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Abstract

Aggravation of water crisis in the world, particularly under conditions of arid climate, makes the public and decision makers put increased attention to predicting future development and searching solution of water challenge to the benefit of the nature and the society.

Experience accumulated by the European Union in long-term planning and methodological tools developed in the EU countries serve as a good guide for developing countries and transition economies to building up their own water development scenarios.

Within the framework of the RiverTwin Project, by using technical approaches developed for the Neckar river basin by the Hohenheim University together with the Stuttgart Technical University, the Aristotle University (Greece), with the participation of Stockholm Environment Institute, the team of SIC ICWC together with its partners from BWO "Syrdarya" and CWSIR has adapted and complemented the system of models to specific conditions of the Chirchik-Akhangaran-Keles sub-basin. This basin is a part of water-management system of the Syrdarya river, which, in turn, belongs to one of the most complex, in terms of development and management in arid zone, the Aral Sea basin in Central Asia. Some modifications and extensions to this system of models were caused by the specificities of water-related development, that is irrigated agriculture, and a need to model water distribution between irrigation systems and districts. Besides, we have complex socio-economic environment due to on-going transition from centrally planned economy to market one.

The above-mentioned system of models underlay building up and linking of scenarios for future water-related development in the basin. The general development scenario is based on five main sub-scenarios: climatic, socio-economic, agricultural, water management, and environmental. Each of those sub-scenarios is treated in two options, such as business as usual and optimistic, including their constructing, analysis and output to plausible option by using the system of models and the opinion of stakeholders. This resulted in recommendation of approaches and measures for organization of water-economic monitoring and for transition to integrated water and environmental management in the sub-basin.

1. Introduction

1.1. Background

This report is conclusive within the framework of the project "RiverTwin" – "A regional model for integrated water management in twinned river basins", beginning 2004, end 2006.

1.2. Objective

Developing alternative scenarios of sustainable development of water management for the Chirchik basin.

1.3. Research object

The research object is future water development in the Chirchik – Ahangaran – Keles basin and preparation of some alternative scenarios of this development.

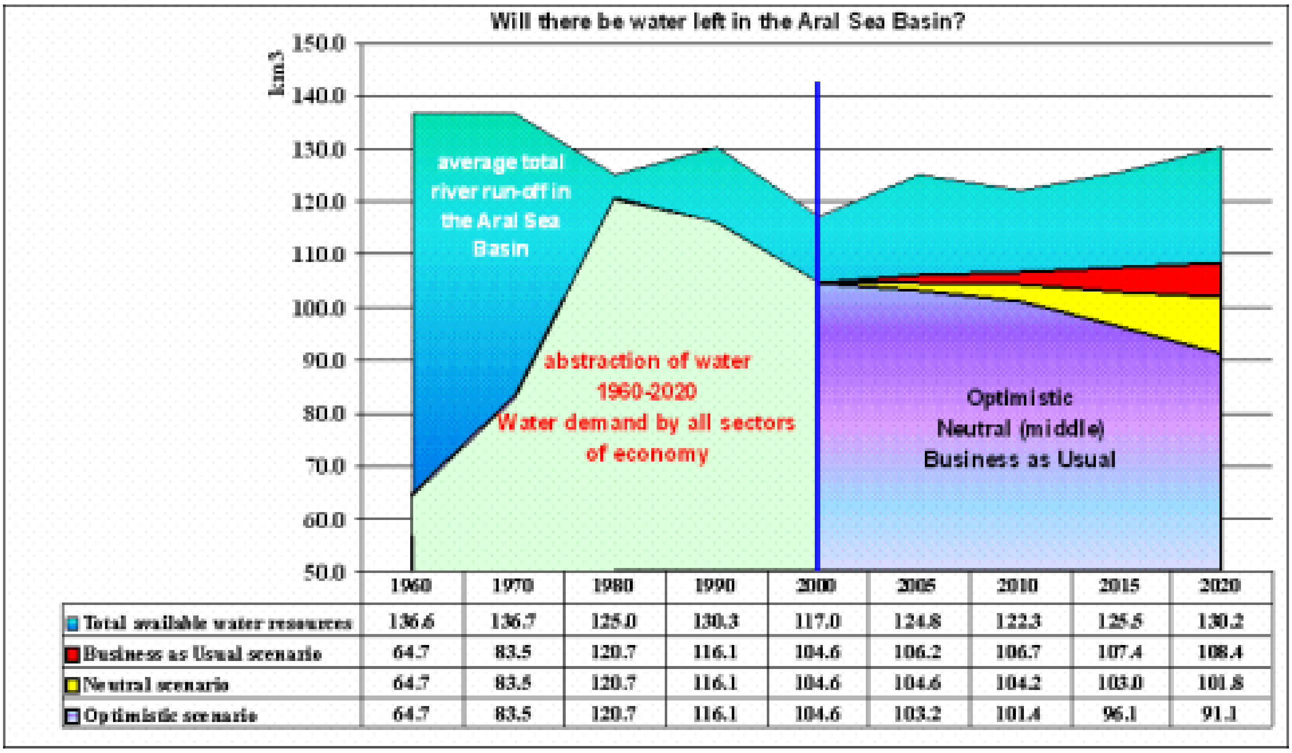
1.4. Status of previous research

During the pre-independence period in Central Asia, water sector development was guided by long-term planning based on the approach of "Basin master plans", "National water scheme of complex water resources use". Two documents related to definition of proper scenarios of water development for ChAKIR basin were produced in the Soviet period.

- "Master plan of Syrdarya river", that included the Chirchik sub-basin (1975, revised 1988);
- "Scheme of complex water use in Uzbekistan", (1988, revised 1999).

But principal difference between scenarios and these water plans is that the latter had the strict targets of planning water requirements oriented to the achievement of directive indicators of former soviet planning system with full absence of alternatives and analyses of possible changes and driving forces of development and present social, economic and water situations. First attempts in preparation of different scenarios of water development were made by SIC ICWC together with UNESCO for Aral Sea Basin in the "Aral Sea Basin Water Vision", 1999 – 2000, according to the set of measures of the World Water Forum 2 (Hague, 2000), and later took development in creation of "Aral Sea basin model - ASBMM" that allowed corrections to previous projection. The both works analyzed two scenarios – "business as usual" and "optimistic", that gave a considerable difference in guaranteed water ability for development and protection of the nature (Fig. 1.1). Scenarios "BAU" would lead to full ignore of nature requirements – not only the Aral Sea itself, but even Aral Sea delta.

As was mentioned in our report D-27, ASBMM uses approach that considers basin and sub-basin (or planning zone) in their interrelation between water and economy. The lowest level of water hierarchy here was planning zone with aggregated consumption of appropriate quantity of water, which influenced the agricultural and associated production and created release of water to river thus causing changes in water quality. The industrial production and general indicators of development based on the trends were estimated from historical series and long-term States provisions.



	1960	1970	1980	1990	2000	2005	2010	2015	2020
🟦 Total available water resources	136.6	136.7	125.0	130.3	117.0	124.8	122.3	125.5	130.2
🟥 Business as Usual scenario	64.7	83.5	120.7	116.1	104.6	106.2	106.7	107.4	108.4
🟨 Neutral scenario	64.7	83.5	120.7	116.1	104.6	104.6	104.2	103.0	101.8
🟪 Optimistic scenario	64.7	83.5	120.7	116.1	104.6	103.2	101.4	96.1	91.1

Figure1.1. Future of the Aral Sea basin

Our task now is quite different. In the RiverTwin Project we need to prepare scenarios of water sector that would account:

- expected changes in climatic conditions and their impact on water demands and water resources;
- expected changes in socio-economic situation at the level of rayons (districts) as the lower level of administrative units;
- changes that will take place under influence of governance (dissemination of natural income between sphere of economic and provinces; legal, institutional and political regulations in agricultural and water sectors; orientation to the involvement of stakeholders; involvement of investors and creation of adequate climate for them and so on).

Our European colleagues have in their work for the Neckar basin (1) strong and strict, more or less stable trends in development of each administrative unit and they can orient to the proper targets of the European and National strategies (2, 3, 4, 5) that follow the Water Framework Directive. New independent States, including all 5 states in Central Asia, have principally another situation that induces complications of such forecast. None of Uzbekistan, Kazakhstan, and Kyrgyzstan, on the territories of which ChAKIR basin is located, has proper water targets or forecast for future long-term economic development. From this point, any future economic decisions can't be assessed based on historical dynamics of parameters as per capita income, national income. Such approach is not always reasonable since the historical time series were obtained from statistical estimations, where values of macroeconomic parameters could be distorted due to the so called “noise” of random disturbances not linked with specific economic and political decisions and many other specialties of our economies (inflation, exchange rate and so on). Hence, the assessment of future economic decisions based on such information may be doubtful. Taking into account the instability of existing trends in all economic, social and other indicators, we decided to use the analysis of trends and possible scenarios with account of distributing functions and definition of a role of different factors as mentioned in our report D-27.

1.5. Goals and objectives of water sector in the regional socio-economic development

The water sector plays an important role in arid zone in general and, particularly, in the Chirchik-Akhangaran basin and practically makes for a possibility of further development. Water supply contributes in different ways to any field of human or economic activities. Thus, in light of decisions made at Johannesburg Summit 2002, the objectives in water sector would be set from the point of how they are contributing to achievement of Millennium Development Goals. In terms of socio-economic development, which would be reflected in modeling set SEM these objectives are as follows:

- № 1 – no people living below the poverty line;
- № 2 – no hunger and ensure opportunities to increase calorie consumption up to required standard;
- № 4 – improve health and reduce morbidity (in particular, water-borne diseases);
- № 10 – access of population to safe water and sanitation;
- № 11 – environmental well-being and social usability of good clean environment to the benefit of humans (aquacultures, fishery, recreation, etc.)

The goal functions of water and the objectives of water sector are different in socio-economic development both proceeding from goals common for all mankind and based on functional characteristics of the sector. From this viewpoint, the following links between the water sector and other economic sectors would be clearly seen in general economy and social development:

- <u>contributor to sustainable economic progress</u>, where water is not a main factor of production but rather irrevocable (for instance, steel, rubber and chemistry production) or technological element (coolers, slag disposal in chemical plants). Here water consumptively used in quite minor share (2…5 %) guarantees high-tech production processes, mainly, in industry, thus contributing to GDP, employment, development of industries and social welfare of associated workers;
- <u>determinant of municipal economy</u>, where quality of water and access to water for each human according to his/her right, rather than quantity of water for direct use, serve as a guarantee of social (hygienic, domestic, cooking, recreation) comfort through water supply to user and sanitation;
- <u>major role in production of irrigated agriculture</u>, fishery, as a main factor of production volume (as well as in electric energy generation);
- <u>associated role in volume of agro-industry</u> and services that depend on quantity of irrigated agriculture production.

We tried to describe all these directions in our scenarios.

2. General approaches

The elaboration of future development scenarios for basin or sub-basin or for national water sector as a whole is an element of long-term planning, which is represented as strategic planning or vision in many countries. The strategic planning allows us to assess the expected limits of future change in the general socio-economic, environmental, and economic conditions, the driving factors and trends of this change and their relations with the water sector.

These relations are exceptionally many-sided and complex since, on the one hand, water use volumes depend on parameters of the development and resources are subject to water availability in natural sources to be changed and to transboundary water exchange rights (acquired or agreed with owners). On the other hand, usage, direction and regime of water sources define many economic, social, and environmental parameters and consequences of development. In approaches widely used in the world, this vision takes shape in form of a "strategic planning", which consists of a sort of three components: analysis (history, "status quo", and driving forces); development scenarios; and, action plan.

SP approaches are based on understanding and assessment of relationship between the core potentials of any natural-anthropogenic unit, such as basin, sub-basin or its part within the national boundaries. These are natural resource, productive resource, human resource, and financial resource potentials (7,8). Preservation, use, augmentation or losses of those potentials are subject to "governance" and style, methods and principles of "management". Exactly these determinants of development form careful or destructive treatment of the potentials, following of up-to-the-minute or long-term interests. This is reflected in Figure 2.1.

When analyzing driving forces taken in those approaches, we should understand that the approaches (political, cultural, socio-economic) and respective trends have been stabilized as far as it is possible in the present world vulnerable to occasional and unforeseen pressures. However, at least EU conducts regular monitoring of all these processes and has political, socio-economic, and nature protection culture. And our Central Asian region being the quite dynamical environment of transition economies lacks this.

By following the logic and analysis of driving forces in both of the above-mentioned documents, we will try to formulate their differences and effects:

1. Demographic factors – the most similar since here the main two factors such as population growth and distribution will play a key role in increasing load on water use, water quality, and food demand (hence, water and land demands). But some specific elements arise here. These are migration, both transnational and internal depending on political factors, socio-economic factors (job places, employment, standard of living) that can greatly intensify dynamics in both directions (+ or -). Population distribution (rural or urban) is more dynamic here as well. Depending on "in-depth distribution" due to poor development of transboundary links and

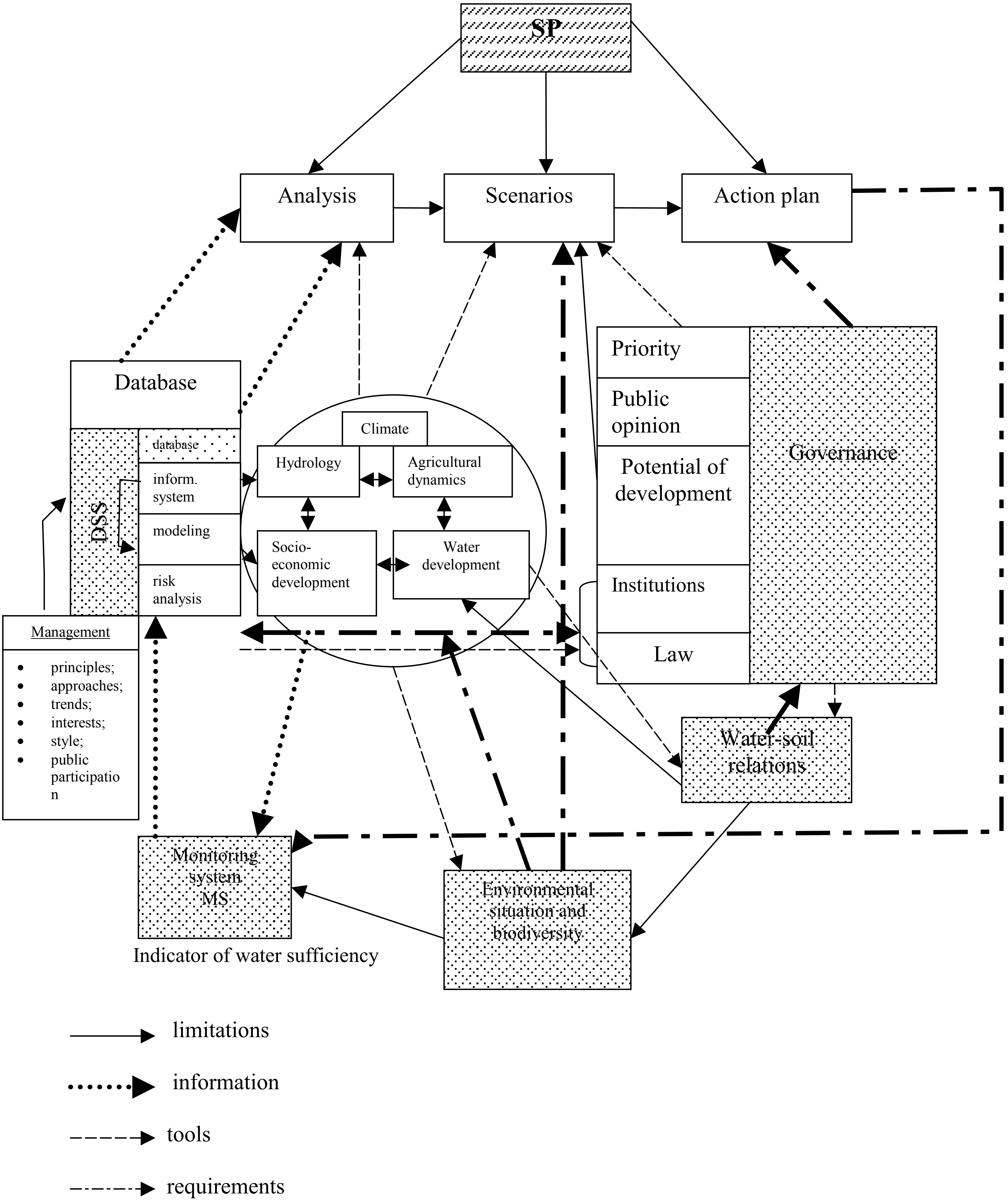


Figure 2.1. Scheme of interlinks in long-term planning

traditions, rural population stability may be quite low and create load on more "water-intensive sectors of employment". Sustained great share of rural population will create also heavy environmental load expressed in pollution of groundwater, deforestation, overgrazing, intensive desertification and natural degradation.

2. Macroeconomic development as reflected in adopted by EU factors such as GDP, GDP per capita, fuel and energy prices and especially agricultural output and input prices plays a primary role. But industrial development direction is particularly important. The region suffered from considerable decline in most sectors as compared to previous production volumes (several times in some zones). At the same time, the capital assets and resource potential substantially remained, including human resources and reconstruction opportunity. Growth or decline of any direction will be subjected to the market factors, a possibility to restore these resource potentials to a new technological level, the political priorities, and a probable financial competitiveness at the world market. It is clear that transition economies have quite great and high-qualified resource potential of cheap labor, but it's difficult to predict the area of labor application – either in developing and reconstructing industrial potential in their native countries or forced to migrate to Central Europe markets (if EU policy permits). All the factors - such as agricultural output prices (internal and world); national policy supporting agricultural producer in advanced countries; customs and tax policies; fertilizer, machine, and equipment prices; country orientation to food self-sufficiency or import – determine whether agricultural production would be profitable and competitive or would have to survive. This also influences cropping patterns that is of primary importance in estimation of water requirements, in development of irrigation. There is also a pan-European factor: whether EU will keep subsidizing its own agriculture or cut subsidies. This could impact local and export price conditions.
3. Agricultural development in all transition economies has undergone periods of decline, stagnation related to disaggregating of larger farms, and privatization, which followed quite different principles both in the countries and in regions. Land privatization or long-term rent or transfer to temporal use, sustainable cooperation, conditions of new infrastructure formation for production or processing, water use and land reclamation system – all these are quite diverse. And yet, besides purely market factors, political direction in each country and zone development does not play a key role for agricultural scenario. Political priorities will also be crucial in technological improvement and in aspiration to achieve potential water and land productivities. Agricultural extension services in Central Asia, despite those in EU, are infant and, therefore, intrusion of scientific and technological progress is quite slow. For instance, in China and India agricultural growth was based on adoption of zonal high-productive and drought tolerant varieties through a network of state seed farms, whereas in Russia, Ukraine and other transition economies this has not been developed at all.

   Another one factor typical for these countries is that development of the private sector causes reduction of cropland which is more often taken for private buildings. In some areas this trend is very intensive. Though, at the same time, agricultural production for individual consumption increases, it is usually not taken into account.

   Soil fertility could considerably decrease. Due to destructive momentary use of agricultural land, reduced amounts of applied fertilizers and manure, and almost full lack of crop rotation, many areas show loss of both the index of quality and yield of soil and the soil structure. This causes drop in natural fertility. Substantial investments are needed to prevent these phenomena. Eventually, drainage and irrigation network, sustainable operation of which is undermined due to under-financing of rehabilitation work, also leads to soil fertility losses, salinization and even desertification. All this may have ambiguous effect on crop yields and, simultaneously, on gross production in agriculture.

   An important issue arises under influence of climate change in all areas of irrigated agriculture in arid and semi-arid zones of transition economies. Rise in t^o increases water use by 5 – 10 %. Besides, rise in average air t^o by 2^o extends the growing season to additional 20 days. This creates an opportunity for more intensive production of double crops (for example, green gram, maize, pea, kidney beans after winter wheat). Under conditions of private or rent-based farming, this factor may lead to increase in water use.

Let us review the key positions in scenario development through SP approaches with reference to the RiverTwin Project.

2.1. Driving Forces and Political Leverage

Taking into account major directions and goals of MDG regarding water development (ensuring sustainable drinking water supply; famine fighting and food supply; employment and ecological well-being), analytical review should be focused on the following:

- assessment of status of socio-economic development in light of population growth, well-being, industrial and social resource potential usage, drinking and household water supply, sanitation, living conditions, etc.;
- analysis of agriculture, including land use, soil fertility, achieving the potential productivity, irrigated and rainfed land fertility changes, agricultural development, processing, marketing, sale, and infrastructure;
- identification of destabilizing factors for prospective water development and management (demographic changes, climate change, groundwater level and resource decrease, political instability, price increase or cutting, structure deterioration, economic decline, dropped water user's paying capacity, etc.);
- assessment of present water conditions (meeting society and nature needs; availability of competing demands and contradictions; adequacy of water use and management to international approaches and requirements of rational water use; availability of temporal or quantitative shortages; water quality and environmental conditions);
- assessment of the environment related to water resources and having impact on human resources;
- assessment of existing and utilized material, financial and other resources and their expected dynamics in the future;
- evaluation of available water development options that could have substantial effect on prospective water balance (a need for irrigated land expansion, prospects of radical reorganization of water-management systems, possibility to utilize additional water resources, flow regulation in upper reaches, etc.);
- assessment of institutional and legal aspects of the present management in light of their disadvantages and improvement possibilities, readiness of the system for transition to IWRM;
- identification of the key challenges of future development based on achievement of MDG goals.

All these aspects are addressed in similar reports of the Work Package WP7, the results of which should be used in building the development scenarios.

Estimation of governance level and its ability to cope with water problems is of particular importance in strategic planning. Level of governance is estimated in several directions:

- expression of understanding and political will by the government and parliament regarding fundamental issues of water and environmental development;
- attitude to transition to IWRM;
- involvement of decision makers on inter-sectoral basis in solution of those issues;
- public awareness and involvement in management;
- readiness for legal, institutional, and financial changes;

- readiness for financial support of water-management measures and strict adequacy of economic climate to rational water use.

2.2. Development Scenarios

Elaboration of future development scenarios is one of the important components of the SP system and is assessed on the basis of interlinked key elements of the analysis that determine its objectives and, simultaneously, orientation, opportunities and prospects.

Building of the probable forecast of future water development in the basin or its part is based on combination of a number of plausible thematic scenarios describing different dynamics of water balance's elements in the way of meeting water demands of the society and the nature:

- socio-economic options;
- agricultural development options;
- climate scenarios;
- natural resource change options;
- water project development options.

All these scenarios depend on national policies or on policies of several countries in case of transboundary basins.

Interaction of thematic options of future dynamics while constructing the integrated scenario is shown in Figure 2.2.

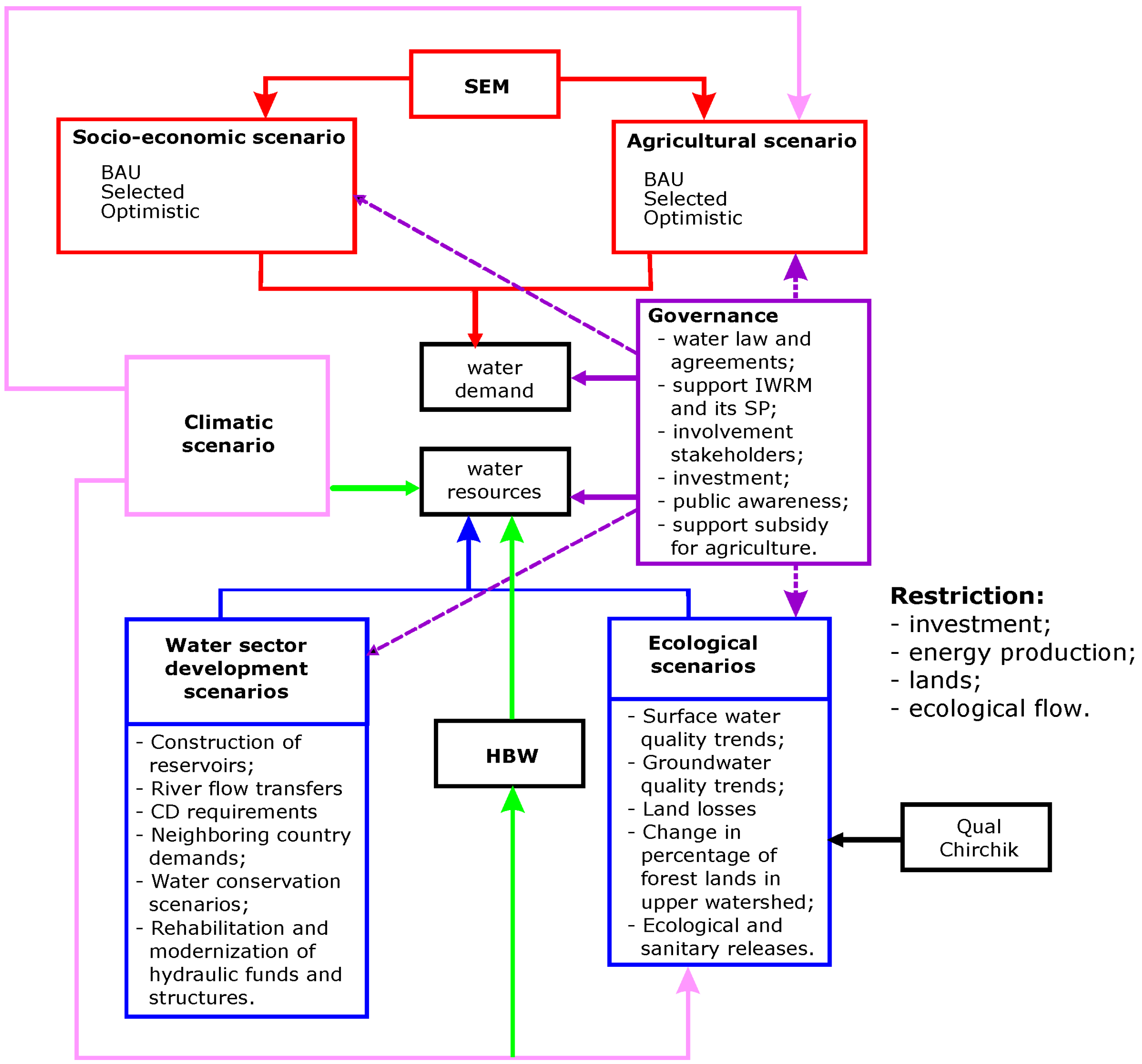


Figure 2.2. Scheme of interlinks between specific scenarios and principal modeling

1. Future socio-economic development is determined by a few key directions that are characterized by the following indicators:

   - demographic indicators (growth, mortality, migration, employment);
   - gross national income and its growth rates;
   - gross domestic product and its growth rates;
   - change in industrial production volume;
   - change of energy demands and requirements;
   - change in services sector output;
   - capital investments, including local, loans, foreign;
   - degree of provision with public utilities;
   - degree of provision with sanitation facilities;
   - degree of provision with gas supply;
   - capacities to meet national food demand.

   When building special sub-scenarios, it should be kept in mind that those can not be established on a random basis. Components of a special scenario, for example, of socio-economic development, are bound up with relations and dependencies that should be presented in form of a matrix, which determines independent factors and those caused by some dependencies typical for these subjects. This should be reflected in socio-economic development models. Some indicators of this development depend on other scenarios – agricultural, water sector development – but mainly on “governance” line. Therefore, when building scenario matrix for any block, both internal elements of the relationship and effect on them or their dependencies on elements of other scenarios should be included (Figure 2.3).
   All the indicators can be combined in a great number of options, where the boundary ones are:

   - "business as usual" (BAU) – based on current trends;
   - "optimistic option" – maximum desirable, though, in most cases, hardly feasible.

   Construction of the option "BAU" is based on prolongation of all trends, even if these trends lead to abrupt changes and declines, with account of their interlinking and interaction. Construction of current trends determines both progress factors and, particularly important, destabilizing factors, such as:

   - population growth and increased demographic pressure;
   - loss of economic potential;
   - intensification of social tension;
   - deterioration of capital assets and lack of funds for their rehabilitation;
   - deterioration of some of economic relations;
   - deterioration of human potential;
   - change in external global factors (product prices, raw material prices, etc.).

		1	1.1	1.2	1.3	1.4	2	2.1	2.2	2.3	2.4	3	3.1	3.2	4	4.1	4.2	4.3	5	6	6.1	6.P.1	6.P.2	6.2	6.3	7	8	9.1	9.2	9.3	9.4	10	Water		Ecology	Agriculture	Water sector development	Climate	Governance
																																	Resources	Consump-tion					
1	Population, including																																						
1.1	rural																																						
[illegible]	urban																																						
1.3	migration to urban areas																																						
[illegible]	to rural areas																																						
2	GDP, including per sector																																						
2.1	Industry																																						
[illegible]	Agriculture																																						
[illegible]	Construction																																						
2.4	Services sector																																						
3	GDP per capita																																						
3.1	rural																																						
[illegible]	urban																																						
4	Employment – workplaces																																						
[illegible]	Agriculture																																						
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5	Electric energy generation																																						
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6.1.1	Industry																																						
6.1.	Services																																						

2	sector																																						
6	Attracted loan																																						
6	Public ±																																						
7	Export																																						
8	Import																																						
9	Provision of population with: communications																																						
9	water supply																																						
9	gas supply																																						
9	electricity																																						
9.4	sewerage																																						
10	Feel-good degree																																						
1	Demand for agricultural products																																						

Figure 2.3. Key indicators of the socio-economic scenario

"Optimistic option" considers possibilities of complete (or close to complete) use of available potential of industries, natural mineral resources, desirable demographic level. Needed capital investments and other necessary resources (related material, human, etc.) are determined for this.
The “expectable” option is formed between those two extreme options on the basis of feasible probable investments and other resources, as well as from expert judgments.
The problem of finding the "actually expectable" option is based on estimation of cost and resource indicators of the factors that are necessary to achieve the “optimal option”, comparing them with actual resources – available or possible to find and on assessment of limitations or obstacles to implement this option, as well as of possible measures to remove the limitations. First tool for such estimation is a modeling of macroeconomic indicators that should be specified through discussion of the desired option with stakeholders, as well as by questioning (or holding round-table) the decision makers. Market and globalism factors are of key importance here.

2. Agricultural development is a determinant of water sector development. Its trends are so many-sided and diverse and depend on many uncertainty factors, and, in general, are problematically definable. Nevertheless, it is necessary to focus on the following key factors:

- growth of all used agricultural lands;
- growth of irrigated land;
- use of all agricultural lands and possibilities of their improvement;
- use of irrigated lands and possibilities of their improvement;
- crop yield changes;
- change in economic land productivity;
- crop patterns;
- livestock production;
- change in profitability of agricultural production;
- change in volume and profitability of associate sectors and processing sectors, possibilities of their development;
- change in fish production volume.

Besides main (primary) indicators, the agricultural production dynamics depends on natural environmental conditions, current water supply, state of land, provision with fertilizers, chemicals, equipment that can be determined, for example, by the EPIC model. However, there are also secondary indicators such as state of infrastructure, processing, institutional structure, extension services, mechanization base, etc.
Here, the destabilizing factors are:

- deterioration of soil fertility;
- changes in demand and prices of agricultural production;
- deterioration of irrigation and drainage infrastructure, etc.

Again, similar to item 1, we should assess here “business as usual” option and, at the same time, extreme “optimistic” option – achievement of potential productivity, as well as real option.
It is necessary to determine the following through expertise:

- changes in prices of agricultural output;
- possibility to expand capacities of agricultural infrastructure;

- prospects of farm restructuring and farm effect on irrigated agriculture productivity (by comparing productivities of different farm forms);
- possibility of high-level processing of agricultural output.

According to scenario matrix for socio-economic block components, we can build the same matrix for agricultural scenarios.

The real option is determined the same way as in item 1 but the role of modeling is more important and justified here since there are a lot of models (EPIC, CROPWAT, ISAREG) that can quite accurately find the possibilities and the cost of land productivity improvement when improving water use, technologies, changing crop patterns, etc. However, here response is more drastic than in socio-economic block, depending on political guidance reflected in support, development and subsidizing of agriculture.

3. Climate change options impact both water demand, particularly in irrigated agriculture, and water resources. Probable temperature growth, changes in precipitation and other climatic parameters may impact crop water consumption due to increased evapotranspiration but, at the same time, may increase or decrease water resources. Glacier recession that may reduce the runoff's glacier component in the long-term is especially dangerous. Nevertheless, taking into account uncertainty of climate scenarios, the comprehensive forecast should include a set of climate scenarios – from the most optimistic one to the most pessimistic one – in order to assess water and resource needs. For pessimistic scenarios – with highest deviation from "status quo" – it is advisable to assess also the possibilities of the "Adapt" program – adaptation of agricultural production to climate change and even possibility to increase agricultural productivity by making use of prolonged potential growing season and producing double crops, applying different mulches, etc. (see research of McGill University and SIC ICWC under the CIDA Project "Water Scarcity and Drought due to Climate Change").

4. Ecological scenarios, including natural resources change need to be analyzed per trend:

- trends of surface water quality and their impact on water quantity if qualitative indicators exceed maximum concentration limit;
- the same trends for groundwater;
- possibility of loosing agricultural land due to salinization, water-logging and other natural phenomena;
- changes in percentage of forest land in upper watershed and probable effect on water availability and hydrological runoff regime.

The first three points are assessed on the basis of trends, while the last one through expertise for the future. These scenarios should be reflected in general land productivity and in water resources.

It is especially important to assess ecological requirements: environmental releases to maintain river deltas as a natural entity and sanitary releases to maintain water releases in light of quality change requirements.

5. Water sector development scenarios. The main dynamic elements of water sector development are as follows:

a) construction of waterworks facilities, development of their hydropower generation and other regimes;
b) flow transfer from one system to another one;
c) probable changes in water demands of transboundary countries;
d) dynamics of the state of irrigation systems and infrastructure, as well as flow regulation;
e) water conservation scenarios depending on system efficiency deterioration.

The assessment of water regime changes should be accompanied with the approximate estimation of needed investments.

Separate definition of specific scenarios and their combination followed by their summarization, linkage and generalization helps to build frames and several key forecasts of comprehensive scenarios that presumably can be defined as:

- BAU;
- Maximum plausible feasible (different from generalized "optimistic" one since a priori it would be unrealistic);
- 1 – 2 interim scenarios.

Generalization of water use scenarios with account of intersectoral linking is made using intersectoral balances and balances of limiting factors (capital investments, water, etc.) and through mathematical modeling.

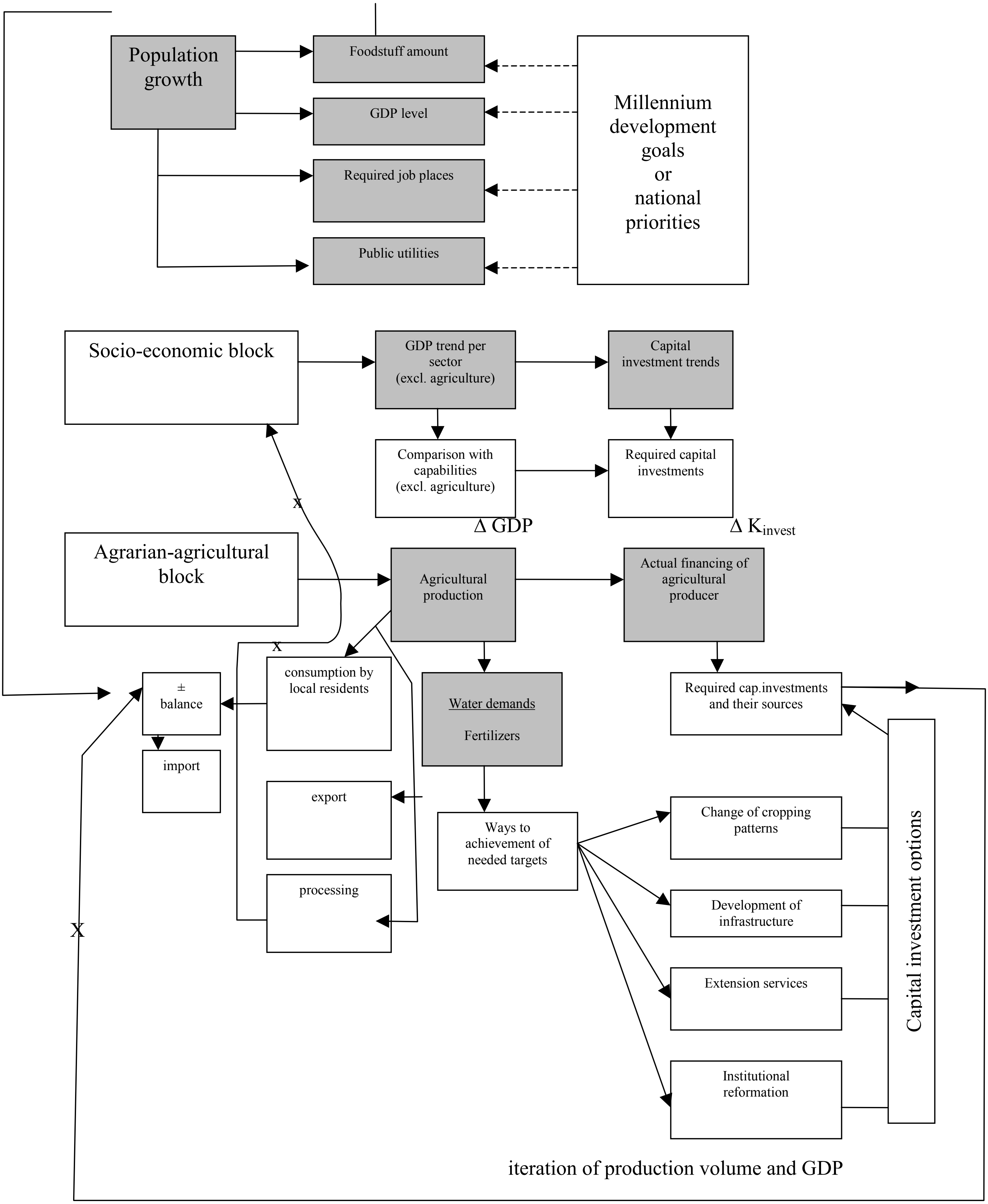
How should the scenarios be interlinked and, as a result, the expected generalized scenarios be developed?

For interlinking of sub-scenarios, it is advisable to select the main indicators of development that are similar to MDGs criteria and identify their links with the key indicators of various sub-scenarios.

We selected seven indicators of socio-economic scenario, four – agricultural scenario, five – water sector development scenario, two – climate, and three – ecological scenarios. As a result, a scheme for inter-sector links and estimation of connections of scenario relationships was built (Figure 2.4). Here, it is important to identify main limitations on resources and on requirements that should be met while assessing the above-mentioned sub-scenarios.

Taking into account basic parameters of population and its growth, current economic, social, and environmental conditions, it is necessary to clarify two types of limitations:

1. Resource limitations –
    a) water resources;
    b) land resources;
    c) energy resources;
    d) inputs (fertilizers, machine, raw materials, etc.);
    e) capital investments;
    f) human resources.


