Research report

1.Preparation (planning & design)

1.2 Development of research methodology

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Table of contents

Introduction

The project research will allow: building a set of scenarios and options of Amudarya transboundary water management in the form of assessments and recommendations for various stakeholders, creating the project database, improving existing tools (models), and developing methodological and training materials.

Given report describes some of the results achieved in the first research stage, namely methodology of the research and the scheme for development scenario combination.

1.Methodology

The methodology of the research efforts carried out as part of the PEER program is aimed at building capacities of scientists from Central Asia on the topics and in the areas considered by USAID as priority ones and in partnership and cooperation with the U.S. scientific community. Notably, it supports scientific and innovation approaches to selection of strategic solutions for the issues related to management, development, food security, environmental sustainability, and transboundary conflicts. As a result of the PEER project it is expected that capacities of Amudarya riparian countries will be improved for effective water management and a platform for scientific cooperation will be established as a mechanism for trust building in the region. Effective project impact on development and formation of a brand new partnership will be facilitated by cooperation with the USAID office in Tashkent.

<u>The use of systems approach and numerical experiment</u>

The control theory provides methods for solution of two major types of problems. The first one – **methods for solution of** control system performance **analysis problems** – will be used in the Project in analyzing a time frame 2010 – 2015. The second type includes the **synthesis problem**, which sets the benchmarks and requirements given which one must decide how management (of water, land) should be performed and existing potentials (hydropower, etc.) should be developed – to be studied in the Project for a time frame 2015 - 2050.

In given research we will apply the **simulation modeling**, which implies numerical experiments. Particular focus will be placed on solution of conflict situations occurring when the common resource is involved in different processes in time and space and in terms of quantity. In case of given basin, operation of objects and processes taking place at the same time or in parallel will be simulated with some time step.

Concerning water resources management, the **systems approach** can be represented as a 'method for solution of problems (tasks), which tries to construct a copy of the real-world system or situation so that as a result of (numerical) experiments with this copy (model) one gains an insight into reality' (A.Biswas, 1985).
The whole set of research in the PEER Project is based on such **modeling and analysis** of various options (scenarios) of water-management system performance and status in the Amudarya basin in the future (up to 2055), with account of climate change, runoff regulation by hydropower reservoirs, water infrastructure development, and water demand changes from the side of drinking water supply, industry, irrigation, and aquatic ecosystems (including the Aral Sea).

<u>Zonation and selection of research objects</u>

The Amudarya basin was divided into **zones in terms of water**. Consequently, the key research objects were identified. Those included river network sections, HEPS cascades, reservoirs, planning zones (PZ), main canals and collectors. Those objects were associated with boundaries of large water-management districts (upper, middle, and lower reaches of Amudarya) at the national level and with basins of main tributaries of the Amudarya River. Based on this zonation and the selected research objects, the data was collected and the structure of the project DB was developed.

In given structure, **water resources** are considered from all **sources**: surface water from rivers, reservoirs, lakes; groundwater; return water (wastewater, drainage water). **Rivers** are divided into balancing sites. We also differentiated between transboundary and local rivers of the small Amudarya basin (SAB), and rivers in Turkmenistan. **Reservoirs and HEPS cascades** located along transboundary rivers and main canals of SAB, as well as reservoirs at local sources (rivers) were pointed out. In **PZs** (see Annex), we singled out zones irrigated from Amudarya, its main tributaries (Vakhsh, Pyandj, Kafirnigan), and local surface sources (conditionally, such rivers as Surkhandarya, Zarafshan, Kashkadarya, Tadjen, Murgab). The Garagumdarya zone (of Karakum canal) is studied separately. PZ is characterized by: irrigation schemes, irrigation and drainage network, water resources (surface, ground), collector-drainage water from irrigated fields, lakes, reservoirs, domestic water supply and industry users, and wastewater. **Irrigation schemes** (within PZ boundaries) are characterized by a number of irrigated land areas usable for crop growing (see Annex). **Transboundary component** of PZ is considered in the assessments of river flow and irrigated areas (differentiation between transboundary and local sources) and in the simulation of a network of interstate rivers and main canals.

