PROJECT

Transboundary Water Management Adaptation in the Amu Darya Basin to Climate Change Uncertainties

Work program item: 3.1 Make series of calculations for different scenario combinations (climate, water, hydropower regimes, innovations, water requirements) for 2016-2055

Report

on position

3.1.1.3. Improving the ASBmm river model interface

3.1.2.8. Improving the ASBmm PZ model interface and integration of PZ model

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Contents

Introduction

Present report shows the results of work undertaken under the following tasks:

- 3.1.1.3. “Improving the ASBmm river model interface” – choosing and customizing new scenarios (in line with the PEER Project requirements), changing modeling period, modifying interface in part of input data of the river model - WAm – adjustments to a new format and user data option, dates of putting new HEPS into operation, etc.,
- 3.1.2.8. “Improving the ASBmm PZ model interface and integration of PZ model - PZm” – changing data input-output forms, arranging access to the model (user’s work with the model), running routine implementing the model, testing PZ in ASBmm for the Amu Darya Basin.

This work was done under guidance of Mr. A.Sorokin, who also provided the scenario data and WAm model structure. Adaptation of PZm to ASBmm was undertaken under supervision of R.Khafazov.

Giver report consists of introduction, three sections showing major results of work, conclusion (findings and future tasks) and an annex with the tables and file structures.

1. Improving the ASBmm Interface

Modifications made:

- In “Select basin” item, we removed the dropdown list for selection of “Planning zone”; now PZ is selected through the interface of PZm,
- In “Climate impact” item, we replaced the option “Minimal” by “REMO”. Also, the “Maximal” option was removed; now WAm and PZm models use the moderate REMO 0406 scenario. It is possible to turn off this scenario (i.e. climate impact), and in this case, for PZ, ETo and ETc are calculated using the climate data over 2010-2015, and river runoff series are modeled without adjustments for climate, using a scenario keeping existing runoff cycles,
- In “Water availability” item, we deleted the period of 2010-2035; now modeling in WAm (user scenario) is done for the period of 2020-2040 (four five-year periods),
- Scenario options “Dry” and “Humid” were removed; now river runoff (for transboundary network and small river network) is modeled under the scenario keeping existing runoff cycles, with or without adjustments for climate impact (see modifications in Annex),
- In “Development” item we deleted options “Business as usual” and “National vision”; now, for the PZm model scenarios are selected by the user through the model interface (BAU, ESA, FSA and innovation scenarios), while in the WAm model the user’s scenario is added. Using this scenario, the user can: set HEPS operation regimes, set dates of putting hydroschemes into operation; input data on indicators,
- Correction was made of text information on the tasks that can be chosen by the user on ASBmm home page: now, the user is able to choose among three tasks, depending on which particular calculation logic is followed (local operation of WAm, local operation of PZm, and joint operation of WAm and PZm.
- The interface function for creation of user’s project was corrected. This function, based on user selected scenarios and inputted data, stores all input and output information and retrieves it, if necessary.

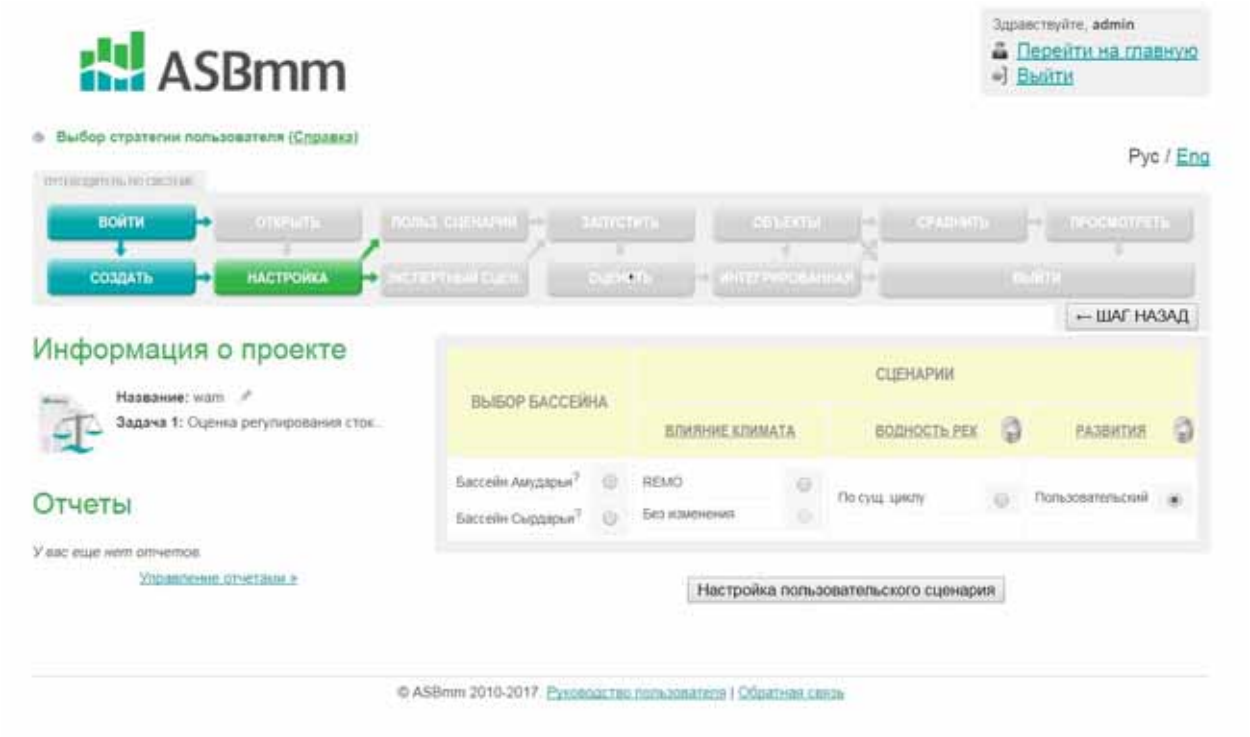

Fig. 1 ASBmm Interface: selection of basin, scenarios, access to data input form for WAm

A code was developed to form **mp.txt** file, which contains information on user's project – selected basin, selected task, selected scenarios (see structure of **mp.txt** in the Annex, with description of corrections made, Table 1). The data in **mp.txt** are read out by **WAm** model.

