PN-ACB-091
94742

Environmental Policy and Technology Project

Contract No. CCN-0003-Q-00-3165

NEW INDEPENDENT STATES

FINAL PROJECT REPORT SUMMARY

Applied Demonstration Project Reports Compilation
English Versions
April, 1997

Delivery Order 8, Task B

Prepared for:
Central Asia Mission
U.S. Agency for International Development

Prepared by:
Central Asia Regional EPT Office in Almaty, Kazakstan
Environmental Policy and Technology Project
For the New Independent States of the former Soviet Union
A USAID Project Consortium Led by CH2M Hill

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Environmental Policy and Technology Project

Contract No. CCN-0003-Q-08-3165-00

NEW INDEPENDENT STATES

REPORT

Amu Darya River Water Allocation Model
Applied Demonstration Project 1
December 20, 1996

by Daene C. McKinney and Akmal Kh. Karimov
Delivery Order 08

Prepared for:
Central Asia Mission
U.S. Agency for International Development

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ENVIRONMENTAL POLICY AND TECHNOLOGY PROJECT

A Project Financed by the U.S. Agency for International Development

Проект финансируемый Агентством по Международному Развитию США

Serving Countries of the Former Soviet Union

Служит странам бывшего Советского Союза

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USAID

ENVIRONMENTAL POLICY AND TECHNOLOGY PROJECT

Central Asian Republics Regional Office

ПРОЕКТ ПО ПРИРОДООХРАННОЙ ПОЛИТИКЕ И ТЕХНОЛОГИИ

Региональный офис республик Средней Азии

This report was completed as part of Task B of Delivery Order 8.

This report has been reviewed for content and approved for distribution to USAID.

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This is the English translation of the summary from an applied demonstration project report. The original full-length report is in Russian and follows the English report.

Executive Summary

During the economic and political transition in the countries of the Aral Sea basin, it is very important to develop water management practices at the international, national and local levels which will be appropriate to the new conditions. Some practices from the western United States can be used if adapted to meet local conditions, national culture and practices. Some of the applicable approaches to water management include the establishment of a drought water bank and support for a water market.

New institutional, economic and technical measures can be examined in the Amu Darya River allocation model which has been developed with both a regional and a local level. At the regional level, the main issues addressed are the interstate allocation of water and the improvement of the environment. At this level, different measures for increasing efficiency in water use can be analyzed.

This report presents brief results and conclusions from the project. A full version of the report in Russian, with extensive details on the project's findings, can be received from the Central Asian Regional EPT office in Almaty or from the authors.

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Acknowledgements

The project's workers are grateful to the managers of USAID's Environmental Policy and Technology Project in Almaty, especially Ms. Barbara Britton, Ms. Alexandra Terninko and Mr. Bryan Bushley, for their assistance in carrying out this research.

Dr. Karimov thanks the employees of University of Texas at Austin, Dr. Daene McKinney and Heming Kay in particular, for creating a supportive condition for his training there. Mr. Karimov learned much from Professor D. Maidment on GIS application in water management, and particularly appreciates Professor Maidment's lectures on the topic. Likewise, Dr. Karimov is grateful to Dr. Morton for his lectures on stochastic programming and the use of GAMS, from which he gained much and to David Watkins, for his assistance and cooperation during Dr. Karimov's training period at the University of Texas.

During Dr. Karimov's study tour to the USA, visits were made to many water management organizations of Texas, California and Arizona. The authors would like to thank the following people in particular for their assistance: Mr. Marshall Jeninks from the US Geological Service, Dr. Quentin Martin from the Colorado River Water Service; Dr. David Ford from California; Bryan Thoreson and Carlos Z. Villalon from the Imperial Irrigation District; Marvin Niemi, Curtis Creel, Barbara Cross and Jack D. Trenthan from the California Department of Water Resources; Dr. J. Lund and Larry Schwankl from the University of California at Davis; and Professor Nathan Buras and employees from the University of Arizona's Hydrology Department.

In addition to results from the work funded by USAID, the results of research carried out by A. Karimov on the ACCELS funded project "Study of the History of the Development of Western USA's Water Sector" and on his dissertation "Optimization of Water Management of the Republic of Uzbekistan" have been used in this report.

Dr. Karimov's visit to the University of Texas was financed by the USIA ACCELS/ACTR program while travel within the U.S. was financed by the EPT Project.

About the Authors

The work done under this project was conducted at the Tashkent Institute of Engineers for Irrigation and Mechanization of Agriculture (TIIMSKH) and the University of Texas at Austin.

Project leaders Dr. A. Karimov and Dr. Daene McKinney are from TIIMSKH and the University of Texas at Austin respectively. In addition, the following people also worked on this project: Professor S. Sh. Mirzaev, TIIMSKH; Dr. F. E. Rubinova, Hydrometeorological Survey of Uzbekistan (SANIIGMI) Institute; Dr. I. Khabibullaev, Dr. T. Mukhamedjanov, Dr. G. Mjelskaya, Dr. I. Gracheva, Institute of Hydrogeology and Engineering Geology; Dr. G. Khasankhanova, Institute Uzmeliovodoproekt.

Section 1
Introduction

Water management has had an important role in the Aral Sea basin since ancient times. The very dry climate and variable river flow of the region have promoted the establishment of relations between members of society regarding water allocation, water use, and water diversion. Water users, communities and countries have participated in these arrangements. These relations have not been constant over time and have been evolving along with the development of new public interrelations.

The economic system of newly independent Uzbekistan is in the process of transferring to market conditions. Farmers in the agricultural sector are a good example of this. Under these conditions the tasks of developing water management strategies are very critical. The creation of new, independent states in this region where the rivers are united requires the development of interstate water management and allocation policies, that are closely connected with legal, administrative, and economical policies.

Models of water allocation for the Amu Darya or Syr Darya Rivers, whose runoff is formed in Kyrgyzstan and Tajikistan, and used in Uzbekistan, Turkmenistan, and Kazakstan, can be very useful for the improvement of water management in the region. That is why the task of the USAID Environment Policy and Technology (EPT) Applied Demonstration Project "Amu Darya River Water Allocation Model" is very important. The approach to creating the model was based on a comparative study of water management in Uzbekistan and the Western USA.

The western states in the U.S. have a long history of water management under market economic conditions. Different kinds of water management have been developed there - from centralized state systems like California to local water management in Texas. Studying the history of water allocation development between the western states in the Colorado river basin and between the USA and Mexico in the Rio Grande basin can be very useful for the Aral Sea basin countries. The task of the authors in this study was not to evaluate the practice of the US water sector, but to define applicable measures and instruments that may be useful (taking into account special local situations - social, economic, technical, and legal) for the water sector in the Central Asian Republics.

Section 2
Water Management in the Western USA and Uzbekistan

The Nukus declaration of the Central Asian Republics regarding the problems of sustainable development in the Aral Sea basin asserted that sustainable development is the main subject of human activity in the basin (September 21 1995, " East Truth"). This declaration was signed by the heads of states of the Republics and it points the way for:

- a transition to a more balanced agricultural and forest economics
- increasing irrigation efficiency through development of economical mechanisms of water use
- promoting long term water and land use

Especially important at the present time for the Uzbekistan water sector is the need to transfer economics to a market system. That is why the experience of the water sector of the western states of California, Arizona and Texas, in the U. S., were studied.

Most of California occupies three river basins; the Sacramento, San Joaquin and Colorado Rivers. The state may be divided into two parts, the North, with rich water resources, and the South, with frequent droughts. A united water system, where water transfers are used widely, was developed in California to provide for user demands. Arizona is in a desert zone with small rivers and very expensive water available from the Colorado River. This has motivated the development of an extensive ground water management system. In Texas a system of rivers and canals that combines the state into one water system is absent, and water management exists at the local level. The state has a very active financial system for supporting water conservation.

Comparative analysis showed that the Uzbekistan water sector management is closer to the California system than to the Arizona or Texas systems, because in both cases centralized water management systems exist. But some differences also exist such as:

1. Differences in water users structure.

   Environmental demands in California comprise about 30% of surface water use. The agricultural sector is not dominated by a single crop. Usually each crop represents less than 10% of the total use, with the only exception being alfalfa, which in the southern part of the state occupies about 30% because of its meliorative function.

   Uzbekistan has made definite steps toward a more suitable crop structure during the last few years. By 1996, the area under grain cropping was increased to by several times up to 1.4 million hectares. Recommended crop rotation includes 20-22% grain and 20-22% of alfalfa. The next steps will be to promote sustainable agrolandscape.

2. Differences in approaches to water conservation.

Uzbekistan has developed an approach to water conservation based on the regulation of water use. Water law and legal documents define the payments and administrative measures for exceeding permitted water use. In California water users have rights for water use and water transferring. The result is that water users can conserve water and sell it in a market. They have the choice to sell their water use rights or to use the water to produce goods and services. In Uzbekistan water users also have rights for water use and water transfer, but since there is no price on water, water users are not interested in water conservation.

3. Differences in financing of water services. The water supply services of the western states in the U.S. have funds for concrete projects and then they must (in principle) produce profits from the project results for further functioning. For example the Texas Water Development Board has funds which provide for:

- loans for water supply projects (Water Supply Account)
- loans for wastewater facilities (Water Quality Enhancement Account)
- loans for flood control projects (Flood Control Account)
- state purchase of an interest in regional water supply and wastewater projects, reservoirs, and flood retention basins (State Participation Account)
- loans and grants for water supply projects and wastewater facilities in certain defined areas (Economically Distressed Areas Program Account)
- loans for agricultural water conservation projects (Agricultural Water Conservation Fund)
- wastewater treatment, storm water pollution control, and non-point source pollution control projects financed with a combination of federal capitalization grants and state funds (State Revolving Fund)
- loans for water, wastewater treatment, and flood control projects (Water Assistance Fund)
- loans for water, wastewater treatment, and flood control projects (Storage Acquisition Fund)

- water research and regional water, wastewater treatment, and flood control planning (Research and Planning Fund)

In Uzbekistan, by law, water services may have beneficial loans for water conservation projects, but when payment for water is absent, users are not interested in water conservation. The availability of financing for water service is connected with the volume of water use.

Section 3
California Water Bank

In 1991 the California Water Bank was conceived as California entered a fifth year of drought conditions. The responsibility for organizing and implementing the bank was assigned to the California Department Water Resources (DWR). A water purchase committee was formed by DWR to negotiate the terms and conditions of a model water contract.

To protect the water rights of sellers and to encourage their participation, several pieces of legislation were enacted. Assembly Bill 9 gave water supplies explicit authority to enter into contracts with the DWR or other water suppliers for the transfer of water outside their service area. Bill 10 stated that no temporary transfer of water for drought relief in 1991 and 1992 would affect the standing of any existing water rights. The transfer of water was deemed to be a beneficial use of water on the lands from which it was transferred, it did not affect, and was not a basis for any loss, of these rights.

The water bank acquired 820,665 acre-feet of water through 348 contracts. Fifty percent of water came from 325 fallow farmland contracts (i.e., not planting or irrigating a crop), thirty-two percent from 19 ground water substitution contracts (using ground water instead of surface water), and eighteen percent from 4 surface water contracts (transferring water from local reservoirs).

A total of 389970 acre-feet was purchased from the 1991 Water Bank by 12 entities. Three jurisdictions, the Metropolitan Water District of Southern California, Kern County Water Agency and the San Francisco Water District, accounted for over 80 percent of the purchases. Roughly 80 percent of the 1991 Water Bank sales were for municipal and industrial uses. The difference between total purchases and total allocation was used for environment needs or stored for the next dry year.

Section 4
Interstate Water Allocation of Common Water Resources

International water allocation is very important for the Aral Sea basin (see Figure 1). In this basin there are two main rivers, the Amu Darya and Syr Darya, whose flow forms in the mountain zones of Kyrgyzstan and Tajikistan and is used in the valley and desert zones of Turkmenistan, Uzbekistan, and Kazakstan. For this reason the experience of the western states in the U.S. in the water allocation of two river basins, the Colorado and Rio-Grande Rivers, was studied. It must be pointed out that this analysis was not done to provide an evaluation of the water allocation between Western USA states or between USA and Mexico. For us the more important point is the process of historical development, which, over time, led to cooperation and understanding.

This analysis showed that when there is water allocation from international rivers, there is a need to develop a basis for international water law that will regulate the partners' relations, their rights and responsibilities, and coordinate their measures for international river basin administration, data collection for water allocation and common planning needs.

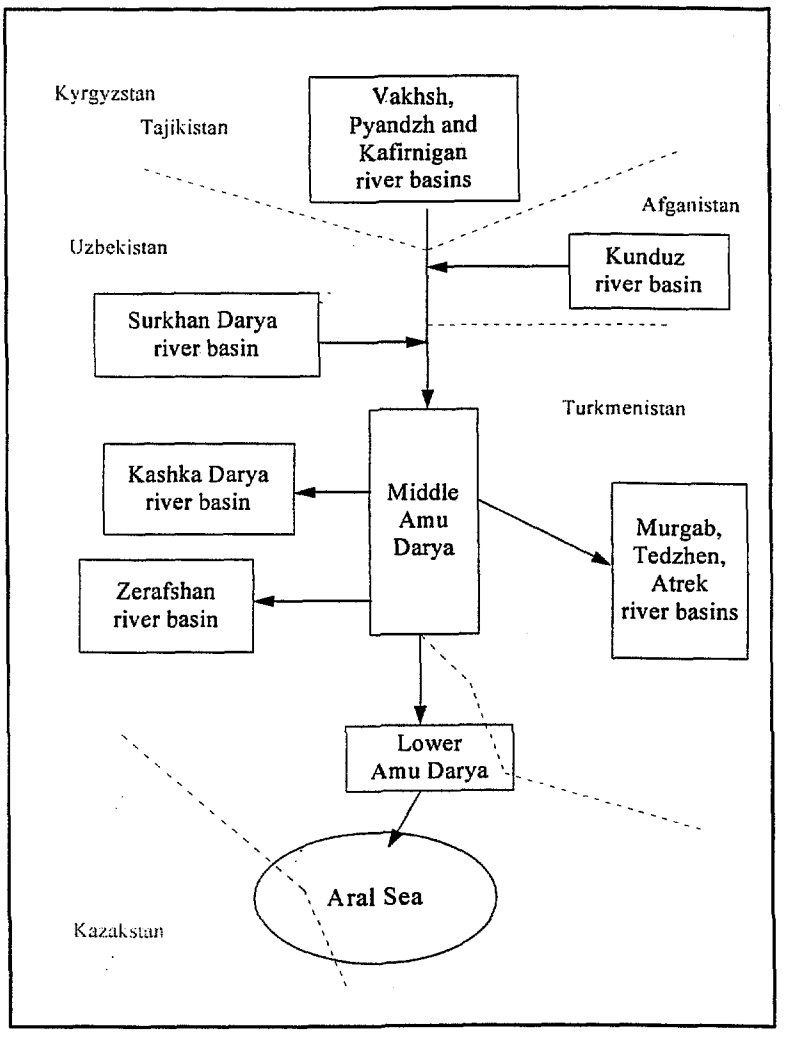

Figure 1. Amu Darya River Basin with international borders shown

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4.1 International Water Law

The main task of international water law is to define the common interests of the affected countries. The law should decide the question about the extent or boundaries of international waters, this may be all or part of a basin, including ground water. In many cases it is very important to include reservoirs in international water, when two or more countries are interested in the reservoir's operation, or when a natural lake or reservoir that has an important role for the basin environment.

Shares in international river flow can be defined in 3 different ways:

1. Main river and tributary flow can be divided between upstream countries, and the water volume of international reservoirs can be divided in relative quantities. In this way, the shares for each country are known in the upstream river. This helps to account of long-term flow variation and the upstream and downstream countries will be in the same positions in dry and wet years. For application of this approach, an international hydrological station should be placed in the upstream river.

2. River flow can be divided between countries by international boundaries in relative shares. In this case, problems may be created by upstream water diversion and international reservoir operation, because upstream countries may wish to manage their shares for purposes which are in conflict with downstream uses, e.g., power production in up-stream countries may conflict with irrigation demands in the middle and downstream countries.

3. Same as (2), but shares can be defined in absolute quantities. When river flow is divided between countries by international boundaries in absolute quantities, it is very important to calculate the river flow exactly and provide measures for water allocation for wet and dry years. According to the downstream needs it is important to include the use of drainage and wastewater flow.

   Water allocation in the Amu Darya river basin has of course been developed differently. As a result, each republic has a quota on water withdrawals which depends on any given year's conditions. However, when water demands are deeply incompatible among countries and among fields of the economy, it is extremely difficult to agree upon quota amounts. In this case, the use of water "shares" would more accurately respond to the current situation and encourage long term cooperation. Quotas on water diversions require the entire basin's close cooperation in planning economic development.

4.2 River Basin Administration

The river basin administration organizational structure and functions should be defined by international water law. This is connected with the desires of each country to evolve to

international water management.

In our case the analysis showed that in principle the Rio-Grande River and Aral Sea basins have developed the same structure. In the case of the Aral Sea the tasks of the Water Commission are more complex, because there are five countries and there exists a great need to improve the legal basis and the monitoring system. The North American Commission's tasks include encouraging the joint economic development of boundary territories.

4.3 Data Collection for Water Allocation

Water allocation modeling can be executed only if correct data about river flow and user demands are available. Unfortunately, a measurement error of more than 5% exists for river flow. If we include this and the time needed for data collection, we will see it is possible to allocate water only for a ten day period and not for shorter periods.

In the southern California's Imperial Valley there is experience with system operation for 24 hour water allocation and demand satisfaction. This system is a pioneer for other districts of the Western USA. Their measurement and transfer system consists of a high velocity radio network that covers the entire district. Information about water diversions in the main and lateral channels is transmitted to dispatchers, where real time operation of the district reservoirs and water allocation for users needs is accomplished.

An acoustic method is used for water measurement in the All American Canal. Solar powered measurement systems are used in the lateral canals. About 80% of the canals have this system. Automatic water measurement is used in about 20% of the farm water allocation systems.

A united information system involving cooperation of users and water supply services of all the basin countries will be very effective in the Aral Sea basin.

Section 5
Amu Darya River Water Allocation Model

The model has three main parts (see Figure 2): a manager program to prepare the network model connecting the supplies with demand sites, an optimization model built on the GAMS software base, and a data base built on the GIS (geographical information system) coverages.

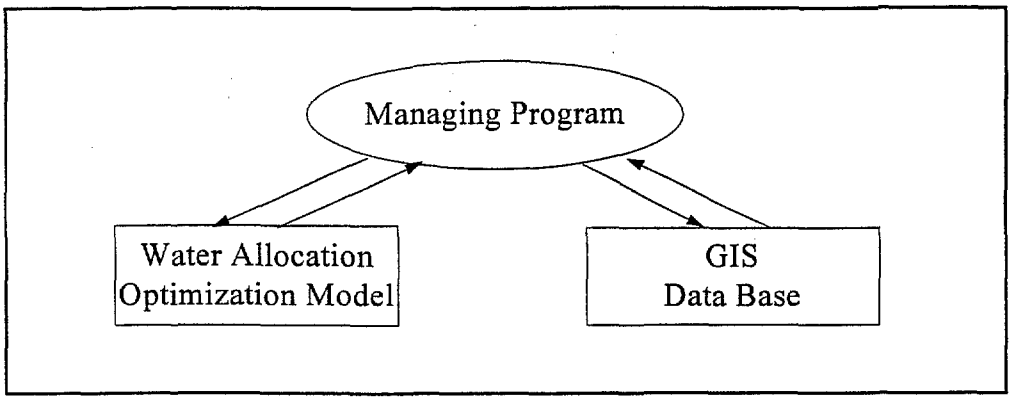

Figure 2: Structure of the water allocation model

There are two levels of detail - regional and local. On the first (regional) level, monthly water allocations are assigned to administrative regions or irrigation zones of each country. The water demands of zones and countries are known from the input data. At the local level, there is a monthly water allocation for irrigation zones. The irrigation demands are calculated within the optimization model by types of soils, crops, climate and the quality of delivered water.

The organizational and legal aspects described above are the basis for water allocation modeling. Optimization was used as the modeling method. The optimization module underlying the model is formed by the function of purpose, by the construction of the system and by its restrictions. The basin's distinctive feature is its international nature, which forces the model to address multiple criteria.

Regional water allocation is calculated in two steps. In the first step, the benefits of each country are optimized with consideration for environmental stability in the region and regional needs, such as drinking water supply for the population which has been decreed by international agreement. In the second step the optimal variant is calculated based on water allocation agreements when water demands are incompatible. Methods for curtailing water supply cause either a relative or absolute decrease in the maximum possible impact on each country.

Table 1 shows the data used for calculating each country's share of the Amu Darya river flow and international reservoirs. These amounts were determined by upstream cross sections. Reservoir water shares refer to initial water storage in the reservoirs.

Table 1

Distribution of the Amu Darya River's Flow
(with 50% probability of receiving at least these amounts annually, given in million cubic meters)

	Water resources (mill. cubic m.)	Kyrgyzstan	Tajikistan	Uzbekistan	Turkmenistan
Upper river flow					
Amu Darya flow	58 501.63				
Pyandzh	*32 822.37*		1685		
Bakhsh	*20 103.72*	172	2936		
Kafirnigan	*3 156.00*		2286		
Surkhandarya	*2 419.54*		230	2189	
Kashkadarya	736.93			985.93	
Zerafshan	4 860.94		291	4392	
Amu Darya flow	49 003.63				
Middle river				10446	18210
Amu Darya flow	20 347.63				
Lower river				13387	4488
Amu Darya River flow	2 472.00				

The objective function for each country includes benefits from using the international water flow combined with other water resources (surface and ground) at present and the effectiveness of water accumulated in the reservoirs by the end of the calculation period.

The model's constraints consist of water/salt balance equations which connect supplies (rivers, reservoirs, ground water) and demands (irrigation zones, power stations). Reservoirs and water transfers can be used for surface water management. For ground water management, underground reservoirs, ground water resources and drainage flow can be used jointly with surface water.

The river node water balance equation is:

$$\sum(\nu(\iota\rho,\iota),Q(\nu,\tau)*(1-\alpha\nu)) - \sum(\nu(\iota,\iota\rho),Q(\nu,\tau)) + \Upsilon(\iota,\tau)-\sum(\xi,\Omega(\iota,\xi,\tau))-\nabla(\iota,\tau) = 0, \quad [1],$$

where

- ι - river nodes,
- τ - piece time,
- $\nu(\iota\rho,\iota)$ - water movement direction,
- $Q(\nu,\tau)$ - river flow in the direction ν,
- $\alpha\nu$ - losses in the direction ν,
- $\Upsilon(\iota,\tau)$ - local water sources in the node ι,
- $\Omega(\iota,\xi,\tau)$- water diversion for user ξ in the node ι,
- $\nabla(\iota,\tau)$ - flow regulation in node ι.

Total water diversion in node ι should be less or equal to the state "share" in river flow:

$$\sum((\iota,\xi), \Omega(\iota,\xi,\tau))\$Rv(\sigma,\iota) \leq \Delta(\sigma) \quad [2],$$

where

- $Rv(\sigma,\iota)$ - link between node ι and the state (σ)
- $\Delta(\sigma)$ - the "quota" or "share" of the state.

The model's limitations are reservoir volume, construction parameters and other data. All these data are available from the GIS data base. The model allows calculation of water diversions for each irrigation zone and reservoir release for each month. The present model can be applied in river basin administrations with international water.

Section 6
Kashkadarya River Water Allocation Model

The water allocation model's goal is the optimal distribution of the basin's water resources to maximize the effect of water use while considering environmental protection and the preservation of water resources.

