Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

SIC ICWC

IWMI
International Water Management Institute

IWRM-Fergana Valley Project

REPORT

on Position B 1.1. «Elaborate a user-friendly water management manual based on IWRM approach of SDC»

Co-Director of IWRM-FV Project from SIC ICWC, Prof.	**Dukhovny, V.A.**
Deputy Director of SIC ICWC	**Sokolov, V.I.**
Leader of Block 1	**Mirzaev, N.N.**

Tashkent – 2011

CONTRIBUTORS TO THIS REPORT

Mirzaev, N.N. Leader of Institutional Aspects of IWRM Block	Report preparation
Saidov, R. Consultant on Institutional Issues	Participation in collection and processing of materials
Ergashev, I. Consultant on Water Distribution	Participation in collection and processing of materials
Suleymanov, F. Consultant on Institutional Issues	Participation in collection and processing of materials
Yun, N. Assistant to Leader of Institutional Aspects of IWRM Block	Participation in collection of materials and execution of the report
Mirkamilova, Sh. Technical Specialist of Institutional Aspects of IWRM Block	Participation in collection of materials and execution of the report

Project “Integrated Water Resources Management in the Fergana Valley”

INTEGRATED WATER RESOURCES MANAGEMENT

MANUAL

VOLUME I I

WATER MANAGEMENT IN IRRIGATION SYSTEMS

Tashkent – 2011

Project “Integrated Water Resources Management
in the Fergana Valley”
(IWRM-FV)

Executors:

International Water
Management Institute (IWMI)

Scientific Information Center
of the Interstate Commission
for Water Coordination (SIC ICWC)

Swiss Agency for Development
and Cooperation (SDC)

Acknowledgment

The authors acknowledge their indebtedness to SDC for the financial assistance to the Project, as well as to the Project Co-Directors Prof. V.A. Dukhovny and Dr. H. Manthrithilake for their contribution.

They also express their appreciation to the national executors of the Project for their consultation and contribution to the preparation of materials for this work.

As well, they are grateful to the reviewers for their comments and proposals and to everyone who have taken part in the preparation of this Manual.

For more information on the IWRM-FV Project, please visit the website:
http://iwrm.icwc-aral.uz
Please send your comments and suggestions to the following address:
nazir_m@icwc-aral.uz

FOREWORD

Since September 2001, the Integrated Water Resources Management in the Fergana Valley (IWRM-FV) Project has been carried out with the financial support of the Swiss Agency for Development and Cooperation (SDC). The project execution is entrusted to the Association of IWMI and SIC ICWC.

The Project has been implemented with the support from the Ministry of Agriculture and Water Resources of the Republic of Uzbekistan, Ministry of Agriculture, Water Resources, and Processing Industry of the Kyrgyz Republic, and Ministry of Land Reclamation and Water Resources of the Republic of Tajikistan.

The project facilities are the main canals of the Fergana Valley: South Fergana Main Canal (SFMC), Aravan-Akbura Canal (AAC), and Khodja-Bakirgan Canal (KBC).

The ultimate goal of the IWRM-FV Project is to contribute to the improvement of livelihood, environment, and social harmony by restructuring rural areas in the republics participating in the Project, i.e. Kyrgyzstan, Uzbekistan, and Tajikistan. This restructuring includes implementation and pilot testing of the IWRM principles, including both involvement of water users in the water governing institutions’ activities in the Fergana Valley and improvement of water management tools.

The project goal at the pilot canal level is to improve the quality of water distribution in systems (canals) on the basis of the water distribution stability, equity, and efficiency principles. This goal is to be achieved through the activity which includes the following aspects: organizational, technical, technological, and capacity building. Both the institutional and technological aspects of water management are considered within the IWRM-FV Project. This Manual covers the technical and technological aspects of water distribution.

The water resources management process is composed of the following stages:
- drawing up of water use and water distribution plans;
- implementation of the water use and water distribution plans (adjustment, water rotation);
- monitoring and assessment;
- taking water distribution decisions for the next base period.

All of these stages have certain shortcomings. Taking into account those, a water management system was developed and improved in the course of the implementation of the IWRM-FV Project, which includes:
- management information system (MIS): water distribution planning and assessment models and software;
- System of water distribution indicators for the assessment of water management quality;
- Participation of water users in the decision making process (through their representatives in CWC).

MIS-Fergana includes the software for the calculation of main water distribution indicators: available water supply; stability; uniformity; efficiency; specific water supply. In future, as the database (DB) and software develop, the composition of the used indicators can and must be extended.

Water distribution assessment is a difficult problem: both internal and external water distribution assessment is required; the indicators should continuously be upgraded and, ultimately, facilitate decision making aimed at improving water productivity.

In the water distribution assessment process, it is necessary to always pursue answers to the following questions: Am I doing everything right? Is what I am doing right at all?
The answer to the first question is to be given by an internal assessment, while that to the second question can be provided by an external assessment. Answering the first question, you are assessing the water management quality; and answering the second one, you are assessing the water governance quality.

At present, the IWRM-FV Project developments are used in the operation of Automated Control Systems (ACS) introduced on AAC, SFMC, and KBC.

Water distribution monitoring and assessment results have shown that the reforms at the pilot canals had positive effect on the water management quality as follows: water supply stability and uniformity enhancement and specific water supply decline tendency is observed on all pilot canals.

This Manual represents a new version of the “Operating Manual…” that has been improved in terms of the context and form. It has become more understandable for the user. Moreover, this version has been supplemented with a section covering the issues of the calculation and organization of water rotation in irrigation systems.

The Manual is not a detailed water management instruction with a set of all standard tables (forms) and reference data. Our purpose is to give only water management basics in an easily accessible form (allowing for our recommendations) and raise the user’s knowledge level.

In the Manual, in connection with the liquidation of kolkhozes (sovkhozes) and, instead of those, formation of water users’ associations, the term “water use plan” is used instead of “economic plan of water use” and the term “water distribution plan” (implying the plan of water distribution throughout the main canal system) is employed instead of the term “systems water distribution plan”.

Since nowadays the basic form of the association of water users in CAR is WUA, from now on for simplicity reason we shall say only of WUA, meaning all types of associations of water users. Similarly, since the most popular form of an agricultural enterprise is the individual farm, from now on when saying of farms, we shall imply all types of agricultural enterprises.

The Manual is designed for water management organizations, water users, and other persons interested in water management matters. To broaden the readers’ outlook, additional information is given in the annexes to this Manual.

CONTENTS

INTRODUCTION

The main purpose of the irrigation system operating service is to create conditions for achieving high and stable crop yield on irrigated lands on the assumption of effective use of water and land resources.

Special structures (operating organizations), i.e. irrigation system administrations, canal management organizations, hydrotechnical units, reservoirs, etc., have been established for the operation of irrigation and drainage systems.

The following are among the operating organizations (Annex 3):

- Objects of operation: technical facilities designed for water withdrawal, distribution, supply, and diversion, i.e. reservoirs, canals, key units, pumping stations, irrigation and drainage network, collectors, drains, etc.
- Means of operation: units and equipment by means of which the technical facilities are operated, i.e. water accounting stations, groundwater level observation wells.
- Subjects of operation: operating personnel who carry out works for the operation and maintenance of irrigation and drainage network.

The operating personnel are charged with the following duties:

- Drawing up and implementation of water use and water distribution plans (hereinafter referred to as plans); improvement of irrigation technology; control of water losses within the system.
- Repair of canals, flumes, pipelines, and structures; cleaning canals from sediments and weeds; carrying out afforestation along canals and at key structures.
- Prevention of salinization and swamping of irrigated lands; improvement of land reclamation state; diversion of wastewater outside the system.
- Protection of canals, structures, and reserves from erosion and inundation by flood water: equipping the delivery points with water measurement devices; improvement of the system's technical facilities; enhancement of the system operation level; application of achievements and best practices in science and technology.
- Implementation of the mechanization of operational works as well as automation and telemechanization of control in the systems.
- Carrying out of production experiments in the systems in order to improve the operation and enhance the systems; certification of those; cadastre and accounting of irrigated lands.

This Manual deals only with the issues of drawing up, adjustment, and implementation of water use and water distribution plans. This Manual rests on a traditional method of drawing up and adjustment of water use and water distribution plans.

Despite that the traditional method of drawing up and adjustment of water use and water distribution plans has some shortcomings (Annex 4), it has no alternative suitable for the water use and water distribution practice.

There are also flaws in the management of planning as well as plan implementation process. These shortcomings in the IWRM-FV Project zone have partially been removed by establishing MIS-Fergana (Annex 5) and new institutional structures (WUA, UCWU, CWC).

Owing to the use of the MIS, water use plans have become more explicit. Owing to the new institutional structures, the role of water users in water governance rises: they take part in the process of water distribution monitoring, assessment, and decision making.

The organizational and technological stages of water governance and management are given in Table 1.1. Union of (Main) Canal Water Users (UCWU) participates in the decision-making process through its representatives in CWC.

Table 1.1. Organizational and technological stages of water governance and management

Stage	Type of activity	Executors	Result (output)
1	Preparation of CMO infrastructure for the season (maintenance, cleaning, etc.)	CMO, WUA	Report from water users (WUAs, shirkats) regarding the readiness of irrigation and drainage systems
2	Formation of initial information for drawing up of water use plans (WUP)	WUs	Initial information for WUP
3	Drawing up of WUP (determination of water demand for the base period (year, season))	CMO	WUP
	Coordination of WUP with CWC	CWC	Minutes
4	Approval of WUP	CMO	Approved WUP
5	Submission of WUP to a superior WMO	CMO, WMO	
6	Conclusion of water supply contracts between CMO and water users (WUA, shirkats, etc.)	CMO, WUs	Water supply contracts
7	Conclusion of water withdrawal contracts between CMO and WMO[1]	CMO, WMO	Water withdrawal contract(s)
8	Assessment of water supply (right to water) on PC (water withdrawal to PC from an irrigation source – canal, reservoir)	WMO	Seasonal water discharge (flow)
9	Seasonal adjustment of WUP (setting guaranteed water withdrawal to PC and water supply from PC – seasonal limited water withdrawal and water supply broken down by ten-day periods of the vegetation period)	CMO	Adjusted seasonal WUP
10	Coordination of adjusted WUP with CWC	CWC	Memorandum of agreement
11	Approval of adjusted WUP[2]	CMO	Approved adjusted WUP
12	Assessment of water demand for the ten-day base period (collection of water applications) for groups of off-takes	WUs	Applications of water users of off-take groups
13	Assessment of the water supply (right to water) by the head of PC off-takes for the ten-day base period (in absolute and relative values)	WMO, reservoir	Water discharge (flow) for the ten-day base period
14	Ten-day-period based adjustment of WUP	CMO	Planned ten-day period

---

[1] In Kyrgyzstan and Tajikistan, water withdrawal and water supply agreement with CMO is concluded for planned water withdrawal (water supply); in Uzbekistan, for limit water withdrawal (water supply) fixed by a superior WMO (Position 9).

[2] Positions 9-11 are characteristic only of Uzbekistan.

Stage	Type of activity	Executors	Result (output)
	(estimation of the limit for the ten-day base period) for off-take groups		limits
15	Updating water demand (collection of applications for within-ten-day adjustment of WUP; re-distribution of water to water users' off-takes within the total water limit set for the water user) for off-takes	CMO, WUs	Updated applications for the ten-day base period
16	Within-ten-day adjustment of WUP (re-distribution of water between water user's off-takes; updating of limits for water users/off-take groups)	CMO	Updated limits for off-takes
17	Delivery of adjusted WUP to executors (hydraulic sites)	CMO	
18	Water supply to off-takes in accordance with an established limit	CMO	Reports of water supply-withdrawal
19	Monitoring and control of water distribution (collection of data on actual water supply to off-takes and water users)	CMO	Actual data
20	Calculation of the actual water right, application, and limit values and water distribution indicators (stability of average daily water supply during the ten-day period; water supply against the planned (limit); water supply stability and equity; efficiency; specific water withdrawal (water supply))	CMO	Water distribution indicators
21	Working meetings (progress meetings, CWC Board meetings, CWC meetings) for the analysis of water distribution (to hydraulic sites and water users) and taking decisions on the improvement of water distribution	CMO, CWC	Minutes of meetings

The terms "governance", "equity", and "water right" are key ones. From our point of view, introduction of the term "water quota (right)" would simplify understanding of the WUP adjustment process. However, water management organizations and water users are used to call "limit" both the water volume to which they have a right and the water volume which is decided to be supplied to the water user after having coordinated water "supply" and "demand" (i.e. application), although these "limits" have different meanings which may not coincide. Therefore, the terms "limit-quota" and "limit setting" have been introduced.

The principle of total water supply equality can also be defined as the principle of the equality of relative losses from water deficit. The traditional proportionality principle can be considered as a particular case of the equality of total water supply level for the case when the hydrogeological conditions of the zone commanded by the canal slightly vary in space and time (throughout the vegetation period). Such situation is characteristic of AAC and KBC.

At the present stage of water allocation development in CAR, the equity criterion is represented by water supply uniformity. The equity principle contradicts the economic optimality principle. This contradiction can be removed in future through the introduction of such concepts and processes as fixed water right, water right market, and water rights trading.

Reservoirs

Toktogul reservoir

Andijan reservoir

Akburasay river

Canals

SFMC intake

AAC intake

KBC intake

Dam on the Khodjabakirgansay river

SFMC (hydraulic site)

Hydraulic site “Palvantash” (SFMC)

SFMC

Gauging stations

Gauging station on the main canal (SFMC)

Gauging station at the WUA’s gate

Gauging station at the farm’s gate

Venturi flume

Gauge well

Source: reports of the IWRM-FV Project executors.

2. WATER USE AND WATER DISTRIBUTION PLANNING

Water distribution and use in all sections of the irrigation system are carried out proceeding from water demand data. To determine water demand, irrigation system water use and water distribution plans are drawn up.

Water use and water distribution planning is carried out based on the bottom-up principle: beginning from the irrigation contour to the point of water withdrawal to a main canal. At that, the number of canals may considerably vary depending on the complexity of the irrigation network.

Water use and water distribution plans are drawn up for seasons (vegetation period (April-September) and non-vegetation periods (October-March)), for average annual climatic conditions.

When planning water use and water distribution, all types of water (surface, subsurface, ground, etc.) should be taken into account as well as water demand by all types of water users: both major (agricultural) and other water users that take water from both associations of water users and directly from the main canal system (not through the irrigation system of associations of water users).

A water distribution plan is to be prepared based on a water use plan. It is coordinated with the irrigation source regime, canal conveying capacity, and reclamation conditions of the system.

Water use and water distribution plans are to be drawn up on an annual basis.

Water use and water distribution plans must be drawn up, as a rule, for every season separately (vegetation and non-vegetation periods). However, according to superior water management organizations, as well annual plans covering the period from February (March) to October (November) can be drawn up.

Among other water users are homestead lands, nature reserves, fishery, hydropower industry, public utility and industrial enterprises, etc.

The water use plan allows for irrigated cropping pattern, soil-reclamation state of irrigated lands, technical parameters of the irrigation system (performance factor, discharge capacity), etc.

The water use plan is a part of the water user's production plan. It is made to organize water supply to irrigated lands in line with approved crop irrigation regimes and subject to territory planning and labor organization.

The water use plan also takes into consideration the water demand by other water users that take water directly through the irrigation service of the WUA.

The water use and water distribution plans are adjusted depending on the actual existing water content in the irrigation source as well as weather and economic conditions in the target year.

If an irrigation source completely meets water demand, all canals will always work in compliance with the water use plan.

At water shortage in the irrigation source, the water use and water distribution plans are to be adjusted based on priority and proportionality principles. At that, the priority water users' limits-quotas are not cut down or are done in part.

Subject to weather and economic conditions water use plan adjustment is carried out taking into account water users' applications.

Basically, with the existing planning practice the value of planned water supply for a season for a farm (accordingly for WUA and CMO) resulted from WUP is the limit-quota of the farm. Thus, the farm's limit-quota depends on cropping pattern, technical condition of farms network, and applied irrigation technology, i.e. it may change from year to year.

Under these conditions, the farm is not to profit from the transition to growing non-hydrophilous crops, raise the efficiency of the irrigation network, and apply a new irrigation technology, because its limit-quota will accordingly decrease in this case.

To stimulate water saving, it is necessary to fix a limit-quota for the farm. Then, on the contrary, the cropping pattern will depend on the planned limit-quota. In other words, the farm will have to "cut the coat according to the cloth" and not the other way round.

2.1. Initial and Calculation Information

Initial and calculation information for drawing up water use plan:

- Crop irrigation regime (Annex 6) is set allowing for the type of crop, hydromodule zone, and climatic zone.
- Map (scheme) of water user's irrigated lands with plotting irrigation and collector-drainage network, points of water delivery from the inter-farm network, hydraulic structures, gauging stations.
- Linear scheme and technical characteristics of the water user's irrigation network (efficiency factor, discharge capacity).
- Soil map of WUA's irrigated lands with plotting farms; boundaries, irrigation contours, and hydromodule zones.
- Cropping pattern for the planned year in terms of hydromodule zones (HMZ), crops, and canals.
- Data of WUA irrigation sources, including internal sources (springs, wells, collector and drainage networks).
- Data of water supply rates for other (non-agricultural) water users ("production and technical needs" etc.).
- Irrigation and ten-day period water duties serve as calculation information for drawing up water use plans. Those are calculated based on the crop irrigation regimes (Annex 7).
- Others.

Initial and calculation information for drawing up water distribution plan:

- The water use plans of the WUAs located in the main canal zone.
- Map (scheme) of water user's irrigated lands with plotting irrigation and collector-drainage network, points of water delivery from the main irrigation network, hydraulic structures, gauging stations (Fig. 2.1).
- Linear scheme and technical characteristics of the water user's irrigation network (efficiency factor, discharge capacity).

- Data of the water supply rates for other water users (homestead lands, ecology, drinking water supply, public utilities, etc.). The water supply rates for other water users are set according to relevant normative documents.
- Other.

2.2. Water use and water distribution plans design algorithm

Farm

1. Calculation of the ten-day water supply from the farm to the irrigation contour

$$TWS_{IC} =(TH_{IC} * IA_{IC}) / EF_{IC}, \tag{2.1}$$

where

TWS_{IC} – ten-day water supply from the farm canal to the irrigation contour.

TH_{IC} – ten-day water duty of the irrigation contour.

IA_{IC} – irrigated area of the irrigation contour.

EF_{IC} – irrigation contour efficiency factor

$$EF_{IC} = EF_{IT} * EF_{TID}, \tag{2.2}$$

where

EF_{IT} – efficiency factor of the irrigation contour irrigation method.

EF_{TID} – efficiency factor of the temporary irrigation ditch of the irrigation contour.

2. Calculation of the ten-day water supply to the lowest/lower-order farm canal

$$TWS_{Fclo} = \Sigma TWS_{IC} / EF_{Fclo}, \tag{2.3}$$

where

TWS_{Fclo} – ten-day water supply to a lower-order farm canal that supplies water directly to the temporary irrigation contour of the irrigation contour.

ΣTWS_{IC} – total ten-day water supplies to the irrigation contours irrigated from a lower-order farm canal.

EF_{Fclo} – lower-order farm canal efficiency factor.

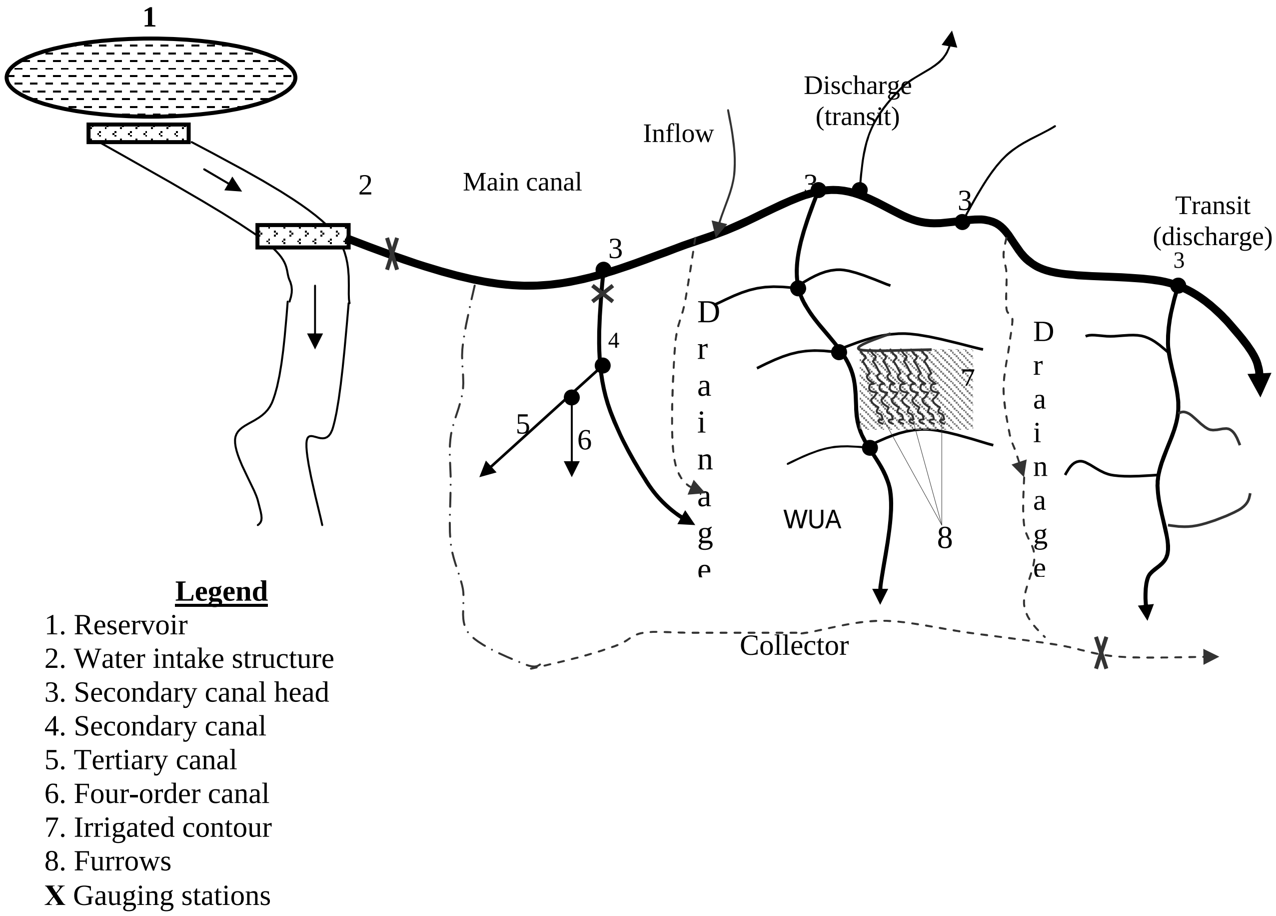


Figure 2.1. Layout of the irrigation and drainage system.

3. Calculation of the ten-day water supply to a higher-order farm canal

$$TWS_{Fcho} = \Sigma TWS_{Fclo} / EF_{Fcho}, \tag{2.4}$$

where

TWS_{Fcho} – ten-day water supply to a higher-order farm canal that supplies water to lower-order farm canals.

ΣTWS_{Fclo} – total ten-day water supplies to lower-order farm canals.

EF_{Fcho} – higher-order farm canal efficiency factor.

If there are canals of even higher order, the calculations go on up to the highest-order canal that takes water directly from the farm irrigation source.

4. Calculation of the ten-day water supply to the farm (at the farm gate).

$$TWS_{Fcho} = \Sigma TWS_{Fclo} / EF_{Fcho} \quad (2.5)$$

$$TWS_{F} = TWS_{Fe} + TWS_{Fi} \quad (2.6)$$

$$TWS_{Fe} = \Sigma TWS_{Fclo} , \quad (2.7)$$

where

TWS_F – ten-day water supply to the farm.

TWS_{Fe} – ten-day water supply to the farm from an external irrigation source.

TWS_{Fi} – ten-day water supply to the farm from an internal irrigation source.

ΣTWS_{Fcho} – total ten-day water supplies to higher-order farm canals that take water directly from the sources of external irrigation of this farm.

Water Users Association

5. Calculation of the ten-day water supply to the lower-order WUA canal [3]

$$TWS_{WUAclo} = (\Sigma TWS_{Fcho} + \Sigma TWS_{Ocho}) / EF_{WUAclo} , \quad (2.8)$$

where

TWS_{WUAclo} – ten-day water supply to the lower-order WUA canal that supplies water directly to the canals of farms and other water users.

ΣTWS_{Fcho} – total ten-day water supplies to higher-order farm canals that take water from a lower-order WUA canal.

ΣTWS_{Ocho} – total ten-day water supplies to higher-order other water users' canals that take water from a lower-order WUA canal.

EF_{WUAclo} – lower-order WUA canal efficiency factor.

6. Calculation of the ten-day water supply to the higher-order WUA canal

$$TWS_{WUAcho} = \Sigma TWS_{WUAclo} / EF_{WUAcho} , \quad (2.9)$$

where

TWS_{WUAcho} – ten-day water supply to the higher-order WUA canal that supplies water to higher-order WUA canals.

ΣTWS_{WUAclo} – total ten-day water supplies to lower-order WUA canals.

EF_{WUAcho} – higher-order WUA canal efficiency factor.

---

[3] WUA canals are, as a rule, former on-farm canals.

If there is a WUA off-take of even higher order, the calculations go on up to the highest-order WUA canal that takes water directly from the WUA irrigation source.

7. Calculation of the ten-day water supply to the inter-WUA canal (at the WUA gate)

The WUA may have, generally, both external and internal irrigation sources. So,

$$TWS_{WUA} = TWS_{WUAe} + TWS_{WUAi} \tag{2.10}$$

$$TWS_{WUAe} = \Sigma TWS_{WUAcho} + \Sigma TWS_{Fcho}\ , \tag{2.11}$$

where

TWS_{WUA} – ten-day water supply to the WUA.

TWS_{WUAe} – ten-day water supply to the WUA from an external irrigation source.

TWS_{WUAi} – ten-day water supply to the WUA from an internal irrigation source.

ΣTWS_{WUAcho} – total ten-day water supplies to higher-order WUA canals that take water directly from external sources of irrigation of this WUA.

ΣTWS_{Fcho} – total ten-day water supplies to higher-order farm canals that take water from the external sources of irrigation of this WUA.

Main canal

8. Calculation of the ten-day water supply to the lower-order inter-WUA canal[4] (ten-day water supply from a main canal)

$$TWS_{IWUAclo} = \Sigma TWS_{WUAcho} / EF_{IWUAclo}\ , \tag{2.12}$$

where

$TWS_{IWUAclo}$ – ten-day water supply to the lower-order inter-WUA canal that supplies water directly to higher-order WUA canals and other water users.

ΣTWS_{WUAcho} – total ten-day water supplies to higher-order WUA canals that take water from a lower-order inter-WUA canal.

$EF_{IWUAclo}$ – lower-order inter-WUA canal efficiency factor.

9. Calculation of the ten-day water supply to the higher-order inter-WUA canal

$$TWS_{IWUAcho} = \Sigma TWS_{IWUAclo} / EF_{IWUAcho}\ , \tag{2.13}$$

where

$TWS_{IWUAcho}$ – ten-day water supply to the higher-order inter-WUA canal that supplies water to lower-order WUA canals.

---

[4] An inter-WUA canal is, as a rule, a former inter-farm canal.

$\Sigma TWS_{IWUAclo}$ – total ten-day water supplies to lower-order WUA canals.

$EF_{IWUAcho}$ – higher-order inter-WUA canal efficiency factor.

If there is an inter-WUA canal of even higher order, the calculations go on up to the highest-order inter-WUA canal that takes water directly from the main canal.

10. Calculation of the ten-day water supply from the main canal

Water from the main canal is supplied to secondary canals which can be inter-WUA, WUA, and farm canals, as well as canals that supply water to other water users.

$$TWS_{Mc} = \Sigma TWS_{IWUAcho} + \Sigma TWS_{WUAcho} + \Sigma TWS_{Fcho} + \Sigma TWS_{OWUho}\ , \qquad (2.14)$$

where

TWS_{Mc} – ten-day water supply from the main canal.

$\Sigma TWS_{IWUAcho}$ – total ten-day water supply from the main canal to higher-order inter-WUA canals.

ΣTWS_{WUAcho} – total ten-day water supplies to higher-order WUA canals that take water directly from the main canal.

ΣTWS_{Fcho} – total ten-day water supplies to higher-order farm canals that take water directly from the main canal.

ΣTWS_{OWUho} – total ten-day water supplies to other higher-order water users directly from the main canal.

11. Calculation of the ten-day water supply to the main canal.

$$TWI_{Mc} = TWS_{Mc} / EF_{Mc}\ , \qquad (2.15)$$

where

TWI_{Mc} – ten-day water supply (head water intake) to the main canal.

TWS_{Mc} – ten-day water supply from the main canal.

EF_{Mc} – main canal efficiency factor.

12. Calculation of ten-day water flow

$$TF = TWS * T_{sec} = 0.0864 * TWS * T_{day}\ , \qquad (2.16)$$

where

TF – ten-day water flow, mln. m^3.

TWS – ten-day water supply, m^3/s.

T_{sec} – length of the calculation ten-day period in seconds.

