Transboundary water management adaptation in the Amudarya Basin to climate change uncertainties

Report on Position 4 “Development of the Database”

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Introduction

Given report describes the project results on position 4 “Development of the Database”. The following work was completed:

- Development of project DB, testing
- Adaptation of the project DB’s interface to the database of the Planning Zone Model,
- Collection, processing and input of data into the PZ model,
- Processing and input of project results into the project DB

The above work was done by a project team (R.Toshpulatov, I.Ergashev) under coordination of A.Sorokin.

The project DB contains 2 Mb of data, including the data on:

- 3 states – Tajikistan, Turkmenistan, Uzbekistan,
- 13 planning zones (provinces) of Amudarya Basin’s riparian countries,
- Historical data on 2010-2015 and for the future period 2020-2055,
- 9 scenarios,
- 59 categories,
- 210 indicators

The DB Interface – 10 Mb.

1. Objective and tasks

The objective of work is to create a project DB, adapt it to the PZ model and fill its with retrospective data and project results in form of indicators.

The tasks were as follows:

A) Develop DB and interface

B) Collect, process and input the data into the model and DB, following the structure of the latter (i.e. data category, objects, parameters) – see Annex 1
   Retrospective data;
   - Data over the base period (2010-2015)
   - Data on scenarios over 2016-2055 – input data and calculated indicators (results of calculations by the PZ model and hydropower model

C) Prepare (select) the data for calculations in the PZ model, including import of the data from the water requirements model (G.Solodkiy), data on cropping patterns, economic data (Sh.Muminov), data on water resources (D.Sorokin) – see Annex 1

2. Work scope for development of DB and interface

An information system was developed and located on SIC's servers. The access to the system is available on http://cawater-info.net/peer.

Resource functionality:

- Multi-language, support of two languages: Russian and English
- User authorization
- Data input via Interface
- Tabular and graphical data output

The web-site is designed in Google's Material Design format. Web-application is operated as SPA (single page application) through AJAX. The system consists of client-side and server-side. Server is realized on Yii as API; the data is transferred to the client-side in JSON format. The data is stored in MySQL DBMS.

2.1 Web-server's system requirements:

- Interpretator PHP 5.1 and later version
- Apache HTTP Server
- Database MySQL 4.1 and later version with support of MySQLi or pdo_mysql extension.

2.2 Web-server's technical requirements:

- Hard disk space – 10 Mb
- Single core processor with memory clock 2.4 GHz

- RAM 512 Mb

2.3 Software environment:

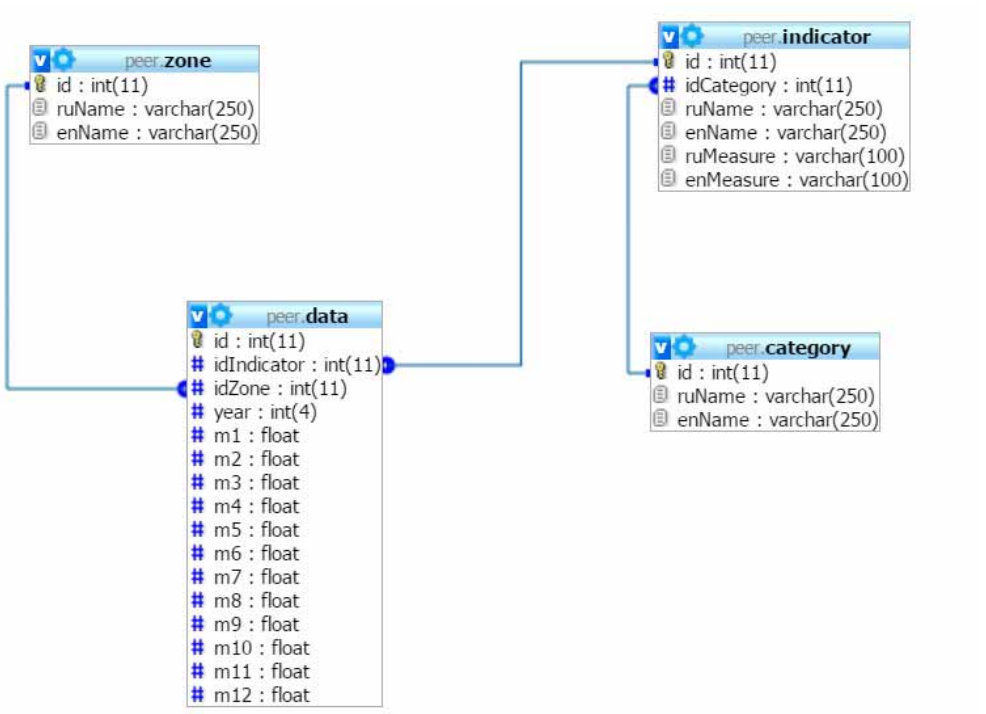
1) **Yii** – framework written in PHP, implements MVC. Architecture and functionality:

- Better performance compared to other PHP-based frameworks
- MVC framework
- Interfaces DAO and ActiveRecord to handle databases (PDO)
- Internationalization support
- Page and individual fragment caching
- Error trapping and processing
- Input and validation
- Authentication and authorization
- Use of AJAX and integration with jQuery
- Generation of the base PHP-code for CRUD-operations (scaffolding)
- Style support for their easy change
- Possibility to connect third-party libraries
- Database migration
- Automatic testing
- REST support

2) **AngularJS** is a JavaScript-based framework with open-source code. It is designed for development of single-page applications. It aims to extend browser applications based on MVC, as well as to simplify both the development and the testing of such applications. The framework works with HTML, which has additional custom tag attributes embedded into it. Angular interprets those attributes as directives to bind input or output parts of the page to a model that is represented by standard JavaScript variables. The values of those JavaScript variables can be manually set within the code, or retrieved from static or dynamic JSON resources. Angular implements the MVC pattern to separate presentation, data, and logic components. Using dependency injection, Angular brings traditionally server-side services, such as view-dependent controllers, to client-side web applications. Consequently, much of the burden on the server can be reduced and web-application is less heavy.

