PEER Project - "Transboundary water management adaptation in the Amudarya basin to climate change uncertainties"

Research report

1. Preparation (planning & design)

1.1 Study of TWM in the basin

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Introduction

The aim of activities carried out within the PEER Project is to increase adaptive capacity of countries in the Amudarya basin to effectively manage transboundary water resources in the context of climate change and other uncertainties. This aim may be achieved through **the integrated study of tasks and problems related to transboundary water resources management** in the Amudarya basin with the focus on the current state (2010…2015) and the future (2015…2050).

The aim of the first stage of research is the establishment of methodological and information basis for project research. The report describes a part of the results achieved during the first stage: **the analysis of tasks and problems related to water resources management** in the Amudarya basin and the suggested **logical model of management based on this analysis**.

1. Water resources management in the Amudarya River basin

For the purposes of the PEER Project under water resources management we understand **a decision-making process** and **provisions for implementation of these decisions**. The whole process may be divided into two parts: the task of planning should be solved at the first stage (desirable mode of operation), whereas the tactics for plan implementation which ensures maximum approximation of the plan to the fact should be developed at the second stage. Similar approach may be applied to "management focused on the long-term future". In this case, the "plan and forecast" may be replaced by **scenarios of plausible development** of which the most realistic management (development) **strategy** is chosen. Given strategy can be adjusted in the process of its step-by-step implementation. The difficulties in water resources management in the Amudarya basin are directly linked with the decision-making process (development of control actions) and implementation of decisions.

Currently **ICWC** is the only body making decisions on allocation of transboundary water resources in the whole small basin of the Amudarya River. **Basin Water Organization (BWO) Amudarya**, being the Executive Body of ICWC, is responsible for management and control of water intakes in the Amudarya River basin. It consists of the Headquarters in city of Urgench and four operational branches placed in the cities of Kurgan-Tyube, Turkmenabad, Urgench, and Takhiatash. BWO Amudarya cooperates with the UzGlavHydromet of the Republic of Uzbekistan for sharing of necessary information; every day from the UzGlavHydromet BWO receives hydrological data on gauging stations of the Amudarya River, on the Nurek reservoir, and forecasts of flow probability, and, if necessary, they together take measurements at gauging stations in the lower reaches of the Amudarya River - Tuyamuyun GS and Kipchak GS that belong to the Republic of Uzbekistan. BWO Amudarya controls all pumping stations located on the Amudarya, Pyandj, Vakhsh and Kafirnigan Rivers and on interstate canals, as well as a part of river water intakes that are not on BWO's balance. As part of general agreement between the Central Asian states, intergovernmental management and distribution of water resources concern only the following rivers: the Pyanj, Vakhsh, Kafirnigan and Amudarya Rivers.

Water allocation in the basin is carried out on the basis of limits (or quotas) that have been established by ICWC for the growing and non-growing seasons since 1992 for the: upper reaches (Kyrgyzstan, Tajikistan, and Uzbekistan), middle reaches (Turkmenistan, Uzbekistan) and lower reaches (Turkmenistan, Uzbekistan) of the Amudarya River. Water allocation in the middle and lower reaches is enshrined in the Agreement between Turkmenistan and the Republic of Uzbekistan on water cooperation (Chardjev Agreement 1996). This quota principle, which is observed by the parties, implies that Turkmenistan and Uzbekistan have equal (50/50) shares of flow of the Amudarya River at the Kerki GS – upstream of intake to Garagumdarya (Karakum Canal). It should be mentioned that ICWC pursues a policy of reduction of water withdrawals by 1-1.5% annually. Unfortunately, the planned by ICWC reduction of water withdrawal is not fulfilled; at the same time, the analysis of setting and use of quotas showed that this reduction could be implemented.

The main functions of BWO Amudarya (as an executive body of ICWC) are: correction and approval of seasonal water use limits, medium-term planning **approved by water management and energy agencies of the riparian states**, operational management and control. BWO Amudarya in cooperation with SIC ICWC takes part in **long-term planning**.

The difficulties BWO Amudarya encounters when planning and implementing the plan while allocating river flow is, first of all, **the absence of data** on flow forecast for **all tributaries** of the Amudarya (including the Pyanj River) and the lack of **routine mechanism for receipt and transmission** of the **data** on flow rates at border stations, upstream and downstream of large hydraulic structures; better organization of this data transmission at all key river sections of the Amudarya river channel (Termez, Kelif, Kerki, Turkenabad, Ilchik, Bir-Ata, Tuyamuyun, Kipchak, Samanbay and Kyzyldjar) would undoubtedly result in improvement of water management and control over water losses and water allocation (water intake).

