COMPETING WATER DEMANDS IN JORDAN:

THE NEED AND OPPORTUNITY FOR IMPROVED WATER MANAGEMENT

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ABSTRACT

Jordan does not have a water supply sufficient for current and future irrigation, domestic, and industrial needs. The Jordan Valley Authority (JVA) provides irrigation water to about 23,000 hectares (57,000 acres) of land in the Jordan Valley where a variety of crops are raised. Water supplied from the Jordan River and its tributaries is limited, and storage is very limited. Domestic and industrial water supplies are also taken from the river, and demands will increase as the population and industrial base expands. Per capita water use is very low, so opportunities to conserve domestic water are limited. Thus the agricultural sector is faced with losing an ever increasing amount of water to domestic and industrial uses; however, much of this water will return to the agricultural sector as treated waste water.

There are several opportunities for improving the efficiency of water use in the Jordan Valley including: rehabilitation of the irrigation water delivery system; improvement of the operation and maintenance of the system; upgrading the skills of JVA operations and maintenance personnel; development of water delivery schedules that are compatible with cropping patterns and on-farm irrigation systems, particularly micro-irrigation systems; providing water of adequate quality for use with micro-irrigation delivery systems; training and providing information and technical assistance to farmers; and assisting in the development of water user organizations.

This paper discusses the activities that are currently underway and are proposed to conserve water in the Jordan Valley.

INTRODUCTION

In 1993, the population of Jordan was about 4,000,000 and water use was estimated as shown in Table 1.

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By the year 2025, the population of Jordan is projected to grow to 12,300,000. In the Amman area, the population is expected to grow from an estimated 1,500,000 in 1993 to 5,360,000 in 2025, with water use increasing from 57 million cubic meters (MCM) (46,000 acre feet) to 266 MCM (216,000 acre feet). While there are alternatives for developing new water supplies for the increased population, they are expensive and/or involve international considerations. There will be continued pressure to reallocate water from irrigation to domestic use, and therefore there will be a need to conserve irrigation water to the extent possible. Fortunately, there are many opportunities for improved water management and water savings in the Jordan Valley. In addition much of the Jordan Valley is ideally situated to receive waste water from the Amman area, so that as Amman obtains additional fresh water supplies and provides adequate waste water treatment, there will be an increasing water supply for the Jordan Valley.

Table 1. Water Use in Jordan in 1993.

Type of Use	Million Cubic Meters	Acre Feet	% of Total Use
Municipal	214	175,000	22
Industrial	33	27,000	3
Livestock	10	8,000	1
Irrigation	726	590,000	74
Total	983	800,000	100

The United States Agency for International Development (USAID) is currently assisting Jordan in water conservation efforts by sponsoring the Water Quality Improvement and Conservation (WQIC) Project. Development Alternatives, Inc. (DAI) is the primary contractor on the WQIC Project, and is working with the JVA to conserve and improve the quality of water delivered for irrigation in the Jordan Valley.

IRRIGATION IN THE JORDAN VALLEY

The Jordan Valley, Figure 1, is Jordan's most important agricultural production area. The area has fertile, flat-lying soils, and varies from 200 to 406 meters (656 to 1332 feet) below sea level. The valley is about 150 km (93 miles) long and varies from 4 km (2.5 miles) to 16 km (10 miles) wide. The mild winters make it an ideal area for growing off-season fruits and vegetables. Crops grown include citrus, banana, many varieties of vegetables, and field crops such as alfalfa and wheat. Irrigable land in the valley totals about 36,000 hectares (89,000 acres), with about 29,000 hectares (72,000 acres) equipped with an irrigation distribution network developed by the Jordan Valley Authority (JVA). About 6,000 hectares

