

5. Develop a verification plan that makes it possible to track the impact of policy interventions on groundwater use, on the socio-economic status of groundwater users in uplands irrigated agriculture, and on aquifers.

6. Link this program to the integrated water quality/quantity-monitoring program for the AZB.

Design and implement a comprehensive wastewater reuse plan for the AZB and north Jordan Valley

To be safe, sustainable, and economically efficient, wastewater reuse must be by design, not by accident. In addition, it must be integrated with wastewater collection and treatment. While the Wastewater Management Policy statement for Jordan clearly emphasizes wastewater treatment sufficient for unrestricted use in irrigated agriculture, actual implementation lags behind stated policy objectives. Even the designs of soon-to-be-initiated wastewater treatment facilities do not adequately consider wastewater reuse. For example, the USAID funded wastewater treatment plant located near North Shuna calls for zero discharge to the Jordan River. But the plan for this plant does not explicitly address how to use the treated effluent in irrigated agriculture; how to integrate it with the existing delivery system operation; or what the implications are of on-farm reuse.

A comprehensive wastewater reuse plan includes a detailed analysis of the area that will be receiving the treated wastewater. This analysis must identify the nature of the demand for water and the associated water quality requirements. These must then be integrated with the characteristics of the expected influent and the wastewater treatment facility designed accordingly. Analytical questions that must be addressed in devising an integrated wastewater reuse plan include:

What are the water requirements (quantity and quality) for sustainable use of treated wastewater in the recipient area?

How does the demand for water vary throughout the year? Are there times when the water quality requirements are more or less stringent?

What is the nature of alternative or additional water sources?

What options exist to blend treated wastewater with these other sources? Does blending change the treatment requirements?

Do opportunities exist for conjunctive use of wastewater that will minimize its negative effects or reduce treatment costs?

During times of low demand or no demand what options exist for storage of treated wastewater, or for using it for other beneficial uses (such as leaching soils and land reclamation)?

What is the irrigation technology in the recipient area? Is it appropriate for treated wastewater, or will programs need to be implemented to upgrade/modify existing irrigation technology? For example, how are the filtration requirements for trickle irrigation methods affected by the suspended organic material in the treated wastewater?

Can/should the water demand of the recipient area be altered? In other words, are there other crops more suited for irrigation with treated wastewater or with less stringent treatment requirements? If so, it may be more cost effective to get farmers to shift cropping patterns than to implement higher levels of treatment.

Can water quality constraints to unrestricted use be managed via irrigation practices, or do they require additional wastewater treatment?

As part of designing and implementing an integrated wastewater reuse plan for the AZB and north Jordan Valley, the WPT recommends the following two sub-activities:

1. Design and implementation of an irrigation water management program for a portion of the Jordan Valley receiving wastewater that focuses on managing salt and other water quality parameters and the integrated use of treated wastewater; and

2. Design and implementation of a low-cost, post-secondary treatment program for wastewater in the AZB that addresses current limiting factors to the safe and sustained reuse of wastewater.

Irrigation water management program for a portion of the Jordan Valley receiving wastewater

Data on the quality of treated wastewater in the AZB reviewed by the WPT suggest that salinization in the middle Jordan Valley, although coincident with the use of treated waste water from As-Samra and the KTR, may not be due to salinity levels in this treated wastewater. If this proves to be the case, it will be important to develop a program for improving the sustainability of irrigated agriculture in the Jordan Valley. Without such a program, many of the potential benefits of treating wastewater in the AZB for use in irrigated agriculture will be lost. Elements of a program might include:

Assessing renewable water supplies, including treated wastewater, in the Jordan Valley. This assessment requires identifying the place of use for treated wastewater; determining the comparative advantage (summer crops in winter) of middle Jordan

Valley agriculture; analyzing the viability of varying crop area annually depending on the water supply; and determining land reclamation requirements in the Jordan Valley to match land area to water supply and assessing the adequacy of drainage for the leaching required.

Converting the GIS system for the Jordan Valley into a spatial decision support system (DSS) focused on the environmental sustainability of agriculture in the Jordan Valley. Presently soil data are collected without adequate geographic referencing. Support might be needed to remedy this problem.

Assessing opportunities for wastewater reuse in upland and midland irrigated agriculture. Currently a few hundred hectares are using restricted irrigation along the Zarqa River, upstream of KTR. Direct irrigation is also practiced on-site at As-Samra. It may be better in some cases to reuse treated wastewater close to where it discharges from the treatment plants rather than always conveying it for reuse in the Jordan Valley. Also, there may be opportunities to use treated wastewater in the uplands or midlands in the summer and Jordan Valley in the winter.

Evaluating the opportunity of integrating operations/releases of the KTR to leach soils. Irrigation demand in the middle Jordan Valley is very low in July and August. Treated wastewater needs to be stored during these months or reused in the uplands. There might be an opportunity for soil leaching irrigations to take place. However, because temperatures in the Jordan Valley can reach 45°C, with correspondingly high evaporation rates during July and August, leaching at this time might actually result in salt accumulation. Thus, slug leaching is the only potential alternative, and this may not be practical except on well-drained, highly permeable soils.

Assessing the possibility of increasing irrigation frequency flexibility in the middle Jordan Valley. The use of moderately saline water to irrigate salt sensitive crops, as are commonly grown in the Jordan Valley, requires high frequency (daily or every other day) irrigation. Current practice in the Jordan Valley for irrigation is on a twice a week rotation. Higher frequency irrigation requires water storage facilities on-farm or some means of obtaining water out of turn. An on-demand irrigation system has implications for the delivery system. These include system capacity, automation, transient storage/regulatory capacity, user integrity, and means of water allocation. There is an on-demand irrigation test being conducted by the French on a farm at the extreme north end of the Jordan Valley. Water savings on this experimental farm in the Jordan Valley are reportedly substantial. (Note that the irrigation on this farm is crop driven rather than farmer determined.)

