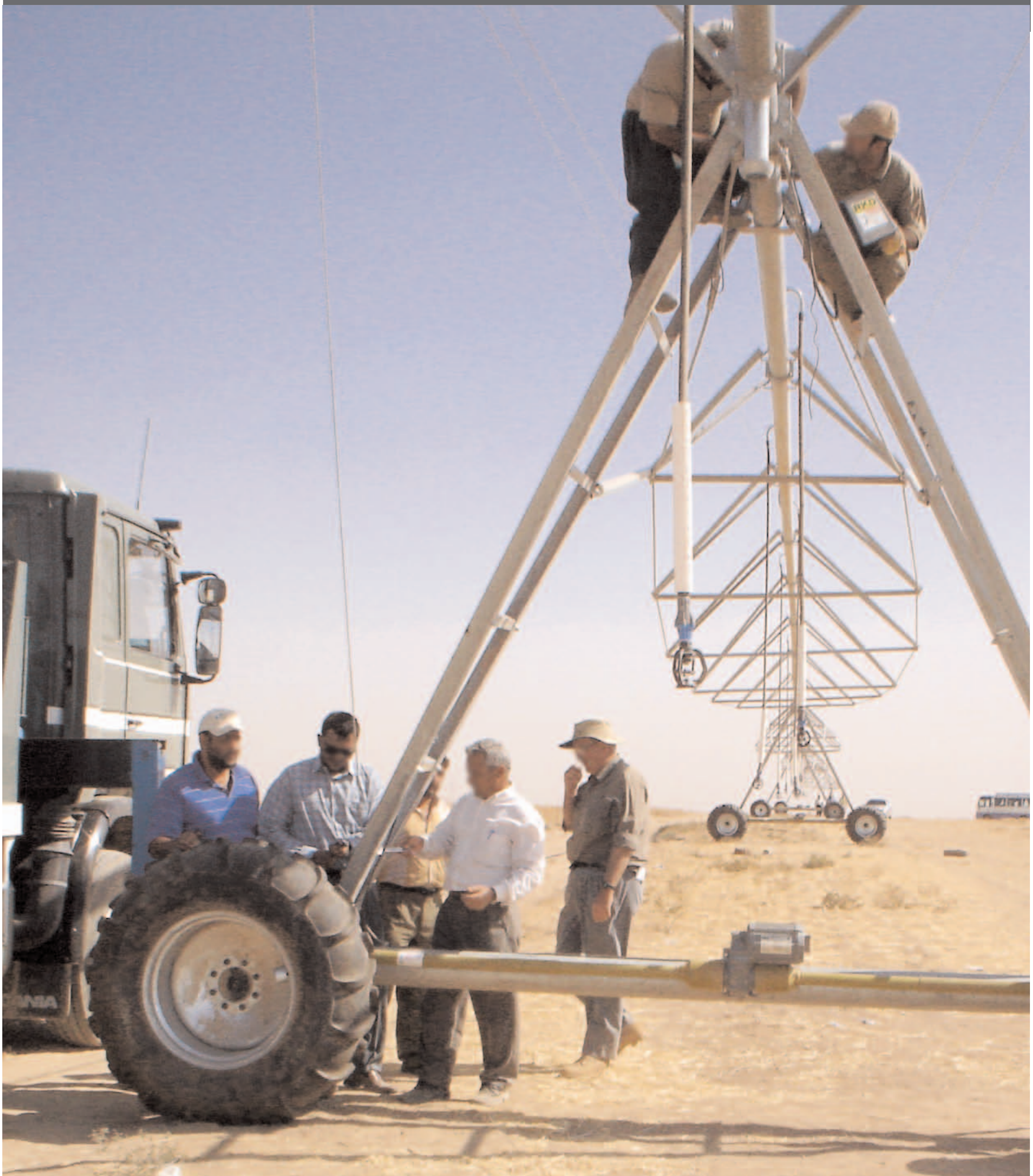
2.4 INFRASTRUCTURE FOR IMPROVING WATER USE EFFICIENCY



INTRODUCTION AND BACKGROUND

Saline soils are exacerbated by improper irrigation and inadequate drainage.

Agricultural production in Iraq depends heavily on irrigation. According to the results of the ARDI AEZ program (see Section 3.1), the total irrigated area in Iraq during the 2004 – 2005 period was approximately 3,543,000 hectares, accounting for 51% of the total cultivated agricultural land. Of the irrigated areas, approximately 63% receive water through gravity fed irrigation systems, 36% from rivers and major channels via pumps, and the remaining 1% from ground water aquifers and springs. The main irrigated crops are wheat, barley, rice, maize, vegetables, and date palms. In the arid southern regions of Iraq, irrigation is necessary year-round. In the northern region, irrigation is necessary during the dry, hot summers, and there is some supplemental irrigation during the winter season.

Iraq has an existing, although poorly maintained, irrigation and drainage infrastructure. Prior to 1980, the previous regime maintained and made improvements to water-related infrastructure. Irrigation canal systems were upgraded with new infrastructure, including regulators and pumps to distribute water to agricultural areas, and many canals were lined with concrete to reduce water loss and drainage problems. The government maintained this infrastructure through a network of district-level Water Resource Directorates until onset of the Iran-Iraq war (1980 – 1988), when the government diverted its resources into the war efforts and seriously neglected the nonmilitary infrastructure. This neglect continued through the period of UN sanctions (1990 – 2003).

ARDI conducted irrigation projects in these governorates.

Failure in distribution pipe from junction box.

Culvert blocked by years of accumulated debris.

The poor condition of Iraq's water sector has resulted in numerous problems for agricultural production. Overirrigation in the upper reaches of the canal systems, underirrigation in the lower reaches, and other forms of poor agricultural management have caused water logging and salinization, significantly reducing the productivity of agricultural lands. A high water table associated with salinity problems affects more than half the irrigated area in Iraq. In addition, there has been a decrease in the supply of water available in Iraq and the quality of the available water has deteriorated over the past two decades, largely due to development activities in Turkey and Syria. The salinity of the Tigris and Euphrates rivers during the summer months is deteriorating downstream to an alarming level. These problems are affecting the central and southern regions of Iraq most profoundly, including the governorates of Wassit, Missan, Kerbala, Babylon, Baghdad, Diyala, Najaf, and Thi-Qar. These are arid regions in which farmers depend on year-round irrigation for agricultural production.