0.0864 – conversion factor.

T_{day} – length of the calculation ten-day period in days.

13. Calculation of water flow in progressive total

$$PF = \Sigma TF, \qquad (2.17)$$

where

PF – water flow in progressive total for the calculation period (during the vegetation period, from the first ten-day period of April until the calculation ten-day period).

ΣTF – total ten-day water flows for the calculation period.

2.3. Example of water use and water distribution plans

Individual farm

Below, examples of the designing water use and water distribution plans for a conventional main canal (Fig. 2.2).

Individual farm 1 (F1)

1. F1 irrigation sources: tertiary canal 111[5].
2. Canals servicing F1: four-order canals 1111 and 1112.

$$TW_{1111} = \Sigma TW_{IC} / EF_{1111}$$

Similarly, TW_{1112}.

$$TW_{F1} = TW_{111} = (TW_{1111} + TW_{1112}) / EF_{111}$$

where

ΣTW_{IC} – total ten-day water supply to irrigation contours 1111;
TW_{F1} – ten-day water supply to F1.
TW_{111} – ten-day water supply to canal 111.
TW_{1111} – ten-day water supply to canal 1111.
EF_{1111} – efficiency factor of canal 1111.
EF_{111} – efficiency factor of canal 111.

Individual farm 2 (F2)

1. F2 irrigation sources: tertiary canal 112 and secondary canal 11 as well as on-farm irrigation source – well for irrigation of 2. The peculiarity of F2 is that this has no on-farm irrigation source.
2. Canals servicing F2: four-order canals 1121 and 1123, tertiary canal 115, as well as canal 21.

---

[5] Here, the first figure one unit stands for the number of the main canal; second – secondary (relative to the main canal) canal number; and the third – tertiary canal number; etc.

Estimate of the ten-day water supply to F2 is carried out in the same way as was done for F1.

$$TW_{F2} = TW_{1121} + TW_{1123} + TW_{115} + TW_{21} ,$$

where

TW_{F2} – ten-day water supply to F2.

TW_{1121}, TW_{1123}, TW_{115} – ten-day water supply to F2 farm canals from external irrigation sources (from the main canal system).

TW_{21} – ten-day water supply to canal 21 from an external source of irrigation of F2 (from an irrigation well).

Individual farm 3 (F3)

1. F3 irrigation sources: tertiary canal 112 (this is an inter-farm canal belonged to the Water Users Association, numbered 1 (A1)).
2. Canals servicing F3: four-order canals 1122 and 1124.

Estimate of the ten-day water supply to F3 (similarly to that done for F1 and F2).

$$TW_{F3} = TW_{1122} + TW_{1124} ,$$

where

TW_{F3} – ten-day water supply to F3.

TW_{1122}, TW_{1124} – ten-day water supply to canals 1122 and 1124.

Individual farm 4 (F4)

1. F4 irrigation source: tertiary canal 112 (this is an inter-farm canal belonged to the Water Users Association, numbered 1 (A1)).
2. Canals servicing F4: four-order canal 1126 and five-order canals 11251 and 11252 that take water from canal 1125.

Estimate of the ten-day water supply to F4.

$$TW_{F4} = TW_{1125} + TW_{1126} ,$$

where

TW_{F4} – ten-day water supply to F4.

TW_{1125}, TW_{1126} – ten-day water supply to canals 1125 and 1126, respectively.

$$TW_{1125} = (TW_{11251} + TW_{11252}) / EF_{1125} .$$

Water Users Association

WUA 1 (A1).

1. Source of irrigation of WUA 1 (A1): secondary canal 11. A1 has no on-farm irrigation source.
2. Canals servicing A1: tertiary canals 111, 112, 115.

Estimate of the ten-day water supply to canals 111 and 115 has already been done in the course of the estimate of water demands for F1 and F2.

Estimate of the ten-day water supply to canal 112. Water is supplied from canal 112 to farms F2 and F3 as well as other water users: homestead lands (canal 1127) and production and technical needs (canal 1128).

$$TW_{112} = (TW_{1121} + TW_{1122} + TW_{1123} + TW_{1124} + TW_{1125} + TW_{1126} + TW_{1127} + TW_{1128}) / EF_{112}.$$

Estimate of the ten-day water supply to A1.

$$TW_{A1} = TW_{111} + TW_{112} + TW_{115}.$$

Main canal

Estimate of the ten-day water supply to (intake from) main canal.

$$TW_1 = (TW_{11} + TW_{12} + TW_{13} + \ldots + TW_{1N}) / EF_1,$$

where

TW_1 – ten-day water supply to the main canal.
TW_{1N} – ten-day water supply from the last (end) secondary canal.
EF_1 – main canal efficiency factor.
TW_{11} – ten-day water supply to the inter-WUA canal 11.

$$TW_{11} = (TW_{111} + TW_{112} + TW_{113} + TW_{114} + TW_{115} + TW_{116}) / EF_{11}.$$

EF_{11} – efficiency factor of the inter-WUA canal 11.

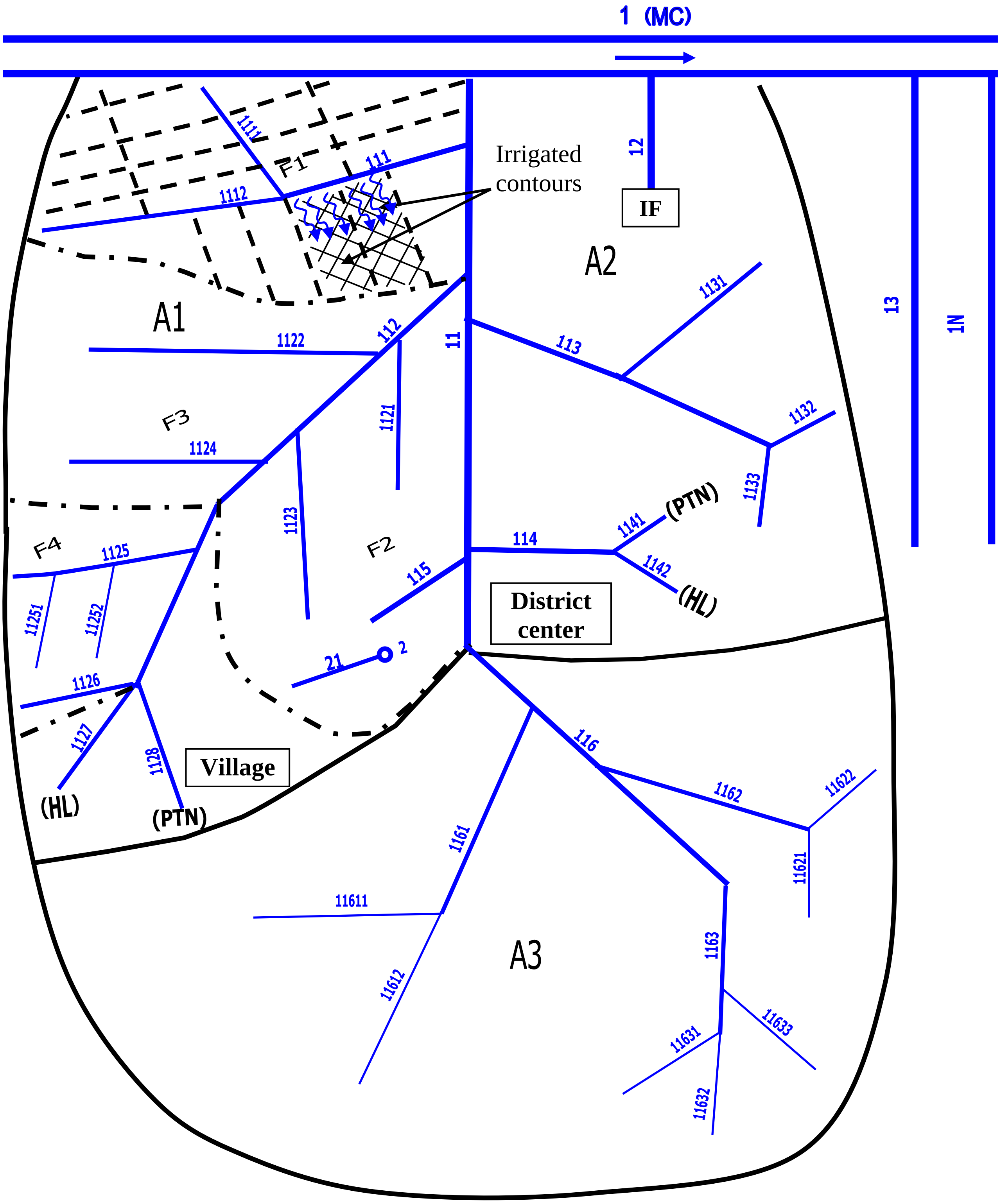


Figure 2.2. Fragment of the main canal scheme

Legend:

○ – internal irrigation source

A1, A2, A3 – Water Users Associations

F1, F2, F3, F4 – farms

IF – industrial facility

PTN – production and technical needs

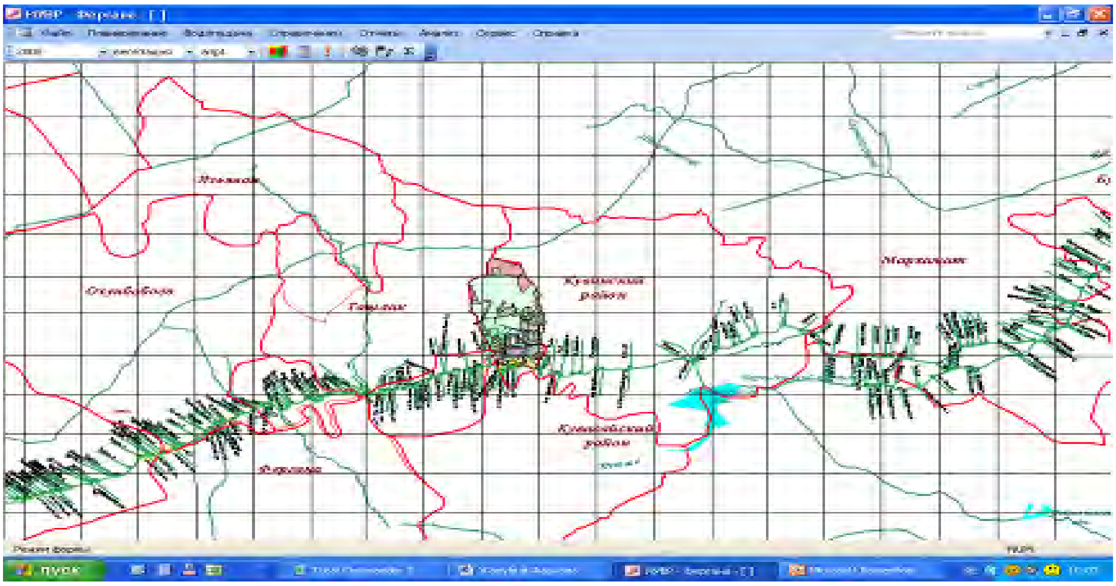
HL – homestead lands

1 – main canal (MC)

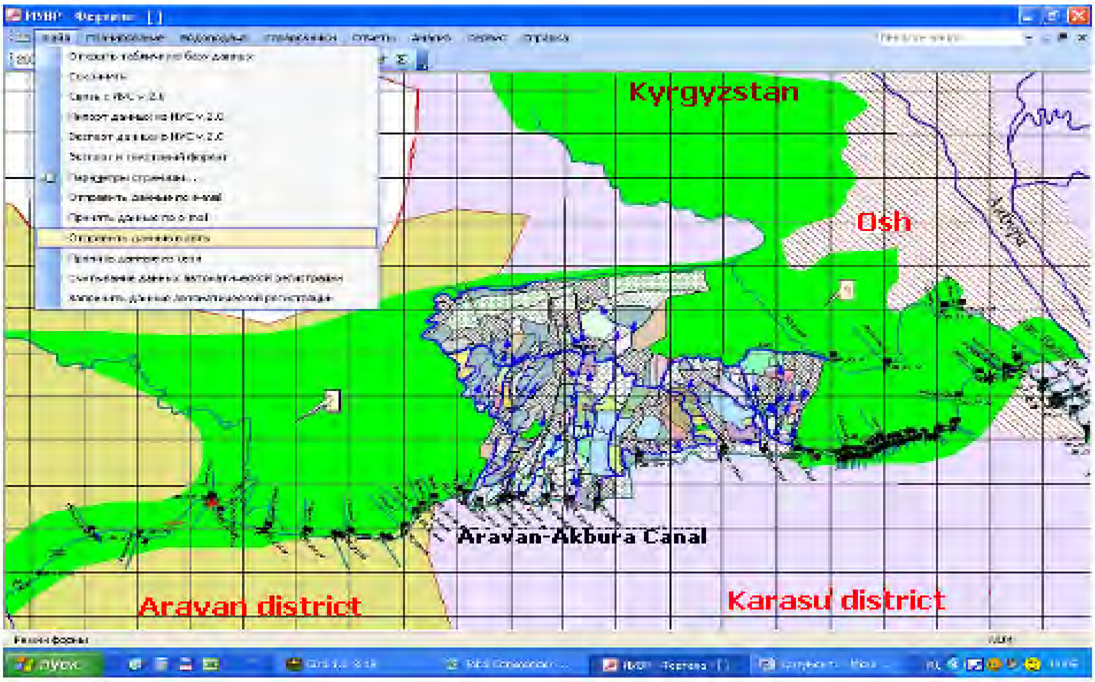
11, 12, 13, 1N – secondary canals

111, 112, … 116 – tertiary canals

MIS «Fergana»

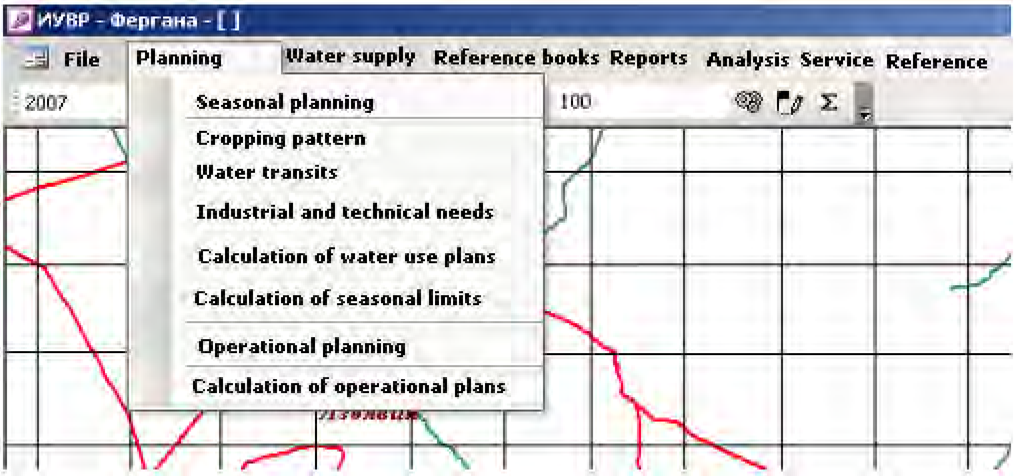


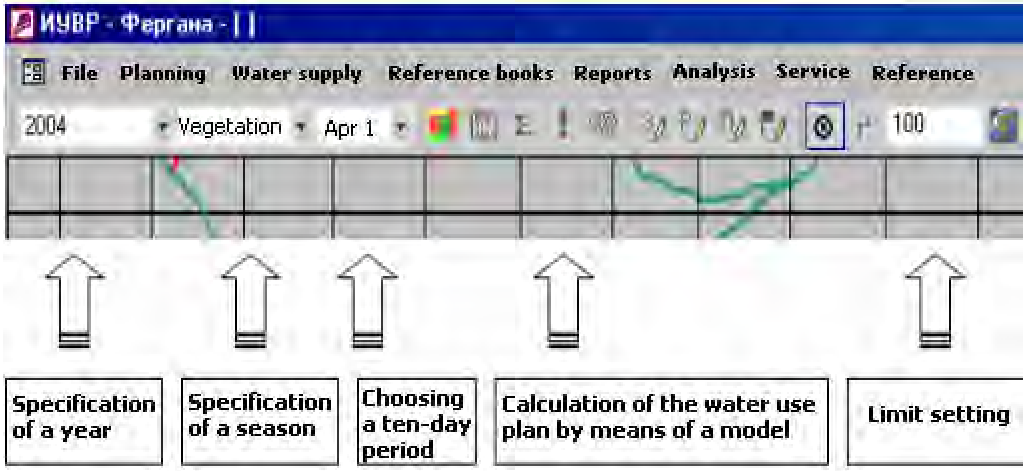
SFMC map



AAC map

KBC map





Specification of a year

Specification of a season

Choosing a ten-day period

Calculation of the water use plan by means of a model

Limit setting

3. IMPLEMENTATION OF THE WATER USE AND WATER DISTRIBUTION PLANS

After water use and water distribution plans are drawn up, they start their implementation stage which includes the following types of activities:
- Preparation of the irrigation system.
- Seasonal and operational adjustment of the plans.
- Water supply to water users.
- Monitoring and assessment of water use and water distribution.

Preparation of the irrigation system

In the issues related to rational use of irrigation water and timely irrigation at high-technical level, thorough preparation of the irrigation system, land reclamation equipment, and irrigated lands for running water and carrying out of irrigation is essential.

Main types of the works for the preparation of the irrigation system:
- Operational planning of the fields.
- Repair of canal sand structures.
- Cleaning the network from sediments.
- Repair of water measuring facilities.
- Guidance (training) of the operation personnel.

Seasonal and operational adjustment of the plans

They may have to deviate from the outlined water use and water distribution plans in the following cases:
- Change of crop areas and cropping pattern;
- Departure of weather conditions from those provided for according to average long-term meteorological conditions (abundant precipitation, sharp fall of temperature, occurrence of hot dry winds and harmseals, strengthened wind activity, etc.);
- Dramatic rise or drop of groundwater table;
- Change in the water content of the irrigation source;
- Accident at the irrigation system.

The task of the seasonal and operational water use and water distribution plans is to fairly set limits-quotes and limits-settings for water users taking into account available water resources and water users' applications.

Water supply to water users

Analysis of the water use practice shows that departure of the actual water supply value from the set limits takes place to a greater or lesser extent, as a rule, on all pilot canals. When supply water to water users, the main objective of the operation service is to minimize the departure of the actual ten-day water supply from the limits-settings to ensure high level of the following water supply indicators:
- Stability.
- Equity.
- Efficiency.

When the water content of irrigation sources is changed or in case of accidents in the system, water supply is to be regulated by special directions set for the system by the organizations that approve water distribution plans.

Water users must be given advance notice about changes in water supply, and they accordingly will change their irrigation plans. If water supply is dramatically reduced, special mobilization measures should be worked out that enable use water in the farm in the most economical way.

In the case of forced temporary increase of water supply, the water user is to receive water and make additional irrigation of the fields and crops for which overload is not dangerous.

If it is necessary to reduce water supply for internal reasons, the WUA must beforehand (2-3 days earlier) inform of this the management of a relevant hydraulic site.

Monitoring and assessment of water use and water distribution

Monitoring and assessment of water use and water distribution are needed to take effective and fair decisions at operational adjustment of water use and water distribution plans for the upcoming ten-day period, season, year.

The main water supply indicators are:

- Sufficiency of water supply.
- Stability.
- Equity.
- Efficiency.
- Specific water supply.
- Water productivity, etc.

Poor transparency is inherent in the water distribution plan implementation stage: top-down adjustment is carried, as a rule, without participation or low participation of downstream structures, viz. limit for provinces is determined at the republican level; for districts at the provincial levels; etc. Analysis shows that at that limits-quotes and limits-settings are set not always strictly in line with the proportionality principle.

Therefore, the role of the public (water users and other water users), which is to promote meeting the water distribution stability, equity, and efficiency principles in every way possible, is especially important at this stage. For that such institutional structures as UCWU and CWC have been set up within the project.

Establishment of Canal Management Organizations (CMO), UCWU, and CWC at SFMC, AAC, and KBC within the project has created prerequisites for solving water distribution organization problems. Establishment of these structures is not an end in itself. They are needed for creating conditions (transparency, openness) for equitable (uniform), stable, and effective water distribution.

KBC WC Board meeting

SFMC WC Board meeting

3.1. Preparation of the irrigation system

Repair and cleaning of hydraulic structures and facilities

The preparation works begin from bringing of the whole irrigation, collector and drainage, and discharge network with structures on those to a normal technical state.

In addition to the repair of canals and structures in the autumn-winter period, they are cleaned from sediments and silts; in winter, these are equipped with water distribution and water regulating facilities and devices as well as water measuring equipment.

Special attention is given to the equipping of water delivery points with water measuring facilities. For all the facilities intended for water accounting, calibration tables and schedules are drawn up or updated.

Operational planning of the fields

The irrigated area is levelled up before starting irrigation. This requires annual operational planning of irrigated areas which allows removing back ridges, dead furrows, and remains of the irrigation network.

Operational planning of the fields is carries out after harvesting crops in the second half of summer or in autumn; planning is not recommended to be made in winter.

Higher soil moisture at this time complicates the work of openers, rises the degree of soil puddling, and lowers the planning quality. Moreover, in spring, because of planning works, the time of sowing crops is delayed, the surface layer of the soil is dehydrated.

Guidance

Guidance of operational personnel in the preparation period is very important. It is carried out by senior engineers of the system. Besides the section workers of the system, local agronomists are invited to meetings. At such meetings, a plan is to be thoroughly considered and concrete procedure of its realization is to be set.

At that, special attention should be paid to hot (critical) periods of the system operation. For these periods it is necessary to specify how, when operations related to the water use at units and in farms should be carried out.

Opening canal

Before an irrigation season, special commissions check the readiness of irrigation systems for running water through. The defects detected during the checking are to be removed within the time established by the commission.

The first water distribution operation according to the order is inspection of the system’s readiness to receive water and its ability to maneuver its discharge. Such an inspection of the abilities and state of key units and important sites, testing of structures, mechanisms, and signaling equipment is carried out by inspecting the sites and examination of the structures by the chief engineer and regular dispatchers of the system. If defects in particular parts of the system are discovered, required scope and term of repair works are to be determined.

The system opening time assigned by the plan should be considered as approximate canal operation schedule. Just before the opening the canal these terms should be specified. The system manager introduces adjustments on the basis of the familiarization with general progress of spring agricultural works in irrigated districts and specification of the expected need for water for the pre-sowing period.

Actual time of water running to the system is announced by a special system order. At that, two terms are to be assigned: canal opening time and time of the first water supply to farms.

At the first scheduled time, water is supplied only to the main system. The supply is carried out little by little, gradually raising the horizon; the full water discharge is delivered to command centers and directed for disposal. The garbage collected at the first water run as well as foreign floating things is removed; the structures and canals at the units are examined when being filled with water.

After the first water run is made, system canals are filled with water, and the units are tested and operate faultlessly, they begin supplying water to farms. Water users must be notified in advance of the time of the first water supply to farm’s off-takes.

At water running, canals are filled gradually: water discharge in small canals is to be raised by not more than 20 %; on large canals, by not more than 10 % from the normal level. Every following opening of the sluice gates for filling the canals is performed only after the water level therein gets stable. The interval between the re-regulation of the sluice gates should be in any case no longer than two hours.

While the canals are being filled, all the operating personnel of the system are to be posted at the most important sites and units so that to ensure control over the canals and structures state. After those are filled up to a normal level and cleaned from floating matters and garbage, they proceed to water supply to water users according to their applications.

Operations schedule

Water is distributed in the system on the basis of an operations schedule by direct instructions of the dispatcher. Operations schedules are drawn up for every ten-day period in accordance with an approved water distribution plan and taking into consideration available water resources.

In an operations schedule, water arrival and distribution by the irrigation system’ units beginning from its head and up to the points of water delivery to the user. At that, for each ten-day period they are to specify the volume of water intake and order of water distribution among districts, operational sites, and hydrotechnical units in the system.

Control over the execution of the operations schedules of water intake and distribution is entrusted to the dispatcher on duty. Every day, according to the data of measured water discharge and level in the irrigation source, he/she is to determine a possible water intake volume.

Is the possible water intake volume is more than the planned one, they set designed (planned) discharges in the water apportioning points; if less, they do as follows. A deviation of the water intake value within 10 % from the planned is to be considered when drawing up an operations schedule. At stable deviations of more than 10 %, the system water distribution plan is to be amended.

Subject to the established water distribution balance, the dispatcher on duty is to give directions to operating sites concerning water apportioning among the system units. The dispatcher’s directions are compulsory for all the persons in charge of the sections or sites of the system.

When coming on duty, the dispatcher is to become minutely acquainted with the operations schedule of water apportioning during his/her duty tour, get information from the one replaced by him/her about the state of the system and instruction of the chief, chief engineer of the system, or head of the water use division concerning the plan implementation procedure.

All further water intake and water distribution operations are to be performed in accordance with a plan by direct instructions of the system dispatcher on duty.

3.2. Adjustment of water use and water distribution plans

The need to deviate from the water use and water distribution plans set may arise in the following cases:

- At precipitation of considerable intensity and duration, it may become possible to either postpone the irrigation time or cancel it. This issue is to be addressed by the WUA Council. CMO is informed by means of applications about the changes introduced in the irrigation plan by the WUA.

- In the same manner, the water use plan is to be adjusted if air temperature abruptly drops. At a cold snap, either the water application time may be postponed or water application rates be reduced.

- With prolonged hot dry winds additional water application and higher water application rates are required. In this case, terms for additional water supply are to be set. This shall be permitted by CMO.

- At dramatic rise of groundwater table, which may cause increase in the recharge volume, one should revise the irrigation regime of the field where groundwater has risen to reduce water supply (stop last irrigations, decrease water application rates, etc.).

The possibility to compensate the volume of water not taken in the previous period by additional water supply in following periods shall be determined during operational adjustment of the water distribution plans taking into account water demand and supply.

Specification of the areas under crops in the irrigation system for the summer period shall be finished by June 1; for the winter period, by December 1.

When natural and economical conditions change, the water use and water distribution plans are to be adjusted. At that, non-irrigation water users (cultural and technical as well as environmental needs)

Types of adjustment

There are types of adjustment different in terms of time:

- Seasonal.
- Ten-day period.
- Within ten-day period (i.e. it may be less than ten days).

Depending on the purpose, there are the following adjustment types:

- Right for water (limit-quote)[6] and
- Water demand.

Water use and water distribution plans are adjusted in the following cases:

---

[6] “Limits” set by the Ministry for SFMC and “water apportioning percentage” and used on KBC are, in fact, limits-quotes on water.

- Steady deviation of irrigation source water content indicators from planned values, on the basis of updated monthly forecasts of irrigation source water content (at that, the water right is adjusted too and water limit-quote shall be determined).
- Change of the irrigation are size or cropping patter based on the actual crop sowing data.
- Change of the agricultural technology and reclamation state of an irrigated area, which may cause the need for change in water consumption towards reduction or increase.
- Departure of meteorological indices of the target year from average long-term (considerable precipitation, high atmospheric temperature, etc.).

Water distribution principles

If aggregate volume of water users' applications for water exceed forecasted water resources reserves (established limits on water intake) of irrigation sources, operational water distribution is caries out based on the following principles:
- Priority of a certain water users group, and
- Proportional reduction of water supply to non-priority water users.

Among priority water users are:
- Industrial enterprises.
- Hydropower plants.
- Urban and rural public utilities.
- Fishery.
- Regulating releases.
- Particular representatives of agricultural water users dealing with seed farming, growing medicinal herbs and other high-value crops.

By the decisions of the bodies that approve irrigation system water use plans other water users can also be included in this group as well as some of the above-listed water users can be excluded from it.

The existing total water resources shortage can be allocated among other categories of water users to which water is to be supplied on the basis of the following criteria:
- In proportion to irrigation source water supply availability as against the total water supply application by water users.
- In compliance with priority factors.

Priority factors can be adopted based on:
- Expert evaluation of water management and/or agricultural bodies.
- Evaluation of expected economic losses from water resource deficit and principles of their distribution among water users.

Water distribution criteria and priority factors are determined in each specific case by the bodies that approve irrigation system water use and water distribution plans.

3.2.1. Seasonal adjustment

Adjustment of water right (limit-quote)

Seasonal adjustment of water limit-quote is carried out subsequent to the results of the updated forecast of irrigation source water content for a planned period (vegetation).

Seasonal adjustment of water limits-quotes across the system and for water users is made based on the priority and proportionality principles allowing for the limits-quotes on water intake (proportionality factor for the season), set in accordance with inter-governmental agreements, and water use and water distribution plans specifying the water users' needs for irrigation water.

$$TLQs = PFsm * TWSp , \tag{3.1}$$

where

TLQs – ten-day limit-quote (result of the seasonal adjustment of the water use (water distribution) plan).

PFsm – seasonal proportionality factor for the main canal (seasonal limit-quote for the main canal, in relative values).

TWSp – ten-day water supply according to the seasonal water use (water distribution) plan.

Basin Irrigation System Administrations fix limits-quotes for district Irrigation System Administrations, and the latter set quotes for WUAs. The WUAs, in turn, fix limits-quotes for the WUA canals, individual farms (peasant farms, dekhkan farms) located in their territory.

