

## 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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Introduction

- 1. Improving the ASBmm Interface
- 2. Integrating PZ model into ASBmm
- 3. Extending operational life of ASBmm

Conclusion

Annex

#### 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.

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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.

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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 %, highwater years P < 25 %, and average water years),</li>
- 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 %, highwater years P < 25 %, and average water years),</li>
- 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 tailwater 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).

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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.

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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.

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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 **W**wam 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 **WCpz** 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\ **CoIPZ\_s1.txt**
- C:\ASBmm\WAm\A6-10\ **CoIPZ\_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\ CoIPZ\_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  $\tau_0$  :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

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
Т3	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 1 "mp.txt" file structure

Table 2.	Options	to put ir	to operation	the Roghun	HEPS
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Indicator	Pessimisti	c 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 kr	n³ 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	Ene	ergy	Energy-irrigation			
Regulation	Seas	sonal	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		

			<u> </u>						
Code	Name	Year	Monthly (OctoberSeptember) runoff (Mm3)						
			1 2 3 4 5 6 7 8 6 9 10 11						
I_1	Inflow to Toktogul reservoir	Period of	Naryn river runoff – total inflow to reservoir						
I_2	Naryn river – lateral inflow	2014	Karasu river runoff, right-bank, left-bank						
I_3	Inflow to Andizhan reservoir	2014 -	Karadarya river runoff – total inflow to reservoir						
I_4	Karadarya river –lateral	2008	River runoff in the interstream area of Naryn and						
	inflow	nor 25	Karadarya: Mailisu, Kughart, etc.						
I_5	Syrdarya river – lateral inflow	per 25-	Fergana valley and middle reaches' river runoffs						
		year	(Gavasay, Aksu, etc.), excluding Akhangaran,						
		period of	Chirchik, Keles						
I_6	Akhangaran river – resources	calculated	Akhangaran river runoff – inflow to Akhangaran						
	-	flow	reservoir + lateral inflow by sais						
I_7	Chirchik river – resources	probabilit	Chirchik river runoff – inflow to Charvak reservoir						
		у -	(total of three rivers) + lateral inflow by sais						
I_8	Keles river – resources	5	Keles river runoff						
I_9	Arys river – resources	5 options	Arys river runoff						

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

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

Code	Planning zone	Year	Monthly (OctoberSeptember) runoff (Mm3)											)	
			1	2	3	4	5	(	6 <sup>′</sup>	7 8	3	)	1	1	1
													0	1	2
K_1	Naryn upper reaches (Kyrg)	Period of	Naryn river runoff												
K_2	Middle Naryn (Kyrg)	2014 – 2008	Naryn river runoff												
K_3	North Fergana (Kyrg)	2000	Naryn river runoff, river runoff in the interstream area												
		per 25-	of	Nar	yn a	and	Kara	ıdar	ya (	Maili	su,	Kug	har	t, e	etc.),
		year	run	off	of ri	ivers	in t	he	right	-banl	c of	Syr	dar	ya 1	river
		period of	within the boundaries of Fergana Valley (excluding												
		calculate	Cha	adak	sai,	Alm	asai,	and	l sais	of A	shtsa	mga	ır n	nass	if)
IZ A	Naman ann Namm (U-h)	d flow	Dere	ff	- f	Nam		1	1.1	: 41		.::			
K _4	Namangan-Naryn (U2b)	probabilit	Kui	1011 15 of	01	inary dom:	/n, C	nac	laksa	1, AI	mas	ai ri	ver		right
		у-	Dan	K OI	Syl	uary	a)								
K_5	Andizhan (Uzb)	5 options	Runoff of Naryn, Karadarya, Mailisu, Akbura,												
		2 options	Aravansai rivers (left bank of Syrdarya)												
		-													
K _6	Namangan-Syrdarya (Uzb)		Syrdarya river runoff												
K 7	Fergana (Uzb)	-	Runoff of Naryn, Karadarya Syrdarya Isfairamsai												
			Sha	khii	mard	lan,	Šok	ch.	Ab	shirsa	i (	left	b	ank	of
			Syr	dary	/a)										
		-											<u> </u>		
K_8	Khojikent (Taj)		Rui	noff	of	Nar	yn, S	syrc	larya	, Ak	su,	Kho	jab	akir	gan,
			rive	ers,	Ash	tsam	gar n	nass	S1Î						
K 9	Kampyrayat (Kyrg)	-	Ru	noff	of tr	ibut	aries	of I	Karao	larva	rive	r			
	· · · · · · · · · · · · · · · · · · ·	-								<b>,</b>					
K_10	South Fergana (Kyrg)		Ru	noff	of S	yrda	rya r	ive	r and	of le	ft-ba	ınk o	of S	Syrd	arya
			wit	hin	the	bour	ndarie	es c	of Fe	rgana	Va	lley	(ex	cclu	ding
			Isfara)												
K 11	Isfara (Tai)	-	Isfara river runoff												
<u></u>			1510	uun											
K_12	Lakat-Savat (Taj)		Ru	noff	of ri	vers	of Sl	hak	hrista	an sin	k				
			KUNON OF HVEIS OF SHAKIHISTAN SHIK												