When ARDI initiated reconstruction and development activities in 2003, the water sector was suffering from over 20 years of neglect, resulting in poor agricultural production to such an extent that many farmers left their lands altogether. While the government's existing policy was to invest in new infrastructure, ARDI programs stressed improving the performance of existing infrastructure, working directly with the farmers themselves, and strengthening the intuitions serving the farmers.

All of ARDI's activities undertaken for the water resources sector were participatory and based on principles dictated by the water demand management approach (supplying water based on the crop needs, both in quantity and time). ARDI worked on increasing institutional capacity of the Ministries of Agriculture and Water Resources in Baghdad and the Ministries of Agriculture and Irrigation in Erbil and Sulaymaniyah. ARDI also considered it important to work directly with agricultural producers and related NGOs to improve water management and crop production.

ARDI's projects in the water sector included:

- Physical improvements to existing irrigation infrastructure – canals, structures, and laser land leveling;
- Expanding access to highly efficient irrigation equipment;
- Introducing small-scale irrigation systems;
- Addressing issues of drainage and salinity; and
- Improving data collection for water resource planning.

PHYSICAL IMPROVEMENTS TO WATER MANAGEMENT INFRASTRUCTURE

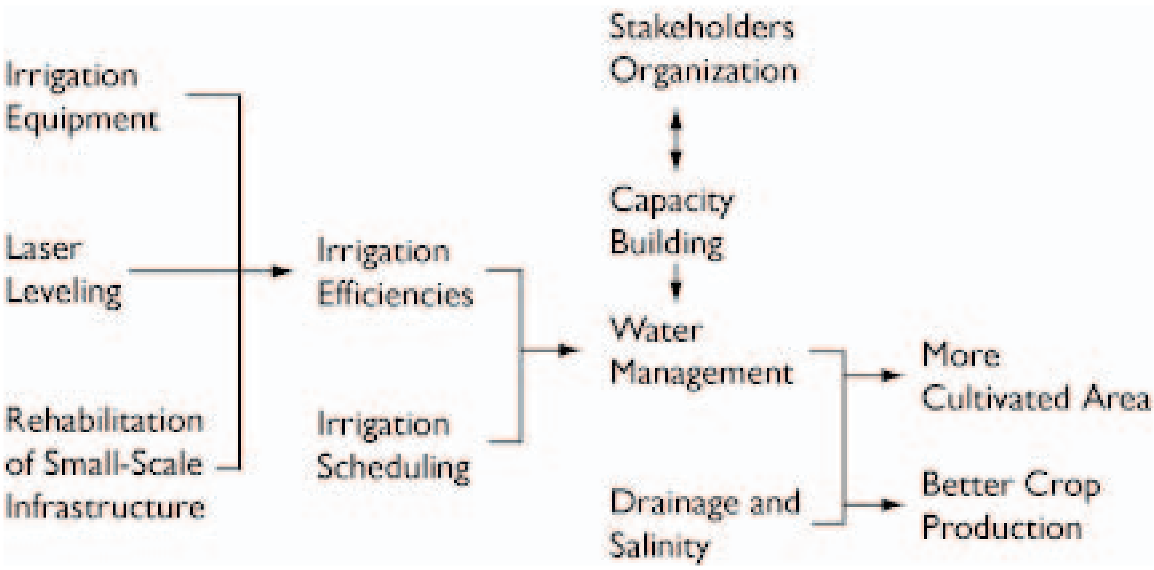


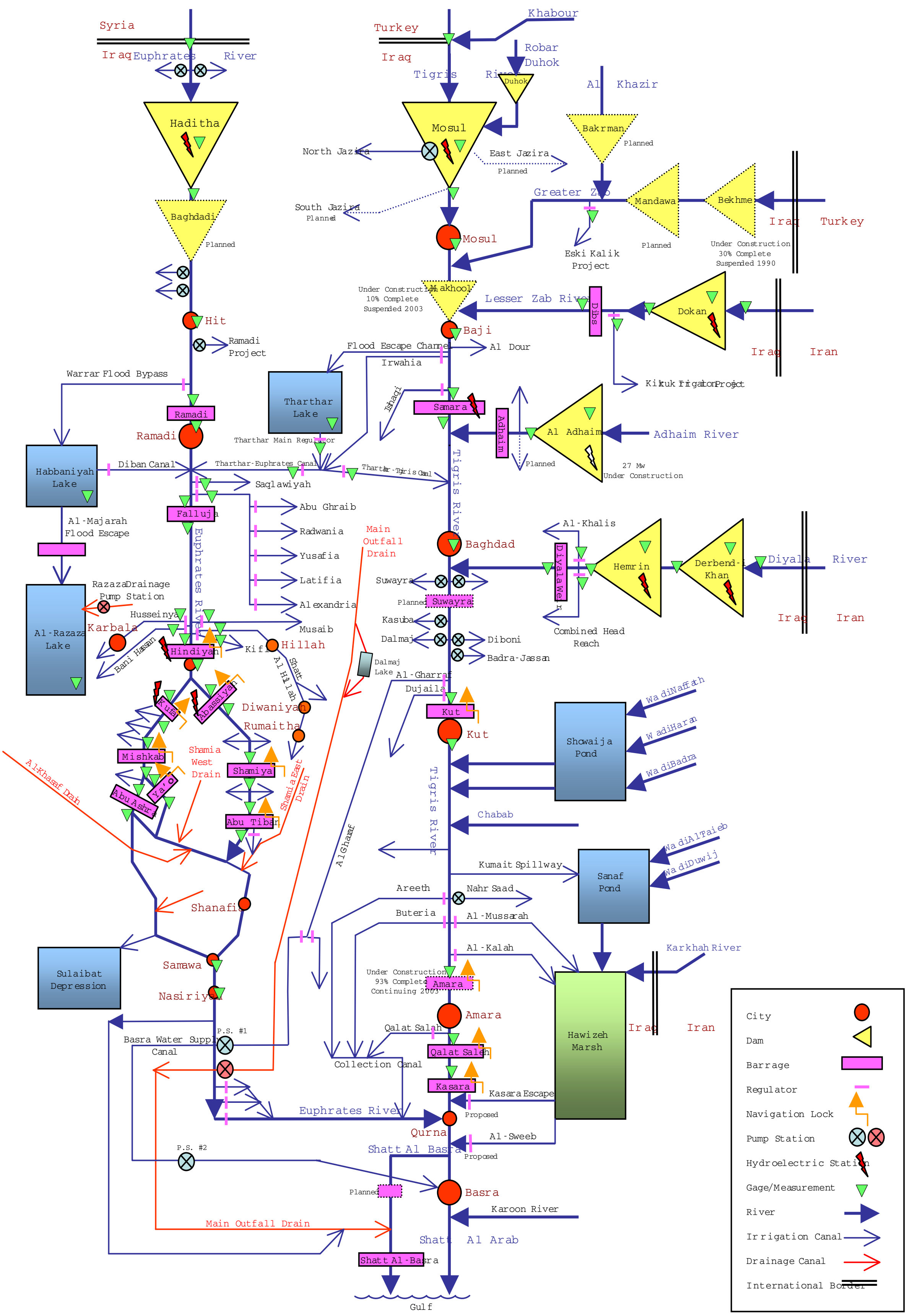
Figure 1 ARDI's approach to reconstruction and development of the water sector, which illustrates the emphasis on improving water management conditions.