Providing farmer training, mentoring, and information services to achieve better salt management practices and improve irrigation management on-farm. Evaluation of on-farm irrigation performance in the Jordan Valley conducted under the WQIC project suggests that the greatest opportunity for water savings lies in improving on-farm water management (including salt management) rather than additional investment in high technology hardware. Improving on-farm water management requires applying the right amount of water at the right time—irrigation scheduling. Under the WQIC project, a Jordan Valley Irrigation Advisory Service was conceptualized and is just now beginning to function. A needs assessment for this service should be conducted with particular focus on the implications and management of lower quality (treated wastewater and brackish water) irrigation water, and assisting farmers in the safe, sustainable, and effective use of such water.

Developing and implementing an operational plan for the use of treated wastewater within the central Jordan Valley. Eventually there may be more treated wastewater than demand for it in the currently irrigated area of the Jordan Valley, at least during certain times of the year. At some point additional storage may be needed. However, for now excess water might be applied in the off-season for leaching and land reclamation. The use of surplus treated wastewater might also be considered for reclamation of the newly completed Karameh Reservoir. Solutions for the management and use of treated wastewater to bridge between now and 2004 and 2008, when new wastewater treatment facilities are expected to come online, should be considered. Coordination/integration of anticipated reuse with the design of these facilities should also take place.

Evaluating the opportunity cost of not improving the quality of treated wastewater, particularly water coming from KTR. Such a study should assess implications for marketability of produce, on-farm water management, irrigation equipment (filtration requirements, plugging of emitters, etc.), land degradation, irrigation distribution system operations, etc. It will provide an indication of the benefit of improved treatment, and what the most cost-effective treatment might be, and may suggest the appropriate crops to be grown and the best method of, and schedule for, irrigation.

Because the *Amman-Zarqa Wastewater Master Plan* addresses near future plans for wastewater treatment in the AZB, it should be thoroughly reviewed to see how it addresses the integrated reuse of the treated wastewater.

Low-cost, treatment program for wastewater and stormwater runoff in the AZB

It is well recognized that with regard to wastewater management an "ounce of treatment is worth a pound of cure." This suggests that future wastewater treatment facilities in the AZB, and elsewhere in Jordan, should treat wastewater up to the point where the marginal costs of treatment equal the marginal benefits of treatment. Both the government and donors recognize this fact, and planning for additional treatment plants appears to be considering it. Until these additional plants come on-stream, it will be important to identify and evaluate the technical and economic feasibility of low cost interventions that improve water quality in the AZB. This requires identifying:

The current limitations to the safe and sustainable use for irrigation of the water currently discharging from KTR;

Inexpensive methods to reduce BOD_5 and nutrient loading associated with stormwater runoff and industrial wastewater prior to its entering the As-Samra plant;

Low-cost, in-stream methods to improve the over-all water quality of the Zarqa River and the discharge from wastewater treatment plants in the AZB and from the King Talal Reservoir so that the water meets standards for "unrestricted" agricultural use; and

The possibilities of disinfecting using chlorination, ozonation, or other methods.

Experience elsewhere in the world suggests that technical and economic feasibility studies need to be conducted for the following possible interventions.

Use of constructed wetlands to reduce pollutant loading in treatment plant influent and effluent. Constructed wetlands for wastewater treatment have been used throughout the world and should be considered in Jordan as an alternative to conventional secondary and advanced treatment methods. Advantages of using constructed wetlands include: low cost of construction and maintenance; low energy requirements; minimal training requirements for operational personnel; and more flexibility and less susceptibility to variations in the loading rate than conventional treatment systems.

Disadvantages include the increased land area required compared to conventional systems; a possible decrease in performance during winter months; and, if designed improperly, a potential increase in mosquito populations.

The following should be taken into account when evaluating wetland potential for advanced (polishing) of wastewater:

Land requirements. Average effluent flow from the As-Samra treatment plant ranges between 137,000 and 165,000 m^3/day. Using the rule of thumb of 0.6 to 1.6 hectares per 1000 m^3/day of effluent, between 99 and 264 hectares may be required to reduce nutrient and fecal coliform levels. Because of these land requirements, using As-Samra as a pilot may be too risky; therefore, initial attention might be placed on using wetlands for polishing effluent from smaller plants within the Amman-Zarqa basin, such as the one at Jerash, where average discharge is around 1700 m^3/day. If such a program is implemented on a trial basis, lessons learned could be applied to As-Samra and other treatment facilities throughout the country.

- Decreased performance during winter months. This is common in temperate climate areas that are subject to freezing and icing conditions. However, in Jordan, plants could be selected that are not so affected by the climatic conditions. If such plants exist, climate would not limit the use of wetlands as a viable alternative to conventional wastewater treatment.

- Mosquito control. The suppression of mosquitoes in constructed wetlands has been a concern in the United States. Mosquitoes are common inhabitants of natural wetlands and their invasion of constructed wetlands should be expected. For this reason, the design and operation of constructed wetlands must take account of the potential for explosive mosquito populations and the annoyance and vector capabilities of some mosquito species. Design must factor in the species composition likely for the constructed wetlands and the conditions that favor mosquito production. Design options might include use of a gravel substrate wetland that eliminates standing water, or a layout that favors the application of an insecticide. Interventions regarding wetlands development should also take into account the findings of the vector control study at As-Samra funded by USAID.

The purpose of this intervention is to evaluate the effectiveness (and safety) of wetlands in the AZB on both a small scale (for stormwater/industrial wastes) and on a larger scale (for secondarily treated municipal wastewater). This intervention would include the development of design criteria, plant selection, bench scale tests, studies, and cost-benefit analyses.

Use of artificial rapids to increase the assimilation capacity of the Zarqa River. Monitoring of the Zarqa River shows that reduction of BOD occurs naturally between the As-Samra treatment plant and the KTR. The construction of rapids may improve this natural process. While it is not possible to know without some evaluation if artificial rapids can increase aeration, the use of drop structures, grade control measures, and artificial rapids have been shown to work elsewhere. The purpose of this intervention would be to evaluate the effectiveness of artificial rapids on the assimilation capacity of the Zarqa River. This intervention would include the development of design criteria, location selection, technical and feasibility studies, and cost-benefit analysis.