3) MySQL is an open-source relational database management system. MySQL was owned and sponsored by a single for-profit firm, the Swedish company MySQL AB, now owned by Oracle Corporation. The product is disseminated under GNU General Public License and under own commercial license. In addition, developers offer additional functionality for licensed users upon their requests. Thanks to exactly such requests, the replication mechanism was added in very earlier versions.

3. Structure of links between tables in MySQL DBMS



Category table

Column	Type	Null	By default	Comments
id	int(11)	no		code
ruName	varchar(250)	no		Category
enName	varchar(250)	no		Category
group	enum('planning_zone', 'transboundary_network', 'climate', 'energetics')	no		module
schema	enum('retrospective', 'perspective')	no	retrospective	scheme
sort	int(10)	yes	0	sorting

Indices

Index	Type	Unique	Packed	Column	Unique elements	Comparison	Null	Comment
PRIMARY	BTREE	yes	no	id	59	A	no	

Data_monthly table

Column	Type	Null	By default	Comments
id	int(11)	no		code
idIndicator	int(11)	no		indicator
idZone	int(11)	no		Planning zone
scenario	varchar(20)	no	default	scenario

year	int(4)	no		year
m1	float	yes	*NULL*	January
m2	float	yes	*NULL*	February
m3	float	yes	*NULL*	March
m4	float	yes	*NULL*	April
m5	float	yes	*NULL*	May
m6	float	yes	*NULL*	June
m7	float	yes	*NULL*	July
m8	float	yes	*NULL*	August
m9	float	yes	*NULL*	September
m10	float	yes	*NULL*	October
m11	float	yes	*NULL*	November
m12	float	yes	*NULL*	December

Indices

Index	Type	Unique	Packed	Column	Unique elements	Comparison	Null	Comments
PRIMARY	BTREE	yes	no	id	12532	A	no	
idIndicator	BTREE	no	no	idIndicator	348	A	no	
idZone	BTREE	no	no	idZone	26	A	no	

Data_vegetation table

Column	Type	Null	By default	Comments
id	int(11)	no		Code
idIndicator	int(11)	no		Indicator
idZone	int(11)	no		Planning zone
scenario	varchar(20)	no		Scenario
year	int(4)	no		Year
vegetation	float	no		Vegetation period
nonVegetation	float	no		Non-vegetation period
yearly	float	no		Annual

Indices

Index	Type	Unique	Packed	Column	Unique elements	Comparison	Null	Comments
PRIMARY	BTREE	yes	no	id	1104	A	no	
idIndicator	BTREE	no	no	idIndicator	29	A	no	
idZone	BTREE	no	no	idZone	1	A	no	

Data_yearly table

Column	Type	Null	By default	Comments
id	int(11)	no		Code
idIndicator	int(11)	no		Indicator
idZone	int(11)	no		Planning zone
scenario	varchar(20)	no	default	Scenario
year	int(4)	no		Year
val	float	no		Value

Indices

Index	Type	Unique	Packed	Column	Unique elements	Comparison	Null	Comments
PRIMARY	BTREE	yes	no	id	14668	A	no	
idIndicator	BTREE	no	no	idIndicator	232	A	no	
idZone	BTREE	no	no	idZone	54	A	no	

Indicator table

Column	Type	Null	By default	Comments
id	int(11)	no		Code
type	enum('monthly', 'yearly', 'vegetation')	no	monthly	Type of indicator (monthly /yearly)
idCategory	int(11)	no		Category
ruName	varchar(250)	no		Indicator
enName	varchar(250)	no		Indicator
ruMeasure	varchar(100)	yes	*NULL*	Unit
enMeasure	varchar(100)	yes	*NULL*	Measure
sort	int(10)	yes	0	Sorting

Indices

Index	Type	Unique	Packed	Column	Unique elements	Comparison	Null	Comments
PRIMARY	BTREE	yes	no	id	225	A	no	
idCategory	BTREE	no	no	idCategory	225	A	no	

Scenario indicator

Column	Type	Null	By default	Comments
id	varchar(20)	no		Code
ruName	varchar(255)	no		Name in Russian

enName	varchar(255)	no		Name in English
ruDescription	varchar(255)	yes	*NULL*	Description in Russian
enDescription	varchar(255)	yes	*NULL*	Description in Engilsh
sort	int(10)	no		Sorting

Indices

Index	Type	Unique	Packed	Column	Unique elements	Comparison	Null	Comments
PRIMARY	BTREE	yes	no	id	9	A	no	

Table scenario_indicator

Column	Type	Null	By default	Comments
id	int(11)	no		Code
scenario	varchar(20)	no		Scenario
indicator	int(11)	no		Indicator