The majority of irrigation in Iraq uses the gravity surface method, which involves creating earth channels for water conveyance and water applications by furrows or in basins. The water use efficiency of these irrigation systems is often low in Iraq, either because existing infrastructure has not been maintained, or because appropriate structures to improve efficiency were never built.

ARDI canal infrastructure rehabilitation activities included canal cleaning and rehabilitation of structures such as regulators and drainage pumping stations, with the goal of improving the distribution and conveyance efficiencies in the irrigation water network. These activities were quick-impact, with uncomplicated designs requiring relatively low capital investment, and an opportunity for participatory development, as the benefited farmers were involved in many of the projects. Many of the projects were identified through requests from the Departments of Agriculture, Water Resources Directorates at the governorate and district levels, and farmers themselves.

MINISTRY OF WATER RESOURCES

SCHEMATIC DIAGRAM FOR STORAGE AND CONTROL OF WATER IN IRAQ



CANAL CLEANING

Canal cleaning in Muthanna governorate.

Thousands of kilometers of irrigation canals in Iraq are not able to deliver adequate irrigation water to agricultural land because they are blocked with weeds, mud. and other debris, due to the lack of routine maintenance over many years. In addition, many of the underground pipe drains and drainage ditches that are designed to prevent waterlogging and salinization of the soil are blocked and require cleaning.

According to Iraqi law, farmers are required to maintain their own (tertiary) irrigation canals, while the government authority in charge of water resources in an area is charged with maintaining primary and secondary canals. Many farmers who depend on tertiary irrigation canals for agricultural production have not maintained them because they do not have the resources to pay for cleaning. This has resulted in reduced agricultural productivity and lower income, leading farmers further into poverty.

Cleaning canals is an extremely labor-intensive process that creates an opportunity for farmers to participate directly in the rehabilitation of the irrigation canals that serve their land. For canal cleaning activities, ARDI worked with local NGOs or the district Water Resources Directorate to organize local farmers into labor teams. ARDI supplied labor teams with tools such as shovels and rakes, and the NGO or Water Resources Directorate provided supervision. The farmers received modest

THE THREE CATEGORIES OF IRRIGATION CANALS:

- **Primary:** the major canal coming from a water source such as a river or reservoir;
- **Secondary:** canals extending from primary sources, and directed toward villages and their fields; and
- **Tertiary:** canals directed from secondary sources into individual farmers' plots.

Manual cleaning of canals provides need income for local farmers and villagers.

cash wages for their labor, which supplied an immediate injection of cash to the local economy. They also kept the tools used to clean the canals, which they will use in future years to maintain them.

The principal idea behind canal cleaning is to improve the flow conditions in the canal by diminishing the roughness coefficient, (*n*) (sometimes called the resistance coefficient), which is a measure of the roughness of the sides and bottom of the canal. The higher the roughness coefficient (*n*), the lower will be the discharge capacity of the canal will be.

Table 57 Values of the Coefficient *n*

Canal lined with finished concrete:	0.012 – 0.014
Canal lined with formed, rough concrete:	0.013 – 0.017
Earth canal, uniform, cleaning completed:	0.016 – 0.018
Earth canal, uniform, short grass, few weeds:	0.022 – 0.027
Earth, fairly uniform, no vegetation:	0.022 – 0.025
Earth, fairly uniform, some weeds:	0.025 – 0.030
Vegetated canal:	0.040 – 0.050

The ARDI canal cleaning projects changed *n* from the existing condition of over 0.050 to about 0.018. This enabled restoration of the original flow conditions.

ARDI cleaned a total of 1,167 km of 311 canals, providing 6,380 farmers with temporary jobs and benefiting over 85,000 farmers (see Table 58). The direct impact of cleaning these canals was dramatic, increasing water flow to farmers' land by an average of 150%. The improved irrigation enabled many farmers to begin summer cropping in areas where none had been possible for many years, increasing the productivity of the land and increasing farmers income through the sale of summer crops for the first time in 15 or 20 years. Farmers in northern Iraq benefited from improved supplemental irrigation during the winter season, while farmers in southern Iraq gained much more efficient year-round irrigation.

Due to the lack of maintenance over the last 15 or 20 years, the condition of the canals in southern Iraq was very poor. As a result, parts of irrigated land received no water, and other parts did not receive enough to meet crop water requirements. The problem was compounded by increasing salinization resulting from poor drainage and a general lack of proper water management practices, causing many farmers to abandon their lands. The remaining farmers are struggling to cope with the further deterioration of canals due to silting and blockage, resulting from a lack of maintenance. This blockage impedes the flow of water to irrigate crops, causing high losses through seepage, and also obstructs systems of drainage that protect land from salt buildup.

In addition water use fees are not collected by the GOI. This results in increased water use and reduced funds for system maintenance.

TABLE 58 DIRECT IMPACT OF IRRIGATION CANAL CLEANING AND STRUCTURE REHABILITATION

Canal Length Cleaned (km)	Number of Structures Rehabilitated	Agricultural Land Benefited (ha)	Families Benefited	Workers Employed
1,167	48	283,000	85,165	6,380

IRRIGATION STRUCTURE REHABILITATION

(1) Construction of a head regulator, before rehabilitation, and (2) after, (3) culvert beneath road, (4) pipe flume in northern Iraq, (5) karezes tap into a mountainside, (6) canal lining.