Major **flow forecast** for the basin is made at the beginning of April using the analysis of snow reservers formed in winter; the assessmnents before this period are not reliable. If forecasts do not fit the reality, particularly, in dry years, considerable negative effects may occur. In addition, an updated forecast in April will not allow changing the crop structure and cropping pattern and correcting effectively water allocation.

Regular errors in the calculation of channel balance of the Amudarya River are linked to the fact that **channel losses** and seepage into the river channel in some reaches are incorrectly accounted, as well as the so called "channel regulation," i.e. the accumulation of water in the river channel during floods and its delivery during the low-water level and other factors are not considered. Integration of these components into the balance can improve accuracy of the forecast of river flow transformation in space and time and, thus, improve the efficiency of water resource management, including the control over water distribution.

Next problem is **the approval of operation regime of the Nurek reservoir by states** during the low-water years. The analysis of operation of the Nurek reservoir reveals that when natural water deficit occurs during low-water years, the energy generation regime of the reservoir leads to well lower water supply of irrigated lands in Turkmenistan and Uzbekistan. At the same time, operation of the Nurek reservoir is not always effective in terms of electricity losses. **Idle water discharge** is observed. However, this would have been reduced if reliable flow forecast for the Naryn River had been made.

Regulation functions of the reservoirs in the Amudarya Basin deteriorate because of **siltation of the usable storage capacity of reservoirs**. Siltation of the Nurek reservoir constrains the possibility of seasonal regulation of flow in the Vakhsh River. This constraint is directly linked with inaccuracies in calculations while planning the operation regime of the reservoir, as well as with idle water discharge in case of overfilling. Today, actual volume measurements of the Nurek reservoir are not enough reliable. They do not allow making necessary analysis and explaining siltation processes in the reservoir. Hence, any reliable forecast of siltation in the reservoir for the future is not possible (Petrov G.N., 2009).

The effectiveness of **water management in the lower reaches** of the Amudarya River mainly depends on coordinated actions of BWO Amudarya, Nizhneamudarya Basin Irrigation System Administration (Republic of Uzbekistan), Ministry of Water Resources of Turkmenistan and Division of the Tuyamuyun Hydroscheme Operation. This relates to control over interstate objects at the boundaries of provinces, water intakes from the river, as well as over sanitary and environmental releases into the Delta fulfilled on the basis of channel balances and flow losses calculations. The important task is planning and observance of the efficient operation regime of the reservoirs of the Tuyamuyun hydroscheme that would minimize water losses in the reservoirs.

Control over distribution of flow from the Amudarya River is made through step-by-step water balance calculations, from the upper water intake to the lower one and flow imbalances are derived from the water balance equation for each of such river section. Depending on degree of flow imbalance, one may identify possible surplus or shortage of water diverted into irrigation system. Unfortunately, BWO Amudarya performs such control virtually manually, without appropriate **information and analytical support** (DB, models).

The main task of the Tuyamuyun hydroscheme is to regulate the system of basin management in the lower reaches of the Amudarya and thus: 1) to ensure drinking water supply to population at the expense of the Kaparas reservoir, 2) to minimize adverse impacts of water availability extremes (droughts, floods) and create favorable conditions for maintaining equitable water delivery at transboundary level, including water delivery to Prearalie, 3) to strengthen capacities at the national level in terms of guaranteed water use, loss reduction and sustainable water supply.

At present, the siltation of in-stream reservoirs of the Tuyamuyun hydroscheme is estimated at 1.1…1.2 km³. Degree of siltation changes every year: it decreases with flushing, i.e. there is a **possibility to manage siltation and sediment transport processes** in the waterworks facility. The basic principle of flow redistribution between the reservoirs of TMHS consists in the priority drawdown of the in-stream reservoir (as compared to off-stream reservoirs) and simultaneous filling of all reservoirs (in case if such filling is possible). This helps to significantly reduce **flow losses** both in the in-stream reservoir and in lower reaches of the Amudarya River. Turbid water delivery along the river channel and to the lower canals may reduce water losses by 1.2…1.4 times in the lower reaches.