The model's operational goal is formed by the following aspects: the effect of irrigation, the effect of water accumulation in reservoirs and aquifers for future benefits, and the damage inflicted by water diversions. The impact of crop irrigation is estimated from the reduction in yield caused by water scarcity and soil salinization.

The model's resulting nonlinear objective function is:

$$Zir=MAX(\Sigma(\iota,\xi',\tau),P(\iota)*a*(\Omega(\iota,\xi',\tau) + U(\iota,\xi,\tau)) /Tr(\iota,\tau))**u\omega*Na(\iota)**u\epsilon$$
$$**exp(-\phi\omega*Na(\iota)-\phi\epsilon*(\Omega(\iota,\xi',\tau) + U(\iota,\xi,\tau)) /Tr(\iota,\tau))) \quad [3],$$

where:

ξ' - irrigation ,
a, $u\omega$,$u\epsilon$,$\phi\omega$,$\phi\epsilon$ - parameters,
$P(\iota)$ - soil fertility,
$Na(\iota)$ - land salinity
$Tr(\iota,\tau)$ - irrigation demands in zone (ι).

This expression represents soil productivity based on a given year's water supply and the degree of soil salinization under the current level of soil fertility. This expression had been used earlier by F. Serebryannikov in 1986.

Thus, for each of the system's "units" producing a water demand, water/salt balances are calculated for aeration zones and areas of water saturated fine earth. According to Myatiev-Girinsky, water flows vertically in such zones. These flux points are supplemented by horizontal surface and ground water flows.

The Kashkadarya water allocation model complements the regional model. Its distinctive features include the following:

- a more detailed use of GIS to accumulate and manage a data base.
- calculation of water demand within the water allocation distribution module.

The following water management options are used to determine optimal water allocation scenarios, depending on natural conditions:

1. Surface water:

   - water flow transfers within the basin-- looking at all possible options given the existing canals.

- river flow regulation in reservoirs.

2. Ground water is managed through methods of regulating ground water storage and the artificial replenishment of aquifers. This measure is efficient both for irrigation and non-irrigation needs.

3. Water use also results in return flows, and one indicator of the degree of optimization reached in water allocation is the effectiveness with which this return water is used.

   Part of this flow, in accordance with water quality requirements, is reused in conjunction with surface water and pumped water.

During model development, an expert evaluation was conducted on water management methods. Management methods and targeted water uses are proposed for each ground water source.

The standard software for optimization calculation (GAMS) was used in constructing the model. The methodical approach to optimization used here, together with the management of all components of water resources and water demands based on GIS, should be broadly used in planning the water economy and system operations.

Section 7
Conclusions and Recommendations

- International water law in the Aral Sea basin should be developed. This law should define shares, rights and responsibilities of each country in international water. Water saving practices within a republic, and a water bank, will be more effective if an international water law determining each nation's water shares has first been established.

- The comparative analysis of water management in the western states in the U.S. and Uzbekistan showed that the following measures can be applied in the Uzbekistan water sector

1. A legal base for water use should be created that includes conditions that will promote the implementation of economical mechanisms in the water sector and raise the interest of water users in water conservation. It is necessary to develop the Uzbekistan law "About water and water use". In particular, the following should be added:

   To Article 24:

   > Water users have rights for water use and for water transfer for a defined price or rent to other users directly or through a water bank. If the water transfer is outside of the local water supply agency, permission from the committee that is responsible for water use rights is needed. If the water transfer is within an administrative district the local water agency must simply be notified.
   >
   > The transfer of water does not affect and is not a basis for any loss of water rights if the transferred water does not cause a decrease in river flow. This savings or transfer can be considered a beneficial use of the water in the land from which it was transferred.

   To Article 31:

   > Short term water use can be applied only in special conditions as a temporary measure.
   >
   > Both actual water users and water user associations can be considered "water users" in this context (water user associations seem to be effective during the transition of establishing such users as farmers). Water management on the local level will thereby be characterized with the functions of

two structures; a water service which has the right to regulate, protect and supply water while reimbursing its expenses, and an association or group of water users, which has the right to use and transfer a defined amount of water.

2. A water bank should be established. The objective of the water bank is to raise the interest of water users about water conservation and the selling and purchasing of water. Water users will have two alternatives:

   - They will have water use rights without payment
   - With additional payment water users may participate in the water market when they wish

   The water bank can be established in river basins or by administrative regions (oblasts).

3. Direct agreements between different users for selling and purchasing water should be promoted. This will result in conserved water from one region being transferred to other regions where payments are possible.

4. Implement pricing for the last 10%-15% of irrigation's water supply as an initial step.

5. Full payment for natural resources use should be applied in the second step. This measure allows a sharp increase in the efficiency of natural resources use, and it will decrease all types of unproductive losses of water.

6. Ground water management zones should be established. These agencies can be established under the hydrogeological services which have highly skilled specialists. This measure is possible and will be effective in zones where there are important needs for ground water protection and artificial ground water recharge.

7. The interstate basin water organizations can adapt the experience of the Imperial Irrigation District in solving issues of interstates water allocations.

- The Amu Darya and Kashkadarya river water allocation models should be applied by the Basin Water Management Association (BVO) Amu Darya and in the Water Survey of the Kashkadarya oblast. These regional and oblast level water management organizations should test the models and input any necessary additional information.
- A Single Information System in the Aral Sea basin should be developed to include the

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existing data bases of the hydrogeological and hydrometeorological services, the ministries of melioration and water management, planning and research institutes, and institutes of higher education.

- GIS should be used more broadly in water management.

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Appendix A
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7. Joint Surface and Ground Water Use for Irrigation (S. Sh. Mirzaev and A. K. Karimov) Tashkent, 1989

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The result of research carried out by A. Karimov on the ACCELS funded project "Study of the History of the Development of USA's Water Sector" and on his dissertation "Optimization of Water Management of the Republic of Uzbekistan" have been used in this report.

Environmental Policy and Technology Project

Contract No. CCN-0003-Q-00-3165

NEW INDEPENDENT STATES

FINAL PROJECT REPORT SUMMARY

Short-Term Forecasting of the Amu Darya's Flow, Based on a "Reservoir" Model
Applied Demonstration Project No. 2

By Sergey Myagkov
October 1996
Delivery Order 08, Task B

Prepared for:
Central Asia Mission
U.S. Agency for International Development

Prepared by:
Central Asia Regional EPT Office in Almaty, Kazakhstan
Environmental Policy and Technology Project
For the New Independent States of the Former Soviet Union
A USAID Project Consortium Led by CH2M HILL

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Acknowledgments

The authors would like to express their appreciation to the Environmental Technology and Policy Project specialists for their devoted attention and efficient solution of arising technical problems. The authors are thankful to the employees of the Hydrometeorology Service of Turkmenistan and Uzbekistan, the Ministry of Water Management of Turkmenistan, and the "Amu Darya" Basin Water Organization (BWO) for their assistance with the project.

About the Authors

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Dr. E.D. Kalandarov - researcher, director of "Amu Darya" BWO

A.V. Kasianov - researcher, engineer, software development

L.A. Shayakhova - researcher, computer operator

V.A. Novikova - researcher, computer operator

Materials and Reports

During the course of the project the following materials have been published and presented at seminars:

"Mathematics Modeling and Modern Methods of Hydrological Calculation and Forecasting" Yu.M. Denisov, S.V. Myagkov, SANIGMI

"River and Computer," S.V. Myagkov, "Pravda Vostoka," Tashkent, March 22, 1996

"A Look at the Desert From Space," S.V. Myagkov, "Pravda Vostoka," Tashkent, June 18, 1996

"The Mysterious Amu Darya," S.V. Myagkov, "Pravda Vostoka," Tashkent,July 30, 1996

"The Problems of Water Storage in the Desert," S.V. Myagkov, L. Shayahova, at the FRIEND seminar, WMO Publ.

"A Model for the Forecast of Drainage Water," S.V. Myagkov, at the 3rd USA/CIS Hydrological Seminar, Tashkent, Sept. 1996

Project Summary

Purpose and Scope of Project

The purpose of this project was to develop a computer modelling program to provide short-term forecasts of flood movement in the Amu Darya River. At present the Aral Sea problem is typical of the problems facing the planet, especially in the Central Asian countries. The main water sources for the Aral Sea are the Amu Darya and the Syr Darya rivers. The water from these rivers is used intensively for the economic sectors in the Central Asian countries. In order to use it efficiently and manage it optimally during operations, a 1-5 day advanced forecast for the Amu Darya flow (the Tuyamuyun Reservoir inflow) is required.

Many researchers have tried to develop a model showing the changes in the Amu Darya's river flow during flooding. The resulting models did not meet the accuracy requirements for hydrological forecasting due to the very complicated hydrological process. The initial information is not sufficient for the detailed equations of the Saint-Venan-type model. The simplified models of Kalinin-Milukov or Maskingam do not take into account that the flood's lag time depends upon water discharge.

Project Results and Findings

During this project the "reservoir model" for river flow in an unstable channel was used. The model is based on the non-linear relationship between water discharge and the river channel's hydraulic parameters, taking into account the Amu Darya channel's high level of instability. The "reservoir model" allows water discharges in the lower reaches to be calculated based on known water levels and discharges in the upper reaches. The main advantages of the model are the dependence of flood lag upon flood discharge and the use of standard observations made at the hydrologic stations as primary model parameters, which simplifies its adaptation to a real water body and facilitates its further use.

When the model was first tested on the Amu Darya River in 1992, it showed good correlation between the measured and calculated hydrographs, which indicated good prospects for positive results on this project.

As is well known, the technology for hydrologic forecasting requires that predetermined values be obtained at precise times and at the lowest possible costs. This package of programs was developed to reduce costs by simplifying work for staff. The programs are designed for specialists with different qualifications and include a hydrologic model and hydrologic database.

The forecast's lead time is determined by the long distance on the river between the Kerki gauge line and the Darganata gauge line (434 km), with the flood peak's lag-time being two to five days.

The following work has been completed under this project:

- A hydrological database adjusted to river reaches has been developed.
- Programs for visual analysis and statistical processing of the measured hydrologic data have been worked out.
- Flow data have been transferred to magnetic tapes and checked by matching hydrographs.
- Essential water use information for the middle Amu Darya River has been collected and shown in the summary table.
- Methods have been developed for adapting the hydrologic model to different information systems.
- Numerical experiments were conducted to assess the compatibility of the forecast method for the Amu Darya River during the period of 1985 - 1996.
- Technology for automated forecasting using computer programs has been developed.

The results of numerical experiments for the period of 1985 - 1996 showed that it is possible to use this project's results for short-term forecasting of the Amu Darya River's flow in the Darganat section and for inflow to the Tuyamuyun Reservoir. The forecast method was rated 95 percent accurate according to W. Juemou's method, based on the World Meteorological Organization's standards (see W. Juemou., 1994, *Methods for Verification of Hydrological Forecasts WMO / TD - No 617*) and 82 percent accurate according to Uzbekistan's system, based on up to a 10% deviation from actual discharges. The efficiency constituted less than 0.29 for the whole period, where 0.75-0.8 is rated as satisfactory, 0.6-0.75 is good, and less than 0.6 is excellent.

Application of Results

The results and the hydrologic model could be used in water management agencies for research on modelling river flow during flooding.

The results of the project could be used in the future for:

- developing forecasting methods in other basins
- modeling optimal water use
- river channel balance calculations
- modeling the movement of pollutants in the river
- building a network model for the river basin

Greater detail on what these uses entail is provided in the full-length report.

For the best use of the project results it is necessary to distribute the program package and the model description among the main users, the hydro-meteorological services of Turkmenistan and Uzbekistan and the BVO "Amu Darya."

The results may also be used to develop an optimal water use regime, for example in calculating the movement of pollutants along the Amu Darya or developing a forecasting method for the Syr Darya River.

The program package and the hydrologic model are also recommended for use by water agencies to:

- develop the optimal water use regime in the Amu Darya basin and coordinate it among different water agencies and the Central Asian Republics.
- carry out control evaluations of water protection measures, for example calculating the water balance along the river considering water users demand on the regional level, or determining the water resources deficit in the Amu Darya basin.

Potential Impacts

The results of this project may help in addressing controversial issues related to computations of water balance and flow in the Amu Darya basin.

Utilization of the model during regular flow periods will improve the operating regime of the Tuyzmuyunsk hydro unit and reduce the wasting of water, and improve the water management regime in the lower Amu Darya River. Using the model for calculating river flow during flooding will aid in developing methods for optimal water management of the middle Amu Darya, by imitating the work of water diversion operations under any given conditions of water use.

The results of this project could be used to assess the influence of water-saving technologies on the water regime of the Amu Darya and to improve the environmental conditions of the Aral Sea basin by saving water.

Regional Cooperation

Regional cooperation took place under this project through the open exchange of hydrologic information between the hydro-meteorological services of Uzbekistan and Turkmenistan, and in consultations on the best way to present computer programs and the hydrologic model.

Environmental Policy and Technology Project

Contract No. CCN-0003-Q-00-3165

NEW INDEPENDENT STATES

FINAL PROJECT REPORT SUMMARY

Optimization of a Surface Water Quality Monitoring Network for the Aral Sea Basin Applied Demonstration Project No. 3

Raisa Toryanikova, November, 1996

Delivery Order 08, Task B

Prepared for:
Central Asia Mission
U.S. Agency for International Development

Prepared:
Central Asia Regional EPT Office in Almaty, Kazakstan
Environmental Policy and Technology Project
For the New Independent States of the former Soviet Union
A USAID Project Consortium Led CH2M Hill

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Acknowledgements

The authors would like to express their appreciation to the National Weather Forecasting Services of the Republic of Kazakstan, Kyrgyz Republic, Republic of Tadjikistan, Turkmenistan, and Republic of Uzbekistan for providing information and assisting with the work of this project. The authors are thankful to the employees of the Environmental Policy and Technology Project, USAID for their assistance and guidance with the project.

About the Authors

Dr. Raisa Toryanikova (Chemistry) - head of the Water Surface Quality Research Laboratory of SANIGMI named after V.A. Bugaev, specialist in water quality estimation, behavior of pesticides in natural environment, development of analytical methods of water quality and monitoring system. She has more than 50 publications.

Muratbek Bakanov - deputy director of the Hydrometeorology Agency under the government of the Kyrgyz Republic. Specialist in the organization and functioning of system for monitoring the natural environment.

Nina Budnik - head of the Republican Center of Control Over the Pollution of Natural Environment (Tadjik Gidromet). Specialist in the organization and functioning of system for monitoring the natural environment.

Eduard Pozdnyak - chief engineer of the Monitoring Center, Kazgidromet. Specialist in the organization and functioning of system for monitoring the natural environment, and author of more than 20 scientific publications.

Yuri Fedorov - head of the Center of Ecological Monitoring (CEM), Turkmengidromet, the Ministry of Water Use and Environmental Protection. Specialist in the organization and functioning of system for monitoring the natural environment.

Dr. Tatiana Ososkova (Chemistry) - head of the Department of Ecological Monitoring Over Natural Environment Pollution, Glavgidromet Uzbekistan, author of 30 publications. Specialist in the organization and functioning of system for monitoring the natural environment. Author of year-books on estimation and quality of water resources and efficiency of water protection measures. Focal Point GEF.

Dr. Faina Rubinova (Engineering) - leading researcher of the Hydrology Research Department of SANIGMI, hydrologist, specialist in estimation of man-made influence on river flow and hydrological regime. Author of 5 monographs on estimation of flow and hydro chemical regime of the Central Asian rivers. She has more than 100 publications.

Olga Smolkova - head of the Water Surface Monitoring Laboratory of the Department of Pollutant Monitoring, Glavgidromet Uzbekistan. Author of year-books on estimation and quality of water resources, author of 20 publications.

Regional Cooperation

The present project allowed the experts from the five republics of Central Asia to develop a standardized methodological manual, which can be immediately applied to updating the national monitoring systems and so provide compatibility and reliability of the water quality data in the Aral Sea basin.

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Dr. Vladislav Talskikh (Biology) - head of hydrobiological laboratory, Department of Monitoring, Glavgidromet Uzbekistan, has 30 scientific works on hydro-biological monitoring, evaluation and classification of water surface quality, including the handbook on hydrobiological monitoring of freshwater ecosystems, author of Hydrobiological year-books.

Dr. Galina Tolkacheva (Chemistry) - head of Department of Research and Forecasting of Natural Environment Pollution (SANIGMI named after V.A. Bugaev), specialist in migration and transformation of pollutant in natural environment, author of more that 70 publications in ecology.

Project Summary

Purpose of Project

The objective of the project was for a group of specialists from all five republics of Central Asia to prepare recommendations on the development and updating of a single interstate system of monitoring surface water quality for the Central Asian region. To accomplish this goal, the group also was tasked with the following:

- identifying the structure of the monitoring system
- preparing a list of indicators
- unifying the region's existing programs and determining which methods to use for sampling and analysis of water quality indicators

Project Results and Findings

The project inventoried each country's monitoring stations for surface water quality in the region, identified the problems in their operation, completed an in-depth evaluation of water quality and zoned the basic water catchment areas by water quality.

Based on the group's recommendations, a plan for a regional monitoring system was developed which will determine the basic methods and rules for it's operation.

The network of stations to be set up for regional monitoring will be based on the existing national systems and will take into account both the interests of international surface water quality management and of all the countries in the region. Development of the monitoring system was aimed at:

- the unification and standardization of the methods and procedures of testing and sample analysis
- integration of the interpreted data into diverse subsystems of monitoring
- improving and updating the survey programs, taking into account that the situation has changed since they were first developed
- searching for data exchange options
- improvement of software

Taking into consideration the requirements for a regional monitoring system, a list of stations was made and the corresponding apportionment of territory to be covered was determined, thereby defining a structure for the monitoring network. The regional monitoring system

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includes 43 water bodies and 77 points or monitoring stations. This information was presented in the form of a diagram and a list of monitoring stations and their specifications. The list of stations and the structure for the monitoring network were discussed with, and agreed upon by, the researchers representing the five Central Asian Republics on the project.

Through the analysis of pollution sources (point and non-point) as well as available data on the content of pollutants in the water bodies of Central Asia, a list of compulsory (basic) indicators and secondary indicators for monitoring the composition and properties of water was determined.

Four types of programs were developed for monitoring the composition and properties of water and the conditions in the water bodies of the Aral Sea basin:

1. A program for defining the characteristics of water quality. By using a standardized method of measurement, this program will produce compatible data on the basic indicators of both water composition and properties and pollutants throughout the region.

2. A program to survey the quantity of pesticide residue in the surface water of the Aral Sea Basin. Agriculture in the Central Asian states makes wide use of a diversity of pesticides.

3. A program of hydro-biological monitoring, which is an important element in assessing the quality and condition of surface water. Hydrobiological monitoring is the cheapest type of monitoring and is an integral part in surveying the condition of water bodies and streams. It will allow for the evaluation of not just the pollutant content of the water but also the corresponding response of water life.

4. A program to survey the pollutants, mainly pesticides, in bottom sediments. This is a new program for evaluating the pollutant balance in water bodies.

In addition, a program is proposed for monitoring, when necessary, the sections of water bodies which are not included in the regular monitoring regime (e.g. in order to obtain water quality data under an emergency situation) and for monitoring the water bodies and streams to determine and specify the location of monitoring points and survey gauges.

From the process of analyzing the existing methods of monitoring and the capacities of the laboratories, some standardized methods of analysis for the indicators of surface water composition and properties were recommended. The list of methods and procedures were agreed upon by the researchers from all five republics and arranged in the form of a "Manual on Methods..." which was passed to all five hydrometeorological services of the Central Asian Republics.

The following regulatory documents were dispatched to the researchers in each republic in the course of the project implementation:

basin's regional water quality monitoring network

- recommendations on the methods for hydro-biological monitoring of the water bodies of the Central Asian region

- methodological procedures, to control the accuracy of the surface water polluter indicator measurements

If the requirements and recommendations found in these above-mentioned documents are followed, the resulting data will be compatible across the region and the data's quality will be guaranteed. Application of a single computer program to set up a data base and data processing is envisaged in order to process and synthesize survey results.

The complete report includes specifics on all recommendations.

Policy Recommendations

A regional monitoring system is of international importance. Its efficient operation will depend on the presence of a regional coordination center, technical maintenance of the network, development of curriculum and training, agreements on data and information exchange and analysis at both national and regional levels, and sufficient funding.

Therefore, it is necessary to develop a legal and economic framework on which to set up a regional monitoring system. Technical assistance from donor-countries in the form of equipment for the network and personnel training is also needed.

Taking into account the difficult economic situation of the newly independent countries of Central Asia, the problem of funding the regional monitoring system must be resolved. In this connection, some policy decisions should be made at the government level and by the heads of hydro-meteorological services, with possible assistance from the Executive Committee of the Interstate Council on the Problems of the Aral Sea (ICAS), on signing the following interstate agreements or protocol on the following topics:

- status and operation of the regional monitoring system
- funding amount and options
- data exchange guidelines and procedures

In addition, a regional coordinating center must be set up to work on eco-analytical, methodological and information issues such as:

- the organization of an external control system, independent of governmental jurisdictions

- development of and updating of methods to determine the indicators of water quality

- control over the quality of analytical procedures

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- preparation, publication and distribution of information on water quality in the region

The basis for any interstate agreements shall be the Nukus Declaration (September, 1995) which was signed by the heads of the five Central Asian states and envisages "development of a regional system of control over the environmental situation, especially of water resources, and setting up of a system of compulsory information exchange on environmental monitoring.

The conclusions, findings and recommendations can be used for implementation of the projects (2.1, 3, 4, 6, 7) of the "Program of Concrete Actions on Improving the Ecological Situation in the Aral Sea Basin," developed by the World Bank.

Potential Project Impact

The reliable, accessible information on water quality which will be obtained through this regional monitoring system will help avoid many potential conflicts in operating the transboundary water streams and water reservoirs.

The operation of regional monitoring will permit:

- the obtainment of unbiased and compatible information on surface water quality in the Aral Sea basin.
- the development of a common data base on water quality and the ecological state of the regional water bodies, for implementing an effective interstate water protection policy in the region.
- economically feasible decisions to be made on the distribution of water resources according to its quality, and on the basis of accurate and current information.
- priorities to be identified and adequate programs for water quality management to be designed. This will help financial and technical resources be used more effectively to solve the most pressing problems in restoring water quality, which in the long run will prevent negative effects on human health.
- the evaluation of the efficiency of the policies and steps undertaken to improve water quality and rehabilitate ecologically unfavorable water bodies in the region.

Organization of the regional monitoring system will serve to preserve, restore and further develop the national monitoring systems as well as raise their methodological level.

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Environmental Policy and Technology Project

Contract No. CCN-0003-Q-00-3165

NEW INDEPENDENT STATES

FINAL PROJECT REPORT SUMMARY

Assessment of Water Management's Impact on the Syr Darya's Tributaries (Within Kazakstan)

Applied Demonstration Project No. 4

Nekipelova L.K., November 1996

Delivery Order 08, Task B

Prepared for:
Central Asia Mission
U.S. Agency for International Development

Prepared by:
Central Asia Regional Office in Almaty, Kazakstan
Environment Policy and Technology Project
For the New and Independent States of the Former Soviet Union
A USAID Project Consortium of CH2M HILL

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Summary Report

Project Purpose and Scope

The purpose of this project was to assess the water management impact on the flow the Syr Darya River's tributaries, within the territory of Kazakstan, and to restore natural flow values by different methods.