The effectiveness of a canal irrigation system often depends on hydraulic structures and other infrastructure that make the efficient distribution of water possible. Like the canals themselves, this hydraulic infrastructure had been badly neglected by the Iraqi government over 20 years of wars and sanctions. To improve the efficiency of the canals in delivering irrigation water to agricultural land, ARDI rehabilitated a wide range of canal structures, including:

- **Regulators,** which are gates of various sizes that divert water from one canal into another and control the flows throughout the irrigation systems. In some circumstances, pumps may be used near a regulator, or elsewhere along the canal, to maintain flow capacity in the drainage system or to deliver water for irrigation.
- **Culverts,** which are structures that carry water underneath roadways to reach agricultural lands.
- **Pipe flumes,** which are structures that carry water across drains to reach agricultural lands.
- **Karezes,** which are traditional irrigation structures that tap ground water through gravity flow. These are used in mountainous areas of northern Iraq.

ARDI also carried out **canal lining,** which is the process of lining a canal with concrete to reduce seepage and increase capacity, delivering significantly more water directly to agricultural lands.

In addition, ARDI worked in northern Iraq to construct **water storage facilities** at the village level. Vegetables and fruit trees are widely grown in many areas of northern Iraq, and farmers depend on irrigation from mountain springs. Water basins enable the storage of water from these springs during nonirrigated times, when it would otherwise run off and be wasted. This water can be saved for use during the dry season or other times when rainfall and water from the springs is scarce. ARDI constructed 20 of these basins, in close coordination with village councils. Those councils are administering the basins to ensure fair and equitable use of the stored water by village farmers.

In order to build capacity within the GOI to carry out rehabilitation and maintenance activities for Iraq's irrigation canal system, ARDI trained 14 engineers from the Ministries of Agriculture and Water Resources in design of hydraulic structures. The training course was delivered in coordination with the Department of Water Resources of the College of Engineering at the University of Baghdad.

CASE:
REGULATOR INCREASES EQUITABLE WATER DISTRIBUTION AND IMPROVES RICE YIELDS

In Muthanna governorate there is a subdistrict known for production of high-value Anbar rice, which sells for around $1.20 per kg. This region produces yields of up to 4.0 mt/ha, much higher than average yields in other parts of Muthanna. Due to the poor management of irrigation, water did not reach many farms so farmers could plant their lands. Other farmers receive some water,

but not enough to meet the rice crop water requirements. The result was reduced productivity: some farms were producing only 2.8 mt/ha. ARDI installed a regulator on the irrigation canal that serves the farms in this subdistrict, which permitted equitable distribution of irrigation water year-round. This more efficient use of water will enable farmers to increase their yields by 1.2 mt/ha, back to 4.0 mt/ha, adding value to production of up to $1,440 per ha.

CASE: REPAIR OF A DETERIORATING CANAL SYSTEM

At a village in northern Iraq, located 80 km away from an urban area, a system using natural springs irrigates approximately 40 ha farmed by 80 families. The main crops grown are tomatoes, apricots, sesame, cucumbers and other high-value vegetables. The irrigation system was composed of an earth canal and a deteriorating intake and turnouts. Most of the water diverted was being lost to seepage, limiting the chances for some farmers to produce good yields, especially those farmers located at the tail of the canal.

ARDI rehabilitated the intake, including a small weir, lined 1,300 m of canal with concrete, and constructed complementary infrastructure like drops, and foot and car passages. Farmers are now able equitably to irrigate these 40 ha during the summer and to supplement the area with additional water during the rainy season. The completion of this project also encouraged the return of farmers who had previously left their lands due to poor agricultural production.

LASER LAND LEVELING

(above) A tractor pulls the laser guided scraper to level the land.

(below) Laser beam receptor on the scraper feeds a signal to the scraper control unit.

While the use of the gravity surface method of irrigation via open canals is the most popular method, it is estimated that it currently wastes over 60% of water. The main factor causing this loss is the uneven fields, which results in uneven water distribution. Areas of high elevation do not receive sufficient water, while areas of low elevation become waterlogged and prone to salt buildup. Fields must be as level as possible for gravity surface irrigation, so that moisture content is constant throughout the field, enabling uniform crop growth and reduction of weeds.

ARDI implemented a project to introduce laser land leveling that is much more accurate, less costly, and more efficient than traditional leveling methods. The system consists of a laser transmitter placed in the field, and a laser receiver, electrical control computer, and hydraulic control valve connected to a four-wheel drive tractor.

The use of laser land leveling requires a relatively high initial capital investment in equipment, and a high level of skill to correctly level land. ARDI worked with an NGO that was formed to provide laser land leveling services to farmers. ARDI provided a training course in laser leveling for the eight members of the NGO staff, including a surveyor, two engineers, two tractor mechanics, and three experienced tractor drivers. The course included training in laser system operation and maintenance; principles, methods, advantages and problems

Laser emitters like this one, send signals to the scraper mounted receiver to lower or raise the scraper blade.

associated with laser leveling; and how to carry out the laser leveling operation. The course also included some business management training, including how to calculate the operating, administrative, and overhead costs of the system. ARDI granted the NGO the equipment necessary to capitalize it and begin operations. The NGO is now providing laser land leveling services to farmers for a fee, in order to help it expand its services, and help farmers create even fields and ultimately optimize water-use efficiency for improved crop production.

EXPANDING ACCESS TO HIGHLY EFFICIENT IRRIGATION EQUIPMENT

Rotating center pivot sprinkler with drop spray heads.

As noted previously, traditional gravity surface irrigation methods using earth channels for water conveyance and on-farm distribution can be highly inefficient, resulting in water losses of over 60 percent.. The use of highly efficient, pressurized irrigation systems such as sprinklers, minisprinklers, center pivots, hose move, and drip irrigation is an excellent way to increase water use efficiency on agricultural lands and eliminate most conveyance losses.

Under the Oil-for-Food program, the previous regime purchased more then 2,000 of these pressurized irrigation systems. However, government staff were never trained in the installation and operation of the systems, and most of the systems were never distributed to farmers.