Scenarios

Assessment of the Amudarya Basin development in the PEER Project is made on the basis of national economic sector **development scenarios**, mainly, of irrigated agriculture & agrarian sector and hydropower that are built with account of national development strategies and programs. Demands of drinking water supply, natural environment, and industry are priority ones. The main indicators in scenario assessments include: productivity of water, land, and hydropower. Major control actions are: operation regimes of reservoirs and HEPS, cropping patterns, innovation technologies for conservation of water resources and improvement of crop yields. For assessments of the future for 2016-2055 the PEER Project will consider: climate scenarios, natural river flow series, Nurek HEPS operation scenarios, agricultural development and cropping patters scenarios.

Selection of climatic scenarios

Global climate changes are very complex; therefore, modern science cannot state definitely what we can expect in the future, especially taking into account that such changes are shaped by both natural and socio-economic factors that contribute to greenhouse gas emissions. There are multiple scenarios of development.

The three-dimensional numerical general circulation models (GCM) have been considered to be the most reliable tool for modeling of physical processes that drive climate changes [Agaltseva N.A., 2002]. These models use different input data and scenarios of greenhouse gas emissions and produce different results; therefore, given the significant uncertainty of estimations, at the regional level (Aral Sea basin, Amu Darya basin) usually several scenarios and models were selected; **regional climatic scenarios** we built using the method of averaging for the results of models from the world's leading climate centers - HadCM3, Hadley Centre, Great Britain; ECHAM4, Max Planck Institute, Germany, etc. [Agaltseva N.A., Bolgov M.V. et al., 2011].
Climatic scenarios are built on the basis of IPCC greenhouse gas emission scenarios that characterize changes in average values by 2030, 2050, 2080, etc. The emission scenarios are developed from various assumptions about dynamics of socio-economic factors and, accordingly, different levels of greenhouse gas emissions. These scenarios are updated every

year and published in special reports. The following groups of such scenarios are examined: B2 (moderate, more humid option), A2 (drier option), A1B and others.

At present, future regional climate changes are estimated through a set of global atmosphere-ocean general circulation models of **new generation**. Two approaches are used for construction of climatic scenarios of Uzbekistan. First one is a standard approach to climatic scenario building **on the basis of generally accessible data of climatic models from the MAGICC/SCENGEN base**. Climatic scenarios are built on the basis of an ensemble of the climatic models MAGIC/SCENGEN, version 5.3, with account of success rate statistics of the models for plain and mountain areas in Central Asia. Such an approach helps to choose those models that most accurately describe climate changes in the CA region and, based on averaged characteristics, have future climate change scenarios for given time in the future (in 30, 50 years and so on). These models for the area of this region give significant variation of expected increases in the mean annual temperatures by 2080 (from 9.3 to 3.3°C). This is related to different sensitivities of the models and other reasons (resolution, stage of development, correctness of model parameterization for particular region, data quality, etc.).

Another approach to scenario building became available through cooperation with the Central Asian Water (CAWa) project financed by the German Federal Foreign Office as part of the German Water Initiative for Central Asia within the Berlin Process initiated in April 2008. GFZ German Research Centre for Geosciences (GFZ) in Potsdam has been coordinating this project. In this case, it is possible to get output data of the **global circulation models** with high spatial resolution to construct series of future climate change scenarios. For assessment of climate change impact on crop water requirements and water resources in the **PEER Project** we use the output from the REMO-0406 and REMO-0507 models, with the spatial resolution of 0.5° and 0.16°, based on greenhouse gas concentration scenarios CMIP3 SRES-A1B. As part of the CAWa project, **University of Wurzburg** has got the results of regional climate modeling for Central Asia that covers the **whole area of the Amudarya basin**.

Adaptation will mean self-tuning to ensure sustainable development and stability, in terms of a number of indicators, of evolving system. Adaptation to climate change implies development of measures and identification of control actions that facilitate the development of riparian countries and Amudarya basin in general. Analysis of water management and energy entities in the basin indicates to their **adaptability** (for “soft” climatic scenarios).