WAm ASMmm includes the following types of files:

- Executable files – GAMS-programs (extension **".gms"**)
- Text files of the model (extension **".txt"**)
- Text files with input data (extension **".txt"**)
- Text files with output data (extension **".dat"**)

After modification of the Interface, WAm's files are located in the following directories:

Directory	**Basin**	**Period**
C:\ASBmm\WAm\S1-5	Syr Darya	2020/2021 - 2024/2025
C:\ASBmm\WAm\S6-10	Syr Darya	2025/2026 - 2029/2030
C:\ASBmm\WAm\S11-15	Syr Darya	2030/2031 - 2034/2035
C:\ASBmm\WAm\S16-20	Syr Darya	2035/2036 - 2039/2040

C:\ASBmm\WAm\S1-5	Amu Darya	2020/2021 - 2024/2025
C:\ASBmm\WAm\A6-10	Amu Darya	2025/2026 - 2029/2030
C:\ASBmm\WAm\A11-15	Amu Darya	2030/2031 - 2034/2035
C:\ASBmm\WAm\A16-20	Amu Darya	2035/2036 - 2039/2040
C:\ASBmm\WAm	Syr Darya and Amu Darya	2020/2021 - 2039/2040

Main files of **WAm** (e.g. those in C:\ASBmm\WAm\S1-5) contain the following information:

s1.gms – GAMS-program (basic),

s1_1.txt - Structure, input data processing,

s1_2.txt - Algorithms, target functions, restrictions,

s1_3.txt, **s1_3int.txt** - Formation of output data (**s1_3loc.txt** subprogram also exists but it generates reports that have no information links to the interface and are accessible in C:\ASBmm\WAm\Report **)**,

riv_s1.txt - River flow – in two options: consideration of climate impact and no climate impact,

int_s1.txt, intPZs1.txt - water delivery to PZ (from transboundary network in WAm), formed in two options: from DB (in case of local operation of WAm) - int_s1.txt; and, from ***PZm (in case of joint operation of WAm and PZm) -*** **intPZs1.txt,**

col_s1.txt, colPZ_s1.txt – discharge of collector-drainage water into the river network in WAm, formed in two options: from DB (in case of local operation of WAm) - col_s1.txt; and, from ***PZm ((in case of joint operation of WAm and PZm) –*** **colPZ_s1.txt,**

res_s1.txt – volume of water in reservoirs by the beginning of calculation period (five-year): for first five-year the data is read out from DB, while for other five-year periods, the volume is determined as follows: water volume in reservoir by the beginning of five-year period = water volume in reservoir at the end of previous five-year period.

rivRs1.dat , **R_s1.dat** – river water balance (river network in WAm),

intRs1.dat - estimated water delivery to PZs in the basin (from WAm's network),

intPZs1.dat - estimated water delivery to a particular PZ (from WAm network), in case of joint operation of ***WAm*** and ***PZm*** is input information for ***PZm*** showing available water supply for PZ from transboundary network

hpsRs1.dat , **hp_s1.dat** - operation regime of HEPS,

resRs1.dat , **v_s1.dat** – reservoir water balance (WAm's network),

Lake_s1.dat – inflow to lakes in Prearalie and to the Aral Sea (in case of Syr Darya Basin – to Arnasay).

In total, **168** main files and a few additional (work) files are formed in 8 directories for WAm model.

Folder C:\ASBmm\WAm contains:

File name	File content
START_S.BAT	File of sequential model run for 4-year periods for Syr Darya basin
START_A.BAT	File of sequential model run for 4-year periods for Amu Darya basin
MP.txt	File containing user matrix (strategy) codes
S_USER.TXT	File containing user data (user's scenario) for Syr Darya river basin
A_USER.TXT	File containing user data (user's scenario) for Amu Darya river basin

Folder C:\ASBmm\WAm**REPORT** contains the following files: **int_rs1.dat** (estimated water delivery to PZ, available water supply), **res_rs1**.dat (reservoir water balance), **hps_rs1.dat** (operation regime of HEPS), **riv_rs1.dat** (river channel balance).

There are more than 200 files in ASBmm – WAm.

Modifications were made in the user form (window), which enables the user to select regimes and input his/her data.