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	Included	in WAM	Included in PZM					
area	Sources	Rivers	Sources	Rivers				
Naryn river	Inflow to Toktogul	Sum of rivers	1.Naryn upper	Supply from Naryn				
	reservoir	(Naryn, Torkent,	reaches (Kyrg)	river and its tributaries				
		Chichkan,						
		Uzunakhmat)						
	Naryn river –	Karasu – left, right	2.Middle Naryn	Supply from Naryn				
	lateral inflow		(Kyrg)	river				
			3.North Fergana					
			(Kyrg)					
Karadarya upper	Inflow to Andizhan	Sum of rivers	9.Kampyravat	Supply from				
reaches	reservoir	(Karadarya, Yassy,	(Kyrg)	Karadarya and its				
		Kurshab, Zerger)		tributaries				
Fergana Valley -	Karadarya river –		3.North Fergana	Main:				
rivers in the	lateral inflow		(Kyrg)	supply from Naryn				
interstream area of				river				
Naryn and				Local: Mailisu,				
Karadarya			5 Andiahan (Uah)	Kugart rivers				
			5.Andiznan (UZD)	wialli:				
				and Karadarya rivers				
				Local: Mailisu				
Fergana Valley _	Svrdarva river –		3 North Fergana	Main:				
rivers of the right-	lateral inflow		(Kvrg)	supply from Naryn				
bank of Syrdarya			()-8/	river				
jj				Local: rivers of right				
				bank (except for				
				Chadaksai, Almasai)				
			4.Namangan-	Main:				
			Naryn (Uzb)	supply from Naryn				
				river				
				Local: Chadaksai,				
				Almasai				
Fergana Valley –			6.Namangan-	Supply from the				

