DRAINAGE IN THE ARAL SEA BASIN: PAST AND FUTURE

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ABSTRACT

The geography and climate conditions definite the importance of irrigation development for life and economic activity within the Aral Sea Basin. Irrigation in Central Asia was the basis for development, employment and welfare of populations in all its history. In the conditions of arid climate the large-scale utilization of land for irrigated agriculture depends on the artificial drainage. This problem deals with two major land quality problems in the Aral Sea Basin. These are the interrelated issues of salinity and waterlogging caused by high groundwater levels. Only about 60% of the irrigated land (1999) are classified as non-saline, according to the Central Asian standards (the main criterion is total amount of toxic salts in the soil). This paper describes current situation and possible solutions for soil salinity problems in the Aral Sea Basin.

INTRODUCTION

The Aral Sea Basin, which geographically coincides with boundaries of the biggest part of Central Asia, is located in the heart of the Euro-Asian continent. The Aral Sea Basin covers the whole territory of Tadjikistan, Uzbekistan, and part of Turkmenistan, three provinces of the Kyrgyz Republic, and the southern part of Kazakhstan (see Fig. 1). This territory covers an area about 1.55 million km^2. The population in the region was about 39.8 million inhabitants in 1998.

The western and the north-western parts of the Aral Sea Basin are covered by the Kara Kum and Kyzyl Kum deserts. The eastern and south-eastern parts are situated in the high mountain area of the Tien Shan and Pamir mountain ranges. The remaining part of the basin is the various types of alluvial and inter-mountain valleys, dry and semi-dry steppe. The landlocked position of Central Asia, within the Euro-Asian continent, determines its sharply continental climate, with low and

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irregular precipitation. Large daily and seasonal temperature variations are characteristic of the region, with high solar radiation and relatively low humidity.

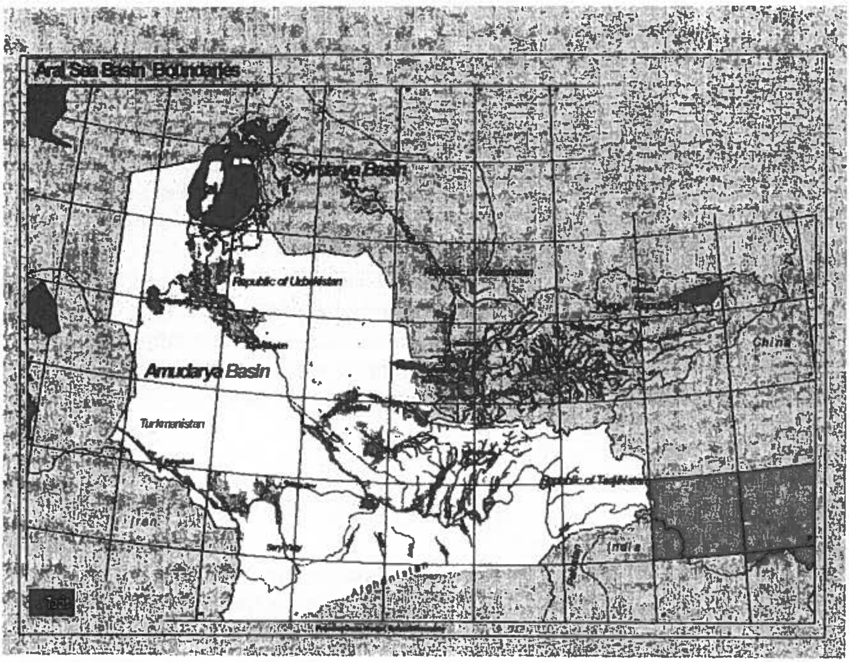


Fig. 1. Map of the Aral Sea Basin.