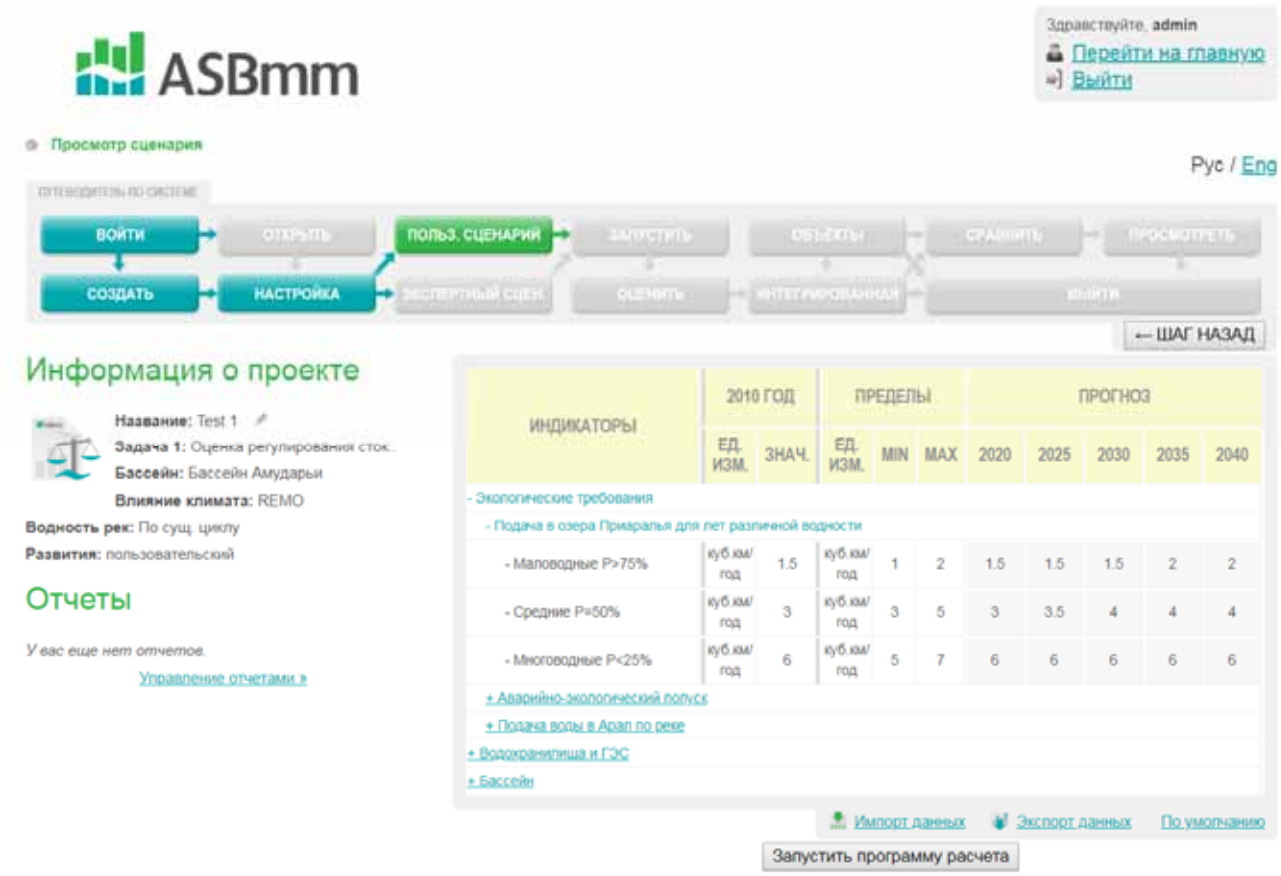

Fig. 2. User menu window: selection of regimes and input of data on the Amu Darya basin

For the Syrdarya River basin:

- Selecting volumes of annual water supply to the lakes in Prearalie depending on yearly flow conditions (low-water years P >75 %, high-water years P < 25 %, and average water years),
- Selecting volumes of annual environmental and emergency water releases from the Syrdarya River to Arnasay depending on yearly flow conditions,
- Selecting volumes of annual water supply to the Aral Sea depending on yearly flow conditions – to its Northern part (Syrdarya River basin) and discharge into the Eastern part of the Large Aral Sea (Amudarya River basin),
- Setting required amount of electricity generated by HEPS on the Naryn River and Bakhri Tochik reservoir per season (growing and non-growing seasons) – demand,

- Selecting operation regimes of HEPS on the Naryn River and Bakhri Tochik reservoir - energy or energy-irrigation,
- Setting regional price for electricity generated by HEPS in summer and winter,
- Setting population dynamics in the countries (within the basin).

For the Amudarya River basin:

- Selecting volumes of annual water supply to the lakes in Prearalie depending on yearly flow conditions (low-water years P > 75 %, high-water years P < 25 %, and average water years),
- Selecting volumes of annual water supply to the Aral Sea depending on yearly flow conditions (Eastern and Western parts),
- Setting required amount electricity generated by HEPS in Tajikistan per season (growing and non-growing seasons) – demand
- Selecting operation regimes of large HEPS in Tajikistan (at the tail-water of the Nurek HEPS) – energy or energy-irrigation,
- Setting regional price of electricity generated by HEPS in summer and winter,
- Setting dynamics of population growth in the countries (within the basin).

Dates of construction and putting into operation of the Roghun HEPS were changed (see Annex, Table 2). The option where the height of the Roghun HEPS is 335 m was adopted. End of the construction, filling of the reservoir, and putting into operation of this hydroelectric power station at its design capacity are planned for 2030 (reservoir will be filled in parallel with the construction).