Population growth
Foodstuff amount
GDP level
Required job places
Public utilities
Millennium development goals or national priorities
Socio-economic block
GDP trend per sector (excl. agriculture)
Capital investment trends
Comparison with capabilities (excl. agriculture)
Required capital investments
Δ GDP
Δ Kinvest
Agrarian-agricultural block
Agricultural production
Actual financing of agricultural producer
x
x
± balance
import
consumption by local residents
export
processing
Water demands
Fertilizers
Ways to achievement of needed targets
Required cap.investments and their sources
Change of cropping patterns
Development of infrastructure
Extension services
Institutional reformation
Capital investment options
X
iteration of production volume and GDP

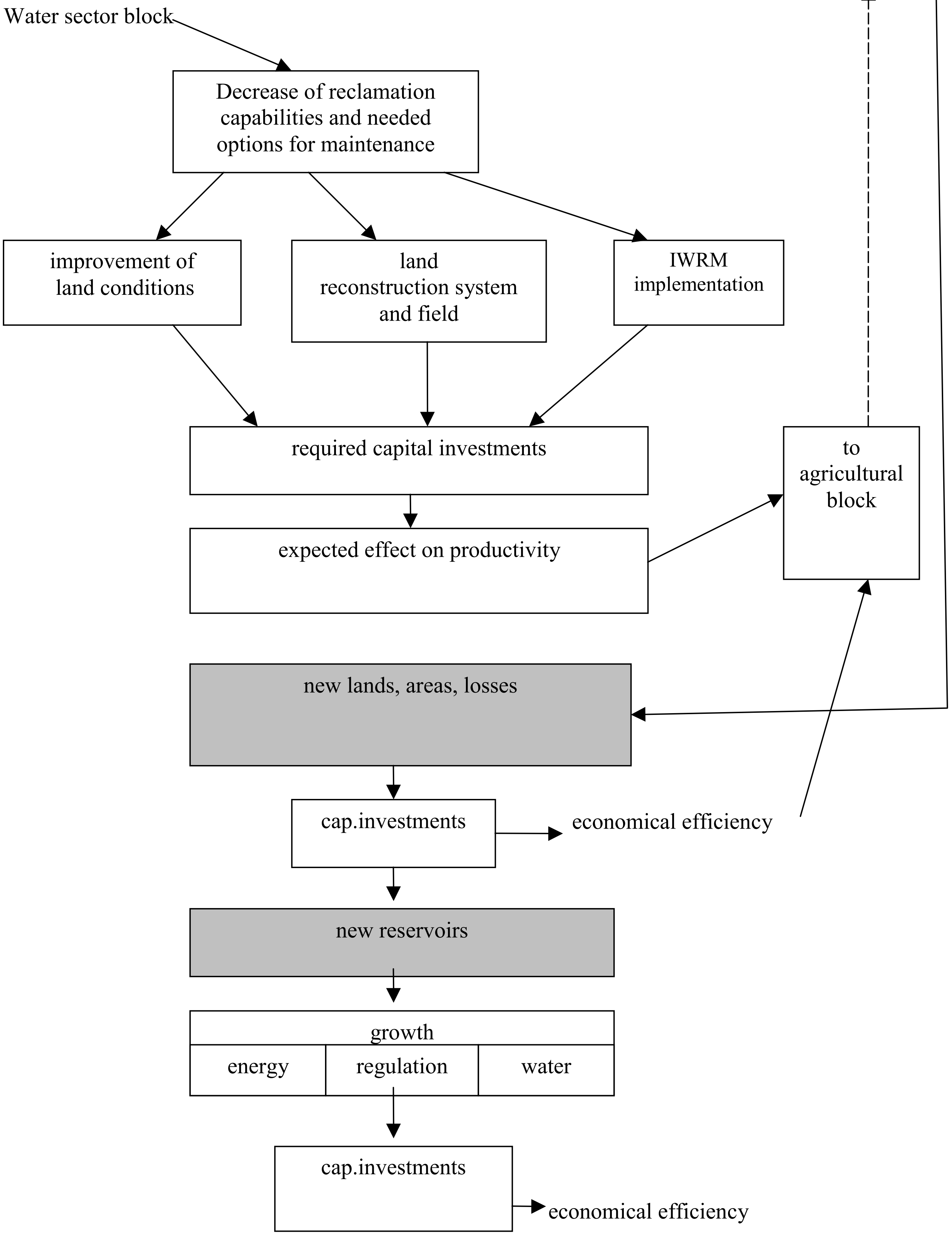


Figure 2.4. Way of scenarios interlink

2. Requirements regarding well-being, living standard, ecological and food safety that meet the intended millennium goals or national priorities:

   - eliminating poverty – availability of people who subsist on 1 US $ per day;
   - ensuring food safety – 70 % of foodstuff is to be produced in situ;
   - ensuring water quality, environmental water releases, small reservoir demands, etc.

   From this point of view, it is necessary to develop an algorithm for generalization of scenarios and to verify them using respective limitations (Fig. 2.5).

   1) All demographic growth parameters for two extreme scenarios (BAU and "optimistic") are calculated and, based on them, the following values necessary for achievement of MDGs are determined:
      - amount of foodstuff and its comparison with actual current production and food “export-import” ratio;
      - GDP volume required to ensure the intended level of national income per capita in order to eliminate poverty;
      - employment rate;
      - provision with water supply and sanitation.
   2) Trends are identified in actual GDP, including per sector and by comparing with production capabilities, and a possibility to achieve needed GDP level and required capital investments are estimated;
   3) Financing sources for operating costs and capital investments and their distribution among sectors are determined;
   4) Probable external sources of capital investments are estimated.

3. Agricultural scenarios.
   Present agricultural production with its real financing and production volume is broke up among consumption, export, processing and compared with required amount of foodstuff and raw material from socio-economic forecast. At the same time, GDP in agriculture and associated inputs are estimated.
   Comparing with agricultural production capabilities, measures and capital investments required for improvement of current production effectiveness through change in cropping patterns, development of infrastructure, extension services, and institutional reformation. This results in estimation of possible realistic and needed capital investments.
4. Water block scenario should start with estimation in option “Business as usual” of the rates of land potential reduction and of necessary measures for its restoration through land improvement, system reconstruction, and IWRM implementation. Needed capital investments per each direction and expected effect in money terms are established.
   All this is inputted into agricultural scenario and then production effectiveness is examined. At the same time, an option of new land development at a rate of business as usual is inputted. In order to achieve the required level of agricultural production, appropriate increase in rate of new land development and its effectiveness after inputting data into agricultural development scenario are estimated.
   Particular section in water sector scenario refers to launching of new reservoirs, their costs and effectiveness in terms of water and electric energy production.
   Economical efficiency of all these water-related measures is estimated on the “costs-effect” basis.
5. Climate scenario is considered in two options – minimum and maximum changes.

The above sequence of computations in each block is joined in two extreme scenarios – “optimistic” and BAU – on the basis of end results.

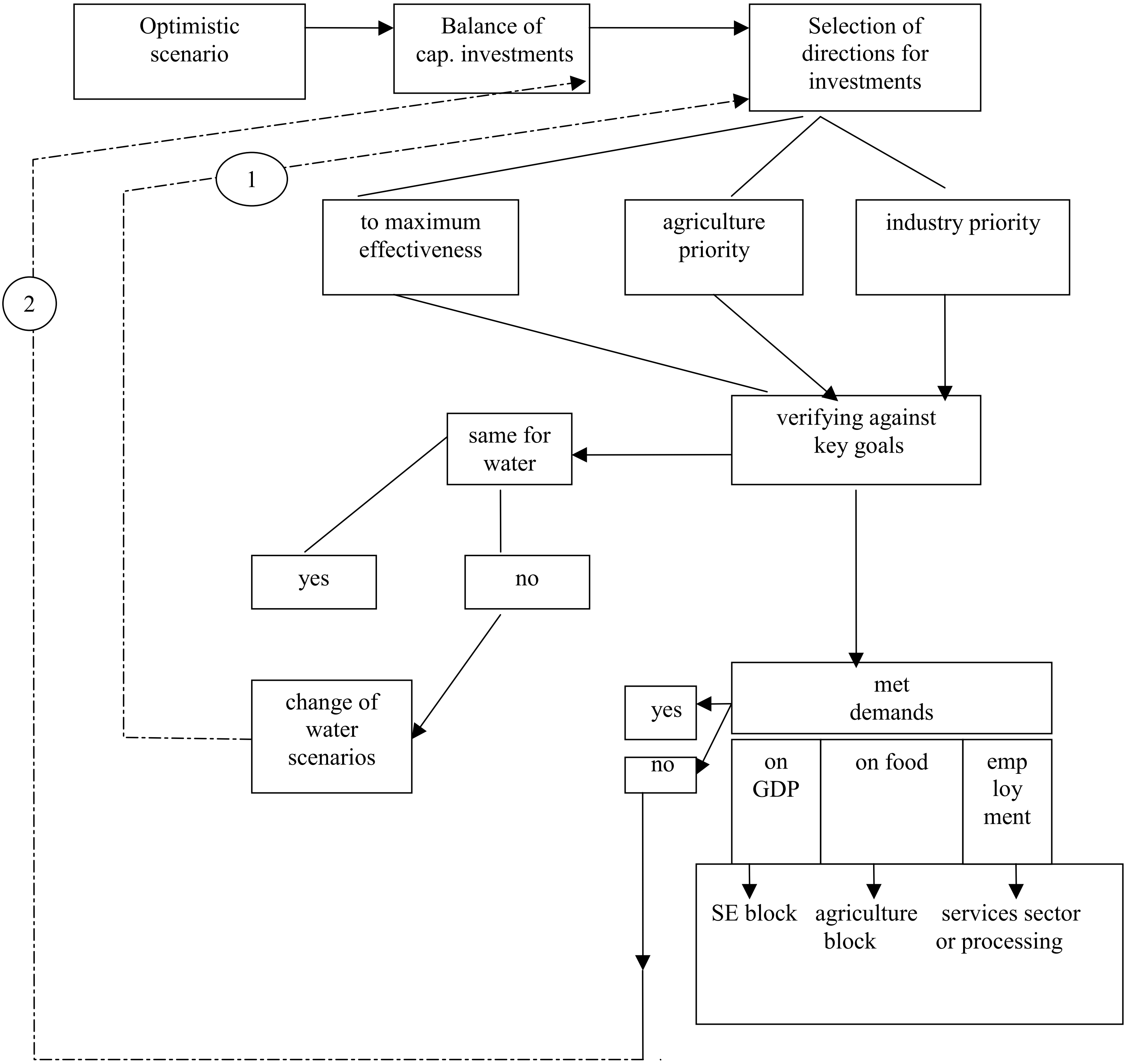


Figure 2.5. Scheme of iteration of generalized development scenario calculations

2.3. Action plan – support of policies

By comparing formed scenarios, one can prepare analysis of political, social, water-management and other measures that could facilitate progress in water sector.

At this stage, “target groups” of stakeholders and decision makers that will be involved in further consideration of the analysis of probable impact and of actions plan should be identified. Selection of the “target groups” should be linked with selection of “ownership” – decision makers should adopt the “actions plan” for future development.

Based on analysis of scenarios building and their modeling, an action plan and a set of tools for implementation of this plan are being formed.

The action plan should analyze in more details all measures, activities, investments that were identified during search of expected scenario, for maximum meeting of goals and criteria under existing limitations.

Particular attention should be paid to:

- role of governance in implementation of intended scenarios;
- search of capital investments;
- monitoring of development according to scenarios;
- implementation of IWRM.

3. Review of scenario building

As was described in the previous section, the general development scenario of the Chirchik-Akhangaran-Keles basin rests on 5 sub-scenarios: climatic, socio-economic, agricultural, water-management, and environmental.
The process of building each of those scenarios is described below.

3.1. Climatic scenario

Taking into account that the climate model of IWS-SW was submitted by the moment of completion of work on river flow forecast (milestone 6.6), elaborations of Uzgidromet were taken as basic climatic scenarios, particularly, as the latter were adjusted and adapted using a great deal of observations by this institution.
Previous analysis revealed impracticability of selecting a single general circulation model meant to describe climate on the territory of Uzbekistan and adjacent mountainous terrain in the best way.
Two basic models: 1) HadCM2 (UK, Hadley Centre); 2) ECHAM4 (Germany, Max Planck Institute) were chosen for developing regional climatic scenarios.
The ECHAM4 climatic model has been developed on the basis of the model created by European Center of Medium-term Weather Forecasts (ECMWF) and parameterization elaborated in Hamburg, enabling to use this model for simulation and forecast of climate. It is a model of transient state. The model incorporates 19 levels in atmosphere and 11 in the ocean. According to the outputs of the model, there will be global warming by +3°C in 2071-2100; global precipitation is expected to rise by 1.97% of 1961-1990 norms. In addition, in the given variant of calculations consideration is given to mitigation produced by sulphate aerosol.
The HadCM2 climatic model is a version of UK Meteorological Office (UKMO). It is a model of transient state. The model incorporates 19 levels in atmosphere and 20 in the ocean. According to the outputs of the model, there will be global warming by +3.1°C in 2071-2100; global precipitation is expected to rise by 5.01% of 1961-1990 norms. In the given variant of calculations consideration is also given to mitigation produced by sulphate aerosol.
To develop regional climatic scenarios with regard to the territory of Chirchik-Ahangaran area the method of statistical interpretation was employed in the present paper; this method is based on the "ideal forecast" concept with application of step-by-step multiple linear regression. Anomalies (obtained from archival materials) of climatic parameters in the "month" time span placed in mesh points are used as predictors in the statistical interpretation method. The predictors are actual data on climatic parameters registered by stations of Chirchik-Ahangaran area and adjacent mountainous terrain.

Table 3.1

List of reference stations with their numbers as indicated in the unabridged register

Stations in Chirchik-Ahangaran area	
36. Tashkent	42. Pskem
37. Tuyabuguz	43. Dukant
38. Kokaral	44. Oygaing
39. Kaunchy	9. Chatcal (Kyrgyzstan)
40. Dalyverzin	
41. Syrdarya	

Major part of statistical interpretation methods are developed for some specific applications, i.e. with the purpose of utilizing final results for making assessments concerning dependence of agriculture, forestry, water resources, etc. on climate. These methods are applicable only for some specific geographic region and can not be easily used with regard to different physiographic conditions. Regional climatic scenarios, constructed on the basis of statistical interpretation of models, involve retention of statistical dependencies between large-scale and meso-scale climate in future.

This procedure allows obtaining scenarios detailed in terms of territorial peculiarities and take into consideration regional specific features. Average monthly air temperatures by selected models (HadCM2 ECHAM4) are represented in the form of anomalies; as to monthly precipitation totals they are represented in percentage of 1961-1990 norms.

Development of scenarios for the nearest future has been carried out according to the mean emission scenario (IS92a) and medium level of response to increase in greenhouse gas concentration in atmosphere. Calculated values correspond to average values for 30-year period as of 2030, i.e. the range of average-out covers the period of 2011-2040. Statistical interpretation method enabled us to calculate expected by the scenario changes as applied to separate stations in Uzbekistan and Kyrgyzstan (Table 3.2).

Table 3.2

Changes in average monthly air temperatures in the ECHAM4 model by 2030
(deviations from reference norm)

Station number	**Months**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
36	1.6	1.7	0.6	0.5	1.0	0.7	0.7	1.1	0.9	0.8	0.6	0.7
37	1.7	2.0	0.6	0.5	0.8	0.5	0.6	0.9	0.6	0.7	0.3	0.7
38	1.7	2.0	0.6	0.5	1.1	0.5	0.7	1.0	0.8	0.8	0.5	0.7
39	1.7	1.9	0.6	0.5	0.9	0.7	0.7	0.7	0.8	0.7	0.5	0.9
40	1.7	2.0	0.6	0.5	1.0	0.6	0.6	1.0	0.6	0.5	0.5	0.9
41	1.7	2.0	0.6	0.5	1.0	0.5	0.6	0.8	0.8	0.6	0.4	0.8
42	1.2	1.4	0.7	0.6	0.9	0.9	1.4	1.4	1.4	1.2	0.4	0.7
43	1.1	1.3	0.8	0.6	0.9	1.2	1.3	1.3	1.7	1.4	0.9	0.6
44	0.9	1.3	0.8	0.9	1.4	1.0	1.5	1.4	1.6	0.8	0.4	0.7
9	0.6	0.8	1.0	1.1	0.5	0.7	0.9	1.1	0.9	0.9	0.9	1.0

Table 3.3

Changes in average monthly air temperatures in the HadCM2 model by 2030
(deviations from reference norm)

Station number	**Months**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
36	1.0	1.1	0.4	0.4	0.6	0.5	0.3	0.8	0.7	0.9	0.3	0.6
37	1.0	1.2	0.4	0.4	0.5	0.3	0.3	0.6	0.4	0.9	0.3	0.6
38	1.1	1.2	0.4	0.4	0.8	0.3	0.6	0.9	0.7	0.8	0.3	0.6
39	1.0	1.2	0.4	0.4	0.6	0.5	0.5	0.5	0.7	0.8	0.3	0.8
40	1.1	1.2	0.4	0.4	0.8	0.4	0.4	0.7	0.4	0.7	0.3	0.8
41	1.1	1.2	0.4	0.4	0.7	0.4	0.3	0.6	0.6	0.7	0.3	0.7
42	0.8	0.9	0.4	0.4	0.6	0.6	0.8	1.0	1.1	1.2	0.3	0.7
43	0.7	1.1	0.4	0.5	0.6	0.8	0.7	1.0	1.2	1.5	0.7	0.6
44	0.6	0.9	0.5	0.7	1.0	0.5	0.9	1.1	1.2	0.7	0.3	0.6
9	0.6	0.8	1.0	1.1	0.5	0.7	0.9	1.1	0.9	0.9	0.9	1.0

There was no possibility to construct constraint equations for stations, which actually did not register precipitation during summer months, therefore expected by scenarios values remained unchanged, i.e. they correspond to the reference norm of 1961-1990 (100%).

Table 3.4

Changes in precipitation in the ECHAM4 model by 2020 (ratio to the reference norm in %)

Station number	**Months**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
36	103	106	123	105	92	142	196	192	121	90	117	114
37	103	112	117	106	90	190	166	100	107	91	128	126
38	102	112	115	106	85	94	128	100	111	91	127	130
39	104	110	118	105	93	128	178	100	130	90	121	122
40	102	111	115	106	91	76	153	118	114	94	126	122
41	103	114	121	109	95	88	144	100	102	91	122	125
42	105	107	116	104	93	101	138	134	117	90	109	114
43	103	109	114	107	92	120	138	160	119	90	120	122
44	103	108	117	104	92	99	143	140	108	91	122	117
9	105	105	105	101	95	89	131	124	121	94	108	115

Table 3.5

Changes in precipitation in the HadCM2 model by 2020 (ratio to the reference norm in %)

Station number	**Months**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
36	115	121	107	97	116	183	160	149	107	123	122	115
37	118	121	108	97	116	183	100	134	109	130	131	118
38	119	120	107	92	106	183	100	137	109	130	134	119
39	117	121	106	101	116	183	100	156	108	128	126	117
40	116	121	108	97	88	183	140	145	114	130	127	116
41	120	121	109	104	104	183	100	126	108	129	129	120
42	115	121	108	99	116	158	145	146	102	114	121	115
43	117	121	110	97	116	168	160	149	105	127	129	117
44	117	121	108	97	115	171	150	130	105	130	125	117
9	114	113	106	100	96	149	134	146	111	114	126	114

Regression equations constructed within the framework of this method's implementation enable us to generate only preliminary assessment of changes in humidity under conditions of the climatic scenario. For practical purposes, in order to develop a scenario of relative humidity for the nearest future such values may be used, which are averaged-out for the last ten years as the analog of future warming.

Table 3.6

Average values of relative humidity (%) for the period of 1991-2000
(as analog humidity scenario)

Station number	**Months**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
36	73	68	63	59	58	48	44	44	49	59	69	72
37	81	76	68	60	56	45	44	45	48	57	71	80
38	87	84	76	69	65	56	58	63	65	69	79	86
39	85	80	71	63	59	49	47	50	54	63	76	85
40	80	76	73	65	60	50	51	57	61	69	77	80
41	88	83	76	70	65	58	59	62	64	72	82	88
42	69	68	67	60	62	54	47	39	41	53	65	70
43	57	61	68	62	61	49	43	39	42	50	56	56
44	72	72	75	72	65	61	57	49	49	59	69	71

Calculations of Uzgidromet's climatic scenarios were compared with recent calculations by IWS-SW (Wei) on mean monthly temperatures and on precipitation. Regarding mean monthly temperatures, correlation between two scenarios is very high and equal to 0,89 – 0,958 for various stations. Data on weather station Pskem are shown below for comparison (Table 3.7). As to precipitation, which is the main factor of runoff generation in HBV model, forecasts obtained from IWS-SW's scenarios raise doubts for two reasons:

- trends in this scenario are not stable; at the same time, analysis of climate trends for the whole period of observations shows that actual directivity of trends is well-defined in all basin's weather stations from one climatic zone (6); moreover, earlier model simulations in the same work and new calculations of Uzgidromet under the project (Table 3.8) show an increase in annual precipitation that corresponds to actual trend (Figure 3.1);
- comparison of simulated and actual precipitation on climatic scenarios of IWS-SW № 1 - that are closer to Uzgidromet's calculations and actual data than variant 2 – show (Table 3.9) considerable discrepancies between calculated and simulated trends and data. As a result, climatic trends of ECHAM and HADCM2 were taken as calculation indicators.

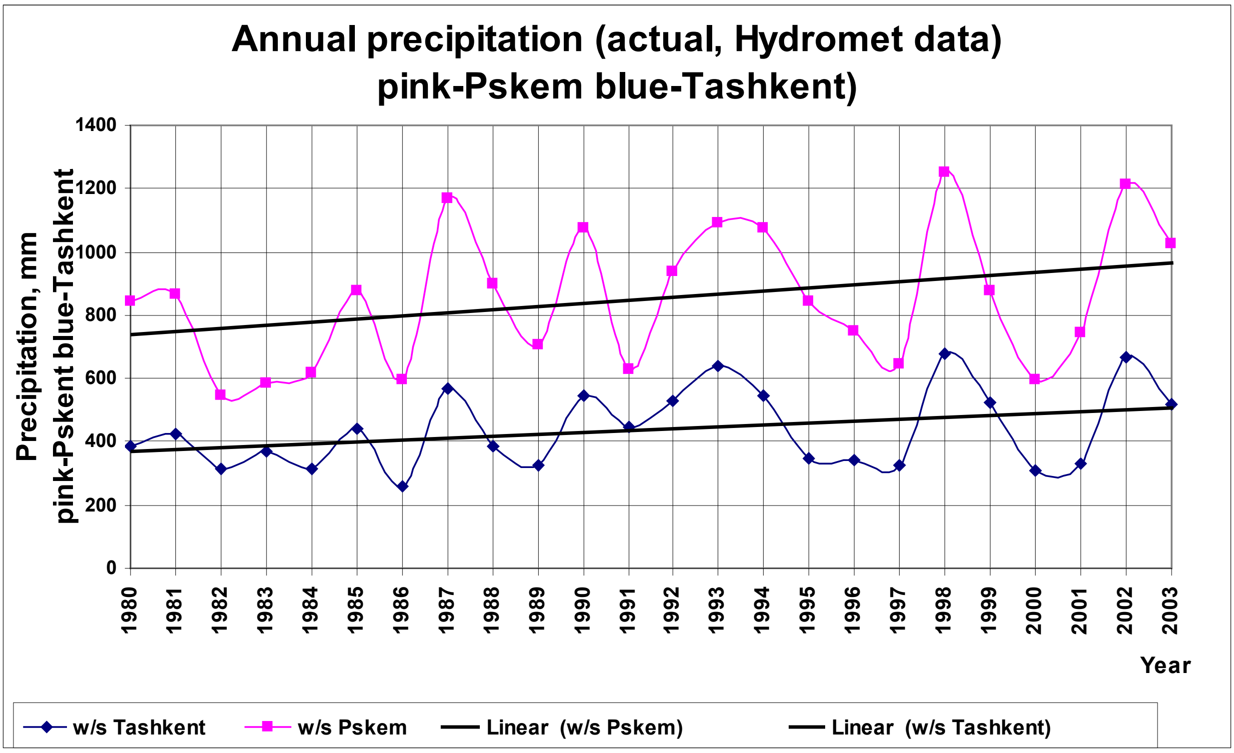


Figure 3.1. Annual precipitation

Table 3.7.

Difference between mean monthly temperatures (weather station Pskem) calculated by Wei and those obtained using data from the model ECHAM, %

Month	2005	2010	2020	2030
1	128,7	962,3	205,3	161,1
2	75,6	6,8	161,7	169,1
3	62,9	79,4	78,8	46,8
4	40,6	22,8	59,5	33,9
5	26,3	35,2	21,5	11,0
6	19,9	22,1	12,8	13,3
7	22,2	18,7	14,6	8,6
8	18,2	17,6	4,6	0,1
9	28,9	16,1	20,1	30,5

10	22,3	14,8	40,5	55,3
11	135,8	53,5	15,1	43,9
12	53,9	67,9	2302,8	143,6
Correlation	0,952	0,956	0,958	0,929

Table 3.8

Changes in annual precipitation over 20 years (2003 – 2022) according to results of calculation in the models ECHAM and HADCM2, %

Month	Dukant	Oigaing	Pskem	Tashkent
ECHAM	8,2	3,4	7,4	9,9
HADCM2	12,2	8,0	11,7	13,0
Wei's variant 1	-1	5,6	9,5	9,6
Wei's variant 2	-3,5	1,4	-5,9	-6,8

Table 3.9

Annual precipitation in different weather stations, mm

	2000		**2001**		**2002**		**2003**	
Weather station	Wei 1	actual	Wei	actual	Wei	actual	Wei	actual
Dukant	757	638	1071	805	690	1144	719	1118
Oigaing	757	518	823	719	688	1057	686	872
Pskem	698	597	872	745	628	1214	888	1026

Figures 3.2 – 3.2k shows trends based on the two options (ECHAM and HADCM2).

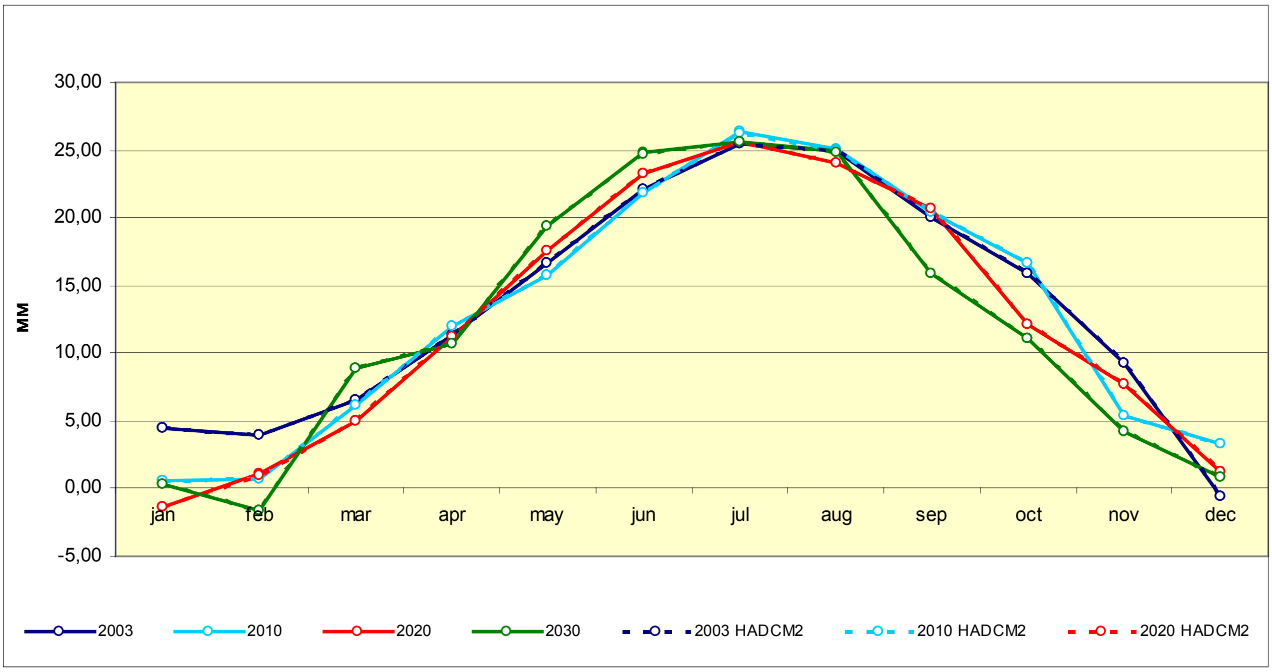


Figure 3.2. Comparison of mean monthly temperatures by two options (ECHAM and HADCM2), w/s Angren

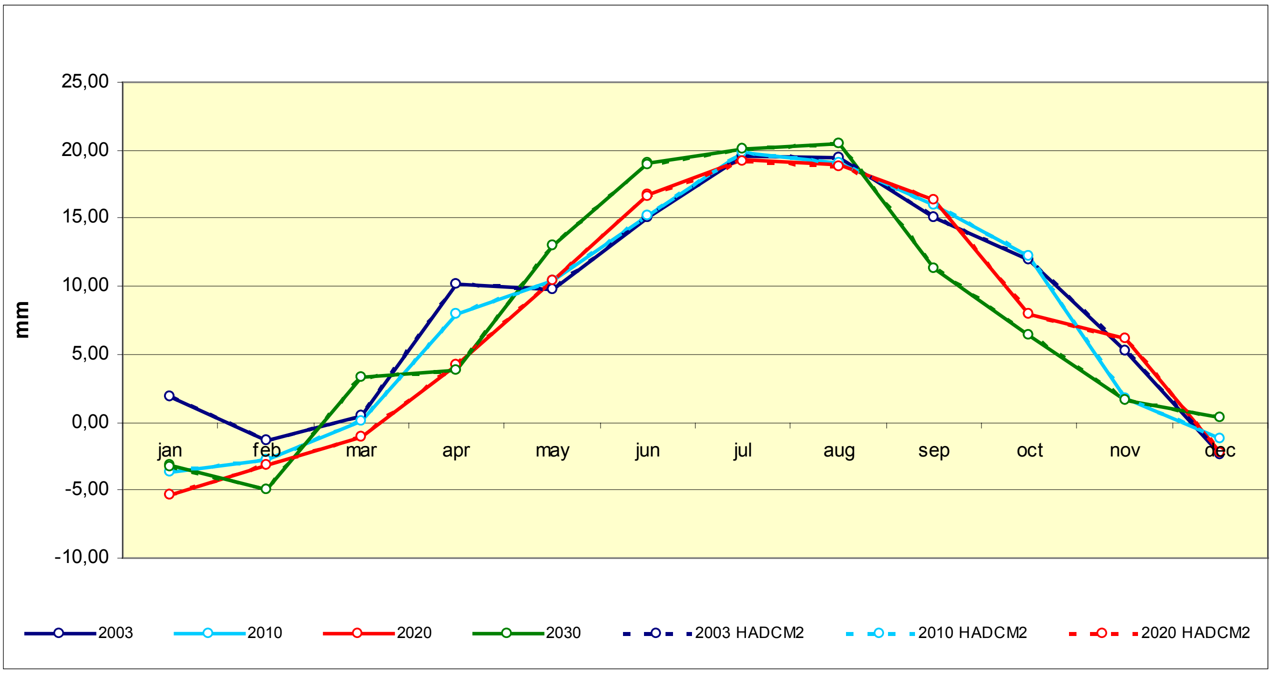


Figure 3.2a. Comparison of mean monthly temperatures by two options (ECHAM and HADCM2), w/s Dukant

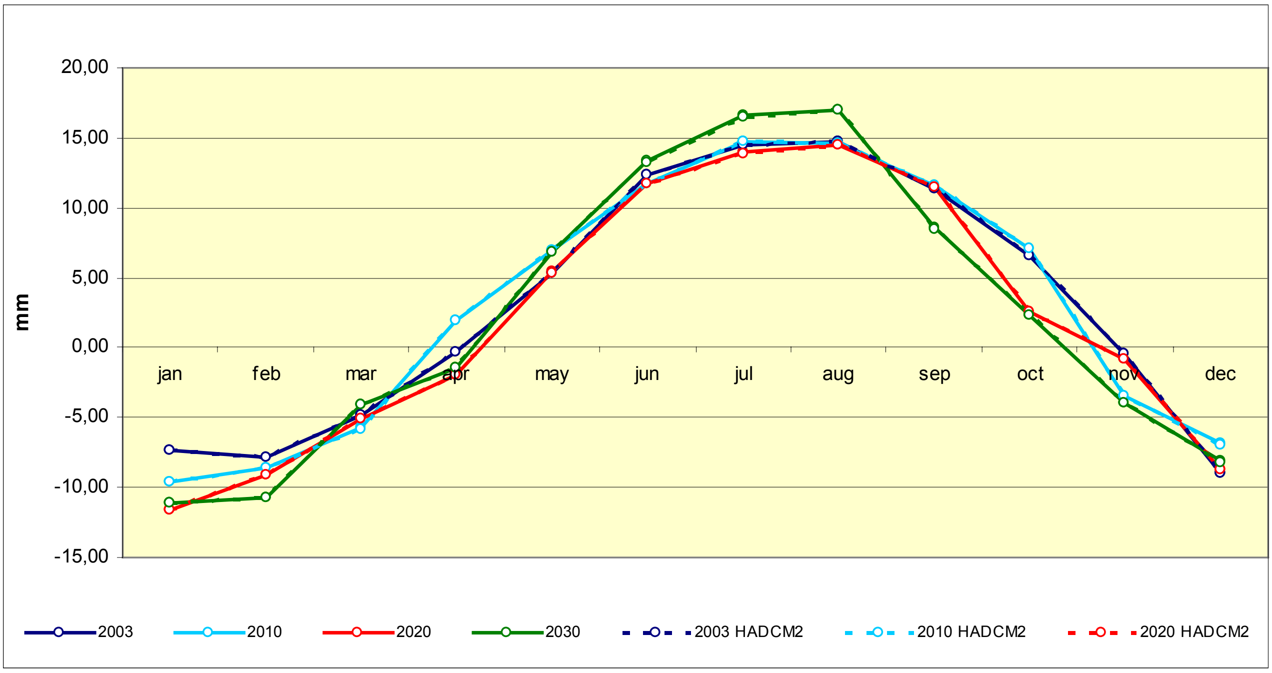


Figure 3.2b. Comparison of mean monthly temperatures by two options (ECHAM and HADCM2), w/s Oigaing

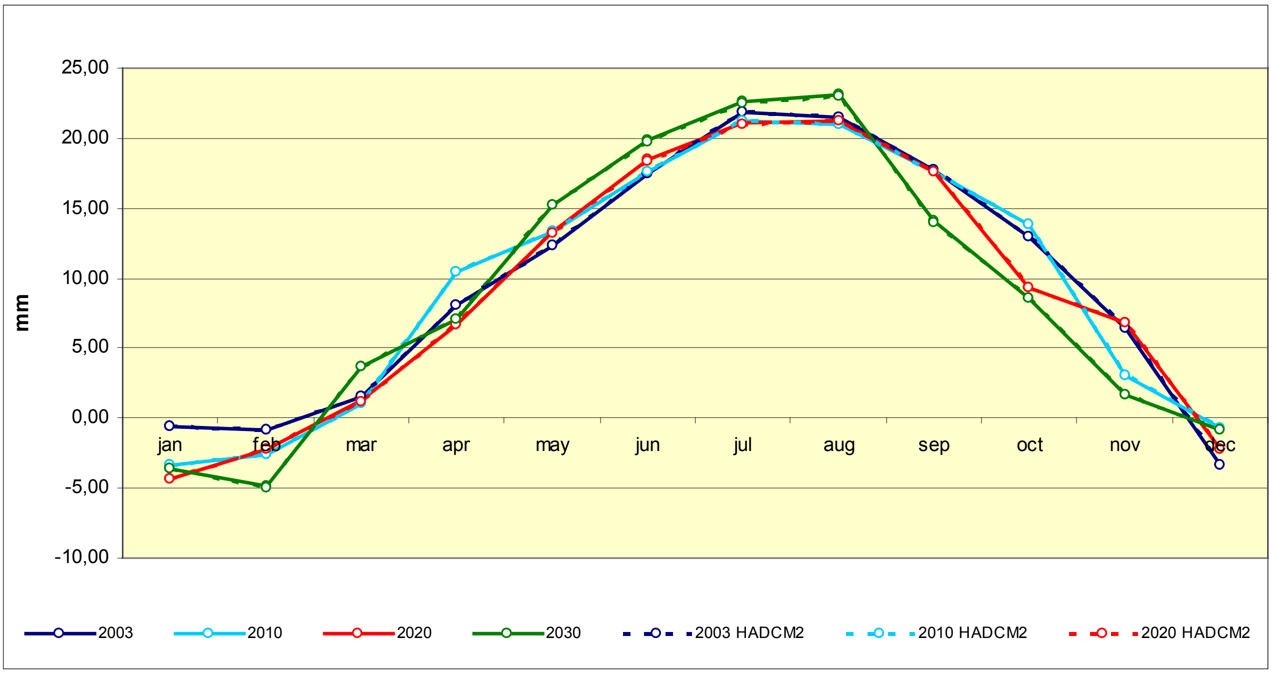


Figure 3.2c. Comparison of mean monthly temperatures by two options (ECHAM and HADCM2), w/s Pskem

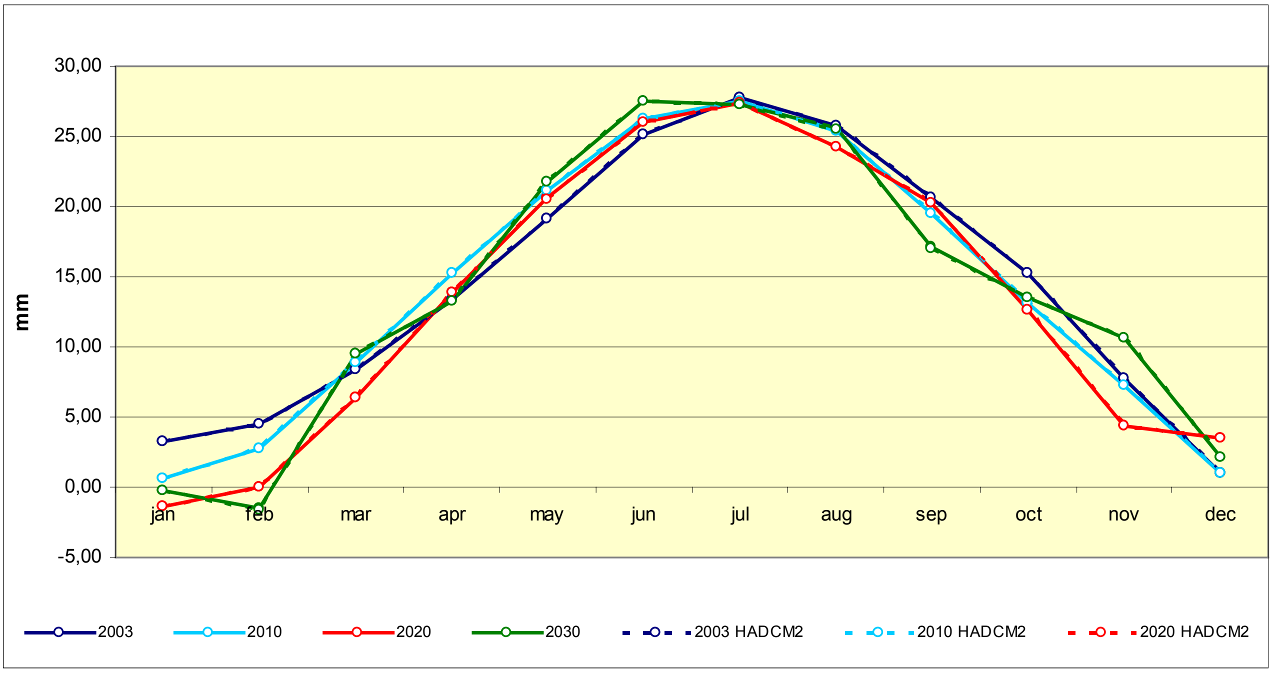


Figure 3.2d. Comparison of mean monthly temperatures by two options (ECHAM and HADCM2), w/s Syrdarya