Use of disinfecting (chlorination and ozonation) to reduce total and fecal coliform counts. Total and fecal coliforms must be reduced if treated wastewater effluent is to meet standards for unrestricted use in irrigated agriculture. The reduction of fecal coliform counts could be achieved by using more effective methods of disinfecting such as chlorination, ozonation, or filtering the water in the soil column. Chlorination was used at the As-Samra plant, but its use was suspended by the Health Ministry because of fears that the chlorine might combine with residual organics to form trihalomethanes or other potentially hazardous substances. The use of effluent chlorination is common in the United States and Europe, and should be reevaluated for use at the As-Samra plant. If found ineffective or potentially harmful, chlorination at the points of lateral off-takes from the KAC might be more effective and safer. In both cases, care needs to be taken so that chlorine in the irrigation water supply does not exceed crop toxicity levels. The purpose of this intervention would be to evaluate the effectiveness and safety of chlorination for the control of total and fecal coliform counts. This intervention would include the development of design criteria, location selection, technical and feasibility studies, and cost-benefit analysis.

Other methods of disinfecting, such as ozonation should also be evaluated. Unlike chlorination, ozone has other beneficial impacts such as increasing dissolved oxygen. Recent advances in ozone generation have made its use economically more feasible. A detailed engineering feasibility study and cost benefit analysis should be made of this possibility.

Evaluate the use of reverse-osmosis. Reverse-osmosis which takes advantage of the hydraulic head between the KTR and the Jordan Valley might be a cost effective way to treat discharges from KTR so that releases from the dam meet standards for "unrestricted" use in irrigated agricultural. It is likely that the cost of installing a reverse-osmosis treatment facility would be beyond this particular project. However, an evaluation of the technical and economic feasibility of such a facility could be conducted under this activity.

3.2.3 Policy Support Activities

The three policy support activities are:

Adapt (through technical assistance, training, hardware and software as needed) the integrated water quality/water monitoring system for the AZB so that it can be used for policy purposes and as a prototype for other basins;

Adapt (through technical assistance, training, hardware and software as needed) the ministry's policy analytical/predictive tool-kit so that it can be used for evaluation/prediction of the consequences of policy interventions in the AZB and as a prototype for other basins; and

Sustain, consolidate and plan for strategic expansion of the MIS developed under the WQIC project, and adapt it to serve the needs of the policy implementation program in the AZB.

Each of these activities is discussed in detail below.

Adapt the integrated water quantity and water quality monitoring program for the AZB

An integrated water quality and water quantity monitoring network is critical to planning and implementing policy interventions and to verifying the expected effects from policy interventions in the AZB. This network needs to be integrated and comprehensive so that parameters or characteristics analyzed in one part of the basin can be tracked throughout the basin. An integrated, comprehensive network is also important for identifying point sources of pollution, for understanding the hydrology (flow paths) of the basin, and for targeting effective interventions.

To evaluate the impact of policy interventions, a water quantity/quality monitoring network must:

- Integrate surface water, groundwater, and wastewater monitoring programs. This integrated program must be able to track the available water supply, extractions, return flows, treatment, reuse, and final discharge to salt sinks. The capacity to track permits estimation of a water balance, and a salt and conservative element balance.

- Generate high quality, reliable monitoring data that meets generally accepted quality analysis/quality control (QA/QC) requirements. These needs can be met either through in-house laboratories or by contracting monitoring out to the private sector. The WQIC supported development of the WAJ Central Laboratory. The final WQICP report to USAID shows that the project procured and installed equipment, developed standard operating systems, and trained staff. However, much more needs to be done if the Central Lab is going to be primarily responsible for analyzing water quality samples. Several planned technical/training assignments in laboratory operation and management, QA/QC, and health and safety were started under WQIC, but not completed. Some equipment is still in the procurement stage, while the procurement of other equipment is on hold until the lab's new building is finished. This building is now under construction and is due to be completed by the end of this year. Once it is completed, new furniture will need to be purchased, and a library, conference rooms, and offices will need to be equipped. The Laboratory Information Management System has been procured, but not installed.

The WQIC Project developed an extensive monitoring program for aquifer specific water levels, for groundwater quality, and for surface water flow and quality throughout the AZB. MWI has installed monitoring equipment in specific aquifers and surface water gauging stations have been or are being installed in the AZB. WAJ has monitoring programs for wastewater influent and effluent from its wastewater treatment plants in the basin, and it is monitoring well abstractions in the uplands in the basin. JVA monitors water flows and water quality from the basin and from the King Talal Reservoir (KTR) that are used for irrigation.

Currently, water quality and quantity data from the monitoring programs of MWI, WAJ, and JVA are not completely integrated into one information system. Lack of integration may have important implications for the ability to monitor and assess the impact of policy interventions designed to improve water use practices. For this reason, the new policy implementation program will need to answer questions like:

Does the current organization of water quality/quantity monitoring programs for the AZB meet the evaluation/assessment requirements of a new policy based intervention program? If not, what needs to be done to create an integrated monitoring program that can be used for policy purposes?

Do the current linkages between the monitoring programs of JVA, WAJ, and MWI meet the needs of a policy based intervention program, or do these programs need to be more integrated? If they need to be more integrated, how should this be done?

Whom should MWI rely on for monitoring water quantity/quality? Should it contract out monitoring services to the private sector, or should monitoring be done by the Central Laboratory? If it is to be done by the Central Laboratory, what additional support, if any, should be given to the Central Laboratory?

If the lessons learned in the AZB policy implementation program are to be used in other water basins, what support should be given to development/expansion of monitoring programs in other basins, and when will it be needed?

A needs assessment should be undertaken as an initial step to answer these questions and to design a program.

Adapt and expand the ministry's policy useable analytical tools for the AZB

If data are to be useful to policy analysts, policy-makers, and operators of water systems, they must be linked with analytical/predictive tools that make it possible to predict and evaluate outcomes of policy interventions. Fortunately, the Ministry and the donors, including USAID, have developed a substantial analytic "tool-kit" for MWI. This tool-kit includes an old (1977) water master plan and a new (under development) digital master plan, groundwater models for many of the country's aquifers, surface water models for several water basins, and a water quality model for the Zarqa River.