Project Results and Findings

Based on the assessment of human impact on the Syr Darya River's tributaries within the Kazakstan territory, the following conclusions could be made:

- The highest decline in flow, caused by man as opposed to a natural decline, occurred on the Arys River after the introduction of the Arys Channel, with an average decrease of 55% (80% in dry years and 35% in wet ones).
- In the Keles and Bugun' river basins there were no significant anthropogenic changes found within the observation period resulting from an unchanged level of human activity.
- In the Shayan River basin human impact is not significant.
- The results of the three applied methods for assessing anthropogenic changes in river flow and flow restoration to those under natural conditions (statistical, water balance and mathematical modeling methods) were similar. This confirms the validity of the results obtained and the possibility of using the restored rows in hydrologic estimates.
- Given the decline in the quality of hydrologic observations, the KazNIGMI mathematical flow model should be considered as the most acceptable and promising method for natural river flow restoration and assessment of human activity impact on water resources.

The main tributaries of the Syr Darya River are the Arys, Keles, Bugun and Shayan rivers, located on the right bank part of the basin on the south-western slope of the Karatau range and the western part of the Talassian Alatau. The rivers are mainly fed by melted snow waters. The share of rainfall, ground and glacier input is considerably lower. The largest part of the annual precipitation occurs in winter and spring. Snow cover used to be unstable and is retained mainly on northern exposure slopes. The major volume of the flows occurs during the period from February to May. Agriculture is known to be the main water user in the area.

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The Arys River is the second place for the catchment area in the examined region. The catchment area of the basin is 14900 km^2 with a prevailing western orientation. There are about 300 main and on-farm channels within the Arys River basin. The major part of the water consumed is used for regular and estuary irrigation. The area of irrigated farmlands makes up about 50 thousand hectares, and the area supplied with water, about 435 thousand ha. In 1965, the Arys Main Channel was put into operation with a release capacity of 45 m^3/s.

The Keles River basin down to the Akdjar node (catchment area of 1960 km^2) is comprised of 80 main channels. The Bugun River basin, down to the Krasny Most village (catchment area 2160 km^2), is comprised of 20 main channels. The irrigated territory is 50 thousand ha and the water supply area, 420 thousand ha. Within the Shayan River basin, down to the node 3.3 km below the Akbet River estuary (catchment area about 485 km^2), water related activity is low with only one channel being operated.

For southern Kazakstan, with a typically dry climate and water restraints, assessment of the water management activity impact on river flows is extremely topical. The problem is complicated by the fact that most rivers of the region are subject to intensive human impact. Under these circumstances, the task of river flow forecasting and the development of hydroengineering facilities and irrigation systems become even more complicated. In order to overcome these difficulties, it is necessary to restore the natural river flow, making it available for hydrological forecasts, estimation of construction parameters and more substantiated water planning and management.

Project Methodology

As a methodological foundation for the assessment of water management impact on water availability in the rivers and river flow restoration, one of the standard statistical assessment methods, the linear trend method, was used, as well as a simplified channel balance equation method. We also used an improved conceptual mathematical model of mountainous river flow formation, developed by the Kazak Hydro-meteorology Scientific Research Institute (KazNIGMI, which is presently known as KazNIIMOSK) under the guidance of V. V. Golubtsev. The model was successfully adapted to a number of mountainous rivers of Kazakstan. The model was also used for water resource vulnerability assessment under the possible impact of anthropogenic changes of climate, implemented under the joint Kazak-American Country Studies Project.

In the KazNIGMI model, a river basin is represented as three sequentially connected reservoirs, located one above another and identified as surface water, deep and shallow groundwater sources, and another reservoir, characterizing flow formation within the hydrographic network. The model includes a description of some elementary water balance processes such as snow stock formation and water inflow to basin surface, changes in water stock, freezing and thawing of soil and grounds, total evaporation, surface water, and deep

and shallow groundwater flow formation, formation of water inflow to river network, and flow hydrograph at the rear node (*i.e.* a range of models describing elementary watershed process). The basic principles of the model were elaborated in works by A. N. Vazhnov, V. D. Komarov, Yu. M. Denisov, and Yu. B. Vinogradov.

A specific feature of the KazNIGMI model is that even with limited information available, it is possible to simulate river flow from each of the altitude zones, various landscape parts of the basin and mountain slopes of different exposition. Model parameters could be changed, depending on the elevation of the area, angle and exposure of the mountain slopes, and the profile of the underlying surface (bare, forested, glacier covered, *etc.*).

The main input data used for flow hydrograph modeling were daily precipitation totals and average daily air temperatures. The data were obtained through observations at meteorological stations, located within or in proximity of the basin. The KazNIGMI flow model makes it possible to estimate water inflow to the watershed area, flow amounts during different calendar periods (10 day period, month, year), and flow hydrograph at the rear node of the basin.

During the adaptation of the model to the conditions in the basins concerned, the characteristics of the processes of the freezing and thawing of soils and grounds, snow stock formation, precipitation gradient and air temperature were assessed, depending on area elevation, dynamics of parameters throughout the year, and hydrographic and gypsographic characteristics of the basin with due consideration to the different slope exposures.

Initiation of significant flow changes was identified by plotting integral curves of the type:

$$\Sigma(Q)=\varphi(\Sigma\prod) \qquad (1)$$

$$\Sigma(Q)=\varphi(t) \qquad (2)$$

where $\Sigma(Q)$ is the incremental total of flow values from the beginning of the observation period, and $(\Sigma\prod)$ is the incremental total of simulated values of the water inflow to the surface of the basin, and t - time moment.

The statistical significance of the water management activity impact on the flows of the rivers was determined on the basis of the results of the studies of observation rows for the presence of trends and homogeneity. Homogeneity was assessed according to the criteria of Wilckokson, Fischer, Student and Z-criterion. Independence (incidence) of the initial aggregates was determined by the calculation of the autocorrelation coefficient and the Neiman criterion.

Based on the assessment of the Arys River it may be assumed, that the homogeneity and independence of measured flow data are rejected according to all the criteria of the hypothesis. To this end, significant homogeneity disturbance in the series of integral curves became visible in 1965. The disturbance was caused by the introduction of the Arys Channel into operation.

There was no trend observed in the Shayan River's flow, and the homogeneity hypothesis was acceptable according to almost all criteria, meaning that water management activity did not have a significant impact on the flow.

Integral curves plotted for the Keles and Bugun' rivers did not allow us to identify the period of distinct flow disturbance, despite a long history of water withdrawal from the rivers. A series of analogous tests offlow for the observation period revealed their homogeneity and absence of trends. Hence, it can be assume l that the anthropogenic load on Keles and Bugun' flow is of a continuous character, without pointed changes during the observation period. These conclusions are confirmed by dual integral curves plotted for the water inflow to the watershed surface of the Keles (down to the Akdjar node) and the Bugun' (down to Krasny Most village node) rivers, estimated by means of the flow model and the measured flow.

As it was indicated above, natural river flow's restoration was made by means of three principally different methods:

- A statistical method, based on linear trend method for the Arys, Keles, Bugun and Shayan rivers
- A simplified channel balance equation for the Arys, Keles, and Bugun rivers
- Modeling, carried out on the Arys River, the largest tributary of Syr Darya River within Kazakstan, and the Shayan River, the flow of which according to preliminary estimates, did not experience any significant man-made impact

Calculations based on the linear trend method has shown that the estimated flow of the Arys River has been declining since 1951, for an average value of 1.79 m^3/s annually. By 1990, it had declined by 35.4 m^3/s, or by 43% of the initial estimated flow of 84.5 m^3/s. The annual decline for the Bugun' River for the period of 1966-1990 was 0.12 m^3/s; for the Shayan for the period of 1951-1990, 0.016 m^3/s; and for the Keles for the period of 1960-1990, - 0.08 m^3/s. In relation to the initial estimated flows, the decline is 14%, 4% and 5%, respectively, remaining within flow measurement accuracy limits. Hence, statistic assessment of water management activity impact on the flows of the rivers revealed significant changes only for the Arys River flow.

Flow restoration in natural conditions by means of channel balance equation was made through summing up the difference between water intake and discharge values, based on monitoring data, and river discharge values during the flood period.

Model flow hydrographs for the Arys and Shayan rivers for the period of 1951-1990, were produced as a result of numerous experiments on the flow model, and estimations of the spring flood volume values.

Flow rows, restored by two or three methods, were subject to statistical analysis. They were examined for homogeneity, independence and presence of trend. It was revealed, that there was no trend in the rows, and all statistical evaluations (except the Fischer criterion) were within the imposed limits with a 5% significance. The values of spring flood volumes of the Arys River during the period of 1966-1985, restored by means of a simplified channel balance equation (Q_b), flow model (Q_m) and linear trend equation (Q_t) were found to be in proximity to each other. Correlation coefficients between Q_b and Q_mr = 0.95 +/- 0.02, and between Q_b and Q_tr = 0.94+/- 0.02. Hence, we may assume that natural flow restoration was made with sufficient reliability, and the flow rows could be used for estimation of the various hydrologic characteristics and water availability forecast.

Assessment of flow changes, caused by human impact, has shown that the highest changes were found in the Arys River flow. According to the data obtained through the flow model, the average decline amounted to 37%. At the same time, water withdrawal during the period of 1951-1964 was substantially lower at only 5%. After the Arys Channel was put into operation, the volume was increased up to 55%. Flow changes assessment through channel balance equation, decline thereof amounted to 38% in average, and for the indicated periods - 8 and 54%, respectively. Measured flow values as compared to the ones calculated by linear trend equation, were on average lower by 40%, and for the periods of 1951-1964 and 1965-1990 by 13 and 56%, respectively.

The restored and measured Shayan river discharge values have good similarity. The average water discharge for the period of 1951-1990, calculated through the flow model was 5.36 m^3/s, linear trend equation, 5.58 m^3/s, and according to the hydrometric monitoring, 5.30 m^3/s, confirming insignificant water management impact on the Shayan River flow.

Anthropogenic changes in the Keles and Bugun' rivers' flow were relatively low. Calculated by two methods, the average decline was 5-6% for the Keles River (20% in dry years, 1-2% in wet years) and 11-15% for the Bugun' River (50% in dry years, 1-2% - in wet years). There were no trends found in these changes.

Taking into consideration the substantial man-made changes in the Arys River flow, a method was developed for the calculation of water intake volumes, depending on the water availability of the year.

Practical Recommendations and Applications

The following recommendations can be made:

- With the current massive consumption of water in the southern regions of Kazakstan, surface water evaluation should begin with the identification of river flow, which is subject to anthropogenic impact, as it was made under the project. This would avoid significant errors

being made during water management planning and forecasting, as well as in the construction design process.

- The restored flow rows could be used in the development of water availability forecast methods, based on regression schemes, where the stationary character of the rows is of fundamental importance.

In general, the results of the study could be used for and by:

- solution of water and water quality management tasks for the establishment of optimal water use and consumption regimes in the basin of right-bank tributaries of the Syr Darya River within the territory of Kazakstan

- planning for the agricultural lands used for grain and technical crops, the dimensions of irrigated areas, and the water use regimes in years with different water availability

- hydrologic and environmental scientific-research institutes, ministries and committees responsible for water quantity and quality monitoring, water allocation and use (i.e. Ministry of Ecology and Bioresources, State Committee for Water Resources, Kazak Hydrometeorological Survey), as well as design institutes, for carrying out engineering and hydrological calculations for construction design of hydroengineering facilities in the area

- implementation of multipurpose optimization model for water allocation in the Aral Sea region (RIMDESS)

Policy Recommendations:

Project results could be used on:

- the national level for substantiation of population numbers and the elaboration of a concept for employment of manpower which is required for the development of industrial capacities of the region

- the regional level for the development of interstate agreements between Kazakstan and Uzbekistan on water sharing in the Syr Darya River basin

Potential Project Impacts and Regional Cooperation

Results of the work were used by KazNIIMOSK for the development of water availability forecast methods for the Arys, Keles, Bugun' and Shayan rivers, and are currently being used by the Kazak Hydromet Survey in their water availability forecasts, both monthly and during flood periods. The introduction of corrections on the anthropogenic impact into the prognostic values, allowed the State Committee for Water Resources to correct water management activity accordingly.

The main conclusions of the research were reported at the Third Joint Conference on hydrologic and hydrogeologic problems of environment protection, named "Water as Critical Resource: Problems of Conservation, Use and Management" (September 22-26, 1996, Tashkent) and were recommended for publication in the Proceedings of the Conference. Practical orientation of the studies and the obtained results could assist water management experts in other countries to take them into consideration and make appropriate adjustments.

The mathematical model for river flow's formation made by KazNIGMI and used for the assessment of the impact of human activity on the water availability in the rivers and flow restoration in natural conditions, is a universal one and could be successfully applied for the same purpose on other water bodies of the Aral Sea basin.

The project is closely linked with ADP on "Probability Forecast for Aral Sea Levels" since data on the flow of the Syr Darya tributaries below the Chardara Reservoir, is used for the forecasts of water inflow to the Aral Sea and the level of its separate parts

Acknowledgements

The authors would like to express their appreciation to:

The United States Agency for International Development for their support in carrying out the research, in particular Nina Kavetskaya, program specialist. They also are thankful to Paul Dreyer, regional director of the Environmental Policy and Technology Project, Dr. Gregory Lassitor, operations coordinator; Barbara Britton, policy advisor; Bryan Bushley and Alexandra Terninko, program specialists; and Timothy Bondelid and Peter Iliev, authors of RIMDESS, for their help with the organization of this project.

A. Shamen, head of Kazgidromet, and P.Zh. Kozhakhmetov, head of Weather Bureau of Kazgidromet, for providing us with the necessary information.

The State Hydrological Institute (Russia, Saint-Petersburg), for its consultations, reports and discussions during the international conference organized by the USAID in 1996, which were important in the work of the project .

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Dr. V.V. Golubtsov (Geography) - lead researcher of KazNIIMOSK, co-developer of the model of mountain river flow hydrograph and working-out of evaluation of climate changes influence on water resources of Kazakstan.

Dr. V.I. Li (Engineering) - lead researcher of KazNIIMOSK, co-developer of the model of mountain river flow hydrograph and author of working-out of evaluation of climate changes influence on water resources of Kazakstan.

V.P. Popova - Researcher of KazNIIMOSK, the developer of methods of forecasting of natural and consumer flow of Arys, Keles, Bugun, Shayan.

T.P. Stroeva - researcher of KazNIIMOSK, co-developer the model of mountain river flow.

Environment Policy and Technology Project

Contract No. CCN-0003-Q-00-3165

NEW INDEPENDENT STATES

FINAL PROJECT REPORT SUMMARY

"Evaluation of the Influence of Falling Aral Sea Levels on Precipitation in Adjoining Territories"
Applied Demonstration Project No. 5

By Vlasenko E.F., December 1996
Delivery Order 08, Task B

Prepared for:
Central Asia Mission
U.S.Agency for International Development

Prepared by:
Central Asia Regional EPT Office in Almaty, Kazakhstan
Environmental Policy and Technology Project
For the New Independent States of the former Soviet Union
A USAID Project Consortium Led by CH2M Hill

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Summary Report

Project Objectives and Scope

The objectives of this project were:

- To assess the influence that the drying of the Aral Sea has on precipitation over the Aral Sea, the Syr Darya River, and nine of the main grain-producing oblasts of Kazakstan: Torgai, Kostanai, North-Kazakstan, Kokshetau, Akmola, Karaganda, Pavlodar, Semipalatinsk and East-Kazakstan.

- To work out recommendations for the efficient use of the results in the practice, policy and management of water resources.

For this project the following data and information from the last 35 years (1961 - 1995) were used:

- Elevation of Aral Sea water level

- Monthly amount of precipitation from January to December at 22 stations: Torgai, Kostanai, Zhetygora, Petropavlovsk, Kokshetau, Akmola, Atbasar, Karaganda, Bayan-Aul, Pavlodar, Irtyshsk, Semipalatinsk, Kokpecty, Bachty, Ayaguz, Ust-Kamenogorsk, Zaisan, Aral Sea, Barsakelmes, Kazalinsk, Uyaly, Kyzyl-Orda

- Daily weather and thermobaric charts below 5 km elevation, for 1,453 cyclonic occurrences over the sea

Major Results and Findings

Statistical analysis revealed that approximately the same number of cyclones occur in winter and in summer. The distribution of precipitation over the territory of Kazakstan has been studied in this project only during the warm period of the year because of the shortening of the project term. The number of cyclones have been calculated by months and five-year periods. The number of cyclones that move deep out over the Aral Sea was also determined, but it is impossible to say anything definite about the differences in cyclone movement deepening of cyclones over the Aral Sea in the summer period, because these cyclones have not been studied in the winter period. All cyclonic formations have been investigated as they are one of the main elements of the whole atmospheric circulation and the precipitation supplier.

The Aral Sea, due to its geographical location, has an important role in precipitation redistribution not only within the coastal area, but far from its location. It was determined that in the summer period, the Aral Sea water level decline alters the development of global atmospheric processes over the territory of Kazakstan. The mechanism of this alteration lies

in the fact that because of the change of the sea volume and area in the Turansky lowland, a new additional extensive source of warmth has appeared. As a result, the occurrence of cyclones bringing precipitation decreased, especially since 1981. Their paths moved to the north and south of the Aral Sea area, as if to go around the place of warmth. But the cyclones that occur over the Aral Sea have greater speed than before, and move mainly from the southwest to the northeast which differs from the preceding processes. In early years, the cyclonic formations occurred over the sea, moving slowly, developing, and filling with moisture and evenly bringing precipitation to regions of the Republic, north, east and south of the sea location. The number of "dry" cyclones increased after 1981. Such atmospheric processes lead to an increase in the number of days with clear weather in the latitudinal Aral Sea zone and to an increase in the temperature of the air and water, an increase in wind speed, air dryness and evaporation, all of which makes the climate of the middle latitudes become drier.

The following findings serve as one evidence that the drying of the Aral Sea has an effect not only on precipitation changes over the sea and within 100 km of the coastal area as was mentioned in the preceding investigations, but also has an effect far away in the northern, north-eastern and eastern crop producing oblasts of the Republic. They are:

- The amount of precipitation over the Aral Sea and west Kazakstan has decreased. It is best manifested at the meteorological station of Uyaly, located on the south-eastern shore of the Aral Sea, where the trend of precipitation in April was zero.

- The precipitation in the eastern crop producing oblasts is about 30% of the average long-term value.

- There is a tendency for precipitation increases of up to 55% of the average long-term value in the northern and northeastern oblasts, due to the occurrence of the cyclones in these regions.

Thus, the drying of the Aral Sea can be linked not only to the water intake from the Amu Darya and Syr Darya rivers, but to the climate changes in Kazakstan. Certainly, the main cause of the drying of the Aral Sea belongs to the reduction of the water flow from the rivers. In 1961 the rivers brought 56 km3/year into the sea and 9 km3/year was the share of precipitation which fell into the sea. This precipitation share is now 14% of the total moisture source for the sea which is why the precipitation change shouldn't be ignored, especially when the river flows into the sea have decreased to 4 km3/ year. The drying of the Aral Sea results in changes in the development of the atmospheric processes over the Sea, and it in turn results in climatic changes, specifically the changes in distribution of precipitation over the wide area of the Republic. The strengthening of control measures against the desertification of the Aral Sea latitudinal zone, is required.

Conclusions

Based on the findings and results above, the following practical conclusions can be suggested:

- In the coming years the agricultural economy of the country will be as vulnerable as before and the risk of drought will persist at the same level as the last two decades. If the total amount of precipitation is retained at the same level in the northern, central and eastern regions and the climate in these regions grows mild, agricultural management is expected to change. It is necessary to expand the areas under cultivation and to provide education on winter crop sowing.

- The role of snow in agriculture will change. As a result of the climate growing milder, spring crop sowing should be done earlier. Thus, snow will be used for dampening soil as well as surface drainage.

- The vulnerability of agriculture will increase at the border of the zones of Central Kazakstan, namely the Zheskazgan, Karaganda and Torgai regions, which could become more arid zones.

- The reduction of the amount of precipitation in the Aral Sea zone will persist and evaporation will increase. Therefore, even if the Aral Sea were to be completely filled today, the process of evaporation would continue even more intensely for some years before the process of the total circulation would become stable and as it was originally. That is why, at present, the rehabilitation of the Aral Sea is most likely unrealistic.

Practical Application

The information obtained about the changes in the northern, northeastern and eastern oblasts, and the Aral Sea region can be used for the program RIMDESS to design pricing policy, water preservation, and distribution of water use in different economy sectors, such as municipal services, industry, agriculture, hydraulic power engineering and river transport.

The project findings and conclusions can best be used by the enterprises, amalgamations, companies and organizations engaged in agricultural production as this sector is the most affected by the changes of climate and weather conditions. As a result, the implementation of new technologies and methods of agricultural management may be required. The agricultural sector of Kazakstan has always been vulnerable and the question now arises as to whether it will become more vulnerable, which could lead to a decrease in agricultural production.

Political Recommendations:

The following recommendations are given:

- The results, obtained under this project, should be used in the RIMDESS Program in order to assess the political scenario of the water resources management and in the "Program on Concrete Actions for Improvement of the

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Aral Sea Basin Environmental Situation in the Coming 3-5 Years, With the Consideration of the Social and Economic Development of the Region." This program was adopted in accordance with the fulfillment of the Nukus Declaration worked out by the Central Asia States and international organizations, and deals with the problems of sustainable development of the Aral Sea Basin.

- It is necessary to inform the administrative agencies and population about the changes of climate and their effect in different regions of the country. Two to three articles can be prepared on the basis of this project.

- As a result of the climatic changes, an urgent necessity has emerged to establish both local and national public committees to investigate and give explanation for the new situations in ecologically unhealthy zones.

- Controlled population migration is needed. For example, it is necessary to move part of the population from the Aral Sea zone to the environmentally healthier regions with almost the same climate characteristics, e.g. to Torgai, Akmola and other regions.

Potential Impacts

The project's potential impacts are as follows:

- The results of the project concur with the findings of the probability forecast about the temperature and precipitation changes in Kazakstan up to 2010, including global, man-made influences. It was worked out in the climate department of the Kazakh Research Institute (КазНИИМОСК) in 1995. The tendencies obtained under the project reveal the physical mechanism contributing to the climatic warming in Kazakstan and during the time of global warming. This information can be useful not only to research institutions dealing with the Aral Sea problems, but for all institutions and enterprises affecting or affected by the problems of the Aral Sea.

- The obtained findings can have an influence on the answering of controversial questions, which arise during assessment of the direction of change in the water balance of the Sea and river flow.

- The project results were presented at the Third International Conference CIS-USA "Water is a Critical Resource: Problems of Conservation, Use and Management," held in Tashkent September 22-29, 1996.

- A research article has been prepared on the the results of the project work, to be published in a research magazine.

- Taking into consideration the great importance of the Aral Sea's interaction

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with the environment, it is necessary to carry on with the research investigation of the development tendencies of the atmospheric processes during the winter period, as it was determined during the project work that these processes have also changed. The increase in the amount of cyclones in the winter period can contribute to the rise of winter temperatures and to the increase of the precipitation amount. This, in its turn, will replenish Syr Darya waters, because thaw waters are the main water source. The proposed method is a good start for future investigations in case the territory under study is expanded and provided additional information is gathered and used.

Regional Cooperation

There were useful exchanges of opinions and information at the seminars and discussions during the project work. The work results were submitted and discussed at the joint seminar devoted to the Aral Sea problems, held in the Central Asia Hydro-meteorological Institute in September, 1996, where the hydrology and weather forecast departments took part as well. This issue was discussed, also, at the ADP executors' meeting, organized by USAID in October, 1996.