In order to get these systems out of warehouses and into farmers' fields, ARDI conducted a training program for Ministry of Agriculture engineers for the

(top to bottom)
1) Laying the water source pipe, 2) preparing the lateral lines, 3) pressurized line to the system, and 4) installing a control valve.

installation and operation of the systems. ARDI set up 14 demonstration areas: five center pivot systems, three drip systems, three hose move systems, and three minisprinkler systems. A total of 117 MOA officials were trained in installation and operation of these systems, as well as in water management theory including how to calculate peak crop water use, determine a simple irrigation schedule, and calculate pumping times required for each type of irrigation system. The MOA officials are now prepared to provide technical assistance to farmers in installing highly efficient equipment, and to provide advice to help farmers use water more efficiently for agricultural production.

At the same time, the MOA started an awareness campaign to inform farmers about the availability of the pressurized irrigation equipment in the warehouses and began a credit system to help them purchase it. The result of this combined MOA/ARDI effort is that 50 center pivot, 50 drip systems, and 50 solid set irrigation systems have been purchased and installed by farmers.

ARDI also implemented a separate program to install center pivot irrigation systems on farmers' fields in Tameem governorate. At least 380 farmers in the area received center pivot systems during the Oil-for-Food program, but due to a lack of technical assistance never installed them. ARDI worked with a local NGO to provide this technical assistance in system installation and operation. The NGO provided training to farmers while installing a total of 24 systems in the area. The farmers trained are now expected to install their own systems in their own fields.

EXPANDING ACCESS TO SMALL-SCALE IRRIGATION EQUIPMENT

Emitters for the small scale drip systems come in many types and water flows. They require minimal pressure to operate.

While the pressurized irrigation equipment described in the prior section enables the efficient use of water for crop production, millions of small-scale farmers do not have access to these types of systems, due to the high initial capital costs of system installation, its complex operation and maintenance requirements, and because the systems are too large for their farms. However, small-scale farmers can still benefit greatly from irrigation, particularly for the production of high cash-value-crops that can provide an important source of food and income. Low-cost, highly efficient drip irrigation systems called Family Drip Irrigation Systems (FDIS) are ideal for small-scale agricultural production on small plots of land of 100 to 200 square meters. These systems are complete drip irrigation units that work at very low pressure through gravity from a small elevated tank. System operation and maintenance are very simple, requiring no special skill.

In order to increase access to these types of systems, ARDI implemented a project to distribute FDIS to small-scale rural producers and to train MOA officials to provide technical assistance to farmers on the installation and operation of them. The objective of the project was to enable rural farmers, many of whom were previously subsistence-level producers, to generate income through production of high cash-value-crops using the FDIS. The project was also intended to stimulate demand for FDIS in the local market, in order to encourage local production of these inexpensive and simple systems.

(top to bottom)
1) The basic FDIS installed on a farmers field, 2) lateral lines carry water to individual plants, and 3) efficient water use increase plant health and yields.

ARDI initiated the project in Qadissiya with the distribution of 15 FDIS to rural farmers who were previously not generating any income from crop production due to the lack of irrigation. The farmers each received a system, and training on its installation and operation, plus advice on crop production. The success of this program led ARDI to expand the project to eight governorates and 240 farmers.

The expanded project was implemented in close coordination with the MOA in order to build capacity for providing technical assistance to small-scale farmers on FDIS installation, operation, and maintenance. The project trained 58 staff from the MOA on FDIS and on improved water management techniques relevant to small-scale agricultural. ARDI created a *Family Drip Irrigation System Technical Handbook* for use during the training program, which the MOA can continue to use to train staff on FDIS.

When the training was complete, the 58 MOA staff members worked in teams of two to distribute FDIS to the 240 recipient farmers. After all the systems were installed, 58 of the farmers were chosen at random to receive continued technical assistance from MOA staff throughout the growing season. The MOA teams distributed vegetable seeds to the farmers, and visited them to provide advice on irrigated crop production, water management techniques, and to provide assistance with FDIS. These visits were conducted as field days, and other area farmers also attended to learn about using the FDIS to increase their production of high-value cash vegetable crops.

ARDI staff recorded production data to determine the economic benefit of using FDIS to increase agricultural production. The crops cultivated with FDIS were cucumber, okra, squash, melon, and watermelon. On the average, production of these crops doubled using FDIS (See Table 59). With continued extension efforts by the MOA to improve farmers' use of the equipment and application of proper cropping and water management techniques, productivity can be improved even more. These production increases provide additional food security for the farmer and income from the sale of excess crops.

TABLE 59 INCREASE IN YIELD FROM FDIS

Governorate	Number of Systems	Crop	Yield (kg/ha)	Average yield under traditional cultivation (kg/ha)	Difference (%)
Babylon	15	Cucumber	12,630	7,000	80
		Okra	8,000	4,000	100
Basrah	30	Okra	6,300	2,700	133
Kerbala	15	Squash	13,500	7,200	88
Missan	50	Cucumber	11,390	6,400	78
		Okra	8,000	3,800	110
Muthanna	50	Cucumber	12,320	7,400	66
		Okra	8,000	3,500	128
Najaf	15	Melon	11,200	7,000	60
		Okra	8,750	3,800	130
Thi-Qar	50	Cucumber	11,300	6,500	74
		Water Melon	12,000	7,500	60
Wassit	15	Melon	12,080	7,200	68
		Squash	13,000	7,400	76
Qadissiya	15	Tomato	14,000	4,000	250
Total	**255**				

ADDRESSING THE PROBLEMS OF DRAINAGE AND SALINITY

Recently cleaned canal in central Iraq.

While irrigation is important and even essential to agricultural production in some parts of Iraq, poor drainage creates significant problems on irrigated agricultural land. In addition to delivering water for agriculture, irrigation systems must provide a mechanism for removing excess rain or irrigation water or for leaching salts from the soil. Inadequate drainage leads to rising levels of salinity in the soil, with the eventual result that the soil becomes too salty for crop production.

Over the past two decades, the neglect of Iraq's irrigation infrastructure has also resulted in a deterioration of drainage components. As a result, thousands of hectares of agricultural land, mostly in the central and south-central region of the country, are becoming too saline for crops. It is estimated that more than 50% of the agricultural land in this region is affected by high salinity and much of the land has been abandoned by the farmers who previously relied on agricultural production as a source of food and income.

Input pipes carry water to pumps at secondary level.