Indices

Index	Type	Unique	Packed	Column	Unique elements	Comparison	Null	Comments
PRIMARY	BTREE	yes	no	id	228	A	no	
scenario	BTREE	no	no	scenario	16	A	no	
indicator	BTREE	no	no	indicator	228	A	no	

Zone table

Column	Type	Null	By default	Comments
id	int(11)	no		Code
ruName	varchar(250)	no		Name in Russian
enName	varchar(250)	no		Name in English
group	enum('planning_zone', 'transboundary_network', 'climate', 'energetics')	no		Group
isLeaf	int(1)	no		Last nested element
schema	enum('retrospective', 'perspective')	no	retrospective	Scheme

Indices

Index	Type	Unique	Packed	Column	Unique elements	Comparison	Null	Comments
PRIMARY	BTREE	yes	no	id	42	A	no	

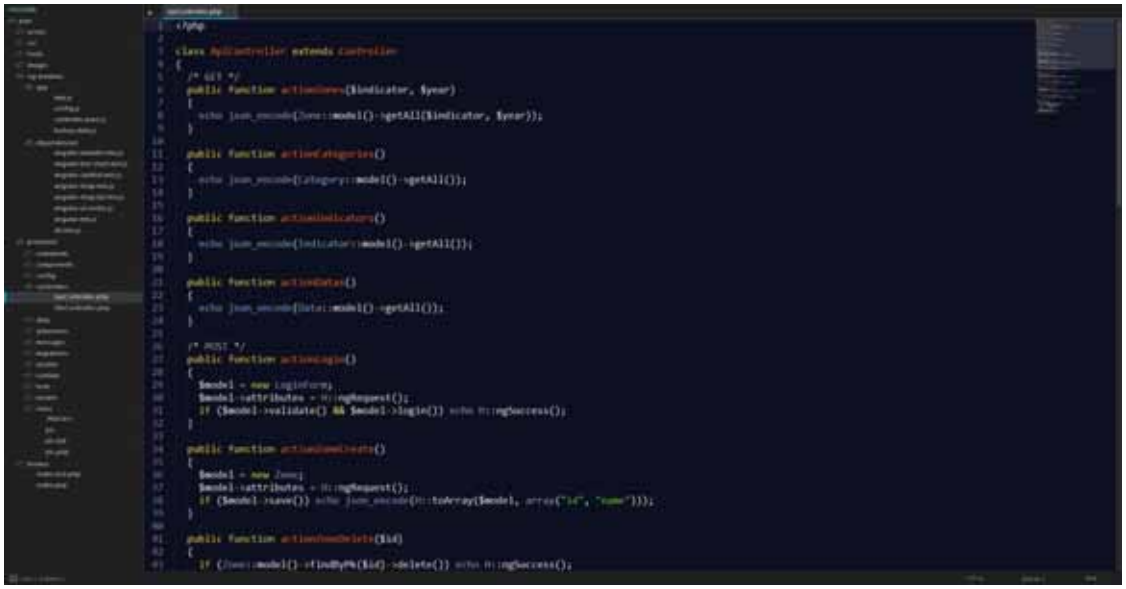
4. File system structure of Project DB

The DB is located in the following directories:

assets/ (cached files of server-side application)
css/ (all css-styles used in the system)
fonts/ (all fonts, including icon fonts used in the system)
images/ (images)
ng-modules/ (parent directory of user application)
protected/ (protected directory containing components of server-side application)
themes/ (interface customization)
ng-modules – basic directory of user interface, here realized as AngularJS-based SPA application; the code is written in Javascript within the framework of MVC, SOLID. The directory is divided into two sections (app, dependencies).

App directory contains models, controllers and configuration files of the user application. Dependencies directory contains relationships of the user application. The components are adjustable and stored in configuration file ng-modules/app/config.js.

Configuration file, section of settings for inquiries to API



ApiController is in the middle between models and inquiries from the side of user

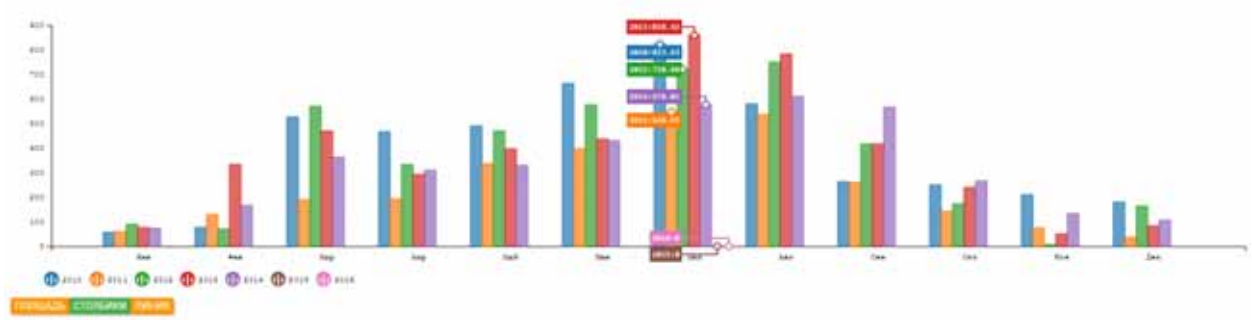
5. Interface

The main page contains the header with the menu, where the user can select a planning zone, modules, language, as well as log in. The logged in user can have access to the button to add new planning zone.