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Environmental Policy and Technology Project

Contract No. CCN - 0003 - Q - 3165

NEW INDEPENDENT STATES

FINAL PROJECT REPORT SUMMARY

"Probability Forecast for Aral Sea Levels"
Applied Demonstration Project No. 6

Shivaryova S.P., September 1996
Delivery Order 08, Task B

Prepared for:
Central Asia Mission
U.S. Agency for International Development

Prepared by:
Central Asia Regional EPT Office in Almaty, Kazakstan
Environmental Policy and Technology Project
For the New Independent States of the Former Soviet Union
A USAID Project Consortium Led by CH2M HILL

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Acknowledgements

Paul Dreyer, Barbara Britton, Brian Bushley, Alexandra Terninko, and **Tim Bondelid**, all of Environmental Policy and Technology Project, USAID
Nina Kavetskaya, USAID
Atamurat Shamen, the head of Kazgidromet
Amirkhan Kenshimov, State Committee on Water Resources of the republic of Kazakstan;
Nikolay Gorelkin, SANIGMI of the Republic of Kazakstan.

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1) "USSR's Seas" project; Hydrometeorology and hydrochemistry of USSR's seas.
Volume VII. Aral Sea, Leningrad, Gidrometeoizdat 1990

2) "Hydrological Problems of the Priaralie." The results of the Project was published in "Hydrology and Ecology" magazine of Kazgidormet, No.3, 1996

Boris Afanasievich Smerdov - project researcher, works at KazNIIMOSK, has 10 publications on level regimes of the Aral Sea, successfully models sea levels on a personal computer. Mr. Smerdov developed the program "ARALUR" for calculation of the sea level and took part in expeditions to the Aral Sea. The results of the project were reported at the CIS - USA conference "Water - Critical Resource: Problem of Preservation, Use and Management," Tashkent, October 1996.

Elena Vladislavovna Bolshakova - project researcher, engineer at TSAI (The Center of Automate Information), has 10 published articles on estimation of economical activity influence on water resources of Kazakstan.

Summary Report

Purpose

The purpose of the project is to develop a scientifically-based probability prognosis for the level of the Aral Sea, including both the big and small seas. The project includes three stages: development and perfection of the author's program for estimating the Aral Sea levels, preparation of files containing archive hydro-meteorological information, calculation of model parameters and creation of a probability prognosis.

Project Results and Findings

With the help of the "ARALUR" program, the future Aral Sea levels modeling has been made. The level calculations were made based on the observed combination of natural water levels, evaporation and precipitation for the period of 1932 - 1994. The selected data is representative for average long-term conditions. The model includes:

- methodology for an estimate of evaporation from water and snow-ice Sea surfaces
- methodology for calculating the amount of atmospheric precipitation falling in the Sea area
- calculation methodology for the Amu Darya and Syr Darya rivers, including water amount differences for the whole extent of the river and amount of water flowing into the Sea
- calculation methodology for the levels of the Aral Sea, including the separate levels of the big and small seas

Level modeling was made for four types of anthropogenic pressures in river basins. The results of calculations showed that it is possible to make the Aral Sea a single water body with a level of 44 m, if beginning in 1996 and continuing for 50 years, the man-made impact on the Aral Sea would not exceed that of the period before 1960.

It is quite doubtful that in the near future, even with the years of abundant water, it will be easy to cut down consumptive water use in the river basins. If the man-made impact in the Amu Darya basin is retained at 23.7 km^3 and in the Syr Darya basin at 9.68 km^3 annually, the irrigation level in the seventies, then the Small Aral level might be kept on the existing check point of 40.2 m, but the level of the Big Aral will continue to fall down. The Big Aral will split into two water bodies by the year 2030. This option seems to be the most workable, as in the Syr Darya and the Amu Darya basins measures to reduce consumptive losses are currently being carried out.

Hydro-meteorological files were set up to confirm the reliability of the model. The files contain monthly information on wind velocity, wind direction, air temperature and humidity, cloudiness, amount of atmospheric precipitation, and information on Aral Sea levels and the Amu Darya and Syr Darya flows.

Based on the methodology, water layers evaporated from water and ice-snow surfaces were calculated for the Small Aral in 1941-1994 and for the Big Aral in 1950-1994. The results are presented on the graph as probability (occurrence) curves. At the probability of once every hundred years, the evaporation from the Small Aral may approach, but go no lower than 883 mm, while the depth of evaporation from the Big Aral can approach but go no lower than 898 mm. The average annual evaporation from the Small Aral surface is 960 mm, and from the Big Aral, 966 mm. In abnormally cold and warm years the maximum difference in evaporation between the Small and Big Aral seas is 36 mm.

Calculated results addressing annual precipitation falling in the area of the Small Aral and the Big Aral are also presented as probability curves. Once in a hundred years 335 mm of annual precipitation is likely to fall on the surface of the Small Aral and 328 mm on the Big Aral surface. Precipitation proposed to be the norm corresponds to the theoretical curve of 50% probability. For the Small Aral it makes up 194 mm a year and for the Big Aral, 174 mm a year. Average long term precipitation for the Small Aral was 198 mm for 53 years, and around the Big Aral, 181 mm for 43 years. This amount is very close to the norm. During the last decade atmospheric precipitation exceeded the norm seven years out of ten. 10-20 mm more precipitation falls in the area of the Small Aral, which is situated north from the Big Aral.

In 1987 the Aral Sea was divided into the Big and Small Aral Seas. In 1995 the difference in the sea levels reached 3.2 m. The Small Aral became a flow-through water body and the Big Aral became closed.

Water balance calculations for the Small and the Big Aral were made for the period of 1988-1994. With the Aral Sea being divided into two seas, equal in-flow and out-flow components are representative for the Small Aral's water balance. The amount of water overflow from the Small Aral into the Big Aral is the resulting figure for the water balance. In 1993 and 1994, which are considered to be years with abundant water, the water overflow was 66% of the Syr Darya flow into the Sea. The water balance of the Big Aral in 1987 - 1994 remained negative, as the water out-flow exceeded the in-flow. As a result, the water level of the Big Aral dropped from 40.5 to 36.6 m. In 1994, the recession intensity decreased because of the increased overflow from the Small Aral into the Big Aral. The highest water balance discrepancy (17.67 km^3) manifested itself in 1990, when it made up 5,8% of the Big Aral water mass which equaled 302.9 km^3 in the beginning of this year. The least discrepancy (0.06 km^3) was 0.025% of the 243.5 km^3 water volume in this part of the Sea in 1992.

These water balance discrepancies allow us to assume that the water balance calculation method is acceptable and might be implemented for calculations given the current deficiency of the Small Aral level observation data and limited information for the Big Aral.

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Application of Results

The developed model allows us to calculate sea levels, taking into account different Amu Darya and Syr Darya water diversion options. The results might be used when projecting water and engineering measures in the Aral Sea basin. The obtained sea level forecast is necessary when solving the problems addressing future strategy for population planning in the region surrounding the Aral Sea. The probability forecast might be useful for the Aral Sea regional oblast administrations, agricultural companies, water organizations, design and prospecting organizations, planning departments, scientific institutions and mass media.

Policy Recommendations

The methodology developed for the sea level prognosis is based on the quantitative evaluation of water resources and water flow losses in the river basins. Thus, it is necessary to develop some international agreements on optimal water allocation, (i.e. on the river flow volumes in the formation zone). To keep the present level of the Aral Sea, regional activities to address decrease in consumptive use are necessary. Efficient republic-level decisions to decrease water withdrawals for irrigation and energy purposes need to be undertaken. Otherwise the Small Aral will be isolated from the Big Aral, and the Big Aral will be split into two parts.

Potential Impact

Partial results of the project were used by the State Committee of Water Resources in working out Stage 1 of the Feasibility Report (F.R.) "Development of Measures for Ecological Rehabilitation of the Kazakstani Priaralye Part." The probability prognosis of the sea level derived from the project will promote a more better-founded economic estimation when working out the F.R. Stage II. The Stage-I results were presented in the International Seminar in April 1996. The scientific basis and findings were published in the journal "Hydro Meteorology and Ecology," Vol. 3, 1996. This article will help specialists to use the results in practice. Taking into consideration the great economic value of the Aral Sea and its interconnections with the environment, it is necessary to continue overall scientific hydro-meteorology and hydro-chemistry research for the Sea and its tributaries. The proposed water balance method for estimation of the sea level is a good start for fulfillment of topical sea hydro-chemistry work, in particular for working out the calculation and forecast method addressing the Small and the Big Aral salinity and pollution problems.

Regional Cooperation

The project contributed to the exchange of hydro-meteorological information and results between the Hydromets and Water Committees of Kazakstan, Kyrgyzstan and Uzbekistan. In the process of the project, a useful exchange of opinions, discussions and presentations developed at the seminars sponsored by USAID in 1995 and 1996.

Environmental Policy and Technology Project

Contract No. CCN-0003-Q-00-3166

NEW INDEPENDENT STATES

FINAL PROJECT REPORT

Water Quality Monitoring in the Epicenter of the Aral Sea Disaster Zone

Applied Demonstration Project No. 7

Bakhtiyar Zhollybekov

October 1996

Delivery Order 08, Task B

Prepared for:

Central Asia Mission

U.S. Agency for International Development

Prepared by:
Central Asia Regional EPT Office in Almaty, Kazakstan
Environmental Policy and Technology Project
For the New Independent States of the Former Soviet Union
A USAID Project Consortium Led by CH2M HILL

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Acknowledgements

The researchers express their gratitude to:

Zh. Niyazov, the owner of the car VAZ 2106, for the timely and dependable providing of car service during the water sampling time.

Ch. Abdirov, the leader of the Karakalpak affiliation, Academy of Science, Uzbekistan (AS, RU) for good project working conditions.

Paul Dreyer, Barbara Britton, Alexandra Terninko, Bryan Bushley of the Environmental Policy and Technology Project, for advice, consulting services and financial support.

Randal Kritkausky, President of the association "Ecology," for a free equipment set (HACH DREL 2000 Tool Kit apparatus set cat N 2322800, HACH DREL 2000 Tool Kit reagent Set Cat N 2352900).

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Oralkhan Turmanova, member of staff of Soil Science and Biotechnology Laboratory, Institute of Bioecology, Karakalpak Affiliation, AS, RU. She has been working in research agencies since 1986. Turmakhanova is the author of over 5 scientific articles.

Tursynay Mamutova, teacher of Chemistry, Biology, Chemistry and Ecology, Secondary school # 28, Nukus. She has been educating the younger generation since 1972. Mamutova was an organizer of students' ecological tourism. She takes part in scientific expeditions with her students involvement. Her students are environmental competition winners on the republic and town scales.

Section 1

Introduction

1.1 Background

Due to the increase of the world population, people are developing industry and agriculture in order to provide themselves with food products. As humans extract more and more chemical elements from the bowels of the earth, these activities result in crucial changes to the natural water composition.

The plowing up of the soil and washing of soluble salts changes the surface and ground water ratios. Rivers are not only natural drainage systems for water flow, but they are also forced collectors for all run-off in a watershed. Pollution of water flows and bodies affects not only the sanitary conditions of the river and water quality but also has a negative impact on humans' health.

The largest quantity of soluble salts is taken to water bodies from irrigated massifs. Because of mineral fertilizers, salts are brought together with effluent and drainage waters into water bodies and water stream flows, and pollute them.

The ecological situation in the area around the Aral Sea becomes worse with each year. Most specialists blame the worsening situation only on the decrease in the level of the Aral Sea. They start "beating bells" but ignore at this point, the role of the Amu Darya river in saving the natural resources and health of the people living in the Region.

Long ago the mighty Amu Darya River brought its curative water to the Aral Sea. At those times the mineralization of the river did not exceed 0.3-0.4 g/l and it was reputed to be the cleanest river in the world. The Amu Darya water became more salty. It was polluted with various chemical substances as the result of unreasonable development and use of the Upper Amu Darya saline lands for growing cotton and other crops. Because of the Amu Darya's hard, mineralized water, an unforeseen situation has emerged in Karakalpakstan.

1.2 Purposes

The purposes of this project are:

- The examining of water-soluble pollutant concentration in the running potable water of Nukus and the regional center of Takhtakupyr, and the analysis of irrigation water in the Kyzketken and Kuanyshzharma Canals, which are in the epicenter of the Aral Sea disaster zone
- Developing recommendatio ıs for use at the governmental national and regional levels

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1.3 Project Research

The following are the project's areas of research:

- The Kyzketken canal and Kuanyshzharma canal. They originate from the Takhiatash hydro-unit and supply drinking water to the Nukus, Kegeilinsk, Bozatau, and Takhtakupyr administrative regions and to part of the Muinak administrative region of Karakalpakstan, which is situated on the right bank of the Amu Darya delta.

- Potable water of the Nukus and Takhtakupyr supply networks, fed from the Tuyamuyun reservoir through more than 300 km-length pipelines.

1.4 Tasks of Research

The research tasks included obtaining reliable and independent information on the chemical composition of potable and irrigation water quality, both monthly and annually, the study of the regularity of the variety of chemical substances by seasons and year, and conducting investigations regarding the applicability of water for drinking and for leaching operations of saline irrigated soils.

The work was started in December, 1995, in the Laboratory of Soil Science and Biotechnology of the Karakalpak affiliate, Academy of Science of Uzbekistan with research leader Dr. B. Zhollybekov.

1.5 Methodology

Water sampling was carried out pursuant to the HACH mobile laboratory requirements. The analyses were made in accordance with the HACH requirements and recommendations and in compliance with the methodologies approved by the sanitary and epidemiological service.

The water quality parameters are evaluated according to the standards of 1994 accepted by the United States Agency for Environmental Protection, to the World Health Organization (WHO) recommendations of 1993 and the GOST (All-Union State Standard) of the Republic of Uzbekistan.

1.6 Special Considerations

The creation of a data base was planned for study of the irrigation and running water quality and open water bodies of the sourthern Aral Sea region. Since the IBM compatible computers arrived late, this goal was not achieved. The data processing, correlation of information, comparison of the analyses of all the water quality paremeters in the zone, and analysis of the impacts of the environmental crisis were all done without the assistance of a computer.

1.7 Relationship to Other Projects

In 1993-1994 monitoring research related to water quality and addressing running and irrigation water, was carried out in the territory of the Republic of Karakalpakstan. The work was done on a voluntary basis. To develop the Project the USA association "Ecology" supplied us with the field mobile laboratory HACH with the set of the apparatus (spectrophotometer, PH-meter, conductometer, titrator and others)

The results of the research were published in local scientific journals and newspapers in Karakalpak and Russian.

Section 2

Results and Findings

Potable water is a problem related to people's health. According to the WHO, 80% of all diseases in the world are closely tied with unsatisfactory quality of potable water and the breaching of sanitary and hygiene water supply standards.

A high level of salt affects vegetational and animal organisms, product quality and soil salinization, and causes boiler scales and corrosion.

2.1 Test Results

In the water running along the Kyzketken Canal, nitrate content did not exceed the maximum permissible concentration (MPC) during the whole observation period. Fluorine content did not make up the necessary norm. Si (silicon) content usually depends upon the flow quantity and season: in summer it amounts to 5-7 mg/l and in winter it is less (2-2,5 mg/l). Sulfate content in April and May, 1994 and in March, 1996, exceeded the normal amount, and the rest of the time it corresponded to MPC (Fig.1) The sulfate concentration in the summer period (June, July 1993 and July 1994) reduced to 150 mg/l.

In June, August, and November of 1993, March of 1994, and January and February of 1996, the chloride content exceeded MPC and reached 550-650 mg/l.

In the Kyzketken Canal, the water contains chlorides. During the winter months when the river is alimented by groundwater, the chloride content does not exceed MPC (350 mg/l). Actual chloride content amounted to 650 mg/l (September 9, 1993). The maximum concentration was observed in September, 1993 (650 mg/l) and the minimum in January, 1995 (50 mg/l).

Iron exceeded norms in August and September of 1993 (0,8 mg/l). The rest of the time its content was below MPC. The least iron concentration was observed in December 1993, in February 1994 and in 1995 when it amounted to 0,002 mg/l.

In July 1993 and in January 1994 Mn (manganese) indices did not exceed norms (0,2-0,7

mg/l). In all other periods they were adequate or below the standard (Fig.2). The minimum Mn concentrations were observed in July, August and December of 1993 and in February, March, August, September and December of 1994.

The copper content in the period from April, 1994 to January, 1995, exceeded the standard and reached 1,46-3,22 mg/l. The rest of the time in all the seasons, the copper content was lower than the MPC index. The least copper concentration was observed in September and December of 1993 and in February, July, August of 1994, when it amounted to 0,5 mg/l.

Polyphosphates in the Kyzketken water during the testing period were below MPC. A pH-water index is one of the most important water quality indices. It creates impact on the vital activity of water plants, firmness of element migration forms, aggressive water impact on metal and concrete. pH-water affects transmutation of biogenic elements and changes the toxicity of pollutants.

H-index of pH during the observation period (from October 1993 to July 1995) was within 7,0, and from August 1995 it made up 8,0-9,0 (Fig. 3).

Water hardness in 1993-1996, monitored monthly and seasonally, regularly exceeded the norm. The maximum hardness (up to 19 mg-equival./l) was observed in March, 1994. Water hardness is a property of natural water that depends upon Ca and Mg salt solutes. Under natural conditions, ions of calcium, magnesium and other alkaline-earth metals that provide hardness are brought in the water because of carbon dioxide and carbonaceous mineral solutes that interact in other dissolving processes. The sources of the ions are microbiological processes in soil, in watershed areas, bed loads and in waste waters of enterprises. High water hardness worsens water organoleptic properties as it makes water bitterish and it affects digestive organs.

Dry residues met the GOST (All-Union State Standards) requirements in June 1993, and in August and September 1995. The rest of the time, monitored monthly and seasonally, they regularly exceeded norms. The maximum dry residue content reached in Kyzketken was 3,5 g/l in December 1994, and its minimum content constituted 0,65 g/l. Water containing large salt amounts negatively affects growing animal organisms, affects production technology and quality of products, causes scales in boilers' shells, corrosion and soil salinization.

If potable water with high levels of nitrate, (25 mg/l - 100 mg/l nitrogen indexes), is used regularly then methemoglobin will be highly concentrated in the blood.. Nitrate ions are the components that are strictly included in drinking water control surveys and seem to be important pollution indices. The drinking water in the supply systems of Nukus did not exceed a normal amount of nitrate in all the seasons from May, 1993 to July, 1996. Maximum nitrate concentration occurred on April 25, 1994 (12,0 mg/l) and the minimum concentration (2,5 mg/l) was on March 25, 1996. Fluorine was regularly lower than the standard.

The maximum amount of silicon in potable water (6,98 mg/l) was surveyed on October 19, 1994, with the minimum content (0,08 mg/l), observed on January 24, 1995. In December 1993, November 1994, and March 1996, the sulfate concentration exceeded the standards.

The rest of the time it was always below the norm. On December 12, 1993 sulfate concentrations of ions amounted to 900 mg/l, and on July 19, 1994 was reduced to 130 mg/l (Fig.4). Overall, the ion-sulfate increases are observed in fall and winter time.

Chloride content exceeded the MPC in January, February, April, May and July 1994, and in January, 1995. The maximum chloride concentration was detected on April 5, 1994, when it reached 1160 mg/l. The minimum chloride concentration (110 mg/l) was observed in 1993,1994.

Increased chlor-ion content is maintained in fall and winter time.

Iron content reached 1,33 mg/l on August 9, 1993. The minimum iron content (0,01 mg/l) was on March 22, 1995. The rest of the time iron concentration was below the standard.

2.2 Health Issues

The study made by physicians on the territory of South Priaralye showed that the reasons for people's deaths have changed recently. Oncology and innate heart diseases, foetus loss and specific diseases caused by environment pollution have appeared. Frequency of reversible health disturbances caused by the same environment reasons has risen. These include nonspecific diseases, anomalies in physical and psychoneurosis development, breaks and complications related to pregnancy matters, etc.

From the sociological research made by the World Bank, it was found that deficiency of good-quality water negatively affects cattle productivity, people's health and labor productivity.

The Karakalpakstan residents now suffer more often from respiratory and dermatology diseases. High infant mortality rates, innate organism breaks and defects, esophagus and stomach cancer, and diarrhetic disturbances are also observed in the area.

The WHO which controls pollution of potable water, emphasizes that when children use water of 100mg/l sodiium concentrations, their arterial blood pressure rises.

2.3 Impacts

Over the years, our water quality monitoring investigations in the epicenter of the Aral Sea Disaster Zone show that because of the human, economic and other activities, negative environmental changes occur that are a threat to peoples' health and natural ecosystem conditions related to genetic funds of plants and animals. Therefore, it seems quite natural that the territory of the Republic of Karakalpakstan be declared as an ecological emergency area.

The human impacts dramatically manifest themselves in a lower river flow and in the acute annual rise of dry residuals, heavy hydro-carbonates, sulfates, chlorides, sodium and

magnesium contents.

Because of irrigation by mineralized water, the soils of the Karakalpakstan area are subject to secondary salinization. The huge cultivated area is brought out of the cultivating rotation and becomes barren.

Serious damage to the natural resources results from the Amu Darya pollution as all negative results of the basin economic activities are concentrated in the Amu Darya delta. The environment permanently suffers from the negative impact of the natural factors and human interference.

Section 3
Recommendations

The problem of supplying the people of the Aral Sea Disaster Zone epicenter with potable water of good quality, will not be solved before concrete measures addressing collector water discharge in the Amu Darya River are carried out.

Despite the fact that they are fed from the Amu Darya River, the Kyzketken and Kuanyshzharma waters get more mineralized and salinity increases the further one goes from the head of the canals.

The changing habitat in the epicenter of the Aral Sea disaster zone and the chemical pollution of potable water sources exceed the adaptive capabilities of a human and it causes negative impact on people's health.