A limit-quote for farms can be calculated based on two principles (if these rules are approved by the general meeting of WUA water users):

- *Equal water supply principle: the traditional proportionality principle with which the limit-quote for farms is determined by multiplying the WUA-wide proportionality factor by planned ten-day water supply values.*

- *Principle of equal total water supply (or equal relative loss): alternative principle with which the limit-quote is calculated taking into account the share of water supply from internal (local) irrigation sources and share of feeding crops due to groundwater (allowance for a hydromodule zone), i.e. the limit-quote for farms can differentiate because it better meets the equity principle.*

As for the principle of the calculation of the limit-quote for WUAs, this may become within the CWC competence.

Adjustment of water demand

Seasonal adjustment of water demand is to be carried out after the cropping pattern of water users' actually irrigated areas (taking into account double crops) is finally specified (early summer, i.e. June).

Changes in planned sowing areas should be introduced in the plan only after its approval by the WUA Board. These have to be considered as new irrigation quotas.

If in the result of recalculations new water demands do not exceed 5 % of the initial plan, water supply is not to be recalculated.

At sizeable deviations from the plan, new water discharge values are to be coordinated with the irrigation system management and submitted for approval.

3.2.2. Ten-day adjustment

Calculation of the ten-day limit-quote

Operational adjustment of a ten-day limit-quote for the main canal (proportionality factor for a ten-day period) shall be carried out by a superior organization depending on the change in irrigation source water content.

Operational adjustment of ten-day limit-quote for districts and further for WUAs and other water users is executed taking into account the ten-day limit-quote for the main canal on the basis of the proportionality principle.

$$TLQt = PFtm * TWSp \,, \qquad (3.2)$$

where

TLQt – ten-day limit-quote (result of the operational adjustment of the water use (water distribution) plan).

PFtm – seasonal proportionality factor for the main canal (ten-day limit-quote for the main canal, in relative values).

TWSp – ten-day water supply according to the seasonal water use (water distribution) plan.

Then, the ten-day limit-quote for WUA is specified allowing for the actual water supply for the period preceding the target ten-day period (it may be that in the preceding ten-day periods the water users received less (or more) water relative to its limit-quote).

Ten-day application

Adjustment of the ten-day water demand (Fig. 3.1) for WUAs is carried out based on the applications from the WUAs for a target ten-day period.

$$TA_{WUA} = \Sigma TA_F + \Sigma TA_O \,, \qquad (3.3)$$

where

TA_{WUA} – ten-day application for water from WUAs.
ΣTA_F, ΣTA_O – total ten-day applications for water from farms and other water users, respectively.

A ten-day application for water reflects the ten-day water demand by water users subject to existing natural and economic conditions.

Ten-day application for water from WUAs should be submitted to the CMO at least 3 days prior to the beginning of a target ten-day period. Absence of a ten-day application, depending on practically established rules, may be regarded in two ways:

- There is no demand for water (it is raining, cool weather).
- The ten-day limit-quote corresponds with the ten-day application.

In the first case, submission of a ten-day application is a rule and absence of that is an exception to the rule[7].

---

[7] This approach is acceptable to SFMC and AAC. In SFMC practice, an application from a WUA to the BISA is to be submitted two times. The first application is without linking water demand to canals; the second one is to be submitted

In the second case, submission of a ten-day application is an exception to the rule and absence of that is a rule[8].

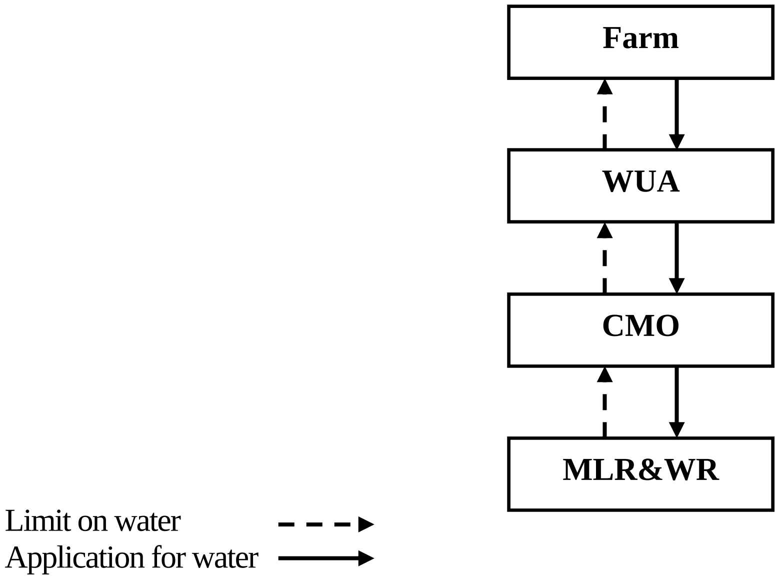


Figure 3.1. Scheme of making water demand (application) and limit on water (limit-quote, limit-setting).

In the absence of an operational application from the water user, the planned water supply is taken instead of that.

Calculation of the ten-day limit-setting

The ten-day limit-setting is calculated by linking the water quotes with the applications for water from WUAs:

- If the sum of ten-day applications from WUAs is greater than the limit-quote by the main canal, the ten-day limits-settings to WUAs are to be considered equal to proportionally cut applications from WUAs (allowing for the actual water supply in previous ten-day periods and other factors).
- If the sum of ten-day applications from WUAs is less (or equal to) than the limit-quote by the main canal, the ten-day limits-settings for the WUAs are to be considered equal to the ten-day applications from WUAs.

After ten-day limits-settings for WUAs are calculated, ten-day limits-settings will be calculated for WUA canals and water users.

3.2.3. Within-ten-day adjustment

During a ten-day period, water redistribution among WUA canals is allowed within limits-settings put for WUAs.

Water is redistributed among WUA canals with the consent of CMO divisions (hydraulic sites) on the basis of secondary (within-ten-day) applications.

---

after aggregate limits-settings are issued to WUAs. The second application represents the information of how limits-settings are allocated among WUA canals.

[8] This approach is acceptable to KBC.

Within-ten-day applications for water from WUAs, executed based on those from farms, are submitted to hydraulic sites a day prior to changing the regime of water supply to the canal.

The possibility to redistribute water among WUA canals complicates the water distribution process but enhances the water management flexibility and productivity.

A need for within-ten-day adjustment is caused by both natural (rains, return flow) and economic factors (fields are not ready for irrigation because they have not yet furrowed or there were troubles with the delivery of fertilizers etc.).

3.3. Calculation and organization of water rotation

The main type of water supply to the water user is planned water supply by continuous current. In the WUA, water is delivered by continuous current to water delivery points of farms (or water users group, i.e. WUG). Within farms (or WUG), water is supplied by turns to the sites of one-time irrigation and cultivation in accordance with the progress of field works (cultivation according to the irrigation plan).

Regular water distribution (water rotation among WUAs) should be carried out only in case of acute water deficit when losses in the network due to insufficient filling of canals are rising.

There are a lot of theoretical schemes for regular water distribution – water rotation. Two or three-cycle water rotation based on successive water supply to distribution units should be considered the simplest practical regular water distribution scheme. With this scheme, main canals operate uninterruptedly and water is supplied to distribution units in turn.

To establish the water supply sequence the distribution units of the system are united into two or three groups (lines) and the duration of water supply to every line shall be set in proportion to the planned water supply to the WUA. That water is not supplied completely to all out-of-operation units. With this scheme, main canals operate continuously and water is supplied to distributing units by turns.

At great water shortage (profound low-water level), a special guard is set at command centers.

Water rotation is widely used in the water allocation practice both in foreign countries and CAR countries. In Kyrgyzstan (Osh and Djalalabad provinces), water rotation is called “avron”; in Uzbekistan (Kashkaradrya province) “avandoz”; and in Tajikistan (Sogd province), “ob gardon”.

With normal water supply availability (i.e. there is no water shortage), water rotation is used only at the lowest levels of water allocation: among irrigation contours, temporary irrigating ditch$^{\text{es, and site distributors9}}$.

With increasing water deficit, water rotation is reasonable to be used at higher-order canals too[10], including water rotation between main canal hydraulic sites.[11]

Types of water rotation (see Fig. 2.2)

---

[9] This is due to that otherwise it would be needed to considerably upsize the site distributors and temporary irrigating ditches, but this is economically unsound (Annex 8).

[10] Despite that in this case the conditions of water supply to irrigated crops may inevitably worsen, water rotation application is beneficial from the perspective of reduction of technical and organizational water losses.

[11] This type of water rotation is used at SFMC (between end hydraulic sites), KBC (inter-district water rotation), AAC (water rotation between the AAC sites 1 and 3).

Water rotation is introduced among:

- Irrigation contours (for example, among the irrigation contours of F1).
- Farm canals (for example, among the canals 1111 and 1112).
- Farms (for example, among F2, F3, and F4). In this case, water is supplied to the canals 1127 (water supply to homestead lands) and 1128 (water supply to industrial and technical needs) by continuous current, and to the canals of F2 (1121, 1123), F3 (1122, 1124) and F4 (1125, 1126) is supplied by turns.
- Water Users' Associations (WUA) (for example, among A1, A2, and A3). In this case, water supply to the canals 114 (water supply to homestead lands and industrial and technical needs) is carried out through continuous current and to the canals 111, 112, 113, 114, 115, and 115 by turns, at that the canals can be grouped).
- Districts. Let us assume that the canals 11, 12, 13, and 1N are in different districts. Then water is supplied to the canal 12 (water supply to an industrial facility) is carried out by continuous current, and to the canals 11, 13, and 1N by turns. If water from the main canal is supplied by transit to another system, this transit water supply as well as water supply to an industrial facility does not share in water rotation.
- Main canals.

Water rotation effectiveness

Effectiveness of water rotation consists in decreasing technical losses of water which would take place at continuous water supply by lower discharges[12].

At the same time, operational (organizational) losses significantly reduce. This is due to the fact that with water rotation it is easier to mobilize water management organizations and water users to control water distribution.

Owing to the above-mentioned advantages of water rotation, they succeed in solving the "head-end" problem consisting in that water users at the end part of the canal are, as a rule, restricted in water in comparison with the farms located at the head of the canal.

Water rotation components

System water supply availability: limit-quote (at acute water deficit it is the same as limit-setting) equal to the ratio of rated water supply to the system to the planned ten-day water supply.

Alternating units: water rotation subjects to which water is supplied by turns (irritation contour, canal, aggregate of WUA, district canals, etc.).

Number of water rotation cycles: figure equal to the number of alternating units (two and three-cycle water rotation are the simplest and widespread).

Water rotation period: duration of the cycle in the course of which water makes a complete rotation between alternating units (as a rule, water rotation cycle is not taken more than a ten-day period).

The duration of a water rotation cycle for an alternating unit is a part of the water rotation cycle (period) within which water comes to the zone of the alternating unit.

---

[12] It is known that at lower water discharge in the canal relative water losses rise and correspondingly canal efficiency decreases. Appropriate formulae are offered for the specification of the canal efficiency; however, in practice the canal efficiency factor is taken as a constant in calculations.

A design water rotation discharge is the water discharge (gross) coming by turns to alternating units (to the system head (system section)) where water rotation is applied.

Water rotation organization scheme

Irrespective of a water allocation level, water rotation looks as follows:

1. A high-order power canal of operates uninterruptedly.
2. Water from a high-order power canal is supplied to lower-order canals by turns.
3. To establish water supply order, the lower-order canals are united into alternating units proceeding from the following characteristics:
   - Maximum capacity of simultaneously operating canals allows accepting forced (with alternate supply) discharge;
   - The effective length of the canals in the established group shall be as short as possible;
   - Water discharges (net) of particular groups of distributors are to be approximately equal.
4. Transit water discharge and water supply to industrial and technical needs are to be excluded from the water rotation.
5. The design water rotation discharge is specified taking into account lateral inflows to the main canal.
6. The design discharges to the canals operating in one line are specified in proportion to ten-day limits-settings set in the result of operational adjustment.
7. The duration of the water supply to each line is set in proportion to limits-settings.

Calculation of water rotation

Initial information:

1. Scheme of the irrigation system where water rotation is applied.
2. Data of ten-day limits-settings on irrigation (hereinafter referred to as limits-settings) by low-order canals where water is supplied by turns: $TLSc_1$, $TLSc_2$, …, $TLSc_m$, where 1, 2,…, *m* represent the numbers of low-order canals. Ten-day limits-settings are set in the following an operational adjustment of a water use plan allowing for lateral inflows, transit, regulating discharges, etc.
3. Data of ten-day limits-settings on industrial and technical needs by low-order canals where water is supplied by turns: $ITNc_1$, $ITNc_2$, …, $ITNc_m$.
4. Data on the efficiency of the high-order canals' sites where water is supplied on a continuous basis: EFs_1, EFs_2, …, EFs_n, where 1, 2,…, *n* represent the numbers of water rotation sites.
5. The capacity of low-order canals (Cc);

Calculation algorithm

Low-order canals involved in water rotation are united into groups of the canals located at the water rotation site, and water will be supplied simultaneously within a water rotation cycle;

1. Ten-day limits-settings (net) for water rotation sites are determined (TLSs).

$$TLSs = \Sigma TLSc, \tag{3.4}$$

where

ΣTLSc is the sum of ten-day limits-settings for the heads of the canals of the water rotation site 1.

2. The efficiency of main canal section that is engaged in every cycle of the water rotation is determined (EFcyc).
3.

$$\left.\begin{aligned} EFcyc_1 &= EFs_1 \\ EFcyc_2 &= EFs_1 * EFs_2 \\ EFcyc_r &= EFs_1 * EFs_2 * EFs_n \end{aligned}\right\} \tag{3.5}$$

where

r is the water rotation number.

4. The design water rotation discharge (DWRD) is determined (ten-day limit-setting at the high-order canal head supplied to water rotation sites by turns):

$$DWRD = TLSs_1 / EFcyc_1 + TLSs_2 / EFcyc_2 + \ldots + TLSs_n / EFcyc_r,$$

where

$TLSs_1$, $TLSs_2$, …, $TLSs_n$ are ten-day limits-settings (net) for respectively 1, 2, …, n^{th} sites of water rotation.

5. Water rotation cycle duration for sites is estimated (WRCDp).

$$\left.\begin{aligned} WRCDcyc_1 &= TLSs_1 * WRP / DWRD * EFcyc_1. \\ WRCDcyc_2 &= TLSs_2 * WRP / DWRD * EFcyc_2. \\ WRCDcycr &= TLSs_n * * WRP / DWRD * EFcyc_r, \end{aligned}\right\} \tag{3.6}$$

where

$WRCDcyc_1$, $WRCDcyc_{2,\ldots}$, $WRCDcyc_p$ are the durations of respectively 1, 2, …, p^{th} water rotation cycles.

WRP stands for water rotation period. Usually, water rotation period is equal to a design ten-day period (in terms of days) minus the time required to regulate water discharge and travel.

6. Calculation of the limit-setting for the water rotation to every low-order canal is carried out (LSwrc).

The limit-setting for the water rotation to every low-order canal located at site 1 is determined by the following formula:

$$LSwrc = DWRD * TLSc * EFcyc_1 / TLSs_1 \tag{3.7}$$

The limit-setting for the water rotation to every low-order canal located at site 1 is determined by the following formula:

$$LSwrc = DWRD * TLSc * EFcyc_2 / TLSs_2 \tag{3.8}$$

The limit-setting for the water rotation to every low-order canal located at the n^{th} site is determined by the following formula:

$$LSwrc = DWRD * TLSc * EFcyc_p / TLSs_n \tag{3.9}$$

7. Total limit-setting for water rotation (irrigation + industrial and technical needs) to every low-order canal is calculated.

$$\left.\begin{array}{c} \Sigma\ LSwrc_1 = LSwrc_1 + ITNc_1 \\ \Sigma\ LSwrc_2 = LSwrc_2 + ITNc_2 \\ \Sigma\ LSwrc_m = LSwrc_m + ITNc_m \end{array}\right\} \qquad (3.10)$$

8. The total limit-setting for water rotation (irrigation + industrial and technical needs) to every low-order canal is compared with the canal capacity. The total limit-setting for water rotation to every low-order canal is to be less than or equal to the capacity of this canal. That is to say,

$$\left.\begin{array}{c} \Sigma LSwrc_1 \text{ shall be less than or equal to } Cc_1 \\ \Sigma LSwrc_2 \text{ shall be less than or equal to } Cc_2 \\ \Sigma LSwrc_m \text{ shall be less than or equal to } Cc_m \end{array}\right\} \qquad (3.11)$$

Otherwise, it is necessary to revise the water rotation organization scheme.

9. Calculation of the technical efficiency of water rotation.

$$\begin{array}{c} {}_{\Delta}Fs = 0.0864 * DWRD * (EFcyc_1 * WRCDcyc_1 + \\ + EFcyc_2 * WRCDcyc_2 + EFcyc_p * WRCDcyc_p - EFcyc_p * WRP), \end{array} \qquad (3.12)$$

where

${}_{\Delta}Fs$ is the water flow saved in the result of application of water rotation in the target ten-day period.

Calculation example

Initial information:

1. Irrigation system scheme[13] and initial information for the calculation of water rotation are given in Figure 3.2 and in Table 3.1.
2. Sufficiency of water supply in the main canal system comes to 60 %. In the issue of operational adjustment of the water use plan limits-setting are identified for secondary canals and water users.
3. Two-cycle water rotation is advisable to be applied.
4. Water rotation period shall be 10 days.

---

[13] The end hydraulic sites of SFMC, where water rotation is practiced under water deficit, served as a model for this example.

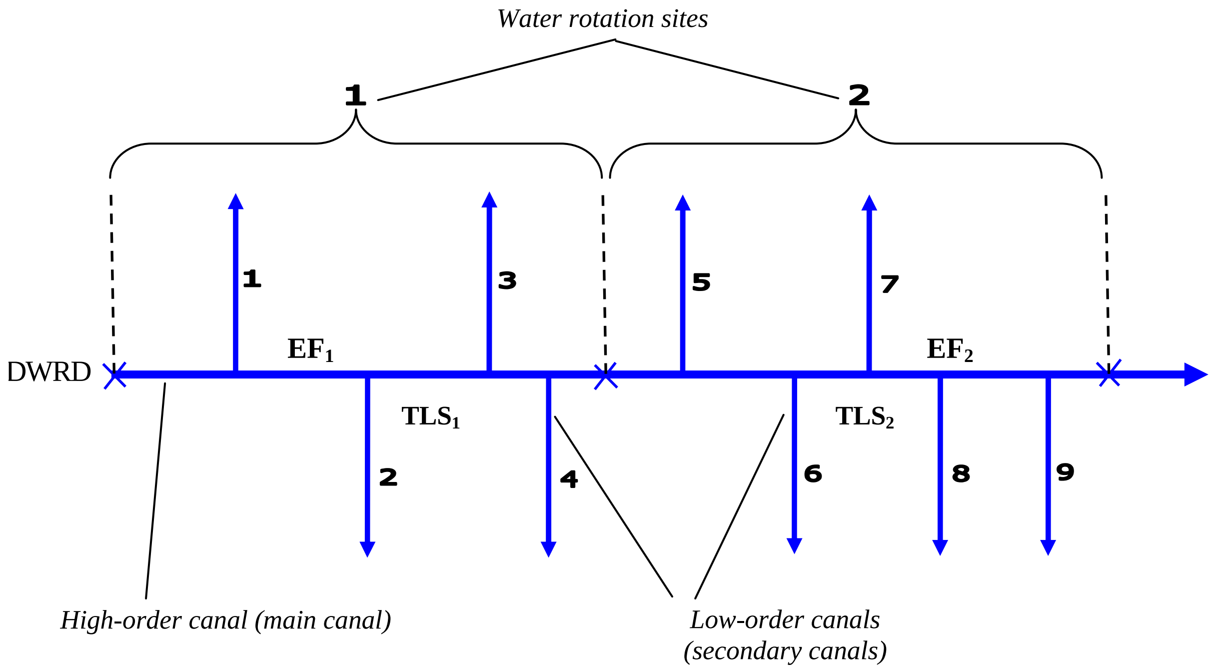


Figure 3.2. Scheme of two-cycle water rotation organization

Table 3.1. Initial information for the calculation of water rotation

Indicator	Unit	Site 1 canals				Site 2 canals			
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***
TLSc	m^3/s	3	6	7	5	4	5	7	8
Cc	m^3/s	7	15	17	13	8	10	14	15
ITNc	m^3/s	0	0.5	0.5	0.5	0	0.5	0.5	0.5
TLSs	m^3/s	21				24			
EFs		0.97				0.91			

Water rotation calculation

Canals shall be grouped. Canals 1–4 are attributed to site 1; canals 5–8 to site 2. Canal 9 is not involved in the water rotation because its water is supplied for industrial and technical needs.

In the first cycle of water rotation, water is supplied to the canals of site 1; in the second cycle, to site 2 canals (see Fig. 3.3).

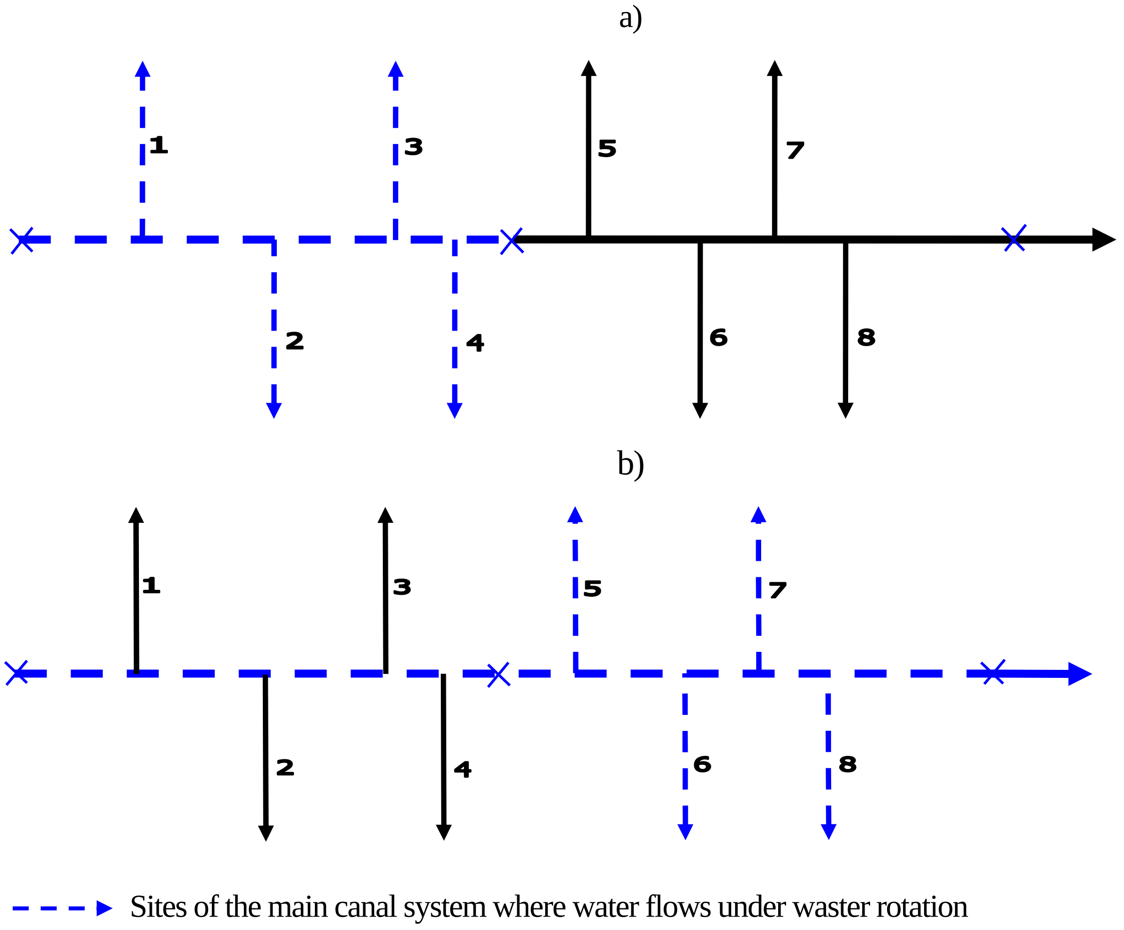


Figure 3.3. Scheme of water distribution under water rotation:
a) in the 1st cycle.
b) in the 2nd cycle.

1. Calculation of ten-day limits-settings (net) for water rotation sites:

$$TLSs_1 = TLSc_1 + TLSc_2 + TLSc_3 + TLSc_4 = 3 + 6 + 7 + 5 = 21\ m^3/s.$$
$$TLSs_2 = TLSc_5 + TLSc_6 + TLSc_7 + TLSc_8 = 4 + 5 + 7 + 8 = 24\ m^3/s.$$

2. Efficiency of the main canal section which is engaged in every water rotation cycle shall be determined:

$$EFcyc_1 = EFs_1 = 0.97.$$
$$EFcyc_2 = 0.97 * 0.91 = 0.88.$$

3. Calculation of the ten-day limit-setting for the high-order canal end:

$$DWRD = TLSs_1 / EFcyc_1 + TLSs_2 / EFcyc_2 = 21 / 0.97 + 24 / 0.88 = 48.84\ m^3/s.$$

4. Calculation of the water rotation cycles for sites:

For site 1:

$$WRCDs_1 = TLSs_1 * WRP / DWRD * EFcyc_1 = 21 * 10 / 48.84 * 0.97 = 4.43 = 4.5 \text{ days}.$$

For site 2:

$$WRCDs_2 = TLSs_2 * WRP / DWRD * EFcyc_2 = 24 * 10 / 48.84 * 0.88 = 5.5 \text{ days.}$$

5. Calculation of the limit-setting at water rotation for low-order canals:

For site 1 (by way of example of canal 1):

$$LSwrc_1 = DWRD * TLSc_1 * EFcyc_1 / TLSs_1 = 48.84 * 3 * 0.97 / 21 = 6.77 \text{ m}^3\text{/s.}$$

For site 2 (by way of example of canal 5):

$$LSwrc_5 = DWRD * TLSc_5 * EFcyc_2 / TLSs_2 = 48.84 * 4 * 0.88 / 24 = 7.19 \text{ m}^3\text{/s.}$$

Calculation for the rest canals is executed in the same manner (see Table 3).

6. Calculation of the total limit-setting at water rotation for low-order canals (by way of example of canal 1):

$$\Sigma LSwrc_1 = LSwrc_1 + ITNc_1 = 6.77 + 0 = 6.77 \text{ m}^3\text{/s.}$$

Calculation for the rest canals is executed in the same manner (see Table 3.2).

7. Comparison of the total limit-setting at water rotation (irrigation + industrial and technical needs) for every low-order canal with the canal capacity shows that the capacity of every canal is enough to organize water rotation.

8. Calculation of the technical efficiency of water rotation:

$$
\begin{aligned}
{}_{\Delta}Fs &= 0.0864 * DWRD * (EFcyc_1 * WRCD_1 + EFcyc_2 * WRCD_2 - EFcyc_2 * WRP) = \\
&= 0.0864 * 48.84 * (0.97 * 4.5 + 0.88 * 5.5 - 0.88 * 10) = 1.64 \text{ mln. m}^3.
\end{aligned}
$$

Thus, owing to introduced two-cycle water rotation in the main canal, 1.64 mln. w^3 of water can be saved. This will be due to increasing efficiency of the part of the main canal where water rotation is applied.

$${}_{\Delta}EF = {}_{\Delta}Fs / 0.0864 * DWRD * WRP = 1.64 / 0.0864 * 48.84 * 10 = 0.04,$$

where

${}_{\Delta}EF$ is a value by which the efficiency of the main canal part where water rotation is applied rises.

Table 3.2. Water rotation calculation

Indicator	Unit	Site 1 canals				Site 2 canals			
		1	2	3	4	5	6	7	8
LSwrc	m^3/s	6.77	13.54	15.79	11.28	7.19	8.98	12.57	14.37
$EFcyc_1$		0.97							
$EFcyc_2$		0.88							
ΣLSwrc	m^3/s	6.77	14.04	16.29	11.78	7.19	9.48	13.07	14.87
WRCD	days	4.5				5.5			

4. MONITORING AND ASSESSMENT OF WATER USE AND WATER DISTRIBUTION

> ***«What is not measured cannot be controlled».***
> ***«If you don't know where you are going,***
> ***any road will get you there».***
>
> **Lewis Carroll**

To improve population wellbeing under irrigated agriculture, it is significant to enhance irrigation water productivity ("yield more crop per drop"). Irrigation water productivity depends on many factors including water management quality at irrigation systems.

The water management process includes a series of stages including that of monitoring and assessment of water use & water distribution.

High-quality assessment of water use and water distribution requires having reliable and complete initial information and system of indicators.

There is a large variety of the indicators that reflect technical, technological, economic, ecological, and other aspects of the water management activity. This work represents main indicators for the analysis and taking decisions on water distribution. In practice, these indicators should be introduced step by step.

A management information system (MIS) has been currently developed and introduced; it includes programs for the calculation of practically required minimum value of main water distribution indicators: water supply availability; stability; uniformity; efficiency; specific water supply. In future, as the database and software are improved, the composition of the used indicators can and shall be expanded.

Water distribution monitoring and assessment is not an end in itself. Assessment is needed for taking a proper decision for the improvement of water distribution for the next five-day period, ten-day period, month, vegetation period, year, and years.

