Automation of the Water Distribution Systems

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A key tool of integrated water resources management is automation of the water distribution system based on introducing the state-of-the-art system of supervisory control and data acquisition (SCADA). This system allows improving the quality, flexibility and reliability of water distribution management and reducing unproductive losses of water resources.

Developing the system of automation and dispatching of the Uchkurgan Hydroscheme was initiated in 2002 simultaneously with launching the IWRM-Fergana Project. The most up-to-date programmable controllers "Decont" manufactured by the company "DEP" (Russia) with home-produced sensors of a water level and gate position were applied in this system.

Introducing the system was funded by the Swiss Agency for Development and Cooperation; and it operates up to now. Specialists of the BWO "Syr Darya", SIC ICWC and SANIIRI monitored this system operation over the period of 2002 to 2007. The framework of archiving and databases were updated to monitor and evaluate qualitative indicators of the system of automation and dispatching of the Uchkurgan Hydroscheme. The system of archiving technological and operational information automatically saves basic values of technological indicators each ten minutes in the form of separated files that can be analyzed to evaluate the quality of system operation.

The updated database allows solving the following tasks:

- transferring the SCADA data directly into the database "MS ACCESS" providing storing and processing these data for solving operational tasks;
- averaging and saving values of measurable parameters over a day, ten-day period and month;
- data input of hourly visual observations (the common method), averaging and saving their values over a day, ten-day period and month;
- detecting deviations (errors) in the data of hourly visual observations against the SCADA data; and
- drafting the reports and diagrams that illustrate the telemetry system operation (the prototype of the SCADA) and the data processed.

One of key tasks of automation and dispatching of the Uchkurgan Hydroscheme is to improve the stability of water delivery through the North Fergana Canal (NFC) and the Additional Feeding Canal (AFC) within the system of the Big Fergana Canal (BFC) under fluctuating of water levels in the headrace channel. At present, the system of automation and dispatching of the Uchkurgan Hydroscheme does not directly receive information on flow rates at the gauging station "Uchkurgan" and in the headrace channel of the BFC; therefore a dispatcher of the Uchkurgan Hydroscheme assigns the required parameters for regulating flow rates through the NFC and AFC depending on current flow rates in the river channel and water use limits established.

Figure 5.26 shows the operational regime of the automation system of the Uchkurgan Hydroscheme over the period of 2005 to 2006. As shown in this figure, under fluctuating of water levels in the headrace channel, flow rates through the NFC and AFC are almost stable within the acceptable accuracy of regulation. Stability of water delivery into the NFC and AFC is ensured by the automation system of the Uchkurgan Hydroscheme at the expense of a capacity of the headrace channel and releases of excess water into the tailrace channel.

An average value of deviations of actual flow rates against the established value under automatic regulating does not exceed 2% for the NFC (1.69% for the AFC).