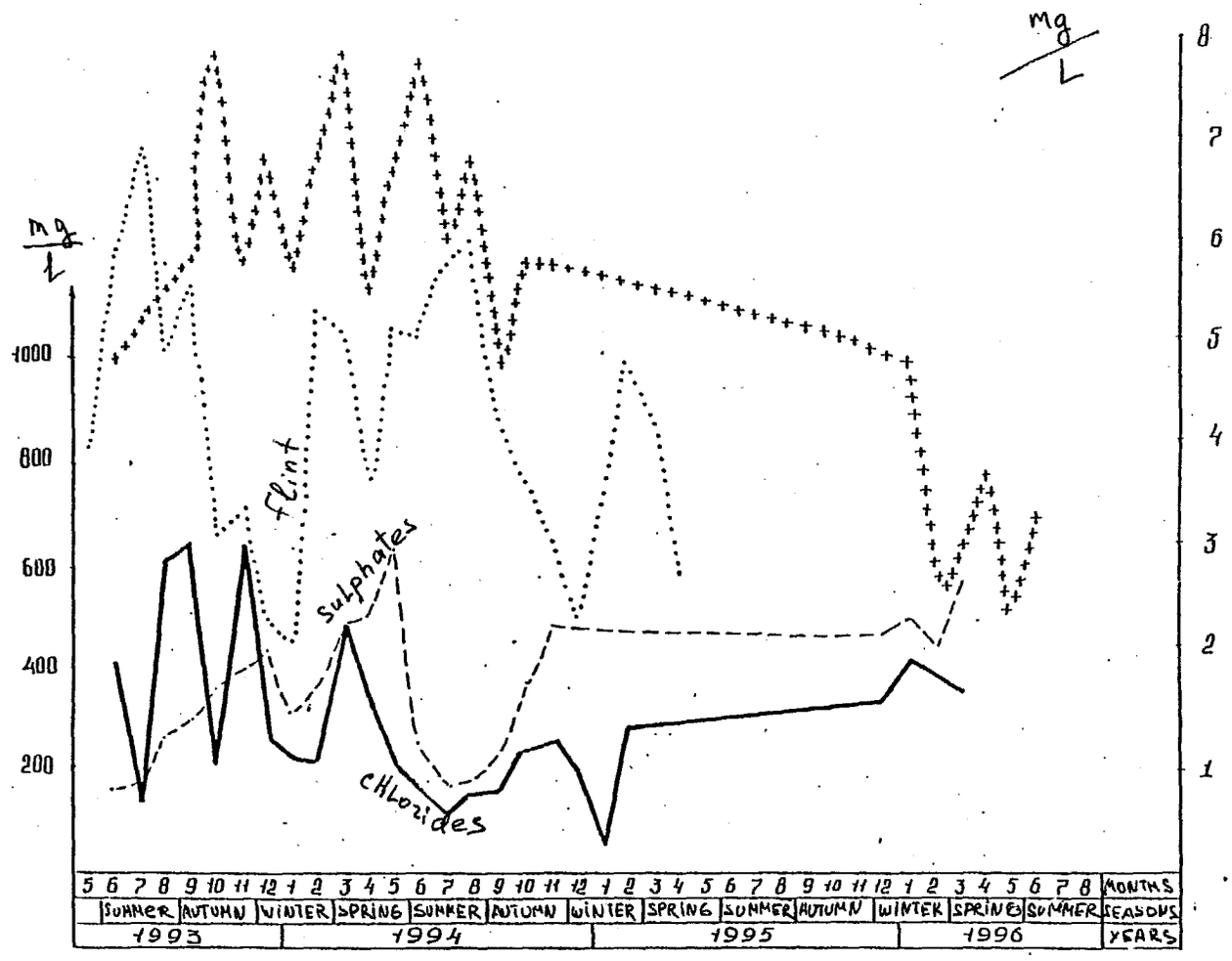
The following measures are required for sanitation of the disaster zone in the area around the southern part of the Aral Sea:

- To flatly outlaw industrial and collector-drainage water discharges into the Amu Darya channel for it's whole extent.
- To drop off and eliminate technical cropping all along the Amu Darya River's extent.
- To set special control points for analyzing and supervising water quality. The points must be stationed at every habitated locality situated near the Amu Darya River.
- To penalize (fine) all of the Amu Darya and littoral polluters. This money would be used to regulate water quality, treat people for health problems and the sanitation of the downstream environment.
- To immediately create water protection zones, consisting of 5-15 km wide protective forested areas, along the whole length of the Amu Darya River.

- To fully protect the Amu Darya River so full ecological disaster in the areas surrounding the Aral Sea may be prevented.

- To pay particular attention to the irrigation water quality when irrigation and water washing processes take place during the spring months of March, April and May and in the fall months of September, October and November when the Amu Darya water is severely polluted (dry residues, hardness, HCO_3, Cl, SO 4, Na, Mg) .

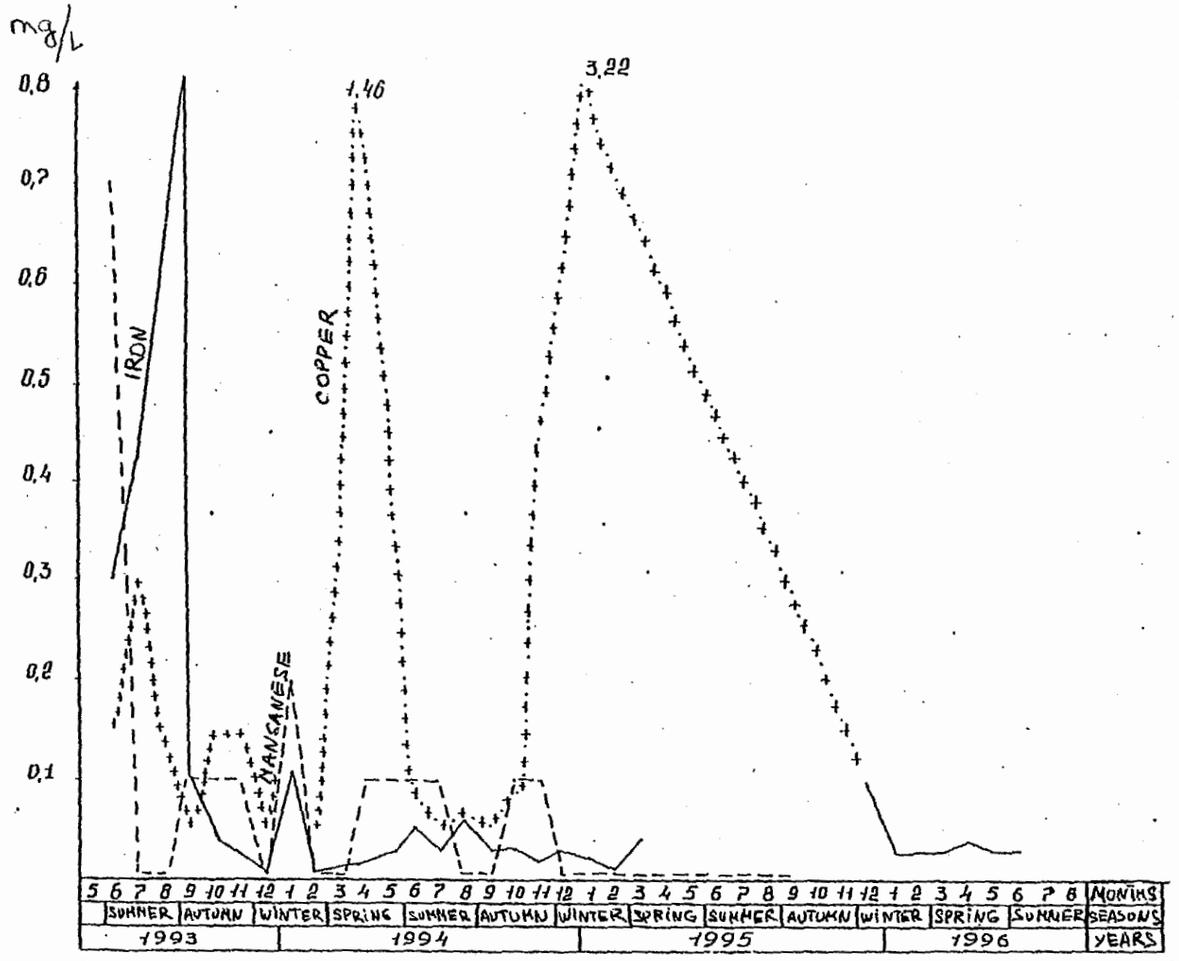
- To recommend to the people who live in the epicenter of the Aral Sea disaster zone, to use only distilled drinking water in March, April, May, September, October and November.



Monthly, seasonal and annual changes of chlorides, sulphates, flints and nitrates in Kyzketken channel water (near Nukus)

Fig. 1.

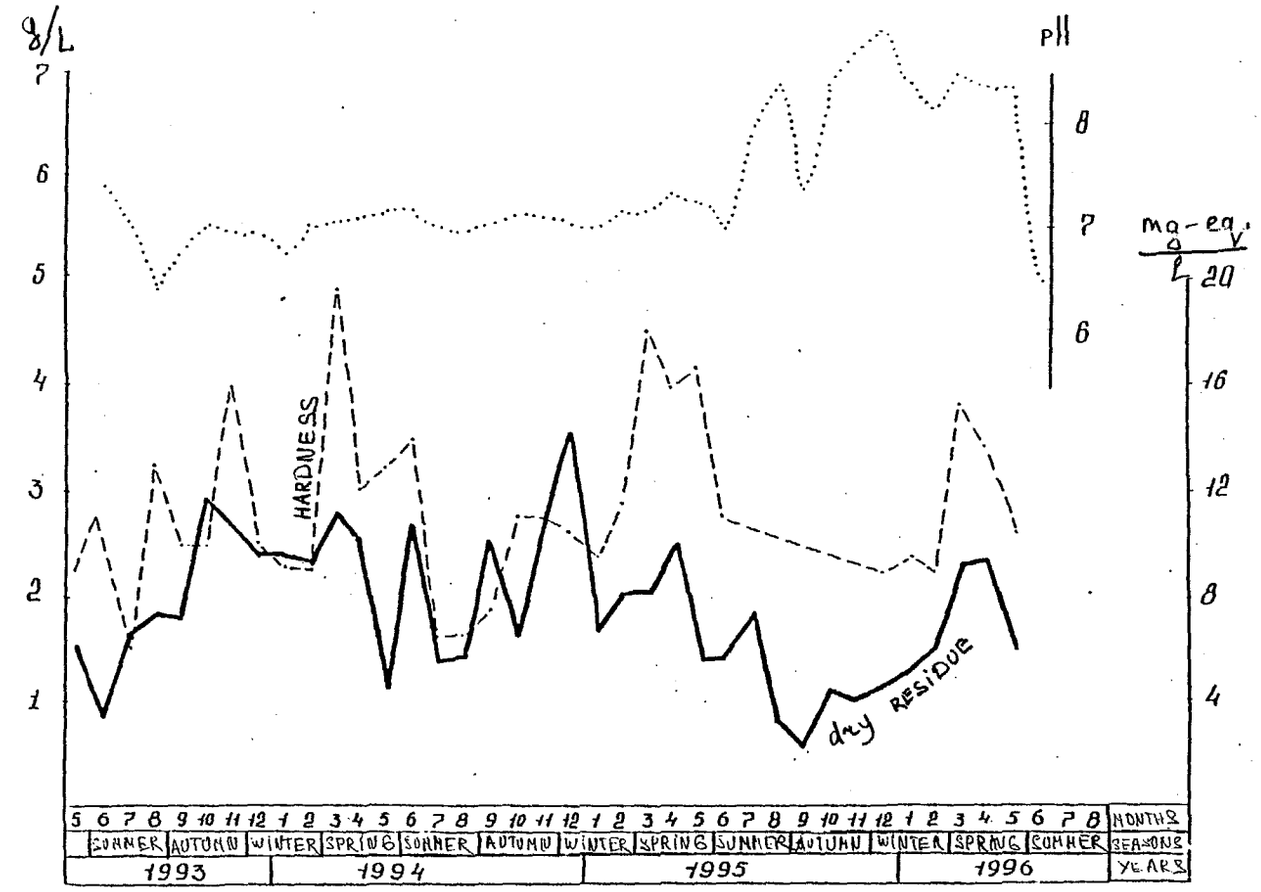
Figure 1



Monthly, SEASONAL AND ANNUAL CHANGES OF IRON, MANGANESE AND COPPER in Kyzketken channel water (NEAR Nukus)

Fig. 2

Figure 2

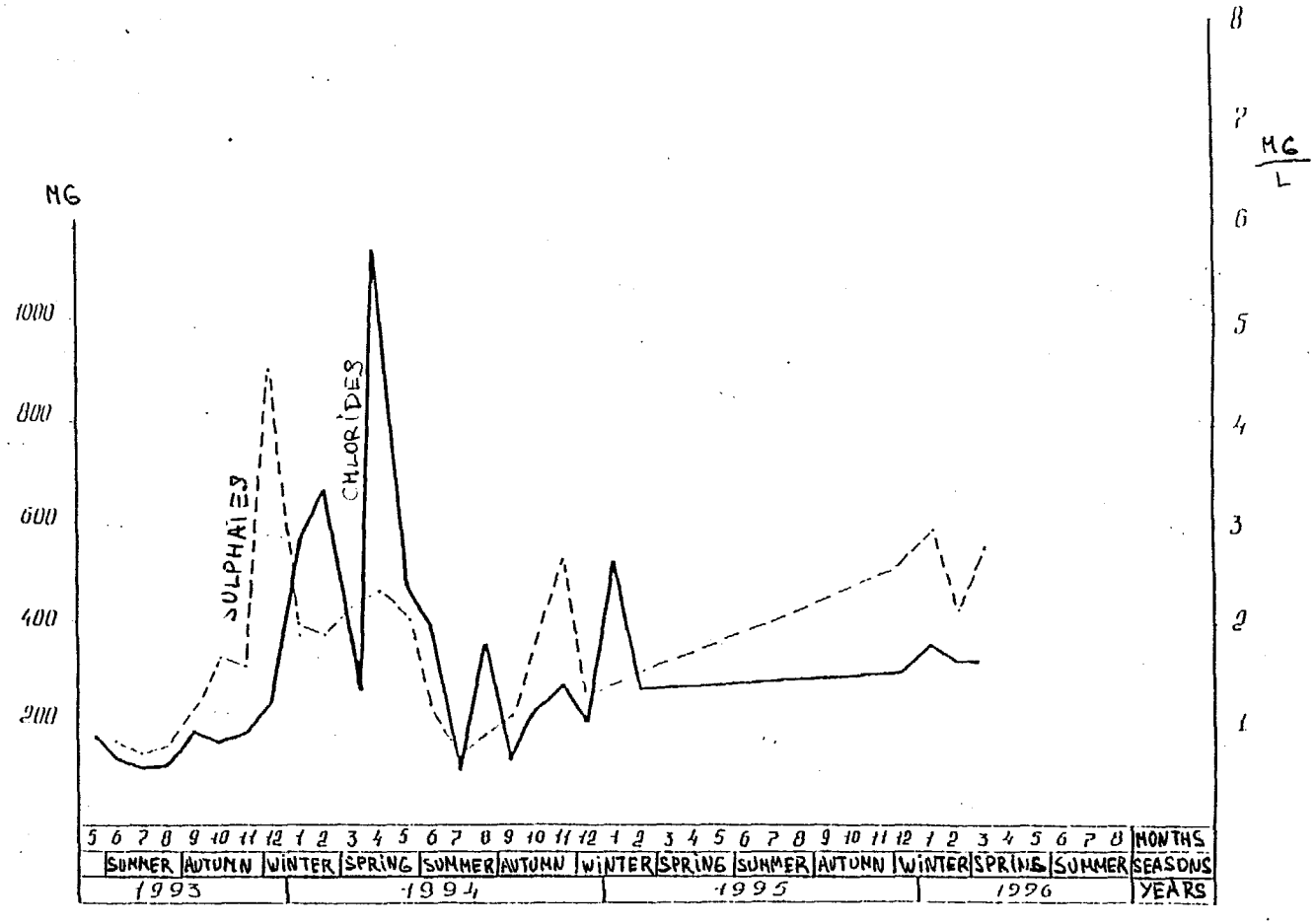


MONTHLY, SEASONAL AND ANNUAL CHANGES OF HYDROGEN INDEX (pH), HARDNESS AND dry RESIDUE IN KYZKETKEN CHANNEL WATER (NEAR NUKUS)

Fig. 3

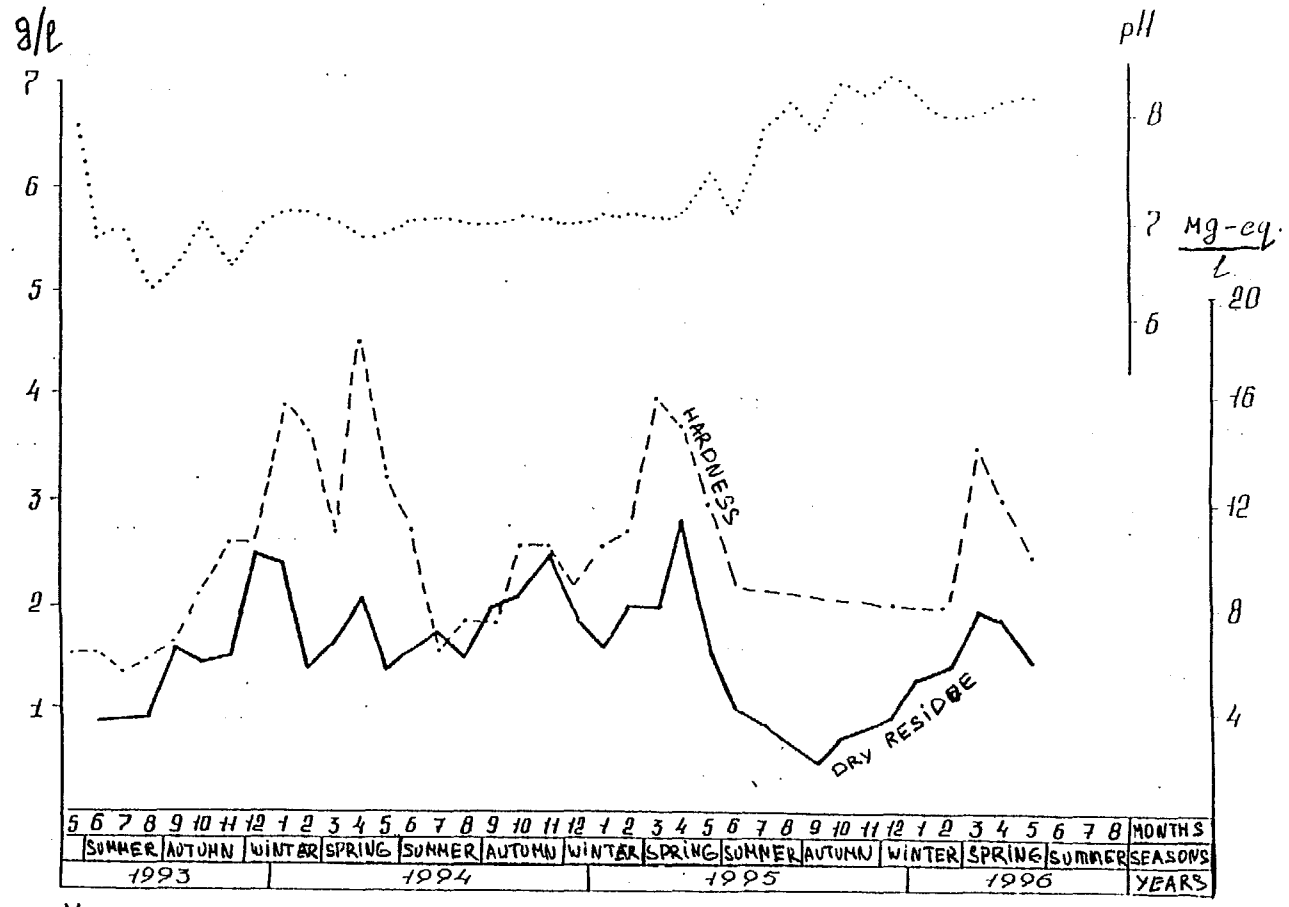
Figure 3

Figure 4



MONTHLY, SEASONAL AND ANNUAL CHANGES OF CHLORIDES, SULPHATES, PLITS AND NITRATES IN CITY WATER OF NUKUS

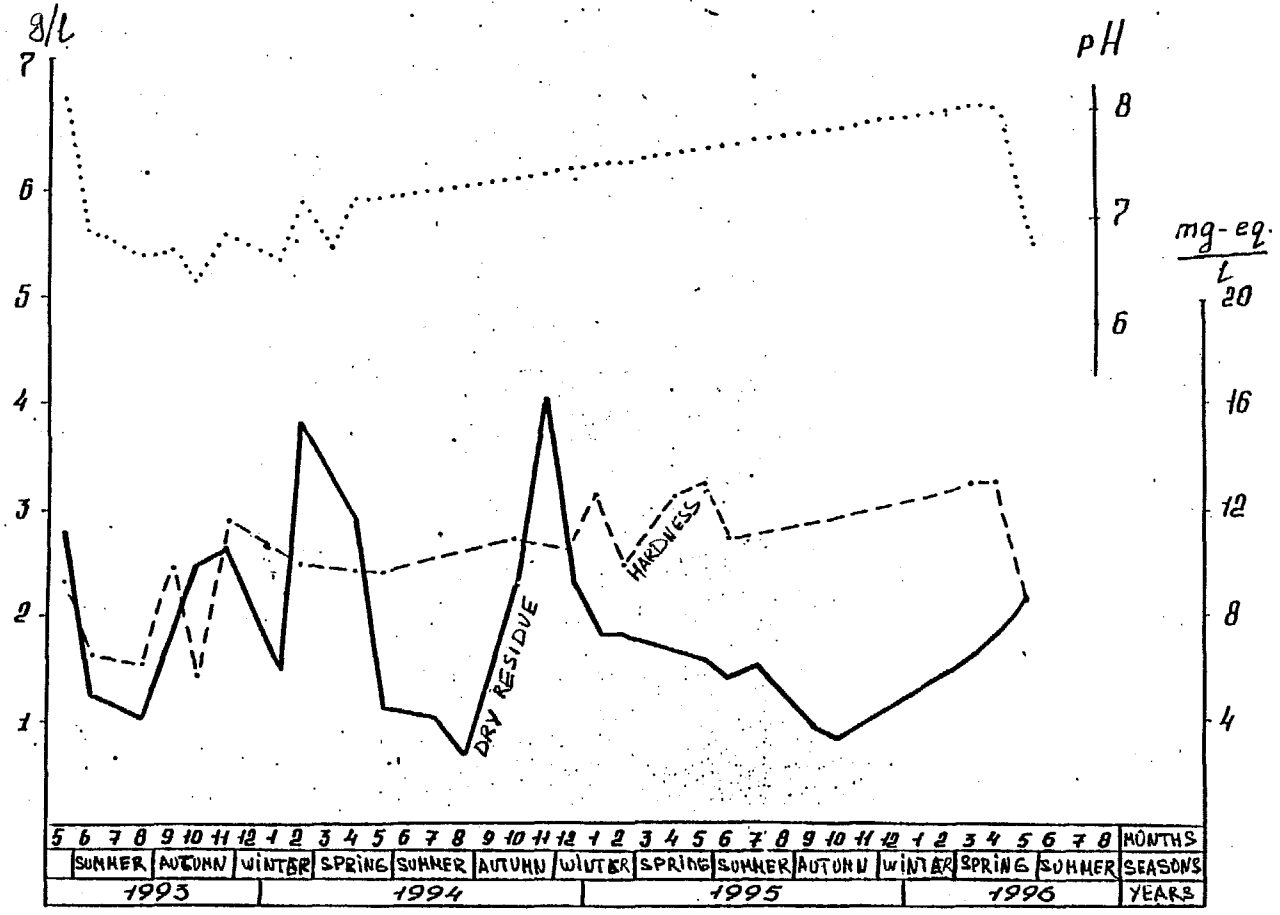
Fig.4.



MONTHLY, SEASONAL AND ANNUAL CHANGES OF CITY WATER HYDROGEN INDEX (pH), HARDNESS AND DRY RESIDUE in NUKUS.

Fig 5

Figure 5



Monthly, seasonal and annual changes of city water hydrogen index (pH), hardness and dry residue in Takhtakulyr regional center.