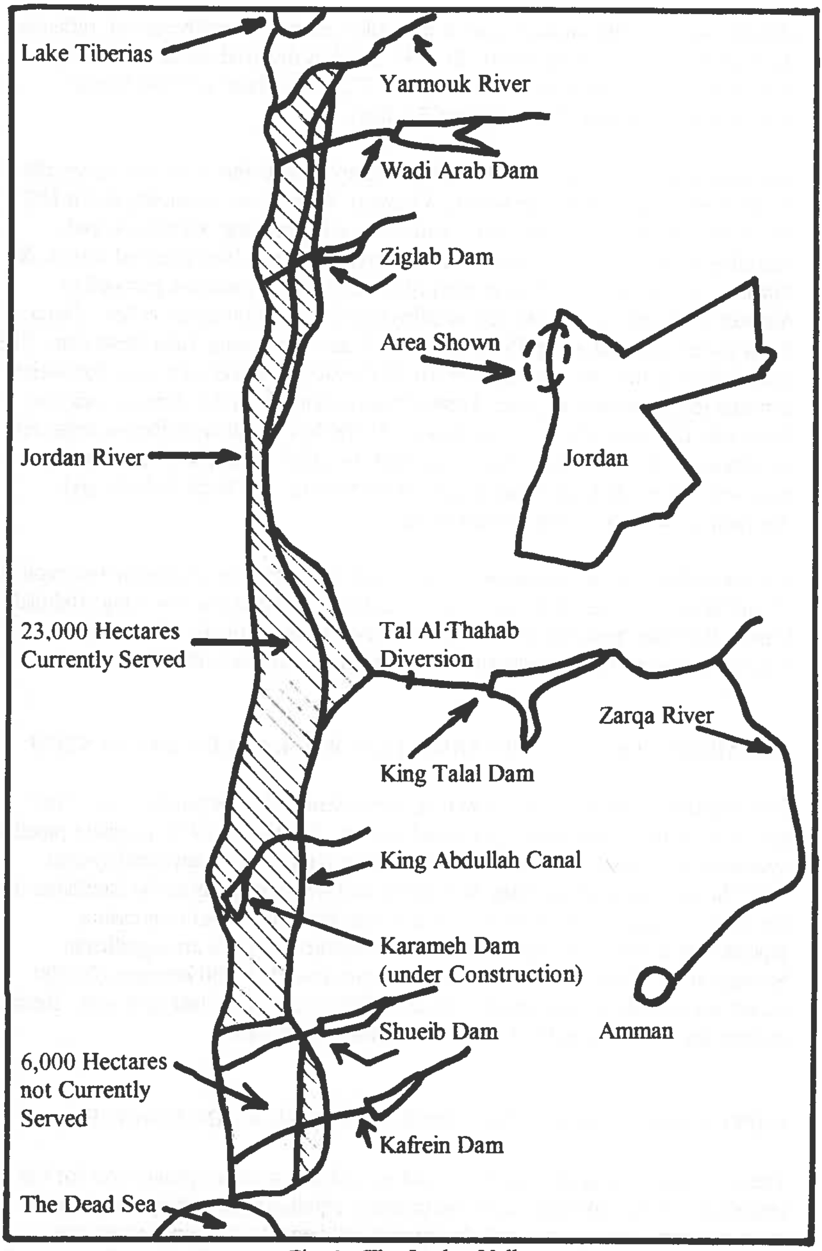

Fig. 1. The Jordan Valley

(15,000 acres) in the southern end of the valley are not currently served, reflecting the scarcity of water in the valley. In 1995 the JVA diverted about 234 MCM (190,000 acre feet) to irrigate the estimated 23,000 hectares (57,000 acres) served, for an average of 1.0 meters (3.3 feet).

The main sources of water for the Jordan Valley include the Yarmouk River, the Zarqa River, and several side wadis. Yarmouk River flows averaging about 100 MCM (81,000 acre feet) per year are diverted into the King Abdullah Canal, including 20 MCM (16,000 acre feet) that are stored and later released from Lake Tiberias. 40 MCM (32,000 acre feet) of the flow in the canal are pumped to Amman for domestic use; the rest is delivered for irrigation in the valley. Zarqa River water is stored in the 75 MCM (61,000 acre feet) King Talal Reservoir. The natural flow in the river averages 65 MCM (53,000 acre feet) per year, but varies considerably from year to year. Treated waste water from the Amman area also flows into the reservoir; the 1994 flow of 51 MCM (41,000 acre feet) is expected to increase to 232 MCM (188,000 acre feet) by 2025. There are small storage reservoirs on Wadi Arab, Wadi Ziglab, Wadi Shueib, and Wadi Kafrein, and diversion structures on other small wadis.

Karameh Dam will be completed in 1997, and will create an off-stream reservoir of 55 MCM (45,000 acre feet) to store winter flows diverted into the King Abdullah Canal. Releases from the reservoir will be used to serve the 6,000 hectares (15,000 acres) in the southern end of the valley that are not yet served.