The rivers originate as a result of snow melt and rainfall in high mountains that reach up to 7,500 m to the west and south. The Amu Darya river originates in Afghanistan and Tadjikistan, and the Syr Darya river in the Kyrgyz Republic. Both rivers fall rapidly to the desert plains of downstream riparians: Uzbekistan and Turkmenistan on the Amu Darya; Uzbekistan , Kazakhstan and – to a small extent – Tadjikistan on the Syr Darya.

The geography and climate conditions define the importance of irrigation development for life and economic activity within the Aral Sea Basin. Irrigation in Central Asia was the basis for development, employment and welfare of populations in all its history. The age of irrigation is the same as in ancient civilization centers of the world - Egypt, Mesopotamia, India, China, Mexico. The Horezm in the beginning of the first millennium BC was known as one of the significant center of agriculture in the world, where the cultivated area was more than two million ha. By archeological investigations it has been identified as an Ancient Ariana. The population of the region has excellent traditions in the usage of water for irrigated agriculture.

The information of Russian geographers at the end of last century showed that irrigated area in old Turkestan within the Aral Sea Basin was estimated at 2.5 to 2.8 million ha. The large-scale expansion of irrigation in the region was promoted by the former Soviet Federal Government to develop the region as an agrarian appendage of the former Soviet Union. So-called "complex" development of irrigated agriculture started at the end of 1950-s. The growth of irrigated area over the region was tremendous: irrigated area was 4.5 million ha in 1960, 5.2 million ha - in 1970, 6.9 million ha - in 1980, and 7.5 million ha - in 1990.

Out of the total area of 155.4 million ha in the Aral Sea Basin, over 59.16 million ha (or 38.1%) are cultivable land. In 1998 the total cultivated area within the Aral Sea Basin was about 10 million ha. This amount includes 9 million ha under the annual crops and about 1 million ha under permanent crops. The suitable area for irrigation is estimated at 32.6 million ha, but economic feasible irrigation potential was estimated at about 10.2 million ha, of which actual irrigated area is 7,948,100 ha (or only 5.1% of total territory of the Aral Sea Basin).

The large-scale irrigation development has changed the hydrological cycle in the region and this has created serious environmental problems in the Aral Sea Basin. The most dramatic was the shrinking of the Aral Sea and disruption of its ecosystems. Other changes included: (1) soil degradation as a result of waterlogging and salinization of irrigated land in the catchment areas of the Aral Sea Basin, (2) crop diseases and insect infestation, due particularly to the cotton mono-crop agricultural development, and (3) adverse health effects from the poor water quality in the main and tributary rivers.

The unexpected collapse of the Soviet Union in 1991 added socio-economic problems to the Aral Sea Basin. With the collapse, prior sources of funds were cut off, and investments in water management, water supply, drainage, land reclamation, and the deltas were abruptly stopped.

DRAINAGE AS A KEY ELEMENT OF IRRIGATION DEVELOPMENT

The peculiarity of the arid zone is that the wide utilization of land for irrigated agriculture depends on the artificial drainage. Two major and interrelated land quality problems have resulted in the Aral Sea Basin. These are issues of salinity and high groundwater - induced waterlogging.

In the past, drainage was constructed only to protect land against waterlogging and to stop malaria. Drainage as a land reclamation measure was carried out on a small scale because of the lack of proper technical facilities. To drain the land, a network of open canals was usually dug. As a result, drainage was seldom sustainable for a long period. Large-scale drainage development in Central Asia began in mid of 1960-s. Drainage has become an inseparable part of the "complex" land reclamation measures aimed at sustaining the agricultural production. It was also raised to a high technical level.