Water distribution indicators are an important instrument for making both short-term and medium and long-term decisions on water management improvement.

Circumspect combination of the indicators helps to see how properly (equitably and effectively) the goals set before water management organizations and water users are considered, take decisions on water resources management in the system.

The indicators also serve as an instrument for:
- ensuring transparency and allowing the civil society and authorities to evaluate the performance level and effectively manage water resources;
- detecting weaknesses in water governance and management;
- detecting intentional and non-intentional mistakes in the reporting by water management organizations.

Water distribution assessment can be internal and external.
External assessment characterizes the costs and results of irrigation system operation; it makes it possible to compare the functioning of a system with other similar ones.

Internal; assessment characterizes the processes progressing inside the system and yielding the results obtained within it; it serves for comparing actual results with those stated (planned).

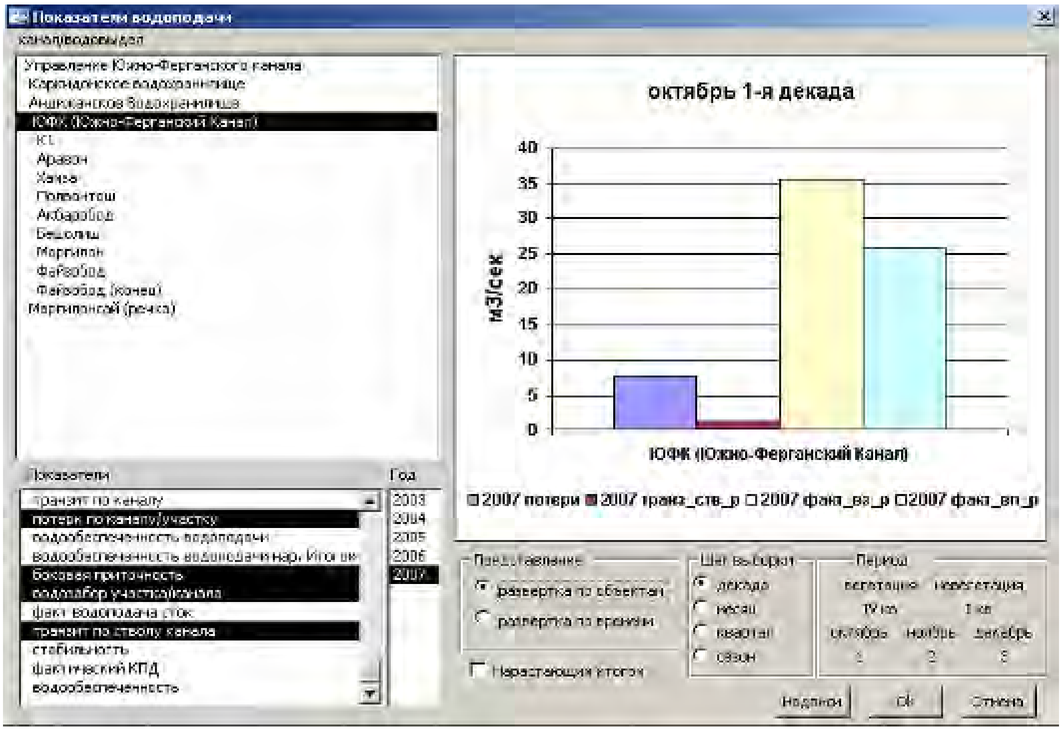
So far, only internal assessment has been applied within the project. For external assessment, additional (from the zone commanded by the pilot canal) information about crop yield, crop prices, cropping costs, operational costs, etc. are required.

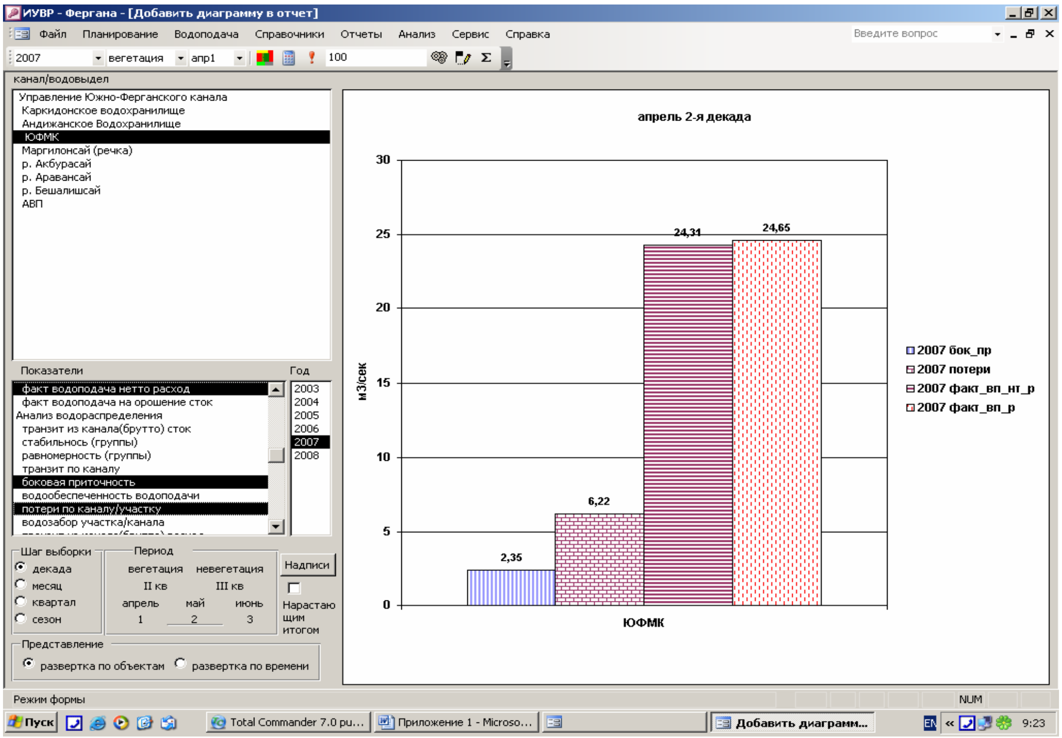
There is a great deal of indicators in domestic scientific literature, but minimum quantity is used in the water distribution practice: chiefly, water supply availability and efficiency factor and more rarely specific water supply (water withdrawal).

The domestic scientific literature pays too low attention to stability and uniformity coefficients, and those are not applied in the water distribution practice.

Calculation of indicators without a computer is rather labor-intensive process and, most importantly, not water management organizations (for the time being their work is poorly focused on maximum satisfaction of client-water user's needs) but water users are interested in water supply stability and uniformity.

In foreign scientific literature, the composition of developed indicators is wide enough and in many respects is identical to that of domestic indicators, but the names of the indicators are somewhat different: water supply availability – adequacy (or efficiency) of water supply; stability – reliability (security); canal efficiency – (water) transport efficiency; and so on. The uniformity indicator, "coefficient of water supply uniformity from a pilot canal to the head and end sites of the pilot canal", has been borrowed form the foreign literature.





4.1. Monitoring

Monitoring of water distribution is specially organized systematic observation over the water state and water distribution process for the purpose of their assessment, control, and/or forecast.

Water distribution ***monitoring objects*** are:

- Water in the main canal over the quantity and level of which regular observation is organized, and
- Process of water distribution from the main canal.

Levels of monitoring (measurement):

- Farm.
- WUA.
- District.
- Province.
- Republic.
- Hydraulic site.
- Main canal (MC).

Points of monitoring (measurement):

- Farm gate.
- WUA etc. gate
- Head of different-order offtakes from MC.
- MC head and tail.
- Points of water inflow to MC.
- Points of transit water supply;

Initial information on water (Annex 9):

- Water discharge (flow) at the monitoring site of pilot (main) canals.
- Water discharge (flow) at the offtakes from a pilot (main) canal.
- Water discharge (flow) at the gate of water users.

Unit of measurement: discharge (l/s, m^3/s); flow (ths. m^3, mln. m^3).

Monitoring frequency:
- Every hour (SFMC monitoring sites).
- 3 times a day (monitoring sites and gauging stations of the offtakes from AAC).
- 4 times a day (gauging stations of the offtakes from SFMC).

Type of information on water depending on its purpose:
- Actual: serves for controlling water distribution.
- Planned: determines approximate water demand.
- Application: specifies water user's demand for water depending on evolving weather and economic conditions.
- Limit-setting: result of the application and limit-quote of the water user.
- Limit-quote: indicates the user's right for water.

Type of information on water depending on place:
- Head intake to MC.
- Water supply from MC.
- Lateral inflow (feed to SFMC from the Karkidon reservoir, Margilansay river, etc.).
- Lateral outflow (water supply to a PC zone; water transit through a PC to the zone of a neighboring system – transit for feeding the Karkidon reservoir, BFC and BAC from SFMC; water discharge from a PC).
- Tail outflow (transit, discharge).

Type of information on water depending on the category of water users:
- Water supply for irrigation.
- Water supply for cultural and technical as well as environmental needs (CTEN): industrial and technical needs, municipal needs, etc.

Type of information on water depending on time:
- Hourly.
- Daily.
- Ten-day.
- Seasonal.
- Yearly.

Regulatory information:
- Canal capacity.
- Crop irrigation regimes.
- Climatic and altitudinal zones.
- Hydromodule zones.

Land information:
- Irrigated acreage under crops broken down by offtakes, climatic zones, and hydromodule zones (ha).
- Irrigated acreage under double and catch crops (ha).

Economic information:

- CMO and WUA water service fees (US $).
- CMO and WUA water service fees collection rate (US $).
- Others.

4.2. Indicators

This section gives a verbal description of the algorithm and examples of water distribution indicators calculation. The formulae for the calculation of the water distribution indicators are given in Annex 10.

4.2.1. Water availability coefficient

$$\text{Water availability coefficient} = \frac{\text{Actual water supply}}{\text{Planned water supply}} \qquad (4.1)$$

An optimum (from the biological point of view) case is that when water availability coefficient equals 1. In practice, water availability coefficient does not always exactly reflect the degree of water supply availability for crops.

Depending on the analysis' purpose, water availability coefficient[14] is calculated for:

- An offtake and a group of offtakes.
- In respect of plan and limit: actual/plan; actual/limit.
- A ten-day period and target period.

A group of offtakes, depending on the composition and number of offtakes within the group and taking water from a PC, can be represented a farm, WUA, district, province, republic, zone of the PC balance site, all the PC (system) zone in whole, etc.

The target period, depending on the number of ten-day periods in the period, can be represented by any span: year; vegetation period, non-vegetation period; part of vegetation or non-vegetation periods (season).

In the water distribution practice, they use calculations based on progressive total, i.e. when an indicator is determined for the period beginning from the first ten-day period and ending by the final ten-day period of the target period[15].

<u>Examples of water availability coefficient calculation</u>

a) Offtake:

- Ten-day period: 3rd ten-day period of April
- Target period: 1-3 ten-day periods of April

$$\text{Water availability coefficient} = \frac{790}{1149} = 0.69$$

---

[14] Water supply availability, stability, uniformity etc. coefficients are non-dimensional. To express the coefficients in percentage, it is needed to multiply those by 100.

[15] Hereinafter progressive-total based calculations are implied.

$$\text{Water availability coefficient} = \frac{583+661+790}{583+829+1149} = \frac{2034}{2561} = 0.79$$

Table 4.1. Calculation of water availability coefficients for an offtake

Indicators	**Unit**	**April**			**For the target period**
		1	**2**	**3**	
Planned water supply	ths. m^3	583	829	1149	2561
Actual water supply	ths. m^3	583	661	790	2034
Water supply availability		1.0	0.80	0.69	0.79

b) Pilot canal:

- Ten-day period: 3rd ten-day period of April
- Target period: 1-3 ten-day periods of April

$$\text{Water availability coefficient} = \frac{52183}{56182} = 0.93$$

$$\text{Water availability coefficient} = \frac{45136 + 49889 + 52183}{35184 + 37595 + 56182} = \frac{147208}{128961} = 1.14$$

Table 4.2. Calculation of water availability coefficients for PC.

Indicators	**Unit**	**April**			**For target period**
		1	**2**	**3**	
Planned water supply	ths. m^3	35184	37595	56182	128961
Actual water supply	ths. m^3	45136	49889	52183	147208
Water supply availability		1.28	1.33	0.93	1.14

4.2.2. Daily water supply stability coefficient[16]

a) Offtake:

Daily water supply stability coefficient = 1 – Root-mean-square deviation of within-day observations over water discharge from Average daily water discharge / Average daily water discharge (4.2)

b) Group of offtakes

Daily water supply stability coefficient for a group of offtakes = arithmetical mean value of daily water supply stability coefficient for offtakes (4.3)

Daily water supply stability coefficient characterizes the level of water discharge stability during the day:

- At the point of water intake from PC (daily stability of head intake at PC).
- At the point of lateral inflows to PC.
- At the control gauging stations of PC.

---

[16] The below-stated formulae for the calculation of water supply (daily and ten-day period) stability coefficients can be used for the calculation of water supply stability coefficients at the control gauging stations of the PC.

- By offtakes (daily stability of water supply).
- By groups of offtakes (farm, WUA, MC, etc.).

Maximum value of water supply stability coefficient is equal to 1.

In the water distribution practice, water supply stability coefficient like the uniformity coefficient is not used yet since its determination without a computer is quite a labor-intensive process and, most importantly, basically water users are interested in water supply stability and uniformity rather than water management organizations.

Example of water supply stability coefficient calculation
a) Monitoring site №1 (head intake):
Days: April 1

Table 4.3. Initial information for the calculation of daily water intake stability coefficient.

Observation time, hour	**(Q)**	**(Q-Qave)**	**(Q-Qave)2**	$\frac{\sum (Q_{ave} - Q)^2}{24+1}$	$\sqrt{6.191}$
1	52.2	-2.18	4.767		
2	52.2	-2.18	4.767		
24	45.9	4.12	16.947		
Average	50.02			6.191	2.48
Total	1200		154.77		

where

Q is water discharge during within-day observations, m^3/s;
Q_{ave} is average daily water discharge, m^3/s.

Daily water intake stability coefficient = $1-\frac{2.48}{50.02} = 0.95$.

Hourly observations over water discharge are organized at the monitoring sites of SFMC.

4.2.3. Ten-day water supply stability coefficient

a) Offtake:

Ten-day stability coefficient = 1 – Root-mean-square deviation of average day water discharge from Average ten-day water discharge / Average ten-day water discharge (4.4)

b) Group of offtakes:

Ten-day stability coefficient for a group of offtakes = Root-mean-square value of average ten-day stability coefficient for a group of offtakes (4.5)

Example of the calculation of ten-day stability for an offtake

Table 4.4. Initial information for the calculation of ten-day water supply stability coefficient

Days	**Q**	**Q – Qave**	**(Q – Qave)2**	**Σ(Q - Qave)2/11**	$\sqrt{0.003273}$
11	0.8	0.02	0.0004		
12	0.8	0.02	0.0004		
19	0.8	0.02	0.0004		
20	0.8	0.02	0.0004		
Total	8.2		0.036		
Average	0.82			0.003273	0.057

where

Q is average daily water discharge, m^3/s;

Q_{ave} is average ten-day water discharge, m^3/s.

Ten-day water supply stability coefficient $=1 - \frac{0.057}{0.82} = 0.93$.

The ten-day water supply stability coefficient for the target period for an offtake (or group of offtakes).

Table 4.5. Calculation of ten-day water supply stability coefficient for the period from the 1st ten-day period of April to 3rd ten-day period of April

Indicator	**April**			**For target period**
Ten-day	**1**	**2**	**3**	
Ten-day stability	0.67	0.80	0.85	0.77

4.2.4. Water supply uniformity coefficient

a) Offtake or a group of offtakes (farm, WUA, district, province, etc.)

Water supply uniformity coefficient = 1 – Absolute value of the difference between the water supply to the offtake (or group of offtakes) and PC water supply availability / PC water supply availability (4.6)

Currently, the fundamental principle of water distribution that results from the principle of social justice is the proportionality principle.

The fairness assessment criterion for actual water distribution among water users is the water supply uniformity coefficient.

The maximum value of the water supply uniformity coefficient equals to 1; the greater the uniformity coefficient, the more equitable is the process of the water distribution from PC.

b) PC

Coefficient of the uniformity of the water supply from PC = Root-mean-square value of the coefficient of water supply by PC water users (4.7)

Examples of water supply uniformity coefficient calculation

a) Offtake:

Ten-day period: 3rd ten-day period of April

Uniformity coefficient $= 1 - \frac{|0.69 - 0.90|}{0.90} = 0.77$

Target period: 1st-3rd ten-day periods of April

Uniformity coefficient $= 1 - \frac{|0.79 - 0.83|}{0.83} = 0.95$

Table 4.6. Calculation of uniformity coefficients for an offtake.

Indicators	**April**			**For target period**
	1	**2**	**3**	
Offtake water supply availability	1.0	0.80	0.69	0.79
PC water supply availability	0.80	0.78	0.90	0.83
Uniformity in the offtake	0.75	0.97	0.77	0.95

b) PC:
Target ten-day period: 3rd ten-day period of April.
Target period: 1st-3rd ten-day period of April.

Table 4.7. Calculation of uniformity coefficients for PC.

Indicators	**Number of water users**			**PC**
	1	**2**	**3**	
Ten-day uniformity	0.70	0.80	0.90	0.80
Ten-day uniformity for the target period	0.80	0.90	1.00	0.90

Ten-day uniformity coefficient $= \frac{0.7 + 0.8 + 0.9}{3} = 0.8$.

Ten-day PC uniformity coefficient for the target period $= \frac{0.8 + 0.9 + 1.0}{3} = 0.9$.

4.2.5. “Head-tail” uniformity coefficient

In the water distribution practice, there is, as a rule, a “head-tail” problem, when irrigation source upstream water users are provided with more water than downstream ones.

The “head-tail” uniformity coefficient indicates the equity of water distribution along the canal.

“Head-tail” uniformity coefficient = 1 – Absolute difference between Water supply to 25% (4.8) of water users of the end site of PC and 25% of Water users of the head site of PC/ Water supply to 25% of water users of the end site of PC

Example of the calculation of "head-tail" water supply uniformity coefficient

Table 4.8. Initial information for the calculation of the "head-tail" uniformity coefficient.

Head site			**End site**		
№	**Water users**	**Water availability coefficient**	**№**	**Water users**	**Water availability coefficient**
1	Uzbekistan	0.94	1	Ulugbek	0.92
2	Rishtan	0.94	2	Tashkent	0.86
3	Khujaobod	0.88	3	Kuchkorchi	0.58
4	Farkhad	0.96	4	Ergashev	0.71
5	Turdiev	0.91	5	Navoiy	0.73
	Average	0.93		Average	0.76

$$\text{“Head-tail” uniformity coefficient} = 1 - \frac{|0.76 - 0.93|}{0.76} = 0.78$$

4.2.6. Efficiency factor (EF)

$$\text{Technical EC} = \frac{(\text{Water supply} + \text{Transit} + \text{Discharge})}{(\text{Head intake} + \text{Lateral inflow})} \qquad (4.9)$$

The maximum value of technical EF cannot be greater than 1. However, in the water distribution practice there are cases when EF is greater than 1 because the distributed inflow to PC is very difficult to allow for.

Water intake to PC can be formed by head intake to PC and lateral inflows. For example, water intake to SFMC is formed due to the head intake from Shakrikhansay as well as lateral inflows from Akburasay, Aravansay, Beshalishsay, Margilansay and due to the fed from the Karkidon reservoir.

$$\text{Organizational EC} = \frac{(\text{Discharge} + \text{Above-plan water supply})}{(\text{Head intake} + \text{Lateral inflow})} \qquad (4.10)$$

$$\text{Operating EF} = \text{Technical EF} + \text{Organization EF} - 1 \qquad (4.11)$$

$$\text{Irrigation system EF}^{17} = \text{Main canal EF} \times \text{Interfarm network EF} \times \text{On-farm network EF} \times \text{Field EF.} \qquad (4.12)$$

$$\text{Irrigation system EF} = \text{Main canal EF} \times \text{Interfarm network EF} \times \text{On-farm network EF} \qquad (4.13)$$

$$\text{Interfarm irrigation network EF} = \text{Main canal EF} \times \text{Interfarm network EF} \qquad (4.14)$$

---

[17] Hereinafter, the term "efficiency factor (EF)" will imply technical EF if definitions like "organizational", "operating" are not given.

Examples of the calculation of PC balance site EF

a) Balance site (BS) EF:

Ten-day period: 3rd ten-day period of April

$$\text{BS EC} = \frac{2589 + 57497 + 0}{61690 + 0} = 0.97$$

Target period: 1st-3rd ten-day periods of April

$$\text{BS EC} = \frac{7388 + 158165 + 0}{170316 + 0} = 0.97$$

Table 4.9. Calculation of BS EF.

Indicators	**Unit**	**April**			**Target period**
		1	**2**	**3**	
Head intake to BS	ths. m^3	54065	54562	61690	170316
Water supply from BS	ths. m^3	2121	2678	2589	7388
Transit through BS	ths. m^3	49956	50712	57497	158165
Discharge from BS	ths. m^3	0	0	0	0
Lateral inflow to BS	ths. m^3	0	0	0	0
BS EF		0.96	0.98	0.97	0.97

b) PC EF

Ten-day period: 3rd ten-day period of April

$$\text{PC EC} = \frac{52183 + 3456 + 5249}{61690} = 0.99$$

Target period: 1st-3rd ten-day periods of April

$$\text{PC EC} = \frac{147208 + 3456 + 9860}{170316} = 0.94$$

Table 4.10. Calculation of PC EF.

Indicators	**Unit**	**April**			**Target period**
		1	**2**	**3**	
Head intake to PC	ths. m^3	54065	54562	61690	170316
Water supply from PC	ths. m^3	45136	49889	52183	147208
Transit through PC	ths. m^3			3456	3456
Discharge from PC	ths. m^3	2587	2024	5249	9860
Lateral inflow to PC	ths. m^3	0	0	0	0
PC EF		0.88	0.95	0.99	0.94

c) Organizational EF of PC

Ten-day period: 3rd ten-day period of April

$$\text{Organizational EF of PC} = 1 - \frac{5249 + 0}{61690 + 0} = 0.91$$

Target period: 1st-3rd ten-day periods of April

$$\text{Organizational EF of PC } = 1 - \frac{9860 + 22245}{170316 + 0} = 0.81$$

Table 4.11. Calculation of organizational EF of PC.

Indicators		**Unit**	**April**			**Target period**
			1	**2**	**3**	
Head intake to PC	actual	ths. m^3	54065	54562	61690	170316
Water supply from PC	actual	ths. m^3	45136	49889	52183	147208
	plan	ths. m^3	35184	37595	56182	128961
Above-plan water supply from PC		ths. m^3	9952	12293	0	22245
Lateral inflow to PC	actual	ths. m^3	0	0	0	0
Discharge from PC	actual	ths. m^3	2587	2024	5249	9860
Organizational EF of PC			0.77	0.74	0.91	0.81

d) Operating EF of PC

Ten-day period: 3rd ten-day period of April

Operating EF of PC = 0.99+ 0.91 -1 = 0.90

Target period: 1st-3rd ten-day periods of April

Operating EF of PC = 0.94+ 0.81 – 1 = 0.75

4.2.7. Specific water supply

Specific water supply = Water supply / Irrigated area (15)

Depending on the type of initial information, they discern actual and planned specific water supply. The specific water supply indicator determined for crops is of the greatest value.

In the water distribution practice, because of the absence or weakness of on-farm water accounting such information is absent or, if present, its credibility is low. Therefore, they usually use the indicator “specific water supply per composite hectare”. Below, the examples of the calculation of specific water supply per composite hectare for an off-take and PC are given for a ten-day period and the target period.

Examples of the calculation of specific water supply (actual)

a) Offtake
Ten-day period: 3rd ten-day period of April

$$\text{Specific water supply} = \frac{790.6}{1691} = 0.47\, ths.m^3 / ha\ .$$

Target period: 1st-3rd ten-day periods of April

$$\text{Specific water supply} = \frac{583.2 + 829.4 + 790.6}{1691} = 1.3\ ths.\ m^3 / ha.$$

a) Group of offtakes

Ten-day period: 3rd ten-day period of April

$$\text{Specific water supply} = \frac{2589.4}{5777} = 0.45\ ths.\ m^3/ha.$$

Target period: 1st-3rd ten-day periods of April

$$\text{Specific water supply} = \frac{2120.9 + 2678.4 + 2589.4}{5777} = 1.28\ ths.m^3/ha.$$

Table 4.12. Calculation of specific water supply

Indicators	**Unit**	**Objects**	**April**			**Target period**
			1	**2**	**3**	
Water supply	ths. m^3	Offtake	583.2	829.4	790.6	2203.2
		Group of offtakes	2120.9	2678.4	2589.4	7388.7
Irrigated area	ha	Offtake	1691			
		Group of offtakes	5777			
Specific water supply	ths. m^3/ha	Offtake	0.34	0.49	0.47	1.30
		Group of offtakes	0.37	0.46	0.45	1.28

4.2.8. Specific water intake (to PC)

Specific water intake to PC = Specific water supply from PC / PC EF (16)

Example of the calculation of specific water intake

Table 4.13. Calculation of PC EF.

Indicators	**Unit**	**April**			**Target period**
Ten-day period		**1**	**2**	**3**	
Water supply from PC	ths. m^3	45136	49889	52183	147208
Irrigated area	ha	83000			
Specific water supply	ths. m^3/ha	0.54	0.60	0.63	1.77
PC EF		0.88	0.95	0.99	0.94
Specific water intake	ths. m^3/ha	0.62	0.63	0.64	1.88

Ten-day period: 3rd ten-day period of April

$$\text{Specific water intake} = \frac{0.63}{0.99} = 0.64\ ths.\ m^3/ha$$

Target period: 1st-3rd ten-day periods of April

$$\text{Specific water intake} = \frac{1.7}{0.94} = 1.88\ ths.\ m^3/ha$$

4.2.9. Irrigation efficiency factor[18]

$$\text{Irrigation efficiency factor} = \text{Total evapotranspiration from the PC zone/ Specific water supply} \quad (17)$$

Example of the calculation of irrigation efficiency factor of SFMC

$$\text{Irrigation efficiency factor of SFMC} = \frac{7.26}{12.5} = 0.58 \ .$$

Table 4.14. Calculation of irrigation efficiency factor for the pilot canals
(vegetation period, 2003)

№	Indicators	Unit	SFMC	AAC	KBC
1	Water intake (head intake + feed – transit)	mln. m^3	1049.78	116.26	129.42
2	Specific water intake for irrigation	ths. m^3/ha	12.50	12.57	16.00
3	Total evapotranspiration	ths. m^3/ha	7.26	7.58	7.73
4	Irrigation efficiency factor		0.58	0.61	0.50

4.2.10. Water productivity factor

$$\text{Physical water productivity factor} = = \frac{\text{Quantity of crop production}}{\text{Quantity of water supplied from PC to yield crop}} \quad (18)$$

$$\text{Economic water productivity factor} = \frac{\text{Cost of crop production}}{\text{Quantity of water supplied from PC to yield crop}} \ . \quad (19)$$

4.2.11. Water service fees collection factor

$$\text{Water service fees collection factor} = \frac{\text{Actual amount of the collected water service fees}}{\text{Planned amount for water service fees}} \ . \quad (20)$$

4.2.12. Specific operation and maintenance costs

$$\text{Specific operation and maintenance costs} = \frac{\text{Specific operation and maintenance costs}}{\text{Water supply}} \ . \quad (21)$$

---

[18] Strictly speaking, this formula should have given other water balance components as well. The formula has been simplified because of problems with getting information on those (precipitation, infiltration, etc.).

4.3. Assessment of water distribution

Assessment is a systematic process of the comparison of the indicators to identify deviations in the water management quality.

The assessment process includes comparison of the following indicators:
- Target periods (days, ten-day periods, season, year, years),
- Types of irrigation systems (IS),
- Irrigation system sites (balance sites),
- Types of water users (farm, WUA, district, province, republic),
- Types (actual, planned, standard).

If initial information is reliable, the assessment has:
- theoretical, and
- practical value.

Assessment has a practical value, viz. it really facilitates improvement of water management quality only when responsible persons:
- Want and (or) have to carry out assessment.
- Can carry out assessment.
- Want and (or) have to take decisions on changing water management quality for better.
- Have the resources (financial, technical, human) to implement the decisions taken.

Factors impeding the improvement of assessment quality and water management quality:
- Financial and economic factors:
    - Disincentive for water management organizations and water users to save water and improve water management quality.
    - Organization of effective monitoring of water management quality requires considerable expenses.
    - Absence of payment for water services. Water service fees payment is an essential but not sufficient condition for the enhancement of assessment quality and water management quality.

- Social and organizational factors:
    - Water management organizations' job is assessed by water management organizations and not by water users (lack of public participation).
    - Other factors.

4.3.1 Types of assessment

Water distribution assessment can be external and internal.
- External assessment characterizes the costs and results of the functioning of irrigation systems; it makes possible to compare the functioning of a system with other similar ones.
- Internal assessment characterizes the processes progressing inside the system and yielding the results obtained within it; it serves for comparing actual results with those stated (planned).