<u>Modeling of river flow</u>

The major sources feeding the rivers in the Amudarya basin are the melt waters of seasonal snow and glaciers. Water content of the rivers depends on their response to climate change. Snow accumulation during cold season mainly shapes the spring and summer flow and this is exactly snow storage that makes major contribution to flow generation in form of melt water flowing to the catchment area and the melt component of growing-season flow. The snow storage downward tendency is observed in the basins of many rivers in the region and this corresponds to temperature growth trends recorded at weather stations throughout the region. With the temperature rise conditions become less favorable for snow storage in mountains, this storage decreases, with the consequent reduction of flow in some zones of catchment.

The **SANIGMI’s flow generation model**, which allows assessing the role and contribution of different sources to river flow, is used as the **main tool for modeling** of river flow in the Aral Sea basin (Denisov M.V., Agaltseva N.A., Pak A.V., 2000). The model calculates flow on the basis of climate scenarios (temperature, precipitation). Other hydrological models also were used for the Aral Sea basin. Those include: **WASA** (German Research Centre for GeoSciences, CAWa Project), **HBV** (Y.Hundecha, A.Bardossy, 2004) and others. Unfortunately, WASA and HBV are not adapted to the Amudarya River basin. The SANIGMI (currently NIGMI - Research Institute of the Center of Hydrometeorological Service at the Uzbek Cabinet of Ministers) model was used for estimation of river flow in the Syrdarya basin (NIGMI, 2014), some rivers of the Amudarya basin (Vakhsh, Kafirnigan, Surkhandarya, Kashkadarya) and the Amudarya River for a long-term, based on climatic parameters of the REMO scenarios. **There are no estimations for the Pyandj River on the basis of NIGMI and other hydrological models** because of a lack of necessary data in terms of quality and quantity and poor calibration. This forced us to use an alternative approach in the PEER Project, alongside with river flow estimations by the NIGMI model. This approach allows constructing future hydrographs of all main tributaries of Amudarya, including the Pyandj River.

Such **alternative approach** implies modeling of river flow by using **historical cycle-series** adjusted for the future, taking into account climate change. This approach applied in the ASBmm package [www.asbmm.uz] and tested against actual data (including comparison of calculated and actual flow series for 2010-2015) is based on the concept of the cyclical nature of natural process variations, which is viewed as progressive development on which climate-driven changes have an impact rather than as simple periodical repetition of observed phenomena; series are corrected by coefficients derived from the NIGMI model's assessments. Thus, the concept of cyclical nature (which takes into account all special characteristics of local flow generation) in given approach is enhanced by hydrological modeling, fitting climatic scenarios. By using this approach in the Project, we project the NIGMI estimation (in form of a deviation from the flow norm by 2020–2060) to natural cycles of flow hydrographs that continue and keep observed trends in the future. Since deviations of flow for 2020–2060 caused by climate change are not shown in the REMO scenario, we calculate these deviations by the balance method on the basis of deviations of flow in Amudarya mainstream and its tributaries.

While using the ASBmm-based approach, we had to fill the existing data gaps and **reconstruct flow series** of such rivers as Pyandj (Tajikistan), Kunduz (Afghanistan), Murghab and Tedjen (Turkmenistan). This way we could estimate water resources in the Amudarya basin for 2010-2015 and construct expected river hydrographs for the future as prolongation of the existing natural cycles adjusted for climate change.

We will use the following calculation scheme for the Pyandj River: relationships between the annual river flow of the Pyandj River, Wp, and the total annual river flow of the whole basin, W, are derived by using SIC's data until 2000. By using the balance method, we estimate the natural river flow in Amudarya Basin for 2000-2015 (as the algebraic sum of measured flow of Amudarya at Kerki station, non-recoverable water intake to Tajikistan and Uzbekistan upstream that station, amount of flow regulation by Nurek reservoir, and channel losses), and then, based on the relationship for Wp(W) we calculate (reconstruct) the river flow of Pyandj River, Wp for 2000-2015.