The basic data on existing drainage in the Aral Sea Basin is presented in Tables 1 and 2. Actually 56.8% of the irrigated area (4,513,253 ha) has drainage. Out of the total drainage, about 59.6% is surface (open) drainage, 26.2% - sub-surface, and 14.2% is vertical drainage (tube-wells), mainly on the foothill slopes or in the area with clay soils. The vertical drainage is more commonly in Uzbekistan, Kazakhstan and Turkmenistan, but during the last seven years (1992-1998) sustainability of this type of drainage was reduced, because power cost increased, absence of spare parts and general shortage of funds for maintenance. In the new reclaimed area (Golodnaya steppe and Djizak steppe in the Syr Darya river basin, Surkhan-Sherabad steppe and Karshi steppe in the Amu Darya river basin (all within Uzbekistan), and also in the zone of the Garakum canal in Turkmenistan), drainage is mainly sub-surface. Advanced sub-surface and vertical drainage provided before the optimal reclamation regime of irrigation with minimum of water consumption rate at 7.5 to 9.0 thous. m^3/ha in comparison with 15 to 16 thous. m^3/ha with old types of drainage.

Table 1. Salinization and Drainage in the Aral Sea Basin (1998)

Country	Area under irrigation	Area salinized		Drained area		
	ha	ha	%	ha	%	% of total
1	2	3	4	5	100*5/2	
Kazakhstan*	742100	210000	28.3	332200	44.8	7.4
Kyrgyz Republic*	462100	21200	4.6	21200	4.6	0.5
Tadjikistan	719200	115000	16.0	328600	45.7	7.3
Turkmenistan	1744100	652290	37.4	1022253	58.6	22.7
Uzbekistan	4280600	2140550	50.0	2809000	65.6	62.1
Aral Sea Basin	7948100	3139040	39.5	4513253	56.8	100

* Only provinces in the Aral Sea basin are included

At present, the main task is to rehabilitate the drainage system to a good working conditions. Collector-drainage network is maintained by the Ministry of Agriculture and Water Management. The farms are in charge for on-farm collectors, vertical drainage and some closed horizontal drainage within farm boundaries. The Ministry make repairs on inter-farm collectors, using funds from the State budget, so their technical conditions is usually satisfactory. The drainage network within farm boundaries is usually not repaired. Due to the current maintenance difficulties, a large number of tube wells and part of the sub-surface horizontal drainage are operated contrary to their design. As more private farms appear in the future, further degradation of drainage systems can be expected unless preventive measures are taken.

Table 2. Types of Drainage in the Aral Sea Basin (1998)

Country	Total Drained Area	With Surface Drains		With Sub-surface Drains		Vertical Drainage (Tube wells)	
	ha	ha	%	ha	%	ha	%
1	2						
Kazakhstan*	332200	163700	49.3	15600	4.7	152900	46.0
Kyrgyz Republic*	21200	11900	56.1	9300	43.9	0	0
Tadjikistan	328600	191000	58.1	137600	41.9	0	0
Turkmenistan	1022253	614572	60.1	322962	31.6	84719	8.3
Uzbekistan	2809000	1709700	60.8	698300	24.9	401000	14.3
Aral Sea Basin	4513253	2690872	59.6	1183762	26.2	638619	14.2

* Only provinces in the Aral Sea basin are included

As it is clear from Table 1, the soil salinity issue is still one of the principal problems in the Aral Sea Basin. Only about 60% of the irrigated area (1998) are classified as non-saline, according to the Central Asian standards (the main criterion is the total amount of toxic salts in the soil). In the upper reaches of the Amu Darya and Syr Darya river basins less than 10% of the area has moderate or heavy salinity, while downstream about 95% of the area is heavy saline. The greatest soil salinity problem is in Uzbekistan, where about 25% of irrigated area are moderate or heavy saline. Salinity is, of course closely tied to natural drainage conditions. Moreover, since 1990, a growing water shortage, lower water quality, and the decay of enterprises responsible for the drainage systems maintenance (lack of repair and maintenance, lack of investments in drainage) has resulted in an increased secondary soil salinization. Losses of crop production due to soil salinization are the problem, since they can reach 30% of yield for cotton, but salinized areas are still cultivated to provide population employment.