The loss of a part of regulating storage in the reservoirs of Nurek and Tuyamuyun hydroschemes may be compensated by regulation of flow in the Amudarya River in **intra-system reservoirs**. Flow regulation in the intrasystem reservoirs has its own peculiarities during low-water and high-water periods (seasons). In case of low-water periods, the intra-system reservoirs, first of all, operate to reduce deficit during the growing season, which may be covered through maximum possible water intake from the Amudarya River during the non-growing season and accumulation of water in the reservoirs by the beginning of the growing season. In case of high-water years, operation of the intra-system reservoirs (and of relevant canals) aims at maximum possible reduction of flood peaks along the Amudarya River.

Meeting the requirements of Prearalie, i.e. **maintenance of the lake systems in the Amudarya River delta**, is possible during normal or high-water periods, when annual inflow to the Samanbay river section is not less than 8 km³. Taking into account technical restrictions of the existing set of structures, in particular of the Mejdurechie reservoir, inflow to the delta must not vary widely within the year, otherwise forced discharge of waste water into the Aral Sea, bypasssing the lake system, may occur. Stream flow can be smoothed through efficient operation regime of the Tuyamuyun hydroscheme that implies gradual increase or decrease of water releases into the River.

One of the factors that is not considered while allocating water and managing irrigation in the Amudarya River basin is the **productivity of land and water resources**. It is obvious that water consumers with higher productive lands bear more losses in case of water deficit than those with lower productive lands. Given fact will be accounted in distribution of water only when compensation of damage in the lower productivity zones will become a state policy. Otherwise, as the result of disproportionate water allocation, social and economic losses related to human resources (employment of the population) and production will exceed potential benefits from the use of higher productive lands.

Low reliability of forecasts and assessments of available water resources, lack of information on the current deficit in the basin and **of unbiased evaluations of potential damages** as the result of low-water level are the main destabilizing factors that complicate control during the growing season in dry years. The dry period 2000-2001provoked the **above-quota water intakes** that became the main reason for **disproportionate** water supply of water users throughout the territory. In 2000, the actual deficit amounted to 59% of the quota in the lower reaches (Republic of Karakalpakstan). If water had been allocated proportionally between the users, the water deficit would have not exceeded 20% of the established water withdrawal quota. What measures could have been taken to reduce water deficit? First, more effective operation of the Nurek reservoir during the growing season 2000 would have resulted in additional drawdown (without damage to the following years) of 0.5..1.0 km³. Second, by the beginning of the growing season, water accumulation (under tight control) could have been 2.5…3.0 km³ more as compared to actual accumulation in in-stream and intra-system reservoirs. However, such actions have not been taken as decision-makers had no appropriate **calculation figures for both given season and also for previous and following seasons**.

To avoid such critical situations, **technical meetings** are held from time to time **on water allocation in the lower reaches of the Amudarya River** (under the Agreement on sharing water resources of Turkmenistan and the Republic of Uzbekistan in the lower reaches of the Amudarya River of May 26, 2007, Urgench) to reconcile the interests of the Republic of Uzbekistan and Turkmenistan. The participants include the Head of BWO Amudarya, representative of the Ministry of Agriculture and Water Resources of the Republic of Uzbekistan, Head of “Dashoguzsuvkhojalik” PA (Turkmenistan), Head of the Nizhneamudarya Administration, Head of Nizhneamudarya Basin Irrigation System Administration and Head of OD of TMHS. Organizations of the upper and middle reaches of the Amudarya River from Tajikistan and Turkmenistan – BWO Amudarya and Sredneamudarya Administration of BWO Amudarya – take part in the **extended technical meetings**. At the meetings, they adjust operation regime of TMHS and water withdrawals to minimize potential negative impacts on the basin; they make decisions on mitigating floods in the middle reaches of the Amudarya River through intakes –by Lebab province of Turkmenistan, etc. **Protocol decisions** of the technical meetings are the subject for fulfillment.