rivers of the right-			Syrdarya (Uzb)	Syrdarya river
hank of Syrdarya			5 Andizhan (Uzh)	Main:
ballk of Syluarya			J.Anuiznan (UZD)	widill.
				and Karadarua riyara
				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	Main:
			(Kyrg)	supply from the
				Syrdarya river Local:
				rivers of left-bank of
				Syrdarya (except for
				Isfara)
				,
			12.Lakat-Savat	Rivers of Shakhristan
			(Taj)	sink
CHAKIR	Chirchik river -		18.Chatkal (Kyrg)	Chatkal river
	resources			
	resources			
	Akhangaran river –		17.Tashkent-	Main:
	Akhangaran river – resources		17.Tashkent- Chirchik (Uzb)	Main: Supply from Chirchik
	Akhangaran river – resources		17.Tashkent- Chirchik (Uzb)	Main: Supply from Chirchik and Akhangaran
	Akhangaran river – resources		17.Tashkent- Chirchik (Uzb)	Main: Supply from Chirchik and Akhangaran rivers
	Akhangaran river – resources		17.Tashkent- Chirchik (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of
	Akhangaran river – resources		17.Tashkent- Chirchik (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area
	Akhangaran river – resources Keles river –		17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik
	Akhangaran river – resources Keles river – resources		17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles
Syrdarya middle	Akhangaran river – resources Keles river – resources no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya
Syrdarya middle reaches	Akhangaran river –       resources       Keles       resources       no	по	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya
Syrdarya middle reaches	Akhangaran river –       resources       Keles       resources       no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main:
Syrdarya middle reaches	Akhangaran river –       resources       Keles river –       resources       no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya
Syrdarya middle reaches	Akhangaran river –       resources       Keles river –       resources       no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local:
Syrdarya middle reaches	Akhangaran river – resources Keles river – resources no	no	17.Tashkent- Chirchik (Uzb)         19.CHAKIR (Kaz)         13.Syrdarya (Uzb)         14.Djizak (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu.
Syrdarya middle reaches	Akhangaran river – resources Keles river – resources no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow
Syrdarya middle reaches	Akhangaran river – resources Keles river – resources no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from
Syrdarya middle reaches	Akhangaran river –       resources       Keles       river –       resources       no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin
Syrdarya middle reaches	Akhangaran river –       resources       Keles       river –       resources       no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya
Syrdarya middle reaches	Akhangaran river –       resources       Keles river –       resources       no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb) 15.Hunger Steppe (Kaz)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya
Syrdarya middle reaches	Akhangaran river –       resources       Keles river –       resources       no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb) 15.Hunger Steppe (Kaz) 16.Tashkent-	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main:
Syrdarya middle reaches	Akhangaran river –       resources       Keles river –       resources       no	no	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb) 15.Hunger Steppe (Kaz) 16.Tashkent- Syrdarya (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main: supply from Syrdarya
Syrdarya middle reaches	Akhangaran river –       resources       Keles river –       resources       no	no	17.Tashkent- Chirchik (Uzb)         19.CHAKIR (Kaz)         13.Syrdarya (Uzb)         14.Djizak (Uzb)         15.Hunger Steppe (Kaz)         16.Tashkent- Syrdarya (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main: supply from Syrdarya
Syrdarya middle reaches	Akhangaran river –       resources       Keles river –       resources       no	no	17.Tashkent- Chirchik (Uzb)         19.CHAKIR (Kaz)         13.Syrdarya (Uzb)         14.Djizak (Uzb)         15.Hunger Steppe (Kaz)         16.Tashkent- Syrdarya (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main: supply from Syrdarya Main: supply from Syrdarya
Syrdarya middle reaches	Akhangaran river – resources No Arvs river –	no Arys river	17.Tashkent- Chirchik (Uzb) 19.CHAKIR (Kaz) 13.Syrdarya (Uzb) 14.Djizak (Uzb) 15.Hunger Steppe (Kaz) 16.Tashkent- Syrdarya (Uzb)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main: supply from Syrdarya Main: supply from Syrdarya