To date most of the Ministry's analytical/predictive work has examined groundwater and surface water management either from a "macro"(regional) perspective, or from the perspective of specific well fields. These efforts may not address the needs of a basin level water policy implementation program, either because they are too broad or too specific to predict/analyze the impact of specific interventions on particular water basins. In addition, except for a Zarqa River model, modeling efforts do not take into account the effects of water quality changes in the aquifers or surface water bodies.

In addition, the development of these analytical/predictive tools has been time consuming and personnel intensive. They have also required substantial investments in hardware and software, and on-going investments for maintenance and upgrading. Unless care is taken, development of tools and upgrading of hardware and software can become ends in themselves.

For this reason, the WPT recommends that the ministry's tool-kit be evaluated from the perspectives of the ability to use it to set policy, plan, predict and evaluate the outcomes of policy interventions. The WPT also recommends that this needs assessment be used to design support programs to complete and/or adapt the tool-kit so it can be used for these purposes.

This needs assessment should answer the following questions:

- Are the analytical tools available in the ministry sufficient for the design and evaluation of specific interventions in the AZB, or can they be modified to be sufficient?
- Can these tools be used for basin level water resource management planning? If not, what are the appropriate steps that need to be taken to design and implement such a plan?
- Is the ministry's regional "macro scale" analysis of groundwater sufficient to evaluate the benefits of specific policy interventions in the AZB?
- What are the data requirements for each tool? Are those data available?

From this assessment, a policy responsive analytical/predictive program for the AZB could be developed that would aid in increasing understanding of:

- The effects of over abstraction;
- The losses of groundwater resources due to pollution;
- The effects of changes in agricultural practices, crop selection, irrigation methods, and other factors on groundwater and surface water resources; and
- Estimates of safe yield for aquifer and surface water systems.

In order to make best use of data and tools, the WPT recommends that consideration be given to developing a Decision Support System (DSS) that includes: 1) models and modeling sub-systems; 2) a data and GIS sub-system[3]; and 3) a dialog subsystem. If developed and used properly, a DSS could, by linking data and analysis to decision-making, improve planning and management in the water sector.

Sustain, consolidate, and plan for strategic expansion of the MIS developed under the WQIC project, and adapt it to serve the needs of the policy implementation program in the AZB

If the Ministry (MWI, JVA, and WAJ) is to use data effectively as inputs into analytical/ predictive tools for identifying, tracking, and evaluating the consequences of policy interventions, it needs a data base and a set of tools that link data to policy interventions. Because the WQIC project provided substantial support for the development of planning and for an MIS in MWI, the WPT recommends that USAID support continued development of this system, adapting it as necessary to the needs of the program described in this report. The WPT recommends that support for this MIS contribute to:

- Sustaining basic system administration support for the MIS developed with USAID support;
- Adopting a strategic approach to completion/consolidation/expansion of the MIS that supports the policy implementation program described in this report; and
- Consolidating the MIS "systems" in the Ministry to reduce redundancy, duplication of effort and investment, poor communications, lack of integration, and conflicts over who is responsible for what.

[3] In the process of developing the DSS, careful consideration should be given both to data requirements and to the type of GIS capability needed.

Sustaining the basic system administration

With WQIC Project support, a Unified Management Information System (UMIS) was created in MWI that is available to users in the Ministry through a Local Area Network (LAN). The LAN links email users, provides access to analytic/predictive software, and provides for some sharing of water data from the ministry-wide Water Information System (WIS) developed by WAJ, JVA and MWI. Unfortunately, the WIS is not yet fully operational. Approximately one-half of the data tables in the WIS have no data in them. Some of these data need to be collected, some need to be verified, and others need to be entered or transferred into the system. While the WIS allows data entry and queries by individual record, it is not yet possible to use the WIS to process data, generate statistical reports, or link data to software packages so they can be used for analysis or modeling. The information directorate's staff in MWI is too small and too over committed to resolve these problems. The directorate needs help in overcoming problems in each of these areas.

The WPT recommends that this help be guided by a needs assessment designed to determine what staff, training, technical assistance, hardware, and software are needed to sustain basic system support functions. This needs assessment should build-on, where possible, the Concept of Operation Plan for the WIS prepared by the WQIC project and the status of existing systems.

Strategic approach to planning for the MIS

The WPT recommends that the MIS needs assessment be used by the Ministry (MWI, JVA, and WAJ) to develop a strategic approach for consolidating/completing/expanding the MIS so that it can be used to support the policy implementation program described in this report. A thorough review of the data needs for the policy implementation program described here is required. This review should include consideration of the data that should go into the WIS system, plans for verifying data quality, plans for data entry/transfer, plans for making the data available in a useable form, and plans for linking the data system to management tools and decision-making.

Questions that need to be answered by this review include:

- How can the capabilities of the WIS system be enhanced (e.g., develop reporting facilities, introduce data processing procedures, and automate publication generation) so that the raw data in the WIS can be used to provide information to analysts and policy-makers working on the policy implementation program described in this report?
- What kind of quality analysis/quality control (QA/QC) procedures should be developed for data flow and validation procedures for the WIS?
- How should analytical and modeling software programs that will be needed for the policy implementation program described in this report be linked on-line with the data in the WIS?

- What staff, training, technical assistance, hardware and software are needed to: critically assess the status of real data needs for the WIS; the status of data availability relative to these needs; and what is needed to complete and sustain a user friendly WIS data-base?
- What staff, training, technical assistance, hardware, and software are needed to get the WIS system operating so that data users can use it to make queries, generate reports, tabulate statistical reports and/or link data to software packages that can be used for policy analysis and modeling for the policy program described in this report?

Should remote sites that collect data from the Amman-Zarqa Basin, including the Jordan Valley, be connected using a wide area network (WAN)? If so, which sites and what hardware and software are required to link these data collection sites with the current LAN.

It is expected that in the course of this assessment, the Ministry will develop a step by step plan for completing, consolidating, and expanding the WIS system; upgrading it on a continuous basis; and developing a capacity to effectively manage it. The plan should also include consideration of forming linkages between remote stations and the current LAN system through a wide-area network. The WPT recommends that USAID provide technical support for this strategic planning process.