To ensure coordinated and mutually beneficial actions of all actors of the water management system in the Amudarya basin, there is a need for common **rules of water management** in the basin. The main purpose is to harmonize the management system in the Amudarya basin and create a stable, sustainable and equitable water supply. One of the main negative impacts on water availability in some areas of the Amudarya basin is the **anthropogenic variability of runoff** directly related to water policies of independent states in the basin. Despite efforts taken on water distribution between the users, it is impossible to completely avoid disproportionate water use even within one country, especially between the middle and lower river reaches. This demands the development and approval of the **unique methods of assessment** related to available water resources that may be used, **mechanisms for** water distribution **planning and control** based on channel water balance. During low-water years, the situation is rather complicated in the basin; it demands certain decisions on **strengthening cooperation**, first of all, by means of additional institutional and legal measures (extension of BWO’s jurisdiction, enhancement of its legal status, etc.). It is important to pave the way for future agreement on water allocation with **Afghanistan,** set **rates of allowable channel losses**, etc. The existing agreements do no cover all issues related to transboundary water sharing in the basin. **Inflow to the Aral Sea is not guaranteed**. There are open questions related to regional and cross-sectoral **information exchange**, protection of international watercourses, **procedures for joint water monitoring along** transboundary rivers, procedures for **dispute settlement**, etc.

Water management practices in the Amudarya basin show that all riparian states are interested in the development of a **coordinated** water **policy** aimed at preventing potential **conflicts** between the states. In this context, for sustainable water management in the basin it is necessary to develop **a long-term water strategy based on the water use scenarios**, climate change (warming) scenarios, adaptation measures, regulation of flow by HEPS cascades, and environmental restrictions. Nowadays it is accepted that at the transboundary level water allocation between the states is based on the **“existing water use” principle** (for which quotas of water withdrawal from transboundary rivers are established) until formulation of a **regional water strategy** that will suit each state and set improved mechanisms and criteria for water allocation in line with the country development strategies for **hydropower and agrarian sectors**. This strategy must incorporate world experience, new approaches, and opportunities that altogether will make a breakthrough in the basin, where sectoral and narrow approach to management becomes ineffective and there is an understanding that only **coordinated actions of all stakeholders** will prevent ecological catastrophe and reduce the risks of food and energy security in the countries.

Meanwhile, as early as now the basin is under conditions that differ from the previously set assumptions, especially, regarding flow and discharge fluctuations that do not agree with those stipulated in the "Comprehensive Master Plans for the Amudarya River basin". Moreover, the current tendencies in stream flow changes and the development of some river reaches and planning zones are not taken into account. All this prevents from continuation according to business as usual scenario.

<u>The long-term water strategy</u> must account fluctuations in water sources in order to define behavior pattern under conditions different from the average ones, and also apply modern methods of water management improvement, including IWRM, water monitoring and prediction, based on RS, and mutually beneficial institutional, legal and financial mechanisms of interaction in this complex management system.

Orientation to the **long-term water strategy** will allow identifying and minimizing (in joint regional projects) the risks of existing destabilizing factors such as population growth and increased water demand, environmental problems, climate change and its impact, Afghanistan’s plans to use the flow of the Amudarya River and its tributaries. For the strategy to be implemented, it will be important to **adopt democratic water governance principles** through participatory water management and gradual transfer of some authority to the lower level of water hierarchy; **foster public ownership**, train strategy implementers and **solve social problems** (access to drinking water, employment, etc.).

2. Logical model of water resources management in the Amudarya River basin

The logical model of water resources management in the Amudarya River basin may be formulated by **studying the components of water management systems** (sections of river network, HEPS and reservoir cascades, planning zones, aquatic ecosystems). It cannot be built only through the analysis of technical characteristics, needs and hydrology of water management systems (planning zones), river sections, HEPS operation regimes. **It is also needed to study legal, social and economic aspects** of issues related to water resources management.

Studying tasks and problems of water resources management in the Amudarya River basin allowed analyzing functioning of water management systems in the Amudarya basin and proposing the **logical model** of water management, which:

- Applies logic in water management, thus **establishing relationships between control and controlled systems**, determines critical **management principles** (that will be accounted in PEER Project research)

- Strengthens management tools (models) through the **logic of analysis and rules of basin functioning and management** (PEER contribution to the improvement of existing basin water management tools).