RETURN WATER GENERATION AND SALT PROBLEMS

The drainage network is a basis for formation of return flow from irrigation, which together with wastewater from industry is a principal pollutant of the water eco-systems in the Aral Sea Basin. Variations of drainage and wastewater formation in the region during the last 25 years are shown on the graphs in Figures 2 and 3. Return water constitutes about 32.2 km^3/year, or 25% of natural river flow in the region. Wastewater constitutes only 7.8% of this amount. Remaining part is drainage water, collected from irrigated areas, which constitutes 30.7 km^3/year, or over 40% of water withdrawal for irrigation. About 4.7 km^3 or 14.2% of return water is re-used, mainly for irrigation. About 17.5 km^3 or 52.7% is a load to the rivers, and 11.0 km^3 or 33.1% are discharged into natural depressions.

Fig. 2. Drainage and Wastewater Variations in the Syr Darya River Basin

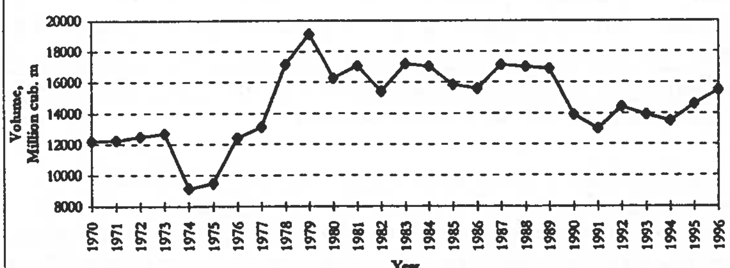
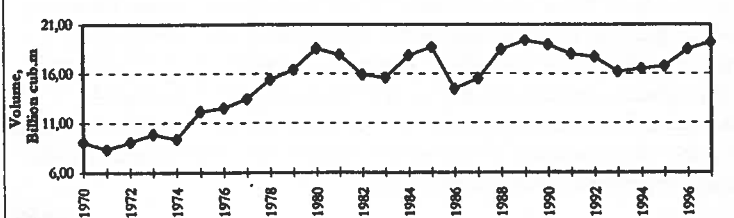


Fig. 3. Drainage and Wastewater Variations in the Amu Darya River Basin



The collector-drainage water has anthropogenic origin and consists of two components. The surface component of return flow is formed by the outfall from irrigated areas, losses from irrigation network, and also from water pumping by vertical drainage systems. Sub-surface components of these waters is formed as a result of infiltration from the irrigated fields and from the irrigation network where infiltrated water feeds the groundwater and then fully or partly discharges to the collector-drainage network.

The investigation of collector-drainage flow formation showed that there is a very close correlation between water withdrawal to irrigation and return of drainage flow by taking into account the lag in time of drainage water formation.

The return flow from irrigation (m^3/ha) is calculated on the basis of:

$$D+C = Oir\{\frac{B}{Ks} + 0.9[\frac{1-Ks}{Ks} + (1-Kir)]\} + (I-O)gw + A*Oc - (Et+U)gw - Wdis, \quad (1)$$

where :

D+C - runoff of drainage-collector waters;

Oir - irrigation water application rate;

B - leaching part of water consumption; water required to support the necessary degree of soil desalinization;

Ks - efficiency of irrigation systems;

0.9 - this coefficient shows the perfect irrigation scheme in use (losses = 10%);

Kir - efficiency of irrigation technique;

(I-O)gw - influx or outflow of groundwater in the irrigated area considered;

A*Oc - portion of infiltration of rainfall (Oc) below the zone of aeration;

(Et + U)gw - part of total consumption satisfied by groundwater (depends on the crop type);

Wdis - runoff dissipation.

Operational (monthly) forecast of collector-drainage runoff is calculated as:

$$(D + C)_t = A1*(D + C)_t -1 + A2*(Oir_{t-1} + Oir_{t-m-1}), \quad (2)$$

where:

(D + C) - runoff of collector-drainage waters;

Oir - irrigation water application rate;

t - index of a month (1,...,12);

m - the value of time lag shift between water diversion for irrigation and collector-drainage formation (in months);

A1, A2 - regression coefficients.