Consolidating the MIS

Currently, each organization in the ministry (WAJ, JVA, and MWI) has its own management information system unit. These units are responsible for the operation and maintenance of servers and workstations and for design, development, and installation of software used by the different sections in each organization. MWI's LAN system links all users (MWI, JVA, and WAJ) and manages the operation of the network. Because the databases for each organization (MWI, JVA, and WAJ) were developed at different times and customized to its own needs, these databases were developed using different software packages. This has tended to limit transferability of data between the different databases and presents obstacles to integration of these systems. Having three different information units in the three organizations (MWI, JVA, and WAJ) has also led to a relatively fragmented system.

The WPT recommends that the Ministry give serious consideration to restructuring these separate MIS systems into one overall MIS unit. Having one body in the ministry responsible for managing computers and information systems all over the ministry would improve efficiency and allocate resources where they are most needed.

One way to restructure would be to create a single unit, and organize it into three sub-units (operation and maintenance, systems development, and data management). The operation and maintenance sub-unit would be responsible for the help desk, network management, Internet access, and general maintenance of the system (including upgrading hardware). The systems development sub-unit would be responsible for system analysis, development, programming, training, and a broad multipurpose GIS that could serve different needs in the ministry. The data management sub-unit would be responsible for data entry, data processing, data verification, and data flow management.

To evaluate and implement this recommendation, the Ministry will need training and retraining, and technical assistance in overall management, organizational design, and wide area networking. It will also need additional hardware and software.

3.3 Conclusions

The Government of Jordan has taken an impressive number of steps that reflect its commitment to improving its capability to strategically manage its very limited freshwater resources. The government's recently approved water policies indicate that it is committed to managing water resources in ways that improve the socio-economic returns to water, sustain irrigated agriculture in the Jordan Valley, and reduce abstractions from groundwater to sustainable or safe yield. The government realizes that it will take time and substantial effort before its own capabilities for data collection, analysis, and policy-oriented model building can support better strategic management of the country's limited freshwater resources.

For this reason, it is important to begin to tackle some of the country's water problems in a way that supports development of both a long-range water policy program and the capabilities within government to manage such a program. The WPT believes the best way to do this is by developing a small number of policy implementation support activities in one water basin—the Amman Zarqa Basin. Proposed implementation activities for the AZB are consistent with the MWI's stated policy objectives, they are implementable within a two to three year period, and they lay the groundwork for development of a full fledged, integrated, water policy implementation plan for the AZB.

The proposed activities achieve two other goals. They link past investments in MWI's MIS to policy-oriented data needs, policy analysis, and policy-oriented modeling activities. Moreover, they provide the basis for real learning in policy implementation that can be extended to the country's other water basins, and to the freshwater supply and use systems for the country as a whole. If successful, the AZB policy implementation support activities could go a long way toward putting Jordan on a more sustainable water use trajectory.

Appendix A

List of Publications Reviewed

Abt Associates, Inc. 1999, Private Sector Participation in the Jordan Water Sectors: Analysis and Recommendations for Reforms, USAID, January, 1999.

Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ), 1998, Economics of Water, October, 1998.

Deloitte and Toche, 1996,, Structural Adjustment and Polic Support Project-Water: Jordan-Final Report prepared of the MWI of the Hashemite Kingdom of Jordan, CIDA, December, 1996.

El-Naser, H. , Zabet, T., and Rimawi, O., 1998a, Two Dimensional Finite Element Model for Groundwater Flow of Dhuleil-Hallabat System, Jordan, Accept for publication by Mu'tah Journal for Research and Studies, Jordan.

El-Naser, H. 1998m Sustainable Development, Us and Conservation of the Jordan River/Jordan, Paper submitted to the FAO office/ Cairo

El-Naser, H, 1998, Current Situation of Jordan's Water Sector, Paper prepared for Conference of Financing Water Projects in the Middle East and North Africa, 18-21m October 1998.

FORWARD, 1998, Design and Implementation of a Financial Accounting System for the Jordan Valley Authority – Work Plan, December, 1998, USAID.

FORWARD, 1998, The Jordan Valley Authority Cost/Tariff Model – Operation and Maintenance Costs, December 1998, USAID.

FORWARD, 1998, The Jordan Valley Authority Cost/Tariff Model – Users Manual, December 1998, USAID.

FORWARD, 1998, The Water Authority of Jordan-Water and Wastewater Cost/Tariff Models, USAID, December, 1998.

IUCN, 1991, NATIONAL ENVIRONMENT STRATEGY FOR JORDAN, A Resource Book of Information and Guidelines for Actions, co-sponsored by the Hashemite Kingdom of Jordan and USAID, August 1991.

Ministry of Water and Irrigation (Jordan), 1988, Law No. 18 of 1988 Water Authority Law, Official Gazette No. 3540, March 17, 1988.

Ministry of Water and Irrigation (Jordan), 1988, Law No. 19 of 1988 Jordan Valley Development, Official Gazette No. 3540, December 17, 1988.

Ministry of Water and Irrigation (Jordan), 1992, Law No. 54 of 1992 Administrative Organization of the Ministry of Water and Irrigation, Official Gazette No 3866, December 1, 1992.

Ministry of Water and Irrigation (Jordan), 1997, Water Sector Investment Program: 1997-2011.

Ministry of Water and Irrigation (Jordan), 1997, Unified Water Resource Monitoring System Program Document.

Ministry of Water and Irrigation (Jordan), 1997, Water Utility Policy.

Ministry of Water and Irrigation (Jordan) , 1997, Jordan's Water Strategy.

Ministry of Water and Irrigation, 1997, Economic and Social Development Plan 1998 – 2002 Water and Irrigation Sector, The Hashemite Kingdom of Jordan.

Ministry of Water and Irrigation (Jordan), 1998, Ground Water Management Policy, February 1998.

Ministry of Water and Irrigation (Jordan), 1998, Irrigation Water Policy, February 1998.

Ministry of Water and Irrigation JVA, 1997 Use of Brackish Water for Sustainable Irrigated Agriculture in the Southern Jordan Valley, Plan of Project, GTZ, October, 1997.