Syrdarya middle reaches ARTUR and small rivers of Syrdarya	Akhangaran river –         resources         Keles river –         resources         no         Arys river –         resources	no Arys river	17.Tashkent- Chirchik (Uzb)19.CHAKIR (Kaz)13.Syrdarya (Uzb)14.Djizak (Uzb)15.Hunger Steppe (Kaz)16.Tashkent- Syrdarya (Uzb)20.ARTUR (Kaz)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main: supply from Syrdarya Main: supply from Syrdarya Local: supply from Akhangaran basin Main: Arvs
Syrdarya middle reaches ARTUR and small rivers of Syrdarya lower reaches	Akhangaran river –         resources         Keles river –         resources         no         Arys river –         resources	no Arys river	17.Tashkent- Chirchik (Uzb)         19.CHAKIR (Kaz)         13.Syrdarya (Uzb)         14.Djizak (Uzb)         15.Hunger Steppe (Kaz)         16.Tashkent- Syrdarya (Uzb)         20.ARTUR (Kaz)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main: supply from Syrdarya Local: supply from Akhangaran basin Main: Arys Local:
Syrdarya middle reaches ARTUR and small rivers of Syrdarya lower reaches	Akhangaran river –         resources         Keles river –         resources         no         Arys river –         resources	no Arys river	17.Tashkent- Chirchik (Uzb)         19.CHAKIR (Kaz)         13.Syrdarya (Uzb)         14.Djizak (Uzb)         15.Hunger Steppe (Kaz)         16.Tashkent- Syrdarya (Uzb)         20.ARTUR (Kaz)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main: supply from Syrdarya Local: supply from Akhangaran basin Main: Arys Local: Bugun
Syrdarya middle reaches ARTUR and small rivers of Syrdarya lower reaches	Akhangaran river –         resources         Keles river –         resources         no         Arys river –         resources	no Arys river	17.Tashkent- Chirchik (Uzb)         19.CHAKIR (Kaz)         13.Syrdarya (Uzb)         14.Djizak (Uzb)         15.Hunger Steppe (Kaz)         16.Tashkent- Syrdarya (Uzb)         20.ARTUR (Kaz)         21.Kzvlkum (Kaz)	Main:Supply from ChirchikandAkhangaranriversLocal:rivers ofinterstream areaSupply from Chirchikand KelesSupply from SyrdaryaMain:supply from SyrdaryaLocal:Sanzar,Zaaminsu,Farish massif + flowtransferfromZarafshan river basinSupply from SyrdaryaMain:supply from SyrdaryaMain:supply from SyrdaryaLocal:supply from SyrdaryaLocal:supply from SyrdaryaLocal:supply from SyrdaryaLocal:BugunSupply from Syrdarya
Syrdarya middle reaches ARTUR and small rivers of Syrdarya lower reaches	Akhangaran river –         resources         Keles river –         resources         no         Arys river –         resources	no Arys river	17.Tashkent- Chirchik (Uzb)         19.CHAKIR (Kaz)         13.Syrdarya (Uzb)         14.Djizak (Uzb)         15.Hunger Steppe (Kaz)         16.Tashkent- Syrdarya (Uzb)         20.ARTUR (Kaz)         21.Kzylkum (Kaz)         22.Kzylorda (Kaz)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main: supply from Syrdarya Local: supply from Akhangaran basin Main: Arys Local: Bugun Supply from Syrdarya
Syrdarya middle reaches ARTUR and small rivers of Syrdarya lower reaches	Akhangaran river –         resources         Keles river –         resources         no         Arys river –         resources	no Arys river	17.Tashkent- Chirchik (Uzb)19.CHAKIR (Kaz)13.Syrdarya (Uzb)14.Djizak (Uzb)14.Djizak (Uzb)15.Hunger Steppe (Kaz)16.Tashkent- Syrdarya (Uzb)20.ARTUR (Kaz)21.Kzylkum (Kaz)22.Kzylorda (Kaz)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main: supply from Syrdarya Local: supply from Akhangaran basin Main: Arys Local: Bugun Supply from Syrdarya
Syrdarya middle reaches	Akhangaran river –         resources         Keles river –         resources         no         Arys river –         resources	no Arys river	17.Tashkent- Chirchik (Uzb)         19.CHAKIR (Kaz)         13.Syrdarya (Uzb)         14.Djizak (Uzb)         15.Hunger Steppe (Kaz)         16.Tashkent- Syrdarya (Uzb)         20.ARTUR (Kaz)         21.Kzylkum (Kaz)         22.Kzylorda (Kaz)	Main: Supply from Chirchik and Akhangaran rivers Local: rivers of interstream area Supply from Chirchik and Keles Supply from Syrdarya Main: supply from Syrdarya Local: Sanzar, Zaaminsu, Farish massif + flow transfer from Zarafshan river basin Supply from Syrdarya Main: supply from Syrdarya Local: supply from Akhangaran basin Main: Arys Local: Bugun Supply from Syrdarya Main: supply from Syrdarya Main: supply from Syrdarya Local: Bugun