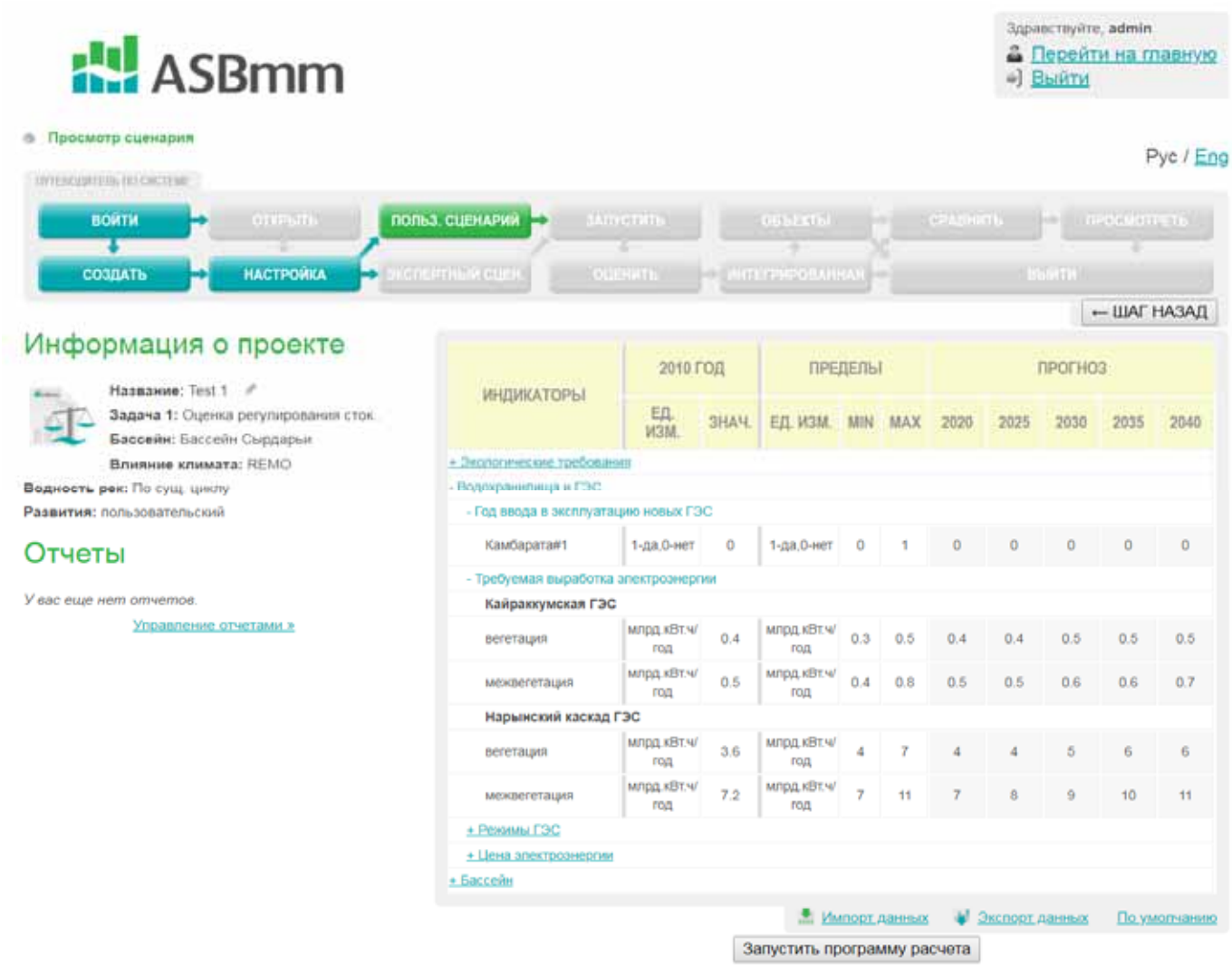

Fig. 3. User menu window: selection of regimes and input of data on the Syr Darya basin

A code was developed to form the files **S_USER.TXT** and **A_USER.TXT,** which contain the data inputted by the user into **WAm** through the user menu (window).

2. Integrating PZ model into ASBmm

For integration of the Planning Zone Model developed by R.Khafazov, we improved the interface in part of the user input form for the PZ model.

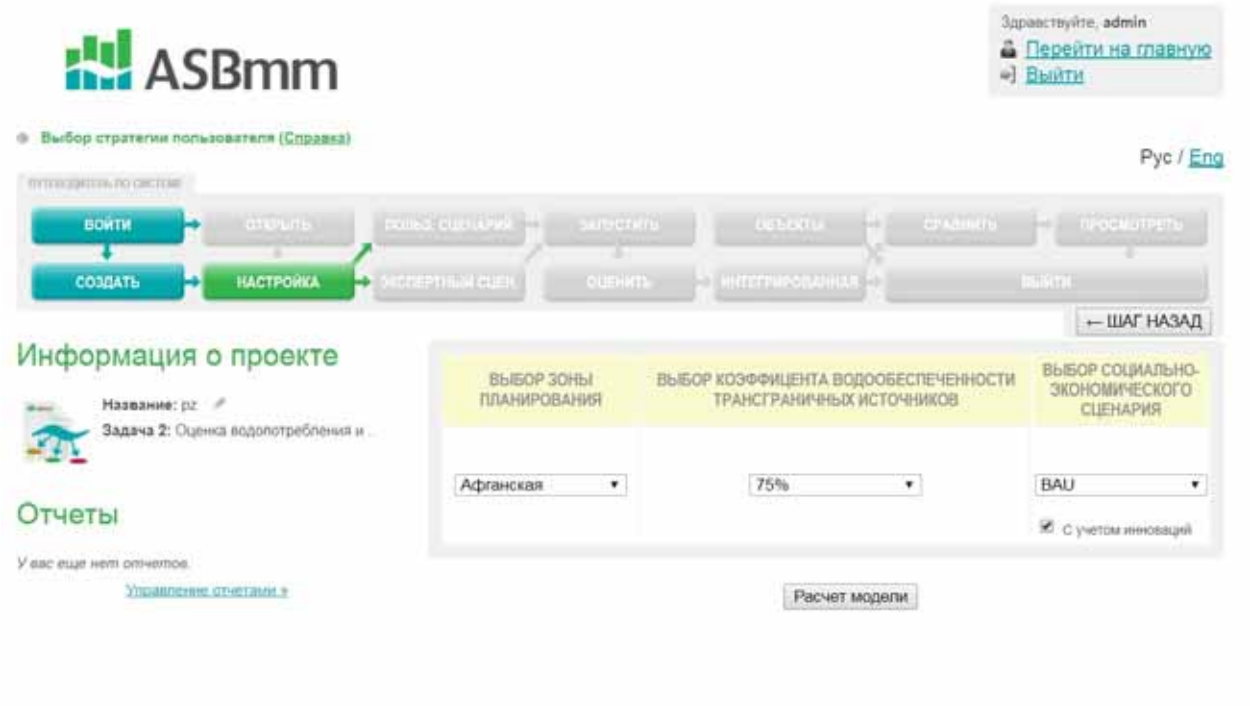

Fig. 4. User menu window: selection of scenarios and regimes for planning zones

The following modifications were made and functionalities were added:

- Planning zone code was changed – taken from the new PZm model,
- Added functionality for selection of coefficient of water availability in transboundary sources (from 5% to 100%).
- Added functionality for selection of socio-economic scenario (between BAU, FSD, ESA).
- Added functionality for selection of Innovation scenario.

When the PZm is run, the new PZ model is open with selected scenario settings and user's data input.

