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TECHNICAL REPORT

Amu Darya River Water Allocation Model

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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 they have been evolving along with developing 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 is 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 Amudarya or Syrdarya Rivers (whose runoff is formed in Kirgyzstan and Tadjikistan, 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 "Amudarya 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.

Western US states 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 account of special local situations - social, economic, technical, and legal) for the water sector in the Central Asian Republics.

This research was conducted at the Tashkent Institute of Engineers for Irrigation and Mechanization of Agriculture and the University of Texas at Austin and was funded by the USAID EPT Project. Dr. Karimov's visit to the University of Texas was financed by the USIA ACCELS/ACTR program. Researchers from the Hydrometeorological Survey of Uzbekistan (Dr. Rubinova), the Tashkent Institute of Hydrogeology and Engineering Geology (Dr. Khabibullaev, Dr. Gracheva, Dr. Mukhamedjanov, Dr. Mjelskai), and the Uzbek Design Institute UZMELIVODHOZ (Dr. Khasanhanova) also participated in the project.

During Dr. Karimov's study tour to the USA, visits were made to the Texas Water Development Board, the US Geological Survey, the California Department of Water Resources, the Imperial Irrigation District, the University of California at Davis, and the University of Arizona, where the authors had meetings with specialists in water management. The report in English presents brief results and conclusions of the project. A full version of the report in Russian can be received from the Central Asian Regional EPT office in Almaty or from the authors.

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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 sustainable development in the basin:

- transition to more balanced agricultural and forest economics;
- increasing irrigation efficiency through development of economical mechanisms of water use; and
- 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 USA states - California, Arizona and Texas, 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:

1. Differences in water users structure (see Table 1). 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, only alfalfa in the southern part of the state occupies about 30% because it has a meliorative function also (see Tables 2, and 3).

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 have rights for water use and water transfer also, but there is absent any guaranty that the water users will preserve their rights after the water saving or transferring to another user.
3. Differences in financing of water services. The water supply services of Western USA states 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 nonpoint 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); and
   - a 75 percent matching grant to districts to purchase (Agricultural Soil and Water Conservation 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 820665 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, 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 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 United Water Resources

International water allocation is very important for the Aral Sea basin. In this basin there are two main rivers - Amudarya and Syrdarya, whose flow forms in the mountain zones of Kirgystan and Tadjikistan and is used in the valley and desert zones of Turkmenistan, Uzbekistan, and Kazakstan. For this reason the experience of the Western USA states in water allocation in 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 for water allocation from international rivers there is a need for the development of a basis of 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.

Section 5

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 (it is possible to include ground water). Many times it is very important to include reservoirs in international water, when two or more countries are interested in the reservoir's operation, or a natural lake or reservoir that has an important role for the basin environment.

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

1. Main river and tributary flow can be divided between upstream countries, also the water volume of international reservoirs can be divided in relative quantities;
2. River flow can be divided between countries by international boundaries in relative shares; and
3. Same as (2), but shares can be defined in absolute quantities.

In case (1), 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.

In case (2), 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 middle-stream countries may conflict with irrigation demands in downstream countries.

In case (3), 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.

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 in the Rio-Grande River and Aral Sea basins the same structure has been developed. 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.

Data Collection for Water Allocation.

Water allocation modeling can be executed only if correct data about river flow and user demands are available. Unfortunately, for river flow, a measurement error of more than 5% exists. 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 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 6

Amudarya River Water Allocation Model

The model has three main parts (see Figure 1):

- Manager program to prepare the network model connecting the supplies with demand sites.
- Optimization model built on the GAMS software base, and
- Data base built on the GIS coverages.

The model has two levels of detail - regional and local. On the first level, monthly water allocations between countries and irrigation zones are decided. 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 hydrogeological conditions. Regional water allocation is calculated in two steps, in the first step the benefits of each country are optimized taking account of the environmental limitations and common aspects of all countries. In the second step the optimal variant is calculated using the share of international river flow of each country as the basis for calculation. The actual shares of each country were determined using upstream stations (in fact, the basin was divided into two parts and river flow is divided between countries in relative shares by boundary lines).

Table 3 shows the data used for calculation of each country shares of the Amudarya river flow and international reservoirs. The objective function for each country includes benefits from international water combined with other water resources (surface and ground) at present and benefits in the future from water saved in reservoirs at the end of the calculated time.

Constraints of the model consist of water and salt balance equations that 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.

Limitations of the model 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 7

Kashkadarya River Water Allocation Model

Optimal water allocation for a river basin using a detailed approach offers management of irrigation demands and conjunctive surface and ground water use. The model allows active management of surface and ground water. Ground water, drainage flow, Kashkadarya river and Amudarya river flow can be used in the basin. The model consists of three parts:
the manager program, GIS data base, and the optimization model. The GIS data base for the Kashkadarya model has more detail than the regional model and it was created with GIS coverages of climate, irrigation systems, administration districts, ground water, and surface water of Kashkadarya oblast. All these data were used for calculation of irrigation demands. The objective of the model is the water allocation between irrigation systems. The objective function consists of present and future benefits from water use and includes crop yields which decrease with water shortage. The model constraints include water and salt balance equations, reservoirs and ground water capacity, requirements to water quality, and quantity of wells.

Section 8

Conclusions and Recommendations

The comparative analysis of water management in the Western USA states 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 water transfer is outside of the local water supply agency, permission of the committee that is responsible for the water use rights is needed. If water transfer will be inside of an administrative district only notification of the local water agency is needed;

the transfer of water does not affect and is not a basis for any loss of water rights, if the water that was saved or transferred, was not the cause of a decrease of river flow, then this savings or transfer can be considered as a beneficial use of the water in the land from which it was transferred.

Article 31:

short time water use can be applied only in special conditions as a temporary measure.

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 rights for water use (that will be without payment), and
   - with additional payment for water users may participate in the water market by their wishes.

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

3. Direct agreements between different users for selling and purchasing water should be promoted. This will result in water saving in one region and transferring to other regions where payments are available.

4. 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.

5. Ground water management zones should be established. These agencies can be established under the hydrogeological services that 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.

6. 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.

7. The Amudarya and Kashkadarya river water allocation models should be applied in the BVO Amudarya and in the Water Survey of the Kashkadarya oblast.