In the course of the water distribution analysis, one should always pursue the answers to the following questions:
- Am I doing everything right?
- Is what I am doing right?

Answering the first question you are evaluating the water management quality (compare the actual to planned (limit)); while answering the second question you are evaluating the water governance quality (compare the achieved with the targeted, with the set standard).

Let us assume that the indicators of water supply availability, stability, and uniformity in the pumping irrigation zone of SFMC are acceptable (i.e. the actual approximates the planned). It would follow from this assumption that water supply is carried out properly and the SFMC operation office is managing water resources well. However, the internal assessment does not allow finding out if the water policy in the SFMC zone effective compared to the systems of other regions and countries.

The external assessment (relatively low physical and economic water productivity) can arouse doubt in the expedience of water supply to the pumping irrigation zone or suggest the idea of the necessity to implement water saving technologies and grow high-value crops in this zone.

4.3.2. Assessment procedure

Analysis of operational (daily, ten-day periods) indicators is carried out throughout the season, and analysis of result indicators is carried out after the season.

Water distribution is reasonable to be made in the following order:

- Calculation of indicators for offtakes, pumping stations, ten-day periods, seasons, water users, districts, provinces, balance sites, monitoring sites, pilot canals, etc.
- Plotting comparison charts.
- Identification of prominent initial data and indicators in the chart (obviously understated or obviously overstated).
- Investigation and explanation of what has caused those deviations.
- Elimination of errors (if detected) in the initial information.
- Analysis of the charts and assessment of the tendencies (in time and space) beginning to show in the water distribution governance and management as well as the causes of these tendencies.

Sharp deviations may issue from the mistakes in the initial information or by other causes:

- EF is greater than unity: presence of a lateral inflow etc.
- Dramatic decrease of EF: water theft or unrecorded discharge, etc.
- Overstated values of specific water supply and water supply availability: improper accounting of transit, etc.
- Understated value of water supply availability: absence of accounting in the return water use plan; theft; inadequate information about irrigated areas; etc.
- High stability: availability of regulating reservoirs; inadequate reporting information; etc.

In the course of the assessment, the tendencies and their causes can be identified:

- Rise of uniformity and stability factors may be caused by increased public participation in water management.
- Rise of water availability factor may be caused both by higher water level in the year and specified area of irrigated areas (reduction of planned water supply).
- Decrease of water availability factor may be caused by both low water level during the year and adjustment of the sizes of irrigated areas (consideration of double crops and intercrops) as well as due to the implementation of water service charge.
- Comparatively high physical water productivity factor in the SFMC zone does not mean that the economic water productivity factor is high too. This is due to low (in comparison to the world market) cotton purchase price.

- Decrease of one or another water distribution indicator may be due to the effect of external causes on agriculture: social upheavals, mass withdrawal of water workers for the works non-associated directly with their direct duties, unexpected intervention in the water distribution process (stopping releases from reservoirs), etc.

Examples of monitoring and assessment of water distribution indicators and their diagrams are given in Annexes 11 and 12.

5. ANNEXES

Annex 1. Abbreviations

AAC	Aravan-Akbura Canal, the Kyrgyz Republic
BISA	Basin Irrigation System Administration
BS	Balance site
BWA	Basin Water Administration
BWO	Basin Water Organization
CDN	Collector & drainage network
CAR	Central Asia Region
CMO	Canal Management Organization
CWC	Canal Water Committees – the governing body for CMO
DB	Database
DWA	District Water Administration
EF	Efficiency factor
FV	Fergana Valley
GS	Gauging station
HMZ	Hydromodule zone
HS	Hydraulic site
IDN	Irrigation and Drainage Network
IF	Individual farm/farm
ISA	Irrigation System Administration
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
IWRM-FV	Integrated Water Resources Management in the Fergana Valley
KBC	Khodja-Bakirgan Canal, Tajikistan
MAWR	Ministry of Agriculture and Water Resources, Uzbekistan
MC	Main Canal
MIS	Management Information System
MLR&WR	Ministry of Land Reclamation and Water Resources, Tajikistan
OFN	On-farm network
PS	Pumping station
SFMC/SFC	South Fergana (Main) Canal, Uzbekistan
SIC ICWC/SIC	Scientific Information Center of the Interstate Commission on Water Coordination
UCWU	Union of Canal Water Users
WMO	Water Management Organization
WU	Water user
WUA	Water Users/ Consumers' Association
WUG	Water Users' Group
WUP	Water Use Plan
WUU	Water Users' Union

Annex 2. Terms and definitions

Actual water supply	Water quantity (runoff volume, discharge) that is actually received by the water user.
Application for water	Water volume (runoff volume, discharge) requested by the water user for an upcoming ten-day period allowing for existing environmental and economic conditions.
Basin management principle	Water resources management according to hydrographic characteristics implemented when allocating water resources within the basins of rivers, lakes, and other water bodies between administrative and territorial units
Canal	Man-made open water conduit.
Canal (system) efficiency factor	Canal (system) water transport efficiency index determined as a ratio of water supply from the canal (system) to water withdrawal to the canal (system).
Climatic zone	Territory with similar climatic characteristics.
Composite (mixed) hectare	Conventional unit of irrigated area composed of all proportional set of the areas under irrigated crops, ha.
Conveyance capacity	Maximum flow that the canal can convey.
Crop (irrigation) water requirement	The volume of irrigation water supplied per unit of irrigated area to grow a crop.
CTEN	Cultural and technical as well as environmental needs
Double crops	Agricultural corps grown after harvesting winter cereals and cotton (fodder crops, vegetables, cucurbits crops, etc.).
Farm	Agricultural enterprise (IF, kolkhoz, DF, SAC) to the gate of which water is delivered by the WUA's irrigation service.
Flow rate (discharge)	Water volume that flows through the effective cross-section of flow in time unit (l/s, m^3/s).
Hydraulic structures	Engineering structures used for water resources management, treatment, supply, and transport of water to water users and water disposal, as well as for the prevention of deleterious effect of water.
Hydrologic regime	Time variation of water level, flow, and volume in water bodies and soils
Hydrological year	Period from October 1 throughout September 30.
Hydromodule zoning	Territory located on lands with similar soil composition and similar groundwater table.
Integrated Water Resources Management (IWRM)	Management system based on accounting and interaction all existing water (surface, underground, and return) resources and associated land and other natural resources within hydrographic boundaries, which links the interests of different water use and nature use hierarchy levels by involving all stakeholders in making decision, planning, financing, protection and development of water resources for stable development of the community and nature protection.
Irrigation and drainage system	System of technologically interconnected structures, facilities, and equipment designed for irrigation, watering, and reclamation of lands.
Irrigation canal	Man-made structure designed to transport water from irrigation sources to the areas that need to be irrigated.
Irrigation contour	Site of the farm's irrigated field which is under one type of crop within the same hydromodule zone and is fed from the same farm's irrigation ditch. Irrigation contour is a unit of water used.
Irrigation hydromodule	Specific rate of water supply per unit of irrigated area for one water application process (l/s per 1 ha).

Irrigation network	System of irrigation canals the provides transport of irrigation water from its source to irrigated land, distribution of water among individual farms or individual lands, as well as water supply to irrigated site.
Irrigation of lands	Artificial moistening of soil to raise its fertility.
Irrigation regime	The aggregate of the number, rates, and time periods of crop and planting irrigation as well as rate and period of water supply for leaching and other types of non-vegetation irrigation.
Irrigation system	System of hydraulic structures to irrigate lands.
Irrigation source	River, canals, springs, irrigation wells from which water comes to the water user.
Irrigation technique efficiency	Index of the efficiency of water use at irrigation determined as a ratio of water volume in a target soil layer to the total water supply to the field.
Leaching requirement	Rate of water supply per unit area to remove excess salts from the soil (m^3/ha).
Limit-quota (right to water)	Water limit (in absolute and/or relative units) which is planned to be supplied by the water management organization to the water user taking into account available water resources, viz. that maximum quantity of water that the water user has the right for.
Limit-setting	Water quantity (in absolute and/or relative units) which is planned to be supplied by the water management organization to the water user (water management organization of lower hierarchy level) based on the coordination of the water user's right to water (limit-quota) with its (water user's) request.
Non-vegetation period	Period from 1 October throughout 31 March
Openness	Accessibility of water use and water distribution related information to all stakeholders.
Organizational losses	Water losses in the canal due to shortcomings in the water flow management (unauthorized discharge).
Planned water supply (plan)	Water quantity (runoff volume, discharge) which is to be supplied in accordance with the water use (water distribution) plan.
Regulating network	Temporary irrigation ditches, auxiliary (field) furrows, irrigation furrows, and patches.
Releases	Periodic or ad hoc water supply from a water reservoir in order to regulate water discharge or level at the downstream site of a watercourse or water level in the reservoir itself.
Runoff volume	Water quantity running through the watercourse section for a certain time interval (l or m^3).
Soil reclamation area	The area that has similar mechanical composition of soils and groundwater depth.
Specific water withdrawal (water supply)	Irrigation water consumption per a composite hectare of an irrigated area (m^3/ha).
Stakeholders	Persons (physical and legal) that have direct or indirect relation to water use and water distribution.
Sufficiency of water supply	Degree of meeting the actual water needs of an industry, system, enterprise: ratio of the actual water withdrawal value (water supply) to planned (limit) value.
Surface water bodies	Permanent or temporary accumulation of water on land surface within the relief shape with boundaries, volume, and water regime.
Ten-day hydromodule (duty of water)	Specific rate of water supply per unit of irrigated area for a ten-day period, l/s per one ha.
Transparency	Opportunity to keep track of the actions of the water use and water

	distribution related decision makers.
Vegetation period	Period from 1 April throughout 30 September
Waste ditch	Man-made structure which is the extension of the distribution network and used for discharging used and excess water into the river channel or natural depression.
Water application rate	Rate of water supply per unit of crop area for one water application (m^3/ha).
(Water) conducting network	System of permanent (main, inter-association, intra-association, on-farm) canals.
Water course	Water body flowing in the downslope direction on earth surface.
Waste/discharge water	Water used or come from a polluted area which is to be discharged into natural or artificial water bodies, or lays of land.
Water distribution plan	Plan of water withdrawal from the irrigation source and delivery of it through a canal system up to the water user.
Water distribution	Activity related to the water withdrawal from irrigation source and delivery to water users.
Water facilities	Man-made hydraulic structures and facilities on water bodies designed to regulate, use, and conservation of water resources, provision the community with water, wastewater disposal, and elimination of deleterious effect of water.
Water intake structure	System of structures and facilities for water withdrawal from water bodies.
Water management organizations	legal entities the activity of which is associated with the regulation, delivery, reproduction of water, water treatment, wastewater disposal, and use of water bodies.
Water (management) sector/industry	Branch of the national economy dealing with the use, protection, and reproduction of water bodies
Water management system	System of interconnected water bodies and hydraulic structures designed to ensure rational use and protection of water as well as disposal of wastewater.
Water management year	Period from April 1 throughout March 31.
Water resources	Total volume of all available types of water (surface, underground, return) which are used or potentially can be used by people and nature
Water saving	Package of measures ensuring rational and effective use of water resources.
Water supply[19]	Process of water supply to a canal.
Water use	Use of water resources in the order established by laws in order to .
Water use plan	Part of the production plan of the water user (farm, etc.) or association of water users (WUA, PC, etc.), which sets forth the water user's demand for water during the vegetation (non-vegetation) period for a year with average long-term climatic conditions.
Water withdrawal/intake	Process of water withdrawal to the canal

---

[19] Water withdrawal and supply are relative concepts: water supply to a lower-order canal is water withdrawal from a higher-order canal.

Annex 3. Classification

Classification of irrigation sources

According to origin:

- Natural (river, sai, lake, spring).
- Artificial (reservoir, canal collector).

According to belonging:

- Regional.
- Republican.
- Provincial.
- District.
- Farm.

According to regulation degree:

- Regulated.
- Partially regulated.
- Non-regulated.

According to the location relative to ground surface:

- Surface.
- Underground.

Classification of water organizations

According to the type of ownership:

- Interstate (BWO).
- Country-wide (CMO, provincial water management organization, district water management organization).
- Public (UCWU, WUA).

According to the establishment principle:

- Administrative (provincial water management organization, district water management organization).
- Hydrographic (BWO, ISA, BWA, CMO).

Classification of irrigation systems

According to the type of water withdrawal

- Gravity.
- By pumping.
- According to belonging.
- Inter-farm system (IFS).
- On-farm system (OFS).

According to technical level (depending on the degree of equipping with hydrotechnical infrastructure):

- Non-engineering (EFs – 0.3-0.5).
- Semi-engineering (EFs – 0.4-0.65).
- Engineering (EFs – 0.5-0.7).

According to technical state:

Grade 1 – good state (no need for reconstruction and reequipping).
Grade 2 – satisfactory (partial reconstruction is needed).
Grade 3 – below satisfactory (much reconstruction and reequipping related works is needed).
Grade 4 – poor (complete reconstruction is needed).

IDS elements:

- Water intake structure.
- Main canal.

- Distribution canals.
- Hydraulic structures.
- CDN (collector, drain line).
- Monitoring facilities and devices (gauging stations, observation wells, hydrometric propellers, leveling instrument, theodolite, etc.).
- Communication facilities (connection, transport).
- Auxiliary infrastructure (maintenance and operation equipment, tools, building, warehouses, building material stocks).

IDS parameters:

- Area under service; cropping pattern of irrigated lands.
- Number of irrigation sources (SI).
- Number and type (category) of the serviced farms-water users (WU).
- Number of water delivery points.
- Total and specific length of irrigation systems (IS) (in earth bed, in lining).
- Equipping with facilities (number and type of gauging stations, hydraulic structures, etc.).
- Conveyance capacity.
- Efficiency (MC, IFS, OFS, system).
- Communication (connection, transport, roads).

IS performance assessment criteria

Technical criteria:

- Minimum technical water losses.
- Water supply stability.
- Maximum physical productivity of water.

Organizational criterion:

- Minimum organizational water losses.

Social criterion:

- Uniformity.

Economic criterion:

- Maximum economic productivity of water.

Classification of water users (agricultural enterprises, organizations)

According to ownership type:

- Public.
- Private.

According to cooperation degree:

- Collective.
- Individual.

According to specialization:

- Crop producing.
- Animal producing.
- Domestic; cultural and technical.

According to size:

- Small-scale.
- Medium-scale.
- Large-scale.

According to form of organization:

- Joint-stock company.
- Corporation.

- Agricultural firm.
- Kolkhoz.
- Cooperative (shirkat).
- Association (of individual farms, peasant (dekhkan) farms).
- Individual farm.
- Peasant (dekhkan) farm.
- Others (homestead lands, subsidiary plots, and lawn-and-garden partnerships).

Annex 4. Water use and water DISTRIBUTION plan drawing up and implementation problems

Shortcomings of the water use plan drawing up

- When drawing up a water use plan (WUP), water losses in the irrigation (inter-farm, on-farm) network but water losses in the field (field efficiency) are taken into account. It is supposed that these losses are allowed for in the irrigation regimes. This supposition is true for Tajikistan and Kyrgyzstan /1, 2/, while the situation in Uzbekistan is unclear: according to scientists /3, 4/, the irrigation technique efficiency is not taken into account in the irrigation regime. This is evidenced by the following extract from the explanatory note for the irrigation regimes, developed by the Scientific Production Association "Soyuzkhlopok" (Soviet Union Cotton) /5/, that are approved and remaining in force up to date: "The main approach to the calculation of water requirement and water application rate is based on the results of field experiments in hydromodule zones… Numerous data of field irrigation experiments reflect the net water requirement and water application rate: they have to be increased by the value of involuntary losses…". It is strange but it's true that a number of surveyed water specialists hold the opposite opinion: they think that losses in the field are not allowed for in irrigation regimes.
- Let us suppose that the field efficiency is allowed for in irrigation regimes. A question arises, how it can be, at least approximately but properly enough, allowed for if the field efficiency depends to a large degree on the field slope, while the irrigation regime differentiates at best according to administrative areas. Taking into consideration that lay of land may highly vary even within the same farm, it becomes clear that the district average field efficiency is an average value "pulled out of a hat".
- In our opinion, the field efficiency must be taken into account not in irrigation regimes but when drawing up a water use for the farm. Based on the cartographic and other materials data for each field, the values of slope and other information have to be determined, proceeding from which one can approximately calculate the field efficiency according to the method by Laktaev, N.T. /6/ and other scientists.

Shortcomings of the initial information

- Crop irrigation regimes (crop water requirement and water application rates as well as their irrigation time[20]) are set according to the climatic zoning for average long-term climatic conditions and not for a specific year[21].
- When calculating the water requirement, crop variety and capacity is taken into account despite there exist the Kostyakov, A.N. and other authors' formulae /7/ according to which the crop water requirement is proportional to its capacity. With such an approach, water requirement for irrigated lands (of farms-water users) where heavy crop is obtained is underestimated as compared to other farms.
- This shortcoming most apparently affects WUPs in Uzbekistan because of inaccurate estimation of water needs of grain crops. Grain crop irrigation regime in Uzbekistan was set for local varieties. Now, as a rule, they cultivate high-yielding Russian varieties of wheat, and irrigation regimes have not been changed officially. The irrigation regime for local grain crops proposes two irrigations. Their crop yield was 18-20 metric centner/ha. Now the varieties have been changed. The wheat is irrigated 4-10 times, and its yield comes to 25-60 metric centner/ha.
- In the water use practice, they try to take into account a shortcoming of WUP when adjusting the WUP; however, at that the proportionality principle is not followed.
- The planned cropping pattern of areas under crop often (usually in Uzbekistan) may differ from the real pattern since double crops and intercrops are not always (or not the full extent) allowed for consciously or for other reasons.

---

[20] At that, the irrigation time is set not for a specific irrigation plot but for the aggregate of irrigation plots, as a rule, of brigade' areas.

[21] In the Fergana province, irrigation regimes of 1986 are employed.

- Because of the absence of information about the actual efficiency of the on-farm network, in the calculations they use normative data the accuracy of which is unknown. Besides, it is known that the efficiency factor is a discharge-dependent quantity, while in the calculations it is given as a constant.
- Planned values of the canals (systems) efficiency quite often differ from the actual values of operating efficiency.
- When considering soil-reclamation maps of farms, a few hydromodule zones can generally be marked out; however in the water use plans there are much less hydromodule zones[22].

Shortcomings in water use planning

- Our experience suggests that in the farms and water management organizations where water use culture is high the attitude to water use planning is very serious. And vice versa, where the agriculture and water sectors breakdown is taking place, they are not in the mood for planning water use.
- In water use plans, internal irrigation sources such as wells, springs, and most important, return water are insufficiently taken into account consciously or unconsciously. If consider that, according to local specialists, the Fergana province takes as much water as flows out of it, it becomes obvious that irrigation reserves associated with the use of return water are very considerable. At the same time, it is worthy to mention that experienced water management organization specialists at water shortage try to consider these internal irrigation sources. It would be better if they had considered those when planning water use.
- In the absolute majority of farms there are no specialists who are able to draw up a full-fledged farm's water use plan and, therefore, these plans, as a rule, have been drawn up (or were drawn up) in district water administrations (rayvodkhozes). However, since there is a large number of farms (their number has risen still more after the restructurization) and the capabilities of the water use department are limited, the water use plans are drawn up in simplified (in even less detail) form.
- Simplified farms' water use plans give the information on at what rate the flow should be supplied from inter-farm irrigation sources at farms' boundaries. It is impossible to know from the plan how water is to be distributed among site and brigade irrigation ditches.
- Restructurization of agricultural enterprises, building up farms require even more specification of the water use plan, but it is even more difficult to do since most farmers have no idea of planning, and WUAs, where present, often because of their incompetence and great number of farms is unable to correctly determine water demand.
- The proportionality principle is often not followed when adjusting WUPs at both inter-system and inter-farm levels as well as during the vegetation period. This is due to both objective reasons (insufficient level of irrigation source regulation and loopback character of irrigation systems) and subjective reasons (making intentional or unintentional errors by the on-farm system operation service when adjusting WUPs).

In recent years, they ceased including industrial and technical needs in the water use plans of farms and systems with some minor exceptions (large plant in the Chkalovsk town, etc.). this is due to that many enterprises do not work, and those working tend to use collector water or have their own well.

In Uzbekistan, a limit on industrial and technical needs is assigned every year, but this limit, according to local water management organization specialists, practically is not applied because they have to pay for this water.

---

[22] The lands on the left bank of SFMC are attributed to Hydromodule Zone 1 in the water use plan, though those require much higher water application rates. Most likely, use and irrigation of such lands by adopted irrigation regimes is not provided for, but they are virtually applied and, being attributed to Hydromodule Zone 1, distort the real water need value.

Shortcomings of the WUP adjustment method

Agricultural crops satisfy their water needs mainly by two types of water: surface water and ground water. WUP reflects the crop demand for surface water. Let us consider two variants of the formation of groundwater regime /8/.

- Groundwater regime takes shape, mainly, due to intense underground inflow, that is to say the groundwater level slightly depends on the fluctuations of surface flow. According to this variant, when adjusting the water distribution plan under water deficit conditions only that water is restricted that is supplied to water users by surface. If water users are located in different hydromodule zones, then by equally restricting the surface part of the total water consumption by crops we unequally restrict the total water consumption.
- To illustrate this idea, let us consider two farms that take water from a single canal but located in different hydromodule zones, for example, in the 3rd and 7th hydromodule zones. Let us assume that the consumptive water use per composite hectare with the use of surface and underground waters comes to 10 ths. m^3/ha, while the water requirement is 7 and 4 ths. m^3/ha, respectively. With the proportionality factor of 0.7, the limit for the first farm will be 4.9 and for the second farm 2.8 ths. m^3/ha. Then the consumptive water use of the first farms will come to 7.9 and second one to 8.8 ths. m^3/ha. Thus, the level of total water supply to the first farm will be 79 %, and to the second 88 %. At water deficit, the water user located in the 7th hydromodule zone will be in more advantageous condition than the one located in the 3rd hydromodule zone. In the water use practice, experienced water management organization specialists try to take into account this shortcoming of the adjustment method through levelling the level of total water supply to farms.
- The groundwater regime is formed owing to losses from irrigation systems and irrigated fields, viz. the groundwater level lowers in proportion to water resources deficit. In this case, proportional drop in the water supply to farms located in different hydromodule zones will also bring to uneven level of total water supply to water users, since the water which, for example, is lost on adyrs (irrigated lands of the left and partially right banks of SFMC) feeds the groundwater of downstream lands.

Shortcomings of WUP implementation

- The fact that for the recent ten years the technical state of canals and irrigation infrastructure (water intake facilities, regulators, sluice gates, pump stations, gauging stations, etc.) have worsened because of dramatic reduction of financing for IDS maintenance and operation prevents efficient online management of water flow for the implementation of WUP.
- Representatives of the local authority quite often interfere in the water allocation process[23] (in Kyrgyzstan, intervention of local authorities has sharply decreased). At that, “sympathy” of a local authority for one or another water users can be due to kindred, friendly relations, or out of mercantile considerations, and at the best for water use effectiveness purposes: it is better to help the water user that uses water to the highest advantage and will give good yield.
- Too low salary of the operational personnel makes them to focus more on by-works (market garden, etc.) rather than their direct duties in order to survive.
- In the water resources management process, the water management organization specialists act proceeding from their experience and intuition rather than calculations and reliable models. There comes a time of the specialists who are able to work out effective water allocation methods. However, the number of such experienced hydraulic engineers in the water and

---

[23] Surveys of water management organization specialists and water users (2003) show that such intervention is typical of the leaders of the local authorities located in the upper reach of the canal.

agricultural sectors is continuously decreasing. In future, the problem related to the lack of skilled hydraulic personnel in the Fergana Valley will become still more critical, this especially concerns the Sogd province where there is no special educational institution.

- Numerous mud torrents cause big problems for water management organizations.
- Repeated stops of canals take place throughout a year for objective (search for a drowned person) and not always objective reasons.
- Low water use discipline at all water allocation levels. Unauthorized water withdrawal (simply speaking, water theft) is an ordinary case. Water theft at SFMC often takes place. Those are detected. For the first time, water thief will be given a caution, for the second time – the offtake will be shut off for three days, and for the third time –a complaint will be lodge against it. As a rule, they do not file an action and do not put into court.
- Absence or insufficiency of intra-system reservoirs (water bodies) for water redistribution in terms of time considerably reduces the possibilities for rational management of the flow.

List of references used for Annex 4

1. Kh.D. Domullodjonov. Recommendations on the calculation of irrigation regime in programming cotton crop rotation yield in the Tajik SSR. Dushanbe, 1983.
2. Recommendations on the improvement of crop irrigation technology in the Tajik SSR through the organization of concentrated irrigation and programming yield. Moscow, 1985.
3. A.F. Baraev et al. Improvement of the on-farm water use plan calculation method. // Improvement of the operation of irrigation and drainage systems of irrigated areas. Tashkent, 1986.
4. Practicals for agricultural hydrotechnical training. / Edited by Prof. F.M. Rakhimbaev. Tashkent: Mekhant, 1991.
5. N.F. Bespaloev et al. Hydromodule zoning and crop irrigation regimes in the Syrdarya province. Tashkent, 1987.
6. N.T. Laktaev. Irrigation of cotton. Moscow: Kolos, 1978.
7. Irrigation regimes and hydromodule zoning in the Uzbek SSR. Tashkent : Uzbekistan, 1971.
8. A.D. Churlyaev. Fergana province. // Irrigation regimes and hydromodule zoning in the Uzbek SSR. Tashkent : Uzbekistan, 1971.

Annex 5. MIS “Fergana”

The information system MIS “Fergana” has been developed within the IWRM-FV Project; it is designed to assess and justify different methods of water resources distribution for irrigated agriculture for the purpose of improving the effectiveness of water use. The MIS “Fergana” ensures solution of various water management tasks at different stages of water distribution management.

The IWRM basis if the multilevel hierarchy in the management structure and integrated interaction between all of its components. This structure is fully supported in the MIS “Fergana” by means of a set of mathematic models and information database flows.

Witch this concept, optimum water resources distribution between the participants in terms of years, months, and ten-day periods is ensured; there every hierarchy level, having its own effectiveness criteria, adheres, by means of information flows (models and databases), the general management strategy set for the system in whole.

The Management Information System (MIS) “Fergana” allows:

1. Carrying out monitoring of the water management system with regard to the changes in:
   - Cropping pattern;
   - Hydromodule zoning;
   - Structure of the water management network (sources, canals);
   - Parameters of the water management network’s elements.

2. Accounting actual water withdrawal from offtakes and canals.
3. Registering the ten-day water supply requests received.
4. Modeling different options of water distribution among water management system participants with different variants of requests and different volumes of water supply to the system:
   - with annual planning;
   - with operational planning.
5. Finding optimum water distribution options:
   - with different water supply sources (annual planning);
   - with water resources deficit (annual and operational planning).
6. Making analysis of water distribution effectiveness:
   - making calculations of water distribution effectiveness factors;
   - preparation of reporting and production documents.

The Management Information System (MIS) “Fergana” is established on the basis of ACCESS and GAMS Database Management Systems and introduced at the pilot canals of the IWRM-FV Project.

Annex 6. Crop irrigation regimes

Crop water consumption rate depends on many factors the basic of which are soil, climatic, and biological.

Sinc eit is very difficult to assess and consider all the factors, scientists proposed a simplified scheme of irrigation regime estimation as function of crop type, hydromodule zone (Table 1), and climatic zone (CZ) (Table 2 and Figure 1).

In spite of that, each republic of CAR applies its own approaches that have certain differences. The following equation is offered to estimate water requirement:

$$M = 10 * К_1 * К_2 * К_3 * (E - O),$$

where

M – water requirement
E – evaporation capacity
O – precipitation total
$К_1$ – factor dependent on cultivated crop type (from 0.55 to 0.88).
$К_2$ – factor dependent on the duration of irrigation period (on climatic zone) (from 0.88 for C-I to 1.08 for Yu-II).
$К_3$ – factor dependent on hydromodule zone (from 0.45 to 1.14).

Table 1. Hydromodule zones

Hydromodule zone	Soils and their sub-bases	Groundwater depth, m
Automorphix, formed under no groundwater influence		
I	Shallow loamy on sandy-pebble deposits and thick sandy	3
II	Medium loamy on sandy-pebble deposits and thick sandy-loamy	
III	Thick loamy and clay loamy	
Of transition row, formed under low groundwater influence		
IV	Slightly loamy and sandy-loamy	2-3
V	Loamy, clay loam	
Hydromorphous, formed under moderate groundwater influence		
VI	Slightly loamy and sandy-loamy	1-2
VII	Loamy, clay loam	
Swampy-meadow, formed under excessive groundwater influence		
VIII	Slightly loamy and sandy-loamy	0.5-1
IX	Loamy, clay loam	

Source: Legostaev, V.M. & Mednis, M.P. Irrigation regimes and hydromodule zoning in the Uzbek SSR. Tashkent, 1971.