There is also an approach, which is based on the stochastic flow fluctuation concept proceeding from the fact that flow process is stochastic and, thus, it can be described by the methods of probability theory and mathematical statistics. Examples of the usage of this approach are the models for Vaksh and Amu Darya Rivers that produce assessments under conditions of high uncertainty [Agaltseva N.A., Bolgov M.V. et al., 2011]. The results of stochastic modeling will not be used in the Project as input information for numerical experiments of flow regulation and distribution in the Amudarya basin but those will be considered in the scenario assessment of future situation in the basin and in comparison of the results from different approaches.

Scenarios of water use and cropping pattern

One of the main project tasks, which is to **study scenarios of water use** in some provinces (planning zones) in riparian countries, is connected directly with the scenarios of **irrigated agriculture development** that are a part of national agricultural and socio-economic development scenarios; the project will study three scenarios: i) business as usual, ii) food security and import substitution, and ii) agricultural export orientation. Food security, import substitution and agricultural export should be in the focus of agrarian policy in the future. Cropping pattern scenarios are based on the analysis of agricultural and water development strategies (scenarios) in all riparian countries of the Amudarya basin for the long-term. These can imply, for example, reduction of cotton area, expansion of wheat and forage areas (according to food security and import substitution scenario), and increase of vegetable, orchard and vineyard areas (agricultural export scenario). These scenarios will reflect national agrarian policies on application of **innovation technologies** (IWRM, drip irrigation, etc.) that improve productivity (yields) and save water (through reduced rates of irrigation and losses of water). All PZs should be adjusted for calculation of water requirements of the following crops: cotton, wheat, maize (grain), rice, vegetables and cucurbits, orchards and vineyards, forage crops (alfalfa, maize (silage), homestead grown crops (for which certain norm of water delivery is set), and other crops (industrial crops, excluding cotton). Double season crops (rice, forage crops, vegetables) that are irrigated during their specific periods of time are also considered.

Water requirements scenarios for non-irrigation sectors (drinking water supply, industry) are built according to existing national strategies and plans for the development of these sectors (up to 2020) and using expert judgments (2020 ahead) that, particularly, take into account trends of population growth and water supply norms per capita (drinking water supply).

<u>Study of water balance and adaptation of ASBmm</u>

The ASBmm set of models is the product, which was generated in cooperation between SIC ICWC (Prof. V.A.Dukhovny, A.G.Sorokin and others) and the UNESCO-IHE Institute for Water Education, the Netherlands (Dr. Joop de Schuter, Dr.Maskey), with involvement of the leading experts from BWO Syrdarya, BWO Amudarya, the Institute of Water Problems, Hydropower, and Ecology at the Tajik Academy of Sciences (Dr. Petrov G.N), GEF Agency, the Institute of Forecasts and Macroeconomic Research of Uzbekistan (Dr. Chepel S.V. The models are supported by information from the SIC's regional database, including the data of SIC's national branches in Central Asia which was collected in national Hydromets, BWOs, Water Ministries and other organizations.