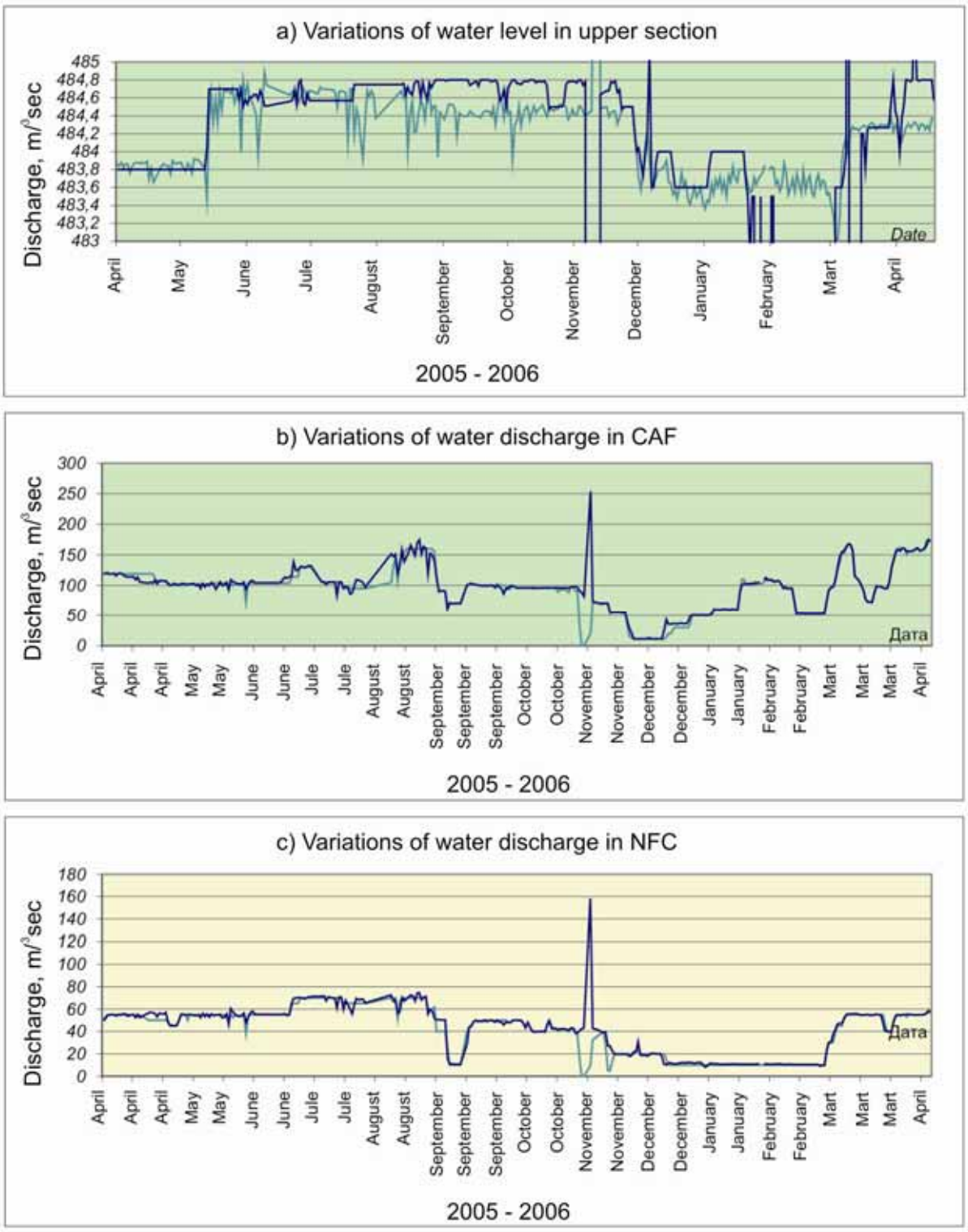

Figure 5. 26 Operational Regimes of the Automation System

of the Uchkurgan Hydroscheme in 2005 and 2006

A maximum value of instantaneous deviations of an actual flow rate against the established value for automatic regulation of a flow rate in the NFC amounts to 11.2% and 1.77% in the AFC (during the

transition period). Analyzing the automation system operation of the Uchkurgan Hydroscheme over the whole period of operation (5 years) shows that the following quantitative and qualitative indicators of water resources management were considerably improved:

- the stability of irrigation water supply through the NFC and FFC in the Fergana Valley was improved at the expense of introducing the system of automatic regulating of water levels and flow rates;

- the measurement accuracy of water levels, flow rates and water salinity, as well as a height of opening the gates of hydraulic structures was raised due to the introduction of the up-to-date technical means for measuring and accounting water resources;

- dataware and the quality of water record keeping was improved based on continuous computerized gathering, storing and processing data on water levels and flow rates;

- the efficiency and accuracy of water resources management were improved at the expense of speed-up of transferring and processing the information on technological processes and the decision-making process; and

- the rapidity of detecting and eliminating failure occurrence in the system equipment and hydraulic structures was increased.

It is necessary to note that the automation system of the Uchkurgan Hydroscheme has raised the O&M level, substantially facilitating activity of operational personnel and improving the quality of water distribution into the NFC and AFC. As a result, the conditions for monitoring the BWO "Syr Darya" and its territorial bodies' activity were created based on the openness and accessibility to information for all stakeholders.

Taking into consideration advantages of the automation system, the project: "Automation of Water Distribution on Pilot Canals in the Frame of IWRM-Fergana Project and the BWO "Syr Darya" Structures" has been proposed as further development of the IWRM-Fergana Project and its tools. This project encompasses:

The basin level:

- the BWO "Syr Darya" structures;

Pilot canals:

- the Aravan-Akbura Canal (Kyrgyzstan);

- the South Fergana Canal (Uzbekistan); and

- the Khoja-Bakirgan Canal (Tajikistan).

The project objective is to put into practice the computer-aided system of regulating and operational monitoring of the water distribution process at the BWO's structures and on pilot canals to ensure

supplying of irrigation water to farmers in due amounts and proper time and to establish the system of monitoring of channel inflow, flow rates and water levels at the water-balance gauging stations and water intakes.