One way to increase production in highly saline soils is through the development and use of salt-tolerant crop varieties. Iraqi researchers have been successful in developing a variety of salt-tolerant wheat that grows well on saline soils. (See Section 2.1 for a discussion of ARDI programs to expand the use of these varieties). However, this technique limits the range of crops that can be grown. The other option is to actually reduce the soil salinity by installing drainage systems that enable proper drainage and to provide a means of leaching salt from the soil in those areas where soil conditions are conducive to leaching. This is more costly and time-intensive, but brings agricultural land fully back into production.

At the beginning of the project, ARDI sponsored training for 19 MOWR and MOA staff, in order to prepare them for implementing the Pilot Drainage Catchment Areas project. The training course, which was held in Holland, addressed many issues related to the problems of waterlogging and salinity, including:

- Agricultural drainage criteria (design criteria and drainage design parameters);
- Water and salt balances (water and salt balance in a pilot area, in drained plots, and the role of the aquifer);
- The effects of drainage (how drainage influences the water table, soil salinity, crop yields, and the socioeconomic conditions in the pilot area);
- Principles of drainage research (interrelationship of drainage and irrigation water management, and how to set up a research program);
- Field research in Pilot Areas (how to plan data collection and how to design, construct, operate, and maintain pilot areas);
- Data management (data handling, analysis, and presentation); and

- Case studies (how to create logical frameworks and computer software to diagnose drainage and irrigation problems and formulate a research program to investigate and solve these problems).

When the training was complete, ARDI and the Task Force selected four pilot drainage catchment areas ranging from 100 ha to 500 ha. Routine soil and water sampling, and groundwater depth measurements, were taken to establish the water and salt balances of each pilot drainage catchment area, including:

- Groundwater depth measurements (monthly, one fixed point per 20 – 30 ha);
- Groundwater salinity measurements (monthly, one fixed point her 20 – 30 ha with a portable conductivity meter) and water sampling to determine Na, Ca, Mg, K, Cl, SO_4, HCO_3 and CO_3 (quarterly, one fixed point per 20 – 30 ha);
- Soil salinity sampling (seasonally per layer of 0.25 m till 2.00 m deep around the fixed point per 20-30 ha for Saturated Soil Paste (SSP) and $EC2_e$ analyses); and
- Crop yield assessments (in-situ where a farmer is cutting fodder crops, and seasonally where a farmer harvests his grain crops, or picks seed cotton). When crop yield assessments are made always a composite soil sample is taken from the top soil (00-25 and 25-50 cm) at the site for SSP and $EC2_e$ analyses.
- Irrigation water inflow: total monthly supply from continuous recordings of the head in calibrated flow measurement devices and salt import on the basis of weekly pen-type electrical conductivity (EC) probe measurements; and
- Drainage water outflow: total monthly discharge from continuous drainage water level recordings at calibrated sections or from the operation hours of a calibrated pump and salt export on the basis of weekly pen-type EC probe measurements.

In addition, in each pilot area a test plot of 10 – 30 ha was established to monitor the impact of drainage systems on reducing soil salinity and improving crop production using traditional (not otherwise improved) farmer practices. Piped drainage systems were installed in these test plots, with pipes located at different depths and spacing to determine the main parameters important in designing future drainage-based soil salinity control investments and practices under the conditions in Iraq.

The routine soil and water sampling, groundwater depth, pipe drain discharge, and piezometric pressure level measurements program in each drainage test plot included:

- Groundwater depth measurements midway between two successive drains with the same depths and spacing (daily in permanent groundwater observation wells with a depth of 2 m). In a few observation wells, measurements have been carried out by water pressure data loggers;

- Groundwater salinity measurements by means of a pen-type EC probe midway between 2 successive drains with the same depth and spacing (monthly in the permanent groundwater observation wells). Quarterly, groundwater samples are being collected to determine Na, Ca, Mg, K, Cl, SO_4, HCO_3 and CO_3 concentrations;

- Measurement of the discharge of selected pipe drains daily by means of bucket and watch, but preferably continuously by an automatic recorder;

- Measurement of the EC of the discharge of the selected pipe drains (daily by means of a pen-type EC probe). Quarterly, drain discharge samples are collected to determine Na, Ca, Mg, K, Cl, SO_4, HCO_3 and CO_3 concentrations;

- Measurement of water levels in a set of 3 piezometers installed preferably within the fenced meteorological station at a depth of respectively 2, 3.5 and 5 m, to detect upward or downward flows in the subsoil (monthly level readings); and

- Soil salinity sampling (quarterly per layer of 0.25 m till 2.00 m deep around the permanent groundwater observation wells for SSP and $EC2_e$ analysis, and to determine Na, Ca, Mg, K, Cl, SO_4, HCO_3 and CO_3 concentrations).

Irrigation water and related salt intake of the different (cropped) drainage trials were calculated on the basis of irrigation water discharge and irrigation time measurements, and measurement of the irrigation water salinity by means of a pen-type EC probe. The automatic recordings of the meteorological station were checked and registered monthly.

In August 2006, ARDI held additional training for 17 MOA and MOWR staff involved in activities in the pilot areas. This training course, which was delivered by the Department of Water Resources of the College of Engineering from Baghdad's University and an ARDI drainage consultant, addressed the following topics about salinity and drainage in semiarid zones:

- Surface water distribution and drainage (international examples; aspects of the Iraqi situation);

- Assessment of salinity drainage projects (agricultural aspects; economic aspects; social and rural health impacts; and, environmental risks and opportunities); and

- Sustainability of salinity drainage projects (institutional requirements; farmers' participation; and financial and O&M aspects).

The Pilot Areas are still in use, and the active involvement of the Drainage and Salinity Committee and the Task Force throughout project implementation should ensure the continuation of the monitoring activities, presentation of analytical interim reports with consolidated field data, and the completion of investigative reports with recommendations for the implementation of drainage-based soil salinity control projects and practices elsewhere in Iraq.