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

Code	Source	Year	Monthly (OctoberSeptember) runoff (Mm3)											
			1	2	3	4	5	6	7	8	9	1	1	1
												0	1	2
I_1	Inflow to Nurek/Roghun		Vaksh - total river runoffs as composed from									rom		
	reservoir	Period of	of tributaries upstream of Roghun hydrosystem											
I_2	Vakhsh river – lateral inflow	2014 -	Lateral inflow into Vaksh from sais											
I_3	Pyandj river – upper reaches	2008	Pyandj - total river runoffs as composed from											
		per 25-	tributaries upstream of Khirmandjo control station											
I_4	Pyandj river – lateral inflow	year	Lat	eral	inflo	w in	to P	yand	j froi	n K	zylst	ı and	l Yak	chsu
		period of	rive	ers										
I_5	Kundiz river – spillway into	calculate	Ru	noff	of K	undu	z rive	er						
	Amudarya	d flow												
I_6	Kafirnigan river – resources	probabilit	Tot	al r	unof	f fr	om	Kafi	rniga	n (	Chin	ar),	Var	zob,

у -

5 options

I\_7

I\_8

I\_9

I\_10

Surkhandarya

Sherabad river - resources

Zarafshan river – resources

Kashkadarya river - resources

resources

river

#### Table 6 Water sources in WAm (Amudarya river basin)

Table 7	Water	resources	of PZ -	supply	from	transboundary	and	local	sources
(Amuda	rya rive	er basin)							

tributaries

Lyucheb, Khanaka and Ilyak rivers

Sangardak, and Khalkadjar rivers

Total runoff from Tupalang, Obizarang, Karatag,

Kashkadarya river runoff as composed from

Zarafshan river runoff as composed from tributaries

Sherabad river flow – Komarchi control station

Code	PZ	Year	Monthly (OctoberSeptember) runoff (Mm3)											
			1	2	3	4	5	6	7	8	9	1	1	1
												0	1	2
K_1	Gharm (Taj)	Period of	Runoff of Vaksh river and its tributaries upstream of											
		2014 -	Roghun hydrosystem											
K_2	Vakhsh (Taj)	2008	Runoff of Vaksh river and its tributaries downstream											
		per 25-	of Roghun hydrosystem											
<u>K_3</u>	Pyandj (Taj)	year	Ru	noff	of Py	yandj	rive	r and	its t	ributa	aries			
<u>K_4</u>	Gorniy Badakhshan (Taj)	period of	Tri	buta	rues	of Py	andj	river	•					
<u>K_5</u>	Upper Kafirnigan (Taj)		Tri	buta	ries o	of Ka	firni	gan r	iver					
<u>K_</u> 6	Lower Kafirnigan (Taj)	d flow	Ru	noff	of K	afirni	gan	river						
<u>K_</u> 7	Karatag-Shirkent (Taj)	probabilit	Ka	ratag	g rive	r run	off (1	tribut	ary o	of Su	rkhar	ıdary	va riv	er)
K_8	Surkhandarya (Uzb)	y - 5 options	Runoff of Tupalang, Obizarang, Karatag, Sangardak,											
		5 options	and Khalkajar rivers and supply from Amudarya river											
<u>K_9</u>	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)		Riv	ver r	unoff	fs of	Kasl	nkada	arya	basin	and	sup	ply f	rom
		-	Zar	afsh	an ba	asin (	Iskia	ingar	) and	l Am	udary	va (N	13)	
K_13	Karshi (Uzb)		Sup	oply	alon	g An	nuda	rya r	iver	(KM	IK) a	nd d	ischa	arge
			fro	m Ka	ashka	adary	a riv	er						
K_14	Zarafshan (Taj)	-	Ru	noff	of Za	arafsł	nan r	iver a	and i	ts trił	outari	ies		
K_15	Samarkand (Uzb)	-	Ru	noff	of Za	arafsł	nan r	iver						
K_16	Navoi (Uzb)		Ru	noff	of Z	arafsl	nan 1	iver	and s	suppl	y fro	m A	muda	arya
		-	rive	er (A	BK)									
K_17	Bukhara (Uzb)		Sup	pply	alon	g Ar	nuda	rya 1	river	(AB	K) a	nd d	ischa	arge
			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 Amudary	of /a (P	Afghanistan's yandj)	rivers,	supply	from			