A key task of automation and monitoring is to establish the system of management and control of canal operation, which allows:

- to improve implementing the plan of water use;
- to create conditions for sustainable, uniform and equitable water distribution excluding unproductive water losses.

Achieving this objective will be provided based on the introduction of the SCADA system on the water intake and check structures, water-balance gauging stations, as well as at the expense of dispatching of all hydraulic structures under management, establishing telecommunications and computerization of transferring, processing and storing information. In addition, special observers who will be provided with communication means and vehicles will monitor the water-balance sites.

Pilot canals to be subjected to automation have different sources of water supply:

- the South Fergana Canal is fed from the Andijan Reservoir of over-year regulation;
- the Akbura River, flow of which is regulated by the Papan Seasonal-Storage Reservoir is the water source for the Aravan-Akbura Canal;
- the Khoja-Bakirgan Canal diverts water from the river of the same name with unregulated flow.

The existing situation in water distribution through irrigation canals and the stochastic nature of flow rates in streams impede uniform water delivery to consumers and meeting the established water use limits. Unproductive organizational water releases result from the inopportuneness and unreliability of information gathered at the gauging stations due to the lack or insufficient accuracy of measuring devices that are used for monitoring flow rates and water levels.

Automation of the main waterworks and the system of gathering information on the water-balance gauging stations and monitoring at the water-balance sites conducted by observers who will be provided with communication means and vehicles are envisaged for ensuring sustainable water distribution providing stable and uniform satisfaction of farmers' requirements.

The system of managing the water distribution process: there are not differences of principle in the system of managing water resources on pilot canals; each republican system is represented by three levels:

- *basin level* where the BWO "Syr Darya" and republican ministries of water resources carry out management functions. At this level, the ICWC establishes limits of water resources use for the irrigation systems and controls their realization;

- *level of the Basin Irrigation Systems Administration, Fergana Valley Main Canals Management Organization (Uzbekistan) and Provincial Water Management Organizations (Kyrgyzstan and Tajikistan).* At this level, the plans of water use with allocating water resources per specific irrigation canals are approved taking into consideration the water use limits established and applications of farmers; and

- *level of the Main Canal Management Organization*, at this level, irrigation water distribution over ten-year periods in accordance with the approved plan is being implemented, as well as the monitoring and adjusting of water delivery every ten days, if necessary.

The main dispatching point (MDP) and water-balance sites with local dispatching points were established on each irrigation canal in the frame of operational water distribution system. The Central Dispatching Point (CDP) that is the central element of water distribution management along the canal was established at the Main Canal Management Organization.

The principle of water distribution through irrigation canals: a key principle of water distribution through irrigation canals is planned water use that bases on stable and equitable meeting of consumers' demands over the entire length of irrigation canals. Plans are drawn up by water resources management organizations based on applications submitted by water users and water use limits established by the Ministries. Water use plans are approved after joint reviewing by the Irrigation System Management Organizations (or Provincial Water Management Organizations), Canal Management Organizations, Canal Water Committees and representatives of water users. Water use plans are the basis for plans of water diversion and delivery to consumers that are being drawn up every ten days and adjusted during the irrigation season depending on weather conditions, general water management situation in the river basin and applications of consumers.

An extent of automation and dispatching of main hydraulic structures and the monitoring system: Headworks of the pilot irrigation canals are equipped with measuring devices of the SCADA system; sensors of water level at upstream and downstream of the structure and position of gates (an extent of their lifting) are installed at all check structures. Dispatching points at headworks are equipped with computers and the system of telecommunication that provides trouble-free communication with the central and local dispatching points and automatic transferring of information according to the established mode. The following components are automatically operating:

- gates of headworks that maintain designated flow rates under fluctuating of water levels in the headrace channel;

- gates of spillways that are operated in accordance with water levels in the headrace channel;

All information registered by sensors is illustrated at the symbolic circuits; and the protection from emergencies (self-locking of gates, exceeding a maximum level, power cutoff, opening a power switchboard by unauthorized persons etc.) is envisaged.

The SCADA system at the main structures includes the following equipment:

- computers (hardware and software);
- programmable controllers;
- input and output modules;
- sensors of water level and position of gates; and
- radio stations with antennas.

Secondary canal head gates are equipped and operate similar to pilot main canals' headworks.