LEGAL ISSUES

Unfortunately, during the former Soviet Union command system the main principle was that a cubic meter of river water used for irrigation and other users would bring more value than the same cubic meter, delivered to the ecological needs. This is causing the degradation of irrigated lands, lower crop yields and additional human health risks. After collapse of the USSR, an integrated regional co-operation has been frustrating, and raises organizational, financial and technical problems. Generally, it has a significant impact on environmental situation and health problems as a whole.

Historically, from the first "Water Law of Turkestan" of 1910, water scarcity and water quality are increasingly seen as a cause of domestic and international conflicts, and therefore is a risk to national stability and security. Water scarcity could contribute to a weak national administration as water scarcity and quality becomes a major threat in developing countries trying to achieve their social development objectives.

First of all, we need to pay attention to the origin of the problems: transformation period to a market economy; raised market economic, social, environmental and health stress; rapidly growing population; insufficient funds and lack of sources of finance; weakness of institutional and legal framework; absence of staff training and brain drain of scientific and engineering staff. These factors lead to many problems in all sectors, including agriculture and water management.

It should be mentioned that at the present time, for most of the regional problems, institutional and international legislation is still lacking especially on transboundary water resources. Water relations needed a legal basis, because rivers in the region became transboundary. This required a new approach to inter-state negotiations in the sphere of water allocation and water use. The solution is to develop the relevant inter-state agreements and procedures in accordance with the international law and taking into account local historical traditions and experience.

The Central Asian states responded quickly to the need for a new legal basis for water allocation and management. Water ministries of these countries jointly declared on September 12, 1991, that joint water resources management would be based on equity and mutual benefits. In order to overcome inherent inter-regional water issues and minimize ethnic tensions, the five Central Asian countries established an inter-state agreement on February 18, 1992.

Each state has the right to manage on its territory by its own national resources and by part of the transboundary water as far as a quota agreed upon with other countries. The Aral Sea and its deltas had been defined as an independent water consumer and have its own quota for water. Transboundary water is the object of common ownership of the states and their development, protection and usage should be carried out on a basis of inter-state agreements by the inter-regional bodies according to the national requests and regional interests.

According to the Agreement on Water Resources Management in the Aral Sea Basin, water allocation should be based on existing uses of water resources. The two river basin agencies should continue to perform basin management under the control of the Interstate Commission for Water Coordination (ICWC) and Basin Water Management Organizations (BWO) of the two main transboundary rivers, Amu Darya and Syr Darya. This management includes transboundary water allocation, monitoring of water use and water quality, data collection and information exchange, analysis, management and forecasting.

Despite the fact that these institutions are working satisfactory, and they have a strong regional framework and mutual understanding on water management issues between themselves and water management bodies in each republic as the members of one "water team", they lack sufficient decision making and regulatory powers at the top level of political power. International agreements on transboundary water are urgently needed.

A strong commitment to address water quality and environmental problems exists and was confirmed by the five Central Asia Head of States in the January 11, 1994, "Plan of Action for Improving the Environmental Situation in the Aral Sea Basin" which includes among other projects, the Water Quality Assessment and Management sub-project that addressed these needs. Also, these issues were included in the scope of work for the Global Environmental Fund's Project "Water Resources and Environmental Management in the Aral Sea Basin" started in 1998.

Creation of a legal framework in the water management sector, combined with modern irrigation and drainage practice, socio-economic and ecological requirements, and suitable low-cost technology would provide an opportunity to coordinate a transforming period in regional joint water management.

Environment and water quality are the most sensitive areas of drainage impact. Therefore, such factors are concerned with solving problems related to drainage and environmental conditions in the Aral Sea Basin. This includes the need for development of a comprehensive scheme for collection and removal of drainage and wastewater in the basin: implementation of advanced and low-cost drainage technology; and support of pilot drainage and irrigation projects. Such actions will require the advanced engineering, institutional and financial measures as well as development of legal, juridical and regulative base for water, drainage, irrigation and environmental management.