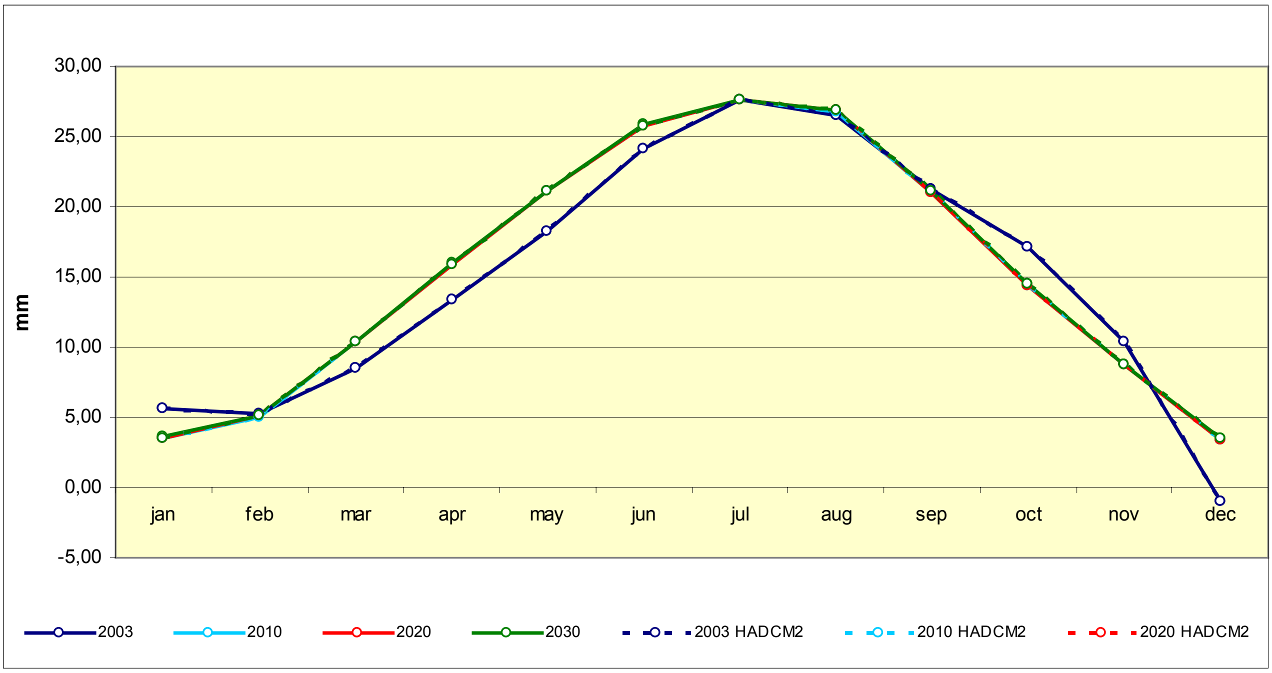


Figure 3.2e. Comparison of mean monthly temperatures by two options (ECHAM and HADCM2), w/s Tashkent

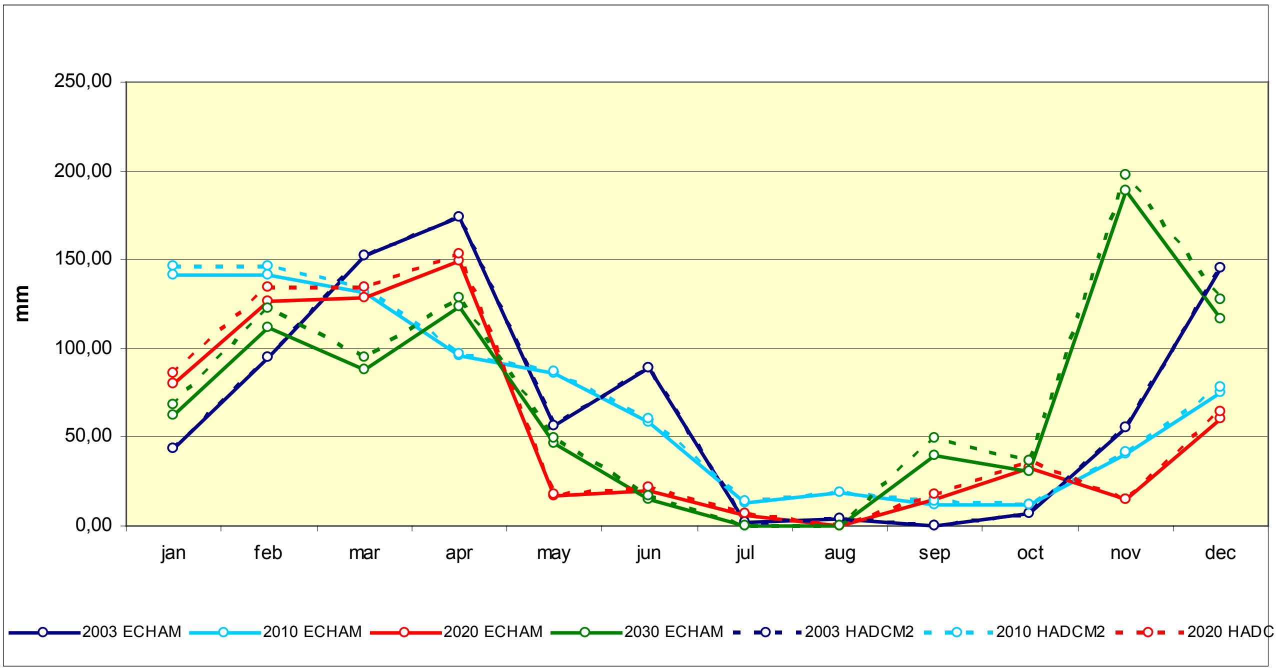


Figure 3.2f. Comparison of mean monthly precipitation by two options(ECHAM and HADCM2), w/s Angren

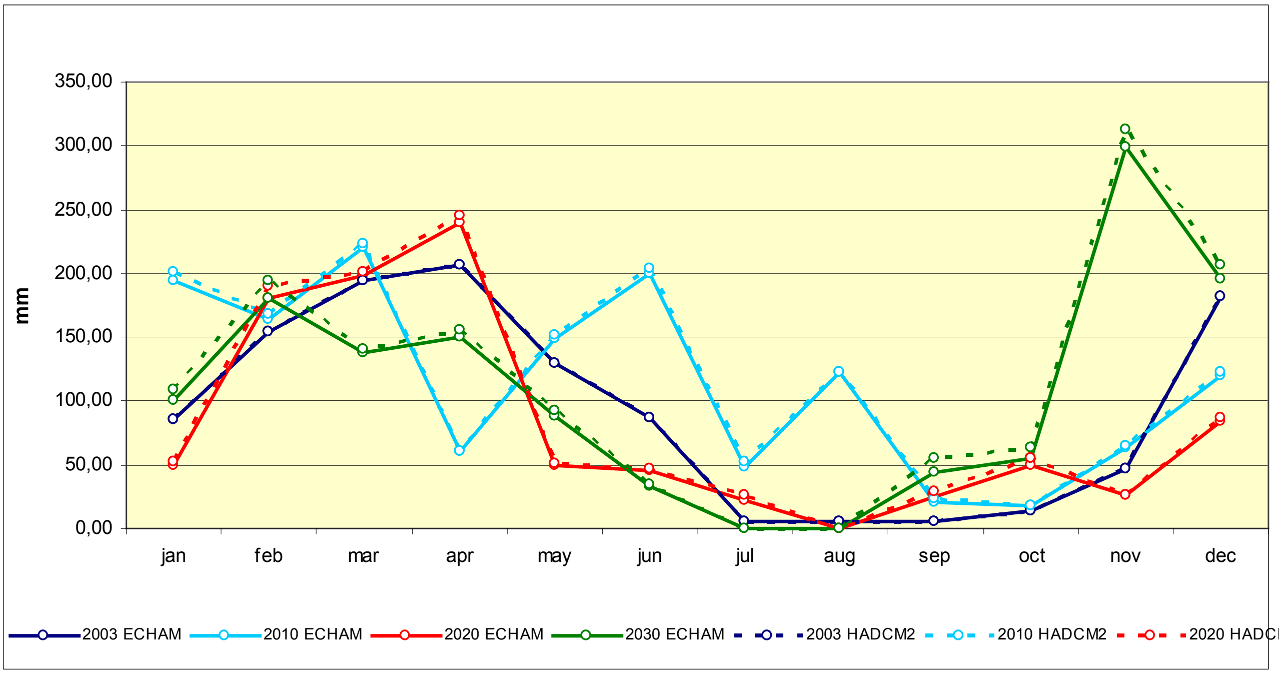


Figure 3.2g. Comparison of mean monthly precipitation by two options (ECHAM and HADCM2), w/s Dukant

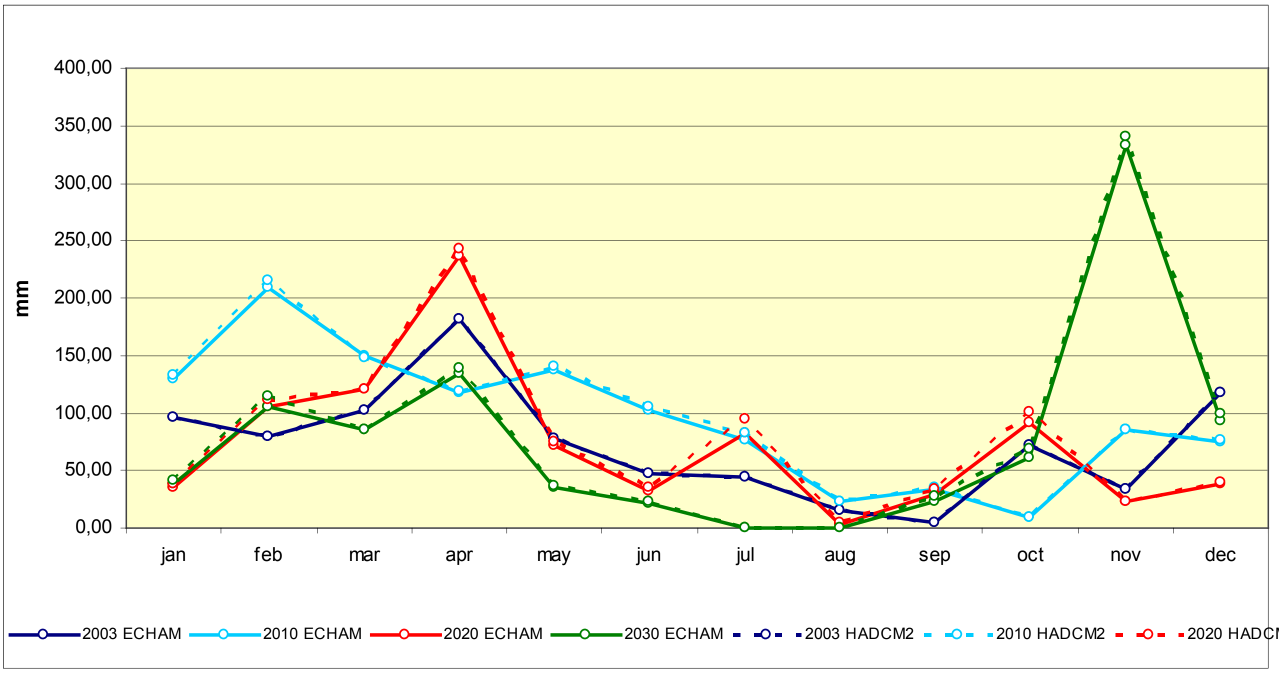


Figure 3.2h. Comparison of mean monthly precipitation by two options (ECHAM and HADCM2), w/s Oigaing

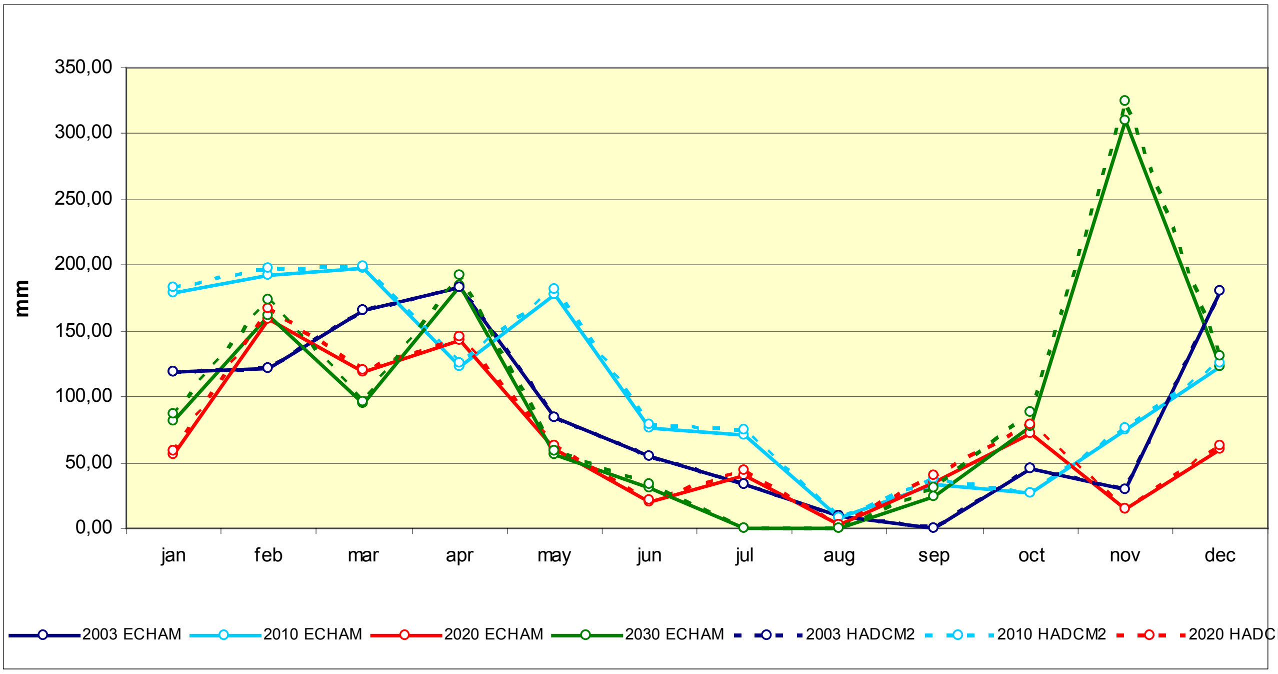


Figure 3.2i. Comparison of mean monthly precipitation by two options (ECHAM and HADCM2), w/s Pskem

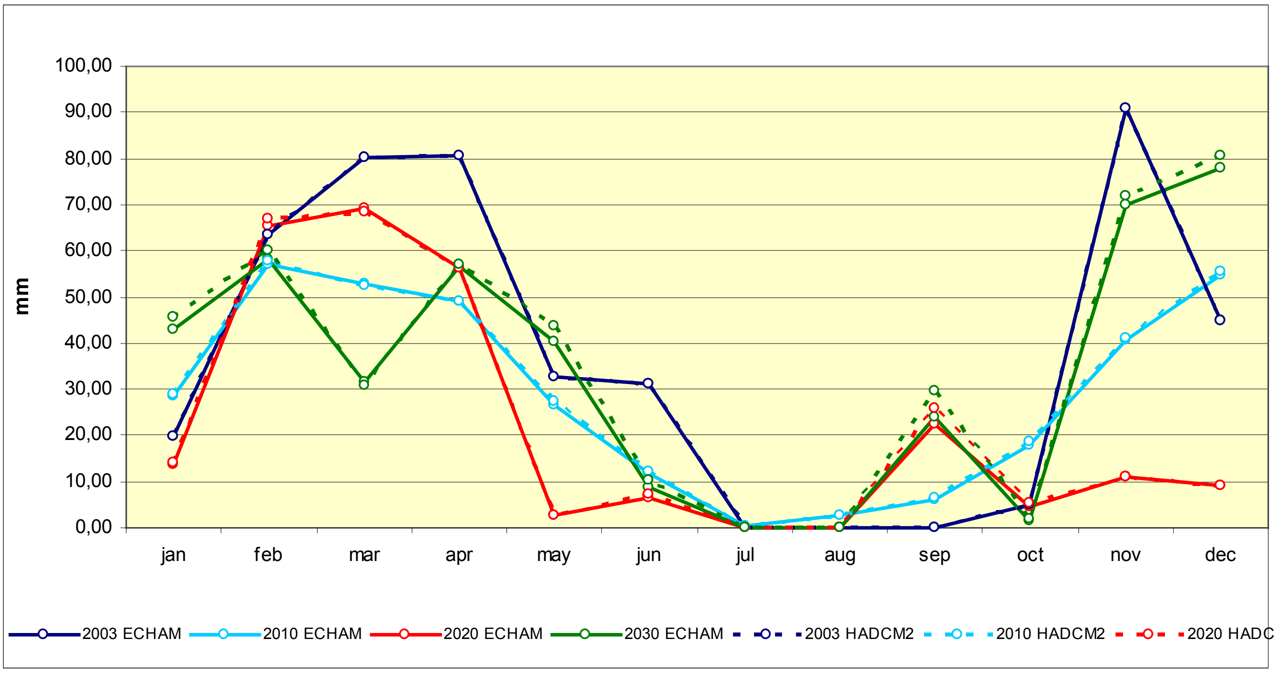


Figure 3.2j. Comparison of mean monthly precipitation by two options (ECHAM and HADCM2), w/s Syrdarya

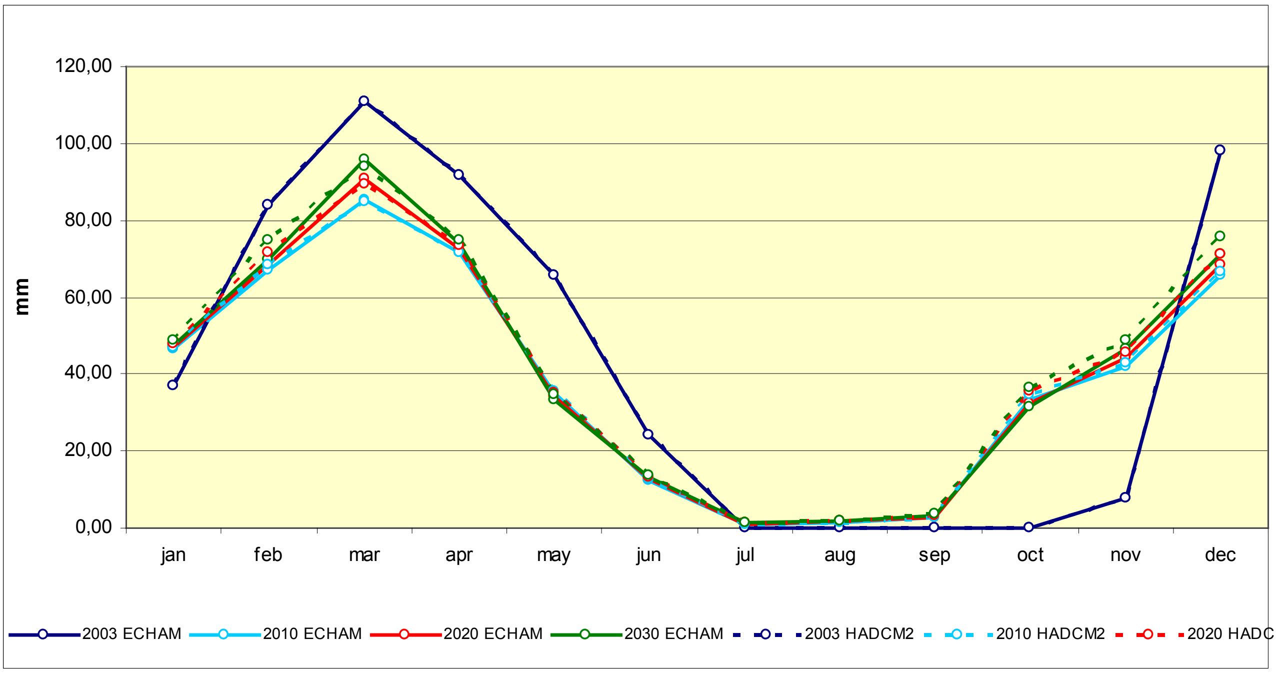


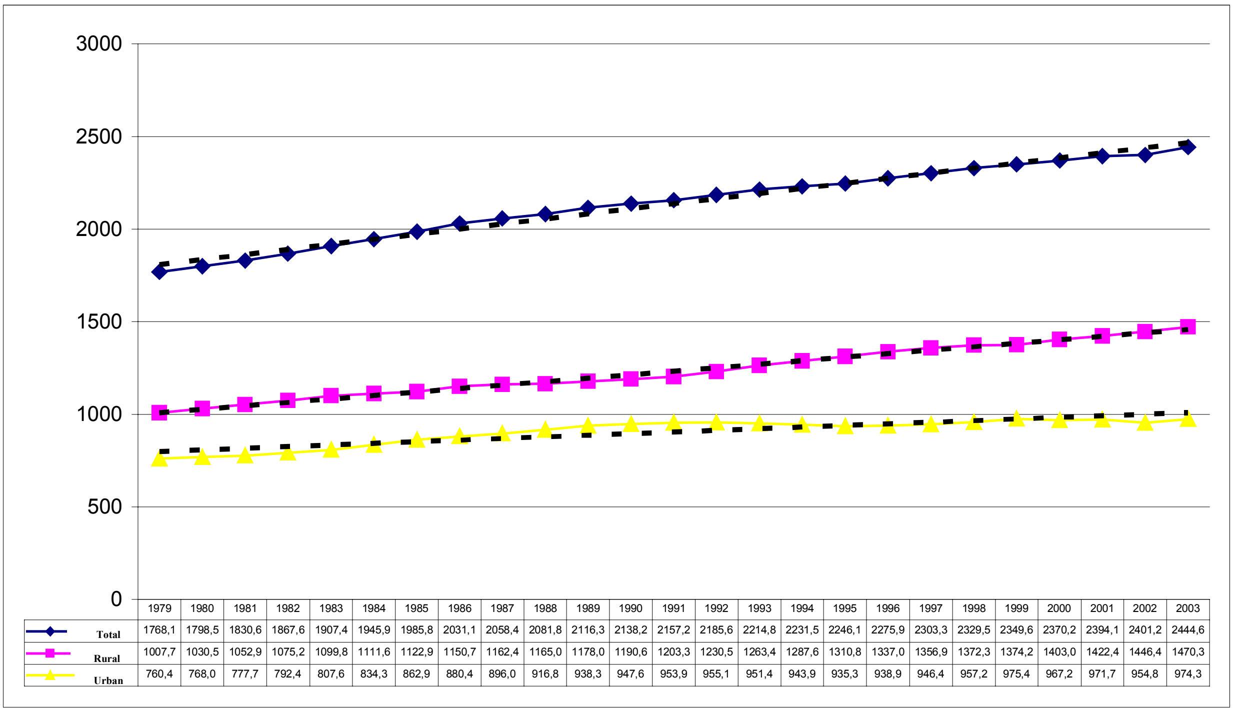
Figure 3.2k. Comparison of mean monthly precipitation by two options (ECHAM and HADCM2), w/s Tashkent

3.2. Socio-economic scenarios

Socio-economic development is characterized by the following main trends and output to the next scenarios.

3.2.1. Demographic indicators

At first glance, population dynamics is estimated by quite smooth trends regarding the total number of population, both urban and rural (Fig. 3.3).



	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
◆ Total	1768,1	1798,5	1830,6	1867,6	1907,4	1945,9	1985,8	2031,1	2058,4	2081,8	2116,3	2138,2
■ Rural	1007,7	1030,5	1052,9	1075,2	1099,8	1111,6	1122,9	1150,7	1162,4	1165,0	1178,0	1190,6
▲ Urban	760,4	768,0	777,7	792,4	807,6	834,3	862,9	880,4	896,0	916,8	938,3	947,6

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
◆ Total	2157,2	2185,6	2214,8	2231,5	2246,1	2275,9	2303,3	2329,5	2349,6	2370,2	2394,1	2401,2	2444,6
■ Rural	1203,3	1230,5	1263,4	1287,6	1310,8	1337,0	1356,9	1372,3	1374,2	1403,0	1422,4	1446,4	1470,3
▲ Urban	953,9	955,1	951,4	943,9	935,3	938,9	946,4	957,2	975,4	967,2	971,7	954,8	974,3

Figure 3.3. Population dynamics (rural and urban) in Tashkent province, except for Tashkent city, thousand people

However, if we consider population growth rates in the province since 1980 to 2005, they are subjected to the jumps and drops, mainly, caused by external factors (Figure 3.4).

By 1986, we observed growth from 1.5 to 2.3 % per year, then the growth rate decreased to 1 % in 1987–1988, the period of Gorbachev's perestroika, and even during USSR collapse, and further during economic decline after gaining of independence to 0.6%, and only recently this indicator gradually increased to 1.5 %. The mean indicators of this trend decrease from 2 to 0.8 % per year. At the same time, rural population trend is much leveled, with decline from 2.2 % to 1.7 % - this is less than the average in the province, with the same declines in typical years but much smoother than in province's cities. Until 1988, population growth rates were kept at 1.5 % in the province's cities; however, since that year and until the peak economic decline in 1991-1996, the period when population extensively left the cities due to lack of job, the growth rate decreased to minus 1.5 % and became positive only in 1997, with following stabilization at 0.8 % by present.

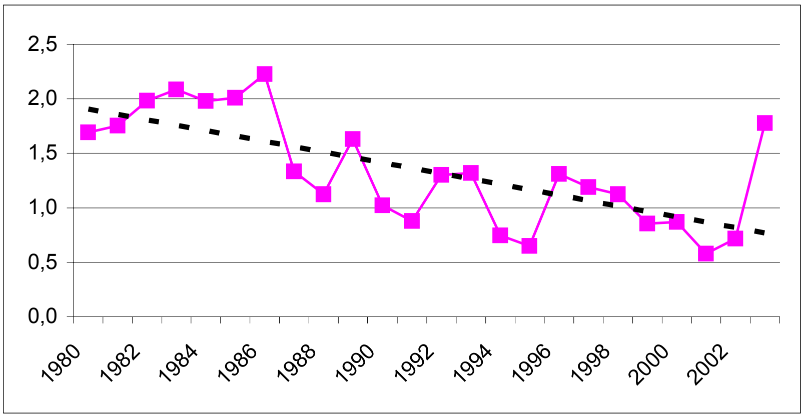


Figure3.4 Population growth rates in Tashkent province, %

Besides migration, the period of gaining independence was characterized by decline of birth rates – from 34.1 – 37.2 per 1000 persons in 1980-1990-s to 18.5 -18 in recent 5 years. This is a result of two factors – depressed confidence of people in social protection and targeting of the government to reduction of population growth rate. Moreover, it should be noted that the death-rate has not changed practically and varied within 6.3 – 7.2 %.

Migration caused by changes in socio-economic conditions plays very important role in population dynamics. Negative migration from the cities reached its peak in 1994-1995, when annual number of leaving people was 27 thousand. Lately, this figure has decreased but still varied within 5 thousand people.

Based on this, two demographic scenarios – "business as usual" and "optimistic" – were constructed. Those scenarios differ mainly in reduced migration and slightly slower rates of population growth.

Those demographic scenarios are shown in the Table 3.10 and demonstrate the following results:

Table 3.10

Indicators of demographic scenarios, thousand people

Indicators	**BAU**				**Optimistic**			
	2005	2010	2020	2030	2005	2010	2020	2030
Province's population, including Tashkent, total	5037,8	5282,9	5845,7	6467,5	5042,8	5126,8	5748,6	6292,7
Population in Tashkent city	2534,4	2625,1	2845,2	3077,7	2539,4	2623,0	2837,4	3061,9
Population in the province:	2503,4	2657,8	3000,5	3389,8	2503,4	2643,4	2911,2	3230,8
Urban	997,5	1056,7	1187,7	1336,8	997,5	1046,0	1149,2	1258,9
Rural	1505,9	1601,1	1812,8	2053,0	1505,9	1597,4	1762,0	1971,9
Migration from village to city	3,72	3,15	4,48	5,07	3,72	1,97	1,44	1,20
Migration of urban population to Tashkent city	0,89	0,94	0,06	1,19	0,89	0,54	0,45	0,39

As shown, the both options have minor differences –all population indicators are within 8 % of absolute value by final period.

It should be noted that though Tashkent city is not included in indicators of Tashkent province, population of the former should be considered in light of meeting food demand of population in provinces and the city.

3.2.2. Provincial employment

This is very important demographic indicator, which determines welfare. Currently, labor resources account for 53.2 % of total urban population (see D-25), of which 20 % is occupied in irrigated agriculture. Taking into account the minor population growth rate at present and the tendency to annual creation of 20 thousand job places in the province (Fig. 3.5), as well as the considerable increase of people involved in agricultural production under restructuring of agriculture, the problem of employment in rural area will be avoided if the downward tendency of employment in industry stops.

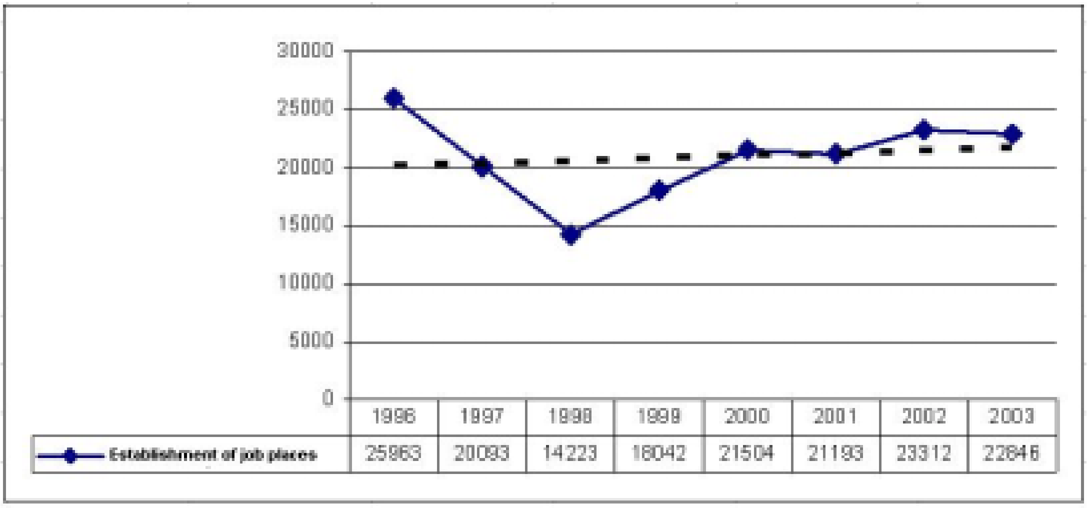


Figure 3.5 Dynamics of job places in agriculture in Tashkent province, number

3.2.3. Growth of gross output and GDP

This indicator is the most difficult to estimate due to the changes in local currency-US dollar exchange rates and the inflation. Though the total production volume and GDP in the republic and in Tashkent province have declined sharply as compared to 1990, the mean GDP growth rates were 103.6 % since 1995. In recent years, the absolute indexes in local currency are notable for continuous growth, which is reflected in the graph below (Fig. 3.6)

Conversion to hard currency made by accounting variable exchange rates and inflations indicates to rather different situation. Figure 3.7 contains three curves of industrial production throughout the province in established prices, comparable prices, and 2002-adjusted prices. The curves show that actually we observe setback in production in prices adjusted to base year. From these positions, it is quite difficult and uncertain to build trend for the scenario "BAU". In this context, we take scenario of gross output in industry and other sectors according to official statistical and directive growth indicators.

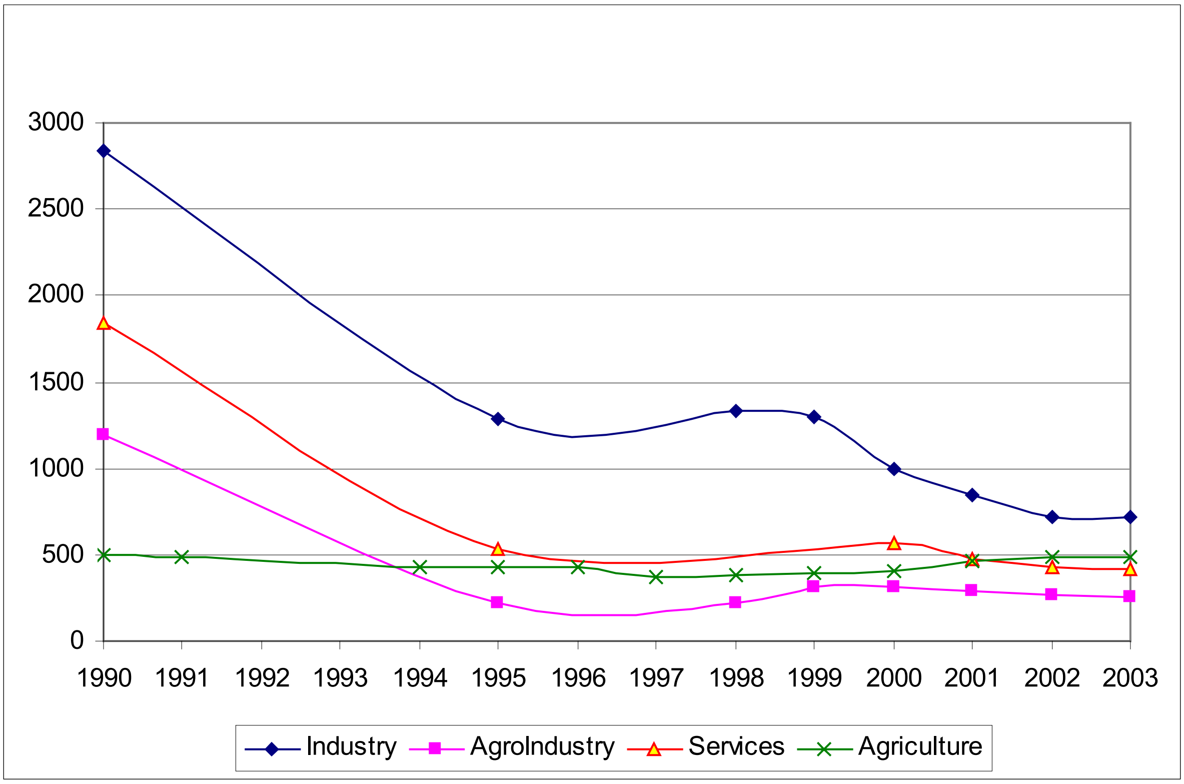


Figure 3.6. Dynamics of production volume in economic sectors (million$/year)

	2002	2003	2004	2005
Established prices	804,3	905,8	1232,8	1407,0
Comparable prices	851,6	839,8	1072,2	1289,3
2001-adjusted prices	851,6	688,6	811,8	696,2

Figure 3.7. Industrial production growth rates for last 4 years, as estimated in different prices

3.2.4. Food supply

As shown in the report D-25, currently in the province, including Tashkent city, population receives on average 2230 … 2250 kcal/person/day through domestic production in irrigated lands and livestock breeding. There is full provision with bred and bakery, milk and dairy products, vegetables and fruits, potato, grapes, 90 % of vegetable oil, and eggs. Shortage is observed regarding meat and meat products, sugar and fish.

As to foodstuffs production dynamics since 1990 to 2003, because of transition to market relations, agricultural production shifted to meeting largely demand of population: grain production per capita increased twofold; potato production increased more than twice; and, production of vegetables became more diverse. Moreover, some change in diet should be noted: more consumption of bread and potato, vegetables, fruits and grapes; less consumption of milk and eggs. It is clear that the economic transformation has led to healthier but, at the same time, cheaper diets. This is also efficient in terms of water use. Upon calculation results in final form, provision with foodstuff will be demonstrated for different scenarios by 2030. However, one may already note that "business as usual" can hypothetically lead to some worsening due to lower land productivity; while in optimistic scenario even meat demand would be satisfied.

3.2.5. Access to piped water-supply and sanitation

According to data from the report D-25, coverage in Tashkent province with piped water-supply is 91.3 %; as to access to sewerage and treatment system, it is provided only for 87 % urban and 15 % rural population. Water supply to settlements amounts to 155 l/day/person in rural area and 290 l/day/person in urban area, including direct supply to population: 89.5 l/day/person and 286 l/day/person, respectively.

In the "business as usual" scenario and even more so in the optimistic scenario the status quo regarding water supply will be improved since following the "Master-plan of water supply in Uzbekistan for 2010…2015", the scope of centralized water supply in the province will increase 14 % by 2010 and 18.5 % by 2015.

Sanitation conditions in urban area have similar tendency, however it is less definite in rural area since centralized capital investments are not available yet in this domain.

3.3. Agricultural scenario

As shown in the reports D-25 and D-27, agriculture is a determinant factor in socio-economic development, for progress of agro-based industries, services and for general welfare in the sub-basin. Scenarios could be shaped only on the basis of quantitative and analytical materials on basin's Uzbek part, which uses more than 90 % of water resources in the basin. Because of privatization of agriculture in Kazakhstan, practically all statistics in South Kazakhstan province, as well as in this republic as a whole are not available.

The developed scenarios show a picture of probable agricultural development in Tashkent province for the mid time span (2003 – 2030) and are comprised of two extreme variants:

- "business as usual" scenario, which rests on recent trends and actual situation in agriculture;
- "optimistic" scenario, which is maximally desirable and partially or hardly feasible, built on higher level of interventions and support from the government, on full (or close to full) use of resource potential, which is necessary for agricultural development.

These scenarios are quantitative and produce numerical estimations of major indicators of probable agricultural development. The scenarios are developed on the basis of existing trends, certain assumptions, key relationships, and driving forces and represent specific numerical indicators, in calculation of which we followed the principles of coherence, internal consistency and credibility of obtained results.

In-between the presented extreme variants, other "prospective" variants may be drawn up and calculated on the basis of formed tendencies, degrees of resource use, different levels of capital investments, etc.

3.3.1. Assumptions used

“Business as usual” scenario

The following assumptions were made in scenario “business as usual”:

- amount of capital investments in irrigated agriculture is kept without changes;
- increase of private sector share in agricultural production and transition to free market economy are gradual;
- irrigated agriculture shows no especial changes in:
  - institutional aspects of water and land management;
  - actual regime of water delivery and crop irrigation;
  - costs spent for rehabilitation and maintenance of inter- and on-farm irrigation and drainage network;
  - costs spent for purchase, maintenance and repair of machines and equipment;
  - access to funds and credits to buy fertilizers, pesticides, new equipment, etc.;
  - services for agricultural producers;
  - purchasing prices of farm produce and the trade policy.

“Optimistic” scenario:

Assumptions made in developing given scenario are as follows:

- amount of capital investments in irrigated agriculture is increased considerably;
- abrupt extension of private agricultural sector, and agricultural development permits using the cost-effective specialization and free choice of cultivated crops;
- irrigated agriculture undergoes positive changes in the following:
  - institutional aspects of water and land management;
  - actual regime of water delivery and crop irrigation;
  - increase of costs spent for irrigation and drainage network rehabilitation and maintenance;
  - optimization of costs spent for purchase, maintenance and repair of machines and equipment;
  - private producer has free access to funds and credits;
  - improvement of services for agricultural producers, removal of restrictions regarding capital expansion and procurement of seeds, fertilizers, insecticides and pesticides, etc.;
  - increase of purchasing prices of agricultural products, and the public trade policy promotes free market and competitiveness.