Automation will be introduced on:

- the South Fergana Canal – 10 main structures and Kirkidon Reservoir's structures (72 gates and 17 dispatching points in total);
- the Aravan-Akbura Canal – 3 main structures (17 gates and 7 dispatching points); and
- the Khoji-Bakirgan Canal – 7 main structures (43 gates and 7 dispatching points).

Four BWO "Syr Darya" structures are also equipped with the SCADA system (46 gates and 5 dispatching points).

Water-balance gauging stations are equipped with the SCADA system (sensors of water level). The SCADA system at water-balance gauging stations includes the following equipment:

- programmable controllers; and
- input and output modules, sensors of water level and radio stations with antennas.

Information on water levels and flow rates is transmitted through radio communication to a local dispatching point (LDP) of a hydro-operational site (a hydro-unit) that operates this water-balance gauging station. The following gauging stations will be subjected to automation:

- South Fergana Canal – 10 gauging stations (one at the headworks, 9 at water-balance sites);
- Aravan-Akbura Canal – 4 gauging stations (one at the headworks, 3 at water-balance sites);

- Khoji-Bakirgan Canal – 3 gauging stations (one at the headworks, 2 at water-balance sites); and 7 dispatching points.

Monitoring at water-balance sites. Objects of automation and computer-aided monitoring on the pilot irrigation canals do not exceed 10% of water distribution infrastructure; therefore, a key role in achieving sustainable and uniform water distribution along the entire length of irrigation canals to meet users' water demands belongs to observers at water-balance sites who monitor off-takes operation.

For the purpose of efficient water resources management, the irrigation canals are subdivided into water-balance (hydro-operational) sites that are the primary level of management hierarchy. A local dispatching point that will be equipped with computer and telecommunication means was established at each water-balance site. A LDP receives information from main structures and water-balance gauging stations and has the staff of observers who monitors water distribution at all off-takes and water diversion by pumping units. Monitoring at water-balance sites is conducted based on visual read-out of information and its transferring to the LDP by observers via their individual radiophones, and data input into the computers by hand. Off-takes at water-balance sites are divided into two groups: "controllable off-takes" and "accountable off-takes." Off-takes (pumping units), unplanned opening or closing of which can considerably affect canal operation, refer to "controllable off-takes" and are characterized by the following parameters:

- within the SFC system, off-takes with a discharge capacity more than 100 l/sec;
- within the AAC and KBC systems, off-takes with a discharge capacity more than 10 l/sec;

Flow rates for such off-takes can be regulated during a ten-day period; and at the same time, flow rates of off-takes with a lesser carrying capacity are not being adjusted. All off-takes are "accountable ones." Water withdrawal is accounted using water-measuring devices; however, water diversion through small off-takes with a discharge capacity less than 5 l/sec is accounted according to their rated discharge capacity.

Water withdrawal by pumping units is calculated taking into account the number of pumping units (PU) under operation and their nameplate capacity and audited according to registrations of an energy meter.

Table 5. 15 Structures under Monitoring

Irrigation canal	Number of off-takes		Total water withdrawal		Small pumping units (Q < 5 l/sec)		
	Total	Including PU	Q, m^3/s	% of Q_{st}	Number	Q, m^3/s	% of Q_{st}
SFC	162	67	92	92	68*	3.89	2.95
AAC	62	5	28.8	87	108	0.54	2
KBC	46	4	32.6	80.2	14	0.07	0.2

* Off-takes with a discharge capacity less than 100 l/sec were included into the group of off-takes non-controllable during a ten-day period within the SFC system

The number of daily observations is established depending on the duration of daylight hours: during the growing season – four times a day, and during the off-vegetation period – three times a day. Time spent by an observer at one structure was estimated based on virtual evaluating duration of each elementary procedure:

- at off-takes: i) readout of an indication of a water-level staff installed in the headrace channel; ii) readout an indication of a water meter' staff and determination of a flow rate using the design chart; iii) transmitting data to a dispatcher; and iv) data recording into the field book;
- at the pumping units: i) visual definition of the number of pumps under operation; ii) reading indication of an energy meter; iii) transmitting data to a dispatcher; and iv) data recording into the field book.

Observers are provided with radio-telephones and vehicles (by mopeds, as expected). The number of observers was specified on the basis of a length of water-balance sites, number of off-takes, and normative working hours.