Fig. 6

Figure 6

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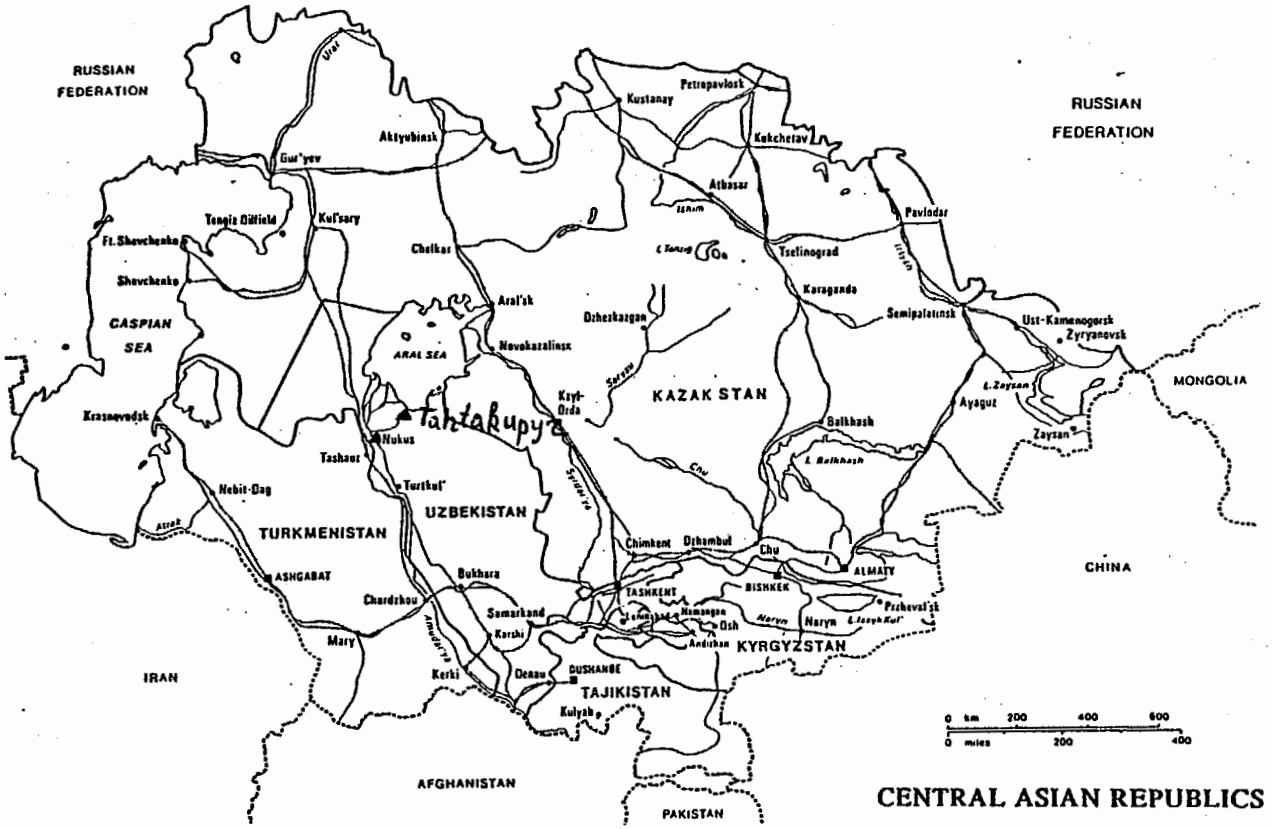

CENTRAL ASIAN REPUBLICS

Environmental Policy and Technology Project

Contract No. CCN-0003-Q-003165

NEW INDEPENDENT STATES

FINAL PROJECT REPORT SUMMARY

RIMDESS Applied Demonstration Projects 8.1, 8.2, 8.3, and 10

Delivery Order 8, Task B

Prepared for:
Central Asia Mission
U.S. Agency for International Development

Prepared by:
Central Asia Regional EPT Office in Almaty, Kazakstan
Environmental Policy and Technology Project
For the New Independent States of the former Soviet Union
A USAID Project Consortium Led by CH2M Hill

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Acknowledgements

Applied Demonstration Project 10:

The authors show special gratitude to Barbara Britton and Alexandra Terninko, coordinators on regional policy for the Environmental Policy and Technology Project, for providing favorable business and creative conditions for implementing the project. They also express their appreciation to Tim Bondelid and Peter Iliev, the employees of the Research Triangle Institute (RTI), for their friendly cooperation and highly skilled practical assistance.

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List of Acronyms and Abbreviations

ADP - Applied Demonstration Project
BOD - Biochemical Oxygen Demand
EPT - Environmental Policy and Technology
RTI - Research Triangle Institute
RIMDESS - River Management Decision Support System
USAID - United States Agency for International Development

cum - cubic meters (m3)
g - gram
l - liter
mg - milligram

Summary Report

Purpose and Scope of Project

As part of the United States Agency for International Development's (USAID) Environmental Policy and Technology (EPT) project activities in Central Asia, the Research Triangle Institute (RTI) adapted a decision support system for the Syr Darya River basin (RIMDESS). Six subcontractors from the four countries in the basin, Kazakstan, Kyrgyzstan, Uzbekistan and Tajikistan, provided the necessary data to RTI. The collected data include the analysis of hydrological and hydrochemical data, information on existing water use control stations, sources of water pollution, population and current water regulations and management in the Syr Darya River basin, and will be used for the purpose of developing a system for water control and water quality management.

There were four applied demonstration projects (ADP) involved in this collection of data in the Syr Darya River basin. ADP 10 included one subcontractor each from Kyrgyzstan, Tajikistan and Uzbekistan who collected baseline data for analyzing the entire basin. ADP 8.1 provided information related to Uzbekistan's water use regulations and pollution sources, ADP 8.2 collected baseline data for the river basin in Kazakstan, and ADP 8.3 collected information on water regulations and laws in Kyrgyzstan.

Project Results and Findings

ADP 10: Regional

The quality of surface water in the Syr Darya River basin is influenced by natural and manmade factors. The geological and hydrological influences are the primary factors, along with collector drainage from irrigated lands.

Within the Kyrgyz portion of the basin, water in general is suitable for a wide spectrum of uses without considerable limits. In the Uzbek and Tajik portions, however, the water quality is close to the "bad" or dangerous category on the pollution index.

ADP 8.1: Uzbekistan

At present Uzbekistan does not have a unified methodology for recording water use and water quality characteristics. In the course of study various methodical approaches were used to collect, generalize and analyze the information about polluting agencies and enterprises. Materials were systematized and prepared for the development of RIMDESS.

Data on the polluters, such as their location, water withdrawals, use, catchment and the content of their discharages in the Syr Darya River basin have been prepared and entered in tables.

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An environmental analysis of the Syr Darya River basin's aquatic ecosystems was carried out. It was found that:

- Water catchment for industrial, municipal, irrigation and cattle-breeding purposes affect the quality of the basin's surface waters.
- Changes in flow mineralization and aggrievement of the chemical composition occur from the upper to the lower Syr Darya
- The Fergana oasis is the main source of salt; the salt content in the upper Syr Darya is 330 mg/l, while in the lower reaches it comes to 1160 mg/l.
- The Tashkent oasis has less of an impact on the Syr Darya's water quality as the main amount of saline water is diverted from the irrigated lands to the Arnasay low area
- Increased amounts of heavy metals, nitrogen and other components is observed in the surface streamflows as a result of industrial effluents.

This project, in conjunction with ADP 10, provided the primary information on Uzbekistan being used in the development of RIMDESS.

The information was compiled and reports were made on an out dated computer, which required more time to complete the work than was assigned by the EPT project and the RTI.

ADP 8.2: Kazakstan

The area of the Syr Darya River basin and reservoirs is 462,000 square km, of which 240,000 square km are within the territory of Kazakstan. The river flow is used intensively (93%). Sixteen reservoirs with 34.6 billion cubic meters of total capacity were built in the upstream and downstream territories of the river. Within Kazakstan the river is characterized by a small stream gradient, low speed, and the existence of old and new deltas. The Arys and Keles rivers are the main inflows of the Syr Darya River.

Sixteen posts of hydrological and hydrochemical control were used to analyze the quantity and quality parameters of the river flow within Kazakstan. The analysis of water quality shows that Kazakstan "receives" water with mineralization over 1.3-1.5 g/l with pollutants and pesticides. In summer time water mineralization in the region of the new delta reaches 3 g/l.

The ecological situation in the Karmakchinsk, Kazalinsk and Aral districts of the Kzyl-Orda region remains critical and there is a tendency for further deterioration of the situation. Therefore the organization of an effective water monitoring system and development of a water control and management system (RIMDESS) in the Syr Darya basin would meet the requirements of the "Program of Concrete Actions...," which was approved by the heads of the Central Asian countries.

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ADP 8.3: Kyrgyzstan

Task 1 was the analysis of water use regulatory documents in the Republic. The government of Kyrgyzstan adopted the following laws to regulate water user relationships:

1) Law *"Nature Conservation,"* of April 17, 1991. This law is the main act of legislation regulating nature use in the Republic. Section 3 of the law reads: "The single regulatory, technical and metrological system has been introduced for the purpose of resource conservation and to meet environmental requirements regulating the marginal permissible impact of productive and other activities on the environment. The maximum permissible impact has to comply with international standards."

   The law "Nature Conservation" was adopted as the basis for elaborating and adopting resource laws that reflect resource conservation and management.

   In other times similar laws were adopted in other countries of the Aral Sea basin. As the allowable environmental impact for production might differ in these countries, discrepencies are seen today in the environmental management of territories whose ecosystems are contiguous.

2) Water Code of January 14, 1992. This law regulates water usage to promote conservation of water resources. Its objective is to prevent industries and other water users from harming water bodies and water facilities.

   This law covers water quality management, water user rights, duties and responsibilities. It also clarifies the respective roles of the national and local administration.

   National roles are governed by international agreements among the country governments. These agreements are formal documents, but they do not reflect all the aspects of an ecosystem approach to water management; they often contradict legislative acts and are presidential declarations.

   Copies of the Water Code, the "Regulations on Surface Waters Protection in the Kyrgyz Republic" and the list of water bodies assigned to different categories were provided to RTI.

3) Decree of the Government of the Kyrgyz Republic, of September 23, 1991. Pursuant to which, water bodies of the Kyrgyz Republic are assigned to different water use categories. The objective of the document, depending upon the category, is to establisl. water quality requirements, set maximum permissible concentration levels for waste water discharged into water bodies, and establish tools for controlling water quality.

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4) "Regulations on Surface Water Protection in the Kyrgyz Republic." Introduced by the State Committee for Nature Protection of the Kyrgyz Republic on January 1, 1994. The objective of this document is to regulate the water quality of all waste waters (including reclamative, drainages, mine and melt water) diverted to flowing water and water bodies.

The following mechanisms are laid out in the Regulations:

- standardization of water quality in water bodies and water streamflows
- water body protection when waste waters, as a result of any economic activities, are discharged
- planning water protection measures
- water quality monitoring and regulation of water users.

5) Water charges for water delivery services in the agricultural sector of the Republic have been introduced and are reviewed annually. In 1966 the following charges were set (with $1.00 = 1200 tyiyns):

- 0.5 tyiyns/sum for Quarters 1 and 4
- 1.5 tyiyns/sum for Quarters 2 and 3.

Local administrations set prices for potable water supply and municipal needs.

Task 2 was a case study research of the water supply and management in the city of Osh. The findings of the research are:

- Osh is a city in the south of Kyrgyzstan, with a population of 300,000. The city is divided by the Ak-Buura River which crosses the town. The water consumption rate ranges from 30 to 40 liters/day for every person, depending upon the dwelling's sanitary and hygienic methods. Osh has 310 industrial enterprises which include plants, factories and other small enterprises.
- Water withdrawal from the upper Ak-Buura are the largest in the Republic and amount to 100,000 cum/day.
- The Ak-Buura River is a transboundary river, with Kyrgyzstan being the formation zone and Uzbekistan the discharge zone. The river's waters flow into the Aral Sea basin and therefore special attention must be given to managing the river's water quality and quantity.
- The primary water characteristics of the Ak-Buura River before the water is taken from it are presented in Table 3, Appendix A.

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- Water is taken out according to the "mountain river out-take" method; without a first-grade pumping station, water is delivered by gravity to the water-filtering station "Ozgor."

- The pumping and filtering station Ozgor, with a capacity of 100,000 cum/day includes the following facilities:

  --mixing chamber
  --flocculation chamber
  --settling tank
  --filtering station
  --clean-water reservoir
  --second-grade pumping station
  --town water-supply system

  The diagram is presented in Figure 1, Appendix F.

- The reagents used for water purification and disinfection are listed below, along with the quantity that is used annually:

  --Liquid chlorine: 108 tons. One dose is 3 mg/l
  --Aluminum sulfate, 10%: 576 tons. One dose is 80 mg/l;
  --Soda ash, 6 - 7%: 108 tons. One dose is 15 mg/l. It is used during 6 months.
  --Calcium hypochlorite, for disinfecting facilities and networks: 10 tons
  --Sodium (potassium) silicate: 22 tons. One dose: 3 mg/l

- Household and industrial waste water flows into the sewage treatment constructions which include:

  --lattice girder constructions
  --primary settling tank
  --aeration tank
  --secondary settling tank
  --contacting reservoir
  --bioponds, discharge in the Ak-Buura River

  The diagram is shown in Figure 2, Appendix F.

- Household and industrial waste water flows into the sewage treatment constructions in the amount of 80,000 cum/day. The outlet flow is 70,000 cum/day. The treatment effect according to BOD (Biochemical oxygen demand) is 85.5%, and for suspended solids, 83%. (See Appendix B).

Applications of Results

Recommendations for the application and use of the results of these projects are as follows:

- Recommendations for the RTI:

    1. To develop RIMDESS in the Syr Darya River basin.

    2. To elaborate unified requirements for recording water use and water quality at the source of pollution.

    3. To develop indicators for collection and summarizing water use information.

- RIMDESS should be approbated for Uzbekistan in the State Conservation for Nature Protection.

- As a result of the collection, analysis and systematization of hydrological and hydro-chemical indices of water flow, an integral picture was developed on water quality and the main pollutants in different branches of Kazakstan's economy. The results might be used by the Kzyl-Orda and South-Kazakstan regional ecology and bio-resources administration, Aral-Syr Darya basin water economy unit, and the sanitary-epidemiological services of these regions for the purpose of preventing flow of polluted water into the river, development of sewage disposal measures, and control over the special regime for water protected zones and regions.

- Results of the work might be used for the development of agreements between the countries of the basin for concerted actions on water quality improvement.

Policy Recommendations

Overall recommendations include:

- To promote water use and water quality information, and its delivery and exchange among water users and interested agencies.

- To develop unified normative and legal documents for Central Asian contiguous countries considering water management and water quality.

- To appoint a national agency with the power to carry out unified water quality and management policies.

- To immediately begin the "Water Protected Zones and Regions of Syr Darya River" project, developed by "Kazgiprovodkhoz" Institute in 1992.

- To create a regional center for water quality monitoring with a special hydrochemical laboratory. The center should develop general strategies for providing the required water quality, from its source to the Aral Sea.

- Create an agreement between the countries of the region to ensure the water quality of the Syr Darya River.

Recommendations regarding ADP 8.3, Task 1:

- For the Aral Sea Basin countries:

    1. To develop common limits for permissable environmental impacts, thereby providing ecological safety of water resources

    2. To agree upon those limits and to affect ratification

    3. Interstate environmental indices which identify limits of permissible impact will permit to eliminate harmful effects on one country on another which result from the transport of pollutants in the water.

- To work out an international "Clean Water Law," including transboundary waters. The law provides environmental and economic security for water used multiple times by different countries.

- If the international water quality law, including transboundary waters, is adopted, it is proposed to review the classification of water bodies, to adopt a convention on water body classification and categories and to pay special attention to river formation zones as a factor providing environmental security in the middle and lower Aral Sea basins.

- To develop environmental standards for the marginal indicators and maximum permissible concentrations of harmful substances. At present, the countries in the Aral Sea basin use sanitary and hygiene indices and on their basis water management strategy is constructed. But in reality it does not reflect an ecological approach to water quality and, therefore, does not reflect damage inflicted upon the hydrobiological aquatic environment and ecosystems tied with the environment.

In addition to the foregoing proposals the high priorities for the Aral Sea basin environmental security are:

- To unify legislation in the area of water management.

- To coordinate the laws among the countries and to ratify them

- To develop ecological standards for the Syr Darya and Amu Darya basins and to approve them through a convention.

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- To take inventory of the valid legislative acts and available standards in the area of the Aral Sea Basin countries and to review and re-make them based on ecosystem approach. The renewed acts and standards will secure water flow formation and discharges, eliminate negative impact of the urbanized watershed on water flow quality and quantity and will foster the basin's ecological and economic sustainable development.

Potential Project Impact

- As soon as RIMDESS is introduced in the Syr Darya basin, it will be possible to evaluate water quality and the impact on water quality of different sources and urgent decisions on the elimination of pollutants.

- If RIMDESS runs successfully, wate quality can be monitored and managed in other river basins in Central Asia (Amu Darya and others).

- Work on this project enabled an analysis to be done of river water quality in the content of pollutants entering the river through sewage and collector drainage.

- RIMDESS's introduction will promote specific measures to prevent water pollution and improve water quality. It will promote the development of an international agreement and effective economic mechanisms between countries of the region for dealing with problems of maintaining water quality in the basin.

- The introduction of the project in the four Central Asian countries along the river basin will allow reliable data on water quality indices to be obtained and will improve the ability to manage water quality on the regional (system) level.

Regional Cooperation

- The implementation of the project will create a basis for mutual cooperation between state agencies, economic units, and scientists and specialists engaged in the Aral Sea problem.

- The implementation of this project promoted cooperation between specialists of the Central Asian Republics. These specialists exchanged ideas and information on problems, the application of a common system of management and control over the river basin's water quality and other technical and economic solutions.

APPENDIX A

MINISTRY OF MELIORATION AND WATER INDUSTRY OF KIRGIZ SSR

OSH WATER PROTECTION HYDROCHEMICAL LABORATORY

ANALYSIS No.12

Address _____ Administation Vodokanal

Date of sample taking _____ Analysis commenced on _____

Date of delivery to the laboratory _____ Analysis finished on _____

Name of object	Dry residue mg/l	Smell point	Colour index for 10cm	Trans-parency, for 10cm	Suspend subst. mg/l	PH	Total alka-linity	Oxidi zabili ty	Hard-ness	Oxidi-zabili-ty -- HPK mg/l	Solu-tion O2	BOD 5 mg/l	Nitro-gen ammon. mg/l	Nitro-gen nitrate	Nitrogen Nitrite mg/l	Chlo-rides (Cl) mg/l	Sul-phate mg/l	Sink-ing substa nces, mg/l	Fe
Before purifi-cation	869	5	without colour	5,1	181	7		32,6				93,8	11,8		weak	72,3	212	138	w e a k
Escape to Ak-Buura River	556	with-out smell	--	11,7	39,5	7		7,3				14,5	2,0	0,01	2,6	33,8	124		
Limit admis. con-centra-tion	1000	2 point				6, 5-8,5		15				3		0,39	9,1	300	100		

Percent of purification of suspended substances is 83%, BPK5-85,5%

Head of the laboratory _____ Opinion of sanitary doctor _____ Laboratory Assistant

Appendix A
Table 2

Parameters of water escape (output) into urban water-supply of Osh city

No.	Name of indices	Unit of measurement	Escape	Maximum permissible concentration
1	Smell	point	0	2
2	Smack	point	0	2
3	Colour	degree	0	20
4	PH	PH	8	6,5-8,5
5	Dry residue of	mg/l	300-400	1000
6	Chloride	mg/l	9-15	350
7	Sulphite	mg/l	180	500
8	Nitrate	mg/l	7-9	10
9	Hardness	mg.equ/l	7	7
10	Quantity-index number of intestinal bacillus	number/l	3	3
11	Iron	mg/l	0.02	3
12	Fluorine	mg/l	0.04	1,5

Total population of Osh city - 210 000
Length of the networks:
Water-supplying-380 km
Sewerage-180 km

Prices for water consumed
1) Water-supply services for agricultural purposes-1,5 tyin
2) Water supply services for houshold purposes and drinking-18 tyin for person per month
3) Water supply services for industrial purposes-1 som 85 tyin/m3
4) Water-supply services for utility purposes-68 tyin/m3

1 som-100 tyin-10 cents-0,1 USD

Table No. 3

Data of potable water quality provided to the population of Osh according to
GOST 2874-82
"Potable water", 1995

No.	Place of sample selection	Color index	Smack point	Smell 20^0 point	Turbidity mg/dm^3	Residue Cl_2mg/dm^3	Ammonia mg/dm^3	Nitrite mg/dm^3	Nitrate mg/dm^3	Chloride mg/dm^3	PH	Hardness mol/m^3	Alkalinity mol/m^3
17/	OZGOR* of AkkBuura	0	-	0	0.1	-	H/0	H/0	7.9	9.25	8.25	5	2.5
I	Before water comes to river	0	0	0	0	0.25	H/0	H/0	9.3	10.25	8.25	5.2	-
15/	OZGOR of AkkBuura	0	-	0	0.2	-	H/0	H/0	5.3	8.5	8.25	3.08	2.6
II	Before water comes to river	0	0	0	0.1	0.25	H/0	H/0	4.8	9	8.35	3	-
15/	OZGOR of AkkBuura	0	-	0	0.3	-	H/0	0.035	6.4	9	8.25	3.4	2.6
III	Before water comes to river	0	0	0	0.2	0.25	0.05	H/0	5.3	9.5	8.23	3.2	-
20/	OZGOR of AkkBuura	0	-	0	0.4	-	H/0	0.025	8.26	9	7.35	4.16	2.6
IV	Before water comes to river	0	0	0	0.2	0.25	H/0	0.015	7.53	9	7.35	4.39	-
24/	OZGOR of AkkBuura	0	-	0	5	-	H/0	0.002	6.6	10.5	7.05	4	2.65
V	Before water comes to river	0	0	0	3.6	0.27	H/0	0.001	7.5	11	7.15	4.04	-
27/	OZGOR of AkkBuura	0	-	0	6.2	-	H/0	0.046	5.3	8	7.2	2.42	2.52
VI	Before water comes to river	0	0	0	4	0.5	H/0	H/0	4.4	7.5	7.2	2.32	-
7/	OZGOR of AkkBuura	0	-	0	4	-	H/0	H/0	7.08	7.5	7.3	2	2.57
VII	Before water comes to river	0	0	0	2.7	0.4	H/0	0.001	7.97	8.3	7.3	2.1	-
15/	OZGOR of AkkBuura	0	-	0	3.4	-	H/0	0.025	8.86	9.25	8.65	4.16	2.6
VIII	Before water comes to river	0	0	0	2.1	0.3	H/0	0.015	7.53	9	8.7	4.33	-
5/	OZGOR of AkkBuura	0	-	0	4	-	H/0	H/0	6.64	10	7.5	3.2	2.8
IX	Before water comes to river	0	0	0	2.7	0.4	H/0	H/0	5.7	8.5	7.5	3.25	-
10/	OZGOR of AkkBuura	0	-	0	3.7	-	H/0	H/0	6.53	9	8.35	3.1	2.5
X	Before water comes to river	0	0	0	3	0.3	H/0	H/0	7.04	9	8.35	3.2	-
12/	OZGOR of AkkBuura	0	-	0	1.5	-	0.25	0.038	6.64	11	8	3.05	2.5
XI	Before water comes to river	0	0	0	1	0.3	H/0	0.0022	7.08	12	8.05	3.02	-
24/	OZGOR of AkkBuura	0	-	0	0.24	-	H/0	H/0	6.7	9.25	8.15	3.37	2.52
XII	Before water comes to river	0	0	0	0	0.25	H/0	H/0	7.9	10	8.2	3.48	-