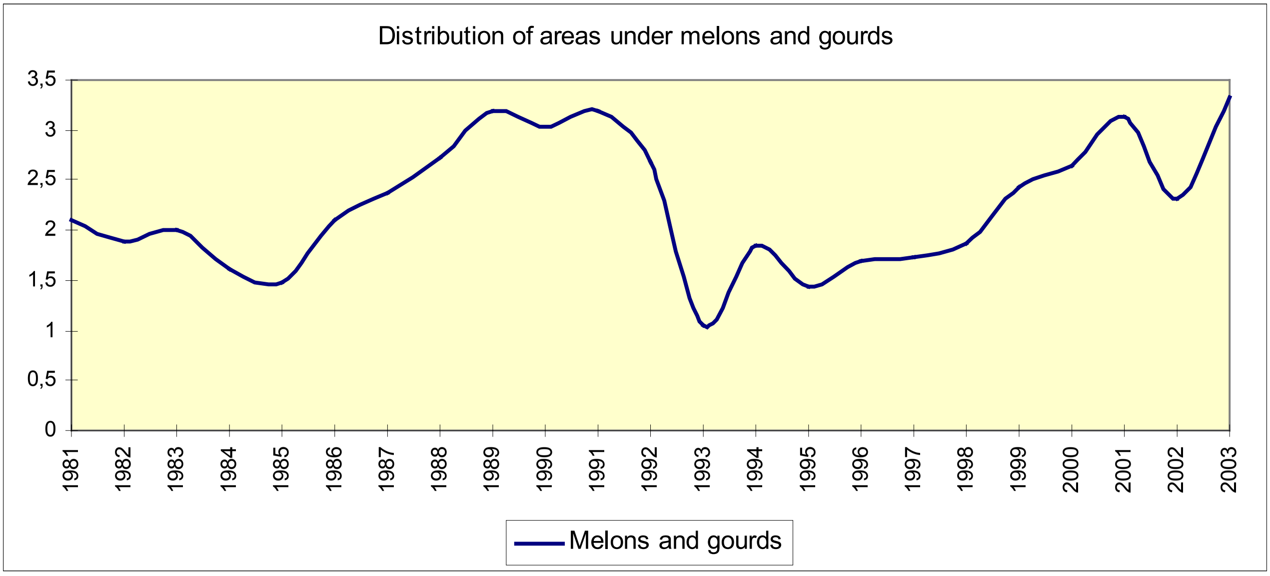
Major difference is that irrigated lands in this scenario should achieve their potential productivity, as described in D-27, section 5.

3.3.2. Change of basic indicators of agricultural production in “business as usual” scenario

a) Cropped land

Farm production in arid zone rests on irrigated lands. Virtually, in recent years of national independence, irrigated area was expanded by 0.27 % per year. This largely differs from the preceding period of 1980 … 1990, when increase in irrigated area was about 2 % per year.

During the same period of time, cropping patterns have greatly changed: reduced areas under cotton and forage crops; extended areas under cereals, vegetables, cucurbits, and corn (Figure 3.9).


Distribution of areas under melons and gourds
3,5
3
2,5
2
1,5
1
0,5
0
1981
1982
1983
1984
1985
1986
1987
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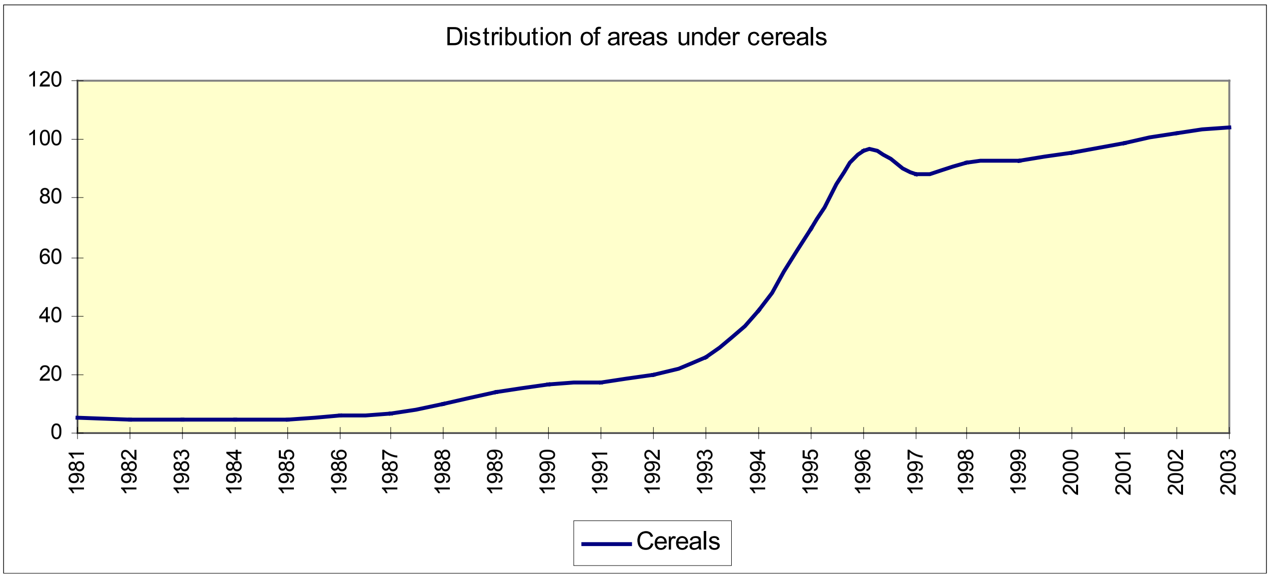
Melons and gourds


Distribution of areas under cereals
120
100
80
60
40
20
0
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
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1992
1993
1994
1995
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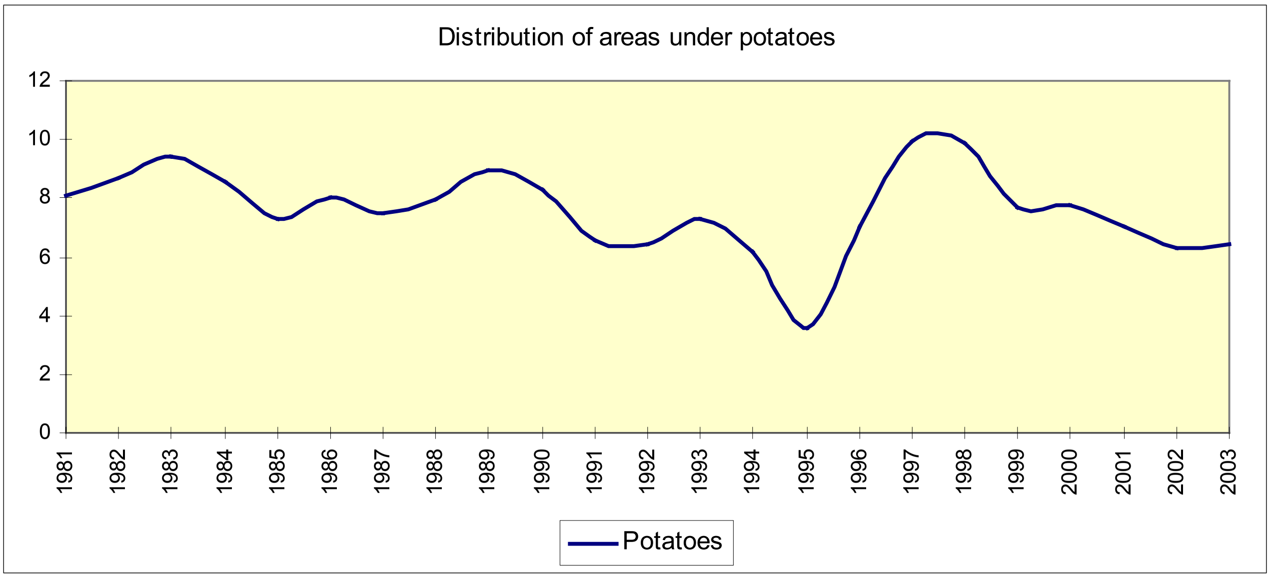
2002
2003
Cereals


Distribution of areas under potatoes
12
10
8
6
4
2
0
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
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1992
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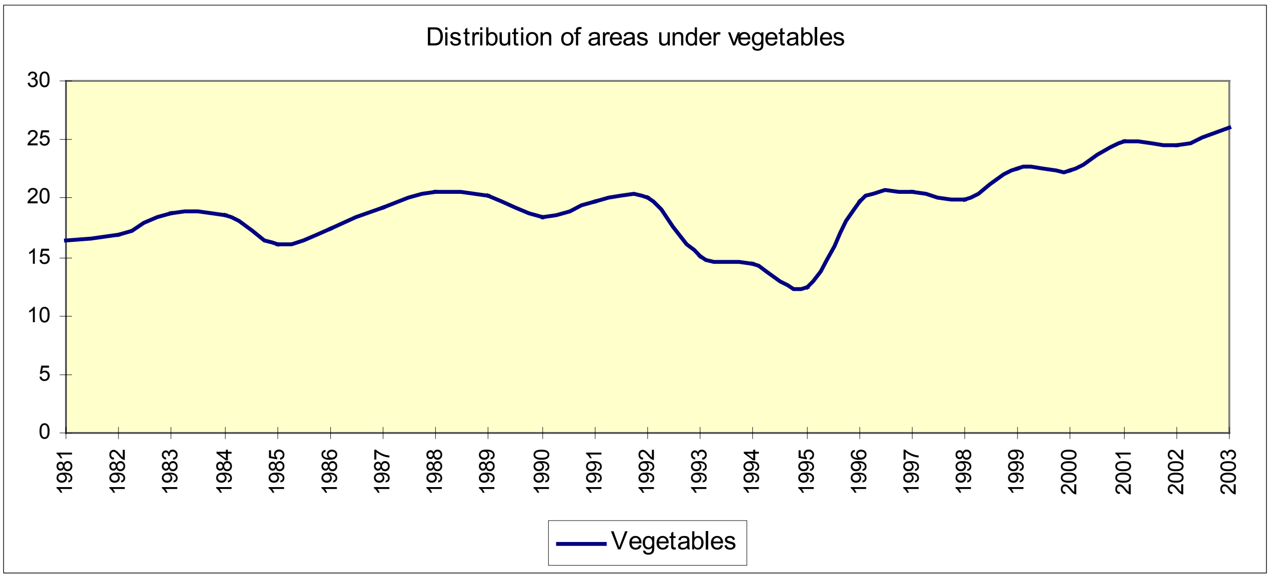
2003
Potatoes



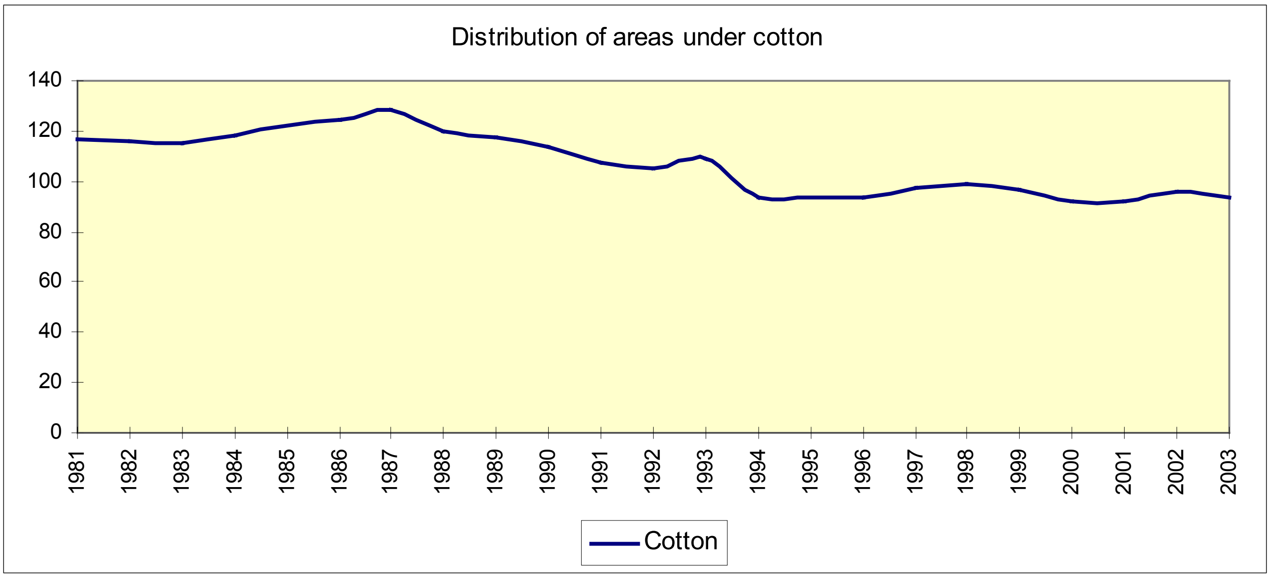


Figure 3.8 Changes in distribution of cropped areas

Indicators considered in the scenario regarding expansion of areas under different crops were calculated using data for 2000 – 2003.

Table 3.10

Cropping patterns by trends (thousand ha)

Year	Cereals	Corn	Rice	Industrial crops	Potato	Vegetables	Cucurbits	Forage crops, total	Fruits grapes	Total
2003	103.8	7.6	8.2	98.4	6.4	26.1	3.3	32.5	24.6	310.9
2010	124.2	6.6	5.9	91.3	4.6	33.4	6.7	24.0	21.1	318.3
2020	149.3	5.0	3.4	76.6	2.7	44.2	17.1	14.4	15.7	329.1
2030	163.0	3.4	1.8	58.7	1.5	53.2	39.8	7.9	10.7	340.3
									Increase	29.4

Most results on distribution of areas under specific crops as calculated from present trends cannot be considered as reasonable and credible. Moreover, the results on a number of crops will never be put into practice. For instance, the following is doubtful: expansion of cereals area up to 47.9 % of total cropped area (first of all, because of low profitability of these crops); 5 times reduction of areas under rice and potato (high-demand crops), as well as under forage crops that are the main nutritive base for animals. 10-times expansion of areas under cucurbits and more than two-fold reduction of orchards and vineyards are also unrealistic.

Industrial crop and vegetable areas derived from trends should be found realistic (long since, the province has been trying to lessen cotton specialization and become a vitamin production base for the capital through vegetable growing). Proceeding from the above-mentioned, we slightly corrected the "business as usual" scenario in terms of areas by incorporating current changes in cropping patterns, internal relationships and specific assumptions in order to keep agricultural logic and practicability of the calculated indicators.

In the corrected cropping patterns, first of all, we maintained existing tendencies by changing slightly indicators on some crops to more realistic and plausible side. Thus, regarding industrial crops than mainly include cotton (96 %), we increased areas by 6 % by 2030, taking into account that cotton is a major strategic crop, which is in high demand at the foreign market and is provided with appropriate production base, processing, and infrastructure. Areas under forage crops were increased by 4.6 %. Being the source of food for livestock, these crops form a basis for crop rotation and soil fertility improvement. Cucurbits area was reduced by 8 % as compared to trend indicators since large-scale produce will not be much in demand and become unprofitable. It is unlikely that areas of orchards and vineyards will decrease, as well as areas under potato (more than 5-times reduction). This allows us to slightly increase these figures against the indicators derived from trends.

Table 3.11

Corrected scenario's cropping patterns on irrigated lands (excluding homestead plots), based on trends and existing tendencies (thousand ha)

Year	Cereals	Corn	Rice	Industr. crops	Potato	Vegeta bles	Cucur bits	Forage, total	Fruits, grapes	Total
2003	103,84	7,59	8,17	98,44	6,43	26,07	3,32	32,49	24,63	310,9
2010	115,54	6,68	7,32	91,67	6,37	33,42	6,37	27,37	23,55	318,3
2020	128,02	5,92	6,58	83,92	5,59	44,10	9,54	24,68	20,73	329,1
2030	136,46	5,10	6,47	79,29	5,10	53,09	12,59	23,48	18,72	340,3

Irrigated area is also comprised of 42,0 thousand ha of homestead plots that are to be extended somewhat through growth of rural population and construction of new houses during 2003 – 2030. It is supposed that ratio of cultivated crops will change a little during the period covered by the scenario.

Table 3.12

Scenario's cropping patterns on homestead plots (thousand ha)

Years	Corn	Vegetables	Potato	Orchards	Vineyards	Total
2003	1,4	6,1	8,0	13,7	12,8	42,0
2010	1,5	6,3	8,2	13,8	12,9	42,7
2020	1,6	6,6	8,4	13,9	13,0	43,5
2030	1,7	6,7	8,7	14,0	13,1	44,2

b) Crop yields

The actual trends are mainly positive on most crops, except for cotton and fruits. Tables 3.13 and 3.14 show indicators derived from those trends for the future.

Table 3.13

Scenario's crop yields on irrigated lands (excluding homestead plots), estimated from trends and corrected on the basis of main tendencies and plausibility (t/ha)

Year	Grain crops			Industrial crops		Vegetables	Potato	Cucurbits
	Cereals	Maize for grain	Rice	Cotton	Kenaf			
2003	4.16	3.84	3.96	2.00	7.37	22.48	21.10	16.8
2010	4.10	3.90	3.80	2.00	7.09	21.40	21.20	17.2
2020	4.10	3.87	3.70	2.10	6.72	20.00	21.50	17.0
2030	4.10	3.72	3.60	2.10	6.48	19.00	21.80	16.6

Table 3.13 (continued)

Year	Forage crops					Fruits	Vineyards
	Maize for silage	Perennial grass of 1st year (hay)	Perennial grass of 2nd -3rd year (hay)	Annual grass (hay)	Root		
2003	26.72	5.47	10.44	8.50	30.64	3.21	2.38
2010	26.30	5.21	9.70	8.10	31.56	3.00	2.30
2020	26.00	5.03	9.16	7.75	30.45	2.69	2.24
2030	25.00	4.90	8.70	7.52	30.00	2.50	2.09

While correcting crop yield indicators in the "business as usual" scenario, we considered plausible situation which would develop by 2020, then yields of many crops would slightly decrease as a result of:

- deterioration of reclamation state of lands;
- decrease in level of soil fertility;
- probable reduction of inputs into agricultural production;
- deterioration of irrigation network, that would have negative effect on regimes of water delivery and crop irrigation;
- reduction of level of mechanical field operations.

In scenario calculations we used a ratio between minimum costs and crop yields, based on available examples from other projects and literature. It is assumed that by 2020 and further on, yields of strategic crops (cotton, cereals, rice) and of potato, which is one of main foodstuffs, would not decrease considerably.

Table 3.14

Crop yields on homestead plots (t/ha)

Year	Maize for grain	Vegetables	Potato	Fruits	Grapes
2003	4.6	30.3	29.9	5.7	4.9
2010	4.5	30.0	29.6	5.6	4.8
2020	4.4	30.0	29.3	5.5	4.7
2030	4.4	30.0	29.0	5.5	4.7

Yields of crops grown in homestead plots are somewhat higher as compared to indicators derived for farm land. This is explained by better and timely treatment of crops and higher norms of organic fertilizers applied in homestead plots. It is supposed that during the period covered by the scenario, yields of crops (except for vegetables) would slightly decrease due to year-round use of lands and deterioration, to a certain extent, of their fertility.

c) Livestock-breeding

Table 3.15

Main indicators of livestock-breeding development in Tashkent province, 1985 – 2003

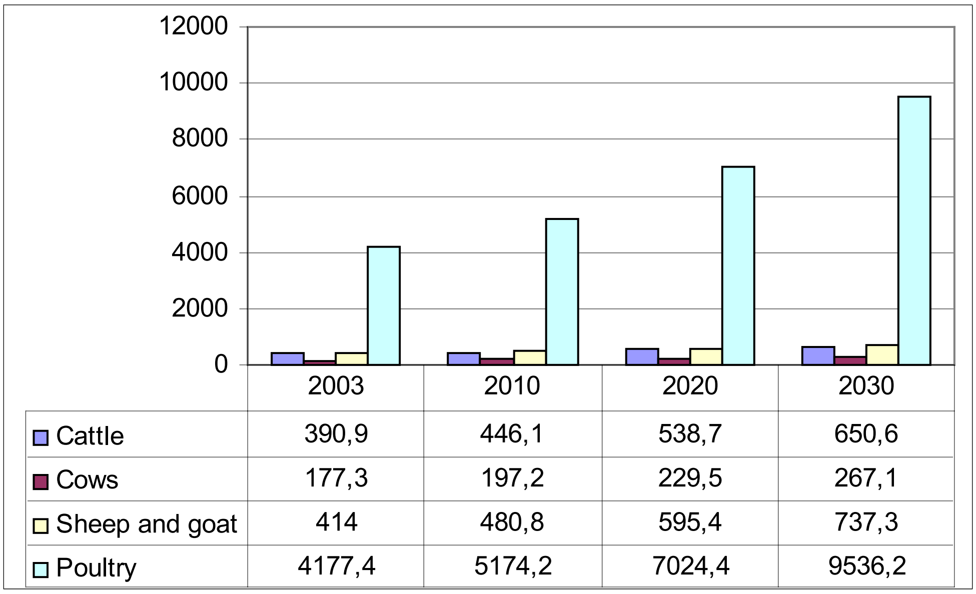
Production indicators	**1985**	**1990**	**1995**	**2000**	**2003**
Meat (live weight), thousand t	90,2	97,5	109,1	96,1	103,8
Milk, thousand t	321,0	377,1	364,7	321,7	358,9
Eggs, million	590,2	645,1	379,2	309	419,0
Mean yield of milk per cow, kg/year	2720,0	3032,0	1956,0	1950,0	2010,0
Egg-laying qualities of hens, eggs/year	169,0	203,0	145,0	158,0	176,0
Cattle, thousand heads	348,2	375,4	362,2	358,1	390,9
incl. cows, thousand heads	135,1	157,4	167,7	165,6	177,2
Pigs, thousand heads	261,8	218,2	109,7	20,5	17,8
Sheep and goats, thousand heads	565,6	582,5	421,8	370,7	413,9
Poultry, thousand heads	7185,3	6185,1	3193,0	3175,9	4177,4

The main causes of decrease in livestock and poultry populations are the reorganization of large stock-farms, the low effectiveness of management after privatization, the lack of feeding stuffs and their poor quality. By 2003, there have been tendency to recruitment of livestock population, except for pigs that were not privatized by local people for religious reasons (in this context, pork production declined more than ten times).

Analysis shows that the slow development rates in livestock-breeding results from tense balance of irrigated lands and the difficulties with allocation of forage crop areas; this mainly relates to relatively low effectiveness and profitability of livestock-breeding sector. Besides, this sector requires relatively huge capital investments and its capital intensity is 2.0 – 2.5 times higher than that in crop production.

Table 3.16

Total livestock population by trends in the “business as usual” scenario (thousand heads)



	2003	2010	2020	2030
■ Cattle	390,9	446,1	538,7	650,6
■ Cows	177,3	197,2	229,5	267,1
■ Sheep and goat	414	480,8	595,4	737,3
■ Poultry	4177,4	5174,2	7024,4	9536,2

3.3.3 Change of basic indicators of agricultural production in optimistic scenario

a) Cropped land

The optimistic scenario assumes more possibilities of feasible extending irrigated area to 32 thousand ha out of available 40 thousand ha reserve. It is supposed that during the period covered by this scenario, homestead plot areas will extend a little through increased rates of rural population growth, with following establishment of new homestead.

Table 3.17

Optimistic scenario’s cropping patterns on irrigated land, excluding homestead plots (thousand ha)

Year	**Cereals**	**Maize for grain**	**Rice**	**Industr crops**	**Potato**	**Vegeta bles**	**Cucur bits**	**Forage crops**	**Fruits, grapes**	**Total**
2003	103,84	7,59	8,17	98,14	6,43	26,07	3,32	32,49	24,60	310,9
2010	97,00	19,78	8,46	86,47	10,53	32,23	3,83	35,27	25,53	319,1
2020	92,35	23,17	9,27	74,14	16,88	42,70	4,30	40,05	28,13	331,0
2030	87,78	26,40	10,29	61,72	22,97	52,81	5,14	45,26	30,52	342,9

Table 3.18

Irrigated areas of homestead plots in optimistic scenario (thousand ha)

Year	**Maize for grain**	**Vegetables**	**Potato**	**Fruits**	**Vineyards**	**Total**	**Increase of irrigated area by 2003**
2003	1,4	6,1	8,0	13,7	12,8	42,0	0,0
2010	1,5	6,3	8,2	13,8	12,9	42,7	0,7
2020	1,6	6,5	8,5	13,9	13,0	43,5	1,5
2030	1,7	6,7	8,7	14,0	13,1	44,2	2,2

b) Crop yields

The suggested crop yields for the scenario period (2003 – 2030) were derived from the prediction estimate of the state of lands, the actual maximum yields in Tashkent province, the assessment of the effect of farm restructuring and transition to market relations. Here we also considered the potential productivities of several crops in given region and probable investments in agriculture.

Table 3.19

Crop yields on irrigated land (excluding homestead plots) in optimistic scenario (t/ha)

Year	**Grain crops**			**Industrial crops**		**Potato**	**Vegetables**
	Cereals	**Maize for grain**	**Rice**	**Cotton**	**Kenaf**		
2003	4,16	3,84	3,96	2,00	7,37	21,30	22,48
2010	4,80	4,90	4,40	2,90	8,50	26,10	24,00
2020	5,65	5,80	4,95	3,80	9,40	31,40	26,70
2030	6,50	6,80	5,50	4,20	10,50	33,00	30,00

Table 3.20

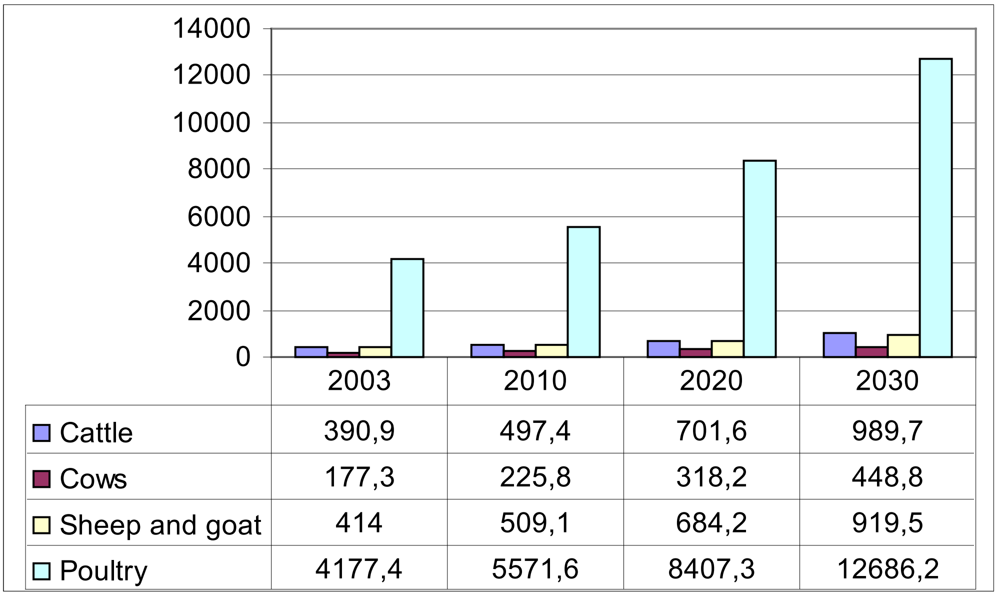
Crops yields on irrigated homestead plots (t/ha)

Year	**Maize for grain**	**Vegetables**	**Potato**	**Fruits**	**Grapes**
2003	4,6	30,3	29,9	5,7	4,9
2010	4,9	31,0	31,5	6,9	5,8
2020	5,8	33,0	33,0	9,5	7,2
2030	6,8	35,0	35,0	11,0	9,0

c) Livestock-breeding

Table 3.21

Total livestock population according to the optimistic scenario (thousand heads)

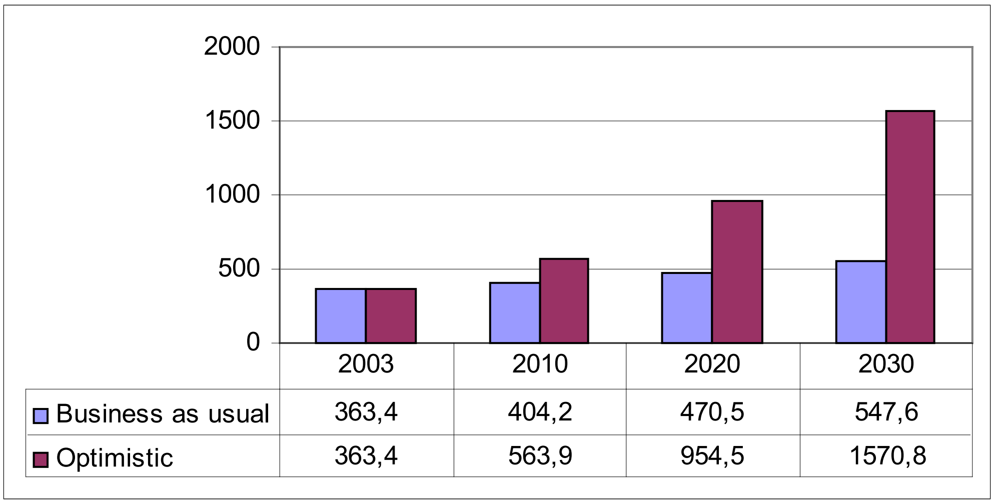


	2003	2010	2020	2030
Cattle	390,9	497,4	701,6	989,7
Cows	177,3	225,8	318,2	448,8
Sheep and goat	414	509,1	684,2	919,5
Poultry	4177,4	5571,6	8407,3	12686,2

In the optimistic scenario, increase of livestock and poultry populations, as well as of meat and milk production results from changes in cropping patterns, including extension of land under forage crops by 40 %, more than three-fold increase in production of maize for grain and silage, rise in credits available for population to buy animals, particularly small ruminants and poultry (Table 3.22).

Table 3.22

Dynamics of milk-yields in different scenarios (thousand t)



	2003	2010	2020	2030
Business as usual	363,4	404,2	470,5	547,6
Optimistic	363,4	563,9	954,5	1570,8

Milk-yield is 2.8 times higher in the optimistic variant.

d) <u>Change in selling-price of agricultural products and material resources</u>
The most uncertain indicator of the future agricultural production volume is the wholesale prices of agricultural products and of material resources needed for their production. For given scenario, they are taken at the level of the year 2003, with minor upward trend, which is based on dynamics during 1996…2003. However, in the structure of costs under this scenario, mechanical work inputs are reduced greatly and hand work inputs are incremented. These changes are taken on the basis of our research under EU-TACIS WUFMAS Project.

I. Business as usual scenario
Agricultural product prices for 2003 are actual. For the period of 2010-2030, typically the prices are kept without changes, except for potato, cucurbits and forage herbs, for which slight decrease in purchasing prices is expected due to limited purchasing capacities of population.

II. Optimistic scenario
Prices of strategic crops (cotton, rice, wheat) will rise since the government will encourage higher yields of these crops and farmer's interests in production of such crops. Rise in prices of other crops will occur because of available means of population to buy wanted products in adequate quantity and possibility to sale vegetables, cucurbits and fruits in neighboring states (a condition of free market relations).

The cost of material resources (seeds, fertilizers, pesticides and insecticides, etc.) is considered and incorporated into variable costs of agricultural production. Their quantification is related to yield level of particular crops (relationship between crop yield and cost of inputs was built). As a whole, prices of material resources have minor changes in the both scenarios. It is assumed also that in the optimistic scenario agricultural product prices will be higher than in the business as usual scenario and will approach current real market prices at the wholesale market since, at present, most of profit from livestock breeding is taken by subpurchasers.

Table 3.23

Agricultural product selling-prices ($/t)

	Cotton			Cereals			Maize for grain		
year	«BAU»	«opt»	%	«BAU»	«opt»	%	«BAU»	«opt»	%
2003	200.0	200.0	0.0	69.0	69.0	0.0	75.0	75.0	0.0
2010	200.0	220.0	+10.0	69.0	70.0	+1.5	75.0	76.0	+1.3
2020	200.0	235.0	+17.0	69.0	72.0	+4.3	75.0	77.0	+2.7
2030	200.0	250.0	+25	69.0	73.0	+6.0	75.0	78.0	+4.0

year	Rice			Kenaf			Potato		
	«BAU»	«opt»	%	«BAU»	«opt»	%	«BAU»	«opt»	%
2003	180.0	180.0	0.0	93.0	93.0	0.0	140.0	140.0	0.0
2010	180.0	190.0	+5.5	93.0	94.0	+1.0	135.0	145.0	+7.0
2020	180.0	200.0	+11.1	93.0	95.0	+2.1	130.0	150.0	+15.3
2030	180.0	210.0	+16.0	93.0	96.0	+3.0	130.0	150.0	+15.3

year	Vegetables			Cucurbits			Root		
	«BAU»	«opt»	%	«BAU»	«opt»	%	«BAU»	«opt»	%
2003	60.3	60.3	0.0	21.5	21.5	0.0	30.6	30.6	0.0
2010	58.0	61.5	+6.0	21.0	22.0	+4.7	30.0	31.0	+3.3
2020	56.0	62.0	+10.7	20.5	22.5	+9.7	30.0	31.5	+5.0
2030	54.0	62.0	+14.8	20.0	23.0	+15.0	30.0	32.0	+6.6

year	Grass (hay)			Maize for silage			Fruits		
	«BAU»	«opt»	%	«BAU»	«opt»	%	«BAU»	«opt»	%
2003	71.0	71.0	0.0	28.7	28.7	0.0	76.8	76.8	0.0
2010	70.0	71.5	+2.1	28.0	30.0	+7.1	76.0	77.0	+1.3
2020	68.0	72.0	+5.5	28.0	30.2	+7.8	76.0	78.0	+2.6
2030	65.0	73.0	+12.3	28.0	30.5	+8.9	76.0	79.0	+3.9

year	Vineyards		
	«BAU»	«opt»	%
2003	120.0	120.0	0.0
2010	120.0	130.0	+4.1
2020	120.0	135.0	+8.3
2030	120.0	140.0	+12.5

Crop yields decrease slightly in the business as usual scenario (the causes: deteriorated soil fertility, reduced inputs and mechanization, deteriorated irrigation network, poor regimes of water delivery and irrigation).

Yields of strategic crops (cotton, cereals) and potato (one of main foodstuffs) remain practically without changes. The optimistic («opt») scenario assumes increase in crop yields to a possibly achievable level for this zone. Moreover, potential yields of some crops will be achieved through application of required fertilizers, investments in agriculture, increment of resource potential and mechanical work, higher interests of producer in final results of his work, cost-effective specialization, and optimization of water delivery and irrigation regimes.

Table 3.24

Comparison of agricultural product prices in different scenarios, $/t

Kind of product		**2003**	**2010**	**2020**	**2030**
meat	BAU	1830	2100	2400	2600
	optimistic	1830	2300	2700	3400
milk	BAU	180,8	190	200	210
	optimistic	180,8	200	230	280
eggs	BAU	81,5	83	85	90
	optimistic	81,5	88	97	128
wool	BAU	394,4	410	420	430

	optimistic	394,4	440	490	520

3.3.4. Capital investments in agricultural production

In order to achieve the optimistic level of agricultural development, capital investments must be increased heavily, including for 27 year (Tables 3.25-3.28).

Table 3.25

Capital investments in livestock-breeding over 2003 – 2030, optimistic scenario (M$)

Year	Fodder base development	Technique and state-of-the-art technologies	Animal health	Procurement of pedigree cattle	Total
2003	0.3	0,1	0.3	0.3	1
2004	1	1.5	0.5	4	7
2005	1	1.5	0.5	4	7
2006	1	1.5	0.5	4	7
2007	1	1.5	0.5	4	7
2008	1	1.5	0.5	4	7
2009	1	1.5	0.5	4	7
2010	1	1.5	0.5	4	7
2011	0.7	2	1	4	7.7
2012	0.7	2	1	4	7.7
2013	0.7	2	1	4	7.7
2014	0.7	2	1	4	7.7
2015	0.7	2	1	4	7.7
2016	0.7	2	1	4	7.7
2017	0.7	2	1	4	7.7
2018	0.7	2	1	4	7.7
2019	0.7	2	1	4	7.7
2020	0.7	2	1	4	7.7
2021	0.5	2.5	1.2	4	8.2
2022	0.5	2.5	1.2	4	8.2
2023	0.5	2.5	1.2	4	8.2
2024	0.5	2.5	1.2	4	8.2
2025	0.5	2.5	1.2	4	8.2
2026	0.5	2.5	1.2	4	8.2
2027	0.5	2.5	1.2	4	8.2
2028	0.5	2.5	1.2	4	8.2
2029	0.5	2.5	1.2	4	8.2
2030	0.5	2.5	1.2	4	8.2
Total:	19.3	55,6	25,8	108,3	209.0

Table 3.26

Capital investments in crop production over 2003-2030, optimistic scenario (M$)

Year	Crop production development	Machine and tractor pool development	Land reclamation	Irrigated land reconstruct tion	New land develop ment	Total
2003	0.73	1.05	0.00	1.27	3.68	6.73
2004	4.00	20.00	0.30	2.50	3.68	30.48
2005	4.00	20.00	0.30	2.50	4.42	31.22
2006	4.00	20.00	0.30	2.50	4.42	31.22
2007	4.00	20.00	0.30	2.50	4.42	31.22
2008	4.00	20.00	0.30	2.50	4.42	31.22
2009	4.00	20.00	0.30	2.50	4.42	31.22
2010	4.00	20.00	0.30	2.50	4.42	31.22
2011	2.60	6.00	0.30	2.50	4.38	15.78
2012	2.60	6.00	0.30	2.50	4.38	15.78
2013	2.60	6.00	0.30	2.50	4.38	15.78
2014	2.60	6.00	0.30	2.50	4.38	15.78
2015	2.60	6.00	0.30	2.50	4.38	15.78
2016	2.60	6.00	0.30	2.50	4.38	15.78
2017	2.60	6.00	0.30	2.50	4.38	15.78
2018	2.60	6.00	0.30	2.50	4.38	15.78
2019	2.60	6.00	0.30	2.50	4.38	15.78
2020	2.60	16.00	0.30	2.50	4.38	25.78
2021	1.85	16.00	0.30	2.50	4.38	25.03
2022	1.85	16.00	0.30	2.50	4.38	25.03
2023	1.85	16.00	0.30	2.50	4.38	25.03
2024	1.85	16.00	0.30	2.50	4.38	25.03
2025	1.85	16.00	0.30	2.50	4.38	25.03
2026	1.85	4.00	0.30	2.50	4.38	13.03
2027	1.85	4.00	0.30	2.50	4.38	13.03
2028	1.85	4.00	0.30	2.50	4.38	13.03
2029	1.85	4.00	0.30	2.50	4.38	13.03
2030	1.85	4.00	0.30	2.50	4.38	13.03
Total	73.23	311.05	8.10	68.77	121.44	582.59

Table 3.27

Capital investments in crop production over 2003-2030, business as usual (M$)

Year	Crop production development	Machine and tractor pool development	Land reclamation	Irrigated land reconstruction	New land development	Total
2003	0.73	1.05	0	1.27	3.68	6.73
2004	0.73	1.05	0	1.27	3.68	6.73
2005	0.73	1.05	0	1.27	3.68	6.73
2006	0.73	1.05	0	1.27	3.68	6.73
2007	0.73	1.05	0	1.27	4.05	7.10
2008	0.73	1.05	0	1.27	4.05	7.10
2009	0.73	1.05	0	1.27	4.05	7.10
2010	0.73	1.05	0	1.27	4.05	7.10
2011	0.73	1.05	0	1.27	3.68	6.73
2012	0.73	1.05	0	1.27	3.68	6.73
2013	0.73	1.05	0	1.27	4.05	7.10
2014	0.73	1.05	0	1.27	4.05	7.10
2015	0.73	1.05	0	1.27	4.05	7.10
2016	0.73	1.05	0	1.27	4.05	7.10
2017	0.73	1.05	0	1.27	4.05	7.10
2018	0.73	1.05	0	1.27	4.05	7.10
2019	0.73	1.05	0	1.27	4.05	7.10
2020	0.73	1.05	0	1.27	4.05	7.10
2021	0.73	1.05	0	1.27	4.05	7.10
2022	0.73	1.05	0	1.27	4.05	7.10
2023	0.73	1.05	0	1.27	4.05	7.10
2024	0.73	1.05	0	1.27	4.05	7.10
2025	0.73	1.05	0	1.27	4.05	7.10
2026	0.73	1.05	0	1.27	4.05	7.10
2027	0.73	1.05	0	1.27	4.05	7.10
2028	0.73	1.05	0	1.27	4.05	7.10
2029	0.73	1.05	0	1.27	4.42	7.47
2030	0.73	1.05	0	1.27	4.42	7.47
Total	20.44	29.40	0.00	35.56	111.87	197.272

Table 3.28

Capital investments in livestock-breeding over 2003 – 2030, business as usual (M$)

Year	Fodder base development	Technique and state-of-the-art technologies	Animal health	Procurement of pedigree cattle	Total
2003	0.3	0.1	0.3	0.3	1
2004	0.3	0.1	0.3	0.3	1
2005	0.3	0.1	0.3	0.3	1
2006	0.3	0.1	0.3	0.3	1
2007	0.3	0.1	0.3	0.3	1
2008	0.3	0.1	0.3	0.3	1
2009	0.3	0.1	0.3	0.3	1
2010	0.3	0.1	0.3	0.3	1
2011	0.3	0.1	0.3	0.3	1
2012	0.3	0.1	0.3	0.3	1
2013	0.3	0.1	0.3	0.3	1
2014	0.3	0.1	0.3	0.3	1
2015	0.3	0.1	0.3	0.3	1
2016	0.3	0.1	0.3	0.3	1
2017	0.3	0.1	0.3	0.3	1
2018	0.3	0.1	0.3	0.3	1
2019	0.3	0.1	0.3	0.3	1
2020	0.3	0.1	0.3	0.3	1
2021	0.3	0.1	0.3	0.3	1
2022	0.3	0.1	0.3	0.3	1
2023	0.3	0.1	0.3	0.3	1
2024	0.3	0.1	0.3	0.3	1
2025	0.3	0.1	0.3	0.3	1
2026	0.3	0.1	0.3	0.3	1
2027	0.3	0.1	0.3	0.3	1
2028	0.3	0.1	0.3	0.3	1
2029	0.3	0.1	0.3	0.3	1
2030	0.3	0.1	0.3	0.3	1
Total:	8.4	2.8	8.4	8.4	28

3.4. Environmental scenario

In terms of environmental status of the sub-basin, its territory is divided into 3 zones (Figure 3.9).