Control and controlled systems

Water management system in the Amudarya basin (as an object of analysis and modeling in the PEER Project) consists of **the controlled part**, i.e. the object of management (–water infrastructure) and the **controlled part**. In the PEER Project, for the purposes of modeling exercises and numerical experiments, the system of water management is considered as a means for **development, assessment and study of alternative strategies** (scenarios). The researcher, via the ASBmm user Web-interface, can form **control actions** as parameters and trends of the studied object. There can be **a feedback**, i.e. when the model of the controlled part outputs information that indicates to management errors and inaccuracies, after that the control actions are revised. These clarifications may relate to demographic trends, sales prices of agricultural output, energy tariffs , cropping patterns, HEPS operation regimes, selection of climate change scenario, agrarian development scenario in PZ, environmental requirements to river flow, etc. In the PEER Project, the controlled part of basin water management system is represented by different economic sectors sharing water; it is studied within the boundaries of states and planning zones in terms of nature, water, energy and irrigation. The planning zone includes all elements of water infrastructure, such as: water supply, hydropower, and, particularly, irrigation and drainage networks; it is located within the boundaries of administrative provinces of the riparian countries or in its part. **The control part** (partly represented through the Web-interface in ASBmm) consists in: **organization of management** (who, where, how and when can organize management, with the use of which means, for which purpose, and for how long), **formation and assessment of control actions** (with account of regulations, "rules" and management logic –principles, criteria, incentives, etc., improvement of the models and Web-interface architecture, preparation and conduction of numeral experiments), **decision making and implementation** (with account of executive orders, public opinion, justification and implementation of management decisions at transboundary, national, sectoral and territorial levels, control over implementation).

Problems, principles and logic of water management

Water management in the Aral Sea basin should be based on reconciliation of interests of the main water users and consumers, setting quotas of water withdrawals from transboundary rivers, development by states of joint decisions on flow regulation by reservoirs and water allocation in extreme conditions (drought, flood), harmonization of operation regimes of interstate reservoirs with hydropower between the countries.

In practice, operation regimes of all main reservoirs with hydropower and water withdrawals in the Amudarya basin are developed by BWO Amudarya and approved by ICWC without participation of national energy companies; however, the former are implemented by energy companies, often without approval of ICWC. Such **management logic** may cause a need for involvement in the management process (to resolve critical situations) of the riparian Governments so that they will have to fulfill dispatcher functions. To prevent this, it is necessary to assign legally BWO with additional mandate to involve national energy companies during planning. If water scarcity is predicted in the Amudarya basin, when developing BWO's plan on flow regulation distribution, the operation regime of the Nurek HEPS and proportional cuts of water intakes should be agreed with energy companies, while the operation regime of the Nurek reservoir should be harmonized with the operation regimes of TMHS reservoirs and intrasystem reservoirs.

In future, there may occur situations associated with **over-regulation of the Nurek HEPS** in order to: i) **better meet winter needs** of Tajikistan for electricity (this may result in decrease of

water releases from the reservoir in summer), ii) **minimize idle water discharge** (this may results in increase of water releases in summer in high-water periods), iii) produce additional energy for export in summer (this may result in increase of water releases in summer in high-water periods). The regulation option of the reservoir that implies an increase of water releases in summer may be suitable for Tajikistan, whereas for the Republic of Uzbekistan this situation is admissible only in case if this summer energy is not supplied to Kyrgyzstan in exchange (return to Turkmenistan) for winter energy; this energy exchange will complicate the situation in the Syrdarya basin – water releases from the Toktogul will decrease in summer and increase in winter; this will lead to more deficit in summer in the Fergana Valley and worsening of flood situation in autumn and winter seasons.
Based on the logical model, which considers all risks and destabilizing factors, it is planned to build analogs of possible conflict situations. It will be taken into account that each state seeks to get water from the limited transboundary source in needed for this state quantity, place, and time in order to meet its demands (ecology, hydropower, irrigation, drinking water, industry). At the same time, it will be assumed that there is a certain common component in the range of states' interest (otherwise, there will be no sense to solve the conflict problem), and this component needs to be found. For example, one can select from the transboundary water resource a certain quantity of water that is used for multiyear year regulation to compensate water and energy shortage. It is assumed that further growth of hydropower development would allow more effective coordination of management to meet demands of irrigation, energy, and nature under conditions of growing flow fluctuations. Afghanistan's demand for water from transboundary rivers will be taken into account, as well as reduction of CDF discharge into the Amudarya River and decrease of its water content will be studied.