REHABILITATION OF THE IRRIGATION WATER DELIVERY SYSTEM

Construction of the irrigation system in the Jordan Valley began in 1956. The system was developed as an open canal system. Starting in 1975, pressure pipeline systems were added to serve new areas, and to replace the open canal system. With the exception of the King Abdullah Canal which remains as the backbone of the delivery system, the entire system has now been converted to pressure pipelines, and water savings from reduced seepage and spills are significant. Savings in the North Directorate, where approximately 9,200 hectares (22,700 acres) are served, are estimated to be 20MCM (16,200 acre feet) per year. Similar savings are occurring in the Middle and South Directorates.

IMPROVEMENT OF SYSTEM OPERATION AND MAINTENANCE

There is a need for upgrading the operation and maintenance procedures for the irrigation system. In many cases the pressure pipeline system is operated as if it were an open canal system, and the operational benefits of a pipeline are not realized. Maintenance is carried out on a “repair as needed” basis, the system is allowed to deteriorate until it reaches the point where complete rehabilitation or reconstruction is required. Many of the pipeline accessories, such as pressure control and air relief valves, are in need of overhaul or replacement. Many of the flow meters at the farm turnouts are broken; mostly by debris in the water carried by the pipeline. Another problem area is the poor condition of many of the vehicles and heavy equipment used for day-to-day operation and maintenance activities. There are also existing shortages of some types of vehicles used for daily operation and maintenance.

Studies have shown that the efficiency of the pipeline delivery system is about 70%. This efficiency is based on inaccurate information and is not a true measurement of the physical efficiency of the pipeline. Daily gate opening measurements at the river offtake head works are used to determine inflow to the Zarqa Carriers I and II pipelines. The gates have been through several major repairs and have not been recalibrated for flow measurement, and a daily reading does not adequately account for rise and fall of the river level. Discharges from the pipeline, and billing, are based on measurements of the time between opening and closing the farm turnout valve by JVA field personnel; all farm turnouts have a flow limiting device. The low efficiencies derive because many farmers have illegal keys to the farm turnout control structure and turn on the water after JVA employees finish work for the day. This illegal water is not accounted for in billing and therefore is considered lost water in calculating delivery efficiency. In fact, physical efficiency of the pipelines is significantly higher than 70% and may be close to the desired 90%. However, management efficiency, as measured by the fees collected for delivered water, is low and can be improved.

Operation and maintenance manuals are now being prepared to assist the JVA in providing good operation and maintenance of the rehabilitated irrigation water delivery system. The manuals emphasize regular inspections, preventive maintenance, and proper procedures for operating and maintaining the pressure pipeline system.

UPGRADING THE SKILLS OF JVA OPERATIONS AND MAINTENANCE PERSONNEL

Staff training in operation and maintenance of irrigation water delivery systems is another need that has been identified. In 1995 and 1996 several groups of engineers from the Jordan Valley Authority travelled to the United States for tours of irrigation projects and intensive training on operation and maintenance of pressure pipeline irrigation systems, irrigation water delivery scheduling, and on-farm water management. In November and December 1995 a training program was conducted in the Jordan Valley on Pressure Pipeline Operation and Maintenance. 23 engineers and field supervisors of the JVA attended the program.

The training programs emphasized the need for developing the above mentioned operation and maintenance manuals, and stressed the need for regular inspections, preventive maintenance, and proper procedures for operating and maintaining the pressure pipeline system.

IRRIGATION WATER DELIVERY SCHEDULING

Irrigation water delivery scheduling has the potential for saving a significant amount of water in the Jordan Valley. On-farm irrigation is in transition from surface methods, primarily furrow for vegetables and small basins for orchards, to trickle and micro-spray irrigation. The more modern methods offer savings in labor costs, higher yield potentials (giving higher returns per cubic meter of water used), and less fertilizer and chemical usage. Compared to surface irrigation methods, trickle and micro-spray irrigation offers opportunities for reductions in the volume of water used for a crop because a smaller surface area and soil volume should be wetted at each irrigation.

A baseline survey of irrigation practices in the Central Jordan Valley showed that irrigation water use efficiencies for the "high technology" or trickle irrigation systems are significantly lower than efficiencies for surface irrigation. These low efficiencies are due to several factors, two of which are discussed below.