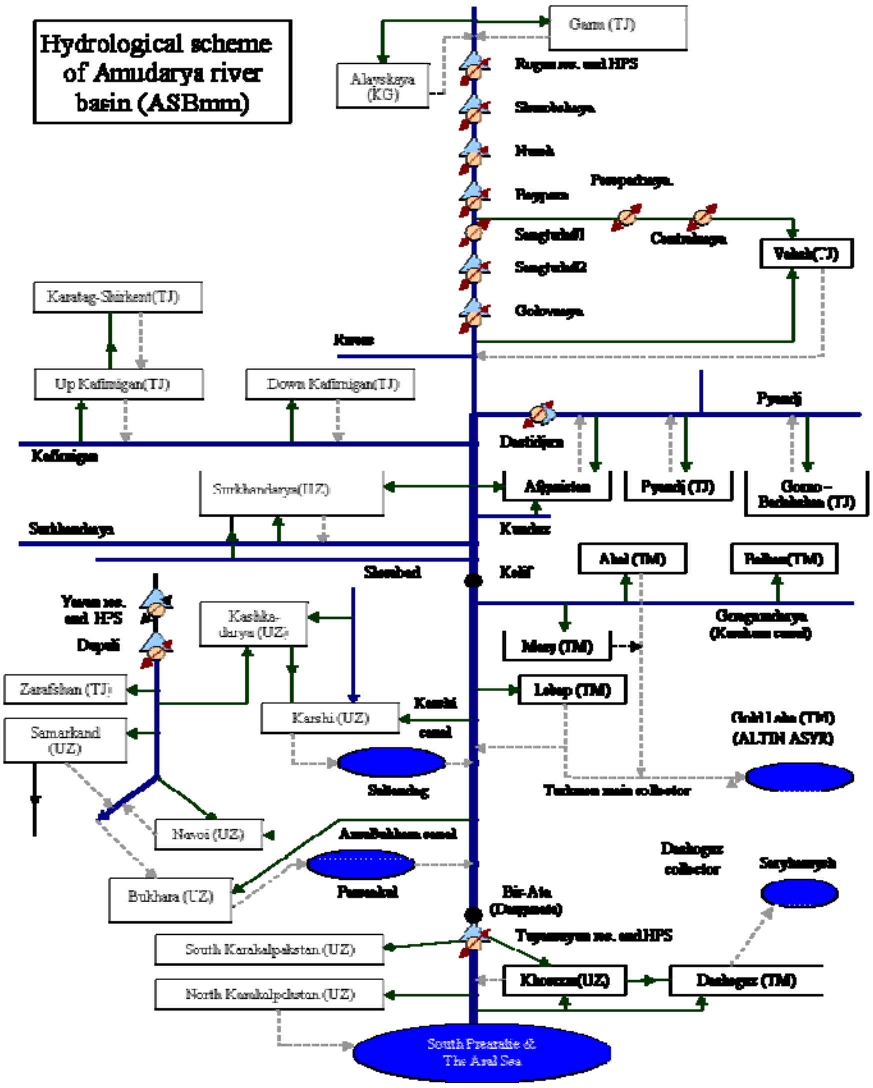
The ASBmm software includes the water allocation model (WAm), the planning zone model (PZm), the socio-economic model (SEm), the user web-interface, and the database. WAm is a specialized computer tool for modeling processes of flow regulation by large transboundary reservoirs with hydropower for major rivers in the Aral Sea basin, for allocation of surface water between the so-called planning zones; the model performs water and salt balance and hydropower calculations on monthly basis for a period of 25 years. PZm is a tool to simulate water requirements in planning zones; the model calculates agricultural output and losses as a result of water scarcity, produces water balances of planning zones in connection with a river network.

Planning zone is a characteristic unit of the water management system and is represented by all elements of its infrastructure, including: i) water supply, hydropower, and especially irrigation and drainage networks; it is located within the boundaries of an administrative province or its part (for example, for the Republic of Karakalpakstan – its southern and northern parts); 22 planning zones are highlighted in the small Amudarya basin.

The concept of ASBmm is based on the following principles of water management in the Aral Sea basin for 2015-2035.

<u>Limits</u> – this is a preset by agreements and observed (controlled) water intake into main canals; non-changeable water quota for riparian countries of the Aral Sea basin (interstate level).

Equitability – principle of water allocation among the countries (not necessarily within one country): water (or its scarcity) is distributed proportionally to the limits of water intake into canals.



Balance – between expected water supply and demand; it can be achieved through management, e.g. by changing water releases from reservoirs, etc.

Optimization - under the established rules (limitations), e.g. water releases from HEPS in winter time will not be guided by electricity demand but rather result from optimization made under the established rules (maximal and minimal water releases).

Compensation – to be made because of the established limitations, e.g. summer water releases from HEPS made to meet the irrigation needs that exceed the energy needs (i.e. compensation of losses in electricity or money equivalent).