The menu on the left contains the list of indicators, as well as edit, add, and delete buttons for categories and indicators activated for authorized uses.

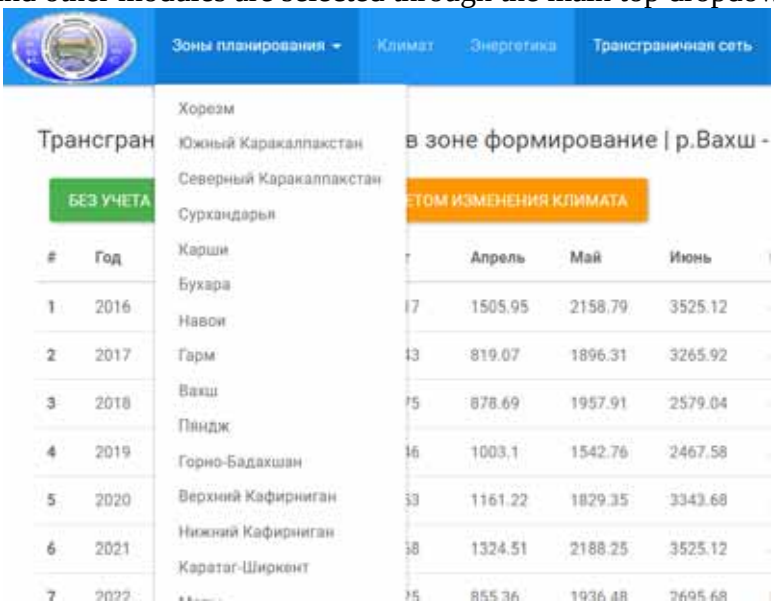
Below the web-site heading, there is a table with the output data on the selected indicator and PZ by year and month, as well as a graph, with the possibility to change the format of information output.

Graph in the form of block-diagram

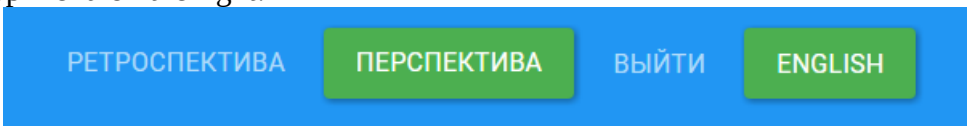


Area graph

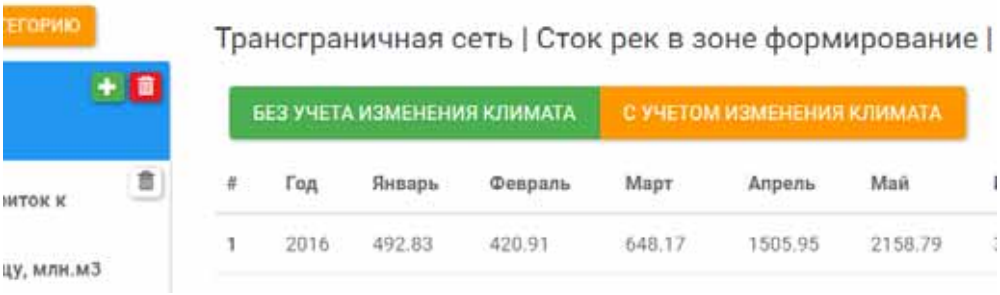
Planning zones and other modules are selected through the main top dropdown menu:



Selection of “Retrospective/Perspective” data, language options, and exit are also in the main top menu on the right:



The panel to select scenarios is located above the main table, below the heading:



6. Scope of work on data collection and input

The data was collected from different sources. The data is divided into two blocks: retrospective data for the base period (2010-2015) and perspective data based on scenarios (2016-2055).

Each block consists of 4 sections:

- Planning zone (PZ)
- Transboundary network
- Climate
- Energy

“Retrospective” Block

Section “PZ” in the Retrospective block consists of the following categories:

- Total irrigated area, including under crops;

- Calculated crop water requirements;
- Crop yield;
- Sale price of crops;
- Water withdrawal by sector
- Water disposal by sector
- Population

For this section, the data source was http://www.cawater-info.net

Section “Transboundary network” consists of the following categories:

- River flow by formation zone, including Vakhsh, Panj, Kafirnigan, Surkhandarya, and Kunduz rivers;
- River flow at gauging stations on the Amudarya River, including the virtual Kerki station, Atamyrat, Birata, Tuyamuyun, and Samanbay;
- Operation mode of the Nurek and Tuyamuyun reservoirs;
- Limit and actual water withdrawal in river reaches;
- CDF discharge into the river.

For this section, the data of BWO Amudarya was used.

Section “Climate” in the Retrospective block contains the data on average temperature and precipitation for all PZs in the Amudarya basin. The data was taken from http://meteocenter.net and www.pogodaiklimat.ru.

Section “Energy” contains the data on discharge of the Nurek HEPS and on energy generation by the Vakhsh hydropower cascade and Nurek HEPS. For this section, the data of CDC Energy, BWO Amudarya, and SIC ICWC was used (data prepared by D.Sorokin).