Ministry of Water and Irrigation JVA, 1998, Terms of Reference and Contract Agreement for Consultant Services for the Jordan Rift Valley Improvement Project, September, 1998.

Ministry of Water and Irrigation JVA, 1998, WMIS-Water Management Information System, Project Phase B: Integration of the WMIS into JVA Water Management Activities, November , 1998.

Ministry of Water and Irrigation WQICP, 1995, Water Monitoring System Long-Term Plan, The Hashemite Kingdom of Jordan, USAID, March, 1995.

Ministry of Water and Irrigation WQICP, 1995, Water Monitoring System Upgrade Plan Vol. 1, The Hashemite Kingdom of Jordan, USAID, August, 1995.

Ministry of Water and Irrigation WQICP, 1995, Detailed Engineering Design & Final Report, The Hashemite Kingdom of Jordan, USAID, August, 1995.

Ministry of Water and Irrigation WQICP, 1995, Water Monitoring System Upgrade Plan Vol. 2 The Hashemite Kingdom of Jordan, USAID, August, 1995.

Ministry of Water and Irrigation WQICP, 1996, The MWI Automation Plan, The Hashemite Kingdom of Jordan, USAID, October 1996.

Ministry of Water and Irrigation WQICP, 1996, Unified MIS Concept of Operation Plan, The Hashemite Kingdom of Jordan, USAID, December, 1996.

Ministry of Water and Irrigation WQICP, 1997, Organization Plan for the Environmental Protection Directorate, Design, Staffing Pattern, and Coordination, USAID, September, 1997.

Ministry of Water and Irrigation WQICP, 1997, Laboratory Operations and Quality Assurance Procedures For Central Laboratory of the Water Authority of Jordan, USAID, July 1997.

Ministry of Water and Irrigation WQICP, 1997, Draft Environmental Protection in the Ministry of Water and Irrigation- Findings of Key Activities, Linkages, and Organization, The Hashemite Kingdom of Jordan, USAID, July, 1997.

Ministry of Water and Irrigation WQICP, 1997, Proposed Policies for the Water Sector – Final Draft, Policy Profiles Vol. 1, The Hashemite Kingdom of Jordan, USAID, January, 1997.

Ministry of Water and Irrigation WQICP, 1997, Proposed Policies for the Water Sector – Final Draft, Policy Profiles Vol. 2, The Hashemite Kingdom of Jordan, USAID, January, 1997.

Ministry of Water and Irrigation WQICP, 1997, Refurbishment Plan for the Sustainable Operation of the Central Laboratory of the Water Authority of Jordan, The Hashemite Kingdom of Jordan, USAID, November, 1997.

Ministry of Water and Irrigation WQICP, 1997, Draft Organization Plan for the Environmental Protection Directorate, Design, Staffing Pattern, and Coordination, The Hashemite Kingdom of Jordan, USAID, September, 1997.

Ministry of Water and Irrigation WQICP, 1998, WQICP Final Report, The Hashemite Kingdom of Jordan, USAID, November, 1998.

Ministry of Water and Irrigation WQICP, 1998, MWI Network Operation, The Hashemite Kingdom of Jordan, USAID, October 1998.

Ministry of Water and Irrigation WQICP, 1998, Acceptance Test Plan for the Unified MIS Network, The Hashemite Kingdom of Jordan, USAID, July 1998.

Ministry of Water and Irrigation WQICP, 1998, Unified MIS Network Installation Report for the Local Area Network at the Ministry of Water and Irrigation's Main Building, Shmeisani, Amman, Jordan, The Hashemite Kingdom of Jordan, USAID, June, 1998.

Ministry of Water and Irrigation WQICP, 1998, Configuration Management Plan for the Local Area Network at the Ministry of water and Irrigation, Main Building, Shmeisani, Amman, Jordan, The Hashemite Kingdom of Jordan, USAID, June, 1998.

Ministry of Water and Irrigation WQICP, 1998, Water Resources Functions and Organizations Assessment Document- Water Quality Improvement and Conservation Project Ministry of Water and Irrigation, The Hashemite Kingdom of Jordan.

Ministry of Water and Irrigation WQICP, 1998, Water Resource Function and Organization Assessment Document, The Hashemite Kingdom of Jordan, USAID, September, 1998.

Ministry of Water and Irrigation WQICP, 1998, Configuration Management Plan for the Local Area Network at the Ministry of Water and Irrigation Main Building Shmeisani, Amman, Jordan, The Hashemite Kingdom of Jordan, USAID, June, 1998.

Ministry of Water and Irrigation WQICP, 1998, Water Information System (WIS) Databases Design Update Document, The Hashemite Kingdom of Jordan, USAID, April 1998.

Ministry of Water and Irrigation WQICP, 1998, Water Information System Databases Users Guide, The Hashemite Kingdom of Jordan, USAID, April 1998.

Ministry of Water and Irrigation WQICP, 1998, Analysis of FOXPRO to ORACLE RDBMS Migration for Groundwater Data, The Hashemite Kingdom of Jordan, USAID, April 1998.

Ministry of Water and Irrigation WQICP, 1998, MWI Software Solutions, The Hashemite Kingdom of Jordan, USAID, October 1998.

PRIDE, 1992, A Water Management Study for Jordan, USAID, August 1992.

SCP-Gersar and Consolidated Consultants, 1997, REMOTE CONTROL OF THE KING ABDULLAH CANAL, dev. Of the Hashemite Kingdom of Jordan MWI-JVA, June, 1997.

USAID/Jordan, 1998, STRATEGIC OVERVIEW, 1997-2001, March,1998.

World Bank, 1997, The Hashemite Kingdom of Jordan Water Sector Review, Rural Development, Water Environment Department Middle East and North Africa Region.