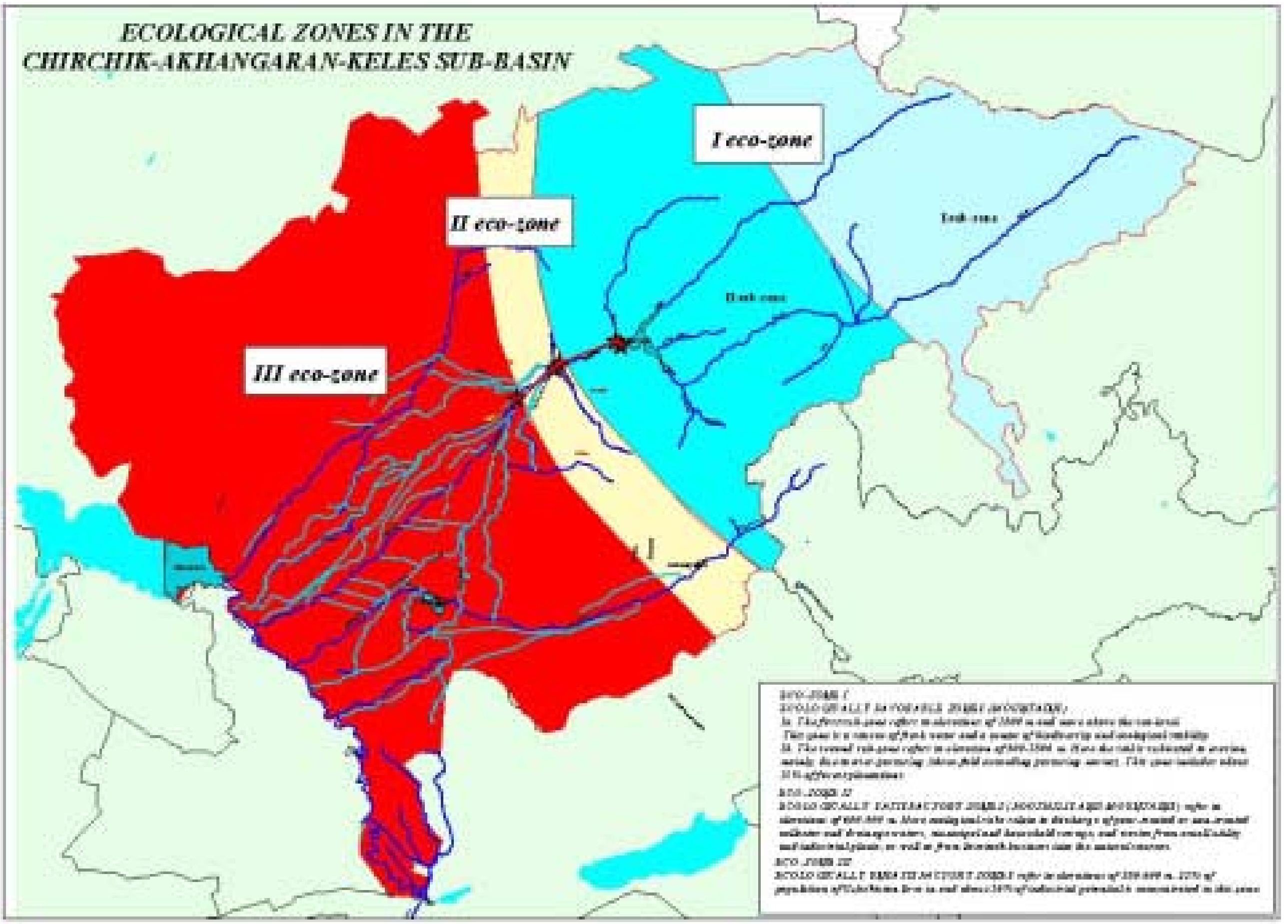


Figure 3.9. Ecological zones of Chirchik-Akhangaran-Keles sub-basin

Those zones were selected mainly according to elevations: the first zone of ecological wellbeing – higher than 900 m above sea-level; the second zone – high elevations of 600 – 900 m; and, the third one – below 600 m.

3.4.1. Characteristics of ecological zones

1. Ecologically favorable zone. The zone is divided into 2 sub-zones:

    1.1. Flow formation, practically without influence of anthropogenic factors;
    1.2. Flow formation with minor anthropogenic influence.

The first sub-zone occupies highlands (from 1800m above sea level and over).
The second sub-zone occupies areas at elevations from 900m to 1800m.
In the first zone the population is substantially satisfied with fuel and timber owing to woody-shrub vegetation in the neighborhood of human settlements; therein grazing is concentrated as well. For lack of an alternative, the local population has to use limited resources of ecosystems that results in their depletion.

2. Ecologically satisfactory zone.

In the second zone, the main industrial polluters include:
in the Chirchik river basin – PO “Elektrokhimprom”, Khodjikent asphalt and concrete mixing plant, Uzbek refractory and high-temperature metals factory (UzKTZhM), etc.;
in the Akhangaran river basin – Angren coal open-cast mine, Angren and Novo-Angren state district power plant, Akhangaran cement factory, Angren petroleum storage depot, Almalyk chemicals plant, etc.

3. Ecologically unsatisfactory zone.

The zone is notable for the highest environmental tension.
Therein the main trends of natural environment degradation are:

- disturbance of environmental flows along the rivers;
- waste disposal and water quality deterioration in the rivers, above all, Chirchik, due to collector-drainage and sewage water;
- industrial pollution and earlier influxes of nitrates into water achieving dangerous limits (now these are stopped).

3.4.2. “Business as usual” scenario

In the first ecological zone, the ecological situation generally remains safe for the most of faunal and floral forms. At the same time, trends of natural equilibrium disturbance have been marked in the zone. So, the deficit of building materials and fuel has resulted in uncontrolled deforestation, excessive grazing, other negative processes that lead to reduction of forests, intensive development of erosion processes.
It is observed in the zone that the habitat of the most valuable faunal forms is moving deep into the mountains where man impact is relatively weaker.
The construction and distribution of trunk roads have imposed excessive load on the zone that in turn leads to destruction of vegetation cover, trees, and bushes. In the recent years there is an increase in “wild tourism” in this zone, which has a negative influence on the environment.
In the second ecological zone, the situation will become even more aggravated with erosion, industrial and demographic pressure and, perhaps, with pollution of river flow under the influence of land development by private business, which is not sufficiently regulated from the position of water disposal and protection of water bodies in this zone.
In the third ecological zone, agricultural pollution through point and areal discharges that contain chemicals and dissolved salts from agricultural fields into collector-drainage network and outside it (the total volume of drainage flow is about 2 billion m^3) represents a danger under business as usual. Moreover, such cases as failure to meet environmental requirements and mismanaged operation of river channels may become more frequent.

3.4.3. "Optimistic scenario".

In the first ecological zone, it seems to be necessary to use a recreation capacity of the Pskem river valley, which is notable for clean air, comfort temperature conditions, and relatively rich flora and fauna. At present, the Pskem river valley is not sufficiently used for recreation purposes. It is explained by the absence of appropriate infrastructure, poor condition of the roads and remoteness from large settlements.
In the long term, it seems expedient to carry out planned recreational development of the zone, which is an integral part of the National Ugam-Chatkal Park.
The recreation capacity of the Pskem valley can be used effectively enough for recreation and rest of population in Tashkent city and the province.
The construction of the Pskem waterworks facility may accelerate the development of the territory for tourism and contribute to the enhancement of recreation infrastructure. In particular, it is planned to construct 4 recreational centers with a total capacity of 10,000 accommodations in the zone of future Pskem reservoir:

1) Tourist hotels with 1,000 accommodations at high elevations, which command a panorama of the reservoir, surrounding mountains and Pskem valley.

2) Boarding houses with 2,500 accommodations at a gentle slope adjoining the reservoir. The closeness to a water area will enable to engage in aquatics.

3) A number of sanatoriums with 2,500 accommodations is expected to be constructed between Teparsay and Takayangak. This territory is most comfortable and located not far from a trunk road.

4) A center of tourism and sports with 4,000 accommodations on the right bank of Urungachsai in the north-eastern part, distant from the future dam. The center is expected to include a national nature park. There, main tourist and excursion routes will be formed.

The impact of the Pskem reservoir on the environment is related to the redistribution of the territory among land and aquatic ecosystems. This impact is limited by the period of stabilizing the biocenosis under new conditions, which usually lasts 10-15 years. The most considerable damage to natural systems is, as a rule, done in the period of construction, when a part of vegetation cover will be destructed. Negative consequences of flora destruction should be mitigated by carrying out follow-up artificial revegetation and new plantations. This is stipulated in the feasibility study of the project, including plantation of ornamental and other valuable plants. To restore the most valuable phytocenoses in the flood zone of the reservoir, the project provides for planting fruit trees, dog-rose, vine and creating artificial reafforestation of coniferous (Crimean pine, juniper, thuja, fir, spruce) and deciduous trees (poplar, ash, maple, willow, etc.) and man-made herbal plantations.

Major negative influence upon faunal forms will be exerted by such factors as blasting operations, noise of mechanisms, and possibility of uncontrolled hunting of valuable animals. Strengthening the forest keeping service can facilitate protection of faunal forms from poachers.

According to design studies, hydro-geological conditions in the river valley will not practically change *in the period of operation* of the Pskem waterworks facility. Furthermore, water-logging of lands in the region is not expected because of the absence of flat areas.

The Pskem reservoir will be characterized by small water surface area (9.82 km^2) as a result of steep sides of the bed, owing to which the waterworks facility will not have a considerable impact on microclimate in the adjacent territory.

It is expected that the population of semi-aquatic birds, the majority of which has economic value, will increase. The project intends to conduct research of local fauna in order to assess their number, availability of forage land per season in year, state of the young and individual populations.

According to the estimates, the quality of water in the reservoir against salinity, content of basic ions and petroleum products, synthetic surfactants and biogenic matters will meet requirements of all kinds of water use and consumption.

Mountainous districts relating to the *first ecological sub-zone* more strongly respond to atmospheric-climatic and anthropogenic impacts. To avoid the aggravation of the environmental situation in this sub-zone in the optimistic scenario, it is necessary to carry out environmental measures.

The measures should be implemented as stipulated in the Decree No.471 issued by the Cabinet of Ministers of the Republic of Uzbekistan on 29 October 2003 “On the establishment of water protection zone and coastal strip of the Chirchik river in Tashkent province and Tashkent city” and Decree No.23 of the Cabinet of 16 January 2002 “On giving a status of especially protected territories to fresh groundwater deposits in Chirchik, Akhangaran and Chimgan zones”.

Compliance with the requirements for environmental flows along the Chirchik, Akhangaran and Keles rivers (Figures 3.10 – 3.12) should be an important element of the “optimistic scenario”. Furthermore, limits on releases within the general balance of the Syrdarya river should be kept in the Chirchik river basin. From these positions, as suggested by BWO, the following constrains for the Chirchik river basin from the side of the whole Syrdarya river basin were included in the model (Table 3.29).

Table 3.29

Requirements and limits on releases from Chirchik-Akhangaran sub-basin to the Syrdarya river (m^3/sec)

growing season: no less than	April	May	June	July	August	September
1994 (high-water)	0	0	0	0	27.4	0
2001 (low-water)	0	30.8	28.3	25.7	1	0
average	0	0	0	0	11.8	0
non-growing season: no more than	October	November	December	January	February	March
1994 (high-water)	705.3	488.8	638.6	211.5	277.5	194.7
2001 (low-water)	800.0	446.1	366.5	319.4	67.2	519.4
average	769.2	566.8	456.9	356.1	320.5	412.0

In the Table:

- requirements for growing season are given under the condition of additional releases for meeting environmental requirements of no less than 100 m^3/sec along the full length of rivers;
- limits for non-growing season are given under the condition of restricted inflow to Shardara reservoir (no more than 1200 m^3/sec).

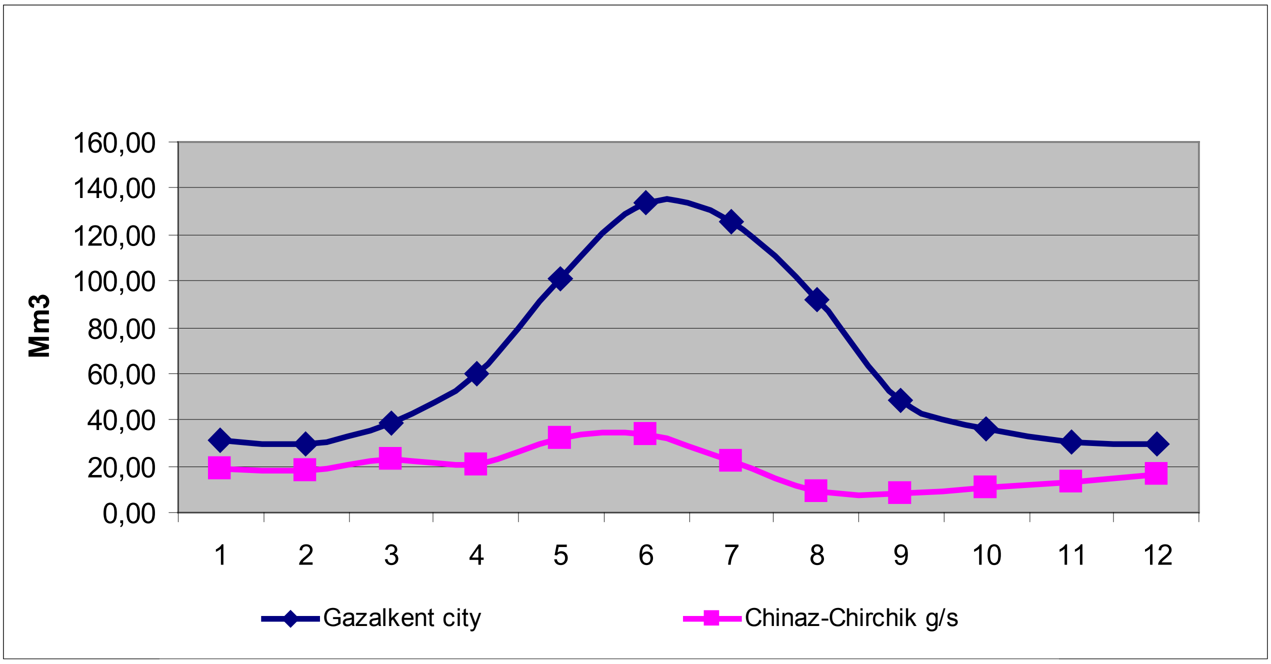


Figure 3.10. Environmental demand in the Chirchik river's sections

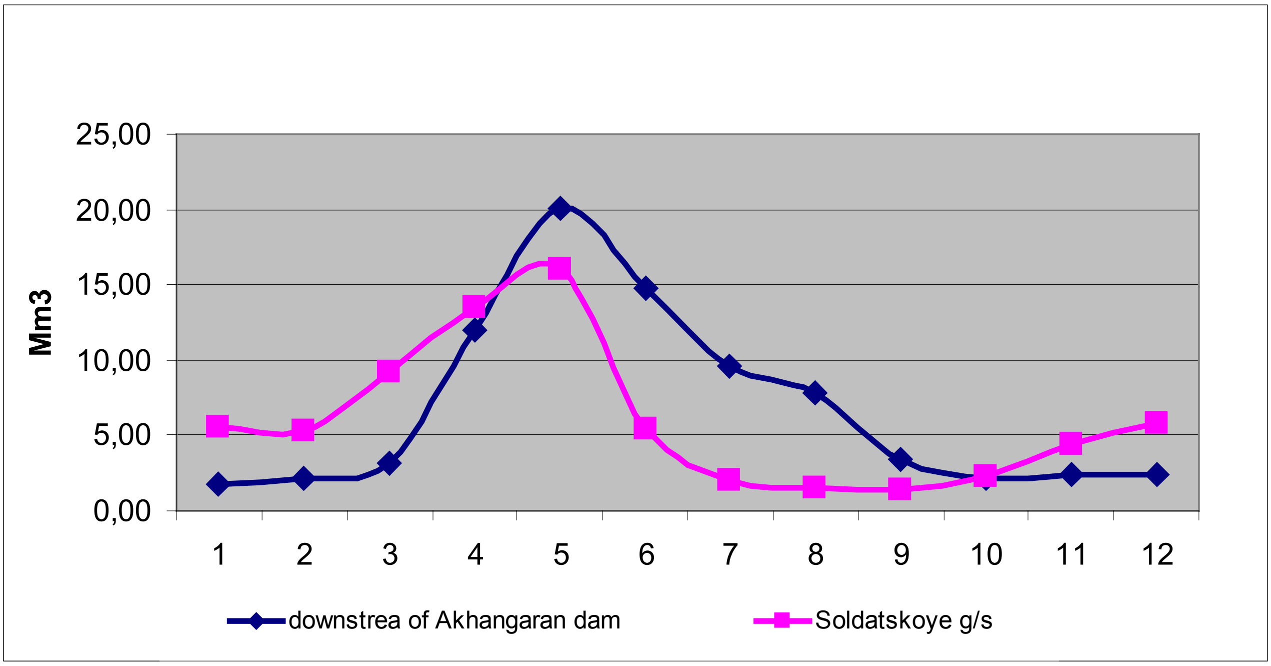


Figure 3.11. Environmental demand in the Keles river's sections

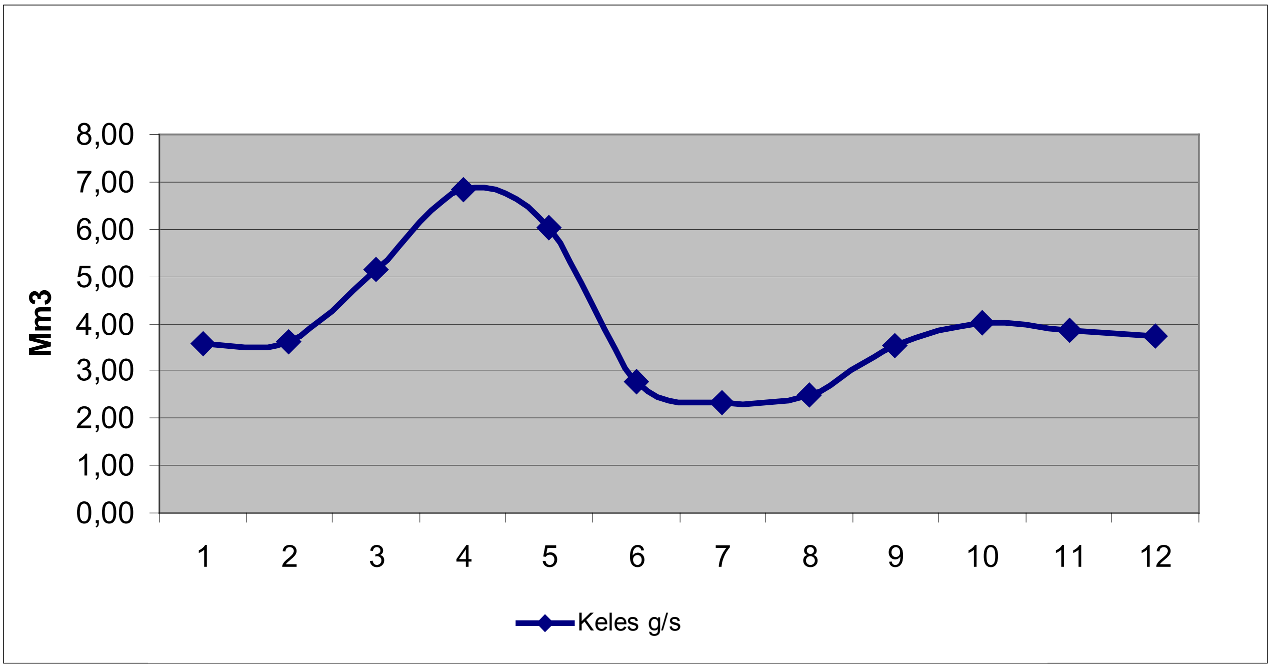


Figure 3.12. Environmental demand in the Akhangaran river's sections

3.4.4. Comparison of economic indicators of the environmental scenarios

The "business as usual" scenario will cause annual damage, of which:

household and drinking water-supply	992,7 thousand $;
fishery	848,6 thousand $;
total –	1841, 3 thousand $.

In the optimistic scenario this damage may be eliminated if 2.6 million $ are invested annually in the period since 2010 to 2015.

3.5. Water-management scenario

The main factors of two scenarios are:

- river flow regulation by additional reservoirs;
- amount of water intakes by neighboring states;
- efficiency coefficient of irrigation systems;
- irrigation technique efficiency coefficient;
- level of water conservation, which is determined by degree of IWRM implementation.

3.5.1. Additional construction of Pskem waterworks facility in the Pskem river

An issue of additional regulation of Pskem-Ugam river flows has been discussed as long ago as during the Soviet time but this was found ineffective. Since independence, it was decided to design Pskem waterworks facility, earlier proposal on which has already showed more cost-effective indicators.

In 1997, JSC "Gidropoject" prepared construction project for Pskem waterworks facility on the Pskem river.

According to this project, Pskem reservoir and HEPS (Ninst=450 MW) were planned to construct 15 km upstream of Charvak reservoir in Bostanlyk district, Tashkent province (capital investments in the waterworks facility (WF) = 610,15 million roubles in 1991 prices). WF will have multi-purpose, i.e. flow regulation upon request of regional water sector and electricity generation, load-factoring and maintenance of energy system frequency in the Republic of Uzbekistan.

The operation of Pskem reservoir, having useful capacity of 486,5 Mm^3, highest controlled water level of 1166 m and dead storage level (DSL) of 1052 m (Vdsl=34,3 Mm^3) in irrigation regime, will allow increase of guaranteed water yield and extend irrigated area to 387,8 thousand ha, and, at the same time, using flow in downstream pool of waterworks facility. Given the installed capacity of HEPS at 450 MW, the mean long-term generation will be 884,5 GWH.

The use of Pskem waterworks facility mainly for hydropower generation is possible only under reduction of new agricultural land, taking into account respective damage to agriculture. Here the mean long-term generation of electricity was found equal 966 GWH. The indicators for justification of reservoir operation regime are given in the Table 3.30.

Table 3.30

Comparative indicators for two operation variants of Pskem WF

№	Item	Units	WF operation regime	
			irrigation	energy generation
1	Irrigated area	thousand ha	387,8	347,2
2	Reduction of irrigated areas	-‘-	40,6	
3	Total net profit	$M\$^{**}$	1352,2	1210,7
4	Decrease of revenue in agriculture	-‘-	141,5	
5	Operation costs	-‘-	92	
6	Lost profits	-‘-	49.5	
7	Electricity generation	GWH	884,5	965,9
8	Surplus electricity generation		81,4	
9	Gross revenue from energy	$M\$^{**}$	3,2	

	trade		
10	Gross revenue, including power grid expenses (k=0,85)	M$**	2,8

* Feasibility Study «Pskem waterworks facility on Pskem river», JSC «Gidroproject»
** prices of the year 1991

Based on calculation results, the “irrigation” regime of reservoir operation was taken as determinant. Here power sector incurs minor losses since a partial loss of revenue under the “irrigation” regime is 17.6 times less than revenue generated in the recommended variant of flow regulation.

Expected beginning and completion of the construction are 2010 and 2020, respectively, in the optimistic scenario. The “business as usual” scenario does not stipulate such construction.

3.5.2. Water withdrawal by Kazakhstan

South Kazakhstan province withdraws water through three canals, such as Zakh, Khanym, and Big Keles transferring water directly to the Keles river. This ensures irrigation of 66,15 thousand ha of present land.

“Business as usual” scenario

As the Table 3.31 shows, over last 8 years, the mean water withdrawal from the Chirchik river to Keles massif is 496,7 Mm^3/year. For this scenario calculation we consider 500 Mm^3 of water.

Table 3.31

Water withdrawal (Mm^3/year) from the Chirchik river to Keles massif over 1995-2003, prospective calculated water consumption and irrigated areas in the zone «ChAB-Keles» (by 2030)[1]

№№	**Year**	**Withdrawal, total**	**Irrigated land area*, thousand ha**
1	2	3	4
1	1995	518,1	
2	1996	503,1	
3	1997	401,4	
4	1998	347,3	
5	1999	455,8	Over 1999-2003, irrigated area – 67,00
6	2000	510,7	
7	2001	588,5	
8	2002	595,2	
9	2003	550,2	
10	**1995-2003** **Average**	**4470.3** **496.7**	**Data from SIC's DB**

Optimistic scenario

According to Master-plan for comprehensive water use and protection in the Syrdarya river basin, full development of Keles massif is planned by extending irrigated area, mainly, through Big Keles canal. It is assumed that by 2030 the irrigated area will be extended here by 31-32 thousand ha, thus amounting to 98 thousand ha, and withdrawals from the Chirchik river will be increased to 1140 Mm^3/year. These scenarios were approved by the Committee for Water Resources of the Republic of Kazakhstan and the Republican State Enterprise “Yugvodhoz” that operated this system.

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[1] Source: data of SIC ICWC Kazakh branch

3.5.3. Efficiency coefficients for irrigation systems

are divided into efficiency coefficient of the system in general, efficiency coefficient of inter-farm network (now, at the level of districts), efficiency coefficient of on-farm network, and efficiency coefficient of irrigation technique.

Coefficient of irrigation technique efficiency, considered in calculating water consumption in the field, was estimated as 0.7 … 0.75, where the lower limit is for business as usual and the upper limit, for optimistic scenario. Efficiency coefficient of irrigation systems for Uzbekistan is taken from data of "Master-plan for development of irrigated agriculture and water sector by 2015", Uzvodproyekt, 2002 (9). However, the "business as usual" scenario assumes decrease in the efficiency coefficient against the current level, based on SIC's observations, due to aging of the system and lack of funds for its timely rehabilitation (Table 3.32).

Table 3.32

Dynamics of inter-farm irrigation network's efficiency coefficient

District	Scenario	2003	2010	2020	2030
Akkurgan	BAU	0.90	0.88	0.84	0.81
	Optimistic	0.90	0.88	0.87	0.87
Akhangaran	BAU	0.85	0.82	0.78	0.74
	Optimistic	0.85	0.86	0.87	0.87
Bostanlyk	BAU	0.94	0.92	0.89	0.87
	Optimistic	0.94	0.90	0.88	0.87
Buka	BAU	0.90	0.88	0.84	0.81
	Optimistic	0.90	0.88	0.87	0.87
Zangiata	BAU	0.83	0.80	0.77	0.73
	Optimistic	0.83	0.85	0.86	0.87
Kibray	BAU	0.84	0.81	0.77	0.73
	Optimistic	0.84	0.86	0.86	0.87
Kuyichirchik	BAU	0.87	0.84	0.81	0.77
	Optimistic	0.87	0.87	0.87	0.87
Parkent	BAU	0.86	0.83	0.80	0.76
	Optimistic	0.86	0.86	0.87	0.87
Pskent	BAU	0.86	0.83	0.80	0.76
	Optimistic	0.86	0.86	0.87	0.87
Tashkent	BAU	0.87	0.84	0.81	0.77
	Optimistic	0.87	0.87	0.87	0.87
Urtachirchik	BAU	0.87	0.84	0.81	0.77
	Optimistic	0.87	0.87	0.87	0.87
Chinaz	BAU	0.85	0.82	0.78	0.75
	Optimistic	0.85	0.86	0.87	0.87
Yukorichirchik	BAU	0.85	0.82	0.79	0.75
	Optimistic	0.85	0.86	0.87	0.87
Yangiyul	BAU	0.86	0.83	0.80	0.76
	Optimistic	0.86	0.86	0.87	0.87

At present, the level of on-farm system efficiency coefficient is very low, according to data of the same Master-plan – from 0.59 to 0.67 for different districts.

Taking into account that on-farm network should be improved at the expense of farmers and under current level of prices, there are very small expectancies that the network will be comprised of flumes, lined canals or pipe-lines. At the same time, it could be assumed that with implementation of IWRM, based on experience in Fergana Valley (10), managerial losses will be reduced by 8 % on average for the period under consideration (Table 3.33).

Table 3.33

Dynamics of on-farm network's efficiency coefficient in Tashkent province

Efficiency coefficient of on-farm systems throughout the province (including WUA's)		2003	2010	2020	2030
	current level	0.67	0.67	0.67	0.67
	optimistic level	0.67	0.69	0.72	0.75

In Kazakhstan, the situation is different:

- Efficiency coefficient of systems 0.55 … 0.56;
- Efficiency coefficient of inter-farm canals 0.87 … 0.89;
- Efficiency coefficient of on-farm network 0.63 … 0.67.

4. Integration of scenarios through the modeling and the interface of common database

As was shown, scenarios of the five main blocks – climatic, socio-economic, agricultural, water-management, and environmental – should be linked and adapted through the system of integrated models described in the report D-32, section 8.
The tool for integration is the user interface and the database. Interface in its last version is integrated one, i.e. includes both the database interface and the earlier described interface of hydrological model components: HBV, HBV GAMS and REQWAT.
The interface (Figure 4.1.) has been developed in accordance with the requirements specified by the Terms of Reference. Development environment is Visual Basic Net. Replacement of Visual Basic Pro by Visual Basic Net was made because of capabilities of wider using ArcGIS program. The main purpose of the user interface (as well as of another one) is to effectively integrate functional components into a single whole system and organize fulfillment of functions so that user could draw all his attention to necessary analytical work, and programs, using which this work is done.
The user interface is a system of blocks: DB block; GIS block; forms for information input and output forms for comparison of scenarios' results; block of scenario selection, time of presentation and downloading designed for user servicing.
The interface permits the user to input, correct data and information in some of models (for example REQWAT). The interface consists of some principal windows:

- blocks of data (climatic, socio-economic, agrarian, hydro-ecological);
- modeling (scheme, scenarios, estimation running, indicators and results of estimation);
- help.

Block of data includes all data gathered in the project in above mentioned directions.

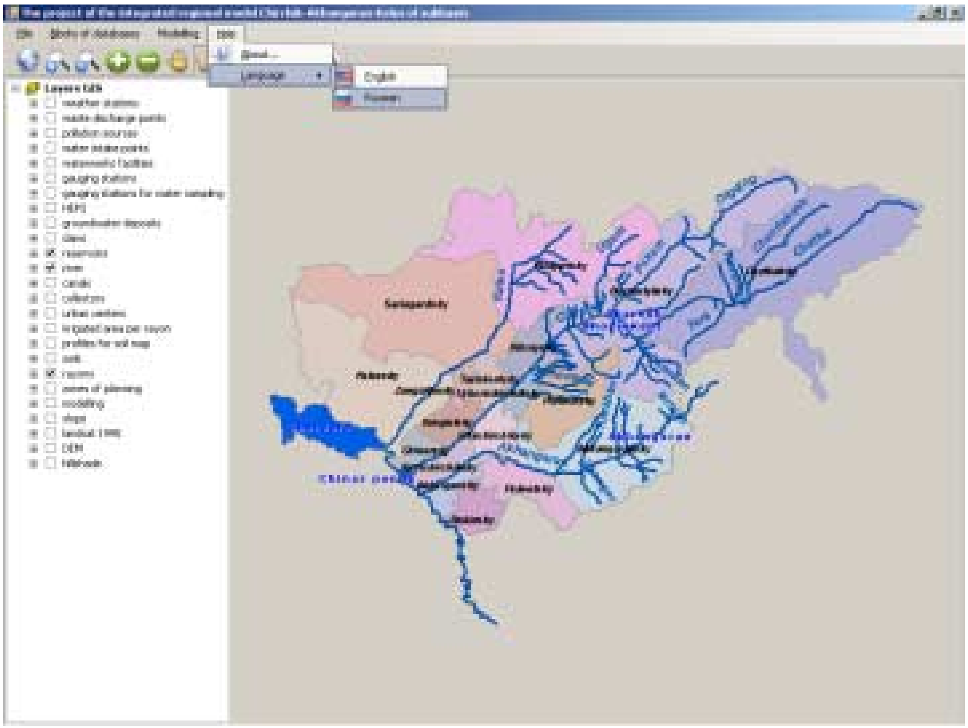


Figure 4.1. Main form of interface

Scheme of models demonstrates linking of scenarios and models included in the interface (Fig. 4.2):

- HBV,

- REQWAT,
- HydRWT (GAMS),
- SEM,
- QUAL-Chirchik

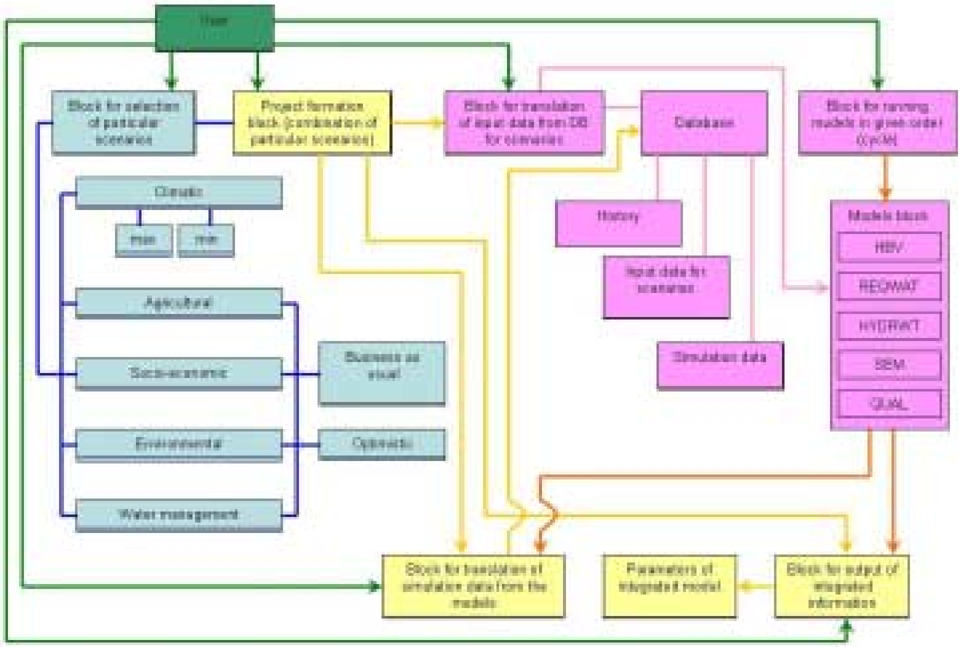


Figure 4.2. Diagram of model coupling through interface

The accepted **levels of coupling** of separate models and modules into the **integrated model**:

- **Program** – coupling of models and modules with each other and with database (DB) through user interface for joint operation, including: (i) development of scenarios, (ii) inputting data into the models from DB on scenarios, (iii) translation of simulation data between the models in a certain order, (iv) outputting simulation data through user interface and their translation into DB.
- **Through DB** – interpretation of model and module simulation results through DB according to the developed system of integrated parameters and indicators that are reflected in the window "indicators".

The following information is collected and stored in DB:

- Basic data for modeling, classified and stored in separate blocks, depending on **type of individual scenarios** and translated on appropriate requests (model- scenario),
- Simulation data (model outputs) – integrated parameters and indicators stored in separate blocks with indication of a **number (name) of combination of individual scenarios**, accepted for simulations.

For each type of individual scenario, DB stores input information on a number of parameters for two extreme cases: (i) “MAX”, (ii) “MIN” (maximum and minimum climate impact) or (i) “Business as Usual”, (ii) “Optimistic” (for other scenario types).

Every from agreed "boundary scenarios", as introduced in the chapter 3, are presented in the interface without ability to change them. But user can create own scenarios including change in each sub-scenarios.
The order of interlinks and sequence of scenarios and model use is very important to take each step from common run.

Run starts from climatic scenarios to HBV – IWS (step 1) and simultaneously passes climatic indicators for selected points and years to SEM – Agrarian model (prototype ACRE) and to REQWAT (step 1a and 1b). HBV-IWS goes to estimation and creation of flow volume in formation zone (step 2) that is input for HBV GAMS (step 2a). Water forming scenarios have two inputs – in HBV GAMS – step 3a for account of Pskem reservoirs and for REWAT – step 3b for different efficiencies of system. Agrarian scenarios introduce to REQWAT their cropping patterns and indicators of yield – step 4a, with account of water requirements from socio-economic scenarios for non-agricultural needs; step 5a – REQWAT will estimate requirements for all needs and give these for account in HBV GAMS – step 6.

HBV GAMS produces formation and distribution of water and by back coupling prepares input to REQWAT (step 7a) that should reflect to Agrarian model (step 8a), to socio-economic scenarios (step 8b). At same time, this new result of Agrarian model related to productivity of land under effect of water availability, , which formulated GNP in agriculture, would feed socio-economic scenarios thru SEM (step 8b).

Water regime of different water bodies from HBV GAMS thru step 7b gives input to the model Qual-Chirchik, that based on the morphological data of rivers' bodies and agrarian scenarios (step 9a) makes ecological assessment of situation in river. Results of water regime estimation – quantity and quality in time (step 10a) and results of Qual-Chirchik (step 10b) should be compared with environment scenarios and its requirement for assessment of degree of satisfaction.

All the results on principal indicators from all the models should be introduced to common DB that executes the role of MosDEW.

Integrated indicators (MosDEW)

A block was developed to output the integrated indicators as a result of operation of the modeling set (this information is stored in DB and displayed upon user request).

Integrated model indicators derived via DB (**basic list**):

- Water supply of irrigated agriculture per planning zone (simulation data from HydRWT),
- Agricultural development indicators – area changes, crop yields, production volumes and incomes in irrigated agriculture per planning zone (simulation data from WEAP , SEM),
- Hydropower generation and deficit per cascade and individual HEPS (simulation data from HydRWT),
- Deficit of environmental releases in control section lines of river network (simulation data from HydRWT),
- Deviation of simulated surface water quality figures from standard indicators (permissible water salinity for drinking water supply, agriculture and fishery) in control section lines of river network (simulation data from QUAL-Chirchik),
- Aggregate regional water balance (simulation data from HydRWT),
- Socio-economic development indicators – demography, macroeconomic indicators, investments, food provision (input data and simulated data from SEM).

Indicators of socio-economic model outputted through the interface:

- population (urban and rural),
- number of workable population (urban and rural),
- number of work places,
- water availability of communal sector,
- water availability of industry,
- gross production volumes per sector,
- gross domestic income of the province GDP,
- personal income, urban and rural,
- food supply,
- employment.