Productivity – a key parameter (indicator) for assessment and comparison of the results.

Cost effectiveness – as a characteristic (quality, attribute) of something, e.g. norms of crop water requirements for drip irrigation, sprinkling, and other innovations.

Effectiveness – in form of achievement of the best result, e.g. improvement of productivity (of hydropower, irrigation) through better water management; increase of efficiency; reduction of losses (of hydropower, irrigation). This is determined by comparing scenarios, operation regimes (HEPS), agricultural development scenarios (food security and import substitution), etc. The practiced way (regime) can be potentially cost-effective but not effective in one or another situation.

Adaptation of ASBmm planned in the **PEER Project** implies, in addition to the research part (rethinking of functioning of individual objects and the system as a whole, revision of some functions, input of new factors and variables), programming work. In this context, update of the functional model of planning zone in ASBmm, **changes in the water balance calculation algorithm** in this model and in the DB structure and the user menu (**Web-Interface**) will be undertaken. All these changes and additions are pursuant to the requirements of the applied in PEER **methodology for modeling the complex systems (Function Modeling) and information flows (Information Modeling) developed in the U.S**. Some changes are also needed to build scenarios and make calculations from 2015 to 2055.

Water balances of planning zones will be studied in combination with water balances of the basin's river reaches (with account of losses in river channel). This will help to define more precisely and augment information on **development patterns of water balance's elements** and correctly adjust the tool of ASBmm for numerical experiments – calculation of planning zone development scenarios.

Inconsistency

It should be taken into account that minor inaccuracy in calculations can lead to quite incorrect results. In other words, the principle of "consistency", when small causes lead to small effects (consequences) is not applicable in modeling water management in the Amudarya basin. For instance, reduction of summer water releases from the Nurek reservoir **during critical periods of time** (while observing total planned water releases during the growing season) may create shortage of water with consequent significant losses of crop yields.

Stochasticity

This phenomenon in physical processes of flow generation of the Amudarya basin's rivers always follows deterministic laws; therefore, one should focus on averaged, more "stable" characteristics when evaluating available water resources. However, in the management of water resources (flow regulation by reservoirs, water distribution between PZ and along rivers) it is very important to keep track of **monthly** (or even ten-day) **variations of flow, losses and shortage of water** due to anthropogenic factor (see "inconsistency").

Threshold values

There are some critical values of external impact that cause radical changes in modeled processes and assessments. Researchers and decision makers should "feel" and knew these **thresholds** and set control actions to avoid them.

Interpretation and issue of understanding

Issues and methods of interpretation of research (numerical calculation) results and representation of data are crucial for shaping decisions and their communication to executors. A model can be complex, but its interface (menu, in which the user works) must be easy for understanding.

2. Scheme of scenario combination

After adaptation, ASBmm is planned to be used for **integrated analysis of alternative development and management options**. The **developed scheme** of combination of all main scenarios showing plausible basin development by 2055 will serve as a reference for planned numerical experiments. This scheme includes: climate change scenarios that impact crop water requirements and river flow regimes; hydrological series of river flow in the flow formation zone; variants of HEPS operation regimes; cropping patterns built on the basis of scenarios of national agricultural development, with account of innovations; options of environmental releases into the lakes of Amudarya delta (Prearalie); and, options for accounting demand of Afghanistan.

Scenario combinations for 2016-2055 are formulated as the "**cases**" collected for particular "**tasks**", such as: assessment of natural water resources; assessment of regulated flow and hydropower generation; estimation of water demand and potential productivity of PZ; assessment of water supply and productivity of PZ under conditions of climate change, flow regulation by HEPS, given various agricultural scenarios and environmental constraints, etc. Examples of scenario combinations are given in Tables 2.1 - 2.2.