“Perspective” Block

Section “PZ” in this block consists of the following categories on BAU, FSD, and ESA scenarios:

- Total irrigated area, including under crops (Sh.Muminov);
- Calculated crop water requirements (simulations of crop water requirements under conditions of climate change simulated by REMO 0406 scenario, derived by G.F.Solodkiy);
- Crop yield (Sh.Muminov);
- Water withdrawal by sector (calculated in the PZ model)
- Water disposal by sector calculated in the PZ model)
- Population (Sh.Muminov);

Section “Transboundary network” consists of the following categories:

- River flow by formation zone, including Vakhsh, Panj, Kafirnigan, Surkhandarya, and Kunduz rivers, by scenario, with account of and without climate change;
- Amudarya River channel balance for energy and energy-irrigation scenarios

For this section, the data was prepared by A.G.Sorokin.

Section “Climate” contains the data on average temperature and precipitation based on the REMO 0406 scenario for all PZs in the Amudarya basin. For this section, he tdata was prepared by G.F.Solodkiy.

Section “Energy” contains the following sub-sections for energy and energy-irrigation scenarios. For this section, the data was prepared by Denis Sorokin.

- Operation mode of the Nurek reservoir
- Discharge at the Nurek HEPS
- Energy generation by the Nurek HEPS and Vakhsh hydropower cascade

7. Example of database filling

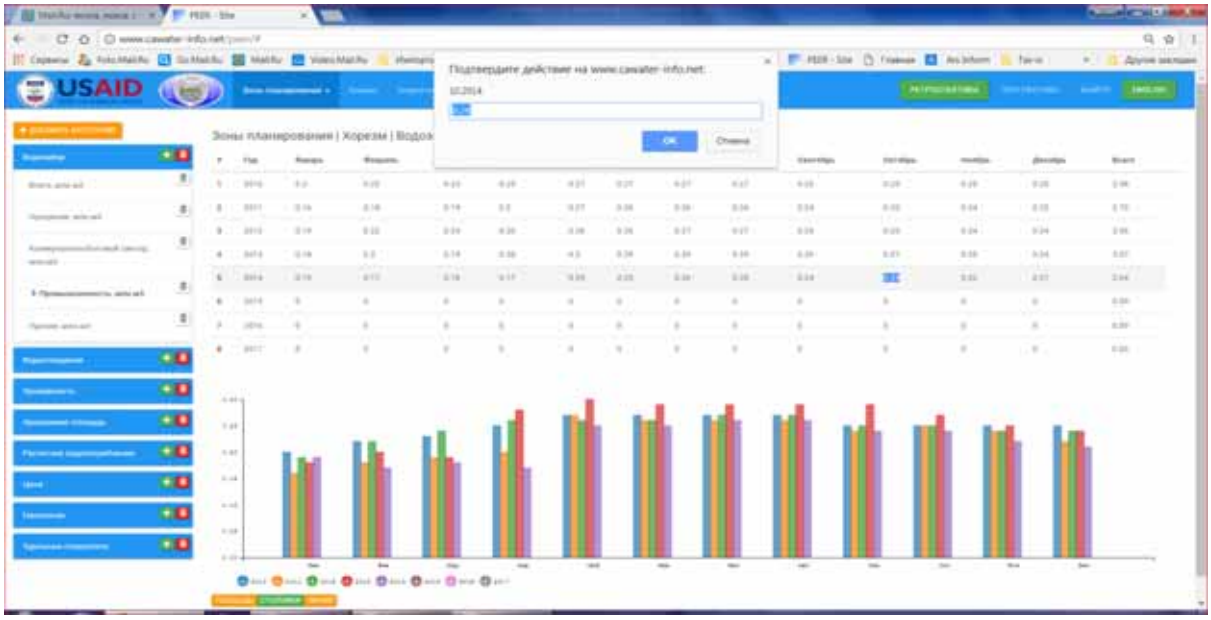


Figure 7.1 Input of data on water withdrawal for industrial and technical needs for October 2014, Retrospective Block