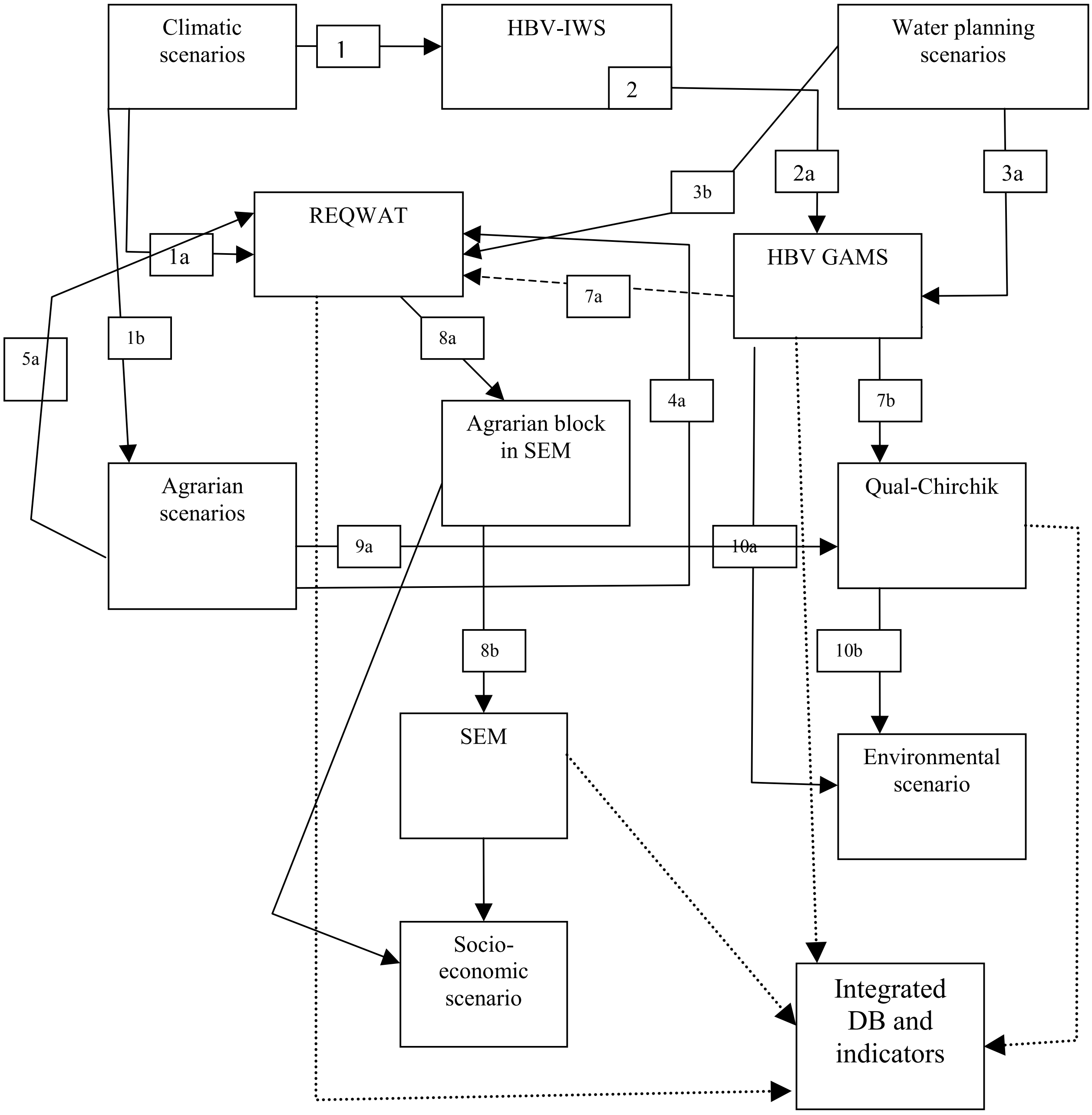


Fig. 4.3.
Run of scenarios and models

——— direct coupling

……………… input into integrated DB

The principal indicators that determine feasibility of BAU integrated scenario and probability (or not) of optimistic scenario are investments. Investments in agrarian sector were introduced in the chapter 3 on the basis of strong analytic component assessment. Situation in industry, agro-industry and services is different, because multi-specific directions of this sector didn't allow using the component assessment and can be done only on the basis of analytical assessment of total influence of investments on the sector productivity and indicators.

These results for one scenario (BAU) are introduced below (Table 4.1).

Table 4.1

Gross product (GP) and investments in socio-economic scenarios "BAU"

	Industry		AgroIndustry		Services	
	GP	Invest	GP	Invest	GP	Invest
	M$	M$	M$	M$	M$	M$
2003	797.40	75.32	330.61	98.89	563.53	323.78
2004	767.81	84.20	332.72	99.39	590.52	328.24
2005	740.39	83.51	335.35	100.00	619.80	332.35
2006	723.01	83.08	338.26	100.68	650.74	335.86
2007	707.17	82.68	341.35	101.40	682.97	338.63
2008	692.78	82.32	344.55	102.14	716.22	340.52
2009	679.76	81.99	347.85	102.91	750.29	341.44
2010	668.00	81.70	351.23	103.68	784.99	341.33
2011	657.38	81.43	354.68	104.48	820.12	340.13
2012	647.81	81.20	358.21	105.28	855.46	337.83
2013	639.17	80.98	361.82	106.10	890.78	334.42
2014	631.38	80.78	365.50	106.94	925.85	329.95
2015	624.32	80.61	369.25	107.79	960.42	324.48
2016	617.93	80.45	373.09	108.65	994.24	318.10
2017	612.11	80.30	377.01	109.53	1027.07	353.31
2018	606.81	80.17	381.01	110.42	1013.37	355.29
2019	601.95	80.05	385.10	111.33	1024.44	353.70
2020	597.49	79.94	389.28	112.26	1047.56	350.07
2021	593.37	79.83	393.55	113.19	1076.43	344.93
2022	589.55	79.74	397.91	114.15	1107.77	338.59
2023	586.00	79.65	402.36	115.12	1139.76	331.31
2024	582.68	79.57	406.91	116.11	1171.34	323.31
2025	579.56	79.49	411.56	117.11	1201.89	314.82
2026	576.62	79.42	416.31	118.13	1231.00	306.03
2027	573.84	79.35	421.17	119.17	1258.41	297.12
2028	571.20	79.28	426.14	120.22	1283.97	288.28
2029	568.69	79.22	431.21	121.29	1307.58	279.64
2030	566.28	79.16	436.40	122.38	1329.22	271.33

Search of realistic scenarios should be based on comparison of indicators – defined in different scenarios and expected in comparison with required investments for transfer from one situation to another.

Possibility of investments same as expected indicators are subject to negotiation process with stakeholders interested in development of water sector.

Interface improvement allows selection and comparison of options based on criteria, restrictions, and integrated assessments and search for rational, optimization solutions through dialogue with user (input of scenarios by user).
The user interface has been constructed, based on the following system principles: dialogue controlled by system, i.e. inflexible “rules of play” are established in working with the system such as what functional components can be handled, what forms of information display can be used, what key parameters should be set to process any information object; mixed structure of dialogue that enables to use simultaneously a number of different elements of dialogue on the screen, edit data fields before input. In other words, user has an opportunity to work with the form until he presses appropriate button that means, for example, exit from the form and so on. Moreover, while developing a user interface, numerous requirements that are usually set to modern software products were fulfilled.

5. Resultant indicators of projected scenarios

Combination of various sub-scenarios, based on results of the main water factors, comes to eight different combinations as shown in the Table 5.1.

Table 5.1
Matrix of hydrological scenarios

	Water	SE BAU	SE Optim.
Climate ECHAM	BAU	1	5
Climate HADCM2	BAU	2	6
Climate ECHAM	Optim.	3	7
Climate HADCM2	Optim.	4	8

Thus, the total quantity of scenarios to be considered is 8. Let us take their combination as generalized scenarios:

№ 1 - Climate ECHAM, water "business as usual", socio-economic and agricultural – «business as usual».
№ 2 - Climate HADCM2, water "business as usual ", socio-economic and agricultural – business as usual.
№ 3 - Climate ECHAM, water "optimistic", socio-economic and agricultural – business as usual.
№ 4 - Climate HADCM2, water "optimistic", socio-economic and agricultural – business as usual.
№ 5 - Climate ECHAM, water "business as usual", socio-economic and agricultural - optimistic.
№ 6 - Climate HADCM2, water "business as usual", socio-economic and agricultural – optimistic.
№ 7 - Climate ECHAM, water "optimistic", socio-economic and agricultural – optimistic.
№ 8 - Climate HADCM2, water "optimistic", socio-economic and agricultural – optimistic.

Let's consider the results from running separate combined scenarios, first of all, water-climatic ones.

5.1. Projection of water-climatic scenarios

We should remind that water-climatic scenario, per se, is notable for the climate model, which determines water resources in the flow formation zone, the presence or non-presence of Pskem reservoir allowing improvement of regulation and distribution functions and of systems' efficiency coefficient, with following effect on amount of water consumption. Main parameters and combination of those four scenarios on water resources are shown in the Table 5.2 and Figure 5.1 demonstrating dynamics of annual flow hydrograph fluctuation.

Table 5.2
Total annual river flow by different scenarios, 2003 … 2030, Mm^3

YEAR	ECHAM	HADCM2
2003	9212	9212
2004	7120	7142
2005	9830	9929
2006	7908	8019
2007	5343	5440
2008	7503	7633
2009	6592	6746
2010	11950	12375

2011	8841	9546
2012	5131	5789
2013	5464	6004
2014	9171	9486
2015	9387	9718
2016	7263	7540
2017	9997	10275
2018	8102	8524
2019	5595	6016
2020	7688	7975
2021	6662	6944
2022	12552	13475
2023	9909	11612
2024	5154	5871
2025	5681	6098
2026	9272	9934
2027	9558	10242
2028	7463	7969
2029	10204	10712
2030	8359	9041

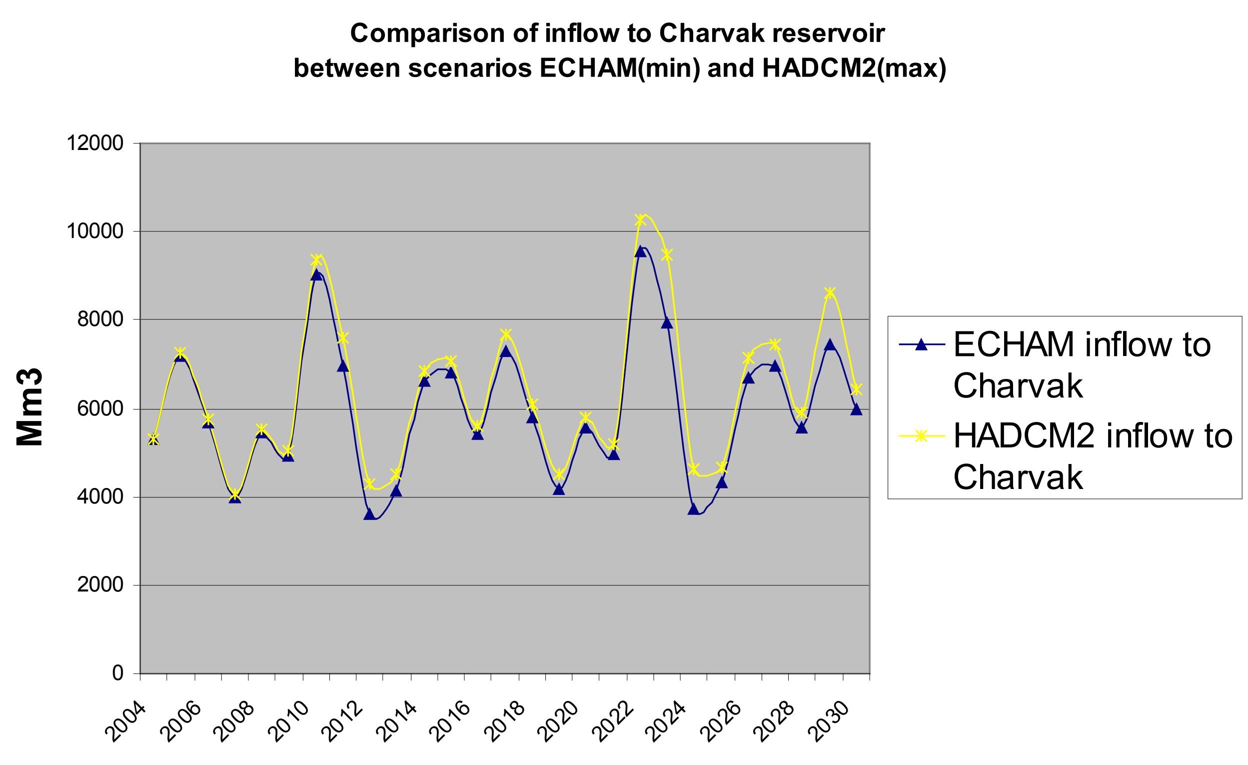


Figure 5.1. Dynamics of inflow to Charvak reservoir over 2003 … 2030

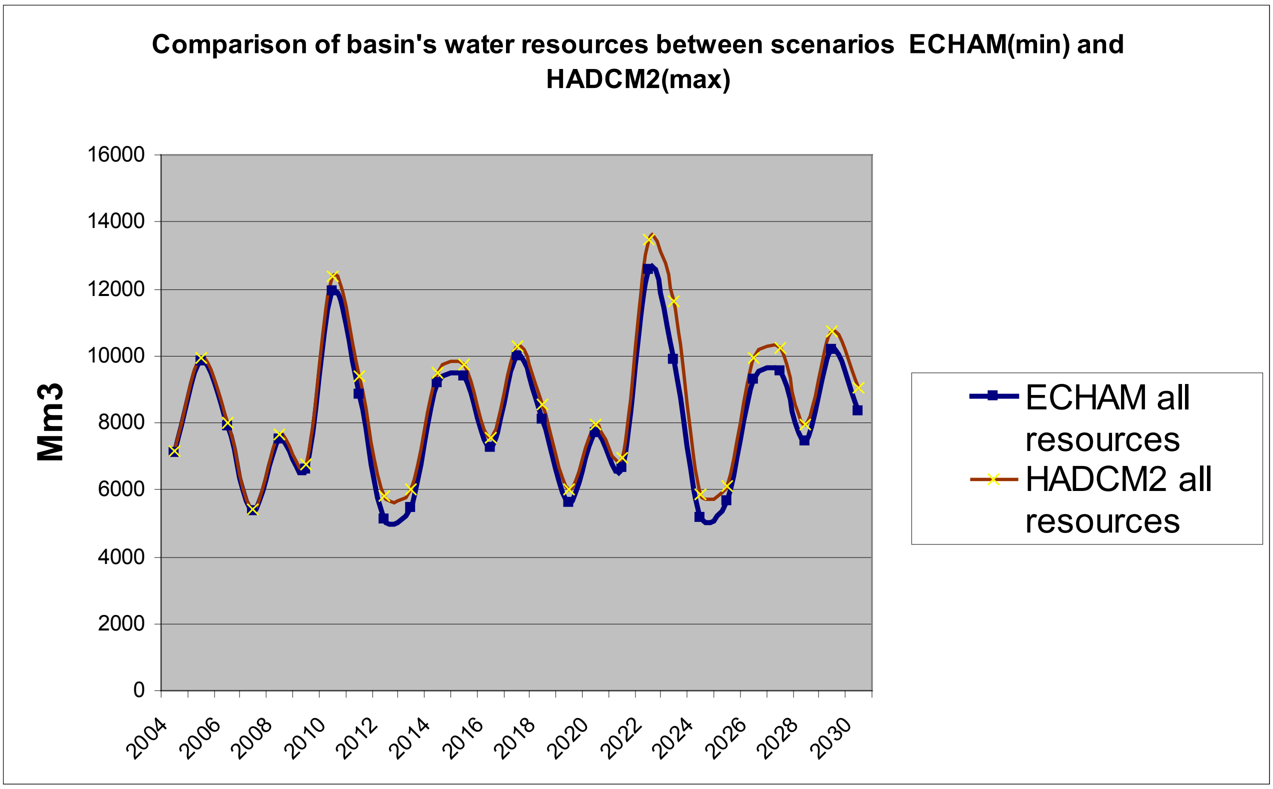


Figure 5.1.a Dynamics of basin's water resources over 2003…2030

As is shown, in general, the courses of two climatic scenarios are quite synchronous, and the annual quadratic deviation of flow is 6.6 % for total water resources and 8.35% for flow to Charvak reservoir (scenario ECHAM BAU and scenario HADCM2 optimistic), while the maximum is 14 % in 2023. Wider spread of deviations is obtained from maximum monthly values (Table 5.3) reaching 16 % in 2011, 18,6 % in 2013, and 25 % (!!) in 2023, as well as minimum values: 30,8 % – 2013; 29,4 and 26 % – 2015-2016. On the other hand, by trend, correlation of maximum and minimum flow values in 2015 to 2017 is notable.

Table 5.3

Relation of characteristic flow indicators for climatic series, 2003 … 2030

	HADCM2				ECHAM			
	Annual flow	Charvak	max monthly	min monthly	Annual flow	Charvak	max monthly	min monthly
2003	9212	6712	2200	155	9212	6712	2200	155
4	7142	5311	1707	123	7120	5295	1700	121
5	9929	7245	2329	166	9830	7176	2315	163
6	8019	5742	1533	227	7908	5670	1522	220
7	5440	4070	916	141	5343	3997	908	138
8	7633	5548	1623	147	7503	5456	1600	144
9	6746	5039	1643	129	6592	4926	1596	122
10	12375	9380	2875	234	11950	9042	2806	225
11	9546	7601	2146	218	8841	6963	2440	206
12	5789	4288	1101	177	5131	3593	965	184
13	6004	4519	1087	202	5464	4153	929	247
14	9486	6846	2057	316	9171	6622	2007	296

15	9718	7063	2272	163	9387	6826	2192	156
16	7540	5608	751	131	7263	5408	1699	124
17	10275	7680	2395	177	9997	7314	2292	169
18	8524	6087	1591	306	8102	5790	1534	224
19	6016	4528	1033	145	5595	4185	928	140
20	7975	5790	1674	154	7688	5583	1628	146
21	6944	5175	1673	135	6662	4971	1600	127
22	13475	10280	2976	260	12552	9540	2823	240
23	11612	9496	2925	248	9909	7944	3162	222
24	5871	4640	1387	156	5154	3718	970	173
25	6098	4653	958	212	5681	4326	940	252
26	9934	7143	2119	335	9272	6688	2012	290
27	10242	7431	2344	173	9558	6944	2194	160
28	7969	5917	1812	136	7463	5553	1706	129
29	10712	8096	2425	448	10204	7465	2298	174
30	9041	6443	1649	252	8359	5966	1553	228

Dynamics of water consumption in irrigated agriculture for four scenarios is shown in the Figure 5.2 and Table 5.4.

Table 5.4

Comparison of calculated water consumption in irrigated agriculture over 2003 – 2030, Mm^3/year

YEAR	ECHAM_AsUsual	ECHAM_Optimistic	HADCM2_AsUsual	HADCM2_Optimistic
2003	2785	2785	2785	2785
2004	2721	2700	2717	2696
2005	2701	2667	2694	2660
2006	2983	2933	2975	2924
2007	3418	3343	3412	3338
2008	3264	3185	3255	3171
2009	3362	3264	3355	3257
2010	3027	2929	3011	2913
2011	2922	2801	2904	2781
2012	3618	3452	3613	3445
2013	3646	3465	3644	3459
2014	3114	2941	3100	2927
2015	3086	2904	3068	2888
2016	3001	2815	2984	2799
2017	2978	2779	2953	2754
2018	3299	3065	3279	3042
2019	3763	3482	3752	3469
2020	3593	3312	3572	3287
2021	3726	3418	3708	3401
2022	3329	3048	3290	3011
2023	3198	2903	3165	2860
2024	3983	3602	3966	3585
2025	4012	3612	4001	3601

2026	3435	3072	3405	3044
2027	3404	3036	3369	3004
2028	3303	2935	3271	2907
2029	3277	2897	3232	2854
2030	3639	3203	3594	3162

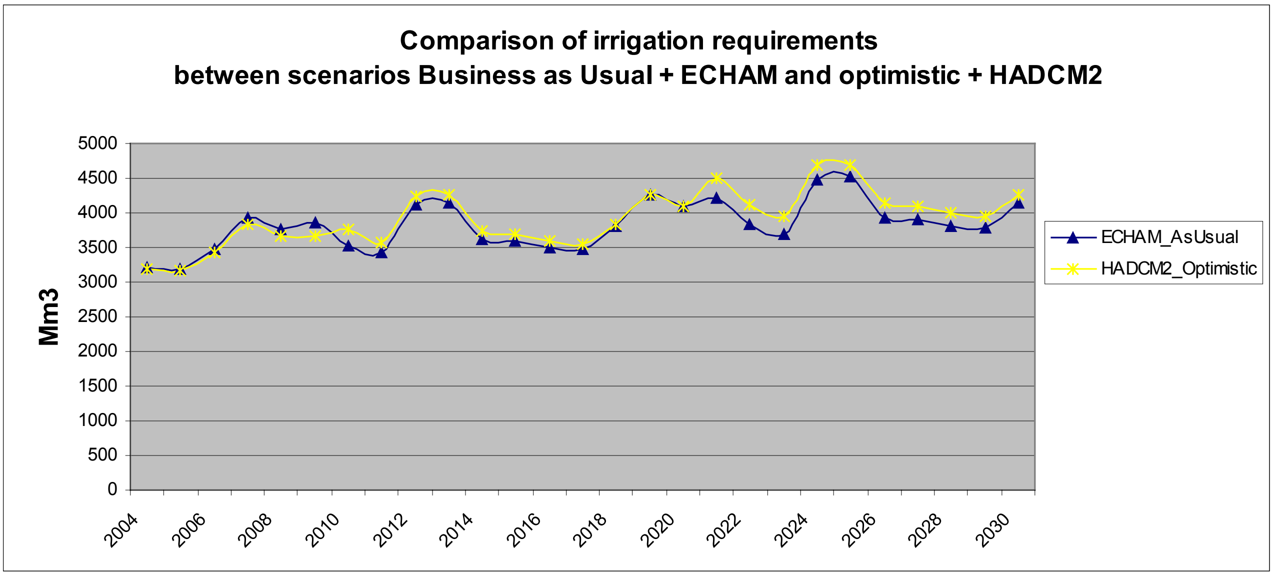


Figure 5.2. Dynamics of water demand in irrigated agriculture, 2003 … 2030

Correlation of annual water consumption values in the options "BAU" and "optimistic" is minor within 1 … 3%, not only for annual but also for monthly water requirements (Table 5.4a), while the difference between the extreme scenarios "ECHAM-BAU" and "HADCM2 optimistic" is considerable and varies within 8 -13 %. Such differences allow us to exclude from consideration scenarios "ECHAM optimistic" and "HADCM2-BAU" and consider only scenarios "ECHAM-BAU" and "HADCM2 optimistic". One should note here that demands of drinking water-supply, thermal electric stations, and industry are met in full, whereas under current level of management the demand of irrigated agriculture is met with large fluctuations in the option “business as usual”. Degree of meeting demand of various irrigation zones is shown in the Table 5.5 for this option. Here, calculated irregularity of water consumption in this scenario corresponds to actual situation of water distribution and water availability in different zones. Comparison of modeling results of water supply and water allocation between planning zones in optimistic scenario showed significant improvement (Table 5.5.):

- average annual delivery to water users increases for irrigation by 165 Mm^3, but in water scarce year (2024), when water demand becomes higher, by 339 Mm^3 or almost 10 % of requirements (Fig. 5.3);
- hydropower generation increases on average 27 year level from 3566 to 3987 or 11 %, but production after putting into operation of Pskem HPS increases by the level of 2030 up to 30 %!;
- average level of water availability between irrigation planning zones increases from 87 to 97 %, quantity of water scarce months reduces from 29 to 19 %, minimal water guarantee for each planning zone increases on 7 %.

Nevertheless, as was indicated in the BWO’s conclusion and negotiations with stakeholders further analytical upgrading of modeling tool needs to be done for clarification of some "bottlenecks" that created obstacles for more equal water allocation between irrigation systems and increase of water availability of water use.

Table 5.4a

Monthly water requirements for irrigation in different scenarios

2010

	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
ECHAM_AsUsual	0	0	37,6	68,9	328,1	739,5	902,2	593,7	206,4	126,2	24,5	0
ECHAM_Optimistic	0	0	36,5	65,9	320,9	726,9	877,3	554,2	199,2	123,7	24,1	0
HADCM2_AsUsual	0	0	37,5	68,2	325,6	736,2	897,5	592,4	203,8	125	24,3	0
HADCM2_Optimistic	0	0	36,1	65,5	318,1	723,9	872,7	553,3	197	122,3	23,6	0

2015

	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
ECHAM_AsUsual	0	0	35,9	5,9	255,7	707	1010,7	662	229,1	145,6	33,9	0
ECHAM_Optimistic	0	0	34	5,6	246,4	682,3	957,7	587,1	217,7	141	32,4	0
HADCM2_AsUsual	0	0	35,7	5,6	249,9	698,5	1009,7	662	228,9	144,4	33,7	0
HADCM2_Optimistic	0	0	33,7	5,2	241	674,5	956,4	587	217,6	140,4	32,2	0

2020

	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
ECHAM_AsUsual	0	0	42	36,5	501,6	914,7	1046,1	679,8	192,7	136,1	43,6	0
ECHAM_Optimistic	0	0	38,4	32,2	467,5	861,8	971,1	590,5	179,6	128,9	41,6	0
HADCM2_AsUsual	0	0	41,8	35,8	500,3	913,8	1042,3	678	184,5	132,9	42,4	0
HADCM2_Optimistic	0	0	38	31,6	465,9	858,5	966,8	588,2	171,7	125,5	40,6	0

2025

	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
ECHAM_AsUsual	0	0	48,5	106,1	667,7	1072,9	1085,4	655,8	220,5	125	30,2	0,1
ECHAM_Optimistic	0	0	37,6	17,6	316,2	903,8	1031	597,6	155,1	119,7	23,9	0
HADCM2_AsUsual	0	0	48,2	105	666,6	1072	1082,7	655	218,4	123,1	30,2	0,1
HADCM2_Optimistic	0	0	43,8	90,6	612,6	990	980,5	544,2	200,6	111,8	27,3	0

Table 5.5

Comparison of dynamics of water delivery to different economic sectors in different scenarios

	INTAKE IRIGATION		VODOKANAL		INDASTIAL+ENERG		INTAKE TOTAL		INTAKE KAZAHSTAN	
	BAU/ECHAM	OPT/HADCM2	BAU/ECHAM	OPT/HADCM2	BAU/ECHAM	OPT/HADCM2	BAU/ECHAM	OPT/HADCM2	BAU/ECHAM	OPT/HADCM2
2003	2836	2836	798	798	476	476	4110	4110	489	489
2004	2718	2785	792	785	438	467	3948	4037	478	480
2005	2806	2834	899	881	465	460	4170	4175	490	490
2006	2933	3016	861	969	487	495	4281	4480	497	488
2007	3400	3333	941	845	451	458	4792	4636	491	492
2008	3218	3207	861	859	463	465	4542	4531	489	489
2009	3098	3088	778	767	450	459	4326	4314	478	479
2010	3250	3118	900	934	476	464	4626	4516	492	492
2011	2965	3318	850	846	409	467	4224	4631	490	773
2012	3276	3517	885	831	431	432	4592	4780	467	708
2013	3305	3540	837	771	456	457	4598	4768	460	711
2014	3086	3293	967	922	473	452	4526	4667	489	757
2015	2949	3219	876	872	440	463	4265	4554	489	772
2016	2892	3082	860	854	475	475	4227	4411	487	777
2017	2983	3160	876	921	446	470	4305	4551	490	778
2018	3281	3303	916	1008	464	487	4661	4798	489	772
2019	3624	3673	837	840	451	455	4912	4968	489	758
2020	3573	3589	888	843	472	449	4933	4881	488	750
2021	3563	3762	802	774	457	438	4822	4974	477	984
2022	3314	3688	900	916	471	466	4685	5070	492	1044
2023	3292	3596	947	888	479	456	4718	4940	497	1047
2024	3694	4033	779	834	427	425	4900	5292	462	978
2025	3707	3938	819	819	440	440	4966	5197	486	954
2026	3161	3526	917	917	477	477	4555	4920	459	929
2027	3310	3524	957	957	477	477	4744	4958	489	957
2028	3156	3477	942	942	475	475	4573	4894	466	999
2029	3197	3571	901	901	446	446	4544	4918	492	1047
2030	3351	3528	939	939	470	470	4760	4937	471	924
	89938	94554	24525	24433	12842	12921	127305	131908	13533	21318
	3212	**3377**	**876**	**873**	**459**	**461**	**4547**	**4711**	**483**	**761**

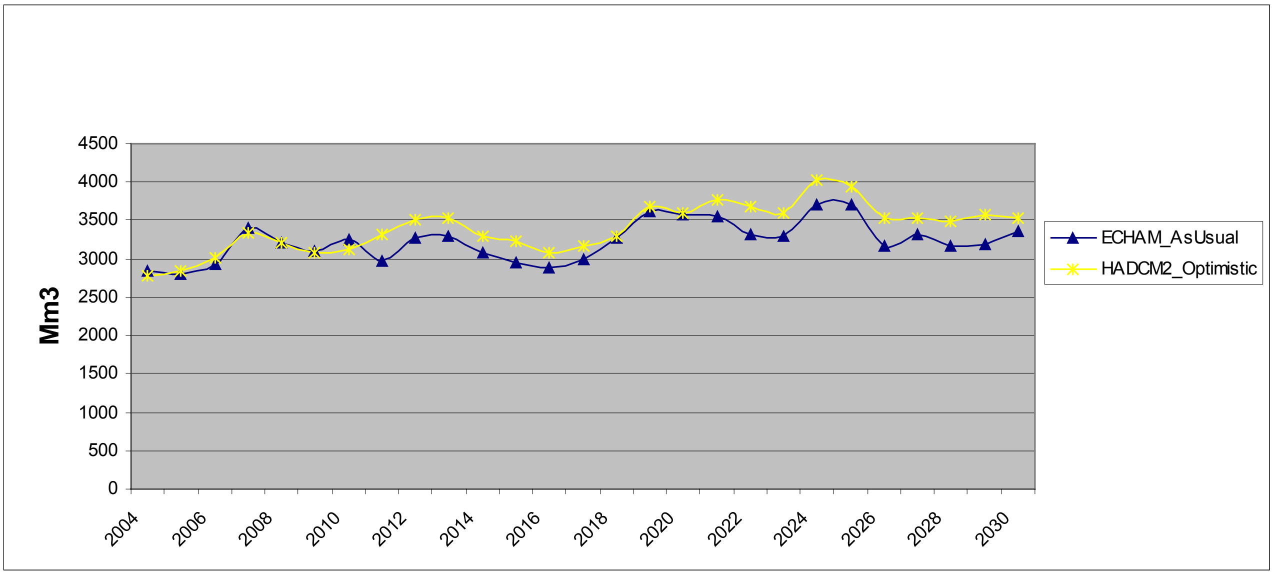


Figure 5.3. Comparison of water withdrawals (simulation) for irrigation in planning zones between scenarios BAU+ECHAM and optimistic+HADCM2

Comparison of guarantee of ecological flow is indicated in the Table 5.6. Quantity of years that do not meet environmental requirements for the Chirchik river is reduced 3 times, but Akhangaran river satisfaction is full in optimistic option.

Table 5.6

Meeting ecological releases along the rivers and in suggested scenarios for environmentally unstable periods

№	Indicator	Options	Units	May	June	July	August
Chirchik river – Chinaz gauging station (mouth)							
1	Environmental requirements	BAU	Mm^3	32	34	22	9
		Optim		32	34	22	9
2	Mean runoff over 2003-2030	BAU	Mm^3	168	233	9	175
		Optim		225	190	20	245
3	Number of irregular supply years*	BAU	%	46	71	100	21
		Optim		14	25	39	0
4	Environmental shortage on mean runoff over 2003-2030	BAU	Mm^3	0	0	13	0
		Optim		0	0	2	0
5	Maximum environmental shortage	BAU	Mm^3	25	26	15	1
		Optim		25	26	15	0
Akhangaran river – Soldatskoye gauging station (mouth)							
1	Environmental requirements	BAU	Mm^3	16	5	2	2
		Optim		16	5	2	2
2	Mean runoff over 2003-2030	BAU	Mm^3	231	335	455	167
		Optim		252	361	542	91
3	Number of irregular supply years	BAU	%	7	0	0	0
		Optim		0	0	0	0

* Years, when even minimum environmental requirements are not satisfied.

5.2. Resulting socio-economic and agrarian scenarios

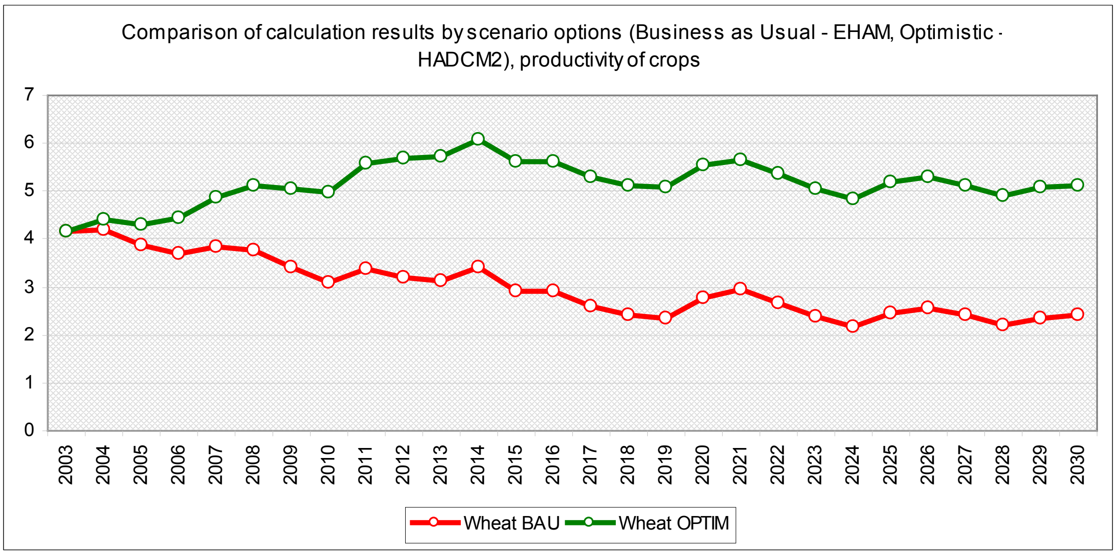
Taking into account that direct impact of water availability is only in agrarian scenarios, we created 4 mixed climate – water – agrarian scenarios that will be combined with the socio-economic scenarios:

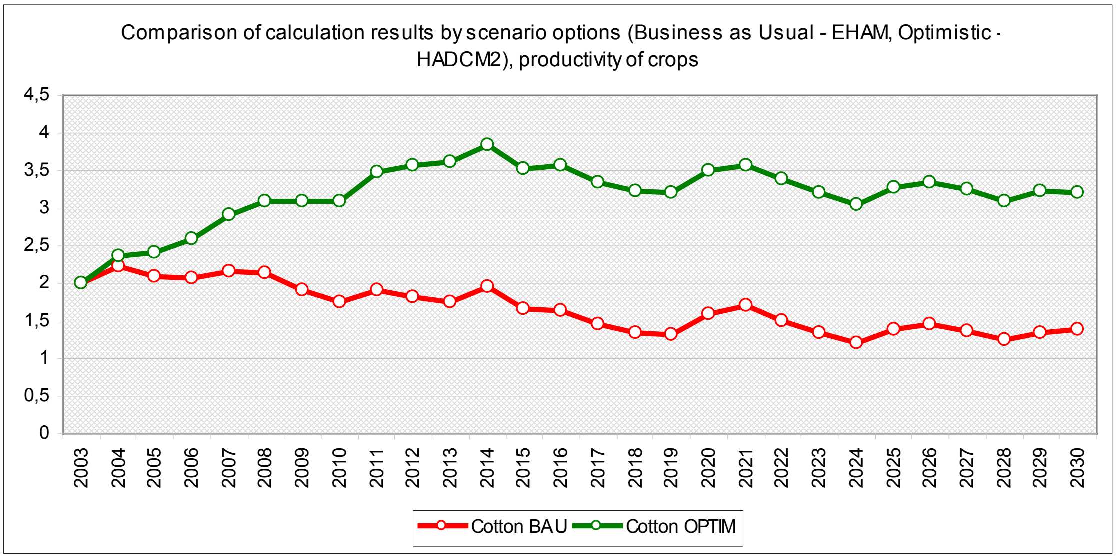
- agrarian BAU – ECHAM BAU;
- agrarian BAU – HADCM optim;
- agrarian optim – ECHAM BAU;
- agrarian optim – HADCM optim.

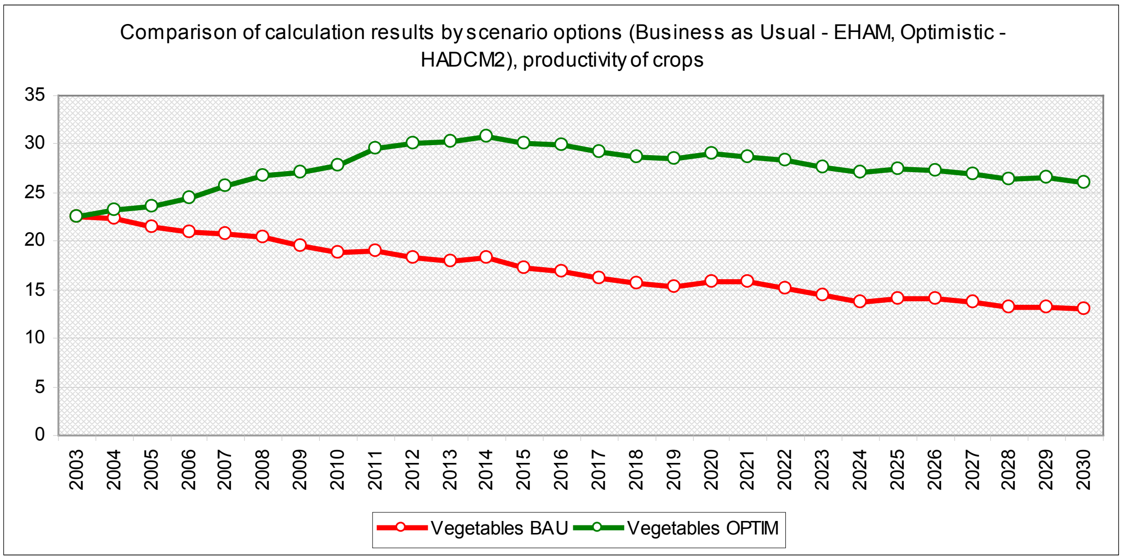
Scenario "business as usual" is built on existing trends. Under this scenario, actual situation in agriculture will be maintained, with some indicators changing for the worse. Determinant factors that ground quantitative scenario indicators are:

- low level of application of mineral fertilizers, their limited variety and untimely application. This has negative effect on soil fertility;
- deterioration of reclamative state of lands, especially of soil structure characteristics caused by under-application of organic and mineral fertilizers, application of earthing methods (aryk silt, barrow soil, etc.) on light soils for their mudding, performance of limited scope of tillage, use of longspan blade levellers;
- reduction of resource inputs in agricultural production and degree of mechanical operations;
- limited access for farmers and land users to funds and loans, narrowness of services, purchasing prices of agricultural products and trade policy;
- impossibility to earn profit, which is necessary for reproduction in lands, poor orientation to market needs due to priority of state order;
- farm restructuring that caused occurrence of huge amount of small owners having limited capabilities to keep modern farming. At present, this has led to decrease in extent of mechanical operations and to drop of crop yields.