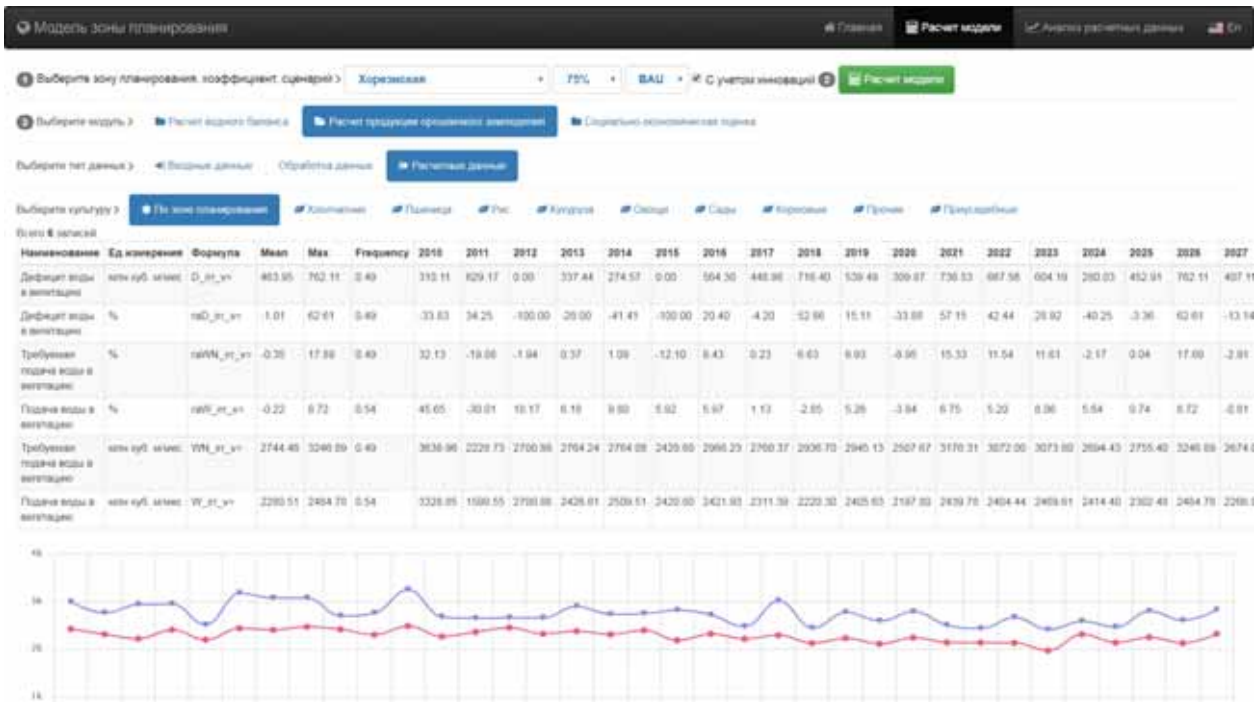

Fig. 5. User window: work with PZ model

Coupling of models

For full integration of PZ model into ASBmm, the models PZm and WAm must be coupled in the ASBmm Interface.

To this end, we developed codes to form files with the output data of PZm. Those files will be used in WAm in the third task (model coupling). Besides, the codes were developed to form files with the output data of WAm. Those files will be used in the PZm model.

Data exchange between PZm and WAm is enabled through the following variables:

- Volumes of water demanded by PZ from transboundary network - **Wpz**
- Volumes of water that can be delivered to PZ from transboundary network - **Wwam**
- Discharge of collector-drainage water from PZ into transboundary river network – **WCpz**

Variable **Wpz** is calculated in PZm for a particular planning zone (PZ), and then the data is arranged by the interface program in four additional files for the Syr Darya Basin (if this PZ is located in given basin):

- C:\ASBmm\WAm\S1-5\ **intPZ_s1.txt**
- C:\ASBmm\WAm\S6-10\ **intPZ_s2.txt**
- C:\ASBmm\WAm\S11-15\ **intPZ_s3.txt**
- C:\ASBmm\WAm\S16-20\ **intPZ_s4.txt**

If that PZ is located in the Amu Dary Basin, the following four additional files are formed:

- C:\ASBmm\WAm\A1-5\ **intPZ_a1.txt**
- C:\ASBmm\WAm\A6-10\ **intPZ_a2.txt**
- C:\ASBmm\WAm\A11-15\ **intPZ_a3.txt**
- C:\ASBmm\WAm\A16-20\ **intPZ_a4.txt**

Besides, the code (index number) of planning zone is written in the end line of file "C:\ASBmm\WAm**mp.txt**". This code is transmitted from PZm to WAm.

Variable **Wwam** is formed through a computer program of WAm in the following 4 files for the Syr Darya Basin (if this PZ is located in given basin):

- C:\ASBmm\WAm\S1-5\ **intRs1.dat**
- C:\ASBmm\WAm\S6-10\ **intRs2.dat**
- C:\ASBmm\WAm\S11-15\ **intRs3.dat**
- C:\ASBmm\WAm\S16-20\ **intRs4.dat**

If that PZ is located in the Amu Dary Basin, the following 4 additional files are formed:

- C:\ASBmm\WAm\A1-5\ **intRa1.dat**
- C:\ASBmm\WAm\A6-10\ **intRa2.dat**
- C:\ASBmm\WAm\A11-15\ **intRa3.dat**
- C:\ASBmm\WAm\A16-20\ **intRa4.dat**

Variable **WC_{pz}** is calculated in PZm for a particular PZ and then the data is arranged by the interface program in four additional files for the Syr Darya Basin (if this PZ is located in given basin):

- C:\ASBmm\WAm\A1-5\ **ColPZ_s1.txt**
- C:\ASBmm\WAm\A6-10\ **ColPZ_s2.txt**
- C:\ASBmm\WAm\A11-15\ **ColPZ_s3.txt**
- C:\ASBmm\WAm\A16-20\ **ColPZ_s4.txt**

If that PZ is located in the Amu Dary Basin, the following four additional files are formed:

- C:\ASBmm\WAm\A1-5\ **ColPZ_a1.txt**
- C:\ASBmm\WAm\A6-10\ **ColPZ_a2.txt**
- C:\ASBmm\WAm\A11-15\ **ColPZ_a3.txt**
- C:\ASBmm\WAm\A16-20\ **ColPZ_a4.txt**

Tables 3-7 in the Annex show the structure of water sources in Syr Darya and Amu Darya Basins, separately for WAm's river network and for PZm's river network. Those include transboundary and local sources that form basic information in ASBmm DB.