Functional tasks of monitoring; reliability and exchange of information: Efficient water distribution based on the proposed system of automation and monitoring should be grounded on reliable accounting of water resources. With that end in view, the IWRM-Fergana Project envisages calibration and metrological assurance of all main structures, water-balance gauging stations and re-attestation and issuing passports of water-measuring devices. The second condition is the efficient interaction of all levels of water management hierarchy. The IWRM-Fergana Project clearly specified functional tasks of participants of management and monitoring activity.

A dispatcher of the LDP is a primary level of gathering, processing and analyzing the incoming information. Data transmitted by observers allow evaluating the uniformity of water delivery to users at the water-balance site, adequacy of water supply against the plan and an amount of unproductive water losses. Key functional tasks of participants of the monitoring process are the following:

Observers at water-balance sites:

- strict implementing the dispatcher's instructions relative to flow rates of irrigation water delivery to users;
- monitoring and accounting flow rates of irrigation water delivery through all relevant off-takes and pumping units;
- monitoring and accounting side inflows and water releases through spillways;
- transmission of data on water levels and flow rates through off-takes, pumping units, water escapes and side inflows to a dispatcher of the LDP by a radiophone;
- implementing measurements in compliance with due time and sequence of observations;
- regular data recording into the field book;

- preventing intervention in gates' operation of off-takes by non-authorized persons; and
- safeguarding and maintenance of the flowing-through section of hydraulic structures, mechanical and water-measuring equipment.

Dispatchers of the Local Dispatching Points (LDP):

- adjusting flow rates established by the CDP for a ten-day period for all off-takes and pumping stations within the water-balance sites;
- gathering and checking information on actual flow rates at non-automated off-takes transmitted by observers via radiophones four times a day in the interactive mode;
- analyzing a daily balance of water resources at water-balance sites, evaluating the efficiency factor of a water-balance site and unproductive water losses;
- regular entering of monitoring data into the database; and
- calculating an average daily flow rate and discharge for each off-take at the hydro-operational site and water-balance gauging station and submitting this information in the form of reports to the CDP.

Dispatchers of the Central Dispatching Points (CDP):

- setting assignments for LDPs' dispatchers regarding flow rates at water-balance gauging stations and all off-takes;
- implementing the planned water delivery by means of instructions to the LDPs and recurrent control of flow rates and discharges over the past periods;
- an everyday reconciliation of reported and actual data on volumes of water delivery to water users with the DP of Basin Irrigation System Management Organization;
- a reconciliation of data between water-balance sites;
- analyzing the daily balance of water resources at water-balance sites and along the irrigation canal as a whole; and
- analyzing water losses and indicators of the water balance at water-balance sites and along the irrigation canal as a whole.

The telecommunication system of the CDP and LDPs

Irrigation canals are equipped with the telecommunication system with state-of-the-art facilities for data transmitting and voice-message reports that solves the following tasks:

- reception and transmitting telemetric information, which is formed by the automation system established in the radio-communication units of the CDP, waterworks and water-balance gauging stations;
- voice radio-communication between the LDPs and observers of hydro-operational sites; and
- provision of the united information system of an irrigation canal based on the computerized network of transmitting, reception, processing and exchanging of information between the CDP and LDPs.

Under the project: "Canal Automation in the Fergana Valley", specifications are set for the following components:

- technological regime;
- analyzing and archiving of information;
- technical means;
- software;
- a telecommunication system; and
- mechanical equipment and power supply.

Developing and implementing the project: "Canal Automation in the Fergana Valley"

It is planned to implement the project: "Canal Automation in the Fergana Valley" on the pilot canals in two stages and to complete all Works in 2008. At each stage, the project implementation schedule sets the following scope of works: i) the detailed design for each water-balance site; ii) equipment procurement according to the specifications; iii) construction works (cable laying, mounting of equipment, installation of devices and sensors etc.); iv) precommisioning; v) calibration testing, attestation, and commissioning of waterworks, gauging stations and water-metering facilities at off-takes; v) training of operational personnel; vi) software development for automation and dispatching. At the final stage it is planned to implement the following scope of works: i) developing a set of software for operative water distribution management along all main canals; ii) precommissioning of all the automation systems and training of operational personnel.

The economic efficiency of the project: "Canal Automation in the Fergana Valley"

Indicators of the economic efficiency that resulted from analyzing of this project parameters are the following: i) investments – USD 1,545,000 funded by the SDC and USD 262,000 budgeted by the water management organizations of the republics; ii) operating costs – USD 332,000 and USD 377,360 prior to and after project implementation respectively; iii) annual net profit due to water savings amounts to USD 719,000 (115.27 million m3 at a water price of 0.006 USD/m^3); iv) the cost recovery – 6 years; v) the net present value – USD 2,477,000 and IRR = 32%. Results of economic analysis are given in Table 5.13.