*"OZGOR" - pumping and filter station

Table 3
Sheet 2

Oxidation mg O_2/dm^3	SolutionO_2 mg O_2/dm^3	COM* mg O_2/dm^3	BOD* mg O_2/dm^3	Iron mg/dm^3	Copper mg/dm^3	Zink mg/dm^3	Flourin mg/dm^3	Manganese mg/dm^3	Dry residue	Sulphate mg/dm^3	Phosphate mg/dm^3	Quantity index	t^0C grades	
1.8	14.1	1.6	2.84	0.05	H/0	-	H/0	H/0	204	93	H/0	30	7	
1.6	-	-	-	0.02	H/0	H/0	H/0	H/0	208	94	H/0	3	10	
1.6	14.7	0.8	1.2	0.01	H/0	-	0.08	H/0	250	68	H/0	10	10	
1.49	-	-	-	0.015	H/0	H/0	0.1	H/0	270	70	H/0	3	10	
1.8	13.8	1.2	0.78	H/0	H/0	-	0.4	H/0	-	-	H/0	10	10	
1.6	-	-	-	H/0	H/0	H/0	H/0	H/0	-	-	H/0	3	10	
0.8	13.53	0.8	1.6	0.1	0.03	-	0.4	H/0	302	193	H/0	50	9	
0.64	-	-	-	0.12	0.03	H/0	0.4	H/0	227	145	H/0	3	9	
0.75	16.2	0.8	2.88	H/0	H/0	-	H/0	H/0	600	197	H/0	30	11	
0.56	-	-	-	H/0	H/0	H/0	H/0	H/0	560	172	H/0	3	11	
0.5	15.7	1.2	0.52	H/0	H/0	-	0.26	H/0	320	82	H/0	120	10	
0.4	-	-	-	H/0	H/0	H/0	0.24	H/0	360	98	H/0	3	13	
0.4	13.8	1.2	1.85	H/0	H/0	-	H/0	H/0	559	197	H/0	120	10	
0.32	-	-	-	H/0	H/0	H/0	H/0	H/0	318	115	H/0	3	15	
0.8	13.53	0.8	1.6	0.1	0.03	-	0.4	H/0	300	153	H/0	70	12	
0.64	-	-	-	0.12	0.03	H/0	0.4	H/0	228	135	H/0	3	12	
2.24	14.2	1.6	1.09	0.1	H/0	-	H/0	H/0	265	71	H/0	1335	9	
1.44	-	-	-	H/0	H/0	H/0	H/0	H/0	288	72	H/0	3	9	
0.95	14	1.2	0.98	0.4	H/0	-	H/0	H/0	280	96	H/0	180	8	
0.79	-	-	-	0.5	H/0	H/0	H/0	H/0	320	98	H/0	3	8	
0.72	12	1.2	1.3	H/0	H/0	-	H/0	H/0	480	138	H/0	180	8	
0.88	-	-	-	H/0	H/0	H/	H/0	H/0	320	103	H/0	3	8	
0.72	13.5	0.8	1.8	0.1	H/0	-	H/0	H/0			H/0	10	8	
0.76	-	-	-	0.12	H/0	H/	H/0	H/0			H/0	3	8	

*COM - Chemical Oxiden Minimum

*BOD - Biochemical Oxiden Demand

Head of Laboratory

Isaeva

Appendix B

EXTRACT
of maximum permissible concentrations of the fixed (normed) water substances of water objects for utility and drinking purposes

No.	Name of the substances	Maximum permissible concentrations
1	2	3
1.	Ammonia/on nitrogen	2,0
2.	Acetone	2,2
3.	Vanadium	0,1
4.	Bismuth	0,1
5.	Tungsten	0,05
6.	DD	0,4
7.	Iron	0,5
8.	Chloric iron	0,9
9.	IM-50/flotation agent	0,1
10.	Cadmium	0,001
11.	Cobalt	0,1
12.	Manganese	0,1
13.	Copper	1
14.	Molybdenum	0,25
15.	Oil polysulfide	0,1
16.	Oil other	0,3
17.	Nickel	0,1
18.	Nitrates /on NO3/	10
19.	Nitrates /on NO2/	1,0
20.	Mercury	0,0005*
21.	Sanonin	0,2
22.	Lead	0,03
23.	Carbon bisulphide	1
24.	SPAV	0,5
25.	Antimony	0,05
26.	Sulphates	500
27.	Titan	0,1
28.	Chlorides	350,0
29.	Zink	1,0
30.	Cyanides	0,1

* For inorganic compounds

Appendix C

EXTRACT

of limited admissible concentrations of fixed water substances of water objects of fish-farms

No. item	Name of the substances	Maximum permissible concentrations
1	2	3
1.	Ammonia	0,05/0,39 on N/
2.	Ammonia salted	0,5
3.	Vanadium	0,001
4.	Tungsten	0,0008
5.	Iron	0,05
6.	Iron sulphate oxide	0,1
7.	Cadmium	0,005
8.	Cobalt	0,01
9.	Manganese	0,01
10.	Copper	0,001
11.	Molybdenum	0,0004
12.	Oil products dissoled	0,05
13.	Nickel	0,01
14.	Nitrate ion /NO_2/	0,08/0,02 on N/
	/NO_3/	40,0/9 on N/
15.	Mercury	0,0001/0,001*/
16.	Lead	0,1
17.	Carbon bisulphide	1
18.	Sulphates	100
19.	Washing paste "Novost"	0,1
20.	Phenols	0,001
21.	Fluoride	0,05**
22.	Chlorides	300
23.	Zinc	0,01
24.	Cyanides	0,05
25.	Chromium/6+	0,001
26.	Phosphorus trichloride-, penta-chloride	0,1

* Maximum permissible concentrations for marine waters

** In addition to the basic content of ftuorides, but not exceeding the cumulative content.

Appendix D

Quality Standards for Irrigation Water

I. Indices, that describe the content of the substances and chemical elements, necessary for normal development of agricultural crops and operation of irrigation system (I group)

Index	Unit of measurement	Allowable quantity
1	2	3
PH		6,5-8,4
Temperature	degree	15-35
Mineralization	mg/l	1000
Hydrocarbonates	mg/l	300
Carbonates	—	6,0
Sulphates	—	500
Chlorides	—	250
Sodium	—	150
Calcium	—	300
Magnesium	—	150
Potassium	—	30
Phosphates	—	10
Nitrates	—	45
Nitrites	—	0,5
Ammonia	—	0,1
Iron general	—	2,0
Zinc	—	1,0
Copper	—	1,0
Boron	—	1,0
Fluorine	—	1,5
Manganese general	—	0,1
Cobalt	—	0,2
Molybdenum	—	0,5

Appendix E
Table 1

Polluting substance	Allowable concentration in utility sewage, sale mg/l
Aluminium	0,5
Nitrogen ammonium	18-20
Iron	1-2
Fat	30-50
Copper	0,01-0,03
CPAV (anionic)	5-8
Sulphates	80-100
Chlorides	40-60
Zinc	0,02-0,3

Based on the content of water from water-supply pipe

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Appendix E
Table 2

Significance of the reducing coefficient k to the allowable concentrations of polluting substances in industrial sewage waters

Substance purified range	Calculated concentration of substance in the residue of dry substance mg/kg	K by multiplicity of the blending of sewage waters in calculating			
		n=1	n=5	n=10	n=20
Escape of purified sewage water into water object for utility usage					
Cadmium	15	0,4	0,08	0,04	0,02
Cobalt	100	0,04	0,008	0,004	0,002
Chromium	700	0,14	0,28	0,014	0,007
Copper	2000	0,2	0,04	0,02	0,01
Nickel	100	0,4	0,08	0,04	0,02
Lead	200	0,8	0,16	0,08	0,04
Zinc	2500	0,43	0,086	0,04	0,02
Escape of the purified sewage waters into water objects of fish-farms					
Cadmium	15	0,8	0,16	0,08	0,04/0,02
Cobalt	100	not introduced	0,8	0,04	0,02
Copper	2000		not introduced		
Nickel	100	not intr.	0,8	0,4	0,2
Lead	200	0,8	0,16	0,08	0,04
Zinc	2500		not intr.		

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Appendix F

Diagram/plan of the pump-filter station "Ozgor"
(see next page)

Ak-Buura river

Municipal water-supply network

Figure 1

Sewerage network

Diagram/plan of the sewerage purification network

Figure 2

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Схема насосно-фильтровальной станции “Озгор”

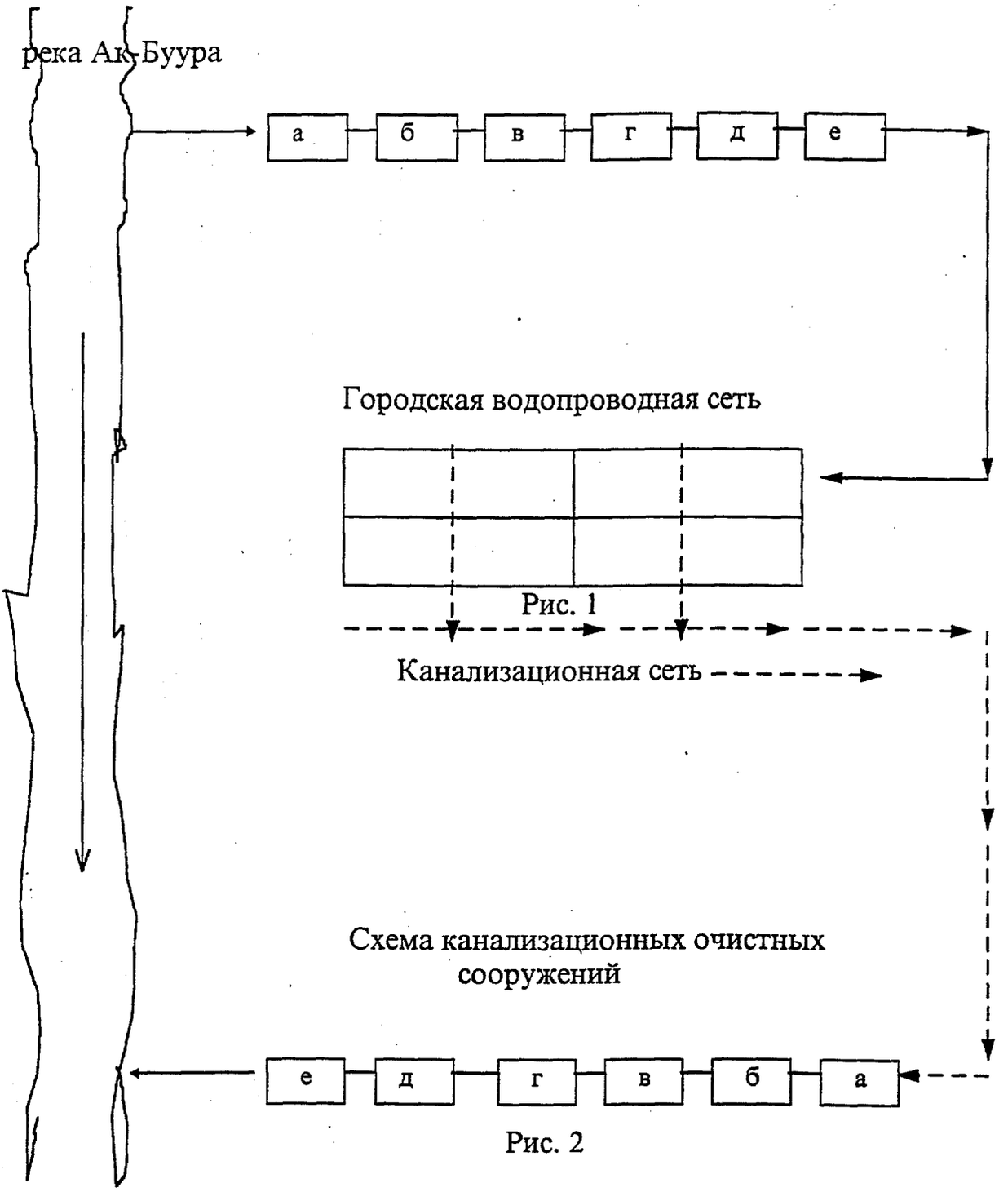

Рис. 2

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Environmental Policy and Technology Project

Contract NO. CCN - 0003 - Q - 3165

NEW INDEPENDENT STATES

SUMMARY FINAL REPORT

Scientifically Based Methods in Water Use; Methodological Recommendations for Irrigation and Hydropower Water Tariffs Applied Demonstration Project No. 9

Dr. D. M. Mamatkanov
Dr. K. E. Shavva
December 1996
Delivery Order 08, Task B

Prepared for:
Central Asia Mission
US Agency for International Development

Prepared by:
Central Asia Regional EPT Office in Almaty, Kazakstan
Environmental Policy and Technology Project
For the New Independent States of the Former Soviet Union
A USAID Project Consortium Led by CH2M HILL

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Acknowledgements

Special appreciation goes to Barbara Britton, Regional Policy Coordinator for USAID's Environmental Policy and Technology Project and to Alexandra Terninko, Program Specialist, for their support.

About the Authors

D. M. Mamatkanov (Kyrgyzstan), PhD. (Engineering) and **Dr. K. E. Shavva** (Kyrgyzstan), PhD. (Engineering) developed the concept of water pricing and the methods for developing the various types of tariffs.

Both men have published more than one hundred articles in the field of water management. In 1995 they published the joint article "Methods of Determination of Regional Multiple Coefficient to increase the Payment for Irrigation Water Over the Limit" in the Russian magazine "Melioration and Water Economy" No. 1.

Project participants from other Central Asian republics can provide detailed information on project results in their respective countries. The teams from these countries were led by:

Dr. V. V.Boltov (Tajikistan) is working on the problem of the transition of water economy and agricultural institutions to operating on a self-financing basis in a market economy.

Dr. A. K. Kenshimov (Kazakstan), PhD. (Engineering), Associate Professor, is the author of 26 scientific works and 2 inventions, devoted to the water consumption regime for crop rotation of rice, water removal and drainage of irrigated lands, protection of objects from underflooding. He participated in the water charges study for the Law of the Republic of Kazakstan *On Introduction of Charges for Natural Resources Management.*

Dr. O. N. Niyazov (Turkmenistan), Senior consultant on water use and law.

Dr. A. A. Rafikov (Uzbekistan), PhD. (Engineering) - a participant and supervisor of paid water use experiments at Engels Irrigation System in Russia, Nikolayev Hydroamelioration System in Ukraine and Bekobad Irrigation System in Uzbekistan. He published more than 70 economic documents, among others, *Operation on a Self-supporting Basis in Water Economy* (collection of systematic documents), Moscow, 1991; *Operation on a Self-supporting Basis in Water Economy* (course of lectures), Tashkent, 1990 and articles in magazines on water pricing.

Summary Report

Purpose and Scope of Project

One of the primary ways to water conservation is to impose a self-financing system and move to paid water use. At this point in time, Russia and some Central Asian republics are moving on such a path. Nevertheless, there are no common approaches or methods for cost-recovery through water pricing. Each country has its own perspective on the issue.

The purpose of the project for this group of participants from the five Central Asian countries in the Aral Sea basin was to develop a "package" of differential methods, based on common methodological principles, which would transfer the water sectors of Kazakstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan to paid water use.

The following scientific and applied economic issues were considered the most immediate:

- the development of a scientifically based concept of water pricing
- the development of comprehensive methods as the basis for charges (tariffs) on water used in irrigation and power generation, as well as the confirmation of their applicability in the Central Asian countries

Major Findings and Results

Pricing Experience in the Region

In the former Soviet Union, water pricing as an effective instrument for encouraging efficient use of water resources was limited frequently to different experiments on the transition of water economy institutions to a self-financing basis, i.e. to be completely self-supporting. Numerous experiments failed to find practical implementation under the state controlled, planned economy.

In the present period of market transition, the majority of Central Asian countries are making attempts to introduce charges for water. In Kazakstan a system of irrigation water charges was established in January 1992 based on the methods designed by the Kazgyprovodkhoz Institute. Penalties for excessive water use were three times that of the regular water price and for unauthorized use, five times; they were established without a methodical base being developed.

Following the Resolution of the Government of the Kyrgyz Republic, irrigation water charges were introduced in May 1995. The rates were not scientifically justified and were calculated to partially cover the operating costs of the budgetary water management institutions.

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The decision to introduce charges for water delivery to the users in Tajikistan was adopted in April 1996.

Since May 1994 a single price for 1 cubic meter of water was set in Turkmenistan. However, according to the Decision of the President, irrigation water within the set limits is supplied free of charge to agricultural institutions. Water used in excess of irrigation norms should be paid at the increased rate.

From 1983-1996, Uzbekistan's Ministry of Water Management studied the introduction of water charges by conducting experiments in 12 region. Simultaneously, a great deal of work was done to scientifically justify the water charges. At present, in response to the Cabinet of Ministers task, the "Criteria for Calculating the Price of Irrigation Water for Different Users" are being developed.

Based on attempts of all the republics to adopt water pricing laws, it is clear that all the states of Central Asia realize the necessity of water pricing to promote the efficient use of water resources. However, common approaches and procedures in water management are not available and each country addresses the problem in their own way.

Major Results

The major results of this project are:

- A scientifically based concept of water pricing has been developed.

- For the first time on the national and regional level, the five Central Asian countries jointly developed a "package" of common methods for calculating differential water tariffs for the following items:

  -- Water as a natural resource, used for irrigation within the limits
  -- Water as a natural resource, used for power generation at hydropower plants
  -- Water delivery within the irrigation limits by water operations organizations
  -- Irrigation withdrawals which exceed the limits
  -- Water, regulated by multipurpose hydro units and irrigation reservoirs on transboundary rivers

- These methods consider local conditions, satisfy all of this project's participants and were recognized as appropriate in the five Central Asian countries. The distinctive aspects of the developed "package" of methods for calculating tariffs in the Central Asian countries include the following:

  --a common methodological approach for the Central Asian states
  --a broader range of tariffs
  --differentiation of tariffs according to the efficiency of irrigation water

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--general accounting for water quality
--gradual transition of water economy to paid water use as the economic potential of water users or their ability to pay grows

- The size of the tariffs on each of the items mentioned above were calculated for the five Central Asian countries.

- The similarity of the existing methods of calculating tariffs in the water economy, in Kazakstan in particular, with the methods developed in the present project, consists of their common procedure for calculating the water delivery costs based on expenses.

Main Principles

The concept of water pricing embraces the following main principles, which were used to develop the "package" of methods for well-founded water tariffs:

- Water resources must meet a combination of needs, including those of the population, different branches of the economy, and the stabilization of the Aral Sea's level.

- Water has value as a natural resource and a raw material for various water users and consumers.

- River flow is a renewable natural resource of stochastic (unstable) character, changing both within a year and over the years. This affects the reliability of the water supply for all users. The estimated water supply must be considered when establishing tariffs for the groups of water users and consumers (water supply, irrigation, hydropower and others).

- Natural river waters are of different qualities, which must be considered when designing water tariffs.

- The developed "package" of methods allows water quality to be considered in a general sense. However, examining its impact on the size of tariffs was not part of this project's scope of work and it is a topic for further work.

- Water pricing should be based on reliable accounting and regulation of water quality and quantity.

- One of the main principles in the fight for water quality is that the polluter pays and compensates damages to those users who suffer from poor water quality.

- Water use in excess of the limit should be paid for at a higher rate.

- The population receives priority in water use and all other users follow.

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- Water use, including water diversion (sewage system, drainage), must be paid for by all branches of the economy and the population (except nature protection agencies), and the charges should cover all costs incurred.

- The water economy's transition to paid water use and recoupment of expenses has to be gradual, so as not to worsen the economic conditions of water users.

- A three stage transition is recommended: the first stage stipulates cost recovery for operations, including maintenance; the second stage covers maintenance and major repairs; and the third stage covers maintenance, major repairs and capital renovations.

- The methods for calculating tariffs for water as a natural resource are based on the costs of:

  -- government supported organizations which study current water resources, compute water quantities, research water quality, or are involved in planning and managing water resources at the national level

  -- research and engineering personnel training

- Methods for calculating tariffs for the services of water supply associations consider the operating costs and profit of water management systems.

- Tariffs for irrigation withdrawals in excess of the limit are based on net profit losses for the downstream consumer.

- When calculating tariffs it is also necessary to take into account:

  -- the degree to which oblasts within a country are supplied with water

  -- the productivity of irrigation water in the country's oblasts

  -- the chance to learn whether or not the water users agree to pay the corresponding price for their water use

  -- the actual economic conditions for financial and economic activities both of water organizations and water users, using price indices which account for inflationary processes

  -- the creation of economic conditions according to the direction of water organization activities

-- profit terms for self-supporting water organizations

- International tariffs for water regulated by reservoirs are based on the expenses of reimbursing operational costs, considering the costs of maintenance, major repairs, and capital renovation.

- International tariffs for water controlled by both multipurpose hydro units and single-purpose irrigation reservoirs take into account the value of water as a natural resource and the value of services for regulating the water in the reservoir.

Tariff Calculations

Charges within the irrigation limits for water as a natural resource vary widely among the Central Asian countries. Thus, at the first stage the water tariff for two regions of Kazakstan comes to \$0.012 per 1,000 m^3; for Kyrgyzstan it ranges from \$0.18 to \$0.6 per 1,000 m^3; for Tajikistan - from \$0.013 to \$0.0017 per 1,000 m^3, for Uzbekistan - from \$0.07 to \$0.44 per 1,000 m^3, for Turkmenistan - from \$0.02 to \$0.0003 per 1,000 m^3.

The calculated tariffs for water management delivery services within the irrigation limits correlate well between Kyrgyzstan, Tajikistan and Uzbekistan, where the rates vary between different regions: for Kyrgyzstan - from \$6.08 to \$7.92 per 1,000 m^3; for Tajikistan - from \$2.35 to \$5.06 per 1,000 m^3 and the rate averages to \$4.76 per 1,000 m^3 in Uzbekistan. Lower prices are set in Kazakstan (\$0.25-\$0.55 per 1,000 m^3) and Turkmenistan (\$0.05-\$0.34 per 1,000 m^3). As stated in the report by representatives from Kazakstan, this difference arises from the fact that when the national currency was introduced, the capital recovery cost was artificially underrated by 8-10 times.

Policy Recommendations

The developed "package" of methods will be given to the national governments of Central Asia for use at the national level as well as at the international level (for use on transboundary rivers). This "package" provides not only the possibility of a single methodological procedure for calculating tariffs, but also considerably expands the areas of its application .

The development and application of these methods will give each country a chance to scientifically base water tariffs for both irrigation and power-generation, which is the basis for market relations in a water economy.

As the participants of this project from Kazakstan and Tajikistan suggest, the existing methods for calculating expenses are far from perfect in their consideration of water quality, operating costs, the insurance fund and normal profit, which can be used for economic incentive funds and capital recovery. In this respect the methods developed in this project are better and they should be considered as the foundation.

Analysis of the calculations on irrigation water showed that:

- The tariffs for water delivery services (taking into account the charge for water as a natural resource) for irrigation were high and agricultural water users were not able to pay because of agriculture's low profitability.

- The transition of the water economy in each country to a self-financing system must be gradual, in step with the stabilization of agricultural production.

- The developed methods presume that the transition will move through three stages: first, the recoupment of operating expenses for maintenance, second, for both maintenance and major repairs, and third, for capital asset replacement or purchases as well as maintenance and major repairs.

- During agriculture's and the water economy's transition to market relations (complete self financing) it is advisable when calculating water tariffs to plan on an equal percent of production costs as profit for both agriculture and water management to create comparable conditions for them.

It is well known that in the middle, and especially downstream Syr Darya and Amu Darya, the water is very mineralized, and its use brings serious damage to the water user. The developed "package" of methods accounts for water quality only in a general sense. However, its impact on the amount of the tariff was not one of this project's tasks, and the following issues should be addressed to as soon as possible:

- water quality requirements, on the territory of each country, of transboundary rivers

- damage assessment on the transmission of poor quality (polluted) water to the neighboring countries

- development of methods for setting tariffs on highly mineralized irrigation water

Potential Impact

It is widely known that the states, located along the Syr Darya and Amu Darya, have exhausted the resources of these rivers and confront both the problem of expanding irrigated lands and the conservation of the Aral Sea as well as water quality improvement in the lower reaches of the rivers.