3. Extending operational life of ASBmm

Due to wear of the hard disk of ASBmm server and loss of the source code and database of the site, a need has arisen for immediate restoration. Recovery from backup copies did not change the situation. Configurations of Apache/IIS web-server and MySQL database were recovered. However, this did not give the desired result.

Finally, it was decided to deploy the site through a set of Denwer distribution packages working in Windows. This set includes web-server Apache, Perl, PHP, MySQL database, phpMyAdmin database utility and Perl scripts to run/stop the Denwer components.

After installation, the fully operational Apache web-server is accessible on a local computer, on which unlimited number of sites can work. This is efficient for development and adjustment of PHP scenarios without a need to upload its files on remote server.

For execution of almost all Denwer's utilities, the Run application is used from subdirectory /denwer (or /etc) in the root directory of Denver installation. When running, a virtual disk is created (Z: by default) to store all project files.

Basic package:

- Apache web-server with SSI, SSL, mod_rewrite, and mod_php enabled.
- PHP interpreter with GD, MySQL, and SQLite enabled.
- MySQL DBMS with transactions-enabled (mysqld-max).
- Template-based virtual host management system.
- Run and end management system.
- Panel phpMyAdmin for DBMS management.
- Core of Perl interpreter without standard libraries (delivered separately).
- sendmail and SMTP-server emulator supportive of joint operation with PHP, Perl, Parser, etc.
- Installer.

At the moment, the ASBmm resource is operational in parallel with the WUEMoCA resource on one server. This may cause conflict between simultaneously operating ports. Since the WUEMoCA resource is based on Java Virtual Machine web-server, while ASBmm is based on Apache,

conflicts of server operations in one port are inevitable. Therefore, it was decided to transfer the ASBmm resource from the standard port:80 to port το :2017.

Conclusion

The completed work allows organizing numerical experiments for assessment of development scenarios in all planning zones in the Amu Darya basin (i.e. those planning zones that are considered in the PEER Project and other PZs in Large Amu Darya Basin, such as Samarkand, Navoyi, Kashkadarya, Upper Kafirnigan, etc.) over 2020-2040.

Access was arranged via ASBmm to PZs in the Syr Darya Basin. By present, testing of the Planning zone model (as part of ASBmm) has been started for the Syr Darya Basin. This includes collection of data, derivation of functional relationships, test calculations of water balance, and calculation of irrigated crop yields and their losses under shortage of water.

The work done for the improvement of WAm interface enables us to start modifying computer programs and information modules of WAm (A.Sorokin – water resources allocation, D.Sorokin – hydropower and flow regulation), i.e. adapt WAm to new scenarios and user's data.

The next important tasks to finalize the new version of ASBmm and make it applicable include:

- Testing of WAm in ASBmm for Amu Darya and Syr Darya Basins,
- Coupling of PZm and WAm – organize data exchange and iterations in calculation (PZm - WAm - PZm) via interface and control program,
- Correction of input parameters,
- Drafting Manual on how to operate new ASBmm version.

ASBmm is to be ready for application in practice (beyond PEER Project) by the end of 2018.

Annex

Table 1 “mp.txt” file structure

UP	77	
B1	0	User did not select the Syrdarya River basin (B1), and the Interface recorded “0”
B2	1	User selected the Amudarya basin (B2), and the Interface recorded “1”
T1	1	Task 1 was selected (T1) “Assessing scenarios for the Amudarya and Syrdarya basins as a whole” (record “1”)
T2	0	Task to operate the Planning zone model (developed by Khafazov R.) was selected
T3	0	Task 3 (T3) “Assessing development scenarios of PZs in the context of basins” was not selected, record “0”
T4	0	
SC1	0	This option is hidden in the interface, record “0”
SC2	1	User selected scenario 2 (SC2) “REMO”, record “1”
SC3	0	User selected scenario 3 (SC2) “Business as usual”, record “0”
SW1	0	This option is hidden in the interface, record “0”
SW2	0	This option is hidden in the interface, record “0”
SW3	0	This option is hidden in the interface, record “0”
SW4	1	User selected scenario 4 (SW4) “Continuation of the existing hydrologic cycle of rivers for 25 years”, record “1”
SD1	0	This option is hidden in the interface, record “0”
SD2	0	This option is hidden in the interface, record “0”
SD3	0	This option is hidden in the interface, record “0”
SD4	1	User selected development scenario 4 (SD4) “User’s scenario”, record “1”
PZ	0	{User does not operate the Planning zone (Task 1), record “0”; in Task 3, PZ code is written instead of “0”

Table 2. Options to put into operation the Roghun HEPS

Indicator	Pessimistic scenario		Optimistic scenario	
Dam height:	H 335 m	H 290 m	H 335 m	H 290 m
Date when the Vakhsh River was dammed	29.11.2016			
Expected period of construction of a 150 meter-high- dam (crest elevation 1,110 m) and putting into operation of two aggregates (stage I)	3 years	3 years	3 years	3 years
Volume of filling to the water level of 1,100 m (stage I)	0.6 km³	0.6 km³	0.6 km³	0.6 km³
Expected date of construction completion (stages I and II)	01.10.2028	01.10.2025	01.10.2028	01.10.2025
Expected period of dam construction (stages I and II)	12 years	9 years	12 years	9 years
Possible ways to fill the reservoir	1.2 - 2.4 km³ annually		In June-July with volume available under better flow conditions (flow probability <95%)	
Estimated period of reservoir construction and filling to the normal water storage	12 years	9 years	16 years	11 years
Possible operation regimes of reservoirs	Energy		Energy-irrigation	
Regulation	Seasonal		Seasonal, multiyear	
Accumulation (+), drawdown (-) of the reservoirs of Roghun and Nurek HEPS in low-water year	0	0	(-) 5.3	(-) 5.3
October-March	(-) 7.55	(-) 7.55	(-) 1.8	(-) 1.8
April-September	(+) 7.55	(+) 7.55	(-) 3.5	(-) 3.5
Water shortage in April-September	11.09	11.09	0	0