Alongside engineering methods to improve water quality drainage including on-farm and inter-farm and national level practices, for sufficient drainage policy on the regional level and improvement of transboundary water quality as a whole, we need suitable legal basis – an inter-state agreement on water quality, including obligations and requirements of the parties on this matter, and general "rules".

Sufficient legal framework on the inter-state level requires new approaches in management, not only on the subject of water management and ecology, but on all sectors of economy and social being. Institutional (especially regional and NGO) and financial frameworks are absolutely essential. This is one of the main subjects of the Regional Water Resources Strategy being jointly prepared by the partners.

The Regional Water Resources Strategy must prepare a number of principal measures (institutional, political and technical) for sustainable development. The regional cooperation should be based on basic principles of international cooperation and international water law: rights of each basin country for equal and reasonable water use; spending not as much as possible, but as much as required; not causing harm and damage to other riparian parties providing democratic management and involvement to all water users; parity, equal responsibilities and rights; cooperating and regularly exchange data and information. The main methods and instruments by which Governments of the Aral Sea Basin can seek to achieve water and related environmental policy objectives according to the above mentioned principles can be classified as regulation on the economic level (market principles, water pricing, taxes, etc.) and on the legal level (legislation, licensing, inter-state agreements, etc.). Water law can be regarded as a link between water policy and water users.

At the present time the following set of draft agreements are being developed:

- Agreement on Institutional Framework of Transboundary Water Management in the Aral Sea Basin.
- Agreement on Transboundary Water Use.
- Agreement on Transboundary Water Planning.

- Agreement on Information Exchange and Development on the Interstate Database on Water and Land.
- Agreement on Protection of Transboundary Water Resources.
- Amu Darya and Syr Darya River Basin Agreements.

These agreements should support implementation of the regional water strategy and regional cooperation in the transboundary water management. These draft agreements are based on the international water law, with regard to the national strategies and laws, and have the objective to create the clear rules on allocation, pollution, water quality and biodiversity as well as a regional data bank. Drainage plans and developments require less data collection and less analysis than a regional water management strategy, yet they have to be included in the general database, like WARMIS[4]. For this reason there is a draft agreement on information exchange between the five participating republics.

Both the water users and decision-makers should develop a new approach to this problem. These agreements should be concluded on the basis of understanding their urgency and necessity. Otherwise, it will not be possible to use this instrument of regulating legal relationships.

FUTURE OUTLOOK

The necessary prospective land reclamation measures in the Aral Sea Basin should include:

- Eliminating the causes of excessive soil humidity and salinity (avoiding excessive supply water and improving water quality);
- Providing more effective drainage of irrigated land by raising the efficiency of current drainage network and rebuilding them where needed.

The drainage problems of the Aral Sea Basin are approached on the basis of actions needed in three principal components:

- completion of drainage facilities as required by design;
- reconstruction of the existing drainage facilities;
- proper maintenance of the existing drainage facilities.

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[4] WARMIS – Water Resources Management Information System, which is under development by SIC ICWC with technical assistance from EU TACIS Program

To start these actions it is necessary to:

- develop a more complete understanding of the present characteristics of land use;
- improve the evaluation method assessment criteria of land melioration and fertility, considering the following: condition of irrigation and drainage networks, shortage of water resources and deteriorating quality or irrigation water. Assess lands in Central Asia using the new criteria and methods;
- develop a system to assess the state of drainage. Identify the operational state of existing drainage facilities and the need for rehabilitation measures;
- determine standards for the drainage system design with consideration of on-farm irrigation demands, water quality and the transition to new regulations on water and land use;
- develop design standards for the operation of drainage systems that will allow responsibility for operation and maintenance to be transferred to Water User Associations.