Use of this project's results will allow the five Central Asian countries to take a better coordinated, unified and scientific-based approach to the water economy's transition to market relations and calculate various tariffs on water use.

The transition to paid water use on the basis of the results of this project will:

- reduce the quantity of water used for irrigation by up to 30% and thereby increase the Aral Sea's water supply
- reduce discharge of mineralized and contaminated water into the rivers
- transfer irrigated agriculture to paid water use and irrigation management to operation on a self-financing basis as is done in the developed countries
- increase the sanitary releases into the Aral Sea to stabilize its level by conserving irrigation water
- encourage water users to apply better, more water efficient irrigation methods (drip irrigation, subsurface irrigation, etc.)

The actual results of the project will be received only after concurrence from USAID and once they have been turned over to the national governments of the Central Asia republics and to the Interstate Council for the Aral Sea for implementation during the transition of water management to paid water use using common pricing methods.

Regional Cooperation

The project promoted closer cooperation between scientists and specialists of neighboring countries on water pricing issues, which allowed them to:

- find and coordinate a common methodological approach to water pricing for irrigation and power generation
- cooperate and exchange opinions on the scientific and economic problems of water pricing
- communicate with leading scientists from the United States and the World Bank, attend lectures on actual water pricing issues in the world, and receive very valuable consultations with these specialists on extremely complicated questions of water pricing, for all of which the project participants are very grateful.

Environmental Policy and Technology Project

Contract No. CCN-0003-Q-00-3165

NEW INDEPENDENT STATES

FINAL PROJECT REPORT SUMMARY

Pricing During the Transition to Paid Water Use and Market Relations in the Central Asian Republics

Applied Demonstration Project 11

by V.A. Dukhovny, M.A. Pinkhasov, N.K. Nosirov, I.U. Umbetaev, M.M. Sarkisov

November 1996

Delivery Order 08, Task B

Prepared for:

Central Asia Mission

U.S. Agency for International Development

Prepared by:
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Environmental Policy and Technology Project
For the New Independent States of the Former Soviet Union
A USAID Project Consortium Led by CH2M HILL

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Summary Report

Purpose and Scope of Project

This project was developed as part of the Regional Cooperation in Water Management activities of the United States Agency for International Development's Environmental Policy and Technology Project (USAID/EPT) in Central Asia. It was developed with the goal of preparing one of the components of the water-land resources management strategy in the Aral Sea Basin. Uzbekistan, Kazakstan, Tajikistan and Turkmenistan participated in the project. The project's task was defined in particular as the establishment of an economic mechanism in the management, use and development of the Aral Sea basin's water resources. This topic concentrates primarily on national aspects, in close coordination with the principles of regional unity and management.

The project's common methodological approaches and principles, which were agreed upon by the project participants, were presented at the first related seminar, held in Tashkent in April, 1996. On the basis of these approaches and principles, the following have been completed:

- an evaluation of government policies and practical measures for the transition to paid water use
- the development of a tariff system and standard packet of regulatory/methodological materials
- an analysis of the legal basis for these proposals and suggestions for their further development
- recommendations for implementing economic tools at different levels of the water resource management hierarchy in the region.

The introduction of water charges is not a new issue for the Central Asia region, as it's various aspects have been discussed and presented to the governments since the 1980s. However, this project has succeeded in summarizing certain results of all the preceding approaches. With the help of the four countries a unified concept has been worked out for establishing an economic mechanism in the water sector, which considers previous experiments as well as the recent experience in water charges, implemented for the first time in the countries of the Central Asia region.

The introduction of a pollution charge was proposed as an element of 'The General Regulations of Water Strategy in the Aral Sea Region.' As it received preliminary approval from the ministerial level members of ICWC (Inter-State Coordination Water Commission), this concept has been thoroughly polished in this project.

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Charges for water are instituted with precise and specific goals in mind. These goals can be achieved if the system of pricing (collection and use) is properly organized and if the system is appropriately connected with organizational, legal and other measures aimed at the sustainability of water management facilities. These goals are:

- the development of economic relations between water management bodies and water users, providing incentives for water conservation
- the elicitation of water users' resources for financing water management measures, and heightening the mutual responsibility of water suppliers and water users in fulfilling their duties
- the development of a "water market" as the main tool for redistributing water resources from less effective water users to more effective ones, and the creation of both public and personal incentives for water users and water agencies in economizing water use
- the creation of economic tools to improve the environmental situation in water use

However, it is necessary to recall that all these results are obtainable only if the water pricing system is gradually introduced, accompanied by balanced collection of measures and initiatives, such as government support, privileges, tariffs, regulations, limitations and organizational reconstruction. These measures will not only create a mechanism for efficiency and economy, they will also serve as a means to support the sustainability of water management and irrigation. Looking at the example of water pricing in Kazakstan and Kyrgyzstan, we see that the lack of a well elaborated strategy and evaluation of the balance between possibilities and needs has led to a situation in Kazakstan where water management has been left without means for development or even existence. The process of decline in the management is seen everywhere, and in some places management has been totally lost, which is very dangerous for the future of irrigated agriculture and water management facilities.

Major Results and Findings

First Priority

At this point in time, the first priority for all the republics is the transition to paid water use in all branches of water use and the experimental introduction of the principle, "the polluter pays."

Types of Water Use Charges

The following types of water use charges are proposed for the relationship between water management organizations and water users during the transition to a market economy:

- complete payment of all expenses, both present and past, made by water management organizations and the governments in the formation, transportation, protection and use of water resources

- charges for water supply services and distribution (or in melioration, for the collection and removal of collector-drainage water)

- participation in financing of water resources production, formation and drawing of additional water resources

- payment for the prevention of or compensation for damages caused by pollutant discharges (or by exceeding the maximum allowable pollution limit).

Pricing Experience in the Region

All the Central Asian republics use a combination of an economic mechanism (water and pollution charges) and strict limits on water use. These methods together form the basis for managing and conserving water resources. This direction is confirmed by both practical and legal steps. On the practical side, payment for water supply services has been introduced in all countries of the region for industrial and municipal water use. In addition, such payments have been introduced for irrigated agriculture in Kazakstan, Tajikistan and Kyrgyzstan, while Uzbekistan and Turkmenistan have introduced penalties for use in excess of the established limit. On the legal side, water laws in three of the five republics, Kazakstan, Kyrgyzstan and Uzbekistan, have stipulated obligatory payments for water supply services.

Direct charges for pollution are not stipulated, although the water laws of all five republics do stipulate compensation for damages related to improper water use.

The experience of all the republics in introducing paid water use has demonstrated that such payment is efficient and effective enough to improve water use and conservation in industrial and municipal spheres. On the other hand, the change to paid water use for irrigated agriculture in Kazakstan, Kyrgyzstan and Tajikistan has revealed that the majority of agricultural water users are currently unable to pay for irrigational water supply services.

Methods for Determining Tariffs

Methods for determining different types of tariffs have been unified and tariffs have been calculated. What makes this method different is that the tariffs include the insurance fund and standardized profit (marginal profit), which is based on average, rather than actual expenses. While the inclusion of the insurance fund in the water charges increases the payments during normal years, during low-water years, it allows water management organizations to be compensated for their costs without any additional payment from water users.

By this method, tariffs are based on average rather than actual expenses. That is, they are based on: a) standard, existing expenses for normal operation in 1995, including operation, maintenance and capital repairs; b) insurance; and c) depreciation expenses on capital assets, that is the sum needed for the complete renewal of assets.

In addition to the expense items listed above, those expenditures necessary for extended reinvestment of funds are stipulated for industrial and municipal water users only. "Standardized profit" is determined on the basis of the system's direct costs, including the necessary funds for economic stimulation and taxation.

The value of direct tariffs for water management services has been set approximately at 5-12 cents/m^3 of water for agricultural users and 25-32 cents/m^3 for industrial and municipal users.

Expenses for the development and improvement of production are considered in the tariffs for all water users except irrigators. Government and other new investors are the recommended financial source for these expenses in irrigation. Government participation in covering agricultural water supply expenses is stipulated in proportion to the government's share in profits from the production, processing and sale of the main irrigated crops.

Water as a Natural Resource

The price for water as a natural resource is set at a basin-wide level according to the proposed methodology developed for this project, which is based on comparative methods of determining water value and marginal costs. However, considering the possibility of including this price during the transition period, this amount is included in full only in the tariff for industrial use and included in part for municipal use. For the remaining water users, especially irrigators, this price is considered in the feasibility studies for new measures. At the same time, this price should next find application in improving interstate relations along transboundary waters, as described more completely in the longer version of the project report.

Practical Applications of Results

1. The suggested approaches make it possible to first select an optimal system of tariffs for different types of water users during the initial stage of the transition to a market economy and then change those tariffs when later improving the market. In particular, the application of an increasing price system with a gradual decrease in the amount of government financing is proposed.

2. Agricultural water users' weak financial position makes government support (subsidies) for them absolutely essential. Willingness to pay for water management services is not sufficient in and of itself. A combination of economic conditions, leading to the successful implementation of pricing tools for water management services, is needed.

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The tax component should be excluded from the price model for water management services. It is also advisable to introduce a draft statute on the provision of tax exemptions for water management services during the initial transition stage.

Most countries subsidize agricultural producers by refunding their water service expenses. In order to support agricultural production during the transition period, it is proposed to subsidize agriculture during the first stage of water pricing by covering 60% of its water supply expenses, which correspond to the expenses of normative water use as well as the financing of agriculture's share of capital investment in water management.

3. Since high mineralization of irrigation water greatly reduces the productivity of agricultural land, this project has proposed corrective coefficients which should be applied to the tariffs for irrigation water.

   The mineralization level of irrigation water in the Amu Darya and Syr Darya basins is currently stabilized, and corrective coefficients can be used until such time as steps are taken to demineralize the water resources in these basins.

4. In order to establish organizational and economic sustainability in the relationship between water management organizations and water users, privatized water users must form associations of municipal water users and land-and-water users. The government should support these associations with a system of preferential crediting and the establishment of a service infrastructure. Such organizational work has been started in the South Kazakstan oblast in the framework of this project within the boundaries of Zhetysaisky district. The establishment of associations and their support by the government should be developed at the second stage.

5. The introduction of payment for water management services underlines the necessity for not only economic reorganization among water users but also for the introduction of market relations among water management organizations at different levels of the water-organization hierarchy. In particular, the combination of government financing and payment for water ought to be accompanied by a renunciation of complete financing from the national budget and gradual water management reorganization (e.g. permitting the sale of conserved water shares) in order to economize water and material resources through economic incentives.

Political Recommendations

- For all countries to indicate through legal documents the necessity for introducing paid water use and payment for pollution. These documents should also establish commercial rights to sell or trade water resources which are conserved.

- To develop international agreements which simultaneously address the establishment of limits on water use and pollution emissions into water sources and introduce

penalties for exceeding these quantity and quality limits. In addition, as in the previous point, the possibility of transferring (selling) portions of these limits from one country to another should be stipulated.

- To stipulate the participation of water users and non-governmental organizations in decision making, at all levels of the hierarchy, on the development and protection of water resources--as opposed to existing legislation in all the region's countries on the involvement of non-governmental organizations in improving water resources management. Also to stipulate the involvement of water users associations in developing organizational structures.

  Government policy on water resource use should be based on a combination of:

  --strict limits on and management of water by government structures

  --eliciting water users' initiatives

  --market relations formed by creating both semiautonomous and independent water users associations in irrigated agriculture and other types of water use.

- To stipulate the introduction of preferential crediting for water users associations and for water management bodies while they introduce pricing tools. To also entice legal entities and natural persons to finance the development and improvement of water management by allowing certain privileges in water allotments.

Potential Impacts

This project has developed one of the most important elements of regional and national water strategies for the countries of the Aral Basin, the "rules of the game," of which the most important aspect is the economic mechanism used to introduce market relations in the region's countries under conditions of transition. It is proposed that further development of this work within the USAID project will lead to such a complete resolution of this issue, that the World Bank will be totally released from its previously perceived need to develop measures on this topic.

The government laws, stipulations and regulations prepared by this project can establish a common economic incentive for countries, water users, and water management bodies in the economical and rational use of water resources in the Aral Sea Basin.

The approaches developed by this project for setting water prices and tariffs tied to water quality, together with the introduction of a defined payment at the national level for exceeding the ecologically safe water consumption limit, allows for the first time the creation of economic incentives for improving water quality in the region and using brackish water. They also allow the creation of a financial tool for measures aimed at environmental

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sustainability in the region. These recommendations must be submitted to the governments for discussion.

Regional Cooperation

The joint work done by the experts of four Central Asian republics on an integrated program and methodology, the constant exchange of opinions with participants from all five countries working on other EPT programs, consultations with foreign experts, and also cooperation with Program 1 of the World Bank and WARMAP have promoted the development of unified approaches and consolidated opinions, which prepare the foundation for decision makers. All of this will encourage consensus reaching on the international level.

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Environmental Policy and Technology Project

Contract No. CCN-003-Q-00-3165

NEW INDEPENDENT STATES

FINAL PROJECT REPORT SUMMARY

Economic Damage Assessment in Water Use: Component of Turkmenistan Applied Demonstration Project No. 12

Sarkisov M.M., November 1996
Delivery Order 08, Task B

Prepared for:
Central Asia Mission
U.S. Agency for International Development

Prepared by:
Central Asia Regional EPT Office in Almaty, Kazakhstan
Environmental Policy and Technology Project
For the New Independent States of the former Soviet Union
A USAID Project Consortium Led by CH2M HILL

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Summary of Report

Purpose and Scope of Project

This project was completed within the framework of a contract signed with USAID's Environmental Protection and Technology Project (EPT). The main purpose was to develop scientifically based methods for economic damage assessment in water management.

Specialists from countries other than Turkmenistan were not involved in the project for the following reasons:

- it was an effort to develop a general approach and methodology
- after the work has been completed, the final report will be delivered to the experts in the involved countries, who will review the report, make suggestions for improving the methodology and come to agreement on its principles and approaches.
- the work must be done in stages, including the improvement of approaches to economic damage assessment.

Project Results and Findings

The quality of water used in different sectors of the economy, taking into consideration the depletion of water resources and increasing manmade pollution, is one of the main causes of the worsening environmental situation in the region. The development of methods to assess economic damages (damage resulting from existing water use activities which cause deterioration of water quality from sources), real assessment of damage, implementing water charges based on quality, and other economic, legal, organizational and technical measures will improve the existing environmental situation.

It is presumed that the development of a methodology for assessing the economic damages arising from water use and water quality deterioration, and the scientific basis for the assessed value, will enable compensation for damages to be completed in a civilized manner, through the principle "the polluter pays." To increase economic interest in preventing water pollution, damage compensation payments should be higher than water treatment expenses.

The necessity to develop approaches for assessment of economic damage value in water use appropriate for all Central Asian Republic (CAR) countries is accepted by the representatives of all countries of the Aral Sea basin. Assessment of damage volume must be based on calculation of its separate components proceeding from the amount of revenues not received and the amount of expenses necessary to prevent consequences of negative influence on natural resources, economy and social sphere of the country.

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The project completed the following:

- a chart identifying economic damage components
- methods for calculating each component
- a case study calculation of economic damage inflicted on agriculture in one section of Turkmenistan where irrigation water is highly-mineralized
- conclusions and proposals

The developed economic damages components chart was submitted for discussion and coordination with representatives of all CAR states at an EPT seminar in Almaty (June 1996). The results of discussions and exchange of views permitted the creation of a calculation methodology appropiate for the Aral Sea Basin countries for the computation of both specific damage components and total damages.

The following components can be found in the comprehensive chart of economic damages from water use and decreased water quality:

- Economic damage to agriculture
- Economic damage to industry
- Economic damage to municipal sector
- Environmental damage
- Social damage
- Implicit (indirect) damage

The damage amount can be calculated on the basis of:

- the cost method, which suggests that damages from the location and operation of water facilities should be calculated by determining the necessary capital investments and current operating costs for full or partial prevention of the damages.
- the method of determining socioeconomic damages from environmental pollution, which proposes to identify the volume of unrealized gross production, gross and net earnings (profit) of some recipients from economic branches or even the national level.
- a combined method, which takes into account both damage prevention costs and the quantity of damage due to social-economic losses.

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Practical Application of Results

The proposed methods of calculating economic damages can be used on an interstate level and for individual water consumers inside the country. They should be implemented by stages, on the basis of one or more components, under separate bilateral or multilateral agreements. For example, during the first stage it will be possible to compensate for agricultural damages only.

The methodical approach, applied in the assessment of damage caused by highly mineralized water irrigation, can be used on the national level in every country for calculating irrigation water rates, taking into account its quality.

The Darganatinksy etrap (equivalent to an U.S. county) of the Lebansky velayat (equivalent to an U.S. state) in Turkmenistan was used by this project for a case study economic damage assessment. However, as the calculations were made primarily for demonstration purposes, damages were considered only for agriculture. All the other types of damages must also be considered for a full economic damage assessment.

Collector drain water is released directly into the Amu Darya River, and irrigation water for the 7700 hectares under cultivation in the Darganatinsky etrap is taken straight from that river. So while the mineralization levels of the water upstream in Kerkinsky etrap are 0.5 g/l, by the time the water reaches Darganatinsky etrap, the levels are 1.5 g/l.

The calculations showed a total of 2004 million manat (just under $490,000) in economic damages to agriculture alone in the Darganatinsky etrap. Damages to agriculture per cubic meter of polluted water used in agriculture total 19.4 manat/m^3 (or $0.0047/$m^3$).

The overall costs of agricultural damage should be covered by the polluters in proportion to their effluents into the river (Turkmenistan 62%, Uzbekistan 38%). If water pricing is actively instituted in Turkmenistan, one way to compensate the irrigators who use polluted water is to reduce the amount they pay for water in proportion to their damages.

Under a separate project, tariffs for normal quality water in Turkmenistan were calculated at 30 manats/m^3 ($0.0073/$m^3$). The difference between the tariff for unpolluted water and the damages caused by their use of polluted water (19.4 manat/m^3) can be used as an adjusted tariff rate for agricultural water users in the Dargantinsky etrap:

30 manat/m^3 - 19.4 manat/m^3 = 10.6 manat/m^3 (Or $0.0026/$m^3$).

Policy Recommendations

- The CAR countries should work out legal documents stipulating obligatory damage compensation in water use.

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- Damage compensation procedures for transboundary water bodies or water bodies located in the territory of another country should be defined by interstate agreement.

- The logical conclusion of the USAID/Central Asian Mission's involvement in this project could be cooperation in the development and approval of the above mentioned interstate agreements among the five CAR countries.

Potential Impacts

The project proposes a solution for one of the most important elements of regional strategy, the development of methods for economic damage assessment in water use. Its implementation will improve the ecological situation in the region of study to a considerable extent.

Development of normative, legislative and interstate documents based on the findings of this project will promote water management activity which considers the economic interests of all countries in the Aral Sea basin in the improvement of the region's ecology.

Regional Cooperation

After completion of the research under the present contract, the proposed methods should be submitted for CAR countries specialists' consideration in order to perfect some elements and develop common methodology for all countries of the Aral Sea basin. This would allow for:

- the elimination of possible disagreements in the methodical approaches of calculating specific elements of economic damage in water use

- the establishment of a system of payment for those cases where damage has been proven, taking into consideration the national currency rate in each representative country

The project is directly connected with World Bank Programs 1 and 3 and with the WARMAP project of the European Union. This connection will assure that any questions under dispute will be quickly resolved and the results accepted at the regional level.

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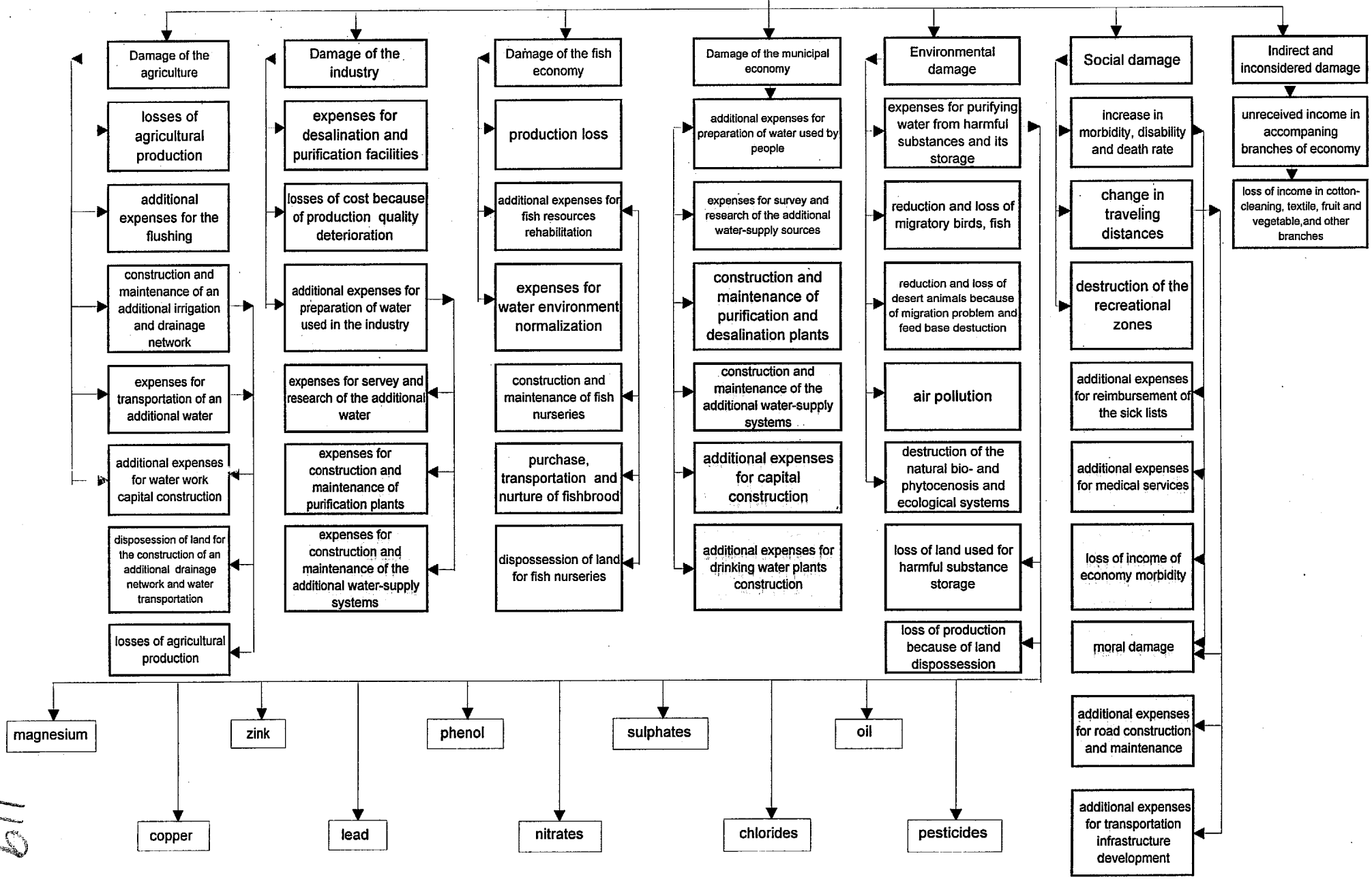
Economic damage in water consumption