Table 2. Altitudinal-belt zones

Name of zone	**Designation of zone**	**Type of soil**

Deserts	A	Desert types of soil formation
	A1	Transitional to sierozem
Ephemeral steppes	B	Light sierozem
	V	Typical sierozem
Forb steppes	G	Dark sierozem

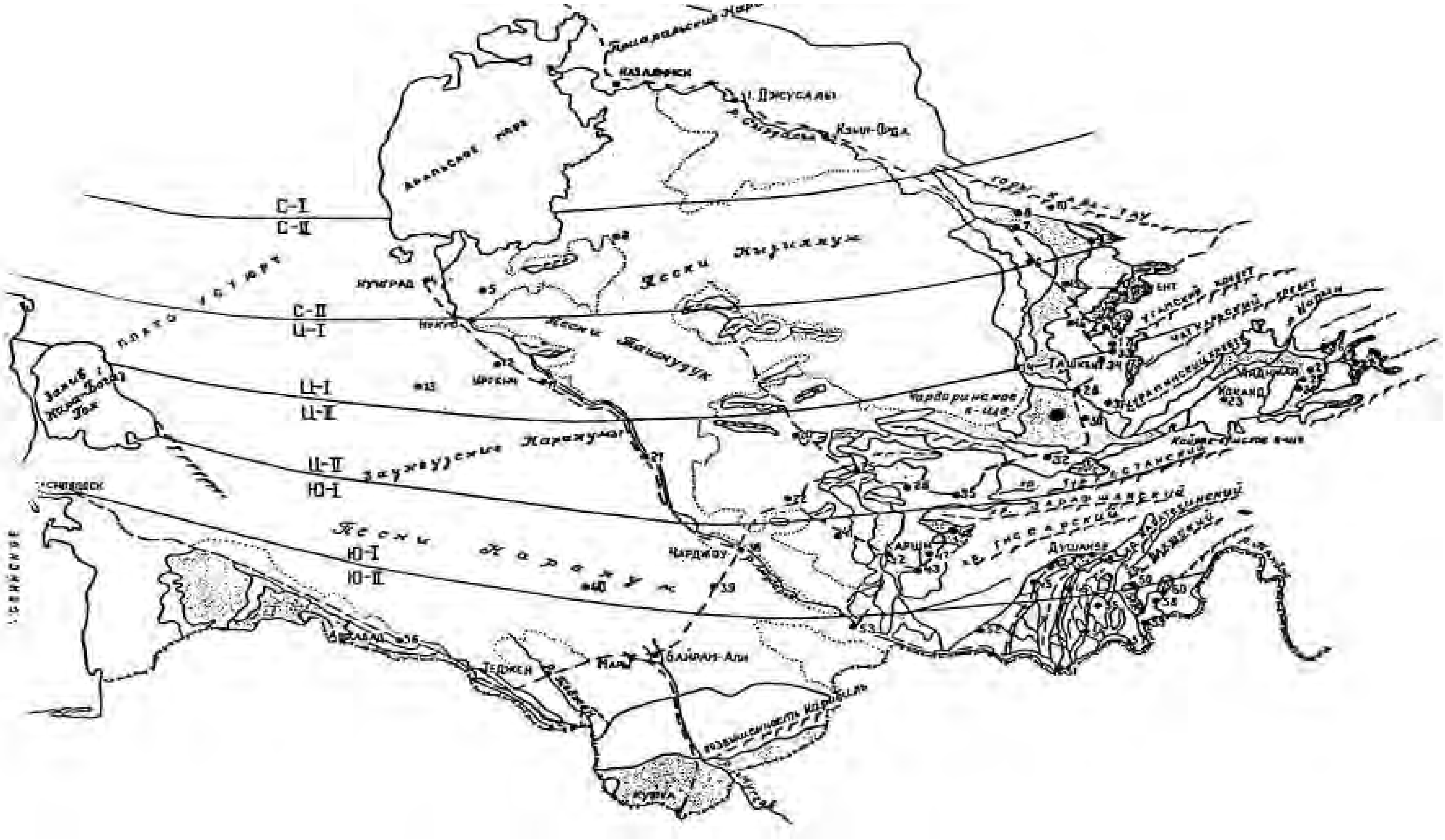


Figure 1. Climatic zones.

Source: Shreder, R.V. et al. Zoning of irrigation regimes. Hydraulic engineering and land reclamation. 1966. № 8.

Annex 7. Calculation of water application and ten-day hydromodule.

1. Hydromodule is determined proceeding from the fixed crop irrigation regime as the ratio of water application rate to water application time, i.e.

$$q_{jn} = m_{jn} / 86.4 \ * t_{jn}, \qquad (1)$$

where

q_{jn} – irrigation hydromodule of the j^{th} crop during the n^{th} water application, l/s/ha
j – crop index
n – crop irrigation number index
m_{jn} – water application rate of the j^{th} crop during the n^{th} water application, m^3/ha
t_{jn} – duration of the n^{th} water application for j^{th} crop, days
86.4 – unit conversion factor

Example of the calculation of irrigation hydromodule

In compliance with the fixed regime of cotton irrigation (see the Table), the first water application at a rate of 900 m^3/ha is to start on May 26 and end on June 22. Number of water application days in May is 6 and in June 20; total duration of the water application is 28 days. The irrigation hydromodule of the first water application is as follows (rounded off to the nearest one thousandth place)

$$q_{jn} = 900 / 86.4 \ * 28 = 0.372 \text{ l/s per ha}$$

2. Ten-day hydromodule of the water application is determined by the formula:

$$q_{id} = (q_n * t_{idn} + q_{n+1} * t_{idn+1}) / T_{id}, \qquad (2)$$

where

q_n – irrigation hydromodule of the n^{th} water application for the crop
q_{n+1} – irrigation hydromodule of the next water application
t_{idn} – number of days of the n^{th} water application for the crop in the d^{th} ten-day period of the i^{th} month
t_{idn+1} – number of days of the $n+1^{st}$ water application in the d^{th} ten-day period of the i^{th} month
T_{id} – number of days in the d^{th} ten-day period of the i^{th} month

Calculation of the cotton hydromodule for the 3rd ten-day period of May:

$$q_{53} = (q_1 * t_{531} + q_2 * t_{532}) / T_{53} = (0.372 * 6 + 0.526 * 0) /11 = 0.203 \text{ l/s}$$

Calculation of the cotton hydromodule for the 1st ten-day period of June:

$$q_{61} = (q_1 * t_{611} + q_2 * t_{612}) / T_{61} = (0.372 * 10 + 0.526 * 0) /10 = 0.372 \text{ l/s}$$

Example of the calculation of ten-day hydromodule

Table 1. Data on cotton irrigation regime

Crop	Number of water application	Water application rate, m^3/ha	Water application time		Duration of water application, days	Irrigation hydromodule, l/s per ha
			beginning	end		
1	2	3	4	5	6	7
Cotton	1	950	26.05	22.06	28	0.372
	2	1000	23.06	14.07	22	0.526
	3	1100	15.07	2.08	19	0.670
	4	900	3.08	20.08	18	0.579

Calculation of the cotton hydromodule for the 2nd ten-day period of June:

$$q_{62} = (q_1 * t_{621} + q_2 * t_{622}) / T_{62} = (0.372 * 10 + 0.526 * 0) /10 = 0.372 \text{ l/s}$$

Calculation of the cotton hydromodule for the 3rd ten-day period of June:

$$q_{63} = (q_1 * t_{631} + q_2 * t_{632}) / T_{63} = (0.372 * 2 + 0.526 * 8) /10 = 0.495 \text{ l/s}$$

The water duties of the rest ten-day periods are calculated in a similar way.

Annex 8. Information from the water rotation theory and practice

Water Rotation Theory

Rizenkampf, G.K.:

"Theoretically, one can put a question of the irrigation regime which fully meets water demand of plants from the physiological point of view, disregarding economic and domestic needs. However, it will be practically impossible to provide simultaneous and short-time irrigation of the whole area which is under the same crop at once; agricultural and organizational & economic requirements are impossible to always conform to the requirements for optimum irrigation regime. Some restrictions may be also due to the river regime, discharge capacity of structures, everyday practice of water users, and a number of other conditions" [1].

Legostaev, V.M.:

"With planned water use, water cannot be transferred from one field to another by following the sign of establishment of optimum irrigation time period for a particular crop.

In this case, water use practice will become like the work of a fire brigade: you water where it is on fire. Great amount of water is spent on its idle run-through, dead water in canals, etc. Also, after-irrigation treatment will be carried out haphazardly spending much time and fuel for moving from one field to another.

With planned water use, adjacent fields must be irrigated in accordance with schemes set in advance. Some of those will, probably, be irrigated somewhat earlier than the optimum time, other later, and yet other in optimum time" [2].

Laktaev, N.T.:

"Only in the very far future, it may be expected that the problem that is popularized nowadays, i.e. carrying out of water distribution and irrigation based on accurate and continuous accounting of objective physiological measures of plants, will be solved.

The difficulties involved in the solution of this problem consist in not only its cybernetic complexity, imperfection of sensors or electronics, but also in the maladjustment of current surface irrigation systems. It is possible to build an experimental system with higher excess capacities, short-term use of water conduits in time, etc. on an area of 100 ha…

However, for now it is hard even to imagine such a system that resembles an urban waterworks system. If such systems are possible in theory, they are only by using subsoil irrigation, closed-conduit waterways..." [3].

Water rotation practice[24]

Uzbekistan

Shakhrisabz district. Here, water rotation is called "avandoz". In 2000, there were both inter-district and inter-farm water rotation. When its turn comes, a farm assigns over fifty people who will watch day and night along the whole length of water flow from a water withdrawal point to the farm.

---

[24] Extracts from a report on the Project "Water and Environmental Management in the Aral Sea Basin", Subcomponent A2 "Participation in Water Saving" (2000).

Tajikistan

Kanibadam district. Inter-farm water rotation is used mainly at the beginning of vegetation period (from March through the 3rd ten-day period of May), when the water level in BFC is low (30 % of water supply availability) and water is absent in Isfarasay. The water flow of 0.5 m^3/s (limit on the water withdrawal to the Kanibadam Concrete Canal from BFC) is divided, by turns, among three farms.

Dj. Rasulov district. Inter-district water rotation through the Khodjabakirgan sai and inter-farm water rotation through the Digmay Pumping Canal (DPC) are introduced in the recent two years in order to save water. Large farms of the district are divided into two groups, each of which is supplied with water for three days.

- "Parrandaparvar" JSC and "Nodirbaev" JSC, "Digmay"
- "Samatov" kolkhoz, "B. Turdiboev" JSC and "Leningrad" JSC.

"Rakhimbaev" JSC. The JSC is located at the end part of the inter-farm canals R-1 and R-2. R-2 supplies water to three farms. Water rotation between the "Rakhimbaev" JSC and "B. Gafurov" kolkhoz is implemented throughout the vegetation period: water is to be supplied to the first farm for 3.5 days, then to the second one for 3.0 days. The implementation of water rotation was initiated by the "Rakhimbaev" JSC located along the canal downstream than the "B. Gafurov" kolkhoz, and therefore the latter did not support it.

Intermediation of the district water administration was unsuccessful, and water rotation was introduced only with the aid of the district administrator. The schedule of the inter-farm water rotation is to be approved by the district authority and district water administration. The stone land of the JSC, water deficit, and charged water use force the JSC to apply inter-brigade water rotation; at that, for example, one brigade receives water for 92 hours while the neighbor for 86 hours.

Kyrgyzstan

Aksu district. There are 12 village authorities in the district. Inter-farm network runs through the territories of four of those, where DWA has introduced water rotation.

Aravanu district. DWA has introduced water rotation in between five WUAs of the district: water is supplied to the WUAs "Sakhiy Daryo" (67 %) and "Obi Khayot" (33 %) for four days; another four days to the rest three WUAs.

List of references used for Annex 8

1. Rizenkampf, G.K. On the new project of irrigation of Golodnaya Steppe. Volume 1. Leningrad, 1930.
2. Legostaev, V.M. Investigation and use of irrigation water in the republics of Central Asia. // Proceedings of SANIIRI. Tashkent,1974. Issue 143. Pp. 135-148.
3. Laktaev, N.T. Cotton irrigation. Moscow, Kolos, 1978.

Annex 9. State standard gost 25855-83 – level and discharge of surface waters

UDC 532.57:006.354

STATE STANDARD

LEVEL AND DISCHARGE OF SURFACE WATERS
General requirements for measurement

GOST 25855-83
(CMEA Standard 3546-82
and CMEA Standard 3547-82)

1. This standard specifies general requirements for the measurement of surface water level and discharge at gauging stations. The terms used in the standard as well as their definitions are given based on GOST 19179-73. The standard is in full compliance with CMEA Standard 3546-82 and CMEA Standard 3547-82.
2. A gauging station should be placed where water gauges can be installed and normally function and be used.
3. The stations where water discharge is measured shall be located near to the gauging stations that measure water level.
4. The gauging station is to ensure a possibility of continuous determination of average daily discharges in a particular place using the link water level-water discharge that is effective preferably for a long period.
5. The gauging station is to be designated by digital code, name of the location site (watercourse, water body, residential settlement, and distance from the watercourse mouth) and, if needed, by geographic coordinates as well as by the name of a higher-order watercourse or its catchment area.

   Each gauging station must have the technical certificate with the data enlisted in the Annex.
6. The gauging station must be equipped with equipment, devices, and facilities appropriate for local conditions and ensure acquisition of data of the following accuracy:

- water level: not less than 1 cm;
- water discharge under standard conditions: with an error of no more than 5 %.

7. The water discharge measured at the gauging station shall be in agreement with that measured at neighboring stations.
8. The water level and discharge shall be measured in accordance with the existing rules.
9. If a water level recorder is absent, measurements are carried out visually by means of a water gauge at a regular time interval but not les than one time at certain times of the day. In extreme cases (flood occurrence period, ice drift, etc.), measurements shall be carried out more frequently.
10. The state of the water gauge shall be examined not less than twice a year; check of elevation datum, inspection of the measuring equipment state, and accuracy of the measurements carried out shall be made not less than once a year.
11. If a water level recorder is available, it is necessary to write down the time (year, month, day, hour, minute) as well as water level read from water gauges on the tape before and after threading.
12. At the gauging stations measuring water discharge, water surface slope is measured, too, in case of need.
13. At the stations where the water level-water discharge relation is not provided, water should be measured at such regular time intervals so that the error of water discharge measurement interpolation will be less than 10 %.
14. The water level and water discharge measurement results shall be recorded in the measurement log.

15. The organizations concerned shall be provided with the information of water level and discharge in accordance with the established procedure.
16. Water level and discharge measurement data shall be processed in accordance with the existing rules for the execution of hydrological works on rivers.
17. The data shall be verified and processed by automatic devices (computers) and by other ways.
18. Average daily, monthly, and annual water discharges as well as their minimum or maximum values shall be determined through the data of discrete (one-off) water discharge measurements.
19. At individual water measurements, it is necessary to determine instantaneous water discharge proceeding from each measurement, appropriate water level as far as possible, area of water cross-section, mean velocity, width of the water area, mean depth, maximum depth, water surface slope as appropriate, and channel roughness factor.
20. To systematize and process records materials, the following periods shall be taken: calendar year, month, day (date) according to the standard time.
21. Monthly and annual characteristic water level and water discharge data (mean, lowest, and highest) as well as the frequency of daily records data shall be determined if appropriate.
22. For statistical processing of data, the water level and discharge series length should be not less than 10 years.

Appendix

Mandatory

Technical certificate of the gauging station

The technical certificate must contain the following information:

- Name of the main catchment basin; names of watercourse, water bodies; name and, if appropriate, geographic coordinates of the station.
- Datum level of the gauging station and elevation system.
- Diagrammatic layout of the site of the station where water discharge is measured.
- Results of the measurements based on which the station has been selected.
- Type of the station (natural or man-made) equipped with instruments and measuring devices.
- Information about the level of equipment of the gauging station (measuring bridge, cable track, floating crafts, etc.), program and time of the measurements.
- Catchment area upstream of the station, km^2.
- Characteristics of natural or artificial impact (channel deformations or nature of ice drift, etc.).
- Description of the channel in the vicinity.
- History of the gauging station (description of the changes of its location, transfer and replacement of equipment).
- Name of the institution under the authority of which the gauging station is.

Annex 10. Formulas to calculate water distribution indicators

1. Water supply coefficient

a) Offtake's:

- Ten-day period

$$V_{di} = \frac{Q^f_{di}}{Q^p_{di}} \quad \text{or} \quad V_{di} = \frac{W^f_{di}}{W^p_{di}}, \quad Q^p_{di} \neq 0,, \; W^p_{di} \neq 0. \tag{1}$$

Target period

$$V^{\int}_i = \frac{\sum\limits_{d \in D} W^f_{di}}{\sum\limits_{d \in D} W^p_{di}} \tag{2}$$

$$W_{di} = Q_{di} \times T_d \tag{3}$$

$$T_d = 0.0864 N_d , \tag{4}$$

where:

V_{di} - water supply coefficient of the i^th^ offtake in the d^th^ ten-day period

Q_{di} - water supply (discharge) to the i^th^ offtake in the d^th^ ten-day period, m^3/s

$V^{\int}_i$ - water supply coefficient of the i^th^ offtake in the target period

W_{di} - water supply (runoff volume) to the i^th^ offtake in the d^th^ ten-day period, mln m^3.

T_d - duration of the water supply in the d^th^ ten-day period, beginning from (in seconds)

N_d - number of days in the d^th^ ten-day period, days

d - ten-day period index

D - set the elements of which represent the number of the ten-day periods within the target period; calculated on a progressive total basis d=$\overline{1,t}$

t - number of the target ten-day period[25]

$\int$ - characteristics of water allocation indicator for the target period

p - planning data characteristics

f - factual data characteristics

i - index of the offtake that supplies water from PC to the PC zone[26], $i = \overline{1,m}$

m - number of the last offtake from PC

---

[25] If a vegetation period (from April throughout September) is considered, the number of the last ten-day period of the vegetation period is 18.

[26] Water from a PC can be supplied also by transit beyond the PC zone: from SFMC transit flow goes to feed BFC and BAC; from AAC, to feed Aravansay; from KBC water is supplied to the pumping irrigation zones of the B.Gafurov and Dj.Rasulov DWAs.

Pilot canal’s (PC):

Ten-day period

$$V_{dc} = \frac{Q_{dc}^{f}}{Q_{dc}^{p}}. \tag{5}$$

Target period

$$V_{c}^{\int} = \frac{\sum\limits_{d \in D} W_{dc}^{f}}{\sum\limits_{d \in D} W_{dc}^{p}}. \tag{6}$$

$$W_{dc} = \sum_{i \in I} W_{di}. \tag{7}$$

where: c - PC characteristics

I - set the elements of which represent the numbers of the offtakes that supply water from PC to the PC zone

2. Daily water supply stability coefficient [27]

To offtake

$$S_{di\varepsilon}^{\alpha} = 1 - \frac{\sqrt{\dfrac{\sum\limits_{\mu=1}^{\kappa} \left(Q_{di\varepsilon} - Q_{di\varepsilon\mu}\right)^{2}}{K + 1}}}{Q_{di\varepsilon}}, \quad Q_{di\varepsilon} \neq 0. \tag{8}$$

$$Q_{di\varepsilon} = \frac{\sum\limits_{\mu=1}^{k} Q_{di\varepsilon\mu}}{K}, \tag{9}$$

---

[27] The below formulae for the calculation of (daily and ten-day period) water supply stability coefficients can be used for the calculation of the coefficients of water discharge stability at the PC’s monitoring gauging stations.

where: $S^{\alpha}_{di\varepsilon}$ - coefficient of the stability of daily water supply to the offtake

$Q_{di\varepsilon\mu}$ - water supply to the i^th^ offtake on the ε^th^ day of the d^th^ ten-day period at the μ^th^ record of water discharge, m^3/s

$Q_{di\varepsilon}$ - average daily water supply to the offtake, m^3/s

α - daily water supply stability coefficient characteristics

ε - day index; $\varepsilon = \overline{1, n}$, n = 10 or 11 days (depending on the number of a ten-day period)

k - number of the last water discharge record within 24 hours[28]

K - number of water discharge records within 24 hours

μ - index of a water discharge record

From PC

$$S^{\alpha}_{dc\varepsilon} = \frac{\sum\limits_{i \in I} S^{\alpha}_{di\varepsilon}}{M}, \tag{10}$$

where: M - number of the offtakes that supply water from PC to the PC zone

3. Ten-day water supply stability coefficient

To offtake

$$S^{\beta}_{di} = 1 - \frac{\sqrt{\dfrac{\sum\limits_{\varepsilon=1}^{n} \left(Q_{di} - Q_{di\varepsilon}\right)^2}{N+1}}}{Q_{di}}, \quad Q_{di} \neq 0 \;, \tag{11}$$

where: S^{β}_{di} - coefficient of the stability of ten-day water supply to the offtake

Q_{di} - average ten-day water supply to the offtake, m^3/s

β - ten-day water supply stability coefficient characteristics

N - number of days in the target ten-day period

n - number of the last day of the target ten-day period

---

[28] At SFMC monitoring stations, hourly observations are performed; at the SFMC offtakes observations are made four times a day; at AAC and KBC, observations are carried out only 3 times a day.

$$Q_{di} = \frac{\sum_{\varepsilon=1}^{n} Q_{di\varepsilon}}{N}. \tag{12}$$

From PC

$$S_{dc}^{\beta} = \frac{\sum_{i \in I} S_{di}^{\beta}}{M}. \tag{13}$$

The ten-day water supply stability coefficient for the target period for an offtake (or group of offtakes) is determined as the arithmetical mean value of ten-day water supply stability coefficients of the target period's ten-day periods.

4. Water supply uniformity coefficient

a) for offtake

For ten-day period

$$U_{di} = 1 - \frac{\left| V_{dc} - V_{di} \right|}{V_{dc}}. \tag{14}$$

$$V_{dc} = \frac{Q_{dc}^{f}}{Q_{dc}^{p}}, \quad Q_{dc}^{p} \neq 0, \tag{15}$$

where: U_{di} - coefficient of the uniformity of water supply from PC to the i^th^ offtake during the d^th^ ten-day period

V_{dc} - coefficient of the PC water supply availability during the d^th^ ten-day period

V_{di} - coefficient of the water supply availability in the i^th^ offtake during the d^th^ ten-day period

Q_{dc} - ten-day water supply from PC, m^3^/s

For target period

$$U_i^{\int} = 1 - \frac{\left| V_c^{\int} - V_i^{\int} \right|}{V_c^{\int}}; \; V_c^{\int} \neq 0. \qquad (16)$$

$$V_c^{\int} = \frac{\sum\limits_{d \in D} W_{dc}^{f}}{\sum\limits_{d \in D} W_{dc}^{p}}; \qquad V_i^{\int} = \frac{\sum\limits_{d \in D} W_{di}^{f}}{\sum\limits_{d \in D} W_{di}^{p}}, \qquad (17)$$

where: $U_i^{\int}$ - coefficient of the uniformity of water supply from PC to the ith offtake during the target period

$\int$ - characteristics of water allocation indicator for the target period

b) for PC

For ten-day period

$$U_{dc} = \frac{\sum\limits_{i \in I} U_{di}}{M}, \qquad (18)$$

where: U_{dc} - coefficient of the uniformity of water supply from PC during the dth ten-day period

U_{di} - coefficient of the uniformity of water supply from PC to the ith offtake during the dth ten-day period

W_{di} - ten-day water supply (runoff volume) to the ith offtake during the dth ten-day period, mln m^3

M - number of the offtakes that supply water from PC to the PC zone

For target period

$$U_c^{\int} = \frac{\sum\limits_{i \in I} U_i^{\int}}{M}. \qquad (19)$$

5. “Head-to-tail” uniformity coefficient

For ten-day period

$$U_d^{\lambda} = 1 - \frac{\left| V_d^{\xi} - V_d^{\theta} \right|}{V_d^{\xi}}; \quad V_d^{\xi} \neq 0. \tag{20}$$

$$V_d^{\xi} = \frac{\sum\limits_{i \in I_1} V_{di}}{L}, \qquad V_d^{\theta} = \frac{\sum\limits_{i \in I_2} V_{di}}{L}, \tag{21}$$

where: ξ - characteristics of 25 % of the farms-water users at the tail section of PC

θ - characteristics of 25 % of the farms-water users at the head section of PC

λ - characteristics of the coefficient that allows for the level of water allocation uniformity between the end and head sections of PC.

I_1 - set the elements of which represent the numbers of 25 % of the farms-water users at the PC's tail section.

I_2 - set the elements of which represent the numbers of 25 % of the farms-water users at the PC's head section.

L - number of the water users that make up 25 % of the total number of the farms-PC water users.

For target period

$$U^{\int \lambda} = 1 - \frac{\left| V^{\int \xi} - V^{\int \theta} \right|}{V^{\int \xi}}; \quad V^{\int \xi} \neq 0. \tag{22}$$

$$V^{\int \xi} = \frac{\sum\limits_{i \in I_1} V_i^{\int}}{L} \qquad V^{\int \theta} = \frac{\sum\limits_{i \in I_2} V_i^{\int}}{L}. \tag{23}$$

6. Efficiency

a) Balance site efficiency
For ten-day period

$$\eta_{dj}^{e} = \frac{\sum\limits_{i \in I_j} W_{di} + \sum\limits_{i \in H_j} W_{di}^{h} + \sum\limits_{i \in G_j} W_{di}^{g}}{W_{dj}^{\phi} + \sum\limits_{i \in R_j} W_{di}^{r}}, \tag{24}$$

where: e - technical efficiency characteristics

r - characteristics of the lateral inflow to PC

H - set the elements of which represent the numbers of the offtakes through which PC water is transited

h - characteristics of transit water discharge (runoff volume)

g - PC water release characteristics

G - set the elements of which represent the numbers of the offtakes through which PC water is released.

R - set the elements of which represent the numbers of the water sources (canal, sai, pump, pumping station, collector, etc.) from which lateral inflow to PC takes place

j - index of balance site

ϕ - characteristics of head water intake (to PC, to PC's balance site)

For target period

$$\eta_{dj}^{\int e} = \frac{\sum_{d\in D}\sum_{i\in I_j} W_{di} + \sum_{d\in D}\sum_{i\in H_j} W_{di}^{h} + \sum_{i\in G_j}\sum_{i\in G_j} W_{di}^{g}}{\sum_{d\in D} W_{dj}^{\phi} + \sum_{d\in D}\sum_{i\in R_j} W_{dj}^{r}}. \tag{25}$$

b) Technical efficiency of PC

For ten-day period

$$\eta_{dc}^{e} = \frac{\sum_{i\in I_c} W_{di} + \sum_{i\in H_c} W_{di}^{h} + \sum_{i\in G_c} W_{di}^{g}}{W_{dc}^{\phi} + \sum_{i\in R_c} W_{di}^{r}}. \tag{26}$$

For target period

$$\eta_{c}^{\int e} = \frac{\sum_{d\in D}\sum_{i\in I_c} W_{di} + \sum_{d\in D}\sum_{i\in H_c} W_{di}^{h} + \sum_{d\in D}\sum_{i\in G_c} W_{di}^{g}}{\sum_{d\in D} W_{dc}^{\phi} + \sum_{d\in D}\sum_{i\in R_c} W_{di}^{r}}. \tag{27}$$

Organizational efficiency of PC

For ten-day period

$$\eta_{dc}^{o} = 1 - \frac{\sum\limits_{i\in G_c} W_{di}^{g} + \sum\limits_{i\in I_g}\left(W_{di}^{f} - W_{di}^{p}\right)}{W_{dc}^{\phi} + \sum\limits_{i\in R_c} W_{di}^{r}}. \tag{28}$$

For target period

$$\eta_{dc}^{\int o} = 1 - \frac{\sum\limits_{d\in D}\sum\limits_{i\in G_c} W_{di}^{g} + \sum\limits_{d\in D}\sum\limits_{i\in I_g}\left(W_{di}^{f} - W_{di}^{p}\right)}{W_{dc}^{\phi} + \sum\limits_{d\in D}\sum\limits_{i\in R_c} W_{di}^{r}}, \tag{29}$$

where: o - characteristics of organizational performance
I_g - set the elements of which represent the numbers of the offtakes where planned water supply from PC has taken place, $I_g \subset I$.

Operating efficiency of PC
For ten-day period

$$\eta_{dc}^{\varphi} = \eta_{dc}^{e} + \eta_{dc}^{0} - 1, \tag{30}$$

where: φ - operating efficiency characteristics

For target period

$$\eta_{c}^{\int\varphi} = \eta_{c}^{\int e} + \eta_{c}^{\int 0} - 1. \tag{31}$$

Irrigation system (PC) efficiency

$$\eta_s = \eta_c \times \eta_\sigma \times \eta_\tau \times \eta_\psi, \tag{32}$$

where: s - operating efficiency characteristics
c - PC (main canal) characteristics
σ - inter-farm network characteristics
τ - on-farm network characteristics
ψ - field characteristics

Irrigation network (PC) efficiency

$$\eta_{\nu} = \eta_c \times \eta_{\sigma} \times \eta_{\tau}. \tag{33}$$

where: ν - PC irrigation system characteristics

Inter-farm irrigation network (PC) efficiency

$$\eta_{\xi} = \eta_c \times \eta_{\sigma}, \tag{34}$$

where: ξ - inter-farm irrigation system characteristics

7. Specific water supply

$$\overline{W}_z = \frac{W_z}{F_z}, \tag{35}$$

where:

$\overline{W}_z$ - specific water supply to the z^th crop, ths m^3/ha

W_z - water supply to the z^th crop, mln m^3

F_z - irrigated area under the z^th crop, ths ha

z - crop index

a) From offtake (gross)

For ten-day period

$$\overline{W}_{di} = W_{di} / F_i \ . \tag{36}$$

For target period

$$\overline{W}_{di} = \sum_{d \in D} W_{di} / F_i \ . \tag{37}$$

b) From PC (net)

For ten-day period

$$\overline{W}_{dc} = W_{dc} / F_c \ , \tag{38}$$

where:

$$W_{dc} = \sum_{i \in I} W_{di}; \quad F_c = \sum_{i \in I} F_i \ . \tag{39}$$

For target period

$$\overline{W}_{dc} = \sum_{d \in D} W_{di} / F_i \ . \tag{40}$$

8. Specific water withdrawal (to PC)

$$\overline{W}^{\omega}_{cd} = \overline{W}_{cd} / \eta_{cd} , \tag{41}$$

where: ω - water withdrawal characteristics

The specific water withdrawal to PC is equal to the specific water supply from PC (gross).