CASE: VALUABLE ORCHARD AND CROP LAND ABANDONED DUE TO HIGH SALINITY

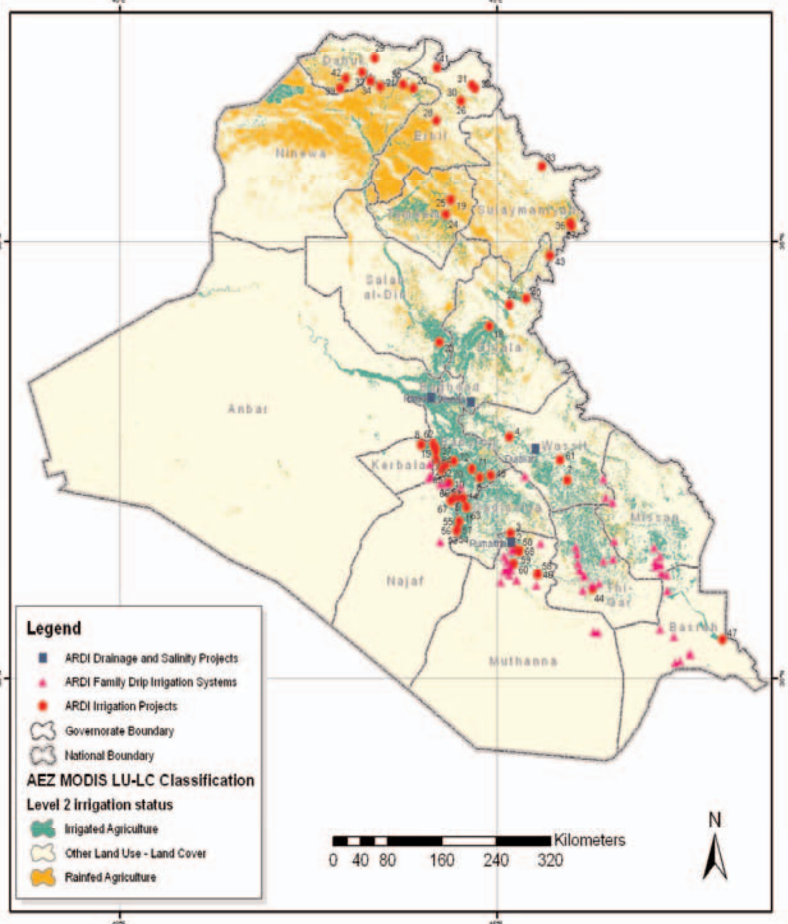
Neglect of drainage systems has led to damage of many thousands of hectares of formerly arable land. In many cases, the land has become so waterlogged and saline (salty) that cropping became impossible, and farmers abandoned their farms. One case of this occurred in Kerbala governorate, in an extremely important agricultural area where date palms, wheat, maize, sesame, tomatoes, and other fruits and vegetables were produced. In 1990, a project was implemented to construct a drainage system, including a nearly 6 km-long drain, and to line irrigation canals to control seepage. However, when the project was not completed and there was no maintenance of the system after 1991, the following problems arose:

1. Blockage in parts of the canal which had mixed with sewage;
2. An increase in the salinity of the soils;
3. The death of 20% of the fruit and date palm trees;
4. The death of 80% of the citrus trees;
5. The abandonment of land by many farmers; and
6. A decrease in the area of cultivated land.

ARDI funded cleaning of the drainage system by providing hand tools and using farmer labor to restore its ability to drain excess water from agricultural fields. The rehabilitated drain will be able to drain 400 ha and reduce salinity, resulting in improved crop productivity and increased income. The farmers kept the tools used to clean the drains and will be able to maintain the drains in the future.

Direct Impact of this Project: Cleaning the drain in this particular area increased the area of agricultural land cultivated by decreasing the area affected by waterlogging and salinity problems. In addition, the entire 400 ha cultivated area benefited from the decrease of the water table levels and of the levels of salinity in the soil. Therefore, farmers are now able to irrigate the entire area during both summer and winter seasons, to increase their productivity and income further. Finally, this project also created temporary employment for cash wages, and encouraged the return of farmers who had left their land due to low agricultural productivity.