Table 5.16
Evaluating the Economic Efficiency of the Project: "Canal Automation in the Fergana Valley"

Objects	Operating costs ,000. *USD*		Investments ,000. *USD*		Net profit		Economic indicators		
	before	**after**	**SDC**	**MAWR**	**Water volume** *mln.m^3*	**Cost** ,000. *USD*	**Cost recovery,** *years*	**NPV over 15 years**	**IRR , %**
BWO „Syr Darya"	74	87.36	305	40	38.8	232.8	**2**	**1039**	**59**
SFC	131	155	725	117	63	378	**7**	**1224**	**36**
AAC	59	64	235	30	7	69.8	**9**	**121**	**19**
KBC	68	71	280	75	6.47	38.8	**7**	**93**	**24**
In total	**332**	**377.36**	**1545**	**262**	**115.27**	**719.4**	**6**	**2477**	

Based on results of the economic analysis of existing systems operation it can be noted that the introduction of the system of automation and monitoring of the water distribution process within the irrigation systems in Central Asian countries is the cheapest measure for water resources savings in comparing with other technical solutions such as canal lining or other measures preventing water seepage losses.

The small-scale enterprise "SIGMA" (Kyrgyzstan), whose production is comparatively cheap, simple for operation and accessible for procurement, taking into consideration available operational and servicing personnel in the region, was selected as the leading Contractor for constructing the system of automation and monitoring.

By the mid of 2008, the following works were implemented in the frame of the project:

1) BWO structures:

- The system of automation and dispatching (SAD) was installed at all planned waterworks and operates since June 2006. The system of automation and dispatching was timely put into pilot operation and now is ready for commissioning;

- The systems of data transmission based on the GPRS were installed on all planned structures. Time delay in data transmission from some structures (gauging stations on Uchkurgan HS and BFC) takes place;

- Specialists of the SSE "SIGMA" debug the system of data transmission installed at BWO waterworks; and

- In February 2007, the SDT at BWO structures was put in pilot operation.

2) AAC structures:

- Detailed design was completed; equipment of the system of automation and dispatching was installed at all planned waterworks;

- The system of data transmission based on radio communication was installed by the beginning of the growing season 2008; and

- The system of automation and dispatching and the system of data transmission with software for monitoring the water distribution process were put in operation in May 2008.

3) SFC structures:

- Mechanical components of main waterworks have been repaired;

- Power transmission lines to waterworks were constructed; and the dispatching points are under construction;

- The detailed design of the system of automation and dispatching (SAD) was completed;

- The detailed design of the system of data transmission (SDT) is in progress; the specifications for equipment are adjusted; and

- Equipment for the SDT was procured, and its assembling and debugging at the Andijan part of the SFC were initiated.

4) KBC structures:

- Rehabilitation of KBC structures funded by the Asian Development Bank are being completed;
- Mechanical components of main waterworks have been repaired;
- Power transmission lines to waterworks were constructed; and the dispatching points are under construction;
- The contract for implementing the Canal Automation Project has been prepared; and necessary agreements were signed;
- Realization of the SDT project was initiated and will be completed to the end of growing season;
- Project works related to installing the system of data transmission were initiated; and
- Monitoring of preparatory works is being conducted.

The system of automation and monitoring of water distribution through irrigation canals allows:

- enhancing the accuracy of measurements of water levels, flow rates and salinity, as well as opening gates of waterworks due to the introduction of the state-of-the-art tools for measuring and accounting water resources (measurement errors are decreased from 10% to 2%);
- improving the dataware based on computerized and continuous gathering, storing in memory and processing the observed values of water levels and flow rates;
- enhancing the operability and accuracy of water resources management by speeding up transmitting and processing operational information and the decision-making process;
- decreasing unproductive water resources use; and
- timely detecting and eliminating failures of the equipment of the management system and waterworks.

It is necessary to note that the systems of automation and dispatching installed at BWO "Syr Darya" structures have raised the level of O&M substantially facilitating activity of the operational staff and improving the quality of water distribution through main canals such as the SFC, Big Andijan Canal, Khakulabad Canal and Akhunbabaev Canal. At that, the conditions for the real system of monitoring by the BWO and its territorial bodies and receiving reliable information on water resources by all stakeholders were created.