Appendix B

Persons Interviewed

Name	Organization	Position	Date
Government Officials			
Dr. Kamel Mahadeen		Minister of Water and Irrigation	8/3/1999
H.E. Eng Qusai Qutaishat	MWI	Secretary General	26/1/1999
H.E. Dr. Dureid Mahasneh	JVA	Secretary General	26/1/1999
H.E. Eng. Nawaf Al Daoud	WAJ	Acting Secretary General	26/1/1999
Dr. Billal Al Bashir	JVA	SG Advisor	26/1/1999
Eng. Zafer Alem	JVA	Deputy SG	26/1/1999
Eng. Dia Al Madni	JVA	Bilateral Section	26/1/1999
Eng. Saed Abu Hawilah	WAJ	Director of Zai Water TP	28/1/1999
Eng. Mahmoud Abu Salim	JVA	Director of Karameh Dam	28/1/1999
Eng. Avadis Serbekian	JVA	Asst. SG for Operation	28/1/1999
Eng. Abdul Wahab Mattar	WAJ	Director of WWTP department	2/2/1999
Eng. Khaild Smadi	JVA	Dams Department	2/2/1999
Dr. Hazim Al Nasir	MWI	Acting SG	2/2/1999
Eng. Mohammed Al Najjar	MWI	Environmental Division	2/2/1999
Eng. Edward Kankar	MWI	Water Resources Division	2/2/1999
Eng. Suzan Taha	MWI	National Water Master Plan coordinator	2/2/1999
Eng. Mahmoud Shloul	MWI	Head of Network Operation Sec.	3/2/1999
Eng. Zuhair Hiasar	MWI	Head of MIS Steering Comm.	4/2/1999
Mr. Mohammed Al Atrash	MWI	Hydrogeologist	2/2/1999
Eng.Ibtisam Saleh	MWI	Database administrator	3/2/1999
Eng. Mohammed Al Mouidi	WAJ	Director of Asamara WWTP	4/2/1999
Eng. Mohammed Al Rashid	WAJ	Upland Water Resources Monitoring	4/2/1999
Eng. Naim Dabbour	JVA	Director of King Talal Dam	4/2/1999
Eng. Yasser Nazzal	MWI	Irrigation Engineer	6/2/1999
Eng. Saleh Malkawi	WAJ	Director of WAJ Labs	1/2/1999
Eng. Suzan Malkawi	WAJ	Head of Environmental Isotopes Sec.	1/2/1999
Eng. Ziad Taani	WAJ	Head of QA/QC at WAJ Labs	1/2/1999
Eng. Farouq Dawabsheh	WAJ	Head of Biochemical WW Div.	1/2/1999
Non-Officials			
Mr. Dario Santo	WQIC project	Senior Hydrologist	27/1/1999
Eng. Samir Kawar		Former Minister of Water	27/1/1999
Eng. Khairi Shukri		Private Farmer	28/1/1999
Dr. Munther Hadaddin		Former Minister of Water	30/1/1999
USAID Officials			
Lew Lucke		USAID Mgmt Mission Director	
Cecily Mango		Water & Env Office Director	
Bill Hoadley		Water & Env Senior Water Advisor	
Abdullah Ahmad		Engineer	

Appendix C

Field Trips

1. Zai Water Treatment Plant

2. Jordan Valley from intake to King Abdullah Canal from the Yarmouk River to Karameh Dam (including visit with a large ago-exporter)

3. Amman/Zarqa Basin from As-Samra Wastewater Treatment Plant to King Talah Dam (including side visits to large farmers irrigating with wells in the uplands)

Appendix D

Background on Reuse of Treated Wastewater in Irrigated Agriculture

Due to the cost associated with treating wastewater to a level fit for direct human consumption and the lack of public acceptability of such water for domestic purposes, use of treated wastewater is limited to irrigated agriculture and certain industries.

Safe and sustainable reuse of wastewater must be by plan and design. The recipient water user must be clearly identified; the water quality requirements of the recipient determined; the wastewater treated to meet those quality requirements; and the management of treated wastewater reuse integrated with other water sources to maximize its beneficial use.

Four constituent categories affect the reuse of wastewater in irrigated agriculture: salt and ion concentrations; nutrient load; pollutants (heavy metals, organic compounds, pesticides, etc.); and microorganisms (microbiological contamination). Typically wastewater treatment is not designed to remove salt from wastewater and, in fact, may result in an increase (~5%) in salt concentration depending on the method of treatment. The same is true for ions (sodium, chlorine, boron, etc.) which may be harmful to crops. If chlorination is part of the treatment process, chlorine concentrations and chlorine compounds will increase in the treated effluent. Salt and ion concentrations can be reduced via reverse osmosis but this is generally too expensive to be warranted for irrigation. (To comply with treaty terms for Colorado River water quality flowing to Mexico, the United States built reverse osmosis (R-O) plants to treat brackish drain water from irrigation return flows near Yuma, Arizona. The R-O plants have never been operated as other methods for reducing the salt load of the Colorado River proved more cost effective even after the investment in construction of the R-O plants. This is due to the relative high energy cost associated with R-O. However, in the case of water from King Talal Reservoir (KTR), 185 m above sea level, utilization of the natural potential energy head for R-O treatment may warrant further investigation and is proposed here as a special study.) Thus, with regard to salinity, the use of wastewater in irrigation is a salt management issue and is discussed in more detail below.

Wastewater rich in mineral and organic nutrients promotes plant life, especially algae. This results in eutrophication and reduction in the dissolved oxygen content, which can cause extinction of other organisms. High nutrient loads in irrigation water can accelerate vegetative growth at the expense of fruit production. Under some conditions, this can lead to increased consumptive water use and sensitivity to moisture deficit. High concentrations of some nutrients, notably nitrates, can burn plants. Nutrients in wastewater can be reduced with effective sludge management, aquatic plants (duckweed), artificial wetlands, etc. Presently the King Talal Reservoir is acting as a secondary treatment facility where nutrient consumption takes place.

Water pollutants such as phenols and other organic compounds, heavy metals, and pesticides are best prevented at their source since treatment can be very expensive. Blending with non-polluted water can be used to dilute polluted water below maximum allowable thresholds, but the required mixing ratios can be very large. The use of polluted water for irrigation can result in contamination of the food product as well as harm to the crop. Fortunately, the amount of toxic organic compounds, heavy metals, and pesticides in treated wastewater effluent appear to be within acceptable levels for safe use in irrigation.