In principle, the proposed actions will minimize water losses in the irrigation network, but will require great capital investment. It will require the following steps:

- implement crop irrigation regimes in accordance with planned crop yields;
- sharply reduce leaching regimes by adoption of intensive methods of crop cultivation (chemical ameliorants and organic fertilizers, deep ploughing, crop rotation);
- secure uniform moistening and soil desalinization and minimize groundwater infiltration through optimization of the size of irrigated plots and land levelling;
- revise crop selection with regard to the environmental, economic and social conditions in the region;
- exclude highly saline lands from cropping;
- raise the efficiency of inter-farm and on-farm canals irrigation networks by installing watertight lining;
- organize the manufacture and large-scale introduction of better farm machinery and improve irrigation technology to achieve a uniform supply of water in furrows and consistent moistening of the root zone;
- organize regular cleaning and maintenance of inter-farm and on-farm collectors and water intakes to prevent further deterioration of primary drains and carry out the appropriate drainage of irrigated lands;
- initiate repair and rehabilitation works of on-farm drains, drainage collectors and tube wells, as well as expansion of the modern drainage technologies.

The next objective is to develop activities and principles for water disposal management. The goal should be to maintain total wastewater quality and quantity on an economically feasible and environmentally sound level, and provide negative balance of salts and other ingredients, irrespective of water availability. Proceeding from this objective, the following tasks should be carried out:

- identify locations, volumes and time of wastewater discharges along the two rivers, as well as qualitative characteristics thereof;
- define measures for addressing pollution of environment by wastewater on the formation sites;
- study and analyze drainage outflow schemes;
- define measures for protecting rivers from pollution by wastewater and collector-drainage effluent at the points of their formation;
- calculate discharge limits for salts and pollutants to the rivers to prevent the maximum allowable concentrations to be exceeded;
- identify the sanitation releases on various sites of the rivers to support minimum epidemiological medical and ecological river discharge.

To meet these tasks it is necessary to undertake the following steps:

- Conduct feasibility study for ecological requirements to the river water quality with consideration of different users' interest.
- Study the existing system of water disposal in the Aral Sea Basin for the following aspects:
- types of wastewater subject to withdrawal (industrial, communal, agricultural);
- water receivers (river, the sea, groundwater horizons, local depressions, etc.);
- types of pollutants (petroleum products, mineral fertilizers, bacteriological pollutants, biogenic substances, etc.);
- degree of wastewater treatment (without treatment, treated by mechanical, physical and chemical, and biological means).
- Inventory the non-point and point wastewater discharge into water sources according to water management districts.
- Prepare schematic mapping of irrigated lands by independent irrigation systems for identification of actual water supply, drainage water discharge, quantitative and qualitative characteristic of water delivered and discharged, assessment of salt and pollutant redistribution processes.
- Assess drainage capacities of irrigated areas in the basin, their efficiency and technical conditions.
- Assess present status of collector-drainage water and prospective to reduce its volume by introducing water saving irrigation technologies, inter-system utilization of drainage water, using it for soil recharge by means of groundwater level regulation (sub-irrigation).
- Study the possibility of circular water supply, secondary and sequential re-use of wastewater; replacing water-cooled systems by air-cooled ones in industry,

introduction of "dry" technologies in various branches of economy (discharging wastewater).

- Study the character of quantitative changes in the composition of collector-drainage water, which is presently disposed to local depressions.
- Assess the efficiency of various options for collection and evacuation of collector-drainage and wastewater to the Aral Sea in both river basins.
- Develop principles for wastewater management, including establishment of limits, regimes and schedules for wastewater disposal into the river.

CONCLUSIONS

Given the large area of the Aral Sea Basin, it's international character, population pressure, scale of irrigation developments, and extensive environmental degradation, the finalization and adoption of the draft agreements are vital. These agreements could then lead to the implementation of Regional Water Resources and Environmental Management Strategy, which has of utmost importance to all the riparian states. The implementation of such strategy would create conditions for ecologically stable socio-economic development of each of the five Basin States and the Basin as a whole. The international community via the World Bank is ready to assist the States of Central Asia in designing and managing such Project to the maximum extent possible.