Table 2.1 Examples of combinations of the scenarios for flow generation and regulation in the Amudarya basin for 2016-2055

Task	Scenario	Case
1.Assessment of natural (non-regulated) water resources in the Amudarya basin	A. Series of river flow rates under natural regime: A1. SIC ICWC, A2. NIGMI (not all rivers in the basin) B. Climate changes: B1. No climate changes B2. REMO-0406	Case 1.1. – combination of scenarios A1., B1 Case 1.2. - combination of scenarios A1., B2
2.Assessment of regulated river flow and hydropower generation by Vakhsh HEPS cascade	A. Series of river flow rates under natural regime: A1. SIC ICWC, A2. NIGMI (not all rivers in the basin) B. Climate changes: B1. No climate changes B2. REMO-0406 C. Operation regimes of Nurek HEPS C1. Operation regime over 2010-2015 C2. Maximizing winter generation C3. Additional generation in summer (export of summer electric energy)	Case 2.1. - combination of scenarios A1., B2.,C1 Case 2.2. - combination of scenarios A1., B2 .,C2 Case 2.3. – combination of scenarios A1., B2 .,C3

Table 2.1 Examples of combinations of the scenarios for PZ development (water regime, productivity) in Amudarya basin for 2016-2055

Task	Scenario	Case
3.Assessment of water requirements and potential land productivity in PZ	B. Climate changes: B1. No climate changes B2. REMO-0406D. D. Agricultural development: D1. Business as usual D2. Food security D3. Fulfillment of export potential	Case 3.1. - combination of scenarios B2., D1 Case 3.2. - combination of scenarios B2., D2 Case 3.3. - combination of scenarios B2., D3
4.Assessment of water	A. Series of river flow rates under natural regime:	Case 4.1. - combination of

supply and productivity of land in PZ under conditions of regulated flow by HEPS and the potential of water intake by Afghanistan	A1. SIC ICWC, A2. NIGMI (not all rivers in the basin) B. Climate changes: B1. No climate changes B2. REMO-0406D. C. Operation regimes of Nurek HEPS C1. Operation regime over 2010-2015 C2. Maximizing winter generation C3. Additional generation in summer (export of summer electric energy) D. Agricultural development: D1. Business as usual D2. Food security D3. Fulfillment of export potential E. Water intake by Afghanistan E1. In water quantities as for 2010-2015 (2.5 km^3) E2. Additional delivery – gradual increase by 3.5 km^3	scenarios A1., B21.,C1.,D2.,E1 Case 4.2. - combination of scenarios A1., B21.,C1.,D2.,E1 Case 4.3. - combination of scenarios A1., B21.,C2.,D2.,E2 Case 4.4. - combination of scenarios A1., B21.,C2.,D2.,E2

Task 1 "Assessment of natural (non-regulated) water resources in the Amudarya basin" is the simplest one; here two cases are proposed. The first case (1.1) implies the assessment of the series of river flow rates in Amudarya basin that are constructed using the method of analogs of historical cycle-series extrapolated to the future (SIC ICWC), while assuming no impact of climatic scenarios on river flow. The second case (1.2) implies consideration of climate changes according to the scenario REMO-0406; the climate impact is accounted through the coefficients (corrections) derived from the results of the NIGMI model.

Task 2 "Assessment of regulated river flow and hydropower generation by Vakhsh HEPS cascade" differs from Task 1 in that the series of natural river flow change through abstraction of water or adding of water from reservoirs. For the Vakhsh River, this is the flow regulated by the Nurek reservoir. The regulated flow of the Vakhsh River and electricity generation by the Nurek HEPS will be studied in three scenarios (regimes): C1.- regime, which follows water releases during the growing season that were practiced in 2010-2015; C2.- regime resulted from maximization of energy generation by the Vakhsh cascade in autumn and winter (this regime will differ from the regime C. but only in dry years with maximal risks for irrigation); C3.- regime stipulating increased releases and generation during the growing season; given regime is possible provided that energy demand increases in summer, and here the following options are possible: electricity export outside Central Asia; transfer of summer electric energy to Kyrgyzstan in exchange for winter one (in this case, there is a risk of changing operation of Toktogul HEPS to "harder" energy regime).