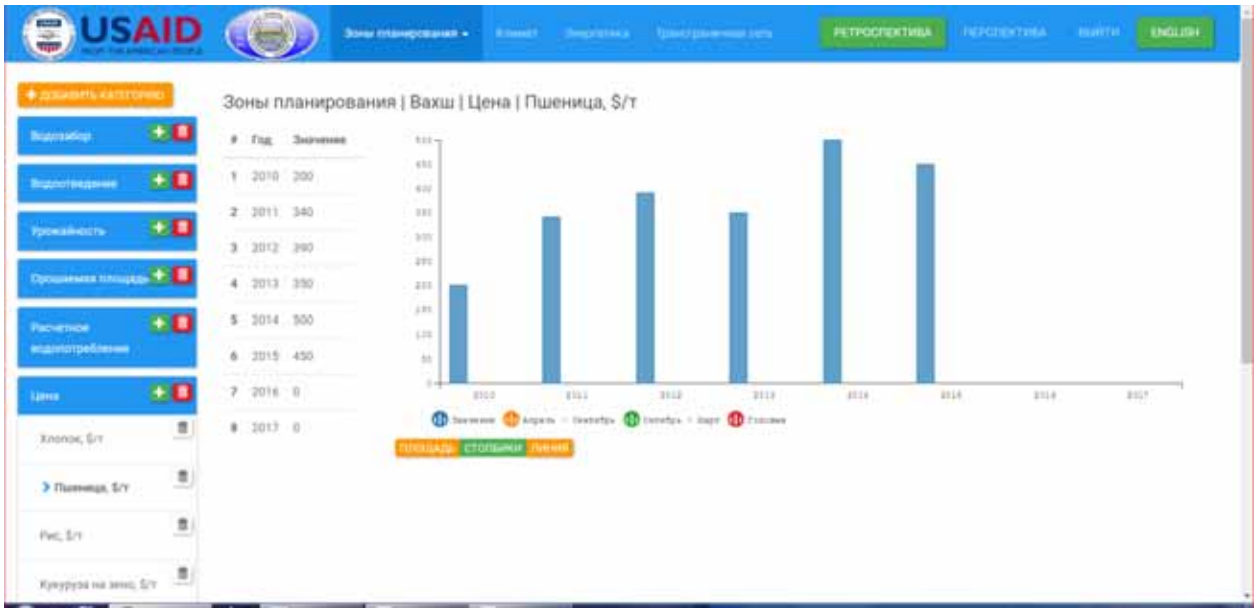


Figure 7.2 The data on wheat prices in the Retrospective Block

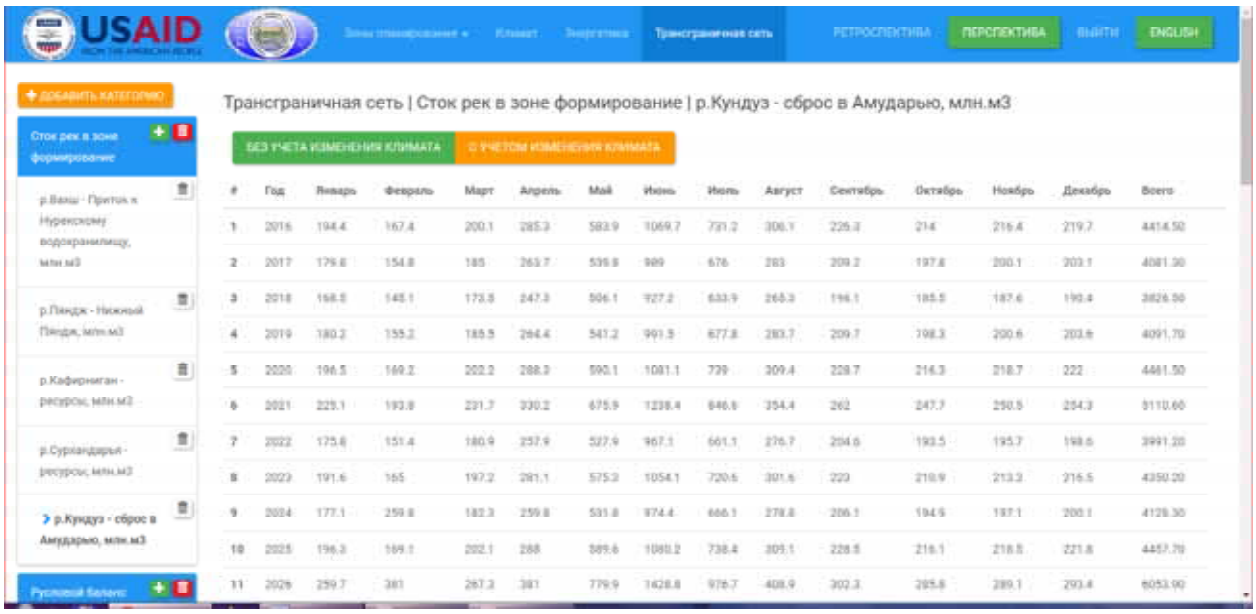


Figure 7.3 The data on the Kunduz River flow, Perspective Block, without account of climate change

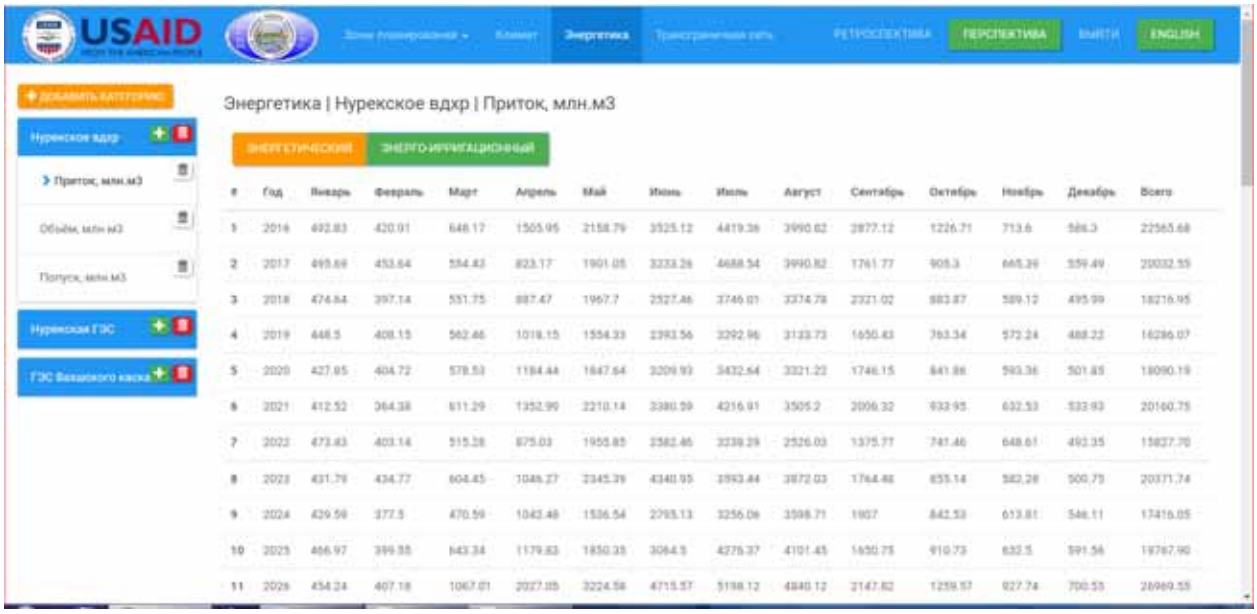


Figure 7.4 The data on inflow to the Nurek reservoir, Perspective Block, energy-irrigation scenario