Currently the irrigation water delivery system is not operated to service on-farm trickle irrigation systems. Trickle irrigation is designed to give the plant a small quantity of water frequently to meet it's transpiration demand. The small quantity of water only wets from to 50% to 60% of the volume of soil containing the roots of the crop, studies have shown that this wetted root volume is sufficient to achieve 100% yield. Therefore, to efficiently use trickle irrigation for some crops, farms must irrigate several times a week during the peak water use period of the crop season. Currently JVA delivers water two times weekly; a schedule suited to surface irrigation at the peak water use period. As a result the farmer is forced to over-irrigate to ensure that enough water is retained in the root zone to carry the plant to the next irrigation period.

Another not insignificant cost to farmers connected directly to the JVA delivery line is the over design of his on-farm delivery system. Because water is delivered twice weekly, the micro irrigation system must have larger main lines to allow irrigation of the entire farm each day water is delivered. All micro irrigation systems evaluated to date have main and submain lines that are significantly oversized, most diameters are double the size that would be needed if demand delivery of water was practiced.

About one half of the farmers have coped with the water delivery schedule by installing reservoirs and pumps to reregulate the water; however in so doing they lose the pressure provided by the pipe delivery system, lose some productive land to the reservoir, and incur fuel and maintenance costs for the pump.

Technical assistance on trickle irrigation system design, installation, and operation is not generally available to the farmers. Most equipment sales agents and manufacturers do not offer no-cost or low-cost services to farmers. It is because of this that most systems are farmer designed. There are private consulting engineers who sell services to wealthier farmers, but most farmers cannot afford to purchase such services. Farmers seeking free or low cost information or assistance in the design and installation of their irrigation system have difficulty in obtaining either. Trickle irrigation is equipment oriented and to achieve high efficiencies of water use requires sophisticated management. As shown in the baseline study, without training and on-going assistance the full benefits from trickle irrigation will not be obtained.

Two pilot study programs are proposed for start-up during the fall 1996 cropping season. An Irrigation Water Delivery Scheduling study will assess the feasibility of JVA changing from the current rotation delivery schedule to a limited-rate on-demand delivery schedule. Under this pilot program farmers will be able to order water for delivery any day and in any quantity, up to a set maximum, throughout the crop season. The total quantity of water used for a crop will not change from current levels, only the water delivery pattern will change. A limited-rate on-demand water delivery pattern is more appropriate for trickle irrigation than is a rotation schedule.

The second pilot program is the establishment of an Irrigation Advisory Service to train and assist farmers in the operation and management of their irrigation systems. The pilot service is envisioned to comprise one junior level field engineer and one supervising engineer from the JVA and one extension agent from the Ministry of Agriculture (MOA). The two pilot programs will work closely together and the primary focus will be the farmers participating in the scheduling pilot program.

QUALITY OF DELIVERED WATER

About 40% of the inflow to the King Talal Reservoir on the Zarqa River is treated municipal waste water from Amman and the surrounding area. The water is high in nutrients and picks up sand and debris as it flow down the Zarqa River to the Tal Al-Thahab intake to the Zarqa Carriers I and II Pipelines. Existing screens and settling basins at the intake are inadequate to remove the algae, moss, and other suspended material in the river. Inspection of non-functioning water meters returned to the JVA workshop shows that trash removal efforts are inadequate. The effect of the trash and debris on drip irrigation systems is also significant.

Those farmers who are using drip irrigation systems use media and screen filters to clean the delivered irrigation water before it is introduced into the lateral lines. However, the smallest media used is about 12.5 mm (0.5 inch) in size and does not remove the smaller inorganic and organic particles. This large media is supplied by companies providing media filters, there are no suppliers of smaller media, though one can find smaller media at crushing plants. In effect, only the large debris is removed from the water, small organic and inorganic particles pass easily through the media filter.

Emitters used typically deliver about 4 liters per hour for vegetable crops, and the small water passages are easily clogged by any sediment or debris in the water. When operated correctly, media filters are ideal for removing organic contaminants, such as algae. Algae is trapped in the upper layers of the filter media bed and removed from the system when the filter is backwashed. Fine inorganic particles are also captured on the upper layers of the bed and in the algae that accumulates on the surface of the filter bed. Screen filters are designed to remove inorganic particles larger than the openings in the screen. When organic material, primarily algae, as well as fine sand are present in the water, and the media filter is not operated properly, screens plug frequently and require manual cleaning. Because it requires frequent cleaning, often the screen element is removed from the filter tank and discarded. The result is that about 75% of all farms experience significant emitter plugging problems beginning the second year of lateral line use.