Task 3 "Assessment of water requirements and potential land productivity in PZ" considers scenarios of agricultural development that include the options of different cropping patterns and innovations (business as usual, food security, agricultural export orientation and fulfillment of export potential), the options of crop water requirements calculation (based on agricultural and climatic scenarios).

Task 4 "Assessment of water supply and productivity of land in PZ under conditions of regulated flow by HEPS and the potential of water intake by Afghanistan" is a very complex one since it implies calculations by the two models of ASBmm (with iteration) – PZ model and the model of water allocation between PZs.

Conclusion

The Project will give possibility to define more exactly and deepen information on the mechanisms of formation of water balance for rivers, water-management districts and planning zones. The scientific community will get a unique experience in implementation of the adaptation approach, which is new for the region and which suggests maximum approximation of real conditions during modeling and fills data gaps.

Annex to Section 1.2 Development of research methodology

Symbol	Name	Explanation
C = { }	**Crops**	**Elements of "Crops" data set**
cot	Cotton	cotton
whe	Wheat	wheat
ric	Rice	rice
mai	Maize	Maize for grain
veg	Vegetables	vegetables: potato, tomato, roots, legumes, cucurbits
orc	Orchards	Orchards and vineyards
for	Forage	Forage crops: maize for silage, alfalfa
oth	Other	Other crops: other cereals and industrial crops – oil-bearing crops, sugar beet, tobacco, etc.
hom	Homestead	Homestead grown crops
	Double crops	Double crops; 9 crops are not included in the set but considered via multiplying coefficients for: a) vegetables (carrot, mung bean, radish, etc.), b) forage crops, c) rice. Planted after harvesting of wheat.
I = { }	**Water sources**	**Elements of "Water sources" data set**
tra	Transboundary	Transboundary water resources
loc	Local	Local water resources
und	Underground	Groundwater sources
dra	Drainage	Collector-drainage water
J = { }	**Sectors**	**Elements of "Water users" data set**
irr	Irrigation	Irrigation
ind	Industry	Industry
dom	Domestic	Domestic sector
fis	Fisheries	Fishery and other users
Z = { }		**Elements of "Planning zones (PZ)" data set**
gar	Garm	Garmskaya PZ, Tajikistan
vah	Vakhshkaya	Vakhshskaya PZ, Tajikistan
pya	Pyandjskaya	Pyandjskaya PZ, Tajikistan
gba	Gorno-Badahshanskaya	Gorno-Badahshanskaya PZ, Tajikistan
uka	Up_Kafirnigan	Verkhne-Kafirniganskaya PZ, Tajikistan
dka	Down_Kafirnigan	Nizhne- Kafirniganskaya PZ, Tajikistan
ksh	Karatag-Shirkent	Karatag-Shirkentskaya PZ, Tajikistan
sur	Surhandarya	Surkhandaryinskaya PZ, Uzbekistan
mar	Mary	Maryiskaya PZ – Mary province, Turkmenistan
aha	Ahal	Ahalskaya PZ – Ahal province, Turkmenistan. Note: quantity of water flowing from the Karakum canal to Balkan province (Caspian Sea basin) is accounted in Ahalskaya PZ
leb	Lebap	Lebapskaya PZ, Turkmenistan
kas	Kashkadarya	Kashkadaryinskaya PZ, Uzbekistan
kar	Karshi	Karshinskaya PZ, Uzbekistan
zar	Zarafshan	Zarafshanskaya PZ, Tajikistan
sam	Samarkand	Samarkandskaya PZ, Uzbekistan
nav	Navoyi	Navoyiskaya PZ, Uzbekistan
buh	Buhara	Bukharskaya PZ, Uzbekistan

hor	Horezm	Khorezmskaya PZ, Uzbekistan
skk	Karakalpak-South	South Karakalpakstan PZ, Uzbekistan
nkk	Karakalpak-North	Northern Karakalpakstan PZ, Uzbekistan
tas	Tashauz	Doshouzskaya PZ, Turkmenistan
ala	Alayskaya	Alayskaya PZ, Kyrgyzstan
afg	Afganskaya	Afghanskaya PZ, Afghanistan