Annex 1

List of data in DB of the PEER Project

Block	Section	Category	Indicator	Period
Retrospective	Planning zone	Water withdrawal, Mm3	Total	2010-2015
			Household use	
			Industrial use	
			Irrigation	
			Other	
Retrospective	Planning zone	Water disposal/use, Mm3	Total	2010-2015
			Household use	
			Industrial use	
			Irrigation	
			Other	
Retrospective	Planning zone	Yield, ton/ha	Cotton	2010-2015
			Wheat	
			Rice	
			Maize for grain	
			Vegetables	
			Orchards and vineyards	
Retrospective	Planning zone	Irrigated area, ths ha	Total	2010-2015
			Cotton	
			Wheat	
			Rice	
			Maize for grain	
			Vegetables	
			Orchards and vineyards	
			Forrage	
			Other	
			Homestead	
Retrospective	Planning zone	Calculated water requirements, mm	Cotton	2010-2015
			Wheat	
			Rice	
			Maize for grain	
			Vegetables	
			Orchards and vineyards	
			Forrage	
			Other	
			Homestead	
Retrospective	Planning zone	Price, $/ton	Cotton	2010-2015
			Wheat	
			Rice	
			Maize for grain	
			Vegetables	
			Orchards and vineyards	
			Forrage	
			Other	
Retrospective	Planning zone	Population	People	2010-2015
Retrospective	Planning zone	Unit indicator	Irrigated area, ha/person	2010-2015
			Water productivity, $/m3	
			Land productivity, $/ha	

List of data in DB of the PEER Project

Block	Section	Category	Indicator	Period
Retrospective	Transboundary network	River flow in the formation zone	Vakhsh River - Inflow to the Nurek reservoir	2010-2015
			Panj River-Lower Panj	
			Kafirnigan River-resources	
			Surkhandarya River-resources	
			Kunduz River-discharge into Amudarya	
Retrospective	Transboundary network	River flow in gauging stations of the Amudarya River	Virtual Kerki (Upstream of Garagumdarya)	2010-2015
			Atamyrat (Kerki)	
			Darganata	
			Tuyamuyun	
			Samanbay	
Retrospective	Transboundary network	Nurek reservoir	Inflow	2010-2015
			Volume	
			Releases	
Retrospective	Transboundary network	TMHS reservoirs	Inflow	2010-2015
			Volume	
			Releases	
Retrospective	Transboundary network	Water intake in reaches	Limit in reach Nurek-TMHS	2010-2015
			Actual in reach Nurek-TMHS	
			Limit in reach Tuyamuyun-Samanbay	
			Actual in reach Tuyamuyun-Samanbay	
		CDF discharge into river	In reach Nurek-TMHS	
Retrospective	Energy	Nurek HEPS	Discharge, Mm3	2010-2015
			Energy generation, mln kWh	
		HEPS of Vakhsh cascade	Energy generation, mln kWh	
Retrospective	Climate	Karshi weather station	Precipitation	2010-2015
			Temperature	
	Climate	Bukhara weather station	Precipitation	2010-2015
			Temperature	
	Climate	Urgench weather station	Precipitation	2010-2015
			Temperature	
	Climate	Nukus weather station	Precipitation	2010-2015
			Temperature	
	Climate	Termez weather station	Precipitation	2010-2015
			Temperature	
	Climate	Kerki weather station	Precipitation	2010-2015
			Temperature	
	Climate	Darganata weather station	Precipitation	2010-2015
			Temperature	
	Climate	Gyshgy weather station	Precipitation	2010-2015
			Temperature	
	Climate	Uchadji weather station	Precipitation	2010-2015
			Temperature	
	Climate	Tedjen weather station	Precipitation	2010-2015
			Temperature	
	Climate	Ashgabat weather station	Precipitation	2010-2015
			Temperature	

List of data in DB of the PEER Project

Block	Section	Category	Indicator	Period
Retrospective	Climate	Dashoguz weather station	Precipitation	2010-2015
			Temperature	
	Climate	Khorog weather station	Precipitation	2010-2015
			Temperature	
	Climate	Dushanbe weather station	Precipitation	2010-2015
			Temperature	
	Climate	Kurgan-Tyube weather station	Precipitation	2010-2015
			Temperature	