Microorganisms are the biggest concern in the use of wastewater for irrigation, not only from the standpoint of contamination of the food product, particularly if likely to be eaten uncooked, but also from the standpoint of the health of farm laborers and others who may come in direct contact with the water. The use of micro irrigation and plastic mulches, both widely practiced in the Middle Jordan Valley (MJVA) where water is received from KTR, can minimize the contamination of produce. The total fecal coliform count (TFCC) in the water from KTR, site 700, immediately upstream of the King Abdullah Canal (KAC) is usually above 1000 MPN/100mL. Less than 1000 MPN/100mL is the Jordanian standard for restricted use in irrigation. (The standard for unrestricted use has not been determined yet, but would certainly be more stringent.) It should be noted that the water in KAC at a sampling site, C0, just below the point of diversion from the Yarmouk River and another sampling site, C1, just upstream of the confluence with KTR, frequently has a TFCC above 1000. The origin (soil born, human waste, etc.) of these coliforms is unknown. What is clear is that the number of colonizing micro-organisms in treated effluent must be reduced further through more effective and complete waste water treatment before wastewater can be used in unrestricted irrigated agriculture. While this can be achieved via chlorination, most plants are extremely sensitive to chlorine, and thus alternatives must be sought.

Thus, the principal limitations to using treated wastewater in irrigation in Jordan are related to salinity of the wastewater and microorganisms remaining in the treated effluent. The latter can only be handled via more effective and complete wastewater treatment. The former is handled via salt management and is the subject of the following discussion.

There are three reasons salt in irrigation water can be a problem: 1) increases the osmotic potential, 2) can be detrimental to soil structure, and 3) specific toxicity to plants. Salt increases the osmotic potential and thus the energy a plant must exert to take up water from the soil. In this sense, salt has the effect of reducing water available to the plant. Salinity in water is measured by its electrical conductivity and expressed in dS/m (mmho/cm). (The electrical conductivity is related to the total dissolved solids, TDS, expressed in parts per million, ppm. For the dissolved solids typical of most water in Jordan 1 dS/m = 640 ppm.)

Not all plants respond in the same way to salt. The range in salt tolerance of agricultural crops is 8 to 10-fold and there is a direct relationship between salt tolerance and yield potential under saline conditions. Most crops presently grown in Jordan are sensitive or moderately sensitive to salt and suffer potential yield losses when the electrical conductivity of the irrigation water is >2.5 dS/m (1,600 ppm) in the case of tomatoes and cucumbers and >1.7 dS/m (1,100 ppm) in the case of citrus.

The average salinity of the treated effluent from As-Samra in 1998 was 1.9 dS/m (1,230 ppm). The average TDS for 1997 at monitoring site 700 was 1.6 dS/m (1,055 ppm), at site C1 on KAC just upstream of the confluence with the Zarqa Drainage, it was 0.9 dS/m (575 ppm), and at site C2 just downstream of the confluence it was 1.4 dS/m (888 ppm).

When the sodium concentration in irrigation water is high or the sodium absorption ratio (SAR)—ratio of sodium ions to calcium and magnesium ions—the soil structure can be adversely affected reducing the permeability of soil to water. Sodicity does not appear to be a problem in the Jordan Valley as gypsum is naturally available in the soil to combine with the sodium, but the SAR of the KAC water, even downstream of the Zarqa River confluence, is low. This should be investigated further.

Specific ions which can be toxic to plants and affect plant growth include sodium, chlorine, and boron. For the water supply of the Jordan Valley, including that portion coming from KTR, sodium and boron should not be a problem. Chlorine could be a slight problem with the KTR water, particularly if applied by sprinklers.

Salt may occur naturally in the soil, accumulate as the result of concentration from evapotranspiration, and be aggravated by salt loading from the application of brackish irrigation water and fertilizer. Farmers in the MJV receiving water from KTR associate the degradation of their land by salt with the As-Samra wastewater treatment facility after it came on line. While the wastewater in the Zarqa Basin certainly contributed to the salt load in the irrigation water for the middle Valley, it is less clear that this is the principal cause of land salinization in the Valley. Water allocation practices that indirectly encourage farmers to irrigate too much land for the available water supply and thereby not achieve adequate leaching may also have contributed. It is also not clear whether drainage is adequate to achieve efficient leaching of salts. Furthermore, natural salt springs in the Zarqa Drainage contribute significantly to the salt load of water coming from KTR reservoir. These springs have been bypassed since late 1996. The average salinity of KAC water below the confluence with water from KTR, monitoring station C2, was nearly three times that (2.3 dS/m versus 0.8 dS/m) in the canal immediately upstream of the confluence at monitoring station C1. In 1997 the average salinity at C2 (1.4 dS/m) was 50% greater than at C1 (0.9 dS/m).

The WPT observed well-established lemon orchards upstream of KTR apparently irrigated directly from the Zarqa River. While the trees appeared slightly chlorotic, they were bearing fruit. Since lemon trees are sensitive to salt this is an indication that the

Zarqa River water, which at that point is nearly 50% effluent from As-Samra wastewater treatment plant, is of adequate quality from a salinity standpoint to be used for irrigation.

The effects of salt on irrigated agriculture can be addressed through appropriate irrigation technologies and water management, assuring sufficient leaching provided the drainage is adequate, and crop substitution in areas where a build-up of soil salinity cannot be controlled at a level acceptable for the crop being grown.

Micro irrigation, the localized application of water on or beneath the soil surface, is an effective way to use moderately saline irrigation water. Experiments have demonstrated that near maximum crop yields can be achieved with moderately saline irrigation water when high frequency irrigation (daily or alternate-day) micro (trickle or drip) irrigation is employed. The implied requirement for high frequency micro irrigation, besides the technology investment, is delivery flexibility. Since water in the Jordan Valley is delivered on a fixed-frequency (twice weekly to three times per week) basis, farmers are required to have on-farm ponds to store water for out of rotation use. Approximately half of the farms in the Jordan Valley have on-farm reservoirs to re-regulate the fixed delivery from the main system.

Currently (1996 data) over half of the total irrigated area (9,600 ha) in the MJV has micro irrigation. The principal limitations to higher irrigation efficiency are low on-farm irrigation management efficiency (irrigation application relative to crop demands) and only fair application uniformities.