9. Irrigation efficiency factor

$$A_c = \frac{E_c}{\overline{W}_c^{\omega}} , \tag{42}$$

where:

A_c - irrigation efficiency factor in the PC zone

E_c - total evaporation from the PC zone, ths m^3/ha

10. Water productivity coefficient

a) Physical water productivity coefficient

Farm

$$P_{xz} = \frac{\Pi_{xz}}{W_{xz}} , \tag{43}$$

where:

P_{xz} - coefficient of the physical productivity of the water supplied from PC to the zth crop in the xth farm, t/m^3

Π_{xz} - quantity of the zth crop in the xth farm gained due to the water supplied from PC, t

W_{xz} - quantity of the water supplied from PC to yield the zth crop in the xth farm, m^3

x - farm index

PC

$$P_{cz} = \frac{\Pi_{cz}}{W_{cz}} . \tag{44}$$

$$\Pi_{cz} = \sum_{x \in X} \Pi_{xz}; \quad W_{cz} = \sum_{x \in X} W_{xz}, \tag{45}$$

where:
P_{cz} - coefficient of the physical productivity of the water supplied from PC to the z^{th} crop, t/m^3
Π_{cz} - quantity of the z^{th} crop gained due to the water supplied from PC, t
W_{cz} - quantity of the water supplied from PC to yield the z^{th} crop, m^3
X - set the elements of which represent the numbers of the farms-water users that receive water from PC

b) Economic water productivity coefficient

Farm

$$\tilde{P}_{xz} = \frac{B_{xz}}{W_{xz}}, \tag{46}$$

where:
$\tilde{P}_{xz}$ - coefficient of the economic productivity of the water supplied from PC to the z^{th} crop in the x^{th} farm, \$/m^3
B_{xz} - value of the z^{th} crop gained in the x^{th} farm due to the water supplied from PC, \$
W_{xz} - quantity of the water supplied from PC to get the z^{th} crop in the x^{th} farm, m^3

$$B_z = C_z Y_z F_z, \tag{47}$$

where:
C_z - z^{th} crop unit cost, \$/t.
Y_z - z^{th} crop capacity, t/ha.
F_z - irrigated area under the z^{th} crop, ha.

PC

$$\tilde{P}_c = \frac{B_c}{W_c}. \tag{48}$$

$$B_c = \sum_{x \in X} \sum_{z \in Z} B_{xz}; \quad W_c = \sum_{x \in X} \sum_{z \in Z} W_{xz}, \tag{49}$$

where:
z - set the elements of which represent the nos. of the crops cultivated in the PC zone.

11. Irrigation service fees collection rate

$$\Omega_c = \frac{O_c^f}{O_c^p}, \tag{50}$$

where: Ω_c - irrigation service fees (ISF) collection rate for the target period (month, year, season, entire period from the introduction of charged water use). In the last case, ISF is to be determined by progressive total.

O_c^f - actual amount of the collected payments for irrigation services for the target period.

O_c^p - planning amount of the payments for water services (payment arrears) for the target period.

12. Specific operation and maintenance costs

$$\tilde{\Psi}_c = \frac{\Psi_c}{W_c}, \tag{51}$$

where: $\tilde{\psi}_c$ - specific operation and maintenance costs, \$/m^3

ψ_c - operation and maintenance costs, \$.

W_c - water supply, m^3.

List of symbols

A – irrigation efficiency factor
B – value of agricultural production
C – crop unit cost
c – PC characteristics
D – set the elements of which represent the numbers of the ten-day periods within the target period
d – ten-day period index
E – total evaporation from the PC zone
e – technical efficiency characteristics
F – irrigated area
f – factual data characteristics
G – set the elements of which represent the numbers of the offtakes through which PC water is released
g – PC water release characteristics
H – set the elements of which represent the numbers of the offtakes through which PC water is

transited

h – water transit discharge (runoff volume) characteristics

I – set the elements of which represent the numbers of the offtakes that supply water from PC to the PC zone

i – index of the offtake that supplies water from PC to the PC zone, $i = \overline{1, m}$

J – set the elements of which represent the numbers of balance sites

j – index of balance site

K – number of the water discharge records within 24 hours

k – number of the last water discharge record within 24 hours

L – number of the water users that make up 25 % of the total number of the farms-PC water users

M– number of the offtakes that supply water from PC to the PC zone

m – number of the last offtake from PC

N – number of days in the target ten-day period

n – number of the last day of the target ten-day period

O – amount of the payments for water services

o – characteristics of organizational performance

P – coefficient of economic water productivity

p – planning data characteristics

Q – water discharge

q – characteristics of water inflow to PC

R – set the elements of which represent the numbers of the water sources (canal, sai, pump, pumping station, collector, etc.) through which lateral inflow to PC takes place

r – characteristics of the lateral inflow to PC

S – stability coefficient

s – irrigation system characteristics

T – duration of the water supply in the d^{th} ten-day period

t – number of the target ten-day period

U – uniformity coefficient

V – water supply availability coefficient

v – PC's irrigation system characteristics

W – runoff volume

X – set the elements of which represent the numbers of farms-water users

x – farm-water user index

Y – crop yield

Z – set the elements of which represent the numbers of crops

z – crop index

Ω – water service fees collection rate

ω – water withdrawal characteristics

α – daily stability coefficient characteristics

β – ten-day period stability coefficient characteristics

ε – day index; $\varepsilon = \overline{1, n}$, n = 10 or 11 days (depending on the ten-day period number)

φ – operating efficiency characteristics

η – efficiency factor

λ – characteristics of the "head-to-tail" water supply uniformity

μ – indices of water discharge records within 24 hours

$\int$ – characteristics of water allocation characteristics for the target period

ξ – characteristics of the weighted average water supply to 25% of the farms-water users at the tail section of PC

θ – characteristics of the weighted average water supply to 25% of the farms-water users at the head section of PC

σ – inter-farm network characteristics

τ – on-farm network characteristics

ψ – field characteristics

ϕ – characteristics of head water intake (to PC; to PC's balance site)

ξ – characteristics of the inter-farm irrigation system of PC

Annex 11. Examples of water distribution monitoring and assessment

Below, examples of the analysis and assessment of water distribution on pilot canals are given in the form of comments to the water distribution indicator charts. At that, they used fragments from the works executed in the course of the IWRM-FV Project implementation (Pilot canals components).

Comment to Figure 1:

The chart indicates that irrespective of water dryness water deficit usually takes place in the beginning of the vegetation period: April, May, and early June; while in the third ten-day period of September[29] surplus water is observed. The period when water supply is largest is from the second ten-day period of June until August. In this period in low-water years (2002 and 2003), there is abundance of cheap water which they try to use to pumping irrigation zone lands. Water flow in the canal began decreasing from August, in other words water shortage is again gradually taking place. This is explained by that the irrigation source (Khopdjabakirgansay river) is a glacier-fed river.

Comment to Figure 2:

"Analysis of the data of departure of water supply to farms from the fixed "water allocation rate" shows that such a departure always takes place. At that, greatest departures (over 100 %) happen on a regular basis in the same farms: excess water is taken in the "Bobokolonov" and "Nabiev" farms; the "Leningrad" farm withdraws less water than required. In 2003, there was zero departure on the canal in whole and quite negligible in the districts. (This is an extract from the report for 2003).

Now, it is found out that these departures were due to that water was transited through the "Bobokolonov" and "Nabiev" farms' offtakes to the pumping irrigation zone, and it had nothing to do with the KBC zone.

Comment to Figure 3:

KBC efficiency during the whole vegetation period is 0.8; it varies from a ten-day period to a ten-day period from 0.44 to 0.87. The cause of a very low efficiency in the third ten-day period of April (0.44) is that water escape took place in that period, which was not recorded in reports.

Comment to Figure 4:

Analysis of the specific water supply from AAC shows that the actual water supply on AAC in whole is much less than the planned. Allowing for the losses in the inter-farm and on-farm networks, the specific water supply value at the field level is less than the total evapotranspiration (7.58 ths. m^3/ha).

---

[29] Great amount of excessive water withdrawal against the planned take place in this ten-day period.

Under water deficit conditions, such a low specific water supply value can be explained by either that the data is inaccurate or, if the data is true, the fact that water usage charge makes water users to select economically sound water supply rates, at which maximum income is reached rather than maximum crop yield.

Comment to Figure 5:

The diagrams illustrate the security of water supply limit against the planned. If the limits were set based on the pro rata rule (i.e. according to the established limiting method), all the water supply values broken down by ten-day periods, balance sites, and the canal in whole should be equal.

However, the diagrams show a quite different picture, from which it becomes clear that the limits are set not proceeding from the pro rata rule. This is accounted for by both the elements of voluntarism and flaws in the adjustment principle itself.

With a traditional approach, we evenly limit the part of the total water consumed by a crop, which, according to the water use plan, is delivered by surface. If water users were under similar hydrogeological conditions, the adopted approach would secure the equal water supply principle. However, the hydrogeological conditions of water use substantially differ from each other, and application of a traditional approach brings to water discrimination against the water users located, for instance, on automorphic soils.

Comment to Figure 6:

The departures of the actual water supply value from the planned are even higher: from 0.42 to 6.57. At that, it is characteristic of the vegetation period of 2003 that the lowest water supply on balance sites and on SFMC in whole is observed within the period from the third ten-day period of June throughout the third ten-day period of July, reaching the minimum in the second ten-day period of July.

This fact astonishes since SFMC is supplied with water from two reservoirs. There are different reasons for this: the plan (water demand) is made incorrectly; actual data are inaccurate; the reservoirs are improperly operated.

Comment to Figure 7, 8:

Figure 7 shows the results of the calculation of the specific water supply at SFMC balance sites and on SFMC on the whole. On SFMC and almost at all balance sites, excess (relatively little) of the actual specific water supply over the planned one takes place.

As for the specific water supply through the offtakes of the 1st balance site (Fig. 8), here excess of the actual specific water supply over the planned one is great enough. The highest actual specific water supply (up to 18 ths. m^3/ha) are characteristic for the pumping irrigation lands.

Comment to Figure 9-11:

The analysis of the results of the calculation of efficiency at SFMC balance sites and broken down by ten-day periods of the 2003 vegetation period indicates that the SFMC efficiency is sufficiently high, and at times (mainly in April) it becomes higher than 1 at some balance sites and on the canal on the whole. This is due to existing unaccounted water inflow in the canal.

However, extremely high efficiency in some ten-day periods at balance sites V-VIII and extremely low efficiency (second ten-day period of April at balance site 8) is most likely due to not inflows but inaccurate data for these ten-day periods.

There is more or less water inflow on all pilot canals, since at some sites the canals work as collectors[30]. Such an inflow is most characteristic of SFMC, since many pumps supply water to the adyr lands located mainly on the left bank of the canal as well as because of water outcrop from Margilansay.

Owing to extreme water permeability of soil on adyr lands, irrigation water flows again into the canal in the form of surface or groundwater flow. This inflow is practically difficult to be accounted, by virtue of which it is equal zero in the calculations and accordingly the efficiency value comes out overrated, at that there are cases when ten-day period efficiency is higher than 1.

According to the operational data, there is no water discharge from the pilot canals, that is the organizational efficiency is equal to 1. Water discharge in emergency case (e.g. mud flow) is a desperate measure, and it cannot be viewed as organizational loss.

At the same time, it is quite obvious that it is also the fault of canal operation services that there are great organizational losses in the inter-farm and on-farm networks.

---

[30] Return groundwater back and destroy the concrete lining of the canals.

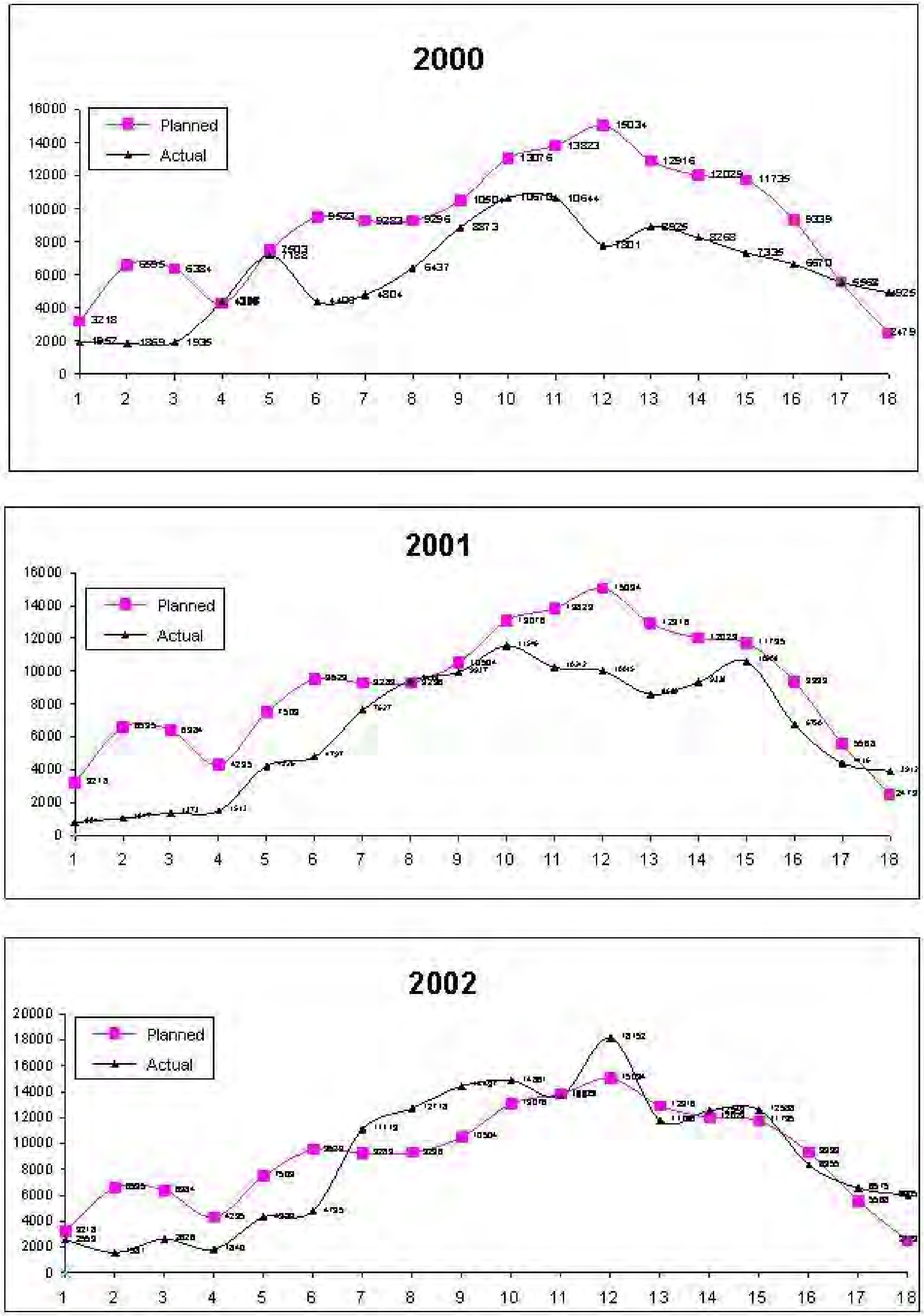


Figure 1. Planned and actual water withdrawal on KBC for the years 2000-2002.

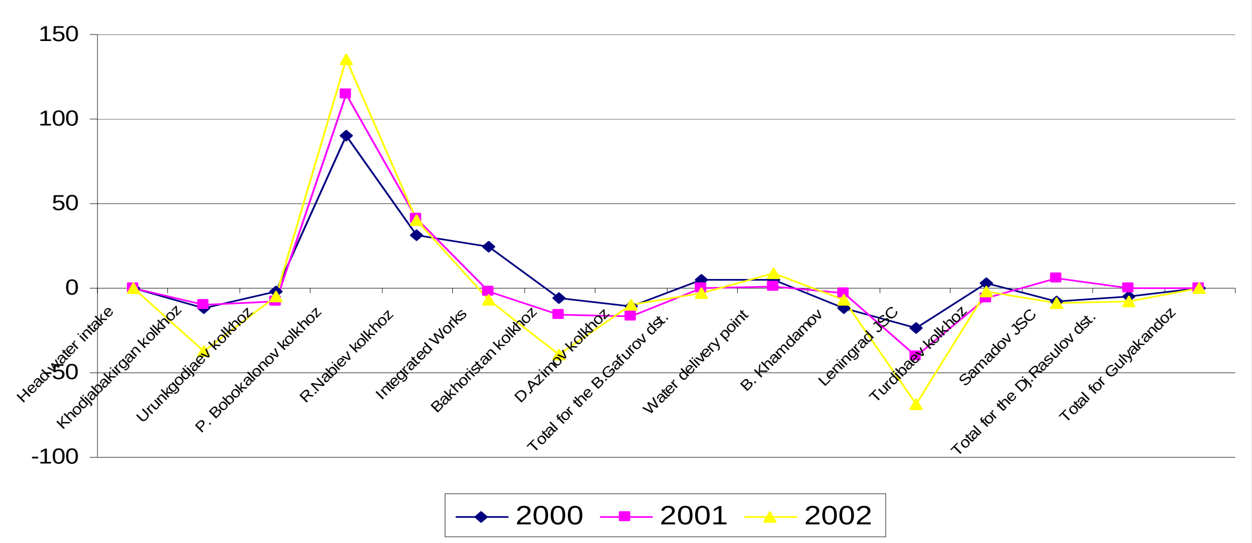


Figure 2. Departure of water supply to farms from the fixed water allocation rate during the vegetation period, %.

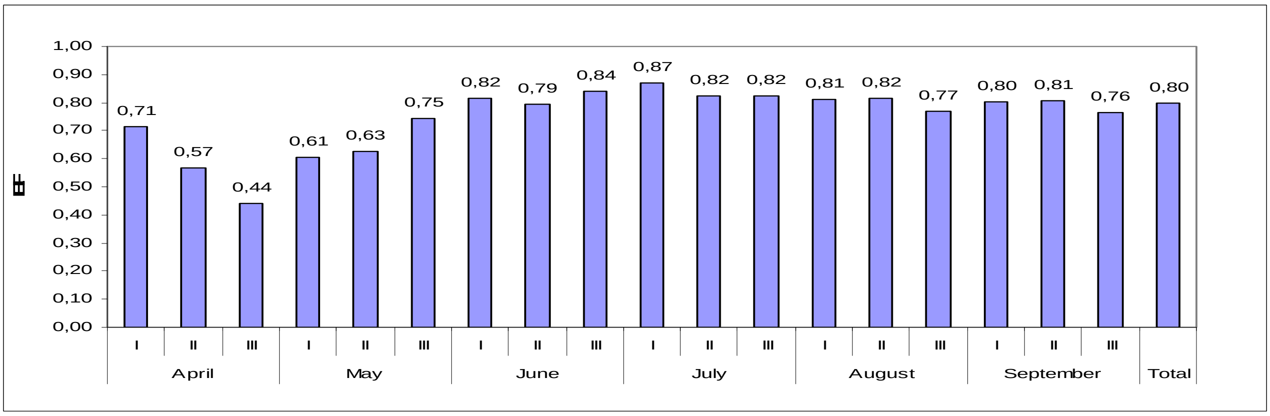


Figure 3. KBC efficiency (vegetation period of 2003).

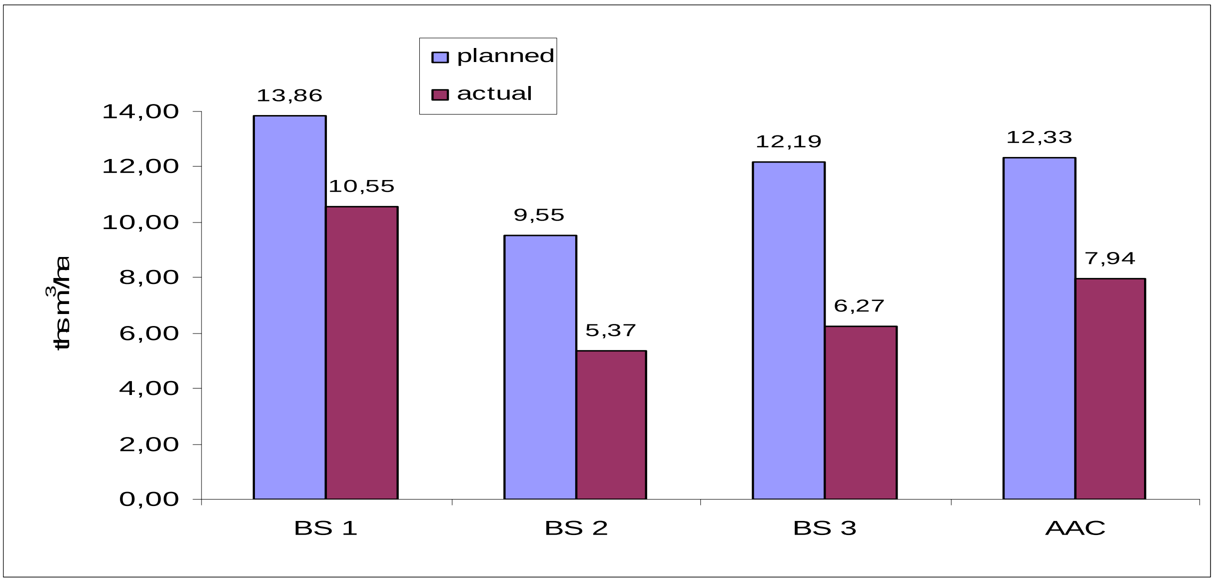


Figure 4. Planned and actual specific water supply from AAC balance sites (vegetation period of 2003).

Figure 5. Limit-to-planned water supply ratio at three SFMC balance sites.

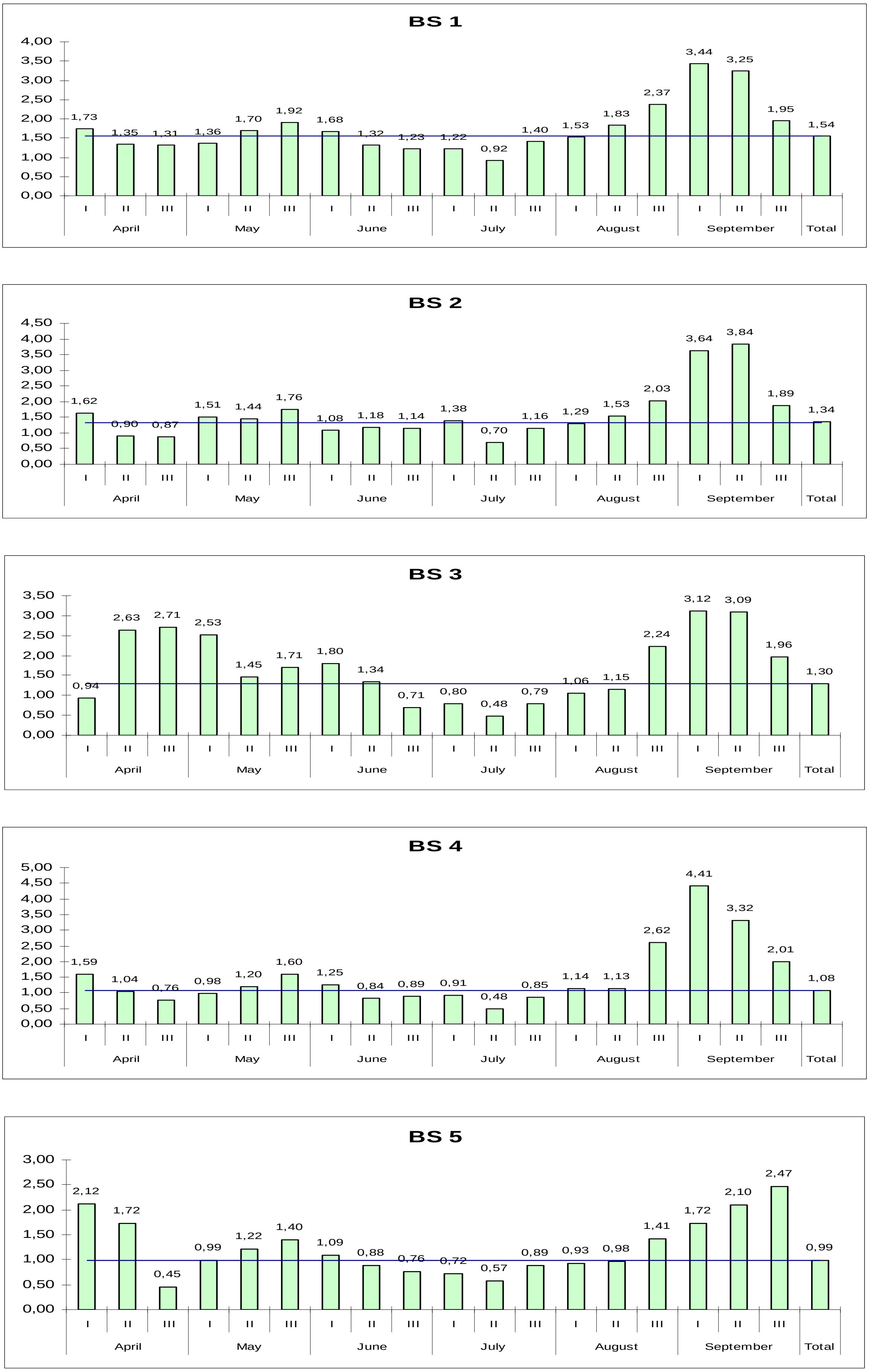


Figure 6. Water availability at five SFMC balance sites (actual/plan).

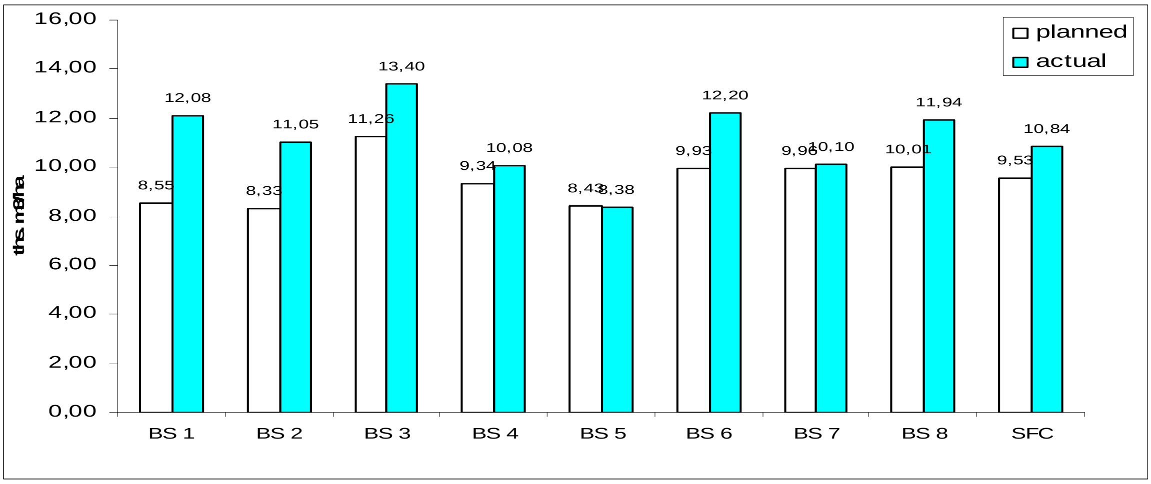


Figure 7. Planned and actual specific water supply from SFMC balance sites (vegetation period of 2003)

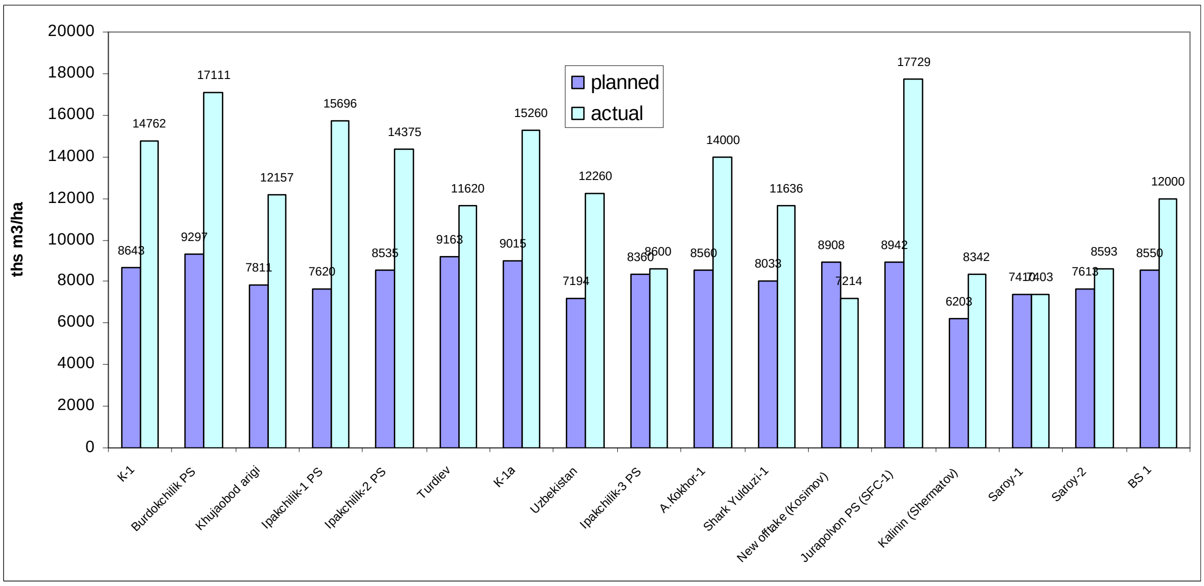


Figure 8. Planned and actual specific water supply by the offtakes of the 1st SFMC balance site.