As a result, tendency to reduction of land productivity will be leading in these scenarios, based on the algorithm that was proposed in report D 32, not only by natural reason, but also man – induced. This will be reflected in the level of BAU yield by 2030 somewhat less than predicted in the Tables 3.19 – 3.20 by estimation of potential productivity of lands.
Optimistic scenarios will also have impact on this factor, only implementation of modern technology, FAO norm of fertilizers will reduce this impact significantly even to positive trend in last 10 years of predicted period (Fig. 5.3).


Comparison of calculation results by scenario options (Business as Usual - EHAM, Optimistic - HADCM2), productivity of crops
7
6
5
4
3
2
1
0
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Wheat BAU
Wheat OPTIM


Comparison of calculation results by scenario options (Business as Usual - EHAM, Optimistic - HADCM2), productivity of crops
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Cotton BAU
Cotton OPTIM


Comparison of calculation results by scenario options (Business as Usual - EHAM, Optimistic - HADCM2), productivity of crops
35
30
25
20
15
10
5
0
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Vegetables BAU
Vegetables OPTIM

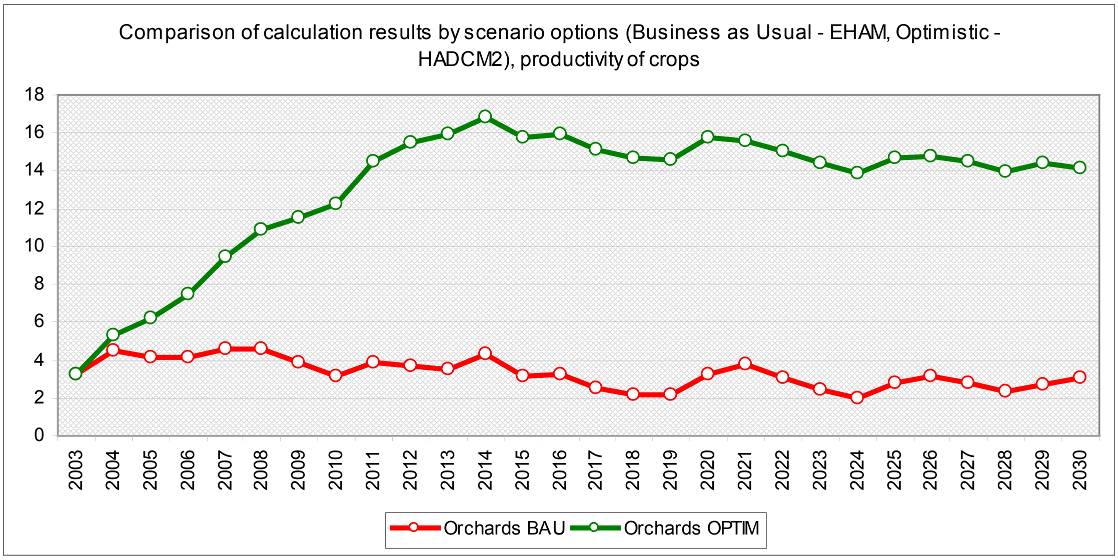


Figure 5.3. Crop productivity calculation results in different scenario options

The implementation of this scope of measures will allow mobilization of more incentives and investments from own resources of agrarian sector that will increase for the whole period of forecast from 210 to 791 million USD.

On the base of such initial position, in order to implement the optimistic socio-economic scenario, we need more than 1678 million USD of investment. This is two times more than investments made in the scenario "business as usual" at present level. Such shift will require gradual input of material resources into the sector, and it is proposed to use cheap methods and technologies at the first stage of scenario implementation. One of ways to achieve quantitative indicators of this scenario is to develop extension services for farmers and to raise the level of agricultural knowledge of land users. Agricultural development is feasible only in case of using cost-effective specialization and free choice of cultivated crops. Besides, it is necessary to make institutional changes in the field of water and land resources management, develop machine and tractor pools with full set of necessary agricultural equipment, optimize maintenance, develop selection and seed-farming, and undertake stock breeding in animal husbandry. An important factor for scenario implementation is unrestricted access for producer to funds and loans. This will allow him to choose independently seeds, fertilizers, pesticides and insecticides, and veterinary medicines. Support of the government is expected through rise of purchasing prices of strategic crops, in trade policy and promotion of free market and competition.

We received, as a result, 4 different options of crop yields, productivity of land and GNP in agrarian sector. Below dynamics of yield as a main indicator of productivity is given.

Table 5.7

Projection of crop yields for different scenarios, t/ha

Crops		**Scenarios**				
	Agrarian	actual	BAU	BAU	Opt	Opt
	Climate-water		ECHAM	HADCM - optim.	BAU ECHAM	Opt. HADCM
		2000	2030	2030	2030	2030
Farms						
cucurbits		17,0	9,77	9,80	24,68	24,77
grapes		2,38	4,27	4,23	10,95	17,00
cereals		4,16	2,43	2,43	5,09	5,11
potato		21,18	11,51	11,54	24,70	24,78

maize	3,83	2,12	1,12	6,03	6,05
maize for silos	26,87	14,93	14,98	32,90	33,09
perennial grass for cattle	26,90	15,99	16,04	36,74	36,85
perennial grass for hay	10,44	6,04	6,056	15,05	15,09
grass first year for cattle	15,68	10,47	10,50	34,98	25,05
grass first year for hay	5,47	3,29	3,30	7,70	7,72
vegetables	22,49	13,08	13,12	25,94	26,02
rice	3,96	2,36	2,37	5,17	5,19
fruits	3,21	3,03	3,24	14,05	14,09
cotton	2,28	1,39	1,39	3,20	3,21
root crops	30,64	17,35	17,40	31,67	31,76
Non-irrigated lands	2003				
cereals	0,91	1,22	1,22	1,61	1,62
grass for hay	4,42	3,30	3,30	4,55	4,56
fruits	1,13	1,32	1,32	1,73	1,74
cotton	0,73	0,79	0,79	1,08	1,09
grapes	2,30	2,62	2,63	3,45	3,46
Private plots					
grape	4,90	8,31	8,33	22,38	22,45
maize	4,60	4,63	4,64	8,05	8,08
vegetables	30,3	30,64	30,73	35,25	35,35
potato	29,9	31,01	31,10	31,01	34,20
fruits	5,7	6,51	6,53	18,52	18,68

The forecast of yields resulted in small impact of water-climate scenarios and principal difference in agricultural scenarios BAU and optimistic. Such result is clear because curve of influence of water availability on the yield has in the range 0,80 … 1,0 of water availability small reaction of yield (Fig. 5.4). Their impact is felt more only in water scarce years, where this small difference in water availability acts simultaneously with other occasional factors.

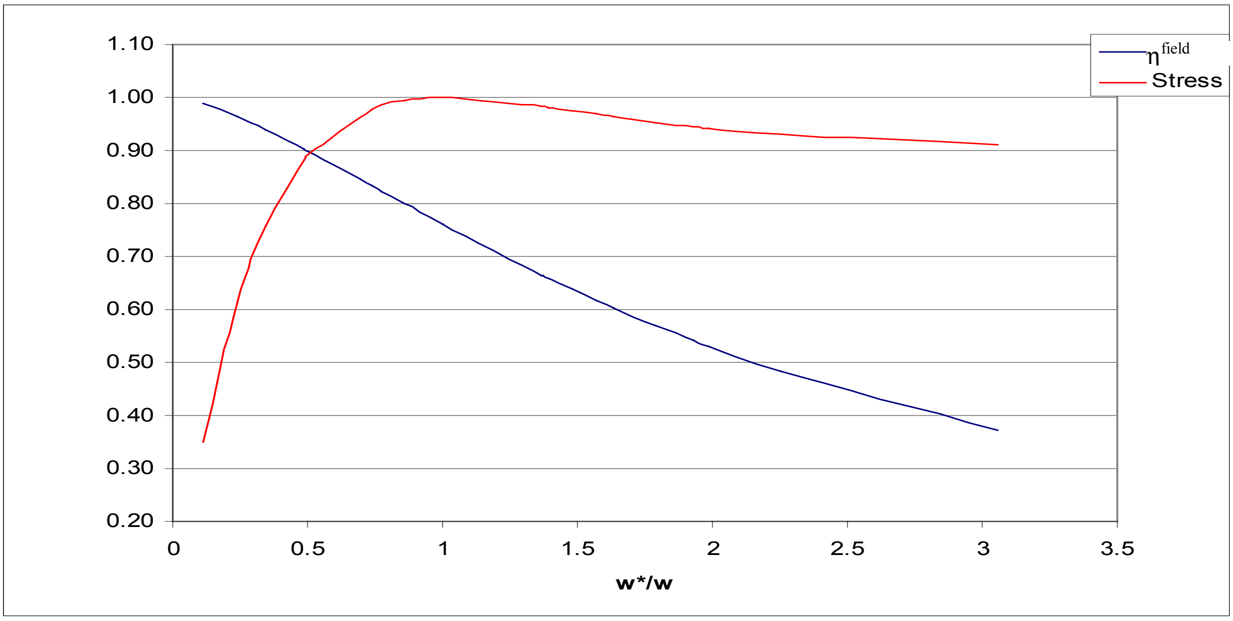


Figure 5.4. Functions of efficiency and stress depending on water availability in the district

Practically – agrarian optimistic option by the level of yield is approaching to potential productivity of this land that was predicted in the socio-economic modeling (deliverable D 32). This level based on exclusively high potentialities of getting high yields under conditions of irrigated agriculture in Uzbekistan (11):

orchards, grapes	20,0 – 30,0 t/ha
cotton	4,5 – 5,0 t/ha
maize for grain	10,0 – 12,0 t/ha
cereals	7,0 – 9,0 t/ha
rice	7,5 – 8,5 t/ha
potato	35,0 – 40,0 t/ha
maize for silage	45,0 – 53,0 t/ha
perennial grass	35,0 – 40,0 t/ha
vegetables	32,0 – 38,0 t/ha
cucurbits	34,0 – 43,0 t/ha
root crops	40,0 – 50,0 t/ha

Achievement of this level requires:

- completion of process of farm restructuring;
- establishment of extension service for development for each farm of adapted recommendations to achieve potential yield and strong following by these technological rules;
- almost two-fold increase of fertilizer input;
- access to credit line;
- creation of conditions for stable and guaranteed water supply through implementation of IWRM;
- creation of market infrastructure.

The interesting aspects in this forecast are as follows:

- the total volume of agrarian products in BAU scenarios reduced by 2030 to 40 million USD or 17 % of initial level, livestock at the same time goes up by 60 million USD or 30 %. Decline in agrarian production is caused by steady deterioration of land fertility as a result of insufficient input in lands;
- the total volume of agrarian products in optimistic scenarios in 2030 is almost two times more than in BAU and 1,7 times higher than in 2003; situation in livestock production is improving in both scenarios, only in BAU from 237,3 by 298,7 million USD or 125,87 % and in optimistic - from 237,3 by 623,8 million USD or 262,87 % (Fig. 5.5).

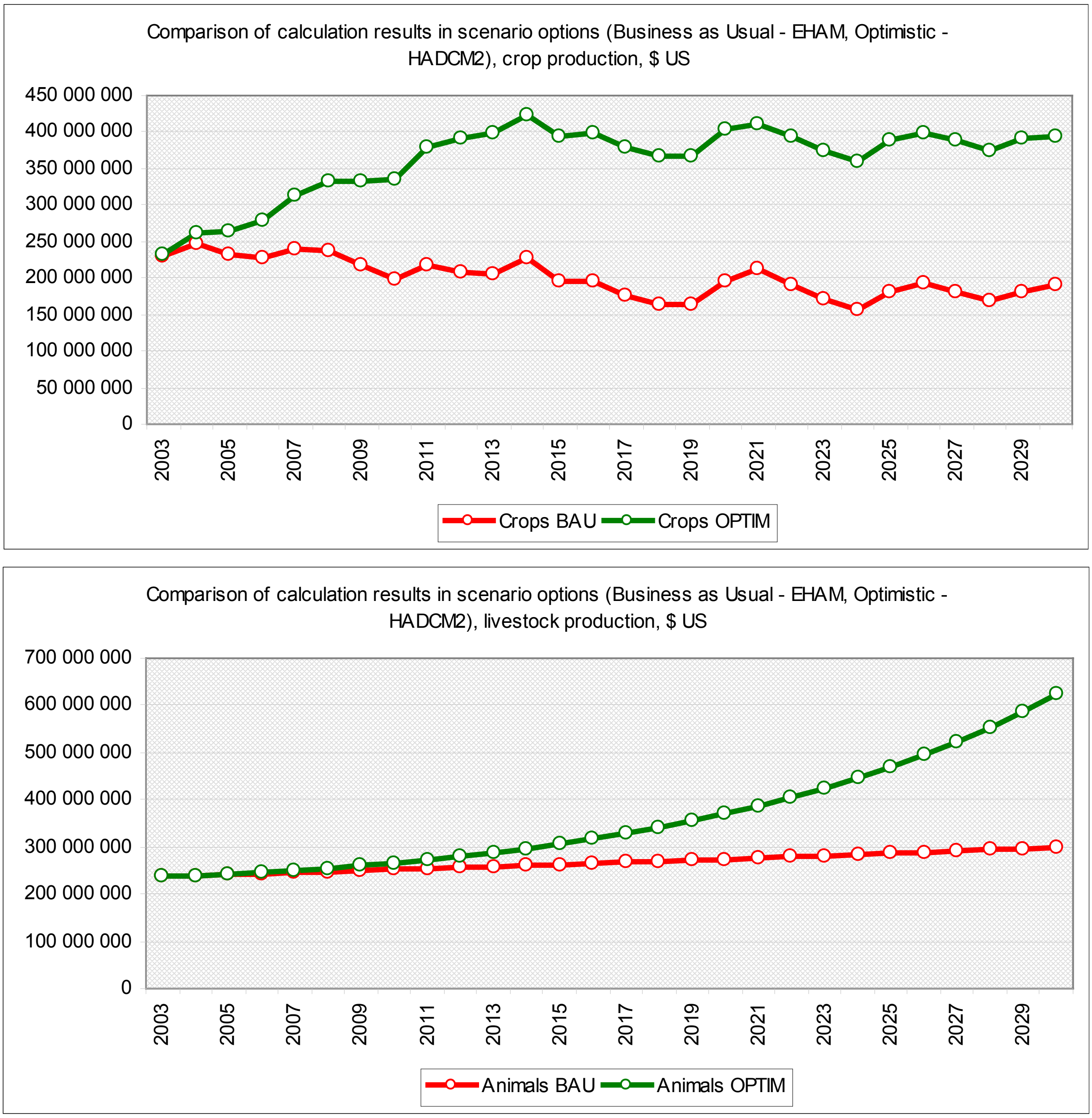


Figure 5.5 Crop and livestock production in 2 scenario options

As a result, in both scenarios we have got different tendencies in crop production and especially main foodstuff production.

Table 5.8

Comparison between production and consumption, thousand t

	Production, annual			Consumption, annual			% of satisfaction		
	2003	BAU 2030	opt. 2030	2003	BAU 2030	opt. 2030	2003	BAU 2030	opt. 2030
Vegetable	828,33	602,54	1067,37	571,915	750,234	729,948	145	80	146
Wheat	450,49	305,02	627,01	872,663	1144,753	1113,8	52	27	56
Potatoes	375,39	341,5	464,13	142,979	187,558	182,487	263	182	254
Rice	32,42	20,98	46,84	49,303	64,675	62,927	66	32	74
Fruits	215,19	304,68	993,12	192,282	252,234	245,414	112	121	405
Meat	72,09821	94,6576	197,4328	147,909	194,026	188,78	49	49	105
Eggs (pcs.)	419003,2	479403,3	1003673	295818	388052	377559	142	124	266
Milk	356,172	465,9474	972,0029	912,106	1196,493	1164,141	39	39	83

GNP in agriculture	352,7601	355,4689	751,7381						

The livestock, even in BAU scenarios, gave positive trends in satisfaction of food production of all types, but satisfaction in BAU of crops for almost all kind of products became worse. "Optimistic" scenarios produced very important positive result in increase of wellbeing of agrarian population – GNP in agricultural sector instead of 118 % growth in BAU scenarios has 346 % growth in optimistic scenarios that means that this should provoke growth of GNP in rural area at least 2,5 times!!!

5.2.1. Building socio-economic scenarios

Socio-economic scenarios are based on the following forecasts:

- demographic indicators in two options;
- development of three main economic sectors that are 100% covered with water-supply (industry, agro-industry and services);
- agricultural development depending on degree of water-supply.

Undoubtedly, dynamics of agro-industry and services sector, as is shown in the report D-25 and D-27, indirectly depends on water supply, since volume and GDP of these sectors are derivatives of agriculture. The complexity of building socio-economic scenarios is that the main determinant of these scenarios – amounts of investment made in the sectors – is uncertain to a great extent. The financing sources are, first of all, internal investments that for the scenario "BAU" are less than 20 % in industry, 90 % in agro-industry, and 75 % in services. At the same time, interesting fact occurs from actual trends and inputs in the scenario "BAU" – values of specific required capital investments in the sectors are quite different, both regarding maintenance of available assets and their development.

In the scenario "BAU", industrial production, which does not depend on agricultural production and water availability, will keep falling until level of own investments and borrowed funds promotes stabilization and maintenance of this industry. Given current investments of 115-120 M$/year, such level will be achieved around 2020, when volume of industrial production changes within 1 % per year. Agroindustry started to grow and current level of investments would ensure slow but regular growth of this sector. Faster growth is observed in services sector since 2000, with the average rate or more than 2 % per year, and even in the scenario "BAU" it will increase almost two-fold in 2030 (Table 5.9).

Table 5.9

Dynamics of socio-economic indicators in BAU scenarios

BAU	Industry					AgroIndustry				Services			
	GP	GDP	Ext_Invest	Invest	Int_Invest	GP	GDP	Ext_Invest	Invest	Int_Invest	GP	GDP	Ext_Invest	Invest
	M$	M$	M$	M$	M$	M$	M$	M$	M$	M$	M$	M$	M$	M$
2003	797.40	167.45	55.39	115.19	59.80	322.14	112.75	8.00	67.26	59.26	524.99	393.74	83.69	187.07
2004	788.41	165.57	65.00	124.13	59.13	320.55	112.19	8.00	83.04	75.04	533.85	400.38	83.69	214.58
2005	779.56	163.71	65.00	123.47	58.47	320.35	112.12	8.00	83.00	75.00	545.40	409.05	83.69	216.18
2006	771.02	161.91	65.00	122.83	57.83	320.83	112.29	8.00	83.10	75.10	558.44	418.83	83.69	217.91
2007	762.92	160.21	65.00	122.22	57.22	321.65	112.58	8.00	83.27	75.27	572.33	429.24	83.69	219.69
2008	755.32	158.62	65.00	121.65	56.65	322.65	112.93	8.00	83.48	75.48	586.77	440.08	83.69	221.46
2009	748.27	157.14	65.00	121.12	56.12	323.74	113.31	8.00	83.70	75.70	601.61	451.21	83.69	223.19
2010	741.77	155.77	65.00	120.63	55.63	324.89	113.71	8.00	83.94	75.94	616.76	462.57	83.69	224.87
2011	735.81	154.52	65.00	120.19	55.19	326.07	114.12	8.00	84.19	76.19	632.17	474.13	83.69	226.48
2012	730.37	153.38	65.00	119.78	54.78	327.27	114.54	8.00	84.44	76.44	647.83	485.87	83.69	228.03
2013	725.39	152.33	65.00	119.40	54.40	328.50	114.97	8.00	84.69	76.69	663.70	497.77	83.69	229.50
2014	720.84	151.38	65.00	119.06	54.06	329.74	115.41	8.00	84.95	76.95	679.77	509.82	83.69	230.88
2015	716.67	150.50	65.00	118.75	53.75	331.00	115.85	8.00	85.21	77.21	696.02	522.02	83.69	232.18
2016	712.85	149.70	65.00	118.46	53.46	332.28	116.30	8.00	85.47	77.47	712.45	534.34	83.69	233.39
2017	709.31	148.96	65.00	118.20	53.20	333.58	116.75	8.00	85.74	77.74	729.03	546.77	83.69	243.98
2018	706.03	148.27	65.00	117.95	52.95	334.90	117.21	8.00	86.01	78.01	711.79	533.84	83.69	242.38
2019	702.96	147.62	65.00	117.72	52.72	336.23	117.68	8.00	86.29	78.29	711.62	533.71	83.69	242.37
2020	700.08	147.02	65.00	117.51	52.51	337.59	118.16	8.00	86.56	78.56	719.69	539.77	83.69	243.13
2021	697.34	146.44	65.00	117.30	52.30	338.96	118.64	8.00	86.85	78.85	731.91	548.93	83.69	244.24
2022	694.74	145.90	65.00	117.11	52.11	340.35	119.12	8.00	87.13	79.13	746.28	559.71	83.69	245.48
2023	692.24	145.37	65.00	116.92	51.92	341.76	119.62	8.00	87.42	79.42	761.80	571.35	83.69	246.73
2024	689.82	144.86	65.00	116.74	51.74	343.20	120.12	8.00	87.71	79.71	777.98	583.49	83.69	247.95
2025	687.48	144.37	65.00	116.56	51.56	344.65	120.63	8.00	88.01	80.01	794.56	595.92	83.69	249.10
2026	685.19	143.89	65.00	116.39	51.39	346.12	121.14	8.00	88.31	80.31	811.39	608.54	83.69	250.16
2027	682.94	143.42	65.00	116.22	51.22	347.62	121.67	8.00	88.62	80.62	828.40	621.30	83.69	251.14
2028	680.74	142.96	65.00	116.06	51.06	349.13	122.20	8.00	88.92	80.92	845.54	634.16	83.69	252.02
2029	678.56	142.50	65.00	115.89	50.89	350.67	122.73	8.00	89.24	81.24	862.79	647.09	83.69	252.79
2030	676.41	142.05	65.00	115.73	50.73	352.23	123.28	8.00	89.55	81.55	880.10	660.07	83.69	253.47

Optimistic scenario assumes drastic increase in production capacity and partial reconstruction, at least aspired, up to level of the year 1990, of industrial potential through attraction of capital investments for prospective activities in mountain area and for further development of recreation and tourism infrastructure and agricultural processing that have all available capabilities. But the needed amount of capital investments for achievement in this scenario of 70 % of the year 1990 level is estimated at the year 2030 level as 993 million USD annually, that is two fold more than current level of investments (Table 5.10). The main direction is creating investment climate attractive for external investors since natural potential of mineral, availability of vacant and unfinished dwelling and development of regional infrastructure (energy, road) allow production of great effect for expansion of production capacities.

Table 5.10

Optimistic scenario 1 for socio-economic development

OPT_1	Industry		AgroIndustry		Services	
	GP	Invest	GP	Invest	GP	Invest
	M$		M$		M$	
2003	797.40	115.19	322.14	67.26	524.99	187.07
2004	926.77	669.51	320.55	83.04	528.57	138.54
2005	1010.77	675.81	320.35	83.00	532.15	139.05
2006	1069.91	680.24	320.83	83.10	535.74	139.56
2007	1115.80	683.69	321.65	83.27	539.35	140.06
2008	1155.07	686.63	322.65	83.48	542.99	140.56
2009	1191.51	689.36	323.74	83.70	546.65	141.06
2010	1227.21	692.04	324.89	83.94	550.35	141.55
2011	1263.30	694.75	326.07	84.19	554.06	142.05
2012	1300.33	697.52	327.27	84.44	557.81	142.54
2013	1338.48	700.39	328.50	84.69	561.59	143.03
2014	1377.77	703.33	329.74	84.95	565.39	143.52
2015	1418.08	706.36	331.00	85.21	569.22	144.01
2016	1459.27	709.45	332.28	85.47	573.07	144.49
2017	1501.15	712.59	333.58	85.74	576.96	150.92
2018	1543.56	715.77	334.90	86.01	554.25	147.55
2019	1586.32	718.97	336.23	86.29	545.20	146.16
2020	1629.29	722.20	337.59	86.56	542.57	145.75
2021	1672.34	725.43	338.96	86.85	543.03	145.83
2022	1715.35	728.65	340.35	87.13	545.01	146.13
2023	1758.22	731.87	341.76	87.42	547.75	146.56
2024	1800.87	735.07	343.20	87.71	550.89	147.04
2025	1843.23	738.24	344.65	88.01	554.23	147.55
2026	1885.25	741.39	346.12	88.31	557.69	148.08
2027	1926.86	744.51	347.62	88.62	561.23	148.61
2028	1968.04	747.60	349.13	88.92	564.81	149.14
2029	2008.74	750.66	350.67	89.24	568.44	149.68
2030	2048.96	753.67	352.23	89.55	572.11	150.22

Optimistic scenario 2 (realistic) for socio-economic development

OPT_2	Industry		AgroIndustry		Services	
	GP	Invest	GP	Invest	GP	Invest
	M$		M$		M$	
2003	797.40	115.19	322.14	67.26	524.99	187.07
2004	814.29	201.37	320.55	83.04	528.57	138.54
2005	826.44	202.28	320.35	83.00	532.15	139.05
2006	835.12	202.93	320.83	83.10	535.74	139.56

2007	841.31	203.40	321.65	83.27	539.35	140.06
2008	845.77	203.73	322.65	83.48	542.99	140.56
2009	849.07	203.98	323.74	83.70	546.65	141.06
2010	851.62	204.17	324.89	83.94	550.35	141.55
2011	853.73	204.33	326.07	84.19	554.06	142.05
2012	855.62	204.47	327.27	84.44	557.81	142.54
2013	857.41	204.61	328.50	84.69	561.59	143.03
2014	859.22	204.74	329.74	84.95	565.39	143.52
2015	861.08	204.88	331.00	85.21	569.22	144.01
2016	863.05	205.03	332.28	85.47	573.07	144.49
2017	865.12	205.18	333.58	85.74	576.96	150.92
2018	867.30	205.35	334.90	86.01	554.25	147.55
2019	869.58	205.52	336.23	86.29	545.20	146.16
2020	871.96	205.70	337.59	86.56	542.57	145.75
2021	874.42	205.88	338.96	86.85	543.03	145.83
2022	876.95	206.07	340.35	87.13	545.01	146.13
2023	879.53	206.27	341.76	87.42	547.75	146.56
2024	882.16	206.46	343.20	87.71	550.89	147.04
2025	884.81	206.66	344.65	88.01	554.23	147.55
2026	887.49	206.86	346.12	88.31	557.69	148.08
2027	890.17	207.06	347.62	88.62	561.23	148.61
2028	892.86	207.26	349.13	88.92	564.81	149.14
2029	895.54	207.47	350.67	89.24	568.44	149.68
2030	898.21	207.67	352.23	89.55	572.11	150.22

Besides, placement in the basin of the city of Tashkent as a huge centered consumer of goods, food, and services, where up to 30% of all national paying capacities and considerable number of foreigners are concentrated, opens great opportunities for rapid development of agro-industry and services. One particularly should note a tendency to development and growth of prosperous section of the population. This section tends to place their high-comfortable and expensive dwellings outside the megapolis, primarily in Kibray or Parkent districts but within the area of close connection with the city. This will promote growth of those less capital intensive but more cost effective economic sectors.

Not taking into account very brave expectation of "optimistic" scenarios, we use feasible approach that we call realistic (except for agricultural development) that is shown in the Table 5.10. As the Table shows, in order to transit from the scenario "BAU" to optimistic scenario in socio-economic development, the province needs annual capital investments of more than 500 millions or three times more than current ones.

In this scenario we don't expect additional big investments – only reallocation of 100 million USD annually from service sector to industry, taking into account that scale of self-development of this sector will guarantee sufficiency of services to population.

Comparative table for all scenarios and all indicators is given below (Table 5.11)

Table 5.11

Main calculation results on suggested scenarios

№№	Indicator	Units	Actual 2003	Calculation options		Expected for 2030 (realistic)
				BAU	Optim.	
1.	Mean long-term resources in the basin, mean for 2003-2030	km^3	8.390	8.677	8.973	
1.1	Surface runoff	km^3	7.890	8.107	8.403	
.	of which:	M^3				
	• Chirchik with tributaries	M^3	7000	7088	7363	
	• Akhangaran	M^3	720	729	747	
	• Keles	M^3	70	176	176	

1.2.	Groundwater flow	km^3	0.500	0.570	0.570	
2.	Population for 2030, total	thousand per.	4930	6 468	6 293	
	• Tashkent province	thousand per.	2430	3 390	3 231	
	• incl. rural population	thousand per.	1470	2 053	1 972	
	• urban population	thousand per.	960	1 337	1 259	
	• Tashkent city	thousand per.	2500	3 078	3 062	
3.	Gross production volume for 2030, total	M$	2112.88	2398.48	3989.99	2839.24
	▪ industry	M$	797.40	676.41	2048.96	898.21
	▪ agro-industry	M$	322.14	352.23	352.23	352.23
	▪ agriculture	M$	468.35	489.74	1016.69	1016.69
	▪ services sector	M$	524.99	880.10	572.11	572.11
4.	GDP by 2030, total for province	M$	1026.47	1280.87	1734.38	1492.73
4.1	same per capita	$/capita	422.4	377.8	536.79	462.03
5.	Agricultural gross production volume by 2030	M$	468.58	489.74	1016.69	
	• cereals	thousand t	450.03	305.02	627.01	570.5
	• cotton	thousand t	189.19	142.20	333.49	246.9
	• vegetables	thousand t	827.50	602.54	1067.37	894.5
	• fruits	thousand t	215.19	304.68	993.12	530.0
	• potato	thousand t	375.39	341.50	464.13	439.5
	• meat	thousand t	72.10	94.66	197.43	121.7
	• milk	thousand t	356.17	465.95	972.00	841.6
6.	Crop area by 2030	thousand ha	380.28	416.1	421.7	
7.	Crop yields by 2030	t/ha				
	▪ cotton	t/ha	2.01	1.39	3.21	2.8
	▪ cereals	t/ha	4.16	2.43	5.11	4.7
	▪ potato	t/ha	21.18	11.51	24.78	22.5
	▪ vegetables	t/ha	22.49	13.08	26.02	24.9
	▪ fruits	t/ha	3.21	3.03	14.09	11.0
	▪ grapes	t/ha	2.38	4.21	17	12.0
	▪ rice	t/ha	3.96	2.36	5.19	4.4
8.	Water withdrawal, mean for 2003-2030, total*	Mm^3	4110	5509	5977	
	• for irrigation, Uzbekistan		2347	3691	3882	
	• for irrigation, Kazakhstan		489	483	761	
	• Vodokanal network		798	876	876	
	• other (industry, heat energy, etc.)		476	459	461	
	* beside this, transit flow thru TEPS		1730	1500	1500	
9.	Wastewater disposal, mean for 2003-2030	Mm^3	2917	2476	2492	
10.	Supply with foodstuff by 2030, %					
	• bread		52	27	56	
	• vegetables		145	80	146	
	• fruits		112	121	405	
	• meat		49	49	105	
	• milk		39	39	83	
11.	Electricity production in HEPS, mean for 2003-2030, total	MkWh	3892	3566	3987	
11.1	incl. Pskem HEPS	MkWh	0	0	344	1200
12.	Capital investments in agriculture and water sector for 2003-2030	M$		237	791.6	

5.3. Validation of ecological scenarios

Observance of environmental demands, using the results of balance hydrological modeling as indicated in the Table 5.6, was checked on the model Qual-Chirchik. Description of this model based on the Qual2k is attached in Annex 1.

Principal dynamics of environmental indicators is shown in the Figure 5.6.

This data supported results getting by balance modeling for BAU scenarios.

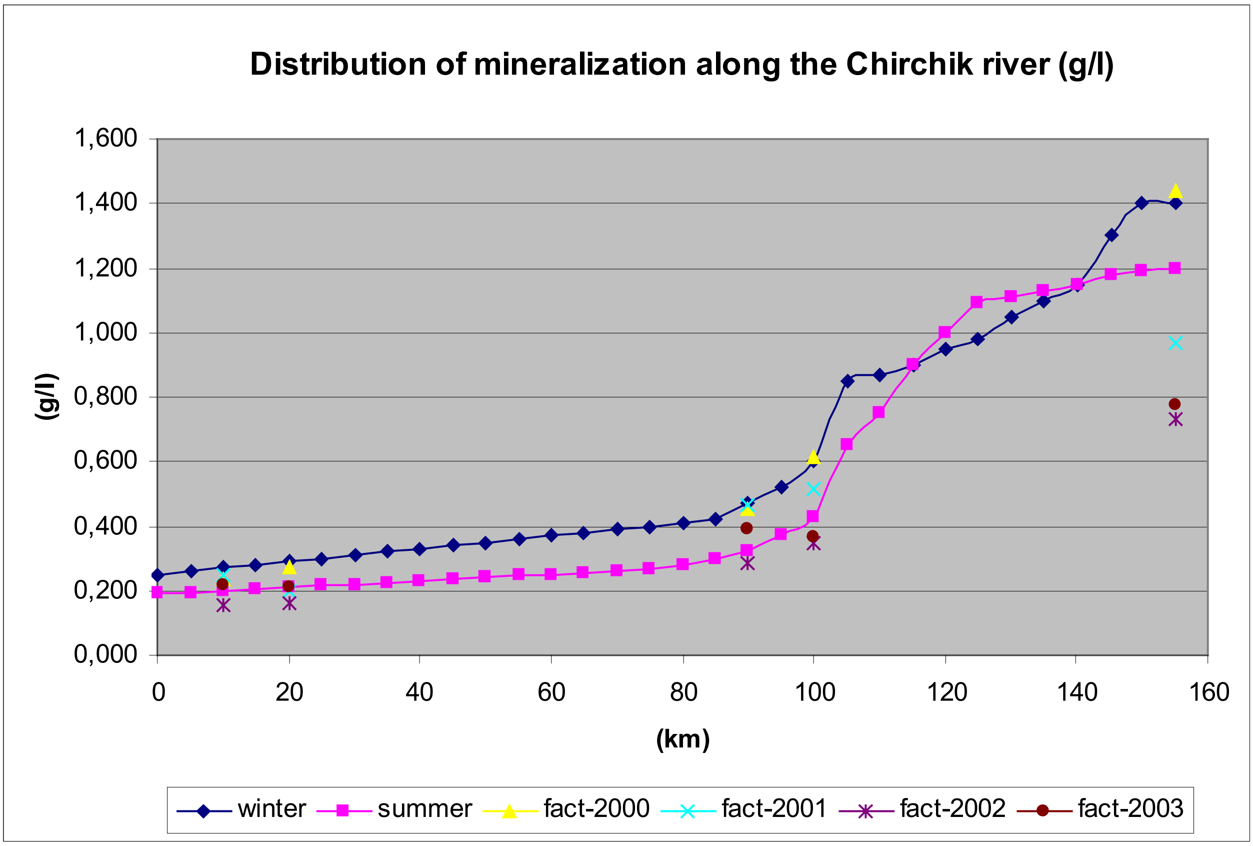


Figure 5.6. Distribution of mineralization

6. Water resources management in the sub-basin and scenarios of its improvement

Current state of water management in the Chirchik sub-basin is characterized by considerable complexity and diversity, redoubled by multiple hydraulic structures and their various sectoral combinations and subordinations, such as hydropower, irrigation, and water-supply, on the one hand, and by government bodies of the three countries that share the sub-basin, on another hand.

The prerequisites of strong management within the basin are available, since there is Basin Water Organization – BWO "Syrdarya" – which is responsible for water management at the interstate level.

BWO "Syrdarya" through Chirchik territorial management organization operates 5 large head water intake structures on interstate canals ("Left-bank Karasu", "Big Keles main canal", "Zakh", "Khanym", "Parkent"), gauging stations (GS) at those canals, head section of the canals up to boundaries of GS.

BWO's functions include: garmonization of water allocation plans, prepared on the basis of hydrometservice's forecasts and submitted to ICWC for approval twice a year – at the beginning and the end of growing season, between the agencies of State Joint-Stock Company "Uzbekenergy" and the national institutions operating irrigation systems in Kazakhstan and Uzbekistan.

Surface water management at the national level within the basin is under control of the Committee for Water Resources in Kazakhstan and Ministries of Agriculture and Water Resources in Kyrgyzstan and Uzbekistan, respectively.

Kyrgyzstan: the project zone is under jurisdiction of Djalalabad Basin Water Management Administration (BWMA).

Kazakhstan: Keles massif of Shymkent (South Kazakhstan) province is under whole jurisdiction of Aralo-Syrdarya BWMA. National public enterprise (NPE) "Yugvodkhoz", which was established on the basis of Shymkent Provincial Committee for Water Resources in 1999, is responsible for water management. NPE " Yugvodkhoz" has 7 branches (Turkestan, Sary-Agash, Makhtaaral, etc.), of which Zakh-Keles branch is responsible for water management in Keles massif.

Water management structure in Shymkent province also includes State Public Utility Company (SPUC) "Ontustyk su sharuashylygy". The company has 10 district branches. Keles massif of provincial NPE relates to control zone of Sary-Agash branch of NPE "Yugvodkhoz", while in the area of provincial SPUC it refers to service area of its Kazygurt branch.

Uzbekistan: Water delivery to 15 districts in Tashkent province that are located entirely within Chirchik-Akhangaran basin and to Tashkent city (16 planning zones) is controlled by Chirchik-Akhangaran Basin Administration of Irrigation Systems (CABAIS). As for 2004, CABAIS serves more than 386 thousand ha of irrigated lands in Tashkent province. Waters from the Chirchik river irrigate more than 300 thousand ha of lands, Akhangaran river supplies water to about 41 thousand ha, and Syrdarya serves about 36 thousand ha. Springs, sais and collectors irrigate 7,7 thousand ha of land.

CABAIS is comprised of management organizations of: 1 – Tashkent main canal; 2 – Bozsu irrigation system (IS); 3 – Parkent-Karasu IS; 4 – Akhangaran-Dalverzin IS; 5 – Tashkent municipal water organization.

Agencies of SJSC "Uzbekenergy" control Charvak reservoir with HEPS, Gazalkent and Khojikent hydraulic systems with HEPS, operating under daily regulation regime, as well as Bozsu cascade of 16 small HEPS' located in Bozsu canal.

Besides, three thermal power plants (TPP) – Tashkent, Novoangren, and Angren – are located in the basin. Head intakes of those plants are operated by SJSC services (Table 6.1). Taking into account importance of this system for electricity generation in the republic (more than 70 % of total generating capacities), water is delivered without restrictions; however, requirements to water withdrawals cause some disbalance in on-line water distribution in the basin.

Groundwater management in form of control over parameters and water table is under jurisdiction of agencies at the Ministry for Geology, its Tashkent hydrogeological field office. Public water-supply organizations are responsible for groundwater intake, as well as treatment and disposal of wastewater.

Control over environmental conditions is under responsibility of Tashkent provincial environmental authority.

The described sectoral interaction structure is shown in Fig. 6.1.

Major disadvantages of current management system are as follows:

- the Chirchik-Akhangaran-Keles sub-basin is one of water-abundant ones, though, at the same time, tense water zones in the region. If one compares the net need of all water consumers, which varies within 6,5 … 7,0 km^3 (report D-25), it is 2,5 … 3,0 km^3 a year less than the mean long-term water resources in the sub-basin or, at least, 1 km^3 less, even if include meeting of environmental requirements. Nevertheless, specificities of TPP regime, particularly of Tashkent TPP, make it difficult to meet all requirements of other water users since given only 4 Mm^3/year of consumptive use of Tashkent rayon electric station, its water withdrawal is 1,3 … 1,7 km^3/year. In next 30 years, this, as water distribution in the scenario "BAU" shows, will create great difficulties for equal and equitable water supply of a range of districts, even under average supply of irrigation within 90 %. Such districts as Kuyi-Chirchik, Yukori-Chirchik, Pskent, and Urtachirchik face regular water deficit;
- poor inter-departmental coordination and information exchange. Groundwater management matters are solved independently by water users, who abstract water from aquifers. Moreover, large aquifers, such as Chirchik and Akhangaran, have hydraulic links with surface water, and thus call for coordination of actions in these matters among downstream areas. In general for Tashkent province, in context of improvement of water management effectiveness, coordination among Ministry of Agriculture and Water Resources, State Committee for Nature, Ministry for Geology and Mineral Resources, and Ministry of Energy is particularly important;
- conflicting interests of energy, irrigation and environmental requirements. Charvak reservoir and other waterworks facilities for energy generation in the basin, controlled by SJSC "Uzbekenergy" (Ministry of Energy) of Uzbekistan, with the autonomous control of large HEPS and a system of power canals at thermal power plants, create, as mentioned above, artificial water shortage and, moreover, do not take into account nature demand. As a result, virtually fish productivity came to zero;
- water users and other stakeholders are not involved absolutely in water allocation, management and control over the state of waterways and water bodies.