Table 3 Water sources included in WAm (Syrdarya River basin)

Code	Name	Year	Monthly (October….September) runoff (Mm3)											
			1	2	3	4	5	6	7	8	6	9	10	11
I_1	Inflow to Toktogul reservoir	Period of 2014 – 2008 per 25-year period of calculated flow probability - 5 options	Naryn river runoff – total inflow to reservoir											
I_2	Naryn river – lateral inflow		Karasu river runoff, right-bank, left-bank											
I_3	Inflow to Andizhan reservoir		Karadarya river runoff – total inflow to reservoir											
I_4	Karadarya river –lateral inflow		River runoff in the interstream area of Naryn and Karadarya: Mailisu, Kughart, etc.											
I_5	Syrdarya river – lateral inflow		Fergana valley and middle reaches' river runoffs (Gavasay, Aksu, etc.), excluding Akhangaran, Chirchik, Keles											
I_6	Akhangaran river – resources		Akhangaran river runoff – inflow to Akhangaran reservoir + lateral inflow by sais											
I_7	Chirchik river – resources		Chirchik river runoff – inflow to Charvak reservoir (total of three rivers) + lateral inflow by sais											
I_8	Keles river – resources		Keles river runoff											
I_9	Arys river – resources		Arys river runoff											

Table 4 Water resources of PZ – supply from transboundary and local sources (Syrdarya river basin)

Code	Planning zone	Year	Monthly (October….September) runoff (Mm3)											
			1	2	3	4	5	6	7	8	9	10	11	12
K_1	Naryn upper reaches (Kyrg)	Period of 2014 – 2008 per 25-year period of calculated flow probability - 5 options	Naryn river runoff											
K_2	Middle Naryn (Kyrg)		Naryn river runoff											
K_3	North Fergana (Kyrg)		Naryn river runoff, river runoff in the interstream area of Naryn and Karadarya (Mailisu, Kughart, etc.), runoff of rivers in the right-bank of Syrdarya river within the boundaries of Fergana Valley (excluding Chadaksai, Almasai, and sais of Ashtsamgar massif)											
K _4	Namangan-Naryn (Uzb)		Runoff of Naryn, Chadaksai, Almasai rivers (right bank of Syrdarya)											
K _5	Andizhan (Uzb)		Runoff of Naryn, Karadarya, Mailisu, Akbura, Aravansai rivers (left bank of Syrdarya)											
K _6	Namangan-Syrdarya (Uzb)		Syrdarya river runoff											
K _7	Fergana (Uzb)		Runoff of Naryn, Karadarya, Syrdarya, Isfairamsai, Shakhimardan, Sokh, Abshirsai (left bank of Syrdarya)											
K _8	Khojikent (Taj)		Runoff of Naryn, Syrdarya, Aksu, Khojabakirgan, rivers, Ashtsamgar massif											
K _9	Kampyravat (Kyrg)		Runoff of tributaries of Karadarya river											
K_10	South Fergana (Kyrg)		Runoff of Syrdarya river and of left-bank of Syrdarya within the boundaries of Fergana Valley (excluding Isfara)											
K_11	Isfara (Taj)		Isfara river runoff											
K_12	Lakat-Savat (Taj)		Runoff of rivers of Shakhristan sink											

K_13	Syrdarya (Uzb)		Syrdarya river runoff
K_14	Djizak (Uzb)		Runoff of Syrdarya, Sanzar, Zaaminsu rivers, Farish massif + flow transfer from Zarafshan river basin
K_15	Hunger Steppe (Kaz)		Syrdarya river runoff
K_16	Tashkent-Syrdarya (Uzb)		Syrdarya river runoff + flow transfer from Chirchik-Akhangaran basin
K_17	Tashkent-Chirchik (Uzb)		Runoff of Akhangaran, Chirchik, Ugam rivers and other tributaries, sources of the interstream area of Chirchik and Akhangaran
K_18	Chatkal (Kyrg)		Chatkal river runoff
K_19	CHAKIR (Kaz)		Runoff of Chirchik and Keles rivers
K_20	ARTUR (Kaz)		Runoff of Arys and Bugun rivers
K_21	Kzylkum (Kaz)		Syrdarya river runoff
K_22	Kzylorda (Kaz)		Syrdarya river runoff, rivers of south-west slope of Karatou range (Chayan, Karachik, etc.).

Table 5 Relationship of water resources in transboundary/main and local sources in Syrdarya basin

Water-management area	Included in WAM		Included in PZM	
	Sources	Rivers	Sources	Rivers
Naryn river	Inflow to Toktogul reservoir	Sum of rivers (Naryn, Torkent, Chichkan, Uzunakhmat)	1.Naryn upper reaches (Kyrg)	Supply from Naryn river and its tributaries
	Naryn river – lateral inflow	Karasu – left, right	2.Middle Naryn (Kyrg)	Supply from Naryn river
			3.North Fergana (Kyrg)	
Karadarya upper reaches	Inflow to Andizhan reservoir	Sum of rivers (Karadarya, Yassy, Kurshab, Zerger)	9.Kampyravat (Kyrg)	Supply from Karadarya and its tributaries
Fergana Valley - rivers in the interstream area of Naryn and Karadarya	Karadarya river – lateral inflow		3.North Fergana (Kyrg)	Main: supply from Naryn river Local: Mailisu, Kugart rivers
			5.Andizhan (Uzb)	Main: supply from Naryn and Karadarya rivers Local: Mailisu
Fergana Valley – rivers of the right-bank of Syrdarya	Syrdarya river – lateral inflow		3. North Fergana (Kyrg)	Main: supply from Naryn river Local: rivers of right bank (except for Chadaksai, Almasai)
			4.Namangan-Naryn (Uzb)	Main: supply from Naryn river Local: Chadaksai, Almasai
Fergana Valley –			6.Namangan-	Supply from the