The Tal Al-Thahab diversion and intake structures on the Zarqa River need to be upgraded to improve the quality of water provided to the JVA distribution system. A bar screen with an automatic power operated rake at the river diversion, enlarged settling basins, and screens below the settling basins need to be installed. Improving the quality of the delivered water would allow farmers to use the proper media sizes in filters and reduce the need for frequent back flushing of media filters and cleaning of screens. USAID and the JVA have agreed to share the cost of rehabilitating this weir. The work is scheduled for completion by the end of 1997.

TRAINING, INFORMATION, AND TECHNICAL ASSISTANCE FOR FARMERS

A lack of training and the unavailability of information on management and maintenance of micro irrigation systems are two reasons the performance of such systems in the Jordan Valley is well below an optimum level. Under the WQIC Project, materials for training farmers and assisting personnel in micro-irrigation system operation and maintenance, on-farm irrigation system management, and irrigation practices and equipment evaluation are being prepared.

The training material is being prepared in a modular format. A total of 20 modules are being prepared in the three areas. Most modules are independent and do not depend upon another for material. This format requires some duplication of material but allows the trainer to select modules to suit the training requirement and time restrictions for a given program.

Currently most farmer are applying quantities based on JVA crop water allocations. These allocations were derived in the early 1960's for surface irrigation and assume average levels of efficiency in water delivery and application and include a leaching factor. Now many on-farm systems are pressurized, application efficiencies are higher, and soil salinities have been reduced. Neither JVA nor farmers take these changes into consideration when determining application amounts. Everyone assumes water applications should be the same as before. Farmers use all the water they can get and complain that they are not getting enough. The end result is significant over irrigation. An example of the significance of the problem is available.

One of the better educated farmers (MS Agronomy) in the Middle Jordan Valley has been cooperating with researchers from the University of Jordan, the work is co-sponsored by the French Mission Règionale Eau Agriculture and the WQIC Project, in determining proper irrigation schedules and application quantities for open field and greenhouse tomato and cucumber crops. The research program is using Water Mark™ soil moisture sensors and Class A evaporation pans to provide the necessary data. In the first crop season the farmer reduced his water use on tomato and cucumber by 50% with no negative effect on crop yields. For a strawberry crop irrigated using Water Mark™ soil moisture information, water use was reduced by 75%.

The cooperating farmer has a new system and high distribution uniformities (>80%). The water use savings derive from using soil-water tensions to indicate plant moisture needs and determine irrigation application schedules. These numbers are indicative of the savings possible when farmers have the information available to allow them to properly operate their on-farm irrigation water application system.

WATER USER ORGANIZATIONS AND ORGANIZATIONAL LINKAGES

A pilot Water User Organization (WUO) is being considered for the Jordan Valley with the following purposes:

- Making bulk sales of water to the head unit on the line;
- Having farmers manage distribution along the line, ending the need for farmers to confirm deliveries individually;
- Assisting users in resolving potential or actual water conflicts on the line;
- Introducing irrigation extension information and/or water conservation measures;
- Working with farmers to produce seasonal cropping plans;
- Assigning JVA staff to work closely with the lateral group, mirroring what was done in the 1960s, before the rapid expansion of the system;
- Providing sensitization and training to both farmers and JVA staff; and
- Assisting with or linking to marketing imperatives.

Sustainable irrigation water conservation can only occur where there is a concerted and co-ordinated effort by all players in the arena. To effectively conserve irrigation water the farmer needs information on daily crop water use, irrigation scheduling, quantities of water to apply at each irrigation, and efficient operation of the irrigation system. At a minimum, programs concerning irrigated agriculture conducted by the JVA, MOA, National Center for Agricultural Research and Technology Transfer (NCARTT), and the universities in Jordan should be co-ordinated. Each organization's contribution can complement input from others to support irrigation water conservation.

CONCLUSION

There are many opportunities for the conservation of irrigation water in the Jordan Valley. The efficiency of the JVA irrigation water delivery system can be increased from about 70% to 90%, distribution uniformity of drip systems can be increased from about 64% to 80%, and crop water applications can be better matched with crop water needs. Taken together, the saved water could exceed 88 MCM (71,000 acre feet) of the current annual water usage in the Valley. The saved water could be used to increase the cropping intensity factor (winter and summer season crops) on existing cultivated lands and to reclaim and bring new land under irrigation.