All those disadvantages will become deeper unless measures to change ways and principles of water management are undertaken in the basin.

Table 6.1. Energy generation in HEPS and TPP

Energy generation	**units**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Republic of Uzbekistan	MkWh	54078,6	50881,5	49122,4	47737,8	47429,4	45487,9	46001,3	45914,2	45319	46839,9	47928,3
SJSC "Uzbekenergy"	"-"	52887	49584	47917	46483	46423	44027	45134	44506	43933	46034	47153
including												
Total HEPS	"-"	4817	5460	6331	6934	5337	5292	5045	6009	5326	4248	4708
of which:												
Cascade of Urta-Chirchik HEPS	"-"	2555	2893	3765	4193	3051	3105	2856	3614	3120	2311	2613
Cascade of Chirchik HEPS	"-"	935	897	1067	1218	1019	892	966	1114	1044	938	997
Cascade of Kadyri HEPS	"-"	320	312	337	335	312	299	326	310	267	266	314
Cascade of Tashkent HEPS	"-"	131	153	164	163	141	122	129	107	69	89	123
Cascade of Nijne-Bozsu HEPS	"-"	207	241	242	246	231	213	210	221	194	136	188
Cascade of Shaarikhan HEPS	"-"	55	49	56	52	39	47	41	23	50	42	59
Cascade of Samarkand HEPS	"-"	74	95	80	83	64	58	85	67	62	44	62
HEPS of Chirchik basin	"-"	4277	4640	5711	6290	4857	4736	4613	5456	4806	3826	4356
% of total generation in HEPS’	%	88,7897	84,9817	90,2069	90,7124	91,0062	89,4936	91,4371	90,7971	90,237	90,0659	92,5234
Total TPP	MkWh	48070	44424	41586	39549	41086	38735	40089	38495	38607	41787	42445
% TPP of total generation in energy stations	%	90,8919	89,5934	86,7876	85,0827	88,5035	87,9801	88,8222	86,494	87,877	90,7742	90,0155
of which:												
Tashkent TPP	MkWh	11771	10629	9313	9263	10764	9746	10048	8332	7882	9583	10503
Novo-Angren TPP	"-"	5264	4657	3902	4904	5124	5812	6572	6852	7646	7376	7882
Angren TPP	"-"	2131	1330	1303	898	629	657	712	733	833	766	582
Syrdarya TPP	"-"	14998	13751	13806	12084	13084	11991	12404	12606	12402	13548	12478
TPP of Chirchik-Akhangaran basin		34164	30367	28324	27149	29601	28206	29736	28523	28763	31273	31445
% of total generation in TPP’	%	71,0714	68,3572	68,1095	68,6465	72,0464	72,8179	74,175	74,0953	74,502	74,8391	74,0841

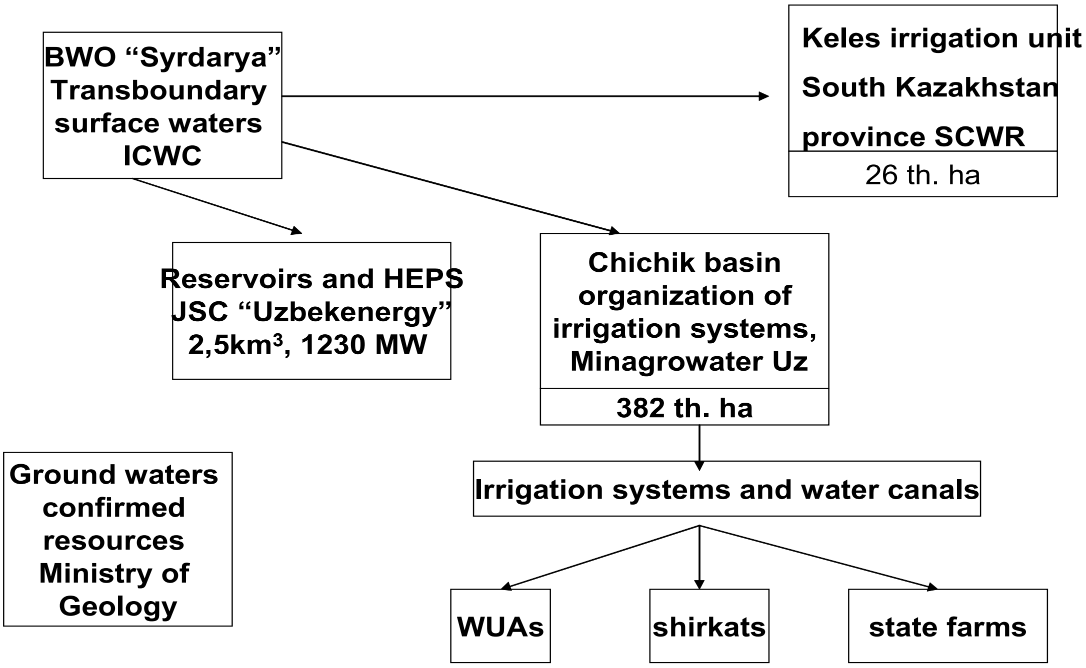


Figure 6.1. Managing system of water resources

<u>Transition to integrated water resources management in the basin.</u>

Approaches to development and implementation of IWRM in the Aral Sea basin have started to be discussed actively and implemented in the region since 1998, when within the framework of ICWC, water-management institutions of the five countries together with Canadian and Swiss colleagues and ESCAP attended to elaborate strategic plans for basin management, based on accumulated international experience. Though integrated management, per se, titled as <u>comprehensive development and irrigation</u> has been implemented successfully in water management practices, first, in Hunger Steppe and then in many other zones, this method, being different from and having many features of IWRM, had the main disadvantage – no public participation.

Implementation of IWRM in practices and recognition of IWRM as the main direction in Water Codes of Kazakhstan and Kyrgyzstan and in decisions of ICWC allows clear emphasizing of its major characteristics:

- hydrographic management within the boundaries of basin morphology and water systems;
- public participation in management and planning;
- modern use and linkage of all water types (surface, ground, and return);
- intersectoral coordination and integration;
- priority of nature requirements and their meeting;
- orientation to potential water productivity;
- informativity and openness of management.

In this context, it is advisable to initiate transfer to IWRM in the Chirchik-Akhangaran-Keles sub-basin but at higher level than in the Fergana Valley, to the so-called integrated water-environmental management. To this end, it is proposed to organize a Council for basin hydro-environmental management. Structure of this Council is shown in Fig. 6.2.

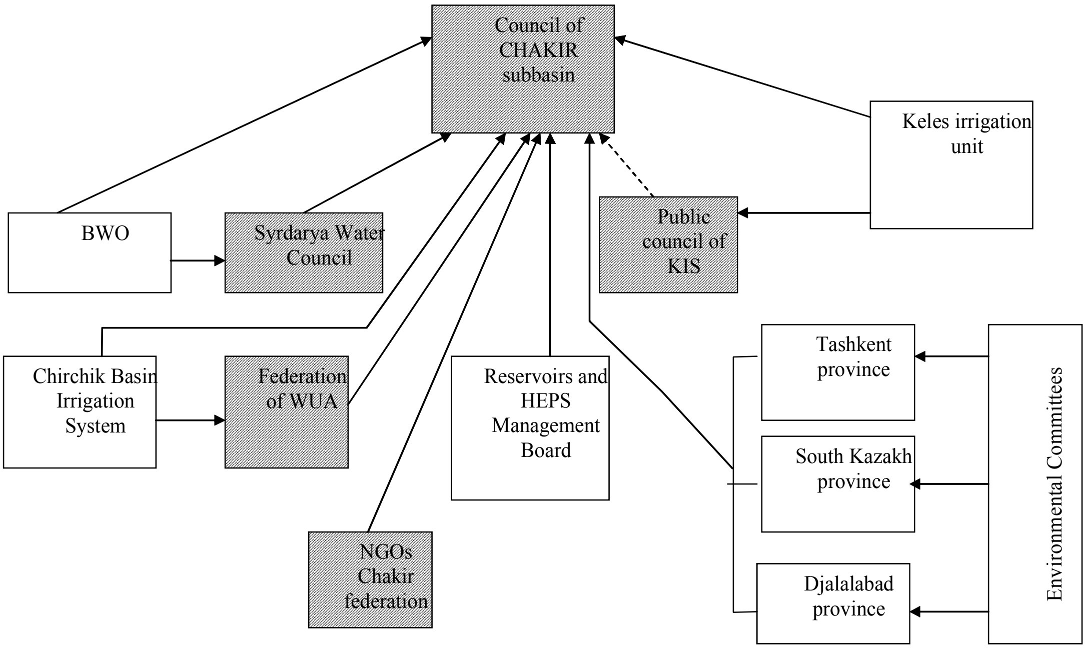


Figure 6.2. Transfer to hydro-environmental management (proposal)

The Council of Basin is a voluntary association of major institutions participating in water management and use in the basin and should fulfill functions of coordination, harmonization of operation regimes and water delivery volumes, as well as joint planning of both long-term, annual, and monthly distribution of water resources and joint actions aimed at improved water use and environmental well-being.
It is supposed that the Council, like French Water Councils, will consist of:

- representatives of BWO "Syrdarya" and its Water Council suggested for establishment in draft Agreement on institutional improvement of ICWC;
- Chirchik Basin Administration of Irrigation Systems and Keles IS (Zakh-Keles branch of NPE);
- public committees of canals and district WUA’s federations that will be established at irrigation systems, similar to respective units as established within the project “IWRM-Fergana”;
- representatives of Environmental Committees of three provinces: Tashkent, South Kazakhstan and Djalalabad;
- management boards of Charvak HEPS and Bozsu HEPS cascade;
- representatives of NGO or their water federations, etc.

The Council of the Basin at its General Assembly will elect the board and leader of the Council and prepare by-laws and provisions for elaboration of rules for operation and interaction between members of the Council, for formation of budget, work plan and set of measures to coordinate and adjust water use in the sub-basin.

7. Conclusion

1. Three years of collaboration with the European team under the leadership of Hohenheim University permitted to organize, for the first time, big and valuable work at the subbasin level on detail description of all spectrum of development in complicated situation of transition economy and projection of different scenarios for future development in water, agricultural and partly socio-economic sectors.
2. This time is quite short for such a big work and moreover for implementation to stakeholders. It required as shown in final report big preparatory activities, practical validation and work for detail account of all specificities in each of planning zones of our modeling. The total cost of implementation of the results, according to cost estimation in the final activity report, is 369.5 thousand Euro.
3. The principal achievement is that the integrated set of scenarios and models together with integrated interface as the main representative mechanism showed its workability. Moreover, joint work with stakeholders has led to generation of their interest in such approach, tools and scenarios building as preparation to Broad Strategic Planning.

References

1. Zukunftsperspektiven für ein integriertes Wasserressourcen-Management im Einzugsgebiet Neckar, Baden Wurttenberg, Regienzung spzasidium Stuttgart, UmweltMinisterium, 2006, 60 pages

2. European environment outlook. EEA Report No. 4/2005.

3. European Outlook on Water Use. Final report, Martina Florke and Joseph Alcamo, Center for Environmental Systems Research, University of Kassel.

4. Environmental Policy. Water Framework Directive – summary of river basin district analysis 2004 in Germany, Federal Ministry for the environment, nature conservation and nuclear safety, 2005.

5. Transactions of the seminar of ICWC and ESCAP on strategic planning and sustainable development (Cholpon-Ata, 27-30 August, 2002). Tashkent, SIC ICWC, 2002, vol.1, p. 103, vol.2, p.64.

6. Agaltseva N.A. “Assessment of climate change impact on water desalination in the Aral Sea basin” in “Dialogue on water and climate – the Aral Sea basin”, Tashkent, 2002, p. 3-59.

7. Dukhovny V.A. "Governance and IWRM", "Proceedings of IWRA Conference", Dundy, 2004, 16 p.

8. Dukhovny V.A., Pereira L.S. "Future trends in water management for Central Asia", collection of articles “Irrigation management for combating desertification in the Aral Sea basin”, Tashkent, "Vita Color", 2005

9. Master-plan for development of irrigated agriculture and water sector by 2015, Uzvodproyekt, 2002.

10. Dukhovny V.A., Sokolov V.I. “IWRM-Fergana – experience and lessons learnt in CA – towards WWF4”. SIC ICWC, 2005, 95 pages.

11. Farming systems in Uzbek SSR. Edited by Lapkin K.I., Ryzhova S.N., Rudakova G.M. et al., Publishing house "Fahn", Tashkent, 1973.

Annex 1

Models used in the project “RiverTwin” and proposals on their adaptation to the Chirchik-Akhangaran basin

(QUAL – Chirchik, Moneris)

report WP-6

Tashkent 2006

List of executors

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1. INTRODUCTION

1.1 Background

This work is undertaken within the framework of the project ***RIVERTWIN - "A regional model for integrated water management in twinned river basins"***, beginning - 2004, end - 2006.

1.2 Objective

Development of hydrodynamic model **QUAL-Chirchik** to study distribution of admixtures under conditions of various flows and temperature fluctuations in the river. Coupling of the model with the general set of models contributing to functioning of the **Integrated regional model** for the **Chirchi-Akhangaran-Keles** basin.

1.3 Research object

The research object is Ecological model **for the rivers** Chirchik, Akhangaran, **and** Keles, **including water intakes and discharge of wastewater to collectors.**

1.4 Status of research

The set of models in the Ecological Block (QUAL -Chirchik), **describing different processes of pollution distribution in the** Chirchik-Akhangaran-Keles **basin, relies on the base models:**
Hydraulics: – flood motion over river network (**Wave-2002**),
Ecology of river: - distribution of admixtures and heat in rivers (**QUAL2K),**
Ecology of territory: - emission of nitrates and phosphorus into river system **(MONERIS)**
The initial version **(MONERIS)** uses regression equations, the coefficients of which have been derived using the results of processing of in-situ measurements carried out in objects in Germany. It is impossible to directly transfer numerical values of coefficients derived in a similar way to objects in another region. Therefore, while developing a base version **(MONERIS - Chirchik),** elements of the Agricultural Block that are based on the following conditions have been used:

- Each crop requires a certain amount of fertilizers a year (norm of nitrates and phosphorus).
- Fertilizer consumption rate is proportional to actual amount of applied fertilizers and biomass growth rate of specific crop.
- Removal of a part of these fertilizers to river systems results from natural water outflow and surplus over amount required for given crop, at specific time.

For **QUAL -Chirchik,** a version of the **Wave-2002** model, based on a system of quasi-linear differential equations in partial derivatives that result from "shallow water" theory, has been proposed as a base model describing flow hydrodynamics. Other equations describing the processes of admixture and heat transport correspond to the model **(QUAL2K).** The **Wave-2002** model has been developed to study non-steady hydrodynamic conditions of single-phase fluid in terms of mountainous location. In addition to transient condition, the objectives of the **QUAL -Chirchik** model include terms of matching of head water intakes operation with requirements of all sectors of economy, in regard to water supply and collectors concerning wastewater discharges. Therefore, it is necessary to extend the base model in the following ways:

- matching boundary conditions with the **Art_reservoir** model,
- adding equations simulating the operation of head water intakes and check structures,
- adding equations simulating water exchange with groundwater.

Moreover, while extending algorithm, it is necessary to foresee a capability to calculate flows for rivers with periodically drying channel.

2. MATHEMATICAL MODEL

2.1 Basic flow equations

Mathematical description of unsteady-state flows in open channels is usually based on equations of the shallow water theory, which represents mechanism of flow of free-surface fluid. Equations of the shallow water theory are derived from general hydrodynamic equations (Euler equations), with two main assumptions:

- Prevalence of horizontal flow over vertical one,
- Incompressibility of fluid.

For shearing flows, where energy dissipation at the expense of turbulent and viscous tangential stresses becomes important, additional terms is incorporated into momentum conservation equation for consideration of loss of momentum. Shallow water equations may be also derived from Reynolds equation; in this case, flow is described by average velocities rather than by actual ones, and the additional term, due to energy dissipation, in the momentum conservation equations is derived from viscous and turbulent tangential stress tensor. In the resulting system, number of unknown values is higher than number of equations; therefore, to close the system, as in the previous case, one needs any hypothesis on relationship between tangential stresses and average flow parameters. By present, there exist many mathematical models /2, 4, 5, 6, 8, 9, 10, 17, 19, 20/ used in the studies of unsteady-state fluid flows. Original equations (variant of the **model Wave 2002**) for constant density flow in open channel are as follows in conservation laws' form:

$$\frac{\partial}{\partial t}\int_{x_1}^{x_2}\omega\, dx + [\omega u]_{x_1}^{x_2} = \int_{x_1}^{x_2} q dx\,, \tag{2.1}$$

$$\frac{\partial}{\partial t}\int_{x_1}^{x_2} u\omega\, dx + [uQ + P]_{x_1}^{x_2} = -g\int_{x_1}^{x_2}\left[\omega\left(\frac{\partial z_\Delta}{\partial x} + \frac{u|u|}{C^2 R}\right) - \int_0^h \frac{\partial b}{\partial x}(h-\xi)d\xi\right]dx\,, \tag{2.2}$$

here:

$$[y]_1^2 = y_2 - y_1;\;\; P = g\int_0^h b(h-\xi)\, d\xi;\;\; \omega(x,h) = \int_0^{h(x)} b(x,\xi)d\xi; \tag{2.3}$$

where: t – time,
x – coordinate along axis of channel,
u=u(x,t) – flow velocity in x axis direction,
ω (x,t) – flow cross-section area,
Q(x,t) – discharge (Q=ω × u);
q (x,t) –lateral inflow (outflow) per unit length, which is orthogonal to main stream,
g –gravitational acceleration;
h(x,t) – flow depth along x axis, where channel line is located;
b(x, ξ) – channel width in section x at a depth of ξ from ordinate of channel bottom;
z^d (x)–ordinate of channel bottom;
C - Chezy coefficient (C=$\frac{1}{n}R^Y$),
n(x) - channel roughness factor (0.01 < n < 0.04),
Y – indicator, which depends on n and R in general case,
R – hydraulic radius (R= ω / χ),
χ - wetter perimeter.

Parameters n and *Y* cannot be received from the shallow water theory; therefore we determine them from field observations, for example, well-known expressions for *Y*:

Y = 1/6 - Manning approximation,

$Y = 2.5\sqrt{n} - 0.13 - 0.75\sqrt{R}(\sqrt{n} - 0.1)$ - N.Pavlovsky approximation.

Similar formulas exist for “n” as well.

The decision variables in equations (2.1), (2.2) are: ω(x,t) – flow cross-section area and Q (x,t)- discharge, through which other flow parameters are calculated using formulas (2.3). The system of equations (2.1), (2.2) refers to quasi-linear system of hyperbolic partial equations, which has waves of various order. This system is subjected only to numerical integration. For model **QUAL-Chirchik** equation (2.2) is simplified by the following assumptions:

- flow in the river is smoothly varying,
- flow in the river is slowly varying.

Taking into that the pressure force can be removed to the right side of the equation (2.2) after differentiation with respect to “x”, the first assumption allows reducing the equation to the following form:

$$\frac{\partial P}{\partial x} = g\omega\frac{\partial h}{\partial x} + g\int_0^h \frac{\partial b}{\partial x}(h-\xi)d\xi . \qquad (2.4)$$

$$\frac{\partial}{\partial t}\int_{x_1}^{x_2} u\omega dx + [uQ]_{x_1}^{x_2} = -g\int_{x_1}^{x_2}\omega(\frac{\partial z}{\partial x} + \frac{u|u|}{C^2 R})dx , \qquad (2.5)$$

Here: z – level of flow free surface.

The second assumption allows setting the right side of equation (2.5) equal to zero; finally, we have:

$$u|u| = C^2R \times (-\frac{\partial z}{\partial x}); \qquad (2.6)$$

Taking into account that $(\frac{\partial z}{\partial x} = -J)$, J – slope of flow free surface, from (2.6) we will get:

$$Q = sign(J)\omega C\sqrt{R|J|} , \qquad (2.7)$$

here $$sign(x) = \begin{cases} = +1 & ïðè \quad x > 0 \\ = 0 & ïðè \quad x = 0 \\ = -1 & ïðè \quad x < 0 \end{cases}$$

This version of mathematical model is referred to as N.M.Bernadsky’s model [11] and helps to study unsteady-state flows with backward water flow. The limited nature of the model becomes apparent in simulating supercritical flows (when Froude number is higher than 1), for example, non-submerged flow out of gate have parameters $Q > 0$ at $J < 0$ that are not described by given model. In order to fully formulate the boundary problem, it is necessary to set initial and boundary conditions. Initial conditions are determined by the state of water in the river in start time, i.e.

$$Q(x,0) = Q(x) \quad \text{and} \quad \omega(0, x) = \omega(x), \qquad (2.8)$$

and, at the same time, set operating range (since the operating range is fixed, in the point of time *t* = 0 it fully covers the whole are to be simulated).

The boundary conditions are based on number of characteristics falling under the operating range. Number of characteristics is determined through velocity and Froude number of ingoing stream. Froude number in the shallow water theory plays a role of Mach number in the gas dynamics equations. For non-prismatic channels, the Froude number is defined as:

$$\mathbf{Fr} = (b\times u^2)/(g\times\omega) \qquad (2.9)$$

In the **model Wave 2002** the operating range extends from left to right; the same order is held for **QUAL-Chirchik,** i.e. the left boundary will be the beginning of specified area (x=0), while the right boundary will be its end (x=L). In the initial version of **Wave 2002,** the required number of boundary conditions is determined through velocity and Froude number:

For left boundary, x=0 : (2.10)

$u > 0$

$Fr < 1 \Rightarrow$ one condition,
$Fr > 1 \Rightarrow$ two conditions,

$u < 0$

$Fr < 1 \Rightarrow$ one condition,
$Fr > 1 \Rightarrow$ none,

For right boundary, x=L: (2.11)

$u > 0$

$Fr < 1 \Rightarrow$ one condition,
$Fr > 1 \Rightarrow$ none,

$u < 0$

$Fr < 1 \Rightarrow$ one condition,
$Fr > 1 \Rightarrow$ two conditions.

After simplifications made for the model **QUAL-Chirchik,** the resulting system of equations has only one characteristic, and therefore (2.10), (2.11) are reduced to the following form:

For left boundary, x=0: (2.12)

$u > 0$

$Fr < 1 \Rightarrow$ one condition [z(t) or Q(t)],
$Fr > 1 \Rightarrow$ $Q(0,t) = Q(t)$,

$u < 0$

$Fr < 1 \Rightarrow$ one condition [z(t) or Q(h)],
$Fr > 1 \Rightarrow$ none,

For right boundary, x=L: (2.13)

$u > 0$

$Fr < 1 \Rightarrow$ one condition [z(t) or Q(h)],
$Fr > 1 \Rightarrow$ none,

$u < 0$

$Fr < 1 \Rightarrow$ one condition [z(t) or Q(t)],
$Fr > 1 \Rightarrow$ $Q(L,t) = Q(t)$,

The whole river is divided into reaches (in form of oriented graph) that can be interfaced sequentially or parallel. The river reach is a section of channel between check structures. Each river reach has boundary conditions (2.12) at its head and conditions (2.13) at the end. The number of control stations inside the reach is free and depends on required accuracy. First river reaches of the model **QUAL-Chirchik** are coupled on left boundary either with the model **HBV**, for Keles river, or with the model **Art_reservoir,** for Chirchik and Akhangaran rivers. When coupling with the model **HBV,** the condition Fr < 1 is taken and the following discharge hydrograph is set:

$$Q^{WAVE}(0,t) = Q^{HBV}(t); \qquad (2.14)$$

When coupling with the model **Art_reservoir,** the number of characteristics is determined by flow character of incoming stream, which, in turn, depends on operation regimes of HEPS and spillway works (two boundary conditions are needed in general case); however, taking into account (2.12) we will also have:

$$Q^{WAVE}(0,t) = Q^{Art}(t), \qquad (2.15)$$

Interfacing of river reaches between each other in places, where hydraulic structures are located, can be written in general form. Let a set of river reaches $\{r\}^+$ comes into and a set of river reaches $\{r\}^-$ comes out the junction point "j". Check structure is dedicated to maintain given level to ensure required withdrawal of water by head intakes. This maintenance may by described as z(t); thus, for the sets $\{r\}^+$ and $\{r\}^-$ we have:

$$z_r(L_r,t) = z_j(t); \ \forall r \in \{r\}^+ \qquad (2.16)$$

$$Q_r(0,t) = Q_r[z_j(t)]; \ \forall r \in \{r\}^- \qquad (2.17)$$

On the right boundary of last river reaches the following condition is used in the model **QUAL-Chirchik**:

$$Q_r(L_r, t) = Q_r[h(L_r,t)] ; \qquad (2.18)$$

Workability of (2.18) comes from the fact that bottom level at the end of river reaches is higher than water horizons in the Syrdarya river where water is released from the rivers Chirchik, Akhangaran, and Keles.

2.2 Approximation of equations

In order to approximate the equations (2.1) – (2.2), a river reach is covered with non-uniform mesh, with whole and fractional indexes along coordinate "x".

$$\Omega_r = \{ x_j = x_{j-1} + \Delta_j; \quad j = 0, 1, 2, \ldots, N_r; \quad \sum_{j=1}^{N_r} \Delta_j = L_r \}; \qquad (2.19)$$

$$\partial\Omega_r = \{ x_0 = 0; \quad x_N = L_r \}; \quad x_{j\pm1/2} = (x_j + x_{j\pm1})/2 ; \qquad (2.20)$$

Variables ω, q, h, b, z^d, C are determined in coordinates with whole indexes, while the others, in coordinates with fractional indexes. Thus, in our system sections with the whole indexes play a role of "balancing sites" in QUAL2K. The described algorithm is based on four-point implicit difference scheme built by integro-interpolation method [17]. In this case, mass variables are calculated in integral points, while *u* and *Q,* in fractional points. Such division in calculating various parameters of flow coincides, in some measure, with recommendations of S.Hert [21]. The initial system of equations (2.1) – (2.2) with regard to (2.6) and (2.7) is approximated by the following formulas:

$$\omega_j(t) = \omega_j(t-1) + \frac{\tau}{\Delta_j}[Q_{j-1/2}(t) - Q_{j+1/2}(t)] + \tau \sum_{i\in\{j\}} q_j^i(t);$$

$Q_{j\pm1/2}(t) = u_{j\pm1/2}(t) \times \omega_{j\pm1/2}(t);$

$u_{j\pm1/2}(t) = Sign[J_{j\pm1/2}(t)] \times C_{j\pm1/2}(t) \times \sqrt{R_{j\pm1/2}(t) \times |J_{j\pm1/2}(t)|}\ ;$

$C_{j\pm1/2}(t) = [C_j(t) + C_{j\pm1}(t)]/2;\quad R_{j\pm1/2}(t) = [R_j(t) + R_{j\pm1}(t)]/2;$

(2.21)

$C_j(t) = C_j[\omega_j(t), n_j],\ \ b_j(t) = b_j[\omega_j(t)],\ \ R_j(t) = R_j[\omega_j(t)],\ \ h_j(t) = h_j[\omega_j(t)],$

$J_{j+1/2}(t) = [z_j(t) - z_{j+1}(t)]/\Delta_{j+1/2};\quad \Delta_{j\pm1/2} = (\Delta_j + \Delta_{j\pm1})/2;\quad z_j(t) = z^d_j + h_j(t);$

$\omega_{j+1/2}(t) = [\omega_j(t) \times (1+\alpha_{j+1/2}(t)) + \omega_{j+1}(t) \times (1-\alpha_{j+1/2}(t))]/2;\ \ -1 \le \alpha_{j+1/2}(t) \le +1\ ;$

$\alpha_{j\pm1/2}(t) = \alpha[\frac{\tau \times u_{j\pm1/2}(t)}{\Delta_{j\pm1/2}}];$

Here: τ - integration interval (time increment), {j} – set of inflows and outflows in section “j” . Equations (2.21) represent a system of non-linear algebraic equations with respect to variables $\omega_j(t)$ and $u_{j\pm1/2}(t)$, solution of which is made by method of successive iterations in each time interval “τ“, (GAMS algorithms). In **QUAL-Chirchik** algorithm the volume of balancing site becomes a function of time, therefore, in order to harmonize equations of the model **Qual2K**[2], it is necessary to make appropriate transformations in all equations.

2.3 Heat balance equations

Heat distribution over river system is described through change in enthalpy of each balancing site, we have:

$$\frac{\partial}{\partial t}\int_{x_1}^{x_2}[T\times\omega]dx + [T\times Q]_{x_1}^{x_2} = \int_{x_1}^{x_2}[\sum_{i\in(x_1^2)+} T^i q^i - T\sum_{i\in(x_1^2)-} q^i \pm T^g q^g - Tq^E + T^p q^p]dx$$

$$+\frac{1}{\rho^w c^w}\int_{x_1}^{x_2}[J^0 + J^A - J^{br} - J^c - J^E]b(x)dx\,; \qquad (2.22)$$

Where, T – Celsius temperature; c^w – water specific heat capacity under constant pressure; ρ^w – water density; $\{x_1^2\}^+$, $\{x_1^2\}^-$ - sets of inflows and outflows in a site $[x_1,x_2]$, respectively; q^g – inflow to (outflow from) groundwater; q^E – evaporation flux; q^p – water flow, from precipitation; J^0- solar radiation heat flow; J^A – heat flow from atmosphere; J^{br} – back long-wave radiation heat flow; J^c – convection heat flow; J^E- flow resulting from latent heat of water evaporation; b – channel surface width; symbols and meaning of given heat flows strictly correspond to similar heat flows in **QUAL2K**. Taking equation (2.21) into account, we set up difference equation for approximation of equation (2.22), which will be used in place of equation (26) [1], adopted in **QUAL2K**. Let us denote enthalpy of flow area per unit of length by $\aleph$, $\aleph(t) = T(t)\times\omega(t)$, then enthalpy flow is: - $\aleph(t)\times u(t)$. Putting this expression in equation (2.22), we get:

$$\aleph_j(t) = \aleph_j(t-1) + \frac{\tau}{\Delta_j}[(\aleph\times u)_{j-1/2}(t) - (\aleph\times u)_{j+1/2}(t)]$$

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[2] Numeration of equations is given according to Chapra, S.C. and Pelletier, G.J. 2003. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality: November 2003.

$$+\tau\,[\sum_{i\in\{j\}^+}(T\times q)^i_j(t)-T_j\sum_{i\in\{j\}^-}q^i_j(t)\pm(T\times q)^g_j(t)-(T\times b\times u^E)_j(t)+(T\times q)^P_j(t)]$$

$$+\frac{\tau\times b_j}{\rho^w_j c^w}[J_r{*}(t) - J_j^{br}(t) - J_j^c(t) - L^{\mathrm{w}}\times u_j^E(t)]; \qquad (2.23)$$

$$\aleph_{j+1/2}(t) = [\aleph_j(t)\times(1+\alpha_{j+1/2}(t))+ \aleph_{j+1}(t)\times(1-\alpha_{j+1/2}(t))]/2$$

$$-\frac{\tau\times h_{j+1/2}(t)\times\gamma_{j+1/2}(t)}{\Delta_{j+1/2}}[T_{j+1}(t)-T_j(t)]\ ; \qquad (2.24)$$

Where: u^E – water evaporation rate; L^{w} – latent heat of water evaporation; J^{br} - back long-wave water radiation heat flow; J^c- heat flow resulting from gradient of temperature on the surface of section "water – air"; J* - resulting heat flow from solar radiation and atmospheric radiation ($J^* = J^0 + J^A$). The index (inferior) of this flow indicates that this flow depends on time, but is equal for the whole river site, since its value does not depend on water temperature in control station, and characterizes external climatic influence alone. In open streams, "γ" that is determined as longitudinal dispersion factor, for which there are various equations [1],[9], has dimension [m2/sec]. The other variables correspond to equation (2.21).

2.4 Admixture transport equations

Admixture distribution over river system is described through change in specific mass of suspended or dissolved components of each balancing site, given:

$$\frac{\partial}{\partial t}\int_{x_1}^{x_2}[s^v\times\omega]dx+[s^v\times Q]_{x_1}^{x_2} = \int_{x_1}^{x_2}[\sum_{i\in(x_1^2)+}s^{v,j}q^i - s^v\sum_{i\in(x_1^2)-}q^i \pm s^{v,g}q^g + s^{v,p}q^p]dx \qquad (2.25)$$

Where: s^v - concentration of "*v*" admixture,
Taking equation (2.22) into account, we set up difference equations for approximation of equation (2.25), which will be used in place of equation (26) [1], adopted in **QUAL2K** . Let us denote specific mass of suspended or dissolved components in flow area S, $S^v(t) = s^v(t)\times\omega(t)$, then mass flow is: - $S^v(t)\times u(t)$. Putting this expression in equation (2.25), we get:

$$S^v{}_j(t) = S^v{}_j(t-1) + \frac{\tau}{\Delta_j}[(S^v\times u)_{j-1/2}(t) - (S^v\times u)_{j+1/2}(t)]$$

$$+\tau\,[\sum_{i\in\{j\}^+}(s^v\times q)^i_j(t)-s^v{}_j\sum_{i\in\{j\}^-}q^i_j(t)\pm(s^v\times q)^g_j(t)+(s^v\times q)^P_j(t)] \qquad (2.26)$$

$$S^v{}_{j+1/2}(t) = [S^v{}_j(t)\times(1+\alpha_{j+1/2}(t))+ S^v{}_{j+1}(t)\times(1-\alpha_{j+1/2}(t))]/2$$

$$-\frac{\tau\times h_{j+1/2}(t)\times\gamma^v{}_{j+1/2}(t)}{\Delta_{j+1/2}}[s^v{}_{j+1}(t)-s^v{}_j(t)]\ ; \qquad (2.27)$$

In open streams, "γ^v" that is similar to longitudinal heat dispersion factor and determined as longitudinal admixture dispersion factor, for which there are also various equations [9], has dimension [m2/sec]. The other variables correspond to equation (2.21).

Set of inflows $\{x_1^2\}^+$, – formed by using the **HBV-Chirchik** and **Moneris- Chirchik** models, set of predetermined outflows $\{x_1^2\}^-$, - formed by using the irrigation systems model "Ir_sys". Moreover, there is alternating inflow (outflow), resulting from interaction between surface river flow and channel flow.

$$
\begin{aligned}
& q^g(x) = \alpha(x) \times (Q(x) - Q^*(x)) + \beta(x) \times (Q(x) - Q^*(x))^3 \\
& q^g(x) - \inf low(outflow)\_from\_groundwater\_level \\
& Q^*(x) - average\_annual\_flow \\
& Q(x) - actual\_flow
\end{aligned}
\tag{2.28}
$$

Where: *β(x)* – parameter, which is determined in process of calibration.

3. MONERIS - CHIRCHIK

The base model **Moneris** describes nitrate and phosphorus emissions into river systems in Germany, resulting from different activities. The main elements of the model are: set of regression equations derived by using the results of on-site investigations in Germany. The **Moneris-Chirchik** is a model describing emission of nitrates and phosphorus into river systems resulting from agricultural production. The main equations in this model are based on the following conditions:

- Each crop requires a certain amount of fertilizers a year (norm of nitrates and phosphorus).
- Fertilizer consumption rate is proportional to amount of applied fertilizers and biomass growth rate of specific crop.
- Removal of a part of these fertilizers to river systems results from water surplus over amount required for given crop, at specific time.
- Water surplus results from deviations as compared to ideal water delivery caused by both objective (sudden precipitation) and human factors.

$$
\begin{aligned}
& \frac{dm^{N,r}}{dt} = -[\alpha^{N,r} m^r + \beta^{N,r} \delta w^r(t)] \times m^{N,r}; \\
& \frac{dm^{P,r}}{dt} = -[\alpha^{P,r} m^r + \beta^{P,r} \delta w^r(t)] \times m^{P,r}; \\
& \delta w^r(t) = \begin{cases} w(t) - w^{*,r}(t) \mid w(t) > w^{*,r}(t); \\ \quad 0 \mid w(t) \le w^{*,r}(t); \end{cases} \\
& \frac{dm^r}{dt} = f^r(m^N, m^P, \ldots, w, t); \\
& m^N(t) = \sum_{r \in R^d} [\Omega^r \times \beta^{N,r} \times \delta w^r(t) \times m^{N,r}(t)]; \\
& m^P(t) = \sum_{r \in R^d} [\Omega^r \times \beta^{P,r} \times \delta w^r(t) \times m^{P,r}(t)];
\end{aligned}
\tag{2.29}
$$

4. REFERENCES

1 Chapra, S.C. and Pelletier, G.J. 2003. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality: November 2003.

2 Boris J.P., Bouk D.L. Solution of continuity equations by flow correction method – In collection: Controlled nuclear fusion. - M.: Meer, 1980. - p.92-141.

3 Voevodin A.F., Shugrin S.M. Numerical methods for estimation one-dimensional systems. - Novosibirsk: Nauka, 1981. - 208 p.

4 Voltsinger N.Ye., Peskovskiy R.V. Shallow water theory. Oceanological problems and numerical methods. - L.: Gidrometeoizdat, 1977. - 207 p.

5 Gladyshev M.T. Numerical modeling of unsteady-state flows in open channels. – Journal "Water Resources", No. 3, 1981. - p.119-125.

6 Godunov S.K. et al. Numerical solution of multidimensional problems in gas dynamics. - M.: Nauka, 1976. - 400 p.

7 Denisov Yu.M. General principles of linear modeling the river flow transformations. – Journal "Meteorology and hydrology", № 3, 1969. - p.70-78.

8 Dynamics of continuum in design of hydraulic structures, edited by Lyather V.M., Yakovlev Yu.S. – M. Energiya, 1976. - 392 p.

9 Identification of hydraulic models \Edited by Artsimovich G.V.\- Novosibirsk: Nauka, 1980. - 160 p.

10 Karaushev A.V. River hydraulics. - L.: Gidrometeoizdat, 1969. -415 p.

11 Lavrentiev M.A., Shabat B.V. Hydrodynamic issues and their mathematical models. - M.: Nauka, 1973. - 416 p.

12 Laithill D. Waves in fluids. - M.: Meer, 1981. - 598 p.

13 Landau L.D., Livshits Ye.M. Hydrodynamics - M.: Nauka, 1986. - 736 p.

14 Rozhdestvenskiy B.L., Yanenko N.N. Systems of quasi-linear equations. - M.: Nauka, 1978. - 688 p.

15 Rouch P. Computational hydrodynamics. - M.: Nauka, 1980. – 616p.

16 Samarskiy A.A., Popov Yu.P. Difference methods for solving problems in gas dynamics.- M.: Nauka, 1980. - 352 p.

17 Stoker J.J. Waves in water. - M.: IL, 1959. - 617 p.

18 Theoretical principles and construction of numerical algorithms for mathematical physics problems. - M.: Nauka, 1979. - 295 p.

19 Uizem J. Linear and non-linear waves. - M.: Nauka, 1977.- 624 p.

20 Hert S. Optional Lagrange-Euler numerical method. In collection: Numerical methods in fluid mechanics. M.: Nauka, 1973. 157 p.

21 Tuchin A.I. About numerical modeling of breakthrough waves in moving mashes. - In collection: Abstracts of republican scientific and technological conference "Implementation of research in water sector", Tashkent, 1982. - p.244-246.

22 Tuchin A.I. Specificities of numerical study of quasi one-dimensional hydrodynamic problems in mass Lagrange variables. In collection: "Research on functioning and mathematical modeling of water objects and systems under conditions of catastrophic events and natural disasters" - Tashkent, SANIIRI, 1985. - p.5-24.