For the scheme of distribution of regulating functions between the reservoirs of the Vakhsh-Amudarya cascade, we propose to consider such **operation of TMHS**, which follows certain rational regime based on a number of rules. Water inflow to the hydroscheme is considered as a variable, through which the operation regimes of TMHS and the Nurek reservoir are linked and the regimes are corrected. The rational operation regime can be achieved in the process of step-by-step building of particular solutions. The volumes of flow regulation in intrasystem reservoirs (and relevant water intakes to the canals) are estimated, taking into account the following conditions that are fulfilled in the order of priority: compensation of the Pyanj River flow and of regulated Vakhsk river flow according to the requirements of the Amudarya middle reaches; re-distribution of residual flow (inflow to the Tuyamuyun hydroscheme) according to the requirements of the Amudarya lower reaches. In case of dry years, the intrasystem reservoirs should operate, first of all, **to reduce water deficit in the growing season** that is to be overcome through maximum possible intake from the Amudarya River in the non-growing season and accumulation of water in the reservoirs by the beginning of the growing season. In case of very **humid years**, the intrasystem reservoirs (and relevant canals) should operate for maximum reduction of flood peaks in the Amudarya River. This **management logic** is based on practices of flow regulation and its allocation in the basin.

As an option for improvement of interactions between BWO Amudarya and national water authorities, it is advisable to establish and develop a **Basin Water Council** as a voluntary organization of stakeholders in the basin for involvement of stakeholders in in the development of agreed operation regime, evaluation of water supply reserves and water saving possibilities, as well as for harmonization of relations with the national water suppliers.

<u>Upgrade of mathematical models</u>

In the PEER Project, the mathematical model of water management in the Amudarya River as part of the ASBmm software (www.asbmm.uz) will be upgraded in the following directions: integration of logical operators, such as **"If…, then…; or – else**". The logical operators will be integrated into the algorithm of water **balance of planning zone**. The water balance depends on **of the transboundary and local water source use practices**. The following options will be offered: **“basic”** option that corresponds to the existing agreement between countries on water use quotas and **“transboundary water saving”** option. Under the first option, transboundary water to the planning zone is supplied according to the established water quotas, based on flow probability: if there is enough water in the rivers, full volume of in water quota is supplied, or the latter is cut proportionally in case of flow deficit. For the second option, the water needs of a planning zone are covered, first, through local water, and the rest is covered from transboundary river; herewith, the “basic” option’s limitation is applied, i.e. one cannot take more water from transboundary rivers than it is set by water quotas. This calculated intake from transboundary and local sources forms two options of water balance, which includes return (collector-drainage) flow, lateral inflow to the rivers, and water losses and deficit in the planning zone.

Modeling of **lateral inflow to the rivers** is based on the description of functions of its elements: CDF from the planning zone discharged into rivers (some quantity of CDF is flows to the neighboring planning zone, some quantity is reused for irrigation and the rest is discharged into lakes and rivers), wastewater from the domestic sector and industry discharged into the rivers, as well as the discharge of the residual flow along small rivers. In the models, the groundwater component of the lateral inflow to the rivers is accounted as a part of channel losses (negative component), alongside with evaporation and seepage losses, as well as “channel regulation” (recharge of the river channel and flood plain at the peak of flood and drawdown of accumulated water at the ebb of flood). The lateral inflow to the rivers that includes return flow from irrigated fields is described as a function of water intake of the previous period of time and water availability in the area of return flow formation. This logic defines the **hypothesis and type of empirical relationships** in the planning zone model.

Recommendations for water resources management (that can be used by analysts and decision-makers) developed by the PEER Project will provide alternatives based on the **analysis of cause-and-effect relations** for a wide range of input data.

At the current stage of cooperation, the riparian countries of the Amudarya basin are not ready to apply water management methods that are based on **sharing of upstream and downstream benefits in the form of production revenues**; however, informing of decision-makers on such benefits will help to maintain positions and resolve controversies. Thus, **information on the basin benefits (as well as on damages)** must be assessed in the modern tools (models) of water resources management.

When developing **criteria for assessment of alternatives** in the PEER Project, the following indicators may be incorporated into the models: water and energy deficit (including per person) derived from assessment of resource balance and on the basis of “supply-demand” and “production-need” analysis. Here, we can use such terms as **“water security”** and **“energy security**”. **“Food security”** may be characterized by water and land productivity and produced quantity of scarce products in irrigated agriculture under conditions of short or enough water supply that are considered as strategic products in national agrarian policies. In literature (David Grey, Claudia W. Sadoff., 2007), these terms are defined in a different way: they imply secure access to water, energy and food.