ARDI Crop-Soil-Water Relationships Projects



Key to Irrigation Projects

No.	Project	Governorate	Donnum
1	Construction of Al-Khdirawy Canal regulator in Al-Warka'a Sub-District-Al-Muthanna	Muthana	1,500
2	Construction of Abu-Kohuf regulator in Ar-Rumaitha District -Al-Muthanna Governorate	Muthana	5,000
3	Irrigation canals cleaning project in Al-Hilal Sub-District	Muthana	22,850
4	Reconstruction of Al Jadwal Cross Regulator, Wassit Governorate	Wassit	40,000
5	Reconstruction of Om Al Warid Head Regulator	Babylon	60,000
6	Rehabilitation of the Om Hayaya Head Regulator	Najaf	26,000
7	Reconstruction of Hannoon Cross Regulator	Wassit	180,000
8	Reconstruction of Shleet regulator	Karbala	9,400
9	Improving the Drainage Conditions of a Waterlogged Affected Area	Muthana	2,080
10	Reconstruction of the Monather Pumping Station between Hilla-Kifil Canal and the Euphrates River	Babylon	13,804
11	Reconstruction of Al Mishkhab Cross Regulator	Najaf	50,000
12	Construction of head regulator and retaining walls for Eshan Graed Canal	Babylon	5,490
13	Rehabilitation of retaining wall and pipe flume in Al-Ajda'a River	Babylon	4,600
14	Irrigation Canals Cleaning in Al-Mhannawiyah	Qadessiyah	8,000
15	Cleaning and Rehabilitation of drainage canal in Al Hindia	Karbala	1,650
16	Cleaning of Irrigation and Drainage Canals in Al-Buhwaichma and surrounded villages	Muthana	21,320
17	Irrigation Canals Cleaning in Al-Warka'a District	Muthana	16,010
18	Main Baquba Drain Cleaning Project	Diyala	39,844
19	Installation of Center Pivot Irrigation Systems in Tameem Governorate, Phase II	Tameem	1,800
20	Irrigation Canal Cleaning in 45 villages in Dinarta Sub-District	Ninewah	16,365
21	Cleaning Shekhan Irrigation Canal	Ninewah	9,108
22	Cleaning Jalwla Irrigation Canal	Diyala	5,530
23	Cleaning Al-Dujeel Irrigation Canals	Salahaddin	7,350
24	Gordara Irrigation Canal Cleaning in Taza District	Tameem	10,000
25	Installation of Center Pivot Irrigation Systems in Tameem Governorate	Tameem	1,800
26	Water Storage Facilities at 5 Villages (Bardgrka, Gochar, Dargala, Kawlokan and Jundean) in Rawanduz	Erbil	450
27	Cleaning Khormal Irrigation Canal	Suleymaniyah	24,700
28	Cleaning Irrigation Canals in 4 Villages in Salah el-Din Sub-District (Kore, Almawani Saru, Almawani Xwaru and Ziarat)	Erbil	4,000
29	Water Storage Facilities in Qadesh Village	Dohuk	150
30	Cleaning of Irrigation Canals in 6 Villages of Rawandoz Subdistrict	Erbil	6,700
31	Cleaning Irrigation Canals in (Mjesar, Shiwan, Mawatawa, Kazhak, Qaletan, Kawna Sidakan)	Erbil	2,950
32	Rehabilitation of the Baskadere Irrigation Project	Dohuk	160
33	Cleaning Irrigation Canals in Bewre	Suleymaniyah	838
34	Village Water Storage Facilities in Shekhan District	Ninewah	185
35	Village Water Storage Facilities in Akre District	Ninewah	156
36	Rehabilitation of Zamagy Sarw Kareze, Halabja District	Suleymaniyah	156
37	Constructing Al Bashiyah pipe culvert on Al Salamiyah main drain	Karbala	3,000
38	Cleaning Irrigation Canals in Dasnee, Bekapooshik, Zheen and Zhozhel villages	Erbil	2,500
39	Cleaning Irrigation Canals in Fayda	Ninewah	2,575
40	Cleaning Brikura Irrigation Canal	Diyala	11,000
41	Rehabilitation of the Moka (Sherwan Mazin) Irrigation Project	Erbil	110
42	Village Water Storage Facilities in Dahuk	Dohuk	221
43	Cleaning Belula Irrigation Canal	Diyala	5,000
44	Irrigation canals cleaning in Sayed Dekheel–Nassriya	Thigar	6,750
45	Shomaly Pumping Station Emergency Regulator	Babylon	240,000
46	Civil and Engineering Works for Canal at Al-Bidairy Irrigation System	Muthana	6,000
47	Irrigation Canals Cleaning in Abu alkhaseeb	Basrah	7,800
48	Irrigation Canal Cleaning, Small Irrigation Canals Project	Muthana	7,800
49	Irrigation Canal Cleaning, Al Dokhan Village Project	Muthana	4,875
50	Irrigation Canal Cleaning, Eastern Drainage Canals Project	Muthana	6,825
51	Rehabilitation of Al Tayyah Culvert	Babylon	2,500
52	Rehabilitation of Al Haminiyah Culvert	Babylon	2,500
53	Abu Jagi Head Regulator Reconstruction	Najaf	1,000
54	A'al Majid and A'al Awad Irrigation Head Regulators Reconstruction.	Najaf	1,100
55	Al Gowah and Al Ghallal Irrigation Head Regulators Reconstruction	Najaf	1,300
56	Al Ghazali and A'al Habib Irrigation Head Regulators Reconstruction	Najaf	1,100
57	Irrigation Regulators Reconstruction for Jannabiyat Al Mishkhab Canal	Najaf	2,000
58	Install Pumping Station for Al Bidairy Irrigation System	Muthana	6,000
59	Reconstruction of the Al Thail Regulator for the Al Thail Drain	Muthana	3,000
60	Rehabilitation of the Um Al-Agaf Pump Station	Muthana	30,000
61	Reconstruction of Al-Bassrokiyah Cross Regulator	Wassit	20,000
62	Raising the Canal Banks for Transporting Drainage Water	Karbala	70,000
63	Reconstruct Al Khashaniyah Head Regulator	Qadessiyah	2,000
64	Re Construction of Al E'aywiq Canal Pipe Flume	Karbala	3,000
65	Re Construction of Al Behta Canal Pipe Flume	Karbala	300
66	Rehabilitation of the Om Hayaya Regulator	Najaf	26,000
67	Al Kufa Drain Rehabilitation Project	Najaf	30,000
68	Construction of Irrigation Regulator at Al Mhaddad Pumping Station	Muthana	60,000
69	Rehabilitation of Tertiary Canal System at Al Hilla-Kifil Reclamation Project, Phase II	Babylon	5,000
70	Rehabilitation of Tertiary Canal System at Al Hilla-Kifil Reclamation Project, Phase I	Babylon	5,000
71	Reconstruction of Al-Khamisiyah Canal Bridge	Babylon	75,000
72	Rehabilitation of Tertiary Canal System in Al Nasiryah Reclamation Project	Babylon	10,000

INSTITUTIONAL CAPACITY BUILDING IN THE WATER SECTOR

ARDI provided international observation tours in specialized irrigation disciplines (ie. London flood control district)

Training was an important component of ARDI's work in the rehabilitation of Iraq's water sector. In every activity carried out, ARDI sought to develop the capability of Iraqi people to continue reconstruction and development. This training included:

- 19 MOA engineers were trained in designing and implementing pilot areas for drainage systems to reduce soil salinity;
- 58 engineers were trained in Family Drip Irrigation System operation and maintenance to assist farmers in utilizing these systems to increase production of high-cash-value crops;
- Over 5,000 farmers were trained through employment in cleaning canals to improve irrigation and received tools for ongoing maintenance;

Irrigation engineers received training in Excel and in CROPWAT, a specialized planning tool for irrigation.

- 117 MOA staff received training in operation and maintenance of highly efficient irrigation equipment, especially those systems held by the government through the Oil-for-Food program and currently being sold to farmers;
- 2 MOA senior staff members attended the *8th International Seminar on Participatory Irrigation Management* in Tarbes, France. The seminar addressed developing cooperation between government and the private sector to improve water management;
- 14 MOA technicians were trained in the design of hydraulic structures to improve gravity surface irrigation systems;
- ARDI sponsored training for 19 MOWR and MOA staff in Holland, in order to prepare them for implementing the Pilot Drainage Catchment Areas project.
- 56 people from twelve governorates and the national Agriculture, Extension and Irrigation offices of the MOA were trained in irrigation scheduling. They learned to assess soil by feel, calculate irrigation needs, find and use weather data in planning, and use Excel and CROPWAT computer software in planning. Most importantly, they received training in teaching farmers some of these skills and water management techniques; and
- 10 professionals were trained in Amman, Jordan in water management techniques. They observed sophisticated water management systems employed in Jordan's Central Valley.