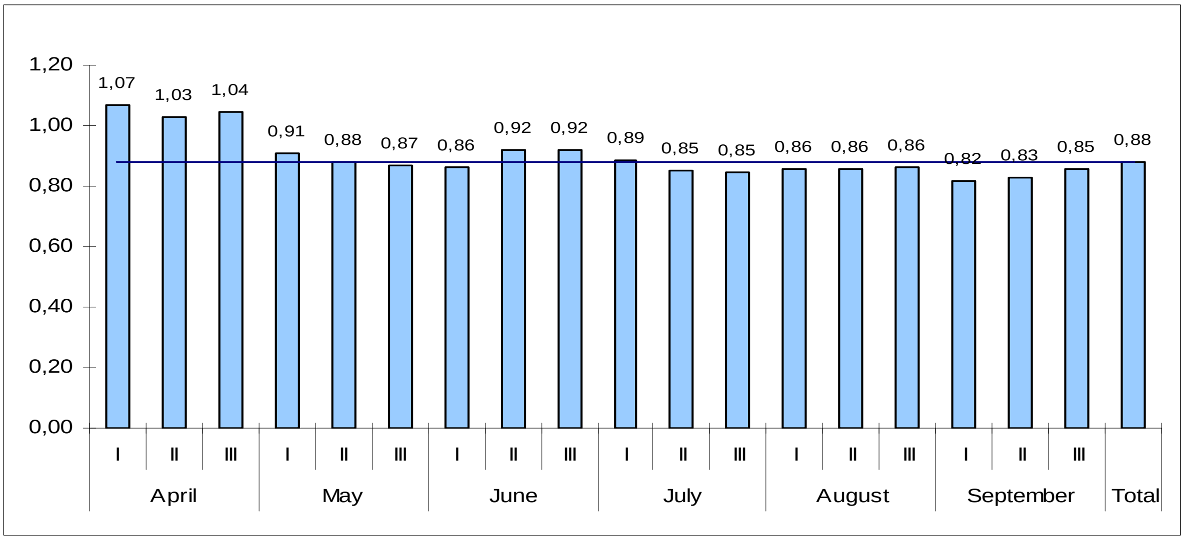


Figure 9. SFMC efficiency broken down by ten-day periods (2003).

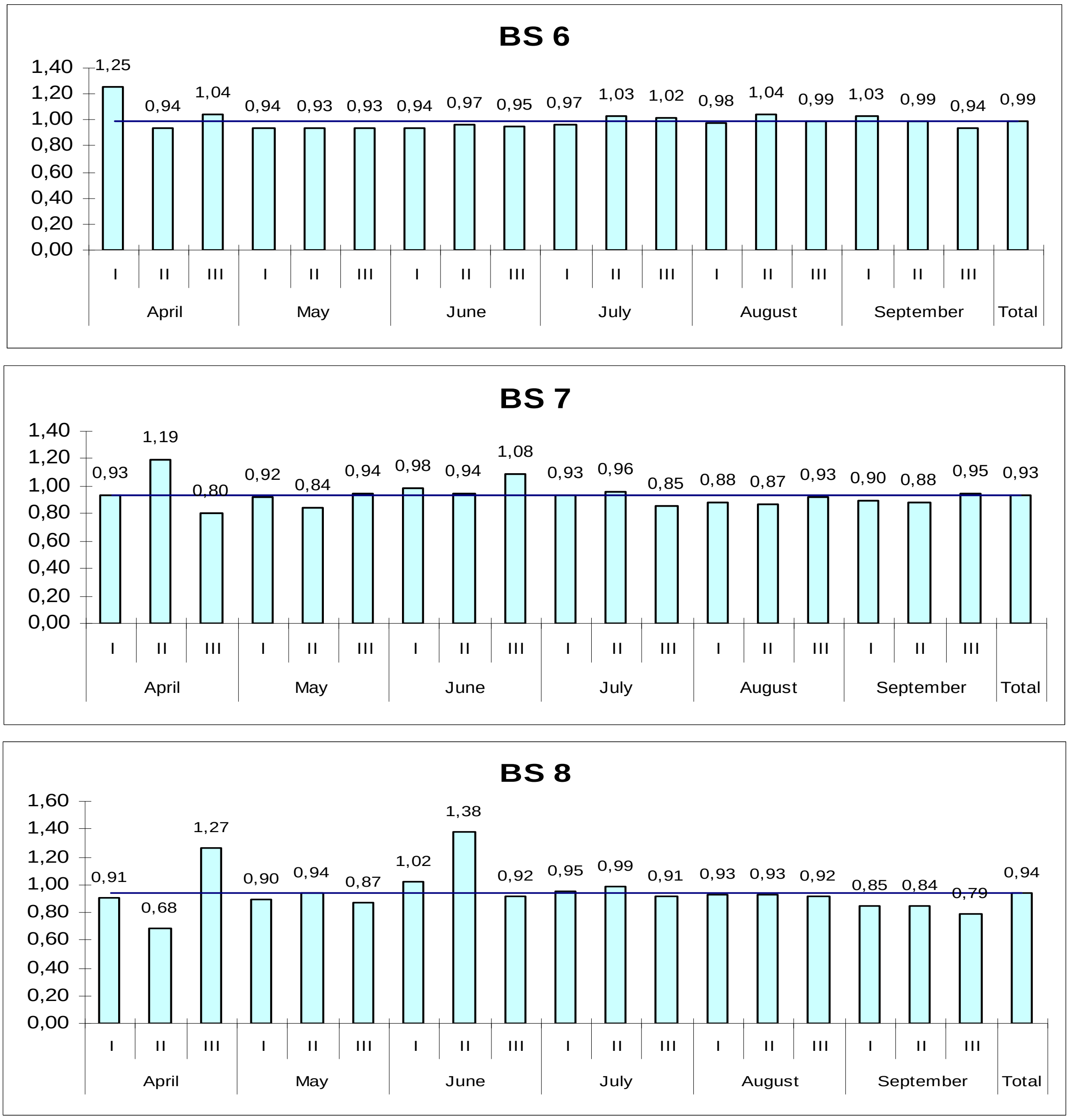


Figure 10. SFMC balance sites' efficiency broken down by ten-day periods (vegetation period of 2003).

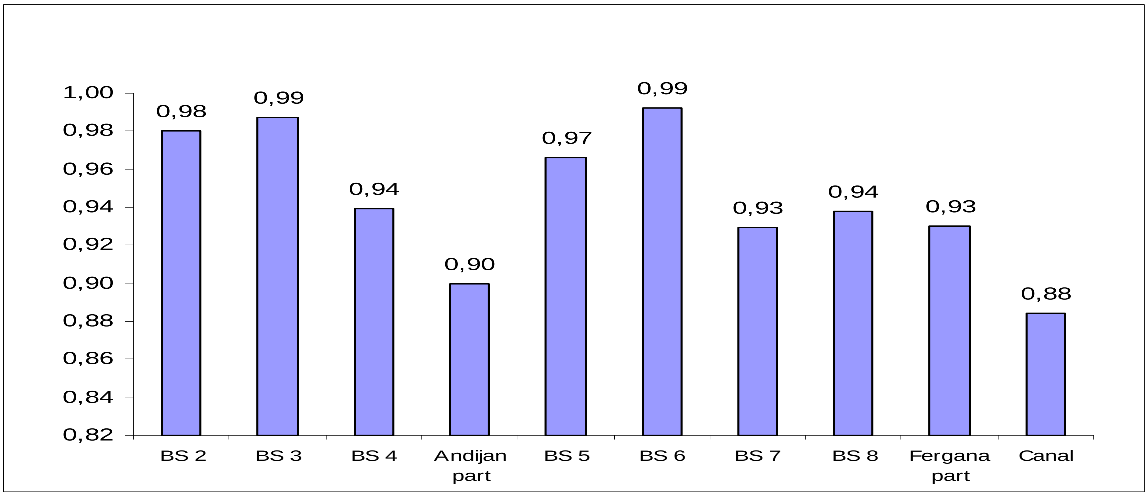


Figure 11. SFMC balance sites' efficiency (vegetation period of 2003).

Annex 12. Water distribution index diagrams.

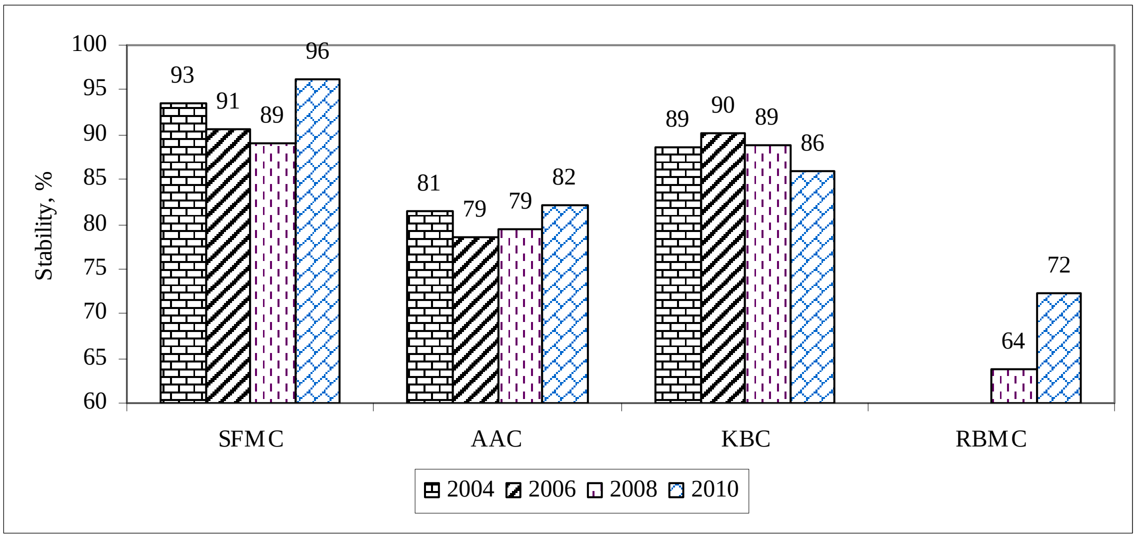


Figure 1. Stability of head intake to PC.

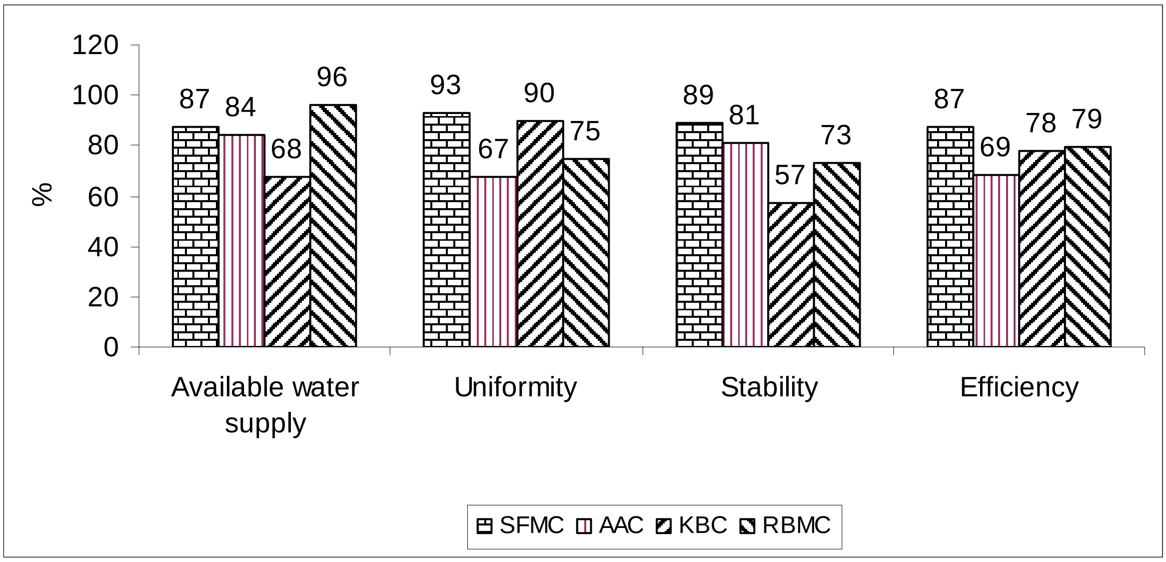


Figure 2. Water distribution by PC in 2010.

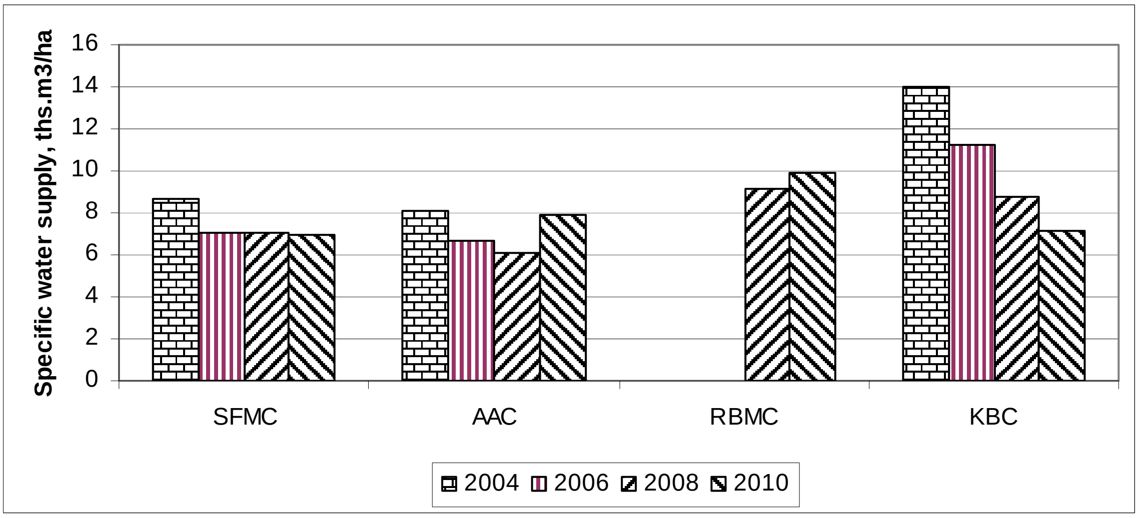


Figure 3. Actual specific water supply from PC.

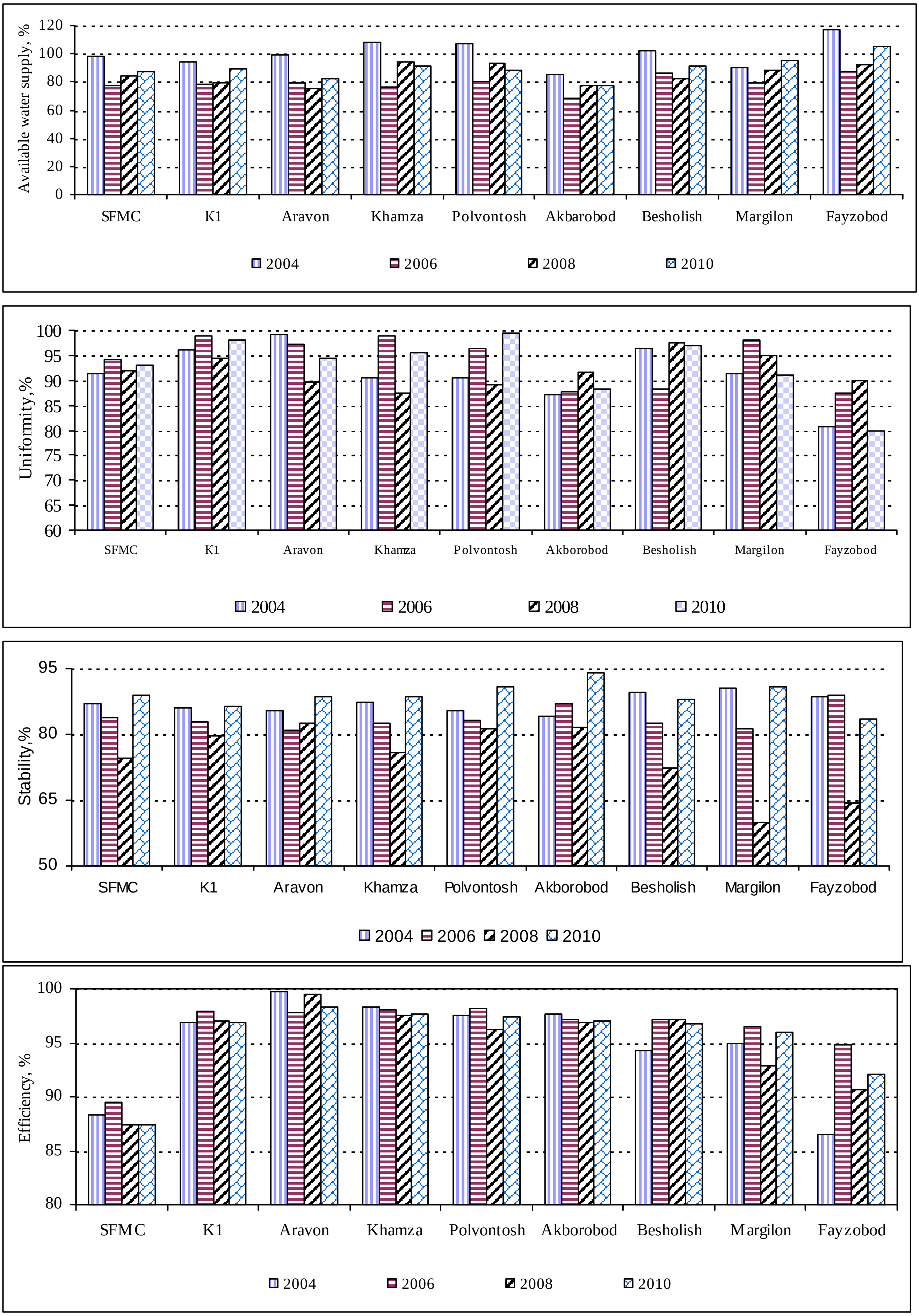


Figure 4. Water distribution at SFMC balance sites.

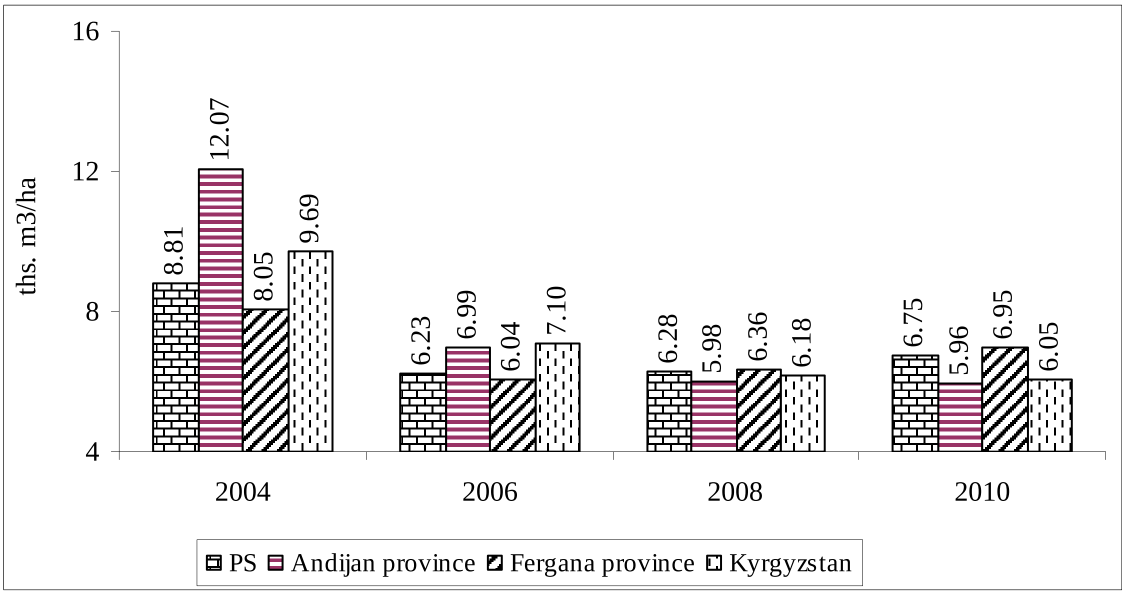


Figure 5. Actual specific water supply by SFMC PS (Andijan and Fergana provinces).

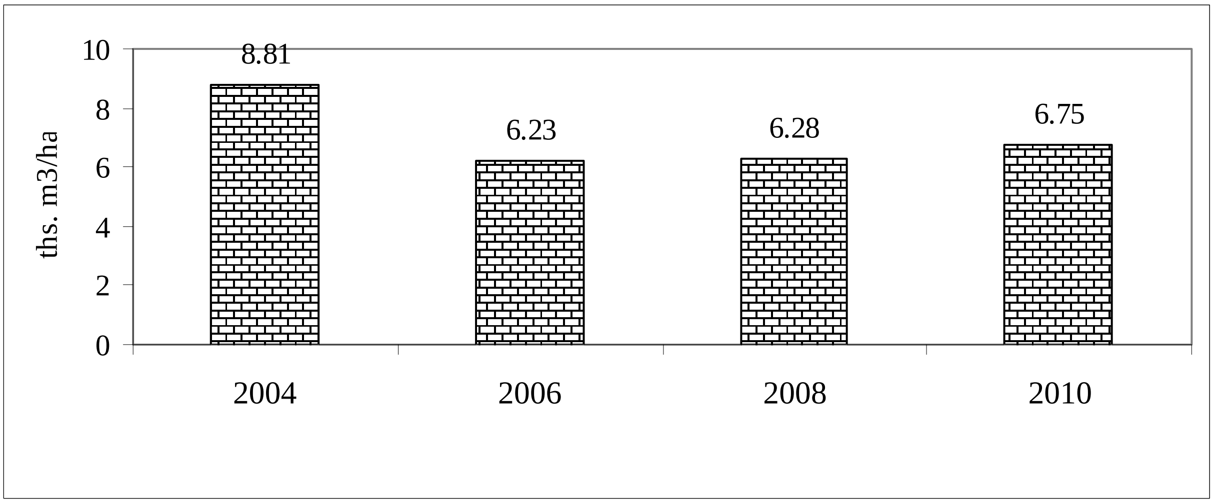


Figure 6. Actual specific water supply by SFMC PS.

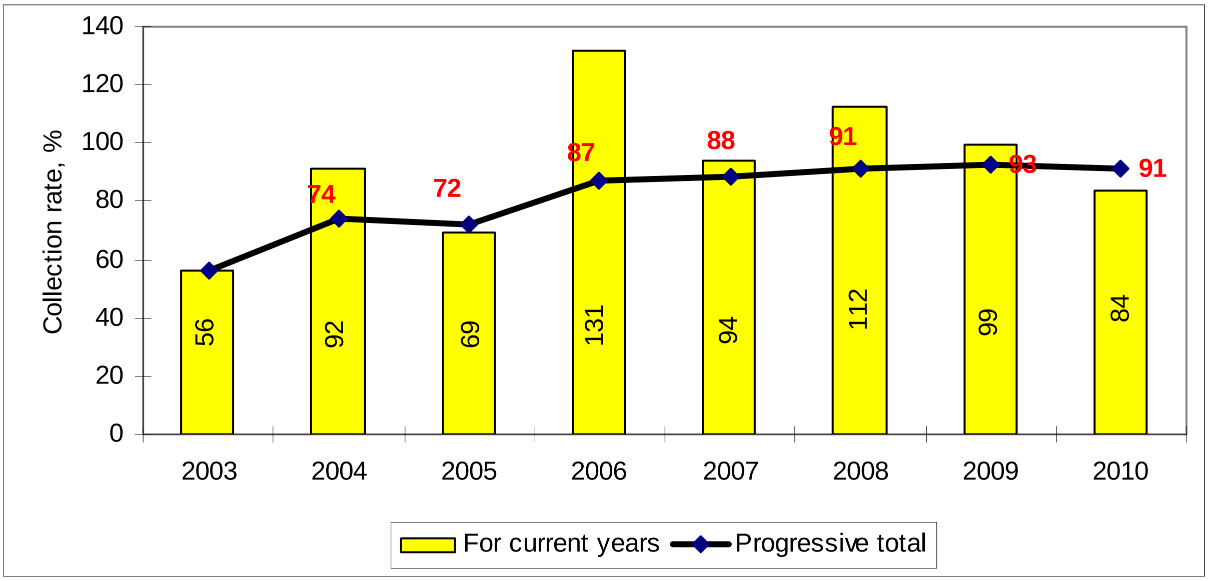


Figure 7. Fees collection rate on AAC.

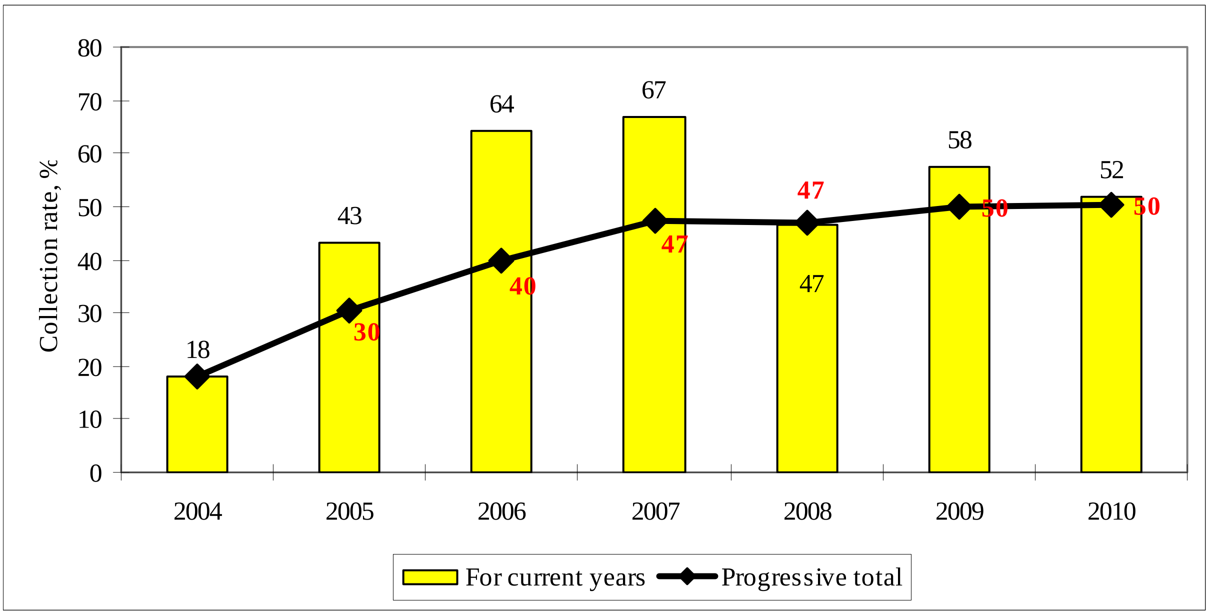


Figure 8. Fees collection rate on KBC.

Manual writers:

Regional Group


Mirzaev, N.N.
Block 1 Leader


Saidov, R.R.
Water Governance Consultant


Ergashev, I.
Water Distribution Consultant


Suleymanov, F.Yu.
Consultant on Instituional Issues


Yun, N.M.
Assistant


Mirkamilova, Sh.N.
Technician

National Office Managers


Kholikov, A.T.
Republic of Uzbekistan


Tajibaev, K.E.
Republic of Kyrgyzstan


Khomidov, A.A.
Republic of Tajikistan

Edited in
Scientific Information Center
of Interstate Commission for Water Coordination

Republic of Uzbekistan, 100187,
Tashkent, Karasu-4, B. 11
Telephone: + (998 71) 265 92 95, 266 41 96
Fax: + (998 71) 265 27 97
E-mail: dukh@icwc-aral.uz; dukh@rol.uz