Research methodology (see section 1.2) assumes application of new approaches based on advanced US experience, particularly in part of adaptation of existing model and tools for water management to conditions and characteristics of the Amudarya basin. For adaptation of ASBmm, the system approach will be used. According to such approach, the components (planning zones, rivers, lakes, reservoirs, HEPS) are considered as large complex systems – models of management and, simultaneously, as the elements of a general system – model of management at country and basin level. The following methods of complex system modeling are planned for use: methods of ICAM (Integrated Computer-Aided Manufacture) developed in US for the industry computerization program, including Function Modeling – re-thinking and development of radically new function processes, Information Modeling – building of an information model on a new logical level - software, which implements new function processes and logics in ASBmm.

Decision-making process

When making decisions, there may appear **the conflict of goals**, which should be resolved by decision-makers. In this case, decision-making functions can be distributed between decision-makers and analytical researchers (who have models and information at their disposal). Decision-makers will define problems, goals, **preferences in goals**, whereas researchers will prepare materials on **alternatives**. The researcher should clearly distinguish between the outcomes obtained on the basis of "real (or actual) data" and those based on "expert judgment" that are subjective but often important for decision-making process. If the proposed materials are not satisfactory for decision-makers, further communication of decision-makers and analysts is needed. Changes can be made in limitations, control actions, criteria (for example, the balance of interests and target indicators, feasibility). Alternatives should be of informative character, "transparent" and understandable, in the form of values of the main target function (optimization) and the set of additional indicators. Selection of alternative and the alternative itself are accompanied by risks.

The set of alternatives should contain both long-term and short-term options. The first ones aim at improved performance of the systems or adoption of new and more efficient irrigation technique; the second ones imply involvement of additional water sources from CDW or waste water, as well as the possibility of optimal reduction of water supply that has minor effect on yields (this task was addressed in the "Scheme for Integrated Use and Protection of Water Resources in the Syrdarya River Basin" in 1978).

Decisions made in one country may affect the other country's interests. To find a trade-off, as a rule, technical solutions and economic justification are not enough; **the assessment of social consequences** is necessary; the decisions may concern **legal and political issues**. In this case, it is possible to involve policy-makers who have more "policy-oriented' information regarding urgent problems, reforms, transboundary cooperation, existing mechanisms for coordination between the countries, national agrarian and energy strategies, programmatic implementation of innovations, reconstruction of water and power facilities, political decisions on adaptation, investments, etc. **The search for trade-off** is based on defense of the sovereign rights of each state; however, it is also important to respect rights of other countries and follow the key principles of the international water law, such as equitable and reasonable water use and no harm. When searching for trade-off decision, an analysis can be conducted to exclude certainly ineffective decisions and undertake step-by-step search with use of the certain **logical rule**, for example, the so-called **Pareto principle**, which can be defined as follows: "any change that does not cause damage (as compared to the previous change) and brings benefit (revenue) to some water consumers (users) should be considered as improvement."

Guidelines for water sector development

One of characteristics of the Amudarya River basin is the limited nature of water resources and, consequently, limited production of food and vulnerability of aquatic ecosystems. This manifests in uneven distribution of water scarcity in space and time and in unequal consequences for states, water-management districts, and users (consumers). The natural water scarcity is aggravated by artificial shortage caused mainly by operation of large reservoirs with hydropower. Moreover, aquatic ecosystems need stable annual supply. The Planning zone model of ASBmm in the PEER Project is upgraded to consider these features through a range of principles that will be recommended (as PEER Project outputs) as common guidelines for national water sector development until 2050. For instance, all riparian countries seeking consensus in water management should agree with the following point: no development in the riparian countries is possible without **innovations** and measures aimed at reduction of unit (per capita) water demand, with ensured **observance of water limits** set for the countries from transboundary rivers and **environmental flows**. The second important point: one should acknowledge that contradictions between hydropower and irrigation demands for river flow exist and will remain in the future. These contradictions can be solved through efficient operation of large reservoirs and cascades of HEPS according to the rules (restrictions) and in line of principles (allocation of water for mitigation of scarcity in dry years, meeting of environmental demand, etc.) as agreed by the states. .

Conclusion

The logical model combining the interstate and national management levels will be used for studying elements (objects) of water-management systems, building and studying scenarios of water and hydropower development in the riparian countries under conditions of demographic growth, potential climate change and other future challenges. Here, the aspects related to water protection will be taken into account as well.