Annex 1, continued

Block	Section	Category	Indicator	Period	Scenario		
Perspective	Planning zone	Water withdrawal, Mm3	Total	2016-2055	BAU	FSD	ESA
			Household use				
			Industrial use				
			Irrigation				
			Other				
Perspective	Planning zone	Water disposal, Mm3	Total	2016-2055	BAU	FSD	ESA
			Household use				
			Industrial use				
			Irrigation				
			Other				
Perspective	Planning zone	Yield, ton/ha	Cotton	2016-2055	BAU	FSD	ESA
			Wheat				
			Rice				
			Maize for grain				
			Vegetables				
			Orchards and vineyards				
Perspective	Planning zone	Irrigated area, thousand ha	Total	2016-2055	BAU	FSD	ESA
			Cotton				
			Wheat				
			Rice				
			Maize for grain				
			Vegetables				
			Orchards and grape				
			Forrage				
			Other				
			Homestead				
Perspective	Planning zone	Calculated water requirements, mm	Cotton	2016-2055	BAU	FSD	ESA
			Wheat				
			Rice				
			Maize for grain				
			Vegetables				
			Orchards and vineyards				
			Forrage				
			Other				
			Homestead				
		Population	people	2016-2055	BAU	FSD	ESA
Perspective	Planning zone	Unit indicators	Irrigated area, ha/person	2016-2055	BAU	FSD	ESA
			Water productivity, $/m3				
			Land productivity, $/ha				
Perspective	Transboundary network	River flow in formation zone, Mm3	Vakhsh River - inflow to the Nurek reservoir	2016-2055	With no account of climate change	With no account of climate change	
			Panj River - Lower Panj				
			Kafirnigan River - resources				
			Surkhandarya River - resources				

Block	Section	Category	Indicator	Period	Scenario		
			Kunduz River- discharge into Amudarya				

Block	Section	Category	Indicator	Period	Scenario		
Perspective	Transboundary network	River channel balance, Mm3	Inflow to the Nurek hydroscheme	2016-2055	With no account of climate change	With no account of climate change	
			Water releases from the Nurek hydroscheme				
			Panj(Khirmandjoy gauging station) + Kokcha River (discharge into Panj)				
			Kafirnigan River basin (recorded surface water inflow)				
			Surkhandarya River basin (recorded surface water inflow)				
			Vakhsh River flow: mouth				
			Panj River flow: Lower Panj gauging station				
			Kunduz River-discharge into Amudarya				
			Kafirnigan River flow: mouth				
			Surkhandarya River flow: mouth				
			Amudarya River flow: Inflow to the middle reaches (Kelif gauging station)				
			Amudarya River flow: inflow to the Tuyamuyun hydroscheme (Birata gauging station)				
			Supply to the Aral Sea from river and CDW				
			Water intake				
			Water losses				
			Deficit				
Perspective	Transboundary network	Water intake in reaches	Limit in reach Nurek-TMHS	2016-2055	Energy	Energy-irrigation	
			Actual in reach Nurek-TMHS				
			Limit in reach Tuyamuyun-Samanbay				
			Actual in reach Tuyamuyun-Samanbay				
		CDF discharge into river	In reach Nurek-TMHS				
ctive		Nurek reservoir	Inflow	2016-2055	Energy	Energy-irrigation	
			Volume				
			Water releases				
			Discharge, Mm3				

Block	Section	Category	Indicator	Period	Scenario		
Perspec	Energy	Nurek HEPS	Energy generation, mln kWh	2016-2055	Energy	Energy-irrigation	
		HEPS of the Vakhsh cascade	Energy generation, mln kWh				
Perspective	Climate	Karshi weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Bukhara weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Urgench weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Nukus weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Termez weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Kerki weather station	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Darganata weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Gyshgy weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Uchadji weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Tedjen weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Ashgabat weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Dashoguz weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Khorog weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Dushanbe weather	Precipitation	2016-2055	REMO		
			Temperature				
	Climate	Kurgan-Tyube weather station	Precipitation	2016-2055	REMO		
			Temperature				

List of input data for the planning zone model over 2010-2015

Water layer required for soil leaching
Efficiency of on-farm network
Efficiency of inter-farm network
Efficiency factor of irrigation technique
Leached lands /Irrigated area
Industrial water use
Household water use
Other types of water use
Limit on water withdrawal from transboundary sources
Limit on water withdrawal from local sources
Possible water withdrawal from transboundary sources
Possible water withdrawal from local sources
Possible water withdrawal from ground water sources
Water withdrawal from CDF for reuse/Water intake for irrigation, including leaching
Minimum possible water withdrawal from CDF for reuse
Maximum possible water withdrawal from CDF for reuse
Minimum water volume in the reservoirs
Maximum water volume in the reservoirs
Water volume in the reservoirs by the beginning of month
Water volume in the reservoirs by the end of month
Water losses in the reservoirs
Coefficients of functional relationship between drainage water and water intake for irrigation
Coefficients of functional relationship between waste water and water intake for non-irrigation purpose
Local water sources flowing to or formed in PZ
Total CDF from neighboring PZs

CDF into neighboring PZs/Total return flow
CDF into lakes and depressions in PZ /Total return flow
CDF into transboundary rivers /Total return flow
Total crop area, including area under double-season crops
Water layer required for irrigation, excluding leaching
Net irrigated area
Area under double-season crops /Net irrigated area
Crop evapotranspiration
Groundwater contribution
Effective precipitation
Water withdrawal from transboundary water resources
Total actual water withdrawal
Water withdrawal for irrigation, including leaching
Total drainage and waste water
Total return flow into lakes and depressions
Return flow into rivers
Return flow into neighboring PZs
Yield, ton/ha
Crop sale price, $/ton
Population in PZs