rivers of the right-bank of Syrdarya			Syrdarya (Uzb)	Syrdarya river
			5.Andizhan (Uzb)	Main: supply from Naryn and Karadarya rivers Local: Akbura, Aravansai
			8.Khojikent (Taj)	Main: supply from Naryn and Syrdarya rivers Local: Aksu, Khojabakirgan, Ashtsamgar massif
			7.Fergana (Uzb)	Main: supply from Naryn and Karadarya and Syrdarya rivers Local: Isfairamsai, Shakhimardan, Sokh, Abshirsai
			11.Isfara (Taj)	Isfara
			10.South Fergana (Kyrg)	Main: supply from the Syrdarya river Local: rivers of left-bank of Syrdarya (except for Isfara)
			12.Lakat-Savat (Taj)	Rivers of Shakhristan sink
CHAKIR	Chirchik river – resources		18.Chatkal (Kyrg)	Chatkal river
	Akhangaran river – resources		17.Tashkent-Chirchik (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area
	Keles river – resources		19.CHAKIR (Kaz)	Supply from Chirchik and Keles
Syrdarya middle reaches	no	no	13.Syrdarya (Uzb)	Supply from Syrdarya
			14.Djizak (Uzb)	Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin
			15.Hunger Steppe (Kaz)	Supply from Syrdarya
			16.Tashkent-Syrdarya (Uzb)	Main: supply from Syrdarya Local: supply from Akhangaran basin
ARTUR and small rivers of Syrdarya lower reaches	Arys river – resources	Arys river	20.ARTUR (Kaz)	Main: Arys Local: Bugun
			21.Kzylkum (Kaz)	Supply from Syrdarya
			22.Kzylorda (Kaz)	Main: supply from Syrdarya Local: rivers of south-

				west slope of Karatou range (Chayan, Karachik, etc.).

Table 6 Water sources in WAm (Amudarya river basin)

Code	Source	Year	Monthly (October….September) runoff (Mm3)											
			1	2	3	4	5	6	7	8	9	10	11	12
I_1	Inflow to Nurek/Roghun reservoir	Period of 2014 – 2008 per 25-year period of calculated flow probability - 5 options	Vaksh – total river runoffs as composed from tributaries upstream of Roghun hydrosystem											
I_2	Vakhsh river – lateral inflow		Lateral inflow into Vaksh from sais											
I_3	Pyandj river – upper reaches		Pyandj - total river runoffs as composed from tributaries upstream of Khirmandjo control station											
I_4	Pyandj river – lateral inflow		Lateral inflow into Pyandj from Kzylsu and Yakhsu rivers											
I_5	Kundiz river – spillway into Amudarya		Runoff of Kunduz river											
I_6	Kafirnigan river – resources		Total runoff from Kafirnigan (Chinar), Varzob, Lyucheb, Khanaka and Ilyak rivers											
I_7	Surkhandarya river – resources		Total runoff from Tupalang, Obizarang, Karatag, Sangardak, and Khalkadjar rivers											
I_8	Sherabad river – resources		Sherabad river flow – Komarchi control station											
I_9	Kashkadarya river – resources		Kashkadarya river runoff as composed from tributaries											
I_10	Zarafshan river – resources		Zarafshan river runoff as composed from tributaries											

Table 7 Water resources of PZ – supply from transboundary and local sources (Amudarya river basin)

Code	PZ	Year	Monthly (October….September) runoff (Mm3)											
			1	2	3	4	5	6	7	8	9	10	11	12
K_1	Gharm (Taj)	Period of 2014 – 2008 per 25-year period of calculated flow probability - 5 options	Runoff of Vaksh river and its tributaries upstream of Roghun hydrosystem											
K_2	Vakhsh (Taj)		Runoff of Vaksh river and its tributaries downstream of Roghun hydrosystem											
K_3	Pyandj (Taj)		Runoff of Pyandj river and its tributaries											
K _4	Gorniy Badakhshan (Taj)		Tributarues of Pyandj river											
K _5	Upper Kafirnigan (Taj)		Tributaries of Kafirnigan river											
K _6	Lower Kafirnigan (Taj)		Runoff of Kafirnigan river											
K _7	Karatag-Shirkent (Taj)		Karatag river runoff (tributary of Surkhandarya river)											
K _8	Surkhandarya (Uzb)		Runoff of Tupalang, Obizarang, Karatag, Sangardak, and Khalkajar rivers and supply from Amudarya river											
K _9	Mary (Turk)		Supply from Amudarya river											
K_10	Akhal (Turk)		Supply from Amudarya river											
K_11	Lebap (Turk)		Supply from Amudarya river											
K_12	Kashkadarya (Uzb)		River runoffs of Kashkadarya basin and supply from Zarafshan basin (Iskiangar) and Amudarya (M3)											
K_13	Karshi (Uzb)		Supply along Amudarya river (KMK) and discharge from Kashkadarya river											
K_14	Zarafshan (Taj)		Runoff of Zarafshan river and its tributaries											
K_15	Samarkand (Uzb)		Runoff of Zarafshan river											
K_16	Navoi (Uzb)		Runoff of Zarafshan river and supply from Amudarya river (ABK)											
K_17	Bukhara (Uzb)		Supply along Amudarya river (ABK) and discharge from Zarafshan river											
K_18	Khorezm (Uzb)		Amudarya river runoff											
K_19	South Karakalpakstan (Uzb)		Amudarya river runoff											
K_20	North Karakalpakstan (Uzb)		Amudarya river runoff											

K_21	Dashouz (Turk)		Amudarya river runoff
K_22	Alay (Kyrg)		Runoff of Kyzylsu river (tributary of Amudarya)
K_23	Afghanistan (Afg)		Runoff of Afghanistan's rivers, supply from Amudarya (Pyandj)